Observations with the Plateau de Bure Interferometer of the circumbinary disk around the young double star GG Tau. The figure shows the superposition of the high resolution continuum map (in color) with three velocity channels (black contours) of the $^{13}$CO J=1-0 emission. These observations reveal unambiguously that the material is located in a rotating ring (cf. Dutrey, Guilloteau and Simon, 1994).
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1. INTRODUCTION

In 1993 again a wealth of scientific results has been produced with both the 30m telescope and the Plateau de Bure interferometer by a still growing user community. A flavor of the results obtained should be provided by the summary of highlights in Chapter 2 of this report.

At the 30m telescope the users benefited from further improvements of some of the SIS-receivers, including a very performing 345 GHz system on loan from the MPE, and from the availability, for the first time, of a 7-channel bolometer which was provided for this observing run by the MPIfR.

At the interferometer the commissioning of Antenna 4 was successfully completed and throughout much of the year the interferometer operated as a 4-element array. The doubling of instantaneous baselines has significantly increased the mapping efficiency of the instrument as witnessed e.g. by the successful studies of circumstellar rings and outflows associated with young stellar objects, and circumstellar envelopes around evolved stars.

On the personnel side, two major changes occured in 1993 concerning the IRAM-Granada station management which went from Albert Greve to Wolfgang Wild who joined IRAM in the fall of the year, and the Grenoble receiver group which is now headed by James Lamb who joined IRAM in October of 1993.

New projects which have started include the preparation of dual-channel receivers for the interferometer, a multibeam heterodyne system for the 30m telescope, and the acquisition of a 37-channel bolometer array in a cooperation with the MPIfR. IRAM will in particular be responsible for providing the necessary data reduction software as part of the Grenoble software package.

Concerning future developments, the most important event was the discussion at the June 1993 Council Meeting of a funding scheme for Antenna 5. Hopefully a solution will eventually also be found for Antenna 6. Given current economical conditions, funding of one more antenna puts a major extra burden on the IRAM partners, and it is clear that the funding has to be spread out over several years. Nevertheless, one of the options presented by IRAM has been adopted and is now being implemented. It allows first contracts for subsystems of Antenna 5 to be signed in 1994. Connected to the enhancement of the interferometer capabilities was a geological study for the extension of the baselines towards the west and in the northern direction on the Plateau de Bure.

In preparing for Antenna 5 and in view of the pinhole problems in the surface layers which cover the carbon-fibre panels now in use on the Plateau de Bure telescopes (see Annual Report 1992), IRAM began the study of an alternative design based on panels made from aluminium alloy. Two full-size prototype panels have actually been built and are now undergoing detailed testing. They have to comply with the same specifications, including dimensions and weight, as the carbon-fibre panels. A call for tender has verified the feasibility of the series production of the new panels in industry and its economical attractiveness.
2. HIGHLIGHTS OF RESEARCH WITH THE IRAM TELESCOPES IN 1993

2.1 SUMMARY

Of the many projects done at IRAM's observatories or published in 1993, some highlights were:

- Detections with the 30m telescope of continuum emission from quasars at redshifts of 3.2 and 4.7, which may be thermal emission from dust.

- A CO study at the 30m telescope of 35 distant ultraluminous galaxies which indicates that these galaxies are opaque to all wavelengths shorter than 100 microns, with a constant ratio of CO flux to 100-micron flux of about 4 km/s.

- A new catalog of the millimeter flux variations of 118 quasars and radio galaxies at 90, 150 and 230 GHz, from observations with the 30 m telescope.

- Maps with the 30 m telescope of the peculiar elliptical galaxy NGC 1275 (= 3C 84), that show the 6 $10^9$ solar masses of molecular gas is apparently in a rotating disk of radius 3 kpc.

- Interferometer maps of HCN in the central few hundred parsecs around the nucleus of the Seyfert galaxy NGC 1068. The distribution of the molecular gas may account for the anisotropy of the nuclear radiation observed in the visible and ultraviolet.

- Maps with the interferometer of the southwest part of the galaxy M82, in the HCN line. The maps resolve the central molecular ring into numerous giant molecular clouds similar to those in the center of our Galaxy.

- A map made with the 30 m telescope and the MPIfR 7-channel bolometer array, of the continuum emission from cold dust in the edge-on spiral galaxy NGC 891. The dust emission is closely correlated with the CO emission and poorly correlated with the distribution of atomic gas.

- Interferometer observations of molecular absorption lines from gas in our Galaxy toward the extragalactic sources 0212+735, NRAO 150, BL Lac, 2013+370, and 0727-115.

- A search for molecular oxygen in cold dark clouds, with negative results. The result suggests the carbon to oxygen ratio in dark clouds may be higher than its "standard" cosmic abundance ratio.

- A new survey at 250 GHz of radio continuum emission from 270 stars. With the current bolometer sensitivity, nearly all types of stars in the Hertzsprung-Russell diagram can be detected at the 30 m telescope.
- Interferometer maps in $^{13}$CO of a thin disk in Keplerian rotation around the close binary GG Tauri. The line and continuum data suggest that in the disk, CO is depleted by a factor of 20 relative to its abundance in the general interstellar medium.

- Detection with the 30 m telescope of a submillimeter hydrogen recombination line maser in the young, massive star MWC 349. The data suggest the masers come from the inner edge of a rotating and contracting disk around the star.

- Interferometer maps of C$^{18}$O, HCO$^+$, CH$_3$CN, H41$\alpha$, and H59$\gamma$ lines and the mm continuum near the ultracompact H II region W3(OH). The methyl cyanide (CH$_3$CN) images show two compact sources, one toward the water masers east of the H II region and another at the position of the OH masers seen against the H II region.

- Interferometer maps of the 95 and 98 GHz molecular lines of the MgNC, C$_4$H, and C$_3$H radicals in the carbon rich stellar envelope IRC+10216. The emission arises in a shell of radius 15 arcsec, unlike the centrally peaked emission of NaCl, SiO, SiS, CS and CO.

- Interferometric detection of CO in the troposphere of Neptune.

- Detection with the 30 m telescope, of acetonitrile (methyl cyanide) in the atmosphere of Titan.

EXTRAGALACTIC RESEARCH

Distant Sources (> 70 Mpc)

Dust in a Quasar at a Redshift of 4.7?
Continuum emission at 1.25 mm has been detected at the 30 m telescope from two quasars at high redshifts: the quasar 1202-0725 at a redshift of 4.7, and the quasar 2132+0216 at a redshift of 3.2. Fluxes are about 10 mJy, and if the emission is coming from the quasars and not from other sources in the beam, then the rest-frame wavelengths would be 220 and 300 microns, respectively. If the emission is thermal radiation from dust, the signal level implies an enormous amount of interstellar matter, and it should be possible to detect CO. Searches for CO at the 30 m telescope in these objects, however, have been negative, possibly because of the limited redshift range covered in the spectral line searches so far.

Ultraluminous Galaxies
Measurements at the 30 m telescope of 35 ultraluminous galaxies show that the CO line flux, in units of Jy km/s, is remarkably proportional to the far infrared flux at 100 microns, in Jy, with a ratio of CO to far IR flux equal to 4 km/s. This proportionality supports a model in which the dust radiation from ultraluminous galaxies is opaque for all wavelengths shorter than 100 microns. This provides additional evidence that the dust mass in the center of these galaxies is high and that the central gas mass is a large fraction of the dynamical mass. These considerations yield a relation between the distances to the galaxies and the ratio of the gas mass to CO luminosity.
**New Millimeter Flux Catalog**

A third IRAM catalog has been published of flux densities of 118 extragalactic radio sources observed at 90, 150, and 230 GHz at the 30 m telescope. The sources are mostly flat-spectrum quasars and a few radio galaxies with high flux densities at millimeter wavelengths. This third instalment presents previously unpublished measurements from November 1990 through the end of 1992. The publication also provides figures showing the millimeter flux variations from 1984 through 1992 of 83 sources from all three IRAM catalogs.

---

**Fig. 2.1** HCN and radio continuum emission in the nucleus of the galaxy NGC 1068. The HCN emission mapped with the IRAM interferometer is shown in color (blue = weakest features, in the ring around the center, typically 3 K km/s; red = molecular cloud at the nucleus, 21 K km/s). The synthesized beam of 3" x 2" is shown at lower left. The white contours show synchrotron emission from the nuclear jets at a wavelength of 6 cm, as mapped with the VLA in 1986.
2.2.2 Nearby Galaxies (10 < D < 70 Mpc)

The Dense Obscuring Material in the Nucleus of NGC 1068
The interferometer has been used to map the HCN emission at 88.6 GHz around the nucleus of the Seyfert 2 galaxy NGC 1068. This galaxy is known to have an active central source ejecting relativistic electrons into jets which extend into two opposite directions. In recent years, evidence has accumulated that the nucleus is surrounded by a large amount of hot, dense molecular gas extending over a 350 parsec region. This evidence came from infrared spectroscopy and broad-band imaging, from optical and ultraviolet images showing a conical beaming of this radiation, and from millimeter interferometry in the CO line. The new results from the IRAM interferometer (Fig. 2.1) show that in contrast to the CO maps, in which the dominant feature is an outer ring 15" from the nucleus, the HCN is weak in the ring, but strongly peaked near the nucleus, in a 7" region extending northeast-southwest where a stellar bar is seen in the infrared. At the nucleus, the HCN/CO brightness ratio has a very unusual ratio of about 2:1. In other galaxies, the ratio is typically in the range 1:100 to 1:10. This indicates that the HCN is in dense, opaque clumps without the usual rarefied envelopes. These diffuse envelopes may have been stripped away by the intense radiation and wind from the active nucleus. The interaction between the directed wind and radiation from the nucleus with the central bar and disk of molecular clouds may explain the strong NE/SW asymmetry in the brightness of the continuum radio emission and the narrow line optical emission.

CO Mapping of NGC 1275
The peculiar giant elliptical galaxy NGC 1275, in the Perseus cluster of galaxies is one of the strongest extragalactic radio sources, having a Seyfert nucleus emitting hard X-rays. NGC 1275 is thought to be accreting an X-ray cooling flow of 200 solar masses per year, and is probably interacting with another galaxy. CO emission from NGC 1275 was discovered with the 30 m telescope in 1988, indicating $6 \times 10^9$ solar masses of molecular gas. The galaxy has now been mapped in CO(1-0) and (2-1) at the 30 m telescope. The maps show that most of the molecular gas is within a radius of 3 kpc from the center of NGC 1275, and appears to be rotating in a disk at position angle of 120°. The total velocity spread of the rotating structure is about 450 km/s, which, depending on the inclination of the rotating disk to the line of sight, may be consistent with a stellar mass of about $10^{11}$ solar masses interior to a radius of 3 kpc.

2.2.3 The Nearest Galaxies (< 10 Mpc)

Dust Distribution in the Edge-on Spiral Galaxy NGC 891
The 30 m telescope has been used with the MPIfR 7-channel bolometer array to map the 1.3 mm continuum emission from the edge-on spiral galaxy NGC 891. This continuum emission arises mostly in cold (< 20 K) dust associated with molecular clouds. It correlates remarkably well with the CO emission and poorly with HI emission, up to a radius of 7 kpc from the center of the galaxy. The H$_2$ mass derived from the cold dust emission is about 3 times lower than that derived from CO, and about 20 times higher than the mass of gas associated with the warm dust observed by the IRAS satellite.

HCN in the inner region of M 82
The IRAM interferometer has mapped the south-west part of the central starburst region of the galaxy M82 in the HCN(1-0) line, with a 3"x 2" beam. The central molecular ring is resolved into individual giant molecular cloud complexes with sizes and masses similar to those in the
central parts of our Galaxy. The dense molecular cores do not coincide with supernova remnants in the center of M82, but do seem to be embedded in a huge photodissociation/photoionization region. An intense and compact (4") molecular complex of $1.2 \times 10^7$ solar masses is displaced by about 5" from the M82 nucleus. This peculiar complex coincides with the 12.4 micron peak and with the radio recombination line centroid, and hence is a very active site of star formation. The global HCN(1-0)/HNC(1-0) line ratio in M82 is 2-to-1, about the same as in hot, dense star formation regions in our Galaxy. The mass of gas derived from the molecular line observations is a very large fraction (about 40%) of the dynamical mass within the same region, as derived from the rotation curve. This unusual situation may help explain why M82 is undergoing a powerful nuclear starburst at the present epoch.

**Fig. 2.2:** *left:* Map made with the 30 m telescope of the 1.3 mm continuum emission from cold dust in the edge-on spiral galaxy NGC 891. *right:* Optical photograph of NGC 891.
2.3 YOUNG STELLAR OBJECTS

A Submillimeter Recombination Line Maser in MWC 349
The first detection of a radio recombination line maser at submillimeter wavelengths has been made with the IRAM 30 m telescope and confirmed with the JCMT. The line is the hydrogen 26α-line at 353 GHz. The recombination-line masers in the young, massive star MWC 349 are thought to originate on the inner edge of a circumstellar disk, where the disk's gas is ionized by the ultraviolet radiation from the star. The star also produces a strong, opaque, stellar wind. At frequencies lower than 100 GHz, the opaque region is larger than the disk, preventing the masers on the disk's inner edge from being seen at centimeter radio wavelengths. The differences between the blue- and red-shifted maser spikes in velocity, line width, intensity and degree of maser saturation can be explained if the disk containing the masers is rotating and also contracting toward the star at a velocity of 5 km/s or less.

Images of the Rotating Ring around 00 Tauri
Interferometer observations of the 2.6 mm line emission from 13CO show a fully resolved, rotating thin disk around the young close binary star 00 Tau. The rotation curve and geometry agree well with a model of a Keplerian disk inclined 43° to the line of sight and orbiting a binary system with a total mass of 1.2 solar masses, consistent with the stellar luminosities (Fig. 2.3). Interferometer images of the dust continuum emission show that the disk extends to an outer radius of at least 800 AU, but has a large inner hole of radius 180 AU, probably due to tidal forces induced by the binary star, in an eccentric orbit. The dust ring may be located at the position where the orbital period of the disk is in resonance with the period of the binary star. Angular momentum transfer from the binary to the disk will increase the orbital eccentricity and stop further accretion onto the stars, increasing the lifetime of the circumbinary disk. The dust continuum flux and the 13CO and C18O line fluxes imply the CO abundance in the disk is about 20 times lower, relative to the total mass of gas and dust, than it is in the general interstellar medium.

The Molecular Surroundings of W3(OH)
IRAM interferometer maps have been made of the compact H II region W3(OH) in the mm continuum and in the molecular lines of C18O, CH3CN, and HCO+ (Fig. 2.4), and the hydrogen recombination lines H41α and H59γ. The ionized gas in the compact H II region is detected in the recombination lines and in its free-free continuum emission. The methyl cyanide (CH3CN) images show two compact sources, one at the cluster of water masers to the east of the H II region and the other at the high-density molecular clump that contains the OH masers seen toward the H II region. Both molecular sources have temperatures of order 100 K. At 111 GHz, there is also a compact, 112 mJy continuum source at the water maser cluster. If this emission is from dust, then the gas mass associated with the source at the water maser cluster is 30 solar masses, and the mass loss rate is about 5 x 10^-3 solar masses per year, presumably from a young OB star still surrounded by a very thick cocoon of dust, with a column density of 3 x 10^{25} cm^-2.
Fig. 2.3: Rotating ring around GG Tauri: comparison of model (left column) and interferometer observations (right column). Part 1, upper panels: Spatially integrated $^{13}$CO intensity vs. velocity (topmost scale). Part 2, middle panels: Position-velocity diagrams in the plane of the disk. The solid curves show the expected loci for Keplerian rotation for 1.2 solar masses and a disk inclination of 43°, contour step 1 K; the model has been convolved with the interferometer beam of 2.6" x 2.0". Part 3, bottom panels: Continuum emission from dust in the disk, contour step 2 mJy/beam; continuum beam 2.1" x 1.4".
Fig. 2.4: Interferometer maps of gas near the compact H II region W3(OH) in the molecular lines of C$^{18}$O (left), HCO$^+$ (middle), and CH$_3$CN (right). The cross is the map phase center, near the main H II region, the filled circles are the positions of water masers and the open triangle is the HCN peak. Note that the molecules are all peaked near the location of the water masers.

CIRCUMSTELLAR ENVELOPES

2.4.1 Radio Continuum Emission from Stars

A New Survey at 250 GHz of Radio Continuum Emission from Stars

The 30 m telescope has been used with the MPIfR bolometer to survey 270 stars of different types for 250 GHz continuum emission. The results show early type stars often have fluxes that deviate from that expected from a uniformly expanding wind, probably because of temperature and density fluctuations in their lower atmospheres. For Wolf-Rayet stars, this deviation seems to depend on effective temperature. A substantial fraction of the 250 GHz flux of pre-main sequence stars seems to come from shells of warm dust. Nearby giants and supergiants show ample 250 GHz emission from a transition layer between their photosphere and chromosphere. Optically variable stars are not very strong emitters at 250 GHz, except for a few β Lyrae type stars and symbiotic stars.

Chemistry and Dynamics of Stellar Envelopes

MgNC and the Carbon-Chain Radicals in IRC+10216

The infrared source IRC+10216 is a famous evolved star whose circumstellar envelope has an extremely rich spectrum of molecular lines. About 50 molecules, including highly refractory compounds and highly reactive species have been identified in this dusty envelope. The IRAM interferometer has mapped IRC+10216 with resolution 4" x 3" in the 95 and 98 GHz lines of the MgNC, C$_4$H, and C$_3$H radicals (cf. Fig. 2.5).
Fig. 2.5: Maps from the IRAM interferometer, with a 5\" beam, of the circumstellar envelope of IRC+10216, in MgNC (top), C₄H (middle), and C₃H (bottom). A point-like mm continuum source coinciding with the IR source (cross) has been removed from the maps. Each box shows the emission in a velocity range of -21 to -34 km/s. The C₄H and C₃H maps lack some short spacing information, as the interferometer data for these two molecules have been combined with only a single spectrum from the 30 m telescope.
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 x 10^{16} cm). The patchy appearance of the MgNC, C4H, and C3H maps reflects a clumpy gas distribution. The shell-like distribution is the result of a time-dependent chemistry. Since the three radicals peak at the same radius, they must form almost simultaneously. This suggests a common formation mechanism, such as desorption from dust grains. The shell where MgNC and the carbon chains are detected is shifted by 2" from the infrared source, possibly suggesting the presence of a binary star.

2.5 MOLECULES, ASTROCHEMISTRY

No Molecular Oxygen in Cold Dark Clouds
A search for molecular oxygen has been carried out with the 30 m telescope toward the prototypical dark clouds TMC2, L134N, and B335, in the 234 GHz line of 16O^{18}O. Upper limits to the O2 / CO abundance ratio are about 0.2 in all three clouds. These are the first limits to the O2 abundance obtained toward dark clouds, and they are similar to those previously obtained toward warm clouds. Chemical equilibrium models predict a value of [ O2 / CO ] = 0.5, if the abundance ratio [ C / O ] = 0.4 , the cosmic value. The models could be brought into agreement with the negative results from the observations if the carbon to oxygen ratio in dark clouds is actually 0.7, instead of its textbook value.

Interferometer Observations of Molecular Line Absorption in Interstellar Clouds
The IRAM interferometer has been used to detect absorption line profiles of 13CO, HCO^+, C2H, CN, HCN, and HNC in a nearby molecular cloud in our Galaxy, on the line of sight to the extragalactic source BL Lac. A total of 12 lines were detected, corresponding to relatively low optical depths of 0.3 to 1.5 . Because the excitation is quite weak, the column densities are extremely reliable. The relative abundances of 13CO, HCO^+, C2H, CN, and HCN are similar to those in TMC-1, the well-known dust cloud in Taurus, but N2H^+ (not detected) and HNC are deficient toward BL Lac by factors of three to six. It appears that there is less than one magnitude of optical extinction associated with the molecular cloud. The absorbing gas is probably only 330 parsecs from the earth, with a mass of only a tenth of the mass of the sun. Additional detections of Galactic molecular line absorption have been made on the lines of sight to the extragalactic continuum sources 0212+735, 0355+508 (NRAO 150), 2013+370 and 0727-115. In the directions toward 0215+735 and 0355+508 (Fig. 2.6), the HCO^+ absorption profiles have more and wider lines than are seen in 13CO. Some very strong HCO^+ components are absent in the 13CO emission profiles and are either quite weak or absent even in 12CO emission. The absorption lines probably come from gas in the outer envelopes of molecular clouds, where the visual extinction is 1 magnitude or less. At such low densities, models of dark cloud chemistry do indeed predict unusual variations of the HCO^+/CO ratio.
Fig. 2.6: Emission and absorption profiles from gas in our Galaxy, seen in the direction of the extragalactic continuum sources 0212+735 and 0355+508 (NRAO 150). The emission line spectra are from the NRAO 12 m telescope, and the absorption lines were detected with the IRAM interferometer.
2.6 SOLAR SYSTEM

**CO in the Troposphere of Neptune**

The CO J=1-0 line has been detected with the IRAM interferometer in the atmosphere of Neptune. The line has been detected in absorption, with a linewidth greater than 5 GHz and a line to continuum ratio of 5.3 ± 1.5 percent. Such a detection is probably only possible with an interferometer, and also requires an accurate calibration of the receiver's sideband gain ratio to a precision of better than 2 percent. This result means that CO, which had been detected previously in Neptune's stratosphere, is also present in the planet's troposphere, with a mixing ratio of 0.8 to 1.5 parts per million. Hence the CO abundance is about the same in the troposphere as it is in the stratosphere. This means the CO probably does not originate from infalling debris, as had been suggested previously, but from the interior of the planet (Fig. 2.7).

**Acetonitrile in the Atmosphere of Titan**

Titan is the only satellite of the solar system known to have a substantial atmosphere, mostly molecular nitrogen. The gas methane, CH₄, was discovered by G. Kuiper with near-infrared spectroscopy of Titan's atmosphere in 1944. In 1980 the Voyager spacecraft detected in Titan's atmosphere many more simple hydrocarbons, probably made in methane photochemistry, as well as the gases carbon dioxide CO₂, hydrogen cyanide HCN, cyanogen C₂N₂, and cyanoacetylene HC₃N. Subsequently, the 30 m telescope was used in 1985 to observe the millimeter lines of HCN in the atmosphere of Titan. This was the first ground-based detection of a molecule in a satellite of the solar system at millimeter wavelengths. The 30 m telescope has now been used again to find in the atmosphere of Titan the molecule acetonitrile (or methyl cyanide, CH₃CN). This is the first new organic molecule to be detected.
Since Titan's diameter is only a fraction of an arcsecond as seen from the earth, it is a point source for a millimeter interferometer. The IRAM interferometer has been used to measure the HCN J=1-0 line at 3.4 mm with high sensitivity (Fig. 2.9) and to obtain an accurate measurement of the line to continuum ratio at this wavelength. Preliminary estimates indicate that hydrogen cyanide, HCN, is about 300 times more abundant than acetonitrile, CH₃CN, in Titan's atmosphere.

Fig. 2.8: Detection of acetonitrile on Titan. Seven individual line components of CH₃CN (numbered 0 to 6) are shown on this spectrum taken in June 1993 with the 30m telescope.

Fig. 2.9: Observation of the HCN J=1-0 line at 88.6 GHz in the atmosphere of Titan. The line was detected in the IRAM interferometer's lower side band, while Titan's continuum radiation was detected with high sensitivity in the upper side band.
3. PICO VELETA OBSERVATORY

3.1 STAFF CHANGES

In June 1993 we lost one of our senior colleagues and friend, Dr. Hans Steppe, who was one of the first scientists to join the IRAM staff. He lost his life in a tragic mountain accident in Austria.

In the fall of the year Albert Greve who had served as Station Manager in Granada since the beginning of 1991 returned to Grenoble. He was succeeded by Wolfgang Wild who took office in October 1993.

With Spain now being a full member, the IRAM Council approved a new procedure for the appointment of the Deputy Station Manager for the Granada station. Juan Penalver agreed to serve in this capacity while continuing at the same time with his tasks as chief telescope engineer.

In order to compensate at least in part for the loss of astronomical expertise in the astronomers' group in Granada, caused by the return of the former Spanish Co-Director of the station to Yebes and the untimely death of Hans Steppe, it was decided to increase the number of post-doc positions and to recruit an additional astronomer-cooperant.

Further staff changes occurred in the operators' and in the receiver group. Since one engineer had left and as Hauke Hein was supporting the work at the H.H.T. (Arizona) during a six months period, it was decided to delegate one receiver engineer from Grenoble to Granada.

3.2 30m TELESCOPE OPERATION

The operation of the telescope was productive and smooth during most of the time, also because of relatively mild climatic conditions. The telescope was regularly maintained for approximately 12 hours per week, including receiver fillings, receiver maintenance, test tunings, and computer and backend maintenance. A longer maintenance period of roughly 7 days was used for a general revision of the subreflector and improvement of the electrical distribution system. There were no major mechanical or electrical failures during 1993.
For better evaluation of the telescope operation, we introduced, in the middle of 1993, a more
detailed log-book with entries made by the telescope operators. Based on these data, the
telescope operational statistics for the period June to December 1993 is shown in Fig. 3.1.

**30M Time Distribution (%)**
during the period Jun.93 to Dec.93

- Stop Tech. Problems (0.8%)
- Stop Meteorological (6.2%)
- Stop Wind (10.3%)
- Used Mainten. (7.7%)
- Used Tech. Time (8.8%)
- Used Observ. (66.2%)

**Fig.3.1**: Distribution of telescope time for the period June to December 1993

For the majority of astronomical projects, we were able to make receiver tunings well in
advance of the actual observations. The constant availability of a receiver engineer or
technician at the site helped a lot towards the smooth receiver operation. The Granada
astronomers provided throughout the year assistance in the observations, taking also care of
the pointing and calibration. An extension of the spectral line calibration catalog to higher
frequencies is nearing completion. The pointing model of the telescope has been investigated in
detail; further measurements of the anomalous refraction have been made.

High quality observational data are, to a large extent, obtained through observations with the
wobbler. In the past, frequent failures of the wobbler occurred in wintertime because of icing
cauised by the residual humidity of the compressor air. The installation of an air-dehumidifier
has solved this problem. The status of the wobbler is now thoroughly checked by a dedicated
PC.
As a follow-up on earlier concerns about wind forces on the telescope, IRAM asked advice from an expert for wind effects on buildings/structures from the Technical University Aachen.

**INFRASTRUCTURE**

After 12 years of use, the access road to the telescope shows signs of deterioration. In a longer-term plan, we have started repairs: the construction of a wall in the upper bend to avoid further ground erosion, part of the road has been reconstructed in the lower bend, the drainage system has been cleaned and improved.

The leaky water distribution tank, located close to the Laguna, has been replaced by a bigger steel tank. A better water filter has been installed at the telescope.

A heat-humidity-interchanger has been installed at the telescope, to provide better climatized air. The climatization-ventilation system of the Granada offices has been completely renewed. At the telescope, the carpet of the dining room has been replaced, the windows have been repaired, the rooms have been painted.

**REFLECTOR SURFACE**

39 GHz phase retrieval holography measurements using the geostationary satellite ITALSAT were made in June, July and September. The coordinates provided by the Italian Telespazio have now sufficient accuracy for us to track the satellite without preliminary determination of the orbit at Yebes.

After correcting the phase retrieval maps for defocus, coma and astigmatism, very good correspondence was found between the transmitter holography map (made at 86 GHz, 11 degree elevation) and two subsequent ITALSAT maps (43 degree elevation). On the basis of this agreement it was decided to adjust the reflector surface; this was done in December 1993.

Considerable time and thought were spent to understand the misalignment of the subreflector and also the astigmatism of the telescope. The astigmatism is found to be variable in amplitude during daytime due to solar heating. The surface adjustment was directed to reduce the nighttime astigmatism to low values, but a variable daytime astigmatism will remain. However,
the measured systematic wavefront errors are now below the precision specification of the telescope.

3.5 RECEIVERS

The junction of the 230 G1 receiver was changed for a niobium junction.

The LO coupler of the 3 mm Schottky pointing receiver was repaired, and the receiver can be tuned again. At the same time, an attempt to install the second mixer was not successful since only one mixer survived the cooldown. Unfortunately, the working mixer also suffered a serious degradation during cooldown, resulting in a much higher receiver temperature.

The IF of the 3 mm SIS receiver has been changed to 1.5 GHz, the IF of the other receivers is 4 GHz. The down-converter of the 3 mm SIS receiver has been changed accordingly.

The Granada receiver staff has started the construction of a second 3 mm SIS receiver, expected to be ready in approximately one year.

Special receiver installation and related astronomical tests and observations involved:
- the MPE 350 GHz receiver built by H.Rothermel (11 days),
- the MPIfR 7-channel 230 GHz bolometer array (37 days),
- the IRAM single-channel 230 GHz bolometer IBOL-B (10 days).

Test were made with the IRAM 350 GHz SIS receiver in preparation for future use (1994) by guest observers

A Martin-Puplett interferometer for the measurement of the receiver sideband rejection has successfully been completed, and the instrument is installed in the focus cabin. The final application requires further studies of its characteristics and automation for remote use.

The Granada receiver engineers participate in the design of the optics for the 37-channel bolometer array.
The IF distribution box was completed and installed at the telescope via OBS all the backends as well as to fully configurate (both correlators, automatic attribution of subbands without intervention of the observer, bandwidth, resolution) and setup the backend control thereby has been built and calibrated. The quality of the holography is now determined only by atmospheric instabilities and the signal level of the measurements is now determined. A special backend for holography has been built and calibrated. The quality of the holography is now determined only by atmospheric instabilities and the signal level of the measurements is now determined.
Work on the 1 GHz processor for the filterbanks was continued.

Preliminary investigations were made about the "platforming" effect of the correlators, and several causes of this effect were found. A first modification was made to cure the dominant effect which reduced the "platform height" by a factor of 3 or 4. Correction of other causes of this effect is pending, the ultimate goal is to reduce this effect below the observable level.

3.7 COMPUTERS

The computer group, assisted by some astronomers, participated in the incorporation and programming of the backend distribution box. The members of the computer group were involved in tests of the MPIfR multibeam bolometer, the Cologne AOS, and participated in the computer and software definition of the coming IRAM 37-channel bolometer array.

The 'quick-look' display at the telescope has been changed to an X-terminal providing faster display and more flexibility.

The Granada computer now has access to Internet via a permanent link to the University of Granada and RICA (Red de Investigaciones Científica Andaluza). Since Internet is the de facto communication standard in the astronomical community, the access of the local network via SPAN is no longer maintained. It is planned to extend Internet to the telescope.

A hardware failure interrupted the computer link to the telescope for 2 months. The lack of communication demonstrated clearly the importance of the radio link. Equipment has been purchased which gives higher reliability and more flexibility to connect the Granada office and the telescope.

Nearly all offices now have either an X-terminal or a PC. The PCs are integrated into the local network (Decnet, PathWorks) and allow terminal emulation using the X-protocol.

3.8 VLBI

A 3 mm/1 mm VLBI campaign was successfully executed in April, a 7 mm campaign was made in July. 7 mm and 3 mm VLBI observations may now be considered as routine observations (with support from the MPIfR).
3.9  SAFETY

The computer-backend room at the telescope was equipped with a new fire extinguishing system.

A training in fire-extinguishing was provided by the Granada fire brigade, and the telescope personnel also participated in a First Aid course. Four more fire hoses have been installed (2 in the building, 2 in the telescope), 20 extra fire extinguishers have been bought.

3.10  ADMINISTRATION - ACCOMODATION - TRANSPORT

The Ratrac has been made more comfortable for personnel transport. The bottles with liquid helium and nitrogen are now transported outside the person cabin.

As in the years before, the Granada office handled the transport and accommodation (and many special wishes) of approximately 200 visitors.
4. PLATEAU DE BURE OBSERVATORY

4.1 INTERFEROMETER STATUS

Although in operation now since three years, the interferometer has been significantly upgraded in 1993.

The most significant progress has come with antenna 4. However, many difficulties were encountered during the commissioning of this antenna:

The deicing system of the subreflector legs was not reliable, and almost caused the destruction of one leg.

The antenna suffered from pointing problems in elevation

Switching from three to four antennas has revealed a number of subtle problems with the correlator system: timing problems, problems with the Walsh functions for cross-talk reduction and sideband separation, bandpass calibration accuracy, etc. These problems have been corrected now. Since the general software policy adopted for Plateau de Bure data was to store all parameters used to control the interferometer, data acquired while these problems existed can usually be corrected a posteriori.

Progress has continued on the pointing. The pointing jumps in elevation which affected antenna 1 and 4 have been clearly identified as resulting from hysteresis effects in the subreflector actuators. The replacement of the actuators in antenna 1 cured the problem, but for antenna 4, the spare actuators ordered from the manufacturer turned out to be incompatible with the models we had (despite the fact that they have the same reference numbers).

Another important step in improving the array sensitivity has been the understanding of the origin of losses due to phase noise in the local oscillators of some antennas. This was due to poor harmonic mixer performances, and to high frequency noise coming from aging power supplies in antenna 2.

Along the same line, the receiver alignment (and hence the illumination of the antennas) has been improved on two antennas. Repeated holography measurements have help to systematically improve the surface quality (now about 70 µm on all antennas).
Fig. 1: The 10 m fully operational elements of the Plateau de Bure interferometer (photo: A. Rambaut/IRAM).
4.2 OBSERVING PROJECTS

The Plateau de Bure Interferometer has fully completed 75 projects. For the second consecutive year, an exceptionally bad weather period during the fall delayed quite significantly a number of projects, so that late in 1993, 16 projects were still awaiting completion.

The repartition of the 91 projects per country is the following:

<table>
<thead>
<tr>
<th>Country</th>
<th>By First Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRAM</td>
<td>24.0</td>
</tr>
<tr>
<td>Germany</td>
<td>22.0</td>
</tr>
<tr>
<td>France</td>
<td>28.0</td>
</tr>
<tr>
<td>Spain</td>
<td>7.0</td>
</tr>
<tr>
<td>USA</td>
<td>9.0</td>
</tr>
<tr>
<td>Others</td>
<td>1.0</td>
</tr>
</tbody>
</table>

These numbers are a very poor representation of the effective use of the interferometer, since projects range from small detection experiments carried out by one or two astronomers, to large, multi-national collaborations equivalent to several complete syntheses. The original PI is not necessarily the first author on the publication. For example, US projects are generally carried out in collaboration, and often turn out to be published with a first author from IRAM.

Per category of projects, the repartition is

- Star Formation, PMS: 22
- Circumstellar Envelopes: 22 ¹)
- Galaxies: 24
- Molecular Clouds: 10
- Solar Systems: 2
- Others: 12

¹) including one project equivalent to several syntheses

The range of topics covered by the interferometer continues to increase. Unfortunately, the visibility of results obtained with the Plateau de Bure Interferometer is still very low due to the
slow rate of publication. While this is somehow understandable because of the complexity of
the instrument, it is important that this be changed.

4.3 DATA ANALYSIS

The advent of the new correlator required a significant upgrade of the CLIC package. As
usual, the upgrade has been made in an upward compatible way. The new CLIC version
completely handles the six units of the correlator, with four antennas, and is also able to
process data coming from the old correlator system. Special care has been taken to handle
phase closure relations and broad-band signals ("pseudo-continuum" channels) in order to
leave open the possibility of self-calibration and hybrid mapping when the four antennas are
used.

While developing this new CLIC version, a number of subtle errors in the previous CLIC
program were discovered. The most significant one is the 98 kHz shift of the LO3 system
which had not been accounted for. Other errors were only relevant for very special cases, and
normally did not occur in standard data reduction, provided the guidelines described in the
documentation were strictly followed.

Some problems were also encountered in the new CLIC program which have only recently
been solved. It is important to note that most problems were only discovered during full scale
data reduction of projects in Grenoble. Many subtle problems were related to compiler bugs or
undiagnosed compiler misuse; the expertise in this field has increased significantly and we hope
to reduce such effects to a negligible amount in the future.

Less visible but also very important progress has been made for the mapping stage, with the
development of a more flexible, interactive, CLEAN-based deconvolution program, and, in
collaboration with the Observatoire de Grenoble, a completely redesigned version of the GreG
plotting package. The new versions incorporate a comprehensive handling of color displays
(bitmap) and completely supersede the previous GreG/GRAPHIC programs. The new facilities
forced some incompatible changes in some command names, although most users may not
even notice.

These facilities are now released as standard part of the GILDAS package, and support for the
older versions has been terminated. A new version of CLIC allowing antenna-based calibration
of all parameters is under test, but not yet fully debugged.
A software exportation system has been built. The software is available from anonymous ftp (on iraux2.iram.fr). The source code and an installation procedure are available for Unix computers. Successful installations have been performed on several platforms: HP 700, IBM RS/6000, SUNs.

Support for VMS could no longer be provided during the last years. Some work is going on with the Observatoire de Grenoble to try to bring the VMS version up-to-date. However, because of manpower limitations, it is likely that further development will no longer occur under VMS.

OTHER DEVELOPMENTS

4.4.1 LO System
The second generation LO system is now working in the lab. A gain of 15 dB in phase noise is obtained as compared to the current generation. A high precision frequency synthesizer will allow better Doppler tracking, specially at 230 GHz. Final integration, including software development to control the systems, has started.

4.4.2 Baseline Extension
A geodetic survey has been carried out to control the ground quality and find out the possible positions of new stations for the extension of the baselines. An increase of the baseline length by 50 % is possible, and studies are under way to optimize the choice of the station positions.

Phase monitoring

We are beginning to study possibilities for compensating the atmospheric phase fluctuations by monitoring sky emissivity variations. Such a system, if feasible, should allow the recovery of a significant amount of observing time.
5. GRENoble HEADQuARTERS

5.1 SIS GROUP AND RECEIVER GROUP ACTIVITIES

5.1.1 General

A second SIS User Meeting was held at IRAM on November 4 and 5. Representatives from the following institutions attended the meeting:

University of Groningen/SRON, University of Cambridge, Rutherford-Appleton-Laboratory, Laboratoire de Spectrométrie Physique - Grenoble, Laboratoire d’Astrophysique - Grenoble, Observatoire de Bordeaux, CNET-Paris, University of Bremen, CNES-Toulouse, Max-Planck-Institut for Radioastronomy at Bonn, KOSMA-Cologne, DEMIRM/ENS-Paris, Max-Planck-Institut für Extraterrestrische Physik-Garching, LETI-Grenoble.

5.1.2 Junction Fabrication

100 GHz
Junctions with an integrated tuning circuit were fabricated for the first time.

230 GHz
A second iteration with modified tuning circuit was made.

345 GHz
IRAM junctions with integrated tuning structure were delivered to the MPIfR for the SMT.

460 and 690 GHz
For these frequencies, devices for quasioptical receivers with biconical antenna (460 and 690 GHz) were made for the MPE. A waveguide version for 690 GHz was delivered to the MPIfR.

5.1.3 Junction Development Related Activities

Current Density
For junctions operating at sub-millimeter wavelengths, a fabrication process was developed to obtain current densities up to 10 000 A/cm².
Energy Gap
The gap frequency \( f_g = 2 \Delta /h \) of good niobium is about 730 GHz at 3 K. For practical niobium junctions \( f_g \) is often below 691 GHz, an important astronomical frequency. A fabrication process has therefore been developed which could help to increase the energy gap \( \Delta \). For junctions with current densities up to 5000 A/cm\(^2\), a gap frequency of 710 GHz at 3 K has been reached in this way.

Double-Barrier Junctions
Various tests were carried out with double-barrier junctions. Irradiation up to 350 GHz showed coherent response of the two superimposed junctions. First mixer experiments in the frequency range from 180 to 250 GHz gave DSB receiver noise temperatures around 100 K. Compared to single-barrier devices, drawbacks were noted. The J-V curves indicate heating and/or non-equilibrium effects in the middle electrode, the junction pair becomes non-uniform after moderate thermal annealing and needs a larger magnetic field to suppress Josephson effects.

Resonances with the Integrated Tuning Circuit
The interaction between the Josephson oscillation and the integrated microstrip resonator of the mixer can create self-induced current steps in the Junction I-V curve. This effect has been studied in some detail for mixer circuits designed for frequencies up to 690 GHz. For certain tuning structures, the location of the current step is closely related to the design frequency. Thus a simple dc measurement of the current step can show if the circuit resonates at the desired frequency.

NbN Junctions
First NbN devices have been fabricated. The MgO tunnel-barrier was made by sputter deposition of MgO or by oxidizing a sputtered Mg film. The quality of the I-V curves is not good enough for SIS mixers so far.

NbN films were delivered to the university of Cologne for measurements of the surface roughness, the transition temperature, and of radio frequency properties.

For the investigation of various process steps, NbN mixers were fabricated from trilayers made by the Electrotechnical Laboratory in Japan. Such a mixer was tested in the MPE. The DSB noise temperature at 220 GHz was 320 K.
Fig. 5.1: Application of the electron-beam microscope to study the quality of photoresist stencils. To define the area of an SIS junction, a wafer is first covered by a photoresist, then exposed to light through a chrommask, thermally annealed, again exposed to light (without mask), and finally developed. In the present case these process steps left a small resist stencil which defines the later junction area. The aim which was successfully achieved was to obtain a stencil with re-entrant walls.

Fig. 5.2: The same as above except that this time the mask was the "negative" of the one used before.
New Equipment
A field emission scanning electron beam microscope was installed and is used for process improvements.

5.1.4 - New Receivers and Upgrades at the Telescopes

Dual-Channel Receiver for Plateau de Bure
At the end of 1992, it was decided that too much time had been wasted with the the Air Liquide cryocoolers, and that they were unlikely to ever provide a reliable cryogenic platform for future receivers. Even before the contract with Air Liquide was formally terminated, it was decided to start the development of an interim dual-channel receiver based on a commercial hybrid cryostat from Infrared Laboratories. This cryostat comprises a CTI350 GM cryocooler, that cools the two heat shields and the IF amplifiers, and a 5-liter He bath.

The receiver features two mixers in the 3mm and 1.3mm bands, that can operate simultaneously in orthogonal polarizations. The two local oscillators are fed into the dewar by stainless steel waveguides and reach each mixer through a sidewall multihole coupler, fabricated in IRAM. This is made possible by the modest LO power requirements of SIS mixers. The suppression of the quasi-optical diplexer eliminates one adjustment and one potential source of instability. The signal beams are refocussed by two elliptical mirrors and recombined in a polarization grid. Such refocussing, together with polarization flipping by roof-top mirrors and internal polarization diplexing, allows a cold load calibration of each receiver. The design ensures a wavelength-independent illumination.

At of end 1993, the cryogenic tests were completed, and a hold time of 21 days was achieved in the working configuration. The two receivers were operated simultaneously; only a weak interference was noted when the signal frequencies are harmonically related.

![Graph](image)

Fig. 5.3: Receiver temperature measurements for the first 3mm and 1.3mm dual channel which is being readied for Plateau de Bure.
Fig. 5.4 : The first PdB dual channel receiver (hybrid cryostat) mounted in its support structure. One dewar window and elliptical mirror can be seen on the front side.

**MK III Receiver for PdB Antenna 4**
The 3mm receiver built in 1992 for antenna 4, in a traditional MK III cryostat, was installed successfully early in 1993, and has worked properly since then.

**230 GHz Receiver at Pico Veleta**
A new mixer was installed in the 230 GHz receiver at the end of 1992, and was mentioned in the previous annual report as having stability problems. These problems were diagnosed and solved early in 1993. The actual performance recorded during operation at the telescope is shown in Figure 5.5.
Fig. 5.5: SSB receiver temperature measured at the telescope of the 230 GHz receiver after the replacement of the mixer.

345 GHz Receiver for Pico Veleta

The 345 GHz SIS waveguide receiver developed at IRAM in 1992 was installed at the 30-M telescope and offered for two weeks in March for scheduled observing. The forward coupling efficiency was measured as 0.8, but the aperture and main beam efficiencies still reflect the imperfections of the dish. The DSB receiver noise measured at the telescope is shown in Figure 5.6. Later in 1993, this receiver was modified to include LO injection by a waveguide coupler. Since the backshort is operated at a fixed position, only the local oscillator needs to be adjusted during operation.

![Graph showing SSB receiver temperature](image1)

Identical junctions have been provided to the MPIfR and have been installed in a receiver which will go to the H.H.T. (Arizona). Differences in performance are probably caused by substantial differences between the MPIfR and IRAM mixer block designs.

![Graph showing DSB receiver noise](image2)
Fig. 5.7: Dual-channel receiver being characterized under computer control. From left to right: receiver engineer, phase lock monitor, receiver dewar, X-window display, local oscillator modules.

Fig. 5.8: Series production of the new remote control system units.
5.1.5 - Future Receivers and Laboratory Developments

Remote Control for Receivers
The new receiver remote control system has been through an intense development phase during 1993. The hardware comprises four main parts:
1) a VME rack containing the processor, Ethernet interface, digital, A/D and D/A interfaces;
2) an intermediate rack containing analog modules;
3) a shielded interface to sensitive electronics, directly attached to the cryostat;
4) a local oscillator module, including also the room-temperature IF amplifiers.

The choice of VME gives access to numerous industry-standard hardware, software, and communication components.

By the end of 1993, all modules had been tested with base-level software. Modules for 8 remote control systems (each capable of controlling up to 4 receivers) have been fabricated by subcontractors and are being tested and integrated. The same control system, with minor variations in software and IF frequency, will be used for future receivers and upgrades at both sites.

SIS Mixer Progress
Improved laboratory results have been obtained in the 1.3mm band, with a receiver using LO injection via a waveguide coupler and cold optics. The frequency coverage is still not adequate for telescope use. A 3mm-band waveguide mixer featuring a fixed waveguide stub tuner is under test. It gives very promising results: a 20-dB rejection of the USB can be achieved at all frequencies across the tuning band.

Laboratory Instrumentation
The mm-wave vector network analyzer built by IRAM around an HP8510 has been extended to the 1.3mm frequency band, delivering a 40-dB dynamic range. It is extremely valuable to check numerous components such as couplers, horns, etc... before integration into systems.

A Martin-Puplett interferometer has been built. Associated with a chopped load and a PC-based interactive software, it allows automated and accurate measurement and optimization of the noise and sideband ratio of receivers, eliminating the need for extra signal sources and calibrated power meters. It has also been used as a Fourier transform spectrometer to measure the frequency response of the IBOL-B single-channel bolometer.
Closed-Cycle Cryocoolers

Following detailed investigations involving visits to the manufacturers and users in Japan, Daikin closed-cycle cryocoolers were selected for future PdB receivers and for the 30-M multibeam heterodyne receiver. Both Daikin and Sumitomo cryocoolers showed an excellent reliability record in field use; Daikin was selected because of available technical support in Europe by APD (UK). The Daikin cryocooler provides 3 watts of cooling power at 4.2K, to be compared with 100 mW nominal for the Air Liquide machine, and typically 20 mW for a hybrid cryostat. The contract for five units was signed on 29-Oct-93, and deliveries are due in April and May 1994.

5.2 BACKEND DEVELOPMENTS

5.2.1 Next Generation Backends

Several technologies for a next generation ultra-wideband backend have been carefully considered, for some of these experimental results are available, but none of these technologies was found mature enough to be chosen as a baseline for a new big development project.

The technical activities of the BE Group have instead been concentrated on the development of an enhanced LO distribution system for the interferometer in order to replace the aging Camac-based one which is actually limited to 4 antennas.

5.2.2 Progressive Withdrawal of Camac

The digital phase rotators and phase meter modules have been re-designed in VME standard and make use of the most recent DDS (Direct Digital Synthesis) technology. The whole system is modular and allows the extension to 5 or 6 antennas. It offers an upward compatibility with the existing one. A unique phase meter has been built which has shown an absolute accuracy of 16 bits per turn (15 seconds of arc). This will help in reducing to 0.5 degree @ 1 mm the phase drift due to the coaxial cable.

5.2.3 A New Low-Noise 2nd LO

The phase noise of the present 2nd LO reduces the sensitivity of the interferometer by ~ 5% at 100 GHz, and would cause a ~ 20% loss at 220 GHz. A new DRO-based motorized oscillator block, associated with high-speed electronics has been designed, and demonstrated a 15 dB yield in phase noise, thus reducing the associated sensitivity loss to
the 1% level. A new master synthesizer and high quality diplexers have been purchased. The IF transportation system design has been modified to remove several small effects found during the past years. Its bandwidth has been raised from 600 to 900 MHz to allow for future improvements.

5.3 COMPUTER GROUP

In 1993, the first HP workstations have been updated to model 735 which reaches a CPU performance of 147 SPECmarks. Later we received 2 new workstations HP9000/735 with the aim of enhancing the data analysis capabilities. These stations were funded by the Volkswagen foundation in connection with the VLBI project. All HP stations are by now equipped with 80MB of RAM.

Two color printers have been purchased. The first printer from Canon is connected to a PC, itself on the network. PostScript files produced either on VMS or UNIX can be processed and printed from the PC. This printer has also scanning and photo-copying possibilities. The Tektronix printer purchased later in 1993 interpretes Adobe 2 PostScript files. It is directly connected to a UNIX station which behaves as a printer server for all the workstations.

Communication between the PCs and the workstations has been improved. Some PC's (those used by the astronomers) use the TCP/IP protocol layer from FP Software on which an X emulation software has been installed. For the other PCs a new version of PathWorks is being installed. This version is compatible with LAN-Manager which gives now full connectivity possibilities to VMS and UNIX since a LAN-Manager server runs on iraux1, an HP UNIX workstation.

In order to match the address scheme of RENATER (the French Research network), we have recently changed our Internet network address. Our network which corresponds to a Class C Internet address format (193.48.252.*) has been split into 3 subnetworks, one for the Plateau de Bure and two for Grenoble. In such an operation, host addresses, which would have corresponded to the fourth subnet, cannot be used.

Subnets at Bure and at Grenoble are linked via routers, modems and a permanent line with a bandwidth of 19 kbps. The router at Grenoble also connects our subnets to the World Internet via the next node on grenet.fr. The next operation has been to install a name server and to obtain an internationally recognized domain name. The domain name of our network is iram.fr with a primary name server on iraux2.iram.fr. Any machine on our network can be
called (e.g. with ftp, telnet ...) by either its Internet address number or its domain name (for instance 193.48.252.22 or iraux2.iram.fr).

Mail routing facilities have been installed on all UNIX workstations. Messages can be sent or received from any station. However we suggest to use the common mail address iram.fr to contact a person at Grenoble (the received mail message will be seen from any station at Grenoble). For the Plateau de Bure the address is iraux3.iram.fr.

With these new possibilities of connectivity we made available the Astrophysics Data System. Catalogue services and the abstract database are of a great use for the scientists.

Mosaic, a user-friendly software distributed by the US National Center for Supercomputer Applications is now available. It is a distributed hypermedia system designed for information discovery and retrieval via Internet and in particular to the World-Wide Web (WWW), an information system based on hypertext. We have installed a WWW server on iraux2.iram.fr in order to test the potential possibilities of this new concept and to make available IRAM information, data and scientific results. For WWW experts the URL (Uniform Resource Locator) of this server is http://iram.fr/www/iram.html.

5.4 TECHNICAL GROUP

5.4.1 General Developments

In 1993 we were able to purchase of a numerically controlled lathe. This equipment allows the manufacturing of corrugated aluminium mandrels for the electro-forming of horns, as well as for the production of corrugated focusing lenses. At the same time a more efficient software for the numerically controlled milling machine was purchased (cf. Fig. 5.9). It allowed us to manufacture the first elliptical mirrors in our workshop.

New forming techniques have been developed, together with local manufacturers. An electro-erosion technique is now used for cutting out 115 to 350 GHz mixer backshorts, and for the realization of rectangular holes in the waveguides for the fixation between couplers and mixers.

Several mixers, couplers, transitions, etc. were manufactured in the mechanical workshop, especially -for the first time- the 350 GHz coupler and the polarization lens for Pico Veleta whereby it was necessary to manufacture special tools for the numerically controlled milling machine (see Fig. 5.10 ).
The new approach improves the need accuracy and reliability of the fabrication equipment and usage.

Fig. 0: The three-axis control is automatically controlled.
The overall number of internal requests for manufacturing reached a total of 268, of which 52 were executed by external subcontractors. Fig. 5.11 below shows the evolution of the workload over the last five years.

![Graph of workload evolution](image)

**Fig. 5.11:** The evolution of the workload in the IRAM mechanical workshop over the last five years.

### 5.4.2 Drawing Office

A large number of design studies have been carried out. These include:

- for the new receiver for Plateau de Bure which uses an Infrared Laboratory cryostat, the support structure which accommodates its 115-230 GHz elliptical mirrors, as well as its calibration loads and the integration of polarizers needed for VLBI experiments (cf. Fig. 5.3);

- the new supports for the 3mm, G1, 2mm receivers on Pico Veleta, and the mechanics for the polarization lens.

- the modification of the sputter chamber in the SIS laboratory, the pivoting mirrors, and the boxes for polarization separators, etc.
Technical Support for Plateau de Bure

The technical group has been responsible for all mechanical aspects concerning the four antennas on Plateau de Bure. It is working in close collaboration with the local maintenance group in order to improve the operational performance of the interferometer and to reduce the downtime due to technical problems to a minimum.

The drawing office has also been responsible for the proper administration of all related technical documentation and its updating.

Antenna 4 on Plateau de Bure

The technical group contributed to the successful completion of antenna 4 and carried out all necessary adjustment tests concerning the mechanical operation.

The project was completed on schedule within the cost envelope as foreseen in December 1990. The first astronomical tests could be made in April 1993.
6. PERSONNEL AND FINANCES

In 1993, IRAM had a total of 108 employees. Of these, 94 were IRAM staff members, and 14 were PhD students, post-docs or cooperants. Of these, 8 worked in Grenoble and 6 in Granada. Five persons with temporary contracts had to be hired in addition for the maintenance of the observatory on 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 BMFT (Verbundforschung).

IRAM's financial situation in 1993 and the budget provisions for 1994 are summarised in the following tables. Expenditures in the operations budget correspond closely to the original estimates. In the investment budget some underspending occurred, mostly due to unforeseen delays. The corresponding budget provisions will be needed in 1994 and should therefore be transferred.

The major items in the investment budget were: 3.4 MF for receivers and backends, 1.7 MF for new laboratory equipment, 0.9 MF for cryogenic components, 0.8 MF for computer equipment, 0.4 MF for improvements in the existing IRAM antennas in Spain and France, with an additional 0.4 MF for VLBI. In the area of administration and transport 0.7 MF were spent, and 0.3 MF for improvements in the infrastructure.

Income other than contributions from the IRAM partners was higher than foreseen due to income related to special projects (e.g. NbN sputter system, VLBI), or as a result of 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 mostly been resolved. The tax office has reimbursed the V.A.T. since 1988, but the reimbursement for 1986 is still pending. According to a court decision in Madrid, IRAM can not be reimbursed any more for the V.A.T. of 1987.

The planned extension for the Grenoble headquarters could only be started at the end of 1993 (0.2 MF) due to delays in getting approval from the local authorities. Because of urgent needs, temporary solutions had to be found within the existing headquarters building to accomodate some the activities of the receiver group and to find office space for new students.
## BUDGET 1993

### Expenditure

<table>
<thead>
<tr>
<th>BUDGET HEADING</th>
<th>APPROVED BUDGET KFF</th>
<th>ACTUAL BUDGET KFF</th>
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<tr>
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### Income

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<td>Contribution IGN</td>
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<tr>
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<td><strong>Total</strong></td>
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<td><strong>78.818</strong></td>
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**BUDGET PROVISIONS 1994**

### Expenditure

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### Income

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

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<tr>
<th>Date</th>
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<td>Jan 5 - 19</td>
<td>141.92</td>
<td>Mapping of HDO on Mars and search for minor species (NO, SO, ClO)</td>
<td>115,143,250</td>
<td>Encravenz, Lellouch, Gulkis, Paubert</td>
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<td>268.92</td>
<td>Search for molecular lines in comet Swift-Tuttle 1992t</td>
<td>88,145,225,265</td>
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<td>274.92</td>
<td>Observations of 3C 273 at mm wavelengths as part of a multifrequency campaign</td>
<td>90, 210</td>
<td>Staubert, Steppe</td>
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<td>Mm continuum flux measurements of the 16 detected CGRO sources</td>
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<td>148.92</td>
<td>Molecular oxygen in the z=2.3 galaxy ?</td>
<td>112,129,236</td>
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<td>199.92</td>
<td>The chemistry of S-type stars</td>
<td>90, 147, 244</td>
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<td>High angular resolution study of molecular chemistry towards photodissociation regions (PDRs)</td>
<td>86, 271</td>
<td>Fuente, Martin-Pintado, Rodriguez</td>
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<td>Key Project : Small scale structure of pre-star forming clouds</td>
<td>115, 230</td>
<td>Falgarone et al.</td>
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<td>Correlation between gas density and infrared colors</td>
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<td>Boulanger, Falgarone</td>
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<td>Flux densities of the planets at 350 GHz, telescope behaviour at 350 GHz</td>
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<td>A study of the envelope-outflow interaction region in the proto planetary nebula CRL 618</td>
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<td>Search for recombination line masers at 350 GHz</td>
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<td>Search for the (CII) 158μm line at high redshifts</td>
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<td>Guelin, Hills, Lequeux, Mac-Mahon, Omont</td>
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<td>Probing the different molecular gas components in the nucleus of IC 342</td>
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<td>Isotopic CO investigations of cloud dispersal around T-Tauri stars</td>
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<td>224.92</td>
<td>A search for NaH in circumstellar and interstellar clouds</td>
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<td>A 6 GHz-wide band survey of the 0.8mm spectrum of IRC+10216</td>
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<td>130, 233</td>
<td>Cernicharo, Bujarrabal, Santaren</td>
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<td>Search for LiH primordial lines</td>
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<td>Dust emission from NGC 3627</td>
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<td>Kruegel, Lemke</td>
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<td>Feb 16 - Mar 2</td>
<td>205.92</td>
<td>The 230 GHz continuum dust emission of NGC 2146</td>
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<td>Small scale anisotropy of the cosmic microwave background at 230 GHz</td>
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<td>Cold dust in M51 and NGC 891 : a key to the molecular gas content of spiral galaxies</td>
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<td>Guelin, Garcia-Burillo, Mezger, Kreyza, Haslam, Lemke, Sievers</td>
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<td>A black hole near a molecular cloud?</td>
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<td>Bolometer survey of Myers cores with no embedded sources</td>
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<td>Mapping the circumstellar dust material around young luminous stars</td>
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<td>Mapping of young rotating cores in spiral arms</td>
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<td>Spatial distribution and mass of the circumstellar material around</td>
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<td>Bolometer observations of Asteroids</td>
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<td>Molecular gas in the central regions of M31</td>
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<td>The atmosphere of Io</td>
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<td>CO emission of the hypergiant III complexes in M101</td>
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<td>A search for the rotational Raman spectrum of SiO in O-rich evolved</td>
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<td>Calibration of the spectral survey made in IRC+10216 with the 30m</td>
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<td>High velocity ionized gas near young high-mass stars</td>
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<td>Distribution of SO in the carbon-rich TMC-1 filament</td>
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<td>Dense gas in absorption line systems towards quasars</td>
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<td>Molecular line observations of cold compact dust cores in the</td>
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<td>HNCO as a tracer of gas shocked by the explosion of SgrA-East</td>
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<td>A search for CO in X-ray absorbed elliptical galaxies</td>
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<td>The &quot;cloverleaf&quot;: An excellent candidate for CO and CI emission from a quasar at z=2.5</td>
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<td>Barvinis, Antonucci, Coleman</td>
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<td>Circumstellar CO around bright oxygen-rich semi-regulars</td>
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<td>CO mapping of the two component wind from the nearby semi-regular X Her</td>
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<td>High angular resolution molecular line observations of the clump-interclump structure in the Rosette molecular cloud</td>
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<td>A search for dense clumps in molecular outflows</td>
<td>97, 146, 220</td>
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<td>HNC and dense gas in a primaeval starburst</td>
<td>105, 110, 140, 245</td>
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<td>Multiline study of dense molecular gas in Arp 220</td>
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<td>Radford, Solomon, Downes</td>
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<td>The HNC and DCN luminosities of ultraluminous galaxies</td>
<td>89, 87, 142, 267</td>
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<td>Search for continuum mm dust emission from QSO's with z&gt;4</td>
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<td>Omont, McMahon, Bergeron, Kreysa, Greve, Cox</td>
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<td>Molecular gas content in IRAS blue compact dwarf galaxies</td>
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<td>Petrosian, Comte, Turatto</td>
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<td>H2S in absorption towards W49</td>
<td>168, 208, 99</td>
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<td>A detailed study of an extremely quiescent core : L 1498</td>
<td>244, 147, 98</td>
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<td>Distribution of HCO+ and CS in W49</td>
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<td>Van der Werf</td>
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<td>Venus' mesosphere global circulation and CO distribution</td>
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423. **THE ANALYSIS OF SIS MIXER PERFORMANCE IN THE 80-120 GHz FREQUENCY RANGE**  
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