Annual Report 2017

Institut de Radioastronomie Millimétrique

IRAM Annual Report 2017

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Introduction

We present you in the following our yearly report as a cross-section through the progress which has been achieved at IRAM during 2017. While steep progress has been regular IRAM news for quite some time, the past year has been exceptional and particularly full of important events and achievements.

NOEMA has made truly groundbreaking progress during 2017. Not only has the 9th antenna been added but also the upgrade with the most advanced receivers in any mm-wave interferometer has been completed during 2017. The key event however was the successful installation and commissioning of the new correlator PolyFiX, which brings NOEMA now very close to full speed. With this installation IRAM has fulfilled all core topics of its technological promises as put forward in the proposal of the NOEMA project. Adding antenna 9 and the high efficiency correlator PolyFiX generates the biggest single sensitivity jump the IRAM Interferometer has ever experienced. The first data sets show excellent quality and proof that PolyFiX boosts NOEMA into a totally new performance range.

With the antenna 10 foreseen to enter operation in June 2018, NOEMA Phase 1 will be achieved in its main goals. But things will not stay at this level; in fall 2017 the Max-Planck Society decided to dedicate the financial means to build antenna 11, and in the following the IRAM partners have found an agreement, which allows to kick-start NOEMA Phase 2 with these funds.

At the 30-meter Telescope, the NIKA2 instrument was offered to the global science community for the first time and now delivers data of stunning quality. IRAM has triggered a process to evaluate the possibilities of refurbishing and upgrading the 30-meter Telescope in order to foster the optimal use of NIKA2 and upcoming spectroscopic multibeam developments.

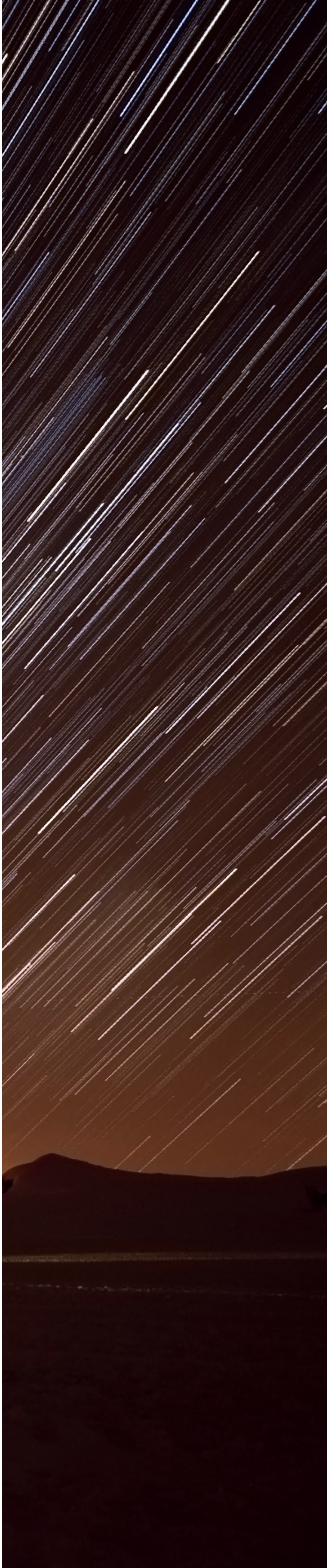
Meanwhile IRAM has continued to draw worldwide interest and in December 2017 new strategic partnerships with the Purple Mountain Observatory of the Chinese Academy of Science and Nanjing University have been concluded. They will strengthen the science community around IRAM and accelerate the next steps for NOEMA.

Astrophysics has seen great events during the last 18 months with the gravitational wave detection of merging black holes and neutron stars as well as many other exciting results. The public interest in these achievements is very high, and this general interest for astrophysical questions inspires and further motivates IRAM staff in its mission. Observational astrophysics progresses through many different paths: from the collection of large data sets to find or proof statistical laws and correlations, to the investigation of single objects or events that enlarge our understanding of fundamental physical and chemical processes in the Universe. IRAM has not stood aside with a number of high impact Large Programs, in particular in extragalactic astronomy, and at the same time many important smaller projects. Among the most spectacular were the detection of the highest redshift host galaxy known so far and the participation in groundbreaking global mm-VLBI sessions to learn more about the vicinities of massive black holes.

The particular progress of 2017 reflects the exceptional support through our partner organizations and the work of highest quality of my colleagues here at IRAM.

With best regards

Karl-Friedrich Schuster



Highlights of research with the IRAM telescopes

An artistic illustration of the black hole horizon at the center of our Galaxy. Credit: M. Moscibrodzka, T. Bronzwaar and H. Falcke, Radboud University.

THE ANATOMY OF A GIANT MOLECULAR CLOUD

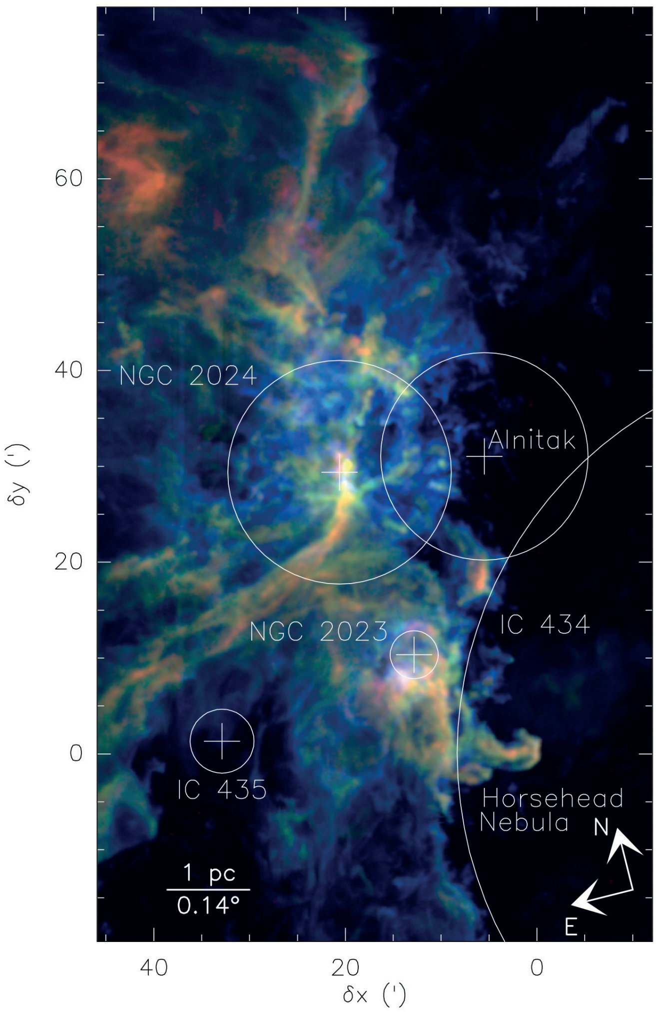
Understanding the formation and evolution of stars from interstellar condensations is undoubtedly one of the key research areas in observational astronomy. With about $7\times10^4\,M_\odot$, the Orion B Giant Molecular Cloud (GMC) is a massive interstellar reservoir of cold molecular gas and dust, and one of the most active stellar nurseries in the Galaxy to investigate its star formation efficiency. Powerful winds and ultraviolet radiation generated by newly born stars in Orion B are gradually eroding and disrupting their parental clouds, and this is how the two iconic regions, the Horsehead and Flame nebulae, were shaped.

The most comprehensive millimeter survey of this GMC is being carried out in the frame of Orion-B, an IRAM 30-meter Large Program led by Jérôme Pety (IRAM & Observatoire de Paris) and Maryvonne Gerin (LERMA). The IRAM telescope captured the signals of many molecular species like the CO isotopologues, CS, cyanides, CH_3OH, and small hydrocarbons, over a field of view of 1.5 square degrees. The wide range of conditions found in this region allowed the team to obtain a statistically significant breakdown of the region's activities.

In a first study, Pety and collaborators investigated the relation between the gas and dust, and how the physical conditions depend on the intensities of the molecular lines. The authors find a correlation with the illumination by ultraviolet light from massive young stars at the edges of the map, but no simple correlation between the gas densities and the fraction of molecular emission. The paper concludes that the relationships between the line emission and the gas physical properties are more complicated than usually assumed, and thus emphasizes the role of the local chemistry for the intensity of the emission.

The project also aimed at adapting statistical methods and machine learning tools to identify how molecular diagnostics can be used to characterize a wide variety of galactic and extragalactic regions. Using the Mean-Shift clustering algorithm, the team was able to disentangle different physical environments on the basis of a restricted sample of molecular line intensities (CO isotopologues, HCO^+, and CN). In another study, the team showed that key factors for the matter evolution, like its density or the UV illumination, can be approximately retrieved without any additional information with the well-known method of Principal Component Analysis.

Finally, the Orion-B collaboration shed light on why molecular clouds are so inefficient at forming stars: Gravity should condense the matter of the cloud to form dense cores and stars, however, at most only a few percent of the cloud mass is forming stars. One key parameter that could control the star formation efficiency is the nature of the motions of the gas. While compressive motions can trigger the collapse of cores, rotational motions offer an effective resistance to gravitational collapse. This study quantifies for the first time the fraction of compressive motion that is injected in the Orion B cloud. The cloud's motions are on average mostly injected through vortices. This is consistent with the fact that Orion B is the local GMC with the lowest star formation efficiency.



Composite image of the ^{12}CO (blue), ^{13}CO (green) and $C^{18}O$ (red) (1–0) peak-intensity main-beam temperatures. The circles show the typical extensions of the H II regions and the crosses the position of the associated exciting stars. The σ-Ori star that excites the IC 434 H II region is located 0.5° East of the Horsehead nebula. Work by Pety et al. 2017, A&A, 599, A98, Gratier et al. 2017, 599, A100, and Orkisz et al. 2017 599, A99.

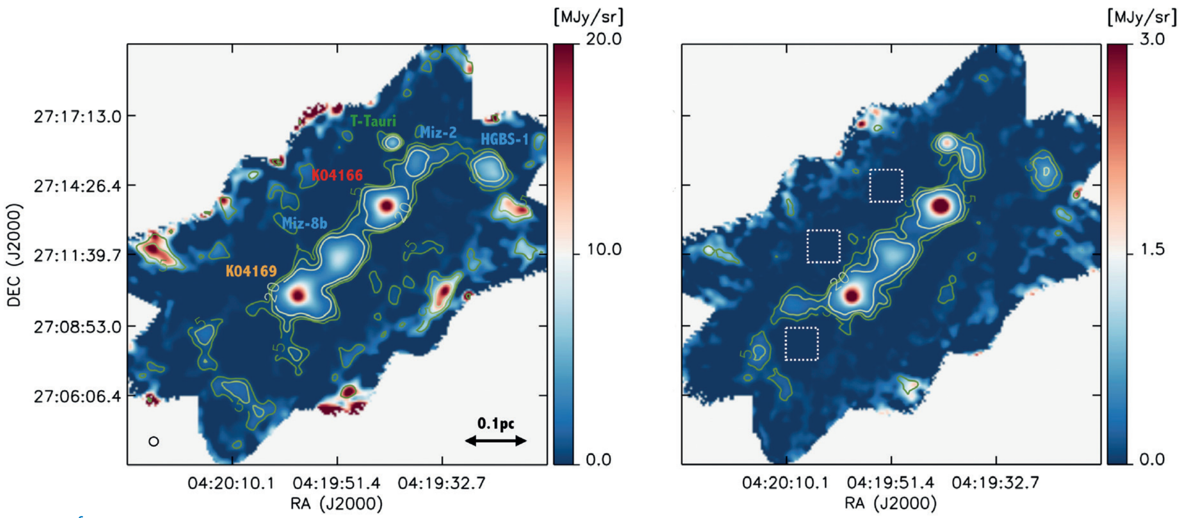
ON THE DUST PROPERTIES IN A TAURUS FILAMENT

The study of the dust properties in the diffuse interstellar medium, prestellar regions and protostellar cores is key for the understanding of the physics and chemistry of star formation. Though mass estimates are crucial to assess the gravitational collapse conditions for the birth of new stellar objects, most of these estimates rely on dust models that need accurate observational constraints.

To gain better insights into the dust properties of star forming regions, Andrea Bracco (CEA, Saclay) and collaborators looked at possible changes in the dust emissivity along the B213 filament in the Taurus molecular cloud, one of the most famous low-mass star-forming regions in the Gould Belt. They made use of the dual-band capability of the NIKA camera at the IRAM 30-meter Telescope to simultaneously observe the filament at 1.2 mm and 2.0 mm. This region is of particular interest since it harbors three prestellar cores, two Class 0/I protostellar cores and one Class II object that were very likely generated from the same parent filament.

By means of the ratio map of the two NIKA bands and Herschel data to derive accurate radial temperature profiles, Bracco and collaborators found systematic spatial variations of the emissivity index β in the protostellar cores that are not observed in the prestellar core. While in the former case β decreases towards the center (with β varying between 1 and 2), in the latter it remains constant ($\beta = 2.4 \pm 0.3$). Moreover, they were able to show that the dust emissivity index appears to be anti-correlated with the dust temperature - the higher the dust temperature, the lower β. This finding is consistent with previous observational work.

The authors of the study suggest that the observed radial decrease in β towards the center of protostellar cores is tracing the dust evolution from the prestellar to the protostellar stage, and that this is likely due to both grain-growth and dust temperature effects in the millimeter range.

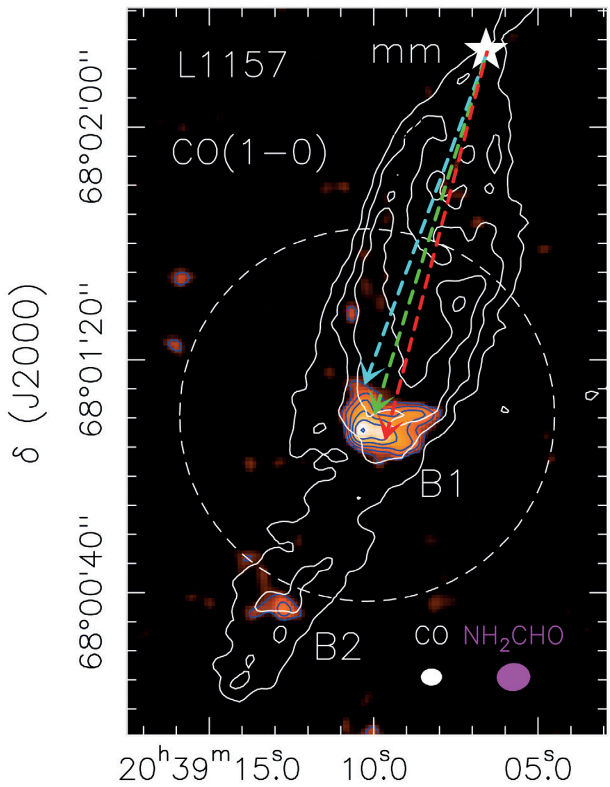


Dust continuum maps of a portion of the B213 filament obtained with the NIKA camera on the IRAM 30-meter Telescope at 1.2 mm (left panel) and 2.0 mm (right panel). Work by Bracco et al. 2017, A&A, 604, A52.

FORMAMIDE IN SHOCKS: THE SMOKING GUN OF GAS-PHASE PREBIOTIC CHEMISTRY

Interstellar complex organic molecules (iCOMs) contain at least six atoms including carbon and hydrogen. Formamide (NH_2CHO) is a particularly relevant iCOM in the context of prebiotic chemistry, as it has been proposed to be a key precursor of both metabolic and genetic macromolecules. Intriguingly, formamide is a relatively common species in the interstellar medium, observed in regions forming Solar-type stars as well as in external galaxies. How this molecule is synthesised in space is a matter of hot debate. The two current theories predict its formation by reactions in the gas phase or on the icy mantles covering interstellar dust grains. The first theory proposes synthesis via reaction of formaldehyde (H_2CO) and amidogen (NH_2), whereas various mechanisms have been suggested for NH_2CHO formation on the grain surfaces like the combination of amidogen (NH_2) and formyl radical (HCO).

In order to test these theories, Claudio Codella (INAF-Arcetri) and collaborators imaged the NH_2CHO emission in the star forming region L1157 with NOEMA at ~5" resolution in the 3 mm band, in the frame of SOLIS (Seeds Of Life In Space), an IRAM Large Program led by Cecilia Ceccarelli (IPAG) and Paola Caselli (MPE). L1157 hosts L1157-mm, a low-mass protostar driving a precessing and episodic jet that excavated two main cavities, called B1 and B2. In particular, B1 consists of a series of young (kinematical age ~1000 years) shocks caused by different episodes of ejection impacting against the cavity walls. Previous observations revealed that



NOEMA map of the L1157 southern outflow lobe. The precessing jet ejected by L1157-mm (white star) excavated two cavities, B1 and B2, traced by CO (white contours). NH_2CHO emission is shown in colour. Arrows mark the projected directions of different shock episodes forming B1. Work by Codella et al. 2017, A&A, 605, L3.

the jet impact on B1 caused partial erosion of grain cores and ices, thus producing large quantities of gaseous SiO, H_2O, and CH_3CHO among several other species. Hence, L1157-B1 is a perfect site to study the chemical reactions occurring when previously frozen species are injected into the gas phase, as their relative abundance evolution depends on the relative efficiency of the various reactions.

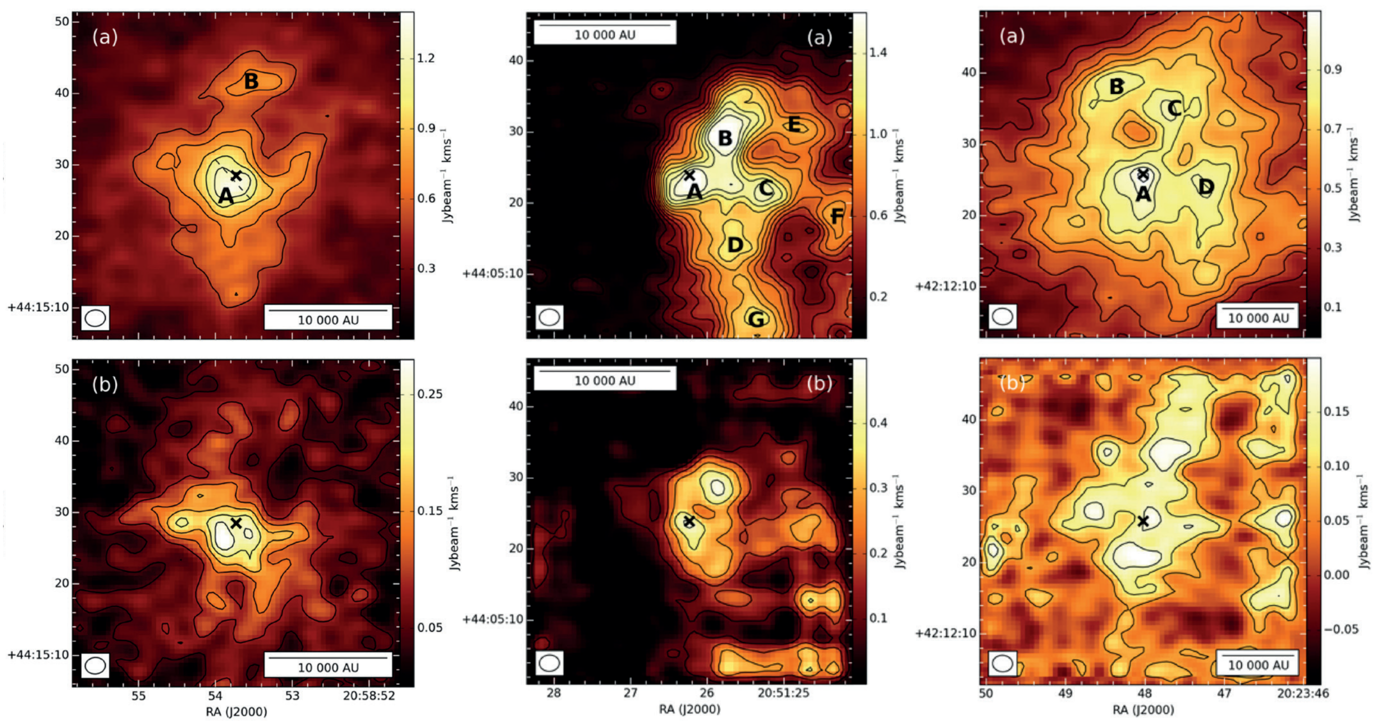
The excellent sensitivity provided by NOEMA allowed Codella and collaborators to obtain the first image of formamide emission in a protostellar shock. In addition, they were able to follow its chemical evolution with time by measuring the NH_2CHO/CH_3CHO abundance ratio throughout the shocked gas, as regions closer to the location of the most recent jet impact are also the youngest. Interestingly, the NH_2CHO and CH_3CHO spatial distributions are anti-correlated, which is only possible if formamide is mostly synthesised in the gas phase. Chemical modelling, including the reaction between NH_2 and H_2CO, indeed successfully reproduces the observed abundances.

These new SOLIS observations represent the smoking gun of gas-phase chemistry at work to form formamide, a key precursor of pre-biotic material.

TOWARDS AN EVOLUTIONARY SEQUENCE OF FU ORIONIS TYPE STARS?

FU Orionis type objects are pre-main sequence, low-mass stars with large outbursts in visible light that last for several years or decades. They are thought to represent an evolutionary phase during the life of every young star when accretion from the circumstellar disk is enhanced during recurring time periods. These outbursts are able to rapidly build up the star while affecting the physical conditions inside the circumstellar disk, and thus the ongoing or future planet formation. In many models, infall from a circumstellar envelope seems to be necessary to trigger the outbursts.

To characterize the circumstellar material around FU Orionis type stars, a team led by Orsolya Féher (Konkoly Observatory, Budapest) observed the rotational transition of ^{13}CO (J=1-0) and $C^{18}O$ (J=1-0) towards a sample of eight northern FU Orionis type stars using NOEMA and the IRAM 30-meter Telescope. The aim of the survey was to provide insights into the evolutionary state of this class of objects by investigating the physical and dynamical properties of the molecular environment around the stars on a scale of a few thousand astronomical units.



Integrated ^{13}CO (top) and $C^{18}O$ (bottom) intensity maps of the FU Orionis type stars V1057 Cyg (left), V1515 Cyg (middle) and V2492 Cyg (right). Work by Féher et al. 2017, A&A, 607, 39.

Strong ^{13}CO and $C^{18}O$ emission was detected in all eight stars, revealing the presence of extended circumstellar molecular structures and the high level of clumpiness at various spatial scales and with complex kinematics. While the ^{13}CO emission was used to derive the kinematic temperatures (10-40 K) of the envelopes, the optically thin $C^{18}O$ emission was used to determine gas densities (0.5–5×10^{22} cm^{-2}) and masses (1-20 $M_{\odot}$). Interestingly, the observed gas masses correlate well with the 10 µm silicate feature i.e. this feature appears in emission towards the stars with the lower mass envelopes (1-3 $M_{\odot}$), while it shows up in absorption for the stars with the higher mass envelopes (4-20 $M_{\odot}$). Since FU Orionis type stars fall into two evolutionary categories based on the appearance of the silicate feature, Féher's study suggests that a determination of the evolutionary state of FU Orionis type stars based on the mass of the envelope is a priori possible. However, the classification of these stars into one of the two categories turns out to be difficult because of the structural complexity of the circumstellar structures and a lack of spatial resolution. Moreover, while some of the stars' physical parameters are characteristic of young, embedded Class I stars, others show signs of early or late Class II objects. This diversity seems to reinforce the theory that FU Orionis type stars are Class I and Class II young stellar sources in a transitional evolutionary phase with bright infall driven eruptions.

NOEMA LOOKING INTO THE CRADLE OF A FUTURE PLANETARY SYSTEM

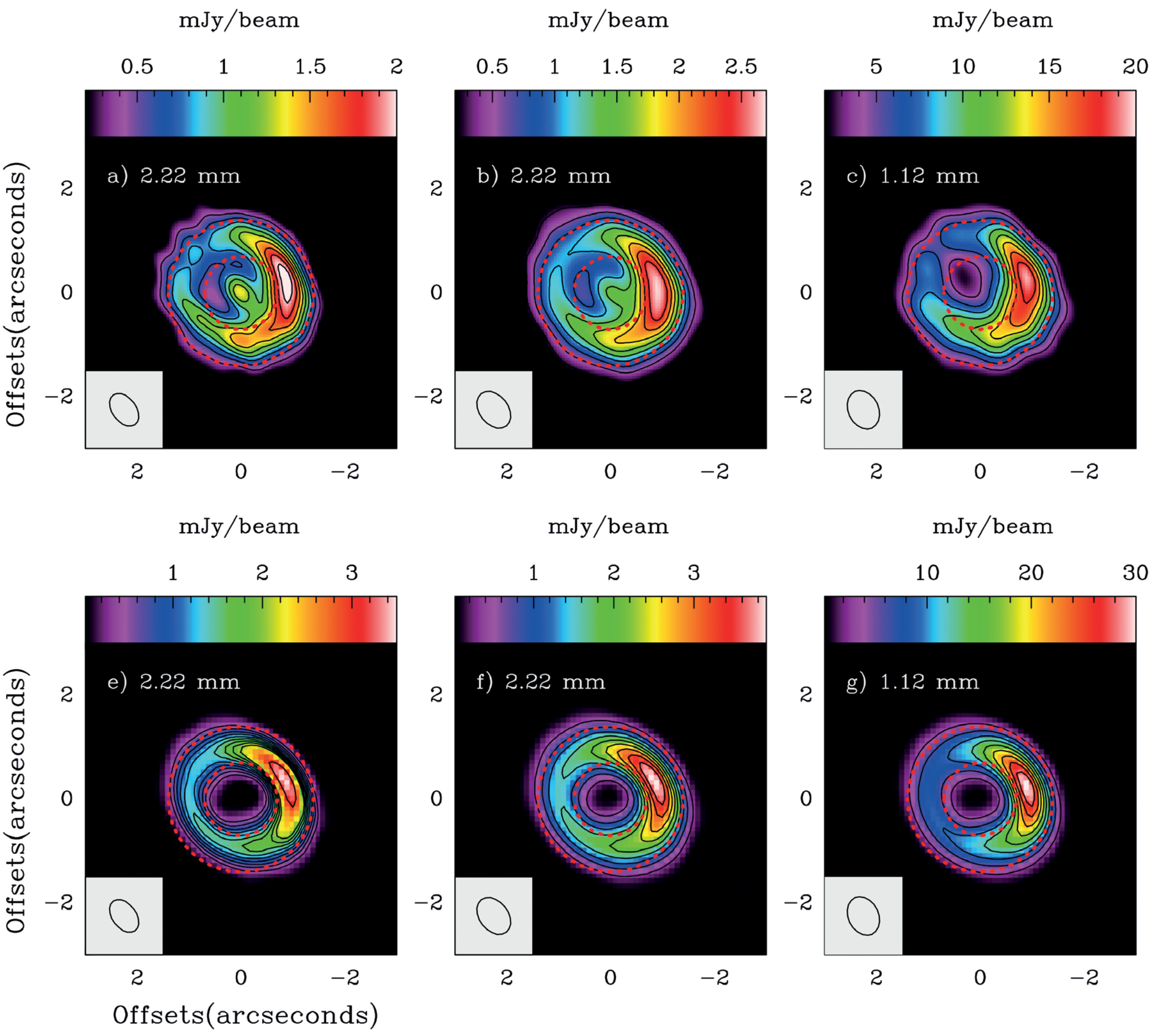
The formation of planets is one of the biggest unresolved questions of science. The most widely accepted theory states that planets form in a protoplanetary disk of gas and dust around young stars. Dust grains collide and stick together to form larger and larger agglomerates. When these clumps reach sizes of approximately one kilometer (planetesimals), they may attract each other directly through mutual gravity and eventually form moon-sized proto-planets.

The physical mechanism behind the formation of planetesimals remains, however, poorly understood. One of the caveats is the rapid radial drift of large dust particles towards the star due to their interaction with the disk gas. Planetesimal formation should thus occur on timescales shorter than the radial drift of solid particles, which can be very fast for cm-sized bodies. One way to halt the radial drift is to trap particles in regions like the sharp boundaries of a gap carved out by a massive planet. These so-called dust traps are promising locations for the formation of planetesimals and planetary cores, and are nowadays receiving extensive theoretical attention.

Disk observations can bring valuable constraints on the dust trap scenario for planetesimal formation. This is the case of transition disks, which are protoplanetary disks that feature a dust emission ring surrounding a dust cavity in their inner regions, and which are thought to be due to forming planets.

The comparison between theoretical models and observations is not straightforward, however. The reason is that, even in the era of large (sub-)millimeter telescopes like NOEMA and ALMA, resolving disks with good sensitivity remains challenging. AB Aurigae is one of the few nearby transition disks that allow a fair comparison with models.

To address this question, an international team led by Asuncíon Fuente (OAN) and Clément Baruteau (IRAP) started a project aimed at mapping the dust continuum emission in AB Aurigae with ~0.7" resolution at 1.1 mm and 2.2 mm using NOEMA. The images show significant azimuthal variations of the continuum emission along the ring at both wavelengths, which suggests a size segregation of the dust grains. Comparison between the observations and the two-fluid gas-and-dust hydro-dynamical simulations by Baruteau and collaborators shows that the lopsided distribution of dust particles in AB Aurigae can be explained by dust trapping in an end-of-life gas vortex formed outside the gap of a massive planet in the disk. The vortex's decay implies that the large dust particles have started to spread out of the vortex, which is needed to account for the flux variations along the ring. In addition, the observations allowed the researchers to constrain the size distribution and the total mass of solid particles in the ring, which was found to be of the order of 30 Earth masses, enough material to form future rocky planets.



Top panels: ~0.7″ images of AB Aurigae obtained with NOEMA in the continuum at 2.2 mm and 1.1 mm. The image in central panel has been derived from the 2.2 mm observations by tapering them down to the angular resolution of the 1.1 mm image.

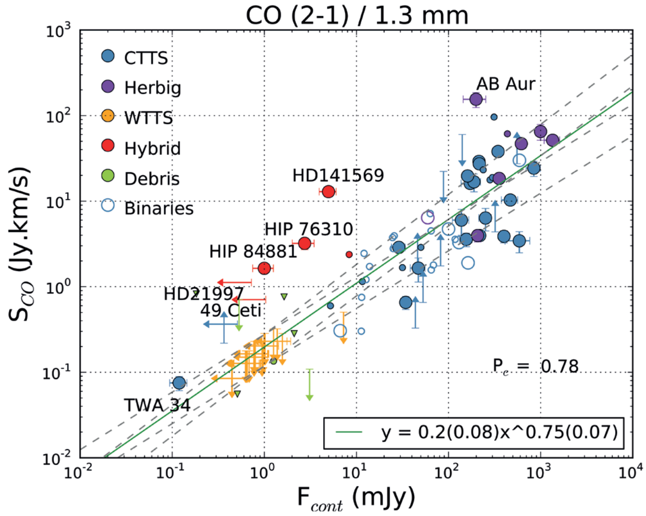
Bottom panels: model predictions based on the gas-and-dust hydro-dynamical simulation. Work by Fuente et al. 2017, ApJL 846, L3.

ON THE NATURE OF HYBRID DISKS

Our comprehension of the structure of protoplanetary disks has progressed tremendously in the last decade, in particular thanks to millimeter astronomy. For example disks have been shown to host various substructures, possibly linked to planetary formation, such as internal cavities or rings and gaps, and to contain molecular gas and dust. While observations of rotational lines allow the study of the molecular content of gas-rich disks, many main-sequence stars harbor gas-poor debris disks, where the dust, blown out the system by the stellar radiation pressure, is steadily replenished through collisions of larger invisible bodies. There are only a handful of remarkable objects, known as hybrid disks, where the main-sequence stars are surrounded by a dusty disk containing substantial amounts of gas.

Jessica Péricaud (LAB) and collaborators carried out a deep search for hybrid disks in 25 A-type stars through the ^{12}CO J=2-1 and J=3-2 lines with the IRAM 30-meter and APEX Telescopes. This is to date the most sensitive survey and yielded only a single tentative detection of a hybrid disk, confirming that such disks are rare (detection rate of 7-12%) and that they are likely to correspond to a short-lived transition phase. The authors combined these results with previous measurements of Herbig Ae stars, classical T-Tauri stars, weak-line T-Tauri stars, hybrid disks and debris disks from the literature, and found a correlation spanning 4 orders of magnitude between the CO line integrated emission and the millimeter continuum flux density.

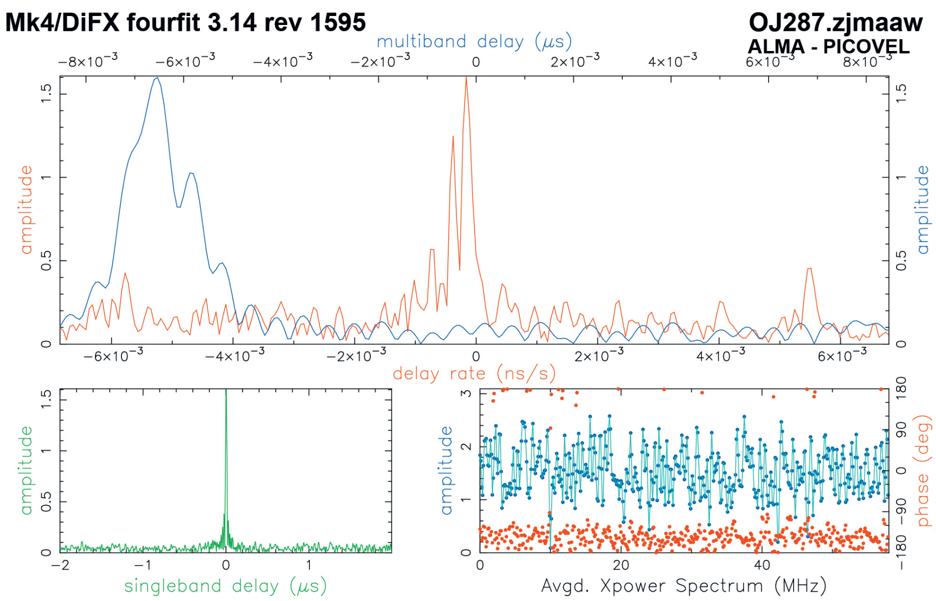
The absence of a break in the slope of the correlation suggests that ^{12}CO is optically thick in all the observed sources. Another salient feature is that the hybrid disks lie well above the main trend, which provides yet another hint that they are in a short-lived transition stage and suggests there is a deficit of dust emission or an excess of CO emission. The excess emission cannot be attributed to the destruction of comets and planetesimals, as in the case of β Pictoris, since their reservoirs would be exhausted far too quickly. This points towards a faster evolution of the dust than of the gas in hybrid disks. In the future, more sensitive observations will extend this work towards lower-mass stars.



^{12}CO (2-1) emission plotted with the corresponding continuum measurement, the fluxes being normalized at 100 pc. The Pearson correlation coefficient of the data is indicated in the lower right-hand corner. Work by Péricaud et al. 2017, A&A, 600, 62.

IMAGING THE BLACK HOLE AT THE CENTER OF OUR GALAXY

Black holes are fascinating objects predicted by general relativity. Their mass is high enough that even light cannot escape, and are therefore not directly observable. However, because of their immense gravitational attraction on their surroundings, the presence of these objects is indirectly established. The limit beyond which light and obviously all matter are trapped by the black hole is called the horizon of the black hole. Before matter crosses this boundary, the theory predicts that a final puff of light of hot excited gas is emitted before sinking into the black hole. The emission, which is lensed by the gravitational field of the black hole, can be observed in the millimeter wavelength range. Very long baseline interferometry (VLBI) observations may provide the ability to map the horizon of a black hole and to sense the dynamical evolution of black hole accretion.



Fringe plot of the baseline between ALMA and the IRAM 30-meter Telescope showing the detection of a strong correlated signal at 228.2 GHz towards the BL Lac object 0851+202.

Thanks to a worldwide network of millimeter observatories, and for the first time in the history of astronomy, an international team of astronomers joined up in an attempt to produce the first image of Sgr A*, the supermassive black hole (4.3×10^6 $M_\odot$) at the very center of our galaxy. This worldwide project, called the Event Horizon Telescope (EHT), combines observatories across four continents, from Europe to the South Pole through Chile and Hawaii, to map the horizon of Sgr A* at 230 GHz with a spatial resolution of 26 micro-arcseconds. The IRAM 30-meter Telescope is the only observatory in Europe that took part in this observing campaign, and is, after the ALMA observatory, the most sensitive telescope of the current network.

Most of the data collected in the April EHT campaign have been going through a first stage of processing at the MIT Haystack Observatory (Westford, USA) and MPIfR (Bonn, Germany). First images of Sgr A* are expected to be released next year. In the near future, the NOEMA Observatory will enter the EHT project and be the most sensitive EHT station of the northern hemisphere.

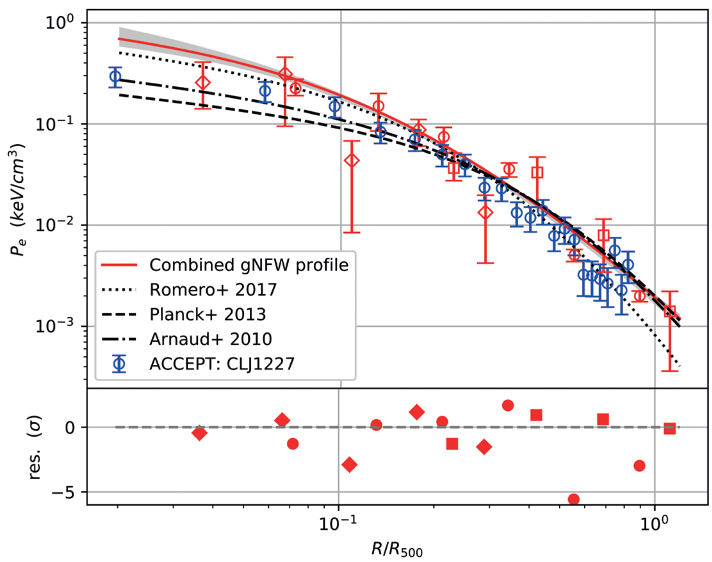
PROBING THE PRESSURE PROFILE IN THE MOST DISTANT GALAXY CLUSTER KNOWN

The Sunyaev-Zel'dovich (SZ) effect is a powerful tool for studying clusters of galaxies because it is proportional to the integrated electron pressure along the line of sight, and its intensity does not suffer from cosmological dimming. Cluster pressure profiles may provide insights into the thermodynamic state of a cluster, in particular the intracluster medium (ICM). Only recently, sensitive, resolved SZ studies of galaxy clusters have become common, and thus have enabled non-parametric pressure profile constraints from SZ data.

Given the novelty and importance of non-parametric pressure profile SZ constraints, a team led by Charles Romero (IRAM) aimed to constrain the pressure profile from four separate instruments, thereby checking for consistency between the instruments, and also providing constraints over a large range (factor of 20) in spatial scales. The authors chose the high redshift ($z = 0.89$) galaxy cluster CLJ 1226.9+3332, for which SZ data from NIKA, MUSTANG, Bolocam, and Planck exist. The overlap in spatial scales probed by these four datasets is critical to checking the degree of consistency between instruments.

The authors find good agreement among NIKA, MUSTANG and Bolocam. The individual pressure profiles are also consistent with a single parametric profile fit in this work, and a parametric profile of this cluster from a previous study. Planck was used to constrain the total signal, thus it contributed to narrow down the outermost pressure profile bin.

Although the parametric fitting suggests at a sharp bend in the pressure profile at moderate radii, the authors note that this is likely due to the merger scenario proposed in previous studies. The authors foresee that the versatility of non-parametric pressure profile studies will render them useful to ongoing SZ observations and the NIKA SZ Large Program.

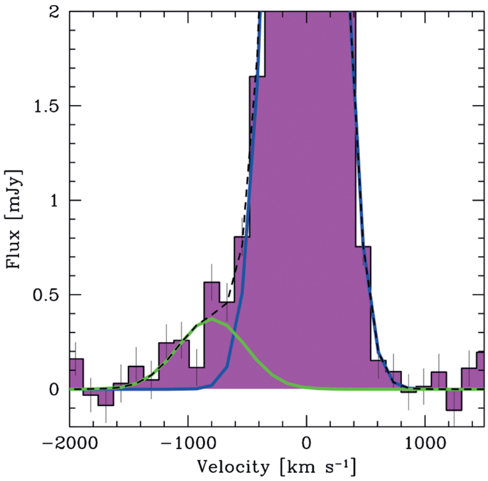


Red points are from SZ data; circles from NIKA, diamonds are from MUSTANG and squares from Bolocam. Good agreement is found between SZ instruments, and fair agreement is found with X-ray data. The black curves show parametric pressure profiles from other works; Romero et al. 2017 is for the same cluster, while Planck et al. 2013 and Arnaud et al. 2010 are sample-averaged pressure profiles. The blue points come from X-ray data. Work by Romero et al. 2017, ApJ, 838, 86.

A MASSIVE MOLECULAR OUTFLOW IN THE HIGH-REDSHIFT UNIVERSE

Massive molecular outflows powered by active galactic nuclei and by supernovae explosions are considered a key mechanism in the cycling of baryons between galaxies and their surrounding environment, and finally in the regulation of the growth of galaxies and of their central supermassive black holes. These massive outflows of molecular gas are nowadays routinely observed in nearby galaxies, but are still largely unexplored in the distant Universe, because of their faintness. It is crucial, however, to understand the impact of these processes at early cosmic epochs, when galaxies and supermassive black holes had just started to assemble and grow.

To shed new light on the role of outflows in the high-redshift Universe, an international team of astronomers led by Chiara Feruglio (INAF-Trieste) used the NOEMA Interferometer to obtain the most sensitive observation ever of the molecular gas in the host galaxy of the broad absorption line quasar APM 08279+5256 at redshift z=4. While there is extensive evidence for the presence of powerful winds of ionized gas in APM 08279+5255, direct evidence of the presence of a molecular wind counterpart has not yet been provided.



NOEMA spectrum zoomed-in around the $^{12}CO(4-3)$ emission line. The spectral profile suggests the presence of an energetic (1300 km/s) molecular outflow (green line) in APM 08279+5255. Work by Feruglio et al. 2017, A&A, 608, 30.

To address this question, Feruglio and collaborators invested time on NOEMA and detected blue-shifted $^{12}CO(4-3)$ emission suggesting the existence of molecular winds blown by the supermassive black hole and expelling large amounts of molecular gas out of the host galaxy. This is the first detection of a massive molecular outflow at redshifts beyond 3. The gas mass entrained in the flow is estimated to $M(H_2)=4\times10^8\,M_\odot$, and the outflow rate to several $10^3\,M_\odot$/year. The result confirmed the possibility that massive molecular outflows play an important role in the early stages of evolution of massive galaxies.

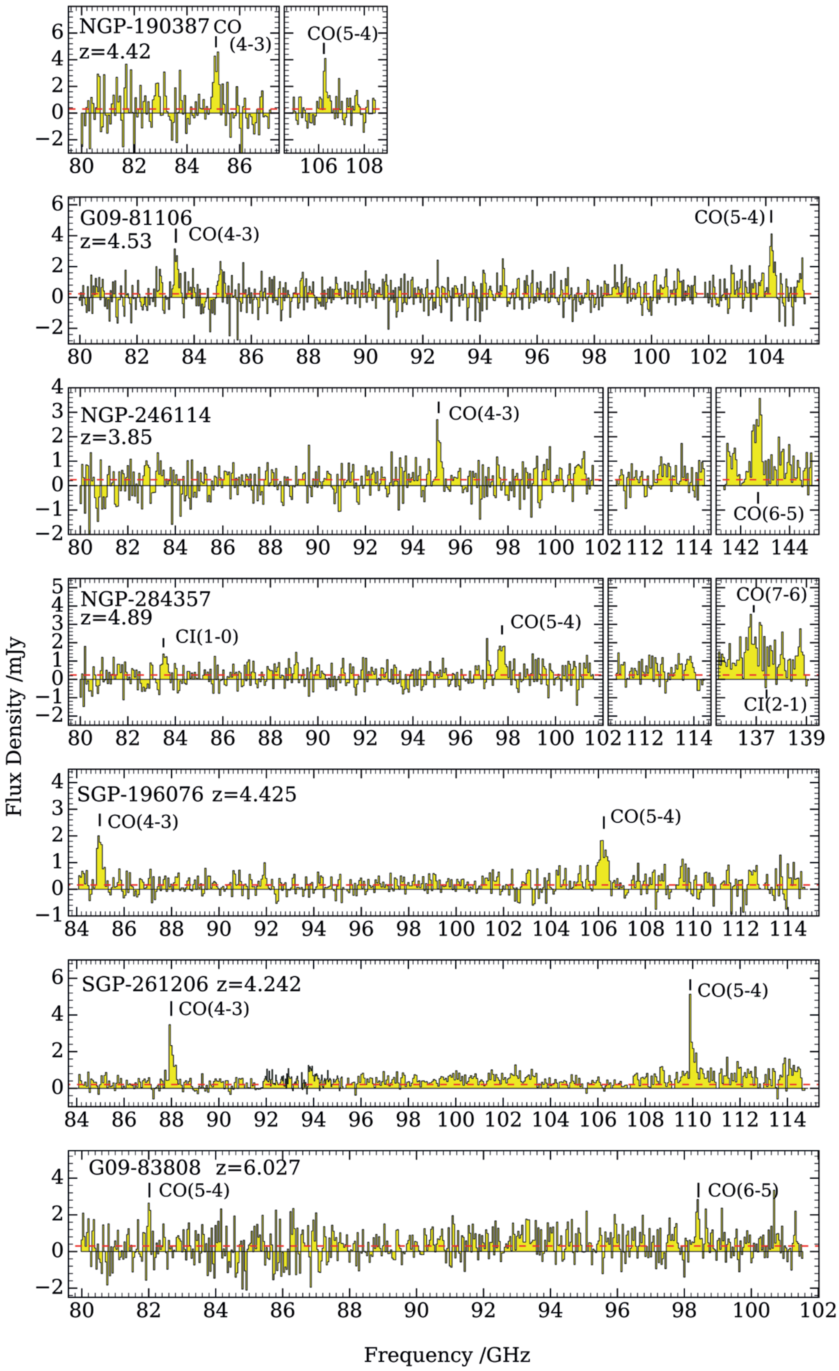
The NOEMA data delivered another surprise. An unexpected spectral line popped out in the NOEMA data at a frequency of 94.83 GHz. The authors of the study identified it as the (5-4) transition of diazenylium (N_2H^+), which is the first observation of this molecule at high redshift. The serendipity of the unexpected detection clearly demonstrates the power of the NOEMA Interferometer for molecular line surveys of galaxies in the early Universe.

THE MOST DISTANT, LUMINOUS, DUSTY STAR-FORMING GALAXIES

In the decade since the discovery of the population of dusty star forming galaxies (DSFGs), the SPIRE camera aboard Herschel and the SCUBA-2 on the JCMT detected significant amounts of DSFGs. Optical and near-IR spectroscopic observations confirmed that the DSFGs are more abundant in the high redshift Universe, with a redshift distribution that peaks between z=1 and z=3. However, a well-established population of massive elliptical galaxies, the assumed descendants of DSFGs, also exists at z=2-3. Though this implies that DSFGs must be present in significant numbers at higher redshifts, only a small number of DSFGs are known at redshift > 4.

To address this contradictory issue, a team led by Fudamoto (Geneva Observatory & ESO) has exploited the widest available far-IR imaging survey to create a large sample of reddest DSFGs with improved photometric redshifts. Using mainly NOEMA, the researchers have conducted follow-up observations of a subsample of 17 DSFGs by spectrally scanning the 3 mm waveband over bandwidths of ~20 GHz to unambiguously derive their spectroscopic redshift. They also added the observations of 4 southern targets done with ALMA to increase the sample size.

Multiple emission lines and transitions were detected towards 7 targets that helped to unambiguously establish the redshifts of these sources and to identify molecular and atomic species. The redshifts were in the 3.85 to 6.03 range, and in most cases are well matched with previous photometric redshift estimations. With the spectroscopic redshift, Fudamoto and collaborators have performed spectral energy distribution fitting in the far-IR, and explored molecular gas masses assuming average emission line ratios for CO rotational transitions. The authors have found that the galaxies contain extraordinary IR-luminous starbursts with average star formation rates of 2900 $M_{\odot}$/years, molecular gas masses of ~10^{11} $M_{\odot}$, and dust masses of ~10^{9} $M_{\odot}$. The gas depletion time-scale of around $5{\times}10^{7}$ years is consistent with the idea that these DSFGs may indeed be the progenitors to the massive red-and-dead galaxies at redshifts 2-3 found by near-IR imaging surveys.



Band 1 spectra of seven dusty star forming galaxies (DSFGs) with clear multiple line detections, thus yielding unambiguous redshifts, extracted at the positions where continuum is seen. Red dashed lines show the median continuum flux density. All but two of the spectroscopic redshifts agree well with previous photometric estimates. Work by Fudamoto et al. 2017, MNRAS, 472, 2028.

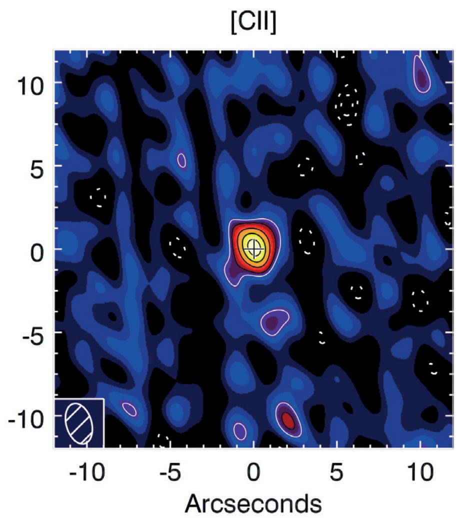
THE YOUNGEST QUASAR IN THE UNIVERSE

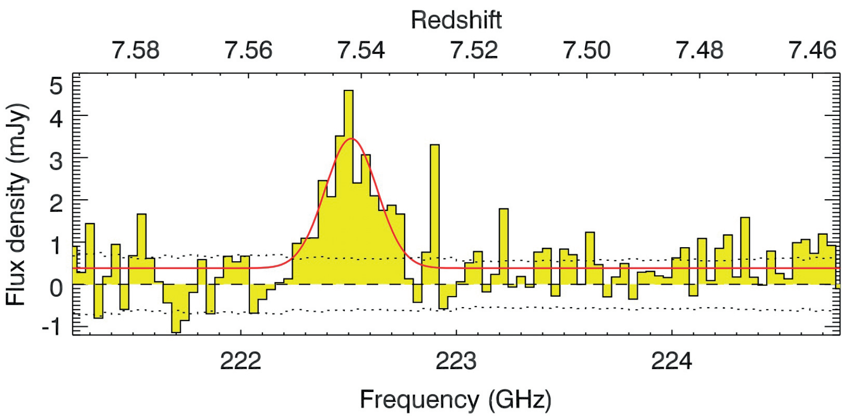
Quasars are the most luminous objects in the early Universe and unique laboratories to investigate the first stages of galaxy formation. As they are powered by supermassive black holes in the centers of their host galaxies, their study promises fundamental constraints on the buildup of supermassive black holes, and important insights on the morphological, dynamical and chemical layout of early galaxies for numerical models of evolution of our Universe.

In a recently published study led by Bram Venemans (MPIA), an international team of astronomers targeted the quasar J1342+0928 with NOEMA only a few days after Eduardo Bañados (Carnegie Institution for Science) had discovered the quasar with the Magellan telescopes in Chile. The NOEMA observations show clear traces of heavy elements in the quasar's host galaxy. The detection of the [CII] line at 158 μm and of the dust continuum reveals that the newly discovered quasar is very special indeed. The [CII] line, in particular, allowed to determine with high precision the quasar redshift to z=7.54, making it the most distant, and therefore also the youngest quasar detected so far. The emission observed shows the quasar as it was 13 billion years ago, a mere 690 million years after the Big Bang.

With those observations, the astronomers were able to examine the quasar's host galaxy. Venemans' analysis suggests the host galaxy contained huge amounts of dust and heavy chemical elements already at a very early stage of the Universe, and that it must already have generated a large number of stars. These results are a challenge for models of galaxy evolution, which need to explain how a galaxy can produce the observed amounts of chemical elements in such a short time.

The light of this distant quasar also carries crucial information on the so-called cosmic reionization phase. The timing and specifics of this phase transition in the evolution of the Universe are still open questions but the authors conclude that the significant fraction of neutral hydrogen in J1342+0928 is favoring models that predict that reionization has possibly started at a later stage in the history of the Universe.





Left: spectrum of the [CII] line, which allowed a precise determination of the quasar's redshift of z=7.54, and of the underlying thermal dust continuum emission.

Right: velocity-integrated map of the quasar's host galaxy in the [CII] line at 158 μm.
Work by Venemans et al. 2017, ApJL 851, L8.

The 30-meter Telescope

The year 2017 saw a strong increase of the number of Large Programs at the 30-meter Telescope, highlighting the continuing success of these programs. These requests between 100 and 550 observing hours each, extend over several semesters, and comprise larger groups of investigators combining different areas of expertise, leading to a public data release, and in most cases to a burst of publications. In 2017, four Large Programs used the EMIR multi-band receiver, covering a range of topics from elemental abundances and the structure of nearby Galactic molecular clouds, to the study of isotopic ratios in the nearby galaxy M51 and a study of the molecular gas content in AGNs. In addition, an increasing number of projects are using the 30-meter Telescope to map the extended emission of sources, complementing interferometric high angular resolution observations with NOEMA or ALMA.

The successful completion of the commissioning of NIKA2 resulted in an upcoming dedicated publication by Adam et al that paved the way to initiate regular science observations, which started during a first week of pooled observations in October. In the year, three of the NIKA2 Guaranteed Observing Time Large Programs were started. The GASTON project maps a part of the Galactic plane at 1.15 and 2.0 mm wavelengths, NIKA2SZ will map the structure of the thermal Sunyaev Zel'dovitch effect in a large sample of galaxy clusters, while N2CLS will conduct deep integrations towards two fields attempting to detect hundreds of dust-obscured optically-faint galaxies at high redshifts. In addition, several relatively short open time projects were started. The major remaining obstacle, which needs to be solved in the course of 2018, is the missing IRAM data processing software. Observers, aided also by knowledgeable IRAM astronomers, currently have to rely heavily on the IDL data pipeline, which was developed to move forward with commissioning and science observations by the NIKA2 consortium. Commissioning of 1.15 mm polarimetry is progressing, but will need more time in 2018.

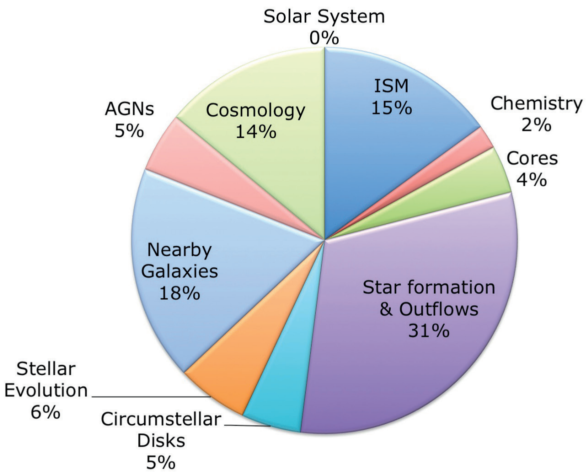
MRTCAL is the new calibration software for the heterodyne receivers and is fully integrated into the GILDAS suite of software packages. Step-by-step, MRTCAL will replace MIRA in the online data processing of 30-meter data. In February, a major milestone was achieved by changing to MRTCAL for the bulk of the default online processing of the spectroscopic data. This step was achieved after a careful and well documented test and commissioning phase, and was followed-up by a close monitoring of the resulting calibrations, and tracking of any issues. MRTCAL has been in stable operation since then. Over the course of the year, work continued to prepare for processing of polarimetry data taken with XPOL/EMIR, and of continuum scans, in order to fully replace MIRA.

The internet connection to both the observatory and the IRAM offices in Granada is now done via fast radio links and/or via commercial fiber links. These links allow connection speeds of up to 300 Mbit/s. Work has continued to prepare for a dark fiber connection, which will in the future allow for speeds of 10 Gbit/s. This work is done in close collaboration with RedIRIS, the Spanish academic and research network.

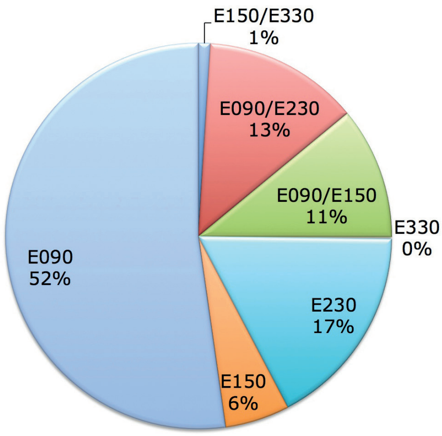
Following a first meeting in 2016, a second IRAM-internal workshop was held in Granada in April. It focused on the antenna control system (NCS), network, remote observations, and future data storage systems, and more globally on identifying and discussing areas for a possible future refurbishment of the 30-meter Telescope. As conclusion of the two workshops in 2016 and 2017, three performance areas were identified: an improvement of the surface accuracy of the primary mirror at its optimum elevation, but also at low and high elevations, an improvement of the servo system especially under windy conditions, and an improvement of the thermal control of the back structure under day and night time conditions. Though the performance of the 30-meter Telescope is better than the original specifications in all of these areas, further improvements should be feasible and would yield a significantly better performance especially in the 1 mm band. As the surface of the primary mirror needs to be repainted, one idea is to combine these works. In September, the feasibility of undertaking this work was discussed with MT Mechatronics (Mainz, Germany) who, given their expertise with large radio-telescopes, will aid in the preparation of a preliminary study to be completed in early 2018.

ASTRONOMICAL PROJECTS

During the year, a total of 243 projects were observed at the 30-meter Telescope. This number includes four Large Programs with EMIR, three with NIKA2, and three Director's time projects. About 13% of these proposals were scheduled in pool weeks. About 22% of the scheduling units were observed remotely. Galactic topics were addressed by about 63% of the scheduled projects, while 37% were devoted to nearby galaxies and more distant objects. EMIR was by far the most used instrument (93% of the time). The remaining time was dedicated to observations with HERA (0.6% of the time) and NIKA2 (6% of the time). In October, regular NIKA2 science observations started successfully in a first week of pooled observations. During the scheduling year, 167 astronomers visited the telescope to support projects, 18 of which came to support the observing pools. As in previous years, two groups of master students and their tutors visited the telescope to observe short projects as part of their training courses.

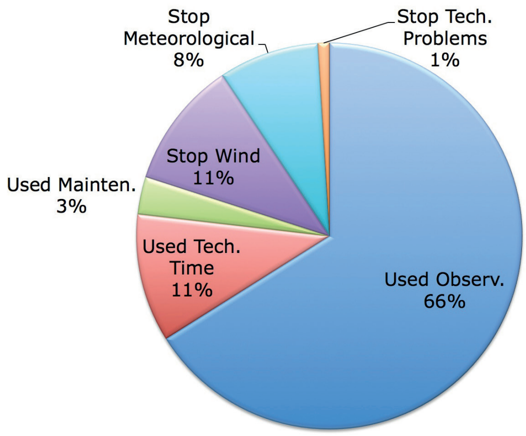


Time distribution of scientific categories observed in 2017.



Usage of EMIR bands in 2017.

OBSERVATORY OPERATION

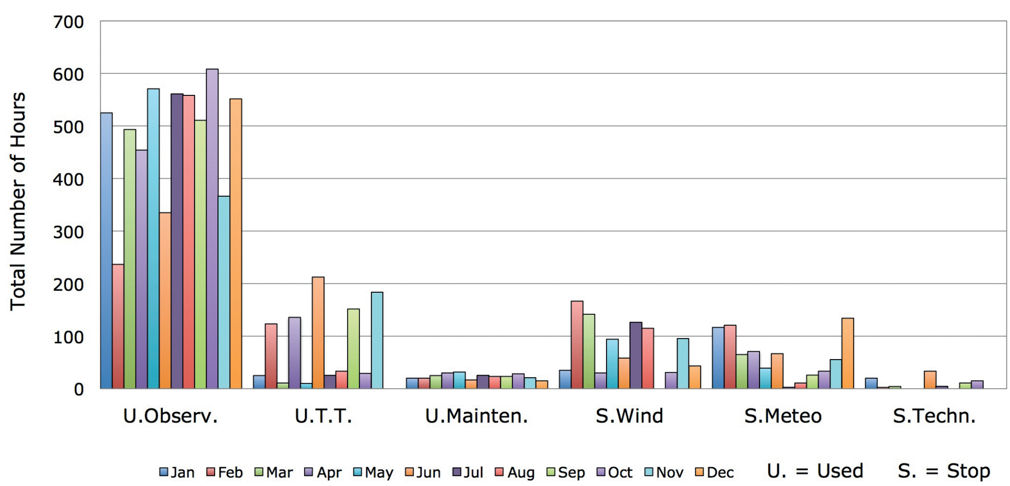


Usage of the total time at the 30-meter Telescope.

Similar as in previous years, 66% of the total available time were used for observations using one of the available frontends EMIR, HERA, or NIKA2. Regular maintenance on Tuesdays accounts for 3% of the time, while an additional 11% were used to advance several technical projects, including an investigation of radio interferences with EMIR, improvements of the paKo observer interface, improvements of the inter-process communication, and NIKA2 polarimetry, along with an additional week of heavy maintenance of telescope, frontends and computers. In total, 20% of the available time was lost due to poor weather conditions. The telescope had to be stopped for technical problems in the telescope and computer areas for about 3 days (1% of the time). The issues within the telescope area were caused by failures of servos, tachos, spindles and wobbler. Such failures are rare and can be solved relatively quickly, as spares are stored at the telescope, and as there always is, for each of the technical areas, an engineer on standby on weekends and feast days, ready to go to the telescope if needed.

As with previous years, the main activities carried out by the telescope group are related with the daily operation of the observatory, which means: the maintenance of the systems and equipment of the observatory, helping with the daily problems concerning the observations and operation, and the reparation of broken equipment.

Additionally, some other activities carried out by the telescope group during 2017 were as follows. The TPOINT software for the analysis of the antenna pointing model was acquired. Results with the FIT software have been compared with equal results and some new parameters could be included in the pointing model for a small improvement. The cooling compressor for the air conditioning system in the receiver room, which was installed in 2016, was put into operation permitting to achieve the correct temperature in the receiver room with the new NIKA2 equipment working fully. Maintenance of the oil in the antenna equipment has continued. Oil is analyzed annually and the oil in three of the six gearboxes was replaced along with the oil of the antenna platform, which was filtered reducing its impurities. In the electricity area, a bypass switch was installed for the operation with the diesel group. In this way a possible failure of the automatic electrical switch of the diesel group is avoided. All the big electrical power switches were greased to guarantee the correct operation. A new electrical contract was signed that will save around 20% of the electricity



Monthly time distribution of observing time, technical projects (T.T.), maintenance, time lost due to high wind speeds, and other adverse meteorological conditions, and technical issues.

cost. The external walls of the observatory building were repaired and painted. A new air compressor for the pneumatic system of the observatory (receiver equipment and more) was installed as a spare in case of necessity. In regard to the old maser EFOS10, an intervention by T4Science was done in October to demagnetize it and replace an internal ion pump. Due to an increasing number of problems with the old maser, even after the intervention, a new maser was bought by MPIfR/Bonn. The new iMaser 110 arrived to Granada in December. Several long time official activities have been successfully done: the High Voltage revision (every three years), the Low Voltage revision (every five years) and the Diesel Tank revision (every five years). The 20 000 liters diesel tank was filled with 6 000 liters (the previous full filling was done in 2009) and the four big bottles for the fire extinguishing in the computer/spectrometers room were revised and certified (every ten years). The following three internal documents were elaborated: "Antenna Azimuth Axis Tilt with High Winds", "Axial Focus dependence from DB and DQ temperatures", and "EFOS10 Status".

Several training courses were organized: a cooking course was undertaken by the kitchen staff, and an Alexander Technique workshop was organized in Granada.

FRONTENDS

There were no major additions to the frontend area. Substitution of a damaged vacuum pump on the NIKA2 bolometer finally solved a long standing reliability problem. The addition of filters in the local oscillator path of the E230 EMIR band has reduced even more the presence of radio frequency interferences on the EMIR bands. The situation of the HERA receiver is being evaluated.

NIKA2

All the NIKA2 parts on the initial list of spares have been received. A second list of spares, including other important and critical components like the Cryomech helium compressor and pulse tube assembly, is in preparation.

The turbo molecular pump, the source of many reliability problems, was finally replaced and connected to the water cooling circuit. The temperatures inside the pump are now stable and no more time is lost due to this particular issue. Mechanical vibrations induced by the pulse tubes, another source of extra noise and loss of performance in the past, is becoming less of an issue. Detailed documentation on pulse tube adjustment is now available. While the careful alignment of the pulse tube remains in the hands of a few well trained experts, more staff, including telescope operators, were trained to read the signs of extra noise in the noise power spectra. The experience gained in 2017 shows that the alignment remains stable over several warm-up/cool-down cycles.

Some issues with the reading of the internal thermometers are still unsolved. Observations are not affected by this problem. There are plans to replace some modules on the readout electronics.

EMIR

To aid in the fight against locally generated interferences, a waveguide filter was added to the local oscillator of the E230 band. Now, all the LO systems where Gunn devices are used (all bands except the E330, where a YIG is used) are equipped with waveguide filters.

The periodic maintenance on the cryogenic equipment needs to be done more frequently. This is probably a sign of ageing of the cryogenic components. A replacement of the Sumitomo cold head is under investigation.

A single sideband (SSB) rejection measurement system has been installed at the telescope aiding in the determination of the receiver band rejection, which is needed for a reliable calibration. This system should allow the remote measurement of the rejection at any particular frequency and band of the EMIR receiver. The system simultaneously controls the signal generation, the EMIR calibration optics and the data acquisition, and should provide a fast estimation of the SSB rejection. At the moment, the system is not available to astronomers as tests/modifications are still ongoing. Initial measurements against those obtained from astronomical lines indicate a good agreement in the calculated SSB rejection.

HERA

The multibeam receiver is being investigated and evaluated. Some of the instability problems, initially suspected as an ageing problem on the mixers, were finally identified as a degradation of the coaxial IF cables. All nine cables of the HERA-2 polarization were consequently replaced.

VLBI

As requested by the EHT consortium and to be compatible with the actual band used in ALMA and other participating observatories, the IF band used for VLBI observations will be modified from the actual 4-8 GHz band to the 5-9 GHz range. The proposed solution, in principle transparent for non-VLBI observations, will soon be implemented and tested, and it should be ready for the scheduled EHT observation early next year.

A new maser was purchased and will be soon installed at the telescope. A new set of high quality coaxial cables, for the three reference frequencies, was installed from the base of the tower, where the maser will be located, up to the receiver cabin.

Members of the VLBI/EHT team at the IRAM 30-meter Telescope in April 2017. From left to right: Salvador Sanchez (IRAM), Rebecca Azulay (MPIfR), Ignacio Ruiz (IRAM), Heino Falcke (Radboud University, Nijmegen), Thomas Krichbaum (MPIfR).

COMPUTERS & SOFTWARE

The year saw several upgrades and improvements to the computer networks, internet connectivity and computer infrastructure. These efforts were started in 2016 and will continue for most of 2018. They are leading to lower operational costs, better resource utilisation, improved science support, and overall enhanced security.

Network cabling at the observatory at Pico Veleta was upgraded to support high-speed networking up to 10 Gbit/s. Old cables were removed where possible. In addition, a commercial 300 Mbit/s fibre connection was put in place at the observatory, similar to what had already been done in the offices in Granada. The fibre connection provides an additional phone line in the control room, and, most importantly, serves as a redundant link to the observatory. New 10 Gbit/s switches were installed both at the observatory and at the office in Granada, improving communication between the main servers tenfold.

New storage appliances by NetApp were purchased and installed. They host user home directories, virtual machines as well as newly observed data. Their configuration is still ongoing.

As for science support, TAPAS was improved to support observations in Galactic coordinates. NIKA2 observations and data processing were supported as well by purchasing extra disk-space, extra IDL licenses as well as rationalising the use of available hardware and software resources. Routine support for NCS, EMIR and HERA continued as usual. MRTCAL, the calibration software for spectroscopic data, has been successfully used for online data processing since February.

In terms of general computer infrastructure, a move towards service virtualisation continued with the purchase and commissioning of three servers. Virtualisation is an industry standard technique to achieve better computer hardware utilisation and shorter service downtime resulting in improved reliability and lower operational costs. New laptops were purchased for PostDocs and staff members, and old computer monitors were replaced. New computers were also purchased for the reception, remote observing, staff and for general use.

SAFETY

A First Aid training course was given by the public emergency service on June 26, with the participation of 23 IRAM workers. The new Prevention Delegate P. Mellado has been elected on May 9th. A new semi-automatic defibrillator has been installed in the Granada office.

MISCELLANEOUS

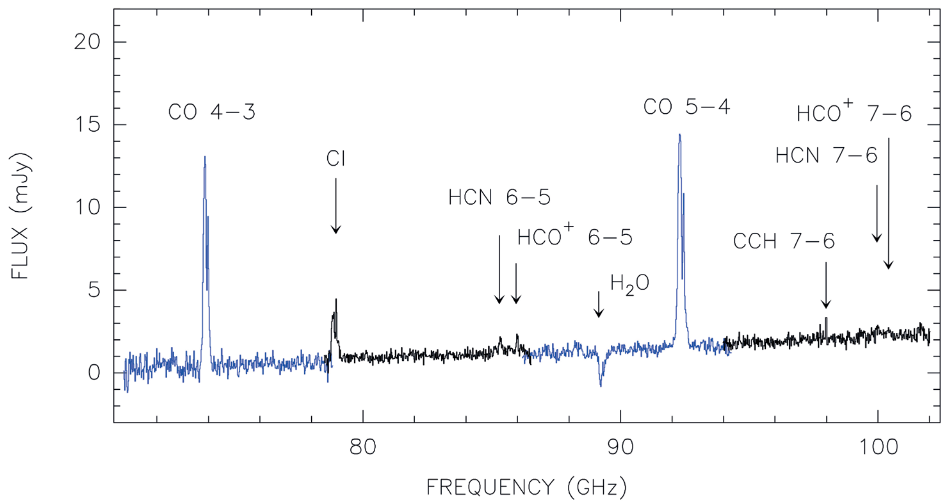
As in previous years, IRAM offered guided tours through the observatory and public talks during the summer months. Four public visits to the 30-meter Telescope and to the optical telescopes at the Observatorio de Sierra Nevada (OSN) were organized jointly by the astronomy groups at IRAM and the Instituto de Andalucia (IAA). Another four visits to the 30-meter Telescope were organised in the framework of the Campus de Excelencia with school pupils during their stay at the Universidad de Granada.

NOEMA Observatory

The NOEMA Observatory has seen several remarkable achievements in 2017: the delivery of antenna 9, the completion of the receiver upgrade program, the installation of the new correlator (PolyFiX) and related software upgrades, and, by the end of the year, the start of scientific operations with the full 9-element interferometer. This tour de force delivered the largest leap in performance the observatory has ever seen.

The delivery and commissioning of antenna 9 was the first highlight in the year. The astronomical commissioning was phased up with the annual maintenance period to ensure that NOEMA would not operate with less than eight antennas over the summer period. The first fringes with antenna 9 were obtained on April 1 towards a set of bright quasars, and within only one day of the delivery of the antenna to the astronomical commissioning team. By mid-April, the antenna was found to perform according to expectations and was made available for scientific observations.

In regard to the receiver upgrade project, all antennas were equipped with new receivers by the end of May. These receivers, which are a key part of the Phase 1 upgrade program of the NOEMA Interferometer, are dual sideband mixers designed to operate in orthogonal linear polarization, and to cover a nominal bandpass of 8 GHz in each sideband and in the two polarizations. The new receivers were found to provide excellent performance in all three spectral windows (Band 1: 72-116 GHz, Band 2: 127-179 GHz, Band 3: 200-276 GHz).



First wide-band spectroscopy with PolyFiX. This molecular survey demonstrates the power of NOEMA for molecular surveys of galaxies at high redshift. The spectrum, which was observed towards HLS J091828.6+514223, a lensed sub-millimeter galaxy at z=5.25, required two receiver tunings (blue and black) and about 4-5 hours per tuning to cover nearly 32 GHz of bandwidth in two polarizations.

The implementation of the PolyFiX correlator was the second highlight of the year. To this end, the NOEMA Observatory was shut down for science observations until the end of November. The wideband (WideX) and narrowband correlators were decommissioned on September 11. The WideX correlator has thus served for 7 years, and the narrow-band correlator was operational for almost 18 years. The new correlator processes 32 GHz of bandwidth with a nominal spectral resolution of 2 MHz, and in parallel currently provides 128 frequency windows of 64 MHz with a spectral resolution of 62.5 kHz.

Software installation and commissioning were started at the end of September, and all major components were tested and verified by an interdisciplinary team composed of people from the frontend, backend, software and astronomer groups, as well as observatory staff at Plateau de Bure. The engineering teams also performed a number of concurrent maintenance tasks on the antennas to take advantage of the shutdown period. To facilitate the deployment of the new correlator and the analysis of the first science verification observations, the antennas were arranged in the most compact configuration of the array to minimize the effects of atmospheric phase decorrelation. The major goal was to resume regular scientific observations in time for the upcoming winter semester 2017/2018.

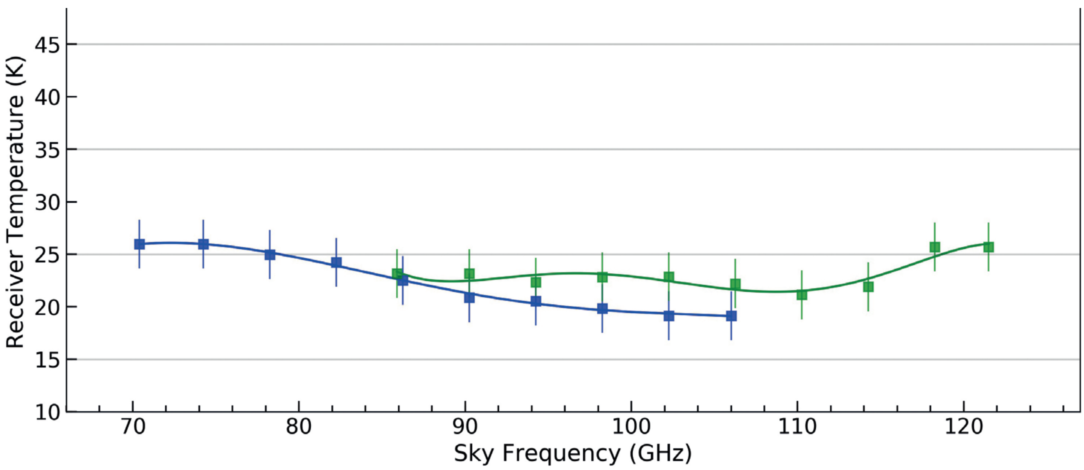
By the end of the year, the successful installation and excellent performance of the new wideband receivers, the availability of an additional antenna and the breakthrough capabilities of PolyFiX resulted in the interferometer's more than 10-fold increase in mapping speed. All these achievements paved the way for the observatory's most remarkable milestone in 2017: the opening of NOEMA to the astronomical community for regular science observations with nine antennas.

OBSERVATIONS

The antennas, receivers and the correlators, all worked well throughout the year. As usual, all observations were performed exclusively in the service-observing mode.

At the beginning of January, the interferometer was already in its most extended configuration (A), and was operating with all eight antennas simultaneously. The antennas were moved into the compact D configuration on January 20. On March 27, antenna 9 was moved out of the construction hall to undergo two and a half weeks of intense commissioning. On the same day, antenna 5 was brought into the hangar for the start of the annual maintenance period. Antenna 9 joined the science array on April 13, so that eight antennas were always available for observing during the summer period.

Observing conditions at the beginning of the year were outstanding in terms of atmospheric transparency and stability, and on average very good until the end of April. Acceptable 3 mm and occasionally fair 2 mm observing conditions were still met in the summer months during the second part of the night and typically lasting until around noon. Observing was stopped mid September to



SSB noise temperatures of a Band 1 NOEMA receiver averaged over 4-12 GHz and both polarizations. The curves are for the LSB (blue) and USB (green) sidebands.

disassemble the old correlators and install the PolyFiX correlator. Science observations were resumed at the end of November.

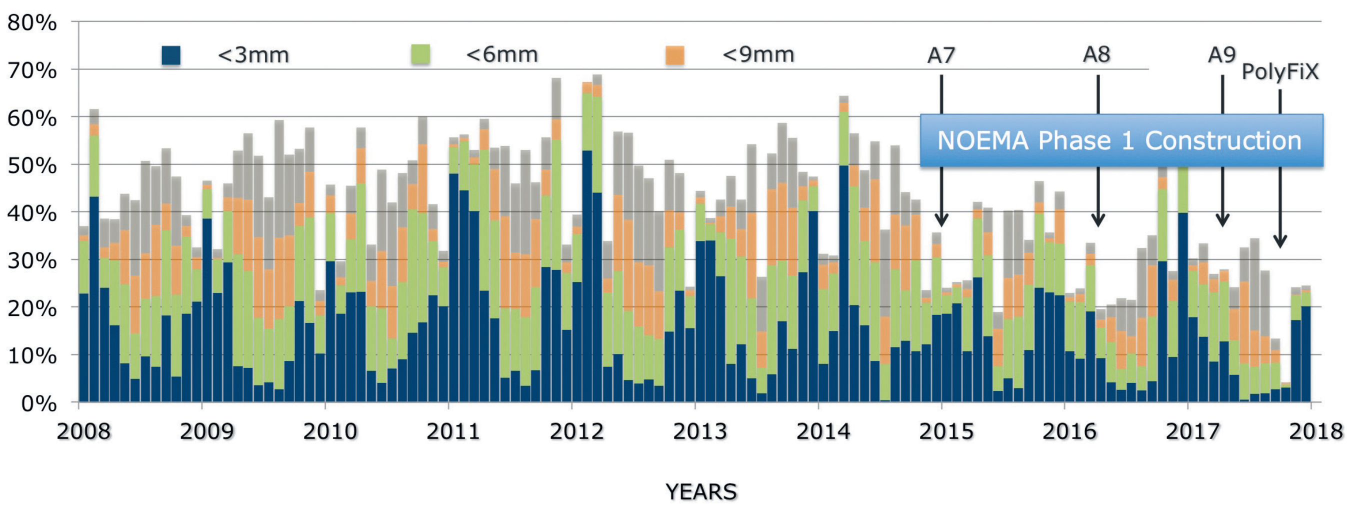
The NOEMA project foresees continued science operation during upgrade to minimize losses. With a detailed optimization of the different steps and procedures roughly half of the usual science observing time could be offered since the start of the antenna and instrumentation commissioning in 2014. The percentage of observing time invested in 2017 on science programs for the user community was on average 25% of the total time, or equivalently, 92 days. An additional 35% were for technical operations and developments: software work, commissioning and science verification operations (14%), installation of new equipment (7%), receiver tunings for user projects (6%), array reconfigurations (4%) and array improvements and maintenance work (4%); the remaining 40% were lost due to weather constraints.

The program committee met twice during the year, around four weeks after the deadlines for the submission of proposals. It reviewed 196 regular proposals and recommended 121 of them (16% less compared to 2016). Over the year, NOEMA also received 14 Director's Discretionary Time (DDT) proposals and 7 IRAM internal science demonstration and verification projects. The latter were selected to validate and illustrate the technical and scientific capabilities of the upgraded NOEMA array to the astronomical community. Including the backlog of projects from 2016, science goals from 87 proposals were scheduled at the NOEMA Observatory, including science from 3 Large Programs, 14 DDT proposals and 4 science demonstration programs out of 7. This corresponds to 171 individual sub-projects (23% less compared to 2016) that received time on the interferometer. All proposals were submitted and evaluated through PMS, the web-based Proposal Management System. The proposals to which time was granted in the course of the year are listed at the end of the annual report.

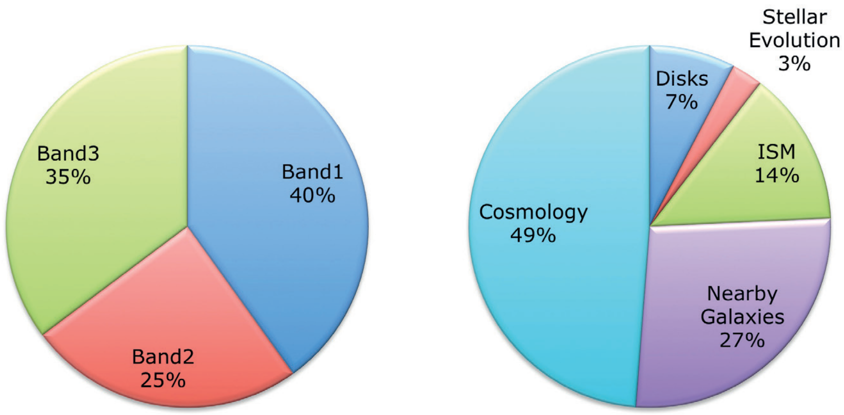
Due to the large investment in technical time necessary in the current extension phase of the NOEMA project, no new Large Programs were accepted for the interferometer under the Calls for Proposals in 2017. The plan is to reopen in 2018 the possibility of submitting Large Programs to NOEMA. Also, due to the preparation, installation, and commissioning of PolyFiX, NOEMA did not participate in the 2017 GMVA sessions. To compensate for the technical risks all projects of the winter semester 2017/2018, including A-rated projects, were observed on a best-effort-only basis.

Despite the three-month shutdown of the observatory for the deployment of PolyFiX, NOEMA continued to provide unique and extremely exciting scientific results and to demonstrate its effectiveness at exploring the interstellar medium in galaxies in the high-redshift Universe. As in previous years, the observing time requested to carry out extragalactic research was above the level of time requested for galactic science. This relates largely to the fact that only the broadband but lower resolution WideX backend could be connected to more than six antennas. The largest amount of observing time was invested in the most compact configuration of the interferometer between spring and autumn in the detection of line-emission from molecular and

NOEMA correlation time and atmospheric water vapor statistics during on sky operation over the last ten years. The overall correlation time accounts for about 25% of the total time in 2017. Arrows indicate periods of antenna commissioning and the shutdown period for the deployment of PolyFiX. Band 3 (196 – 280 GHz) and Band 4 (275 – 373 GHz) programs and observations in the most extended configuration (A) were for the most part carried out in the winter months when the atmospheric stability and transparency are highest.



atomic transitions in galaxies at high redshift. The scientific section of the annual report presents some of the outstanding results obtained in 2017 with the NOEMA Interferometer.



Requested observing time by receiver band and science category.

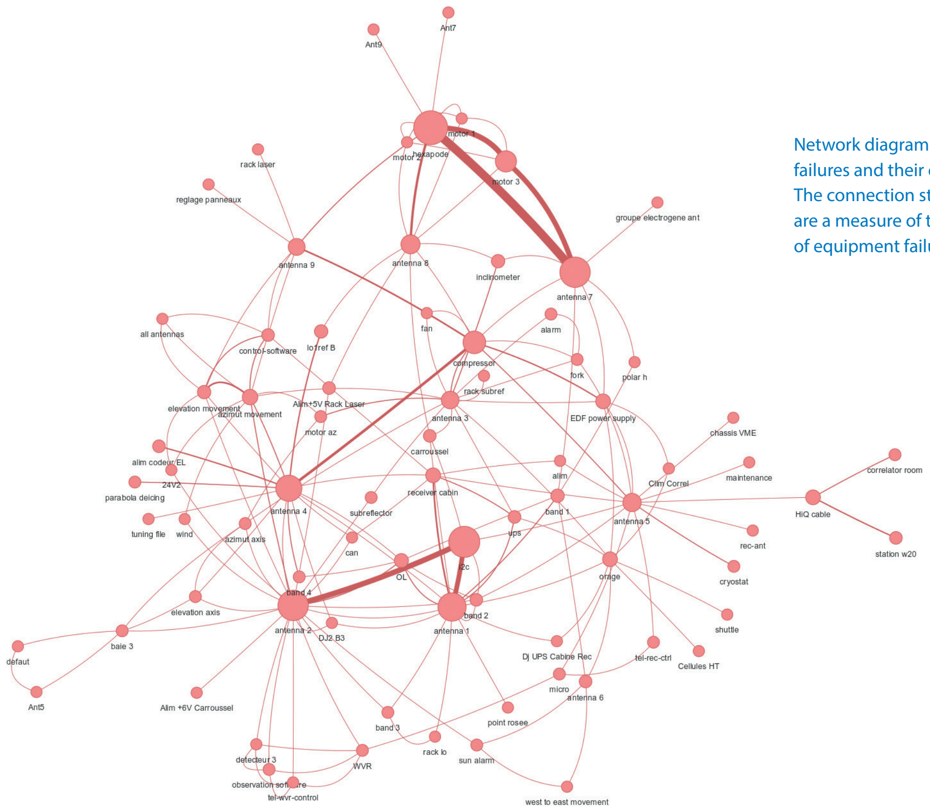
ONGOING COMMISSIONING WORK

The integration of the PolyFiX correlator into the NOEMA array was the most significant event during the intense activities of the software integration and commissioning teams. The start of the PolyFiX implementation phase began on September 20 with the delivery of the correlator to the software integration team. The goals were to take the correlator from the technical validation stage reached at the end of fabrication to an instrument that meets the science requirements, and to deliver quantitative information on the performance of the interferometer as a whole in terms of sensitivity, image quality and accuracy. The vast majority of the investigations were aimed at detecting, understanding and correcting those characteristics that were not within the specifications. To achieve this objective, the commissioning team set up specific test procedures, performed a series of measurements, and processed large amounts of data to identify areas for improvement and assess the effectiveness of software changes for a sustainable operation of the interferometer. By the end of the year, those efforts have resulted in a clear confirmation of the instrument's capabilities and a reliable operational performance. Most of the commissioning operations were made in close collaboration with the computing and engineering teams in an effort to build understanding and support across the groups. Further and refined commissioning work of PolyFiX will continue in 2018.

Within the scope of the commissioning activities, work was also necessary to assess the performance of the 2SB receivers in each sideband and polarization, and over the full 8 GHz IF bandwidth. Noise measurements were performed to identify and correct for instability issues, and remove losses due to tuning parasites and self-inflicted interferences. While the noise performance figures of the Band 1 receivers were much improved by the end of the year, work will continue in 2018 to further optimize Bands 2 and 3. In addition, significant efforts were also made to improve the operational reliability of the receivers for astronomical observations.

The activities related to the commissioning of antenna 9 included single-antenna verifications such as pointing and tracking, surface accuracy measurements, assessment of the interferometric efficiency, and verification of the overall interferometer performance. The first results from the commissioning and science verification operations show that antenna 9 is one of the best NOEMA antennas. The surface quality of the antenna was improved from 68 μm RMS at delivery to about 33 μm by means of holographic measurements. The surface panels of all other antennas were also readjusted where necessary, and iteratively improved by holographic observations. All in all, the primary surfaces of all antennas are showing excellent mechanical stability over the years, and a median surface RMS of 35 μm.

The construction of antenna 10 was pursued with some delays due to the interruption of the operation of the cable car. The mounting of the reflector was started at the end of the year, and first



Network diagram showing equipment failures and their connections. The connection strength and the circle sizes are a measure of the rate of occurrence of equipment failures.

science observations with the antenna are planned for summer 2018. NOEMA Phase 1 will be achieved with the delivery of the antenna for science operations.

Coupled to the arrival of the new NOEMA antennas, the observatory's integrated alarm system underwent a major redesign and upgrade. The project's purpose is to enhance the safety of personnel and equipment, and to improve the overall monitoring of the observatory. The new system is planned to become fully operational in 2018. Along the same line of operational improvements, a Pareto Chart software was developed and implemented to monitor the rate of occurrence of equipment failures, rank these failures in order of priority, and address them more effectively.

Furthermore, work continued on the development of a new multi-channel water vapour radiometer with improved stability and sensitivity. The new radiometer will allow easy identification of satellite interference and will have improved maintainability but, most importantly, it will help to further improve atmospheric phase corrections on the long baselines and at high frequencies. According to planning, the prototype radiometer successfully completed a first series of tests, and should be operational in one NOEMA antenna by the end of 2018.

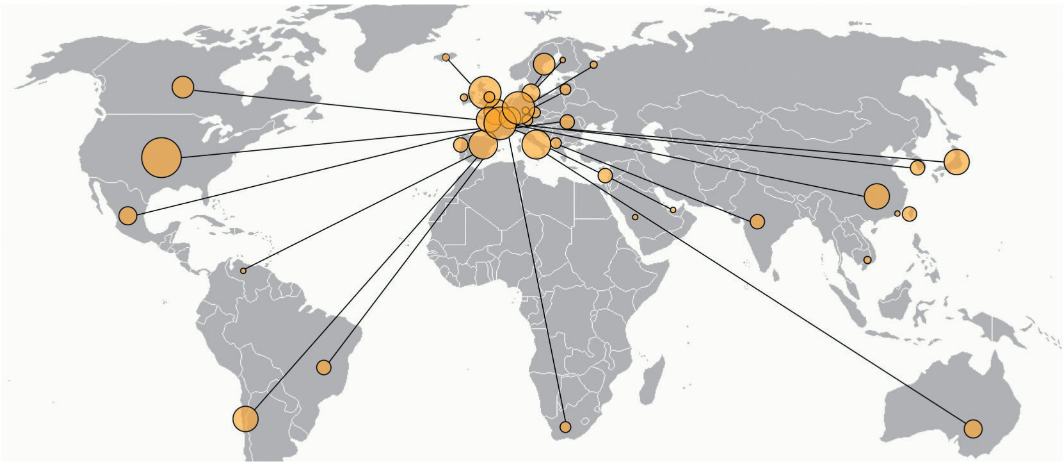
USER SUPPORT

One of the central missions of the NOEMA Science Operations Group (SOG) is to ensure that the NOEMA Observatory provides the users with the means to conduct cutting-edge research. The SOG is part of the Astronomy and Science Support Group, a group of astronomers and software engineers with a wide range of expertise and technical knowledge in millimeter wave astronomy and associated techniques. The SOG astronomers regularly act as astronomers on duty to optimize the scientific return of the instrument, directly on the site or remotely from Grenoble. The SOG also provides technical support and expertise on the interferometer to investigators and visiting astronomers for questions related to instrumental performance, observing procedures, data reduction and calibration, pipeline-processing, and archiving of NOEMA data. The SOG interacts with the scientific software development group for developments related to the long-term future of the interferometer, performs the technical reviewing of the science proposals, collaborates with technical groups to ensure that operational requirements are being met, and keeps documentation up to date. Providing the best science data is at the core of the SOG's mission.

As in previous years, the SOG managed to meet the objectives in 2017 and overcome organizational and technical development challenges in the NOEMA project. The requirements for the evolution of the tools for preparing and executing the data processing pipeline that are necessary to efficiently integrate the PolyFiX correlator into NOEMA end-to-end operations were one of the key development activities of the SOG. Much time was invested in adapting the calibration and imaging pipelines, as usual with contributions from the GILDAS group.

The IRAM headquarters hosts a regular stream of visiting astronomers from all around the world that stay at the institute for periods between a few days and a few months. While some of the visiting astronomers come to calibrate and analyze data from the NOEMA Interferometer, others are part of our visiting astronomers program aimed at training research scientists and postgraduate students in interferometry techniques, instrumentation and data reduction, and at strengthening science collaborations. In 2017, advice and assistance was given to 33 investigators from Europe and overseas, visiting IRAM Grenoble for a total of 130 days to reduce and analyze data from the interferometer. Further assistance was provided to experienced astronomers from Cavendish Lab/Cambridge, Dark Cosmology Center/Copenhagen, IAC/Tenerife, MPIA/Heidelberg, LERMA/Paris, MPE/Garching, MPIfR/Bonn, OSO/Chalmers, University of Boston, University of Hertfordshire and University of Michigan for a total of 95 days, to calibrate and analyze 13 NOEMA projects remotely from their home institutes. In total 51 science projects received support and advice. Compared to previous years, the overall level of user support remained manageable despite a significant increase in the support provided to remote users. IRAM astronomers collaborated on 39 projects in which they were directly involved.

The European Union's Horizon 2020 research program having been reestablished in 2017, financial support was made available to facilitate access to the NOEMA Interferometer for European astronomers.



Geographic distribution of NOEMA users across the world between 2010 and 2017. During this period, 1790 individual investigators from 43 countries submitted proposals for the NOEMA Interferometer.

DATA ARCHIVES AND POLICIES

The data headers of observations carried out with NOEMA and the former Plateau de Bure Interferometer are conjointly archived at the CDS, and are available for viewing via the Centre de Données astronomiques de Strasbourg (CDS) search tools. In 2017, the archive contained coordinates, on-source integration time, frequencies, observing modes, array configurations, project identification codes, etc. for observations carried out in the period from January 1990 to September 2016. The archive is updated at the CDS every 6 months (May and October) and with a delay of 12 months from the end of a scheduling semester in which a project was observed in order to keep some pieces of information confidential until that time.

Upon completion of an observational program, access to the science data is limited to the principal investigators and to their delegates. While the proprietary period of Large Programs is set to end 18 months after the end of the last scheduling semester in which the program was observed, the proprietary period of science data from standard NOEMA observing programs is set to end after 36 months after the end of the last scheduling semester. While a web-based tool to submit requests to access the raw observing data will be made available to the user community in 2018, no support will be provided in the coming years for the reduction and analysis of these data.

The IRAM Large Program Archive (ILPA) is the collection point for research carried out at the IRAM observatories in the framework of a Large Program. The goal of ILPA is to provide images, calibrated data cubes, and visibility data from the 30-meter Telescope, NOEMA, and the former Plateau de Bure Interferometer. These science ready products are made available to the astronomical community at the end of the regular data proprietary period. ILPA is the result of a joint effort between IRAM, the principal investigators of the Large Programs and their collaborators.

SITE ACTIVITIES

While the main focus at the NOEMA Observatory has been on the deployment of the new correlator and the construction of antenna 9 and 10, significant efforts have also been put into the regular maintenance program of the eight antennas. As in previous years, a huge investment in coordination and integration of the technical departments and external suppliers was required to achieve the necessary level of efficiency in both planning and execution, and a sustainable balance between science production, construction activities and maintenance work. As in 2016, to ensure that antenna maintenance work is made to match the schedule of the different activities, part of the maintenance was carried out outside the hangar.

As in previous years, the maintenance of the NOEMA antennas was done in parallel with the assembly of the new antennas. The construction of antenna 9 having already been successfully finished by the end of 2016, the empty space in the observatory's hangar could thus be used for the maintenance of other antennas. During a period of 24 weeks, all eight NOEMA antennas were brought successively inside the hangar (A5-A2-A3-A4-A1-A6-A7-A8) and underwent a thorough maintenance by the observatory's technical staff. As usual, particular care was given to the sealing of the antenna back-up structure and control electronics. Also worthy of note is the realization of vibration measurements on the geared motors in the frame of monitoring the antennas tracking performances. During the whole maintenance period, the construction of antenna 10 continued in the rear side of the hangar.

Track extension project and bypass tracks

This year has seen the focus on the preparation of the environmental dossier, which will be submitted to different administrative departments (DDT, DREAL, CSRPN, Natura2000) in early 2018. One of the main measures proposed, to compensate for the impact of the construction works, is a survey of the Plateau de Bure snow-beds by the ORCHAMP observatory (Observatoire des Relations Climat – Homme – milieux Agrosylvopastoraux du Massif alPin). The observatory's mission is to measure the link between local climate changes, changes of land use, and biodiversity in the alpine area.

As it was suspected that the site could reveal traces of human activity during the Mesolithic period, an archeological assessment of the track extension area was performed, at the request of authorities. An archeological team of INRAP (Institut National de Recherches Archéologiques Préventives) visited the site and carried out a search around the future construction area using the observatory's excavator. No significant traces of human activity were found and no further archeological excavation work is planned.

Top: Weather station at the end of the northern track with the Alps in the background.

Bottom: Weighing one antenna. The antenna is jacked up at each corner to install the precision load cells.

To anticipate potential operational difficulties in the use of the extended tracks, three independent but movable weather stations, powered by solar panel, were positioned close to the far end of the future tracks. These weather stations are operational since autumn and will provide a picture of how the meteorological parameters vary over the plateau. Should the parameters be significantly different across the plateau, the weather stations will be installed permanently to ensure the NOEMA antennas are operated using the most accurate atmospheric model.

Sections of the future baseline extensions, on which the antennas will move, will not be horizontal but have a slope of 1-2 % depending on the track's direction. In order to identify potential constraints on the antenna side, as the ability of the antennas to slow down and speed up on a slope, and the risk of buckling of the yoke's lifting rams, it was important to measure the actual weight of the antennas. Over the years, the antennas had undergone several design changes and thus only a very rough estimate of their weight was possible. To get a precise answer to this question, the weights of a first-generation antenna (A4) and one of the most recent (A9) were measured. The carriage and the antenna mount had to be lifted in three steps in order to install the high precision load cells under the antenna. The results showed that the new antennas are slightly lighter (125.9 tons) than the first-generation ones (128.6 tons) and that their carriages weigh about 22 tons each.

The final acceptance of the observatory's new bypass tracks took place in summer 2017. The intermediate winter period allowed a thorough functional validation of the tracks and identified some cracking patterns on the concrete surface that have rapidly been repaired by the construction company. At the beginning of winter 2017, the company organized the transport down to the valley of the last machines left on site.

Observatory infrastructure and access

The exterior facades of the living quarters, having particularly suffered during winter 2016/17, underwent repair work to the basement walls. This was necessary to protect the external insulation and to improve the visual aspect of the building. The external wood cladding that surrounds the building was dismounted and replaced by stained wood slats. The fasteners on the walls were also renewed to consolidate the cladding and improve resistance against ice and snow during the harsh winter periods.

The emergency staircases outside the first-floor living quarters have been replaced and modified in early summer. This new equipment with standard-size steps is much safer and much easier to keep free from snow and ice.

The 2016 refurbishment of the correlator room paved the way for the successful deployment of the new correlator (PolyFiX). Two helicopter rotations were scheduled for the transport of the different correlator units, carefully wrapped up in reinforced transport boxes.

In the context of the plan to refurbish the building of the lower cable car station, an architect was commissioned to tailor the existing space in a more rationale way, both for the storage and the passengers waiting areas of the cable car. In addition, the architect was asked to design a weather protected area that covers half of the actual car parking area to limit the accumulation of snow and ice on cars parked for longer periods of time.

The former upper station was completely emptied to provide extra storage space. While the ground floor is in the process of being rebuilt, the external access to the station was sealed off. Furthermore, the concrete slab of the floor was scratched, and the drain pits emptied and cleaned. A new concrete slab, and a complete redesign of the lower area, with storage area and shelves, is planned for 2018. The upper part of the building is still under study, but will probably be dedicated to scientific laboratories.

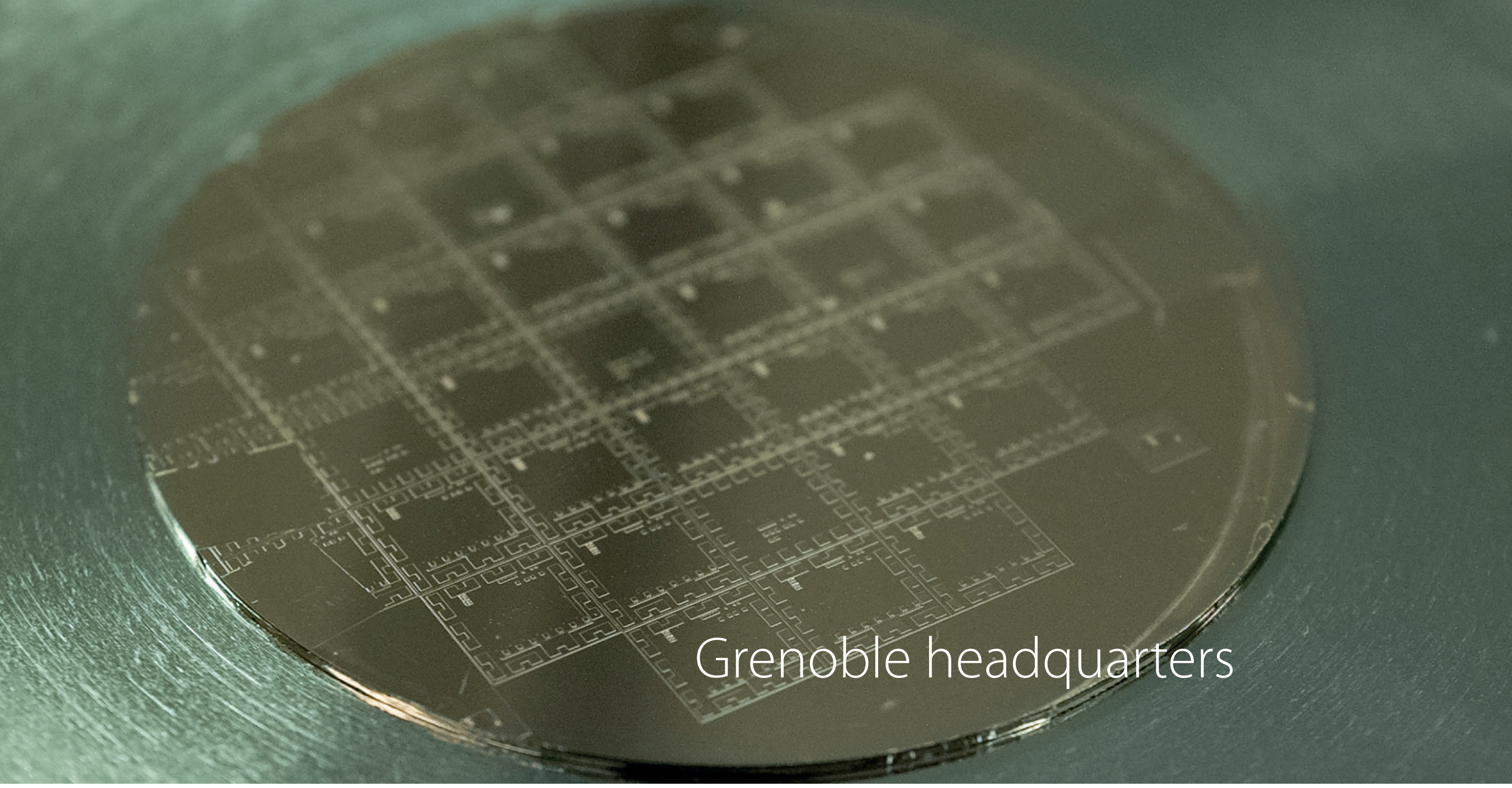
Due to the temporary shutdown of the cable car, alternative means of transport to the observatory had to be found. The pedestrian access route through the ski resort of SuperDévoluy was reactivated as of January 1st. Two specific vehicles were bought to drive the personnel, as well as external persons, to the NOEMA Observatory.

Shipping the first set of PolyFiX units by helicopter to the NOEMA Observatory.

Rotations are now ensured by means of a modified four-wheel Volkswagen Crafter with 9 seats in the summer period, and of a PistenBully PB600 snow groomer equipped with a rear cabin with 20 seats in the snow periods. As before, the vehicles are driven by a driver from the ski resort and each rotation is supervised by a professional mountain guide who oversees the safety and the smooth access to the site.

The route to the summit of the Plateau de Bure, called "La Fenêtre", is important for the observatory for several reasons. It provides the pedestrian access to the observatory and is the corridor where the EDF high voltage line and the optical fibers run together. The same passage is close to a ski lift and part of a long hiking trail (GR94B). A few years ago, rock instabilities and cliff movements were detected on both sides of the passage that could pose a hazard for pedestrians and for the electrical and optical underground connections. These rock masses are monitored by an automatic sensor system funded by IRAM, that warns about any untimely movement in the area. Under the drive of IRAM, a concerted action by local actors (Municipality, IRAM, EDF, Ski resort) and directed by the prefecture was launched to secure the area and eliminate the potential risk of falling unstable blocks of rocks. The identified areas are scheduled for mining in May 2018. To prevent possible breaks or damage to the optical fibers, spare fibers were placed in a protective sheath and moved outside of the mining areas. The next stage of the project will be to reposition the cable networks along the passage of "La Fenetre" and the deployment of a stable and sustainable walkway.

In order to preserve the working environment, the observatory made an important effort to clean up the combes around the NOEMA Observatory. In 35 years of activity, various waste had accumulated below the observatory. In collaboration with the local representative of the Natura2000 network, the waste was collected at different places, packaged in order to be airlifted to the lower station and transported to an industrial dump.

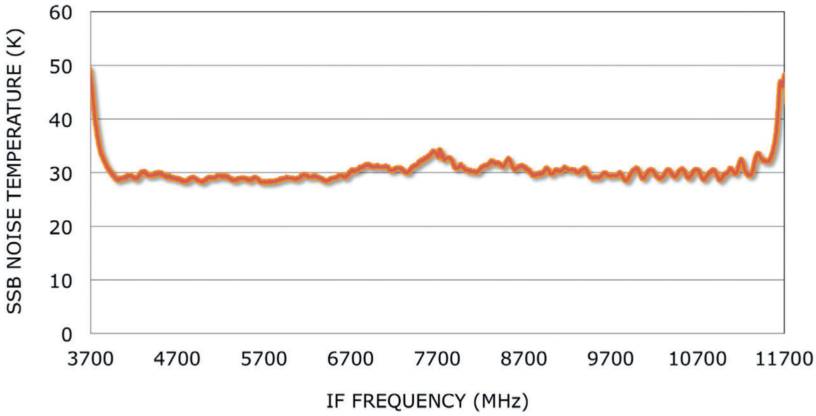


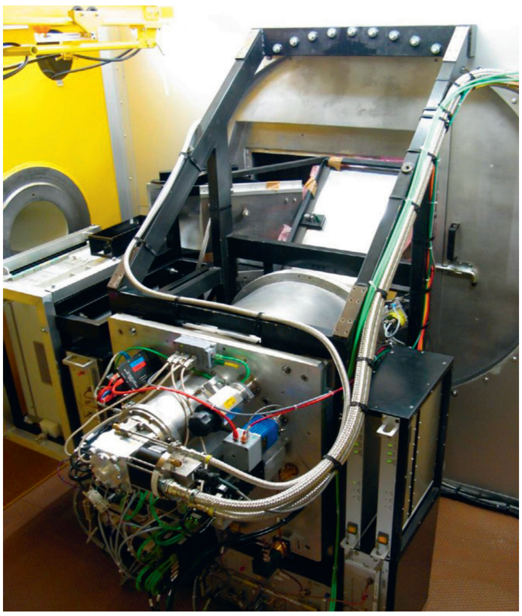
Frontend Group

The IRAM Frontend Group is responsible for the design, construction and maintenance of the receiver systems installed on both NOEMA and the 30-meter Telescope. The maintenance, in particular, represents a continuous effort that involves several interventions on site, and is critical for a smooth operation of the observatories.

NOEMA RECEIVERS

New NOEMA receivers were installed in February on the new antenna 9 and in May on antenna 6. After that last installation, all antennas at the observatory are equipped with the new receivers, a critical milestone for the NOEMA project. After the installation of the new PolyFiX correlator during the fall, all receivers have been characterized on-site in the 8-12 GHz bandwidth, which was not possible before since the previous generation of backends was only processing the 4-8 GHz band. Noise and stability were found to be within specifications, definitely proving the extremely high performances and reliability of these receiver systems. An additional receiver was assembled in the Grenoble laboratories that went through the now-standard test suite. It will be deployed on antenna 10 in early 2018.





Left: LSB mixer noise temperature at 84 GHz LO over the 4-12 GHz IF of the NOEMA Band 1 receiver. The temperature is averaged over both polarizations.

Right: the NOEMA frontend system. The assembly shows the receiver and optics vacuum vessel (center), the head of the 4 K cryocooler (front), the LO and control electronics (bottom), and the 22 GHz water vapor radiometer (left).

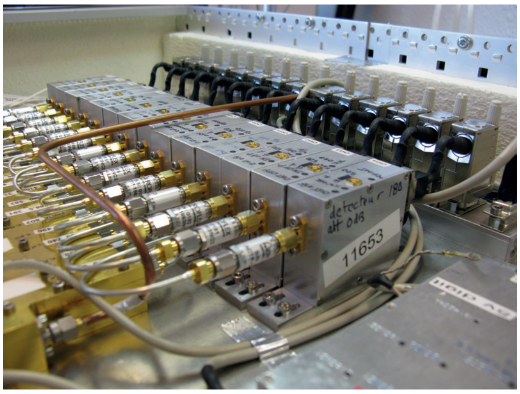
Additional developments were taking place to further improve the capacities of the NOEMA receivers in the near future. In particular, new generation EtherCat-based electronics cards were being tested, to control the junction biases. New mixer designs with improved performances were finalized.

NOEMA receivers installation schedule								
A7	A1	A2	A8	A3	A4	A5	A9	A6
Dec. 14	Nov. 15	Dec. 15	Apr. 16	Jun. 16	Aug. 16	Oct. 16	Feb. 17	May 17

Installation dates of the NOEMA receivers.

NOEMA WATER VAPOR RADIOMETERS

Water Vapor Radiometers (WVRs) are a central element in the phase calibration process of the array. For the NOEMA project, a new WVR system has been designed. It provides 14 (instead of 3 in the current generation radiometers) channels to sample the 22 GHz water line. Measurements are then used to derive the phase offset introduced on the signal by the water vapor present in the atmosphere; this phase offset is corrected in real-time by the correlator system. A prototype of the new WVR has been assembled and will undergo a complete testing phase before being deployed at the observatory in 2018.



The 14 detectors assembled within the prototype of the new generation Water Vapor Radiometer.

DUAL-BAND NOEMA RECEIVERS

In a specific upgrade, NOEMA will have the capacities to observe simultaneously with two receiver bands. The LO system and signal transport equipment are already in place and a second PolyFiX correlator will be built. The receiver optics has also to be modified in order to ensure the two selected bands are looking at the same position in the sky. Design studies have been started to investigate the different possibilities: warm or cold, fixed or movable optics. A prototype of a new optical module combining two bands and the associated OMTs was manufactured.

PHASE MONITORING PROJECT

In close collaboration with the SubMillimeter Array (SMA) group from the Center for Astrophysics (Harvard, USA), an atmospheric phase monitoring system was built and installed on the roof of the Grenoble building for testing. Composed of two commercial TV antennas connected as interferometer, the system observes the broadband 12 GHz signal from geostationary telecommunication satellites and allows for detection and monitoring of the atmospheric phase at that frequency. A similar system is operated at the SMA observatory on Mauna Kea (Hawaii). Depending on the test result, it may be deployed on the Plateau de Bure, in order to better characterize the current atmospheric conditions and provide input to the dynamic scheduling of the array.

AETHRA AND RADIONET

IRAM is a major partner in the European Union's Horizon 2020 funded program RadioNet. In particular, the Frontend Group is heavily involved in the JRA AETHRA project (Advanced European Technologies for Heterodyne Receivers for Astronomy), which gathers research and development activities in more than 10 leading institutes across Europe in the field of sub-mm receiver technologies. IRAM is specifically working on two projects:

- Development of a receiver using direct amplifiers (LNAs) in the 70-116 GHz frequency range.
- Prototyping of a multi-beam receiving system at 230 GHz, with mixers, amplifiers, and LO distribution integrated in the same mechanical blocks.

Both projects are very ambitious and will pave the way for future developments in particular for multi-beam arrays for the 30-meter Telescope.

RECEIVER FOR THE MAX-PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH

Dual-band receiver constructed by IRAM for the Max-Planck-Institute for Solar System Research.

During the last years, IRAM has designed and assembled a complete dual-band (2 mm + 1.3 mm) receiver for the Max-Planck Institute for Solar System Research (MPS) in Göttingen, Germany. The receiver is based on NOEMA developments, and is in particular equipped with the Band 2 (2 mm) and Band 3 (1.3 mm) 2SB mixers. In 2017, the final testing of the receiver and its control system took place in the Grenoble laboratories. The dual-band receiver was delivered to the MPS in April 2017. It will be used as radiometer for atmospheric sounding and be installed at the Zugspitze scientific station in the German Alps.

Superconducting Devices Group

As in previous years, the work of the Superconducting Devices Group has focused around the three main themes: SIS junction devices, KID development, and other nanofabricated microwave components. After the finishing of the SIS junction devices production for the NOEMA receivers in 2015, the group has been able to invest its resources fully in research and development projects. This has resulted in several exciting new results.

PROTOTYPE ARRAYS FOR NIKA2 IMPROVEMENT

Kinetic-Inductance Detector (KID) development has focused on the development of a prototype detector array that would take full advantage of the angular resolution of the IRAM 30-meter Telescope. A small field-of-view array was developed for the 1.2 mm channel of NIKA2, which employs smaller pixels. Laboratory tests, in collaboration with the NIKA2 team at the Néel Institute, revealed that the individual pixels of this array will indeed improve the angular resolution from the 10.9" currently obtained by NIKA2 to an estimated 10.2". As an added bonus, the pixels were also a factor 2 more sensitive than the actual NIKA2 pixels. Work on this project will continue in 2018, with the goal of proposing a possible upgrade of the NIKA2 260 GHz arrays.

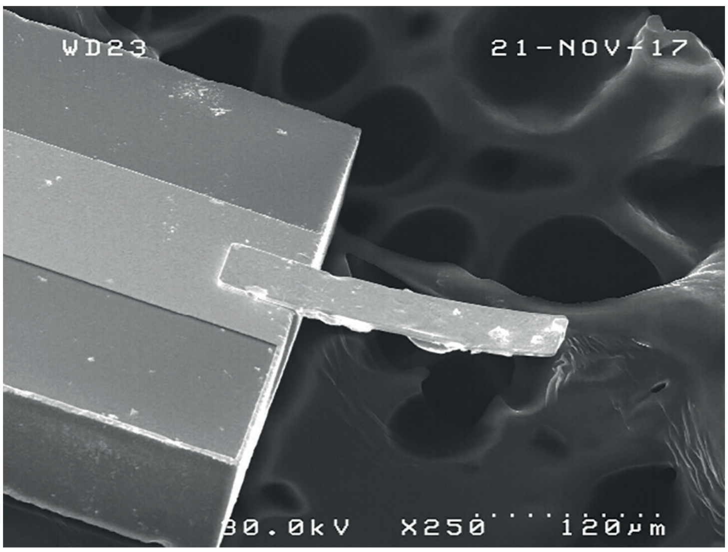
WAFER LAPPING MACHINE

In January, the group acquired a wafer lapping machine. This machine has been set up to reduce the thickness of SIS junction wafers, from an initial thickness of 280 µm to the desired thickness of 90 µm. This crucial final step of the SIS junction fabrication process has until now been subcontracted. By acquiring this machine, the group has gained complete independence from subcontractors for the SIS fabrication. This is advantageous for the stability and reliability of the SIS production line, but it has also allowed the group to launch new ideas for device production that where impossible to develop using a subcontractor.

The new wafer lapping machine.

BEAM LEADS

In 2015, the group launched a project to propose free-standing beam leads on quartz-based devices. These beam leads act as contact pads and will facilitate the packaging of the devices, while reducing significantly the stray inductance caused by the currently used bond wires. The first functional microwave devices using this technology were delivered to the Frontend Group, and are currently being tested. The work in this project now focuses on stabilizing and professionalizing the fabrication procedures, so that this technology will become a standard part of the group's capabilities.



Scanning Electron Microscope (SEM) image of a free-standing gold beam lead on a device substrate. The beam lead is approximately 4 µm thick and extends about 150 µm from the edge of the fused silica substrate.

OTHER DEVELOPMENTS

Besides the major developments outlined above, the group participated in and launched several smaller development projects, ranging from dichroic filters, to flat silicon optics, to improved superconducting materials for KIDs. Moreover, first steps were made to develop a silicon-on-insulator technology for the SIS devices. All of these developments will continue in 2018.

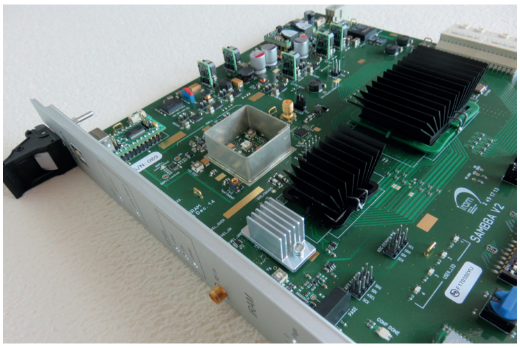
With respect to the ageing equipment in our clean room, discussions have been ongoing with a multitude of suppliers. This has already resulted in the acquisition of a new wafer dicer, planned to arrive January 2018. A long-term investment plan to renew and improve the equipment is being developed to consolidate the group's world leadership in superconducting millimeter-wave detectors.

Backend Group

Almost all of 2017 was dedicated to the series production, assembly and testing of PolyFiX, the new correlator system for NOEMA. By October, the backend group successfully delivered and installed the complete PolyFiX system to the NOEMA Observatory.

DIGITAL CORRELATOR

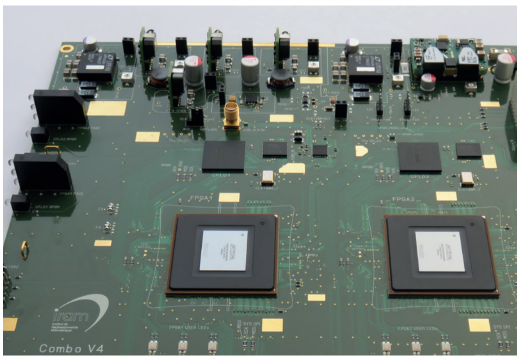
The PolyFiX correlator hardware and gateware developments continued all along the year's first semester with the goal of having the complete system installed on site in the summer. The different cards composing the system went through a last design iteration prior to go to series production.



Close view of the PolyFiX Digitizer card showing the 8 GHz PLL shielded enclosure, the Analog Front-End stage, the 8 GSps ADC and the antenna-processing FPGA.

Digitizer card

The design and tests of the second version of the Digitizer card were finished during winter and then immediately produced in series. All of the 118 fabricated cards underwent unitary tests before integration into the system. Notably, the ADC interleaving parameters were adjusted with help of test software that performed the statistical and spectral analyses of the samples captured by the ADCs.



Close view of the PolyFiX correlator card showing the baseline-processing FPGAs. Each of them ensures the processing of 66 crossspectra and of 12 antenna power spectra over four 64 MHz windows, each with a spectral resolution of 2 MHz resolution, and of one 64 MHz window with 62.5 KHz resolution.

Correlator card

A series of 78 correlator cards underwent laboratory unitary tests in early 2017 prior to their integration in the PolyFiX cabinets. Simultaneously, the FPGA designers were highly committed to a sustained effort in the development of the VHDL code in order to get the firmware ready for the signal processing and the 6+3 Gbps serial data transmission system. By end of June, such work was crowned by the acquisition of the very first cross-spectrum, a major milestone in the development of the PolyFiX project.

System test

Once the whole set of cards composing the PolyFiX system had passed the stand-alone tests, all cards were integrated into the cabinets for a final check with a specifically developed real-time test software. While PolyFiX was designed to provide a correlation capacity for up to 12 antennas, by the end of the summer it was populated with digitizer boards for 10 antennas. The remaining digitizer boards will be installed later on after successful debugging.

Technician performing system integration tests on a PolyFiX unit before its shipping to the NOEMA Observatory.

SYSTEM DELIVERY AND ON-SITE INSTALLATION

To avoid generating a delay in the testing of the correlator real-time data acquisition software packages, the first two PolyFiX cabinets whose processing of one polarization and two 8 GHz sidebands was already functionally validated, were transported to the observatory in early September, while the two remaining cabinets were undergoing final integration tests in the Backend laboratory.

The installation of the PolyFiX correlator at the observatory started with the dismantling of the 18 years old narrowband correlator and its 7 years old wideband companion (WideX). Soon after, all the cabling was installed to accommodate the first two cabinets in the correlator room.

Then, in a second shipment phase, the PolyFiX system was completed with the last two cabinets to support the processing of the second polarization outputs. After a successful connection to the rest of the system, PolyFiX was available for software commissioning in early October.

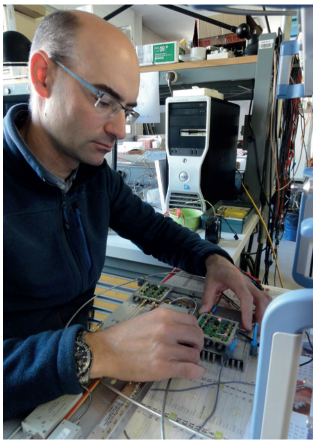
The total processing bandwidth of PolyFiX is 32 GHz, on two simultaneous polarizations, with a channel spacing of 2 MHz. In parallel, 128 frequency windows of 64 MHz, corresponding to one fourth of the total bandwidth, can be allocated within this bandwidth for spectral zooms with 62.5 KHz resolution.

These capabilities correspond to a 20 peta-MAC/s processing speed, which is more than a 20-fold increase in speed with a slightly lower power consumption (8 KW) with respect to the previous correlator system.

The first PolyFiX cabinets carefully packed and ready for shipping to the observatory.

Front view of the full PolyFiX system. Each of the four cabinets is processing an 8 GHz sideband from the NOEMA receivers.

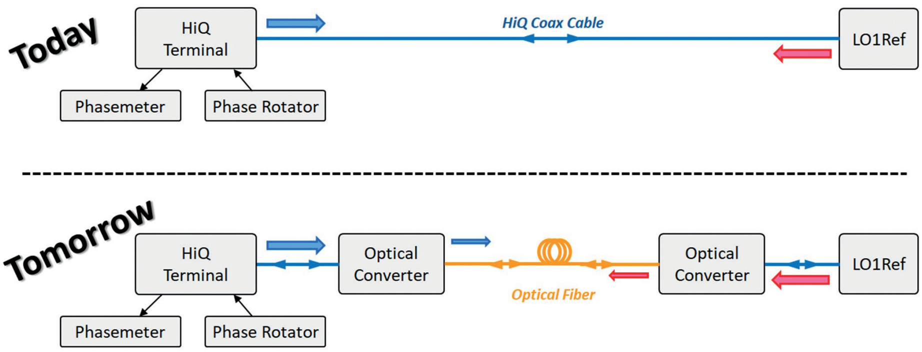
PHASE REFERENCE TRANSMISSION OVER FIBER



In regard to the NOEMA baseline extension project, the current LO Control system will not be suitable anymore. The reason is that the current system is based on a round-trip measurement that would suffer from excessive attenuation of the reference signals by the HiQ coaxial cables.

The Backend Group started preliminary studies for a future optical transport system of the reference signals. The design is targeted as an add-on module that will be introduced at both ends, as a substitute to the current coaxial cables. Several commercial optical links have already been selected for performance evaluation. A fine-phase measurement setup will also be built in parallel to perform laboratory tests and characterization. The plan is to build a test bench and to perform the first on-site measurements in 2018.

RF engineer testing the optical modules.



Sketch of the future optical system for the transport of NOEMA reference signals.

Mechanical Group

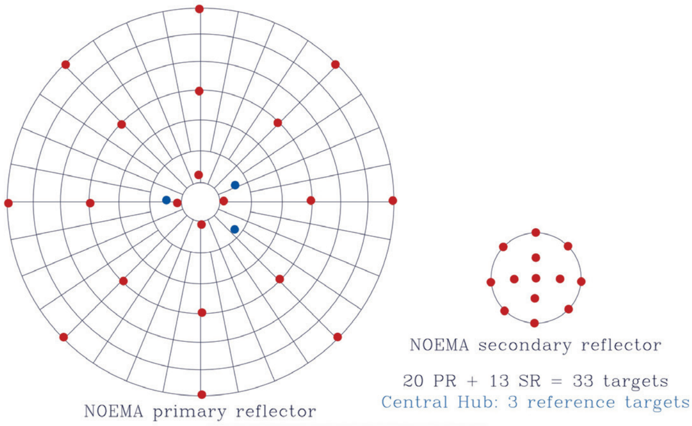
The group has dealt with a total of 123 requests for mechanical components, 105 of which were handled internally, and 18 were subcontracted to outside companies. The group's main activities were driven by the construction of antenna 9. While the antenna was handed over to the commissioning team in March, the validation of the functional aspects was only completed in September. The latter operation was made in close collaboration with the NOEMA system engineers.

MECHANICAL WORKSHOP

The workshop produced a large number of microwave components for NOEMA and NIKA2, among which mixers, couplers and horns. In addition it manufactured prototypes in collaboration with engineers from the IRAM Frontend Group. Coupled to the need to gain expertise in the electrical discharge machining process, parts were produced with the laboratory machines that have undergone a conceptual analysis to evaluate future production opportunities for an electrical discharge machining.

TECHNICAL SUPPORT FOR THE NOEMA ANTENNAS

The group took an active role in the deformation analysis of the primary surface of antenna 8. The scope of the project was to look for possible elevation-dependent surface deformations in a thermally stable environment. For this purpose the antenna was entered into the hangar and equipped with 33 sensors, 20 on the main reflector and 13 on the secondary mirror. A series of measurements were made by cycling the antenna 3 times between an elevation of 5° and 90° in steps of 10°. All measurements were made with an AT960 LR LEICA laser tracker in collaboration with SETIS, IRAM's metrology service provider.



The target distribution as shown by the red circles – 4 targets on ring 1 panels, 8 on ring 3 and 4 panels, 8 on ring 6 panels and 13 on the secondary mirror. In addition, 3 reference targets (blue circles) were placed in the central hub.

The mechanical group designed, produced and installed the pieces to fasten the targets on the panels, and the mechanical interface to support the laser tracker on the central hub. The main difficulty was to design a support for the laser tracker that was rigid enough at all elevations to perform surface measurements with an accuracy of a few microns.

The measurement points were fitted with parabola (main reflector) and hyperbola (subreflector) shapes, taking into account the surface-normal offsets due to the tracker ball supports. Based on the reference targets placed within the central hub, it was concluded that the laser tracker support installed on the crown of the central hub was stable, and was only showing minor elastic deformations. Moreover, the main reflector structure was found to show no significant second-order surface deformation with elevation. Elevation dependencies of tilts, shifts and focal variation were to good approximation sine or cosine, as one would expect for a homological reflector structure. The focal point of the main reflector and the hyperboloid focal point only moved by about 280 µm along the optical axis, over the measured range of elevations. This displacement is within the range of displacements expected for an active correction of the subreflector position. By the end of 2017, the residual lateral translation of the focal point together with the shifts and tilts of the optical components were the subjects of a study to refine the pointing model of the NOEMA antennas.

NOEMA ANTENNA TECHNICAL REVIEW PROCEDURES

At the beginning of the NOEMA project, the Antenna Work Package Group (ANT) was facing organizational challenges and the need to adapt work processes. Work to prepare for the retirement of a senior staff member of the group, the organization of the batch conversion of drawings into electronic 3D CAD files, and the launching of the challenge of constructing between 4 and 6 antennas in the shortest possible time, were some of the issues the ANT Group had to deal with. Under these circumstances, there was a clear need to develop project management oriented tools in order to follow up on the construction of the antennas and make sure that they meet expectations and requirements.

The procedures, amongst which the preparation and submission of a detailed planning and the implementation of mechanical, functional and safety checklists that had been put in place and applied for antenna 7, have evolved over time. Coupled to a high-quality assembly and testing, these procedures allowed to complete the construction of antenna 9 in 2017 within time and budget constraints, and to make the antenna

NOEMA engineer performing a system verification review in the pedestal of antenna 9.

available for scientific observations after a relatively short commissioning time. A specific shared folder structure was put in place, where the checklist and manufacturer conformity certificates are stored.

Four verification reviews that included the filling of checklists have taken place during the construction of antenna 9 to make sure that every sub-assembly was in good shape at each stage of the construction. The first review consisted in mechanical checks and was conducted at the end of the installation of the carrier, pedestal and fork, and after the alignment of the azimuth and elevation axes. The second review was made after the installation of the thermal insulation of the fork, and when most of the electro-technical work and most of the positioning of the central nodes were completed. The third review was performed next to the assembly of the primary reflector and after the installation of the subreflector positioner (hexapod). The final checklist session was held at the end of the antenna assembly and before handing the antenna over to the commissioning team. The final review consisted essentially in a series of functional and safety checks.

Computer Group

NEW WEB APPLICATIONS

The Computer Group installed ownCloud, an open source self-hosted file share application, very similar to Dropbox. With this web application, IRAM users can easily share documents, even big files like videos or computer-aided-design drawings, with virtually anyone in and outside IRAM. This application covers a real need, and many users have immediately adopted it.

Some IRAM astronomers wished an easier tool to share and comment scientific news among them. For this scope, a WordPress-based blog named Astrolife was created. Astronomers enjoy it because it is an easy web application to animate their scientific local life and allows most of them to send every week new posts to the blog.

The Computer Group installed GitLab, a self-hosted open source development platform, that offers built-in version control, issue tracking, code review, continuous integration and more. GitLab is a tool, very similar to GitHub, that improves developer effectiveness. It runs at IRAM since January 2017 and twelve months later, it was already hosting 40 projects.

SOFTWARE UPGRADE

The virtual Windows servers were upgraded to Windows Server 2016 Datacenter. This new version has an easier and nicer graphical interface than Windows Server 2012, but the main reason for the upgrade was to benefit from an unlimited number of virtual Windows instances. This feature is exclusive to the Datacenter edition.

HARDWARE UPGRADE

The NOEMA acquisition servers were upgraded to support the new PolyFiX correlator and its huge data rate requirements. The 4 new servers are high-end Dell PowerEdge R630 servers with dual Intel Xeon E5-2667v4 CPU, 512 GB of RAM and six 10G Ethernet interfaces.

The headquarters Xen cluster was upgraded with new nodes. The cluster has still 3 nodes but with much more cores and memories (28 cores / 384 GB of RAM per node). It runs Citrix XenServer 7.2. The former Xen cluster was retrograded as a staging cluster to test new software, operating systems and recovery procedures in a realistic environment without interfering with operations.

NETWORK UPGRADE

The French national effort to deploy a very high-speed network for every citizen runs slower than expected. As a consequence, no high speed Internet connection is available yet at the ski resort of Super Devoluy, underneath the NOEMA Observatory. For this reason, IRAM has subscribed a temporary 8 Mbps SDSL line to transfer the observed astronomical data between the ski resort and its headquarters. The optical fiber connection between the observatory and the ski resort is already operational.

Science Software Activities

NEW CALIBRATION SOFTWARE FOR THE IRAM 30-METER TELESCOPE

Mid-February, the new MRTCAL software replaced MIRA to calibrate on-line spectroscopic data, except for observations carried out in polarimetry mode. After years of development and preparation, the transition to the new calibration software has gone smoothly and without any interruption to observations. Additional adjustments to the on-line behavior of the software have been made in the three months after the swap and they have proven to be robust. The benchmarks show that MRTCAL is not only significantly improving the calibration scheme for broad-bandwidth data but is also about 10 times faster than MIRA. The calibration software also corrects for approximations in the Earth orbital motion and for other effects that were not previously accounted for by MIRA. All of these improvements will be decisive for the best possible use of the future heterodyne multi-beam cameras at the IRAM 30-meter Telescope. Finally, work is underway to ensure that the spectral polarimetry mode will also be handled by MRTCAL.

SOFTWARE INTEGRATION OF POLYFIX

The integration of PolyFiX in the online data acquisition software of the NOEMA Interferometer was an important achievement of the science software team. Much preparatory work was necessary prior to the on-site software integration phase that led to the September to November shutdown of NOEMA science operations. The interferometer's ability to cover 16 GHz bandwidth in each polarization and the requirement to simultaneously acquire continuum and spectroscopic data at different spectral resolution, make PolyFiX an extremely versatile and powerful spectrometer. This versatility and the associated increase in the data rate by a factor of up to 30, called for a major upgrade and a thorough optimization of the acquisition and online calibration software. Considerable software modifications were made in the RDI and CLIC raw data format, in OBS, the interferometer control interface software, and in XYAFF, the tool that monitors the quality of the acquired data. The transition from single-sideband receivers to receivers that deliver simultaneously both the LSB and USB sidebands, also required a thorough revision of the calibration steps (radio-frequency bandpass, amplitude, phase, absolute flux), which are used during the offline data reduction and calibration processes. The calibration pipeline underwent significant revision that resulted in better-structured software and major performance boosts with up to 8 hours of observations reduced and calibrated in less than 30 minutes. During the commissioning phase, first steps were undertaken to stabilize the pipeline behavior, but further optimization of the calibration algorithms and pipeline will continue in 2018, as experience will increase with NOEMA's new capabilities. Finally, the advent of PolyFiX triggered a series of changes in MAPPING, the GILDAS imaging and deconvolution software. The definition of the spectral axis was modified to improve corrections on Earth's orbital motion in the tables that contain calibrated visibilities for synthesis imaging. This work on the imaging software is made in collaboration with the Observatoire de Bordeaux and is laying out the path to further extend the broad bandwidth and high spectral resolution capabilities of NOEMA.

OBSERVATORY MANAGEMENT SYSTEM AND SCIENCE SOFTWARE GENERAL SERVICES

Several years ago, the Science Software team started refurbishing the software system that handles the submission and subsequent management of science proposals by creating the web-based Proposal Management System (PMS). Based on the success of PMS, the team started to develop the Setup Management System (SMS), a web-based application for the creation of observing procedures for the execution of astronomical projects at the NOEMA Observatory. Both systems share the same kernel engines and have the same look-and-feel. They are thus collectively named Observatory Management System (OMS). SMS allows the IRAM contact scientists to fine-tune the observing procedures of accepted projects to ensure the best possible science is done in accordance with the project goals. In this line of reasoning, SMS proposes potential solutions to adapt frequency setups optimized for a source at a given LSR velocity to a source with a different velocity, thereby saving many time-consuming manual operations to the contact scientist. This system also ensures that all the parameters required to monitor the scheduling and completion of an astronomical project are included in its observing procedure. By the end of the year, OMS was integrating into one framework a suite of software tools developed over the years by the NOEMA Science Operations Group. In the course of this project, the flexibility of PolyFiX challenged both the design of Proposal and Setup Management Systems. Much work for the delivery of PMS and SMS was done in February and September, respectively.

All of the above listed software developments are dependent on the common GILDAS services e.g. OMS makes extensive use of ASTRO, the GILDAS program that encodes ephemeris information of astronomical targets. The handling of astronomical map projections was extended to include new representations like the Mollweide projection. Less visible but important efforts were also made to support the parallel compilation of the GILDAS source code to speed up future software developments and allow users to take advantage of the multicore architecture in the execution of GILDAS programs.

Astronomers and software engineers at one of their weekly meetings.

IRAM ARC Node

IRAM is a node of the European ALMA Regional Center (ARC) network, the structure responsible for the ALMA science operations in Europe. While the central ARC at ESO Garching is responsible for the scientific operations of the ALMA observatory, the nodes are more specifically in charge of supporting users, in particular during the data reduction phase.

IRAM's involvement in the ARC is part of a long-term, global involvement in the ALMA design, construction, and support. One of the main goals of the IRAM ARC node is to provide to the astronomical community a common support for the IRAM and ALMA facilities, hence maximizing the scientific synergies between the observatories.

ALMA USERS SUPPORT

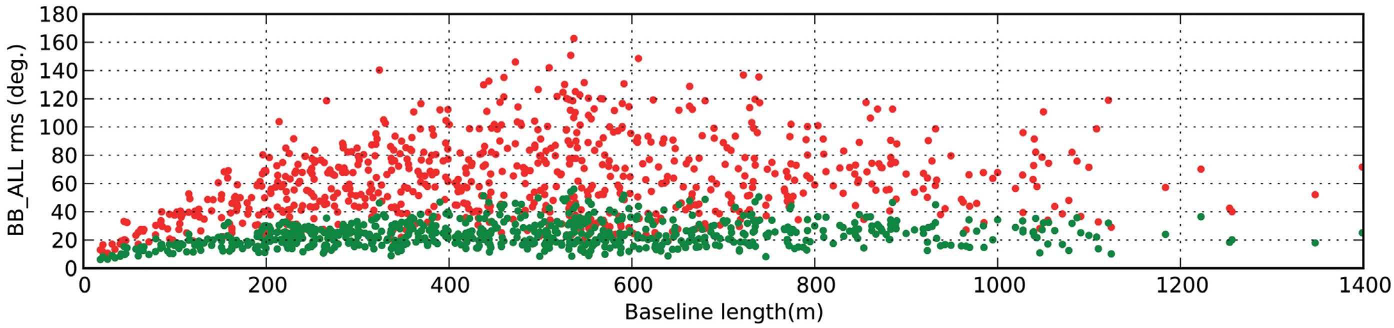
The ARC node staff acts as "Contact Scientists" for the accepted ALMA projects, providing help and expertise to check and validate the Scheduling Blocks that are created from the initial proposals. The IRAM ARC node supports projects from the French, German, and Spanish communities. In 2017 (Cycle 5), this amounted to 80 projects, including two Large Programs and 2 DDTs.

A major service provided by the ARC node is the face-to-face support for data reduction: users can obtain direct help from an IRAM astronomer for the data reduction, in a way similar to the support provided for the NOEMA projects. Travel funding is available for users affiliated to the IRAM funding agencies. In 2017, 15 projects were supported during face-to-face visits in Grenoble. Part of the travel funding was made available by the European MARCUs initiative.

TELESCOPE CALIBRATION SOFTWARE

Since 2003, IRAM has been responsible for the development and maintenance of one of the key software for the real-time operations of ALMA, the Telescope Calibration (TelCal) software. TelCal is performing all real-time calibrations necessary to operate the array. Both astronomers and software engineers were involved in this work that largely relied on the experience obtained from the Plateau de Bure and NOEMA systems.

The contract with ESO and therefore the involvement of IRAM came to an end in December 2017, marking the completion of a very successful development and contribution to the ALMA project.



Example of result of TelCal processing, showing for all ALMA baselines, the phase RMS as measured on sky (red points) and after phase atmospheric correction (green points).

Administration

Digitization and its resulting paperless processing continued within the administration. IRAM is continuously striving to find global solutions involving both the French and Spanish sites.

A time-management tool was set up for all French sites with the objective of implementing it on the Spanish sites in 2018. The introduction of such software tool at the upstream of the payroll, secures the integrity of the provisioned data. In addition, it allows managers to have a comprehensive management tool for the working hours and activities of their employees. This software is available for all employees via a simple Internet connection while retaining the maximum security required. This has been made possible thanks to the technical support of the Computer Group.

Beyond this step, the administration of IRAM has given itself a challenge: go paperless by 2020 but ensure a real-time accessibility to information from everywhere over the Internet.

IRAM employed 30.8 FTE in Spain and 81.4 FTE in France. It should be noted that in 2017 nearly 20% of the IRAM employees in France were aged less than 35 years. Its recruitment strategy is intended to attract highly specialized people in various sectors while ensuring gender diversity and generation renewal.

FINANCIAL RESULTS

Income in k€	Actual 2017
Contributions from associates	23 616
Other income including budgetary result	13 704
Total income	**37 320**

Expenditure in k€	Actual 2017
Operation	12 128
Investment	2 960
Total expenditure	**15 088**

Project reserve in k€	Actual 2017
NOEMA Phase 1	5 086
NOEMA Phase 2	11 256
NOEMA Dual Band extension receiver + second correlator	3 875
Other	2 015
Project reserve in k€	**22 232**

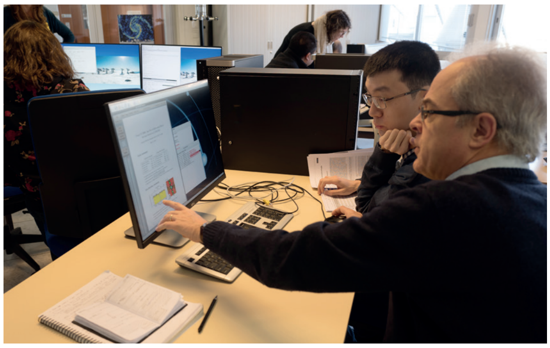
SAFETY

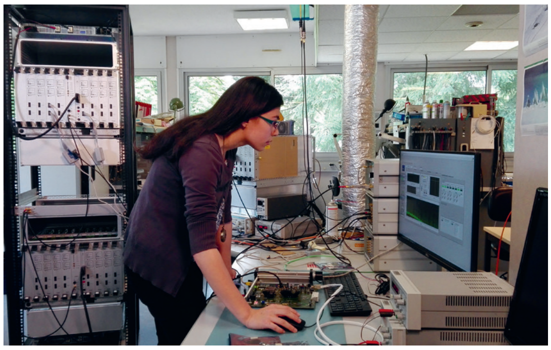
IRAM continued to drive a pro-active approach to safety management. As in previous years, the staff participated in safety practices to minimize exposure to risks in the workplace, and when travelling between the headquarters and the NOEMA Observatory. In this context a two-day training on driving safety was held in October for the personnel working and having duties at the observatory. The training was mainly focused on driving in winter road conditions.

To protect the staff at the NOEMA Observatory from chemical and fire fumes, all the observatory's dorm rooms were equipped with escape hoods. This equipment is simple to don and provides effective protection for several minutes in emergency situations.

The NOEMA Observatory was equipped in October with two fully autonomous digital radio systems for out of area operations or in case of failure of the NOEMA radio relay system. The new systems work on standby power for up to 24 hours, are able to communicate reliably with radio relay stations in the vicinity of the observatory, and provide accurate geo-positional information to local emergency services.

Within the context of fire risk analysis, the smoke detectors were replaced in all of the NOEMA antennas with optical detectors, which are more sensitive to the early smoldering stage of a fire.



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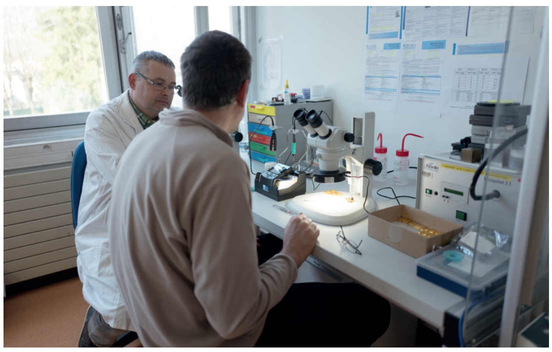

IRAM staff list

IRAM Headquarters, Grenoble, France

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SANTIAGO Joaquín	
SERRANO David	
SIEVERS Albrecht	
TORNE Pablo	
UNGERECHTS Hans	

Telescope schedules

30-METER TELESCOPE

Project	Title	Authors
085-16	Search for gas emission from Centaur object 174P/Echeclus in outburst (ToO)	Emmanuel Lellouch, Raphael Moreno, Dominique Bockelee-Morvan, Gabriel Paubert, Nicolas Biver
086-16	Probing the nucleus ice composition of comet 41P	Nicolas Biver, Dominique Bockelee-Morvan, Jacques Crovisier, Pierre Colom, Jeremie Boissier, Darek LIS, Raphael Moreno, Gabriel Paubert, Neil Dello Russo, Harold Weaver, Ronald Vervack, Boncho Bonev
087-16	The first detailed look at the outbursting comet 41P/Tuttle-Giacobini-Kresak	Barbara Handzlik, Michal Drahus, Waclaw Waniak
088-16	Galactic Isotopic Ratio of $^{18}O/^{17}O$	Zhiwei Liu, Jiangshui Zhang, Yaoting Yan, Qihui Chen
090-16	Physical properties of extreme outer Galaxy clouds between 35°<L<45°	Yan Sun, Yang Su
091-16	Molecular gas in the Virgo cirrus	Simone Bianchi, Carlo Giovanardi, Edvige Corbelli, Leslie Hunt, Laura Magrini, Viviana Casasola, Jacopo Fritz, Jonathan Davies, Martha Haynes, Riccardo Giovanelli, Maarten Baes, Samuel Boissier, Mederic Boquien, A. Boselli, Matthew Smith, Christopher Clark, Ilse De Looze, S. Di Serego Alighieri, Marco Grossi, Thomas Hughes, Suzanne Madden, Ciro Pappalardo, Nathalie Ysard, S. Zibetti, A. P. Jones, Marco Bocchio, Luca Cortese, Manolis Xilouris
093-16	Properties of molecular gas in Taurus	Frank Israel, Michiel R. Hogerheijde
094-16	The main COM reservoir in Pre-stellar Cores	Izaskun Jimenez-Serra, Paola Caselli, David Quenard, Anton Vasyunin, Serena Viti, Nuria Marcelino, Leonardo Testi
095-16	Origin of the efficient non-thermal evaporation of methanol in the Barnard 5 molecular cloud	Vianney Taquet, Eva S. Wirstrom, Steven Charnley, Jaime Pineda, Alvaro Hacar, Alyssa Goodman
096-16	Investigating Nitrogen fractionation in L1544	Silvia Spezzano, Paola Caselli, Luca Bizzocchi
098-16	C_3O origin and extent in the L1544 prestellar core	Charlotte Vastel, Bertrand Lefloch, Cecilia Ceccarelli, Romane Le Gal
099-16	Methanol formation inside and outside prestellar cores	Aurore Bacmann, Alexandre Faure, Enrique Garcia-Garcia, Laurent Pagani
100-16	Dust and CO distribution toward the pre-stellar core L429	Ana Chacon-Tanarro, Luca Bizzocchi, Jaime Pineda, Paola Caselli, Silvia Spezzano, Jorma Harju
101-16	A 3 mm line survey of L483	Marcelino Agundez, Nuria Marcelino, Mario Tafalla, Jose Cernicharo
102-16	A Search for hydroxy methanol, CH_2OH in interstellar space	Stephane Bailleux, Celina Bermudez, Belen Tercero, Nuria Marcelino, Marcelino Agundez, Jose Cernicharo
103-16	Formation Mechanism of Formaldehyde Proved by the ^{13}C Species	Kento Yoshida, Nami Sakai, Yoshimasa Watanabe, Rafael Bachiller, Bertrand Lefloch, Cecilia Ceccarelli, Satoshi Yamamoto
104-16	Survey of Sulfur-bearing Species in Hot Corino Sources	Yoko Oya, Nami Sakai, Yoshimasa Watanabe, Satoshi Yamamoto
105-16	The abundance of HCN in prestellar cores	Victor de Souza Magalhaes, Pierre Hily-Blant, Alexandre Faure, Malcolm Walmsley
106-16	Sulfur chemistry in dark clouds: H_2S	Asuncion Fuente, Evelyne Roueff, Izaskun Jimenez-Serra, Paola Caselli, Jose Cernicharo, Maryvonne Gerin, Nuria Marcelino, Marcelino Agundez, Valerio Lattanzi, Jacob Laas, J. Malinen, Javier R. Goicoechea, Alvaro Hacar, Mario Tafalla, Rafael Bachiller, Jerome Pety, Barbara Michela Giuliano, Guillermo M. Munoz Caro, Sandra Trevino-Morales
108-16	Characterizing infall in the youngest protostellar envelopes	Anaelle Maury, Mathilde Gaudel, Arnaud Belloche, Sebastien Maret, Claudio Codella, Sylvie Cabrit, Philippe Andre, Patrick Hennebelle

Project	Title	Authors
109-16	Connecting Chemical and Protostellar Evolution: N_2D^+/ N_2H^+ in Orion Protostars	John Tobin, Amelia Stutz, S. Thomas Megeath, Zsofia Nagy, M. Dunham, Friedrich Wyrowski, Nicolas Billot, James di Francesco, Thomas Stanke, Sarah Sadavoy, Guillem Anglada, Mayra Osorio Gutierrez, Nickalas Reynolds, Ana Karla Diaz Rodriguez
110-16	Exploring Chemical Composition of the Low-Mass Protostar in Isolated Condition	Muneaki Imai, Nami Sakai, Ana Lopez-Sepulcre, Yoko Oya, Yoshimasa Watanabe, Satoshi Yamamoto
111-16	Bridging the large-scale envelope structure and disk formation	Daniel Harsono, John Tobin, Nadia Murillo, Ewine F. Van Dishoeck, Ruud Visser, Jes Jorgensen
113-16	The Galactic cold cores molecular follow-up: the filament-core connection	Julien Montillaud, Mika Juvela, Isabelle Ristorcelli, L. Viktor Toth, V. -M. Pelkonen, Sarolta Zahorecz, Karine Demyk, Alessio Traficante, Hong-Li Liu, Ke Wang, Tie Liu, Alana Rivera-Ingraham, Edith Falgarone, M. Cunningham, David Eden, Jinhua He, Paul F. Goldsmith, L. Bronfman, Ken'ichi Tatematsu, Kazuhito Dobashi, Patricio Sanhueza, J. Malinen
116-16	Constraining the excitation conditions of ^{15}N-bearing molecules in massive dense cores	Francesco Fontani, Paola Caselli, Luca Bizzocchi, Pierre Hily-Blant, Cecilia Ceccarelli, Laura Colzi
117-16	Kinetic Temperature Structure of Massive Dense Clumps	Xindi Tang, Christian Henkel, Karl M. Menten, Yan Gong, Jarken Esimbek, Jian-Jun Zhou, Cosmos C. Yeh, Da-Lei Li, Yu-Xin He
119-16	High J transitions of Phosphorus Nitride in massive dense cores	Francesco Fontani, Victor Rivilla, Paola Caselli, Maria Teresa Beltran, Anton Vasyunin
120-16	Discovering more pieces of the astrochemical puzzle	Victor Rivilla, Maria Teresa Beltran, Francesco Fontani, Paola Caselli, Anton Vasyunin, Jesus Martin-Pintado, Riccardo Cesaroni
121-16	A new insight into the CN/HCN/HNC photochemistry	Asuncion Fuente, Sandra Trevino-Morales, Jose Cernicharo, Evelyne Roueff, Alvaro Sanchez-Monge, Javier R. Goicoechea, Paolo Pilleri, Maryvonne Gerin, Jerome Pety, Santiago Garcia-Burillo, Jean-Christophe Loison, Kevin M. Hickson
122-16	NIKA2 GT-LP set 1: Galactic Star Formation with NIKA2 - GASTON	Nicolas Peretto, Philippe Andre, Alexandre Beelen, Alain Benoit, Aurelien Bideaud, Nicolas Billot, O. Bourrion, M. Calvo, A. Catalano, Gregoire Coiffard, Barbara Comis, Francois-Xavier Desert, S. Doyle, Carsten Kramer, Samuel Leclercq, Juan Macias-Perez, Frederic Mayet, A. Monfardini, Francois Pajot, Enzo Pascale, Laurence Perotto, Giampaolo Pisano, Nicolas Ponthieu, Vincent Reveret, Alessia Ritacco, Louis Rodriguez, Charles Romero, Florian Ruppin, Karl-Friedrich Schuster, Albrecht Sievers, Robert Zylka, Remi Adam, Peter Ade, Frederique Motte, Aurore Bacmann, Andrew Rigby, Isabelle Ristorcelli, Pablo Garcia, Anaelle Maury, Jean-Francois Lestrade, Yoshito Shimajiri, Andrea Bracco, Bilal Ladjelate, Ana Duarte Cabral, Sarah Ragan, Jane Greaves
124-16	ORION B: The anatomy of a Giant Molecular Cloud	Jerome Pety, Maryvonne Gerin, Emeric Bron, Viviana Guzman Veloso, Jan Orkisz, Sebastien Bardeau, Javier R. Goicoechea, Pierre Gratier, Franck Le Petit, Francois Levrier, Harvey Liszt, Karin Oberg, Nicolas Peretto, Evelyne Roueff, Albrecht Sievers, Pascal Tremblin
127-16	A project for Master students of Grenoble University: Radiatively Driven Implosion in M20	Bertrand Lefloch
128-16	The CO^+ chemistry in photon dominated environments (II)	Sandra Trevino-Morales, Asuncion Fuente, Alvaro Sanchez-Monge, Javier R. Goicoechea, Paolo Pilleri, Volker Ossenkopf-Okada, Jose Cernicharo, Sara Cuadrado, Carsten Kramer, Jose Ricardo Rizzo
131-16	Exploring the chemical richness of the Ring Nebula (cont.)	Paolo Pilleri, Karine Demyk, Jose Cernicharo, Christine Joblin, Arancha Castro-Carrizo, Marcelino Agundez, Nick Cox, Luis Velilla Prieto
133-16	Enhancement of complex organic molecules in PDRs	Gisela Bano Esplugues, Paola Caselli, Stephanie Cazaux, Marco Spaans
136-16	Shocked molecular clumps around Cassiopeia A - A key probe of CR acceleration and asymmetric SN explosion	Li Jiangtao, Ping Zhou, Zhiyu Zhang, Yang Chen, Joel N. Bregman
137-16	Characterizing the remarkable IRAS 04166 jet	Mario Tafalla
138-16	Star formation triggered by a cloud-cloud collision in L1188	Yan Gong

Project	Title	Authors
139-16	A study of water emission at 183.3 and 325.15 GHz of star forming regions and Protoplanetary disks	Jose Cernicharo, Juan R. Pardo, Javier R. Goicoechea, Asuncion Fuente, Claudia Marka, Albrecht Sievers, Luis Velilla Prieto, Santiago Navarro, Roberto Neri
140-16	Protostellar outflows and turbulence in the Cepheus dense clumps	Anaelle Maury, Stephane Corbel
141-16	Gas Components Along the Lines-of-Sight Towards the Arched-Filaments in the GC	Pablo Garcia, Nicholas Abel, Markus Roellig, Michael Burton, Martin Steinke, Rebecca Blackwell
143-16	Nature of the Spiral Arms Connecting the Candidate Planet-Forming Disk HL Tau	Hsi-Wei Yen, Shigehisa Takakuwa, HauYu Baobab Liu, Naomi Hirano, Chin-Fei Lee, Pin-Gao Gu, Sheng-Yuan Liu, Chun-Ju Wu
145-16	Ortho-to-Para ratio of H_2CO as a thermometer for disk chemistry	Liton Majumdar, Anne Dutrey, Stephane Guilloteau, Edwige Chapillon, Pierre Gratier, Valentine Wakelam
146-16	Gas in the Needle	Attila Moor, Jane Greaves, Agnes Kospal
147-16	CN(1-0) observations in high-mass filaments: a pre-study for unveiling the role of B-fields through the Zeeman effect	Gemma Busquet, Nacho Anez, Josep Miquel Girart, Amelia Stutz, Qizhou Zhang, Thushara Pillai, Carmen Juarez
149-16	The magnetic field in photodissociation regions	Marta Alves, Paolo Pilleri, Francois Boulanger, Edith Falgarone, Thomas Troland, Richard Crutcher, Jose Cernicharo, Sandra Trevino-Morales, Javier R. Goicoechea, Asuncion Fuente
150-16	A measurement of the magnetic field toward the First Hydrostatic Core B1b through the rotational lines of the 3Sigma molecule SO	Jose Cernicharo, Maryvonne Gerin, cristina puzzarini, Asuncion Fuente, Andres Asensio Ramos, Nuria Marcelino, Javier Trujillo Bueno, Gabriel Paubert, Maria Jesus Martinez Gonzalez
151-16	Short spacings for ALMA C_4H, CN and CO maps of the circumstellar envelope IRC+10216	Michel Guelin, Jose Cernicharo, Arancha Castro-Carrizo, Marcelino Agundez
152-16	A sensitive 2 mm line survey of IRC+10216: searching for the building blocks of dust grains	Jose Cernicharo, Marcelino Agundez, Michel Guelin, Luis Velilla Prieto, Claudia Marka, Carsten Kramer, Claudine Kahane, Sarah Massalkhi
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182-16	MAPI: Monitoring AGN with Polarimetry at the IRAM-30m	Ivan Agudo, Carolina Casadio, Jae-Young Kim, Ioannis Myserlis, Thomas Krichbaum, Emmanouil Angelakis, Eduardo Ros, Helmut Wiesemeyer, Anton Zensus, Clemens Thum, Venkatessh Ramakrishnan, Jose L. Gomez, Alan Marscher, Svetlana Jorstad
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197-16	A NIKA2 survey of dusty starbursts in the early Universe	Ivan Oteo, Rob Ivison, Michal J. Michalowski, Dominik A. Riechers, Joshua Greenslade, Malcolm Bremer, Paul van der Werf, Stephen Serjeant, Helmut Dannerbauer, Steve Eales, Ismael Perez-Fournon
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199-16	NIKA2 GT-LP set 1: High-resolution tSZ observations of a large sample of clusters of galaxies (NIKA2SZ)	Frederic Mayet, Barbara Comis, Remi Adam, Peter Ade, Nabila Aghanim, Philippe Andre, Monique Arnaud, Rafael Barrena Delgado, Iacopo Bartalucci, Alexandre Beelen, Alain Benoit, Aurelien Bideaud, Nicolas Billot, O. Bourrion, M. Calvo, A. Catalano, Nicolas Clerc, Gregoire Coiffard, Marco De Petris, Francois-Xavier Desert, Marian Douspis, S. Doyle, Chiara Ferrari, Carsten Kramer, Samuel Leclercq, Juan Macias-Perez, Jean-Baptiste Melin, A. Monfardini, Francois Pajot, Enzo Pascale, Laurence Perotto, Giampaolo Pisano, Etienne Pointecouteau, Nicolas Ponthieu, Gabriel Pratt, Vincent Reveret, Alessia Ritacco, Louis Rodriguez, Charles Romero, Jose Alberto Rubino Martin, Florian Ruppin, Karl-Friedrich Schuster, Albrecht Sievers, Robert Zylka, H. Aussel
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086-17	Constraining the initial conditions of star formation with chemistry	VIDAL Thomas, Neil Vaytet, Valentine Wakelam, Pierre Gratier

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124-16	ORION B: The anatomy of a Giant Molecular Cloud	Jerome Pety, Maryvonne Gerin, Emeric Bron, Viviana Guzman Veloso, Jan Orkisz, Sebastien Bardeau, Javier R. Goicoechea, Pierre Gratier, Franck Le Petit, Francois Levrier, Harvey Liszt, Karin Oberg, Nicolas Peretto, Evelyne Roueff, Albrecht Sievers, Pascal Tremblin
D01-17	CO and N_2 depletion in L1512	Laurent Pagani, Charlene Lefevre, Shih-Ping Lai, Sheng-Jun Lin, Pierre Lesaffre
D02-17	The magnetic field in photodissociation regions	Marta Alves, Paolo Pilleri, Francois Boulanger, Edith Falgarone, Katia Ferriere, O. Berne, Thomas Troland, Richard Crutcher, Jose Cernicharo, Sandra Trevino-Morales, Javier R. Goicoechea, Asuncion Fuente, Santiago Navarro
D03-17	Confirming the radical NCO in space	Nuria Marcelino, Marcelino Agundez, Jose Cernicharo
GMVA-16B-346	Ultra-deep imaging of the BH jet base and accretion flow of M87 from 100 to 7 Rs	Keiichi Asada, Rusen Lu, Thomas Krichbaum, Kazuhiro Hada, Kazunori Akiyama, Walter Alef, Lindy Blackburn, Geoffrey Bower, Michael Bremer, Avery Broderick, Vivek Dhawan, S. Doeleman, Akihiro Doi, Heino Falcke, V. Fish, Gabriele Giovannini, Jose L. Gomez, Marcello Giroletti, Paul Ho, Mareki Honma, David Hughes, Makoto Inoue, Michael Johnson, Motoki Kino, Shoko Koyama, Jonathan Leon-Tavares, Michael Lindqvist, Andrei Lobanov, Ivan Marti-Vidal, Alan Marscher, Satoki Matsushita, Monika Moscibrodzka, Jonathan McKinney, Shin Mineshige, Cornelia Mueller, Hiroshi Nagai, Masanori Nakamura, Gopal Narayanan, Scott Noble, Monica Orienti, Hung-Yi Pu, Eduardo Ros, H. Rottmann, Karl-Friedrich Schuster, Hotaka Shiokawa, Pablo de Vicente, R. Craig Walker, John Wardle, Anton Zensus
GMVA-16B-169	Probing the Jet-Collimation Region in NGC1052 with high-fidelity mm-VLBI imaging	Anne-Kathrin Baczko, Robert Schulz, Eduardo Ros, Matthias Kadler, Thomas Krichbaum, Manel Perucho, Anton Zensus
GMVA-16B-113	Imaging of the Gamma-Ray Emitting Regions of Blazar Jets	Alan Marscher, Thomas Krichbaum, Svetlana Jorstad, Mason Keck, Jae-Young Kim, Jose L. Gomez, Ivan Agudo, Jeffrey Hodgson, Pablo Galindo, Bindu Rani, Carolina Casadio, Bong Won Sohn, Michael Bremer
GMVA-16B-148	Understanding jet formation and testing the binary SMBH model in OJ287	Jose L. Gomez, Thomas Krichbaum, Andrei Lobanov, Alan Marscher, Gabriele Bruni, Svetlana Jorstad, Stefanie Komossa, Yuri Kovalev, Carolina Casadio, Jae-Young Kim, Laura Vega-Garcia, Ivan Marti-Vidal, Jeffrey Hodgson, Pablo Galindo, Ivan Agudo, Sol N. Molina, Uwe Bach, Yosuke Mizuno, Jose M. Marti, Manel Perucho, Eduardo Ros, Anton Zensus
GMVA-16B-312	Imaging the Global Magnetic-Field Structure Near Sgr A*: 3mm VLBI with GMVA+ALMA	Michael Johnson, Christiaan Brinkerink, Lindy Blackburn, Cornelia Mueller, Geoffrey Bower, Heino Falcke, Laurent Loinard, S. Doeleman, V. Fish, Thomas Krichbaum, Jonathan Leon-Tavares, Antonio Hernandez, Remo Tilanus, Gisela Ortiz, Raquel Fraga-Encinas, Ciriaco Goddi, Adam Deller, Anton Zensus, David Hughes, David Sanchez-Arguelles, Alfredo Montana, Grant Wilson, Monika Moscibrodzka, Jason Dexter, Kazuhiro Hada, Guangyao Zhao, Motoki Kino, Bong Won Sohn, Jonathan McKinney, Katherine Rosenfeld, Andrew Chael, Hotaka Shiokawa, Keiichi Asada, Ilse Van Bemmel, Katherine Bouman, Mareki Honma, Kazunori Akiyama, Rusen Lu, Huib van Langevelde, Michael Kramer, Luciano Rezzolla, Roman Gold, Avery Broderick, Edgar Castillo, Dick Plambeck, James Moran, James Cordes, John Wardle
GMVA-16B-324	Probing the active collimation region of the relativistic jet in 3C 273	Kazunori Akiyama, Keiichi Asada, Jose L. Gomez, Denise Gabuzda, Kazuhiro Hada, V. Fish, Colin Lonsdale, Lindy Blackburn, Katherine Bouman, Andrew Chael, S. Doeleman, Mareki Honma, Michael Johnson, Shoko Koyama, Alan Marscher, Yosuke Mizuno, Hiroshi Nagai, Masanori Nakamura, Hung-Yi Pu
GMVA-17B-299-MV001	Search for an intermediate-mass gravitational lens towards PKS1413+135	Harish Vedantham, A. C. S. Readhead, Talvikki Hovatta, Walter Max-Moerbeck, Timothy J. Pearson, Preeti Kharb
GMVA-17B-297-MM012	Imaging of the Gamma-Ray Emitting Regions of Blazar Jets	Alan Marscher, Thomas Krichbaum, Svetlana Jorstad, Mason Keck, Efthalia Traianou, Jose L. Gomez, Ivan Agudo, Carolina Casadio, Jeffrey Hodgson, Jae-Young Kim, Bong Won Sohn, Michael Bremer, Antonio Fuentes

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01_2016.1.01176.V	Looking into the throat of the magnetized gamma-ray blazar 3C279	Thomas Krichbaum, Alan Marscher, Svetlana Jorstad, Tuomas Savolainen, Ivan Marti-Vidal, Rusen Lu, Jae-Young Kim, Alan L. Roy, J. Wagner, Eduardo Ros, H. Rottmann, Geoffrey Crew, Cornelia Mueller, Michael Bremer, Jonathan Leon-Tavares, D. Muders, Axel Weiss, Anton Zensus, Karl M. Menten, Karl-Friedrich Schuster, Frederic Gueth, Heino Falcke, Lucy M. Ziurys, Daniel Marrone, Blundell Ray, David Hughes, Sheperd Doeleman
02_2016.1.01290.V	Pinpointing the highly magnetized twin-jet base near a supermassive black hole	Matthias Kadler, Eduardo Ros, Anne-Kathrin Baczko, Sheperd Doeleman, Christian Fromm, Thomas Krichbaum, Rusen Lu, Ivan Marti-Vidal, Manel Perucho, Robert Schulz, Remo Tilanus, Anton Zensus, Heino Falcke, Cornelia Mueller, Geoffrey Bower, Walter Alef, H. Rottmann, Andrei Lobanov
04_2016.1.01114.V	Imaging the candidate binary SMBH in OJ287	Jose L. Gomez, Thomas Krichbaum, Stefanie Komossa, Andrei Lobanov, Alan Marscher, Gabriele Bruni, Svetlana Jorstad, Yuri Kovalev, Carolina Casadio, Jae-Young Kim, Rusen Lu, Laura Vega-Garcia, Ivan Marti-Vidal, Jeffrey Hodgson, Ivan Agudo, Sol N. Molina
06_2016.1.01154.V	Imaging the black hole shadow and jet launching region of M87	Sheperd Doeleman, Christian Fromm, Yosuke Mizuno, Christiaan Brinkerink, Cornelia Mueller, Ciriaco Goddi, Monika Moscibrodzka, Heino Falcke, Remo Tilanus, Michael Johnson, Lindy Blackburn, Hotaka Shiokawa, James Moran, Abraham Loeb, V. Fish, Geoffrey Crew, Lynn Matthews, Kazunori Akiyama, Colin Lonsdale, Ken Young, Michael Bremer, Karl-Friedrich Schuster, Frederic Gueth, Carsten Kramer, Laurent Loinard, David Hughes, Mareki Honma, Kazuhiro Hada, Hiroshi Nagai, Keiichi Asada, Geoffrey Bower, Paul Ho, Makoto Inoue, Masanori Nakamura, Hung-Yi Pu, Do-Young Byun, Zhiqiang Shen, Satoki Matsushita, Chih-Wei Huang, Hiroaki Nishioka, Dimitrios Psaltis, Feryal Ozel, Daniel Marrone, Lucy M. Ziurys, Avery Broderick, Tim Johannsen, Britton Jeter, Mansour Karami, Thomas Krichbaum, Rusen Lu, Walter Alef, Alan L. Roy, H. Rottmann, Eduardo Ros, Anton Zensus, Michael Kramer, Karl M. Menten, Rolf Gusten, D. Muders, John Conway, Ivan Marti-Vidal, N. Nagar, Jason Dexter, Charles F. Gammie, John Wardle, Roman Gold, Jonathan McKinney, Dick Plambeck, Gopal Narayanan, Peter Schloerb, John Carlstrom, Fumie Tazaki, Jonathan Leon-Tavares, Ming-Tang Chen, chun-Che Lin, Oliver Porth, J. Weintroub, Yau De Huang, Luciano Rezzolla
07_2016.1.01404.V	Imaging the shadow of a supermassive black hole: Event Horizon Telescope observations of Sgr A*	Sheperd Doeleman, Christian Fromm, Yosuke Mizuno, Christiaan Brinkerink, Cornelia Mueller, Ciriaco Goddi, Monika Moscibrodzka, Heino Falcke, Remo Tilanus, Michael Johnson, Lindy Blackburn, Hotaka Shiokawa, James Moran, Abraham Loeb, V. Fish, Geoffrey Crew, Kazunori Akiyama, Colin Lonsdale, Ken Young, Michael Bremer, Karl-Friedrich Schuster, Frederic Gueth, Carsten Kramer, Laurent Loinard, David Hughes, Mareki Honma, Kazuhiro Hada, Hiroshi Nagai, Keiichi Asada, Geoffrey Bower, Paul Ho, Makoto Inoue, Masanori Nakamura, Hung-Yi Pu, Do-Young Byun, Zhiqiang Shen, Satoki Matsushita, Chih-Wei Huang, Hiroaki Nishioka, Dimitrios Psaltis, Feryal Ozel, Daniel Marrone, Lucy M. Ziurys, Avery Broderick, Tim Johannsen, Britton Jeter, Mansour Karami, Thomas Krichbaum, Rusen Lu, Walter Alef, Alan L. Roy, H. Rottmann, Eduardo Ros, Anton Zensus, Michael Kramer, Karl M. Menten, Rolf Gusten, D. Muders, John Conway, Ivan Marti-Vidal, N. Nagar, Jason Dexter, Charles F. Gammie, John Wardle, Roman Gold, Jonathan McKinney, Dick Plambeck, Gopal Narayanan, Peter Schloerb, John Carlstrom, J. Weintroub, chun-Che Lin, johnson Han, Ming-Tang Chen, Ziri Younsi, Oliver Porth, Jonathan Leon-Tavares, Fumie Tazaki, Yau De Huang, Luciano Rezzolla
10_2016.1.01518.V	Ultra-high-resolution imaging of 100-RS-scale structure of the archetypical quasar 3C 273	Kazunori Akiyama

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X053	PHIBSS2: molecular gas at the peak epoch of galaxy formation	Francoise Combes, Santiago García-Burillo, Roberto Neri, Linda Tacconi, Reinhard Genzel, Thierry Contini, Alberto Bolatto, Simon Lilly, Frédéric Boone, Nicolas Bouché, Frédéric Bournaud, Andreas Burkert, Marcella Carollo, Luis Colina, Michael Cooper, Pierre Cox, Chiara Feruglio, Jonathan Freundlich, Natascha Förster Schreiber, Stéphanie Juneau, Katarina Kovac, Magdalena Lippa, Dieter Lutz, Naab, Alain Omont, Alfio Renzini, Amélie Saintonge, Philippe Salomé, Amiel Sternberg, Fabian Walter, Ben Weiner, Axel Weiss, Stijn Wuyts
L14AB	Fragmentation and disk formation during high-mass star formation	Henrik Beuther, Thomas Henning, Hendrik Linz, Siyi Feng, Katharine Johnston, Rolf Kuiper, Sarah Ragan, Dmitry Semenov, Frédéric Gueth, Jan Martin Winters, Karl M. Menten, James Urquhart, Timea Csengeri, Pamela Klaassen, Joseph C. Mottram, Peter Schilke, Melvin Hoare, Luke Maud, Stuart Lumsden, Maria Teresa Beltran, Riccardo Cesaroni, Malcolm Walmsley, Alvaro Sanchez-Monge, Qizhou Zhang, Cornelis Dullemond, Frederique Motte, Philippe André, Gary Fuller, Nicolas Peretto, Roberto Galvan-Madrid, S. Longmore, Sylvain Bontemps, Th. Peters, Aina Palau, R. Pudritz, Hans Zinnecker
L15AA	Seeds Of Life in Space	Cecilia Ceccarelli, Paola Caselli, Francesco Fontani, Claudio Codella, Bertrand Lefloch, Charlotte Vastel, Jaime Pineda, Andy Pon, Pierre Hily-Blant, Roberto Neri, Luca Bizzocchi, Izaskun Jimenez-Serra, Felipe Alves, Rafael Bachiller, Sandrine Bottinelli, Emmanuel Caux, Gaëlle Dumas, Robert Lucas, Linda Podio, Anna Punanova, Nami Sakai, Satoshi Yamamoto, Serena Viti, Anton Vasyunin, Francois Dulieu, Alexandre Faure, Silvia Spezzano, Laurent Wiesenfeld, Nadia Balucani, Ali Jaber Al-Edharil, Albert Rimola, Ian Sims, Patrice Theule, Piero Ugliengo, Ana Chacon-Tanarro, Rumpa Choudhury
S16AG	Velocity structure of a quiescent portion of the NGC 2024 filament	Philippe André, Yoshito Shimajiri, Vera Konyves, Doris Arzoumanian, Eva Ntormousi, Patrick Hennebelle, Arabindo Roy, Nicola Schneider, Bilal Ladjelate, Alexander Men'shchikov
S16BF	Tracing the Physics of the Molecular Cloud Lifecycle in IC 342	Andreas Schruba, Diederik Kruijssen, Alex Hygate, Erik Rosolowsky, Eva Schinnerer, Jérôme Pety, Karin Sandstrom, Antonio Usero, Adam Leroy, Eric Emsellem, Annie Hughes, Frank Bigiel
E16AA	Resolving the mm emission from the Components of T Tau	Karl-Friedrich Schuster, Vincent Pietu, Edwige Chapillon
E16AB	Monitoring the first ever detected accretion burst from a massive (proto)star: How accretion turns into ejection	Riccardo Cesaroni, Alessio Caratti O Garatti, Roberto Neri, Jochen Eisloeffel, L. Moscadelli, Tom Ray, A. Sanna, Bringfried Stecklum, Malcolm Walmsley
E16AC	$^{27/26}$Al ratio in the remnant of a stellar merger	Tomasz Kaminski, Karl M. Menten, Nimesh Patel, Romuald Tylenda, Jan Martin Winters
E16AD	Revealing the nature of an ultra-red SMG SPIRE dropout: Highest redshift Dusty Starburst or an extremely cool z=2 source.	Joshua Greenslade, David Clements, Helmut Dannerbauer, Tai-an Cheng
E16AE	Dust-Obscured Bulge Growth in Milky Way and Andromeda Progenitors	Erica Nelson, Ken-Ichi Tadaki, Linda Tacconi, Dieter Lutz, Natascha Förster Schreiber, Reinhard Genzel, S. Wuyts, Emily Wisnioski
E16AF	Molecular Gas in the Host Galaxy of FRB 121102	Geoffrey Bower, Melanie Krips, Huib van Langevelde, Pablo Torne, Laura Spitler, Cees Bassa, Shami Chatterjee, Casey Law, Shriharsh Tendulkar
E16AG	Adding short baselines to previously obtained configuration A observations of LARS 8 to get insight into massive clump formation and distinguish between 'in-situ' disk fragmentation and accretion	Johannes Puschnig, Matthew Hayes, Göran Östlin, John M. Cannon, Edmund Christian Herenz, Oscar Agertz, Veronica Menacho Menacho, Melanie Krips

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E16AH	The FIR properties of a bright quasar at a new redshift record.	Fabian Walter, Bram Venemans, Eduardo Banados, Roberto Decarli, Xiaohui Fan, Hans-Walter Rix, Chiara Mazzucchelli, Emanuele Paolo Farina, Jinyi Yang, Feige Wang, Daniel Stern
E16AI	Is ID 12646 a very massive and dusty galaxy at z=6.4?	Guilaine Lagache, Alexandre Beelen, Daizhong Liu, Rémi Adam, Emanuele Daddi, Nicolas Ponthieu, H. Aussel, Matthieu Bethermin, Alexandre Beelen
E16AK	The remarkably dense molecular outflow of Mrk273	Rebeca Aladro, Melanie Krips, Susanne Aalto, Sabine König
W16AA	Are changes in Io's bulk atmosphere the cause for magnetospheric variability?	Lorenz Roth, Alvaro Sanchez-Monge, Joachim Saur, G. Randall Gladstone, Kurt D. Retherford, D. Strobel, Katherine de Kleer, Peter Schilke, Sven Thorwirth, Mizuki Yoneda, Nickolay Ivchenko, Alvaro Sanchez-Monge
W16AE	The role of the carbon isotope ratio in ^{15}N-measurements of protostars	Susanne Wampfler, Jes Jorgensen, Martin Bizzarro
W16AF	The main reservoir of sulfur on dust grains in the shocked region L1157-B1	Siyi Feng, Claudio Codella, Izaskun Jimenez-Serra, Paola Caselli, Cecilia Ceccarelli, Francesco Fontani, Bertrand Lefloch, Serena Viti, Leonardo Testi, Rafael Bachiller, Ian Sims, Nadia Balucani, Roberto Neri, Vianney Taquet, Francois Dulieu, Jaime Pineda, Andy Pon, Anton Vasyunin, Eleonora Bianchi, Jonathan Holdship, Linda Podio, Silvia Spezzano, Jacob Laas
W16AI	Phosphorus Chemistry in Solar-type Star Forming Regions	Bertrand Lefloch, Claudio Codella, Cecilia Ceccarelli, Linda Podio, Serena Viti, Charlotte Vastel, Izaskun Jimenez-Serra, Rafael Bachiller, Cecile Favre, cristina puzzarini, Nadia Balucani, Vincenzo Barone
W16AN	Constraining the Spatial Abundance of HCN Towards Five Protostars	Thomas Rice, Edwin A. Bergin
W16AQ	The disk-jet-outflow system of the almost massive YSO AFGL490	Claudia Marka, Katharina Schreyer
W16AZ	NOEMA Follow Up Imaging of a Young Solar System Analogue	Sasha Hinkley, Jean-Francois Lestrade, Grant Kennedy, Elisabeth Matthews, David Wilner, Jonathan P. Williams, Mark C. Wyatt, Brendan Bowler, Dimitri Mawet, Karl Stapelfeldt, Deborah Padgett
W16BC	Probing the dust trap in AB Aur - a cradle of planets?	Asuncion Fuente, Clement Baruteau, Roberto Neri, Jose Cernicharo, Rafael Bachiller, Marcelino Agundez, Javier R. Goicoechea
W16BD	An intriguing circumbinary, hybrid disk candidate in the Pleiades	Emmanuel Di Folco, Anne Dutrey, Jessica Pericaud, Stephane Guilloteau, Vincent Pietu
W16BE	Mapping the central outflow kinematics of the AGB star RS Cnc	Jan Martin Winters, Hoai Do Thi, Nhung Pham, Pierre Darriulat, Thibaut Le Bertre
W16BH	UV- and X-ray-driven Molecular Chemistry in the Planetary Nebula NGC 7027	Joel Kastner, Valentin Bujarrabal, Miguel Santander-Garcia, David Wilner, R. Montez, Javier Alcolea, Pierre Hily-Blant, Thierry Forveille, Jesse Bublitz, Young Sam Yu, Isabel Aleman
W16BS	In-Situ Disk Fragmentation VS. Accretion: What drives the massive Clump Formation?	Johannes Puschnig, Matthew Hayes, Göran Östlin, John M. Cannon, Edmund Christian Herenz, Oscar Agertz, Veronica Menacho Menacho
W16BW	A shocked, dense wind in Mrk231? - a search for luminous H_2S in the fast AGN outflow	Susanne Aalto, Sabine König, Nanase Harada, Johan Lindberg, Sebastien Muller, Francesco Costagliola
W16CD	Quenching processes in HCG 57a and HCG 82b	Monica Rodriguez, Francoise Combes, Philippe Salomé, Pierre Guillard
W16CE	Jet-ISM interactions in NGC 4258	Quentin Salome, Philippe Salomé, Francoise Combes
W16CG	IRAS 17208-0014: An AGN-driven outflow in a starburst-dominated ULIRG?	Antonio Usero, Santiago García-Burillo, Susanne Aalto, Almudena Alonso-Herrero, Miguel Pereira Santaella, Francoise Combes, Francesco Costagliola, Bjorn Emonts, Santiago Arribas, Christian Henkel, Leslie Hunt, Roberto Neri, Montserrat Villar-Martin, Paul van der Werf
W16CQ	Gas at the extreme: MACSJ0717.5+3745	Pascale Jablonka, Francoise Combes, Tim Rawle, Chris Haines, M. Jauzac, Santiago García-Burillo, Eva Schinnerer, Frank Bigiel, Monique Arnaud, Melanie Krips
W16CT	Dust-obscured bulge growth in Milky Way and Andromeda progenitors	Erica Nelson, Reinhard Genzel, Natascha Förster Schreiber, Linda Tacconi, Ken-Ichi Tadaki, Emily Wisnioski, Stijn Wuyts, Dieter Lutz

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W16CV	Observing the Rotation Curve and Baryon Content of a z~1.3 Twin of NGC891 and the Milky Way	Reinhard Genzel, Natascha Förster Schreiber, Dieter Lutz, Rodrigo Herrera-Camus, Linda Tacconi, Hannah Uebler, Sirio Belli, Erica Nelson, S. Wuyts, Richard Davies, Ken-Ichi Tadaki
W16DA	The build-up of galaxies: NOEMA view on galaxy growth at z~2	Joseph Hennawi, Roberto Decarli, Fabian Walter, Sebastiano Cantalupo
W16DD	I. Continuum Observation of Gravitationally Lensed Submm Galaxies	Firas Mazyed, Denis Burgarella, Veronique Buat, Javier Alvarez Marquez, Hyung-Mok Lee, Stephen Serjeant
W16DJ	The Gas Mass and Excitation Conditions in a Normal Galaxy Near the Peak of Cosmic Star Formation Activity	Rodrigo Herrera-Camus, Linda Tacconi, Reinhard Genzel, Alberto D. Bolatto, Dieter Lutz, Natascha Förster Schreiber, Ken-Ichi Tadaki
W16DO	Observing the neutral carbon lines in lensed high-z ultra-luminous infrared galaxies with bright H_2O emission	Chentao Yang, Alexandre Beelen, Alain Omont, Roberto Neri, Dominik A. Riechers, Rob Ivison, Zhiyu Zhang, Yu Gao, Yinghe Zhao, Paul van der Werf, Paola Andreani, R. Gavazzi, Eduardo Gonzalez-Alfonso, Melanie Krips, Ivan Oteo
W16DR	Probing molecular gas excitation in a `normal' star-forming galaxy at z = 3.2	Avani Gowardhan, Dominik A. Riechers, Emanuele Daddi, Roberto Neri, Helmut Dannerbauer, Riccardo Pavesi
W16DS	The puzzle of the Garnet: [CI] and CO in the first extragalactic [CII] absorber at z=3.4	Nicole Nesvadba, Raoul Canameras, Edith Falgarone, Brenda Frye, Ruediger Kneissl, Sabine König, Douglas Scott
W16DX	CO delensing of six ACT-selected DSFGs	Axel Weiss, Fabian Walter, Roberto Decarli, Amitpal Tagore, Charles Keeton, Tobias Marriage, Jesus Rivera, Andrew Baker, Axel Weiss, Tobias Marriage
W16DZ	Tracing [CI] emission from a template starbusting galaxy at z = 4.05	Georgios Magdis, Emanuele Daddi, David Elbaz, Daizhong Liu, Francesco Valentino, Diane Cormier, Matthieu Bethermin, Fabian Walter, Dominik A. Riechers, Chris L. Carilli, Jacqueline Hodge, Dimitra Rigopoulou, Sune Toft
W16EB	Probing the Highly-Excited Buried Nucleus of the Exceptional Starburst AzTEC-3 at z=5.3	Dominik A. Riechers, Chris L. Carilli, Roberto Neri, Riccardo Pavesi, Eva Schinnerer, Alexander Karim, Nick Scoville, Vernesa Smolciç
W16EC	Molecular Gas and Quasar-Galaxy Co-evolution at z>5.6	Qiong Li, Ran Wang, Fabian Walter, Bram Venemans, Eduardo Banados, Xiaohui Fan, Linhua Jiang, Alain Omont, Dominik A. Riechers, Chris L. Carilli, Frank Bertoldi, Roberto Neri, Xue-Bing Wu, Michael A. Strauss
W16EE	Witnessing the massive and dusty star formation at very-high redshift: follow-up of three candidate z~6 NIKA sources	Guilaine Lagache, Rémi Adam, Daizhong Liu, Alexandre Beelen, Nicolas Ponthieu, Emanuele Daddi, H. Aussel, Matthieu Bethermin
W16EH	Torn apart by its own monster: ultimate quasar feedback in a primeval galaxy	Roberto Maiolino, Claudia Cicone, Simona Gallerani, Roberto Neri, Andrea Ferrara, Fabrizio Fiore, Enrico Piconcelli, Chiara Feruglio, Frank Bertoldi, Stefano Carniani
W16EK	[CII] and Dust Emission in the Most Distant Galaxy with a Two-Line Redshift	Fabian Walter, Pascal Oesch, Roberto Decarli, Daniel Schaerer, Frederic Boone, Rychard Bouwens, Miroslava Dessauges-Zavadsky, Richard Ellis, Yoshinobu Fudamoto, Garth Illingworth, Ivo Labbe, Guido Roberts-Borsani, Renske Smit, Dan Stark
D17AA	Confirming a new super-lensed z=2.04 SMG: A 'big brother' of the Cosmic Eyelash	Helmut Dannerbauer, Anastasio Diaz-Sanchez, Susana Iglesias-Groth, Rafael Rebolo, Ricardo Genova-Santos
D17AB	CO Rotation Curves in the Outer Disks ofz~1-2 Star-Forming Galaxies	Reinhard Genzel, Sirio Belli, Alessandra Contursi, Natascha Förster Schreiber, Erica Nelson, Roberto Neri, Karl-Friedrich Schuster, Linda Tacconi, Hannah Uebler
D17AE	Molecular Oxygen in the nearest QSO Mrk 231	Junzhi Wang, Yu Gao, Di Li, Yong Shi, Paul F. Goldsmith, Zhiyu Zhang, Min Fang
S17AE	The shock L1157-B1: a cosmic-ray factory?	Ana Lopez-Sepulcre, Marco Padovani, Cecilia Ceccarelli, Linda Podio, Claudio Codella, Gemma Busquet, Bertrand Lefloch, Alexandre Marcowith
S17AF	Monitoring the first ever detected accretion burst from a massive (proto)star: When accretion turns into ejection	Riccardo Cesaroni, Alessio Caratti O Garatti, Roberto Neri, Jochen Eisloeffel, L. Moscadelli, Tom Ray, A. Sanna, Bringfried Stecklum, Malcolm Walmsley
S17AG	Measuring the Mass Available to Young Stars Undergoing Large Accretion Outbursts	Lee Hartmann, Marina Kounkel, Catherine Espaillat, Enrique Macîas, M. Dunham, Zhaohuan Zhu

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S17AP	Search for Molecular Gas in the Extremely Metal Poor Tadpole Galaxy Kiso 5639	Monica Rubio, Bruce Elmegreen, Cinthya Herrera Contreras, Debra Elmegreen, Jorge Sanchez Almeida, Casiana Munoz-Tunon
S17AR	Identifying molecular outflows in our neighborhood	Dieter Lutz, Eckhard Sturm, Annemieke Janssen, Alessandra Contursi, Sylvain Veilleux, Richard Davies, Linda Tacconi, Reinhard Genzel
S17BA	What is the role of molecular gas when galaxies transition from blue to red?	Ute Lisenfeld, Pierre Guillard, Phil Appleton, Katherine Alatalo, Theodoris Bitsakis
S17BC	Starvation or inefficient star formation: the crucial role of molecular gas in Green Valley galaxies	Francesco Belfiore, Roberto Maiolino, Matthew Bothwell, Lihwai Lin, Kevin Bundy, Stefano Carniani
S17BD	The nature of supermassive black hole binary and recoil candidates	Jessie Runnoe, Roberto Decarli, M. Dotti, Michael Eracleous
S17BI	Gas at the extreme: MACSJ0717.5+3745	Pascale Jablonka, Francoise Combes, Tim Rawle, Chris Haines, M. Jauzac, Santiago García-Burillo, Eva Schinnerer, Frank Bigiel, Monique Arnaud, Melanie Krips
S17BJ	Probing the effect of the cluster environments on molecular gas at 1.2<z<1.4	Gianluca Castignani, Francoise Combes, Stefano Andreon, Veronica Strazzullo, Maurilio Pannella, Ian Heywood, Ginevra Trinchieri, Claudia Cicone, Ivy Wong, Luke Davies, Frazer Owen, Anand Raichoor
S17BK	Quenching at high redshifts: mapping the molecular gas in cluster galaxies at z~1.5	Simona Mei, Audrey Galametz, Francoise Combes, Carlos De Breuck, Gael Noirot, Philippe Salomé
S17BL	Triplets of Quasars: Exploring the Formation of a Cluster with NOEMA	Emanuele Paolo Farina, Fabian Walter, Roberto Decarli, Michele Fumagalli
S17BS	Constraining the fraction of molecular outflows in the most luminous QSOs	Frank Bertoldi, Scott Chapman, Andrew Blain, Rob Ivison
S17BT	Disentangling AGN and Star Formation Effects on the Molecular ISM of z~2 SMGs	Chelsea Sharon, Allison Kirkpatrick, Dominik A. Riechers, Riccardo Pavesi, Avani Gowardhan
S17BV	The Curious Molecular Gas Conditions of a z=2.6 Radio-loud Quasar	Chelsea Sharon, Dominik A. Riechers, T.K. Daisy Leung, Fabian Walter, Chris L. Carilli, Axel Weiss, Kirsten Kraiberg Knudsen
S17BW	Molecular gas reservoirs in hyper-luminous QSOs at the Cosmic Noon	Gabriele Bruni, Manuela Bischetti, Valentina D'Odorico, Chiara Feruglio, Enrico Piconcelli, Efthalia Traianou, Thomas Krichbaum
S17BZ	The remarkable FIR morphologies of dusty high-redshift radio galaxies: mergers, or dusty outflows?	Helmut Dannerbauer, Rob Ivison, Roberto Neri, Carlos De Breuck, Ivan Oteo
S17CC	Time Filler: Completing the CO and [CI] Excitation Ladders in Luminous z=5-7 Dusty Starbursts	Dominik A. Riechers, Ismael Perez-Fournon, Roberto Neri, Alain Omont, T.K. Daisy Leung, David Clements
S17CD	A multi-line study of the star-forming medium in an IR-luminous z~6.5 QSO	Roberto Decarli, Fabian Walter, Bram Venemans, Emanuele Paolo Farina, Chiara Mazzucchelli, Eduardo Banados, Dominik A. Riechers
S17CH	A precision test of gamma-ray burst afterglow models	Antonio de Ugarte Postigo, Steve Schulze, Sam Kim, Christina Thöne, Sergio Martin Ruiz, Michael Bremer, Daniel Perley, David Alexander Kann, Luca Izzo, Zach Cano, Ruben Sanchez-Ramirez, Katarzyna Bensch, Michal J. Michalowski, Itziar de Gregorio-Monsalvo, Daniele Malesani, Steve Schulze
D17IA	Deuterium fractionation in Class I L1455 IRS1	Charlene Lefevre
D17IB	The first full mosaic of pre-biotic formamide in the L1157 shock laboratory	Ana Lopez-Sepulcre
D17IE	Water around the AGB star RS Cnc	Jan Martin Winters, Thibaut Le Bertre, Ka Tat Wong
D17IG	A spatially resolved 3mm Line Survey of the metal-poor dwarf galaxy IC10: Studying starburst under 'extreme' conditions	Melanie Krips, Cinthya Herrera Contreras, Roberto Neri
E17AF	Probing the shocked gas origin of the remarkable QSO host galaxy Q2349+12	Scott Chapman, Melanie Krips, Ian Smail, Frank Bertoldi, Arif Babul, Axel Weiss
W17AQ	Chemical differentiation of high-mass protostellar envelopes: clues about the accretion mechanism?	Timea Csengeri, Sylvain Bontemps
W17AX	A warm molecular cloud connecting to the progenitor problem of Tycho's supernova remnant	Ping Zhou, Yang Chen
W17AZ	Does CO depletion happen within the first Myr of disk formation?	Ke Zhang, Edwin A. Bergin, Kamber Schwarz

Ident.	Title of Investigations	Authors
W17BA	Shock tracers in GGTau A	Edwige Chapillon, Anne Dutrey, Stephane Guilloteau, Vincent Pietu, Ya-Wen Tang, Tracy Beck, Jeffrey Bary, Valentine Wakelam, Liton Majumdar, Emmanuel Di Folco, Antoine Gusdorf, Thi Phuong Nguyen, Diep Pham Ngoc
W17BT	Searching for CO emission in IZw 18	Yong Shi, Junzhi Wang, Zhiyu Zhang, Luwenjia Zhou
W17CX	Gas at the extreme: MACSJ0717.5+3745	Pascale Jablonka, Melanie Krips, Francoise Combes, Santiago García-Burillo, Eva Schinnerer, Frank Bigiel, Tim Rawle, Monique Arnaud, M. Jauzac, Chris Haines
W17DG	Detecting the Host Galaxies of Damped Lyman Alpha Systems at z~2	Marcel Neeleman, Nissim Kanekar, J. Xavier Prochaska, Fabian Walter
W17ES	Redshift identification of a z>6 candidate SMG	Soh Ikarashi, Rob Ivison, Karina Caputi, Kotaro Kohno, William Cowley
W17EX	A line scan in the archetypal z=6.42 quasar J1148+5251	Fabian Walter, Dominik A. Riechers, Bade Uzgil, Bram Venemans, Roberto Decarli
W17FB	Confirmation of the [CII] Emission Line from an Ultra-Luminous Source in the Heart of Cosmic Reionization	Pascal Oesch, Fabian Walter, Roberto Decarli, Daniel Schaerer, Frederic Boone, Rychard Bouwens, Miroslava Dessauges-Zavadsky, Richard Ellis, Yoshinobu Fudamoto, Garth Illingworth, Guido Roberts-Borsani, Renske Smit
W17FF	A precision test of gamma-ray burst afterglow models	Antonio de Ugarte Postigo, Christina Thöne, Daniel Perley, Steve Schulze, Sergio Martin Ruiz, Michael Bremer, Michal J. Michalowski, Sam Kim, David Alexander Kann, Luca Izzo, Katarzyna Bensch, Zach Cano, Daniele Malesani, Ruben Sanchez-Ramirez, Itziar de Gregorio-Monsalvo

Publications

The list of publications, conferences and workshop papers as well as theses based upon data obtained by the IRAM user community and IRAM staff members are provided in the following two tables.

IRAM USERS' COMMUNITY

2234	The millimeter IRAM-30 m line survey toward IK Tauri	Velilla Prieto L., Sánchez Contreras C., Cernicharo J., Agúndez M., Quintana-Lacaci G., Bujarrabal V., Alcolea J., Balança C., Herpin F., Menten K. M., Wyrowski F.	2017, A&A 597, A25
2235	History of the solar-type protostar IRAS 16293-2422 as told by the cyanopolyynes	Jaber Al-Edhari A., Ceccarelli C., Kahane C., Viti S., Balucani N., Caux E., Faure A., Lefloch B., Lique F., Mendoza E., Quenard D., Wiesenfeld L.	2017, A&A 597, A40
2236	Interpreting observations of edge-on gravitationally unstable accretion flows. The case of G10.6-0.4	Liu H. B.	2017, A&A 597, A70
2237	A correlation between chemistry, polarization, and dust properties in the Pipe nebula starless core FeSt 1-457	Juárez C., Girart J. M., Frau P., Palau A., Estalella R., Morata O., Alves F. O., Beltrán M. T., Padovani M.	2017, A&A 597, A74
2238	Interactions of the Galactic bar and spiral arm in NGC 3627	Beuther H., Meidt S., Schinnerer E., Paladino R., Leroy A.	2017, A&A 597, A85
2239	Search for aluminium monoxide in the winds of oxygen-rich AGB stars	De Beck E., Decin L., Ramstedt S., Olofsson H., Menten K. M., Patel N. A., Vlemmings W. H. T.	2017, A&A 598, A53
2240	Formation of ethylene glycol and other complex organic molecules in star-forming regions	Rivilla V. M., Beltrán M. T., Cesaroni R., Fontani F., Codella C., Zhang Q.	2017, A&A 598, A59
2241	A multiwavelength observation and investigation of six infrared dark clouds	Zhang C.-P., Yuan J.-H., Li G.-X., Zhou J.-J., Wang J.-J.	2017, A&A 598, A76
2242	Disentangling the ISM phases of the dwarf galaxy NGC 4214 using [C II] SOFIA/GREAT observations	Fahrion K., Cormier D., Bigiel F., Hony S., Abel N. P., Cigan P., Csengeri T., Graf U. U., Lebouteiller V., Madden S. C., Wu R., Young L.	2017, A&A 599, A9
2243	On the chemical ladder of esters. Detection and formation of ethyl formate in the W51 e2 hot molecular core	Rivilla V. M., Beltrán M. T., Martín-Pintado J., Fontani F., Caselli P., Cesaroni R.	2017, A&A 599, A26
2244	Glycolaldehyde in Perseus young solar analogs	De Simone M., Codella C., Testi L., Belloche A., Maury A. J., Anderl S., André P., Maret S., Podio L.	2017, A&A 599, A121
2245	(Sub)millimeter emission lines of molecules in born-again stars	Tafoya D., Toalá J. A., Vlemmings W. H. T., Guerrero M. A., De Beck E., González M., Kimeswenger S., Zijlstra A. A., Sánchez-Monge Á., Treviño-Morales S. P.	2017, A&A 600, A23
2246	Deuteration of ammonia in the starless core Ophiuchus/H-MM1	Harju J., Daniel F., Sipilä O., Caselli P., Pineda J. E., Friesen R. K., Punanova A., Güsten R., Wiesenfeld L., Myers P. C., Faure A., Hily-Blant P., Rist C., Rosolowsky E., Schlemmer S., Shirley Y. L.	2017, A&A 600, A61
2247	Nucleosynthesis in AGB stars traced by oxygen isotopic ratios. I. Determining the stellar initial mass by means of the $^{17}O/^{18}O$ ratio	De Nutte R., Decin L., Olofsson H., Lombaert R., de Koter A., Karakas A., Milam S., Ramstedt S., Stancliffe R. J., Homan W., Van de Sande M.	2017, A&A 600, A71
2248	Submillimeter spectra of 2-hydroxyacetonitrile (glycolonitrile; $HOCH_2CN$) and its searches in GBT PRIMOS observations of Sgr B2(N)	Margulès L., McGuire B. A., Senent M. L., Motiyenko R. A., Remijan A., Guillemin J. C.	2017, A&A 601, A50

2249	ATLASGAL-selected massive clumps in the inner Galaxy. IV. Millimeter hydrogen recombination lines from associated H II regions	Kim W.-J., Wyrowski F., Urquhart J. S., Menten K. M., Csengeri T.	2017, A&A 602, A37
2250	Gravitational collapse of the OMC-1 region	Hacar A., Alves J., Tafalla M., Goicoechea J. R.	2017, A&A 602, L2
2251	ATLASGAL-selected massive clumps in the inner Galaxy. V. Temperature structure and evolution	Giannetti A., Leurini S., Wyrowski F., Urquhart J., Csengeri T., Menten K. M., König C., Güsten R.	2017, A&A 603, A33
2252	A pilot search for mm-wavelength recombination lines from emerging ionized winds in pre-planetary nebulae candidates	Sánchez Contreras C., Báez-Rubio A., Alcolea J., Bujarrabal V., Martín-Pintado J.	2017, A&A 603, A67
2253	Dust and gas in star-forming galaxies at z ~ 3. Extending galaxy uniformity to 11.5 billion years	Magdis G. E., Rigopoulou D., Daddi E., Bethermin M., Feruglio C., Sargent M., Dannerbauer H., Dickinson M., Elbaz D., Gomez Guijarro C., Huang J.-S., Toft S., Valentino F.	2017, A&A 603, A93
2254	The L1157-B1 astrochemical laboratory: testing the origin of DCN	Busquet G., Fontani F., Viti S., Codella C., Lefloch B., Benedettini M., Ceccarelli C.	2017, A&A 604, A20
2255	The final data release of ALLSMOG: a survey of CO in typical local low-M_* star-forming galaxies	Cicone C., Bothwell M., Wagg J., Møller P., De Breuck C., Zhang Z., Martín S., Maiolino R., Severgnini P., Aravena M., Belfiore F., Espada D., Flütsch A., Impellizzeri V., Peng Y., Raj M. A., Ramírez-Olivencia N., Riechers D., Schawinski K.	2017, A&A 604, A53
2256	Testing the universality of the star-formation efficiency in dense molecular gas	Shimajiri Y., André P., Braine J., Könyves V., Schneider N., Bontemps S., Ladjelate B., Roy A., Gao Y., Chen H.	2017, A&A 604, A74
2257	Radial distribution of dust, stars, gas, and star-formation rate in DustPedia face-on galaxies	Casasola V., Cassarà L. P., Bianchi S., Verstocken S., Xilouris E., Magrini L., Smith M. W. L., De Looze I., Galametz M., Madden S. C., Baes M., Clark C., Davies J., De Vis P., Evans R., Fritz J., Galliano F., Jones A. P., Mosenkov A. V., Viaene S., Ysard N.	2017, A&A 605, A18
2258	Molecular gas properties of a lensed star-forming galaxy at z ~ 3.6: a case study	Dessauges-Zavadsky M., Zamojski M., Rujopakarn W., Richard J., Sklias P., Schaerer D., Combes F., Ebeling H., Rawle T. D., Egami E., Boone F., Clément B., Kneib J.-P., Nyland K., Walth G.	2017, A&A 605, A81
2259	A new study of the chemical structure of the Horsehead nebula: the influence of grain-surface chemistry	Le Gal R., Herbst E., Dufour G., Gratier P., Ruaud M., Vidal T. H. G., Wakelam V.	2017, A&A 605, A88
2260	The observed chemical structure of L1544	Spezzano S., Caselli P., Bizzocchi L., Giuliano B. M., Lattanzi V.	2017, A&A 606, A82
2261	Interstellar medium conditions in z ~ 0.2 Lyman-break analogs	Contursi A., Baker A. J., Berta S., Magnelli B., Lutz D., Fischer J., Verma A., Nielbock M., Grácia Carpio J., Veilleux S., Sturm E., Davies R., Genzel R., Hailey-Dunsheath S., Herrera-Camus R., Janssen A., Poglitsch A., Sternberg A., Tacconi L. J.	2017, A&A 606, A86
2262	Physical conditions of the molecular gas in metal-poor galaxies	Hunt L. K., Weiß A., Henkel C., Combes F., García-Burillo S., Casasola V., Caselli P., Lundgren A., Maiolino R., Menten K. M., Testi L.	2017, A&A 606, A99
2263	Fibers in the NGC 1333 proto-cluster	Hacar A., Tafalla M., Alves J.	2017, A&A 606, A123
2264	Search for grain growth toward the center of L1544	Chacón-Tanarro A., Caselli P., Bizzocchi L., Pineda J. E., Harju J., Spaans M., Désert F.-X.	2017, A&A 606, A142
2265	Far-infrared observations of a massive cluster forming in the Monoceros R2 filament hub	Rayner T. S. M., Griffin M. J., Schneider N., Motte F., Könyves V., André P., Di Francesco J., Didelon P., Pattle K., Ward-Thompson D., Anderson L. D., Benedettini M., Bernard J.-P., Bontemps S., Elia D., Fuente A., Hennemann M., Hill T., Kirk J., Marsh K., Men'shchikov A., Nguyen Luong Q., Peretto N., Pezzuto S., Rivera-Ingraham A., Roy A., Rygl K., Sánchez-Monge Á., Spinoglio L., Tigé J., Treviño-Morales S. P., White G. J.	2017, A&A 607, A22
2266	Interferometric view of the circumstellar envelopes of northern FU Orionis-type stars	Fehér O., Kóspál Á., Ábrahám P., Hogerheijde M. R., Brinch C.	2017, A&A 607, A39
2267	Organic molecules, ions, and rare isotopologues in the remnant of the stellar-merger candidate, CK Vulpeculae (Nova 1670)	Kamiński T., Menten K. M., Tylenda R., Karakas A., Belloche A., Patel N. A.	2017, A&A 607, A78

2268	The role of molecular gas in galaxy transition in compact groups	Lisenfeld U., Alatalo K., Zucker C., Appleton P. N., Gallagher S., Guillard P., Johnson K.	2017, A&A 607, A110
2269	Exhaustion of the gas next to the supermassive black hole of M31	Melchior A.-L., Combes F.	2017, A&A 607, L7
2270	Variable millimetre radiation from the colliding-wind binary Cygnus OB2 #8A	Blomme R., Fenech D. M., Prinja R. K., Pittard J. M., Morford J. C.	2017, A&A 608, A69
2271	Dense Molecular Gas Tracers in the Outflow of the Starburst Galaxy NGC 253	Walter F., Bolatto A. D., Leroy A. K., Veilleux S., Warren S. R., Hodge J., Levy R. C., Meier D. S., Ostriker E. C., Ott J., Rosolowsky E., Scoville N., Weiss A., Zschaechner L., Zwaan M.	2017, ApJ 835, 265
2272	Dense Gas in the Outer Spiral Arm of M51	Chen H., Braine J., Gao Y., Koda J., Gu Q.	2017, ApJ 836, 101
2273	Molecular Gas Kinematics and Star Formation Properties of the Strongly-lensed Quasar Host Galaxy RXS J1131-1231	Leung T. K. D., Riechers D. A., Pavesi R.	2017, ApJ 836, 180
2274	ALMA Observations of Vibrationally Excited HC_3N Lines Toward Orion KL	Peng Y., Qin S.-L., Schilke P., Sánchez-Monge Á., Wu Y., Liu T., Li D., Möller T., Liu S.-Y., Feng S., Liu Y., Luo G., Zhang L., Rong J.-L.	2017, ApJ 837, 49
2275	The Compact, ~ 1 kpc Host Galaxy of a Quasar at a Redshift of 7.1	Venemans B. P., Walter F., Decarli R., Bañados E., Hodge J., Hewett P., McMahon R. G., Mortlock D. J., Simpson C.	2017, ApJ 837, 146
2276	High Dense Gas Fraction in a Gas-rich Star-forming Galaxy at z = 1.2	Gowardhan A., Riechers D. A., Daddi E., Pavesi R., Dannerbauer H., Carilli C.	2017, ApJ 838, 136
2277	Submillimeter Array ^{12}CO (2-1) Imaging of the NGC 6946 Giant Molecular Clouds	Wu Y.-L., Sakamoto K., Pan H.-A.	2017, ApJ 839, 6
2278	Molecular Gas Dominated 50 kpc Ram Pressure Stripped Tail of the Coma Galaxy D100	Jáchym P., Sun M., Kenney J. D. P., Cortese L., Combes F., Yagi M., Yoshida M., Palouš J., Roediger E.	2017, ApJ 839, 114
2279	Connecting Clump Sizes in Turbulent Disk Galaxies to Instability Theory	Fisher D. B., Glazebrook K., Abraham R. G., Damjanov I., White H. A., Obreschkow D., Basset R., Bekiaris G., Wisnioski E., Green A., Bolatto A. D.	2017, ApJ 839, L5
2280	A Massive Prestellar Clump Hosting No High-mass Cores	Sanhueza P., Jackson J. M., Zhang Q., Guzmán A. E., Lu X., Stephens I. W., Wang K., Tatematsu K.	2017, ApJ 841, 97
2281	Complex Organic Molecules toward Embedded Low-mass Protostars	Bergner J. B., Öberg K. I., Garrod R. T., Graninger D. M.	2017, ApJ 841, 120
2282	Gas Content and Kinematics in Clumpy, Turbulent Star-forming Disks	White H. A., Fisher D. B., Murray N., Glazebrook K., Abraham R. G., Bolatto A. D., Green A. W., Mentuch Cooper E., Obreschkow D.	2017, ApJ 846, 35
2283	Millimeter Spectral Indices and Dust Trapping By Planets in Brown Dwarf Disks	Pinilla P., Quiroga-Nuñez L. H., Benisty M., Natta A., Ricci L., Henning T., van der Plas G., Birnstiel T., Testi L., Ward-Duong K.	2017, ApJ 846, 70
2284	CARMA Survey toward Infrared-bright Nearby Galaxies (STING). IV. Spatially Resolved ^{13}CO in Spiral Galaxies	Cao Y., Wong T., Xue R., Bolatto A. D., Blitz L., Vogel S. N., Leroy A. K., Rosolowsky E.	2017, ApJ 847, 33
2285	SMA Observations of the Hot Molecular Core IRAS 18566+0408	Silva A., Zhang Q., Sanhueza P., Lu X., Beltran M. T., Fallscheer C., Beuther H., Sridharan T. K., Cesaroni R.	2017, ApJ 847, 87
2286	A Universal Correlation between Star Formation Activity and Molecular Gas Properties Across Environments	Koyama S., Koyama Y., Yamashita T., Morokuma-Matsui K., Matsuhara H., Nakagawa T., Hayashi M., Kodama T., Shimakawa R., Suzuki T. L., Tadaki K.-i., Tanaka I., Yamamoto M.	2017, ApJ 847, 137
2287	Physical Properties of 15 Quasars at $z \gtrsim 6.5$	Mazzucchelli C., Bañados E., Venemans B. P., Decarli R., Farina E. P., Walter F., Eilers A.-C., Rix H.-W., Simcoe R., Stern D., Fan X., Schlafly E., De Rosa G., Hennawi J., Chambers K. C., Greiner J., Burgett W., Draper P. W., Kaiser N., Kudritzki R.-P., Magnier E., Metcalfe N., Waters C., Wainscoat R. J.	2017, ApJ 849, 91
2288	Scale Invariant Jets: From Blazars to Microquasars	Liodakis I., Pavlidou V., Papadakis I., Angelakis E., Marchili N., Zensus J. A., Fuhrmann L., Karamanavis V., Myserlis I., Nestoras I., Palaiologou E., Readhead A. C. S.	2017, ApJ 851, 144

2289	Dynamical Timescale of Pre-collapse Evolution Inferred from Chemical Distribution in the Taurus Molecular Cloud-1 (TMC-1) Filament	Choi Y., Lee J.-E., Bourke T. L., Evans N. J., II	2017, ApJS 229, 38
2290	Star Formation Conditions in a Planck Galactic Cold Clump, G108.84-00.81	Kim J., Lee J.-E., Liu T., Kim K.-T., Wu Y., Tatematsu K., Liu S.-Y., JCMT Large Program "SCOPE" Collaboration, TRAO Key Science Program "TOP" Collaboration	2017, ApJS 231, 9
2291	Spatially resolved variations of the IMF mass normalization in early-type galaxies as probed by molecular gas kinematics	Davis T. A., McDermid R. M.	2017, MNRAS 464, 453
2292	Star formation in nearby early-type galaxies: the radio continuum perspective	Nyland K., Young L. M., Wrobel J. M., Davis T. A., Bureau M., Alatalo K., Morganti R., Duc P.-A., de Zeeuw P. T., McDermid R. M., Crocker A. F., Oosterloo T.	2017, MNRAS 464, 1029
2293	Millimetre spectral line mapping observations towards four massive star-forming H II regions	Li S., Wang J., Zhang Z.-Y., Fang M., Li J., Zhang J., Fan J., Zhu Q., Li F.	2017, MNRAS 466, 248
2294	The effect of ram pressure on the molecular gas of galaxies: three case studies in the Virgo cluster	Lee B., Chung A., Tonnesen S., Kenney J. D. P., Wong O. I., Vollmer B., Petitpas G. R., Crowl H. H., van Gorkom J.	2017, MNRAS 466, 1382
2295	Decrease of the organic deuteration during the evolution of Sun-like protostars: the case of SVS13-A	Bianchi E., Codella C., Ceccarelli C., Fontani F., Testi L., Bachiller R., Lefloch B., Podio L., Taquet V.	2017, MNRAS 467, 3011
2296	A study of singly deuterated cyclopropenylidene c-C_3HD in the protostar IRAS 16293-2422	Majumdar L., Gratier P., Andron I., Wakelam V., Caux E.	2017, MNRAS 467, 3525
2297	Two-dimensional ice mapping of molecular cores	Noble J. A., Fraser H. J., Pontoppidan K. M., Craigon A. M.	2017, MNRAS 467, 4753
2298	The rotational excitation of the HCN and HNC molecules by H_2 revisited	Hernández Vera M., Lique F., Dumouchel F., Hily-Blant P., Faure A.	2017, MNRAS 468, 1084
2299	What drives gravitational instability in nearby star-forming spirals? The impact of CO and H I velocity dispersions	Romeo A. B., Mogotsi K. M.	2017, MNRAS 469, 286
2300	Mass-size scaling $M \sim r^{1.67}$ of massive star-forming clumps - evidences of turbulence-regulated gravitational collapse	Zhang C.-P., Li G.-X.	2017, MNRAS 469, 2286
2301	L1157-B1, a factory of complex organic molecules in a solar-type star-forming region	Lefloch B., Ceccarelli C., Codella C., Favre C., Podio L., Vastel C., Viti S., Bachiller R.	2017, MNRAS 469, L73
2302	Integral field spectroscopy of nearby quasi-stellar objects - II. Molecular gas content and conditions for star formation	Husemann B., Davis T. A., Jahnke K., Dannerbauer H., Urrutia T., Hodge J.	2017, MNRAS 470, 1570
2303	Detection of the HC_3NH^+ and $HCNH^+$ ions in the L1544 pre-stellar core	Quénard D., Vastel C., Ceccarelli C., Hily-Blant P., Lefloch B., Bachiller R.	2017, MNRAS 470, 3194
2304	Massive 70 μm quiet clumps I: evidence of embedded low/intermediate-mass star formation activity	Traficante A., Fuller G. A., Billot N., Duarte-Cabral A., Merello M., Molinari S., Peretto N., Schisano E.	2017, MNRAS 470, 3882
2305	The interstellar chemistry of C_3H and C_3H_2 isomers	Loison J.-C., Agúndez M., Wakelam V., Roueff E., Gratier P., Marcelino N., Reyes D. N., Cernicharo J., Gerin M.	2017, MNRAS 470, 4075

2306	Probing the cold and warm molecular gas in the Whirlpool Galaxy: Herschel SPIRE-FTS observations of the central region of M51 (NGC 5194)	Schirm M. R. P., Wilson C. D., Kamenetzky J., Parkin T. J., Glenn J., Maloney P., Rangwala N., Spinoglio L., Baes M., Boselli A., Cooray A., De Looze I., Fernández-Ontiveros J. A., Karczewski O. Ł., Wu R.	2017, MNRAS 470, 4989
2307	Silicon-bearing molecules in the shock L1157-B1: first detection of SiS around a Sun-like protostar	Podio L., Codella C., Lefloch B., Balucani N., Ceccarelli C., Bachiller R., Benedettini M., Cernicharo J., Faginas-Lago N., Fontani F., Gusdorf A., Rosi M.	2017, MNRAS 470, L16
2308	Testing the variability of the proton-to-electron mass ratio from observations of methanol in the dark cloud core L1498	Daprà M., Henkel C., Levshakov S. A., Menten K. M., Muller S., Bethlem H. L., Leurini S., Lapinov A. V., Ubachs W.	2017, MNRAS 472, 4434
2309	Water Masers Outburst in the Massive Stellar Cluster W49A	Kramer B. H., Menten K. M., Kamiński T., Zhang B., Patel N. A., Kraus A.	2017, IAU Symp. 316, 155
2310	N131: A dust bubble was born from the disruption of a gas filament?	Zhang C.-P.	2017, IAU Symp. 316, 175
2311	Radio and γ-ray loud narrow-line Seyfert 1 galaxies in the spotlight	Karamanavis V., Angelakis E., Komossa S., Myserlis I., Blinov D., Zensus J. A.	2017, IAU Symp. 324, 184
2312	Carbon Monoxide in the Distantly Active Centaur (60558) 174P/Echeclus at 6 au	Wierzchos K., Womack M., Sarid G.	2017, Astron. J 153, 230
2313	Thermochemistry and vertical mixing in the tropospheres of Uranus and Neptune: How convection inhibition can affect the derivation of deep oxygen abundances	Cavalié T., Venot O., Selsis F., Hersant F., Hartogh P., Leconte J.	2017, Icarus 291, 1
2314	Blazar spectral variability as explained by a twisting inhomogeneous jet	Raiteri C. M., Villata M., for the WEBT Collaboration	2017, Nature 552, 374
2315	Gaussian Processes for Blazar Variability Studies	Karamanavis V.	2017, Galaxies 5, 19
2316	Upper Limits to Magnetic Fields in the Outskirts of Galaxies	López E., Armijos-Abendaño J., Llerena M., Aldás F.	2017, Galaxies 5, 55
2317	3 mm GMVA Observations of Total and Polarized Emission from Blazar and Radio Galaxy Core Regions	Casadio C., Krichbaum T., Marscher A., Jorstad S., Gómez J., Agudo I., Bach U., Kim J.-Y., Hodgson J., Zensus A.	2017, Galaxies 5, 67
2318	ALMA Observations of z ~ 7 Quasar Hosts: Massive Galaxies in Formation	Venemans B. P.	2017, Messenger 169, 48
2319	Venus's winds and temperatures during the MESSENGER's flyby: towards a three-dimensional instantaneous state of the atmosphere	Peralta J., Lee Y. J., Hueso R., Clancy R. T., Sandor B. J., Sánchez-Lavega A., Lellouch E., Rengel M., Machado P., Omino M., Piccialli A., Imamura T., Horinouchi T., Murakami S., Ogohara K., Luz D., Peach D.	2017, European Planetary Science Congress 11, EPSC2017-78
2320	Relation between the parameters of dust and of molecular and atomic gas in extragalactic star-forming regions	Smirnova K. I., Murga M. S., Wiebe D. S., Sobolev A. M.	2017, Astron. Rep. 61, 646
2321	Unveiling the L1157-B1 Bow-Shock Structure from Optical to Millimeter Wavelengths	Busquet G., Lopez R., Estalella R., Codella L.	2017, Conf. Proc. Star Formation from Cores to Clusters, 5
2322	a Prestellar Core 3MM Line Survey: Molecular Complexity in L183	Lattanzi V., Bizzocchi L., Caselli P.	2017, 72nd Internat. Symp. on Molecular Spectroscopy, WF06

2323	Mapping Magnetic Fields in Molecular Clouds with the CN Zeeman Effect	Crutcher R.	2017, 72nd Internat. Symp. on Molecular Spectroscopy, TF10
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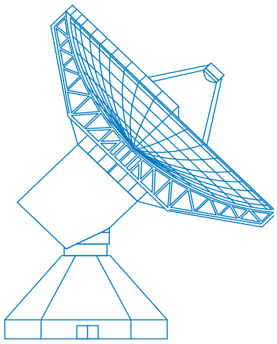
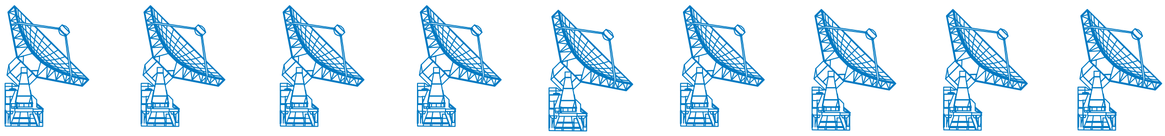


30-meter telescope, Pico Veleta



9 x 15-meter Interferometer, NOEMA

The Institut de Radioastronomie Millimétrique (IRAM) is a multi-national scientific institute covering all aspects of radio astronomy at millimeter wavelengths. IRAM operates two observatories – the 30-meter Telescope on Pico Veleta in the Sierra Nevada and NOEMA, an interferometer of nine 15-meter antennas on the Plateau de Bure in the French Alps.

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