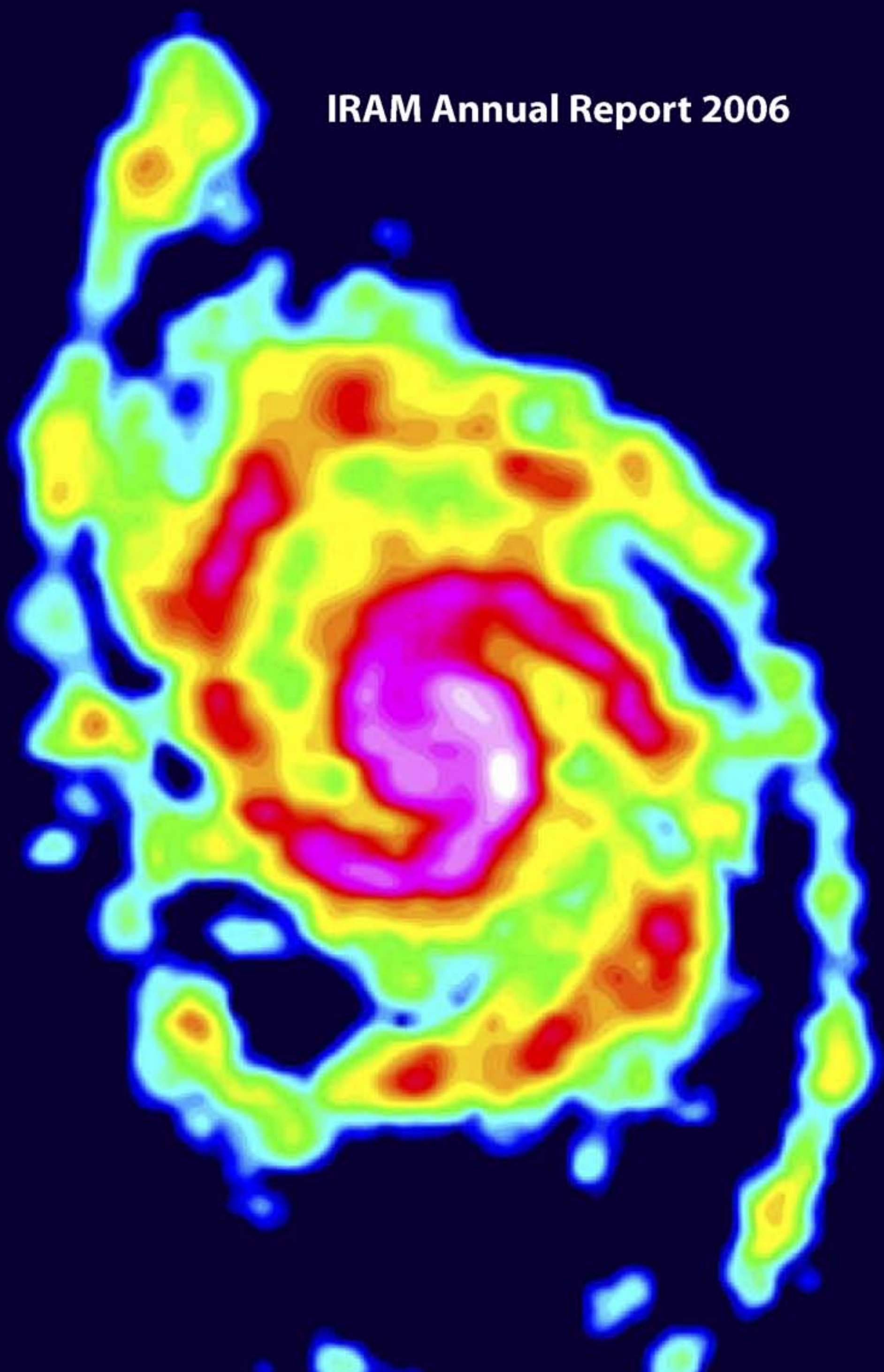

IRAM Annual Report 2006

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Millimétrique

Front Cover

Molecular gas distribution in M51, the "Whirlpool Galaxy", traced in the emission of CO(2-1) from the 30-meter telescope. The CO emission shows the clouds of gas in the arms and inter-arms from where stars are or will be formed (from Schuster et al. 2007).

IRAM ANNUAL REPORT 2006

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2. HIGHLIGHTS OF RESEARCH WITH THE IRAM TELESCOPES IN 2006

2.1 SUMMARY

Among projects at the IRAM telescopes done or published in 2006, a few highlights were:

- **A harvest of line detections from the extraordinary gravitationally lensed quasar APM 08279+52 at a redshift z = 3.9.** Further analysis and new detections in APM 08279+52 have been made with the IRAM telescopes of the CO(4-3), (6-5), (9-8), (10-9), and (11-10) lines, and of the HCN(5-4) line, the C I (neutral carbon) $^3P_1$-$^3P_0$ line, the HCO^+ ion, and an HNC line, possibly blended with CN. The line strengths imply a large mass of warm, high-density (10^5 cm^{-3}) molecular gas in this high-redshift quasar.
- **New maps of molecular gas in nearby galaxies.** Many new maps have been made of nearby galaxies. Some of these new surveys are: a 30m-telescope map of cold molecular gas in the core of the Perseus Cluster; a complete CO(2-1) map of M51, made with the HERA multi-beam array at the 30m telescope, with a new analysis of the radial averages of the CO, H I, and radio continuum; high-resolution interferometer maps of CO and HCN lines from dense molecular gas at the centre of the nearby spiral NGC 6946, showing evidence for bar-driven accumulation of gas at the centre; a 30m-telescope spectral-line survey at 2mm of the starburst galaxy NGC 253; new detections of methanol and of the reactive ion CO^+ in the nucleus of M82, and an interferometer map of thermal SiO in the central region of the nearby spiral IC342. A new analysis has been made of the molecular gas in the Andromeda Galaxy, mapped in CO with the 30m telescope, in comparison with H I maps and infrared maps from the *IRAS*, *ISO* and *Spitzer* satellites.
- **Protostellar disks and outflows.** Some of the new results include: maps of a highly collimated SiO jet in the HH212 protostellar outflow; observations of the disk and outflow of the pre-Main Sequence star HH 30; star formation and fast outflows near the young star cluster IC 348; an extremely high velocity molecular outflow in IRAS 20126+4104; new detections of water in envelopes and disks around high-mass stars; maps of a rotating disk around the young massive star AFGL 490; an analysis of tidal stripping and disk kinematics in the RW Aurigae system and sub-arcsecond imaging of the inner dust disks surrounding the stars LkCa 15 disk and MWC 480.
- **Galactic molecular cloud studies.** A few of the new results are**:** detection of warm water vapour around Sgr B2; comparison of CO and carbon-line maps of the Horsehead Nebula; an analysis of the low sulphur depletion in the Horsehead Nebula; new results on the internal chemistry of starless dense cores; a study of molecular chemistry in the Galactic Centre Ring, and new maps of organic molecules in the Galactic Centre.

- **Pre-planetary Nebulae.** A new high-resolution interferometer study of the remarkable kinematic motion in the pre-planetary nebula M 1-92.
- **Solar System.** An analysis of radio observations at the 30m telescope of comet 9P/Tempel 1 before and after the Deep Impact mission, and an extensive analysis of molecular line observations of four recent comets.

2.2 HIGH-REDSHIFT DETECTIONS

A harvest of line detections from the extraordinary gravitationally-lensed quasar APM 08279+52 at z = 3.91. Quasars are bright accretion disks around super massive black holes at the centres of galaxies. The wind from the accretion disk carries out fast-moving material in a funnel-shaped flow, above and below the disk (Fig.2.1, upper left), which appears in Broad Absorption Lines (BAL) in the UV and X-rays when the edges of the funnel are oriented along our line of sight. At high redshifts, the quasars' host galaxies are young, still forming, and still contain large quantities of gas that has not yet been converted into stars. If we can detect the molecular gas in the quasar's host galaxy, then we can try to measure its chemical components, and its average temperature and density. One of the best objects for this purpose is the BAL quasar APM 08279+52 at a redshift z = 3.91, because it is strongly gravitationally lensed and thus very bright. The gravitational lens makes this quasar appear as a double source (with a very weak 3rd image, in between) at all wavelengths, from radio to X-rays. The high magnification made it possible for the IRAM Interferometer to detect the CO(4-3) and CO(9-8) lines in 1998. Since then, follow-up observations have been made at the 30-meter telescope and with the Interferometer, of other CO lines and other molecules. A new study had been made with the 30-meter telescope of the CO(4-3), (6-5), (9-8), (10-9), and (11-10) lines. Unlike the CO in other QSO host galaxies, the CO lines in APM 08279 continue increasing in strength as one moves up the CO rotational ladder, reaching a maximum at the CO(10-9) line, indicating that the molecular gas is much warmer than in other high-redshift galaxies (Fig. 2.1, *lower left*, from Weiss et al. 2007).

Strong, high-J line of HCN emission in APM 08279: After the initial detections of CO in this object, the IRAM Interferometer was used to detect HCN J=5-4 emission from APM 08279. This was the first clear detection of high-J HCN emission redshifted into the 3-millimeter atmospheric window (Fig. 2.1, *upper right*). The HCN data implied an apparent HCN(5-4) line luminosity of 4 x 10^{10} K km/s pc^2 (about 100 times the CO(1-0) luminosity of the Milky Way!). The 440 km/s line width of the HCN(5-4) line is about the same as for the high-J CO lines in this object, so the emission from both HCN and CO probably comes from the same place - a warm, dense, circumnuclear disk. The ratio of HCN to far-infrared luminosity is 1/2000, comparable to that observed in the very few high-redshift objects so far detected in the lower-frequency HCN(1-0) line (Wagg et al.

2005. ApJ, 634, L13). Because APM 08279 is strong in the mid-infrared, the HCN(5-4) line is probably enhanced by infrared pumping through the 14-micron line of the first vibrational bending mode of HCN (Weiss et al. 2007).

Atomic Carbon in APM 08279: An important tracer of the dense neutral gas in a galaxy's interstellar medium is atomic carbon, and in particular the [C I] $^3P_1 \rightarrow ^3P_0$ line at a rest frequency of 492 GHz. This atomic line is important because compliments the molecular-line probes of the dense, neutral gas and because it provides another estimate of the gas mass, independent of the mass estimated from CO. The line is hard to observe in local-universe galaxies because of poor atmospheric transmission near 492 GHz. At redshifts greater than 1, however, this carbon line moves to frequencies that can be observed by millimetre telescopes, and it has now been detected in APM 08279 with the IRAM Interferometer (Wagg et al. 2006, ApJ, 651, 46). The observed carbon-line luminosity is consistent with the large molecular gas mass inferred from the CO line luminosity.

Further detections of other molecules in APM 08279 (HCO^+, HNC and CN) : After the HCN detection in APM 08279, it made sense to search for the molecular ion HCO^+ and the molecule HNC in the same source. These species have now been found in APM 08279 with the IRAM Interferometer, in the HCO^+ (5-4) line (García-Burillo et al. 2006, ApJ, 645, L17), and in the HNC(5-4) line. The HNC line may be blended with the N= 4-3 line of CN. (Guélin et al. 2007, A&A, 462, L45). These lines have the same centre velocities and line widths as CO and HCN, suggesting that all of these species are in the same circumnuclear disk of dense, warm molecular gas (Fig. 2.1, *lower right*, from Weiss et al. 2007, A&A, in press.).

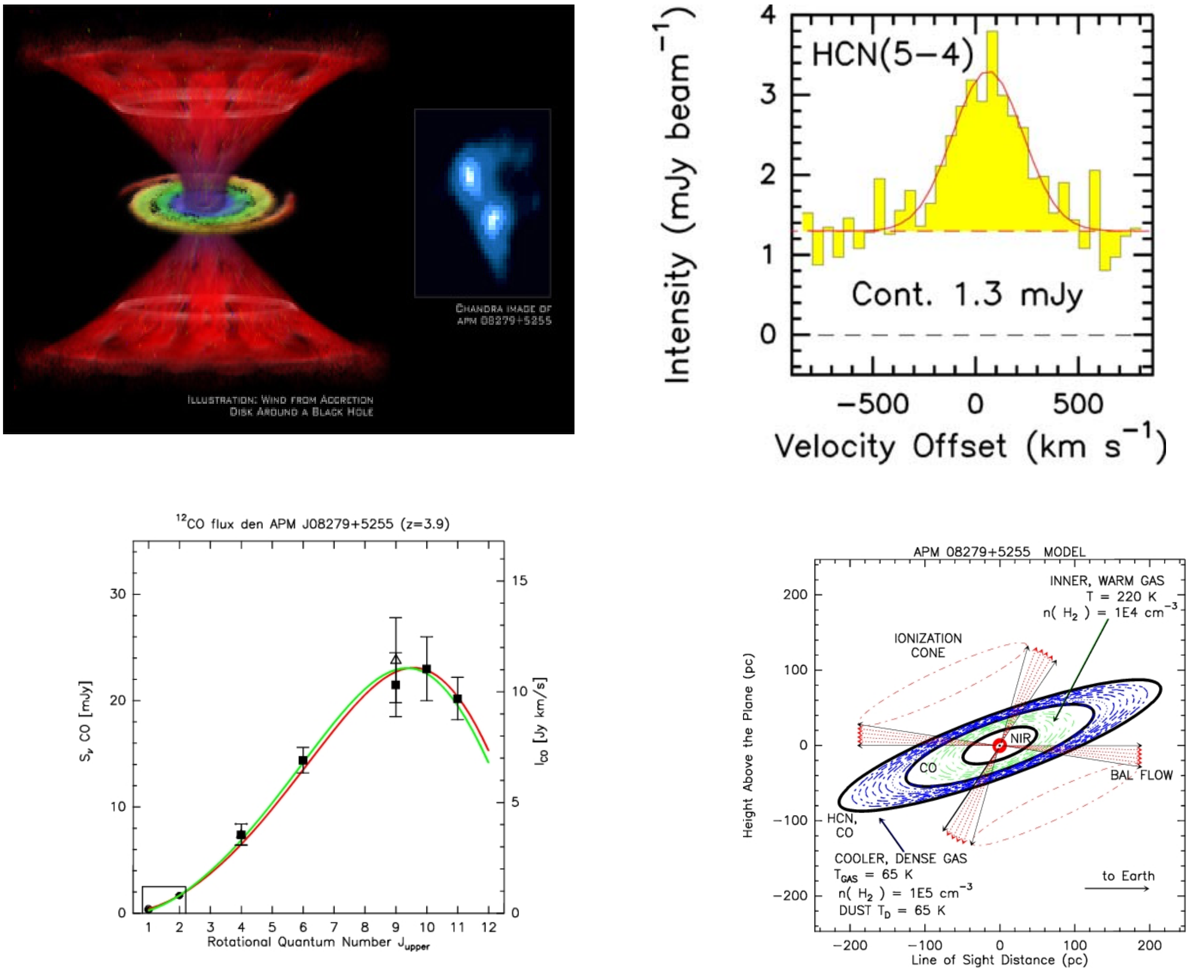


Fig. 2.1: Molecular lines from the quasar APM 08279+5255 at *z* = 3.9.

Upper left: Artist's sketch of the Broad Absorption Line (BAL) outflow from the 0.1-pc accretion disk around the black hole in APM 08279. The blue picture is the X-ray double image, due to gravitational lensing (M. Weiss, NASA-*Chandra*, and Chartas et al. 2002). *Lower left:* CO fluxes vs. rotational quantum number of the transition, from CO lines measured at the IRAM 30m telescope and the IRAM Interferometer. The peak is near J=10, indicating high density and high temperature (A. Weiss et al., 2007). *Upper right:* HCN 5-4 line (emitted at 443 GHz, observed redshifted to 90.2 GHz with the IRAM Interferometer). The line is above a dust continuum of 1.3 mJy (Wagg et al. 2005, plus new data from Weiss et al. 2007). *Lower right:* Interpretation of the IRAM molecular-line data in terms of a two-component disk model. The red arrows indicate the edges of the double-funnel-shaped BAL flow in the upper left picture, part of which is close to our line of sight. The CO and HCN intensities can be explained by a 220 K inner molecular disk of radius 65 to 150 pc, and a 65 K outer molecular disk of radius 150 to 350 pc (A. Weiss et al. 2007, A&A, in press).

Cold Molecular Gas in the Core of the Perseus Cluster of Galaxies. In recent years, extended, cold molecular gas has been detected in several clusters of galaxies containing enormous systems of optical Hα-line emitting filaments, spread over regions of 100 kpc. These filaments are at the boundaries of expanding bubbles of hot, ionised gas surrounding the relativistic jets emanating from the super massive black hole in the giant galaxy at the cluster's core. As the hot (million-degree) gas rises buoyantly out of the gravitational field of the central galaxies, dense parts of the bubbles' outer edges cool to form the ionised (10,000 K) filaments, and some of this cooler gas is drawn back in, behind the expanding bubbles, to fall, in a "cooling flow", onto the large galaxy where it originated. The cold (<100 K) component of this gas is in molecular form, and can be detected in CO lines. One of the first examples of this phenomenon to be detected in CO was in the galaxy NGC 1275, at the core of the Perseus cluster (D = 76 Mpc, 1″ = 370 pc). This galaxy is the host of the famous strong radio source 3C84, associated with the super massive black hole at the galaxy's centre. A new high-sensitivity CO(2-1) map of this region has now been made with the HERA 18-channel receiver at the 30m telescope. The high sensitivity of the new observations (Fig. 2.2) reveals for the first time a collection of weak CO-emitting clouds that appear to be related to the very extended (50 kpc) network of ionised filaments around the hot bubbles. The new data also confirm the previously known concentration of strong CO emission within a radius of 5 kpc of the centre of the galaxy NGC1275, and the weaker CO emission in a flattened structure extending east-west, to a radii of 15 kpc from the centre of the galaxy. The observers also report a tentative detection of HCN(3-2) line in the centre of NGC1275 (Salomé et al. 2006, A&A, 454, 437, and 2007, A&A, in press).

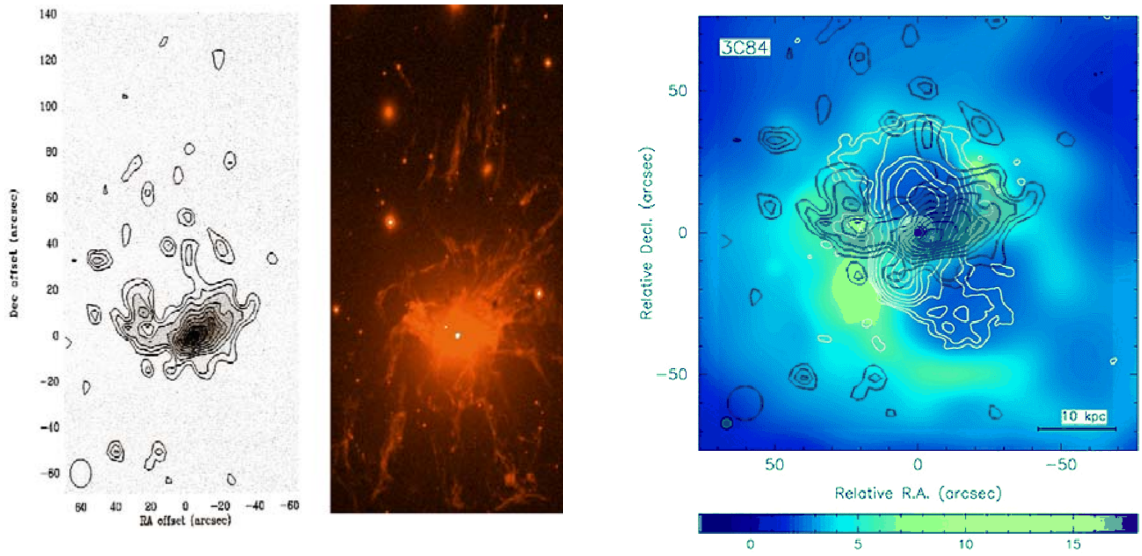


Fig. 2.2: Cold Molecular Gas in the Core of the Perseus Cluster of Galaxies
Left: Integrated CO(2-1) emission mapped at the 30-meter telescope with the HERA receiver. The peak signal is 8.3 K km/s in the 12" beam. *Middle:* Hα image on the same scale, showing the system of filaments around the central galaxy, NGC1275 (Conselice et al. 2001). *Right:* Contours of the CO emission (in black) superposed on the X-ray image (colours; Fabian et al. 2003), and the radio lobes at 90 cm (Pedlar et al. 1990). Diagrams are from (Salomé et al. 2006, A&A, 454, 437)

2.3 NEARBY GALAXIES

A complete CO(2-1) map with the HERA array of the Galaxy M51. The CO(2-1) emission from the nearby spiral galaxy M51 (D=8.4 Mpc, 1"= 41 pc) was mapped with the HERA 18-channel multibeam receiver at the IRAM 30-meter telescope. This is the first fully sampled CO map of M51 that extends out to the northern companion galaxy, NGC 5195, at a projected distance of 10.5 kpc from the centre of M51, and also covers the south-western spiral arm out to a radius of 15 kpc (Fig. 2.3, *upper left*). The data have been compared with maps of the 21cm H I line emission and the radio synchrotron continuum, to investigate the correlation of gas surface density with star formation rates as a function of radius from the centre of the galaxy, out to a radius of 12 kpc. The total mass of the molecular gas is 2 x 10^9 Msun. Most of this mass is concentrated toward the centre, with an H_2 surface density of 70 Msun/pc^2 at the center, falling to 3 Msun/pc^2 at a radius of 12 kpc. The atomic gas density is about one-tenth that of the molecular gas at the centre, becomes equal at a radius of 4 kpc, and is 20 times greater in the outskirts of the galaxy. The star formation rate, estimated from the radio continuum, follows a local Schmidt law, in which the star formation rate is proportional to the 1.4 power of the total gas density (molecular gas + atomic gas). (Schuster et al. 2007, A&A, 461, 143).

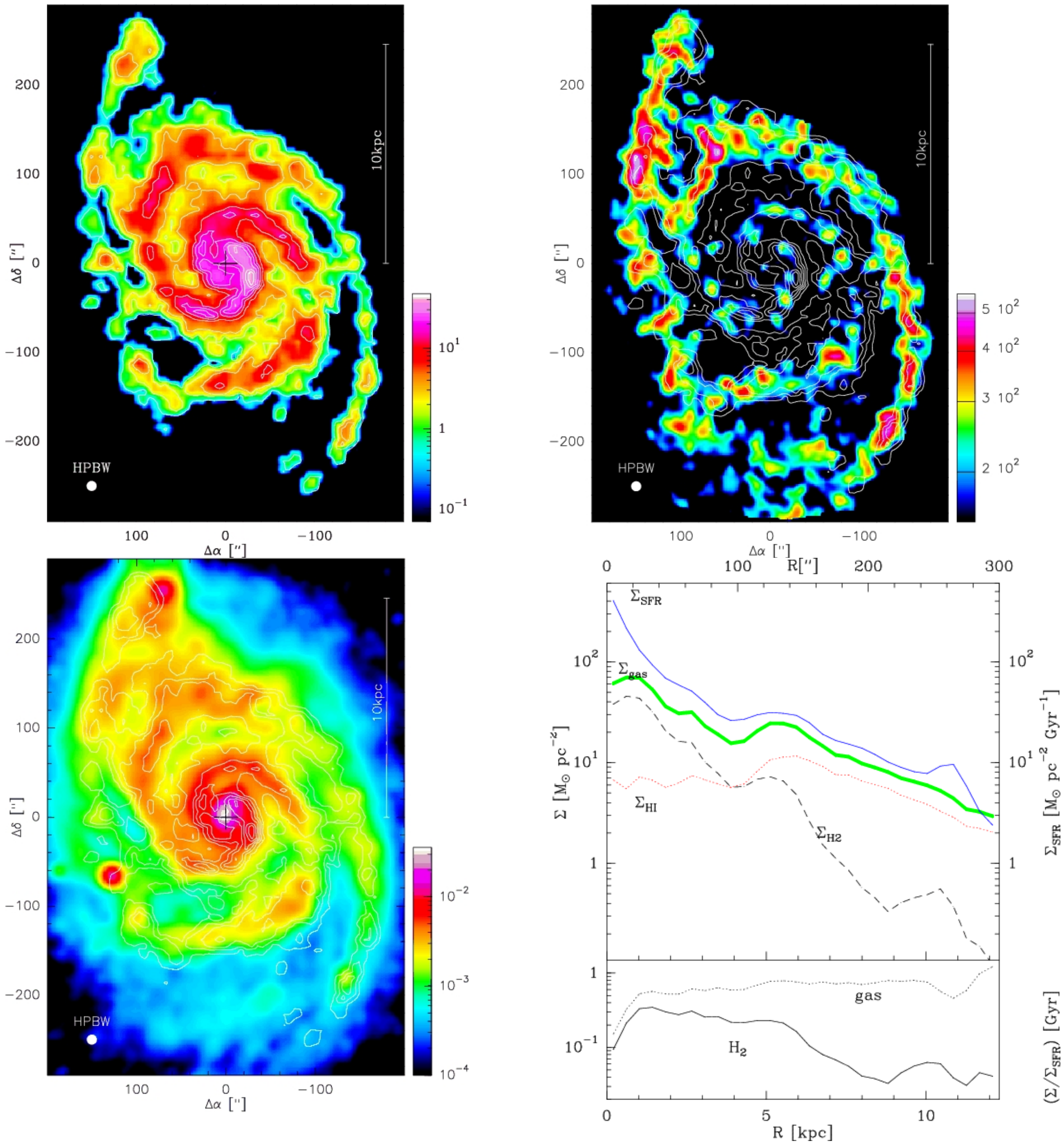


Fig. 2.2 Molecular gas, atomic gas, and star formation in the galaxy M51, and their radial averages *Upper left:* CO(2-1) intensity (K km/s) from the 30-meter telescope, with an 11" beam. *Upper right:* H I intensity (Jy km/s) from the VLA (Rots et al. 1990), at 13" resolution; Lower *left:* VLA-20cm radio continuum (Jy/beam) as a star-formation tracer (Patrikeev et al. 2006) at 15" resolution. Contours in all maps are CO(2-1). *Lower right:* Mean surface density vs. radius of H_2 (dashed), HI (red dotted), total gas (green) and star formation rate (blue). The lower box gives ratios of H_2 and total gas to star formation rate. (Schuster et al. 2007, A&A, 461, 143).

Bar-driven mass build-up at the centre of the galaxy NGC 6946. How does gas fall into black holes at the centres of most large galaxies? The accreting gas has long been thought to come somehow from molecular toroids at radii less than a few hundred parsecs of the black hole. This gas falls or is driven into the central gravitational potential, where it becomes trapped and most of it forms stars. The new extended configuration of the IRAM Interferometer has now been used to study the dense molecular gas in the centre of the nearby spiral galaxy NGC 6946 (D=5.5 Mpc, 1"= 27 pc) at unprecedented spatial resolution in HCN(1-0) and CO(2-1). The gas distribution in the central 50 pc has been resolved, and is consistent with a central gas ring or nuclear mini-spiral that is driven by the inner 400 pc long bar (Fig. 2.4). For the first time, it is possible to directly compare the locations of dense, giant molecular clouds with those of optically visible H II regions in Hubble Space Telescope images. The observations also yield 3mm continuum data and HCN maps that have been used to estimate the star formation rates in young star clusters that are still hidden in dust clouds, and that are not evident in visible or near-infrared images. In this galaxy, the amount of hidden star formation traced by HCN and the 3mm continuum is about twice as high as that indicated by the young stars that have already emerged from their dust cocoons, and can be traced by the near-IR Paschen-alpha line. From the star formation rates in the centre, the authors estimate the build-up of new stars has happened over the past 10 Myr, and is limited to the small, 50-pc region around the nucleus, and is closely related to the driving force of an inner, 400-pc bar. (Schinnerer et al. 2007, A&A, 462, L27).

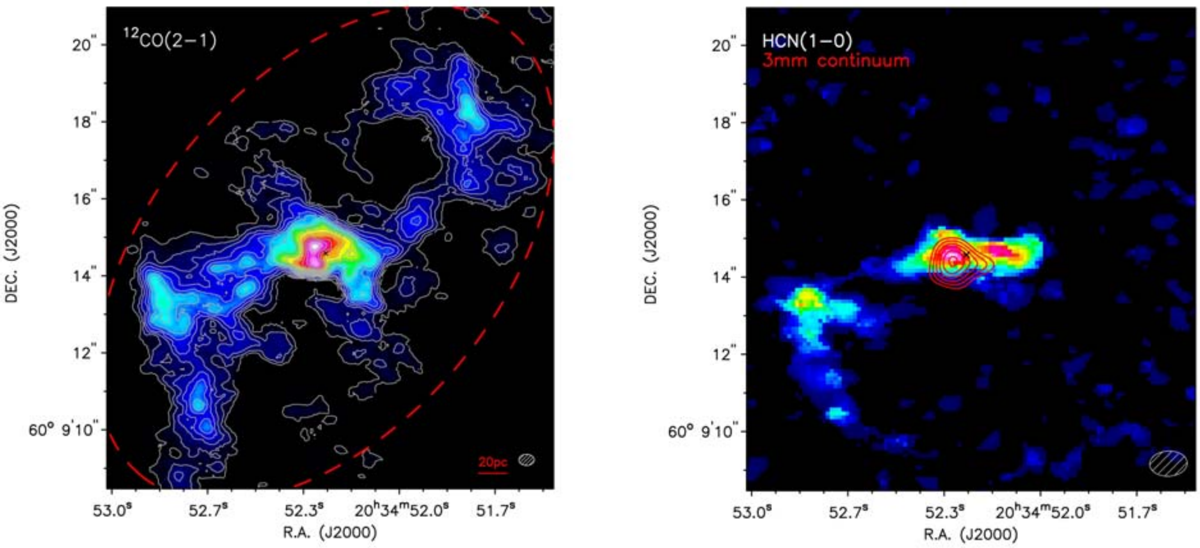


Fig. 2.4 Bar-driven mass build-up at the centre of the galaxy NGC 6946
Left: Interferometer map of CO(2-1) in the centre of the galaxy NGC 6946, made with a 0.4'' x 0.3'' beam (small ellipse in lower right corner). The integrated CO intensity is shown in colour and in contours of 0.6 Jy km/s. The large dashed ellipse indicates the location of the inner 400-pc stellar bar. *Right:* The same region in the HCN(1-0) line (color) and the 3mm continuum emission, in red contours (Schinnerer et al. 2007, A&A, 462, L27).

A 2-mm spectral-line survey of the starburst galaxy NGC 253. The first unbiased molecular line survey of an extragalactic source has been made with the 30m telescope toward the centre of the starburst galaxy NGC 253 (D = 3.5 Mpc, 1" = 17 pc). The scan covers most of the 2mm atmospheric window, from 129 to 175 GHz (Fig. 2.5). The observers have identified 111 spectral lines from 25 different molecules, 8 of which are detected for the first time in an extragalactic source. Among these newly detected extragalactic molecules are the rare species ^{34}SO and $HC^{18}O^+$, and tentative detections of two deuterated species DNC and N_2D^+. No organic molecules with more atoms than methanol (CH_3OH) were detected. The molecular line ratios and column densities in the centre of NGC 253 resemble those in the centres of two other nearby galaxies, IC342 and NGC 4945, but are clearly different from those in the nearby starburst M82. The molecular chemistry of the centre of NGC 253 also shows a striking similarity with that observed toward the molecular clouds in the centre of the Milky Way, which are thought to be dominated by low-velocity shocks. This resemblance strongly suggests that the cloud heating in the centres of NGC 253 and our Galaxy is due to the same mechanism (Martín et al. 2006, ApJS, 164, 450).

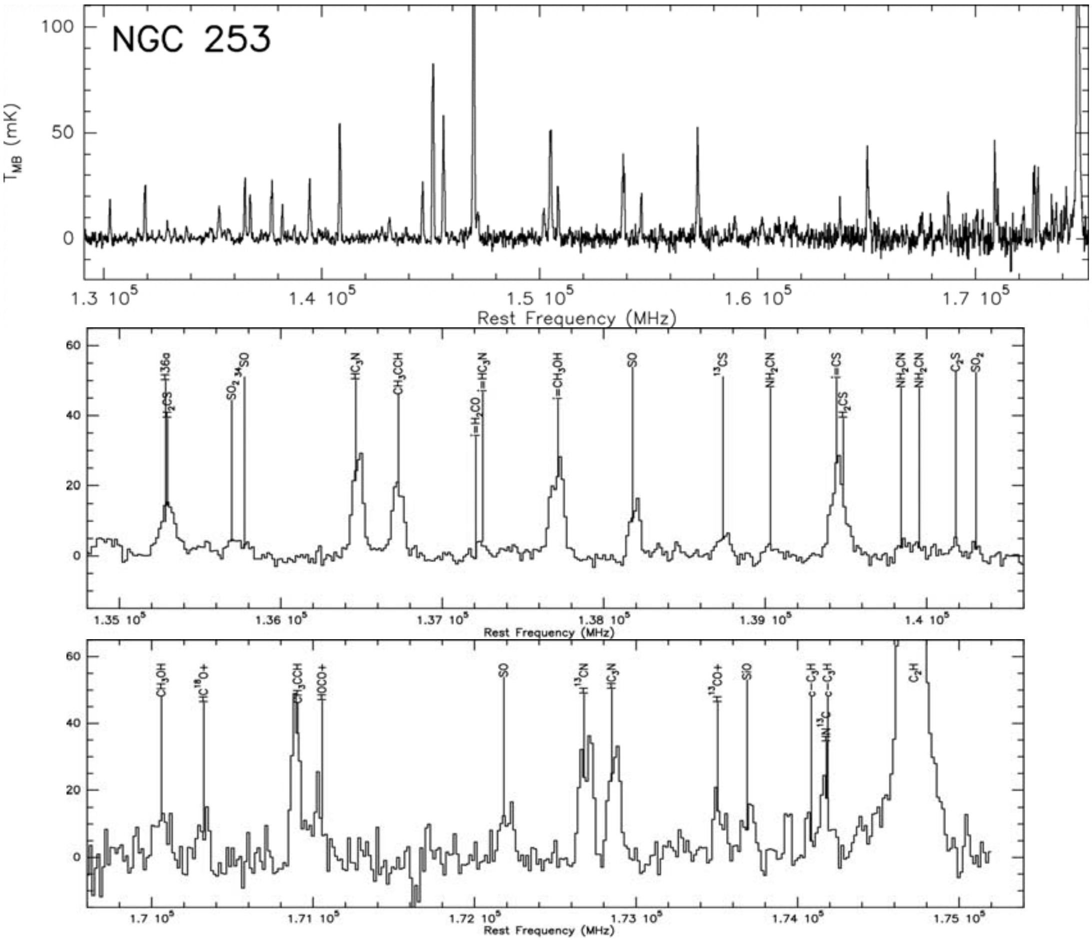


Fig. 2.5: A 2-mm spectral-line survey of the center of the starburst galaxy NGC 253. The survey, done with the 30m telescope, covers 129 to 175 GHz, and shows 111 spectral lines from 25 different molecules (Martín et al., 2006, ApJS, 164, 450).

Molecular Gas in the Andromeda Galaxy A survey of the CO(1-0) line in the Andromeda galaxy (M31) – at D=0.78 Mpc (1″ = 3.8 pc) - observed on-the-fly at the 30m telescope has been compared with H I maps from Westerbork and with mid- and far-infrared maps from the *IRAS*, *ISO*, and *Spitzer* satellites (Fig. 2.6). The CO line was detected from over radii from 3 kpc to 16 kpc from the center of the galaxy, with maximum intensity at a radius of 10 kpc. The molecular gas is concentrated a two-armed spiral pattern with a pitch angle of 7°, and often coincides with the dark dust lanes seen in the visible. The rotation of the galaxy is nicely traced in the IRAM CO map, taken with a beam of 23" (Fig. 2.7). The arm/interarm CO brightness ratio is 20. The apparent gas-to-dust ratios increase by a factor of 20 between the centre of the galaxy and a radius of 14 kpc. This may be due to the dust becoming colder at large radii. The molecular gas correlates better with cold dust than atomic gas. The mass of the molecular gas within 18 kpc of the centre of M31 is 3.6 x 10^8 Msun. This is 7% of the total neutral gas mass in the galaxy (Nieten et al. 2006, A&A, 453, 459).

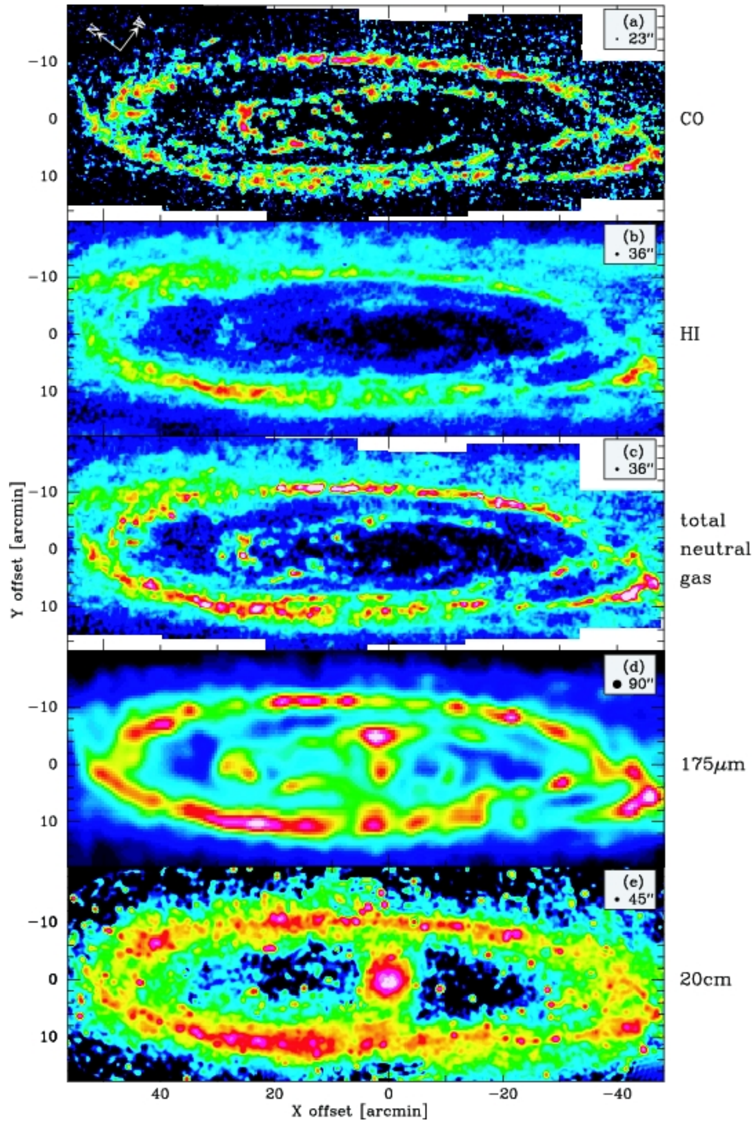


Fig. 2.6: Neutral gas, cold dust and radio continuum in M31. Top to bottom: a): CO(1-0) observed with the 30m telescope by Nieten et al. (2006); b): atomic hydrogen observed in the 21cm line with the Westerbork telescope by Brinks & Shane (1984); c): the total neutral gas (H I and H_2 derived from CO); d): emission from cold dust observed at 175μm by the *ISO* satellite by Haas et al. (1998); e): radio continuum at 20cm observed with the Effelsberg 100m telescope by Beck et al. (1998).

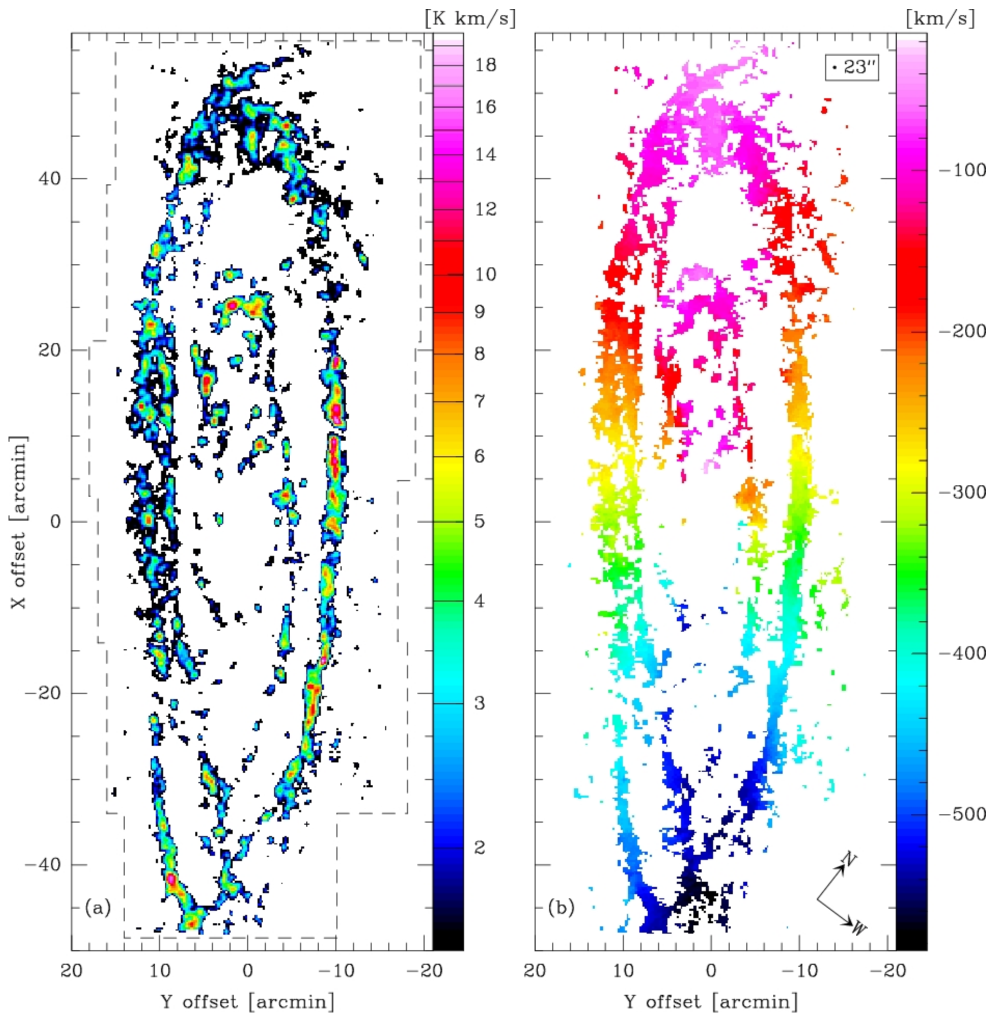


Fig. 2.7: CO(1-0) intensities and velocities in the Andromeda galaxy.

The data were taken with the IRAM 30m telescope with a 23" beam. *Left:* Integrated CO intensity, with line strength indicated by the colour scale to the right. *Right:* CO velocities, in km/s, corresponding to the colour scale to the right (Nieten et al. 2006, A&A, 453, 459).

2.4 PROTOSTELLAR OUTFLOWS AND DISKS

A highly collimated SiO jet in the HH212 outflow. New maps with the IRAM Interferometer of SiO in the HH 212 protostellar outflow (D=460 pc, 1″=460 AU) show that the SiO(2-1) and (5-4) line emission is confined to the outflow axis of a highly-collimated bipolar jet that is only 0.35″ wide close to the protostar (Fig. 2.8). This means that the SiO is not tracing a wide-angle outflow cone of entrained gas, but rather the narrow primary jet with a semi-opening angle of <6° near the protostar. The jet can be traced down to 500 AU of the driving source, in a region that is highly obscured in infrared images of H_2. Where both species are detected, the SiO has the same kinematics and structure as the H_2, so both molecules are tracing the same material.

Velocity cuts perpendicular to the jet show no sign of jet rotation. The central dust continuum peak observed at 1.4mm is unresolved. The 1.4mm dust temperature is > 13 K, with a spectral slope of 2, as in a Rayleigh-Jeans spectrum, meaning that the dust is probably close to being optically thick. The continuum is probably in an edge-on disk with a diameter of < 117 AU. (Codella et al. 2007, A&A, 462, L53).

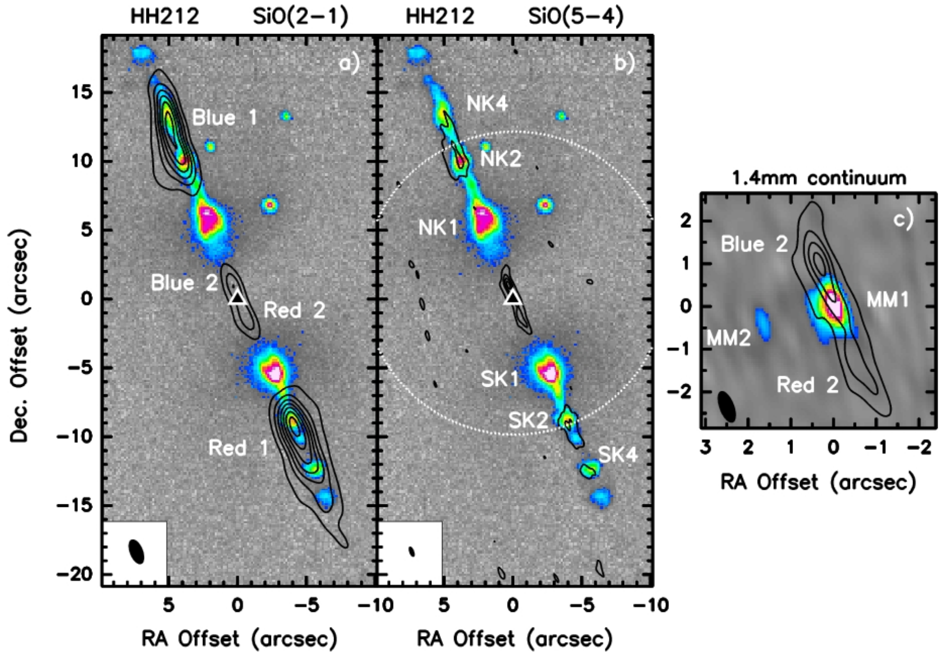


Fig. 2.8 The outflow from HH 212, traced by silicon monoxide

Left: Map of the integrated emission in the SiO(2-1) line, made with the IRAM interferometer at 86.8 GHz, with a beam of 1.9"x 0.9". The SiO contours are superposed on an infrared image (grey scale) in the 2-micron line of H_2. *Middle:* SiO(5-4) interferometer map at 217 GHz, with a beam of 0.78"x 0.34". *Right:* The inner 5" of the SiO(5-4) map (contour lines), superposed on the 1.4mm continuum emission (colour) from dust in the disk around the protostar MM1, the source of the outflow jets (Codella et al. 2007, A&A, 462, L53).

Observations of the disk and outflow of the young star HH 30. Herbig-Haro 30 is a pre-Main-Sequence star in Taurus at a distance of 140 parsecs (1″=140 AU). Optical images from the Hubble Space Telescope show a flared, edge-on disk, and a highly collimated jet. New observations with the IRAM Interferometer in the ^{12}CO, ^{13}CO, and C^{18}O(1-0) and (2-1) lines show a disk in Keplerian rotation, with an outer radius of 420 AU (Fig. 2.9). The rotation velocities imply that the star has a mass of 0.45 Msun. The CO(2-1) map also shows a highly asymmetric outflow, coming from the *inner* parts of the disk, and detected only in its north-eastern outflow lobe. This northeastern lobe is a cone with an opening angle of 60º. The CO outflow velocity along the wall of the cone is 12 km/s, with no sign of rotation (Fig. 2.10). The highly collimated optical jet seen by the HST lies precisely on the axis of the conical CO outflow. (Pety et al. 2006, A&A, 458, 841).

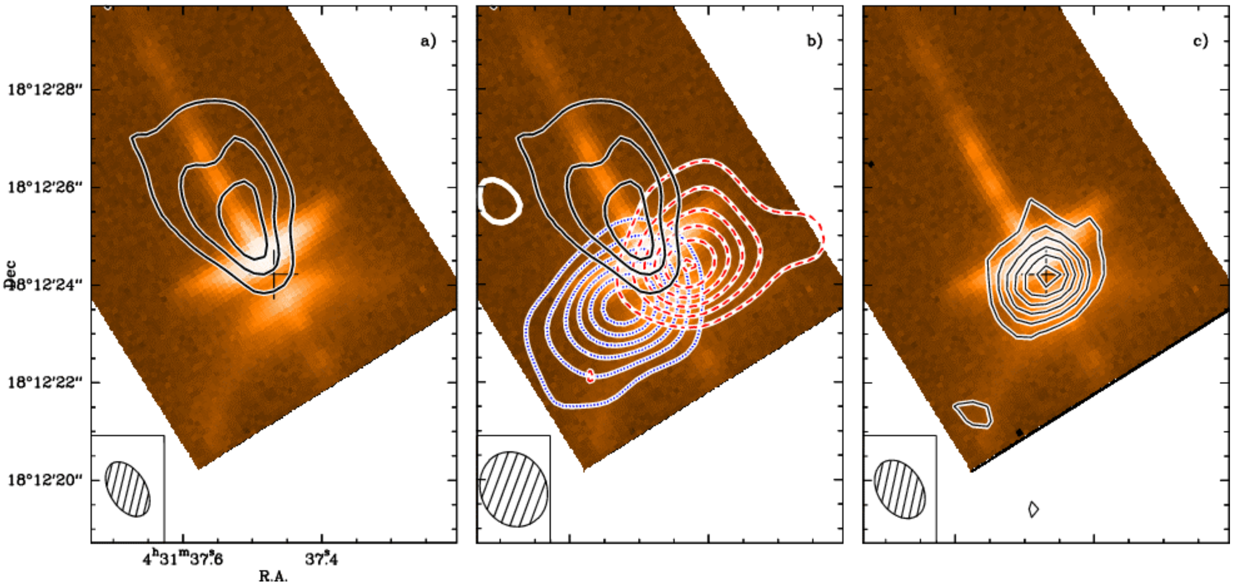


Fig. 2.9 CO outflow and dust disk of the young star HH 30

Left: IRAM Interferometer map of the $^{12}CO(2\text{-}1)$ outflow (v< 4 km/s and v>11 km/s), along the axis of the optical jet. *Middle:* The 12CO contour map of the outflow, from the left panel, is combined with the $^{13}CO(2\text{-}1)$ contour maps of the blue and red-shifted emission from the rotating disk. *Right:* The contours show the 1.3mm dust emission from the HH30 disk, seen edge-on around the young star. In all three diagrams, the Interferometer contour maps are superposed on the near-infrared image from the Hubble Space Telescope (Burrows et al. 1996). The interferometer beams shown in the insets in the lower left of each figure are typically 1.3″ x 0.9″ (Pety et al. 2006, A&A, 458, 841).

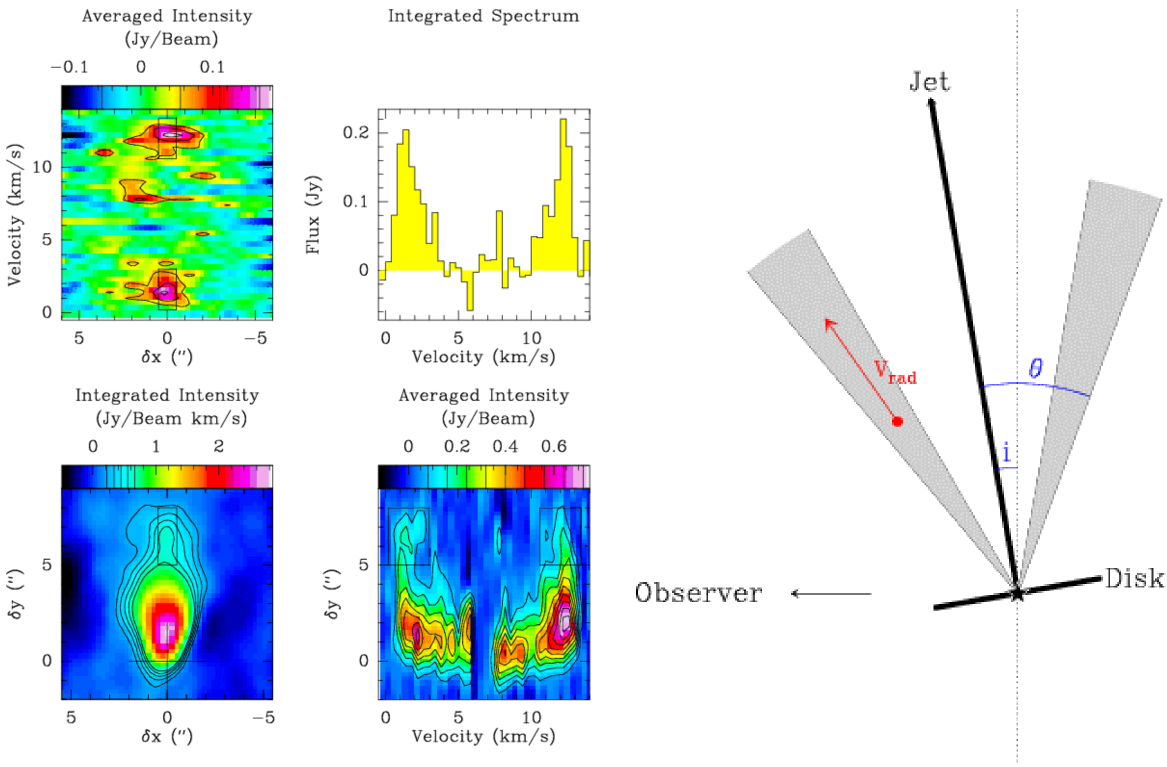


Fig. 2.10 CO outflow cone from the young star HH 30: data and model
Lower left: IRAM Interferometer map of the CO(2-1) outflow only (the CO in the rotating disk has been excluded). *Top left:* Position-velocity cut *perpendicular* to the outflow, showing CO emission from the two sides of the outflow cone. *Lower middle:* Position-velocity cut *along* the outflow. The velocity pattern indicates constant outflow speed. *Upper middle:* Integrated spectrum along the outflow, showing two line peaks, from opposite sides of the outflow cone. *Right panel:* Sketch of the model for the outflow cone, relative to the protostellar disk and to our line of sight. (Pety et al. 2006, A&A, 458, 841).

Disks around young stars: Sub-arcsecond imaging of the inner dust disks surrounding the stars LkCa 15 disk and MWC 480. The IRAM Interferometer has been used to map the dust continuum emission at 1.4 and 2.8mm from the proto-planetary disks around the pre-Main Sequence stars LkCa 15 and MWC 480 at D=140 pc (1″=140 AU) and displayed in Fig. 2.11. For the disk around LkCa 15, the observations show a cavity, with a radius of 50 AU. This cavity may be due to the tidal disturbance from a low-mass (<0.2 Msun) companion star, or possibly a large planet (>0.005 Msun), in an orbit about 30 AU from LkCa 15 itself. These observations mean that models of steady-state viscous disks are too simplistic to describe the inner 50 pc of "proto-planetary" disks, and that instead, the evolution of the disks is probably strongly influenced by the formation of planets. Unlike the dust emission of LkCa 15, which is optically thin, the dust emission in the disk around the star MWC 480 has an opaque core that is resolved at 1.4mm, and has a radius of 35 AU. Because the dust core is resolved, one may determine its temperature.

These disks have also been mapped with the IRAM Interferometer with sub-arcsecond resolution in CO (Fig. 2.12), and with a 4" beam in HCO^+. The observations show typical CO temperatures of 25 K. The CO emission thus comes from the warmer gas, while the observed dust emission comes from a colder layer (10 K), probably in mid-plane of the disk that is better shielded from starlight than the higher layers of the disk. The authors find evidence for vertical temperature gradients in the disks, and higher disk temperatures for hotter stars. Most of the off-plane CO gas is colder than 17 K, below the temperature at which CO would normally condense on grains, so there must be some other explanation for why the CO abundance is still high. One clue may be that the disk scale heights are about 50% higher than expected from hydrostatic equilibrium. This may indicate that turbulent mixing in the vertical direction is important for the disk chemistry, as is also photo-dissociation at the disks' outer edges due to ultraviolet radiation (Piétu et al. 2006, A&A, 460, L43, and 2007, A&A, in press).

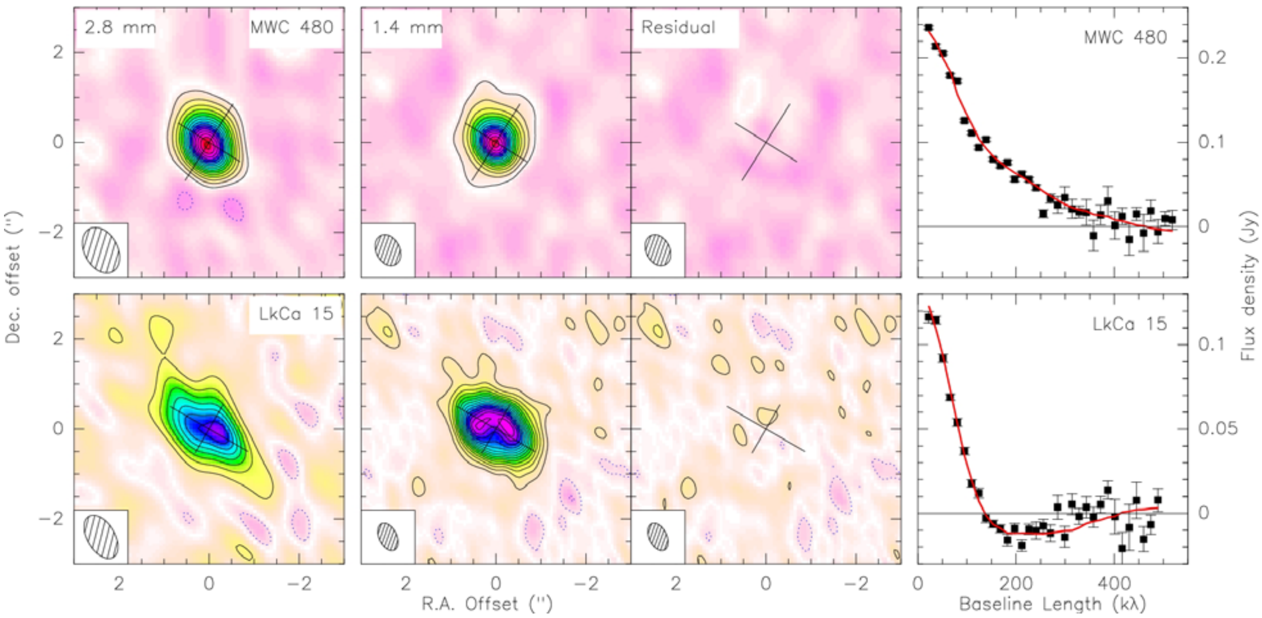


Fig. 2.11 IRAM Interferometer maps of dust in the disks around LkCa 15 and MWC 480

From Left to Right: High-resolution continuum images at 2.8mm (beam 1.1″ x 0.7″) and 1.4mm (beam 0.73″ x 0.53″), the residuals at 1.4mm after subtraction of the best disk model, and the interferometer visibilities as a function of baseline, after de-projection and azimuthal averaging. The points are the data and the curve is for the best-fit model (Piétu et al. 2006, A&A, 460, L43).

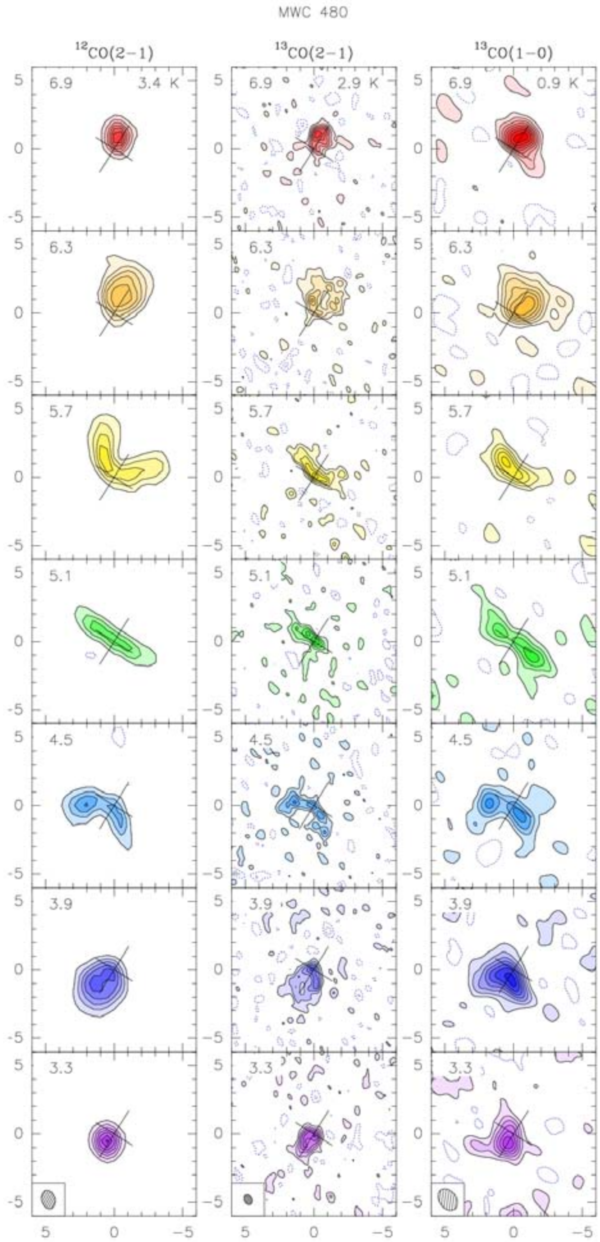


Fig. 2.12: CO in the disk around the star MWC 480. *Left to Right*: Channel maps of 12CO(2-1) with a beam of 1.4″ x 1.0″, ^{13}CO(2-1) with a beam of 0.77″ x 0.57″, and ^{13}CO(1-0) with a beam of 2″ x 1.2″. Velocities (km/s) are indicated in the upper left corner of each box. Contour units (K) are in the upper right of the top panels (Piétu et al. 2007, A&A, in press).

2.5 EVOLVED STARS

Remarkable kinematic motion in the pre-planetary nebula M 1-92. The oxygen-rich pre-planetary nebula M 1-92 ("Minkowski's footprint") is one of the few such objects whose molecular gas has been studied with high enough spatial and spectral resolution (at a distance of 2.5 kpc, 1″ = 2500 AU) to draw reliable conclusions about the gas motions. New long-baseline observations with the IRAM Interferometer (Fig. 2.13) now reveal an astonishing result. Contrary to previous conclusions, it now appears that the two molecular outflows in this object - the double-lobed, bi-polar, major axis outflow and the equatorial, disk-like, minor axis outflow - both started at the same time, about 1200 years ago, and that *the speed of both outflows linearly increases with distance.* This "Hubble-like" velocity field, with V just simply proportional to R greatly helps to clarify the interpretation and the modelling of the data, but it also demands an explanation of what causes such an unusual pattern of two perpendicular, accelerated outflows. A promising idea by Matt et al. (2006) is that following an abrupt change in the structure of the stellar core (e.g, a core collapse), differential rotation between the spinning-up stellar core and the overlying layers of the star lead to a release of magnetic energy in both the equatorial plane, where the twisted-up magnetic fields is strongest, and along the magnetic poles, which become a fast-flowing jet axis inside a bi-polar `magnetic balloon'. This means that the bi-polar lobes of M1-92 are not, as was previously thought, the remnants of a former red giant circumstellar envelope, left over from the AGB phase, being hit by some kind of post-AGB flow. Instead, the bi-polar lobes and central 'disk' of M1-92 are formed directly from gas very recently expelled from the upper layers of the star itself. This model, if borne out by further high-resolution molecular observations in other sources, may help to explain the puzzling shapes and multiple outflows observed in other pre-planetary nebulae as well (Alcolea, Neri, & Bujarrabal, 2007, A&A, in press).

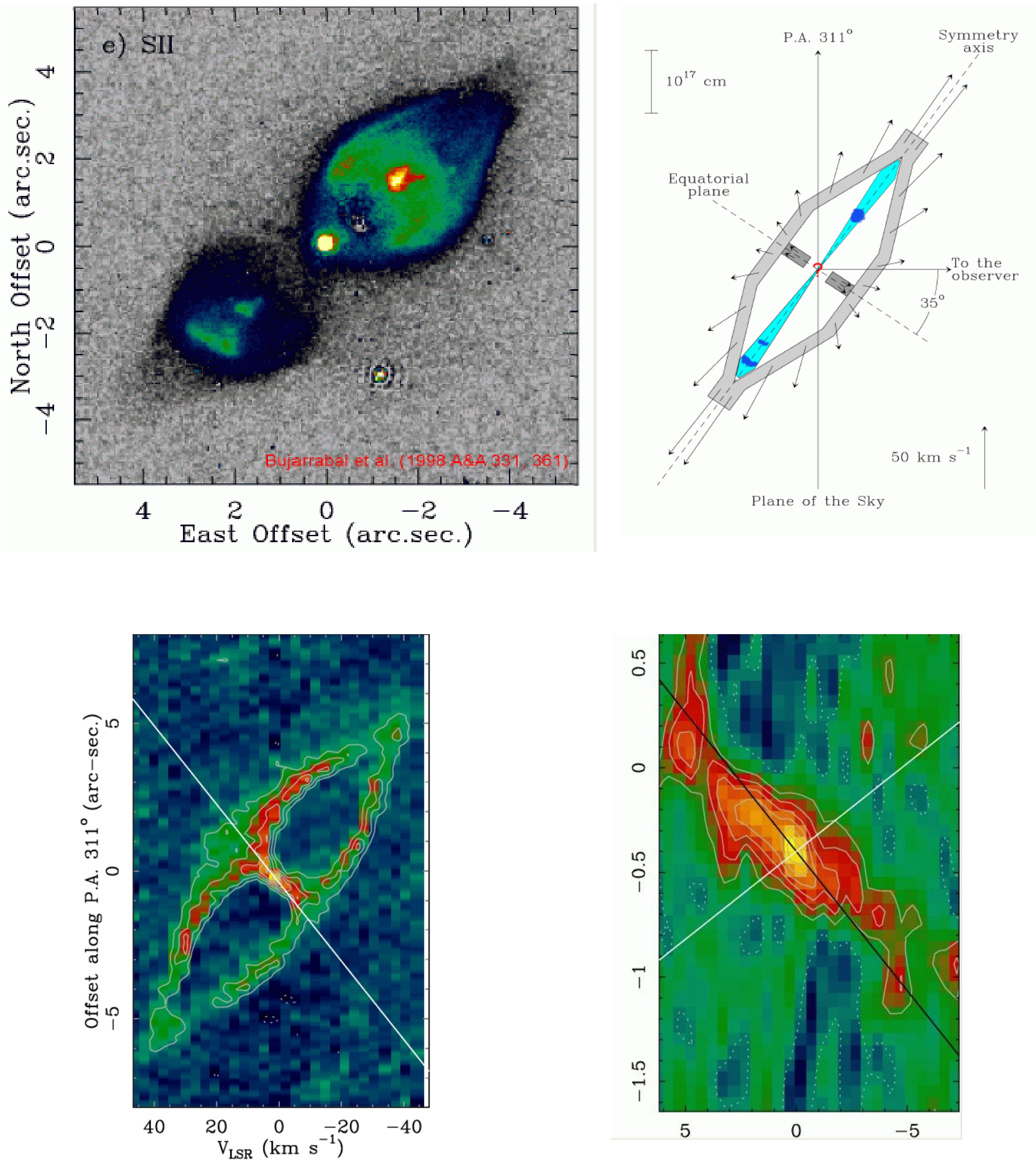


Fig. 2.13 Outflowing molecular gas in the pre-planetary nebula M 1-92 *Upper Left:* Hubble Space Telescope image of M 1-92 in the Sulfur II line (from Bujarrabal et al. 1998). *Upper Right:* Model of the nebula showing the inclination to the line of sight. *Lower Panels:* Position-velocity diagrams, from $^{13}CO(2\text{-}1)$ observations with the IRAM Interferometer, along the symmetry axis at p.a. 311 deg. (*Left*) and with a zoom into the central part (*Right*). The major axis cut shows positive velocities in the southeast, negative velocities in the northwest (Alcolea et al. 2007, A&A, in press).

2.6 SOLAR SYSTEM

Radio observations of comet 9P/Tempel 1 before and after the Deep Impact mission. Comet 9P/Tempel 1 was the subject of worldwide observations in 2005. The NASA Deep Impact mission reached the comet on 4 July 2005, delivering a 370 kg impactor, which hit the nucleus of the comet with a speed of 10 km/s, excavating a cloud of gas and dust. The comet was observed both before and after the impact with many space- and ground-based telescopes, including the IRAM 30m telescope. The IRAM observations detected HCN(1-0) and (3-2) both before and after the impact. Prior to impact, the production rates (or their upper limits) of HCN, H_2S, CH_3OH, CO, and CS were typical of short-period comets. The HCN line intensities were variable, with a possible periodic time variation of 1.7 days, indicating preferential outgassing from a "hot spot" toward the sun, and probably related to the rotating aspherical shape of the comet's nucleus (Fig. 2.14). Post-impact observations at IRAM and the Caltech Submillimeter Observatory did not reveal any significant change of the outgassing rates and relative abundances, except for methanol, which became up to ten times more abundant in the ejecta. The Odin satellite, however, showed a small increasing of outgassing of H_2O, corresponding to a release of 5000 tons of water vapour (Biver et al. 2007, Icarus, 187, 253).

Molecular-line observations of four recent comets. Comets are currently thought to belong to two families, the longer-period "Oort Cloud" comets, and the short-period "Jupiter family" comets. Despite their names, the Oort Cloud comets are presumed to have formed in the giant planet region, and were then expelled by gravitational interactions to the outer parts of the solar system. In contrast, the "Jupiter family" comets may have accreted directly in the Kuiper Belt beyond Neptune in a very cold environment, and not changed much since they were formed. Four comets thought to originate in the Oort Cloud were observed with the IRAM 30m telescope and other radio telescopes in 2001 and 2002. A comparative study has now been published of these four comets: C/1999 T1 (McNaught-Hartley), C/2001 A2 (LINEAR), C2000 WM_1 (LINEAR) and 153P/Ikeya-Zhang. Observations of the molecules carbon monoxide, methanol, formaldehyde, hydrogen cyanide, carbon monosulfide, methyl cyanide, and the species HNC, and HNCO show that all these four comets belong to the same family, their molecular relative abundances are significantly different, especially for the volatile species CO and H_2S (Fig. 2.15). In particular, comet C2000 WM_1 is quite depleted in these volatiles, suggesting that it may have a different origin or evolutionary history than the other three comets. The observations also show significant increases in the ratios of the production rates of CS-to-HCN and HNC-to-HCN with decreasing distance from the

Sun. The origin of HNC in cometary comae is currently unexplained. The HNC may be produced by photodissociation or thermal degradation of a parent molecule, which becomes more efficient the closer the comet is to the Sun. (Biver et al. 2006, A&A, 449, 1255).

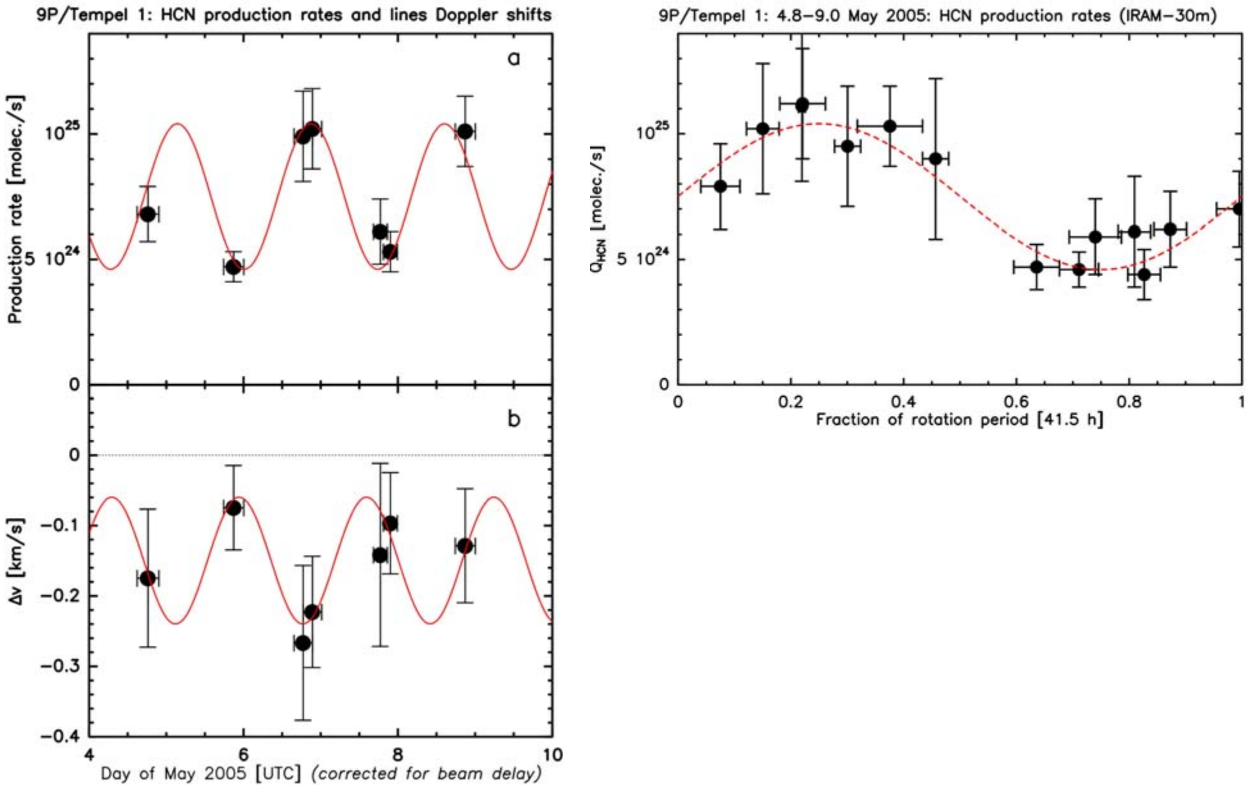


Fig. 2.14 Using HCN lines to derive the rotation period of the nucleus of Comet Tempel 1 *Upper left:* HCN production rates (in molecules per second) derived from IRAM 30m observations. The red curve shows a possible periodicity of 1.7 days, in May 2005. *Lower left:* Doppler shifts (in km/s) of the HCN(1-0) and (3-2) lines, measured at the IRAM 30m telescope. The variations indicate the possible rotation period of a hot spot on the surface of the comet's nucleus. *Right panel:* HCN production rates plotted versus their location in the best-fit rotation period of 1.73 days. (Biver et al. 2007, Icarus, 187, 253).

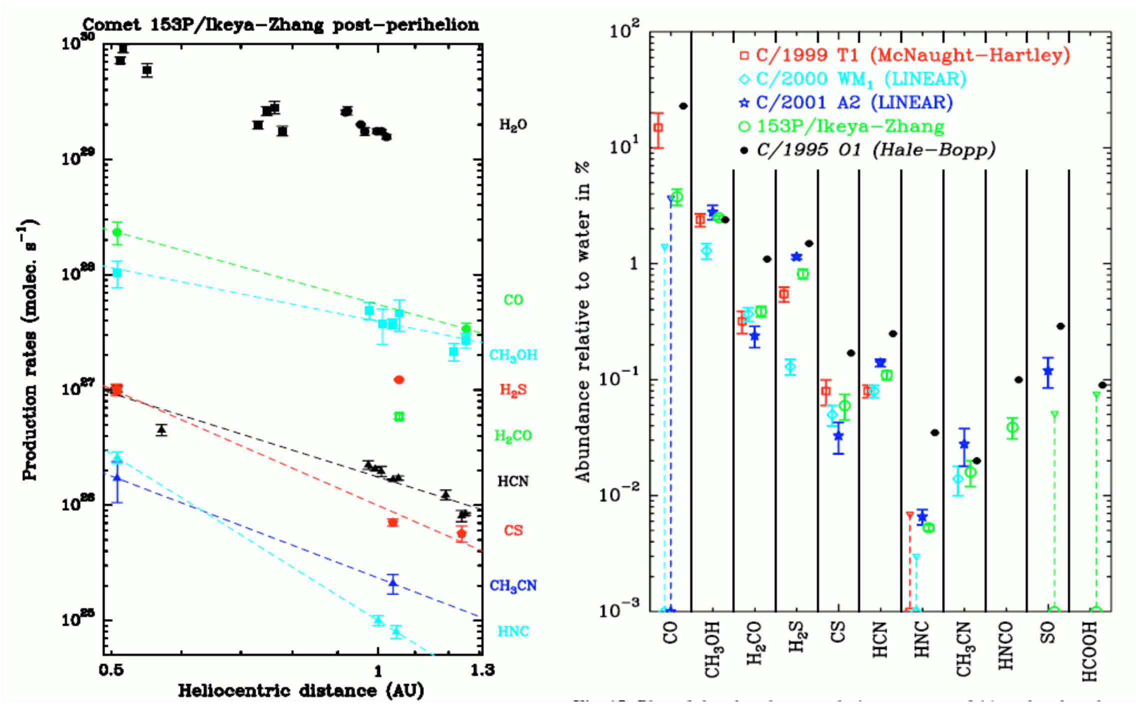


Fig. 2.15 Molecular-line production rates and abundances in four recent comets

Left: Evolution of post-perihelion production rates in comet 153P/Ikeya-Zhang, for different molecules observed with the 30-meter telescope (except for H_2O, measured by the *Odin* satellite, and in the IR). *Right:* Abundances relative to water of 11 molecules observed or searched for in recent comets. The abundances of HNC and CS vary with distance from the Sun, and are here plotted for a heliocentric radius of 1 AU (Biver et al. 2006, A&A, 449, 1255).

3. PICO VELETA OBSERVATORY

3.1 Telescope Operation

Like in any typical year, about 67% of the total time in 2006 could be used for observations. The stops of the antenna due to technical problems are with 1.7% higher than typical values of <1%. Most of this increase was related to the problems in the new control system (NCS) during the first half of 2006.

After the NCS was introduced in November 2005 without a major shutdown of the telescope, it has been used for all observations. During 2006, the reliability of several critical subsystems of the NCS was improved, and the changeover to VME and Linux was completed. In December 2006, the last “old” control subsystem, related to receiver control, was changed from OS/9 to Linux. All receivers and backends and all previously available observing modes are now supported in the NCS. For example, the major satellites of the planets as well as comets (general solar system “bodies”) can now be observed. More error and consistency checks were added to the observer's user interface “paKo”. For single-pixel heterodyne receivers the user can now measure the image-to-signal sideband ratio, and antenna tips with the heterodyne receivers are possible.

On-line data processing (ODP) now runs for all receivers and backends, and all observing and switching modes. ODP uses the MIRA software for heterodyne data and MOPSIC for bolometer observations. It applies calibrations, computes results from pointing, focus, and sky-tip measurements, and produces a first-look display of all data. Calibrated heterodyne spectra are automatically written into files in CLASS format.

In December 2006, bolometer observations with the rotated Wobbler and “double-beam” pointing became ready to use; the latter is an example of a new feature that was not possible in the old control system. Information about the NCS, including the user manual and Wiki pages, is available on the IRAM Granada web site. In September 2006 there was an audit of the NCS with external experts who proposed a number of priority items for further improvements.

A large fraction of the telescope time was used to perform pooled observations with weather dependent priorities. There were two kind of pools: a bolometer pool for MAMBO observations as good weather priorities and a HERA pool with high frequency heterodyne observations as first priority. Both pools shared a number of projects with low demands on the atmospheric quality (mostly 3mm and 2mm spectroscopic observations).

A custom design backend was used to record the continuum signal of the receivers every 0.5 msec, enabling the detection of a magnetostar at 87 and 140 GHz.

Finally, in collaboration with the Max-Planck-Institute for Radioastronomy (Bonn), a 2GHz bandwidth FFT spectrometer was successfully tested on astronomical sources.

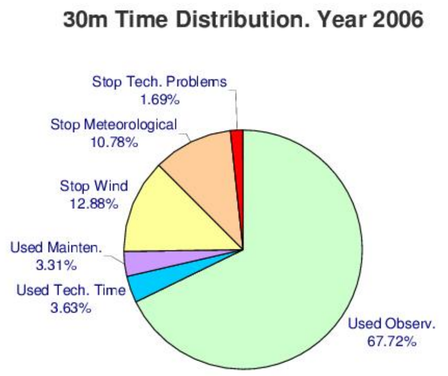


Fig. 3.1: Time distribution at the IRAM 30m telescope in 2006

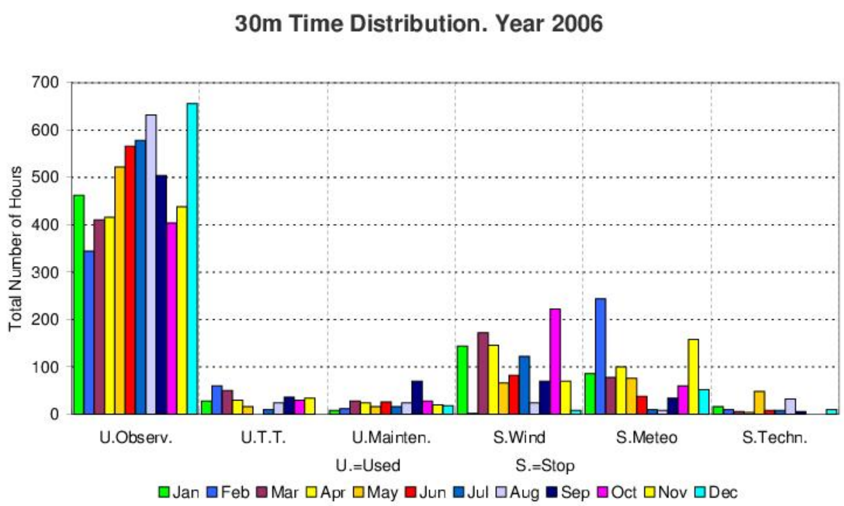


Fig. 3.2: Monthly time distribution at the IRAM-30m telescope showing U.Observ.=used for observations, UTT=used for technical tests, U.Mainten.=maintenance time.

3.2 Antenna and Electronics

As in previous years, the main effort of this and other technical groups at Pico Veleta Observatory was to ensure the daily operation of the observatory, i.e. observing support, maintenance and repair work. A list of other work include: an investigation of the over currents observed in the antenna servo motors; a study of small amplitude antenna oscillations during tracking using encoders and tracking Jupiter at the half power width of the beam; an update of the pointing model using inclinometers; an optimisation of pointing corrections with subreflector rotation; an improvement of the safety of the subreflector spindle control. Programs were developed and used to: read and log the weather and antenna status; to read the antenna motor currents and alert if "backslash" condition; to provide an overview of the temperatures in the antenna to the operator. A failure of the maser implying the loss of hydrogen pressure that prevented its normal operation was solved. At the moment the maser survives without a big maintenance since it was acquired in 1991.

Observations of cross scans on the Moon were used to determine the antenna error beam at different observing frequencies.

Fig. 3.3: A new IF processor for VLBI, VESPA and the 1MHz and 100kHz filter banks.

The CAMAC crates used for all the backend-related activities were definitely removed from the racks and VME crates accommodated instead. Future receivers for the 30-m telescope will have an IF with 4 to 8 GHz; existing backends need to be adapted to the new IF band. A processor for VLBI, VESPA, and the 1MHz and 100KHz filter banks (Fig. 3.3) will feed the old IF distribution box with four channels of (0.1-1.1) GHz down converted from (5.5-6.5) GHz of the new IF. The LO of the processor allows to be externally referenced by the standard 5 MHz from the H_2-maser for the VLBI observations. The processor for WILMA will concatenate four Wilma auto-correlators for each of the new IF and is now under construction.

3.3 Receivers

The last OS/9 microprocessor on the VRX2 machine and the translation of the software modules for receiver tuning and control of the associated hardware (splitter and Martin-Pupplet filters) was replaced. Today all the receiver control dedicated microprocessors are running under a more modern and safer VME Linux operating system.

Compensation of the power difference on sources with a strong continuum component could lead to an important reduction of baselines problems. A 3 mm noise source has been acquired and connected to one of the 3mm SIS receivers. First tests, in manual mode, indicate that a 15 to 20 K power level can be obtained by injecting the noise signal through the wave guide LO coupler. In the future, it is expected to have the noise source connected to the computer so an automatic cancellation of the power difference will be possible.

Some stability problems in the VLBI observing mode were identified in the LO generation chain and required the modification of the Racal Dana synthesizers. This modification has proven to be successful after the October 2006 VLBI session.

The PLL first reference switch box has been modified and now permits polarimetry observations in the 230 GHz band. The use of power splitters instead of the mechanical switches has introduced some leakage of signals in the phase-lock circuit. Further modifications that will correct this problem and allow polarimetry observations on the 150 and 270 GHz bands are in progress.

Work on a new IF processor for the future wideband receivers has been started. Due to the high attenuation of the coaxial cables at 8 GHz and the very wide IF band a high amplification and equalization of the cable loss will have to be installed in the receiver cabin.

3.4 VLBI

Two global 3mm (GMVA) sessions were carried out during two periods (May 5-8) and (October 12-14) with very good quality results. Further details on the VLBI sessions are given in Section 4.8.

3.5 Computers and Software

The computer network between the Granada offices, the Pico Veleta Observatory, and the University of Granada was replaced. We now use RAD WinLink 1000 equipment and run a radio link triangle between the three sites. The radio links to the observatory deliver 15Mbit/s whereas the link between the IRAM office and the University runs at 18Mbits/s. The triangle gives a fallback option in case of a one line failure. An ADSL connection to Internet is now offered as a backup to the radio links.

At the observatory, a new general use system (mrt-lx3) was installed that also serves as a file-server for the project files. This way, offline data analysis is decoupled from telescope control running on mrt-lx1. The new computer comes with 2 dual-core processors, 8 GB RAM, and 8 500GB disks. The disk partition for projects now has more than 600GB. With this machine we started to use ARECA SATA II RAID controllers because of improved performance, reliability and configurability.

The New Control System (NCS) implied that several organisational tasks of the computer group had to be revised, together with the backup routines and the tools needed to handle projects and write them on CDs and DVDs once finished. The computer used by the operators was replaced by a dual-display system with large screens and adapted to monitor and control the NCS. The last OS9-VME system was taken out of operation and replaced by a LINUX-VME system. Today all the telescope control is running under LINUX. Computer group documentation has mostly moved to Wiki-based web pages.

In 2006, the databases of the bolometer pool and the HERA pool were adapted to the NCS. The PHP interface and the databases feeding system were completely adapted at the end of the summer. A new server machine was purchased (gra-lx4.iram.es) that will serve as the data server pool, starting in summer 2007.

A shared project between a group of the Instituto de Astrofísica de Andalucía (IAA) and IRAM was funded for three years by the Spanish Ministry of Science and Education to develop tools for archiving radio data. One of the sub-project is meant to expand the pool database to an IRAM-30m archive after the study of a radio data model suited for the Virtual Observatory.

3.6 Infrastructure

Small repairs of the road from Borreguiles to Radiotelescope were made. A new water tank of 30 m^3 was bought to supply water to the building and new hardwood floors were installed in most of the dormitories at the observatory. The observatory water tank has been sealed, stopping an important water leak. The air conditioning system of the computer-backend room had to be repaired replacing both condensators. New high voltage cabinets to protect the two high voltage transformers have been installed replacing the old ones. The new cabinets have improved facilities for operation and safety. On April 22nd, a lightning broke several equipments including the wind anemometer, the ADC VME card, the alarm system, the GPS unit and some electrical devices.

3.7 Safety

The $20m^3$ diesel tank for the power generators was checked-out in detail by a qualified company and was found to be compliant with the Spanish regulation. A new hardware alarm system was designed and constructed: with its modular design any alarm or status change will be recorded in a log file for later analysis, allowing for a more efficient use. A thermographic revision of the electric installations of the observatory was performed and all the identified malfunctions repaired. Following recommendations of the insurance company, a thermographic camera was acquired, additional fire sensors were installed in the receiver cabin, and the automatic fire extinction of the computer and backend room were ordered.

A "risk evaluation" of all the working positions and of each worker was completed, and a training course on fire extinguishing was given to the staff by the Granada fire brigade. The "Outside Prevention Service" also received a training course on ergonomics and a training course on secure handling of cryogenic liquids was held at the telescope. This course was given by an expert from the Air Liquide Company and was attended guests from the Yebes observatory.

In order to protect the receivers against the strong power pulses of the "Cloudsat" at 94.05 GHz, several protecting methods at different levels (hardware and software) have been implemented, including a program for continuous monitoring of the "Cloudsat" coordinates. Finally, the azimuth emergency limit switches of the antenna have been tested to confirm its correct operation.

3.8 Miscellaneous

During summer, IRAM has offered guided tours and talks to a broader public. These outreach activities were done in a collaboration with the Instituto de Astrofísica de Andalucía (IAA). These activities included public tours in the telescope buildings as well as talks together with the IAA.

The surroundings of the Observatory have been officially declared as a protected area with regard to radio-electric emission (published in the Spanish Buletín Oficial del Estado on 3-April-2006).

The Observatory collaborated with a team of the Instituto Geográfico Nacional to measure the gravity acceleration at the observatory, on the mountains of Pico Veleta and Mulhacén. The University of Applied Science in Iserlohn (Germany) performed an experiment from the roof of the control building to harvest dew water from the atmosphere, using a radiation exchange with the upper atmosphere.

4. PLATEAU DE BURE OBSERVATORY

Two major events had a great impact on the Plateau de Bure Observatory in 2006: the first observations using the new extended baseline configurations of the interferometer and the installation of the New Generation Receivers (NGRx) on all six antennas.

Moving the Plateau de Bure Interferometer into the most extended baseline configuration highlighted the beginning of 2006. The new A-configuration provides a sub-arcsecond resolution (~0.3″ at 230 GHz) equivalent to the spatial resolution of ground-based optical telescopes. Thanks to excellent weather conditions and a perfect preparation of the tracks, the change to the new configuration was accomplished on January 13, 2006. As of February 14, observations of 48 A-configuration tracks, corresponding to 35 astronomical projects, were successfully completed.

Fig. 4.1: The Plateau de Bure Observatory: the 6-element interferometer in an intermediate configuration with the main building and the hangar for antenna maintenance.

The second milestone was reached at the end of 2006 with the successful installation of the dual polarization, 4 GHz bandwidth New Generation Receivers. To undertake preparatory work in the receiver cabins and in the correlator room, all astronomical activities were stopped on September 25. By October 13, the first New Generation Receivers were operational on antennas 1 and 2 and ready to inject the whole 4 GHz band for correlation over an optical fibre connection into the newly installed IF processor. First spectral line observations using the SiO maser features in Orion were obtained in autocorrelation on October 15. Because of major modifications and design extensions to the existing control and data acquisition and reduction software, first stable interferometric fringes could be obtained a week later. By December 7 all six antennas were equipped with the new receivers, and by the end of the year, the commissioning of the new system was rapidly approaching completion. First science results, obtained in the period from December 18 to January 18, 2007, testify to the excellent performance of the new system and mark the beginning of an exciting new era of astronomical observations with the Plateau de Bure Interferometer. A particularly striking example is shown in Fig. 4.2. Regular astronomical operations restarted on January 19, 2007. A detailed report on the performance of the New Generation Receivers will appear in the Annual Report 2007.

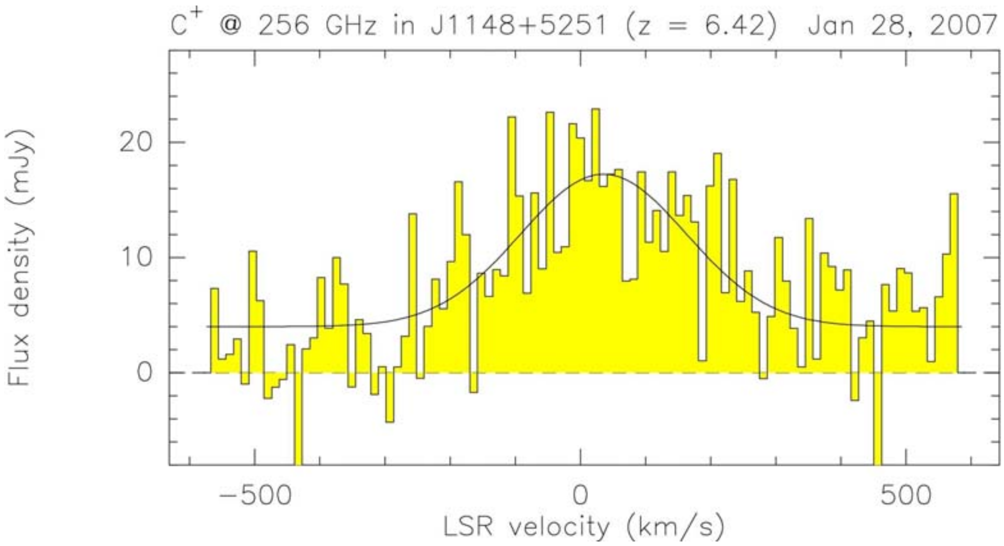


Fig. 4.2: First observations with the New Generation Receivers of the CII emission line towards J1148+5251 at a redshift of 6.42 (Walter et al. 2007). The underlying continuum emission is thermal radiation from dust.

4.1 Observations

In 2006, the Plateau de Bure Interferometer performed according to expectations with almost no downtime due to equipment failure during scheduled observations. The instruments were used throughout the year and up to September 25 without significant problems. All in all, the winter 2005/2006 weather conditions have been excellent at the Plateau de Bure with almost no snow and with long periods of excellent phase stability and low atmospheric opacity. More specifically, the weather conditions on the site were excellent in January, February, March and December, relatively good from spring to fall, and rather poor in November. The percentage of telescope time scheduled for observing programs was on average 50% of the total time (up to 60% from January to April). As in previous years, additional 10 to 15% were spent on receiver tuning, testing equipment, surface adjustments and antenna maintenance; the remaining 35 to 40% were lost due to poor weather conditions. The strong pressure exerted by proposals on the observing time at Plateau de Bure has resulted in the scheduling of many excellent programs. More than 150 different projects, including 13 proposals for Director's Discretionary Time, which correspond to more than 100 accepted programs, were scheduled at the Observatory in 2006, with similar weight on galactic and extragalactic science. Appendix 7.2 details all the proposals to which time was granted in the course of the year, and largely testifies to the high scientific return of the Plateau de Bure Interferometer.

Despite our limited ability to carry out configuration changes in winter conditions, we have successfully scheduled all four (ABCD) configurations of the interferometer in 2006. To optimise the observing of A-rated projects with respect to Sun avoidance limitations and weather constraints, the scheduling of the A and B configurations was readjusted shortly after the beginning of the winter period 2005/2006. As in previous years, a large amount of observing time was invested in the D configuration between spring and fall in the detection of line-emission from carbon monoxide in high-redshift galaxies.

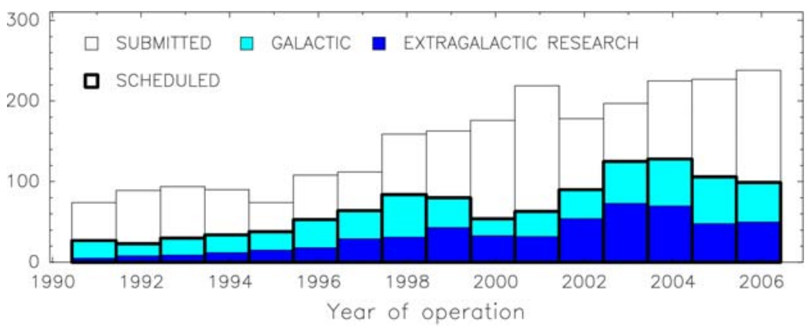


Fig. 4.3: The number of scientific proposals scheduled on the Plateau de Bure Interferometer from May 1990 to May 2006. The average pressure factor was 2.4 in 2006.

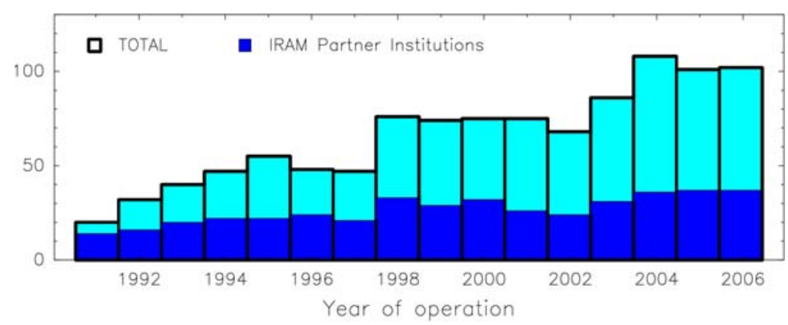


Fig. 4.4: The number of institutions represented annually by users having submitted a proposal for observations with the Plateau de Bure Interferometer.

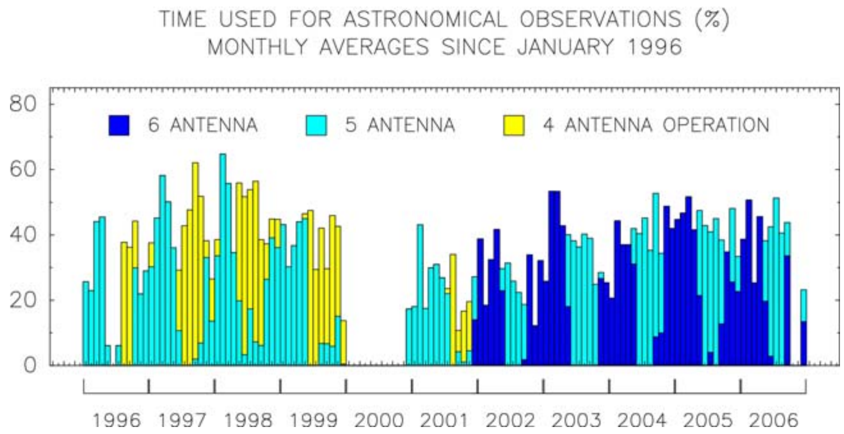


Fig. 4.5: Percentage of net-integration-time invested on astronomical observations in the last ten years. In the May to October period, which coincides with the annual maintenance period, observations are in general made with a subset of the six-element array. Antenna 5 became operational in the summer 1996, Antenna 6 at the end of 2001. As a consequence of the accidents, observations had been stopped from December 15, 1999 to December 1, 2000. The Plateau de Bure Interferometer was also stopped from September 25, 2006 to January 18, 2007 for the installation and commissioning of the new generation receivers.

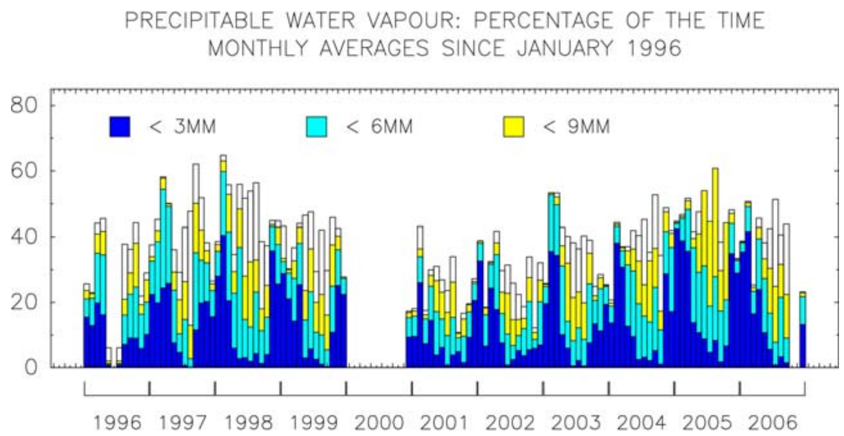


Fig. 4.6: The distribution of the atmospheric water vapour according to the percentage of net-integration time invested on astronomical observations. Observations in the high frequency window (202 to 257 GHz) and observations in extended configurations are for the most part carried out in the winter months.

4.2 Maintenance

The maintenance of the interferometer was carried out from May to October. The logistical services group located at the Grenoble headquarters, coordinated activities related to the maintenance, scheduled transports by helicopter or transports on ground, provided assistance to the observatory staff when needed and coordinated technical activities. Among all the tasks carried out, one can quote:

- The refurbishment of the water tightness and the thermal protection of the cabin receivers, which was made together with the arrival on the site of the New Generation Receivers. This action improved considerably the control of the temperature of the cabin, necessary for a good performance of the 22 GHz receivers and allowed to uncover water leaks, which resulted from a defect of the parabola - cabin receiver connection.
- The refurbishment of the heat insulation of the quadrupodes for antennas 1, 2 and 4 with the change of the heating resistors by new heating mattresses (already used successfully on antennas 4 and 5), which allows for a better control of the temperature of quadrupodes, and thus, a better structural stability of the pointing. Antenna 3 is still to be modified (during the maintenances 2007), due to the lack of time during summer 2006.
- A particular effort was made to improve the rigidity of the subreflectors. All the kneecaps were controlled and more than 30 % of them were changed, which guarantees a better stability of the sets.
- For the extension of the tracks (N49 & E68), some minor problems were cured. They include the refurbishment of the concrete layer between the tracks over twenty metres and the seals, which had lost their water tightness after the construction work in 2005.

4.3 Antenna surface improvements

The surface reflectivity losses revealed on antennas 1, 2 and 4, initially in the fall of 2004, and on antenna 6, in 2006 was a problem of growing concern. To avoid further panel degradation, it was decided to refurbish the remaining Hostaflon panels with a reflective layer of silver paint and to protect them with white cover paint. The Hostaflon film that was still covering a large number of panels was entirely removed in the maintenance period. For this, more than 250 panels were removed from the surface of antennas 1, 2 and 4, refurbished (using the painting procedure) and re-installeded. As of October 2006, antennas 1, 2 and 4 were entirely painted. Marginal signs of degradation or loss of reflectivity, which were estimated to ~10% at 230 GHz, were detected in the silver painted panels of antenna 6; these were painted in the antenna maintenance period of 2001.

A study is underway to assess the long-term performance of electroformed Nickel technology panels (developed by the Italian company MediaLario) as a replacement for the Hostaflon panels. The monitoring of two MediaLario panels, mounted on a rigid and unsheltered platform, tilted up at an angle of 30^{o} facing the south and the north, and exposed to sunlight and changing weather conditions, is in place since March 2005. In the summer of the same year, 18 MediaLario panels were placed on the surface of antenna 4. They were arranged in a uniform way on the surface to minimize asymmetries in the back-structure due to their larger weight. While first signs of degradation were observed in the summer at the panel edges and corners of the two test panels, a thorough panel inspection of the MediaLario panels in place on the antenna 4 could not reveal noteworthy structural changes.

In May, the secondary mirror of antenna 3 was found to be astigmatic. An accurate inspection of the subreflector revealed that the loss of optical quality was induced by structural weakness in the mirror’s support. As a temporary replacement, it was decided to equip the antenna with one of the first generation (Hostaflon) mirrors, which was refurbished using to the panel painting procedure. Subsequent holographic measurements were made to adjust the alignment of the newly installed subreflector.

Owing to the installation and commissioning of the New Generation Receivers, the surface of the six antennas could not be readjusted in 2006. Nevertheless, a sensitive surface assessment by means of holographic measurements was made at the end of the year with the New Generation Receivers. According to the analysis, the surface accuracy of antennas 1, 2, 3, 4 and 6 was found to be in the 50 to 60 microns range on the inner four rings, and 10 to 40 microns higher on the external two rings.

As in previous years and in connection with the plans to improve the surface efficiency of the antennas for operation at frequencies above 300 GHz, holographic measurements were made to evaluate the long-term stability of the surface adjustments made in 2004 on antenna 5. By the end of 2006, there were no detectable significant changes in the surface precision of the rings 2-4, which were found to have adjustment precision of 20 to 40 microns. The holography results, however, indicate to deviations from the ideal surface of two panels of ring 1 and a dozen panels of ring 5 and 6. As of December 2006, the adjustment precision of ring 1 was 70 microns, whereas for rings 5 and 6 the precisions were 60 and 100 microns. These results are very encouraging and seem to indicate that the surface quality remains stable over periods of two years and more, and, in principle, that antenna efficiencies of 30 Jy/K can be achieved at 300 GHz.

During the maintenances, systematic measurements of the shape of rings 6 and 5 were made with a set of 6 micrometers on all the parabolas, antenna 5 serving as a reference. These measurements allowed us to highlight a certain number of deformations of the surface, which were the object of a report on the general state of the Carbon-fibre parabolas. For the same reasons, antenna 4, with its Carbon-fibre panels, underwent a very detailed examination of its surface state to determine all the types of defects that can degrade the performances of the instrument.

Fig. 4.7: System of 6 micrometers measuring the panels of rings 5 and 6 of antenna 2

4.4 Operator workshops

The Plateau de Bure Science Operations Group (SOG) organized a half-day workshop for the operators and technicians, on September 12th, 2006. The aim of the workshop was to share practical and technical insights among the participants by means of presentations on the Plateau de Bure antenna azimuth and elevation control system and on the antenna de-icing system.

4.5 Data Archive

As a collaborative effort with the Centre des Données Astronomiques de Strasbourg (CDS), data headers of observations carried out with the Plateau de Bure Interferometer are conjointly archived at the CDS, and are available for viewing via the CDS search tools. The archive contains coordinates, on-source integration time, frequencies, observing modes, array configurations, project identification codes, etc. for observations carried out up in the period from January 1990 to March 2006. To preserve the confidentiality of some pieces of information such as frequencies and coordinates, the archive is updated at the CDS every 6 months and with a delay of 12 months from the end of a scheduling semester in which a project was observed.

4.6 The Plateau de Bure Science Operations Group

The Plateau de Bure Science Operations Group is staffed with astronomers that regularly act as astronomers on duty to optimise the scientific return of the instrument, directly on the site or remotely from Grenoble, provide technical support and expertise on the Plateau de Bure interferometer to investigators and visiting astronomers for questions related to the calibration, pipeline-processing and archiving of Plateau de Bure data, and interact with the scientific software development group for developments related to the long-term future of the interferometer. Four astronomers were appointed to the group in 2006.

The year 2006 saw 28 investigators from Europe and overseas visiting IRAM Grenoble and spending a total of 148 days to reduce data from the Plateau de Bure Interferometer, and 5 astronomers reducing data remotely from their home institutes.

Since January 2004, limited travel funds have been made available to eligible astronomers from non-IRAM partner countries for expenses incurred during their stay at IRAM for reducing data from the Plateau de Bure Interferometer. The European Commission in the frame of the FP6 programme makes these funds available. For the year 2006, the Program Committee recommended 14 eligible proposals for observations with the Plateau de Bure Interferometer. Access time was allocated to 11 eligible proposals corresponding to a total of 272 hours of observing time; 64 hours should be scheduled for early 2007. Since the beginning of RadioNet, access time was allocated to 34 eligible proposals (12 in 2004, 11 in 2005) for observations with the Plateau de Bure Interferometer, corresponding to a total of 783 hours (272 hours in 2004, 239 hours in 2005) of observing time. Time was allocated to eligible investigators from United Kingdom (percentage of total time is 57%), Italy (36%), the Netherlands (3%), Portugal (2%) and Sweden (2%) with a balanced distribution between PhD students and post-doctoral researchers (38%) and senior scientists (62%). The largest fraction of eligible users is from the Observatory of Arcetri, Italy.

Fig. 4.8: Participants and lecturers of the Vth Summer School on Millimeter Interferometry

4.7 Fifth Summer School on Millimetre Interferometry

The Fifth IRAM School on Millimetre Interferometry was held from October 2 to 6, at the IRAM headquarters in Grenoble. The school consisted of an intensive series of lectures presented by in-house and invited experts, and practical tutorials to familiarize the participants with different phases of the observing, data reduction and data analysis process. The biennial event was attended by 68 participants, mostly PhD student and postdoctoral associates from Europe and overseas: Germany (17), France (9), Italy (8), Spain (5), IRAM (3), Netherlands (3), Sweden (3), United Kingdom (3), Australia (2), Belgium (2), Finland (2), Poland (2), Switzerland (2), USA (2), Austria (1), Chile (1), India (1), Ireland (1) and Mexico (1). The participants were invited to contribute as much as possible with posters describing research conducted at (sub)millimetre interferometers and single-telescopes worldwide. Some limited financial support was provided by RadioNet, which is a FP6 funded initiative of the European Commission.

4.8 Computers

In connection with the plans to equip all six antennas with New Generation Receivers and following the successful prototype receiver tests on antenna 6 during the winter 2005/2006, the VME racks running OS-9 in the receiver cabin of antennas 1 to 5 have all been replaced with boards running the Real Time Application Interface (RTAI) Linux operating system. The new boards are working as expected.

4.9 VLBI observations

The 3mm Global VLBI spring session took place on May 4-8, 2006. Pico Veleta participated using the NCS and its new capabilities, only limited by bad weather conditions at the beginning of the session. Plateau de Bure experienced a breakdown of the CNRS maser five days before the session. The maser could not be repaired in time and returned to its laboratory in Grasse for repairs and renovations. This resulted in a 100% loss of the phased array in the spring session.

In summer 2006, Plateau de Bure received its new hydrogen maser for VLBI. The maser of the EFOS-C series was ordered in 2005 with an important contribution from the MPIfR Bonn, and its construction in Neuchâtel, Switzerland, took 15 months. The specifications of EFOS-38 were set to perform VLBI up to its highest foreseen frequency band at 350 GHz. This requires not only an excellent long-term stability but also a very clean signal on timescales shorter than one second. During a rigorous testing program, EFOS-38 met and surpassed the specifications. On acceptance by IRAM, the maser was transported to the Plateau de Bure on August 23 and connected to the LO system. Since then, the 5 MHz signal generated by the maser has been monitored against a GPS reference, and has proven to be linear within the precision of the fit over a period of more than three months. This corresponds to a deviation of about one second in six million years.

In recent years, Plateau de Bure could not participate in two Global VLBI sessions due to maser failures. With the new EFOS-38, we are confident that the reliability and quality of VLBI campaigns at Bure will be much improved. The VLBI maser on Pico Veleta is also a Neuchâtel model (EFOS-B series, delivered in 1991), which has already permitted in 2003 VLBI observations at 230 GHz with an excellent stability.

Plateau de Bure obtained its new EFOS-38 maser in time for the Global VLBI session in October 2006. Unfortunately a revision in the time schedule of the new generation receiver installation put the interferometer out of operation for a time window including the VLBI session. Due to the simultaneous installation of a new sub-reflector on the Effelsberg 100-m telescope, the European and transatlantic baselines of the experiment lost a lot of sensitivity and also essential redundancy, should weather conditions result in the dropout of other stations. The VLBI schedulers therefore decided to plan a reduced Global session with projects, which did not critically depend on an optimum UV coverage or high sensitivity. During this reduced October session, the IRAM 30-m telescope on Pico Veleta participated to nearly 100% of the time.

4.10 The 22GHz radiometric phase-correction system

During 2006, the efforts related to the 22 GHz radiometric phase-correction system were concentrated on three main areas; daily monitoring of the hardware and performance of the system, tests to develop a new calibration scheme and characterization of the interference discovered in 2005.

Daily monitoring of the 6 radiometers installed on the Plateau de Bure has proven absolutely necessary for the success of this project. In 2006, the automatic monitoring put into place has often revealed small hardware problems, which have instantly been addressed at IRAM Grenoble. More importantly, the daily monitoring indicated the drawbacks of the calibration scheme used from the onset of this project at the interferometer. The monitoring has also warranted tighter control of the ambient temperatures in the antenna cabins, and has raised the awareness of astronomers and operators with respect to the sensitivities of the 22 GHz system.

The receiver temperature of the 22 GHz receivers has been measured in the past, during intervals of 6 to 12 months. These measured temperatures have been used for the calibration of the system during observations. Regular monitoring, and in particular the analysis of sky-dips, have revealed a more appropriate way of calibrating the system, which circumvents the need to constantly refer to the measured receiver temperatures. Tests of a new scheme have revealed that the calibration achieved results in consistent measurements of the brightness temperature of the water vapour line between the six radiometers. The new scheme, which constitutes a big step in the absolute calibration of the radiometers, will be implemented as of spring 2007.

Finally, the source of interference, which was postulated to be a geostationary satellite in 2005, has been identified, by the work of a summer student, to be Hotbird 6. It was shown that the X-shaped pattern of interference in the first radiometer channel spans across an enormous (~ 20x20 deg) area of the sky. A code was developed to use only the signals of channels 2 and 3 in the presence of this strong signal.

4.11 Plateau de Bure Infrastructure

Safety issues

- As every 2 years, a team of 3 experts worked during 3 weeks on the tightening of the screws of all the buildings (cable car buildings, assembly hall, hotel building, etc.)

- The standardisation of all the electric infrastructures on the Plateau de Bure began, following reports delivered by the control organism "NORISKO". This operation continues in 2007.
- The standardisation of part of the cooking equipments with, among others, the purchase of an oven answering the HACCP standards. This operation will also continue in 2007.

Improvements

- It was decided the build protective cabin around the UPS devices in the hall to protect them from the dust.
- The doors of the garage in G2 and at the basement of the hotel building were renewed to able to resist to the harsh weather conditions of the Plateau de Bure

Blondin

- In 2006, the "blondin" (the cable-car used for material transport only) was stopped to enable the validation of the modifications, which were realized on the control system of cable derailment by company C2eI. Since the system of cable crossing detection, known as "DRVA", showed numerous failures during the fall of 2005, C2ei developed a new, more reliable system. These modifications had to be approved by an official control organism (Bureau VERITAS) and to certify that they complied with the 'CE de type' certification. The new system was declared to be compliant and the CNRS authorized the blondin to restart in April 2006.

Bure Access

- After the selection of a project manager to lead the project of a new cable car to access the Plateau de Bure, a call for tender was issued for a constructor. The project is to build a cable car with a double cable (aller/retour) at the place of the existing one. However, the two offers, which were received, turned out to be much more expensive than foreseen. The call for tender was therefore declared to be unsuccessful. Nevertheless, access by cable car is still considered to be the most viable solution and scenarios are currently under discussion to see how the cable car can be build despite the higher than expected price of the project.

Miscellaneous

- A particular effort was granted by IRAM (in terms of logistics) to help in the implementation of the ROSETTA experiment. This experiment, led by the L2MP, concerns the study of the SEE at high altitude.

5. GRENOBLE HEADQUARTERS

5.1 SIS Group Activities

The SIS junction production for different projects was pursued during 2006, the main emphasis being on the fabrication of junctions for the New Generation Plateau de Bure Receivers in the 100 and 230 GHz bands. A new mixer chip layout for 8 GHz bandwidth using 3 junctions in series was developed within the European FP6 RADIONET/AMSTAR project. The preparation for the ALMA Band 7 production phase continued. Despite important personal changes, the SIS group could keep up with a high efficiency throughout the year.

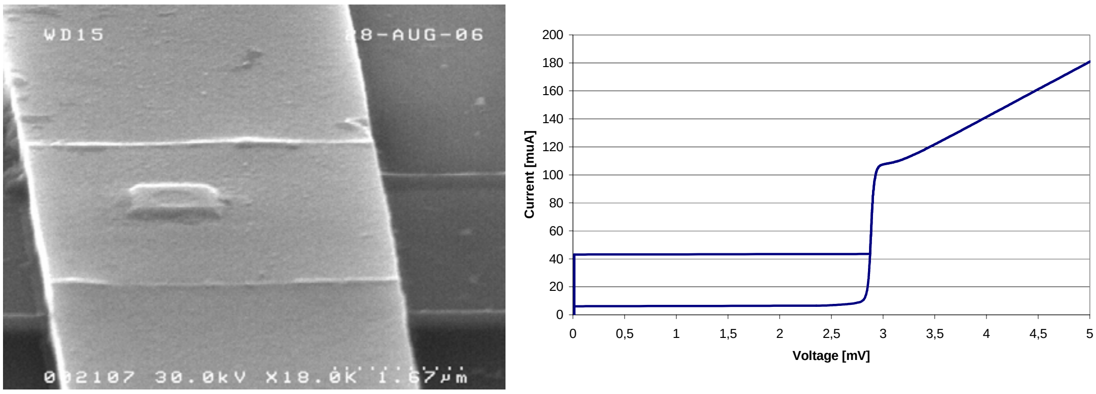


Fig. 5.1: *(Left panel)* An Ebeam microscope image of a 1µm size SIS junction with spin-on-glass and an etched central hole for top electrode contact with the corresponding I/V curve *(Right panel)*.

The layout of new generation mixer chips with increased circuit complexity and higher numbers of integrated SIS junctions require an improved yield without anodisation steps. Two important new techniques were developed to this end and first complete test runs performed during 2006. Use of spin on glass (see Fig. 5.1) or strong substrate bias SiO_2 sputtering is used to cover the etched junctions after removal of the etch resist. Sub-micron Ebeam lithography is used to define the pattern of vias on the SIS junctions. An automatic high precision alignment (< 200nm), which covers the full 2-inch wafer, was developed for this step. The vias for top electrode contacts are then etched through the sputtered or spun-on SiO_2. The new process is very promising due to the suppression of the difficult to control SiO_2 lift-off process (Fig. 5.2).

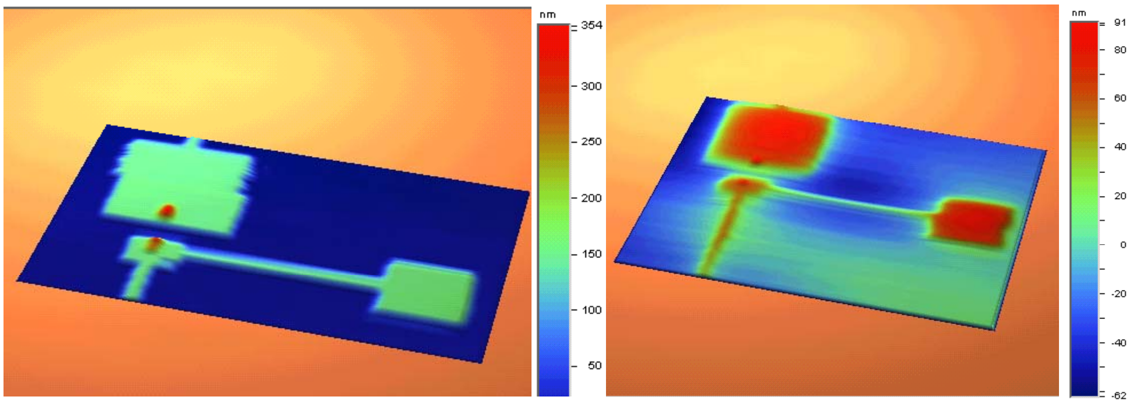


Fig. 5.2: Profile maps from a two-junction structure with integrated tuning before *(Left)* and after *(Right)* the deposition of spin-on-glass. A strong planarization can be achieved, as indicated by the two different scales on the right vertical axis (in nm).

Further work was done to investigate the physics of ultra-thin NbN films for HEB bolometers. The thermal domain in these devices was mapped with a cryogenic scanning Ebeam microscope in collaboration with the University of Tübingen (Fig. 5.3). It could be shown that a standard hot spot model is adequate to describe the normal conducting domain formation under DC bias conditions. A wide variety of alternative substrate material was investigated, some of them with very promising results.

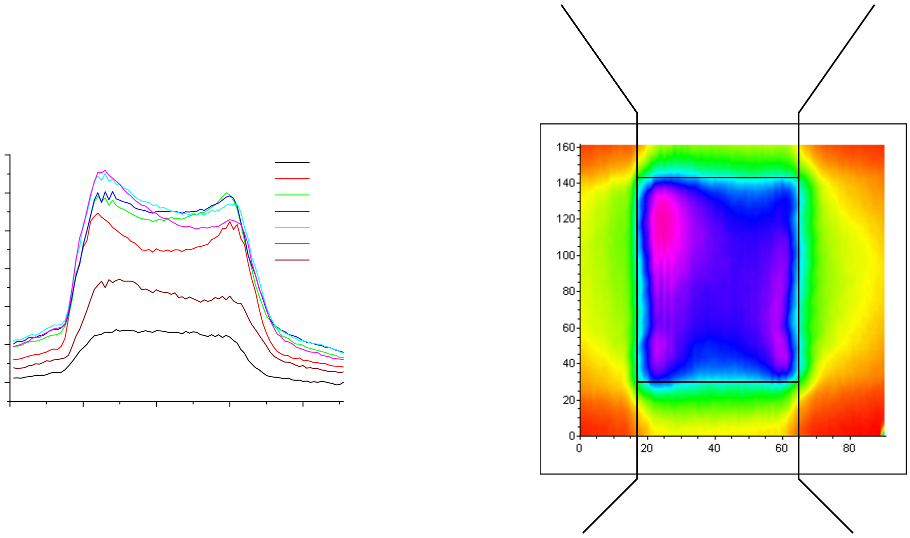


Fig. 5.3: *(Right)* Induced current change image of a 4×9μm big NbN micro-bridge under current bias as obtained with a cryogenic scanning Ebeam microscope (in collaboration with the University of Tübingen). *(Left)* The cuts show the typical double peaked structure, as expected for a standard thermal hot spot model.

Work on cryogenic super-conducting RF MEMS was continued and a 22GHz tuneable filter could successfully be produced. Mechanical characterizations were made to compare elastic modulus of thin films with that of bulk material by in-situ white light interferometry (Fig. 5.4).

A first lifetime test was performed on a capacitive RF switch, which showed that such structures could survive at least 15 kilocycles and probably much more.

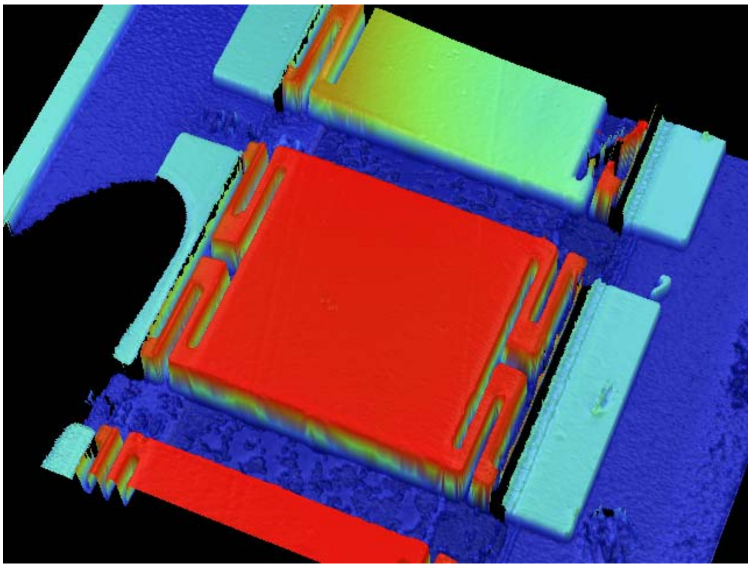


Fig. 5.4: White light interferometry snapshot of the unbiased capacitive Nb-MEMS switch, which was developed at IRAM. The colours code the measured height. The bridge structure has a size of 50×50 μm and a height of 4 μm.

5.2 RECEIVER GROUP

5.2.1 IRAM Receivers

Receivers on the Plateau de Bure Interferometer

In December 2005, the prototype of the New Generation Receivers was installed. It operated for one year, with ad hoc interface hardware to ensure its integration with the older receivers in the rest of the array. A few problems were encountered, that were solved or mitigated. Overall that test period was beneficial to the construction of the remaining receivers, providing useful input and confidence.

During 2006, the construction and testing of the series of six New Generation Receivers proceeded on a tight schedule (see Section 4). From a user point of view, these new receivers have significantly enhanced capabilities as summarized in Table 1.

Fig. 5.5: *(Left)* Three New Generation Receivers at various stages of assembly, as seen on May 16th, 2006. *(Right)* Last of the six receivers being crated for shipment to the Plateau de Bure on Nov. 20th, 2006

Fig. 5.6: A New Generation Receiver installed in one of the Plateau de Bure antennas (picture taken in Dec. 2006).

The new front ends incorporate a number of technical features that are new for IRAM receivers. Those include:

- Closed cycle cryocoolers, eliminating the logistics and operational constraints of liquid Helium refills
- SIS mixers with full height wave guides that can be tuned SSB in upper or lower side band (Band 4 will use dual side band (2SB) mixers operated as SSB)
- Fully reflective optics and corrugated horns with integrated twists
- Remote switching of the eight IF channels into the two available IF transport downlinks and of the two available LO reference uplinks into the four local oscillators
- A new generation of bias and interface electronics, based on the I2C bus and the CAN bus (the latter developed by the Computer group)

Table 1: Observing capabilities of New Generation receivers at the PdBI.

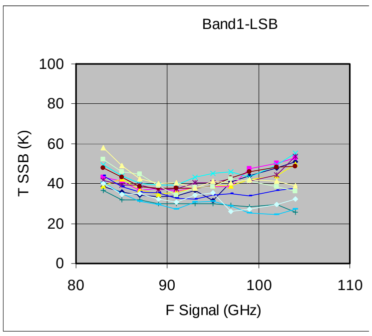
Item	Value	Remarks
RF bands		
Band 1	83–117 GHz	
Band 2	*129–177 GHz*	*Autumn 2007*
Band 3	200–267 GHz	Currently limited to 255 by legacy frequency triplers; expect to lift that limitation in 2007.
Band 4	*275–370 GHz*	*Autumn 2008*
RF response	SSB	LSB or USB possible optimum RF coverage for given LO frequency span.
IF bandwidth	4 GHz	IF band 4–8 GHz
Polarization	Dual linear	Circular available on demand for special experiments (VLBI, polarimetry)
Observing modes	Single frequency, dual polarization	Another band may be in stand-by with LO phase-locked for rapid change

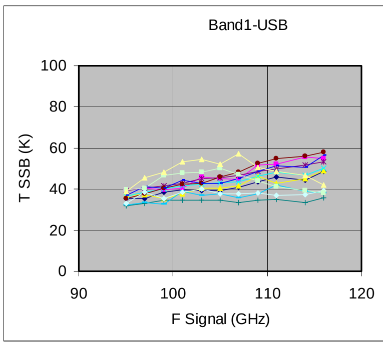
Notes.

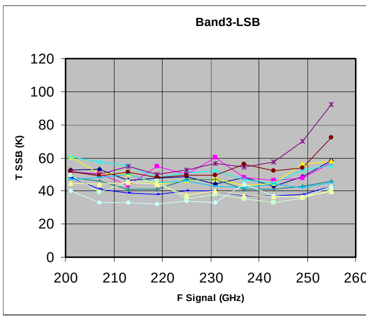
a) A dual frequency, dual polarization observing mode is not excluded in the mid-term future; this requires technical developments (ongoing) on the front end side and increased processing capacity of the IF transport and spectrometers

b) The dual frequency, split-polarization observing mode of the "old" receivers is not available any more, it can be emulated by time-sharing along a UV track that gives more flexibility

c) The available front end IF bandwidth (2×4GHz) cannot be fully processed by the back end at present







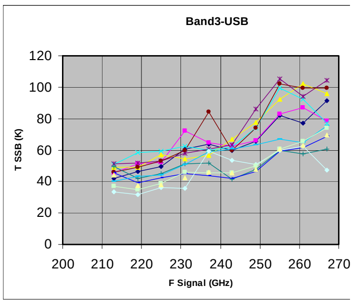


Fig. 5.7: Noise performance for the 12 (6 antennas, 2 polarizations) Band 1 RF (upper panel) and 3 RF channels (lower panel) of the new receivers.

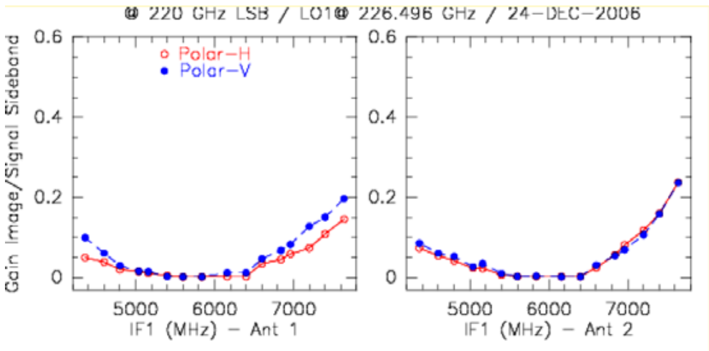


Fig. 5.8: Image gain at 220GHz (LSB) for antennas 1 and 2 as measured during the commissioning by the team of astronomers and operators.

Four-band, dual-polarization receiver for the 30-m telescope

It has been decided to build a four-band receiver for the 30-meter telescope that, while not identical with the New Generation Receivers of the PdBI, would be as close as possible. Some of the differences between these two designs arise from the particulars of the 30-meter telescope, like the f/D value, or the fact that dual-frequency observing is highly desirable. Other differences result from new components being developed since the design of the PdBI receiver was frozen. Despite these differences, the design of the 30-m receiver has a lot in common with the one for PdBI, and, in most cases, is a low-risk modification of a validated solution. From a user perspective, the main differences between the 30-meter and the PdBI receivers are as follows:

- Dual-frequency observing
    - Band 1 / Band 3
    - Band 2 / Band 4
    - Band 1 / Band 2
- Provision for dual sideband mixers in all four bands: the cryostat will be pre-wired for 16 SIS junctions and 16 IF channels
- Band 4 shifted down to ensure continuous frequency coverage; this is currently under discussion and will have no impact on the schedule

The detailed design is fairly advanced, and some components have already been fabricated and validated.

Dual-polarization HEMT receiver for the 30-m telescope

The merit (with respect to SIS) of HEMT receivers has been under discussion in various IRAM meetings and committees for more than ten years. IRAM has already taken a concrete step by borrowing/buying mm-wave HEMT amplifiers from two different sources, and evaluating their performance in the laboratory. While the noise performance that was measured in those tests was not competitive with SIS (see above the achieved performance for PdBI Band 1), we feel that we must be prepared to evaluate and implement the improved HEMT amplifiers that might become available in the future.

IRAM has therefore decided to design, build and install at the 30-meter telescope a single-pixel dual-polarization HEMT 3mm receiver, using available packaged mm-wave MMIC's from JPL or the University of Massachusetts. The design study has started. One should keep in mind that, while the mm-wave amplifier is the most "visible" component, there is definitely a lot more in the complete front-end than meets the eye.

Local oscillators with full electronic tuning

At present, all IRAM astronomical receivers use local oscillator sources based upon a Gunn oscillator, which has two mechanical tuners that are actuated by small motors. Furthermore, other parts of the local oscillator (variable attenuators, frequency multipliers) also require motorized actuators. These systems have, however, several drawbacks:

- The problematic availability of Gunn oscillators: just one supplier can provide the required tuning bandwidth, and our last procurement took ~2 years to complete
- The tuning time, while shorter than the manual tuning of the early 90's, is still finite and significant for observations that call for frequent frequency changes
- The failure rate of motors, while small, is non-zero

These considerations provide a long-term motivation to move to fully electronically tuned local oscillators. On the shorter term, there is the need to provide local oscillators for Band 4 of PdBI and the 30-meter receivers.

While an in-house development has proven to be quite successful, it was decided to build upon that experience and benefit from the design work done at NRAO for the ALMA local oscillators, as well as from available MMIC's. The main reason for that decision is the lower cost of the more integrated NRAO design. In a first step, we will build for IRAM's Band 4 receivers, local oscillators similar to (but not identical with) the ALMA Band 7 LO's. The main differences are in the PLL second reference, in the power stage, and in the monitor and control electronics. As of end 2006, all the key design issues have been examined, and it is planned to build and validate a prototype in 2007.

5.2.2 AMSTAR developments

Sideband separating 100GHz mixer with 8 GHz IF bandwidth (WP 211)

So far, the relative IF bandwidth (one sideband) demonstrated for SIS mixers has been 4% or less. The goal of this project is to develop and test a 100GHz (83-115GHz) sideband separating (2SB) mixer with two IF channels covering each 4-12GHz, for a total of 16GHz of instantaneous bandwidth. As of end 2006, the design of the DSB mixer chip (in two variants) and of the integrated 2SB block is completed. Junctions have been fabricated and tested (as a first step) in a DSB block with a 4-8GHz IF bandwidth, with encouraging results (see Fig. 5.9). In 2007, it is planned to assemble and test the 2SB mixer with 4-12GHz IF.

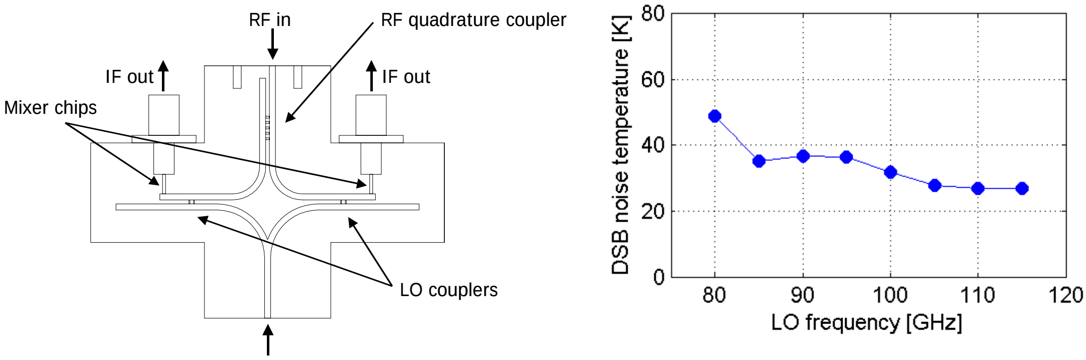


Figure 5.9: *(Left)* Sketch of the integrated 2SB mixer block. (*Right)* First results of the mixer chip test in a DSB mixer block, with 4-8GHz IF bandwidth.

Focal plane array with photonic LO, for the 150GHz band (WP241)

This project is done in cooperation with the Rutherford Appleton Laboratories, who are responsible for the development of the photonic LO. Following the separate testing of the SIS mixer (using a mixer chip designed for the PdBI new receivers) and of the photomixer, an array of four DSB SIS mixers has been successfully operated with a photomixer operating inside the Dewar at 77K.

Work will continue in 2007 to design and build suitable mirror optics (cold and room temperature) to demonstrate the operation of this array at the 30-meter telescope.

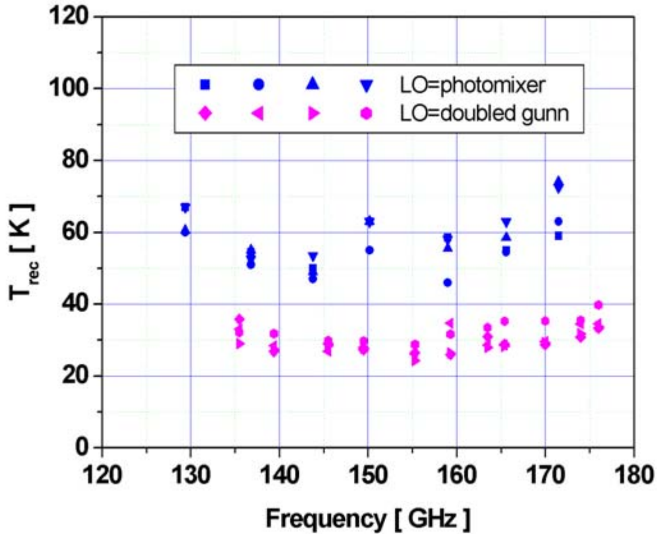


Fig. 5.10: Noise performance of the 150-GHz four-pixel array with either a photonic LO or a more traditional Gunn-doubler LO. In that first experiment with a photomixer operating at 77K, the LO power was not enough to pump the SIS junction at the optimum level; this is believed to be the main cause for the degraded noise performance. This issue has since then been resolved.

5.2.3 Participation in the ALMA project

Band 7 Cartridges

As of end 2006, four cartridges have been fully tested; two of them have been shipped to the North America Integration Center. Two more are fully assembled, and the last two are partly assembled. All sixteen 2SB assemblies necessary for the eight pre-series cartridges have been successfully characterized; the total number of assemblies tested to obtain 16 compliant units was 35.

The Band 7 group went through the Critical Design Review on 16 and 17 August 2006. That review was declared successful, conditional on the performance of two tests (done), one analysis (done), and preparation of missing documentation (in progress).

Calibration

A preliminary study of a versatile calibration device – employing a heated load and a robotic arm – has been completed by IRAM and delivered to ESO, who will take charge of the detailed design and fabrication.

Optics

IRAM has coordinated the design study for the ALMA Front-end optics, including the detailed design of warm optics for bands 3 & 4, and the moulded windows and IR filters. This work is now completed, and awaiting final review.

5.3 BACKEND DEVELOPMENTS

5.3.1 Construction of 7 Laser Transmitter racks

A dual laser IF transmitter was built for each antenna of the Plateau de Bure Interferometer. It converts the two 4-8 GHz IF's into modulated light, which is sent to the building over the mono-mode FO network. All the operating parameters (temperature, current, etc) of the lasers are locally recorded and can be remotely monitored, in order to provide early aging detection.

5.3.2 Construction of the Optical Fiber Receiver unit

In the Bure correlator room, this unit converts the twelve FO signals into electrical signals for the IF Processor. These can be switched to a central noise source to allow quick bandpass calibration of the IF processor and correlators. The unit incorporates a light power monitor interface that helps tracing the attenuation of the FO network.

5.3.3 Completion of the IF processor

This unit implements the new IF frequencies plan. For each of the six Bure antennas, the two 4GHz IF bands are split:

- In two halves of 2GHz that will feed the wideband correlator inputs
- Again into Quarters of 1 GHz that feed the existing correlator

The dual LO2's are phase-steerable and have a frequency resolution of 1.5 milliHertz. All LO's used for this processing are phase-coherent with the Maser to preserve VLBI phased array operation.

5.3.4 Preliminary design of the digital section of the wideband correlator

A feasibility study for the correlator chip has been subcontracted and delivered. The chip channel number, that determines both spectral resolution and power dissipation, was intensively discussed.

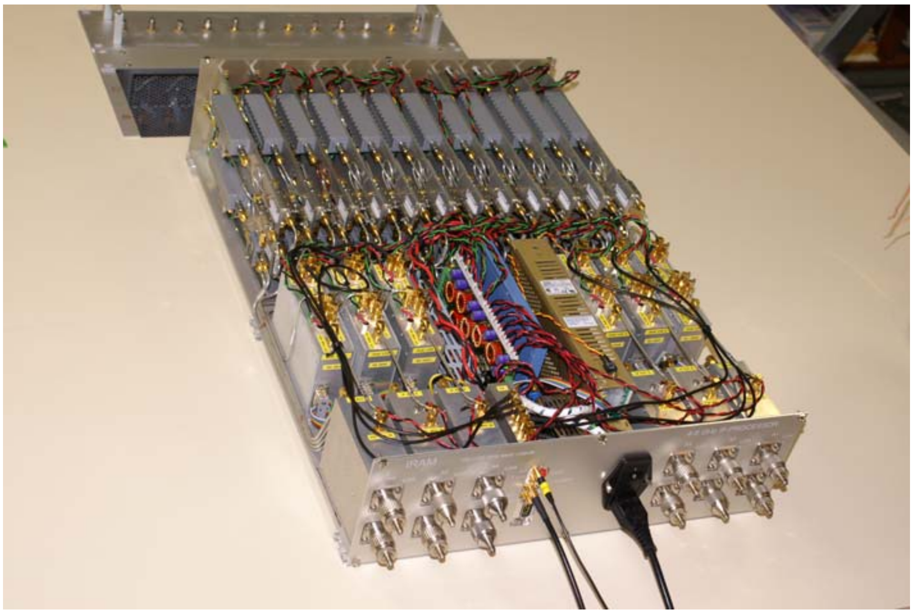


Fig. 5.11: View of the IF Processor and Optic Fiber terminal units.

5.4 COMPUTER GROUP

In 2006, the computer group was involved in the installation of the New Generation Receivers on the Plateau de Bure. After the prototype installation and test in 2005, all the necessary hardware interfaces, CAN and VME, were produced for the 6 antennas and the spares.

For the software, the Single Board Computer file system was reorganized around a new distribution of Linux from RedHat, Fedora Core 4, with a real time kernel and PPS support. For the operators, a new graphical user interface and specific shell commands were introduced and the improved tuning package includes now the adjustment of the mixer magnetic field.

The IF signals are now transmitted via optical links at Bure. In the computer (correlator) room, the photo receivers are monitored and the split IF signals can be controlled with the help of a new developed IF processor unit. The computing facility communicates with the IF processor unit over a CAN bus and provides tools such as a graphical interface and shell commands.

For the future wide band correlator, studies were carried out to figure out the processing requirements and to select a high performance data link. After a 3 months loan, a high rate optical data link developed at CERN was selected. For the data processing load, new FFT implementations were tested on 32 and 64 bit processors.

In Grenoble, the Linux distribution fedora Core 4 was tested thoroughly, customized to the IRAM needs and widely installed on 32 and 64 bit processors, servers, desktops or laptops.

After several months of evaluation, a new, extremely reliable solution for the Plateau de Bure computing architecture was finally selected. All combinations were built around a NAS/SAN file server, which guarantees high performances and reliability with disk RAID solutions. The selected design uses 64 bit diskless servers, which boot through a dedicated Gigabit Ethernet network and with the iSCSI protocol implemented on the SAN server.

In order to improve the collaboration and the communication, a new WEB server was set up with a new version of Horde: a groupware, browser-based suite, which bundles office applications. Users can manage and share calendars and/or notes, read, send and organize emails.

To simplify remote work, for instance at home, out of the Grenoble local area network, a VPN solution for PCs under Windows has been proposed. A solution for Linux with the same protections against the certificate stealing is still under tests.

In order to optimise the utilization of an existing server, a virtualisation solution was set up and is now used for providing 2 accounting Windows server virtual machines and the monitor, control, maintenance and backup were simplified. Finally, in 2006, 168 Windows are installed and maintained on servers, desktops or laptops and 83 PCs run under Linux as main or secondary OS (without including the numerous Single Board computers in the laboratories and at the Plateau de Bure Interferometer).

5.5 SCIENTIFIC SOFTWARE DEVELOPMENT GROUP

Science software activities imply the contribution of full-time software engineers and part-time astronomers. The first goal of the science software activities at IRAM is to support the reduction of the data acquired by the 30m and the Plateau de Bure Interferometer (PdBI). This includes the delivery of:

- Softwares to the IRAM staff for use in the online acquisition system
- Offline softwares to end users for final reduction of their data

However, the GILDAS suite of software is freely available to and used by other radio telescopes.

At the 30-meter telescope, MOPSIC is used to support the bolometer observations while MIRA and CLASS are used to support the heterodyne observations. In 2006, activities were directed toward a better support of the needs of the New Control System and the bolometer and HERA pool observing. In addition, the FITS support of CLASS was largely improved in collaboration with the Paris Observatory and Grenoble Observatory to ensure that CLASS will be able to read the Herschel/HIFI data format. This implied large changes in the On-The-Fly support, which is now available to other observatories.

For PdBI, most of 2006 has been spent to support the new generation of receivers installed in the last quarter. This involved changes in the on-line data acquisition software (in particular the correlator software), the adaptation of ASTRO, the tool to prepare the observations, of CLIC, the on-line and off-line calibration software and OBS, the operator interface. Two main hardware changes triggered important modifications of the above softwares: The new frequency plan, including the more complex modes of the IF processor and correlator, and the shift from dual frequency to dual polarization observations. For example, the data format has been improved to be able to calibrate both polarization together and to prepare for the possibility to calibrate polarimetry. In parallel, efforts were done to improve the accuracy of the calibration of the 22 GHz water vapour radiometers, as this is the key point to improve the atmospheric phase corrections.

While new developments require an important effort of the team during several months to a few years, the constant development and maintenance of the GILDAS infrastructure also requires a large fraction of the effort spread over a longer term. This effort is essential although it is less visible. Daily maintenance includes releases, bug fixes, adaptations to support new computers and compilers, user support and communication through the gildas@iram.fr hot line. For instance, in 2006, we ensured the support of 64 bit machines and we organised the tutorials of the IRAM interferometry school. From the development point-of-view, an important effort was started in collaboration with the Bordeaux Observatory to bind GILDAS to python, the scripting language used in the future ALMA software.

After a long period of manpower shortage, two engineers and two post-docs joined the GILDAS team in 2006. Post-docs managed by senior IRAM astronomers contribute a large fraction of the work. IRAM science software activities thus contribute to train young researchers who will then be ready to perform cutting edge observations.

The expertise at IRAM in the science software area is well recognized by ALMA in various ways. First, parts of the GILDAS softwares are used in ALMA. For instance, the GILDAS imaging simulator was extensively used in 2006 by our Japanese colleagues to tune the design of the Atacama Compact Array. GILDAS was also officially chosen to perform the holography of the ALMA antenna in Chajnantor. Second, IRAM signed in 2006 a contract with EU to commission the interferometric On-The-Fly observing mode at PdBI in the framework of the FP6 program 'ALMA enhancement'. Third, crucial parts of the ALMA computing activities have been hosted by IRAM since several years:

- An IRAM astronomer chairs Science Software Requirements Committee (SSRC) and two other IRAM astronomers actively participate. In the last two years, IRAM particularly contributed to the design of the ALMA science data model, of the observing modes and of the operation software. IRAM also largely contributes to test the ALMA software (in particular the tools to prepare the observations and the off-line data processing package).

- The on-line calibration subsystem (TelCal) is designed and implemented at IRAM by two IRAM astronomers and two software engineers. This year, developments concerned the optical pointing, single-dish holography, and simulation of interferometry. The design of the Calibration Data Model has been refined. Efforts have been made to produce test ALMA data by converting Plateau de Bure data into the ALMA science data model format.

- Two IRAM astronomers have been involved in the integration of software parts at the Alma Test Facility in New Mexico.

Finally, several IRAM astronomers participated for a small fraction of their time in various aspects of the ALMA Science activities: participation to the calibration group, attendance and presentation to the different ALMA Scientific Advisory Committee, referee of ALMA documents, participation to the ALMA Design Reference Science Plan.

5.6 TECHNICAL GROUP

The staff in the workshop has dealt with a total of 208 requests for mechanical components, 125 of which were handled internally whereas 83 were subcontracted to outside companies.

5.6.1 Mechanical workshop

The mechanical workshop produced a large number of microwave components, mixers, couplers and horns for New Generation Receivers for PdBI and the 30-meter (320 GHz and 100/150/230 GHz), ALMA Band 7, and AMSTAR.

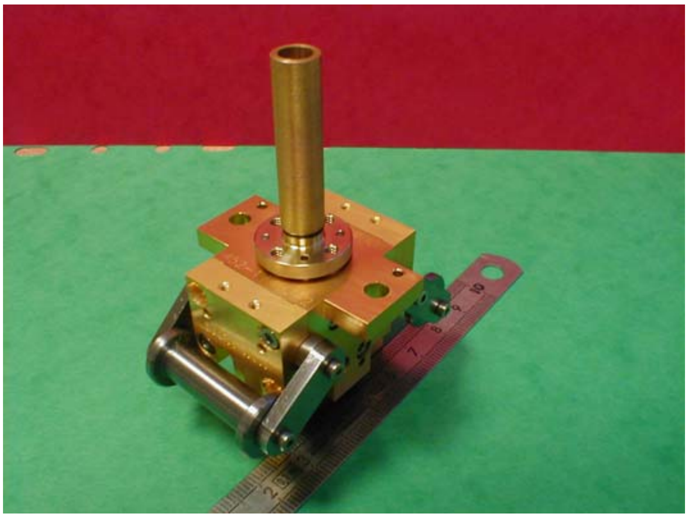


Fig. 5.12: 320 GHz 2SB mixer for New Generation PdBI Receivers and ALMA Band 7

5.6.2 Drawing Office

The drawing office worked on numerous mechanical designs, in close collaboration with the other groups. The activities include:

- The design of all new microwave components New Generation Receivers PdBI, ALMA, and AMSTAR
- The support for the New Generation Receivers in the cabin of the Bure antennas
- Various design work for all groups

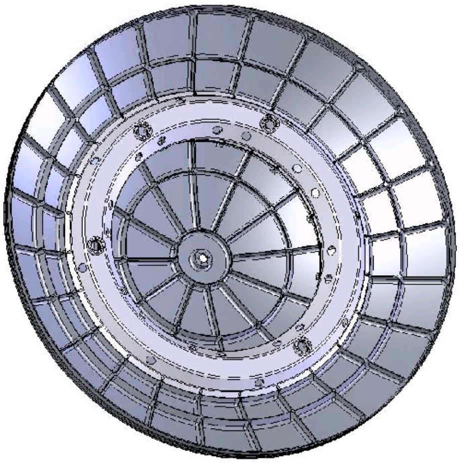


Fig. 5.13: New design for sub-reflector for the 15-meter antenna

5.6.3 Electro-forming

The installation for electro-forming has been running the whole year for the production of the horns for the new Generation Receivers PdBI, ALMA, and AMSTAR.

5.6.4 Technical support for antennas

The mechanical group has taken an active part in preparing the receiver cabin for the New Generation Receivers at Bure and, as in previous years, the mechanical group worked in close collaboration with the technical staff on the Plateau de Bure for the antennas.

6. PERSONNEL AND FINANCES

The IRAM's Administration covers the areas of Human Resources, Finance, and General Services.

6.1 Personnel

In 2006, 105.5 positions were foreseen in the Personnel Plan authorised by the IRAM Executive Council, i.e. 77.7 for France and 27.8 for Spain. In addition to these authorised positions, IRAM also has a number of staff recruited for specific activities such as ALMA contracts, and 0.46 FTE on a specific European contract as ESO subcontractor. IRAM had a total of 101.86 positions filled with staff on longer-term or unlimited contracts, of which 74.14 FTE are in France and 27.72 FTE in Spain. Furthermore, 4.6 post-docs (FR), of which 2 financed by a Marie-Curie European Fellowship, and 1 thesis student (0.25 TE) worked in France, as well as 1.42 post-docs and 1 thesis student (0.83 FTE) in Spain

A revision of the IRAM organisation chart is in process and a new chart will be available in the course of 2007. The distribution of all staff (France and Spain) per nationality is shown in Fig. 6.1.

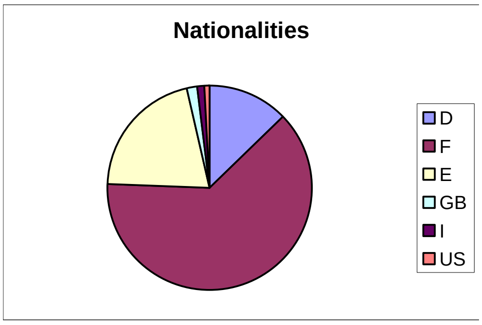


Fig. 6.1: Distribution of the IRAM staff per nationality.

6.2 Finances

The activity of the IRAM Administration in the area of finance include budget preparation and management, annual accounts, liaison with the Auditors and Audit Commission, report to the Executive Council. In order to have more detailed information, the IRAM Administration launched in 2006 a project for analytical accounting, which will be implemented in 2007. This might/will lead to some substantial restructuring of the budgets but should allow a better follow-up.

The IRAM's financial situation in 2006, as well as budget provisions for 2007, are summarised in Tables 2 and 3.

With respect to the closing of the financial year 2006, payments are essentially covered by Associates' contributions of 11.637.929 € (including an additional financing of 492.500€ for investment).

The Associates have approved an increase by 2% of their contribution to the Operation budget, and approved as specific contribution of 1 M€ to the Investment budget to allow the change of all panels on 2 antennas of the Plateau de Bure interferometer.

Table 2: 2006 Operating and Investment Budgets

EXPENDITURE		
Budget heading	**Approved**	**Actual**
Operation / Personnel	7 395 000	7 099 596
Operation / other items	3 392 000	3 011 136
TOTAL OPERATION	**10 787 000**	**10 110 732**
Investment	2 396 062	1 823 894
TOTAL EXPENDITURE excl. VAT	***13 183 062***	***11 934 626***
VAT	879 746	879 746
TOTAL EXPENDITURE incl. VAT	***14 062 808***	***12 814 372***

INCOME		
Budget heading	**Approved**	**Actual**
CNRS contributions	5 469 827	5 469 827
MPG contributions	5 469 827	5 469 827
IGN contributions	698 276	698 276
TOTAL CONTRIBUTIONS	***11 637 929***	***11 637 929***
Carry forward from previous years	661 132	661 163
IRAM's own income	884 001	778 495
TOTAL INCOME excl. VAT	***13 183 062***	***13 077 587***
CNRS contribution for VAT (19,6%) *	879 746	879 746
TOTAL INCOME incl. VAT	***14 062 808***	***13 957 333***

* = 19.6% on CNRS contribution to operation budget

Table 3: 2007 Operating and Investment budgets

EXPENDITURE	
Budget heading	**Approved**
Operation / Personnel	7 505 000
Operation / other items	3 295 500
TOTAL OPERATION	**10 800 500**
Investment - general	1 631 620
Investment - special (antenna panels)	1 000 000
TOTAL INVESTMENT	**2 631 620**
TOTAL EXPENDITURE	***13 432 120***
VAT (19,6%)	897 341
TOTAL EXPENDITURE incl. VAT	***14 329 461***

INCOME	
Budget heading	**Approved**
CNRS contributions	5 798 112
MPG contributions	5 798 112
IGN contributions	740 185
TOTAL CONTRIBUTIONS	**12 336 409**
IRAM's own income	718 211
Carry forward from 2005	377 500
TOTAL INCOME excl. VAT	***13 432 120***
CNRS contribution for VAT *	897 341
TOTAL INCOME incl. VAT	***14 329 461***

6.3 Building and site maintenance

In addition to ensuring that the building(s) is in good state, the group in charge of building and maintenance supervised the extension of the Front-End laboratory, which required more space, and also the construction of an additional floor to the main IRAM building in St Martin d'Hères. The construction was made within time and budget, giving additional room for scientists (post-docs and students) and visitors.

7. ANNEX I: TELESCOPE SCHEDULES

7.1 IRAM 30-meter telescope

Ident.	Title	Frequencies	Authors
205-05	The dynamics and evolution of galaxy mergers : molecular gas in a complete sample of ULIRGs	115.27,230.53	Tacconi, Sanders, Evans, Lutz, Sturm, Dasyra, Armus, Spoon, Veilleux
120-05	Galaxy evolution and star formation efficiency in the last half of the universe	Long list of frequencies	Combes, Garcia-Burillo, Gerin, Schinnerer, Braine, Walter, Colina
127-05	Tracking the age of protostellar cores with the N_2D^+/N_2H^+ ratio	77.1,93.2,154.2,231.3	Volgenau,Emprechtinger, Wiedner, Caselli
163-05	Are truncated stellar disks linked to the molecular gas density	115, 230	Galletta, Bettoni, Casasola, Combes, Pohlen
154-05	The M81 puzzle : a CO(2-1) map of the center	230	Casasola, Combes, Galletta
147-05	3mm HCN vibrationally excited masers in C-rich AGB stars	89, 92	Soria-Ruiz, Alcolea, Bujarrabal, Colomer, Desmurs
132-05	HCN as separator between pure AGN and AGN+starburst/pure starburst ?	177.2, 267.1	M. Krips, R. Neri, A. Eckart, Garcia-Burillo, F. Combes
400-05	MAMBO POOL PROJECTS		
137-05	Neutral carbon lines in dusty quasars and starbursts at high redshifts	139, 158, 164, 230	Weiss, Downes, Henkel, Walter
149-05	CO line SEDs at high redshift	2 and 1mm band	*idem*
234-05	Ram pressure stripped molecular gas in NGC 4522	115, 230	Vollmer, Kenney, van Gorkom
231-05	Infall and outflow motions of massive young stellar objects : a large mapping survey with HERA Probing the formation of high-mass stars in protoclusters	267, 230, 260	Motte, Bontemps, Peretto, Minier, Schuster, Sievers, Thum, Belloche, Schneider
183-05	Benchmarking PDR models against the Horsehead edge : II.1 Fractional ionisation	216, 260	Pety, Goicoechea, Gerin, Roueff, Teyssier, Hily-Blant,
115-05	Triggered massive-star formation on the borders of galactic HII regions	96-110, 144,147,217,219,230,244,267	Abergel, Habart, Joblin Deharveng, Lefloch, Zavagno,
226-05	Search for molecular gas in a high velocity cloud detected with Spitzer	231	Caplan Boulanger, Miville-Deschênes
151-05	Ultracompact HII regions : Do they drive outflows ? and what is their impact on their natal molecular cores	230, 231	Thum, Churchwell, Sievers
218-05	A wide-field CO imaging survey of nearby galaxies	230,229	Cannon, Walter,, Weiss, Brinks, de Blok, Bigiel,
213-05	Probing dense molecular gas tracers in LIGs and ULIGs	87-89, 255-261	Kennicutt Gracia, Garcia-Burillo,
129-05	Seismic oscillations in a starless globule : L429-the second confirmed example	88, 109,265,224,89,219	Planesas, Colina Lada, Teixeira, Muller, Bergin
181-05	Hydrocarbons in the proto-planetary disk of DM Tau	81,247,174,262,249,274,133,198	Ceccarelli, Caux, Dominik, Lefloch, Caselli

Ident.	Title	Frequencies	Authors
131-05	Triggered massive star-formation on the borders of galactic HII regions	96-110, 144-147, 217-267	Deharveng, Lefloch, Zavagno, Caplan
145-05	Unbiased spectral survey of the low-mass protostar IRAS16293-2422	165-178 274-281	Caux, Schilke, Castets, Ceccarelli, Tielens, van Dishoeck, Cazaux, Comito, Kahane, Helmich, Parise, Wakelam, Walter
152-05	Chemical inventory of the hot core NGC 7129-FIRS 2 (II)	112,147,220	A. Fuente, C. Ceccarelli, P. Caselli, J. Rizzo, D. Johnstone
204-05	HCN emission in very isolated galaxies	HCN(1-0) redshifted	Leon, Sabater Montes, Espada, Lisenfeld, Verdes-Montenegro, Verley
190-05	Testing grain surface chemistry in hot core regions	81,98,112,140,149,168	Bisshop, Jorgensen, van Dishoeck
178-05	Benchmarking PDR models against the Horsehead edge : I. Sulfur reservoir		Gerin, Pety, Goicoechea, Roueff, Teyssier, Hily-Blant, Abergel, Habart, Joblin
236-05	CN Zeeman observations	113.3	Falgarone, Crutcher, Troland
208-05	Measuring the molecular gas content in blue compact dwarf galaxies	112.9-115.0, 225.9-230.0	Amorin Barbieri, Planesas, Munoz-Tunon, Alfonso, Aguerri, Cairos Barreto
124-05	Are any SCUBA survey sources galactic ?	115.3, 230.5	Serjeant, Thompson, Dunlop, Glenn White
197-05	A search for CH+ in high redshift objects	112.56,146.76,203.97,224.06, 225.12,234.70	Falgarone, Cernicharo, Black, Phillips, Cox, Hily-Blant
211-05	The molecular gas content of QSO host galaxies	88.7-111.9	Barthel, Evans, Tacconi, Sanders, Frayer, Surace, Vavilkin, Hines
169-05	Surprising chemistry in dust enshrouded AGNs	87-271	Aalto, Wiedner
176-05	Chemical investigation of earth-grazing 73P/Schwassmann-Wachmann 3	88.6-168.8, 220.0-271.9	Biver, Bockelée-Morvan, Boissier, Crovisier, Colom, Lecacheux, Moreno, Paubert, Weaver, Russo
147-05	3mm HCN vibrationally excited masers in C-rich AGB stars	89	Ruiz, Alcolea, Bujarrabal, Colomer, Desmurs
170-05	CO observations of Spitzer z = 2 ULIRGs with strong PAH emission	156, 273	Yan, Lutz, Omont, Frayer, Cox, Helou, Armus, Tacconi
148-05	Cold gas along cooling flow galaxies radio lobes	94	Salomé, Combes
235-05	CO(1-0)in the extreme cooling flow RXJC1504.1-0248	94.85	Edge, Wilman, Swinbank, Salome
150-05	The magnetic activity in the extended atmosphere of AGB stars	86.243	Wiesemeyer, Thum, Baudry, Herpin
216-05	Deep inside the Perseus cluster core	113, 226	Salomé, Combes, Edge, Crawford, Erlund, Fabian, Hatch, Johnstone, Wilman
092-06	Active and quiescent cores in IR dark clouds	86-146	Simon, Rathborne, Jackson, Chambers
072-06	Monitoring winds in Venus' mesosphere in support to Venus Express observations	220, 230	Lellouch, Moreno, Paubert
243-05	Benchmarking PDR models against the Horsehead edge : II.2Fractional ionisation	86.7	Pety, Goicoechea, Gerin, Roueff, Teyssier, Hily-Blant, Abergel, Habart, Joblin

Ident.	Title	Frequencies	Authors
034-06	Jupiter's atmosphere 12 years after SL9 impact	88,115,146,230,244,265,225,236	Marten, Moreno, Matthews
053-06	Sequential star formation in IRAS 00213+6530	230.5,220.4,219.6,267.5	Busquet, Estalella, Girart, Palau
081-06	Prob ing dense molecular gas in LIRGs and ULIRGs : CN & CS	112.3-96.2, 95.7-94	Gracia-Carpio, Garcia-Burillo, Planesas, Colina, Fuente, Usero
080-06	Water in high-mass protostellar objects	80.6, 84.5, 203.4, 225.9	Van der Tak, Herpin, Bontemps, Marseille, Wyrowski, Walmsley
034-06	Jupiter's atmosphere 12 years after SL9 impact	88.6, 115.2, 146.9, 230.5, 244.9,265.8, 225.6, 236.7, 220.7	Marten, Moreno, Matthews
050-06	Testing the binary supermassive BH model for OJ287	86.2	Agudo, Krichbaum, Thum, Ungerechts, Wiesemeyer
300-06	OBSERVING POOL MAMBO		
008-06	Search for complex molecules in vibrationally excited state in the hot core W51e2	85.4, 163.2, 110.1, 140.2, 243.2, 100.7, 134.4, 198.5	Demyk, Wlodarczak
038-06	CO content in the hosts of nearby (z<0.06) QSOs	108.8-113.8, 217.5-227.8	Bertram, Eckart, Fischer, Zuther, Krips, Straubmeier
103-06	Towards completion of an HCN, CO multi-transition line survey of (ultra)luminous IR galaxies [(U)LIRGs]: HCN J=1-0	85.2, 218.2	Gao, Papadopoulos, van der Werf, Isaak, Lilly
015-06	A search for CO emission in high-z QSOs and submm galaxies in the 2mm band	2mm band	Weiss, Walter, Downes, Henkel
108-06	Search for molecular gas in HVCs : using dust emission as a tracer	115.34, 231.68	Dessauges-Zavadsky, Pfenniger, Combes
091-06	Molecular line observations of IR dark clouds	93.2, 244.9, 98.0, 154.2, 279.5	Ragan, Bergin, Wilner
058-06	Molecular gas in radio galaxies with new and re-started activity	115.3, 230.5	Mack, Saripalli, Snellen, Schilizzi, Subrahmanyan
068-06	Counter-rotation in the clump enshrouding IRAS20126+4104 ?	96.4, 112.4, 224.7, 241.0	Cesaroni, Galli, Neri
007-06	Discovery of molecular interfaces in high-mass SFRs ?	89.2, 267.6, 140.8, 225.7, 85.1, 97.3, 206.7, 218.9	Codella, Bachiller, Viti, Williams
089-06	CO isotopic measurements of nuclei	110.2, 115.3, 220.4, 230.5	Israel
112-06	Outflows from massive disk candidates (SMA legacy project)	230.5, 220.4	Beuther, Zhang, Ho, Keto, Patel, Qiu, Sridharan, Zapata, Liu, Su, Chen, Bergin, Calvet, Cesaroni, Beltran
012-06	HNCO and CH_3OH in external galaxies. New tracers of the nuclear activity	131.8, 145.1, 265.8, 259.0	Martin-Pintado, Requena-Torres, Martin, Mauersberger
075-06	HDO in ISO bright H_2O outflows from low-mass protostars	80.6, 241.6	Codella, Tafalla, Santiago, Bachiller, Nisini
030-06	Physical conditions of huge gas condensations in interacting spirals	107.7,108.2,109.0,109.5,225.4, 226.3, 227.9,228.1, 228.5, 228.8	Krmpotic, Klaas, Lemke
069-06	Molecular gas chemistry in AGNs : NGC1068	Long list of frequencies	Usero, Garcia-Burillo, Fuente, Tacconi, Schinnerer, Rizzo
099-06	The dynamics and evolution of galaxy mergers : molecular gas in a complete sample of ULIRGs	115.2	Tacconi, Sanders, Evans, Lutz, Spoon, Armus, Veilleux, Baker, Dasyra, Sturm
020-06	Barnard 1 : a dense core with low-mass star formation activity	Long list of frequencies	Marcelino, Cernicharo, Gerin, Roueff, mauersberger
062-06	Do dense cores form from filament fragmentation ? The Snake case	109.8, 98.0, 147.0, 96.4, 93.2, 219.6, 220.4, 230.5	Hily-Blant, Falgarone, Teyssier, Risacher

Ident.	Title	Frequencies	Authors
114-06	The circumstellar properties of AGB S-stars	86.85, 217.1, 115.2, 230.5	Ramstedt, Olofsson, Schoeier
071-06	The complex circumstellar medium of the carbon star U Cam	91.0, 93.1, 98, 109.2, 113.1, 115.4, 147.0, 220.8, 226.6, 227.4, 234.2, 244.6, 265.9	Lindqvist, Olofsson, Schoier, Neri, Lucas
031-06	A chemical study of the Cepheus B photon dominated regions	87.3, 88.6, 89.2, 113.5, 147.0, 226.9, 265.9, 267.6	Sun, Kramer, Ossenkopf, Mookerjea, Röllig, Ungerechts, Stutzki, Müller
081-06	Probing dense molecular gas in LIRGs and ULIRGs : CN & CS	112.3, 111.5, 110.9, 109.4, 108.8, 97.0, 96.2, 95.7, 94.4, 94.0	Gracia-Carpio, Garcia-Burillo, Planesas, Colina, Fuente, Usero
018-06	Absorption line study of the interstellar medium chemistry	89.3, 85.3, 83.0, 86.7, 87.2, 102.6, 178.3, 168.7	Gerin, Black, Falgarone, Giesen, Goicoechea, Gry, Krelowski, Lis, Neufeld, Vastel, Godard
082-06	Tentative detection of ^{25}MgNC in CRL618 : A possible enhancement of ^{25}Mg	81.9, 93.6, 103.5, 143.2	Ziurys, Halfen, Milam
101-06	Separating starbursts from pure AGN environments : The role of HCO+	89.2, 177.2, 265.9, 267.6	Krips, Neri, Eckart, Garcia-Burillo, Combes
088-06	Organic molecules in the starburst galaxies M81 and NGC253	145.6, 96.7	Muehle, Seaquist, Henkel
100-06	Methanol in the molecular clouds surrounding Sgr A*	96.7	Seaquist, Stankovic, Muhel, Leurini, Menten
098-06	HCN as separator between starburst and Seyfert/LINER galaxies ? Mapping HCN(1-0), HCN(2-1) and HCN(3-2) in M82		Krips, Neri, Eckart, Garcia-Burillo, Combes
096-06	CN in dense cores around Sgr A* - Preparatory observations	113.3, 226.7	Stankovic, Seaquist, Mühle
001-06	Study of the gas-grain chemistry in photon-dominated regions (PDRs)	Long list of frequencies	Fuente, Rizzo, Garcia-Burillo, usero, Alonso-Albi, Roueff, Le Bourlot
086-06	A massive prestellar core in the IRAS 19388+2357 region	112.4, 224.7, 93.2, 145, 242, 230	Beltran, Cesaroni, Brand
056-06	A search for C_3O in IRC+10216	96.2, 115.5, 134.7, 144.3, 202.0	Agundez, Cernicharo, Pardo, Guélin
026-06	Deep HERA mapping of very nearby low metallicity spiral galaxies	230.5	Gardan, Schuster, Sievers, Brouillet, Braine
111-06	The origin of the Fe 6.4 KeV line in the galactic center	219.6, 86.8, 241.8	Requena Torres, Martin-Pintado, Amo-Baladron, Rodriguez-Franco, Martin, Mauersberger
043-06	HNCO emission tracing photodissociated molecular gas around the galactic central cluster	219.8	Amo, Martin, Martin-Pintado
085-06	Maser emission from SiS and its isotopologues	Long list of frequencies	Fonfria, Cernicharo, Agundez, Tercero, Pardo
074-06	Are truncated stellar disks linked to the molecular gas density ?	115.2, 230.5	Asasola, Combes, Galletta, Pohlen, Bettoni
028-06	The CB26 molecular outflow	89, 86, 217, 230	Schreyer, Gueth, Bacmann, Chapillon, Chen, Dutrey, Guilloteau, Henning, Hily-Blant, Launhardt, Pety, Piétu
022-06	Deep inside the Perseus cluster core	113, 230	Salome, Combes, Edge, Crawford, Erlund, Fabian, Hatch, Johnstone, Wilman
013-06	Molecular gas in a long-forgotten submm galaxy behind Abell 1835	115	Ivison, Weiss, Downes, Smith

Ident.	Title	Frequencies	Authors
004-06	CO in the atmospheres of Saturn and Uranus	115, 230	Cavalié, Billebaud, Encrenaz, Lellouch, Fouchet
093-06	Outflow search in selected high-mass star forming regions	HERA	Codella, Goddi, Cesaroni, Beltran, Furuya, Moscadelli
048-06	A kinematic and chemical study of the irradiated dense core ahead of HH 80N	96.4, 104.0, 109.3, 146.9, 159.0, 168.8, 208.7, 244.9	Masqué, Girart, Estalella
027-06	The youngest starless cores	93.2, 219.6	Tafalla, Santiago
009-06	Molecular emission from the peculiar eruptive object V838 Mon	85.6, 86.8, 115.3, 145.6, 173.7, 217.1, 230.5, 236.5, 267.6	Tylenda, Kaminski, Pulecka, Szczerba, Szymczak
044-06	Molecular deuteration in the Orion Bar	85.9, 86.7, 134.3, 144.1, 218.5, 241.6	Parise, Thorwirth, Schilke, Roueff, Leurini, Rolffs
300-06	MAMBO POOL		
047-06	Search for CF+ in M82	102.6, 205.2	Schilke, Black, Neufeld, Thorwirth, Weiss, Wolfire
400-06	HERA POOL		
212-06	Probing the dense gas in LIRGs and ULIRGs : CN, CS and HNC	86.9, 89.1, 96.2, 105.8, 109.4, 111.5, 111.9, 249.4, 251.4, 257.4, 259.1	Gracia-Carpio, Garcia-Burillo, Planesas, Colina, Fuente, Usero
196-06	A search for Sylil cyanide, SiH_3CN, in IRC+10216	79.5, 89.2, 99.4, 109.5, 139.2	Cernicharo, Agundez, Pardo, Guélin
193-06	Molecular gas in tidal dwarf galaxies and other debris : Beyond detection	115.2, 114.3, 88.0, 230.5, 228.6, 227.3, 218.8, 219.4	Braine, Duc, Lisenfeld, Leon, Brinks, Charmandaris
222-06	Testing HCN/HCO+ chemistry and excitation in the starburst template W49	88.8, 89.2, 265.8, 267.6	Wyrowski, van der Tak, Walmsley, Weiss
229-06	Physical properties of the molecular gas in luminous IR galaxies	108.3, 102.1, 105.7, 101.5, 261.2, 252.9, 255.8, 258.7, 254.5, 244.9	Papadopoulos, Gracia-Carpio, Garcia-Burillo, Gao, Planesas, Greve, van der Werf, Isaak
183-06	Full polarization study of CN emission : magnetic field in C-rich AGB stars and (proto-) planetary nebulae	113.1, 113.4	Herpin, Wiesemeyer, Thum, Baudry, Josselin
205-06	Molecular depletion and deuterium fractionation in a pre-stellar core B68	144.0, 279.5	Nakazato, Guélin
198-06	Testing the binary supermassive BH model for OJ287	86.2	Agudo, Wiesemeyer, Thum, Krichbaum, Ungerechts
191-06	Search for TiO_2 toward high mass loss AGB stars and Sgr B2(M)	100.1, 107.2, 154.1, 160.1, 207.2, 218.1, 251.4, 255.9	Müller, Brünken, Menten, McCarthy, Thaddeus
012-06	HNCO and CH_3OH in external galaxies. New tracers of the nuclear activity	131.8, 145.1, 265.8, 259.0	Martin-Pintado, Requena-Torres, Martin, Mauersberger
182-06	Absorption line study of the interstellar medium chemistry	85.3, 88.3, 90.6, 87.2, 113.4, 168.7	Gerin, Black, Falgarone, Giesen, Goicoechea, Gry, Krelowski, Lis, Neufeld, Vastel, Hily-Blant, Godard
162-06	Star formation and molecular gas in the Twins M82 and NGC 253	145.6, 218.5	Mühle, Seaquist, Henkel

7.2 PLATEAU DE BURE INTERFEROMETER

Ident.	Title	Line	Authors
M042	A bright submm source possibly associated with a gravitationally lensed arc	Cont3mm Cont1mm	C.Borys D.Lutz L.Tacconi D.Scott P.Newbury G.Fahlman
N028	CO identification of submillimetre galaxies. II	^{12}CO(3-2) ^{12}CO(4-3)	R.Genzel R.Ivison F.Bertoldi R.Neri P.Cox A.Omont T.Greve S.Chapman I.Smail
N071	HCN in Ultraluminous Galaxies	HCN ^{12}CO(2-1) ^{13}CO(2-1)	D.Downes P.Solomon
O02E*	Search for Glycine and Precursors	Glycine-3mm Glycine-1mm	F.Combes D.Despois G.Wlodarczak A.Wooten M.Guelin N.Brouillet
O02F	Tracing the maser emission in the infrared dark cloud G11.11−0.12	CH_3OH CH_3OH	T.Pillai F.Wyrowski S.Leurini K.M.Menten
O046	Properties and evolution of disks in high-mass YSO	CH_3CN CH_3CN	R.Cesaroni M.Beltrán R.Furuya R.Neri L.Olmi L.Testi C.Codella
O04F	The Equatorial Disks of young Planetary Nebulae	^{12}CO(10) ^{12}CO(21)	R.Bachiller E.Josselin P.Huggins T.Forveille P.Cox
O056	Molecular Gas in the latest-type Spirals: II. Mapping the nuclear CO distribution	^{12}CO(10)	T.Boeker E.Schinnerer U.Lisenfeld
O05A	HCN in Ultraluminous Galaxies	HCN ^{12}CO(2-1) ^{13}CO(2-1)	D.Downes P.Solomon
O060	Molecular Gas in the Local Analogs of LBGs	^{12}CO(10) ^{12}CO(21)	A.Baker L.Tacconi C.Martin R.Genzel D.Lutz M.Lehnert T.Heckman
O067	A PdB Survey of CO in Submillimetre galaxies V.	^{12}CO(21) ^{12}CO(32) ^{12}CO(43) ^{12}CO(65)	R.Genzel R.Ivison F.Bertoldi R.Neri A.Omont P.Cox T.Greve S.Chapman A.Blain I.Smail
P006	Searching for Initial Turbulent Support in the NGC 2264-C Protocluster Condensations	N_2H^+(1-0) $C^{18}O$(2-1)	N.Peretto P.André P.Hennenbelle A.Belloche
P010	Search for circumstellar disks around early-type HBe stars	^{12}CO(1-0) ^{12}CO(2-1)	A.Fuente A.Natta R.Neri L.Testi R.Bachiller
P013	Revealing the molecules ejected from grains at the early shock interaction in the L1448-mm outflow	SO(3-2) CS(5-4)	I.Jiménez-Serra S.Martin J.Martín-Pintado A.Rodriguez-Franco J.M.Winters S.Martín
P016	The enigmatic IRAS object 19312+1950 – Evolved star, interstellar cloud, or both?	SiO(2-1) ^{13}CO(2-1)	K.M.Menten J.Alcolea P.Schilke F.Schuller
P017*	Deep study of the circumstellar envelopes of AGB & early post-AGB stars	^{12}CO(1-0) ^{12}CO(2-1)	A.Castro-Carrizo J.Alcolea V.Bujarrabal M.Grewing M.Lindqvist R.Lucas R.Neri H.Olofsson G.Quintana-Lacaci F.L.Schoïer J.M.Winters
P020	Molecular Gas Chemistry in the Circumnuclear Disk of NGC 1068	HNC(1-0) N_2H^+(1-0)	S.García-Burillo A.Usero A.Fuente F.Boone L.J.Tacconi J.Graciá R.Neri

Ident.	Title	Line	Authors
P036	Millimetre observations of GRB afterglows in the SWIFT era (ToO)	Cont3mm	A.Castro-Tirado M.Bremer D.Bhattacharya S.Trushkin J.Gorosabel S.Guziy A.DeUgarte-Postigo M.Jelinek
P037	Thermal emission from Triton and Charon	Cont3mm Cont1mm	E.Lellouch R.Moreno A.Moullet A.Doressioundiram
P039	Fragmentation in massive precluster cores (II)	NH_2D $C^{18}O$	F.Wyrowski M.A.Thompson A.G.Gibb J.H.Hatchell M.Pestalozzi T.Pillai
P03F	Basic properties and evolutionary diagram for individual OB protostars	SiO(2-1) ^{12}CO(2-1)	S.Bontemps F.Motte N.Schneider
P042	A search for intermediate-mass (IM) hot cores using the PdB interferometer (II)	CH_3OCHO CH_3CN	A.Fuente C.Ceccarelli P.Caselli D.Johnstone E.Dishoeck R.Neri R.Plume B.Lefloch M.Tafalla F.Wyrowski
P043⋆	Ultra-Low-Mass Cores in the ρ Ophiuchi Protocluster	N_2H^+ ^{12}CO(2-1)	P.André J.Greaves F.Motte D.Ward-Thompson
P044	W3IRS5: A Trapezium in its making	SiO(2-1) SiO(5-4)	H.Beuther T.Megeath F.Van der Tak
P047⋆	Benchmarking PDR models against the Horsehead edge: II.2 Fractional ionization	$H^{13}CO^+$	J.Pety J.Goicochea M.Gerin E.Roueff D.Teyssier P.Hily-Blant A.Abergel E.Habart C.Joblin
P048	Distribution of angular momentum in binary protostars	N_2H^+	X.Chen R.Launhardt Th.Henning
P049	High-angular resolution continuum imaging of protoplanetary disks	CO-ISO ^{13}CO(2-1)	V.Piétu S.Guilloteau A.Dutrey J.Pety
P04A⋆	AFGL 2591: A massive circumstellar disk of dust and water	HDO $H_2^{18}O$	F.VanderTak M.Walmsley F.Herpin C.Ceccarelli
P04E	Kinematics of photoevaporating disks around the massive stars in NGC7538 IRS1 and K3-50A	H41α H30α	J.Martín-Pintado C.Thum
P04F	Chemistry in Proto-Planetary Disks (CID) – Part II–III	HCO^+ CN(2-1) ^{13}CO(2-1) HCN(1-0) ^{13}CO(1-0)	A.Dutrey Th.Henning A.Bacmann E.Dartois F.Gueth S.Guilloteau P.Hily-Blant R.Launhardt V.Piétu G.Pineau des Forêts K.Schreyer D.Semenov
P050	Direct Imaging of a Protoplanetary Disk Inner Hole	Cont3mm ^{12}CO(2-1)	D.Wilner L.Hartmann N.Calvet P.d'Alessio
P051	High-angular resolution study of the HH211 circumstellar disk	^{13}CO(1-0) SiO(5-4)	F.Gueth S.Guilloteau
P054	Grain Growth in the Disk of the Pre-Main Sequence Star CQ Tau	Cont3mm Cont1mm	A.Isella A.Natta L.Testi R.Neri
P055	High resolution study of the gaseous disk around the B0 star R Mon	^{13}CO(1-0) ^{13}CO(2-1)	A.Fuente R.Bachiller R.Neri L.Testi A.Natta
P057	Does the candidate Very Low Luminosity Protostar L1148-IRS drive an Outflow?	^{12}CO(1-0) ^{12}CO(2-1)	J.Kauffmann F.Bertoldi T.Bourke P.Myers C.W.Lee A.Crapsi N.Evans M.Dunham T.Huard
P059	Jets from massive protostars – the case of UYSO 1	CS(2-1) ^{12}CO(2-1)	J.Forbrich K.Schreyer T.Stanke Th.Henning
P05B	Do the protostellar molecular jets rotate?	$H^{13}CO^+$ SiO(5-4)	C.Codella S.Cabrit F.Bacciotti R.Cesaroni P.Garcia F.Gueth B.Lefloch D.Panoglu

Ident.	Title	Line	Authors
P05C	The First Extremely High Velocity Outflow in Taurus	SiO(2-1) ^{12}CO(2-1)	J.Santiago M.Tafalla R.Bachiller D.Johnstone
P05E	The molecular disk orbiting the post-AGB star 89 Her	^{12}CO(1-0) ^{12}CO(2-1)	V.Bujarrabal H.Van Winckel R.Neri A.Castro-Carrizo J.Alcolea
P060	Minkowsky's Footprint revisited	^{13}CO(1-0) ^{13}CO(2-1)	J.Alcolea R.Neri V.Bujarrabal
P063	The Identification of Interstellar Aminoacetonitrile	AAN1/2 AAN3/4	K.Menten A.Belloche P.Schilke C.Hieret C.Comito S.Leurini H.Müller
P065	Disk Formation in Early-Type Galaxies	^{12}CO(1-0) ^{12}CO(2-1)	F.Combes M.Bureau L.Young
P067	The distribution of dense gas in the NUGA sources	HCN(1-0) ^{13}CO(2-1)	M.Krips A.Eckart R.Neri S.Garcia-Burillo F.Combes A.Baker L.Tacconi S.Leon L.Hunt E.Schinnerer P.Englmeier F.Boone
P068	A search for a molecular torus in NGC4261	^{12}CO(1-0) ^{12}CO(2-1)	T.Okuda S.Iguchi K.Kohno
P069	Feeding the Nucleus in NGC6946: II. Gas Dynamics in the central 60pc	HCN(1-0) ^{12}CO(2-1)	E.Schinnerer T.Böker E.Emsellem
P06B	High resolution CO(2-1) Imaging toward the Seyfert 2 Nucleus in M51	^{12}CO(1-0) ^{12}CO(2-1)	S.Matsushita S.Muller P.Y.Hsieh J.Lim
P06F	The extended gas distribution in the advanced merger NGC4441	^{12}CO(1-0) ^{12}CO(2-1)	E.Manthey S.Hüttemeister S.Aslto
P071	The formation of bound clusters in starburst	HCN(1-0) ^{12}CO(2-1)	E.Keto L.C.Ho
P074	Radio recombination lines in Arp 220	H40α H30α	A.Baker M.Goss F.Viallefond
P075*	The Counter-Rotating Nuclear Disks in Arp 220	^{12}CO(1-0) ^{12}CO(2-1)	D.Downes A.Eckart
P076	The path of the ULIG phase: close interacting pairs (II)	^{12}CO(1-0) ^{12}CO(2-1)	J.Gracía P.Planesas L.Colina
P077	Probing the Evolution in Radio Galaxies: the CSO 4C 31.04	HCO^{+}(0-1) ^{12}CO(2-1)	S.Garcia-Burillo F.Combes A.Fuente S.Leon A.Usero J.Lim R.Neri
P078	Monitoring of 3C66B for Periodic Flux Variation due to a Binary Black Hole	Cont3mm	S.Iguchi T.Okuda H.Sudou H.Suda
P07A*	High-resolution CO imaging of $z < 0.1$ QSO host galaxies	^{12}CO(1-0) ^{12}CO(2-1)	D.Riechers F.Walter F.Bertoldi K.K.Knudsen J.Kurk C.Carilli X.Fan M.Vestergaard
P07C	Galaxy evolution and Star Formation Efficiency in the Last Half of the Universe	^{12}CO(1-0) Cont1mm	F.Combes S.García-Burillo M.Gérin E.Schinnerer J.Braine F.Walter L.Colina
P07D	Radio Source Contamination in SZ-surveys	Cont3mm Cont1mm	M.Nord K.Basu F.Bertoldi K.Menten C.Carilli H.Bohringer
P086	High resolution mm-Interferometry of Submm-Gala- xies: Resolving spatial and kinematic properties	^{12}CO(2-1) ^{12}CO(3-2) ^{12}CO(4-3) ^{12}CO(6-5) ^{12}CO(7-6)	R.Genzel R.Ivison R.Neri L.Tacconi I.Smail A.Omont T.Greve P.Cox S.Chapman A.Blain F.Bertoldi
P08A	The highest redshifts: Pinpointing mm sources without radio counterpart	Cont3mm Cont1mm	H.Voss F.Bertoldi D.Lutz A.Blain C.Carilli E.Schinnerer

Ident.	Title	Line	Authors
Q011⋆	Unveiling the structure of two far-outer star forming regions	CH_3C_2H(5-4) $HC^{18}O^+$(1-0) CS(2-1) CH_3OH	J.Brand J.Wouterloot F.Fontani L.Moscadelli
Q012⋆	Deep study of the circumstellar envelopes of AGB & early post-AGB stars	^{12}CO(1-0) ^{12}CO(2-1)	A.Castro-Carrizo J.Alcolea V.Bujarrabal M.Grewing M.Lindqvist R.Lucas R.Neri H.Olofsson G.Quintana-Lacaci F.L.Schoïer J.M.Winters
Q014	Multi-wavelength observations of M81* - Probing the (sub)mm-bump	Cont3mm Cont1mm	R.Schödel A.Eckart M.Krips S.Markoff J.Miller
Q015	Imaging the prototypical starburst M82 in SO	SO, CO^+	A.Fuente S.Garcia-Burillo A.Usero J.R.Rizzo M.Gerin R.Neri
Q016	Ongoing star formation traced by methanol in the starburst galaxy M82	CH_3OH CH_3CCH	S.Martin Ruiz L.Martin-Pintado R.Mauersberger
Q017	Does HCN distinguish between pure AGN and starburst environments? Mapping HCN(1-0) in NGC6951 and M82	HCN(1-0) ^{13}CO(2-1)	M.Krips R.Neri A.Eckart S.Garcia-Burillo F.Combes F.Boone E.Schinnerer A.Baker
Q01B	H recombination lines as star formation indicator	H39α H31α	K.Basu K.Menten F.Bertoldi
Q020	HCN and HCO^+ in ultraluminous galaxies	HCN, HCO^+	D.Downes P.Solomon
Q022	Monitoring of 3C66B for periodic flux variation due to a Binary Black Hole	Cont3mm	S.Iguchi T.Okuda H.Sudou H.Suda
Q023	Probing isotopic ratios at redshifts z=0.68-0.9	HCO^+, H_2S SiO, HCO^+(1-2) HNC(1-2), $H^{13}CO^+$ $HC^{18}O^+$, HCN(1-2) $H^{13}CN$(1-2) H_2S(1-2), CS	S.Müller M.Guélin R.Lucas F.Combes T.Wiklind
Q025	A PdB survey of CO in QSOs at z=2	^{12}CO(3-2) ^{12}CO(6-5)	P.Cox I.Smail A.Omont R.Neri A.Beelen K.Knudsen F.Bertoldi D.Alexander A.M.Swinbank K.Coppin J.Stevens R.Ivison M.Page
Q026	The gas content of massive UV bright galaxies at z=2	^{12}CO(3-2) Cont1mm	L.Tacconi R.Genzel D.Erb A.Shapley A.Baker N.Förster Schreiber M.Lehnert N.Bouche D.Lutz C.Steidel M.Pettini
Q027	^{13}CO in a lensed galaxy at z=2.56	^{13}CO(3-2)	C.Henkel A.Weiss D.Downes W.Fabian
Q028	HCO^+: a key to the physics and chemistry of high-redshift ULIRGs	HCO^+(4-3) HCO^+(9-8)	S.Garcia-Burillo M.Guélin P.Cox J.Graciá-Carpio R.Neri P.Planesas P.Solomon L.Tacconi P.Vanden Bout
Q029	HCO^+: A new tracer of high-density molecular gas at redshift 2.6	HCO^+(4-3)	D.Riechers F.Walter A.Weiss F.Bertoldi C.Carilli P.Cox K.Menten
Q02F⋆	A search for CO(2-1) emission from the host galaxies of GRB 000418 and GRB 010222	^{12}CO(2-1)	B.Hatsukade K.Kohno T.Tosaki K.Ohta N.Kawai A.Endo M.Sameshima
Q030	Millimetre observations of GRB afterglows in the SWIFT era (ToO)	Cont3mm	A.Castro-Tirado M.Bremer D.Bhattacharya M.Jelinek J.Gorosabel S.Pandey S.Guziy A.Ugarte-Postigo

Ident.	Title	Line	Authors
Q--1	Flux measurements of Callisto and Ganymede	Cont3mm Cont1mm	R.Moreno
Q--2*	Determination of the molecular gas mass in BzK-5882	^{12}CO(3-2)	R.Genzel L.Tacconi F.Eisenhauer N.Förster Schreiber P.Cox A.Cimatti
Q--3	CN - A New Bright Probe of Dense Gas at High Redshift?	CN(3-2)	F.Walter D.Riechers C.Carilli F.Bertoldi
Q--4	Search for HNC in APM 08279+5255	HNC(5-4)	M.Guelin P.Salome R.Neri S.Garcia-Burillo J.Garcia-Carpio P.Planesas J.Cernicharo P.Solomon P.VandenBout L.Tacconi
Q--5	Search for CO(43) in SMMJ2217	^{12}CO(43)	A.Weiss F.Walter D.Downes C.Henkel
Q--6	CO in a lensed Lyman break galaxy?	^{12}CO(32)	I.Smail M. Swinbank A.Edge J.P.Kneib H.Ebeling R.Ellis M.Pettini

* Projects close to completion on December 31, 2006.

8. ANNEX II: 2006 PUBLICATIONS
8.1 PUBLICATIONS WITH IRAM STAFF MEMBERS AS (CO-)AUTHOR

1123. CONTINUUM EMISSION IN NGC 1068 AND NGC 3147: INDICATIONS FOR A TURNOVER IN THE CORE SPECTRA
M. Krips, A. Eckart, R. Neri, R. Schödel, S. Leon, D. Downes, S. García-Burillo, F. Combes
2006, A&A 446, 113

1124. DEUTERATED MOLECULES IN DM TAURI: DCO^+, but no HDO
S. Guilloteau, V. Piétu, A. Dutrey, M. Guélin
2006, A&A 448, L5

1125. COMPARATIVE CHEMISTRY OF DIFFUSE CLOUDS V. Ammonia and Formaldehyde
H.S. Liszt, R. Lucas, J. Pety
2006, A&A 448, 253

1126. LARGE-SCALE MOLECULAR SHOCKS IN GALAXIES: THE SiO INTERFEROMETER MAP OF IC 342
A. Usero, S. García-Burillo, J. Martín-Pintado, A. Fuente, R. Neri
2006, A&A 448, 457

1127. RADIO WAVELENGTH MOLECULAR OBSERVATIONS OF COMETS C/1999 T1 (McNAUGHT-HARTLEY), C/2001 A2 (LINEAR), C/2000 WM1 (LINEAR) AND 153P/IKEYA-ZHANG
N. Biver, D. Bockelée-Morvan, J. Crovisier, D.C. Lis, R. Moreno, P. Colom, F. Henry, F. Herpin, G. Paubert, M. Womack
2006, A&A 449, 1255

1128. FULL POLARIZATION STUDY OF SiO MASERS AT 86 GHz
F. Herpin, A. Baudry, C. Thum, D. Morris, H. Wiesemeyer
2006, A&A 450, 667

1129. METHANOL DETECTION IN M82
S. Martín, J. Martín-Pintado, R. Mauersberger
2006, A&A 450, L13

1130. A HISTORIC JET-EMISSION MINIMUM REVEALS HIDDEN SPECTRAL FEATURES IN 3C273
M. Türler, H. Ungerechts et al.
2006, A&A 451, L1

1131. TESTING THE INVERSE-COMPTON CATASTROPHE SCENARIO IN THE INTRA-DAY VARIABLE BLAZAR S5 0716+71
L. Ostorero, H. Ungerechts, et al.
2006, A&A 451, 797

1132. DISSIPATIVE STRUCTURES OF DIFFUSE MOLECULAR GAS I. Broad HCO^+ (J=1-0) Emission
E. Falgarone, G. Pineau des Forêts, P. Hily-Blant, P. Schilke
2006, A&A 452, 511

1133. TIDAL STRIPPING AND DISK KINEMATICS IN THE RW AURIGAE SYSTEM
S. Cabrit, J. Pety, N. Pesenti, C. Dougados
2006, A&A 452, 897

1134. MOLECULAR GAS IN THE ANDROMEDA GALAXY
Ch. Nieten, N. Neininger, M. Guélin, H. Ungerechts, R. Lucas, E.M. Berkhuijsen, R. Beck, R. Wielebinski
2006, A&A 453, 459

1135. COLD MOLECULAR GAS IN THE PERSEUS CLUSTER CORE
Association with X-ray cavity, Hα filaments and cooling flow
P. Salomé, F. Combes, A.C. Edge, C. Crawford, M. Erlund, A.C. Fabian, N.A. Hatch, R.M. Johnstone, J.S. Sanders, R.J. Wilman
2006, A&A 454, 437

1136. ORGANIC MOLECULES IN THE GALACTIC CENTER
Hot core chemistry without hot cores
M.A. Requena-Torres, J. Martín-Pintado, A. Rodríguez-Franco, S. Martín, N.J. Rodríguez-Fernández, P. de Vicente
2006, A&A 455, 971

1137. TESTING THE INVERSE-COMPTON CATASTROPHE SCENARIO IN THE INTRA -DAY VARIABLE BLAZAR S5 0716+71 II. A Search for intra-day variability at millimetre wavelengths with the IRAM 30 m telescope
I. Agudo, H. Ungerechts, et al.
2006, A&A 456, 117

1138. LOW SULFUR DEPLETION IN THE HORSEHEAD PDR
J.R. Goicoechea, J. Pety, M. Gérin, D. Teyssier, E. Roueff, P. Hily-Blant, S. Baek
2006, A&A 456, 565

1139. PROBING ISOTOPIC RATIOS AT z=0.89: MOLECULAR LINE ABSORPTION IN FRONT OF THE QUASAR PKS 1830-211
S. Muller, M. Guélin, M. Dumke, R. Lucas, F. Combes
2006, A&A 458, 417

1140. PLATEAU DE BURE INTERFEROMETER OBSERVATIONS OF THE DISK AND OUTFLOW OF HH 30
J. Pety, F. Gueth, S. Guilloteau, A. Dutrey
2006, A&A 458, 841

1141. NGC 2146's STARBURST REGION AND EXTENDED STRUCTURE
A. Greve, N. Neininger, A. Sievers, A. Tarchi
2006, A&A 459, 441

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1233. HIGH-J v = 0 SiS MASER EMISSION IN IRC + 10216: A NEW CASE OF INFRARED OVERLAPS
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D.A. Neufeld, P. Schilke, K.M. Menten, M.G. Wolfire, J.H. Black, F. Schuller, H. Müller, S. Thorwirth, R. Güsten, S. Philipp
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