IRAM 1999

IN MEMORIAM

This Annual Report is dedicated to the memory of the victims of the Plateau de Bure cable car accident on July 1st, 1999, and the helicopter accident on December 15th, 1999 at the Plateau de Bure Observatory. These two accidents have taken the lives of 25 people, who worked for the companies Graniou in Vitrolles, Nera in Gap, Queyras in Saint-Crépin, E.R.I.C. in Grenoble, and S.A.F. in Tallard, as well as for the CNRS-INSU and for IRAM.

ANNUAL REPORT

The victims of the Plateau de Bure cable car accident on July 1st, 1999

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and the victims of the helicopter accident on December 15th, 1999

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ANNUAL REPORT

1999

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1. INTRODUCTION

In 1999 IRAM has been hit by two accidents that overshadow all other events of the year. On July 1st, 1999, on its way up to the Plateau de Bure, the cable car cabin started to slide backwards with increasing speed until it impacted on the ground. None of the 20 passengers survived. It appears that the self-blocking system which should keep the cabin firmly attached to the pulling cable has failed. The cause of this failure is still under investigation. On December 15th, 1999, a helicopter, leaving from the Plateau de Bure, collided with the cables of the cable car and crashed, taking the lives of all four passengers and the pilot. Both accidents have enormously affected the families directly concerned, all their friends, and all of IRAM. Indeed, they have affected the world-wide astronomical community as witnessed by the many signs of sympathy which we have received and which we gratefully acknowledge. Still, it will take a very long time until the consequences of these shocks will be fully understood and overcome where possible, and IRAM will need the continued support of all of its partners and from the wider scientific community for this.

One of the consequences of the cable car accident has been that some of the work, which had been planned for 1999 for the Plateau de Bure, was stopped. This concerns the northern track extension which will probably not be resumed before 2002, and a re-scheduling of the work on Antenna 6 which will be significantly delayed. On the other side, the maintenance work on all other antennas as well as the observations have been carried out as well as possible. The necessary transport of people to and from the Plateau de Bure during this time was provided by helicopter flights. All this was, of course, put in question when one of these helicopters crashed. What activities can and should go on as long as there is no new regular means of transport ? The Plateau de Bure observatory cannot be left without people without risking the complete loss of the installations. The decision was therefore taken to continue to transport, on a voluntary basis, the people necessary to safeguard the station but to stop all other activities for the winter 1999/2000 period.

Before any final decisions will be taken on the future level of activities on the Plateau de Bure and how these will be organised, a number of studies will be executed. These concern the feasibility and safety aspects of various modes of access to the Plateau de Bure, and a risk analysis for the various tasks to be carried out when the observations are resumed and other tasks are (re-)started. First answers are expected for the second and third quarter of the year 2000.

Returning to 1999, we report two important changes in the management of IRAM. Firstly, Rainer MAUERSBERGER became the new Station Manager in Granada, succeeding Wolfgang WILD who took up new responsibilities in the ALMA project. Secondly, Michel GUÉLIN was appointed as the new Deputy Director of IRAM after Stéphane GUILLOTEAU resigned from this post, following his appointment as the European ALMA Project Scientist.

The ALMA project has indeed played an increasing role in the discussions and in the planning of future activities within IRAM as well as with other European institutes. The IRAM Council, at its meeting in June 1999, has confirmed the support of the IRAM partners for a long-term involvement of IRAM in this new project, and has expressed this goal in a letter to the President of the European Co-ordination Committee. On shorter terms, the Council has authorised IRAM to support the current project work at a level of about 7 man-years/year by fully participating in the Phase 1 activities on the European side.

The hope is that there will be a lot of synergies between these new tasks and those which IRAM is doing, and has foreseen to do, to further improve the capabilities of the Pico Veleta and Plateau de Bure Observatories. In the chapters that follow, we first summarise some scientific highlights from the past 12 months period, proceed to describe the changes that have been made at the two instruments, and report on the technical developments of which we mention in particular the completion of the new set of receivers for the 30m-telescope, and the successful completion of the prototyping and testing of all elements of the new 6-antenna Plateau de Bure correlator, the final units of which are now under construction.

Finally, we mention the particular challenges that the new French labour legislation has brought to our administration. The new law limits the average working time per week to 35 hours. This has a number of important organisational and financial consequences which we will have to solve, counting on the help from the IRAM partner organisations.

We enter the year 2000 with a number of heavy burdens from the past, but also with courage and hope because of what has been achieved by the IRAM staff in the past as documented in this and in previous annual reports.

2. HIGHLIGHTS OF RESEARCH WITH THE IRAM TELESCOPES IN 1999

2.1 SUMMARY

Among the projects at the IRAM telescopes that were done or published in 1999, we mention in particular the following ones :

- Detection of CO(2-1) in the host galaxy of the gravitationally-lensed "double quasar" 0957+561 at a redshift of 1.414.
- Detection of CO(2-1) and (5-4) in the extremely red galaxy HR 10 at a redshift of 1.443.
- Proposed identification of the submillimeter source HDF 850.1 in the Hubble Deep Field.
- Detection of CO in the distant radio galaxies 4C60.07(z =3.79) and 6C1909+722(z = 3.53).
- Detection of molecular gas in the tidal debris of galaxy-galaxy interactions.
- Study of the gas dynamics in the luminous merger galaxy NGC 6240.
- Study of bars and warps in the molecular gas in the Seyfert 2 galaxy NGC 1068.
- Maps of thermal SiO emission tracing large-scale shocks in the nuclear disk of NGC 253.
- Measurements of a strong magnetic field in the circumstellar disk of MWC349.
- Maps of the disk and jet in the massive protostar IRAS 20126+4104.
- Dust Continuum Imaging of the HH 24 region in the dust cloud L1630.
- High resolution maps of multiple molecular outflows in AFGL 2688.
- Study of the young, detached shell of molecular gas around the star U Camelopardalis.
- Comparison of molecules found in comet Hale-Bopp with those found in interstellar gas.
- Analysis of the radio continuum emission from comets Hyakutake and Hale-Bopp.

2.2 EXTRAGALACTIC RESEARCH

2.2.1 Distant Galaxies : Two new CO detections at z = 1.4

Detection of CO(2-1) in the host galaxy of the gravitationally-lensed "double quasar" 0957+561 at a redshift of 1.414. The "double quasar" 0957+561 was identified 20 years ago as the first unambiguous example of a double image of a quasar due to gravitational lensing. The two optical images of the same quasar are separated by 6" on the sky. Up to now, radio studies of this object were limited to its centimeter-wavelength synchrotron radiation. Recently, the IRAM interferometer detected the 3-mm continuum emission at the position of the two optical components and from the radio jet. The spectral index from 2 cm to 3mm is –0.6, so the 3-mm flux is also synchrotron radiation, not thermal emission from dust. What is completely new, however, is that the interferometer also detected the CO(2-1) line in the quasar host galaxy (**Fig. 2.1**), and possibly a second, weaker, CO line at a velocity offset of 660 km/s that may indicate a gas-rich companion galaxy. For an adopted magnification factor of 10, and a Galactic ratio of CO luminosity to H_2 mass, the molecular gas mass in the quasar host galaxy is 4 x 10^9 solar masses, a value typical of a large spiral galaxy like the Milky Way. For this particular gravitational lens, the time delays in the optical and radio flux variations have long been used to estimate the Hubble constant. To do this, one needs a model of the gravitational lens, and the new detection of CO in this object may eventually help to constrain these lens models.

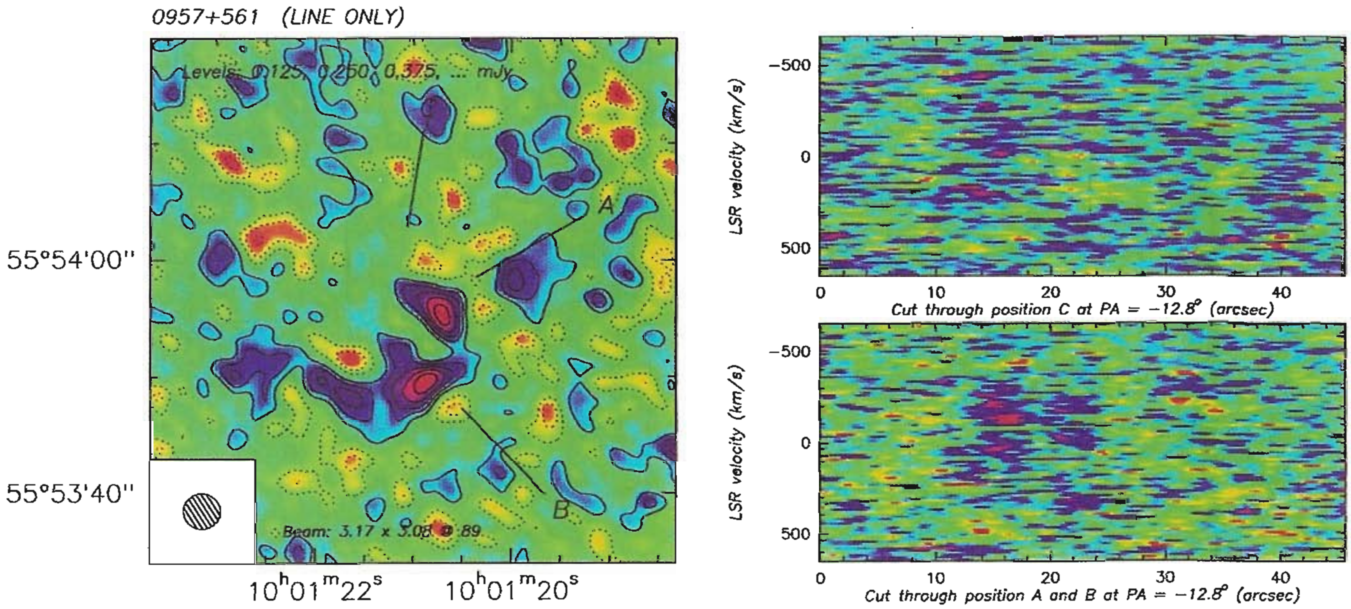

Fig. 2.1 CO emission from the gravitationally-lensed "double quasar" 0957+561 at a redshift of 1.414. *Left :* Map of integrated CO(2-1) intensity, made with a 3″ beam. The two most intense peaks correspond to the two optical images of the quasar. *Right :* CO position-velocity cuts : the upper diagram is a cut through the cm-radio continuum component C (the radio jet), which has no CO emission. The lower diagram is a cut through the radio components A and B, which both show weak CO emission (Planesas et al. 1999, Science 286, 2493).

Detection of CO(2-1) and (5-4) in the extremely red galaxy HR 10 at a redshift of 1.443.

The extremely red galaxy HR 10 was discovered at visible and near-infrared wavelengths by Hu & Ridgeway in 1994. This class of objects with very red colours (their *R*-band emission at 0.8 microns is 6 magnitudes fainter than their *K*-band emission at 2.2 microns) are very faint in the optical range, making them hard to study even with 4-meter optical telescopes. Recent results suggest this class of objects contains both old, passively evolving galaxies, and young, very dusty starburst galaxies. The millimeter continuum emssion from dust in HR 10 was detected in 1997 at the IRAM 30m telescope and the JCMT. The sub-mm continuum yields a far-infrared luminosity of 2 x 10^{12} solar luminosities, placing the source in the class of ultra-luminous infrared galaxies, most of which are starbursts induced by the merger of two galaxies. The CO(2-1) and (5-4) lines from this object have now been detected with the IRAM interferometer. Remarkably, the source HR10, at nearly the same redshift as the lensed quasar 0957+561 (see above) has nearly the same CO(2-1) integrated intensity, 1.4 Jy km/s. Hence if HR10 is unlensed, it must have at least ten times more molecular gas than the Milky Way (Andreani et al. 2000, A&A 354, L1)

Proposed identification of the submillimeter source HDF 850.1 in the Hubble Deep Field.
The Hubble Deep Field (HDF) is one of the deepest images ever taken of the sky. In 1995, the cameras of the Hubble Space Telescope made a 10-day long exposure of a region of the sky covering about 3 x 4 arc minutes, about 1% of the solid angle covered by the full moon. In 1997, the JCMT telescope on Hawaii surveyed the entire HDF at a wavelength of 850 microns, and found five sources of submillimeter emission, the strongest of which was designated HDF850.1. In 1998, the IRAM interferometer, which has a small field of view much like a powerful microscope, was used to look at only 1% of the Hubble Deep Field to detect the dust continuum radiation from the strongest sub-mm source, HDF 850.1, found at the JCMT by Hughes et al. (1998). The IRAM measurement gives an improved source position that suggests an identification with the optical source 3-593.0, a faint object that looks slightly curved, with an arc-like shape on the HDF image (**Fig. 2.2**). This object has a photometric redshift in the range 1.7 to 1.8. In this redshift range, none of the strong UV emission lines are redshifted into the optical band, so as of this writing, there is still no measurement of a spectroscopic redshift for this source. If the HDF 850.1 source is at z=1.7 to 1.8, and unlensed, then its spectral energy distribution suggests it is an ultraluminous infrared galaxy, similar to the ones known in the nearby universe. Another possibility is that the luminosity of the object is somewhat magnified by gravitational lensing by the z = 1 elliptical galaxy 3-586.0, located 1 arcsec from the line of sight to the sub-mm dust source (Downes et al., 1999, A&A 347, 809).

CO(4-3) and dust emission toward two high-z radio galaxies
The interferometer has been used to detect the CO(4-3) line near two distant radio galaxies, 4C60.07 (z = 3.79) and 6C 1909+722 (z = 3.53). In the case of 4C60.07, also dust emission at 1.3mm was detected near the object. The estimated molecular gas masses are large (~1x10^{11} solar masses), as are the far infrared luminosities (10^{13} solar luminosities). What is remarkable about the 1.3 mm dust detection is that the source is 4″ southwest of the core of the double-lobed radio galaxy, and well away from the radio lobes. In the currently popular cosmological model (H_o=65 km/s/Mpc, Ω_m=0.3, Ω_Λ=0.7), this means the dust source is at

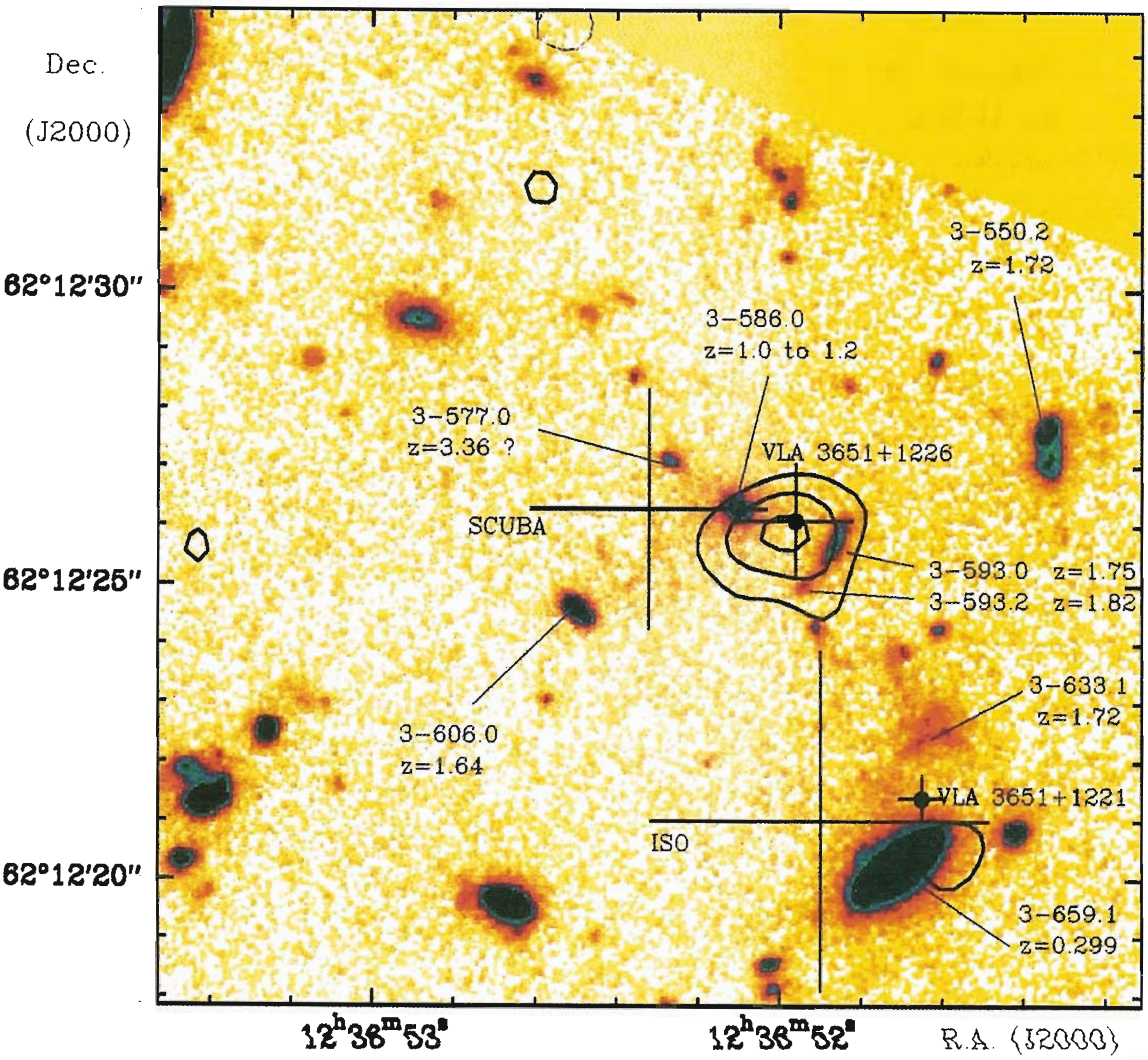

Fig. 2.2 Millimeter dust emission from HDF 850.1 relative to optical objects in a small part of the Hubble Deep Field. The contour lines indicate the thermal dust emission detected with the IRAM interferometer at 1.3 mm, superimposed on a very small part of the optical image of the Hubble Deep Field. The labels next to the galaxy images indicate their numbers in the optical catalog, as well as their photometric redshifts (except for a tentative spectroscopic redshift for the object 3-577.0). The larger crosses indicate the position errors for source detections made with the VLA, the ISO infrared satellite, and the SCUBA bolometer array on the JCMT.

least 31 kpc away from the nucleus of the radio galaxy, and not directly associated with it. The CO emission near 4C60.07 has two distinct features 550 and 150 km/s wide, separated by 700 km/s. The broad-line feature, which has most of the CO flux, is associated with the dust source, not the core of the radio galaxy. The narrow-line feature appears to coincide with the radio galaxy core. One possibility is that the two CO sources are two interacting galaxies. The interaction triggered the formation of the radio galaxy's jet, which has a time scale of 10 million years. The dust source, not visible on optical images, may be the merger partner, in which the interaction has triggered a major starburst, which has a time scale of 100 million years (Papadopoulos et al. 2000, ApJ 528, 626).

2.2.2 Nearer Galaxies

Molecular gas in the tidal debris of violent galaxy-galaxy interactions

The long-exposure images from the Hubble Space Telescope show that galaxies interacted frequently in the past. It was probably these interactions that assembled the large, bright galaxies we see in the present-day universe. The interactions lead not only to the accumulation of gas and stars, but also to the ejection of some of the stars and gas into intergalactic space, often in strikingly long tidal tails. These tails often contain big clumps of stars that resemble small, dwarf galaxies. Isolated dwarf galaxies, not in any tidal tails, are actually the most common type of galaxy in the sky, and many of them contain a large amount of atomic hydrogen gas, as well as ionized gas heated by newly-formed massive stars. It has been suggested that the clumps in the tidal debris of interacting galaxies may evolve into new dwarf galaxies. But new stars are born in clouds of molecular gas, not atomic gas. So to be able to evolve into a real dwarf galaxy and to form new stars, the tidal clumps would have to contain a large amount of molecular gas. Up to now, this molecular gas has not been observed. Things may be about to change with the new, sensitive receivers on the IRAM 30m telescope. This telescope has been used to detect CO in clumps in the tidal tails of the interacting galaxies Arp 105 and Arp 245 **(Fig. 2.3).** Surprisingly, this CO coincides with the atomic hydrogen and has the same line profile, which is generally not true in normal, undisturbed galactic disks (where CO is concentrated in the middle, and the atomic gas usually extends into the outer parts of the disk). In these clumps in the tidal tails, the CO line widths are about 40 km/s, and the gas masses are a few x 10^8 solar masses. How to interpret this discovery ? One possibility is that the molecular gas was originally in the interacting galaxies and was dragged out along with the other debris in the tidal tail. The authors who made this observation at the 30m telescope suggest instead that the molecular gas has been formed on the spot, far from the site of the interaction. They propose that it forms on dust grains, out of the pre-existing atomic gas that was torn out of the parent galaxies by the interaction. The molecular gas will not disperse into intergalactic space, but will form new stars, that will stay together and evolve into a new dwarf galaxy. This is an interesting new discovery with a controversial interpretation, that will undoubtedly lead to many new searches for CO in the tidal debris of interacting galaxies (Braine et al., 2000, Nature 403, 867).

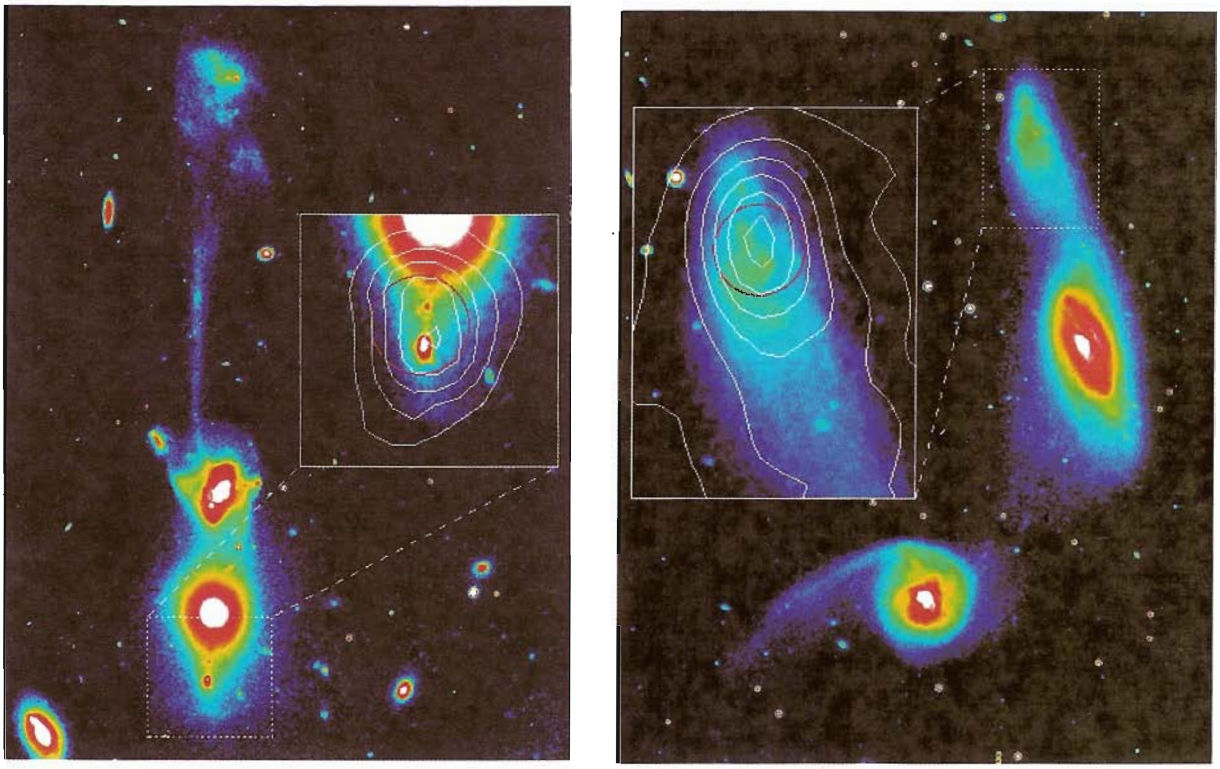

Fig. 2.3 Molecular gas in the tidal tails of interacting galaxies. *Left :* False-color *V*-band image of Arp 105, an interaction of a spiral galaxy with an elliptical galaxy that has generated a clump of stars and gas at the end of the northern tidal tail and another compact clump at the tip of the southern tail from the spiral. The inset is a zoom on the southern clump. The contours show the 21-cm H I emission and the red circle shows where CO was detected with the 30m telescope. *Right :* A similar image of Arp 245, an interaction between two spiral galaxies. The red circle in the inset indicates the location of the CO detection with the 30m telescope (images courtesy of P.-A. Duc).

Gas dynamics in the luminous merger galaxy NGC 6240

NGC 6240 is a well-known example of a merger of two galaxies that has resulted in a prodigous luminosity in the near and far infrared, and a high concentration of molecular gas in its center, that is easily detected in the CO lines. The IRAM interferometer has been used to map CO(2-1) in the central region with 0.5" x 0.7" resolution. About half of the CO flux comes from a rotating, turbulent, thick disk of molecular gas that is centered between the two cm-radio and near-infrared "nuclei". Throughout this region, the molecular gas has linewidths greater than 300 km/s, and some line profiles extend over 1000 km/s to zero intensity

(**Fig. 2.4**). The gas mass within the central 470 pc radius is 3×10^9 solar masses, about half of the total mass in this zone. One interpretation is that NGC 6240 is in the process of forming a central thin disk, in between the former nuclear star clusters of the original merging galaxies. This new central disk, that is now rapidly getting rid of its turbulent energy, may eventually create a major starburst, as is observed in the centers of many other ultraluminous infrared galaxies.

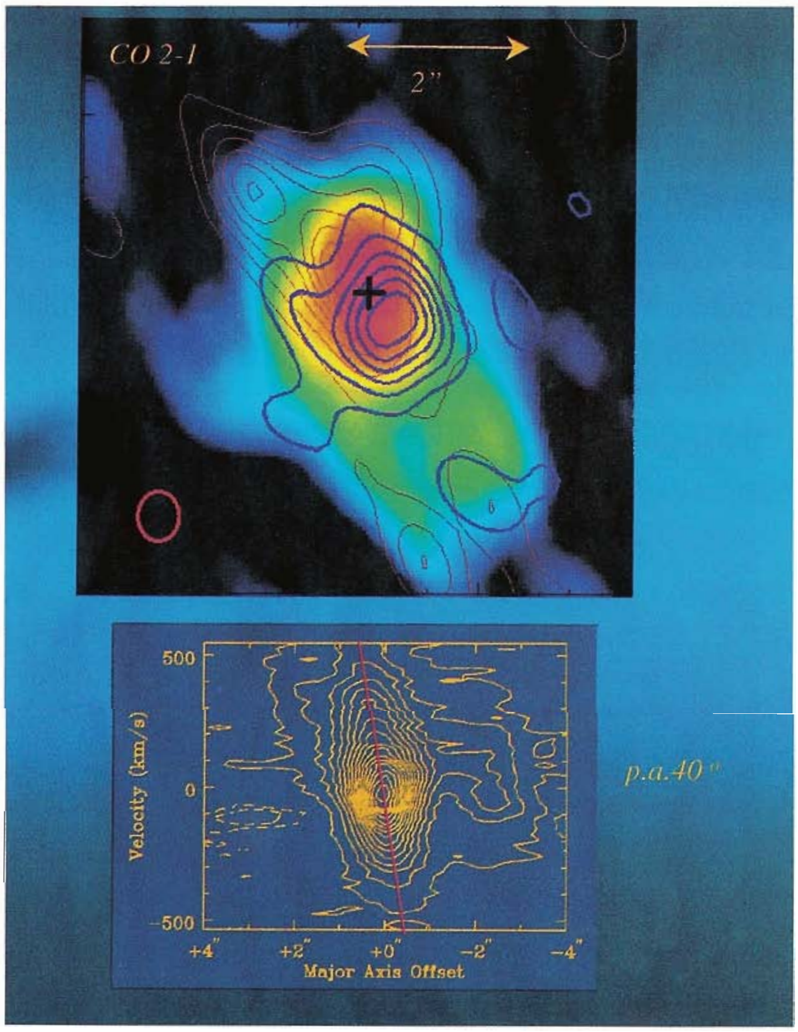

Fig. 2.4 Kinematics of CO(2-1) in NGC 6240. *Upper :* Interferometer map of redshifted CO emission (thin red contours, +345 to +545 km/s) and blueshifted CO emission (heavy violet contours, –535 to –335 km/s), superimposed on a false color image of the integrated CO emission. North is up, east is left, and the cross indicates the peak of the CO flux. The red ellipse at lower left is the 0.5 x 0.7 sec beam. *Lower :* Position-velocity diagram of the CO(2-1) emission along the kinematic major axis at position angle 40° (1999, Tacconi et al., ApJ 524, 732).

Bars and warps in the molecular gas in the Seyfert 2 galaxy NGC 1068.

New interferometer observations have been made of CO(1-0) and (2-1) in NGC 1068 with a resolution of 0.7". The molecular gas of the inner 5" is resolved into a ring with two bright knots east and west of the nuclear continuum emission. On these maps, the molecular gas can be traced for the first time to 0.18" (13 pc) from the nucleus. The high velocities in this region imply an enclosed mass of 10^8 solar masses, most of which is due to a compact, nuclear star cluster. (Previous measurements from H_2O masers imply that 20% of this, 2 x 10^7 solar masses, are in a nuclear black hole.) The new CO maps also show spiral arms of molecular gas 10" (720 pc) from the nucleus. These spiral arms are interpreted as the inner Lindblad resonance of a 17-kpc long, stellar bar-like structure seen at optical wavelengths. The low velocity dispersion in the CO indicates the molecular gas is in a disk with a thickness of 10 pc in the nuclear region and 100 pc in the spiral arms. Kinematic models of the CO motions are consistent with either a warped disk or a 72 pc nuclear bar. Because there is no evidence for such a bar in near-infrared images, the favored explanation is a warped disk. Such a warped disk could also explain the obscuration of the black hole accretion disk, the extinction of light from the nuclear stellar cluster, the infrared polarization, and the direction and location of the cone of ionization from the nucleus (**Fig. 2.5**).

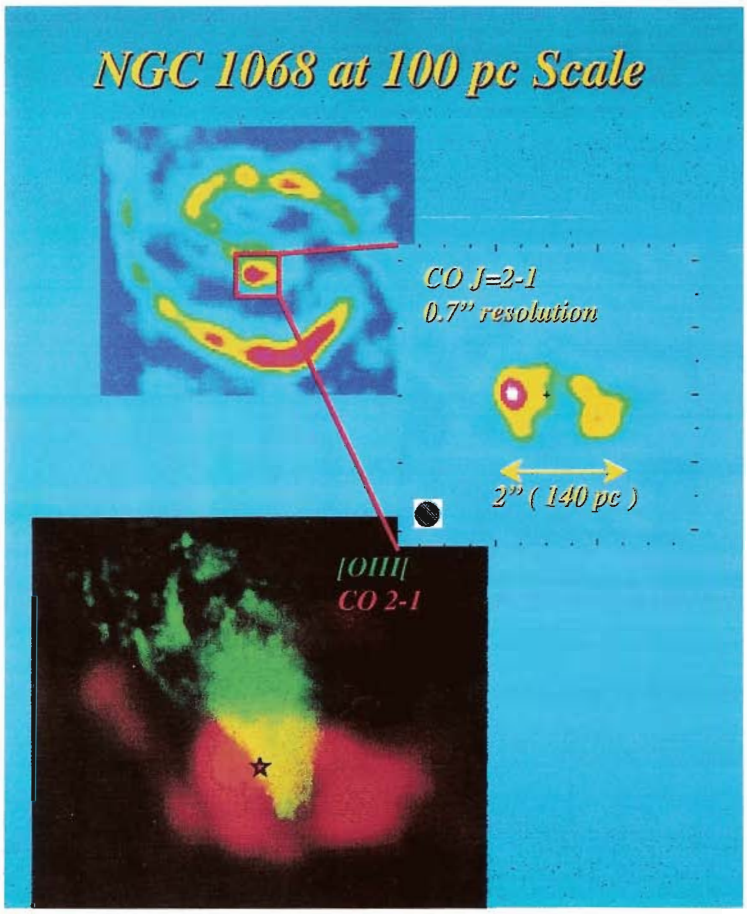

Fig. 2.5 Molecular gas in the Seyfert 2 galaxy NGC 1068. *(Top :)* Interferometer map of CO(1-0) on a scale of 40", showing the spiral resonance ring 720 pc from the nucleus. The central inset shows a zoom on the two CO(2-1) structures east and west of the nucleus. *(Lower :)* The ionization cone from the nucleus, as seen by the Hubble Space Telescope in [O III] (in green ; from Macchetto et al. 1996) is superimposed on the integrated CO(2-1) emission as seen by the IRAM interferometer (Schinnerer et al. 2000, ApJ 533, 850).

Large-scale shocks in the 600-pc nuclear disk of NGC 253, traced in SiO and $H^{13}CO^{+}$

The interferometer has been used to make the first high-resolution SiO map of another galaxy, the edge-on barred spiral NGC 253, which has a strong starburst in its central regions. The SiO(v=0, J=2-1) and $H^{13}CO^{+}$ (1-0) lines come from a 600 x 250 pc circumnuclear disk with a double ring structure (**Fig. 2.6**). The inner ring of radius 60 pc (4") contains the nuclear starburst. The outer ring extends in a spiral arc out to a radius 300 pc (20"). The motions in the circumnuclear disk are not circular. They are interpreted in terms of *two* inner Lindblad resonances caused by the bar, and a trailing spiral arm that crosses the outer ring. Out of the plane of the disk, the SiO maps show two filaments of molecular gas at the inner ring. This may be the molecular gas counterpart of a giant outflow of hot gas that is observed in X rays and optical lines. If so, the molecular gas would be cool gas that is entrained by turbulence on the outer surface of the hot superwind. The SiO abundance is unusually high (a few x 10^{-10} to a few x 10^{-9} relative to hydrogen). The most likely explanations for these high abundances are the shocks in the bar-induced orbits in the disk, and shocks in the wind of hot gas flowing out of the galactic plane.

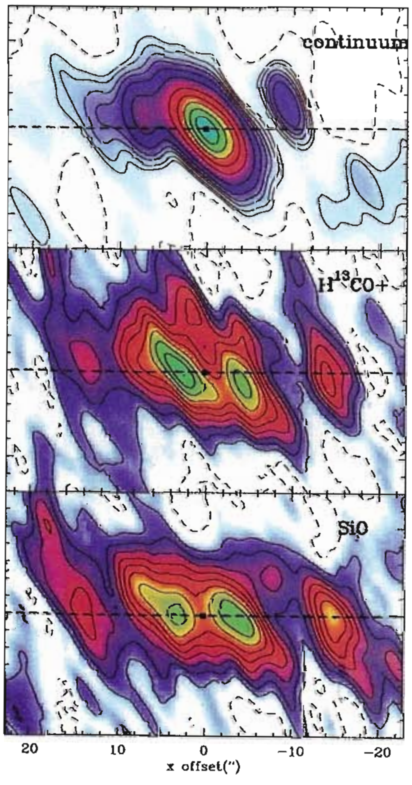

Fig. 2.6 Continuum, $H^{13}CO^{+}$, and SiO line emission from the center of NGC 253. The 86.7 GHz continuum source (*top*), with a total flux of 0.3 Jy, is estimated to be a mixture of synchrotron emission, free-free emission, and dust emission, in roughly equal parts. The two main peaks in the $H^{13}CO^{+}$ (*middle*) and SiO (*bottom*) maps are interpreted as an inner ring, with a radius of 60 pc (4″). The *x,y* coordinate system is along the major and minor axes of the stellar bar, at position angle 68° (Garcia-Burillo et al., 2000, A&A 355, 499).

2.3 STAR FORMATION

2.3.1 Young Stellar Objects

A strong magnetic field in the circumstellar disk of MWC 349

The 30m telescope has been used to measure the Zeeman effect in the H30α hydrogen recombination line maser at 1.3 mm in the disk of the young massive star MWC 349 (**Fig. 2.7**). These are the first quantitative measurements of the magnetic field in the *disk* of any young star. This recombination line originates in the very dense ionized corona of the neutral circumstellar disk. At a radius of 40 a.u. from the star, where the H30α maser is located, the line of sight component of the magnetic field is parallel to the plane of the edge-on circumstellar disk. The Zeeman splitting indicates the magnetic field is 22 milligauss. The energy density in this magnetic field is nearly the same as the thermal energy density of the plasma that produces the recombination line, so the magnetic field may be dynamically important. This high field strength at 40 a.u. from the star makes it unlikely that the magnetic field is of stellar origin. It is probably generated on the spot by a disk dynamo effect.

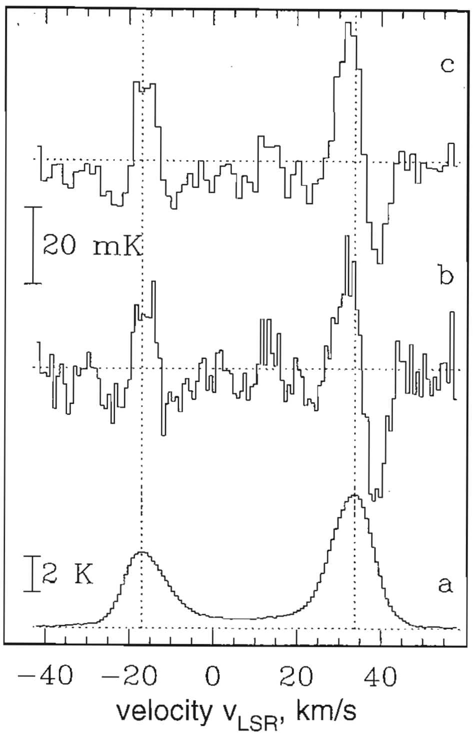

Fig. 2.7 Zeeman observations of the H30α line in MWC 349. *Spectrum a, bottom :* the total power spectrum (Stokes parameter *I*) ; *Spectrum b, middle :* Stokes parameter *V* (right circular polarization minus left circular polarization), observed with the autocorrelation spectrometer with a resolution of 0.7 km/s, and corrected for instrumental polarization. *Spectrum c, top :* Same as *b*, but observed with a filter bank spectrometer with a resolution of 1.3 km/s. The signature of the Zeeman effect is the positive- and negative-going emission, antisymmetric about the peak of the line in total power.(Thum&Morris, 1999, A&A 344,923).

Maps of the disk and jet in the massive protostar IRAS 20126+4104

A new study has been made of the luminous source IRAS 20126+4104, at a distance of 1.7 kpc. Previous maps with the IRAM interferometer had shown this source to have a compact core at the center of its bipolar outflow. The new observations provide higher angular resolution in the methyl cyanide lines, which trace the rotation in the central disk, and better delineate the structure and kinematics of the jet in the thermal SiO and HCO^+ emission, which comes from shocked molecular gas in the jet, and provide high-resolution maps of the continuum emission (**Fig. 2.8**). The interferometer maps have been combined with submillimeter and infrared observations on the JCMT and UKIRT telescopes. The main results of this study is that the disk, as mapped in $CH_3CN(12\text{-}11)$, is elongated perpendicular to the outflow jet. The line-width variation with radius is consistent with Keplerian rotation around a star of 24 solar masses. The blue side of the high-excitation K=8 line profile is absorbed by the dust in the disk, indicating that the central part of the disk is falling inward at 3 km/s. This implies an accretion rate of 10^{-3} solar masses per year. The dust continuum measurements indicate that the average dust temperature is 50 K, and the mass of the disk is 1.7 solar masses within a radius of 550 a.u. The luminosity of the star is 10^4 solar luminosities, which would be too low for a star of 24 solar masses. This fact, together with the evidence for infall, indicates that the object is a protostar, deriving its luminosity from accretion, rather than a zero-age main-sequence star, deriving its luminosity from nuclear burning. If so, IRAS 20126+4104 is the first example of a high-mass protostar with a Keplerian accretion disk and a bipolar outflow jet.

Dust Continuum Imaging of the HH 24 region in the dust cloud L1630

The IRAM 30m telescope has been used to map the dust continuum emission in the region around the Herbig-Haro objects HH 24 and 26 in the dust cloud L1630, part of the Orion B molecular cloud complex at a distance of 400 pc. The observations at the 30m telescope were made with the MPIfR multi-channel bolometer at a wavelength of 1.3 mm, and were compared with observations made with the SHARC bolometer camera at the Caltech Submillimeter Observatory (CSO) at a wavelength of 350 microns. The resolution at both telescopes was comparable, with a beam of 11″ at the 30m telescope and 12″ at the CSO. The maps (**Fig. 2.9**) show a cluster of at least nine protostellar condensations at various evolutionary stages in the region of HH 24 – HH 26. Two of the objects (numbers 3 and 7 on the figures) are previously identified Class 0 protostars, with dust temperatures of about 25 K. In these maps, two new sources (numbers 5 and 6 on the figures) were detected that have a low ratio of their 350/1300 micron fluxes. These low flux ratios, which imply dust temperatures of only 10 K, together with the absence of embedded infrared and cm-radio continuum sources, suggest that these objects are in a early stage of the process of star formation. One of these two sources is quite compact on the 1.3mm image, and may be in the short-lived phase of isothermal contraction. (Lis, Menten, & Zylka, 1999, ApJ 527, 856)

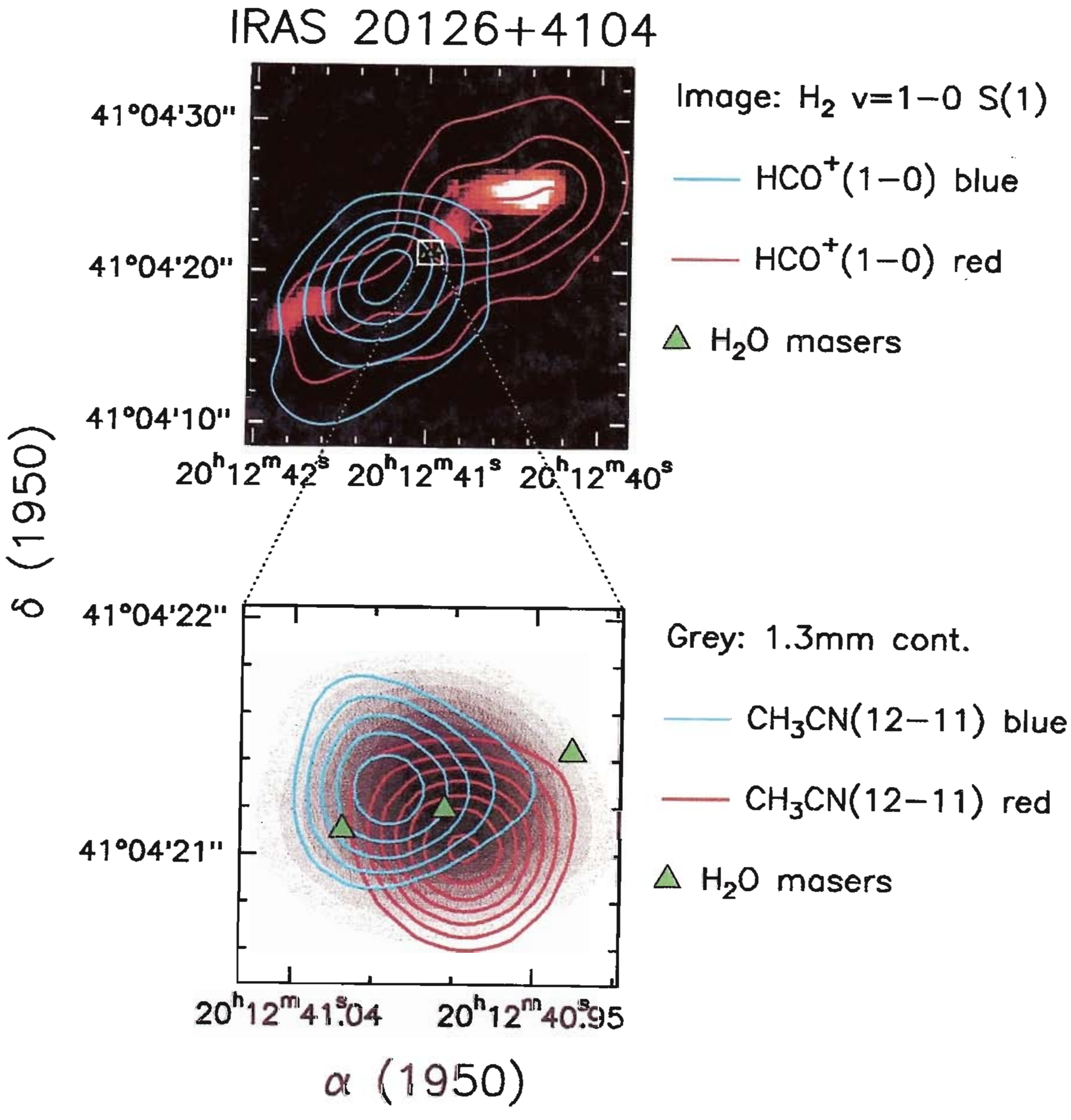

Fig. 2.8. Maps of the disk and jet in the massive protostar IRAS 20126+4104. *Upper :* The red and blue contours represent the red- and blue-shifted lobes of the outflow jet, traced in HCO^+, superimposed on the 2.122 micron v=1-0 S(1) line of molecular hydrogen (false color red image). The H_2 line emission comes from the shocked regions in the flow, and coincides with the SiO emission mapped at millimeter wavelengths. *Lower :* Zoom on the disk at the center of the flow. The background grayscale shows the 1.3 mm continuum emission from dust, while the blue and red contours show the blue- and red-shifted emission from the 12-11 line of methyl cyanide, which probably comes from the two sides of the rotating disk (Cesaroni et al. 1999, A&A 343, 571).

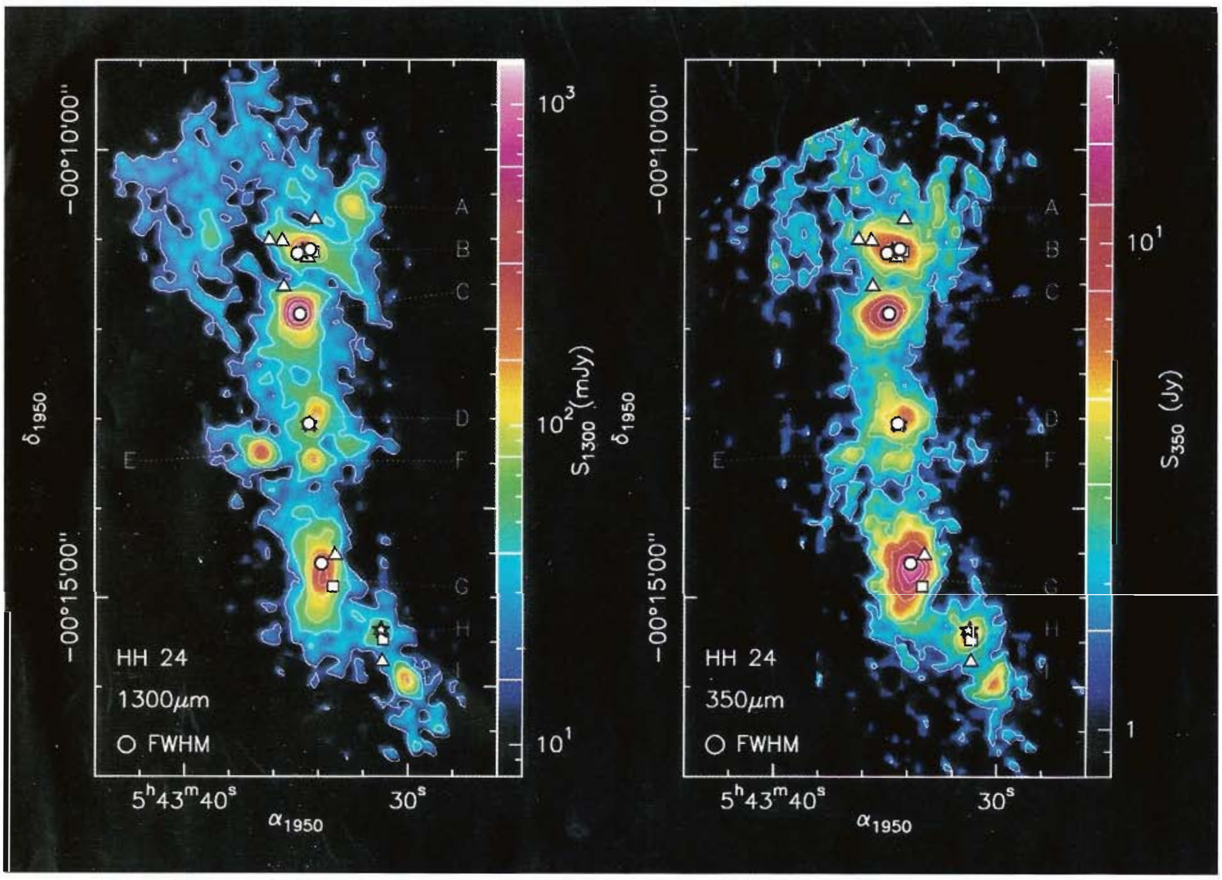

Fig. 2.9 Dust emission from the HH 24 – HH 26 region at 1.3 mm and 350 microns (*Left :*) Map of the 1.3 mm dust continuum emission. The r.m.s. noise level is 5 mJy per beam. (*Right :*) Map of the 350 micron dust continuum emission. The r.m.s. noise level is 400 mJy per beam. In both maps, the small symbols are the positions of Herbig-Haro objects (triangles), IRAS far-infrared sources (diamonds), radio sources at 3.6 cm (circles), and near-infrared sources (stars).

2.4 CIRCUMSTELLAR ENVELOPES

2.4.1 Red Giant Envelopes

The young, detached shell of molecular gas around the star U Camelopardalis

The interferometer has been used to resolve a thin outer shell of molecular gas around U Cam, a semi-regular variable carbon star at a distance of 500 pc. The interferometer maps in the CO(1-0) and (2-1) lines show the shell is at a distance of 6 x 10^{16} cm from the star, with a thickness-to-radius ratio of 1-to-6 (**Fig. 2.10**). The shell is expanding with a velocity of 23 km/s, and has a mass of 10^{-3} solar masses. CO emission is also detected at the star itself, indicating that the present mass loss is only 2.5 x 10^{-7} solar masses per year, at a velocity of 12 km/s. A possible interpretation of the thin, detached shell is that it was produced about 800 years ago during a short period of high mass loss that was about 40 times stronger than at present, and that lasted only 150 years. This may be evidence for theoretical scenarios where a flash of rapid nuclear burning in the helium zone inside the star greatly increases the mass loss, on a short time scale.

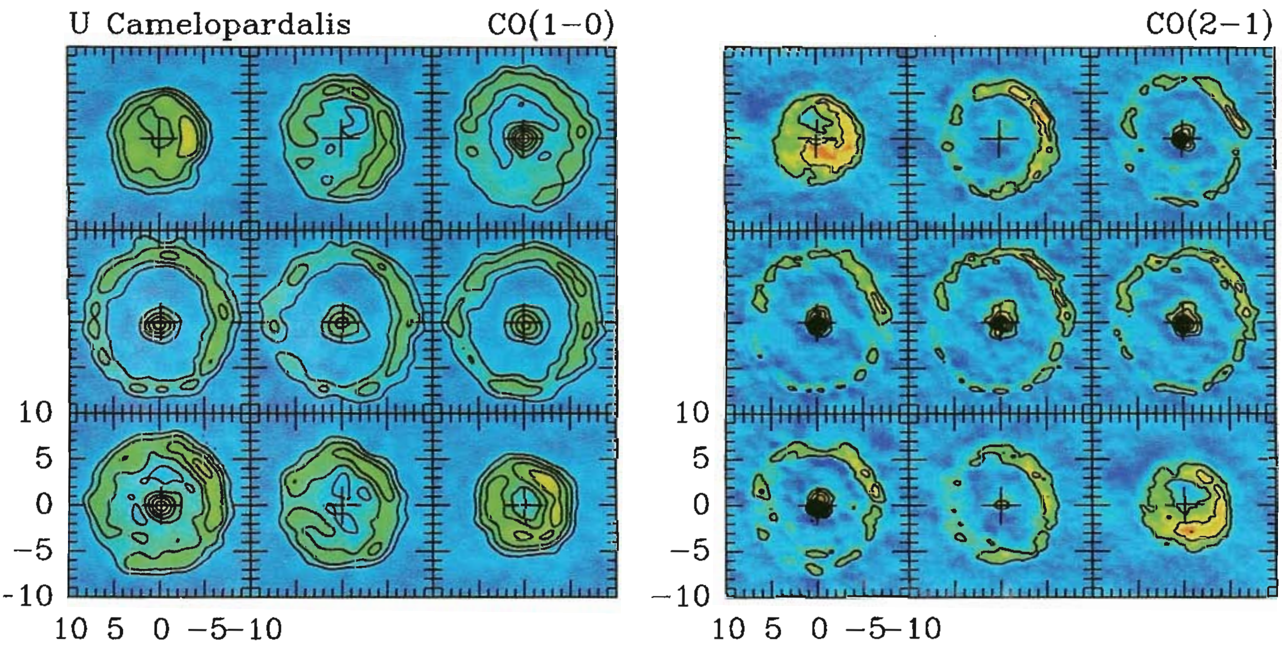

Fig. 2.10. The detached shell around U Cam. The maps show CO in velocity channels spaced every 5 km/s, starting from −14.5 km/s *(upper left corner)* to +25.5 km/s *(lower right corner)*. Note that there is CO emission at the star itself, as well as in the outer shell.. The left series is CO(1-0), with a beam of 2.0″ x 1.6″. The right series is CO(2-1), with a beam of 1.0″ x 0.7″. The position offsets (arcsec) are given at lower left, and the contour step is 50 mJy /beam in both lines (Lindqvist et al. 1999, A&A 351, L1).

2.4.2 Proto-Planetary Nebulae

Multiple molecular outflows in AFGL 2688

High-resolution (1 arc sec) imaging of the proto-planetary nebula AFGL 2688 in the CO(2-1) line and in the 1.3 mm continuum has been done with the interferometer. The maps reveal with unprecedented detail the structure and the kinematics of the gas ejected by the central star over the past few hundred years (**Fig. 2.11**).

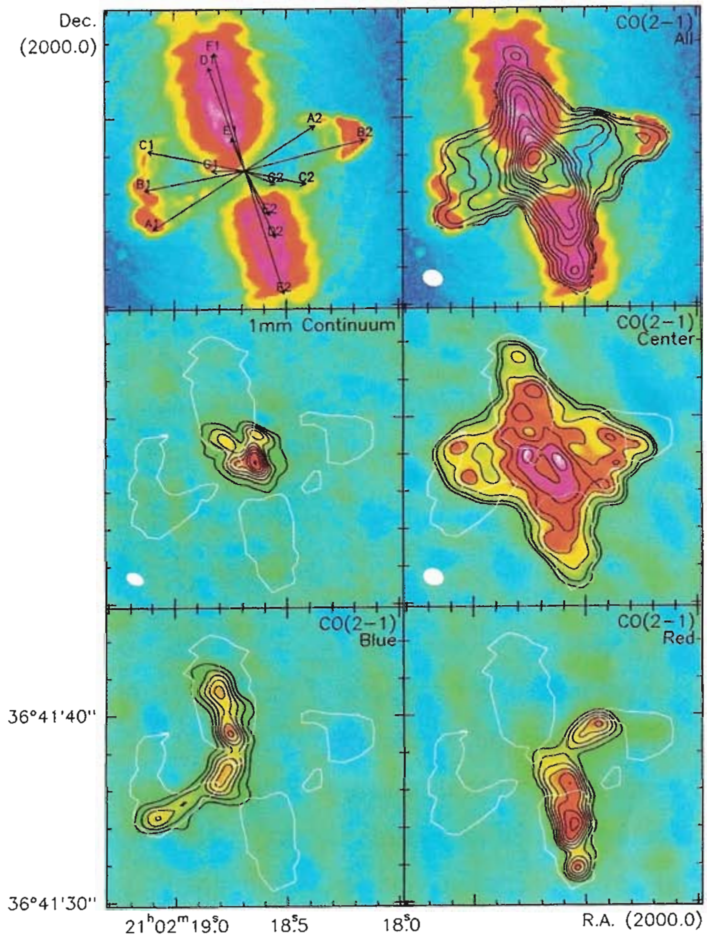

Fig. 2.11 Maps of CO(2-1), dust, and molecular hydrogen in the proto-planetary nebula AFGL 2688. *Top left:* H_2 1-0 S(1) line and nearby 2.15 micron continuum, from Sahai et al. (1998), with arrows showing the outflow axes. *Top right:* CO(2-1), integrated over all velocities, shown as contour levels superimposed on the molecular hydrogen image (in color), showing that the ends of the CO jets coincide with the shocks seen in H_2. *Middle, left:* The 1mm continuum emission (contours and colors), that shows the 1-arcsec central core. *Middle, right:* CO(2-1) at the nebula's systemic velocity, –35 km/s. *Lower left:* Blue-shifted CO, at –60 km/s. *Lower right:* Red-shifted CO at –15 km/s. The small white ellipses indicate the 1-arcsec interferometer beam. (Cox et al. 2000, A&A 353, L25)

The data show that there are two distinct directions of high-velocity outflow away from a central core of gas surrounding the star. One flow direction is along the well-known optical axis, oriented north-south. The other flow direction is east-west, close to the equatorial plane. The north-south and east-west outflows are resolved into a striking series of collimated, bipolar jets. The tips of the east-west outflows coincide with the locations of 2-micron line emission by shock-excited molecular hydrogen. The molecular maps thus provide direct evidence for the impact and likely shaping effects of the high-velocity jets on the nearly spherical molecular envelope that had been previously ejected by the star when it was still in its Asymptotic Giant Branch (AGB) phase. After the current proto-planetary phase, AFGL 2688 will evolve into a 4-lobed planetary nebula symmetric about its central point, similar to many other planetary nebulae with point symmetry. The new molecular line maps show that these symmetries are given to planetary nebulae in the earliest stages of their evolution --- by the jets of molecular gas.

2.5 SOLAR SYSTEM

Comparison of molecules found in Comet Hale-Bopp with those found in interstellar gas.

A recently-published analysis of the molecules observed in 1997 in Comet Hale-Bopp with the IRAM 30m telescope, the IRAM interferometer, and the Caltech Submillimeter Observatory shows interesting parallels with molecules in the interstellar medium. The chemical abundances of volatile molecules in the comet's coma are similar to those inferred in interstellar ices, hot cores in molecular clouds, and bipolar flows around protostars. This suggests that the chemistry that occurs on the surfaces of interstellar dust grains is the same chemistry that created the molecules found in the ices of comets. This means that the cometary volatiles probably formed 4.6 Gyr ago, in the interstellar medium in the pre-solar molecular cloud. Because cometary nuclei accreted in the coldest, most distant regions of the pre-solar nebula, they were not affected by later chemical changes that occured as the inner parts of the solar nebula evolved.

These IRAM/Caltech observations revealed molecular species that were seen for the first time in a comet. These new cometary detections included SO, SO_2, HC_3N, NH_2CHO, HCOOH, and $HCOOCH_3$. Other, previously-detected cometary molecules included HCN, HNC, CH_3CN, CO, CH_3OH, H_2CO, H_2S, CS, OCS, and HNCO. These detections, together with results from other observatories, give a comprehensive view of the composition of the gases that sublimated from the cometary ices and dispersed into the coma of comet Hale-Bopp (**Fig. 2.12**).

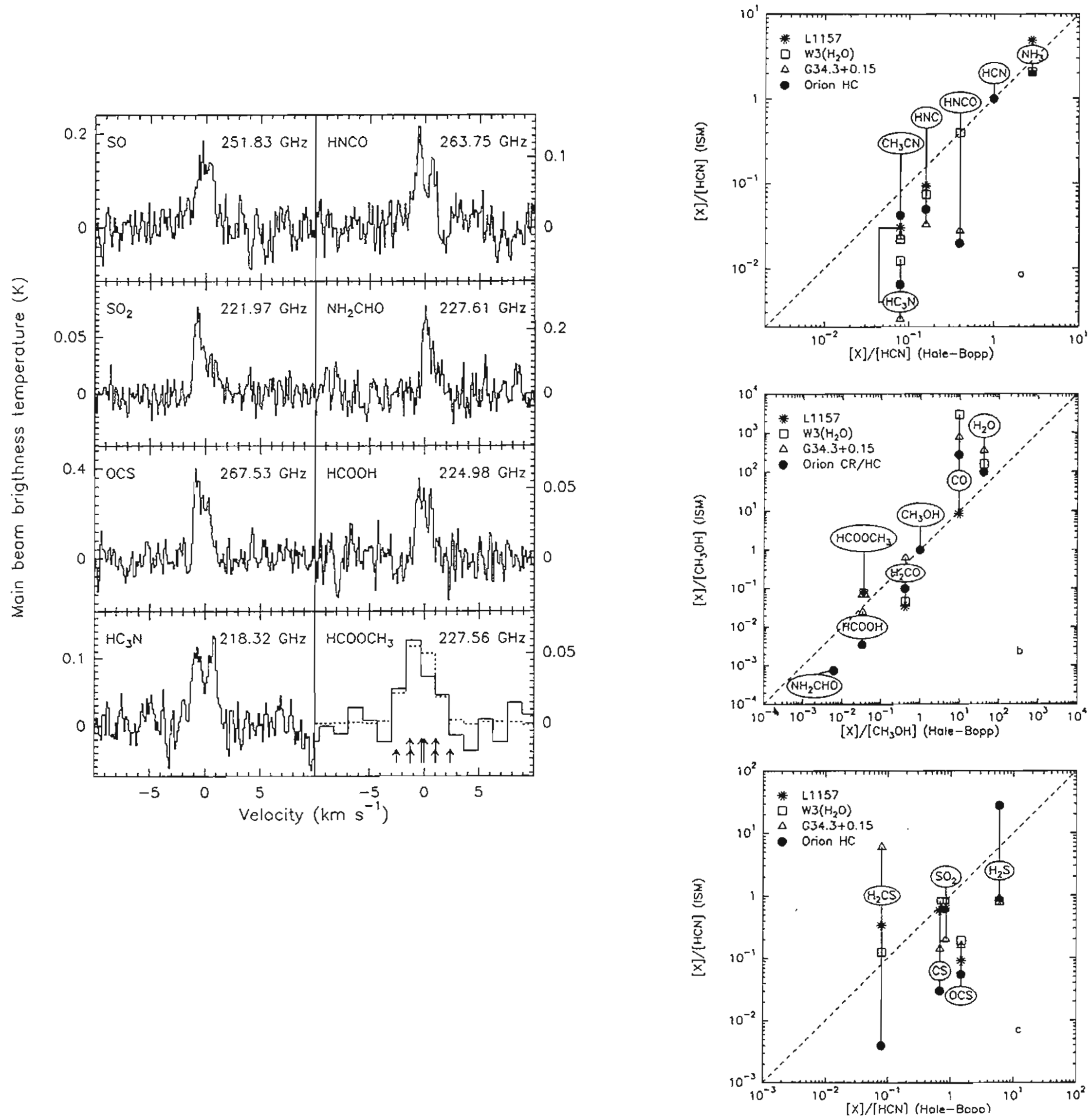

Figure 2.12 *Left :* Spectra of comet Hale-Bopp taken with the CSO, the IRAM 30 m telescope, and the IRAM interferometer in the spring of 1997. *Right :* Molecular abundances in comet Hale-Bopp, compared with those in the bipolar flow L1157 and several hot molecular cores. *Top :* for molecules with nitrogen ; *Middle :* for molecules with carbon, hydrogen, oxygen ; *Bottom :* for molecules with sulphur. The comparisons span several orders of magnitude, and show the similarity of interstellar and cometary ices (Bockelée-Morvan et al., 2000, A&A 353, 1101)

Radio Continuum Emission from Comets Hyakutake and Hale-Bopp

An analysis of the radio continuum observations from comets Hyakutake and Hale-Bopp was published in 1999. The observations included data taken in 1996 and 1997 from the IRAM 30m telescope and the IRAM interferometer, in conjuction with data from the VLA, the HHT, and the Effelsberg 100m telescope, covering frequencies from 22 to 860 GHz. The continuum is thermal emission from both the solid nucleus and the particles in the cometary halo. The observed variation of intensity can be fit with a simple function of heliocentric and geocentric distances, without any outburst or noticeable short-term variability. This means that the determining parameter is the particles' equilibrium temperature as a function of distance from the sun, from which one may estimate the diameter of the nucleus. The most sensitive diameter estimate for comet Hyakutake comes from the visibility measurements with the IRAM interferometer, which gave an upper limit of 2.1 km. The diameter of the nucleus of comet Hale-Bopp was much greater, and could be estimated directly from the visibility measurements with the interferometer, which yielded a diameter of 44.2 km. The diameters of the central parts of the halos of both comets can be measured directly from the 19-channel bolometer observations made at the 30m telescope at 250 GHz, and from the IRAM interferometer observations. The measurements yielded Gaussian half-power diameters of 1870 and 11080 km for the central parts of the halos of Hyakutake and Hale-Bopp, respectively. Very extended radio continuum emission could be detected at more than 10^5 km from the nucleus of Hale-Bopp. The spectral index for both comets was 2.8, indicating similar particle size distributions in both comets. The millimeter continuum data yielded estimates of the dust masses contained in the halo of 6×10^7 kg for Hyakutake and 8×10^9 kg for Hale-Bopp (Altenhoff et al., 1999, A&A 348, 1020).

3. PICO VELETA OBSERVATORY

3.1 Staff Changes

In April Wolfgang Wild left the observatory to become the European project team leader for receiver development for the ALMA project. Rainer Mauersberger (formerly Steward Observatory, Tucson, AZ) took over his duties as station manager of the Pico Veleta Observatory. David Teyssier who had worked as cooperant and astronomer left the observatory, and two new cooperants joined the staff: Bertrand Thomas is working with the receiver group, and Pierre Hily-Blant in the astronomers' group. During the winter 1999/2000 period, Hauke Hein was delegated to the Submillimeter Telescope Observatory on Mt. Graham (Arizona).

3.2 30-m Telescope Operation

The operation of the telescope was generally smooth throughout 1999. As shown in Figures 3.1 and 3.2, almost 2/3 of the time could be used for astronomical observations. About 22% of the time were lost due to meteorological conditions (clouds, wind). After the last heterodyne receiver of the old generation was de-commissioned in the fall of 1999, the regularly scheduled weekly maintenance could be reduced from 13 hours to about 8 hours since the new generation receivers need less frequent servicing. The maintenance time includes receiver filling and maintenance, telescope, computer and backend maintenance. Since the new receivers have turned out to be very reliable, it is not necessary anymore to have a receiver engineer at the site for seven days a week. Over the weekends a receiver engineer is on standby and can be at the telescope within two or three hours if needed. Automatic tuning by the operators is now standard for most of the available frequency band.

9% of the time were used for technical activities, such as completing the refurbishment of the receiver cabin, replacing and repairing equipment, installation of PI instruments and changes in the software.

A very small amount of time (0.5%) was lost due to technical problems. Most of these problems were related to the computers and to the software (40%) or the telescope (45%). Only 15% of the time lost for technical reasons were due to receiver failures.

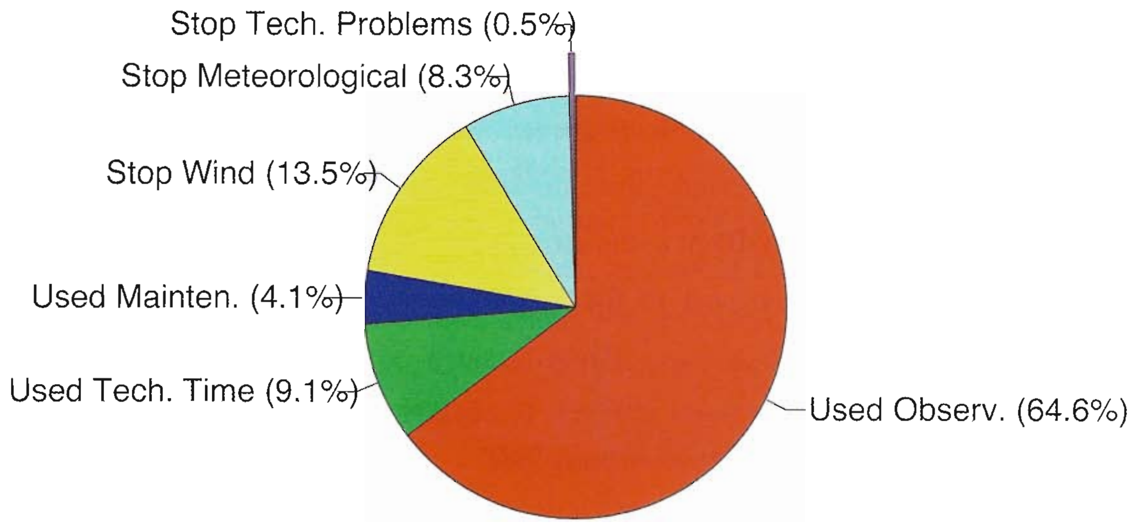

Fig. 3.1: Distribution of the total telescope time for the year 1999. About 67% of the time were used for astronomical observations.

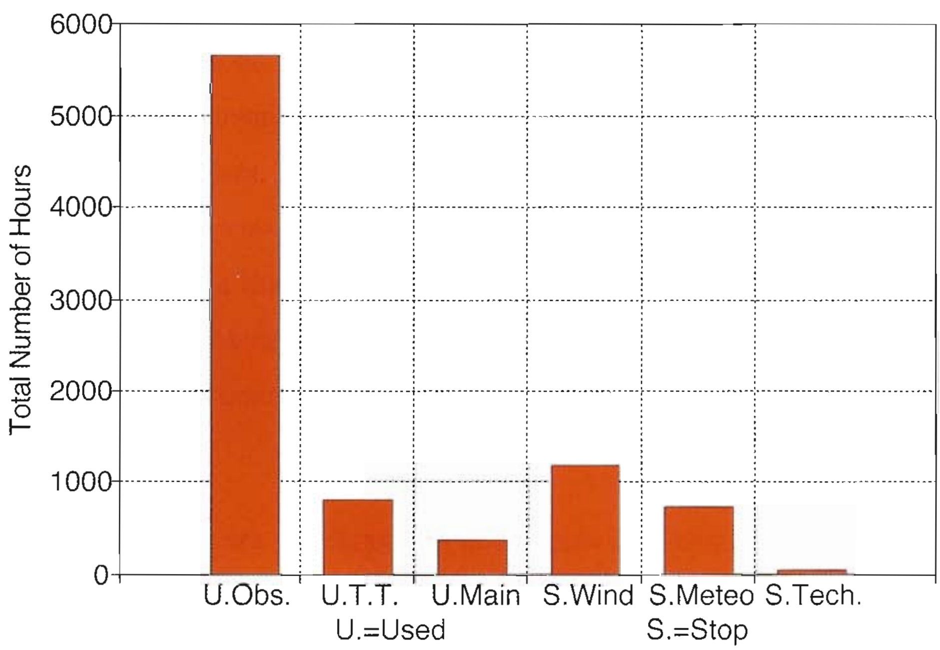

Fig. 3.2: Telescope time during 1999 in hours. The loss of telescope time due to technical failures (of more than 2 hours duration) was 0.5%.

Pointing runs are now scheduled more often, about twice a week, to account for changes in the pointing behaviour of the telescope on timescales of a few days. It is now possible to obtain a pointing run in 2 hours making use of the newly installed inclinometers. Full pointing runs of 6 hours are, however, interspersed in order to understand the significance of the inclinometer measurements.

During the winter of 1999/2000 we applied for the first time a flexible scheduling scheme in order to increase the observing efficiency of the 30-m telescope. The program committee identified a number of highly rated projects with exceptional demands on atmospheric transparency and sky noise. When the quality of the atmosphere was insufficient for those projects, backup projects observable under normal weather conditions were observed either by visiting astronomers or staff astronomers in service mode, or remotely from one of our remote observing stations in Granada or Grenoble.

We are now receiving a detailed weather forecast made by the Spanish Meteorological Institute for the telescope site, which includes predictions on precipitation, wind and cloud cover. This service not only helps in planning astronomical observations but also for scheduling the often difficult transport by car and snow mobile to the telescope. The actually measured wind speed and other data from our weather station can now be seen on the IRAM Granada website (http:\\www.iram.es\weather).

3.3 Antenna

An inclinometer was installed (Figure 3.3) to monitor the tilt of the azimuth axis during 1999 and to investigate its effect on the antenna pointing. The results are summarised in a technical report.

Fig. 3.3: A newly installed inclinometer shall help to understand and to quantify the effect of the tilt of the telescope on the pointing.

Part of the residual astigmatism of the antenna is produced by temperature gradients in the backstructure of the telescope. We have therefore installed four ventilators in the rear part of the antenna frame, just behind the membrane, to homogenise its temperature. Each ventilator consumes 400W and blows 4300 m^3/hour of air. After the installation of the ventilators, the r.m.s. of the temperature in this area decreased by 40%.

A new programmable controller (PLC) for the antenna servo control and interlock system has been bought. The new PLC has been programmed by IRAM staff and is working in parallel with the old one, which is now 20 years old and ready to be replaced. Among other improvements, the new system offers the possibility to transmit the data through an Internet connection for remote trouble shouting and tele-diagnostics.

A new encoder for the position of the subreflector rotation has been installed, and a spare encoder has been purchased. It replaces an obsolete model of an older generation.

3.4. Reflector Surface

A surface adjustment was made in October 1998 and again in July 1999. Both settings were made on the basis of holographic measurements made in September 1998 with the new 39 GHz phase coherent receiver operating at the prime focus. An opportunity to check the new surface occurred during the installation of the new receivers C and D in September 1999. Several good quality maps of the aperture plane phase distribution were obtained. They yield a root mean square error of 52 microns for the paraboloid, when projected onto the aperture plane and amplitude weighted. The value appropriate for secondary focus operation is then 55 microns, after correction for the estimated errors in the subreflector.

This new result is a significant improvement over the corresponding value of 74 microns, measured in September 1998 before the latest surface adjustments. It should be noted that all these estimates of surface error refer to elevation of 43 degrees and to calm night-time conditions. In daytime under full solar illumination the surface error rises to about 66 microns.

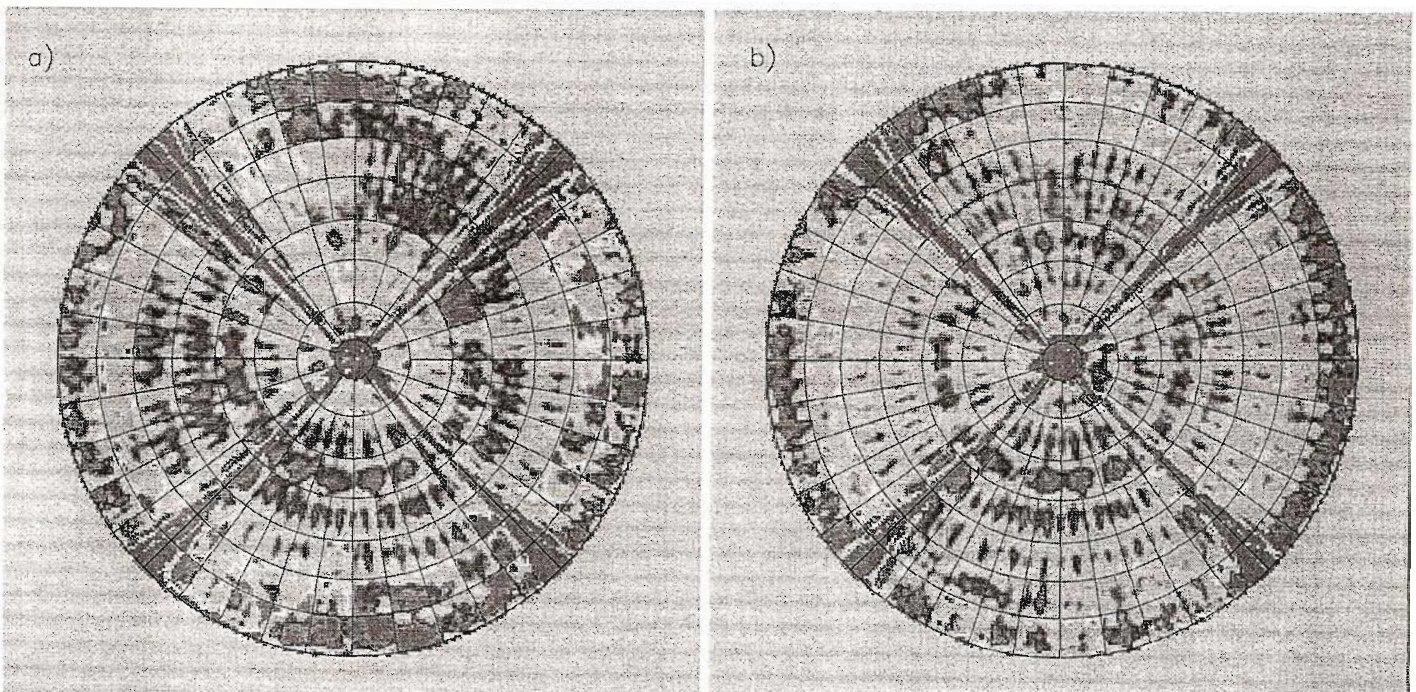

Fig. 3.4: Aperture plane phase distribution before (a) and after (b) the last adjustments.

The improvement in surface quality is displayed in Fig. 3.4, which shows the aperture plane phase distributions before, (a) on the left, and (b) after the last adjustments (on the right). For a clearer display of the fine surface structure, the time variable astigmatism has been removed from these plots. The range of the grey scale is ±0.2 radians at 39 GHz (±120 microns). The visual aspect of these distributions is dominated by an almost regular scalloping of the surface mainly due to the manufacturing errors of individual panels and which contributes about 40 microns to the error budget.

The surface improvement was confirmed by measurements of the beam efficiency using Mars in January 2000 under excellent weather conditions. They are compared with the corresponding values before any surface adjustments (Table 3.1).

Table 3.1: Beam Efficiencies

Frequency (GHz)	July 1997	January 2000
86	0.73	0.78
150	0.54	0.65
235	0.42	0.51

3.5. VLBI

The 30-m telescope participated in April (6 days) and in October (5 days) in the global 3-mm VLBI sessions co-ordinated by the CMVA. Except for a few hours, the autumn observations were lost because of poor weather conditions.

During the autumn session we recorded continuously the total power of the 3-mm and 1.3-mm receivers in order to start the project of phase correction from atmospheric emission measurements. Because of the weather conditions, the data are, however, too few to be useful.

A new MkIV formatter has been bought for Pico Veleta from Allied Signals (USA). It was delivered in September 1999. Also, new heads for the magnetic tape recorder used for VLBI were installed and calibrated.

We have started the preparation of a 2 mm VLBI experiment Pico Veleta and Metsähovi, Finland. The first generation IRAM 2-mm receiver was shipped late 1999 from Spain to Metsähovi.

On May 27/28, 1999, the 2nd mm-VLBI Workshop was held in Granada. It was jointly organised by IRAM and the MPIfR, and by the CMVA. The workshop was followed by a visit to the 30-m telescope on May 29th. Approximately 50 scientists from around the world attended this workshop. The possibility to hold the meeting in the Hospital Real (University of Granada) was greatly appreciated.

3.6 Receivers

Accumulated experience during the past year has shown that the new receiver cabin, with the first set of dual cryostats A and B and the later addition of the two high frequency cryostats, is a complete success. Receiver performance in almost every aspect - reduction in the noise temperature, better stability, ease of tuning, improved focus and relative alignment - has been improved with the consequent gain on the overall telescope efficiency.

The installation of the new dual channel (150 and 270 GHz) C and D cryostats, during October 1999, was the second step toward the renewal of the receiver cabin. The installation itself did not present any special problem. However, a degradation on the noise temperature of the C270 channel - possibly due to mechanical problems caused by the transport - was found. A replacement of the damaged cryostat is expected for summer 2000.

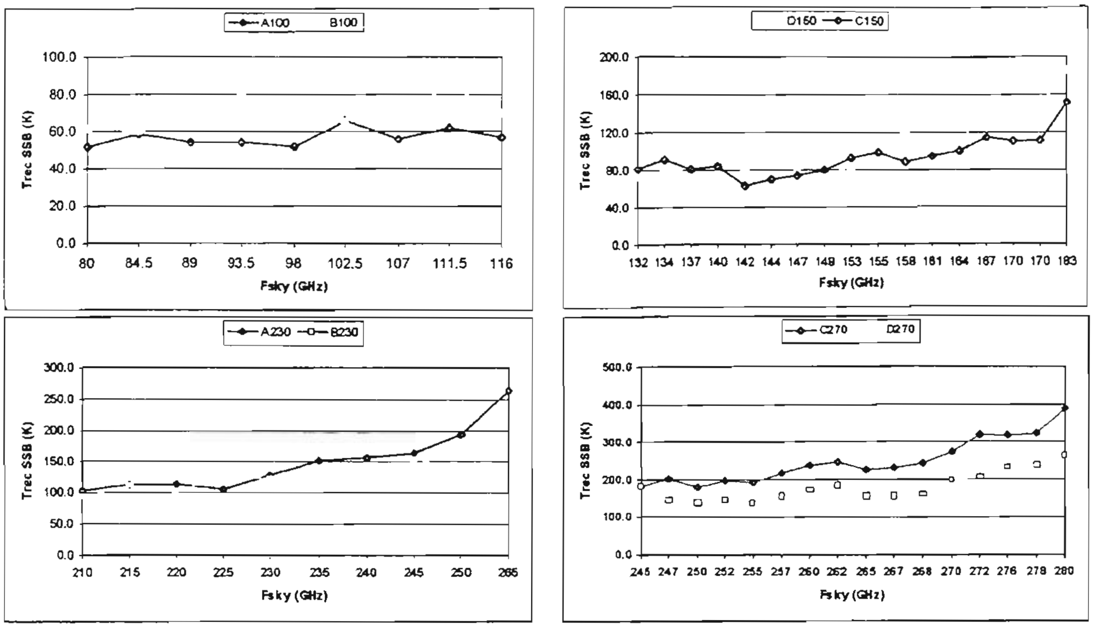

Fig. 3.5: SSB noise temperature of all receivers. Optical losses are included

In order to accommodate the increased number of receivers in the cabin some modifications on the signal distribution scheme were required. Two new boxes: one for switching the IF signals and another one for the two phase-lock reference frequencies were designed and built. The two distribution boxes can be remotely controlled, and changes in the receiver configuration are totally transparent for the astronomers.

Dual receiver polarimetry is a new observing mode for the 30m telescope. Several tests on the 3mm and 1.3 mm bands were carried out during the past year. Those tests involved the design and construction of some special hardware, part of which was built in Granada.

A new line generator system, with complete remote control option, has been finished and tested. The generator is already prepared for the coming multibeam system and will provide a way of checking and measuring the single to double sideband ratio of all receivers.

The ten channels down converter box which will be used for the multibeam receiver is also finished. The modular design will allow an easy access and repair of all the channels. This is the first box, to be used with the first array of nine channels. A second box is already scheduled and will accommodate the second group of mixers of the multibeam receiver.

The new remote control system, with its fully automatic tuning capability, and the improved reliability of the new cryostats have reduced considerably the demands on the receiver group staff at the telescope. Now, receiver tunings are routinely made by the telescope operator and the amount of down time due to problems in the frontend area has decreased considerably.

In the winter 1998/1999 period, the MPIfR had brought a 19 channel bolometer to the 30m-telescope; and during the winter 1999/2000 period, bolometer observations were conducted using a 37 channel bolometer, also provided by the MPIfR.

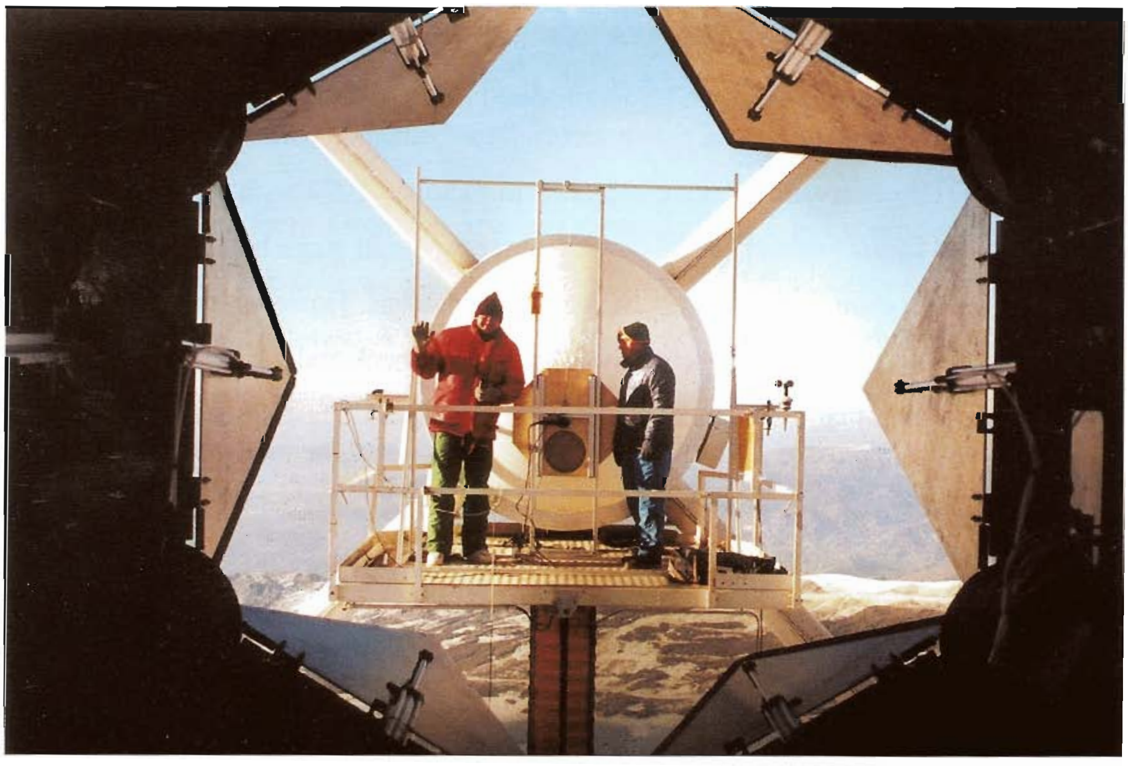

Fig. 3.6: Members of the MPIfR and IRAM staff are aligning the MPIfR bolometer. This photo was taken from the receiver cabin through the vertex window.

3.7 Backends

1999 was almost entirely dedicated to the design of two new filterbanks of 1GHz bandwidth and 4MHz channel spacing. Two units were assembled and completely wired. The full set of printed circuit boards was finished. All technical components perform as expected. Detailed tests will be made in the first half of 2000.

3.8 Computers and Software

Throughout 1999 the computer group was checking computer software of different platforms for the "millenium bug". In the fall, the clocks at the observatory were advanced to December 31, 1999 and a simulation of the "millenium" step was performed with the telescope. Over the new year holidays 1999/2000 the computer group and other engineers were in standby to fix any Y2K related problems. However, thanks to the preventive maintenance done in 1999, observing went smoothly over the "millenium".

The original VME processor boards in the autocorrelator backend, which were limiting the sampling rate for OTF observations, were replaced in October 1999 with newer and faster ones operating under Linux instead of OS-9. The processor load stays below 15 percent at sampling rate of 10 Hz, even in the most complex configurations. However, the data transfer to the antenna control system becomes more and more a bottleneck and we plan to modify the backend control part such that data can be transferred directly to a fast system used for data reduction.

The MPIfR bolometer now comes together with a new backend (BOGLE) which replaces the Drumbeat MPIfR backend. The BOGLE backend has been integrated into the antenna control software. We still offer to use the bolometer with our CAMAC based continuum backend as a backup solution. The data processing for the bolometer has been further improved in co-operation with colleagues from MPIfR and IRAM, Grenoble. Automatic "raw-data" transfer to a fast HP/UX workstation allows to do all data analysis of maps under fast HP/UX and Linux systems.

A monitor has been installed at the entrance of the Granada office which shows information about the telescope status and the ongoing observing program, the state of the main computer systems, and the weather (movie of meteosat images). This provides a "feeling" for what goes on at the observatory.

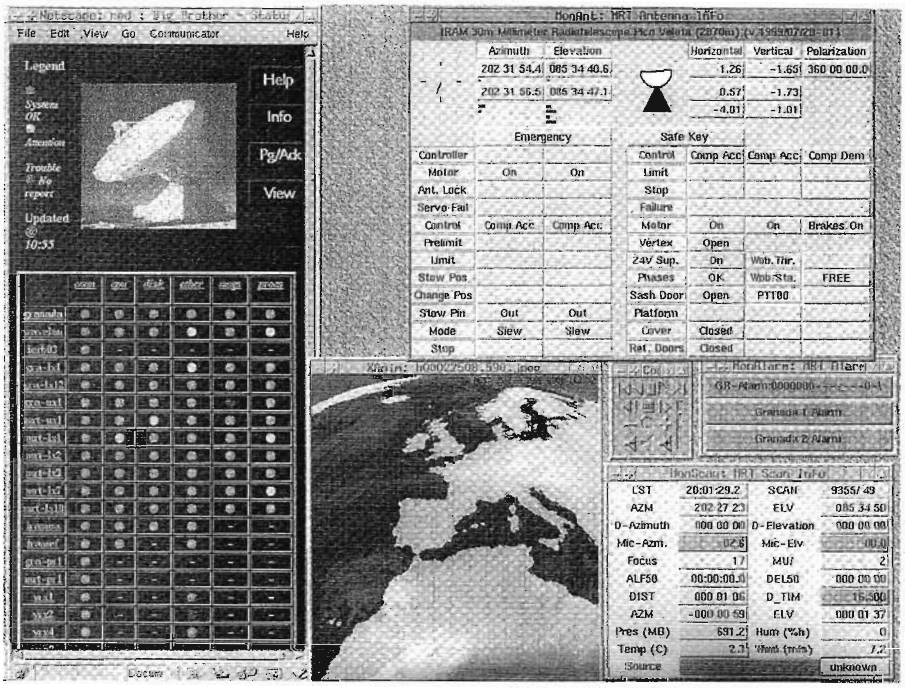

Fig. 3.7: Our status monitor in the entrance lobby of our Granada office

Remote observing from Grenoble and our Granada office is becoming more and more a routine task. Over the year we gained more experience with it, solved smaller problems and implemented new features. A meeting was held at IRAM in Grenoble to discuss future improvements. The need for flexible scheduling was stressed in particular. A remote observing station was set up at the MPIfR in Bonn in November, and it is now fully operational.

Our web-based time estimator software (http:\\www.iram.es and http:\\iram.fr) is used for the majority of observing proposals with the 30-m telescope. Version 2.1 not only handles standard line observations but also on-the-fly observations and bolometer observations.

The computer network is becoming the "nerve centre" of the computer system, and a failure of one of the important units has a big impact on the whole system. We have started to provide for each of the crucial items (switches, hubs, routers, radiolinks, ISDN) backup solutions. More details can be found in the http://www.iram.es/computer/network/ web pages. A new no-break system has been installed in Granada.

Observers can now take their data home on CD, DAT tape or send them via Internet. We started to investigate the use of data base systems. A first application has been implemented and, in particular, access from web pages is possible. We foresee to use data base systems for telescope logging information, especially in the new control system. Besides using Linux now on many desktop systems (replacing all X-terminals), we have also started to use Linux on VME processors and by that, use it for process control tasks.

In the near future, many legacy hardware components of the control system based on CAMAC and VAX computers will be replaced by more modern equipment, in particular VME and computers using some flavour of Unix. For some subsystems, this transition is already in progress or completed. Astronomers and engineers are studying together the features that a new control system (NCS) should provide, including observing modes, telescope control, data acquisition, processing, and archiving; while maintaining the many successful features of the current system.

Among a core of high priority features of the new system are (i) observations with focal-plane arrays, including bolometers and heterodyne multibeam receivers; (ii) fast on-the-fly observations, which can be combined with frequency switching and wobbler switching; and (iii) remote observing, service observing, and flexible observing and scheduling. Linked to these core features is a need to: (i) foresee very large data rates; (ii) optimise the standard observing modes and make them easy to use; (iii) automate where possible.

Information about our plans can be found on the WWW by following links from the IRAM, Granada home page (http://www.iram.es). A first complete draft (1999-12-21) of the document "NCS 30m: Specifications: Observing Modes and User Commands" (http://www.iram.es/FutureControl30M/Specifications/Spec_OM) describes in detail the features we are considering for the NCS at the user level.

3.9 Infrastructure

For an observatory operating with delicate electronics it is very important to have a good grounding to guarantee the safety of the people working at the site and of the electrical installation. Considering that the observatory is constructed on rocky soil this is not a trivial task. Our new grounding, completed in 1999, consists of a 25 cm diameter and 40 m deep hole drilled into the rock. This hole contains a metallic tube filled with 1300 kg of graphite with five electrodes of a special alloy. The conductivity of the new grounding is now 2 ohms. In addition, three high power varistors have been installed between each electrical phase and the electrical earth to protect the electrical installation of the observatory against possible over voltages from lightning or from the electricity supply.

Fig. 3.8: A 40 m deep hole has been drilled into the rocky soil to provide a new electrical grounding of only 2 ohms.

Both high voltage transformers have been equipped with external switches to switch them off remotely in emergency cases in order to minimise the risks for the operating staff. The kitchen has a new electrical distribution system with independent isolation of its different electrical loads. The electrical installation in the Granada office has been equipped with a new electrical distribution system that solves old problems and isolates the supply to the different users.

A new lighting system with high frequency electronic control has been installed in the control room, adjacent offices, the electronic laboratory and in the workshop. This new system improves the quality of the illumination. After the liberalisation of the Spanish electricity market, a new contract was negotiated resulting in a reduction of the electricity costs by 13%.

The 20-m^3 diesel tank was emptied and internally coated with polyester fibre to enlarge its lifetime. Tests were made later to confirm the good sealing and to fulfil the safety conditions according to the Spanish regulations. The sanitary water supply system of the observatory has been equipped with a filter of sand to improve the water quality. The roof of the control building has been isolated after seventeen years with a three layer cover against water and snow. The road from Borreguiles to the radiotelescope has been repaired under our supervision without charge for IRAM by the CETURSA ski company.

A new snow car Kaessbohrer PB 42.240 D has been purchased. It sits 10 passengers in the rear cabin and two persons in the driver cabin. This machine is in permanent radio contact with CETURSA, the radiotelescope, our Granada office and with the IRAM cars. The rear part of the ratrac is equipped with a milling tool permitting to drive on CETURSA ski runways. This insures the safety of the transport since these runways are equipped with labels which are visible even under bad weather conditions.

Fig. 3.9: The new snow car for transporting visiting astronomers and staff to and from the observatory during winter time.

3.10 Safety

The fire detection system in Granada has been connected through the IRAM radio link to the observatory. If an alarm occurs during the night or weekend, the operator can react accordingly.

The operators receive periodic training in fire fighting. The equipment used for the training includes fire proof jackets, trousers, boots, gloves, helmets and breathing systems. It now takes less than 5 minutes for our operators to put on the complete firefighter equipment. Two new autonomous breathing systems have been purchased. The new systems can be used by trained staff in the case of a fire. They have the advantage to deliver positive pressure that facilitates breathing.

A refresher course in first aid was made at the observatory with most of the staff using also our special equipment.

4. PLATEAU DE BURE OBSERVATORY

4.1 Interferometer Status

Operation

Two devastating accidents have afflicted the Plateau de Bure observatory. On July 1st, the fixation of the cable car cabin to the pulling cable failed, causing the cabin to slide backwards and eventually to impact on the ground. At this moment 20 passengers were in the cabin, on their way to the Plateau de Bure, five IRAM employees and fifteen employees from IRAM subcontractors. They all lost their lives. Without cable car, the only means of transport to bring people up and down from the Plateau de Bure was by helicopter. On December 15th, on a flight leaving from the Plateau de Bure, one of these helicopters crashed, killing the four passengers and the pilot. These circumstances forced us to completely stop all activities on the Plateau de Bure except those which are necessary to safeguard the installations. Consequently, the observations have been stopped and have not yet been resumed.

Before stopping, more than 70 observing projects have been executed with the interferometer in 1999 thanks to the sustained efforts made by the Plateau de Bure staff despite the enormous difficulties after July 1st. Compared to previous years, we note an increasing interest in extragalactic research work. Annex I gives a detailed list of all the projects scheduled and brought to completion in 1999.

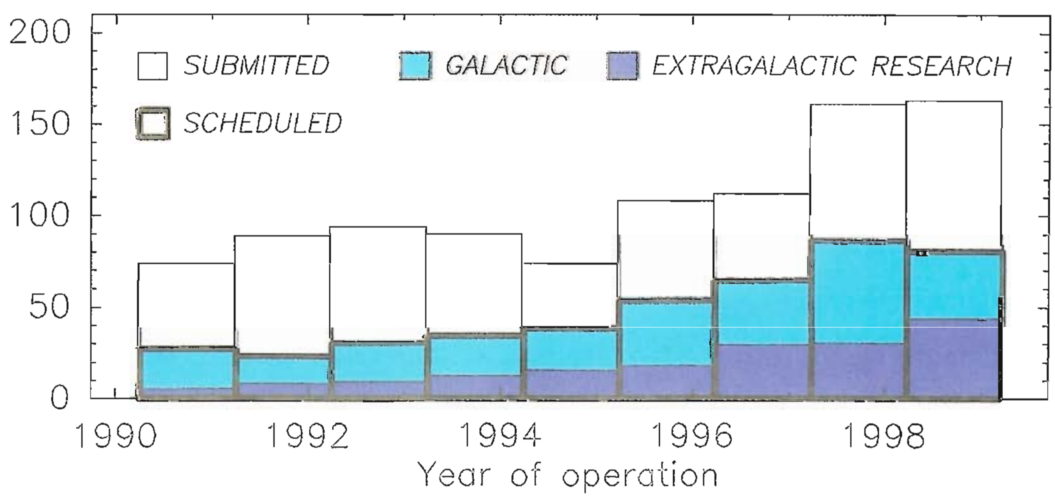

Fig. 4.1: Science at the interferometer since April 1990 and up to April 1999. The average pressure factor is higher than two. Note the steadily increasing interest for extragalactic science. Antenna 4 became operational in 1993, antenna 5 in September 1996.

During the January to June period, the Plateau de Bure interferometer was operated with more than 40% efficiency, the site record for end-winter conditions with rather poor phase stability but relatively good conditions from spring to fall. The remaining 60% of the time went into bad weather, tests and maintenance. On average the weather conditions were not as favourable for high frequency observations as in the previous two years.

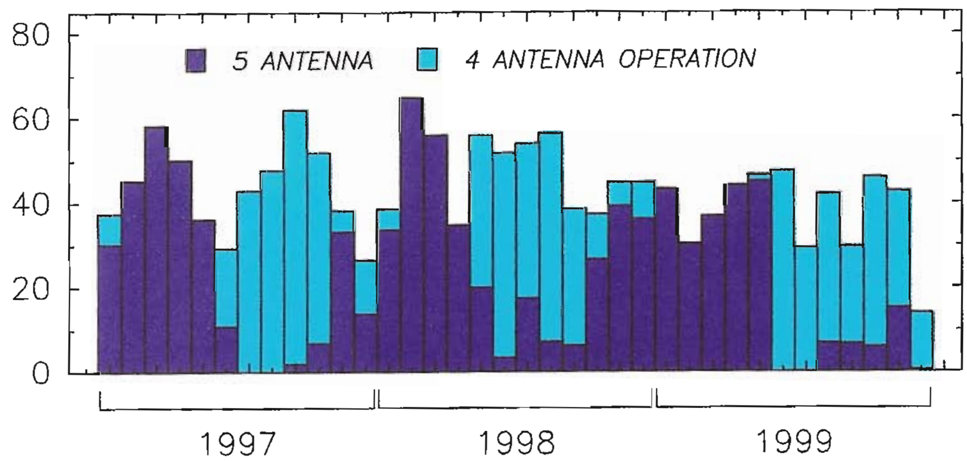

Fig. 4.2: The percentage of time for astronomical observations since January 1997. During the summer months, observations are in general made with 4 antennas. The June to October period coincides with the annual maintenance period of the interferometer.

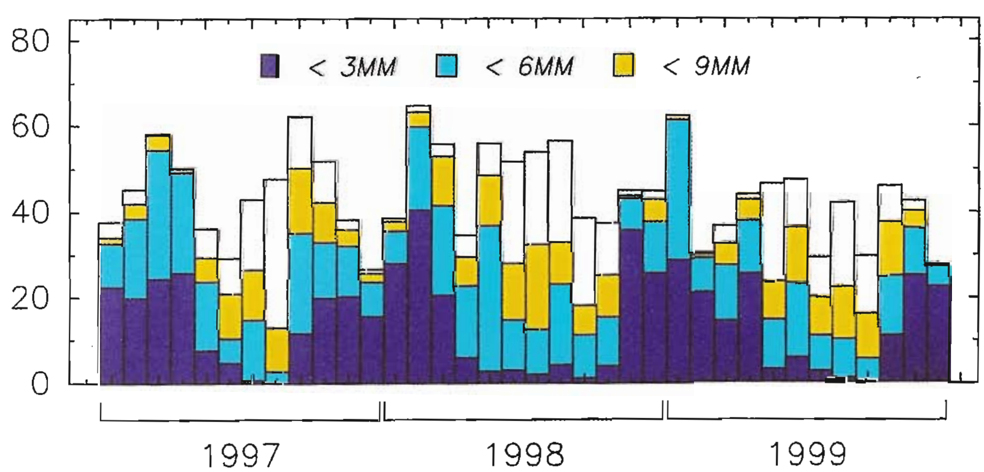

Fig. 4.3: The atmospheric water vapour content recorded on the Plateau de Bure since January 1997. Observations in the high frequency window (205 to 240 GHz) and observations in A and B configurations are for the most part carried out in the winter months. In 1999, contrary to previous years, the Plateau de Bure observatory recorded a very high atmospheric transparency up to the end of April.

Maintenance

As a consequence of the cable car accident, the maintenance resulted in a somewhat longer 4 antenna period despite an effort to limit the work to only the absolutely necessary interventions.

Among the major improvements we note the general replacement of the actuators which control the vertical motion of the subreflectors and which were suspected to cause erratic pointing errors on several antennas. A close inspection revealed that most of the actuators were showing signs of increasing fatigue over the last two years. The new actuators (a new series production) provide a higher positional precision and show reliable performance.

Shortly before the end of the maintenance period, a new aluminium subreflector was installed on antenna 2. The replacement was necessary as the degradation of the Hostaflon conductive layer which had started close to the centre of the subreflector was progressing. Moreover, a close inspection revealed that the carbon fibre layers just beneath had also started to delaminate. The optical quality of the new subreflector was measured by the manufacturer to be better than 12 microns (RMS). This corresponds well to the accuracy of the aluminium subreflector previously installed on antenna 3. The replacement was completed on December 8, but due to bad weather and to the complete stop of the observations after the helicopter accident, the performance of the new subreflector has still not been tested on the sky.

Progress has also been made with the sealing of the backstructure of antenna 5. The adhesive tape which was used to seal the space between adjacent Metawell plates became brittle with time, and it had to be removed from about 50% of the backstructure. It was replaced by rubber joints, a procedure which proved to be efficient and which had already used in the past on all other antennas. The remaining half of the backstructure will probably be treated in the same manner during the maintenance period in the year 2000.

A lot of time was dedicated to the inspection of the reflector surfaces of antennas 1, 2 and 4. More than five thousands stickers had to be placed to stop the degradation of the Hostaflon surfaces. This is a consequence of the longstanding pin-hole problem which affects the lower part of the surfaces of all the first generation antennas.

The quality of the surfaces of antennas 4 and 5 was checked. Surface adjustments were verified by holographic measurements and the surface accuracy found to be better than 50 microns on antenna 4 and better than 60 microns on antenna 5. Panel adjustments were also made for antennas 1, 2 and 3, but could not be verified before the end of 1999.

4.2 Projects under Development

Construction of the 6th antenna

Construction work on the sixth antenna was proceeding practically according to schedule until the cable car accident on July 1st. Up to 90% of the electrical equipment and about half the thermal insulation of the yoke were completed by that time. All activities around antenna 6 had to be stopped after the accident. The work has still not been resumed. A crucial step will be the transport of the central hub which has a weight of about 5 tons, and which is needed before work on the reflector can start. At present its delivery by the manufacturer to IRAM has been delayed because there is no way to bring it up to the Plateau de Bure. Helicopter transport has been considered but abandoned.

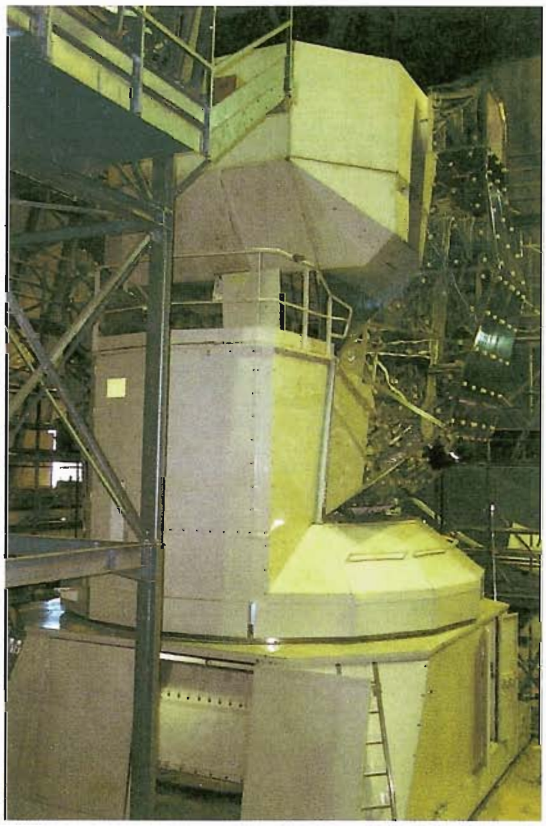

Fig. 4.4: Rear view of antenna 6, as of June 25. Work on the receiver cabin and on the thermal protection of the pedestal was almost completed. To the left and right of the receiver cabin, one notes the naked yoke awaiting the mounting of the thermal insulation.

Extension of the northern track

Construction work on the extension of the northern track to station N46 was stopped after July 1st. The foundations of the station and about 90% of the excavation work for the new part of the track had been completed by this time. It will probably not be possible to resume this work before 2001 or 2002.

4.3 Infrastructure Developments

On each rotation of the cable car, 1000 liters of water had been brought up to the Plateau de Bure. After the accident, the water supply quickly became an issue. As a counter-measure, an external reservoir for rainwater was constructed which ensures the water supply for the sanitary facilities of the observatory in the long-term. The reservoir is equipped with a heating system to melt snow during the winter months. A filtering and water treatment system guarantees a certain quality of this water.

5. GRENOBLE HEADQUARTERS

5.1 SIS GROUP ACTIVITIES

The SIS group develops and fabricates superconducting detectors for the millimeter and submillimeter wavelength range. These detectors are mainly SIS tunnel junctions for IRAM and other mm/submm groundbased observatories and HEB's for space or airborne observatories in the short submm and FIR range.

Material and Thin Film Characterisation

During 1999 a major effort was made to characterise the deposited superconducting and dielectric films which are used in the IRAM process. Such characterisation will help to understand the different physical and chemical processes during and after deposition and allow further improvement of process reliability and device characteristics.

The characterisation of the superconducting Nb films included such parameters as films stress, film texture and grain size as well as surface roughness and post deposition surface oxidation. These parameters are correlated with the superconducting properties such as critical temperature, residual resistance ratio and critical magnetic field. The studies included ultra-thin films where particular physical effects become important due to the limitation of the mean free path of the charge carriers by surface scattering.

Junction Processing

The process for SIS junction production has been transferred from smaller rectangular to round quartz wafers with a standard 2" size. After device processing on 200 µm thick substrates an industrial grinding for the whole wafer is applied to reduce the thickness to 100 or 50 µm for frequencies above 100 GHz. This procedure has largely improved wafer yield and homogeneity and at the same time allows to use industrial wafer handling equipment. Junctions for 100, 230 and 270 GHz have been produced for the IRAM telescopes.

An important development effort has been made over the last year to bring Electron Beam Lithography with the IRAM equipment from an experimental stage to a level of well defined routine operation. For this, automatic alignment and exposure over an entire 2" wafer was

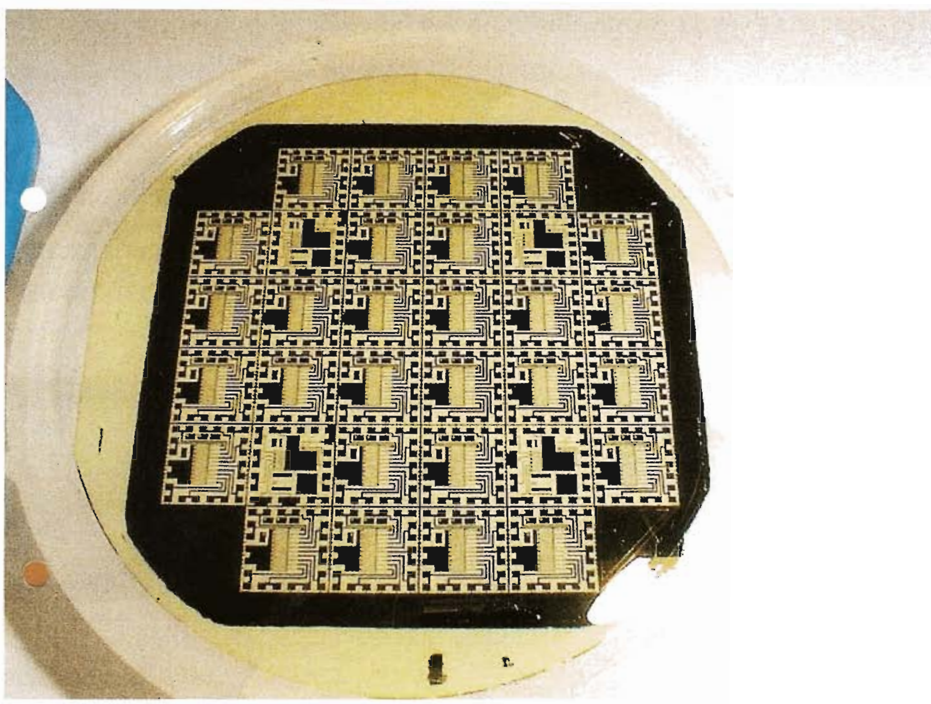

Fig. 5.1: Example for the layout of a 2" size quartz wafer prepared for the Channel 1 HIFI project for the ESA Cornerstone mission FIRST.

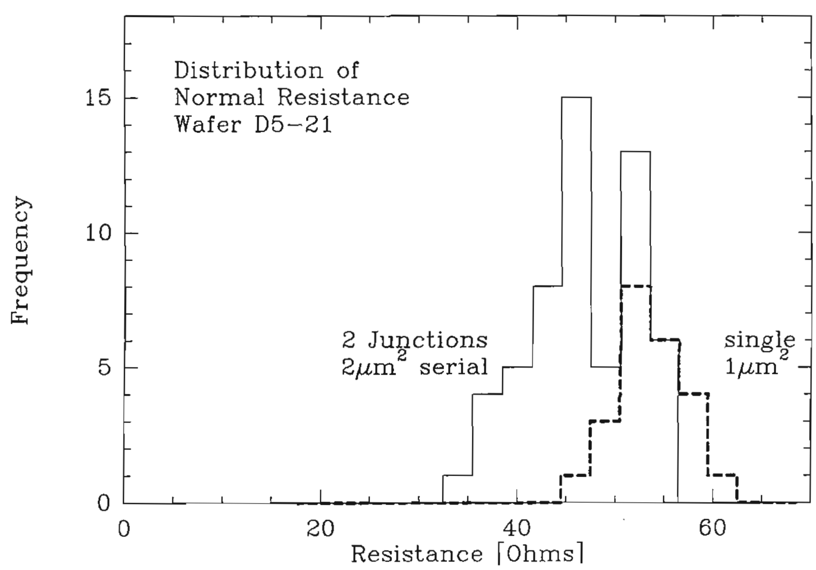

Fig. 5.2: Distribution of normal resistance values for junctions from a single wafer which was used to equip the IRAM 230 GHz multibeam receiver. The double peaked distribution for the 2 μm² size serial junctions is not related to the pair-character of these devices but rather due to a small systematic gradient of junction sizes across the wafer.

established and spatial resolution has been driven to below 100 nm. This development has been crucial to the fabrication of junctions for FIRST HIFI channel 1 which are defined with a newly developed negative resist mix and match process. The possibility to define submicron junctions with high reproducibility will also be a great benefit for future IRAM instruments as well as for the ALMA junction production.

Hot Electron Bolometric (HEB) Mixers

Electron beam lithography with PMMA double layers has been further improved for the definition of ultra small diffusion cooled HEB's, devices which will be used in the SOFIA GREAT instrument. A new antenna detector coupling scheme which reduces RF losses at very high frequencies has been verified with NbN phonon cooled HEB's. Work on improving very thin NbN films by means of buffer layers has been started.

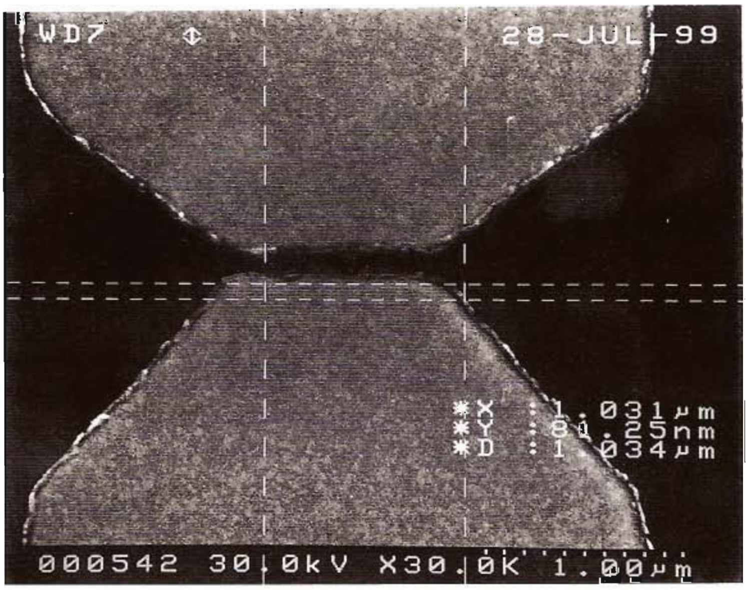

Fig. 5.3: E-beam lithography with a resolution below 100 nm as applied to the fabrication of diffusion-cooled hot-electron bolometric mixer devices.

Cryogenic Planar Resistors

For future, more complex circuits a unique resistive NbN film has been developed which allows to fabricate ultra-small low inductance resistances for integrated high frequency terminations, bias networks or integrated heating resistors. Such resistors can be trimmed with a high precision to a specific value by sequential reactive ion etching steps.

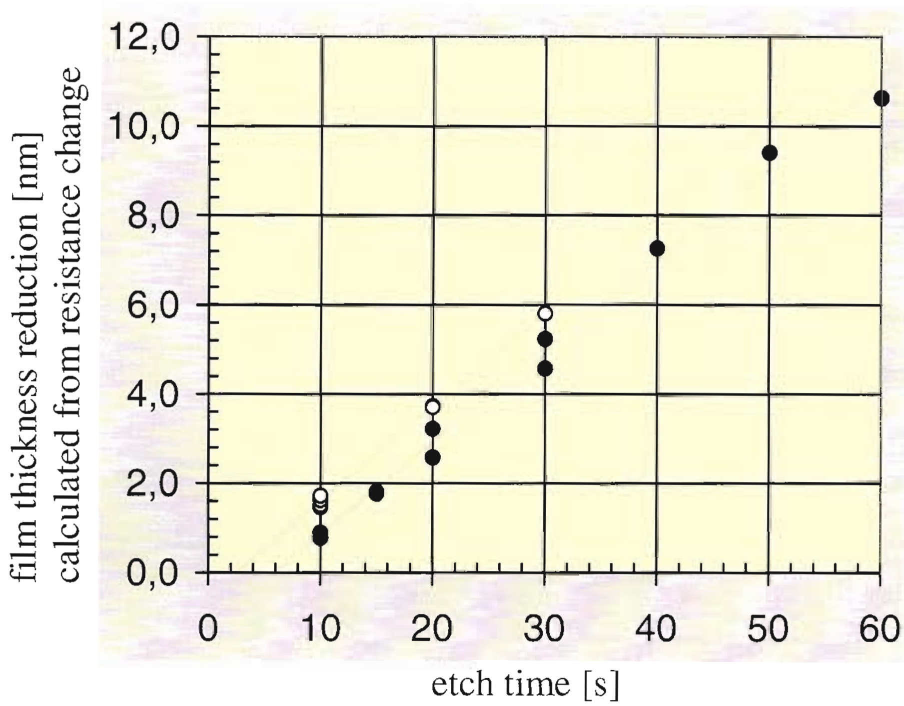

Fig 5.4: Trimming of resistive NbN films by reactive ion etching (black points). Surface oxidation is taken into account for the open circles.

5.2 RECEIVER GROUP ACTIVITIES

5.2.1 Receivers on the telescopes

Pico Veleta receivers

In June, the dual-channel B receiver (100/230 GHz) was replaced with the refurbished prototype, whose optics had been modified to achieve a better agreement of the focus of each of the channels with the common optics' nominal focus. The optics of the dismounted receiver was upgraded in a similar way. That receiver is now available as a spare.

Two dual-channel receivers (150/270 GHz) were constructed. In October, they were installed in the receiver cabin and put into operation, fulfilling the goal of 8 receiver channels available, of which 4 can be used simultaneously. The old 2mm receiver was de-commissioned after more than 10 years of operation.

The construction of a third 150/270 GHz receiver has been completed; it is available as a spare.

Fig. 5.5: A view of the receiver cabin with four dual-channel receivers.

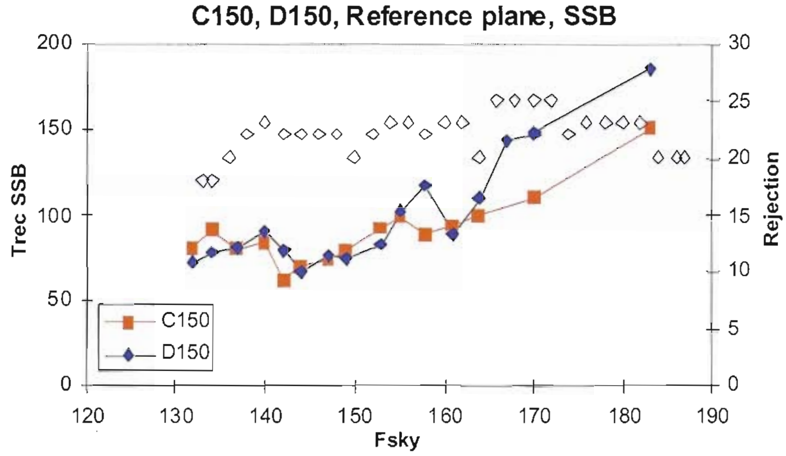

Fig. 5.6: SSB Receiver noise temperatures of the two "150GHz" receivers, measured in the calibration reference plane during commissioning. *Open symbols:* image band rejection, measured in the laboratory

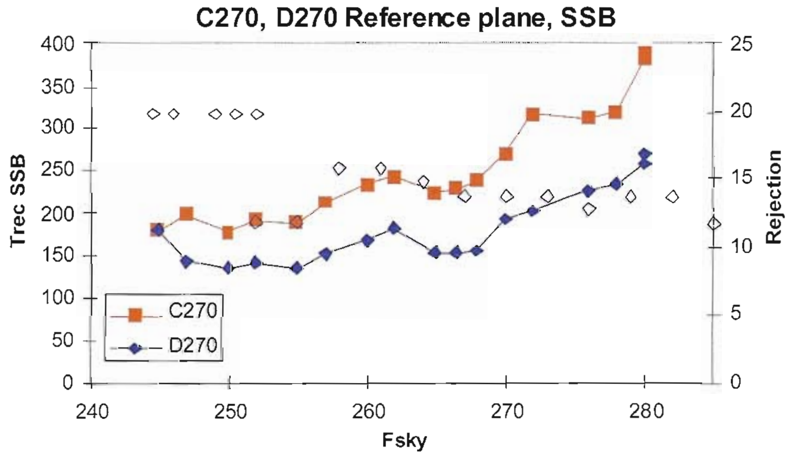

Fig. 5.7: SSB Receiver noise temperatures of the two "270GHz" receivers, measured in the calibration reference plane during commissioning. The D270 has degraded relative to lab measurements. *Open symbols* : image band rejection, measured in the laboratory.

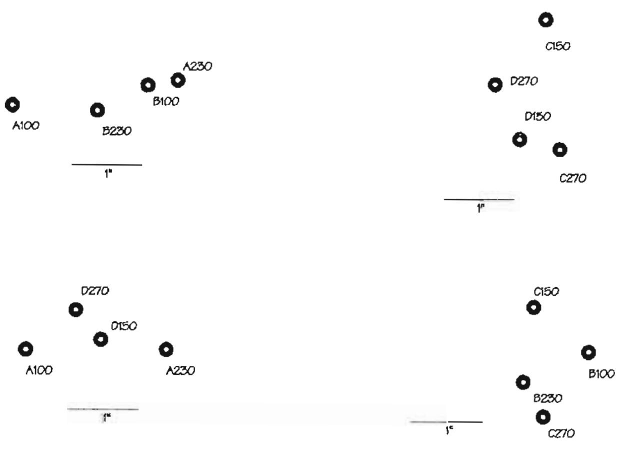

Fig. 5.8: Co-alignment of the receiver beams measured on Saturn during commissioning, in each of the four available 4-receiver combinations. The segment in each frame is 1" long. In any combination, the four beams lie within a circle of 2" *diameter.*

Plateau de Bure receivers

The construction of the dual-channel (100/230) receiver for Antenna 6 has been completed.

The prototype 3-channel 22-GHz water vapor radiometer has been constructed and has passed successfully stability tests to the specifications laid down at the start of the project. For instance, the differential (channel-to-channel) stability, with linear drifts removed (interpolation between two calibrations) is 7×10^{-5} over timescales of 20 minutes.

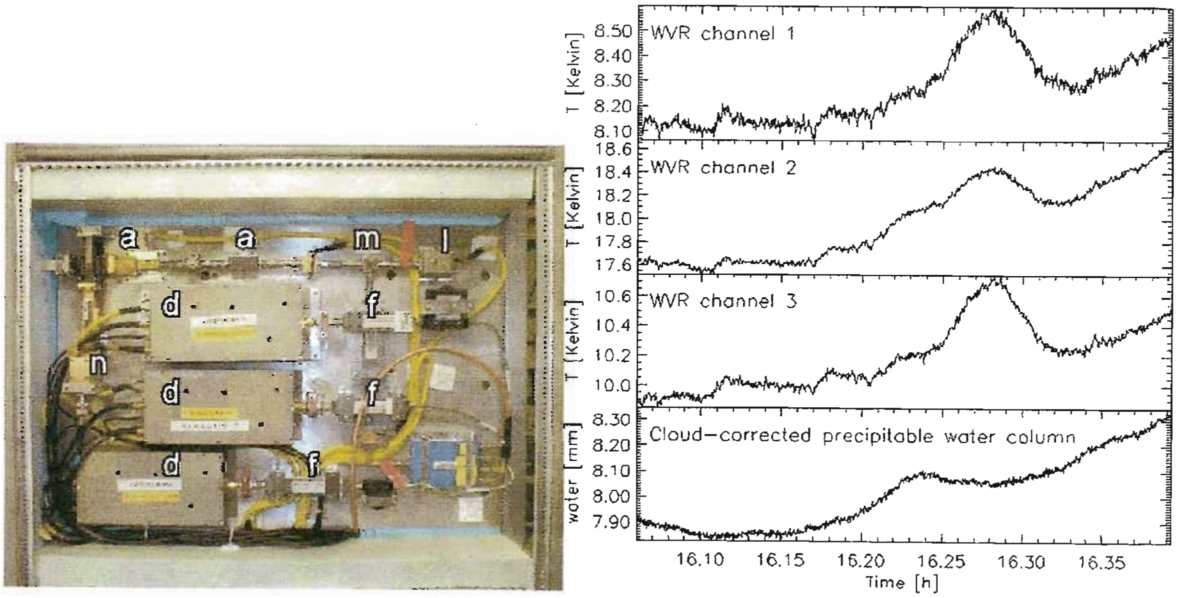

Fig. 5.9: *On the left,* view of the prototype 22GHz water vapor radiometer, with the cover removed. Key to the legend: a: 18-26GHz amplifiers; m: downconversion mixer; l: local oscillator; f: bandpass filters; d: detectors; n: noise diode for calibration.
On the right, first measurements with the prototype 22GHz WVR in IRAM's patio. Most of the fluctuations in the individual channels are due to clouds; the processing algorithm extracts the smoother variation of water *vapor*.

5.2.2 Development work

A new type of harmonic mixer has been developed to extend the capabilities of the mm-wave network analyzer. It uses an anti-parallel pair of commercial beam-lead Schottky diodes. This harmonic mixer allows to perform swept measurements of waveguide components (couplers, horns,...) in amplitude and phase between 250 and 350 GHz with a 40dB dynamic range, using a pump signal in the 20–40GHz range.

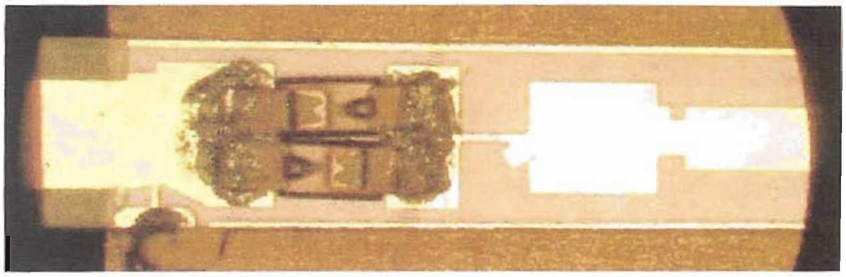

Fig.5.10: Suspended stripline circuit of the new harmonic mixer, including the two anti-parallel Schottky diodes.

5.3 BACKEND DEVELOPMENTS

5.3.1 Six-antenna correlator

The design has been completed for all the modules, and a test unit (1/8) has been assembled and intensively tested. The performance of the IF processor has been found very clean, especially in terms of flatness and dynamic range. The digital section involved 240 correlator chips from the batch, none of which could be found faulty. The delay lines, phase rotators and synthesizers have been manually tested, thanks to a convivial graphic control software.

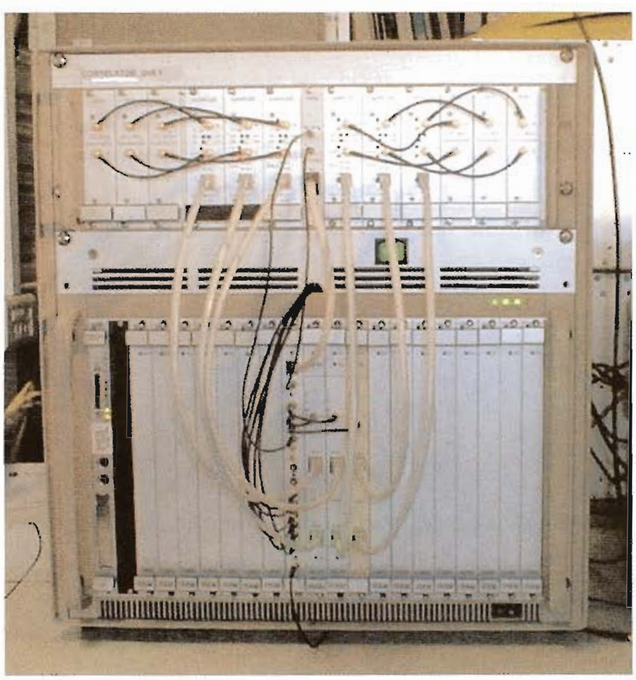

Fig. 5.11: Frontside of the test unit of the new correlator for 6 antennas.

Long term integrations have been performed without PI switching, which show that the machine behaves properly and that no hardware-generated artifacts build up with time. Following the tests, decision to go for mass production has been taken. The 8 units are progressively assembled, as soon as the modules are delivered by the subcontractors. The whole correlator includes 416 printed circuit boards of 17 different types. More detailed technical and progress information on this project can be found on http://iram/TA/backend .

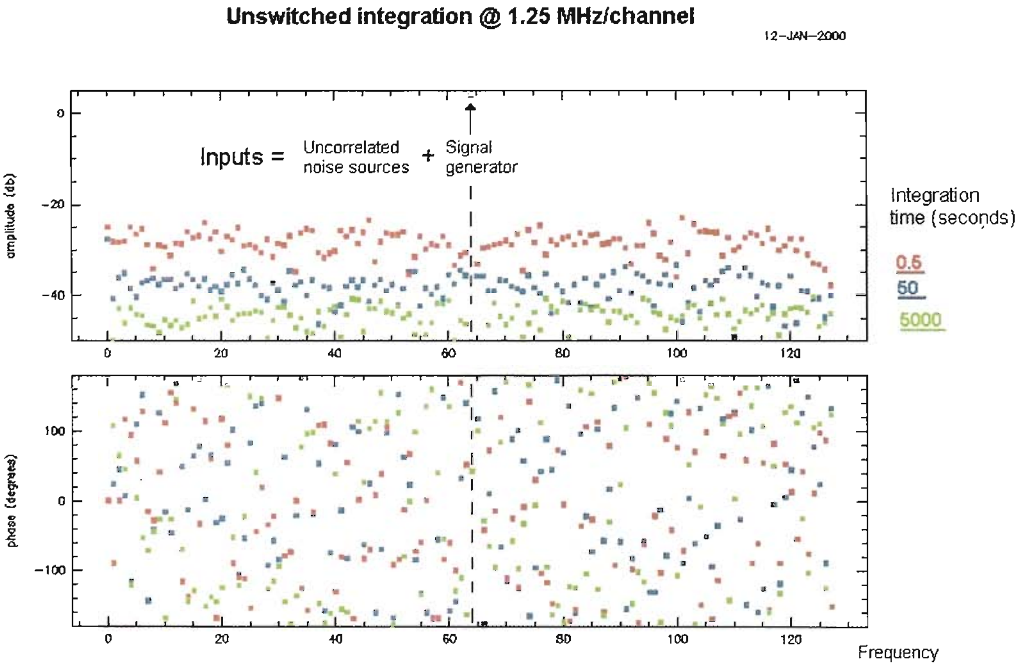

Fig. 5.12: The cross-correlation of two independent noise sources integrating with time. Noise floor decreases with the square root of time, and phases are random, except for channel 64, for which the three dots exactly overlay.

5.3.2 VLBI

A new GPS receiver has been purchased and tested as a Maser monitoring device. In the future it will completely replace the current time/frequency standard, which is a 15-year old home-made design, not accurate enough for VLBI. The Mark IV formatter has been delivered. The tape drive has been ordered. The adder module design has started, after some theoretical points were cleared. Its design is largely digital. A 1 MHz comb generator has been designed, built and tested to serve as the phase calibrator signal for the VLBI experiments. It has been integrated in the correlator ring and can be activated instantly.

5.3.2 Optic fiber

The coaxial cables presently used on the PdB (antenna-to-building links) are expected to degrade the quality of the IF signals, when the IF will expand to the 800-1000 MHz region. Analog OF transmission does not suffer this limitation and has been successfully tested in the lab. Field tests on the North track were scheduled but could not be performed. No electrical problems are expected, but mechanical practicability of the optical connectors is to be seriously examined.

5.4 COMPUTER GROUP

Beyond the general support given to the users of the IRAM computers running under UNIX and VMS, and the support of the PC users, the group has worked to further improve the computing facilities and to participate in new developments. The following examples can be given :

- To further improve the reliability of the users' disks, additional RAID systems have been added for redundant data storage;
- The better protection against power failures by changing the no-break system to one with higher battery power, and an automatic run-down of the computers in the case of a prolonged cuts in the power lines have been installed;
- All systems running under UNIX, VMS, and Windows at IRAM have been successfully prepared for the year 2000 transition;
- To respond to the increased data rates passing the local network, it was decided to install a twisted-pair solution which will allow the Ethernet to run at 100 Mbytes.;

- The group has actively participated in the ongoing development of a wobbling secondary for the SEST. In particular, some sensors and the control electronics had to be tested, modified, and tested again;
- The group also worked on the data acquisition system for the new 22 GHz receiver. Some of this work was carried out as a summer student project;
- For the new 6-antenna correlator, a VME board with a processor under Linux has been tested. This solution is very similar to solutions foreseen for the new 30m-telescope control system which will use the same processor and driver, and coulsd benefit from the same methodology for the software development.
- The software package developed for the MPIfR bolometer array at the 30m-telescope has further been improved and adapted to the new hardware.
- Finally, the group is actively participating in the definition of new software systems for the 30m-telescope, and for the ALMA project.

5.5 TECHNICAL GROUP

5.5.1 Mechanical Workshop

The mechanical workshop lost one of its key members, David Lazaro, who died in the helicopter accident on December 15th, 1999 on the Plateau de Bure. He has contributed enormously to make the technical group act as a team, and he has pushed the quality of the mixer fabrication at IRAM to a level never reached before!

In spite of this loss, the group did produce a large number of microwave components, mixers, couplers, horns and lenses, for three 150/270 GHz receivers, including a spare unit, for the 30m-telescope, and for the 100/230 GHz receiver foreseen for Antenna 6 on the Plateau de Bure.

5.5.2 Drawing Office

The drawing office worked on numerous mechanical designs, in close collaboration with the other IRAM groups. This concerned:

- elements for the multibeam receiver to be installed in the receiver cabin at the 30m-telescope,
- the design of new microwave components, and
- devices to facilitate the test of SIS junctions.

5.5.3 Antenna 6

The technical group is responsible for following the assembly on the mount of antenna 6 on the Plateau de Bure, as well as the subsequent assembly work. As a consequence of the accident of the telepherique on July 1st, 1999 this work had to be temporarily stopped.

5.5.4 Technical Support for the Plateau de Bure

Despite the difficult circumstances, the team supported the maintenance work on the antennas 1-5 which had to be carried out before the winter 1999/2000 period began.

6. PERSONNEL AND FINANCES

6.1 Personnel

In 1999, IRAM had a total of 93.37 staff positions occupied, 66.27 in France, and 27.10 in Spain. The MPIfR (Bonn) and the MPI für Extraterrestrische Physik (Garching) jointly financed half a position in addition in the SIS laboratory for the production of diodes.

The number of positions filled was lower than in 1998, in particular because of the impact of the death of 3 staff members in the cable-car accident on July 1st, 1999. They belonged to the cable-car team.

Furthermore, 7 post-docs (6 FR, 1 ES), 5 PhD students (FR) and 3 « coopérants » (ES), plus 1 person delegated by DEMIRM, Paris in the framework of the FIRST project, worked at IRAM. 1 PhD student in the astronomy group was partly funded by the DFG (through the universities of Würzburg/Potsdam), a second one by the CNRS. 1 PhD student in the receiver group was partly financed by the Italian CNR (through the ARCETRI Observatory).

There was also a need for limited-term contracts to cope with the extra workload during certain periods of the year. This corresponded to :

- 6 man-years on Bure, linked in particular to the construction of antenna 6 in 1999, and also for maintenance and logistic support,
- 2.72 man-years in Grenoble, for replacements and additional tasks in the Administration and technical groups.

6.2 Finances

IRAM's financial situation in 1999, as well as the budget provisions for 2000, are summarised in the attached tables.

1999 - operating budget

a) The total expenditures were as anticipated.

- savings were made under the heating and electricity budget (this budget is by definition uncertain)
- Expenditures for the cable-car were lower than anticipated, since nothing could be done after the accident on July 1st.
- concerning the personnel budget, not all positions were occupied. As mentioned above, three more positions were left open after the cable-car accident (1.7.99), and one more as a consequence of the helicopter accident (15.12.99).
- The savings/non-spendings above were compensated by major expenditures linked to the cable-car and helicopter accidents (payments of indemnities to the families, payments for helicopter flights after the cable-car accident, etc.).

b) Income was in line with the provisions.

For the entire year, the operation budget shows a positive balance of 25.000 FRF, taking into account a carry-forward of 47.000 FRF from the 1998 operating budget.

1999 - investment budget

a) Expenditure concerned mainly :

- the 6th antenna on Bure
- receiver (incl. the multi-beam receiver) and back-end instrumentation,
- VLBI instrumentation for Bure
- ground work for the N-S track extension on the Plateau de Bure

The originally foreseen extension of the headquarter building in Grenoble was postponed for the time being.

b) Income was higher than expected

This was linked in particular to the signature of a contract with CNES for the FIRST project.

Taking into account the carry-forward from the 1998 budget, the 1999 investment budget shows an excess of about 16 MF, with 2.9 MF being committed by contracts/orders signed in 1999.

BUDGET 1999
(in FRF)

1999- EXPENDITURE

Budget heading	Approved	Actual
Operation / Personnel	42 840 000	40 912 137
Operation / other items	14 617 000	16 244 356
TOTAL OPERATION	**57 457 000**	**57 156 493**
Investment (general + 6th antenna)	33 207 714	17 529 281
TOTAL EXPENDITURE excl. VAT	***90 664 714***	***74 685 774***
VAT	5 419 015	5 419 015
TOTAL EXPENDITURE incl. VAT	***96 083 729***	***80 104 789***

1999 - INCOME

Budget heading	Approved	Actual
CNRS contributions	31 128 100	31 128 100
MPG contributions	31 128 100	31 128 100
IGN contributions	3 973 800	3 973 800
Contributions 6th antenna	6 900 000	6 600 000
TOTAL CONTRIBUTIONS	***73 130 000***	***72 830 000***
Carry froward from 98	16 047 714	16 047 714
IRAM's own income	1 487 000	1 965 130
TOTAL INCOME excl. VAT	***90 664 714***	***90 842 844***
CNRS contribution for VAT (20,6%) *	5 419 015	5 419 015
TOTAL INCOME incl. VAT	***96 083 729***	***96 261 859***

* = 20,6% on CNRS contribution to the operation budget

BUDGET PROVISIONS 2000

(in FRF)

2000 - EXPENDITURE

Budget heading	Approved
Operation / Personnel	42 635 000
Operation / other items	15 555 000
TOTAL OPERATION	**58 190 000**
Investment - general	10 260 000
TOTAL INVESTMENT	**10 260 000**
TOTAL EXPENDITURE	***68 450 000***
VAT	5 527 454
TOTAL EXPENDITURE incl. VAT	***73 977 454***

2000 - INCOME

Budget heading	Approved
CNRS contributions	31 654 500
MPG contributions	31 654 500
IGN contributions	4 041 000
TOTAL CONTRIBUTIONS	**67 350 000**
IRAM's own income	1 100 000
TOTAL INCOME excl. VAT	***68 450 000***
CNRS contribution for VAT (20,6%)	5 527 454
TOTAL INCOME incl. VAT	***73 977 454***

7. ANNEX I : TELESCOPE SCHEDULES

7.1 IRAM 30m Telescope

0.1 Jan 05 - Jan 19

Ident.	Title	Freq. (GHz)	Authors
125.98	Molecular line survey in PKS1830-211	83, 90, 135, 151	Combes, Wiklind
123.98	Monitoring of the gravitational lens PKS1830-211	94, 141	Wiklind, Combes
167.98	Using sulfur chemistry to estimate the age of the IRAS2/NGC1333 outflow	104, 165,216, 251	Castets, Loinard, Ceccarelli, Caux
197.98	DCO+ as a tracer of protostellar infall	110, 144, 216	Bachiller, Myers, Tafalla, Mardones, Caselli
124.98	Search for new high redshift molecular absorption line systems		Combes, Wiklind
168.98	Deuterated forms of formaldehyde towards IRAS16293-2422	96, 110, 137	Castets, Loinard, Ceccarelli, Caux
77.98	Completation of a deep investigation of SiO in star-forming regions	86, 130, 217	Codella, Bachiller
156.98	Observations of the hot gas in clusters with diabolo through the Sunyaev-Zel'dovich effect	Diabolo	Desert, Aghanim, Benard, Delabrouille, Puget

0.2 Jan 19 - Feb 02

Ident.	Title	Freq. (GHz)	Authors
87.98	A molecular survey of CRL618 : from mm waves to the near IR	92, 115, 230	Cernicharo, Guelin, Maillard, Neri, Pardo, Martinez
123.98	Monitoring of the gravitational lens PKS1830-211	94, 141	Wiklind, Combes
δ03.99		Remote Observing	Bremer
δ01.99		Remote Observing	Ceccarelli
113.98	Chemical bistability in dark clouds: diagnostic of deuterium fractionation	93, 104, 110, 145	Gerin, Falgarone, Roueff, Pineau des Forets, Schilke
156.98	Observations of the hot gas in clusters with diabolo through the Sunyaev-Zel'dovich effect	Diabolo	Desert, Aghanim, Benard, Delabrouille, Puget
δ15.99		Remote Observing	Bujarrabal
138.98	Small scale structure of the edge of the Horsehead with the 30m	115, 230	Abergel, Boulanger, Coulais, Gerin, Falgarone

0.3 Feb 02 - Feb 16

Ident.	Title	Freq. (GHz)	Authors
159.98	IRAM observations of absorbed, high-redshift ROSAT deep survey sources	Bolometer	Hasinger, Bertoldi, Menten, Zylka
162.98	Deep search for mm sources in the Hubble deep field	Bolometer	Bertoldi, Kreysa, Menten, Zylka, Carilli, Owen, Morrison

0.4 Feb 16 - Mar 02

Ident.	Title	Freq. (GHz)	Authors
158.98	A systematic search for high-mass protostars	Bolometer	Menten, Sridharan, Schilke, Wyrowski
163.98	An unbiased mm continuum survey for protostellar outflow sources in Orion A	Bolometer	Stanke, McCaughrean, Menten, Zinnecker, Zylka
83.98	Unbiased large sclae mapping of the galactic center	Bolometer	Zylka, Mezger, Duschl
159.98	IRAM observations of absorbed, high-redshift ROSAT deep survey sources	Bolometer	Hasinger, Bertoldi, Menten, Zylka
161.98	Deep search for mm sources in the Hubble deep field	Bolometer	Kreysa, Bertoldi, Biermann, Carilli, Gueth et al.

0.5 Mar 02 - Mar 16

Ident.	Title	Freq. (GHz)	Authors
161.98	Deep search for mm sources in the Hubble deep field	Bolometer	Kreysa, Bertoldi, Biermann, Carilli, Gueth et al.
128.98	Are extremely red galaxies dominated by dust ?	Bolometer	Thompson, Omont, Beckwith, Dunlop
79.98	Cold dust associated with molecular and atomic gas in M31	Bolometer	Zylka, Guelin, Neininger
178.98	Mm detection of ELAIS and FIRBACK ISO deep surveys sources	Bolometer	Omont, Guiderdoni, Rigopoulou, Puget et al.

0.6 Mar 16 - Mar 30

Ident.	Title	Freq. (GHz)	Authors
178.98	Mm detection of ELAIS and FIRBACK ISO deep surveys sources	Bolometer	Omont, Guiderdoni, Rigopoulou, Puget et al.
104.98	Dust continuum emission from the Elephant Trunks of M16	Bolometer	Ungerechts, Sievers, Wild, Kramer
122.98	A search for cold dust around pulsars	Bolometer	Wolszczan, Wielebinski
196.98	Searching for extremely embedded objects	Bolometer	Tafalla, Bachiller
116.98	Dust in the low-metalicity dwarf galaxy NGC 1569	Bolometer	Lisenfeld, Sievers, Wild
151.98	Follow-up mm mapping of dark globules discovered by ISOCAM	Bolometer	Bacmann, Andre
152.98	Probing the origin of the initial mass function : wide-field bolo. array imaging of NGC 2068/2071	Bolometer	Andre, Motte, Bontemps, Kaas, Nordh, Olofsson
δ04.99			Mezger, Albrecht

0.7 Mar 30 - Apr 13

Ident.	Title	Freq. (GHz)	Authors
157.98	Protoplanetary disks around solar type stars	Bolometer	Kruegel, Chinki, Gueth, Menten, Siebenmorgen
δ06.99			Andre, Bontemps
δ05.99			Bertoldi, Kreysa, Menten
136.98	HH energy sources, deeply embedded stars and protostellar condensations	Bolometer	Chini, Lemke, Reipurth, Sievers
173.98	The darkest clouds in the galaxy : deep inside galactic GMC's	Bolometer	Perault, Omont, Teyssier, Hennebelle
129.98	Density and turbulent structure of star forming cores	98, 147, 219, 244	Tafalla, Caselli, Myers, Walmsley
δ07.99			Walsh, Klein, Kohle
δ02.99			Schreyer

0.8 Apr 13 - Apr 27

Ident.	Title	Freq. (GHz)	Authors
158.98	A systematic search for high-mass protostars	Bolometer	Menten, Sridharan, Schilke, Wyrowski
144.98	H2C0 and CH3OH in circumstellar disks around young stars	96, 140, 218, 222	Thi, Van Dishoeck, Van Zedelhoff
123.98	Monitoring of the gravitational lens PKS1830-211	94, 141	Wiklind, Combes
85.98	Mars: A determination of the D/H ratio, a study of the H2O distribution...	115, 143, 203, 225	Encrenaz, Lellouch, Forget, Paubert, Gulkis

0.9 Apr 27 - May 11

Ident.	Title	Freq. (GHz)	Authors
100.98	Searches for dust interstellar/circumstellar NaC and KC	154, 205, 231, 223	Ziurys, Guelin, Cernicharo
89.98	Depletion in IC5146	86, 144, 216, 113, 226	Kramer, Walmsley, Lada, Alves, Caselli
123.98	Monitoring of the gravitational lens PKS1830-211	94, 141	Wiklind, Combes
85.98	Mars: A determination of the D/H ratio, a study of the H2O distribution...	115, 143, 203, 225	Encrenaz, Lellouch, Forget, Paubert, Gulkis
92.98	OTF spectroscopy to study the kinematics of the central galaxy	98, 147, 220	Guesten, Zylka, Philipp, Ungerechts
130.98	Measuring the magnetic field in star-forming dense cores	99, 109	Thum, Andre, Morris, Fiebig, Ward-Thompson
110.98	Mapping bipolar molecular outflows from massive stars	86, 99, 220, 230	Lisenfeld, Thum, Ungerechts, Wink

0.10 May 11 - May 25

Ident.	Title	Freq. (GHz)	Authors
54.99	The extent of the molecular gas in the BCD Haro ?	114, 109, 229, 219	Fritz, Heithausen, Klein, Neininger, Huettemeister
123.98	Monitoring of the gravitational lens PKS1830-211	94, 141	Wiklind, Combes
105.98	Molecular gas in the Elephant Trunks of M16 extended OTF maps	98, 109, 115, 147, 230	Ungerechts, Sievers, Wild, Kramer
7.99	SiO in the bright rimmed globule IC1396N:molecular outflow or radiation driven implosion ?	115, 230, 146	Codella, Saraceno, Bachiller
130.98	Measuring the magnetic field in star-forming dense cores	99, 109	Thum, Andre, Morris, Fiebig, Ward-Thompson
140.98	Carbon stars with OH emission:transition from O to C rich stars	86, 130, 219, 88, 146, 244	Szczerba, Omont, Szymczak
70.98	Completion of a study to probing cloud evolution through obs. of sulphuretted molecules	99, 138, 219, 220	Codella, Scappini, Bachiller
167.98	Using sulfur chemistry to estimate the age of the IRAS2/NGC1333 outflow	104, 165, 109, 216, 251	Castets, Loinard, Ceccarelli, Caux
29.99	SiO as a tracer of the evolutionary stage of intermediate mass outflows	86, 144, 230	Fuente, Martin-Pintado, Bachiller, Rodriguez

0.11 May 25 - June 8

Ident.	Title	Freq. (GHz)	Authors
δ09.99			Bockelee-Morvan
43.99	Short spacing components for the CS(2-1) mosaic of GF9-2	98	Wiesemeyer, Gueth, Guesten
65.99	Gas content and star formation efficiency of dwarf galaxies	11, 230	Albrecht, Chini, Lemke
59.99	Chemistry of proto-planetary disks around young intermediate mass stars	89, 113, 147, 219	Wiesemeyer, Mannings, Dutrey, Guilloteau

0.12 June 8 - June 22

Ident.	Title	Freq. (GHz)	Authors
60.99	Dust clouds in the inner parts of M31's bulge	115, 22	Melchior, Viallefond, Guelin, Neininger, Nieten, Loinard
04.99	Dense gas in NGC6946	115, 230	Beck, Thuma, Walsh, Nieten, Wielebinski
36.99	OTF mapping of M31, the closest spiral galaxy	115, 230	Neininger, Nieten, Guelin, Lucas, Wielebinski, Berkhuijsen, Beck, Ungerechts
21.99	Do stars form from molecular gas in tidal dwarf galaxies ?	112	Braine, Duc, Lisenfeld, Leon
68.99	NGC3521 : A hidden merger ?	115	Taylor, Dettmar

0.13 June 22 - July 06

Ident.	Title	Freq. (GHz)	Authors
17.99	On the heating and chemistry of the hot expanding shells in the Sgr B2 envelopes	98, 244, 142, 86, 12	Martin-Pintado, de Vicente, Rodriguez, Fuente
δ08.99			Henkel
53.99	Chemical diagnostics in dark clouds : search of deuterated substitutes	88, 110, 134, 146	Roueff, Tine, Gerin, Pineau des Forets
42.99	Reactive molecular ions in PDRs	86, 89, 103, 208, 236	Fuente, Black, Martin-Pintado, Rodriguez, Garcia-Burillo
69.99	Correlation between gas and dust in L977	108, 112, 219, 224	Tafalla, Alves, Lada
05.99	Distribution and excitation of the molecular gas in the Taffy galaxies UGC 12914/15	108, 226	Davoust, Zhu, Seaquist, Gao

0.14 July 06 - July 20

Ident.	Title	Freq. (GHz)	Authors
66.99	A search for molecular gas in the extreme outer regions of disk galaxies	115, 230	Ferguson, Bertoldi, Wilson
δ11.99			Baudry et al.
30.99	Establishing the link between box-shaped bulges and bars in spirals : NGC1055	114, 229	Garcia-Burillo, Sempere
55.99	NGC3077-Phoenix : Molecular gas in the tidal arms around NGC 3077	115, 110, 220, 230	Heithausen, Walter
46.99	Ring molecules : a search for interstellar Ethylenimine	88, 108, 159, 222	Thorwirth, Mueller, Winnewisser, Schilke, Wyrowski
14.99	The chemistry of compact planetary nebulae	90, 110, 220, 236	Josselin, Bachiller

0.15 July 20 - Aug 03

Ident.	Title	Freq. (GHz)	Authors
26.99	Deuteration in gas phase versus solid phase in a massive protostellar object	90, 110, 226	Dartois, Demyk, Gerin, d Hendecourt
18.99	Follow up detailed study of the very young accreting protostar IRAM 04191	96, 98, 140, 225	Bacmann, Andre, Motte, Despois
20.99	Detection of H2CS toward nearby galaxies : NGC253 and M82	103, 135, 202, 209	Oike, Kawaguchi, Nakai, Takano
10.99	The dynamical behaviour of IR carbon stars	115, 230	Groenewegen, Sevenster, Omont, Habing
52.99	A survey of CO in extreme cooling flow clusters	96, 104, 102, 92	Edge, Fabian, Allen, Crawford

0.16 Aug 03 - Aug 17

Ident.	Title	Freq. (GHz)	Authors
20.99	Detection of H2CS toward nearby galaxies : NGC253 and M82	103, 135, 202, 209	Oike, Kawaguchi, Nakai, Takano
δ11.99			Baudry et al.
51.99	Outflow and core evolution in high mass young stellar objects	110, 147, 210, 220	Cesaroni, Brand, Hunter, Molinari, Sridharan, Testi
52.99	A survey of CO in extreme cooling flow clusters	96, 104, 102, 92	Edge, Fabian, Allen, Crawford
44.99	The darkest clouds in the galaxy : probing the physico-chemical conditions	83, 115, 129, 200, 255	Perault, Teyssier, Hennebelle, Omont
32.99	The evolution of dense cores forming the youngest protostars in Perseus	109, 112, 219, 224	Ladd, Fuller

0.17 Aug 17 - Aug 31

Ident.	Title	Freq. (GHz)	Authors
110.98	Mapping bipolar molecular outflows from massive stars	86, 99, 220, 230	Lisenfeld, Thum, Ungerechts, Winks
49.99	The high density peak in L1544	90	Walmsley, Caselli, Tafalla
02.99	The nature of the magnetic field in the MWC349 disk	230	Thum, Morris
19.99	A polarization study of SiO maser stars	86, 85	Baudry, Thum, Morris, Herpin, Wiesemeyer
34.99	OTF mapping of regions of enhanced dissipation of turbulence	110, 230	Falgarone, Hily-Blant, Boulanger, Teyssier et al.
11.99	Supersonic vortices or small MHD shocks in quiescent clouds ?	87, 89, 110, 220	Falgarone, Pineau des Forets, Pety

0.18 Aug 31 - Sep 14

Ident.	Title	Freq. (GHz)	Authors
44.99	The darkest clouds in the galaxy : probing the physico-chemical conditions	83, 115, 129, 200, 255	Perault, Teyssier, Hennebelle, Omont
27.99	Pre stellar and protostellar cores in the Trifid nebula	115, 110, 86, 93, 130	Lefloch, Cernicharo, Perez-Martinez
28.99	A molecular survey of CRL618 : from mm waves to the near IR	135, 144, 162, 171	Cernicharo, Guelin, Pardo, Neri
58.99	The interaction between giant Herbig-Haro flows and their surroundings	110, 15, 220, 230	Arce, Goodman
δ12.99			Bockelee-Morvan et al.
δ13.99			Guesten et al.
110.98	Mapping bipolar molecular outflows from massive stars	86, 99, 220, 230	Lisenfeld, Thum, Ungerechts, Winks
70.99	High resolution HCN spectroscopy in dark cloudfs	88, 93, 109, 230	Lapinov, Zinchenko

0.19 Sep 14 - Sep 28

Ident.	Title	Freq. (GHz)	Authors
δ13.99			Guesten et al.
62.99	Carbon chains in dense interstellar gas	87, 85, 89, 98	Fosse, Gerin, Cernicharo
Holography			Morris, Lazareff

0.20 Sep 28 - Oct 12

Ident.	Title	Freq. (GHz)	Authors
Holography			Morris, Lazareff
56.99	Ios atmosphere during the GALILEO Io flybys	221, 143, 219, 216	Lellouch, Belton, Strobel, Paubert
24.99	Investigating the chemistry of protoplanetary disks	85, 91, 110, 114, 168	Dutrey, Guilloteau, Guelin

0.21 Oct 12 - Oct 26

Ident.	Title	Freq. (GHz)	Authors
24.99	Investigating the chemistry of protoplanetary disks	85, 91, 110, 114, 168	Dutrey, Guilloteau, Guelin
42.99	Reactive molecular ions in PDRs	86, 89, 103, 236	Fuente, Black, Martin Pintado, Rodriguez, Garcia Burillo
67.99	Chemical differenciation of dense cores	93, 109, 136, 224	Tafalla, Caselli, Walmsley, Myers

0.22 Oct 26 - Nov 02

Ident.	Title	Freq. (GHz)	Authors
36.99	OTF mapping of M31, the closest spiral galaxy	115, 230	Neininger, Nieten, Guelin, Lucas, et al.
47.99	The counter rotating molecular disk of NGC 2683	115, 230	Pompei, Danzinger, Terndrup, Combes
27.99	Pre stellar and protostellar cores in the Trifid nebula	115, 110, 86, 130	Lefloch, Cernicharo, Perez-Martinez

0.23 Nov 02 - Nov 16

Ident.	Title	Freq. (GHz)	Authors
79.99	A study of NO in the Martian upper atmosphere	115, 143, 225, 230	Encrenaz, Lellouch, Paubert, Moreno, Gulkis
36.99	OTF mapping of M31, the closest spiral galaxy	115, 230	Neininger, Nieten, Guelin, Lucas, et al.
15.99	Deuterated formaldehyde in low mass protostars	110, 166, 231, 101	Loinard, Castets, Cecarelli, Caux
82.99	Molecular gas in tidal dwarf galaxies : beyond detection	112, 114, 225, 229	Braine, Duc, Lisenfeld, Leon
19.99	A polarization study of SiO maser stars	86, 85	Baudry, Thum, Morris, Herpin, Wiesemeyer
28.99	A molecular survey of CRL618 : from mm waves to the near IR	135, 144, 162, 171	Cernicharo, Guelin, Pardo, Neri
05.99	Distribution and excitation of the molecular gas in the Taffy galaxies UGC12914-915	108, 226	Davoust, Zhu, Seaquist, Gao
02.99	The nature of the magnetic field in the MWC349 disk	230	Thum, Morris
50.99	Are weak T Tauri stars really diskless ?	230	Weintraub, Kastner, Forveille

0.24 Nov 16 - Nov 30

Ident.	Title	Freq. (GHz)	Authors
169.99	A systematic search for highmass protostars	Bolometer	Beuther, Menten, Schilke, Sridharan
56.99	Ios atmosphere during the GALILEO Io flybys	221, 143, 219, 216	Lellouch, Belton, Strobel, Paubert
201.99	Mapping CO emission in the nearby warped LINER galaxy NGC3718	114, 88, 229	Eckart, Schinnerer, Wild
98.99	Thermal methanol emission in Cepheus A	86, 96, 239, 241	d Hendecourt, Demyk, Dartois
108.99	Circumstellar 36S : a probe of the s-process in C stars	95, 142, 237	Mauersberger, Henkel, Langer, Chin
194.99	A search for D2CO in intermediate and high mass protostars	110, 140,, 236, 211	Loinard, Dartois, Castets, Ceccarelli
124.99	The young detached CO shell around the carbon star U Camelopardalis	115, 230	Lindqvist, Olofsson, Lucas, Schoeier et al.

0.25 Nov 30 - Dec 14

Ident.	Title	Freq. (GHz)	Authors
180.99	Cold dust associated with molecular and atomic gas in M31	Bolometer	Zylka, Guelin, Neininger
138.99	Resolving the abundance structure of low mass cores	Bolometer	Tafalla, Myers, Caselli, Walmsley
178.99	Imaging at 230GHz of plerionic components of galactic SNRs	Bolometer	Bandiera, Cesaroni, Neri
191.99	A wide field blind survey at 240GHz	Bolometer	Bertoldi, Kreysa, Menten, Zylka et al.
119.99	Searching for extremely embedded objects	Bolometer	Tafalla, Bachiller
151.99	The mm wavelength spectral shape of double lobed radio sources	Bolometer	van Bemmel, Barthel

0.26 Dec 14 - Dec 28

Ident.	Title	Freq. (GHz)	Authors
151.99	The mm wavelength spectral shape of double lobed radio sources	Bolometer	van Bemmel, Barthel
178.99	Imaging at 230GHz of plerionic components of galactic SNRs	Bolometer	Bandiera, Cesaroni, Neri
167.99	Supersonic vortices or small MHD shocks in quiescent clouds ?	89, 110, 220, 230	Falgarone, Pineau des Forets, Hily-Blant, Pety
176.99	A molecular survey of CRL618 : Mm and submm waves to the near IR	130, 139, 156, 242	Cernicharo, Guelin, Pardo, Neri
191.99	A wide field blind survey at 240GHz	Bolometer	Bertoldi, Kreysa, Menten, Zylka et al.
99.99	Titan revisited : Detection of complex nitriles CH3CN mand HC5N	88, 109, 147, 220	Marten, Moreno, Hidayat, Paubert
84.99	OTF mapping of regions of enhanced dissipation of turbulence	110, 115, 220, 230	Falgarone, Hily-Blant, Pineau des Forets, Boulanger et al.

7. ANNEX I : TELESCOPE SCHEDULES

7.2 PdB Interferometer

Ident.	Title	Line	Authors
H120	Water abundance in molecular cores: interferometry of $H_2^{18}O$	HDO $H_2^{18}O$	T.Jacq A.Baudry T.L.Wilson P.Gensheimer
I063	CO mapping of the cometary globules in the Helix nebula	CO(1-0) CO(2-1)	T.Forveille P.J.Huggins P.Cox R.Bachiller
I068	Study of the high velocity CO bullets and jets in the BK/KL outflow in Orion A	SiO(2-1) CO(2-1)	A.Rodriguez-Franco J.Martin-Pintado
I073	Bi-modal density distribution in the DM Tau disk	^{13}CO(1-0) $C^{18}O$(2-1)	A.Dutrey S.Guilloteau M.Simon
I074	Mars middle-atmosphere dynamics from mapping of CO	CO(1-0) CO(2-1)	E.Lellouch T.Encrenaz F.Forget S.Guilloteau R.Moreno
I077	Circumnuclear gas dynamics in active galaxies: LINERs vs. Seyferts	CO(1-0) CO(2-1)	E.Schinnerer A.Eckart L.Tacconi
I088	Mapping the gas and dist in the closest protosolar-like nebulae	HCO^+ CO(2-1)	M.Simon A.Dutrey S.Guilloteau
I091	Ram pressure stripping deep in the potential well	CO(1-0)	B.Vollmer C.Balkowski V.Cajatte W.Duschl
I095	The double nucleus of NGC 3504	CO(1-0) CO(2-1)	F.Combes S.Léon E.Emsellem
I102	The extent of SiO thermal emission in AGB stars	^{28}SiO(2-1) ^{28}SiO(5-4)	V.Bujarrabal R.Lucas F.Colomer A.Carrizo J.Alcolea
I106	Molecular gas in distant, ultraluminous submillimetre-selected galaxies	CO(3-2)R CO(7-6)R Cont1mm	P.Solomon R.Ivison D.Downes J.Kneib I.Smail A.Blain
I107	The nature of the nuclear obscuring screen in NGC 4151	CO(1-0) CO(2-1)	E.Sturm L.Tacconi J.Gallimore D.Lutz
I108	X-ray induced ionization in protostellar disks	$H^{13}CO^+$ DCO^+ $C^{18}O$	T.Montmerle N.Grosso
I110	High spatial resolution study of the multiple molecular jets in CRL 2688	HC_3N CO(2-1)	P.Cox R.Lucas S.Guilloteau P.Huggins T.Forveille R.Bachiller J.Maillard A.Omont
I112	GMCs' properties in an external galaxy, M81	CO(1-0) CO(2-1)	N.Brouillet A.Baudry F.Comes M.Kaufman F.Bash
I121	Molecular clouds in M31 at a few pc scale: structure and mass determination	CO(1-0) CO(2-1)	N.Neininger R.Lucas L.Loinard R.Wielebinski H.Ungerechts
I123	Episodic mass loss on the AGB: the young CO shell around U Cam	CO(1-0) CO(2-1)	M.Lindqvist H.Olofsson V.Bujarrabal C.Kahane R.Lucas R.Neri A.Omont
I132	Observations of CS in the planetary nebula NGC 7027	CS(2-1) CS(5-4)	P.Schilke K.Menten
I139	Taming the Dragon II - The quadrupolar outflow of HH288	HCN(1-0) CO(2-1)	F.Gueth P.Schilke M.McCaughrean
I143	The molecular outflow(s) of the W3(H_2O) protostellar cluster	SiO(2-1) CO(2-1)	F.Wyrowski K.Menten P.Schilke C.M.Walmsley
I145	Update on celebrities: W49 and NGC7538 revisited	SiO(2-1) CO(2-1)	P.Schilke F.Gueth K.Menten F.Wyrowski

Ident.	Title	Line	Authors
I151	Mapping the distribution and kinematics of edge-on circumstellar disks: AA Tau, FT Tau, CI Tau	HCO^+(1-0) CO(2-1) Cont1mm	J.Bouvier A.Dutrey
I156	Infall velocity field of the very young accreting protostar IRAM04191	CS(2-1) H_2CO	P.André D.Despois S.Bontemps F.Motte A.Bacmann
I158	Molecular clouds in the irregular galaxy IC10	CO(1-0) CO(2-1)	W.Wild A.Greve H.Ungerechts A.Sievers
I--9	A CO survey of gravitationally lensed quasars	CO(4-3)R Cont3mm CO(9-8)R Cont1mm	R.Barvainis D.Alloin R.Antonucci
I-14	A measure of the CO(5-4) width in BR1202	CO(5-4)R	A.Omont D.Downes M.Guélin
JA04	A Systematic Search for High-Mass Protostars – zooming in on 05358+3543	CO(1-0) CO(2-1)	P.Schilke H.Beuther F.Gueth T.K.Sridharan T.R.Hunter M.McCaughrean B.Stecklum
JB04	A Systematic Search for High-Mass Protostars – zooming in on 05358+3543	SiO(2-1) SiO(5-4)	P.Schilke H.Beuther F.Gueth T.K.Sridharan T.R.Hunter M.McCaughrean B.Stecklum
J005	CO J =2–1/1–0 Mapping of M2-56	CO(1-0) CO(2-1)	C.Sánchez-Contreras R.Neri J.Alcolea V.Bujarrabal
J006	A CO survey of Gravitationally Lensed Quasars	CO(4-3)R CO(3-2)R CO(2-1)R Cont1mm	R.Barvainis D.Alloin R.Antonucci
J007	Gas and Dust around the Herbig AeBe star HD34282	HCO^+(1-0) CO(2-1)	A.Dutrey C.Kahane M.Jura
J008	Mapping the molecular gas and the dust of the HD141569 disk	HCO^+(1-0) CO(2-1)	J.-C.Augereau A.Dutrey A.-M.Lagrange T.Forveille D.Mouillet
J009	High-resolution mapping of a $z \sim 1$ sub-mm lensed ring galaxy	CO(2-1)R CO(4-3)R	J.-P.Kneib R.Ivison G.Soucail I.Smail A.Blain
J00A	Cold Dust and Molecular Gas in Ultracompact HII regions	CS(2-1) Cont3mm	M.Feldt R.Klein P.Schilke B.Stecklum
J00B	CO Mapping of NGC6090: A test of Early Merger Evolution	CO(1-0) CO(2-1)	L.Tacconi R.Genzel M.Lehnert N.Scoville A.Baker
J00C	Circumstellar Disks around Evolved Stars	CO(1-0) CO(2-1)	C.Kahane A.Dutrey M.Jura
J00E	Searching for disks and collimated outflows in isolated embedded intermediate-mass YSOs: The case of AFGL 490	CS(2-1)	T.Henning K.Schreyer E.van Dischoeck R.Launhardt
JA11	Molecular clouds in M31 at a few pc scale: focussing on a spiral arm crossing	CO(1-0) CO(2-1)	N.Neininger M.Guélin R.Lucas L.Loinard R.Wielebinski
JA12	AU-Scale in Molecular Clouds (?)	CCH	R.Lucas H.S.Liszt
JB12	AU-Scale in Molecular Clouds (?)	HNC	R.Lucas H.S.Liszt
J013	Extragalactic Chemistry at High Resolution: SiO Mapping of the M82 Starburst	SiO(2-1) $H^{13}CO^+$	S.Garcia-Burillo J.Martin-Pintado R.Neri
J016	The small-scale structure of NGC 3077-Phoenix	CO(1-0) CO(2-1)	F.Walter A.Heithausen

Ident.	Title	Line	Authors
J018	Unveiling the nature of the QSO absorption line systems	—	M.Dumke M.Guélin R.Neri M.Grewing R.Lucas
J01B	Probing the nucleosynthesis in the young universe	—	M.Dumke M.Guélin R.Lucas F.Combes T.Wiklind
JA1C	Identifying the counterparts of submm galaxies: star formation at high redshift	Cont3mm Cont1mm	D.Lutz D.Hughes J.Dunlop J.Peacock M.Rowan-Robinson S.Serjeant S.Oliver R.Mann R.Ivison L.Tacconi R.Genzel D.Rigopoulou P.Andreani
J01D	CO detection in the extremely red galaxy HR10	CO(2-1)R CO(4-3)R	P.Andreani A.Cimatti H.Röttgering R.Tilanus
JB20	Detection of a population of millimetric	Cont3mm	F.-X.Désert G.Duvert
JC20	sources towards massive clusters	Cont3mm	N.Aghanim M.Giard J.Braine J.-P.Kneib M.Arnaud D.Neumann J.G.Bartlett A.Blanchard J.Delabrouille
J021	Search for 500 AU structures in the ^{12}CO emission of non-star forming clouds	CO(1-0)	E.Falgarone M.Pérault J.Pety J.-F.Panis
JA22	CO mapping of compact planetary nebulae	CO(1-0) CO(2-1)	E.Josselin R.Bachiller
JB22		CO(1-0) CO(2-1)	A.Manchado
J023	Gas Dynamics of Nearby Active Galaxies: III. The LINER galaxy NGC 4736	CO(1-0) CO(2-1)	E.Schinnerer A.Eckart L.Tacconi
J024	Molecular gas in a representative sample of nearby quasars	CO(1-0)	F.Casoli L.Loinard
J025	Search for molecular gas in HVC through QSO absorption	HCO^+(1-0) CO(2-1)	V.Charmandaris F.Combes
J02A	Gas and dust in the $z = 4.424$ galaxy VLA J123642+621331	CO(4-3)R CO(10-9)R	D.Downes E.Richards R.Windhorst I.Waddington
J02F	Small scale structure of the edge of the Horsehead	CO(1-0) CO(2-1)	A.Abergel F.Boulanger A.Coulais E.Habart M.Gerin E.Falgarone
J032	The proto-planetary disk of WW Vul	Cont1mm	A.Natta R.Neri A.Prusti V.Grinin
JA38	Identifying the counterparts of submm	Cont3mm Cont1mm	D.Lutz D.Hughes J.Dunlop
JB38	galaxies: star formation at high redshift	Cont3mm Cont1mm	J.Peacock M.Rowan-Robinson
JC38		Cont3mm Cont1mm	S.Oliver R.Mann R.Ivison L.Tacconi R.Genzel D.Rigopoulou P.Andreani
J03D	Structure in the dust disk around Vega	Cont3mm Cont1mm CO(2-1)	D.Wilner M.Holman P.Ho
J043	Physical properties of protoplanetary disks around isolated Herbig Ae Stars	HCO^+(1-0) CO(2-1)	A.Dutrey S.Guilloteau M.Simon E.Dartois H.Wiesemeyer
J04C	Photochemistry and temperature gradient in the DM Tau disk	HCN ^{13}CO(2-1)	E.Dartois A.Dutrey S.Guilloteau H.Wiesemeyer M.Guélin
JA56	Molecular gas disks in luminous and	CO(1-0) CO(2-1)	L.Tacconi A.Baker
JD56	ultraluminous mergers: A key to merger	CO(1-0) CO(2-1)	P.Englmaier R.Genzel
JF56	evolution	CO(1-0) CO(2-1)	M.Lehnert L.Looney D.Rigopoulou L.Tacconi-Garman

Ident.	Title	Line	Authors
JA59 JB59	A systematic search for high-mass protostars - zooming in on IRAS 19217+1651 and IRAS 20293+3952	SiO(2-1) CO(2-1) SiO(2-1) CO(2-1)	H.Beuther F.Gueth K.Menten P.Schilke T.Sridharan
JA5A JB5A JC5A	Molecular gas and dust at z=3.91	HCN(5-4)R CO(10-9)R CIR CO(10-9)R H_2O(5-4)R CO(10-9)R	T.Wiklind D.Downes D.Wilner R.Neri
JA5E JB5E	Identification of two unusual millimeter sources	Cont3mm Cont1mm Cont3mm Cont1mm	F.Bertoldi K.Menten E.Kreysa F.Gueth L.Tacconi D.Lutz R.Genzel C.Carilli F.Owen
J--1	CO in the quasar PMN J1451-1512	CO(5-4)R CO(11-10)	R.Neri D.Downes I.Hook R.McMahon P.Shaver
J--2	A unique high-velocity jet in the Galactic Center	^{13}CO(1-0) ^{13}CO(2-1)	R.Guesten S.Philipp F.Gueth H.Wiesemeyer
J--3	Follow-up observations on selected galaxies	CO(1-0)R CO(2-1)R CO(4-3)R	D.Downes R.Neri
J--4	Deuterated formaldehyde mapping in IRAS2	D_2CO	L.Loinard A.Castets C.Ceccarelli X.Tielens E.Caux
J--6	Monitoring of the Gamma-ray Burst GRB991208	Cont3mm	M.Bremer A.Castro-Tirado T.Galama

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

749. DEPLETION OF CO IN A COLD DENSE CLOUD CORE OF IC 5146
C. Kramer, J. Alves, C.J. Lada, A. Sievers, H. Ungerechts, C.M. Walmsley
1999, A&A 342, 257

750. WATER LINE EMISSION IN LOW-MASS PROTOSTARS
C. Ceccarelli, E. Caux, L. Loinard et al.
1999, A&A 342, L21

751. THE JET-DRIVEN MOLECULAR OUTFLOW OF HH 211
F. Gueth, S. Guilloteau
1999, A&A 343, 571

752. INTERFEROMETER ^{12}CO OBSERVATIONS OF THE BOX-SHAPED BULGE SPIRAL NGC 4013
S. Garcia-Burillo, F. Combes, R. Neri
1999, A&A 343, 740

753. A STRONG MAGNETIC FIELD IN THE DISK OF MWC 349
C. Thum, D. Morris
1999, A&A 344, 923

754. UNVEILING THE DISK-JET SYSTEM IN THE MASSIVE (PROTO)STAR IRAS 20126+4104
R. Cesaroni, M. Felli, T. Jenness, R. Neri, L. Olmi, M. Robberto, L. Testi, C.M. Walmsley
1999, A&A 345, 949

755. ^{13}CO(1-0) AND ^{12}CO(2-1) IN THE CENTER OF THE BARRED GALAXY NGC 1530
D. Reynaud, D. Downes
1999, A&A 347, 37

756. 86 AND 140 GHz RADIOCONTINUUM MAPS OF THE CASSIOPEIA A SNR
H. Liszt, R. Lucas
1999, A&A 347, 258

757. CO(4--3) AND CO(3--2) STUDIES OF M51 AND NGC 6946
Ch. Nieten, M. Dumke, R. Beck, R. Wielebinski
1999, A&A 347, L5

758. EXTENDED WARM CO GAS IN THREE NEARBY GALAXIES
R. Wielebinski, M. Dumke, Ch. Nieten
1999, A&A 347, 634

759. PROPOSED IDENTIFICATION OF HUBBLE DEEP FIELD SUBMILLIMETER SOURCE HDF 850.1
D. Downes, R. Neri, A. Greve, S. Guilloteau et al.
1999, A&A 347, 809

760. STARS, HII REGIONS, AND SHOCKED GAS IN THE BAR OF NGC 1530
A. Greve, D. Reynaud, D. Downes
1999, A&A 348, 394

761. GG TAURI: THE RING WORLD
S. Guilloteau, A. Dutrey, M. Simon
1999, A&A 348, 570

762. ORFEUS SPECTROSCOPY OF THE O VI LINES IN SYMBIOTIC STARS AND THE RAMAN SCATTERING PROCESS
H.M. Schmid, M. Grewing et al.
1999, A&A 348, 950

763. COORDINATED RADIO CONTINUUM OBSERVATIONS OF COMETS HYAKUTAKE AND HALE-BOPP FROM 22 TO 860 GHz
W.J. Altenhoff, R. Mauersberger, A. Sievers, C. Thum, H. Wiesemeyer, J.E. Wink et al.
1999, A&A 348, 1020

764. DUST AND CO LINES IN HIGH REDSHIFT QUASARS
S. Guilloteau, A. Omont, P. Cox, R.G. McMahon, P. Petitjean
1999, A&A 349, 363

765. GIANT MOLECULAR CLOUDS IN THE DWARF GALAXY NGC 1569
C.L. Taylor, S. Hüttemeister, U. Klein, A. Greve
1999, A&A 349, 424

766. THE CIRCUMSTELLAR ENVIRONMENT OF UX ORI
A. Natta, T. Prusti, R. Neri, W.F. Thi, V.P. Grinin, V. Mannings
1999, A&A 350, 541

767. MID-INFRARED AND FAR-ULTRAVIOLET OBSERVATIONS OF THE STAR-FORMING RING OF M31
L. Pagani, J. Lequeux, D. Cesarsky, J. Donas, B. Milliard, L. Loinard, M. Sauvage
1999, A&A 351, 447

768. CARBON DIOXIDE-METHANOL INTERMOLECULAR COMPLEXES IN INTERSTELLAR GRAIN MANTLES
E. Dartois, K. Demyk, L. d'Hendecourt, P. Ehrenfreund
1999, A&A 351, 1066

769. A CO SURVEY OF THE SOUTHWEST HALF OF M 31
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M. Lindqvist, H. Olofsson, R. Lucas, F.L. Schöler, R. Neri, V. Bujarrabal, C. Kahane
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771. THE ORFEUS II ECHELLE SPECTROMETER: INSTRUMENT DESCRIPTION, PERFORMANCE AND DATA REDUCTIONS
J. Barnstedt, M. Grewing et al.
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772. PHYSICAL PARAMETERS OF GRB 970508 FROM ITS AFTERGLOW SYNCHROTRON EMISSION
T.J. Galama, M. Bremer, et al.
1999, A&A Suppl. Ser. 138, 451

773. DETECTION OF CO (4-3), CO (9-8), AND DUST EMISSION IN THE BROAD ABSORPTION LINE QUASAR APM 08279+5255 AT A REDSHIFT OF 3.9
D. Downes, R. Neri, T. Wiklind, D.J. Wilner, P.A. Shaver
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774. DETECTION OF THE CN ZEEMAN EFFECT IN MOLECULAR CLOUDS
R.M. Crutcher, T.H. Troland, B. Lazareff, G. Paubert, I. Kazès
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775. KINEMATIC INTERPRETATION OF THE CENTAURUS A ABSORPTION-LINE SYSTEM
A. Eckart, W. Wild, N. Ageorges
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776. GAS DYNAMICS IN THE LUMINOUS MERGER NGC 6240
L.J. Tacconi, R. Genzel, M. Tecza, J.F. Gallimore, D. Downes, N.Z. Scoville
1999, ApJ 524, 732

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T.L. Wilson, R. Mauersberger, P.D. Gensheimer, D. Muders, J.H. Bieging
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H.R. Dickel, J.A. Williams, D.E. Upham, W.J. Welch, M.C.H. Wright, T.L. Wilson, R. Mauersberger
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779. SPECTROSCOPIC MONITORING OF COMET C/1996 B2 (HYAKUTAKE) WITH THE JCMT AND IRAM RADIO TELESCOPES
N. Biver, J.E. Wink, R. Moreno, G. Paubert et al.
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IN THE NGC 4631 GROUP
N. Neininger, M. Dumke
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D. Downes
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782. COORDINATED OBSERVATIONS OF COMET HALE-BOPP BETWEEN 32 AND 860 GHz
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783. LONG-TERM EVOLUTION OF THE OUTGASSING OF COMET HALE-BOPP FROM RADIO OBSERVATIONS
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784. EVIDENCES FOR EXTENDED SOURCES AND TEMPORAL MODULATIONS IN MOLECULAR OBSERVATIONS OF C/1995 01 (HALE-BOPP) AT THE IRAM INTERFEROMETER
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A. Dutrey
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787. GAS-RICH GALAXY PAIR UNVEILED IN THE LENSED QUASAR 0957+561
P. Planesas, J. Martin-Pintado, R. Neri, L. Colina
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788. ISO STUDY OF THE RECOMBINATION LINE MASER STAR MWC 349
C. Thum, J. Martin-Pintado, A. Quirrenbach, H.E. Matthews
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eds. S. D'Odorico, A. Fontana, E. Giallongo
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791. MILLIMETER CONTINUUM MONITORING OF EXTRAGALACTIC RADIO SOURCES WITH THE IRAM 30-M TELESCOPE
H. Ungerechts, C. Kramer, B. Lefloch, S. Leon, F. Masset, R. Moreno, G. Paubert, D. Reynaud, A. Sievers, W. Wild
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ASP Conf. Series, Vol. 144, 149

792. OBSERVATION OF MOLECULAR EMISSION FROM HIGH REDSHIFT GALAXIES
A. Omont, P. Petitjean, R.G. McMahon, S. Guilloteau, P. Cox
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793. ISOCAM OBSERVATIONS OF EXTREMELY YOUNG CLASS O CANDIDATES
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ESA Conf. SP-427, Paris, 20-23 Oct. 1999

794. RADIOASTRONOMY AND THE ACTIVE SERVICES IN Ka BAND
D. Morris
1999, 4th Ka Band Utilization Conf.
Istituto Internazionale della Communicazioni, Genova, Italy, 381

795. DUST AND GAS IN LUMINOUS INFRARED GALAXIES: RESULTS FROM SCUBA OBSERVATIONS
U. Lisenfeld, K. Isaak, R. Hills
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eds. V. Ossenkopf et al.
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796. MM-WAVE ABSORPTION SPECTRA: CO MOLECULES AND ISOTOPE RATIOS IN GALACTIC DIFFUSE CLOUDS
R. Lucas, H.S. Liszt
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A. Dutrey, S. Guilloteau
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798. WATER LINE EMISSION IN LOW-MASS PROTOSTARS
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eds. V. Ossenkopf et al.
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799. CARBON-CHAIN MOLECULES AS TRACERS OF TIME-DEPENDENT CHEMISTRY
M.Guélin, N. Neininger, R. Lucas, J. Cernicharo
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eds. V. Ossenkopf et al.
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800. DETECTION OF D_2CO TOWARDS IRAS 16293-2422
A. Castets, C. Ceccarelli, L. Loinard, E. Caux, A.G.G.M. Tielens
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eds. V. Ossenkopf et al.
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801. NEAR INFRARED SPECTROSCOPY AND THE SEARCH FOR CO EMMISSION IN 3 EXTREMELY LUMINOUS IRAS SOURCES
A.S. Evans, D.B. Sanders, R.M. Cutri, S.J.E. Radford, P.M. Solomon, D. Downes, C. Kramer
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802. CFHT WIDE-FIELD DEEP IMAGING OF M33
J.-C. Cuillandre, J. Lequeux, L. Loinard
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803. MILLIMETER-WAVE INTERFEROMETRY OF CIRCUMSTELLAR ENVELOPES
R. Lucas, M. Guélin
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804. OPTIMISING RECEIVERS FOR GROUND-BASED MILLIMETRE WAVE RADIOTELESCOPES
A. Karpov
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805. SUPERCONDUCTING MIXER ELEMENTS FOR TERAHERTZ FREQUENCIES
M. Schicke
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806. 2nd MILLIMETER-VLBI SCIENCE WORKSHOP, Granada, Spain
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807. NEW 8-RECEIVER CABIN OF THE IRAM 30M TELESCOPE
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C. Rösch, F. Mattiocco, K.H. Gundlach, K.-F. Schuster
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K.-F. Schuster, J. Blondel, M. Carter, B. Fouilleux, B. Lazareff, F. Mattiocco, S. Navarro, J.-L. Pollet
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8. ANNEX II: PUBLICATIONS/8.2 USERS' PUBLICATIONS WITH RESULTS FROM THE IRAM OBSERVATORIES

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XII. A SURVEY FOR CO J=3-2 EMISSION
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705. VIBRATIONALLY EXCITED HC_3N
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706. JETS AND HIGH-VELOCITY BULLETS
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IS THE IRc2 OUTFLOW POWERED BY
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A. Rodriguez-Franco, J. Martin-Pintado,
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707. A MOLECULAR CLOUD FORMING
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A. Weiss, A. Heithausen,
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708. EVIDENCE FOR AN EXPANDING
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A. Weiss, F. Walter, N. Neininger, U. Klein
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712. EVIDENCE FOR INWARD MOTION
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THE CASE OF CB3
C. Codella, R. Bachiller
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714. MOLECULAR GAS IN THE BULGE
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716. JET DRIVEN MOLECULAR
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A. Rodríguez-Franco, J. Martin-Pintado,
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717. OXYGEN-RICH SEMIREGULAR
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F. Kerschbaum, H. Olofsson
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718. MILLIMETER AND SOME NEAR INFRA-
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M.A.T. Groenewegen, F. Baas,
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719. EXCITATION AND DISRUPTION OF A GIANT MOLECULAR CLOUD BY THE SUPERNOVA REMNANT 3C 391
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720. DISCOVERY OF AN EXTREMELY YOUNG ACCRETING PROTSTAR IN TAURUS
P. André, F. Motte, A. Bacmann
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J.P. Williams, P.C. Myers, D.J. Wilner, J. Di Francesco
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P. Pratap, S.T. Megeath, E.A. Bergin
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724. THE DISCOVERY OF A MOLECULAR COMPLEX IN THE TIDAL ARMS NEAR NGC 3077
F. Walter, A. Heithausen
1999, ApJ 519, L69

725. LOW-VELOCITY IONIZED WINDS FROM REGIONS AROUND YOUNG O STARS
D.T. Jaffe, J. Martín-Pintado
1999, ApJ 520, 162

726. A MOLECULAR COUNTERPART TO THE HH 1-2 FLOW
A. Moro-Martín, J. Cernicharo, A. Noriega-Crespo, J. Martín-Pintado
1999, ApJ 520, L111

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728. ORBITING MOLECULAR RESERVOIRS AROUND EVOLVED RED GIANT STARS
M. Jura, C. Kahane
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P. Caselli, C.M. Walmsley, M. Tafalla, L. Dore, P.C. Myers
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E.Schinnerer, A. Eckart, L.J. Tacconi
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D.C. Lis, K.M. Menten, R. Zylka
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