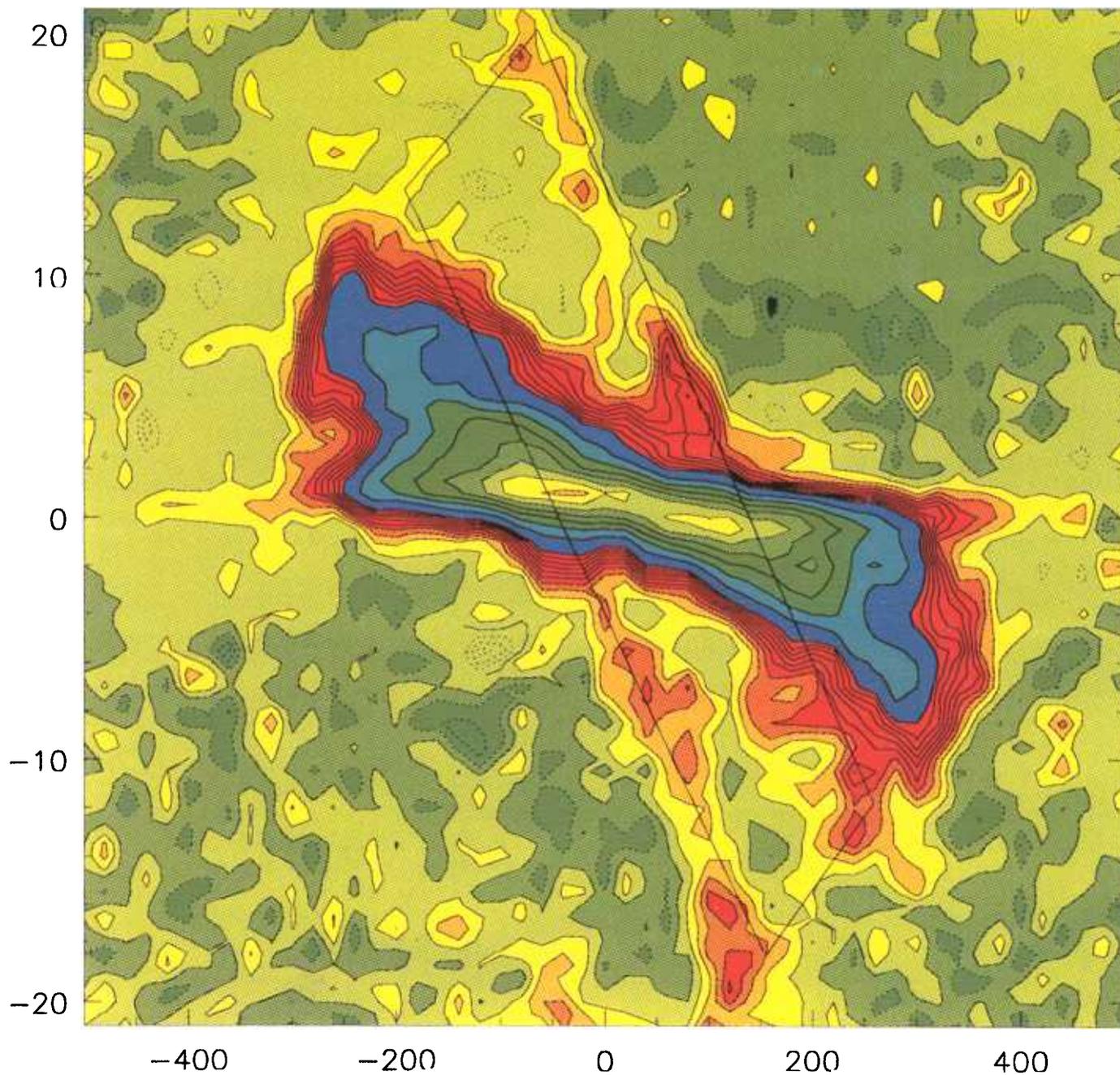


IRAM 1994



ANNUAL REPORT

Front Cover : IRAM Interferometer observations of the CO (1-0) emission in the galaxy NGC 3079. The vertical axis gives the position along the major axis of the galaxy in arcseconds. The resolution is 2 arcsec. The horizontal axis shows the relative velocity of the CO in km/s with respect to the systemic velocity. The resolution is 20 km/s. The contours are iso-intensity contours. The most intense emission (blue color) comes from the nuclear region. The lower-level emission that follows the parallelogram pattern (solid line) seems to indicate the presence of a bar in this spiral galaxy. (Courtesy of L.Tacconi and D.Downes)

ANNUAL REPORT 1994

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1. INTRODUCTION

Among the numerous scientific highlights in 1994 which are summarized in Chapter 2, the first clear detection of fringes over a baseline of 1150 km in a VLBI experiment at a wavelength of 1.3 mm between the two IRAM Observatories on Pico Veleta and on Plateau de Bure deserves special mention because it is the result of a concerted effort between IRAM and institutes in France (Observatoire de Bordeaux), Germany (MPI für Radioastronomie, Bonn), and Spain (Centro Astronomico de Yebes), i.e. from all three sponsoring countries.

Another area where remarkable progress has been made concerns the observations of dust and molecules in very distant objects with redshifts larger than 2, and even as high as $z=4.7$ at the 30-m telescope. These have been made possible by further improvements of the heterodyne receivers which are reaching a receiver noise temperature that has come very close to the ultimate limit (cf. Chapter 5 for details), and by the availability of a multi-channel bolometer built by Dr.Kreysa and his colleagues at the MPIfR.

The VLBI experiment mentioned above also marks the arrival of the first dual channel receiver (3mm+1.3mm) at the interferometer. Given its excellent performance, this system will rapidly be copied and should become available on all four antennas during the first half of 1995.

Some excitement was caused throughout 1994 by a series of Spanish newspaper articles about plans to build a powerful military radar station within 5km of Pico Veleta. Direct as well as diplomatic channels were used to inform the Spanish Government through our partner organisations about our concerns, and it looks as if alternative sites are now being considered.

Concerning future developments, a very important step has been the decision by the IRAM Council in June 1994 to let us go ahead with the construction of Antenna 5 for the Plateau de Bure Interferometer. Since then all major subsystems and components have been contracted directly between IRAM and the suppliers, i.e. without involving a main-contractor. After detailed studies and some prototyping a decision has been taken against installing further carbon-fibre panels, which are used on Antennas 1-4, but to go to aluminium panels for Antenna 5. These new panels will be fabricated against the same set of specifications as the old ones. This solution is not only cost-effective but it also avoids the problem of putting a conductive surface on top of carbon-fibre panels, a problem which we continue to study.

A second very important construction activity has started in 1994 : the extension of the tracks of the Plateau de Bure Interferometer by 120m in the east-west, and by 80m in the north-south direction. This will give us three more stations on the E-W track, and one more station on the N-S track. The work is foreseen to finish in 1995.

2. HIGHLIGHTS OF RESEARCH WITH THE IRAM TELESCOPES IN 1994

2.1 SUMMARY

Of the many projects done at IRAM's observatories or published in 1994, some highlights were:

Detections with the Interferometer and with the 30m telescope of CO emission from the quasar H1413+11 (the "Cloverleaf") at a redshift of 2.5.

Detections with the 30 m telescope at 1.25 mm of thermal continuum emission from dust in the quasar 1202-0725 ($z = 4.7$) and in the radio galaxy 4C41.17 ($z = 3.8$).

Detections at the 30 m telescope of molecular lines in *absorption* against two BL Lac objects. The lines come from galaxies, at $z = 0.24$ and 0.69 , along the lines of sight to the BL Lac quasars.

A 215 GHz VLBI experiment between Pico Veleta and Plateau de Bure that detected the sources 3C273, 3C279, and 2145+067 with signal-to-noise ratios between 7 and 10.

A CO study at the 30m telescope of ultraluminous galaxies which indicates that the ratio of gas mass to CO luminosity is at least a factor of three lower than for galactic molecular clouds.

Interferometer maps of CO and HCN in the central few hundred parsecs around the nucleus of the galaxy NGC 3079 . The velocity pattern of the molecular gas suggests a bar.

Interferometer maps of CO in the center and along the bar of the galaxy NGC 1530. The maps show gas moving on orbits along the bar and, in the center, perpendicular to the bar.

Maps made with the 30 m telescope of the continuum emission from cold dust in the galaxies M51 and NGC4631. The dust emission is closely correlated with the CO emission.

Evidence, from ^{12}CO and ^{13}CO spectra taken at the 30 m telescope, for a thin disk in Keplerian rotation around the T Tauri star DM Tau.

Interferometer maps of outflows from young stellar objects in the clouds L1448 and L1157.

- Detection with the 30 m telescope of the rare isotopomers $^{25}\text{MgNC}$ and $^{26}\text{MgNC}$ in the circumstellar envelope of IRC+10216. A line detected at 234 GHz may be from ^{26}AlF . The derived $^{24}\text{Mg} : ^{25}\text{Mg} : ^{26}\text{Mg}$ ratios are consistent with the solar system values of 79 : 10 : 11.

Interferometer maps of CO in a shell around the protoplanetary nebula M1-92 that show evidence for interaction of a bipolar outflow with the pre-existing circumstellar envelope.

Detections with the 30m telescope of CO, CS and OCS in the atmosphere of Jupiter at the impact sites of the fragments of Comet Shoemaker-Levy.

2.2 EXTRAGALACTIC RESEARCH

2.2.1 Distant Sources (> 70 Mpc)

CO in the Cloverleaf Quasar

After the detections by mm astronomers in 1991 and 1992 of the CO(3-2), (4-3) and (6-5) lines in IRAS FSC10214+4724, an extraordinarily luminous galaxy at a redshift of 2.3, searches were started at millimeter telescopes all over the world for molecular lines from high-redshift objects. One of the first fruits of this intensive search came with the discovery at millimeter wavelengths with the IRAM interferometer, and then confirmed with the 30 m telescope, of CO(3-2) emission from the host galaxy of the quasar H1413+117, otherwise known as the Cloverleaf, because its optical image is gravitationally deflected into four spots on the sky by another galaxy along the line of sight. (Fig. 2.1). The discoverers also claim detections of the CO(4-3), (7-6) and neutral carbon lines at the 30m telescope. The CO detections in 10214+4724 and the Cloverleaf show that these are early-universe galaxies with large amounts of gas. However, it is also obvious that 10214+4724 and the Cloverleaf are **not** the long-sought proto-galaxies made of pristine, unprocessed gas in uncontracted disks much larger than galactic size. They are certainly *young* galaxies, because much of the mass in

their central regions is in molecular gas, not yet condensed into stars, but they have already produced "heavy" elements --- plenty of carbon and oxygen to make carbon monoxide and lots of dust ($>10^8$ solar masses) that radiates in the infrared. Hence these are not primeval or primordial galaxies, but real, albeit young, galaxies that have already formed. In several respects, these objects resemble the infrared ultraluminous galaxies, which are mostly interacting or merger systems.

Dust Detections in High-z objects , Negative Results in Damped Lyman alpha Quasars

Thermal continuum emission from dust has been detected at the 30 m telescope with the MPIfR bolometers from the quasar 1202-0725 at a redshift of 4.7, and from the radio galaxy 4C41.17 at a redshift of 3.8. The spectra of both objects increase steeply at shorter wavelengths, as has been shown by sub-mm detections at the JCMT. The implied dust masses are very large, of the same order as in 10214+4724 and the Cloverleaf quasar. Searches have continued for both continuum and line emission in many other high-redshift objects. No CO has been found in damped Lyman alpha absorption systems along the lines of sight to some quasars. The few positive detections that have been made in high redshift objects are evidently only the tip of the iceberg. They show that millimeter astronomy can potentially make an important contribution to cosmological research if radio astronomers can build a next-generation telescope with a collecting area of $\sim 10,000$ m².

Molecular Absorption Lines from Galaxies along the Lines of Sight to two BL Lac objects

Atomic hydrogen gas in galaxies along the line of sights to the BL Lac objects PKS1413+135 and B0218+357 had previously been detected in absorption with cm-wavelength telescopes. These intervening absorption systems toward the background BL Lac objects have now been detected in molecular lines. Toward the galaxy at a redshift of 0.69 that is absorbing the continuum radiation of B0218+357, four molecular lines were detected with the 30 m telescope: CO(1-2), CO(2-3), HCO⁺(1-2), and HCN(1-2). The absorbing molecular clouds in the galaxies along the line of sight to the BL Lac objects appear to have column densities of molecular hydrogen of at least 10^{21} molecules per cm², similar to Milky Way molecular clouds averaged on 100 pc scales. Toward B0218+357, the foreground galaxy in which the molecular absorption lines have been found is acting as a gravitational lens of the background quasar. (Fig. 2.1)

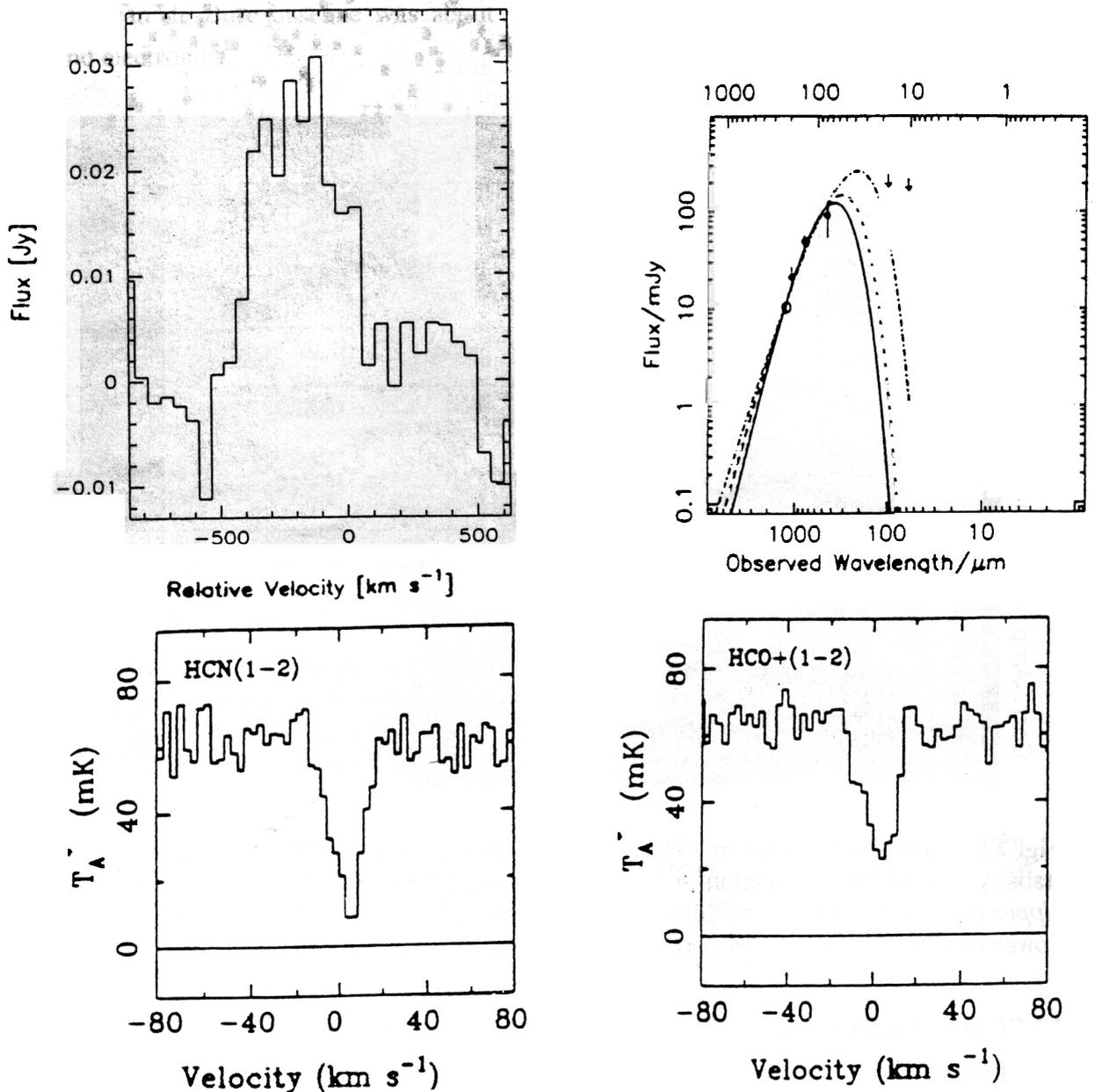


Fig. 2.1 High-redshift CO and thermal dust emission, and HCN and HCO⁺ absorption.

Upper left: CO(3-2) line from the host galaxy of the Cloverleaf quasar, H1413+117, at a redshift $z=2.5$, observed with the IRAM interferometer.

Upper right: Continuum emission of dust in the quasar BR 1202-0725 at a redshift $z = 4.7$; the open circle at 1.3 mm is from the IRAM 30 m telescope; the interpretation in terms of thermal emission by dust has been confirmed by JCMT data (filled circles).

Lower: Detection at the 30 m telescope of absorption lines of HCN and HCO⁺ in a galaxy at a redshift $z = 0.69$ that lies along the line of sight to the BL Lac object B0218+357.

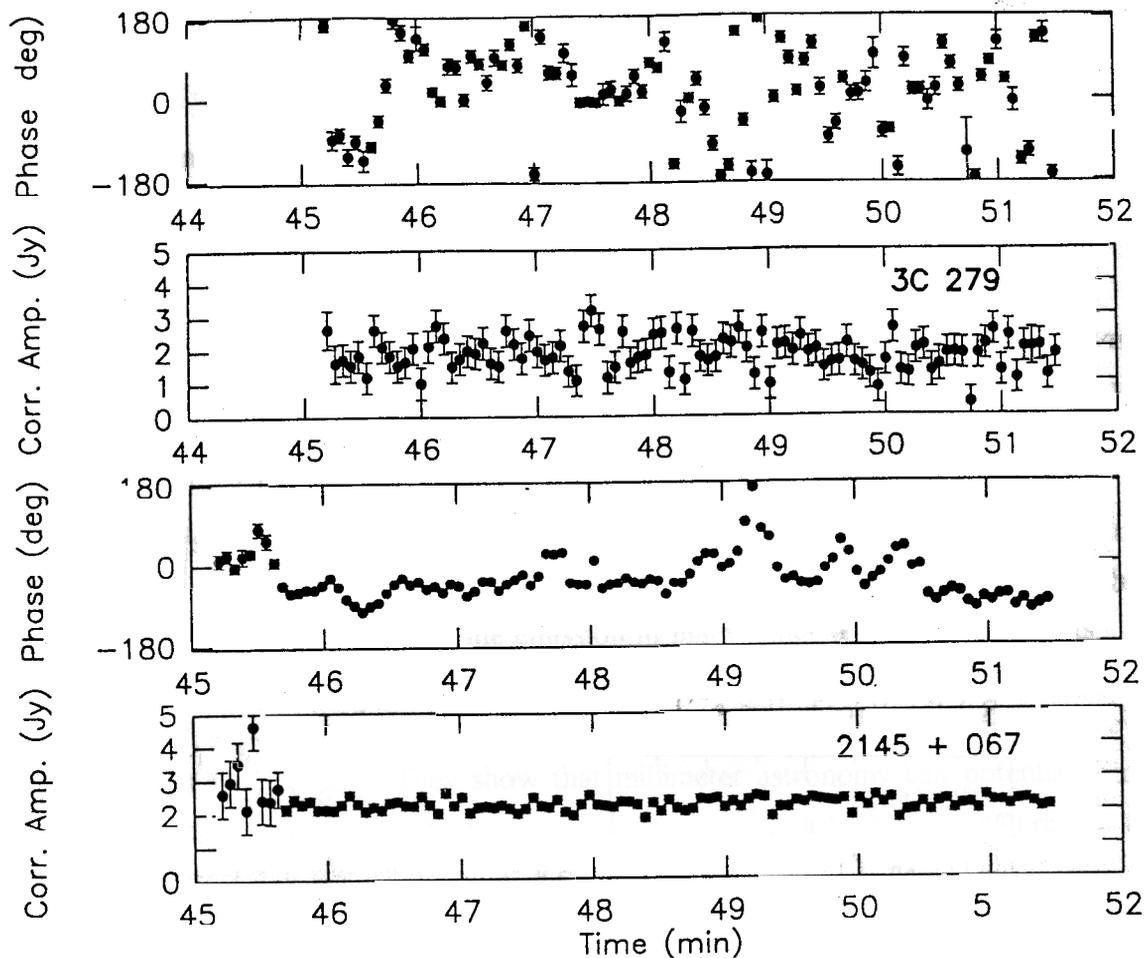


Fig. 2.2 VLBI at 215 and 86 GHz. Two 6.5-minute records showing amplitude and phase stability in a VLBI observation in December 1994 between Pico Veleta and Plateau de Bure. *Upper two panels:* phase and correlated amplitude at 215 GHz on 3C279. *Lower two panels:* phase and correlated amplitude at 86 GHz on 2145+067.

VLBI at 215 GHz between Pico Veleta and Plateau de Bure

VLBI observations were made at 215 GHz on the 1147-km baseline between Pico Veleta and Plateau de Bure in December 1994. The observations were bracketed by VLBI runs at 86 GHz to determine relative antenna positions and clock rates. For Plateau de Bure, the VLBA terminal was borrowed from the Centro Astronomico de Yebes, and the CNRS hydrogen maser was borrowed from CERGA. The experiment was a joint project of IRAM-France, IRAM-Spain, Yebes, MPIfR, Bonn, and the Université de Bordeaux. At 215 GHz, there were eight independent detections of the sources 3C273, 3C279, and 2145+067 with signal-to-noise ratios between 7 and 10, on projected baselines of 670 to 1050 km (fringe spacing 300 to 450 micro-arcsec). For 3C273 ($z = 0.16$), this corresponds to a linear scale of 0.56 pc. For this source, the single-dish flux was 14 Jy, and the correlated flux was ~ 2 Jy, with sample times of

4 sec (Fig 2.2). At 86 GHz, the signal-to-noise ratios on these and other sources on the Pico Veleta to Plateau de Bure baseline was about 100, showing the good performance of the receivers and electronics.

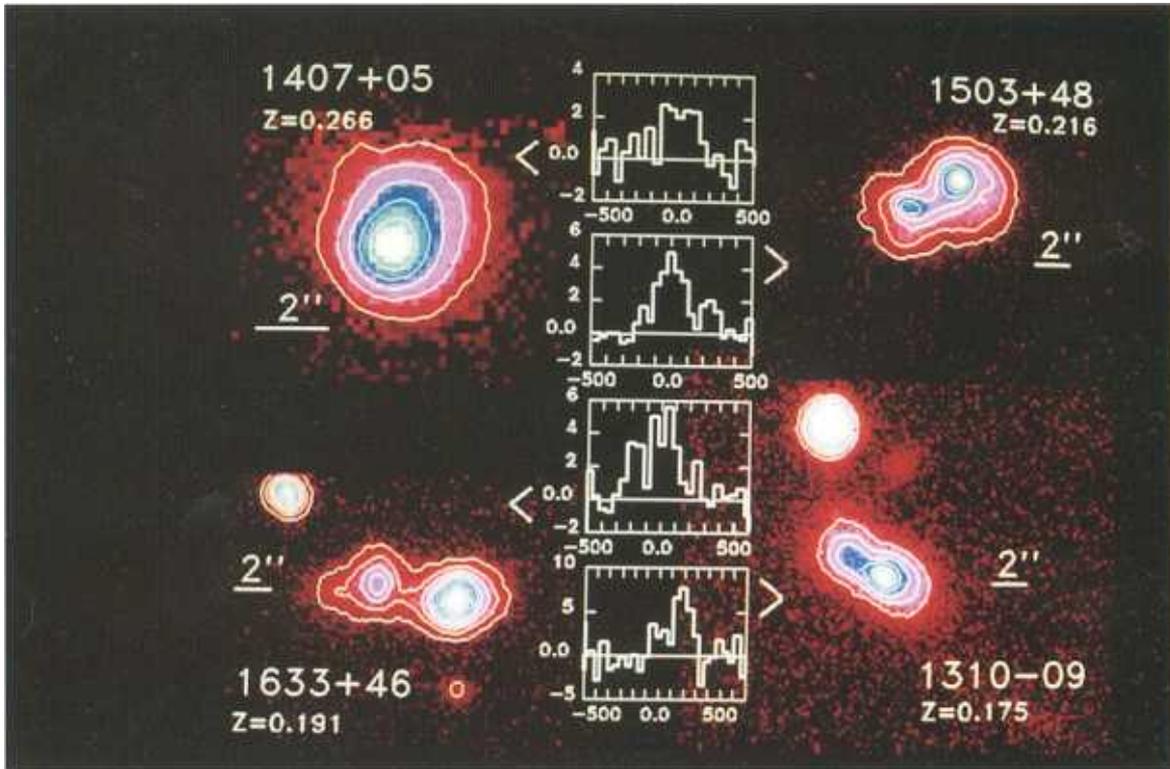


Fig. 2.3 : Ultraluminous Galaxies. Detections with the 30 m telescope of CO emission from ultraluminous, interacting galaxies. The images are R-band CCD images from the Univ. of Hawaii 88-inch telescope. Next to each image is the CO spectrum from the 30 m telescope.

Ultraluminous Galaxies

CO observations have been made with the 30 m telescope of a large sample of infrared ultraluminous galaxies. These galaxies differ from normal galaxies in their very large IR luminosities, typically 10^{12} suns, the strong concentration of molecular gas in their centers, and the ratio of CO to far-IR flux, which is close to that expected from a black body. The 30 m study shows that all ultraluminous galaxies have large amounts of molecular gas, typically 10^{10} solar masses. The integrated CO line intensity is well correlated with the $100 \mu\text{m}$ flux density, as expected in a black body model in which the far infrared radiation is optically thick. This model yields sizes of the far-IR and the CO emitting regions and the enclosed dynamical mass. The ratio of gas mass to CO luminosity is about a factor of three lower than for Galactic molecular clouds, but the gas mass is nevertheless a large fraction of the dynamical mass.

Most of the ultraluminous galaxies in this sample appear to be interacting, but not mergers (Fig. 2.3).

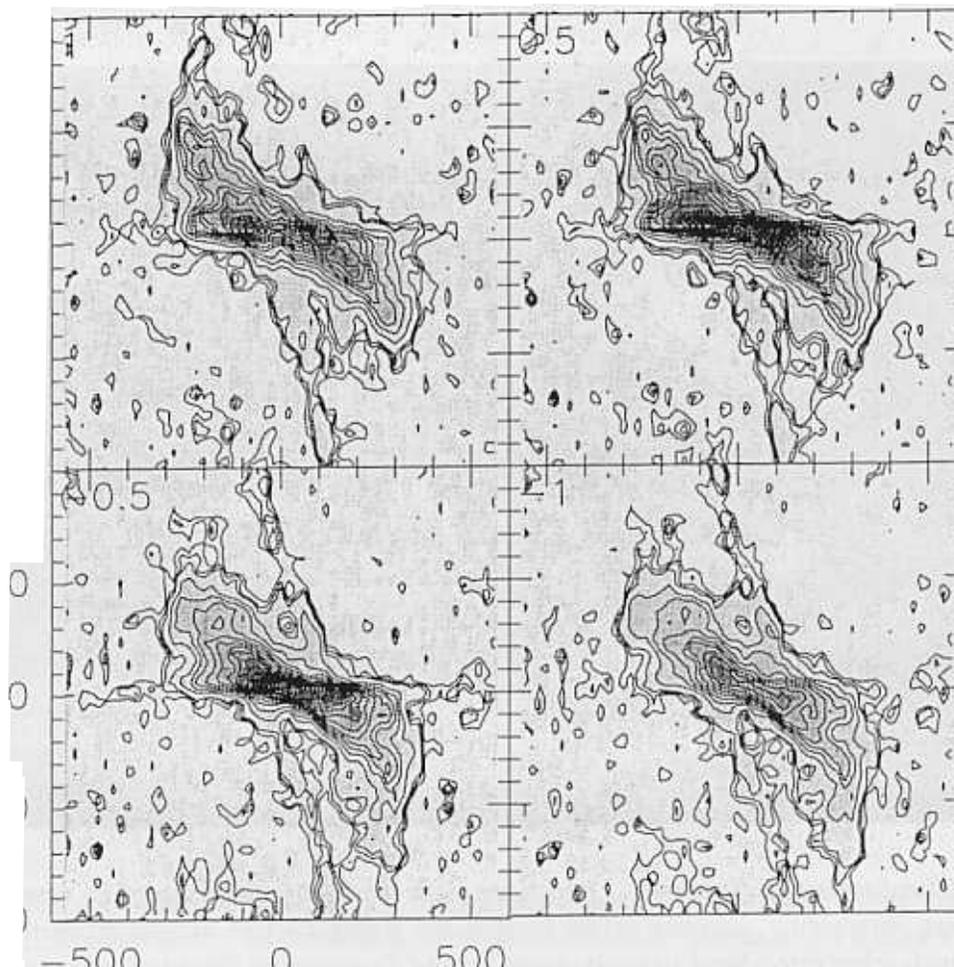


Fig. 2.4 : A Bar in NGC 3079 ? IRAM Interferometer CO(1-0) data on the galaxy NGC 3079. Vertical axis is position along the major axis (arcsec); horizontal axis is relative velocity (km/s). Spatial and velocity resolutions are 2" and 20 km/s, respectively. Contours are 8 mJy steps, up to 32 mJy, and 25 mJy steps from 50 mJy onwards. The most intense emission is from the nuclear region. Lower-level emission further out follows a characteristic parallelogram pattern, typical of a barred spiral. The individual diagrams refer to cuts at different heights above and below the midplane of the galaxy (+1, +0.5, -0.5, and -1 arcsec).

2.2.2 Nearby Galaxies ($10 < D < 70$ Mpc)

Evidence for a Bar in NGC 3079

The interferometer has been used to map the HCN emission at 88.6 GHz and the CO emission at 115 GHz in the central region of the edge-on spiral galaxy NGC 3079. This galaxy is known to have a starburst in its center that ejects a superwind in two enormous bubbles on opposite sides of the galactic plane. The new results from the IRAM interferometer show that

the HCN is strongly peaked near the nucleus, in dense, opaque clumps, while most of the CO emission is concentrated within a radius of 5" from the nucleus. The CO maps also show a faint zone of molecular clouds that have a parallelogram pattern extending over 40" on position-velocity diagrams (Fig. 2.4). This characteristic velocity pattern strongly suggests that NGC 3079 is a barred galaxy, and that the gravitational torques of the bar have driven a large mass of molecular gas into the central 10" region, where it generates a starburst.

Molecular Gas in the Bar in NGC 1530

The interferometer has been used to make a five-field mosaic map of the CO(1-0) in the barred spiral galaxy NGC 1530. The high-resolution CO(1-0) data complement CO(2-1) maps made at the 30 m telescope that show more extended structure. The CO maps show abundant

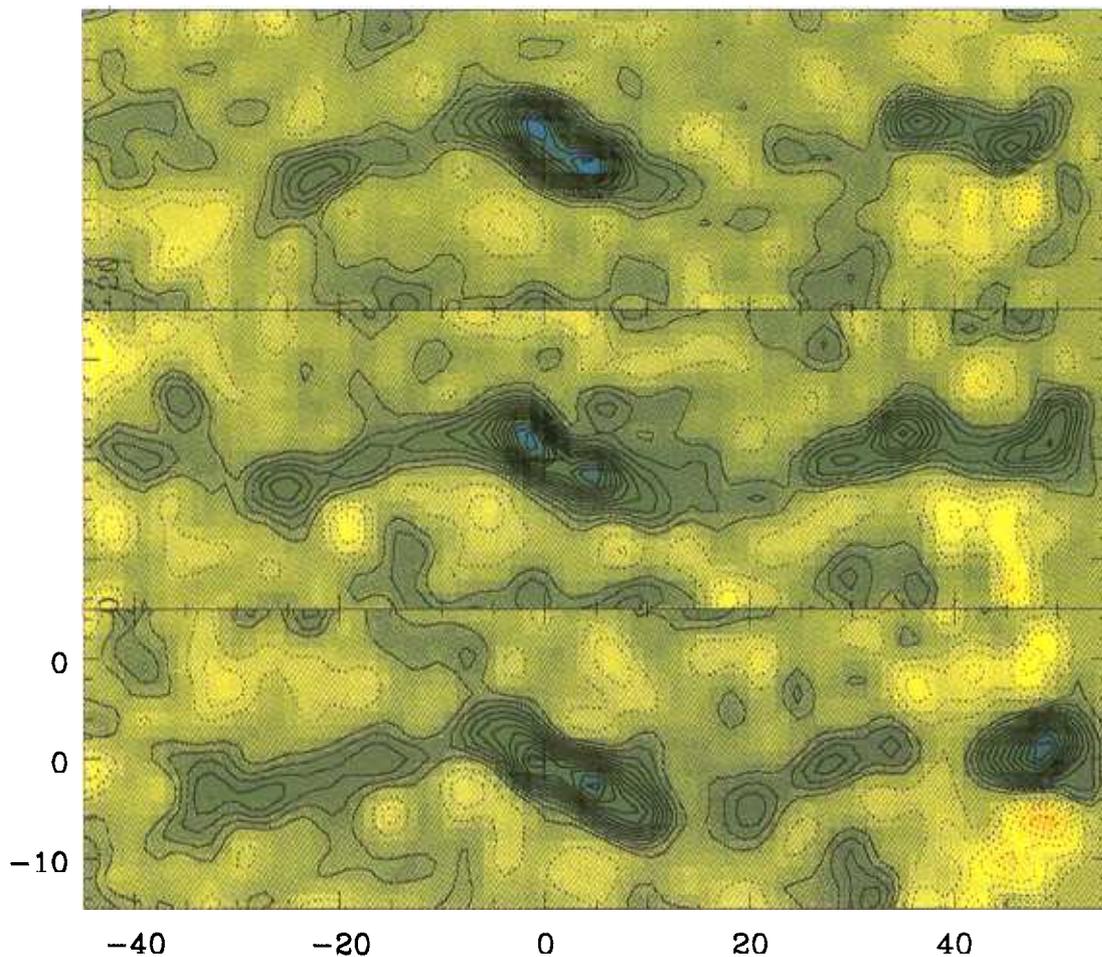


Fig. 2.5: CO in the Barred Galaxy NGC 1530. Interferometer maps of CO(1-0) emission along the bar of the galaxy NGC 1530, in 20 km/s channels centered at -40, -20 and 0 km/s relative to a radial velocity of 2450 km/s. The maps show the extended lanes that are probably shocked gas on both sides of the nucleus. Contour unit is 0.2 Jy km/s in the 4.1" x 3.7" beam.

molecular gas *along* the bar, associated with the dust lanes seen on optical images. Position-velocity diagrams are consistent with the molecular gas moving in elliptical orbits along the bar (x_1 orbits), and in orbits perpendicular to the bar, close to the nucleus (x_2 orbits). In spite of its high CO luminosity and great central concentration of molecular gas, this galaxy has only a modest ratio of far-infrared luminosity to CO luminosity, suggesting a relatively low rate of star formation per unit mass of molecular gas. Although the molecular gas has a latent capacity to create a large starburst, it may be hindered from doing so by the closed x_2 orbits close to the nucleus.

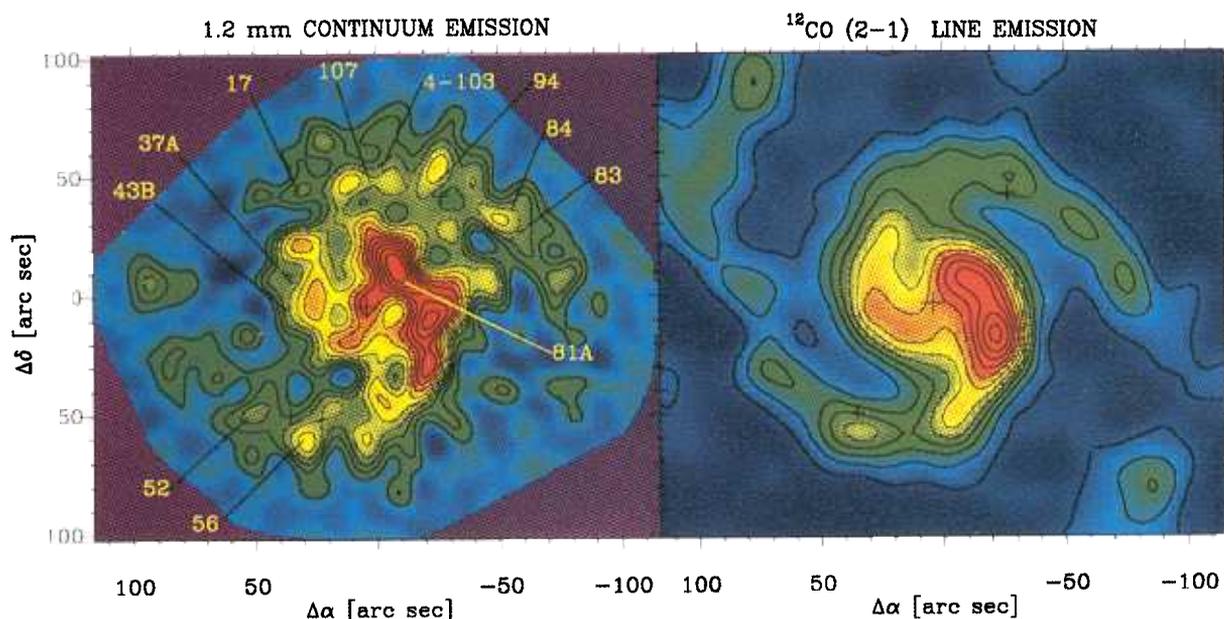


Fig. 2.6 : Dust and Gas in M51. *Left:* Map made with the 30 m telescope of the 1.3 mm continuum emission from cold dust in the face-on spiral galaxy M51. *Right:* Map from the 30 m telescope of the CO(2--1) emission from M51. Both maps are made with the same 12" beam.

2.2.3 The Nearest Galaxies (< 10 Mpc)

Dust Distribution in the Spiral Galaxies M51 and NGC 4631

The 30 m telescope has been used with the MPIfR 7-channel bolometer array to map the 1.3 mm continuum emission from the face-on, grand-design spiral galaxy **M51**. The continuum emission from dust closely follows the spiral pattern traced by the CO molecule (Fig. 2.6). About 15% of the signal in the broad-band continuum data is estimated to come from the CO(2-1) line. The continuum emission correlates well with the CO emission and poorly with H I emission. In M51, the dust emission at 1.3 mm appears to correspond to a mass of

molecular gas that is about one-third that derived from CO and a standard Galactic conversion factor from CO luminosity to H₂ mass. This continuum emission arises mostly in cold (< 20 K) dust associated with molecular clouds. The mass of *cold* dust observed at 1.3 mm is about 100 times higher than the mass of *warm* dust observed by the IRAS satellite. Similar results have been obtained in a map of the dust emission of the edge-on galaxy NGC 4631, where the dust continuum correlates well with the CO emission up to a radius of 2 kpc from the center of the galaxy.

2.3 YOUNG STELLAR OBJECTS

A Keplerian Disk Around DM Tauri

Observations at the 30 m telescope of the 2--1 lines of ¹²CO and ¹³CO show a kinematic pattern and line profile shapes that are consistent with a rotating gas disk around the star DM Tauri, estimated to have an age of five million years. This is the oldest pre-Main Sequence star for which a gas disk showing direct evidence of Keplerian rotation has been detected. The data suggest that the star has 65% of the mass of the sun, and that the disk has a surprisingly large outer radius of 750 AU, a mean temperature of 15 K and a mass of about 0.14% of a solar mass. This mass derived from the CO spectroscopy is much smaller than that derived from the mm and sub-mm continuum emission from dust, which yields an estimate of 0.03 solar masses for the disk. This may mean that the mm continuum emission is dominated by a compact core with a radius of 50 AU, about the size of our solar system. The interesting result of this study is that significant amounts of molecular gas are still present several million years after the formation of a low-mass star.

Outflows from Young Stellar Objects in L1448 and L1157.

IRAM interferometer maps have been made of the bipolar outflows from young stellar objects in the dust clouds L1448 and L1157. The center of the L1448 molecular outflow was mapped in the CO(1-0) line and in the 2.6 mm continuum, with a 3" beam. In the mapped area, there are two partially overlapping outflows from two different continuum sources, L1448/IRS3 and L1448-mm. Both sources are among the youngest known protostellar candidates. The CO maps show weak emission at high velocities, indicating that the jet from L1448-mm has a speed >200 km/s. Comparison of the CO maps with 2.2 μm images of shocked molecular hydrogen indicates that the bow shocks from the thin molecular jets are able to plow out large bipolar cavities that are much wider than the original jets themselves. The blueshifted lobe of

L1448-mm shows evidence of collision with the second outflow in the region, from the young stellar object L1448/IRS3.

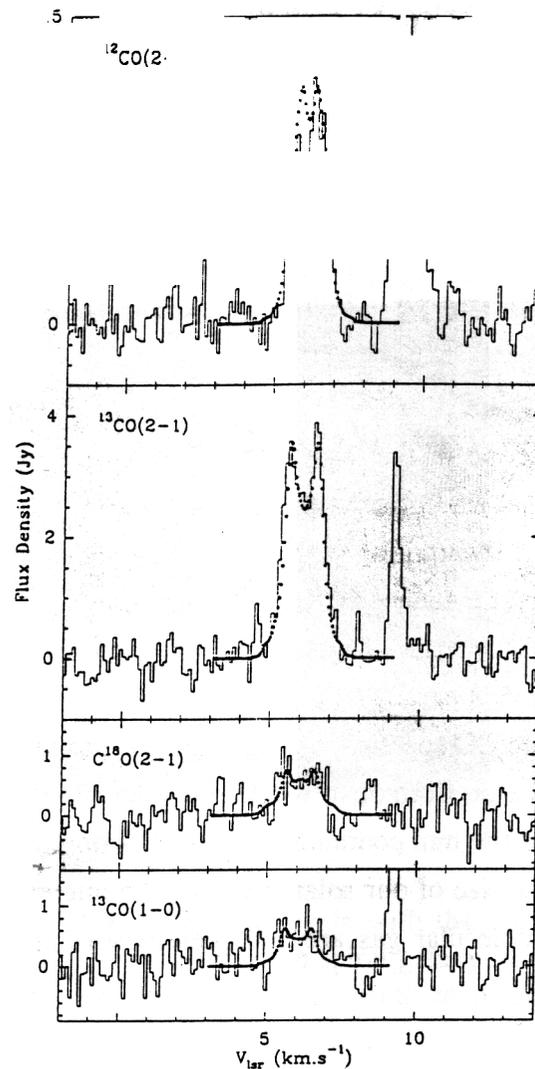


Fig. 2.7: A Disk Around DM Tau. Observations with the 30 m telescope of lines of CO isotopes toward the star DM Tau. Points show model profiles expected from a Keplerian disk.

The southern lobe of the outflow source in the dust cloud L1157 has been mapped in the SiO(2-1) and CO(1-0) lines. The SiO maps show thin structures that are probably the hot, dense bow shocks. In CO, the interferometer data also show the sharp, thin, high-contrast shock structures and also the outlines of the complete wind-blown cavity. Combined CO data from the interferometer and the 30 m telescope show the much more extended (2 arcmin), lower-contrast emission from the envelope of the much wider cavity created by the outflow (Fig. 2.8). The structure in the maps suggests there have been two major outbursts in the past 3000 years, and that the jet may be precessing around a cone with an opening angle of about

15 degrees. The mass of molecular gas in the outflow lobes is about 0.4 solar masses. This is mostly swept-up gas from the parent molecular cloud, rather than gas ejected by the accretion disk itself.

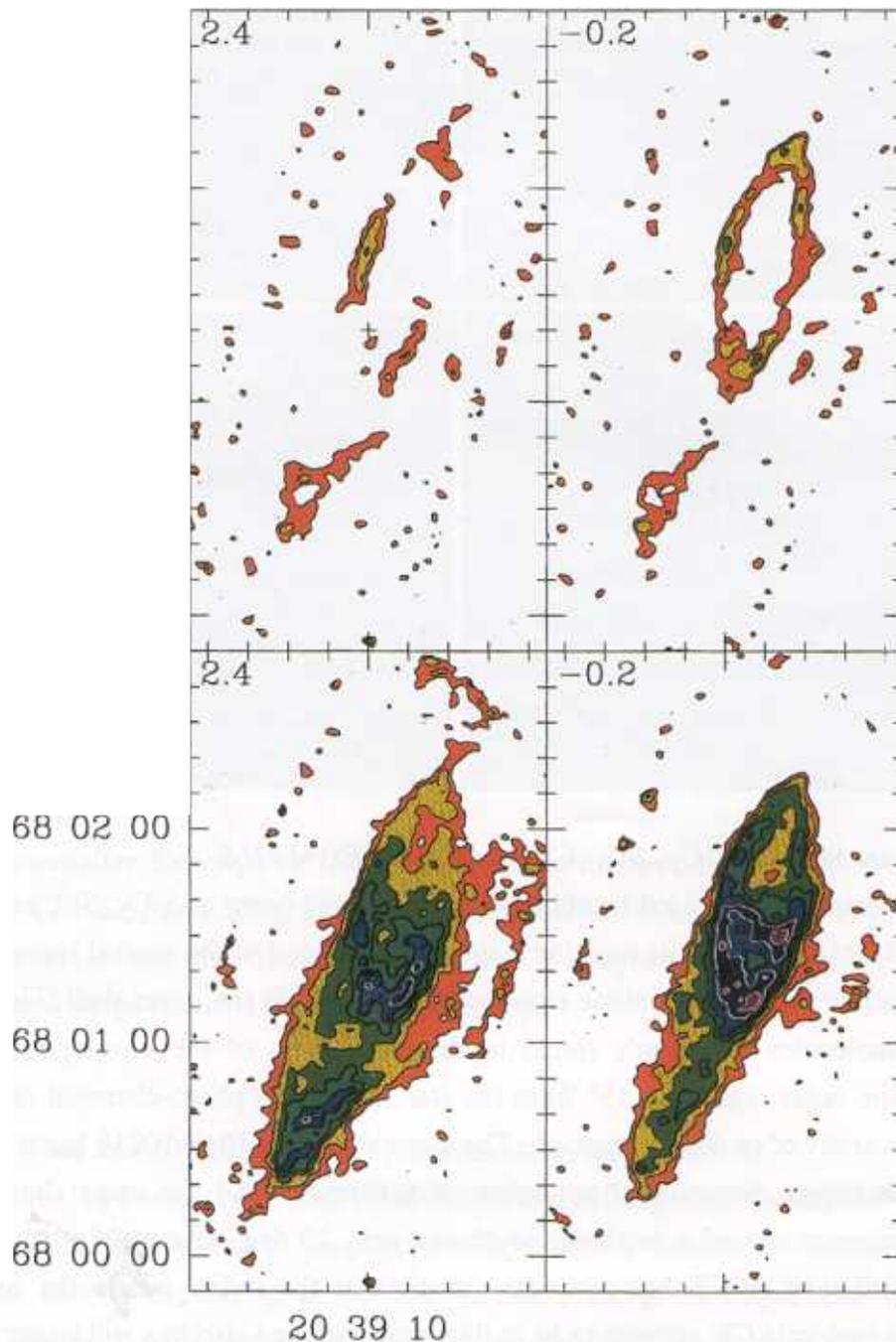


Fig. 2.8 : Outflow in L1157. Mosaic maps of CO(1-0) emission in the southern lobe of the outflow from a young stellar object in the dust cloud L1157. *Upper:* Data from the IRAM Interferometer, in two velocity channels, showing sharp shock fronts and the edges of the outflow cavity. *Lower:* Combination of data from the interferometer and the 30 m telescope, in the same velocity channels. The combined data show all of the CO flux from gas around the wind-blown cavity, extended over 2 arc min.

2.4 CIRCUMSTELLAR ENVELOPES

Rare isotopomers of MgNC and Possible Detection of ^{26}AlF in IRC+10216

The infrared source IRC+10216 is a famous evolved star whose circumstellar envelope has an extremely rich spectrum of molecular lines, many containing carbon atoms. About 50 molecules, including highly refractory compounds and highly reactive species have been identified in this dusty envelope. The IRAM interferometer had previously mapped IRC+10216 in the 3 mm line of the $^{24}\text{MgNC}$ radicals. Unlike the centrally peaked emission of NaCl, SiO, SiS, CS, and CO, the MgNC emission arises in an expanding shell of radius 15" (4.5×10^{16} cm). The 30 m telescope has now been used to detect the rare isotopomers $^{25}\text{MgNC}$ and $^{26}\text{MgNC}$. The derived ratios of $^{24}\text{Mg} : ^{25}\text{Mg} : ^{26}\text{Mg}$ are consistent with the solar system values of 79 : 10 : 11. In addition, a line has been detected at 234.433 GHz that may be the 7-6 transition of ^{26}AlF . If this identification is correct, it will be highly interesting, because ^{26}Al is radioactive with a half-life of 700,000 years. It is believed to be formed from pre-existing ^{25}Mg in the hydrogen-burning shell of Advanced Giant Branch stars more massive than 4 solar masses. The ratio implied by the observations, of $^{26}\text{Al} : ^{27}\text{Al} = 0.04$ in IRC+10216 implies that AGB stars might supply 0.9 solar masses of ^{26}Al to the interstellar medium of the whole Milky Way every million years, which is about the lifetime of the isotope. This is only about one-fifth the amount of ^{26}Al estimated to be in the Galaxy from observations of the 1.8 Mev gamma-ray line from ^{26}Al , so AGB stars like IRC+10216 may not be the main suppliers of ^{26}Al to the interstellar medium.

High-Sensitivity Maps of SiC_2 , SiS, CS, and CN in IRC+10216

The interferometer has been used to obtain maps with a 3" beam of SiC_2 , SiS, and CS in the envelope of IRC+10216. SiC_2 is found in a spherical shell and in the central region, indicating it is formed both in the inner envelope close to the star, and in the outer shell (Fig. 2.9). The SiS and CS molecules are mostly found in the inner parts of the envelope, but are still detectable in the outer region, at 15" from the star, where the photo-chemical reactions give rise to a wide variety of molecular species. The maps show that IRC+10216 has a very clumpy envelope, with strong departures from spherical symmetry. All the maps show molecular distributions oriented around a northeast-southwest axis, 20 degrees east of north. The radial brightness distribution of CS has secondary maxima at the radius where the SiC_2 shell is brightest. The molecule CN appears to be in this same shell and also in a still larger outer shell. This multiple shell structure is probably due to variations in the rate of mass loss from the star as a function of time.

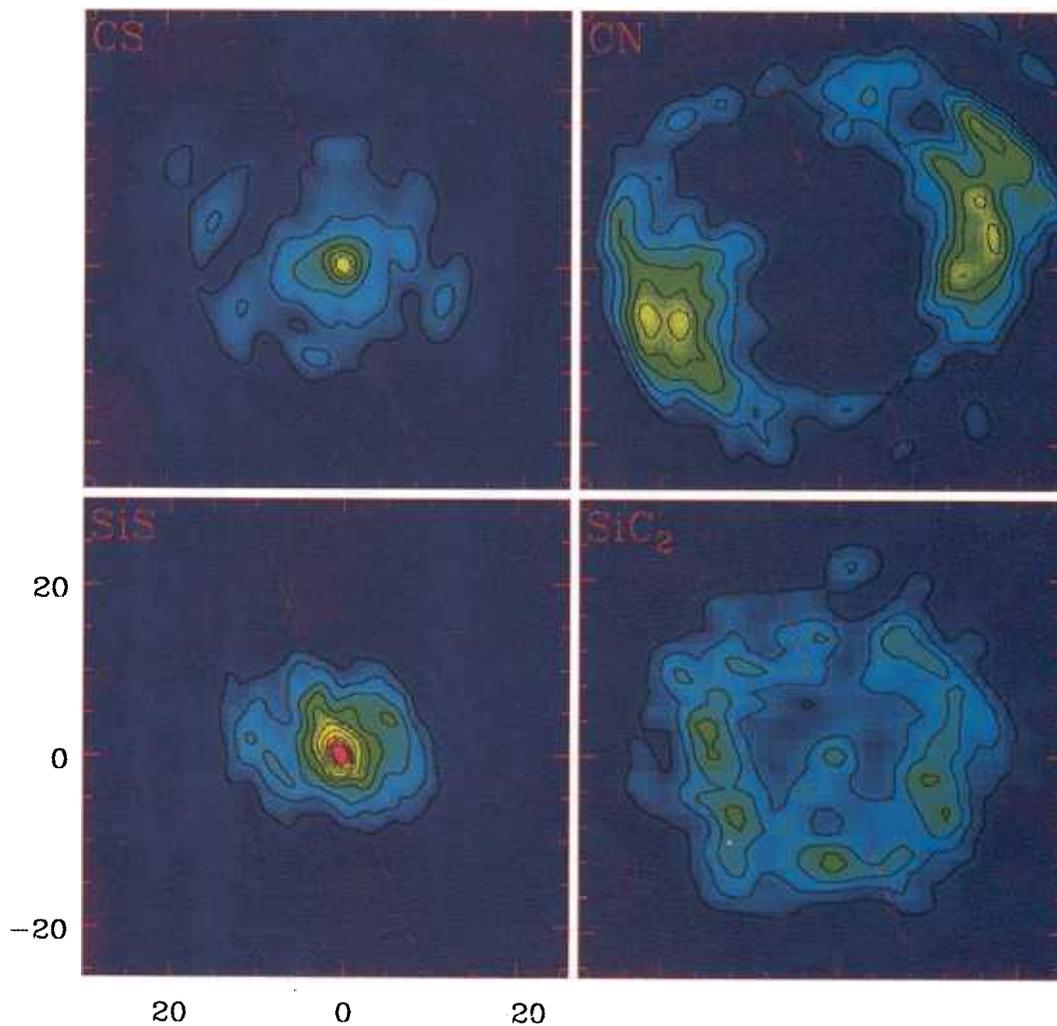


Fig. 2.9 : Circumstellar Envelope of IRC+10216. IRAM interferometer maps of IRC+10216 in lines of CS, CN, SiS, and SiC₂, averaged over velocities -28.5 to -21.5 km/s. Relative coordinates are in arcsec; the dashed line indicates the symmetry axis of the envelope. Synthesized beams range from 3.1" to 3.9" in these maps.

Interaction of Wind and Envelope in the Protoplanetary Nebula M1-92

The interferometer has been used to map the CO(1-0) line in the protoplanetary nebula M1-92. The CO maps (Fig.2.10) show a complex envelope with a central condensation and an elongated shell that is expanding at 60 and 10 km/s along its major and minor axes respectively. The post-AGB star has a 200 km/s bipolar outflow, seen in the optical, that interacts with the quiescent shell that the star had ejected when it was a red giant. The

morphology of the interaction region and the kinematic signature of the winds indicate a very efficient momentum transfer from the wind to the envelope.

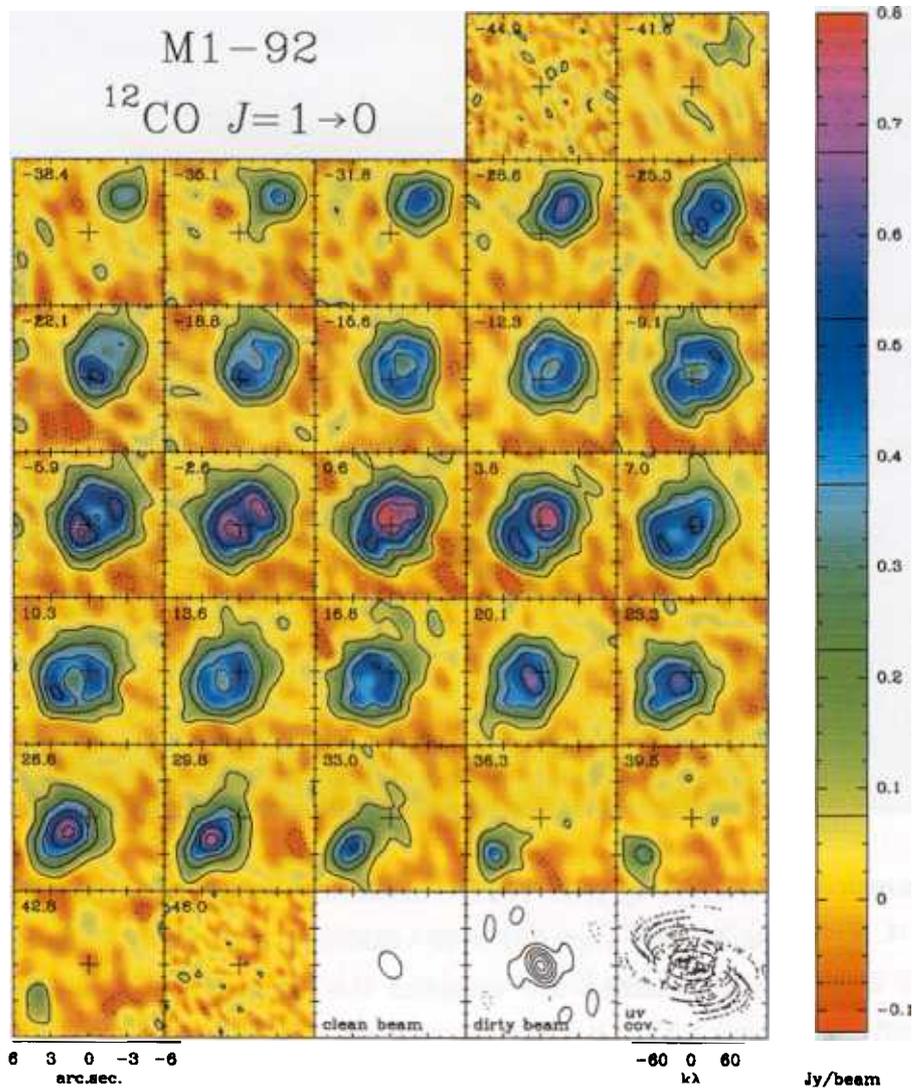


Fig. 2.10 : Molecular Gas around the Protoplanetary Nebula M1-92. CO(1-0) maps from the IRAM interferometer of the protoplanetary nebula M1-92. Labels in boxes are velocities, in km/s. The central star ejects a 200 km/s outflow to the SE and NW, that plows into the circumstellar envelope created when the star was still a red giant.

Observations of 6 cm and 2 mm Formaldehyde Line Absorption in Interstellar Clouds

Millimeter lines of molecules like CO, HCO⁺, HCN, and C₂H in diffuse clouds in our Galaxy can be detected in absorption against distant quasars, even when the visual extinction by dust along these lines of sight is only about 1 magnitude. All of these species can be formed in the gas phase in ion-molecule reactions. Formaldehyde, H₂CO, is a molecule that cannot be

formed in the gas phase at low densities, but may be formed on the surfaces of dust grains. The ortho form of H₂CO has been studied for many years at 4.8 GHz in dark clouds, where it is observed in absorption against the 2.76 K cosmic background. Usually in these clouds, the 2 mm lines are in emission. A new study has now been made of ortho and para formaldehyde, combining observations at 6 cm with the NRAO 43 m telescope with observations at 2 mm with the IRAM 30 m telescope. The lines are all observed in absorption against quasars. The 2 mm absorption lines show that the ortho/para ratio is 3 to 4, which favors the idea that the molecules are formed on the surfaces of dust grains at temperatures of 20 K or more. However, the number of formaldehyde molecules is about one percent of the number of ¹³CO molecules, which, as with other molecules observed in absorption against quasars, is far too high in these low-extinction clouds to be explained by any known process.

2.5 SOLAR SYSTEM

Carbon Monoxide Outgassing from Comet P/Schwassmann-Wachmann 1

The periodic comet Schwassmann-Wachmann 1 has a nearly circular orbit at 6 AU from the sun, slightly farther than the orbit of Jupiter. It frequently has strong outbursts for reasons which are still mysterious because the solar heating is too weak to sublimate water ice. Following the initial discovery of CO(2-1) at the JCMT, the CO(1-0) and (2-1) lines were observed with the 30 m telescope in comet P/Schwassmann-Wachmann 1 in May, July, September and October 1994. The spectra are dominated by a very narrow component with a width of 0.14 km/s. The temperature of the coma is about 10 K and the production rate of CO is 5×10^{28} molecules per second. The CO detections support the idea that the activity which had been known from optical observations is partly due to the sublimation of species like carbon monoxide that are more volatile than water ice.

A Radio Estimate for the Diameter of Chiron

Our solar system is believed to be surrounded by a large, flattened disk of planetesimals, beginning about 36 AU from the sun, beyond the orbit of Neptune. This is the Kuiper Disk, named after G. Kuiper, who suggested its existence in 1951. Objects in this disk can be perturbed by the giant planets to head into the inner solar system where they may evolve into short-period comets. One of these objects is Chiron, discovered in 1977. Like Schwassmann-Wachmann 1, the unusual object Chiron has a large size like an asteroid, but is also emitting gas into a variable coma, more like a comet. Radio continuum observations at the IRAM 30 m telescope have recently yielded a radio photometric radius of 84 ± 10 km, about half of the

published upper limits for this object. Chiron will be at its closest approach to the sun (8.5 AU) in February 1996, offering an opportunity to study the raw material from which the solar system was made. It will also be of interest to try to detect CO and other volatile species in Chiron and other Chiron-type objects: Hidalgo, Pholus, 1993 HA₂, 1994 TA, 1992AD, 1992 QB1, ...

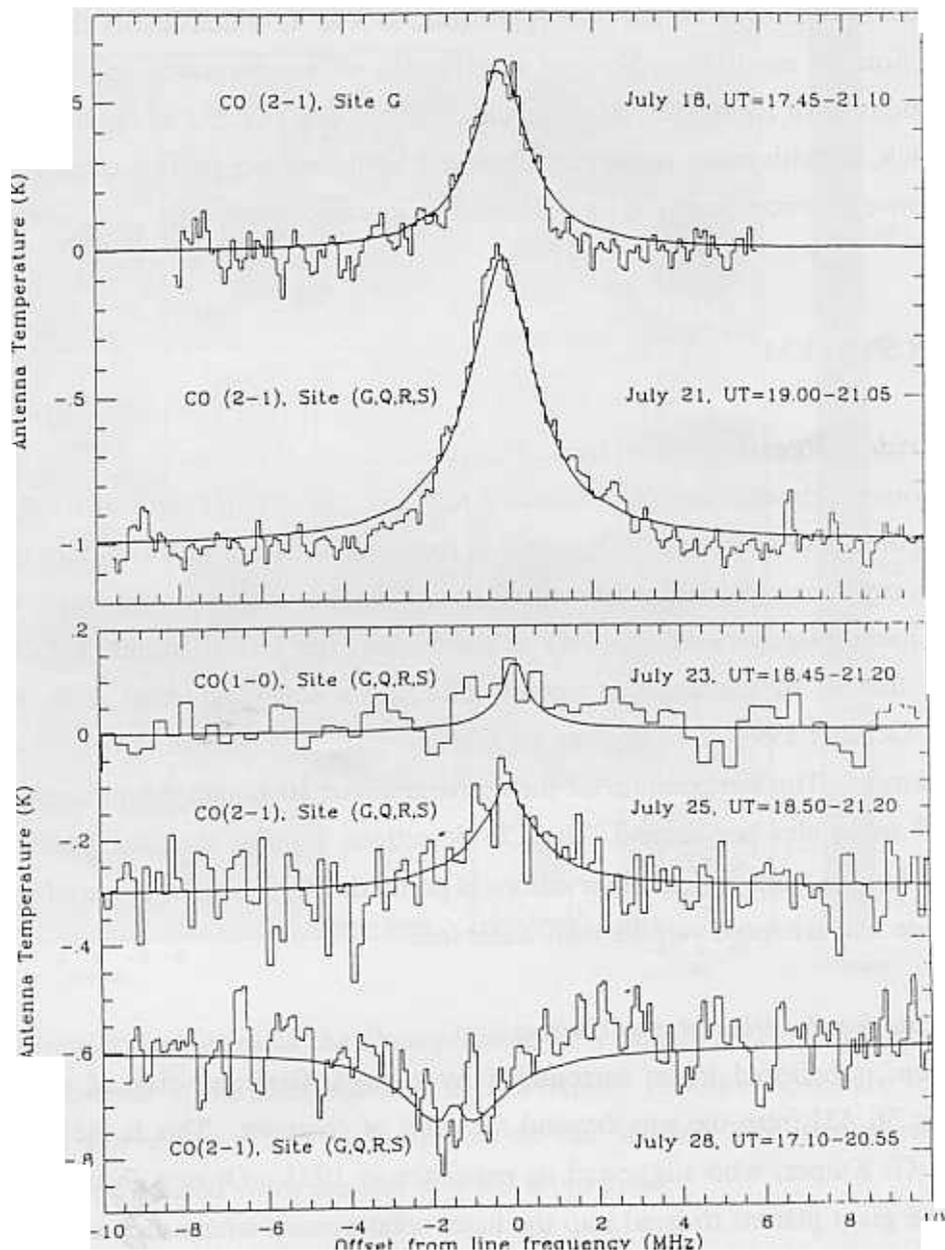


Fig. 2.11 : CO at the Comet Shoemaker-Levy Impact Sites on Jupiter. Evolution with time of the CO lines from some of the impact sites of Comet Shoemaker-Levy on Jupiter, from data obtained at the 30 m telescope.

Chemical Effects in Jupiter's Atmosphere after Impacts from Comet Shoemaker-Levy.

The collision of the fragments of comet P/Shoemaker-Levy 9 on July 16-22, 1994, made large changes in the chemical composition and temperature of the Jovian atmosphere in the impact regions, that persisted for weeks afterward. Observations at the 30 m telescope gave strong detections of the lines of carbon monoxide (CO), carbon monosulfide (CS) and carbonyl sulfide (OCS). The strengths of these lines were unusual, because CO normally has a very low abundance in Jupiter's atmosphere, and CS and OCS had never been detected prior to the comet impacts. The largest fragments (G and K) produced 1×10^{14} g of CO, 3×10^{12} g of OCS, and 3×10^{11} g of CS, most likely through impact-induced shock chemistry.

3. PICO VELETA OBSERVATORY

STAFF CHANGES

The year 1994 saw a significant number of staff changes, mostly in the receiver and astronomy groups. In total, 4 staff members left, and 5 new members joined the Granada group. This required a special effort in training in order to maintain the level of telescope support.

In the astronomy group one post-doc returned to his former institute, and one cooperant finished his term. A resident astronomer, filling the vacant position of a senior astronomer, and a post-doc joined the group. In addition, the CNRS has temporarily allocated an astronomer's position at IRAM-Granada, and this was filled, too.

The head of the receiver group, H.Hein, has been delegated for a period of two years to the Heinrich-Hertz-Telescope (H.H.T.) in Arizona to support the commissioning work. S.Navarro is replacing him as acting head of the receiver group, J.Penalver replaces him as the responsible safety engineer. In addition, a receiver engineer from the Centro Astronomico de Yebes (CAY) has been transferred to the Granada group. A further change in the receiver group concerned a cooperant.

30-m TELESCOPE OPERATION

The operation of the telescope was smooth throughout 1994. The telescope was regularly maintained for about 13 hours per week, including receiver filling, receiver maintenance, test tunings, telescope, computer and backend maintenance. In addition, several periods of technical time were used for larger tasks of improving the telescope, replacing and repairing equipment, and carrying out software and hardware tests. These activities included installation and tests of receivers (345 GHz receiver, MPIfR 7-channel and 19-channel bolometers), the preparation of 3 mm VLBI runs, VLBI tests at 1.3 mm, holography measurements, telescope surface adjustment, frequency switching tests, and the investigation of a suspected subreflector misalignment. Almost all necessary ad-hoc repairs could be carried out during the scheduled maintenance and technical time.

Figure 3.1 shows how the telescope was used during the year 1994. The statistics are based on entries made by the telescope operators.

For the majority of the astronomical projects, we were able to make receiver tunings well in advance of the actual observation. The constant presence of a receiver engineer at the site

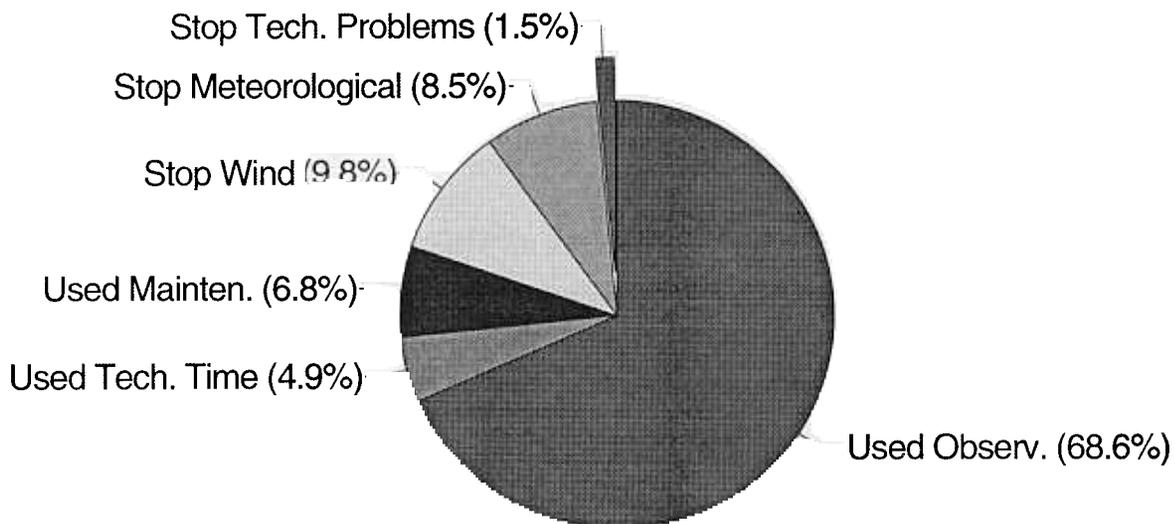


Fig. 3.1 : Distribution of telescope time for the year 1994.

helped a lot towards the smooth receiver operation. The Granada astronomers provided throughout the year assistance and help to the visiting astronomers, taking care also of pointing and calibration measurements, as well as service observing for short projects. The mount of the absorber ring around the subreflector has been improved such that the absorber can be installed and removed quickly. The absorber ring is needed for holography measurements, and is taken off during bolometer observations.

A problem with the Doppler correction of the sky frequency was identified and corrected. This shift could only be observed due to the very high spectral resolution provided by the autocorrelator.

Since April 1994, the wind velocity is recorded every second, following a recommendation from an expert on wind effects. The conclusion is, after eight months of data recording, that the maximum wind velocities were about 40 m/s. Extrapolation of the wind distribution profile shows that wind speeds as high as 60 m/s (as occurred in November 1989) are statistically very unlikely.

All telescope servo motors (some of which have caused problems for various reasons) have now been exchanged by new or modified motors according to the velocity specifications of the antenna. This allows slewing the telescope with the maximum operational speed (which was reduced because of motor failures in the year 1993).

The pointing parameters of the telescope have been regularly updated. We normally achieve an accuracy of 2 - 3" .

3.3 VLBI

In November and December, VLBI experiments at 3 mm and 1.3 mm between the 30m telescope and one antenna of the PdB interferometer were executed in a collaborative effort between IRAM, MPIfR, CAY, and the Bordeaux Observatory. The first attempt in November focussed on 3 mm observations in order to verify the equipment after attempts to correlate data collected in December 1993/January 1994 between Pico Veleta and Effelsberg had failed. Fringes at 3mm were found from several sources, in several cases with an unprecedented high signal-to-noise ratio. In December, a combined 3mm and 1.3 mm experiment was carried out which yielded for the first time ever fringes at 1.3mm with a $S/N > 7$ on three different sources.

3.4 INFRASTRUCTURE

After 13 years of use, the access road from Borreguiles to the telescope has been renewed. The road was repaired and newly paved along the whole length (2.5 km). Fig. 3.2 shows the road under repair.

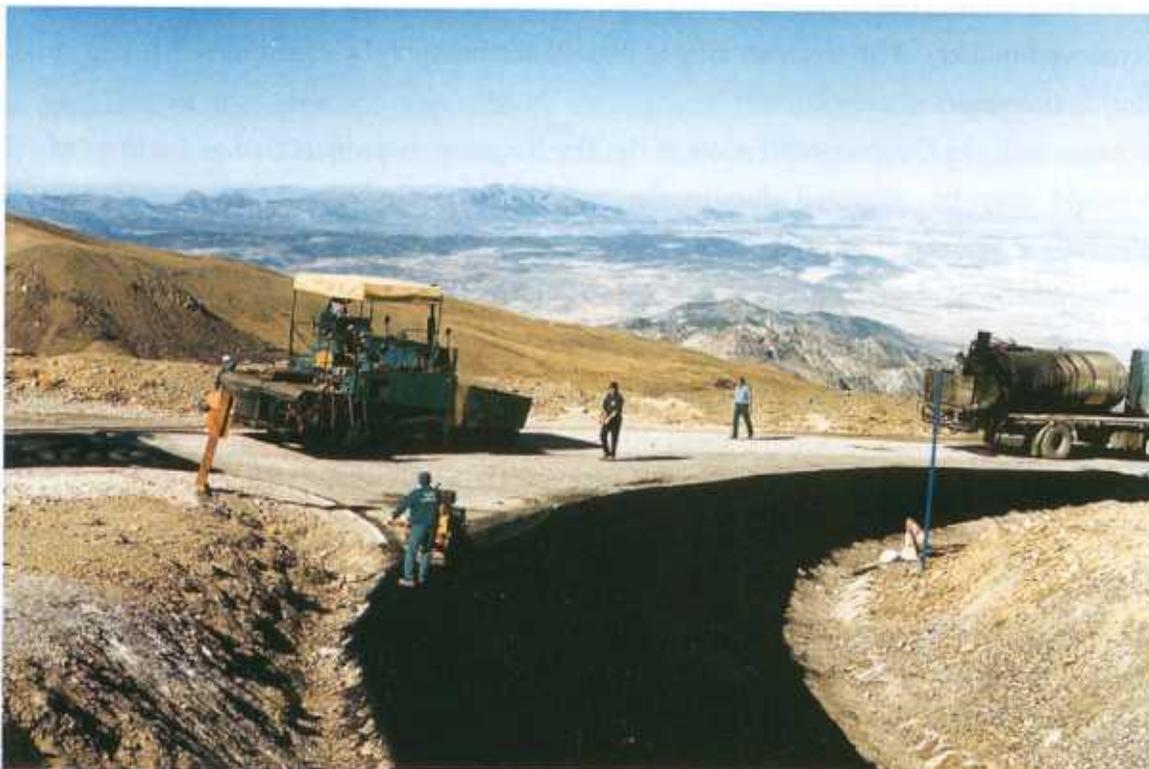


Fig. 3.2 : Repair and pavement of the access road to the telescope

The radiocommunication system has been exchanged at the telescope, the Granada office, and the IRAM cars. Additionally, a relay station has been installed at Pico Cerrajon, between Granada and Pico Veleta. The new radios together with the relay station guarantee a coverage of about 50 km radius and almost no shading zones. In the past, shading has been a problem due to the (by law) limited power of the radios and the mountain environment.

A new telephone system has been installed in the Granada office. The rooms of the residencia are now also equipped with telephones.

The hydraulic system for the platform has been improved with the installation of additional filters, valves, and new pump.

The electricity consumption has decreased by 13% as compared to the average of the years 1986 to 1993 (see Fig. 3.3). The major reasons are the favourable weather conditions throughout the year, and the installation of a heat exchanger and air drying system for the wobbler (which avoids the use of the deicing system for the wobbler during the winter).

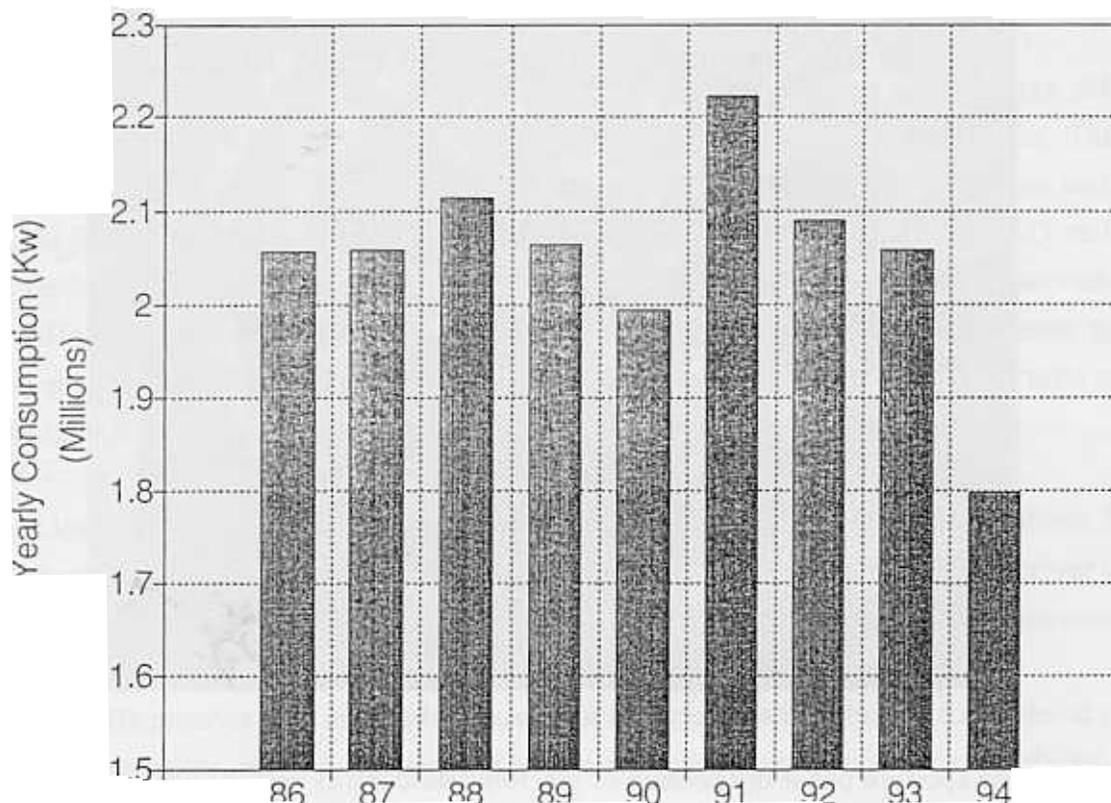


Fig. 3.3 : Yearly electricity consumption at the 30m telescope for the years 1986 to 1994. A reset of the antenna climatization system is now possible without stopping the observations.

3.5 REFLECTOR SURFACE

Test measurements in 1993 had revealed that a rotation of the subreflector about the optical axis of the telescope (so-called "polarization angle") introduced a significant pointing error. The most straightforward interpretation was a tilt of the subreflector mount. However, careful measurements using mechanical means as well as a laser, and subsequent analysis (optical modelling of the telescope) in 1994, showed that the pointing errors were not due to a misalignment of the secondary but were instead caused by a wrong setting of software parameters which were written into the system many years ago.

In March, a non-optimum lateral positioning of the subreflector was detected during antenna test measurements. The position was corrected, and periodically repeated measurements guarantee the optimum position.

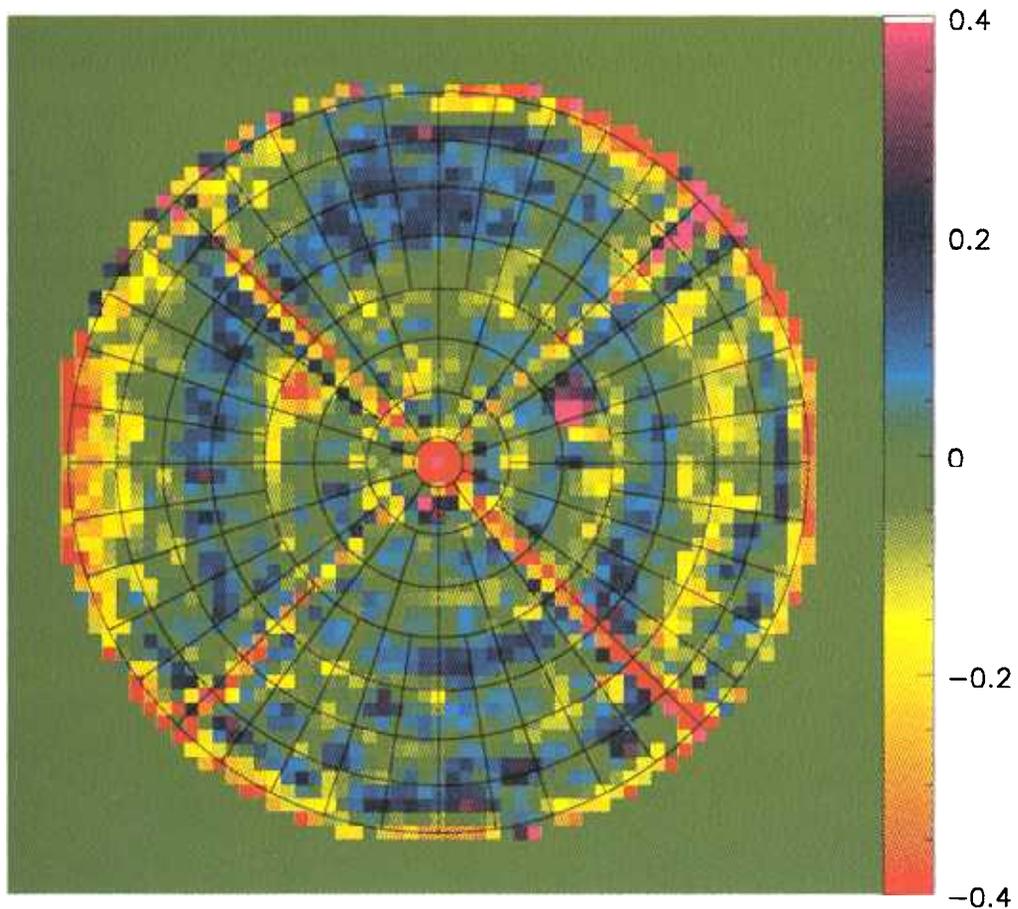


Fig. 3.4 : The aperture phase distribution of the 30m telescope as derived from the November 1994 holographic measurement. The colour scale covers the range ± 0.4 radians ($\pm 240 \mu\text{m}$). A displaced test panel can be seen in the top right hand quadrant.

A surface adjustment was made in July 1994. Subsequent holographic measurements made in November 1994 at 39 GHz, using the geostationary satellite ITALSAT, showed that the nighttime astigmatism is now less than 50 μm peak deflection and makes a negligible contribution to the surface error budget. The overall rms surface accuracy remains unchanged at 70 μm . The surface adjustments of December 1993 and July 1994, together with the recentering of the subreflector in March 1994, have improved the aperture efficiency at 1.3 mm wavelength from about 28 % to 35 %.

3.6 RECEIVERS

In July, the mixer of the 3mm SIS receiver was replaced. The stability has been improved substantially, and the image sideband rejection has increased up to 25 dB or higher. This solves basically the calibration problem at an observing frequency of 115 GHz where a strong oxygen line falls in the upper sideband. The reproducibility of the mixer backshort position is good.

The LO coupler of the 3 mm Schottky receiver was repaired. The receiver can be tuned again and used in the low frequency part of the band. However, due to the improvement of the 3mm SIS receiver stability the Schottky receiver is no longer used as the main pointing receiver.

The mixer in the 230G2 receiver was replaced. It can be tuned to higher image sideband rejections than previously without a significant decrease of receiver performance. The cold HEMT amplifier was replaced by one which has 1 GHz bandwidth. This will allow wideband spectral line observations when the new second down converter is ready. The LO multiplier was replaced by one which also covers the high end of the 1.3 mm band. Observations at 267 GHz are now possible. During the last months the stability of the 230G2 receiver seemed to be slowly degrading and some oscillations in the IF band were found. More tests will be carried out in order to determine the reasons for this degradation.

The 230G1 receiver has been working smoothly during the year until a problem in the backshort drive arose in December. The backshort drive has been fixed and the receiver is now fully operational again. Unfortunately, occasional stability problems can disturb observations.

The 345 GHz receiver was installed and used for observations in February for a period of two weeks. The receiver, using a tunerless mixer, provided very good sensitivity and stability.

A second position for a multi-channel bolometer was made available. The sizes of two mirrors used for the bolometers and the 7 mm receiver were increased to match the field covered by the 19- and the future 37-channel bolometer arrays. For continuum observations, the IRAM

bolometer IBOL-B and later the MPIfR 7-channel bolometer were installed and used for observations on the new position. A rotating mirror switches between the two bolometer positions.

An environmental test of the MPIfR 19-channel bolometer was performed in December 1994 in preparation of the winter observing session.

A polarimeter, consisting of a lambda-quarter dielectric plate switching between two angles, was successfully tested and later used for measurements of the Zeeman effect.

The beam switching chopper has been mounted on a hydraulic system. The chopper can be moved upwards out of the beam easily. The fourth elliptical mirror can now be rotated easier and in much shorter time. This allows faster switching between spectral line and bolometer/holography observations.

Work on the new remote control system for the 30m telescope receivers was transferred to Granada in May 1994.

The Granada receiver staff continued work on a second 3 mm SIS receiver. Unfortunately, the cryostat had to be shipped back to the manufacturer due to a leak in the safety valve.

The calibration flip mirror was replaced by a bigger refocussing elliptical mirror. The spillover losses during the calibration phases are consequently reduced.

The optical design study for the future 37-channel bolometer array has been finished. A final report has been distributed.

The use of frequency switching as an observing mode was tested and improved in several test periods. The results, especially baseline quality, look very promising. A test report is in preparation. In a first step, frequency switching using two receivers will be offered for routine observations. This is expected for early 1995. In a second step, three or four receivers could be switched simultaneously. The hardware for switching four receivers is prepared.

A system supervising the correct frequency settings of the LO synthesizers has been designed, built and installed by the Granada staff. The system allows detection of frequency shifts immediately and avoids loss of observing time.

Following extensive tests, five synthesizers were purchased to replace the old Adret synthesizers (which were failing at an increasing rate) as the first reference in the LO chain.

3.7 BACKENDS

Apart from routine activities (maintenance, repair), work in 1994 has focussed on transforming the two 1 MHz filterbanks (512 MHz bandwidth each) into a flexible system which allows 4 x 256 MHz, i.e. a total bandwidth of 1 GHz. Two units for the 1 GHz filterbank processor were built, calibrated, and first tested on the telescope in December. The processor allows use of the 1 MHz filterbanks as individual units (e.g. 4 x 256 MHz bandwidth), or combinations (e.g. 256 MHz + 768 MHz), or in "series mode" (1 GHz bandwidth). Some software modifications are still required before all options can actually be used for observations.

In a preventive maintenance the 1024 channels of the 1 MHz filterbanks were readjusted, all the VF boards were modified, and the 1024 offsets were newly trimmed.

The front panel of the autocorrelator was partly rewired with semirigid cable in order to prevent wrong connections after tests and board exchanges.

An "artificial pulsar" was built as a test source for a pulsar observation experiment. Preliminary tests of a high-speed sampling setup were made.

3.8 COMPUTERS

The backend software for control of the continuum backend was rewritten. The new version is prepared to handle a large number of channels and uses longer buffers for intermediate data storage. It also provides more means for the on-line monitoring of the data recording.

In cooperation with Albrecht Sievers from the astronomer's group, the OBS and RED program were modified. The new versions write important data into global areas which can be monitored from other terminals. In the receiver cabin, the engineer has now access to the receiver temperatures, the general antenna status, and other parameters.

In January, a Vaxstation 4000/60 was installed at the telescope increasing the computing power by a factor of two. A second Vaxstation 3200 was installed and is available as an immediate backup of the antenna control computer in case of failure. New X-terminals (NCD) with large color screens were installed.

The radio link between Granada and the observatory at Pico Veleta failed due to a hardware problem, and it took two months to get it repaired (mainly because the manufacturer does not exist any more). During this period a modem at 9600 Baud replaced the link. Later in the year, the speed of the modem connection was increased to 19200 baud.

Routers were installed in the Granada office and at the observatory. The radio link is now connected directly to these routers. This opens the possibility to connect telescope computers directly to Internet. This is foreseen for early 1995.

The link to Internet failed several times during the year due to various reasons (breakdown of point-to-point telephone link, routing problems in the University of Granada, etc.). The installation at the University of Granada has been improved and should provide higher availability in the future.

For our Internet domain we installed our own name-server (a PC with the Linux operating system). The Granada computers now form the domain "iram.es" (before they were part of the University of Granada domain "ugr.es").

Electronic mail addresses are as before: <user>@iram.es .

The MOSAIC program is available on the Vax and under Linux, giving access to World Wide Web. However, the Internet link to the University of Granada works currently at a speed of 9600 Baud (which is very slow for Mosaic). Tests with a 64 kBaud ISDN link are going on.

3.9 SAFETY

Fire alarm signals with sounding horns have been installed in five additional points in the telescope control building and the antenna. A fire alarm will now be noticed at any place in the observatory.

Smoke sensors have been installed in all the bedrooms both in the Granada residencia and the observatory. A fire extinguishing training course has been given by the Granada fire brigade to the IRAM staff.

At the telescope, a radio tuned to the frequencies used by the skiing company CETURSA is now available. This guarantees a 24 hour contact with the CETURSA personnel-on-duty during the winter period for medical assistance, emergency transport etc.. The telescope operators have received updated instructions what to do and whom to contact in the case of an emergency.

3.10 ADMINISTRATION - ACCOMODATION - TRANSPORT

As in the years before, the Granada office handled the transport and accomodation (and many special wishes) of approximately 250 visitors.

4. PLATEAU DE BURE OBSERVATORY

4.1 INTERFEROMETER STATUS

One of the major new activities in 1994 was the baseline extension started during the summer which will eventually lead to the addition of four new stations: W20, W23, W27 and N29. These stations improve the resolution by about 50 %, bringing the longest baseline from 288 m to 408 m. They will also allow more symmetric UV coverage for the standard "high resolution" mode (baselines up to 280 m). Because of weather conditions during the fall, only stations W20 and W23 were completed.



Fig.4.1: Work on the E-W track extension from 288m to 408m, including the new stations W20, W23, and W29

A second important step was the successful installation of the first dual-frequency receiver system on antenna 4 during the summer. This receiver not only opens the 1.3 mm window, but also brings a very significant sensitivity improvement at 115 GHz. The 1.3 mm system was used successfully in a mm VLBI experiment with the 30-m telescope on Pico Veleta.

4.2 OBSERVING PROJECTS

In 1994, the Plateau de Bure interferometer has fully completed 56 projects, among which 16 had been started earlier and 40 were new projects. The comparison of this number with the total of 75 projects completed during the previous 3 years (i.e. since 1991) shows the very important improvement brought by the fourth antenna.

The repartition of the 56 projects per affiliation of the First Author is the following :

Country	By First Authors
IRAM	16
Germany	11
France	14
Spain	9
USA.	5
Other	1

Per category of projects, the repartition is:

Category of Projects	
Star Formation, PMS	10
Circumstellar Envelopes	8
Galaxies	24
Molecular Clouds	11
Solar Systems	2
Others	1

As compared to previous statistics, we should note the increase of time devoted to extragalactic studies. This is due to the better imaging capabilities provided near 115 GHz, specially mosaicing capabilities, but also to searches for CO in high-redshift objects.

4.3 DATA ANALYSIS

One major step in the evolution of the CLIC program has been the complete implementation of antenna based calibration capabilities. This proves extremely useful for projects which have relatively weak phase calibrators, as is often the case near 115 GHz.

A second improvement for users is the availability of a deconvolution technique for mosaics, and of an efficient way to incorporate short spacing data from the 30-m. It should be pointed out that these new facilities are the result of a collaboration with F. Viallefond in Meudon, and were part of the PhD thesis of F. Gueth.

These facilities are now released as standard part of the Gildas package. The exportability of this software was improved, and more platforms are now supported. Among these, two deserve special mention : Alpha machines under OSF-1, and PCs under LinUX.

5. GRENOBLE HEADQUARTERS

5.1 SIS GROUP AND RECEIVER GROUP ACTIVITIES

General

Thomas Lehnert followed an invitation to spend two months with the SIS group at the Nobeyama Radio Observatory in Japan to develop double-barrier Nb junctions for a 100 GHz receiver. Berk Plathner accepted a one-month invitation to the Electrotechnical Laboratory in Tsukuba, Japan where he worked on NbN junctions.

An international seminar on Terahertz Electronics in Lille, France, was jointly organised by IEMN, ENS, DEMIRM and IRAM.

Junction Fabrication

100 GHz

A further set of junctions without integrated tuning circuit was produced.

150 GHz

New junctions, for the first time with integrated tuning circuits, were fabricated.

230 GHz

Further sets of devices with areas of 2 μm^2 and 1 μm^2 were prepared.

350 GHz and Higher Frequencies

350 and 460 GHz waveguide mixer elements were fabricated for the MPIfR and new versions of 350, 460 and 690 GHz mixer chips with dipole antennas for the MPE.

690 GHz junctions integrated in a V-antenna and tuning circuit were made for a receiver built by the MPE for the JCMT. These were the first SIS devices successfully used in a radio-telescope at 690 GHz.

5.1.3 Junction Fabrication by Visitors

A member of the MPIfR in Bonn fabricated Nb-mixer elements with Al slot antenna for 810 GHz. Another member of the same institute was trained to fabricate 460 GHz mixer elements for the SMT.

5.1.4 Junction Development and Related Activities

Scanning Electron Beam Microscope

With the help of this microscope, installed in 1993, various process steps (including junction definition by positive and negative photoresist, reactive ion etching and lift-off) have been investigated, and first process improvements have been introduced.

First stencils using electron beam lithography have been made.

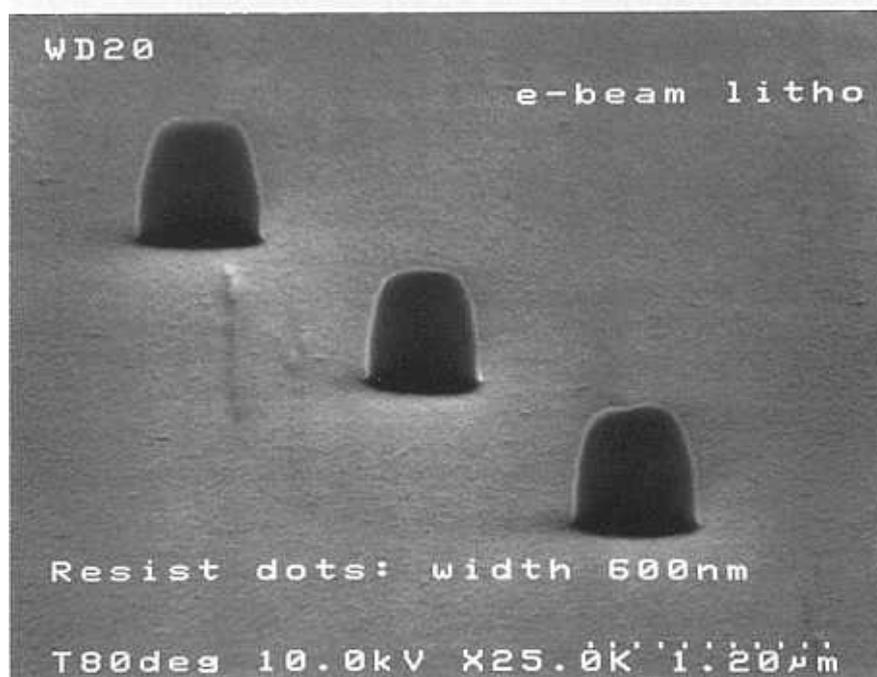


Fig.5.1: Sub-micron resist stencils for junction definition made by electron beam lithography.

Nb Junctions Sandwiched between Al Films

Theoretically Nb junctions should work up to about 1.4 THz, but the Nb embedding circuit only up to about 700 GHz. To increase the latter frequency limit one can try NbN or even a normal metal such as Al for the embedding circuit. A fabrication process has been developed to integrate submicron Nb junctions in an Al antenna and tuning circuit designed for 810 GHz.

Small Nb Junctions

To investigate the limit of optical lithography, Nb junctions defined by crossing resist lines 0.4 µm wide were made and showed good current-voltage characteristics.

Nb Junctions with AlN Tunnel Barriers

Nb junctions generally have Al_2O_3 barriers. For high current densities ($> 10\text{-}20 \text{ kA/cm}^2$) AlN barriers appear to be more suitable. Nb-AlN-Nb junctions have been prepared and an investigation has been started with promising first results.

SIN Junctions

These devices carry no Josephson currents and could therefore be of interest for multi-beam receivers above about 250 - 300 GHz and for harmonic mixers. A new type of Nb-AlOxide-Al junctions with integrated tuning circuit of Nb was made and for the first time successfully tested around 300 GHz (see below).

NbN Junctions

Appropriate sets of sputter parameters for the NbN electrodes and the MgO tunnel barrier were found to obtain NbN-MgO-NbN junctions of good quality and a gap voltage $2 \Delta/e$ close to 5mV which corresponds to a gap frequency $f_g = 1.2 \text{ THz}$ (for Nb, with $2 \Delta/e = 2.8 \text{ mV}$, $f_g = 670 \text{ GHz}$). The next important step for sub-millimeter mixers is to increase the current density from presently 2 to 10 - 20 kA/cm^2 .

For the optimization of the sputter parameters, the surface roughness of NbN films was investigated in collaboration with the University of Cologne and the Forschungszentrum Jülich; X-ray diffraction measurements were made in LETI, Grenoble.

The radio frequency losses of NbN films are an important issue. As a first step measurements have been made in collaboration with the Universities of Cologne and Wuppertal at 90 GHz. The results are in reasonable agreement with theory.

New Equipment

A new dicing machine was installed. The sputter system used for SiO_2 as well as for Cr/Au films was extended to have a load lock and the possibility of bias sputtering. To avoid cross-contamination, an old sputter system was rebuilt and is now in use for Cr/Au films.

5.2 NEW RECEIVERS AND UPGRADES AT THE TELESCOPES

5.2.1 General

As in past years the Receiver Group has been occupied both with new developments and maintenance of existing systems. Timely intervention to remedy cryogenic, LO, or other problems has minimised the time lost due to receiver failures. The group in Grenoble has fully supported the Plateau de Bure Interferometer, as well as assisting the Granada team with its

support of the 30-m telescope. As the age of some of the existing cryogenic systems approaches 10 years, maintenance and repair can be expected to be an increasingly necessary activity.

Numerous items have been provided for the telescopes including circular polarisers for VLBI observations at 86 GHz and 215 GHz at Plateau de Bure and Pico Veleta. A circular polarisation analyser, comprising a dielectric quarter-wave plate and rotation mechanism, was constructed for the 30-m for Zeeman-splitting observations.

Naturally, the Group's activities have required the close collaboration with other groups within IRAM, including the SIS Group (junction fabrication), the Computer Group (software and hardware for the remote control; general computing support), the Backend Group (LO reference sources), the Machine Shop (fabrication and ordering of components), as well as the Staff Astronomers for qualification of receivers and useful advice.

5.2.2 Receiver Developments

Dual-Channel Receivers for Plateau de Bure

The new dual-channel receiver uses an Infrared Laboratories hybrid dewar and has one channel for 86-116 GHz, and a second for 210-245 GHz that may be operated simultaneously. (See the 1993 Annual Report for a more detailed description.) Final details of construction, testing and revision of the first dual-channel receiver were carried out in 1994. This included verification of the VME-based remote control, alignment of the optics, and performance evaluation over the λ 3 mm and λ 1 mm bands. Automatic tuning algorithms were successfully implemented to make frequency changes simple and rapid. Fig. 5.2 shows the receiver noise temperatures measured in the laboratory and on the antenna. The antenna tunings were completely under computer control.

This receiver was installed in antenna No. 4 in August and has been operational since then. Performance at λ 3 mm exceeds that of the Mk-III receivers that it supersedes. Few data are available yet on the operation of the λ 1 mm channel since interferometric observations cannot yet be made. However its use for detection of fringes in VLBI already shows its essential functionality.

Following the success of the receiver it was decided to build three more to furnish the existing antennas with λ 1 mm capability quickly, and allow sufficient time to fully develop the new receivers based on closed-cycle refrigerators. Despite delays in delivery of two new hybrid dewars and repair of a leak in an existing one, more than 60 % of the construction and testing

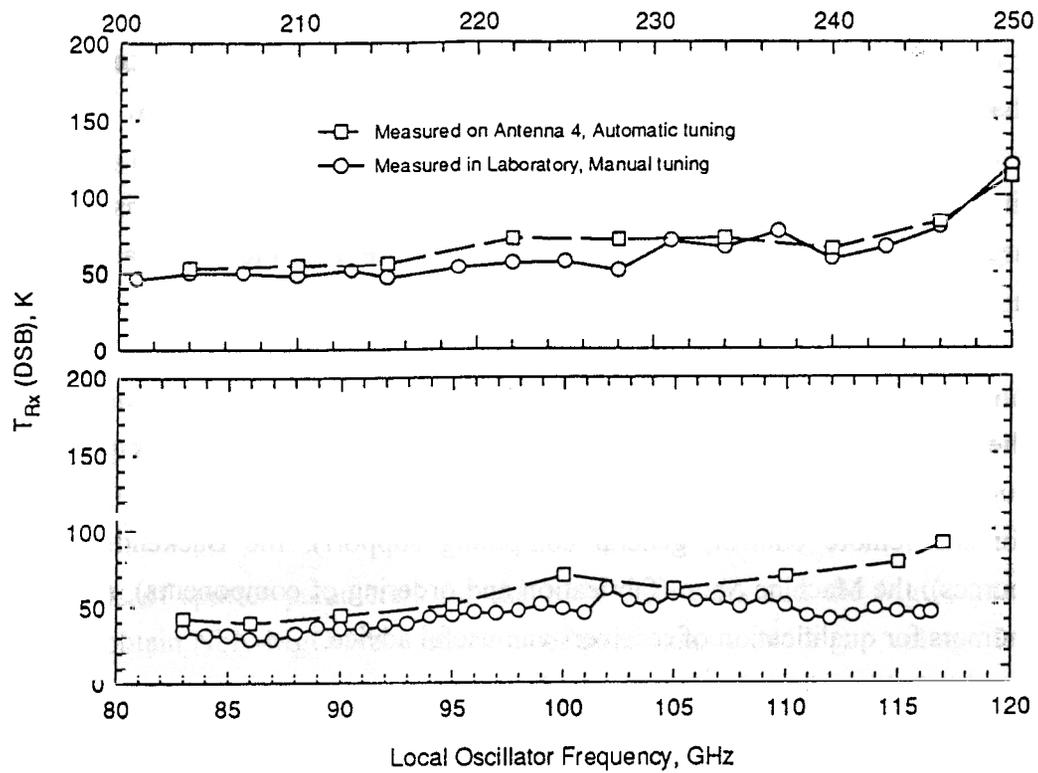


Fig. 5.2: Noise temperatures for the first 2-channel receiver on the PdBI

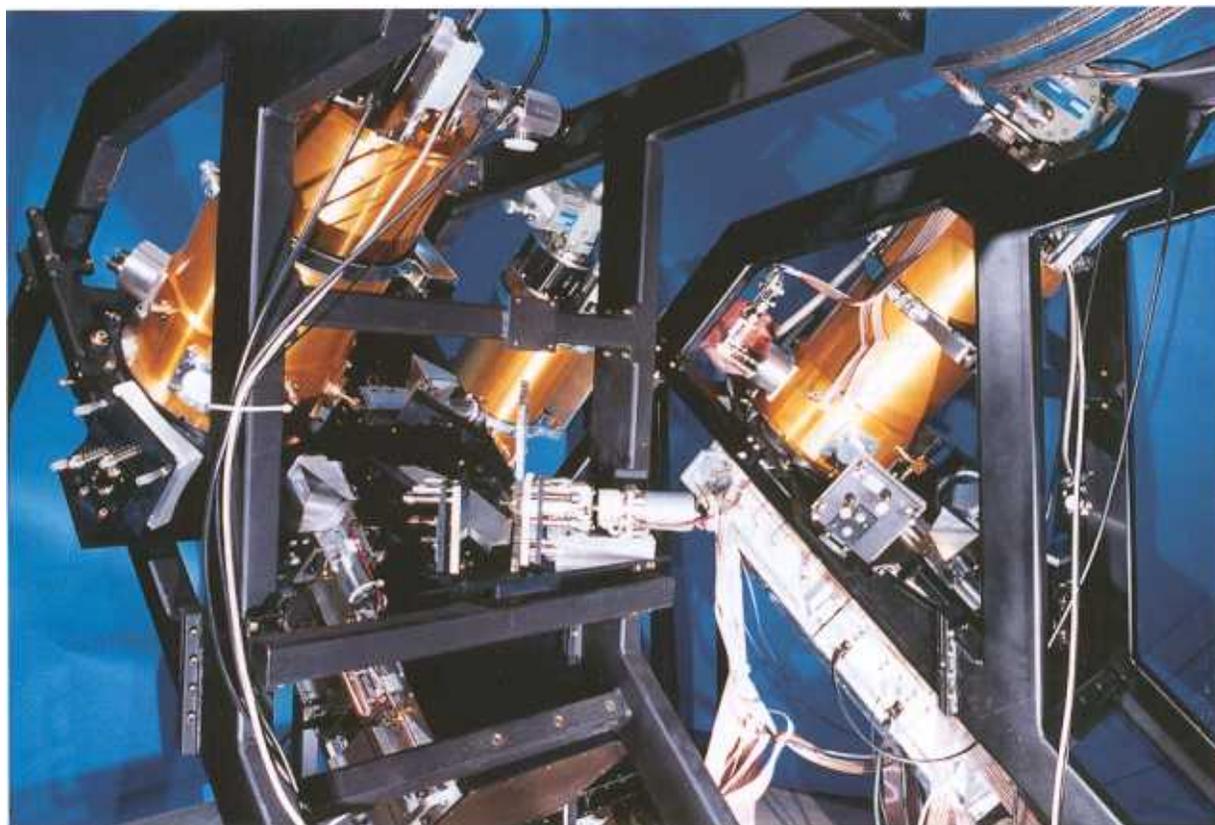


Fig. 5.3: View of 3 of the dual-channel receivers under construction. One of the systems is equipped with a beam switching chopper.

of the three new systems had been carried out by the end of 1994. Fig. 5.3 shows these three systems at various stages of construction. Installation is expected in the first quarter of 1995.

λ 0.8 mm GHz Receiver For Pico Veleta

Further progress in the λ 0.8 mm band receiver for Pico Veleta yielded significant improvements in the performance. The new fixed-tuned SIS mixer (Fig.5.4) operates over a band from 300-360 GHz, with the LO coupled in through a cooled waveguide coupler (although the current LO limited operation to 320-360 GHz). It was installed for two weeks in February with the receiver noise temperature shown in Fig. 5.5. Losses in the optics between the dewar and the telescope reference plane (wide angle sidelobes, ohmic losses, *etc.*) are 7-10 % and so add 20 to 30 K to the DSB noise temperature. The lowest noise temperature measured at the dewar window is about 30K, or about $2h\nu/k$, making it the most sensitive receiver in this band on any telescope. The best SSB noise temperature was $T_{SYS} = 500$ K at 300 GHz for a zenith opacity of 0.17 and an elevation of $\sim 45^\circ$.

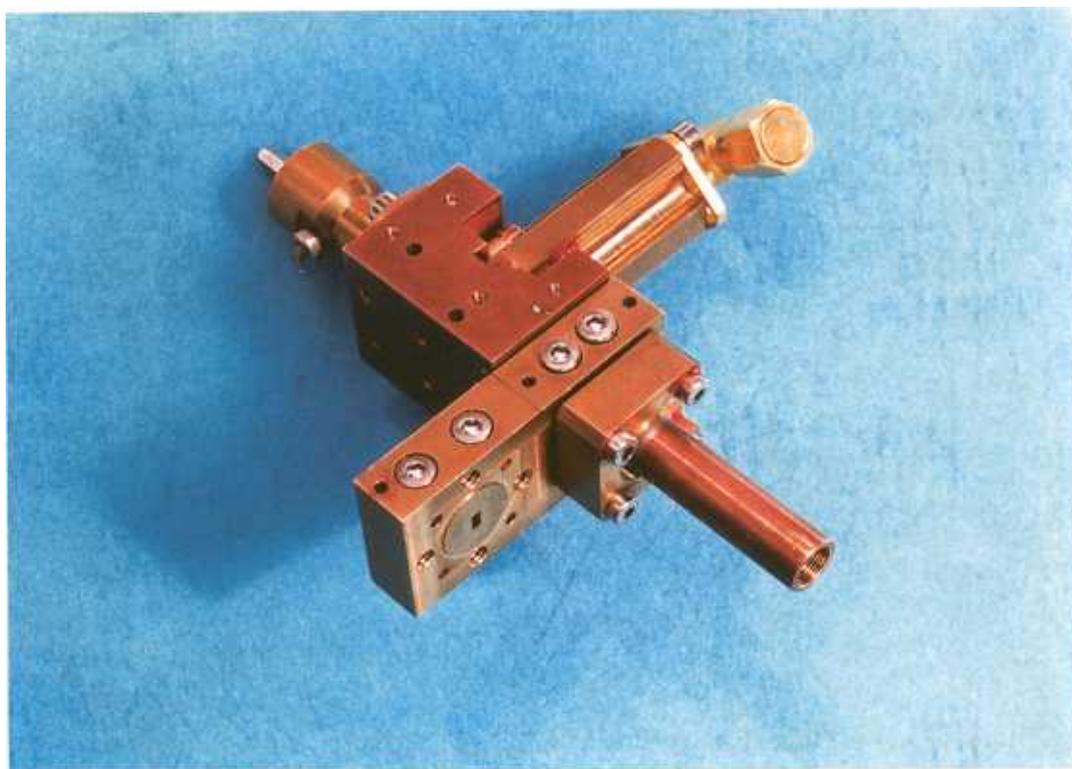


Fig. 5.4: The λ 0.8 mm fixed-tuned SIS mixer with a corrugated horn and waveguide coupler for local oscillator injection.

Operation with a fixed backshort position is particularly advantageous when frequency shifts are required to measure lines comparable in width to the 500 MHz IF bandwidth. The polarisation of the receiver allowed simultaneous operation at 3 mm and 1 mm wavelengths.

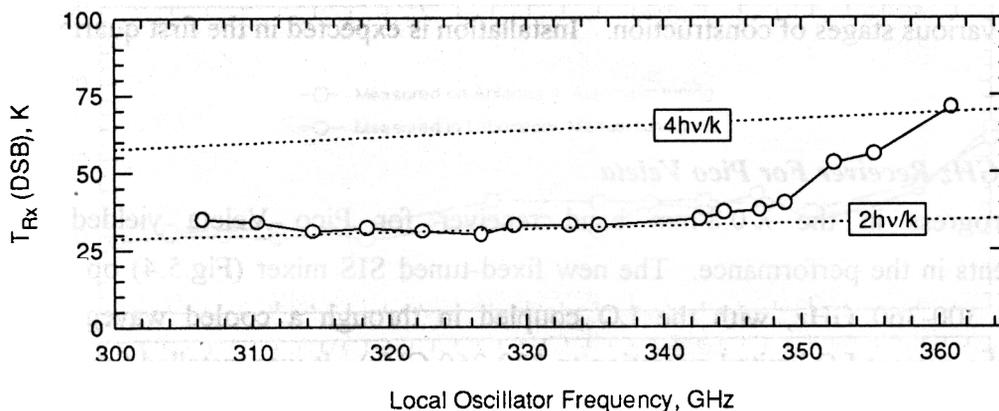


Fig. 5.5: Noise temperature of the λ 0.8 mm receiver on the 30-m telescope.

The high quality of performance on the telescope is illustrated by the spectrum shown in Fig. 5.6.

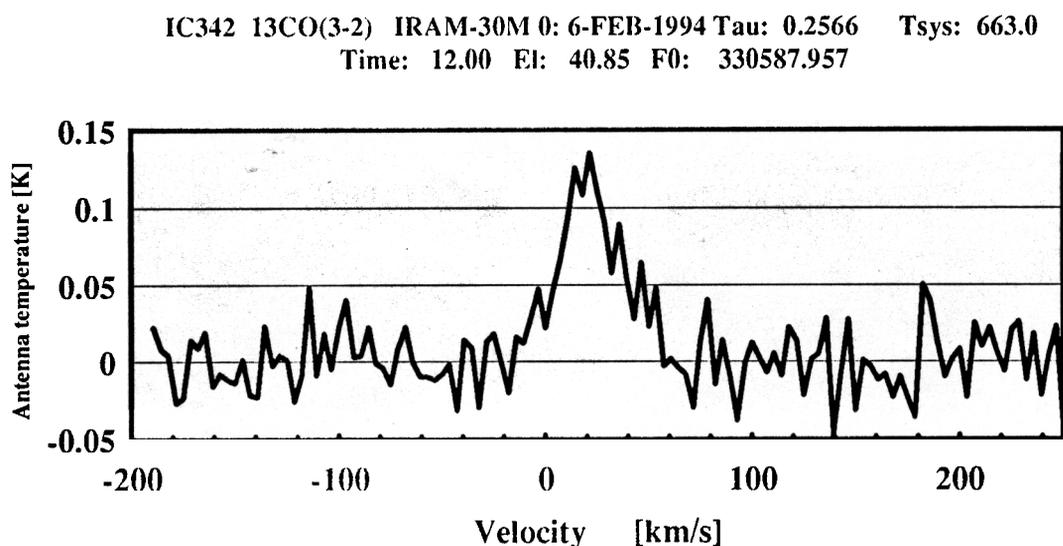


Fig. 5.6: The ^{13}CO (3-2) transition spectrum of IC342 measured with the new receiver at the 30-m telescope (courtesy of Andreas Schulz *et al.*)

New Mixers For Pico Veleta

New SIS mixers were installed in the existing λ 3 mm and λ 1 mm (G2) receivers at Pico Veleta. Improvements in stability allow frequency switching as a viable alternative to wobbler switching for narrow-band spectra.

The λ 1 mm mixer replaced one that had degraded because of mechanical wear. Typically, SSB receiver noise temperatures are now less than 70 K, and can be as low as \sim 55 K with image rejection of at least 17 dB (Fig. 5.7). A new 1.2 GHz bandwidth cooled IF amplifier was installed so that 1 GHz will be available to the spectrometers when the new down-converter is completed. Measurements up to 266 GHz have been made with this receiver.

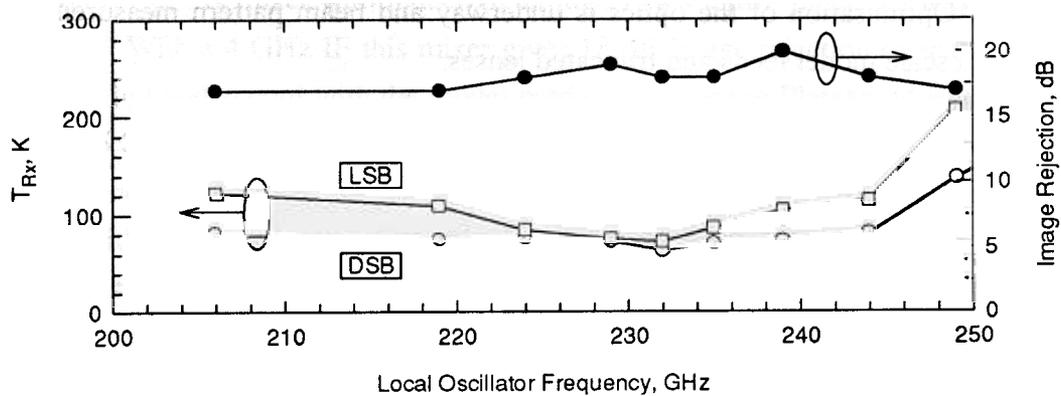


Fig. 5.7: Double- and single-sideband receiver noise temperature and image rejection for the 230 GHz (G2) receiver with the new mixer.

A significant improvement was made at λ 3 mm with the replacement of the mixer with a new design with an E-plane stub. Although the Nb junctions do not have integrated tuning, the DSB noise is \sim 60 K across the 86-115 GHz band and the SSB noise temperature is 65-90 K with an associated image rejection of $>$ 20 dB (Fig. 5.8). With the good stability of the new mixer, the continuum sensitivity of the SIS receiver is now much better than before (typically 0.1-0.2% in a second), and the Schottky receiver is no longer required for pointing.

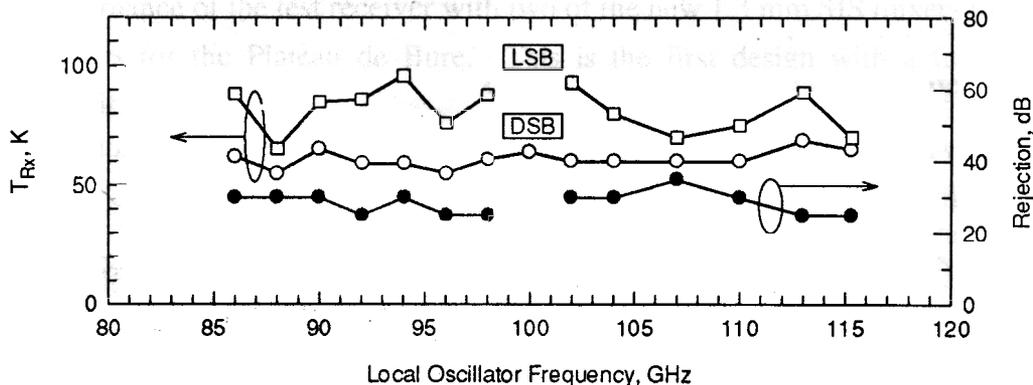


Fig. 5.8: Performance of the 3 mm receiver at the Pico Veleta telescope after installation of the new SIS mixer. Receiver noise is measured in front of the dewar.

λ 1 mm Array Receiver

Design work on the λ 1 mm Array Receiver for Pico Veleta has been concentrated on the optics. Currently, a 3 x 3 array is envisaged with an operating band of 200-250 GHz. Two offset ellipsoids are used to give a 1.4 times reduced image of the focal plane at an array of lenses and corrugated horns. One of the ellipsoids is inside the cryostat and the other is part of a "K-Mirror" that can be used to compensate the rotation of the image at the Nasmyth focus of the telescope. Optimisation of the optics is underway and beam pattern measurements have been made with scale model feeds and truncated lenses.

5.2.3 Mixer Developments

Progress has been made with computer-aided modelling of waveguide SIS mixers. Calculations have been verified in scale model experiments and with existing SIS mixers. Predictions of low-noise fixed-tuned operation with new versions of the Nb junctions and transformers have been confirmed by the performance of the receivers with the new mixers. Modelling of the sideband rejection in the mixers supports optimisation of the design of the mixer and the SIS junctions with the aim of providing stable, low noise receiver operation with good image rejection.

All the SIS mixers consist of a mixer block, a single backshort, and an integrated circuit with the SIS junctions printed on a quartz substrate. Apart from the λ 3 mm mixer, the new designs of the integrated superconducting circuits were conservatively optimised with the mixer model according to different criteria. Criteria for optimisation were: coverage of the specified frequency bands; mixer stability; image rejection using a single backshort, or broadband fixed-tuned operation of the mixer.

Design of Integrated Circuits With SIS Junctions

λ 0.8 mm A design for Nb SIS junctions with inductive integrated tuning has been developed for fixed-tuned operation.

λ 1 mm After the first experiments with partial improvement of the integrated circuit in 1991-1992, a completely new circuit was prepared for single sideband operation in the 205-245 GHz band with 4 GHz IF.

λ 2 mm A new Nb circuit with inductively tuned junctions optimised for fixed-tuned operation of the SIS mixer was prepared for the 130-180 GHz band.

New SIS mixer design and operation

λ 3 mm Mixer A new version of the mixer block was developed to provide ~ 30 dB rejection of the upper sideband in the waveguide band 80-120 GHz. Selectivity of the mixer tuning is due to a fixed tuned E-plane tuner integrated in the block. A single backshort is used for the tuning. The minimum DSB receiver noise in a laboratory test receiver was about 26 K.

λ 1 mm Mixer A mixer with inductive tuning of two $2 \mu\text{m}^2$ junctions was prepared and tested in 1994. With a 4 GHz IF this mixer gives 18 dB image rejection over the whole 205-245 GHz band in good accord with the model prediction. For the Plateau de Bure receiver the IF is lower (1.5 GHz) and the image band rejection is less efficient. Four mixers were prepared for the new generation of the Plateau de Bure receivers (Fig. 5.9). The receiver DSB noise temperature with the new mixers may be as low as 20 K, not previously achieved at this wavelength.

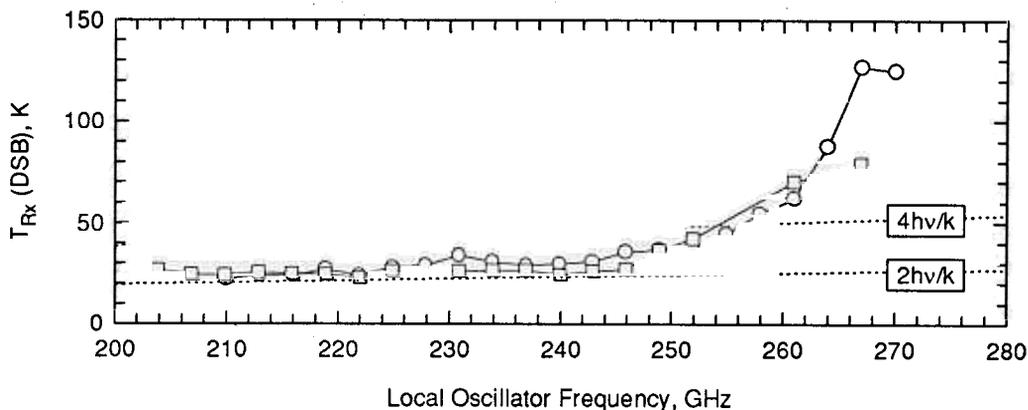


Fig. 5.9: Performance of the test receiver with two of the new 1.3 mm SIS mixers for the dual-channel receivers for the Plateau de Bure. This is the first design with a fully optimized integrated circuit.

λ 2 mm Mixer Developed in 1993-1994, this mixer has an instantaneous bandwidth 125-180 GHz. In the laboratory the DSB receiver noise temperature averages ~ 25 K and the minimum DSB noise temperature is ~ 20 K, making it one of the most sensitive λ 2 mm receivers to date (Fig. 5.10).

λ 0.8 mm Mixer The mixer integrated circuit contains two $1 \mu\text{m}^2$ SIS junctions with $\omega R_N \approx 6$. During 1993-1994 this mixer was prepared for an instantaneous bandwidth 300-370 GHz. Fixed-tuned operation is preferable when the IF to RF ratio is so small that the SSB tuning can not be efficient.

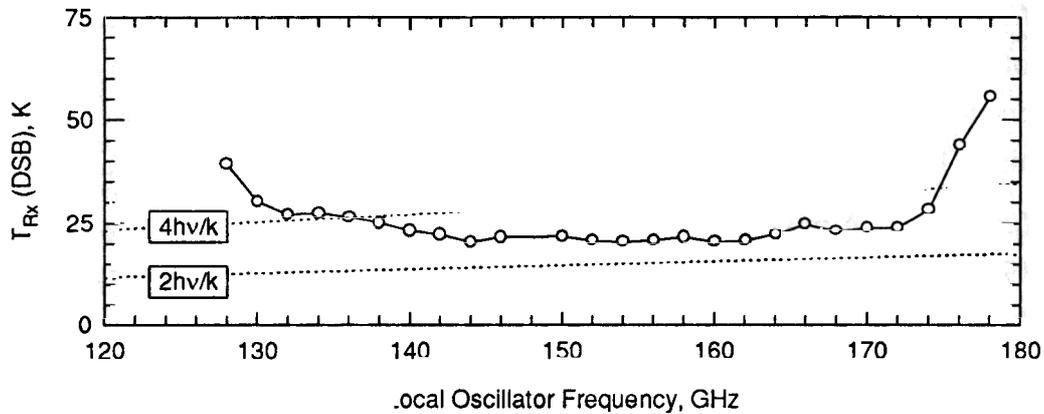


Fig. 5.10: The new fixed tuned λ 2 mm mixer in a laboratory receiver with cooled optics with a minimum DSB receiver noise temperature of 20 K.

SIN Mixer

In addition to the fabrication of mixers for the new dual-channel receivers and for the 30-m telescope, tests were carried out on some different types of junctions produced by the SIS Group. Measurements on an SINS (Superconductor-Insulator-Normal Metal-Superconductor) Nb-Al oxide-Al-Nb junction gave noise temperatures as low as 130 K at 300 GHz without a magnetic field being applied. This device was made using an existing mask for Nb junctions and was far from optimum ($\omega R_N C = 30$) so that significant improvements may be anticipated. A primary advantage of this device is that the absence of Josephson currents allows stable operation without the application of a magnetic field.

NbN Mixer

Another advance was made with the testing of a NbN-MgO-NbN junction array, also made by the IRAM SIS Group. Again, despite a non-optimised geometry, promising results were achieved. In the range 120-180 GHz the receiver noise temperature varied between 65 K and 150 K DSB with $\omega R_N C = 50$ and a physical temperature of 5.6 K. Potentially, junctions made with this material may operate up to ~ 1.3 THz, compared to ~ 700 GHz for Nb junctions.

5.2.4 Instrumentation

Acquisition of the whole of the main laboratory has allowed some rationalisation of the Receiver Group activities. Component and feed measurements are now more closely integrated with the general receiver construction.

Network Analyser

One area has been set aside for mm- λ component testing, particularly with the HP-8710 Vector Network Analyser. Work continues on the application of this to millimetre frequencies and qualification of passive components up to 290 GHz can be carried out with a dynamic range of up to 60 dB in transmission over a 70 GHz range and 30 dB in reflection for a band greater than 50 GHz. The instrument is used to characterise fully all of the passive components (feeds, couplers, *etc.*) used in the receivers.

Antenna Pattern Measurements

A new anechoic chamber has been built in the lab and lined with high-performance absorber. The feed pattern measurement instrumentation has been brought up from the former chamber in the basement. Improvements are underway, such as the use of a subharmonically pumped mixer to increase the sensitivity of measurements in the λ 1 mm band. The proximity of the range to the main laboratory and cryogenic facilities will make it more convenient for measuring the patterns of cryogenic receivers, particularly when the larger systems based on the 4-K closed-cycle systems are under development.

5.2.5 Cryogenics

Closed-Cycle Refrigerators

As announced in the 1993 Annual Report, five 4-K closed-cycle refrigerators were ordered from Daikin (Japan) through APD (UK). The first machine suffered damage in transit and was returned to Japan for repair. It was repaired and has been tested along with the other machines.

None of the machines has met the manufacturer's announced specifications in terms of stability or capacity. Unfortunately, the orientation which has the poorest capacity is the one that would most likely be used on the antenna. Discussions are continuing with the manufacturer.

5.3 BACKEND DEVELOPMENTS

5.3.1 Series Production of the New LO Systems

Coaxial cable terminal equipment to link the antennas with the central building has been produced to satisfy the eventual need for 6 antennas, and two receivers per antenna. A minor problem of oscillation was discovered and fixed while testing the series.

5.3.2 High Speed Correlator Chip Prototype

The Backend Group has played an active role in the evaluation of the high speed performance of a correlator chip developed by the CESR (Centre d'Etudes Spatiales des Rayonnements, a division of the CNES). A printed circuit has been designed around it, using our lab technology in the high-speed digital field. Promising results have been obtained, which support the concept of a spectrometer dedicated to wideband use, with both small size and low power consumption.

5.3.3 Correlator Extension for the 5th Antenna

Several solutions have been investigated to provide the interferometer with a 10-baseline correlator. The rather short schedule does not allow for new developments. It was therefore decided to build the extension on the basis of the same technology that is used in the existing correlator. The architecture has been defined and an internal report describing the adopted solution has been circulated. Some key components announced to disappear from the market fairly soon were immediately purchased. The "Bos chip" which has also been announced to be no longer available must also be ordered as soon as possible.

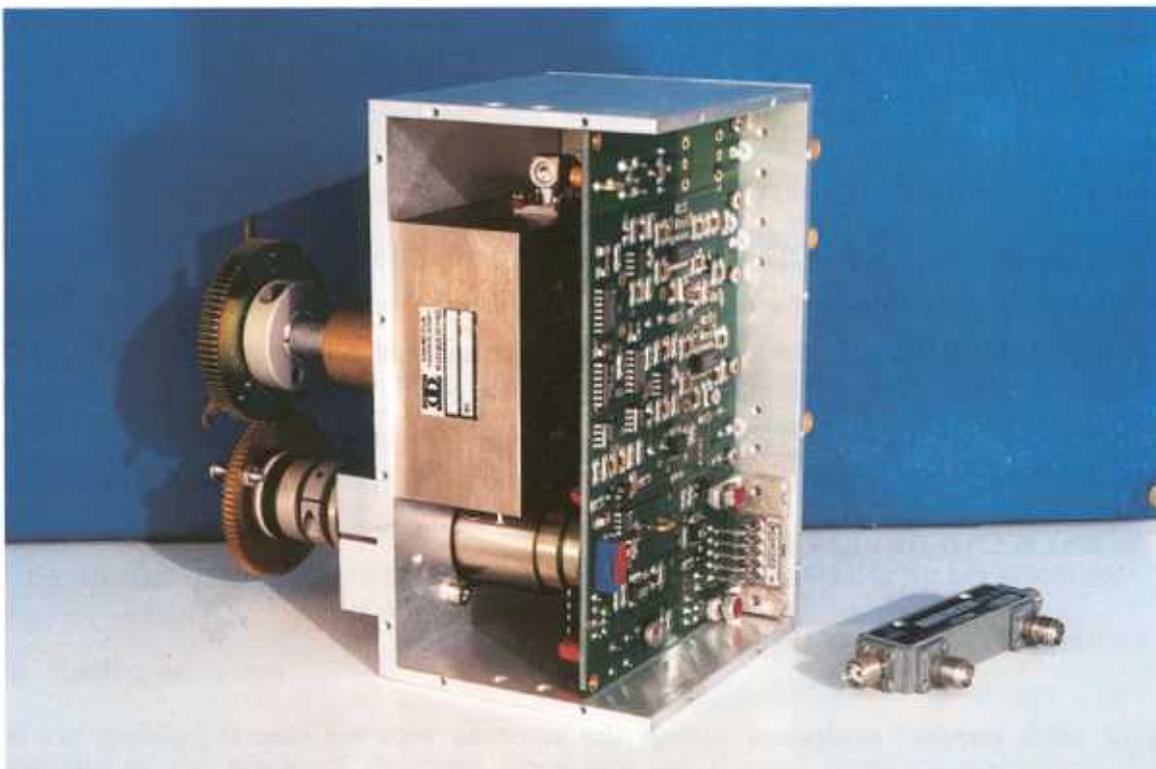


Fig. 5.11: This 1875 MHz oscillator, mounted on silent blocks, delivers an LO reference signal of high spectral purity to the PdB receivers.

5.4 Computer Group

In 1994, work has continued to improve the computing facilities by installing a fast link between the HP work stations. The connection uses FDDI optical cables to a HUB which routes also data to Ethernet. The traffic speed has increased by more than a factor of 5.

A new rewritable optical disk drive is now available from any HP work station. The disks have a total capacity of 600MB on each side.

In order to facilitate data transfers between institutes and especially with Pico Veleta, we have now both standards for tape cartridges, namely DAT and Exabyte on HP-UX and DEC-VMS. In the same context, the archive facility 'tar' is available from UNIX and VMS. For VMS it is, of course, called 'VMSTAR'.

Concerning hardware development, a panel adjustment VME module for the Plateau de Bure has been prototyped and a new incremental encoder interface VME module, foreseen for the new Plateau de Bure antenna control based on VME, has been designed, and tested successfully.

The VME interface for receiver control has been completed and is operational now on Plateau de Bure. Most of the software runs on micros. It is interfaced to a package running on UNIX or VMS. For the time being we use the VMS version integrated into OBS.

Software for the new VME rack in charge of LO1 rotators and phasemeters is under development.

The Computer Group has significantly contributed to the software development for the multi-channel-bolometer-project by writing part of the reduction package called NIC. New commercial or public packages have been installed. These include IDL for scientific and engineering data analysis and visualization (some trouble still remains with the license manager), MIDAS version 94MAY, and AIPS version 15JAN94. On PCs, new packages were made available such as Mathcad for engineering calculations, Excursion for X emulation under MS Window management and Omnipage for character recognition, and to simplify external document acquisition.

On an experimental basis, and to gain experience for possible future use, PVM (Parallel Virtual Machine) has been installed on all UNIX work stations. This package may be used to get a high-performance parallel machine for scientific model calculations which otherwise could take days to run on a single processor.

At the PC-level, tests have been conducted with LinUX, the public domain UNIX for PCs which can be considered as a single user, low price but still performant work station. Standard Gildas software and NIC have been ported to LinUX.

5.5 TECHNICAL GROUP

5.5.1 General Developments

No important investments were made in 1994. Particular efforts have been made to improve the computer systems on the numerically controlled machines. The Window's software SURFCAM allowed us to make series of horns and lenses of high quality with a repeatability of $\sim 3 \mu$. Furthermore the software allowed us to realize more and more complicated forms for waveguides on the numerically controlled milling machine (e.g. 350 GHz coupler). After utilization all programmes are saved on diskettes. In the past, four weeks of machining on the traditional lathe were necessary to realize 10 230 GHz horns , whereas the actual numerically controlled lathe needs only one week.

Machining by chiselling rectilinear waveguide and quartz grooves for the receivers has been developed. The chiselling allows one to obtain an excellent surface finishing, very sharp interior angles at very small dimensional tolerances. All the grooves for 115 - 230 - 345 GHz mixers are currently made by using this technique.

Further to the manufacturing of microwave components, the mechanical workshop has made all equipment for the new HDV10 generation of receivers for the Plateau de Bure Interferometer, including supports, mirrors, motorized hot and cold loads, as well as choppers (cf. Figure 5.12).

The number of internal requests for manufacturing reached a total of 246, of which 54 were executed by external subcontractors.

5.5.2 Drawing Office

Since a draughtsman was engaged in July 1994, the drawing office fully assures the support for all technical groups in IRAM. A large number of tasks have been carried out, e.g. mechanical microwave parts for the receivers, polarization splitters, beam derotators, choppers, junction holders, reflector panels, optical telescopes, ...; the drawing office has especially worked on a detailed design study for the mechanical parts and on the follow-up of the three sets of supports for the HDV10 receivers, including all equipment (cf. Figure 5.12).

The drawing office has also been responsible for the proper administration and the updating of all mechanical plans.

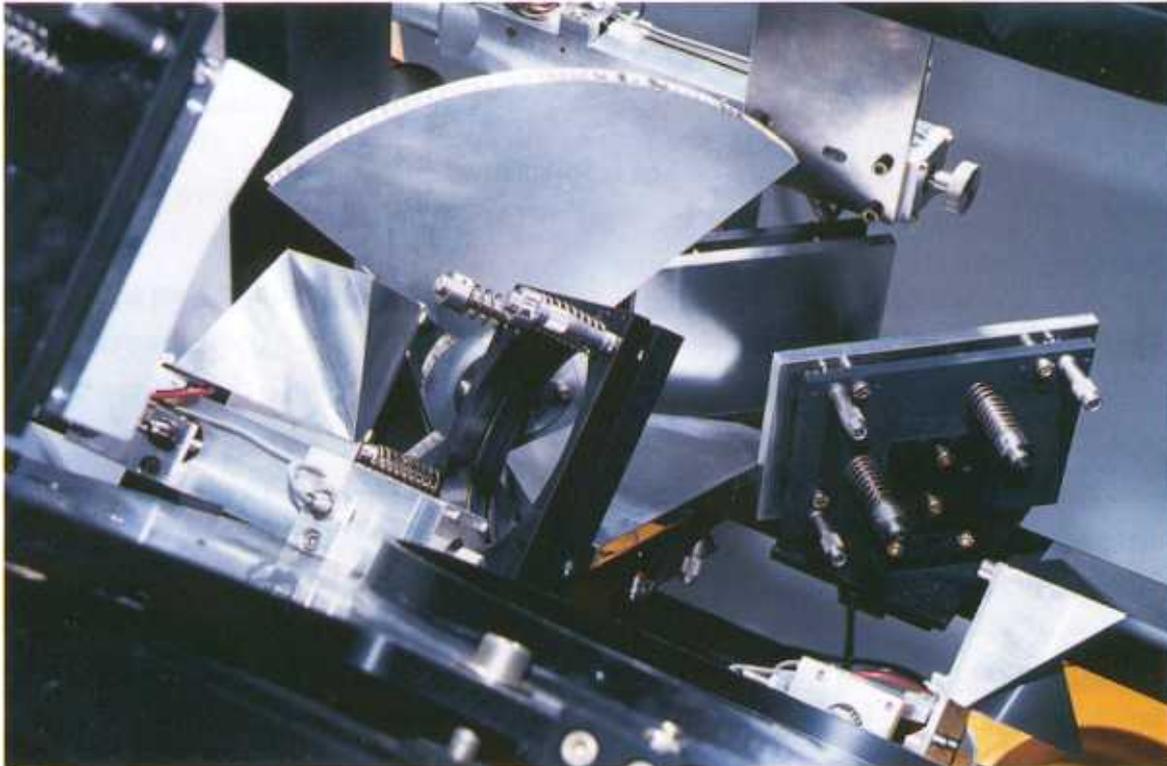


Fig. 5.12: Optical system for the dual-channel receivers. *Right to left* : hot load, mirrors, chopper, grid, cold load, and 230 GHz elliptical mirror. *Lower right:* hot load on 115 GHz input.

5.5.3 Technical Support for Plateau de Bure

The technical group has continued to work in close cooperation with the local maintenance teams in order to improve the existing mechanical systems, and thus those for the 5th antenna already under construction.

5.5.4 Track Extension

The technical group has helped in establishing the financial and technical contracts for the track extension (east-west extension by 120 m with three stations, north-south extension by 80 m with one station). The technical group has also been responsible for the positioning of the tracks and the fixation elements for the antennas at the new stations. Work on the east-west track extension has almost been finished, the remaining work on the north-south extension will be completed in September 1995.

5.5.5 Mount for Antenna 5 for the Plateau de Bure Interferometer

The technical group has been responsible for the preparation of all documents and contracts related to the mount of the new antenna, as well as for the follow-up during the fabrication process.

The planning at the end of 1994 foresees the following remaining activities

- | | |
|---|--------------------------------|
| - transport of major components of the mount to the Plateau de Bure | April 18 - May 5, 1995 |
| - assembly of the mechanical parts of the mount | May 2 - July 21, 1995 |
| - electrical installations | July 10 - Sept. 8, 1995 |
| - installation of thermal covers | Sept. 4 - Nov. 20, 1995 |
| - assembly of the reflector *) | Nov. 15, 1995 - Febr. 28, 1996 |
| - remaining installations and total system tests *) | March 1996 |
| - installation of receivers etc. *) | April 1996 |

*) depending on the decision concerning the choice of panel type



Fig. 5.13: Dimensional check, after welding, of a fork arm (weight 4 tons) for Antenna 5 on a marble-table at Ets. ROCHE at Reims.

6. PERSONNEL AND FINANCES

In 1994, IRAM had a total of 107 employees. Of these, 96 were IRAM staff members. 26.5 staff members worked in Spain, and 69.5 in France. Of the additional 11 PhD students, post-docs and cooperants, 5 worked in Spain and 6 in France. Two persons with temporary contracts had to be hired to help with the maintenance of the observatory on the Plateau de Bure as well as for tasks in Grenoble.

One half of a staff position in the SIS laboratory is jointly financed by the MPIfR and the MPI für Extraterrestrische Physik. The MPG and CNRS contribute to the funding of some of the post-doc positions in Grenoble and Granada. The position of one PhD student in the SIS laboratory is funded by the German BMBF (Verbundforschung Astronomie/Astrophysik)).

IRAM's financial situation in 1994 and the budget provisions for 1995 are summarised in the following tables. Expenditures in the operations budget 1994 correspond closely to the original estimates. In the investment budget some underspending occurred, mostly due to unforeseen delays in connection with antenna 5 for the interferometer and the track extension work on the Plateau de Bure. The corresponding budget provisions will be needed in 1995.

The major items in the investment budget were: 4.0 MF for the track extension, 2.4 MF for antenna 5 on Plateau de Bure, 3.1 MF for the extension of the IRAM headquarters, 4.2 MF for receivers and backends, 2.8 MF for cryogenic components, 0.8 MF for computer equipment, 0.7 MF for improvements in the existing IRAM antennas in Spain and France, 1.3 MF for equipment in the SIS laboratory. In the area of administration and transport 1.1 MF were spent, and 0.7 MF for improvements in the infrastructure.

Income other than contributions from the IRAM partners was higher than foreseen due to interest and exchange rate gains.

The long-standing problem of the reimbursement of the Spanish Value Added Tax (V.A.T.) payments which IRAM had claimed, has now been resolved. The tax office has reimbursed the V.A.T. for 1986. According to a court decision in Madrid, IRAM can not be reimbursed any more for the V.A.T. of 1987.

The extension for the Grenoble Headquarters was finished in the fall of 1994. The ground-floor is occupied by the backend group whereas the first floor provides office space for astronomers and visitors. In the basement, IRAM cars can be parked, as well as material and equipment stored.

B U D G E T 1994

Expenditure

BUDGET HEADING	APPROVED BUDGET KFF	ACTUAL BUDGET KFF
Personnel	38.575	38.285
Operations	14.625	15.114
	53.200	53.399
Investment	32.550	21.309
Value Added Taxes	4.580	4.580
	90.330	79.288

Income

BUDGET HEADING	APPROVED BUDGET KFF	ACTUAL BUDGET KFF
Contribution CNRS	29.450	29.450
Contribution MPG	29.450	28.371
Contribution IGN	3.759	3.759
Contribution Antenna 5	5.900	5.900
Other Income	17.191	19.645
Contribution CNRS for Value Added Taxes	4.580	4.580
	90.330	91.705

BUDGET PROVISIONS 1995

Expenditure

BUDGET HEADIND	APPROVED BUDGET (KFF)
Personnel	39.730
Operations	13.470
	53.200
Investment	21.560
Value Added Taxes	4.650
	79.410

Income

BUDGET HEADIND	APPROVED BUDGET (KFF)
Contribution CNRS	29.450
Contribution MPG	29.450
Contribution IGN	3.760
Contribution Antenna 5	11.300
Other Income	0.800
Contribution CNRS for Value Added Taxes	4.650
	79.410

7. ANNEX I : TELESCOPE SCHEDULES / 7.1. IRAM 30m Telescope

Ident.	Title	Freq. (GHz)	Authors
Jan 4 - Feb 1			
259.93	A gravitational telescope to probe the gas content of distant normal galaxies	133, 102	Casoli, Fort, Boissé, Encrenaz, Horellou
258.93	CO emission primordial galaxies at $z=3.2, 3.6$ and 4.4	85,99,107,149	Casoli, Gerin, Andreani
159.93	Search for CO in high redshift, dusty, radio quiet QSOs	101, 109,137, 141	Omont, Solomon, Radford, Downes, Mac Mahon
251.93	CO distribution in the anemic galaxy NGC 4579	114, 220	Boselli, Casoli, Combes, Lequeux, Gavazzi
151.93	Search for LiH primordial lines	219,220,222,223	De Bernardis, Dubrowich, Melchiorri, Encrenaz, Signore, Maoli
235.93	^{12}CO observations of molecular complexes in the nearby spiral M33	115, 230	Viallefond, Boulanger, Cox, Guélin
196.93	A search for broad SiO maser emission wings in O-rich evolved stard	86, 129, 230	Cernicharo
264.93	Is SO^+ a tracer of dissociative shocks ?	115, 162, 208, 99	Fuente, Cernicharo
288.93	A study of the para-water vapor emission at 183 and 325 GHz	183, 325 MHz	Cernicharo, John
204.93	CO emission in distant radio galaxies	88, 98, 103, 138, 157	Miley, van Ojik, van der Werf
294.93	Investigation of the streaming motions in the SW part of M31	115, 230	Neininger, Guélin, Wielebinski
211.93	Molecular gas in the halo of spiral galaxies : NGC4013	115, 230	Garcia-Burillo, Gomez de Castro, Combes
287.93	CO line observations of molecular gas in Mid and High redshift galaxies	89, 149, 163, 244	Sams, Genzel, Brandl, Schuster
286.93	Investigation of molecular envelopes around T-Tauri stars and their relation to disk/wind activities	219, 220	Schuster, Anderson, Harris
177.93	CO observations of HD 98800 : molecular gas in a protoplanetary disk ?	110, 115, 230	Zuckerman, Kastner, Forveille, Kahane
246.93	A comparison of CN and FIR emission in galactic sources and isotopic variation studies of ^{13}CN and C^{15}N in the peak CN emission ridge north of IRC-2 in Orion A	109, 113, 217, 226	Simon, Saleck, Stutzki, Winnewisser
219.93	Observations of CH_3CCH and search for CH_3OH on Titan	136, 222, 229	Bézar, Marten, Paubert
Feb 1 - Mar 1			
288.93	A study of the para-water vapor emission at 183 and 325 GHz	183, 325 MHz	Cernicharo, John
197.93	Search for redshifted CII $158\mu\text{m}$ emission from high redshift QSOs	85, 87,333, 341, 359	Van der Werf
215.93	Probing the different molecular gas components in the nucleus of IC 342	330, 354, 265, 241	Krause, Schulz, Stutzki, Guesten
K003	Small scale structure of pre-star forming clouds		Falgarone et al.
268.93	CO excitation and H_2 masses of IR luminous galaxies : a proposal to observe the CO(3-2) lines	316,331,338,339	Solomon, Downes, Radford
224.93	Search for high frequency hydrogen recombination lines in active galaxies	91,92,135,133,231	Strelitski, Thum, Smith, Matthews, Martin-Pintado
260.93	H masers from massive young stars	92, 135, 231	Thum, Martin-Pintado
195.93	Molecular clouds in radio loud quasars	94,107,110,214,223	Wiklind, Combes, Leon

Ident.	Title	Freq. (GHz)	Authors
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Mar 1 - Mar 29

K003	Small scale structure of pre-star forming clouds		Falgarone et al.
257.93	Observational tests of chemical bistability in interstellar clouds	97,99,109,138,219	Gerin, Falgarone, Roueff
221.93	Multichannel bolometer observations of stellar disks at 250 GHz	Bolometer	Altenhoff, Quirrenbach, Wendker
243.93	Deep survey of distant galaxies at 1.3mm	Bolometer	Desert, Bernard, Bourhis, Cesarsky, Maffei, Puget
279.93	The mm continuum emission from QSO's with $z > 4$	Bolometer	Omont, McMahon, Bergeron, Cox, Kreysa
284.93	Bolometer observations of Asteroids II	Bolometer	Altenhoff, Johnston, Stumpff, Webster
267.93	The IR jet in IC348 : a young molecular outflow	115, 230	Guilloteau, Zinnecker, Dutrey, McCaughrean
273.93	H recombination line observations of ultracompact HII regions : galactic electron temperature and density gradient	99,135,231	Acord, Walmsley, Afflerbach, Churchwell
290.93	Simultaneous daily mm- γ ray intensity measurement of a complete sample of active galactic nuclei	3mm	Schalinski, Witzel, Krichbaum, Kanbach, Lichti, Rothermel, Wagner
37.94	Absorption lines in Q1413+135	92,142,213,157,235	Wiklind, Combes
251.93	CO distribution in the anemic galaxy NGC 4579	114, 220	Boselli, Balkowski, Cayatte, Casoli, Combes, Lequeux, Gavazzi
228.93	Successive ejection events in the L1551 outflow	115, 230	Bachiller, Cernicharo, Tafalla
231.93	Schock chemistry in the L1157 molecular outflow	90,113,168,215,267	Bachiller, Martin-Pintado, Fuente
244.93	Zero spacing measurement of ^{13}CO 1-0 and C^{18}O 1-0 in the S140 HII region/molecular cloud interface	110,109,217,144	Corneliussen, Stutzki

Mar 29 Apr 26

	Small Scale anisotropy of the cosmic microwave background at 230 GHz	Bolometer	Kreysa, Chini, Biermann
293.93	High resolution imaging of cold dust emission from the Cygnus loop	Bolometer	Haslam, Tuffs, Kreysa, Sievers Lemke
263.93	Cold dust in NGC891, M51 and IC342 : a key to the molecular gas content of spiral galaxies	Bolometer	Zylka, Guélin, Mezger, Kreysa Haslam, Lemke, Sievers Garcia-Burillo
202.93	An expanded survey to search for cold dust disks around main sequence IR excess stars	Bolometer	Stern, Festou, Weintraub
229.93	Cold dust in starburst environments	Bolometer	Reuter, Lesch
198.93	The 230GHz continuum dust emission of N2146	Bolometer	Greve, Sievers
295.93	Observation of the γ 1.3mm emission in the edge-on galaxy NGC4565	Bolometer	Neininger, Zylka, Guélin Dumke, Wielebinski
279.93	The mm continuum emission from QSO's with $z > 4$	Bolometer	Omont, McMahon, Bergeron, Cox, Kreysa
297.93	The first high resolution maps of the Cas A and Crab SNRs at 1.3mm	Bolometer	Holland, Greaves
299.93	The youngest stellar cores in Bok globules - 1.3mm continuum mapping	Bolometer	Launhardt, Zylka
292.93	Dust environment of Herbig Ae/Be stars : LKH α 198 and AB AUR.	Bolometer	Cabrit, André. Thum. Ménard

Apr 26 - May 24

283.93	Diameter determination of 2060 Chiron with the 7-channel bolometer	Bolometer	Altenhoff, Stumpff
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Ident.	Title	Freq. (GHz)	Authors
243.93	Deep survey of distant galaxies at 1.3mm	Bolometer	Desert, Bernard, Bourhis, Cersarsky, Franceschini, Maffei, Puget
223.93	Dust emission in three edge-on galaxies	Bolometer	Wielebinski, Braine, Golla, Kruegel, Reuter, Sievers
210.93	Cold dust around high redshift quasars	Bolometer	Andreani, Casoli, Gerin, Cristiani, La Franca
271.93	Size and density structure of low mass protostellar envelopes	Bolometer	André, Bontemps, Bourhis, Cabrit, Terebey
272.93	Size and density structure of pre-protostellar cores	Bolometer	André, Ward-Thompson
261.93	Thermal dust emission from elliptical galaxies ?	Bolometer	Wiklind, Henkel, Chini, Haslam
234.93	Continuum mapping of the NGC 7538 cluster at 1.3mm	Bolometer	Sandell, Baas
270.93	Continuum observations of dust disks around main sequence stars	Bolometer	Bockelée-Morvan, André, Colas, Despois, Crovisier, Colom, Jorda
236.93	Molecular line observations of high mass star forming GMC cores	96,110,144,147,220	Mooney, Mauersberger, Mezger, Zylka
269.93	Molecules and dust : their spatial distribution at the 10 arcsec scale	115, 230	Boissé, Duvert, Thoraval
208.93	The atmosphere of IO	214,224,143,104,158	Lellouch, Belton, de Pater, Gulkis, Encrenaz, Paubert
252.93	Search for FeO in mass-losing red giants	86, 153	Kahane, Jura, Balm, Kroto
254.93	Nitrogen and oxygen isotopes in the molecular envelopes of evolved stars	86,219,220,224	Kahane, Forestini, Forveille, Guélin, Cernicharo
253.93	Carbon isotopes in the molecular envelopes of evolved stars	86,219,220,224	Kahane, Forestini, Guélin, Cernicharo
242.93	Service observing to detect extremely broad RRLs in G25.5+0.2	85	Walmsley, Churchwell, Goss, Shepherd
192.93	Rapid variability in ²⁸ SiO maser emission	86,129,177	Alcolea, Cernicharo, Bujarrabal
230.93	SiO masers as tracers of the chemical composition of circumstellar grains	86, 129, 215	Alcolea, Bujarrabal

May 24 - Jun 21

37.94	Absorption lines in Q1413+135	92,142,213,235	Wiklind, Combes
38.94	Search for molecular absorption lines in intermediate and high redshift galaxies	96,105,158,226,257	Wiklind, Combes
84.94	CO in early type galaxies with luminous X-ray halos	115, 230	Henkel, Braine, Wiklind
27.94	¹² CO observations of molecular complexes in the nearby spiral M33	115, 230	Viallefond, Boulanger, Cox, Guélin
226.93	Molecular line observations of cold compact dust cores in the galactic center	96,110,147,241	Zylka, Lis, Morris
206.93	A search for circumstellar MgCN	101, 132,142	Ziurys, Apponi, Anderson, Steimle, Guélin
98.94	Molecular spiral structure in M51 : the outer arms	115, 230	Guélin, Garcia-Burillo, Neininger
15.94	CO distribution in the anemic galaxies NGC4579 and NGC4548	115,230	Boselli, Balkowski, Cayatte, Casoli, Combes, Lequeux, Gavazzi
39.94	A gravitational telescope to probe the content of distant normal galaxies	106, 133, 142	Casoli, Fort, Boissé, Encrenaz, Mellier
60.94	How far out is molecular gas detectable ?	109, 115, 219, 230	Braine, Combes, Wielebinski, Van Driel
1.94	The abundance of water in the Milky Way	203, 144, 86	Wilson, Mauersberger, Hein

Ident.	Title	Freq. (GHz)	Authors
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Jun 21 - Jul 19

87.94	The opacity of galactic disks	115, 229, 230	Bosma, Athanassoula
70.94	Search for CO in hyperluminous galaxies	159, 239	Radford, Cutri, Solomon, Downes
7.94	Selective depletion of CO in the GG Tau circumbinary disk	89, 220	Dutrey, Guilloteau, Simon
11.94	What is the best tracer of rotating disks around YSO ?	220, 230, 89	Dutrey, Guilloteau, Simon
93.94	CO observations of powerful radio galaxies at high redshift	87, 100, 145, 162	Evans, Sanders, Downes, Solomon, Radford
8.94	A CH ₃ CN survey towards ultracompact HII regions	110, 147	Cesaroni, Walmsley, Olmi
9.94	A search for high mass protostars	89,96,147, 221	Cesaroni, Churchwell, Felli, Walmsley
10.94	Silicon monoxide towards ultracompact HII regions	86, 130,217	Acord, Shepherd, Churchwell, Walmsley, Cesaroni
31.94	CO studies of galaxies in the Coma/A1367 supercluster	113, 112	Dickey, Kazes, Casoli, Combes, Lavezzi
21.94	CO emission from a gas-rich lensed galaxy at z=1.116	108,163,217	Krishna, Morris, Henkel
19.94	CO+ in photon dominated regions	118,235,236	Stutzki, Sternberg, Stoerzer
96.94	Small scale structure in the high latitude cirrus cloud toward HD 210121	220,230	Stark
18.94	Comet Shoemaker-Levy observations A multiline CO study in the Rosette molecular cloud	109,115,220,230	Festou, Paubert Schneider, Stutzki

Jul 19 - Aug 30

96.94	Small scale structure in the high latitude cirrus cloud toward HD 210121	220,230	Stark
	Comet Shoemaker-Levy observations		Lellouch, Paubert
74.94	Ortho/para abundance ratios in molecular clouds	89,140,150,211,225	Lucas, Liszt
53.94	Confirmation of high redshift galaxy detection at the IRAM 30m	89,149	Sams, Schuster, Brandl
86.94	IRAS 19379+2838, a bipolar outflow or a M star surrounded by a disc ?	115,230	Loup, Josselin, Panis, Waters
81.94	Origin of the anomalous CO emission in cold o-rich circumstellar envelopes	115,130,230	Omont, Loup, Josselin, Barnbaum
83.94	Further search for CO in a dusty, radio quiet QSO at z=3.2	82,109,137	Omont, Solomon, Radford, Downes, McMahon
4.94	Search for glycine		Combes, Rieu
6.94	True velocity dispersion of molecular gas		Combes, Braine
16.94	CO observations of a sample of high redshift radio galaxies	86,90,102,110,137,164	Van Ojik, van der Werf, Miley, Roettgering
34.94	Studies of cold molecular gas (continuation)	88,98,110,115,230,265	Lequeux, Allen
33.94	CO emission from intermediate z progenitors of normal galaxies	150,162,225,243,256	Lo, Steidel, Genzel
56.94	Relating high density gas with Megamaser activity	88	Baudry, Rieu, Baan
36.94	Molecular clouds beyond the optical disk of the galaxy	97,109,146,220,244	Henkel, Digel, Chin, Mauersberger, de Geus, Thaddeus
84.94	CO in early type galaxies with luminous X-ray halos	115, 230	Henkel, Braine, Wiklind

Ident.	Title	Freq. (GHz)	Authors
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Aug 30 - Sep 27

71.94	The moon: brightness at mm-wavelengths	86,150,230	Greve
25.94	High velocity jets and FLIERs in planetary nebulae	115,230	Huggins, Bachiller, Cox, Forveille
24.94	Molecular gas in the halos of planetary nebulae	115,230	Bachiller, Huggins, Cox, Forveille
13.94	Methanol abundance enhancement around young stellar objects	94,109,145,241	Colomer, Bachiller, Walmsley
89.94	A molecular study of the TMC1 filament	97,135,237,85	Cox, Cernicharo
24.94	Molecular gas in the halos of planetary nebulae	115, 230	Bachiller, Huggins, Cox, Forveille
71.94	The moon: brightness at mm-wavelengths	86,150,230	Greve
55.94	Separation of infall and outflow motions in L1527 and L483	115,220,230,140	Myers, Bachiller, Fuller, Mardones
29.94	Isotopic variations and physical parameters in OMC-1 north and NGC 2024 determined from CN, ¹³ CN and C ¹³ N observations	109,217,219	Simon, Stutzki, Graf, Winnewisser
30.94	CN, HCN and its isotopomers as tracers of the physical conditions and the UV field in the cores of S140, S255, S106	88,109,144,259	Simon, Stutzki, Winnewisser
80.94	CO emission from 6 far-infrared detected blue-compact dwarf galaxies	115,230	Krishna, Petrosian, Henkel, Wielebinski
58.94	CO abundances in the far outer galaxy	104,109,115,230	Brand, Wouterloot

Sep 27 - Oct 25

71.94	The moon: brightness at mm-wavelengths	86,150,230	Greve
76.94	Zeeman effect observations with the 113GHz CN lines	113	Crutcher, Kazes, Troland, Lazareff
16.94	CO observations of a sample of high redshift radio galaxies	86,90,102,137,164	Van Ojik, van der Werf, Miley, Roettgering
12.94	A pilot study of the shock in G9.62+0.19	89,138,217	Hofner, Churchwell, Henning
79.94	Observation of CO in P/Schwassmann-Wachmann1 and other distant comets	115, 145, 168, 230	Crovisier, Biver, Bockelee-Morvan, Colom, Jorda, Despois, Paubert
49.94	Mapping the cold molecular gas toward 2013+370	115, 230	Wilson, Solomon, Mauersberger
50.94	Molecular gas toward Cassiopeia A	93, 86, 110	Wilson, Mauersberger
94.94	Gaseous counterparts of low-mass protostellar dust envelopes	86,96,109,216,224,260	Andre, Despois
71.94	The moon : brightness at mm-wavelengths	86,150,230	Greve
95.94	A CO survey of metal-deficient blue compact galaxies	113,114,226,228,229	Thuan, Sauvage, André
35.94	Observations of the gas in the most distant known galaxy	96,144,216	Mirabel, Eales, Hammer, Dunlop, Hughes, Rawlings
90.94	The extent and distribution of dense molecular gas in nearby galaxies	88,139,141,144,145	Gao, Solomon, Radford, Downes
67.94	Envelopes of dark clouds : TMC-1	109,110,112,115	Schilke, Keene, Bourlot, Roueff, Pineau des Forets, Sievers
6-15	Observation of the galactic superluminal source GRS 1915+105		Mirabel
26.94	Molecular gas in dusty proto-planetary systems	110,115,220,230,265	Zuckerman, Forveille, Kastner

Oct 25 - Nov 22

71.94	The moon : brightness at mm-wavelengths	86,150,230	Greve
61.94	Multiline study of AFGL 5376, a 90-pc long supershock in the galactic center region	88,138,220	Uchida, Morris, Guesten, Serabyn

Ident.	Title	Freq. (GHz)	Authors
33.94	CO emission from intermediate z progenitors of normal galaxies	150,162,225,243,256	Lo, Steidel, Genzel
68.94	The high velocity system of NGC1275	112,224	Reuter
62.94	Dense gas in the nuclei of H ₂ O megamaser galaxies	87,114,145,228,230	Henkel, Braatz, Wilson
4.94	Search for glycine		Combes, Rieu
9.94	A search for high mass protostars	88,89,96,147,241	Cesaroni, Churchwell, Felli, Walmsley
53.94	Confirmation of high redshift galaxy detection at the IRAM 30m telescope	89,149	Sams, Schuster, Brandl
78.94	Molecular abundances in Comet P/Borrelly	88,96,145,165,168,225	Colom, Biver, Bockelée, Crovisier, Jorda, Despois, Paubert
178.94	Jet entrainment in the L1157 molecular outflow : short spacing information for the CO map	115	Gueth, Bachiller, Dutrey, Fuente, Guiloteau, Martin-Pintado
213.94	Silicon monoxide towards ultracompact HII regions	86,130,217	Acord, Walmsley, Shepherd, Churchwell, Cesaroni
78.94	Molecular abundances in Comet P/Borrelly	88,96,145,165,168,225	Colom, Biver, Bockelée, Crovisier, Fuente, Martin-Pintado, Rodriguez
189.94	A complete molecular study of the reflection nebula NGC 2068	110,88,90,87,113,97,89	Fuente, Martin-Pintado, Rodriguez
51.94	Mapping of CO and HDO on Venus	230,220,115,225	Encrenaz, Lellouch, Gillet, Rosenqvist, Paubert
211.94	¹² CO Observations of molecular complexes in the nearby spiral M33	115,230	Viallefond, Boulanger, Cox, Guélin
245.94	The Serpens S68 FIRS1 source : From neutral molecular outflows to optical jets and HH objects	86,130,217,230,97,244	Eisloffel, Cernicharo, Guriel, Neri
91.94	CS and SiS vibrationally excited in IRC+10216	108,144,216,145,107	Gonzalez-Alfonso, Cernicharo, Lucas, Guélin
97.94	Did we detect aluminium 26 in IRC+10216 ?	209,261,156,134,201	Guélin, Forestini, Cernicharo

Nov 22 - Jan 3

6-013	The abundance of water at z=2.6		Guélin, Downes
239.94	Star formation in cometary globules	96,109,115,144,220,230	Lefloch, Lazareff, Castets, Cernicharo
180.94	Molecular gas content in Wolf-Rayet galaxies	87,88,146,228,229	Contini, Davoust, Wozniak, Considere
181.94	CO observations of powerful radio galaxies at high redshift	87,104,111,131,232	Evans, Sanders, Solomon, Downes, Radford
247.94	Photo-production of CN in circumstellar envelopes	113,226	Bachiller, Fuente, Bujarrabal, Omont, Loup
234.94	Molecules and dust: their spatial distribution at the 10-arcsecond scale from background stars	115,230	Boissé, Duvert, Thoraval
235.94	Molecules and dust: their spatial distribution at the 10-arcsecond scale from background galaxies	115,230	Boissé, Duvert, Thoraval
217.94	CO, HCN and SO observations of late-type supergiants	88,115,230,219	Blommaert, Groenewegen, Josselin, van der Veen, Omont
105.94	Search for hydrogenous compounds in the Martian atmosphere	115,251,236	Rosenqvist, Marten, Moreau, Dutrey, Guiloteau, Guélin, Moreno
206.94	First chemical study of circumstellar disks	88,113,226,244,260,267	Dutrey, Guilloteau, Guélin
219.94	Search for LiH rotational lines in collapsing primordial clouds at high redshifts	97,145,217	Maoli, de Bernardis, Melchiorri, Encrenaz, Signore

7. ANNEX I: TELESCOPE SCHEDULES / 7.2 IRAM Plateau de Bure Interferometer

Proj.	Conf.	Title	Authors	Molecules	Object
D069	B2	A search for local J=1-0 HCO ⁺ absorption toward extragalactic sources	R.Lucas H.Liszt	HCO ⁺	Line-of-sight of quasars
D040	CD	CO mapping of the cometary globules in the Helix nebula	T Forveille P.Huggins R.Bachiller P.Cox	CO	Helix Nebula NGC7923
D053	CD	Jet entrainment in the L1157 molecular outflow	R.Bachiller A.Dutrey A.Fuente J.Martin-Pintado S.Guilloteau	CO	L1157
D064	CD	Small scale structure of the cloud core region behind NGC2024	R.Simon C.Kramer J.Stutzki G.Winnevisser	CN ¹³ CO	NGC2024
D022	BC	CO in the nucleus of NGC 4826	K.I.Uchida R.Gusten J.Turner	CO	NGC 4826
D068	C2	Observations of Titan in the J=1-0 line of CO	A.Marten A.Dutrey D.Gautier	CO	Titan
E003	D	Dense molecular gas in Seyfert Nuclei: a unifying agent	L.E.Tacconi-Garman et al.	HCN	IZw1 3C120 Mkn3 NGC3227 Mkn270 NGC4051 NGC5506 NGC6764 NGC7469 Mkn463
E007	Any	Molecular Abundances at the onset of dark cloud chemistry	R.Lucas H.Liszt	Many	NRAO150, 3C111, 0528+134 NRAO530 3C454.3
E020	D	HCN observations during the impact of comet Shoemaker Levy onto Jupiter	A.Marten A.Dutrey T.Encrenaz D.Gautier S.Guilloteau E.Lellouch J.Wink C.Thum	HCN	Jupiter
D011	BC	Star formation in W49N: triggered by clump-clump collisions ?	R.Guesten H.Wiesemeyer K.Uchida	C ³⁴ S ³⁴ SO ₂	W49 N
Dx17	B2 C2	Sizes of CO emitting regions in Ultraluminous galaxies	D.Downes S.Radford P.M.Solomon	CO	00057+4021, I Zw 1 02483+4302, VII Zw 31 09320+6134, 10035+4852 10565+2448, Mrk 231 Mrk 273, 17208-0014 Mrk 1027
D037	BC	CO in an unusual luminous IR merger with a molecular tail	Yu.Gao P.Solomon S.Radford D.Downes	CO	Arp 220
D049	BC	Molecular gas kinematics in the Arp 220 starburst	D.Downes S.Radford P.Solomon	CO	89 Her
D051	BC	The circumstellar envelope of the 89 Herculis system	J.Alcolea V.Bujarrabal	CO	NGC 1530
E011	CD	HCN in the nucleus of Galaxy NGC 1530	D.Reynaud D.Downes	HCN	NGC7023
E013	CD	Search for high density clumps in photodissociation regions NGC7023	A.Fuente R.Neri J.Martin-Pintado C.Rogers G.Moriarty-Schieven	NGC7023	HCO ⁺
E015	CD	CO in the nucleus of NGC5907	S.Garcia-Burillo M.Guélin	CO	NGC5907
E017	Any	Molecular absorption in low latitude continuum sources	J.Lequeux R.J.Allen S.Guilloteau R.Lucas	C ₂ H CS CN N ₂ H ⁺ C ₃ H ₂ SO	2013+370 0727-115 1823+210
E021	CD	Detection project on YSO circumstellar disks	A.Dutrey S.Guilloteau K.Schuster F.Menard M.Simon	¹³ CO C ¹⁸ O	T Tauri stars in Taurus region (25)
D039	BC	Millimeter interferometric observations of the Sy1 galaxy NGC7469	R.Genzel L.Tacconi A.Eckart	CO	NGC 7469
E005	D	Extending to the mm range the radio spectrum of Chemically Peculiar stars	F.Leone C.Trigilio C.Umana	Cont	HD37479
E008	B2	AU scale structure in molecular clouds (?)	R.Lucas H.Liszt	CCH	NRAO150, 3C111
E010	CD	¹³ CO in the nucleus of Galaxy NGC 1530	D.Reynaud D.Downes	¹³ CO	NGC 1530
E019	BC	IRAS03282+3035 as an example of the youngest known stellar objects	R.Bachiller A.Dutrey S.Guilloteau M.Tafalla	CS	IRAS03282+3035

Proj.	Conf.	Title	Authors	Molecules	Object
D069	B2	A search for local J=1-0 HCO ⁺ absorption toward extragalactic sources	R.Lucas H.Liszt	HCO ⁺	Line-of-sight of quasars
D040	CD	CO mapping of the cometary globules in the Helix nebula	T.Forveille P.Huggins R.Bachiller P.Cox	CO	Helix Nebula NGC7923
D053	CD	Jet entrainment in the L1157 molecular outflow	R.Bachiller A.Dutrey A.Fuente J.Martin-Pintado S.Guilloteau	CO	L1157
D064	CD	Small scale structure of the cloud core region behind NGC2024	R.Simon C.Kramer J.Stutzki G.Winnevisser	CN ¹³ CO	NGC2024
D022	BC	CO in the nucleus of NGC 4826	K.I.Uchida R.Gusten J.Turner	CO	NGC 4826
D068	C2	Observations of Titan in the J=1-0 line of CO	A.Marten A.Dutrey D.Gautier	CO	Titan
E003	D	Dense molecular gas in Seyfert Nuclei: a unifying agent	L.E.Tacconi-Garman et al.	HCN	IZw1 3C120 Mkn3 NGC3227 Mkn270 NGC4051 NGC5506 NGC6764 NGC7469 Mkn463
E007	Any	Molecular Abundances at the onset of dark cloud chemistry	R.Lucas H.Liszt	Many	NRAO150, 3C111, 0528+134 NRAO530 3C454.3
E020	D	HCN observations during the impact of comet Shoemaker Levy onto Jupiter	A.Marten A.Dutrey T.Encrenaz D.Gautier S.Guilloteau E.Lellouch J.Wink C.Thum	HCN	Jupiter
D011	BC	Star formation in W49N: triggered by clump-clump collisions ?	R.Guesten H.Wiesemeyer K.Uchida	C ³⁴ S ³⁴ SO ₂	W49 N
Dx17	B2 C2	Sizes of CO emitting regions in Ultraluminous galaxies	D.Downes S.Radford P.M.Solomon	CO	00057+4021, I Zw 1 02483+4302, VII Zw 31 09320+6134, 10035+4852 10565+2448, Mrk 231 Mrk 273, 17208-0014 Mrk 1027
D037	BC	CO in an unusual luminous IR merger with a molecular tail	Yu.Gao P.Solomon S.Radford D.Downes	CO	Arp 220
D049	BC	Molecular gas kinematics in the Arp 220 starburst	D.Downes S.Radford P.Solomon	CO	89 Her
D051	BC	The circumstellar envelope of the 89 Herculis system	J.Alcolea V.Bujarrabal	CO	NGC 1530
E011	CD	HCN in the nucleus of Galaxy NGC 1530	D.Reynaud D.Downes	HCN	HCO ⁺
E013	CD	Search for high density clumps in photodissociation regions NGC7023	A.Fuente R.Neri J.Martin-Pintado C.Rogers G.Moriarty-Schieven	NGC7023	NGC5907
E015	CD	CO in the nucleus of NGC5907	S.Garcia-Burillo M.Guélin	CO	2013+370
E017	Any	Molecular absorption in low latitude continuum sources	J.Lequeux R.J.Allen S.Guilloteau R.Lucas	C ₂ H CS CN N ₂ H ⁺ C ₃ H ₂ SO	0727-115 1823+210
E021	CD	Detection project on YSO circumstellar disks	A.Dutrey S.Guilloteau K.Schuster F.Menard M.Simon	¹³ CO C ¹⁸ O	TTauri stars in Taurus region (25)
D039	BC	Millimeter interferometric observations of the Sy1 galaxy NGC7469	R.Genzel L.Tacconi A.Eckart	CO	NGC 7469
E005	D	Extending to the mm range the radio spectrum of Chemically Peculiar stars	F.Leone C.Trigilio C.Umana	Cont	HD37479
E008	B2	AU scale structure in molecular clouds (?)	R.Lucas H.Liszt	CCH	NRAO150, 3C111
E010	CD	¹³ CO in the nucleus of Galaxy NGC 1530	D.Reynaud D.Downes	¹³ CO	NGC 1530
E019	BC	IRAS03282+3035 as an example of the youngest known stellar objects	R.Bachiller A.Dutrey S.Guilloteau M.Tafalla	CS	IRAS03282+3035

Proj.	Conf.	Title	Authors	Molecules	Object
C026	BC	The molecular counterpart of the dust disk in L1551: Origin of the outflow	A.Dutrey S.Guilloteau	CO C ¹⁷ O	L1551-IRS5
C037	BC	M82 - The suicide of a starburst ?	N.Brouillet P.Schilke	HCO ⁺	M 82
C049	BC	Study of the photodissociation region in NGC 7027: HCN	P.Cox S.Guilloteau A.Omont R.Bachiller P.Huggins	HCN	NGC 7027
C054	BC	Shocked molecular gas from the superwind of NGC 3079	L.Tacconi R.Genzel A.Harris P.VanDerWerf	HCN	NGC 3079
C055	BC	Shocked molecular gas from the superwind of NGC 3079	L.Tacconi R.Genzel A.Harris P.VanDerWerf	CO	NGC 3079
C058	BC	Distribution of the molecular gas in the primeval galaxy IRAS 10214+4724	S.Radford D.Downes	CO(3-2)	IRAS 10214+4724
C060	BC	The 200 km.s ⁻¹ outflow in the proto-planetary nebula CRL618: a follow up study	R.Neri J.Cernicharo M.Grewing S.Garcia-Burillo M.Guelin S.Guilloteau R.Lucas	CO	CRL618
D006	CD	Disk versus Infall Envelopes around protostellar sources: a detailed study of L723	S.Terebey P.André D.Despois S.Cabrit A.Baudry	C ¹⁸ O C ¹³ O	L723
D007	B2 C2,D	Extension of CN in C-rich circumstellar envelopes	A.Omont, H.Olofsson R.Lucas	CN ¹³ CO	U Cam, RW LMi Y CVn, LP And
D029	BC	The circumbinary disk of Haro 6-10	J.L.Monin F.Menard J.P.Berger A.Dutrey S.Guilloteau P.VanDerWerf	¹³ CO C ¹⁸ O	Haro 6-10
D038	BC	Imaging Redshifted CO(3-2) from a damped Lyman α absorber	S.Radford	CO	Q0836+113
D043	CD	The inner regions of preplanetary nebula	V.Bujarrabal R.Neri J.Alcolea M.Grewing	CO	R Scutum
D048	BC	CO in the barred Galaxy NGC 1530	D.Downes S.Radford P.Solomon	CO	NGC 1530
D050	BC	CO observations of the FR II powerful radiogalaxy 3C368 at z=1.13	D.B.Sanders K.Chambers A.Evans S.Radford	CO	3C368
D052	BC D	Jet entrainment in the L1157 molecular outflow	R.Bachiller A.Dutrey A.Fuente J.Martin-Pintado S.Guilloteau	SiO	L1157
D053	CD	Jet entrainment in the L1157 molecular outflow	R.Bachiller A.Dutrey A.Fuente J.Martin-Pintado S.Guilloteau	CO	L1157
D054	C1	Molecules in the outer galaxy lines in absorption against quasars	J.Lequeux R.J.Allen S.Guilloteau R.Lucas	HCO ⁺ HCN	0727-115 2013+370
D056	CD	Interaction of Jet with Molecular ISM in the nucleus of NGC4258	K.Y.Lo R.Plante L.Tacconi R.Genzel	CO	NGC 4258
D063	CD	Arp 105: a case for tidal stripping of molecular gas	I.F.Mirabel P.A.Duc J.E.Wink	CO	Arp105
D070	B2	Observations of local J=1-0 CO absorption toward 0355+508	R.Lucas H.Liszt	CO	0355+508
D071	D C1	The HCN envelope around the carbon star U Cam	M.Lindqvist H.Olofsson R.Lucas K.Eriksson B.Gustavsson	HCN	U Cam
D018	C D B2	Do binaries have larger disks than single-stars	A.Dutrey G.Duvert S.Guilloteau M.Simon	¹³ CO C ¹⁸ O	UZ Tau, DD Tau, DG Tau, DL Tau UY Aur, FV Tau
D065	CD	High angular resolution observations IRC+10216: a key to the understanding of chemical processes in circumstellar envelopes	R.Lucas M.Guélín J.Cernicharo C.Kahane	CN C ₄ H ¹³ CO C ₂ S CH ₃ CN	IRC+10216
D066	D	The Cloverleaf: an excellent candidate for CO emission from a quasar at z=2.5	D.Alloin R.Barvainis P.Coleman R.Antonucci L.Tacconi	CO(3-2)	HI143+117
D073	CD	A High angular resolution study of the CO jet in HH111	J.Cernicharo R.Bachiller R.Neri	CO C ¹⁷ O	HH111

8. ANNEX II : PUBLICATIONS/ 8.1 IRAM PUBLICATIONS

450. RADIO EMISSION FROM STARS : A SURVEY AT 250 GHz
W.J. Altenhoff, C. Thum, H.J. Wendker
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451. THE MOLECULAR SURROUNDINGS OF W3(OH)
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8. ANNEX II : INTERNAL PUBLICATIONS/8.3 WORKING REPORTS

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FABRICATION AND MIXER
PERFORMANCE OF Nb/Al DOUBLE-
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Th. Lehnert, S.C. Shi, T. Noguchi

224. PROGRESS REPORT ON ALU-MINIUM
PANELS
D. Plathner

225. TECHNICAL DETAILS ON ALU-
MINIUM PANELS
D. Plathner

226. LONG-TERM STABILITY OF
ALUMINIUM PANELS FOR IRAM 15M
DISHES
D. Plathner

THE ELECTRICAL EFFECTS OF THE
INTER-PANEL SLITS

D. Morris

9. ANNEX III - IRAM Executive Council and Committee Members, January 1994

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