Front Cover :

Observations with the IRAM 30 m telescope of CO emission from the edge-on spiral galaxy NGC 891 displayed as a diagram of radial velocity vs. position along the major axis of the galaxy (from Garcia Burillo et al. 1992). Note the rapidly rotating nuclear disk at the center of the galaxy. The diagram resembles that for our Milky Way.

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1. INTRODUCTION

1991 has been the first year in which both the Pico Veleta Observatory and the Plateau de Bure Interferometer have been fully operating as guest observer facilities. This has greatly enhanced the scientific output, both in quality and in quantity. Some of the new material has already entered the literature, more is still awaiting publication. An overview over some of the results obtained is given in Chapter 2 of this report.

It has been particularly gratifying to see the rise in the number of scientists who start using the interferometer as their new tool. This is a learning process on both sides. The way in which interferometer projects are carried out differs in many important aspects from the more conventional procedures followed at Pico Veleta. The observations for a project normally span several weeks, and both the equipment and the data acquisition are more complex than for single-dish observations. Therefore, they are normally carried out in absentee mode by IRAM staff, who assumes responsibility for the quality of the data. Together with the assistance during the data reduction which is mandatory for first-time observers, this means an increased load on the IRAM personnel, and manpower allocated to Plateau de Bure observations will have to be reviewed.

After Spain had officially joined IRAM in the fall of 1990, the IRAM Council gave the final 'go ahead' for the construction of the fourth antenna for the Plateau de Bure in June 1991. This was a long awaited, very important step which will eventually speed up the interferometer operations by a factor of two for mapping. IRAM had prepared for this decision, and the tendering and contracting actions for the mount of antenna 4 started very quickly after the Council meeting. Most of the reflector components had already been produced in earlier years. Some (of them) still had to be purchased in 1991. A detailed schedule for the construction of antenna 4 is given in Chapter 5 of this report.

Also in 1991, interferometry of a different kind, 'Very Long Baseline Interferometry' (VLBI), has started at the 30m telescope on an experimental basis, offering angular resolutions at the milli-arcseconds and even submilli-arcseconds level. While VLBI has become a regular network activity at cm-wavelengths, mm-VLBI, especially at the shorter mm-wavelengths, is still in a development phase, its growth potential being enormous.

Additional receivers at the 30m telescope, the maintenance of the VLBI equipment mentioned above, and the ever increasing number of tuning requests made it necessary to have receiver engineers on the mountain more frequently than before, and also to use the help from cooperants for these tasks.

In the fall of 1991, the first of the Plateau de Bure antennas reached the end of its 5 year warranty period. Prior to this, IRAM carried out an internal total system's review to identify areas of concern and critical components. As far as hardware goes, the main area of concern are the pinholes which formed in the protective layer on the frontside of the reflectors, primarily on antennas 1 and 2. This phenomenon has been studied in further detail, and various technical and financial scenarios have been discussed both with the manufacturer and the insurance company.

HIGHLIGHTS OF RESEARCH WITH IRAM TELESCOPES IN 1991

SUMMARY

We describe here a small selection from the many programs carried out at the IRAM telescopes or published in 1991. Some highlights are:

- Detection of the CO(4-3) and CO(6-5) lines in 10214+4724, an extremely luminous galaxy at a redshift of 2.286, among the farthest detections of molecular emission lines ever made in astronomy.

- Evidence that ultraluminous infrared galaxies are powered by star formation, not black holes. The evidence is the detection, via the HCN molecule, of large quantities of high density molecular gas in these galaxies, and the good correlation of the mass of this gas with the far infrared luminosity.

- Discovery of a rapidly rotating nuclear disk in the galaxy NGC 891.

- Analysis of the IRAM interferometer maps of the HCN molecule in the center of the galaxy IC 342 and the first determination of molecular line ratios on a scale of 20 pc in a massive galaxy other than our own.

- Measurement of an unusually high $^{18}O/^{17}O$ isotope ratio in starburst galaxy centers, which suggests that starbursts preferrentially form high mass stars.

- New detections of CO in Markarian galaxies and evidence that the 1.3 mm continuum emission and the CO emission both give the same total mass estimate of molecular gas.

- Interferometric observations of SiO $v = 0$ thermal emission from evolved stars and evidence that the sizes of the SiO emission regions may be larger than previously believed.

- A new study of isotope abundances in carbon-rich circumstellar envelopes which sets limits on the total mass loss rates for these stars, showing that such stars cannot be the main sources of oxygen in the interstellar medium.

- New detections of deuterated molecules in Orion.

- Discovery, with the MPIFR bolometer on the 30-m telescope, of a steep rise in the continuum flux at 345 GHz of the galactic center point source Sgr A* , suggestive of a dust disk around the central engine at the nucleus of our Galaxy.

- A new study of HCN, HNC and their isotopically substituted variants in Orion, made with both the IRAM 30 m and the IRAM interferometer.

- The first ground based direct detection of Io's neutral atmosphere by observing SO_2.

- Detection of CO and HCN in Neptune's stratosphere.

GALAXIES

Distant Galaxies (> 70 Mpc)

A Starburst Near the Beginning of Time

The 30 m telescope has detected for the first time the CO(4-3) and CO(6-5) lines in the extremely luminous galaxy IRAS 10214+4724. The CO(3-2) line had been found by Brown and Vanden Bout at the NRAO Kitt Peak telescope, and has now been mapped with the IRAM interferometer. The large amount of molecular gas implied by these detections suggests that most of the mass of the galaxy may be in the form of molecular gas and not stars as in galaxies in the present day universe. The other intriguing result is that most of the carbon and oxygen must have existed already when the universe may have been about a fifth of its present age, presumably due to an earlier (pre-galactic?) generation of stars. The redshift of this galaxy, $z = 2.286$, means the radiation was emitted when the volume of the universe was 36 times smaller than at present, and the average density of the universe was 36 times greater. The distances between the galaxies was 3.3 times smaller, but the galaxies were the same size, since galaxies themselves do not expand like the universe does. This means that mergers of galaxies were more frequent at this early epoch of the universe, and indeed, the global properties of 10214+4724 do resemble those of the ultraluminous merger galaxies in the more local universe.

Dense Molecular Gas and Starbursts in Ultraluminous Galaxies

The 30 m telescope has detected HCN(1-0) emission from five ultraluminous galaxies, three lower-luminosity interacting systems, and two gas rich normal galaxies. There are huge masses of high density gas (2 10^{10} solar masses) in the ultraluminous galaxies, which shows star formation, rather than black holes, generates their infrared luminosity. HCN traces H_2 at a much higher density, ~10^4 cm-3, than CO (~ 500 cm^{-3}). The ultraluminous galaxies Mrk 231, Arp 193, Arp 220, and NGC 6240 have HCN(1-0) luminosities greater than the CO(1-0) luminosity of the Milky Way. Mrk 231 has 3 10^{10} solar masses of H_2 at a density near 10^4 m^{-3}, about 300 times the mass of dense H_2 in the Milky Way. Emission of HCO+ (1-0) was also detected in Mrk 231 and Arp 220 at half the strength of HCN(1-0). The ratio of HCN to CO luminosity is 1/6 for ultraluminous galaxies, but only 1/80 in normal spiral galaxies. A large fraction of the molecular gas in ultraluminous galaxies, perhaps 50 percent, is in very dense regions similar to star forming cloud cores, rather than in the envelopes of giant molecular clouds. The ratio of far infrared to HCN luminosity is similar in both ultraluminous galaxies and normal spirals, including the Milky Way, which suggests the star formation rate per mass of dense gas is independent of the infrared luminosity or the state of interaction. The molecular gas density in the central regions of the ultraluminous galaxies, ~$500 M_{sun}$ pc^{-3}, is similar to the stellar density in the centers of elliptical galaxies, consistent with the idea that some mergers may eventually become ellipticals.

CO in Markarian Galaxies

A new study of CO(1-0) and (2-1) towards 18 active Markarian galaxies, done with the 30m telescope and the SEST telescope, shows the molecular gas is concentrated towards the center of these galaxies, and that the CO (2-1)/(1-0) ratio is 0.5. The 1.3mm dust emission and the CO luminosity give compatible values for the gas mass.

2.2.2 Nearby Galaxies (10 < D < 70 Mpc)

Trace molecules

Three more trace molecules, N_2H^+, CH_3CN and CH_3CCH, have been observed in nearby galaxies (NGC 253, M 82...). Several rotational transitions of the two latter species were detected in NGC 253 and/or M82; their relative intensities suggest gas densities of few x 10^4 cm^{-3} toward the center of these systems.

Rapidly rotating nuclear disk

CO observations of the central region of NGC 891 show a rapidly rotating nuclear disk or ring, similar in its 500 pc size and 250 km s^{-1} rotational velocity to the nuclear disk in the center of our Galaxy (cover photo).

Further mapping of CO emission in nearby galaxies

Maps of the ^{12}CO emission in regions of NGC 1326, NGC 4736, NGC 4631, M100, M101, M33... have been published or were continued.

Molecular spiral structure in M51

The CO(2-1) and (1-0) maps of M 51 made with the 30 m telescope have been analysed in terms of the average gas properties in the spiral arm and interarm clouds, and the implications for cloud evolution. In the interarm regions, the line ratio of $^{12}CO/^{13}CO$ is 1.5 times larger for the 2-1 lines than for the 1-0 lines, suggesting the interarm gas is less dense than gas in the spiral arms. A numerical simulation of cloud motions and evolution by 10^5 test particles in a central gravitational field, perturbed by a spiral density wave triggered by M51's companion, reproduces the gross spiral structure and motions seen in CO. The observed arm-interarm CO contrast can be explained with a constant atomic/molecular gas ratio in the arms and between the arms.

Very Rare CO Isotopomers

The $C^{18}O/C^{17}O$ abundance ratio has been measured in the central regions of NGC 253, M82 and IC 342. This ratio is 8 in M82 and > 6 in IC342, both double that in the interstellar medium in our Milky Way Galaxy. The results can be understood if starbursts in the centers of galaxies preferentially form high mass stars. Since the ^{18}O is mainly produced by high mass stars, such starbursts would yield high $^{18}O/^{17}O$ ratios (and high $^{12}C/^{13}C$ ratios).

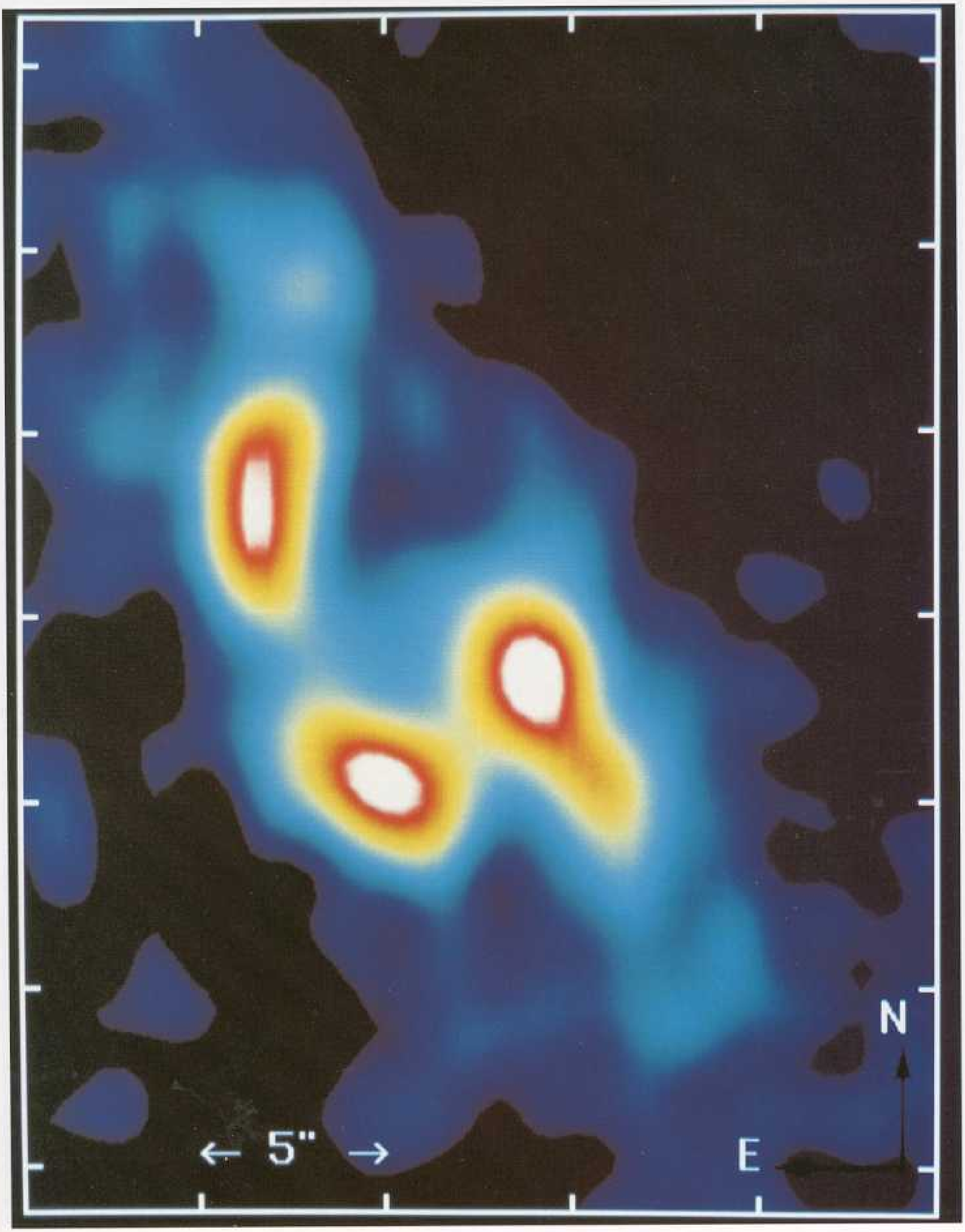


Fig. 2.1 :
Giant molecular clouds near the center of the nearby galaxy IC 342, mapped with the IRAM interferometer in the HCN(1-0) line at a wavelength of 3.4 mm.

2.2.3 The Nearest Galaxies (< 10 Mpc)

HCN in the center of the galaxy IC 342

HCN(1-0) line emission from the center of the galaxy IC 342 has been mapped with the IRAM interferometer at 2.7" resolution. Comparison of this HCN map with other molecular line maps of similar resolution yields the first determination of molecular line ratios on a scale of 20 pc in a massive galaxy other than our own. In the five main clouds within 100 pc of IC 342's nucleus, the CO(1-0)/HCN(1-0) intensity ratio is 7 +/- 2 and is at least twice as high farther out in the mini spiral arms. In the central region, the line intensity ratios of ^{13}CO(1-0)/HCN(1-0) and HCN(1-0)/NH_3 are both ~2. The interferometer also detects 3.4 mm continuum radiation near the center of the galaxy at a level of 27 mJy. Comparison with other maps shows the 3.4 mm continuum is free-free emission rather than thermal radiation by dust. The number of ionizing photons is similar to that in our Galactic center. Since the free-free continuum is associated with only one of the dense molecular clouds traced by the HCN, most of the molecular clouds in IC 342's center are not forming lots of massive stars. The gas in the molecular clouds is probably heated by dynamical friction rather than starlight. Since both the HCN(1-0) and the far IR radiation come from much smaller regions than the ^{12}CO(1-0), the HCN is better correlated with the FIR radiation than is ^{12}CO, but neither HCN nor CO trace star formation. The global ratio of far infrared luminosity to molecular mass is only an indirect indicator of the efficiency of star formation in the center of IC 342. (Figs. 2.1 and 2.2)

Molecular gas in a nuclear ring in NGC 3593

Strong ^{12}CO(1-0) and ^{12}CO(2-1) lines were detected with the 30 m telescope from the lenticular galaxy NGC 3593. Deconvolution of the data to 8" resolution (270 pc at d = 7 Mpc) shows the molecular gas is in a ring of radius 200-350 pc, the turn-over radius of the rotation curve. Probably because of optical extinction, the apparent optical center is 15" from the centers of the molecular ring, the radio continuum and the rotational velocity field. The J = 1 - 0 ring is larger than both the J = 2 - 1 ring and the separation between the radio continuum peaks, suggesting either optically thin CO near the ring's inner boundary, or gradients in density or temperature with maxima near the center. The total molecular masses of 3 10^8 and 4.5 10^8 solar masses derived from the far-IR and ^{12}CO(1-0) fluxes, respectively, indicate dust and molecular cloud properties similar to those in the Milky Way. Molecular gas is 1% of the total mass of the entire galaxy and 8% of the mass in the innermost 700 pc diameter. The mass of molecular gas is 2.5 times that of the atomic gas. This is the first time the three-dimensional Lucy rectification has been used to get the spatial and velocity distribution of extragalactic molecular gas. Another restoration method, simulated annealing, also gave similar flux and velocity distributions.

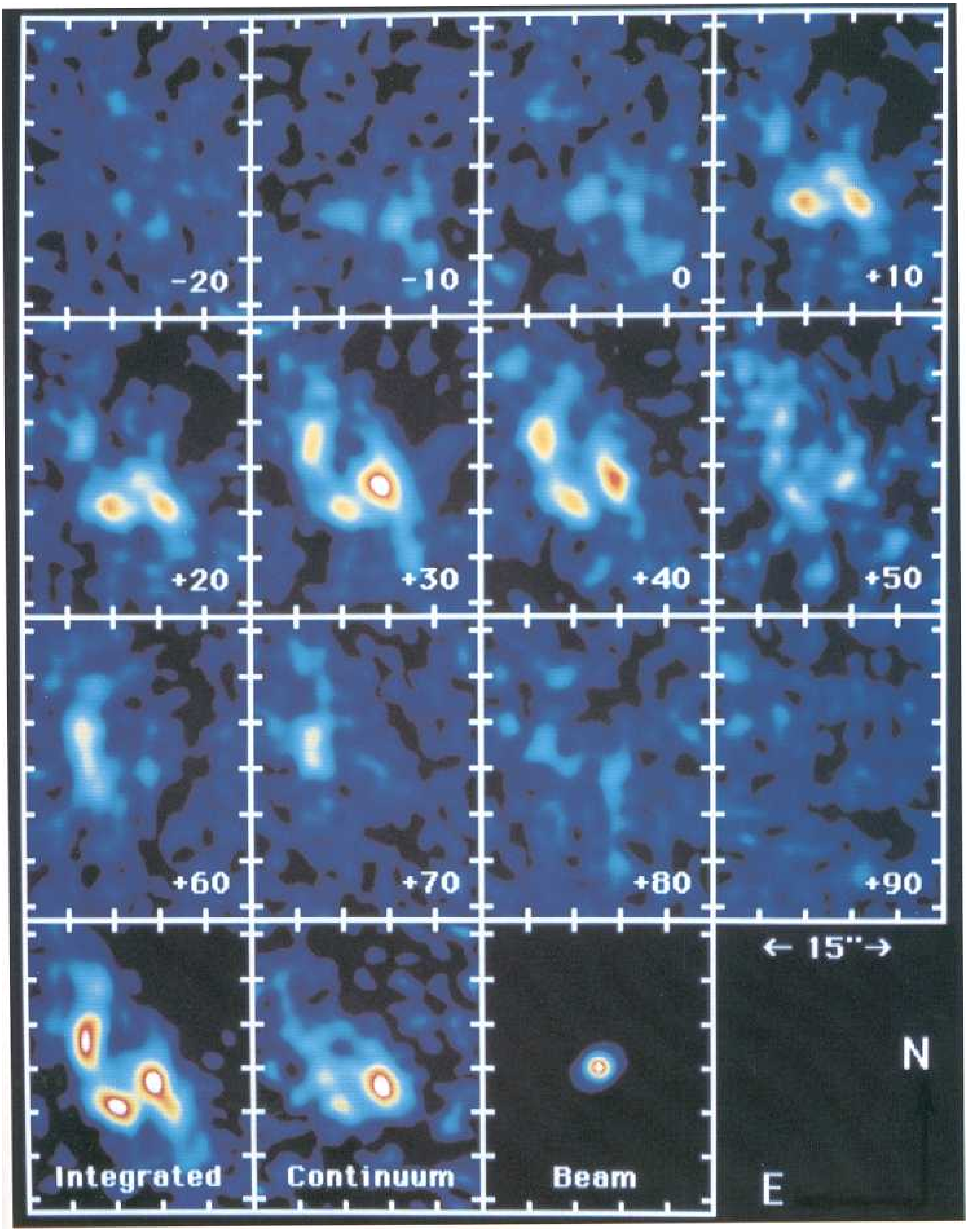


Fig. 2.2 :

HCN molecular emission in the galaxy IC 342, in individual 10 kms^{-1} wide velocity channels of the IRAM interferometer. The figure also shows the HCN line intensity integrated over all velocity channels (as in Fig. 2.1), as well as the millimeter continuum emission. The broad-band continuum is thermal emission from ionized gas, not from dust.

YOUNG STELLAR OBJECTS

Outflows

Thermal SiO in outflows

SiO thermal emission has been mapped in several outflows (L1448, B1, NGC 207, Cep A). This emission is detected at the terminal outflow velocity, presumably associated with shocked gas. The SiO abundance in the shocked component is found to be 10^3-10^5 times larger than in the ambient quiescent gas and, in L1448, reaches 3% of the total silicon abundance.

New outflow SE of NGC 1333

A new bipolar outflow has been found in the direction of IRAS 03282+3035, in the Perseus complex, south-east of NGC 1333. As in the outflow source in L1448, the outflow has many clumps, or "bullets", and a high terminal velocity (70 km s^{-1}).

Orion flows

Maps in several molecular species reveal the structure of the interface between the Orion molecular cloud and the Orion A H II region. Emission of cynanoacetylene, HC_3N, has been studied up to the J = 24 - 23 line. The maps show long and thin (20" by 300") fingers of gas north of the well-known outflow source, IRc2.

Young Stars

The Great Depletion Saga

Discovery :
Previous MPIfR bolometer studies at the 30 m telescope suggested the 1.3 mm continuum peaks in the molecular cloud near NGC 2024 may be isothermal protostars with dense (10^8 cm^{-3}) cold (10-15 K) gas and dust where molecules disappear from the gas by freezing onto grains. Hence molecular lines would give the wrong mass and the continuum dust observations give the right answers.

Counterpunch :
Two recent studies at the 30 m telescope say no. The ^{12}CO & $^{13}CO(2\text{-}1)$ spectra both have Planck brightness temperatures of 45 K. NGC 2024 FIRS-5 & 6 are young outflow sources, and must be hot. Multi-transition CS data also suggest warm gas and a core mass of 13 solar masses, much less than derived from the dust. The authors of these studies claim the cold dust interpretation is inconsistent: the dust spectra are assumed transparent in the temperature derivation, but the derived mass guarantees they are opaque.The real gas and dust are warm (40-60 K) and there is no depletion of molecules onto grains on 10" scales. Molecular lines give the right masses.

Riposte:
Two other new studies of 30-m data on NGC 2024 reach the opposite conclusion. A re-analysis of the 30 m continuum data concludes the warm temperatures derived from the molecules are only in the bar where the condensations are embedded; some of the condensations themselves are cool (< 20 K) and their molecules are frozen onto grains. Ammonia peaks mapped at the VLA coincide with dust peaks found at the 30 m. There is far too little ammonia relative to the masses derived from the dust emission.

Fatal Embarrasment:
The ammonia linewidths are too small! They imply the mass in the condensations is ten times less than given by the dust data. The H_2 density must be 10^7 cm^{-3}, not 10^8. The molecules give the right answer after all.

What's the conclusion of this complex story? The simplest interpretation is that the dust continuum data give the wrong mass, and the virial masses from the NH_3 linewidths give the correct masses for the condensations, and that there is not much depletion of molecules onto dust grains.

Molecular Gas and Dust associated with Herbig Ae/Be Stars

The clouds associated with the Herbig Ae/Be stars LKHa 198, and RR Tau were studied with the 30 m telescope to see the effects of young stars on surrounding gas and dust. Maps of ^{12}CO and ^{13}CO toward these clouds were compared with IRAS maps at 12, 25, 60 and 100μm. The ^{12}CO and ^{13}CO lines toward the reflection nebulosity NGC 7023, are very weak. There is no ^{12}CO and ^{13}CO emission toward VDB 1, the reflection nebula southwest of LKHα 198. Sharp borders are found between the molecular clouds and the reflection nebulosities VDB 1 and NGC 7023. The (2-1)/(1-0) intensity ratios of ^{12}CO and ^{13}CO indicate kinetic temperatures of 15 K and H_2 densities 1 - 5 10^3 cm^{-3} for the molecular cloud. Higher temperatures are found in the gas near the reflection nebula NGC 7023 and the border between VDB 1 and the molecular cloud near LKHα 198. Although massive stars are not being formed in these regions, and the clouds contain only 103 solar masses of gas, the ratios of IR luminosity to gas mass are 5 L_{sun}/M_{sun}, typical of very active star forming regions. The 100μm and ^{13}CO fluxes are correlated, but the slope of this correlation varies over the clouds. The F(100μm)/N(H) ratio, in mJy/10^{20} cm^{-2}, is 1 to 2 for most of the cloud, >10 toward the reflection nebulosities, and 4 to 10 at the cloud edges. Toward the reflection nebulae, the 60/100, 12/25 and 12/100 flux ratios increase, but the 25/60 and 25/100 ratios decrease. All these results for the reflection nebulae can be explained by the effects of ultraviolet radiation on the molecular gas and dust in these regions.

Winds from Massive Hot Stars

The recombination line maser in MWC 349 was monitored with the 30 m telescope over a 1000 day period. The intensities of the masing transitions at 1 and 2 mm vary irregularly by factors of 4 (at 1 mm) and 10 (at 2 mm), on time scales as short as 30 days. The velocity separation of the blue and red maser spikes increases with frequency. The radial velocities of the blue and red spikes at H30α are also variable, but anti-correlated with each other. The intensity ratio B/R of the blue and red maser spikes displayed drastic changes in the first half of the monitoring period, but then settled to a pattern where B/R oscillates only slightly around a value of ~0.9. The recombination line maser is probably unsaturated at 1 and 2 mm with slight saturation setting in at 1 mm. From the intensity variations of the maser spikes and an estimate of the maser gain, the size of the maser region is ~1 mas which is likely to be associated with a rotating disk. The rapid variations in intensity and velocity of the maser spikes are best explained by the simultaneous presence of 10% density inhomogeneities of the central source. Underlying the maser emission lines, broad and weak pedestal features are detected which may arise in an isotropic component of the stellar wind.

Dust Globules

The cometary globule ORI-I-2 has been mapped in several lines of CO, CS and HCN. These observations yield the mass, density and temperature in the globule and some insight on its evolution.

2.4 CIRCUMSTELLAR ENVELOPES

2.4.1 Chemistry and Dynamics of Star Envelopes

Interferometric Observations of SiO v=0 Thermal Emission from Evolved Stars

The IRAM interferometer has observed the SiO $v = 0$, $J = 2 - 1$ emission from the oxygen rich evolved stars RX Boo, VY CMa, R Cas, o Cet, NML Cyg, W Hya, R Leo, IK Tau, IRC+10011, and IRC+10420, the carbon star IRC+10216, and the S-type star χ Cyg. The emission of RX Boo, R Cas, χ Cyg, and IK Tau is circularly symmetric, and the data on the other stars are also compatible with this geometry. In the O-rich and S-type Miras the half power radii of the SiO emitting regions are (1 to 7) 10^{15} cm, larger than adopted in recent models for SiO thermal emission, but much smaller than CO diameters. The emitting regions in supergiants and IRC+10216 are larger than in O-rich Miras.

Except for IRC+10216, the source diameters do not vary with radial velocity. If the envelopes were expanding at constant speed, the diameters would have a clear maximum at the central velocities, and this is not observed. This shows that the terminal velocity is not yet reached at $5 \cdot 10^{15}$ cm from the star, possibly because dust grains may be forming over the whole SiO emitting shell, which is a region much larger than previously believed.

Isotopic abundances in carbon-rich circumstellar envelopes: a further iteration on the oxygen isotope puzzle

The (1-0) and (2-1) lines of the oxygen and carbon isotopomers of CO were studied with the 30m telescope in five dusty, carbon-rich envelopes (CIT6, IRC+10216, CRL618, CRL2688, NGC7027) which represent stellar evolutionary stages from the early asymptotic giant branch to planetary nebulae. The data are compared with predictions from models of nucleosynthesis and dredge-up in red giants. The $C^{17}O/C^{18}O$ abundance ratios, assumed to equal $^{17}O/^{18}O$ in the gas phase, are about 1 in the last four envelopes, and a lower limit of 1 was derived in CIT6. From measured ratios of $^{13}C^{16}O/^{12}C^{17}O$ and $^{13}C^{16}O/^{12}C^{18}O$, and an assumed value of $^{12}C/^{13}C$ for each source, the following ratios were derived: $^{16}O/^{17}O$ = (250 to 850) and $^{16}O/^{18}O$ = (300 to 1300).

The carbon isotopic ratio was derived in CIT6 and CRL618 from the optically thin lines of rare isotopomers of CS, a method previously used for IRC+10216. For CRL2688, and NGC7027, a lower limit to this ratio comes from the CO lines. In the five envelopes, the $^{12}C/^{13}C$ ratios are about 30, significantly larger than previous estimates for CRL 2688 and CRL 618.

The $^{17}O^{18}O$ ratios measured in these five dusty envelopes are similar to those obtained from infrared observations in less opaque C-rich and O-rich envelopes. That is, ^{17}O is enhanced with respect to ^{18}O and ^{16}O by factors of 4 to 5, relative to the remarkably constant values of $^{17}O/^{18}O$ and $^{17}O/^{16}O$ observed in the interstellar medium. This large enhancement sets upper limits on the total mass loss rate for these types of stars. In particular, red giant stars with C-rich (or translucent O-rich) envelopes cannot be the main sources of oxygen (and presumably of star processed matter) in the interstellar medium.

2.4.2 Post Red-Giant Stages

Millimeter recombination lines in the planetary nebula BD + 30^{o}3639

Millimeter recombination lines H30α, H35α, and H41α have been detected with the 30 m telescope in the compact planetary nebula BD + 30^{o}3639. The mm line emission arises in an optically thin, expanding HII region with an LTE electron temperature T^*_e = 8800 +/- 1500 K. Fits of the observed line profiles with a radiative transfer model of the ionized shell yield the expansion velocity of the ionized gas of 20 kms^{-1}.

The observations confirm that the expansion velocity of the ionized gas is considerably smaller than the 52 kms^{-1} expansion velocity of the molecular envelope detected in the CO(2-1) & (1-0) lines. The H38α line contributes ~60 % of the blend with the CO(1-0) line in BD + 30^{o}3639 and completely changes the appearance of the CO(1-0) line profile. In other nebulae with little or no molecular gas, H38α could be mistaken for the CO(1-0) line without careful checks.

Pre-Planetary Nebulae

Four new pre-planetary nebula candidates have been detected in ^{12}CO and ^{13}CO and their ^{12}CO emission mapped; two of these nebula show evidence of a bipolar structure. From these and from previous observations there is a clear correlation between the 60 micron flux and the ^{12}CO (1-0) integrated intensity.

2.5 MOLECULES

New Molecules

Deuterated isotopomers of CH_3CN, CH_3CCH and CH_3OH have been detected in Orion A (OMC1) and/or TMC1. The deuterium enhancement for these molecules, relative to the local interstellar D/H ratio, is a few times 10^3 even in the relatively hot Orion A core gas. Indications are that for the firsr two, the ortho/para abundance ratio is closer to 1 than to 3.

The relative abundances of HCN and its metastable isomer HNC have been studied in the OMC1 cloud, through observations of their rare ^{13}C, ^{15}N and deuterium isotopomers. The HNC/HCN abundance ratio is found to increase from 5 to 80 between the Orion ridge and the Orion-KL core.

New searches for molecular oxygen emisssion in galactic and extragalactic sources have been unsuccessful. New upper limits have been set on this species' abundance.

Astrochemistry

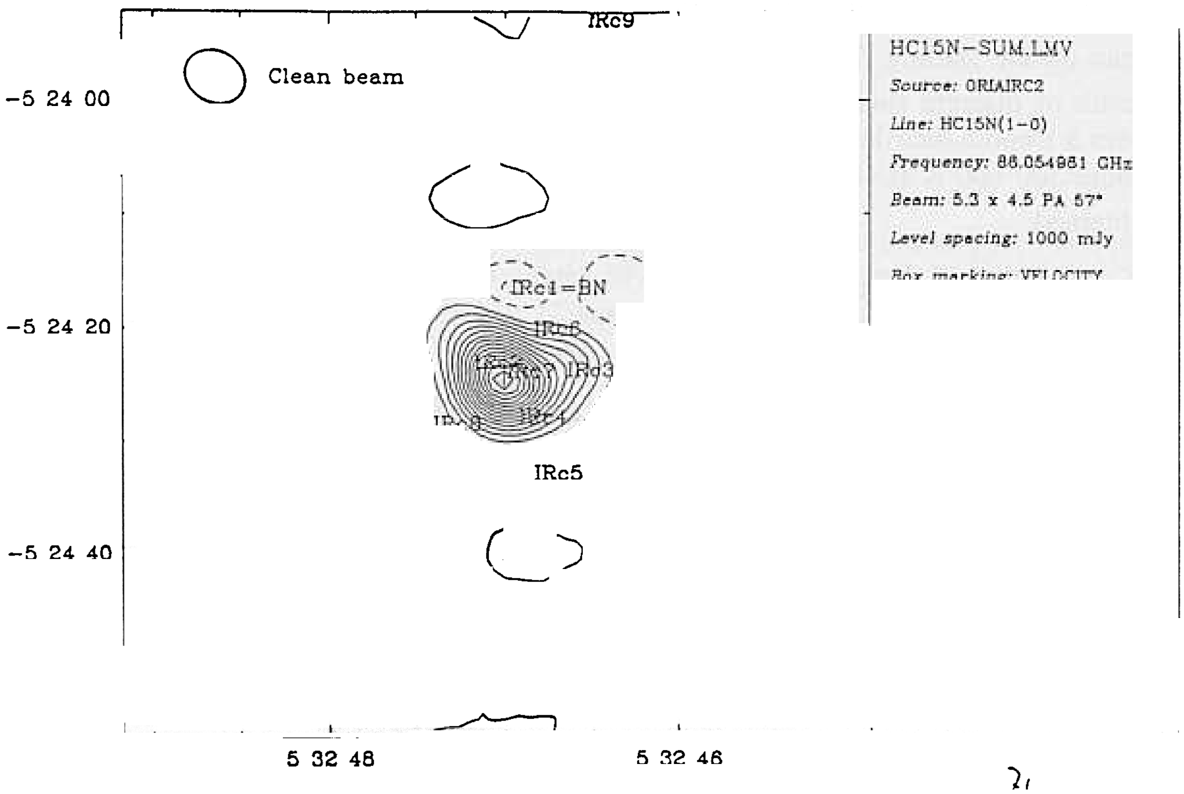
A Study of HCN, HNC and their isotopomers in OMC-1.

New observations of HCN, HNC, and their isotopically substituted variants towards the Orion hot core and ridge were made with the 30 m telescope. The $HC^{15}N(J = 1\text{-}0)$ transition was also mapped with the IRAM interferometer. The HCN, HNC and DCN abundances and density and kinetic temperature were determined at seventeen selected positions in the Orion molecular cloud. The HCN/HNC abundance ratio is very high (~80) in the immediate vicinity of Orion-KL but declines rapidly in adjacent ridge positions to values of order 5. Furthermore, the DCN/HCN abundance ratio increases from 0.001 in the warm gas close to the source IRc2 to values 0.01-0.06 in the extended ridge of the cloud. A rather surprising result is that the $[H^{13}CN]/[HC^{15}N]$ ratio increases from 5-7 over much of the ridge (consistent with the isotope ratio in local interstellar gas) to roughly 15 close to Orion-IRc2. There is reasonable agreement with steady state models of the molecular cloud chemistry. There is a dense clump in $HN^{13}C(1\text{-}0)$ and DCN(2-1) to the northwest of the prominent Peak 1 seen in vibrationally excited molecular hydrogen emission. The relative positions suggest an interaction between the molecular clump and the high velocity outflow emanating from Orion-KL. A new continuum map of the region has also been made with the IRAM interferometer (Fig. 2.3).

2.6 SOLAR SYSTEM

The structure, stability, and global distribution of Io's atmosphere

Millimeter wave observations of SO_2 have allowed the first ground based direct detection of Io's neutral atmosphere. From observations of two SO_2 rotational lines, at 221.965 and 143.057 GHz, and from upper limits on two other lines, basic properties of Io's atmosphere can be derived. The SO_2 atmosphere appears to be stable with time and can be represented by a collisionally thick (10^{11}-10^{12} cm^{-3}) atmosphere (p = 3-40 nb) covering a



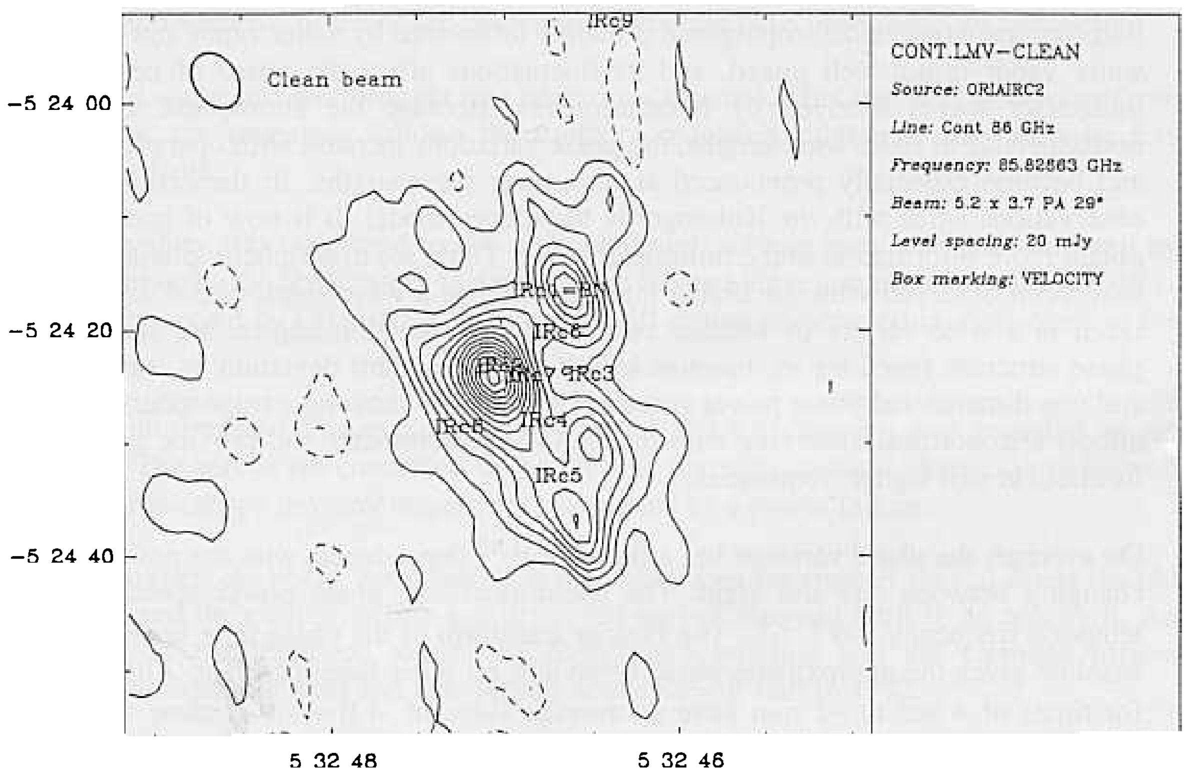


Fig. 2.3 :

IRAM interferometer maps of the $HC^{15}N$ emission (top diagram) and 3.4 mm continuum emission from dust near the powerful outflow source IRc2 in Orion.

limited fraction (5-20%) of Io's surface, with possibly larger pressures on the trailing side than on the leading. The horizontal distribution of gaseous SO_2 is best described as the result of discrete sources (steady or volcanic) rather than by vapor pressure equilibrium over a smooth distribution of surface frosts. The lower atmosphere seems surprisingly hot, about 500-600 K at 40 km. New upper limits on atmospheric H_2S, SO, and CO were also obtained.

CO and HCN on Neptune

The 30 m telescope has been used to detect the CO(2-1) and HCN(3-2) lines in Neptune's stratosphere. CO and HCN have respective mixing ratios of (6.5 +/- 3.5) x 10^{-7} and (3 +/- 1.5) x10^{-10}. CO seems to be present in Neptune's troposphere as well and to slowly decrease with altitude (scale height ~200 km). CO appears to be at least 15 times less abundant on Uranus than on Neptune. An upper limit of 10^{-7} was obtained for CO in Saturn's stratosphere.

2.7 ATMOSPHERIC PHASE FLUCTUATIONS

Interferometric measurements of tropospheric phase fluctuations at 86 GHz on antenna spacings of 24 m to 288 m

Radio propagation in the troposphere is mainly influenced by water vapor and oxygen. The water vapor is not well mixed, and its fluctuations affect the phase of centimeter and millimeter waves received by interferometers. Because the atmosphere is essentially nondispersive at radio wavelengths, the phase variations increase with operating frequency and become especially pronounced at millimeter wavelengths. In the centimeter range, observations agree with the Kolmogorov turbulence model. It is now of great interest to obtain more information in the millimeter range. To do so, tropospheric phase fluctuations have been observed with the IRAM interferometer at a wavelength of 3.4 mm. The data, taken in a wide variety of weather conditions and elevation angles, are summarized as phase structure functions vs. baseline length, Allan standard deviation vs. sampling time, and one-dimensional phase power spectra. These results show how tropospheric turbulence affects astronomical observing with the IRAM interferometer and provide predictions of its effect at still higher frequencies.

On average, the phase variance has a $(\text{baseline})^{1.42}$ dependence, with the power law index changing between day and night. The one-dimensional phase power spectra vary with temporal frequency f as $f^{-2.1}$. The Fourier transform of the phase time series on a single baseline gives the approximate phase behaviour on other baselines. The Allan deviations for times of 4 sec to ~1 min have an average slope of -1.0 +/- 0.2, close to the values expected from the structure function. The level of tropospheric phase fluctuations and the shape of the structure function both agree with previous centimeter wavelength results, after allowance for the different baseline lengths. Comparisons are also made with a recent statistical model of water vapor fluctuations and with Kolmogorov turbulence. From this analysis, it appears that the IRAM interferometer will be seriously limited at higher frequencies and longer baselines, unless further antennas can be added to the array, which would allow corrections for the atmosphere.

PICO VELETA OBSERVATORY

3.1 30-m Telescope Operation

The operation of the telescope throughout 1991 was smooth, also because of many long periods of good weather and the mild winter 1991 - 1992 (February). The telescope was regularly maintained for approximately 12 hours per week, coinciding with the time of receiver filling/maintenance and test tunings. There occurred no major mechanical or electrical failures except a one-week repair of the wobbler (mechanical wear of bearings). This time was also used to paint part of the yoke. No satisfactory solution has (yet) been found to stop the oil spill-over from the AZ bearing. The afternoon time of August was used for a reflector adjustment. The total down-time because of technical problems was ~45 hours.

For the majority of astronomical projects, receiver tunings could be made well in advance due to the availability of sufficient staff. This situation improved the operation of receivers, and can hopefully be maintained.

3.2 Infrastructure

Several improvements of the observatory's infrastructure have been made, or completed.

The second water line was brought into operation (autumn). This line uses also water from the Laguna, the trajectory follows the southern mountain ridge and may thus be less affected by frost.

The observatory was connected to two additional high voltage lines; one line - ordered by IRAM - connects the observatory to a power line located higher up the mountain, the other line was connected by CETURSA from a chair-lift station constructed in 1991 close to the telescope.

A new Uninterrupted Power Supply (UPS) of 100 kVA capacity was installed at the telescope. The servos are connected to the UPS so that astronomical observations, as well as all other telescope movements, are not interrupted by a power failure.

During summer, the heavy construction in the skiing area interrupted several times the old water line and the electricity line and destroyed part of the road (still to be repaired). An inspection of the telescope tower, the observatory building and the Granada offices revealed considerable wear and tear. Repair activities will start in 1992.

Reflector Surface

The reflector was adjusted by turning ~600 panel support screws (~2/3 of the total number). Subsequent 3mm phase retrieval holography may not have produced a full understanding of the present surface precision. The geostationary ITALSAT 39 GHz beacon, at 43 degree elevation, was used in a preliminary holography measurement with the 7 mm VLBI receiver. These measurements should be continued on a regular basis.

3.4 Receivers

The operation of the receivers followed the scheme to a) have always one receiver engineer/technician at the telescope, and b) establish reliable tuning lists across the frequency bands.

In June, the break-down of the cryostat of the 2mm SIS receiver was repaired within two weeks.

The 3mm SIS receiver caused permanent problems by being unreliable in its tuning parameters so that also a reliable tuning list could not be established. A new mixer was installed in December.

The 230 GHz G1 (old) SIS receiver - with Pb junction - performed well. A second 230 GHz G2 (new) SIS receiver was installed in autumn. This receiver uses (since December) a 4-element Nb junction with Josephson noise suppression by a magnetic field. The receiver shows good performance though only over a somewhat reduced frequency band.

The 7mm (43 GHz) VLBI Schottky receiver (delivered by the MPIfR) was installed in August and used successfully in the first VLBI experiment in September (Onsala - Effelsberg - Pico Veleta).

Tests were made with an open-structure 345 GHz SIS receiver (Rothermel), and regular observations are planned early 1992.

The telescope performance at 350 GHz was investigated with the MPIfR bolometer. The MPIfR group also tested a 230 GHz bolometer-polarimeter and a 230 GHz multibeam bolometer array. The MPIfR 230 GHz bolometer was available for regular observations.

Unfortunately, the 3mm Schottky receiver remains to have only one channel because the diode lost contact during warm-up of the receiver for installation of the second mixer.

The first unit (prototype) for remote receiver control was completed in the Granada laboratory and shipped to Grenoble in autumn for installation on a 3mm Kerr-mixer receiver.

3.5 VLBI Equipment

The following VLBI equipment was installed and successfully commissioned:

- 7 mm (43 GHz) Schottky receiver
- GPS unit for clock timing from satellite signals
- Hydrogen Maser Clock
- VLBA terminal and Tape Unit.

Members from the MPIfR VLBI Group helped to train the local receiver-, backend- and computer-groups to operate and maintain this equipment. As soon as possible, VLBI tests will be performed at 3 and later at 1 mm wavelengths.

3.6 Backends

The IF distribution box (installed in 1990) worked well. The same holds for the 1 GHz equalizers of the IF chain.

The backends (one 100 kHz 256 channel filterbank, two 1 MHz 512 channel filter-banks, one AOS and an expander) were regularly monitored and maintained. The auto-correlator was maintained, though not improved, in view of two new auto-correlators built in Grenoble and delivered in December.

The work on the 1 GHz bandwidth/1 MHz processor continued, though at a reduced rate. Priority was placed on the design and construction of a new IF distribution box to accomodate the new correlators (8 additional input ports).

3.7 Computers

The VAX-station IRAME-C was installed at the telescope to improve the data reduction facilities; another VAX-station for Granada has been ordered.

The operating system of the VAX computers was changed to VMS 5.4; the PCs were upgraded to use DECwindows and thus provide access to CLASS.

At the telescope an ATARI ST computer was installed for storage and display of the last 10 scans, with the possibility of local hardcopies on a printer. The software of the emulator was developed in Granada.

The software for the receiver remote control unit was developed at Granada and tested in Grenoble on the 3mm Kerr-mixer receiver. The complete system = receiver + control unit + PC + software will be installed on the telescope early 1992.

A UPS-unit and air conditioning were installed in the Granada computer room; the installation of air conditioning in the radio link room resulted in a reliable operation without break-down.

4. PLATEAU DE BURE OBSERVATORY

Observing Projects

After a little more than 12 months of regular observing, the Plateau de Bure interferometer has fully completed about 26 projects. A detailed list is given in Appendix Ib. The project size varies between a few hours (A043,B001) to the equivalent of several syntheses (A069), although most projects require full mapping.

So far only one project had to be cancelled after the first configuration because of insufficient sensitivity. This gives a precise idea of how many projects can be carried out with the current three antenna system: 25 to 30 per year. Effectively, about 30% of the total time could be used for astronomical observations whereas the remaining 70% went into maintenance, tests, and improvements, or were lost due to bad weather.

The repartition of the 26 projects per country is the following: IRAM 5.5, Germany 5.5, France 9.5, Spain 4.0, and USA 1.5. These numbers are obtained by counting only the first authors. If all authors are counted, the numbers for France and Spain slightly decrease, whereas all others slightly increase. IRAM's share may seem high, but it must be taken into account that many projects have emerged from ongoing collaborations, and that some projects which are technically difficult ones need the participation of an experienced IRAM astronomer. Per project category, the repartition is: Star Formation 11, Circumstellar Envelopes 6, Galaxies 5, Others 4. This rather uneven distribution is partly driven by the limitations of the current spectral correlator.

Data Reduction

The observations with the interferometer are carried out by two IRAM operators and one IRAM astronomer on the site. IRAM astronomers are also responsible for "quick-look" tests to check the data quality. From thereon all further data reduction steps are in principle the responsibility of the Principal Investigator. As a rule, he/she should come to Grenoble to work on one of the IRAM computers where the necessary software packages have been installed.

In practice the data reduction has been a real burden for IRAM in 1991. Firstly, because the anticipated computer power needs were somewhat underestimated. Secondly, because observers tend to underestimate the time needed to reduce and analyse their data, especially during the startup and learning phase. The latter effect was somewhat off-set by a smaller than anticipated flow of visitors who came to Grenoble for data reduction.

To improve the computer situation, IRAM has purchased one HP 730 workstation, and obtained one HP 720 on a CNRS special contract for software development. Each machine is now equipped with one drive for rewriteable, removable optical disks of 2x325 MBytes capacity (2 faces), and 1.2 GBytes hard disks, plus one 400 MBytes system disk. One face of one optical disk is devoted to one interferometer project for permanent storage, while the hard disks will be used as fast scratch space for interactive data reduction. The HP 700s workstations also share some disk space with the main VAX-4000, which is connected to Plateau de Bure.

Software upgrading to use the GILDAS software (GreG, CLASS, CLIC, and all tasks) on the HP systems has been going on since September. GILDAS is now fully operational and runs typically 5 to 15 times faster on the HPs than on the VAX-4000 for data reduction, and the optical disks allow very fast setup times for each project. Visitors actually no longer use the VAX to reduce their data, except for the initial step of downloading the uncalibrated data from the Plateau de Bure archive.

4.3 Operations

4.3.1 Two major bad events first

After a configuration change on May 24th which involved a station which had not completely been cleaned from snow, the reflector of Antenna 2 touched the snow and several panels at the lower rim were badly damaged. Thanks to the availability of spare panels, the antenna was back into operation after only one month. The surface was properly realigned through holography.

On December 4th, during maintenance work on the cables of the telepherique, B.Aubeuf, the responsible group leader, was severely injured. Thanks to the rescue team and the competence of a team of surgeons, he stands a good chance to recover almost completely from this severe accident.

4.3.2 Hardware Upgrades/Changes

A very stable inclinometer, NIVEL20, which uses the level of the liquid as a mirror, has been tested in January on Antenna 1. A resolution of 0.2 arcsec was within reach in 60s or less. The installation was ccompleted with external help (from a student) in spring, and the related documentation was ready in June. Two other NIVEL20 sensors are now purchased for Antennas 2 and 3. They will be installed in the course of 1992.

An anticollision ultrasonic sensor has been tested at the end of the year, following the snow accident. A model from HONEYWELL has now been selected.

To accelerate and simplify snow clearance at Bure, a multi-purpose "ratrack" machine was selected as a replacement for both the bulldozer and the lifter which were used until now. A 370 HP ratrack was purchased from KASSBOHRER in December, and was delivered at Bure at the beginning of 1992.

The procedures for station changes have been simplified with new codes on the antenna carriage microprocessors. Centering sensors for the pedestal are now in use, a single lifting position was retained on each track: this eases the adjustment of the jacks and should allow more frequent use of automatic procedures when telescopes are moved from one station to another. New safety regulations have been imposed in June for these operations, with simple check-lists (snow clearance and move) to be filled in.

During maintenance sessions it was discovered that a few major system components needed replacements: one harmonic mixer (LO1) on Antenna 1; one FET in the first IF amplifier chain on Antenna 3; the main CAMAC controller and one crate controller. (There were no spares for these, although 9 crates are currently in use at Bure; since then, two spare units have been bought and are now available). A further replacement concerned the system which controls the load on the two DIESEL generators of the Plateau de Bure station.

In addition, numerous electronic boards were tested, exchanged and repaired during regular maintenance sessions. The experience which has built up since the commissioning of the telescopes has led to the decision to increase the number of spare parts for certain critical components in order to minimize downtimes of the interferometer.

4.3.3 Remaining problems

Although 18m of bad cables were replaced in October 1990 on the cable-car, close to the counterweight, the same effect is slowly but steadily building up again on the lower part of the cables which runs on rollers to allow a vertical movement of the counterweight. POMA, the firm who delivered the cable to IRAM, and APAVE, our technical consultants on cable-car matters, finally agreed, on the basis of several studies, that the weight of the counterweight should be increased to limit its vertical movement. This operation is foreseen for the spring of 1992.

The road cover between the tracks is needs to be partially replaced to have a smoother surface, last not least to facilitate the snow cleaning.

The number of small pinholes on the reflecting surfaces continued to increase in 1991. The surfaces are now regularly inspected by MAN and IRAM and, as a temporary protection, the pinholes are sealed of by stickers. These stickers have no effect on the observations at 3 mm, and will hardly affect the observations at a wavelength of 1 mm. However, the need remains to find a permanent solution to the problem.

Another area of concern are the METAWELL plates used as the backside cladding of the reflectors and also on the telescope mounts. The delamination problem which occured earlier seems to be limited to an early lot, primarily used on the reflector of Antenna 1 and on the mounts. More recently produced plates use a different type of glue that seems to be much better adapted to the climatological conditions that prevail on the Plateau de Bure. As a consequence, the entire METAWELL cladding of reflector 1 has been replaced in 1991 by new plates. What remains is the fixation problem, with only part of the silent blocks being replaced by a new design, and the Scotch tape problem (alu or other); the lifetime of the Scotch tape, which is used to seal the area between adjacent METAWELL plates, seems to be limited to 18 months, if not 12. The time needed to renew it is 4 to 5 days per antenna, i.e. this problem has a non negligible impact on the availability of the telescopes !

The staffing of the Plateau de Bure observatory is still under review. One more position may have to be added to local technical team to allow a continuous support of the observations. At present, on Saturdays, and Sundays, technicians in 'stand-by' can be called upon to come to the mountain. This usually means a stand-still for at least several hours.

Some maintenance problems occurred repeatedly, and more permanent solutions must be found for them:

- (i) burnt paint on quadrupod legs. This has been solved by new protections, and an increase of the Sun's avoidance radius to 30 degrees in software (28 on optical sensors);
- (ii) grounding defects on deicing blankets of panels: the new model should avoid this after complete replacement which is performed as faults show up;
- (iii) bad reproducibility of subreflector actuators (end contacts, ice, or encoding system), at least once per year per antenna;
- (iv) cryogenic faults: iced back-shorts when tuning mixers, blocked pipes during fill-up with Helium. This calls for closed circuit cryo systems;
- (v) water accumulating in some parts of the pedestal, calling for a better evacuation (condensed water, or melted snow and ice?);
- (vi) encoder's bulbs do not have the expected lifetime (MTBF) and must be too often replaced. This requires a large number of spares in stock.

The weekly "operator's report" is now regularly copied to Grenoble for archiving which eases the following up of such maintenance problems.

Staff Changes

A. Oberti has retired in April 1991, and B. Aubeuf was appointed as the new responsible for the cable-car.

In December 1991, Th. Crouzet has been hired as the new Station Manager, succeeding J. Delannoy upon his retirement. The new Station Manager will be based on the site but keep close contact with Headquarter staff through regular visits to Grenoble. He is responsible for the coordination of all technical work at the observatory as well as for the observatory logistics (in collaboration with the Head of Administration in Grenoble, M.Malzacher). He also coordinates the group of operators (in close collaboration with the Plateau de Bure coordinator in Grenoble, S. Guilloteau).

Conclusions

The 1991 observing campaign has shown that the programs recommended by the Program Committee can be executed in a reasonably efficient manner. Several of the procedures have been standardised with numerous steps automated (command procedures are good examples, they exist e.g. for snapshot observations). Some important procedures, like e.g. configuration changes, have, however, so far escaped automation, primarily due to adverse climatic conditions and other physical or instrumental problems. There is obviously room for further improvements in this respect based on accumulating experience.

5. GRENOBLE HEADQUARTERS

5.1 SIS Group and Receiver Group Activities

General

To extend the collaboration and to learn more about the requirements for SIS junctions of the various receiver groups, an SIS User Meeting was held at IRAM on October 28 and 29. The following institutions were represented: ENS/DEMIRM, Paris; CNES, Toulouse and Paris; INSU, Paris, MPI für Extraterrestrische Physik, Munich, MPI für Radioastronomie, Bonn; University of Cologne and IRAM. The next meeting will take place in the Paris area in November 1992 and will be organized by IRAM.

Junction Fabrication and Development

100 GHz

(a) More standard junctions were fabricated for the 30-m telescope and the Plateau de Bure Interferometer.

(b) For the first time, junctions have been made with integrated tuning structure.

150 GHz

(a) To replace the Pb/Bi/In junctions, Nb junctions were also made for this frequency but not yet implemented.

(b) Two of these junctions (80 Ω) were given to the University of Cologne for the Gornergrad telescope; a receiver noise temperature of about 70 K DSB has been obtained.

230 GHz

As mentioned in the 1990 Annual Report, the results at 100 GHz with Nb junctions have been so encouraging that we started the development for 230 GHz. Meanwhile a number of two- and four-junction arrays have been made. Receivers with these junctions are meanwhile on the 30-m telescope (junctions with tuning structure are being prepared for 1992/3).

230 GHz junctions were also given to the group of astrophysics of the University in Grenoble, to the MPI für Radioastronomie in Bonn (for direct detector experiments), and to the Harvard Smithsonian Center for Astrophysics in Boston.

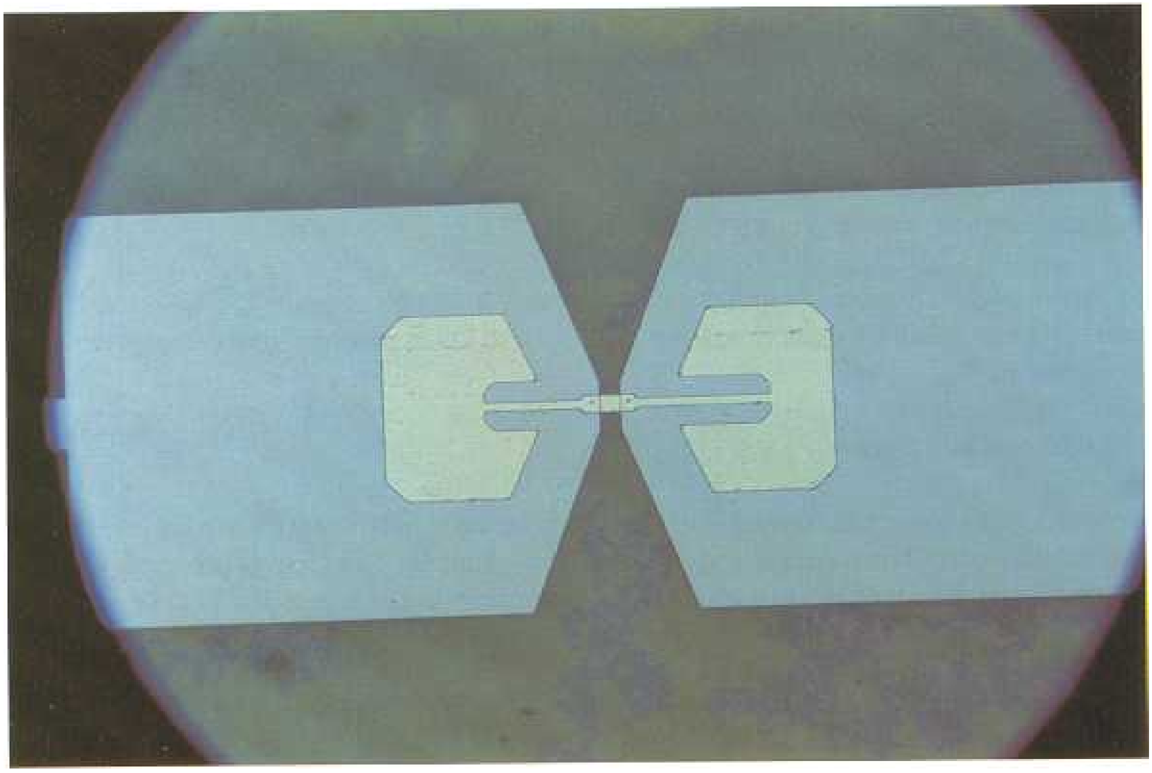


Fig.5.1:
Two serially connected SIS-junctions with tuning structure to compensate the junction capacitance in the vicinity of 230 GHz. Note the asymmetry in the tuning structure which helps to increase the useable bandwidth. The underlying larger areas belong to the low-pass filter for the IF output.

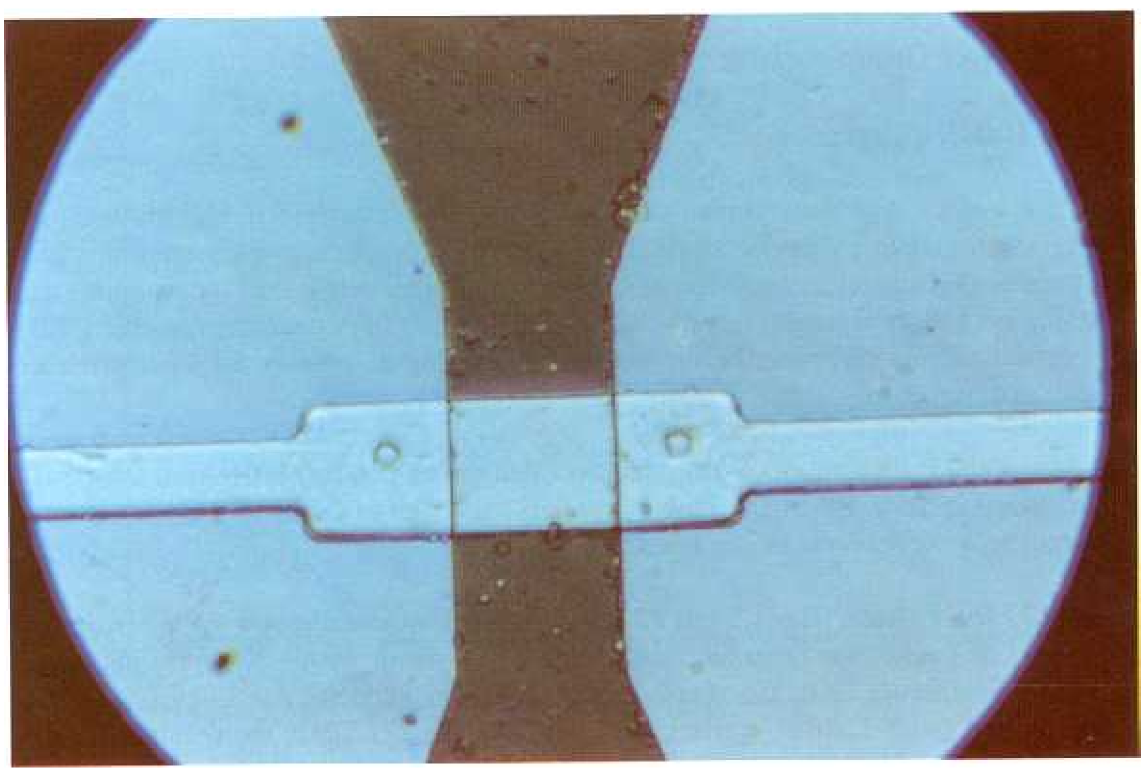


Fig.5.2:
Enlargement from Fig.5.1. Each of the two junctions has an area of about 2 μm^2 .

345 GHz

(a) Waveguide junctions of the standard IRAM design were fabricated for the MPI für Radioastronomie, but not yet tried out.

(b) A set of junctions with inductive tuning and a dipole antenna for an open structure receiver have been fabricated for the MPE. Best DSB receiver noise temperatures are about 100 K.

345, 460 and 600 GHz

Junctions with inductive tuning and log. per. antenna were fabricated for the MPI für Radioastronomie. The receiver and the tuning structure for 345 GHz is presently under test in Bonn. First results indicate a receiver noise temperature of about 300 K DSB.

5.1.3 Others

The evaporation of SiO_2 by an electron beam has been replaced by rf sputtering which is expected to give more reproducible films. The dielectric properties of the SiO_2 films have been investigated (in collaboration with the MPI für Radioastronomie) by testing capacitors and (in collaboration with the MPE) by ellipsometric measurements. It was concluded that the SiO_2 films have properties close to those expected for quartz.

5.1.4 Receiver Group Activity

Receiver Repairs/Upgrades

3mm Pico Veleta: The 3mm mixer was replaced in December 1991. The previous mixer had degraded, and in particular its settings were not reproducible even on timescales of days, presumably due to degradation of the backshort. The new mixer incorporates a non-contacting backshort vacuum-coated with Parylene. It was fully characterized for DSB and SSB performance in Grenoble before being shipped. Fig 5.3 shows SSB performance of the new mixer on the telescope.

2mm Pico Veleta: The previous 2mm receiver had developed a cold Helium leak and was fully replaced in June 1991. The new mixer still uses a Lead junction. Fig. 5.4 shows the performance of the receiver on the telescope.

1.3mm #2 Pico Veleta: The 1.3mm #2 receiver was first installed on the 30-m telescope in August 1989. After the Lead junction failed, a new mixer with a Niobium junction was installed in September 1991. Good results were obtained, especially at 230 GHz: 80K DSB and 125K SSb (with 12dB rejection). However, around 222 GHz, the receiver noise was degraded, and the sideband ratio was perturbed. This behaviour was analyzed (see below), and a modified structure was implemented. The new mixer was fully tested (DSB and SSB), and installed on the telescope in December 1991. No telescope results are shown because a minor cryogenic problem prevented extensive use in December 1991.

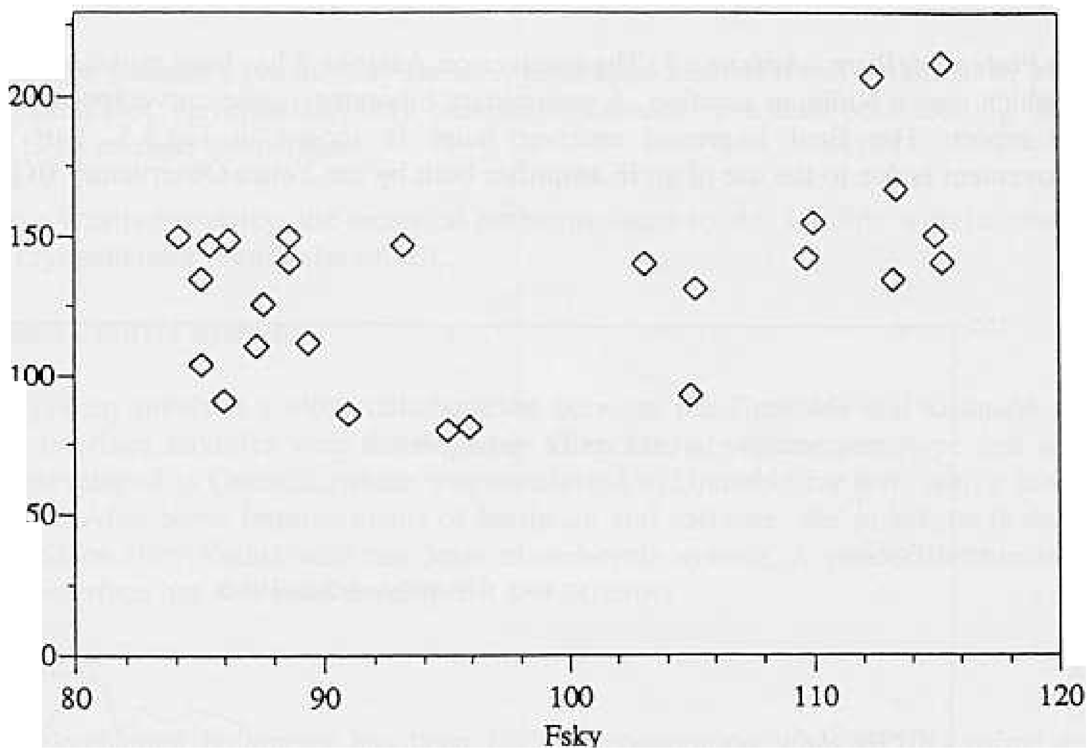


Fig.5.3:
Receiver temperature (SSB) of the new 3mm mixer installed at the 30m telescope in December 1991.

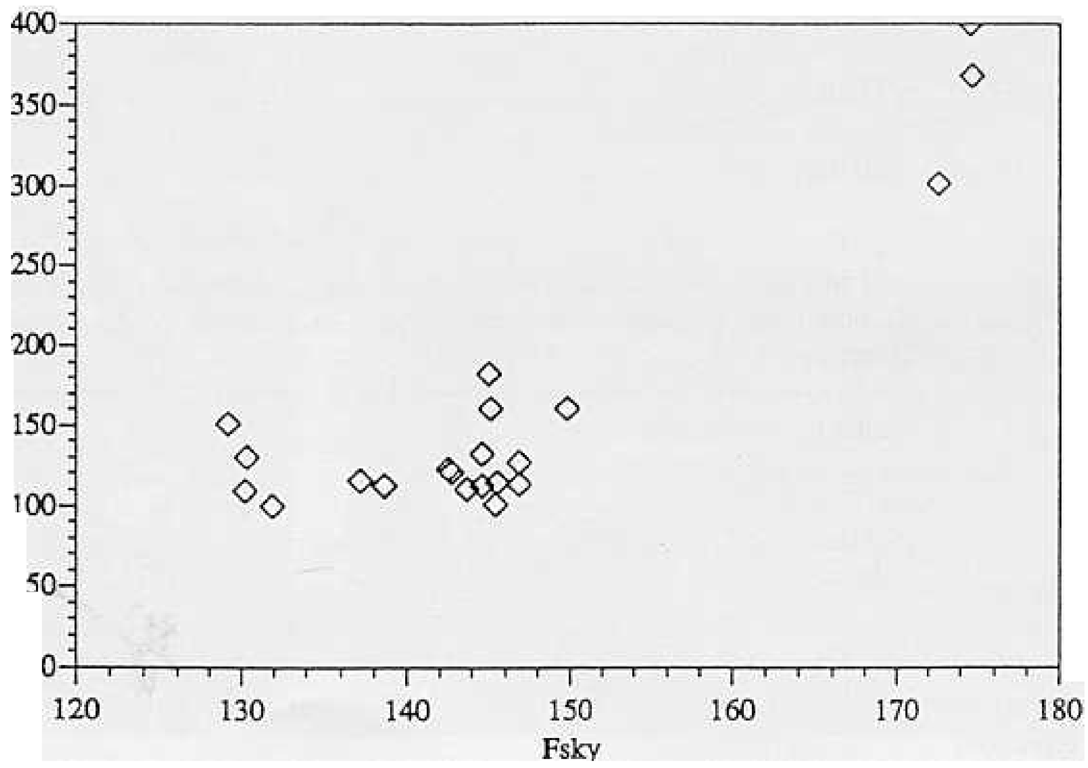


Fig.5.4:
Receiver temperature (SSB) of the new 2mm mixer installed at the 30m telescope in June 1991.

3mm Plateau deBure - Antenna 3: The receiver on Antenna 3 has been replaced by a new one which uses a Niobium junction. A preliminary laboratory noise curve appeared in the 1990 report. The final improved receiver noise is shown in Fig.5.5. Part of the improvement is due to the use of an IF amplifier built by the Yebes Observatory (IGN).

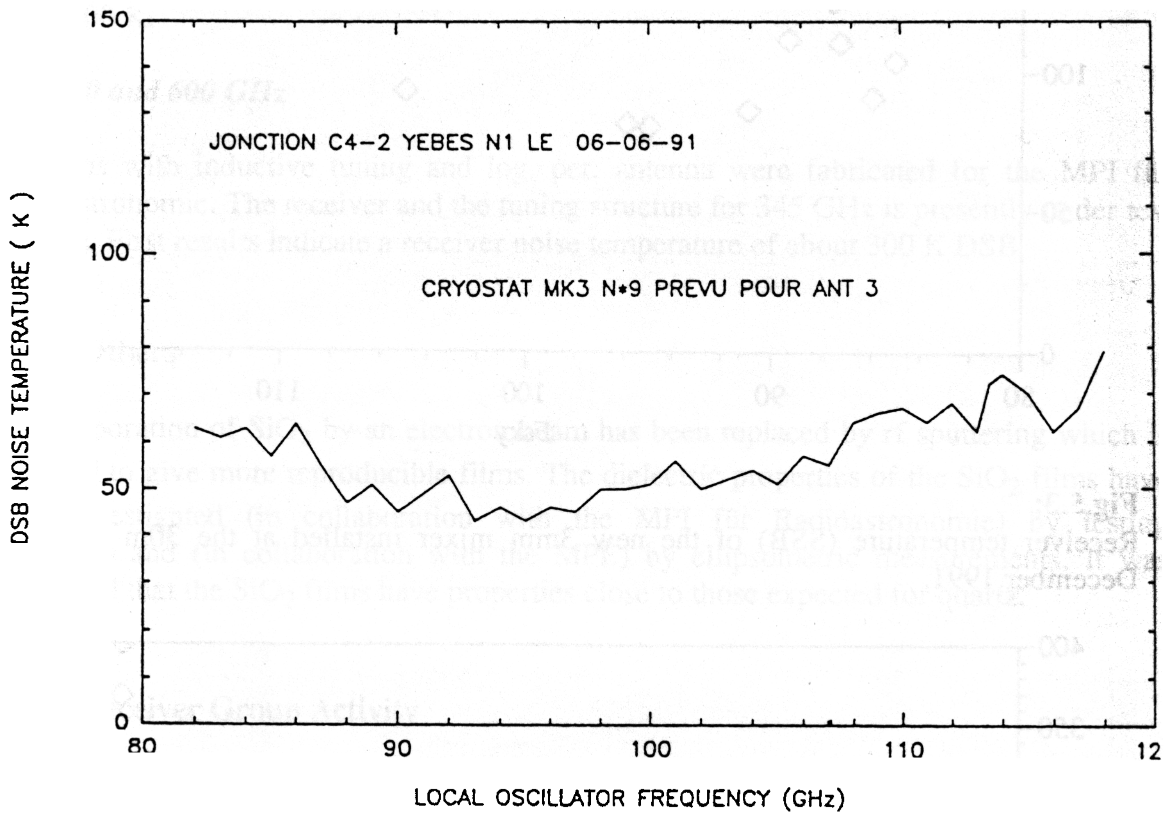


Fig.5.5:
Performance of the new 3mm receiver on Antenna 3 of the Plateau de Bure Interferometer. This receiver uses a Niobium junction built at IRAM, and an IF amplifier built at the Yebes Observatory.

5.1.5 Receiver Construction

A new 3mm receiver is being prepared for Pico Veleta. This receiver incorporates a number of features:

- a prototype closed-cycle refrigerator (CENG/Air Liquide), which will eliminate tedious Helium fillings;
- a two-backshort mixer purchased from NRAO, which provides consistent sideband rejection;
- cold optics, and LO injection through a waveguide and custom-designed sidewall coupler;
- a new automated receiver control system, described in more detail below.

These new features pave the way for next generation receivers, and a number of problems have been met. Nevertheless, very encouraging results have been obtained, e.g. less than 50K DSB receiver temperature.

After a frustrating delay, the technical problems faced by Air Liquide with its production unit cryogenerator seem to be solved.

Remote Control System

This system involves a close collaboration between the Grenoble and Granada groups. After interface modules were developed in Grenoble, a working prototype and software were developed in Granada, which was transferred to Grenoble for tests with a laboratory receiver. After some improvements of hardware and software, the prototype is due to be installed on Pico Veleta with the 3mm closed-cycle system. A production version with VME interface has also been developed.

Bolometer

A single-channel bolometer has been built in cooperation with MPIfR, using a 0.3K minifridge built by CNRS (Service d'Aéronomie). This is scheduled to be tested on the site early 1992, and, if successful, it will be offered as a common-user instrument.

Fig. 5.6

The 345 GHz SIS receiver built by H. Rothermel at the Max-Planck-Institut für Extraterrestrische Physik, Garching, installed in the receiver cabin at the 30m telescope.

5.1.6 Development Activities

Mixer Modelling and Design

Progress has been made in several directions. Scale-model measurements with the network analyzer and computer-aided modelling now allow us to understand better the behavior of the standard reduced-height waveguide mixer, and to predict its performance. For instance, the peak in receiver noise occurring around 220 GHz in the first Nb 1.3mm mixer was diagnosed and in a suitably modified structure moved down to 210 GHz, where it is less objectionable for astronomical use.

A completely new structure was developed in the 3mm band, featuring full-height waveguide and inductive compensation of the junction. The design goal, a flat noise curve across the 80-115 GHz band, has been reached. The results of laboratory measurements are shown in Fig. 5.6.

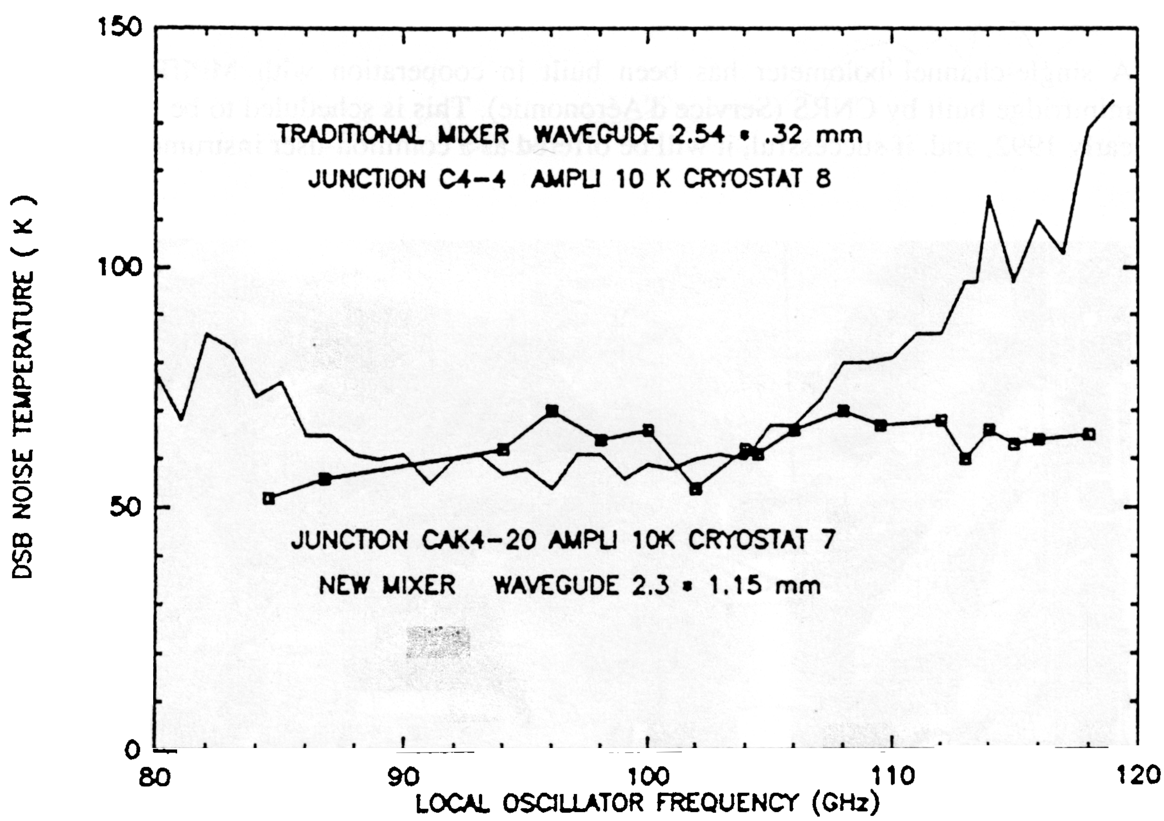


Fig.5.6:
Comparison of the performances of a traditional mixer and one built with the new waveguide design and inductive compensation of the junction.

Inductively compensated junctions for the 1.3mm and 0.8mm bands have been designed and fabricated. At the time of writing, very encouraging results have been obtained in the 1.3mm band.

5.1.7 Instrumentation

The HP8510 network analyzer is now routinely used, both in the standard microwave range and in the millimeter domain thanks to the IRAM-built extension, to characterize components and dielectric materials.

A setup allowing simultaneous measurements of conversion losses in both sidebands has been used to characterize 3mm and 1.3mm mixers before installation on the 30-m telescope.

5.2 Backend Developments

New spectrometers built for both sites

The prototype unit of the new digital correlator was ready in April when extensive tests began under local software. Some modules were corrected to take system effects into account. The system met all its specifications, was accepted, and its duplication was started. A total of 8 units will be constructed.

The new generation of correlators will add 18432 channels to the PdB interferometer and 4096 to the 30-m telescope. The machines are made out of 290 modules of 11 different types, including 10% spares.

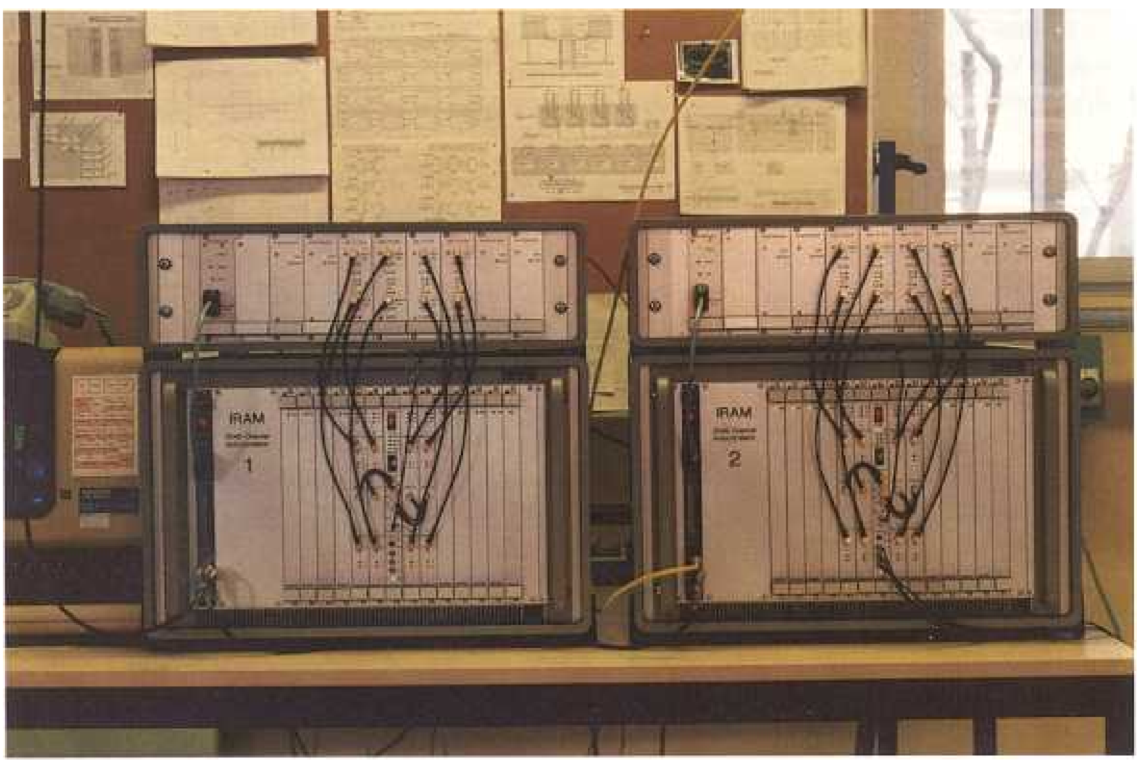


Fig.5.7:
Frontside view of two completed spectrometers ready to go to the 30m telescope.

The purchase of all components and the subcontractor management was performed by the Backend group technicians. The Granada lab contributed by furnishing some modules, too. By December, all the modules were built, 50% tested. Very low fault rate has been observed.

The final assembly of the two units dedicated to the 30m telelescope experienced minimal difficulty. The initial 3-year schedule has been exactly met, resulting in operational hardware delivery early in January 1992.

At the same time, one user's manual and 6 different technical manuals have been edited by recompiling the design and service documents produced over the past three years.

During this production period, engineering activities continued. They concerned i.a. the development of interferometer-specific modules, such as signal and LO distributions, and fringe rotators.

5.3 Computer Group

5.3.1 General Computing Facilities

The most noticeable change concerns the rearrangement of the computer and terminal rooms in July 1991. A spacious and well equipped 'user room' is now available for staff astronomers and visitors who come to Grenoble to reduce their interferometer data.

This 'user room' not only features terminals and workstations which provide access to the IRAM VAX-cluster and the HPs (see below) and the related periphery but there are also MACs and PCs for text editing, design of electronic circuitry, and other applications.

Also other very important but less visible improvements have been made. Early in 1991 a new microVAX 4000 model 300 was added to the VMS cluster. Its name: IRAM04. It became the most powerful VAX/VMS server at IRAM with 8 times the CPU performance of a VAX-11/780. Its main features are: 32 Mbytes of memory, a DSSI disk of 1Gbytes, and a 1.2Gbyte SCSI extra disk. Now the VMS cluster is composed of this new server plus 2 work stations (VS3200 and GPX) all running DECwindow.

To achieve an integration of the personnel computers for sharing files, printers and services in general, PATHWORK for MACs has been added and an improved version for PCs has been installed. The integration based on Ethernet thin wire cable connections has proved to be an efficient and valuable solution.

Meanwhile it has been proposed to use UNIX RISC work station to reduce the interferometer data. The Risc machines are today the best price/performance solution for intensive calculation and fast scientific visualization. After an evaluation of different stations from several manufacturers with standard calculations including mapping and cleaning, it has been decided to buy a HP 730. This machine will be offered with priority to visitors coming to Grenoble to process their data from the Plateau de Bure interferometer. The HP 730 delivers 72 SPECmarks, 76 MIPS and 22MFLOPS. It has been purchased with 32 MBytes of memory, a 400 MBytes internal disk and with DAT and CD ROM drives. Its customization includes the installation of EMACS, a well known editor, and tools as DECTERM to create X DEC terminal windows, NPRINT to use the VMS cluster printers, and facilities to create project accounts.

Recently also a HP 720 has been received. This machine purchased with French funds to help interferometry imagery and algorithm development will primarily be used by staff members from IRAM and GAG.

For both HP work stations, extra magnetic disks and writable optical disk drives have been ordered. Raw and reduced data will be kept on optical disks (one per project) and magnetic fast disks will serve mainly as scratch space.

PC users with Ethernet connection to the VAXes can run X terminal emulation under DECNET. However, to support various network protocols, larger color scales and fast window management, NCD X color terminals have been purchased and installed in the offices of some of the astronomers. With both DECNET and TCP/IP being available, those terminals can serve directly X applications running on HP/UNIX and VAX/VMS.

Our computers are now connected to GRENET, the campus Ethernet network with an access to Internet. Our subscription to Fnet, the French branch of EUnet gives us the opportunity to send and receive mails to our address IRAM.GRENET.FR.

5.3.2 Software Development

To go to VME has been a key decision for the IRAM development which include the spectral correlators and the tuning of the future receivers under microprocessor control. For all VME micros the common features are OS9 for the operating system, C for the programming language, Ethernet-TCP/IP for the communications, and NFS to provide virtual disks for the software development.

Most of the routines for the correlator acquisition, control and preprocessing have been written and tested. Those routines include the connection between the OS9 micros and the filter and LO black box, the correlator configuration, the sampler level adjustment, the acquisition synchronized on external interrupts, the preprocessing as FFT and clipping correction, and the data transfer to the VAX.

An operational version of the software for the Pico Veleta correlator based on specifications from Grenade should be assembled and tested soon. It is interesting to note here some figures obtained with the 68030 microprocessors clocked at 25MHz:

A 256 channel FFT takes 35ms and up to 12 bands (FFT) should be considered by each micro with the Bure configuration.

A maximum transfer rate of 1.1 Mbits/s is obtained on Ethernet with TCP/IP and when collisions are avoided.

For the receiver control, the VME microprocessor is interfaced to a bus already developed and used at IRAM-Granada.

Written in C, elementary control of motors has been achieved in continuous or in pulse mode. With this technique, a module has been written to set and to phase-lock the frequency of a local oscillator, and the complete adjustment of a receiver will be tested as soon as a receiver will be available.

Technical Group

General Developments

The numerically controlled milling machine purchased in 1990 was equipped with a video camera with magnifying optics (0-60x) to facilitate the fabrication of delicate components with small dimensions and/or high precision requirements. The possibility to use data files produced by CAD software as programming input for the NC machine has become standard practice.

Fig.5.8:
The IRAM NC milling machine equipped with a video camera for close monitoring of work in progress.

In response to more ever more demanding requests, new fabrication methods have been considered and partially already applied in-house and with external sub-contractors. These include the use of electro-errosion, cold stamping (for small waveguide structures), and ion etching.

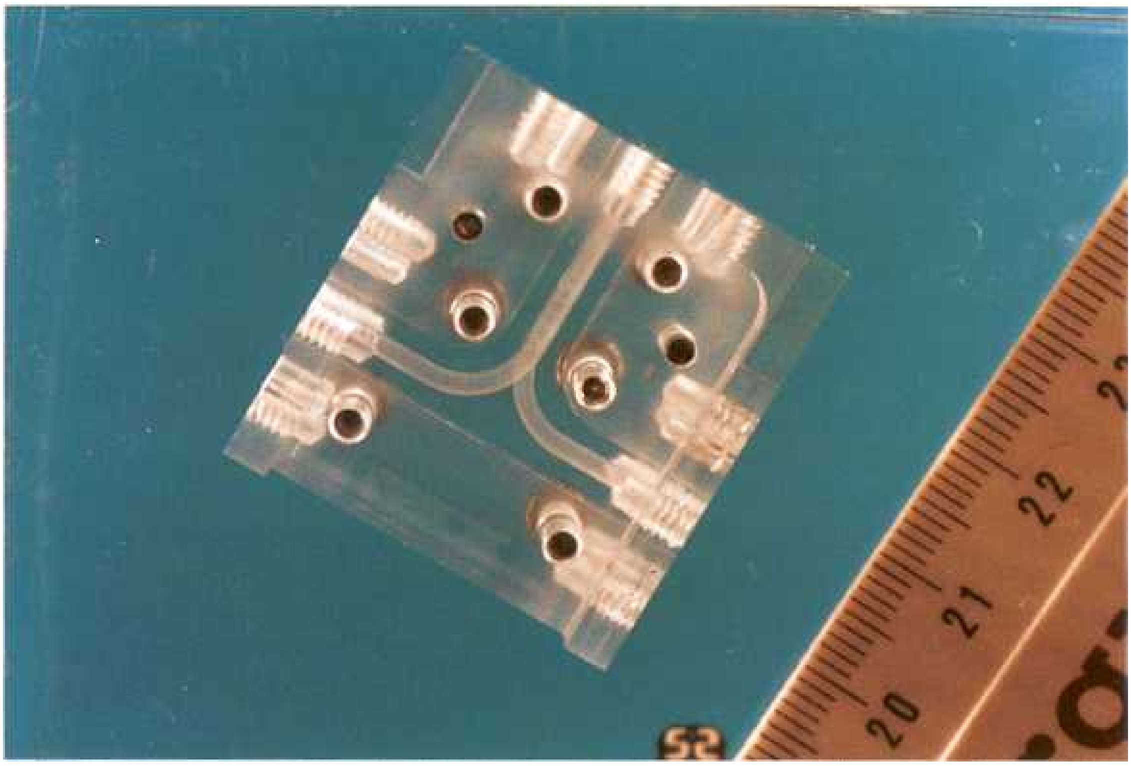


Fig.5.9:
Mock-up of a sidewall coupler for the 2mm band. Such plastic models are used to verify the programming of the NC milling machine.

Fig.5.10:
The elevation frame for the fourth antenna mount during fabrication at FERRY-CAPITAIN. This part interfaces with the central hub of the reflector.

The overall number of internal requests for manufacturing has continued to increase from 213 in 1990 to 273 in 1991. For 33 of these external subcontractors were chosen.

Technical Support for the Plateau de Bure Installations

The group responded to a number of request for mechanical improvements of the existing telescope mounts, and continued its responsibility for keeping an updated set of drawing and documentation related to the Plateau de Bure Installations.

Mount for Antenna 4 for the Plateau de Bure Interferometer

The technical group was responsible for the preparation of all documents related to the new antenna mount. The group prepared the various contracts and monitored closely their progress during the fabrication phase.

The construction of the mount advanced according to schedule and within the financial envelope foreseen.

The planning at the end of 1991 foresees the following milestones for 1992/1993:

- transport of major components of the mount to the PdB	March 1992
- assembly of the mechanical parts of the mount	April-June 1992
- electrical installations	July/August 1992
- installation of thermal covers	August-October 1992
- assembly of the reflector	October-December 92
- remaining installations and total system tests	January/February 93
- installation of receivers etc.	March 1993

6. PERSONNEL AND FINANCES

In 1991, IRAM had a total of 104 employees. Of these, 95 were IRAM staff members, and 9 were PhD students or post-docs, 5 in Grenoble, 4 in Granada.

One of the staff positions in the SIS laboratory is jointly financed by the MPIfR and the MPI für Extrarerrestrische Physik. The MPIfR also finances one of the post-doc positions in Spain, and one of the students has a French/Spanish scholarship.

IRAM's financial situation in 1991 and the budget provisions for 1992 are summarised in the following tables.

The total expenditures in 1991 were higher than originally foreseen.

In the course of the year, 3.1 MF were invested in new laboratory equipment, and 9.1 MF were paid in connection with the 4th antenna for the Plateau de Bure interferometer. Further investments were made in receivers and backends (3.3 MF), computers (0.8 MF), administration and transport (0.1 MF), and Pico Veleta infrastructure (0.5 MF). The planned extension of the SIS laboratory for the development of junctions for submm astronomy includes a NbN sputter system and an electron microscope, to be financed by CNES, the MPIfR, the MPE and a donation from Advantest Coporation, Japan. Initial investments for this extension in 1991 were 1.6 MF.

Income other than contributions was higher than foreseen due to income related to special projects (e.g., NbN sputter system).

The reimbursement of Spanish Value Added Taxes, a longstanding problem, has only partially been resolved. The tax office reimbursed the V.A.T. for 1988 and 1989, but the taxes for 1986 and 1987 have not yet been paid back to IRAM. The 1986 reimbursement depends on the outcome of a court decision in Madrid, and the claim for the 1987 reimbursement must still be submitted to the tribunal.

The Instituto Geografico Nacional (IGN), Madrid, has joined IRAM as an official partner on 28 September 1990. IGN now participates with 6% to the annual operations and investment budgets, as well as with a one-time contribution of 16.2 MF in recognition of the investments paid by INSU and MPG in the past.

Negotiations have been started both with the manufacturer and the insurance company to explore possible financial arrangements should the surface panels of the Plateau de Bure antennas need a new protective cover.

BUDGET 1991

Expenditure

BUDGET HEADING	BUDGET KFF	ACTUAL KFF
Personnel	33 496	31 753
Operations	13 804	15 691
	47 300	47 444
Investments	26 600	19 727
Value-added Taxes	4 033	4 033
	77 933	71 204

Income

BUDGET HEADING	BUDGET KFF	ACTUAL KFF
Contribution CNRS	25 751	25 751
Contribution MPG	25 751	25 751
Contribution IGN	20 628	20 628
Other Income	1 770	8 363
Contribution CNRS for Value-added taxes	4 033	4 033
	77 933	84 526

BUDGET PREVISIONS 1992 (KFF)

Expenditure

BUDGET HEADING	APPROVED BUDGET
Personnel	33 660
Operations	15 059
	48 719
Investments	9 460
Value-added taxes	4 224
	62 403

Income

BUDGET HEADING	APPROVED BUDGET
Contribution CNRS	27 156
Contribution MPG	27 156
Contribution IGN	3 467
Other Income	400
Contribution CNRS for Value-added taxes	4 224
	62 403

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

IRAM 30-M TELESCOPE			JANUARY 1991—JANUARY 1991		Update: May 1992
Week	**Date**	**Ident.**	**Title**	**Freq.(GHz)**	**People**
01/02	Jan 1–15	120–90	A highly collimated bipolar outflow in the core of OMC–1	115,220,230,345 147,245	Schmid-Burgk, Güsten, Mauersberger, Wilson
		145–89	Gaseous content of circumstellar matter around young stellar objects in the RHO Ophiuchi cloud core	110,137,141,216 220,226	Montmerle, André, Despois, Martin-Pintado
		267–90	Duration of extreme mass-loss of OH/IR stars	110,220,140	Forveille, Omont, Kahane, Habing, Heske
		204–90	Are all the protoplanetary nebulae bipolar?	89,90,115,130 220,230	Bujarrabal, Alcolea, Planesas
		219–90	Zero spacings for the SiO maps made with the IRAM Interferometer	86	Martin-Pintado, Wilson, Fiegig, Güsten, Walmsley Schilke, Cesaroni, Duvert, Wink
		243–90	The remarkable outflow system from OMC–1 S6 : very high velocities, widespread shock chemistry	81...89,138,150 217..230,345,347	Schmid-Burgk, Henning, Muders
		135–90	Kinematics of a very small cloud in the Orion region	220,230,115,110	Rodriguez, Gonzalez, Martin-Pintado, Bachiller
		243–89	A detailed study of the very extended high velocity gas around Orion/IRC2	86,115,130,154 230	Martin-Pintado, Rodriguez, Bachiller, Wilson
		149–90	Io's atmosphere from microwave lines of SO_2	219–235	Lellouch, Belton, de Pater, Paubert
		286–90	Temporal variability and composition of Io's atmosphere	138–146,216–230	Lellouch, Belton, de Pater, Paubert
		150–90	Correlated observations of a sample of AGN together with ROSAT and IUE	cont.	Staubert, Courvoisier, Walter, Grewing
		272–90	Distribution of physical conditions of the molecular gas in NGC 1068	86,89,98,147 245	Planesas, Martin– Pintado Gomez-Gonzalez, Bachiller
		130–90	Monitoring of MWC 349	92,160,231	Thum, Martin-Pintado, Bachiller
03/04	Jan 15–29	84–90	A study of the water vapor emission toward molecular clouds and evolved stars at 183 and 325GHz	183,325	Cernicharo, Gonzalez, Thum, Bachiller
		56–90	Search for vibrationally excited HCN masers	177,265,87,172 258,259	Lucas, Cernicharo
		178–90	Protoplanetary sources: The role of the 21um feature	86,91,113,145,226	Henkel, Omont, Mauersberger, Cox

Week	Date	Ident.	Title	Freq.(GHz)	People
		168–90	CO in a giant irregular: The case of NGC 4449	115,230	Klein, Becker, Hunter, Henkel
		9–90	Giant molecular clouds and and star formation in nearby dwarf gal.	115,230	Becker, Sage, Henkel
		195-90	Protonated HCN in cold clouds	148,222	Schilke, Henkel, Walmsley, Millar
		150–90	Correlated observations of a sample of AGN together with ROSAT and IUE	cont.	Staubert, Courvoisier, Walter, Grewing
		277–90	The HCN/HNC ratio in oxygen–rich stars	88,91	Lewis, Henkel
		212–90	CO obs. of radio–quiet quasars: nature of the host galaxy	177,225,84,111	Alloin, Antonucci, Barvainis, Gordon
		165–90	Exploration of CO in elleptical galaxies	115,230	Gordon
		216–90	The molecular cloud content of elliptical galaxies. What is the physical state of the ISM?	115,230	Wiklind, Combes, Dupraz, Henkel
05/06	Jan 29–Feb 12	165–90	Exploration of CO in elleptical galaxies	115,230	Gordon
		216–90	The molecular cloud content of elliptical galaxies. What is the physical state of the ISM?	115,230	Wiklind, Combes, Dupraz, Henkel
		273–90	CO(2–1) obs. of the radiololoud quasar III Ww2	105,211	Steppe
		222–90	A molecular study of the tear drops in the Rosette	115,230,110,220, 97,147,86,142	Gonzalez, Cernicharo, Gomez–Gonzalez
		185–90	Low ^{13}CO emission in mergers: Photo–dissociation or abundance effects?	110,220,147,218	Casoli, Combes
		184–90	Search for CO asymmetry in 8 spirals of the Coma supercluster	115,230	Casoli, Gavazzi, Boissé, Combes, Verter
		261–90	Study of the edge–on galaxy	115,230	Garcia–Burillo, Guélin, Cernicharo, Dahlem
		262–90	Study of the first members of a remark–able new family of carbon–chain molecules	89,102,104,146	Guélin, Cernicharo, Paubert, Thaddeus
		260–90	Molecular spiral structure in M51	110,115,220,230	Garcia–Burillo, Guélin, Lucas, Cernicharo, Greve, Neri
07/08	Feb 12–26	260–90	Molecular spiral struct. in M51	110,115,220,230	Garcia–Burillo, Guélin, Lucas, Cernicharo, Greve, Neri
		243–90	The remarkable outflow system from OMC–1 SI:very high velocities, widespread shock chemistry	81...89,138,150 217..230, 345,347	Schmid–Burgk, Henning, Muders
		130–90	Monitoring of MWC 349	92,160,231	Thum, Martin–Pintado, Bachiller
		51–89	Observations of CO in the giant star forming complexes NGC5447 and NGC5471	115,230	Viallefond, Cox, Boulanger, Lequeux, Perault
		270–90	Correlation of gas density with infra–red colors	98,110,115,147 220,230	Boulanger, Falgarone

Week	Date	Ident.	Title	Freq.(GHz)	People
		65–90	Internal motions and density in dense cores: hith resolution obs. of-C_3H_2		Fuller, Myers, Falgarone, Puget
		48–90	High density small scale structure in the edges of molecular clouds		Falgarone, Philipps
		250–90	The structure of cold cloud cores	Bolo.	Mezger, Haslam
		252–90	$\lambda 870\mu m$ maps of the massive star forming cloud cores M17, W31 and NGC6334	Bolo.	Haslam, Sievers
		246–90	A search for dense central condensations in cloud cores detected in the Taurus cloud	Bolo.	Haslam, Zylka
		248–90	Sgr A* and its environment at $\lambda 870\mu m$	Bolo	Zylka, Mezger
08–09	Feb 19–Mar 5	250–90	The structure of cold cloud cores	Bolo.	Mezger, Haslam
		252–90	$\lambda 870\mu m$ maps of the massive star forming cloud cores M17, W31 and NGC6334	Bolo.	Haslam, Sievers
		246–90	A search for dense central condensations in cloud cores detected in the Taurus cloud	Bolo.	Haslam, Zylka
		248–90	Sgr A* and its environment at $\lambda 870\mu m$	Bolo	Zylka, Mezger
		254–90	Proto-planetary disks around main sequence stars	Bolo.	Chini, Kreysa
		255–90	Dust emission from quasars	Bolo.	Chini, Kreysa
		256–90	Dust emission from active galaxies	Bolo.	Chini, Kreysa
		257–90	Cold dust in spiral galaxies	Bolo.	Kreysa, Chini
10–11	Mar 5–19	276–90	The pulsar supernova connection: a deep continuum survey of nearby recent supernovae at 1.3mm wavelength	Bolo.	Tuffs, Chini, Wagner
		257–90	Cold dust in spiral galaxies	Bolo.	Kreysa, Chini
		274–90	Flux density measurements of compact steep-spectrum sources at 90 and 230 GHz	Bolo.	Steppe, Salter, Saikia
		50–90	Correlated observations of a sample of AGN together with ROSAT and IUE	Cont.	Staubert, Courvoisier, Walter, Grewing
		287–90	Are x-ray selected BLLacs the parent population of radio-selected BLLacs ?	230	Gear
		226–90	Are massive disks powering molecular outflows ?	230	André, Cabrit, Lada
		240–90	A search for remnant circumstellar dust disks around young solar-type stars with age > 10 Myr	230	Cabrit, André, Strom, Edwards, Skrutskie
		210–90	1.3 mm continuum emission from circumstellar envelopes	1.3mm	Walmsley, Steppe, Forveille, Omont
		234–90	Radio stars with suspected variability	250	Altenhoff, Wendker, Thum
		235–90	Search for radio emission of Be stars	250 Bolo.	Wendker, Thum, Altenhoff

Week	Date	Ident.	Title	Freq.(GHz)	People
		232–90	Investigations of stellar winds of B supergiants and of Be stars	250 Bolo.	Wolf, Stahl, Altenhoff
		151–90	A search for dusty primeval galaxies	1.3mm	Clements, Quenby, Joseph
		203–90	1.2mm continuum observations of an optically selected subsample of quasars	250	Roland, Andreani, Cristiani, La Franca
		237–90	Continuum observations of nearby comets	250 Bolo.	Altenhoff, Kreysa, Schmidt, Thum
12–13	Mar 19 – Apr 2	176–90	Molecular absorption lines in galaxies and quasars	88,96–99, 104–115	Eckart, Genzel Madden, Schuster, Harris
		175–90	912CO/^{13}CO Ratio in the QSO I Zw 1	110,230	Eckart, Genzel, van der Werf, Schuster, Harris
		78–90	Photodissociation regions and the abundance of warm carbon monoxide	260	Stutzki, Harris, Graf, Genzel
		57–90	Determination of the physical conditions of the regions where SiO and SiS emission arises	86,130,215,85 128,212,91, 127,217	Martin–Pintado, Bachiller Fuente, Gomez–Gonzalez
		79–90	The molecular interstellar medium of M83	115,230	Jackson, Genzel, Eckart, Harris
		77–90	S140 molecular cloud core	145,230,245	Stutzki, Güsten
		183–90	A study of ^{29}SiO and ^{30}SiO maser emission towards evolved stars	84–86,126–129 169–172,210–215	Cernicharo, Bujarrabal, Lucas
		72–90	Probing the birthsites of massive stars–follow–up	96,172,239,241 245,259,265,338	Güsten, Serabyn Fiebig, Schulz
		286–90	Temporal variability and composition of IO's atmosphere	138–146 216–230	Lellouch, Belton de Pater, Paubert
4–15	Apr 2–16	172–90	Probing the birthsites of massive stars–follow–up	96,172,239,241 245,259,265,338	Güsten, Serabyn Fiebig, Schulz
		280–90	A search for vibrationnally excited CS	243	Walker, Serabyn, Güsten, Black
		49–90	Multifrequency CS observations of bipolar outflows	98,146,244	Rudolph, Rieu, Bachiller
		192–90	Molecular gas in blue compact dwarf galaxies	230,115	Sage, Wiklind, Henkel
		211–90	Molecular and atomic radio lines in QSO absorption systems	91,129 140,211	Khersonskij, Slysh
		221–90	Shock chemistry in the cold cloud L1448	88–102,138–162	Martin–Pintado, Bachiller, Fuente, Planesas
		186–90	Gas response at the resonance in the grand design spiral NGC 4321	115,230	Elmegreen, Casoli, Combes Guélin, Garcia–Burillo, Beckman

Week	Date	Ident.	Title	Freq.(GHz)	People
16-17	Apr 16-30	186-90	Gas response at the resonance in the grand design spiral NGC 4321		Elmegreen, Casoli, Combes Guélin, Garcia-Burillo, Beckman
		274-90	Flux density measurements of compact steep-spectrum sources at 90 and 230 GHz	Bolo.	Steppe, Salter, Saikia
		221-90	Shock chemistry in the cold cloud L1448	88-102,138-169 220-245	Martin-Pintado, Bachiller Fuente, Planesas
		191-90	Molecular gas in QSOs	98	Roland, Jaffe
		200-90	Density distribution of compact molecular objects B335	140,225	Evans, Zhou, Kömpe, Walmsley
		223-90	The effects of density on the star formation efficiency	97,146,244 96,144,241	Lada, Evans, Falgarone
		227-90	Nature of the ρ OPH outflow sources	115,147	André, Despois, Lada, Martin-Pintado,Montmerle
		225-90	Very dense gas in star formation regions: a multitransition CS study of H_2 O maser sources	98,147,244,96 144,241	Jaffe, Martin-Pintado Gomez-Gon zalez, Evans, Plume
		181-90	Are grain mantles the source of the remarkable gas phase enhancement of sulfur dioxide molecules around GSS 30 ?	168,167,229	Wootten, Loren, André
		207-90	Densities and column densities of clouds toward CAS A	110,220 230, 109	Przewodnik, Wilson Mauersberger, Kömpe
		166-90	Search for sulfur compounds in Venus atmos.	138-168, 216-221	Bézard, Lellouch, Marten, Paubert
		242-90	Relation between atomic and molecular gas content in IRAS galaxies ; and the efficiency of star formation	108-115 215,230	Dennefeld, Bottinelli Gouguenheim, Martin
		230-90	Galactic center molecular clouds associated with unusual HII regions	98,244	Morris, Serabyn
18-19	Apr 30 - May 14	242-90	Relation between atomic and molecular gas content in IRAS galaxies ; and the efficiency of star formation	108-115 215,230	Dennefeld, Bottinelli Gouguenheim, Martin
		230-90	Galactic center molecular clouds associated with unusual HII regions	98,244	Morris, Serabyn
		163-90	CO in Markarian galaxies	110-115,220-230	Chini, Krügel, Steppe
		283-90	Chemical signatures of of protostellar regions	86-104,217-265	Gredel, van Dishoeck Blake
		101-90	The search for CO in infrared quasars-continued	108-84	Wilson, Mauersberger, Kömpe Sanders, Scoville, Zensus
		199-90	The line formation process in infrared QSO's	210-220,80-90 128-135	Wilson, Mauersberger, Scoville Sanders, Zensus, Kömpe
		177-90	A massive CS outflow towards G34.26	98	Cesaroni, Churchwell, Kömpe, Walmsley
		219-90	Zero spacings for the SiO maps made with the IRAM Interferometer	86	Martin-Pintado, Wilson, Fiebig, Güsten Walmsley, Schilke, Cesaroni, Duvert, Wink

Week	Date	Ident.	Title	Freq.(GHz)	People
		A057	IRAM 30m and PdB CO Observations of the spiral structure in NGC 6946		Boulanger, Casoli, Combes Guilloteau, Lequeux, Rieu, Viallefond
!0-21	May 14 - May 28	1057	CO observations of the spiral structure in NGC 6946		Boulanger, Casoli, Combes, Guilloteau Lequeux, Rieu, Viallefond
		41-91	Giant molecular clouds in the nearby irregular galaxy IC 10	115, 230	Becker, Greve, Johanson
		12-91	Carbon monoxide isotope ratios in low-mass galaxies	110	Becker, Freudling, Greve, Wilson
		133-90	The dynamics of the circumnuclear disk in SgrA	145, 240	Mezger, Wilson, Zylka, Mauersberger
		14-91	Study of the CO distribution in the edge-on galaxy NGC 4631	115,230	Golla, Krause, Wielebinski
		20-91	CO study of the central region of the barred spiral galaxy NGC 5383	114,228	Wielebinski, Brouillet, Garcia-Barreto, Klein, Reuter
		32-91	Stellar flares on AD Leo and AE Agr: multiband observations	CONT	Lecacheux, Dulk, Bastian, Bookbinder, Belkora
		16-91	The compact region of annhiliation of positrons in the galactic center	39,93,97,220,230	Mirabel, Morris, Duc
		9-91	The discrimination between O- and C-rich circumstellar envelopes from mol. obs.	38,90,130,244	Bujarrabal, Omont, Fuente, Alcolea
		0-91	The molecular envelope of Betelgeuse	38,89,90,115 130,146,220,230	Bujarrabal, Lucas, Alcolea
		74-91	HIGN resolution molecular study of photodissociation regions	38,90,91,97 109,113,146,165 219,220,226,244	Fuente, Martin-Pintado, Bachiller, Cernicharo
		50-91	High resolution obs. of CO emission in the envelopes of evolved stars : a key to the ultimate revolution of the stars with high mass-loss	115,230	Lucas, Guilloteau, Guélin, Neri Cernicharo, Forveille, kahane, Loup Morris, Omont, Bujarrabal, Martin-Pintado, Rieu
22-23	May 28 - Jun 11	58-91	^{13}CO line emission from ultraluminous IR galaxies	10,220	Radford, Downes, Solomon
		59-91	CO in extremely distant luminous galaxies	110,220	Downes, Solomon, Radford
		258-90	Hot water around late-type stars	96,139,232,263 336	Menten
		67-90	The mass loss rate of short period Mira variables from CO(1→ 0 and 2→1) measurements	115,230	Wood, Hekkert, Habing van der Bliek

Week	Date	Ident.	Title	Freq.(GHz)	People
24–25	June 11 – June 25	12–91	Rare molecules in evolved planetary nebulae		Bachiller, Huggins, Cox, Forveille, Lequeux
		52–91	Millimeter recombination lines in planetary nebulae BD+30°3639	36,147,231	Bachiller, Huggins, Cox, Forveille, Lequeux
		150–90	Correlated observations of a sample of AGN together with ROSAT and IUE	cont	Staubert, Courvoisier, Walter, Grewing
		61–91	The large scale interaction of the HII region and the ambient gas in Orion A High velocity filaments and bullets	86–245	Martin–Pintado, Rodriguez, Bachiller, Wilson
		36–91	HCN and HNC chemistry in Orion–KL	36–90, 148	Schilke, Walmsley
		39–91	Protonated HCN in cold clouds and the galactic center	75,86,148	Schilke, Walmsley, Henkel, Millar
		77–91	Methyl cyanide as a probe of kinetic temperature in dense molecular clouds	110, 147, 220	Evans, Martin– Pintado, Gomez–Gonzalez, Plume
		33–91	CS absorption line observations of spiral arms	98, 147	Greaves, Moore, Williams
		49–91	HC3N and HC5N around IRC+10216	32,101,164,218	Kahane, Jura
		53–91	Steps towards a molecular Tully–Fisher relation		Kazes, Dickey
26–27	June 25 – July 9	54–91	Molecular clouds within 10 PC of galactic center		Wright, Ho, Guesten
		16–91	Density structure in cold molecular clouds	80,85,145,150	Cox, Guesten
		40–91	Catalogue of calibrated spectra for redshifted CO	110,115,220,230	Liechti, Steppe
		5–91	Multi–level HNCO observations of nearby starburst galaxies	220	Rieu, Jackson, Henkel, Mauersberger
		47–91	D/H in the galactic center (III)	85,144,216,220	Jacq, Walmsley
		258–90	Hot water around late–type stars	96,139,232,263,336	Menten
		53–91	The small scale structure of a GMC	110,220	Dutrey, Duvert, Castets, Bachiller, Bally Walmsley, Boulanger
28–29	July 9 – July 23	26–91	C2H in circumstellar envelopes: a tracer of acetylene and dust condensation	87,174,262	Tejero, Cernicharo, Omont, Mailla
		51–91	A fresh look at the electron density problem: measurements of the DCO+/HCO+ abundance ratio in four cloud cores	72,86,144,216	Guélin, Cernicharo, Rowe, Valiron

Week	Date	Ident.	Title	Freq.(GHz)	People
		67–91	CO photodissociation at the edges of IRC+10216		Guélin, Cernicharo, Lucas, Kahane
		70–91	Search for the HCCN radical and for the C4H4 molecule in interstellar clouds	87,109,110,131	Guélin, Cernicharo, Bogey
		13–91	The transition of atomic to molecular gas in MCD 176.6+24.5	90,109,230	Heithausen, Schneider, Wouterloot
		25–91	The very small scale structure of molecular clouds : High angular resolution isotopic CO mapping of 1457 and NGC 1499	09,110,218,220	Zimmermann, Herbertz, Stutzki
30–31	July 23 – August 6	59–91	Multi–transition CS observations of outer–galaxy massive star forming clouds	97, 146	De Geus, Brand, Wouterloot, Rudolph
		81–91	The molecular cloud content of elliptical galaxies:What is the physical state of the ISM ?	3,115	Wiklind, Combes, Dupraz, Henkel
		80–91	CO distribution in elliptical galaxies		Wiklind, Lees, Combes, Dupraz, Henkel
		43–91	CO observations of old dust–forming	110,220,115,230	Shore, Starrfield, Braine
		35–91	Getting the most out of NGC 6946	110, 220	Braine, Casoli, Combes, Viallefond
		34–91	Strong CO in an isolated galaxy	110,115,220,230	Braine, Combes, Shore
		22–91	Deuterium chemistry search for CH2DCN, CH2DCCH and CH3CCD	80–226	Gerin, Combes, Encrenaz, Laurent, Wlodarczak
32–33	Aug. 6 - Aug. 20	34–91	Strong CO in an isolated galaxy		Lecacheux, Dulk, Bastian, Bookbinder, Belkora
		11–91	The starburst galaxy NGC660: CO in the polar ring ?	4, 220	Combes, Casoli, Dupraz, Gerin, Van Driel
		38–91	CO line observations of bright carbon stars	115, 230	Groenewegen, De Jong, Loup
		2–91	Molecular gas in a cluster environment	115, 230	Sage, Henkel, Mauersberger
		39–91	Protonated HCN in cold clouds and the galactic center	74,86,87,148	Schilke, Walmsley, Henkel, Millar
		65–91	Is the envelope in DR21 very dense ?		Wilson, Mauersberger, Henkel, Hüttemeister
		64–91	Rho Oph B:A high density, cold cloud	144,147,241,245	Wilson, Mauersberger, Koempe
		19–91	A multilevel study of extragalactic H2CO	140,145,218,225	Huettemeister, Baan, Henkel, Mauersberger
		48–91	Isotopic ratio on Titan	39, 259	Bézard, Marten, Coustenis, Paubert
		37–91	Venus mesophere dynamics from CO lines	115, 220, 230	Lellouch, Goldstein, Rosenqvist, Paubert, Bougher

Week	Date	Ident.	Title	Freq.(GHz)	People
34–35	Aug.20 – Sep. 3	37–91	Venus mesophere dynamics from CO lines	115, 220, 230	Lellouch, Goldstein, Rosenqvist, Paubert, Bougher
		30–91	The formation of C3H2:Observations in M17	85, 90, 145	Giard, Falgarone, Pauzat, Cox
		31–91	Correlation between gas density and infrared colours	110, 147, 230	Boulanger, Falgarone
		75–91	Mapping of the H20 vertical distribution in the upper atmosphere of Venus from a study of the 226GHz line	225	Encrenaz, Lellouch, Rosenqvist, Gulkis Paubert, Belton, de Pater
		71–91	Molecular emission from circumstellar regions of young stars	109, 146, 244	Fuller, Masson, Myers, Falgarone
		45–91	Comparison of the small scale structure in dense cores with and without stars		Fuller, Falgarone, Myers, Puget
		61–91	The large scale interaction of the HII region and the ambient gas in Orion A high velocity filaments and bullets	86,98,113,132,226 232, 245	Martin– Pintado, Rodriguez, Bachiller, Wilson
		124–91	Continuum observations of asteroids at 86GHz	86	Altenhoff, Johnston, Stumpf, Webster
		120–91	Internal motions and density structure in dense cores:High resolution observations of C_3H_2	82,85,145	Fuller, Myers, Falgarone, Puget
36–37	Sep. 3 – Sep 17	163–91	Discrimination between O and C C rich circumstellar envelopes from molecular observations	85,88,113,130, 244	Bujarrabal, Omont, Fuente, Alcolea
		157–91	A study of the 28SiO maser emissionin VY CMa		Cernicharo, Bujarrabal
		62–91	A search for hot CO(v=1) towards shocked regions of the interstellar medium	114, 228	Cernicharo, Gonzalez, Bachiller, Martin–Pintado Gomez–Gonzalez
		134–91	Chemistry in the molecular envelope of NGC 7027		Cox,Omont,Guilloteau, Bachiller, Huggins, Forveille
		57–91	A molecular study of the tear drops in the Rosette nebula	115,230,110,220,97	Gonzalez, Cernicharo,Gomez–Gonzalez

Week	Date	Ident.	Title	Freq.(GHz)	People
38–39	Sep 17 – Oct 1st	131–91	Is there an intrinsec difference between Seyfert 1 and Seyfert 2 galaxies		
		132–91	The Iram line calibrator catalog continued:Cablibration in 1.3mm window		Koëmpe, Mauersberger
		159–91	Is a galaxy's HCN luminosity a good indicator of its star forming rate ?		Solomon, Radford, Downes
		160–91	L1287-RN01B: A unique FUOri object associated with a molecular outflow	86, 130, 144, 230	Guilloteau, Lazareff, Le Floch, Staude
		164–91	A search for signs of ongoing star formation in the dense cores of the Taurus complex	115, 230	Le Floch, Cernicharo, Lazareff
40–41	Oct 1st – Oct 15	131–91	Is there an intrinsec difference between Seyfert 1 and Seyfert 2 galaxies	110–115, 220–230	Steppe
		97–91	The molecular outflows of youngest stellar objects	115,230	Bachiller, Juan
		129–91	Circumnuclear molecular gas in Seyfert gal.	115, 230	Planesas, Colina, Martin-Pintado, Diaz
		130–91	Molecular gas in 3 selected nuclear starburst galaxies	115, 230	Planesas, Colina, Diaz
		109–91	Shock chemistry in the cold cloud L1448	90, 221	Martin-Pintado, Fuente, Bachiller
		94–91	So and So^2 probes of shocked extragal. gas		Henkel, Mauersberger, Omont, Sage, Schilke Hüttemeister, Walmsley
		103–91	Molecular gas in the tidal arms and dwarf galaxies of the M81 group		Brouillet, Baudry, Henkel, Sage
		150–91	Molecular clouds in the dwarf elliptical galaxy NGC185.	115, 230	Wiklind, Henkel, Rydbeck
42–43	Oct 15 – Oct 29	129–91	Circumnuclear molecular gas in Seyfert gal.	115, 230	Planesas, Colina, Martin-Pintado, Diaz
		130–91	Molecular gas in 3 selected nuclear starburst galaxies	115, 230	Planesas, Colina, Diaz
		73–91	Systematic observations of anomalous refraction at 86GHz	86	Altenhoff, Downes, Penalver
		93–91	Search for PH3 in Uranus and Neptune	86, 160	Lellouch, Rosenqvist, Encrenaz, Paubert
		113–91	Evidence of protostellar collapse in B335	140, 225	Evans, Zhou, Kömpe, Walmsley
		114–91	Very dense gas in regions of massive star formation.Multitransition CS study of water maser sources	98, 147, 224	Jaffe, Martin-Pintado, Gomez-Gonzalez, Plume, Evans

		115-91	The effects of density on the star formation efficiency		Lada, Evans, Falgarone
44-45	Oct 29 - Nov 12	170-91	Observations of AE AQUARII	Bolometer	Lecacheux, Dulk, Bastian, Bookbinder, Abada
		171-91	Search for $^{13}CO(J=3\text{-}2)$ and CI emission in IRAS 10214+4724	100,149,246	Brown, Vanden Bout
		155-91	Isotopic and molecular abundances in IC10	38,97,110,220	Becker, Greve, Johansson
		88-91	A search for molecular gas in an SBO galaxy with counter-rotating ionized gas and stars	115,230	Sage, Henkel, Wiklind
		144-91	NGC1569: A post-starburst galaxy with CO(2-1)/CO(1-0) ratios 1 ?		Becker, Greve, Johansson
		92-91	Studies of the molecular gas in SO galaxies	115, 230	Li, Seaquist, Sage
		108-91	The large scale interaction of the HII region and the ambient gas in Orion A. High velocity filaments and bullets	115,130,230	Rodriguez, Martin-Pintado Wilson, Bachiller
		99-91	CO observations of far-IR bright radio quiet quasars		Barvainis, Alloin, Antonucci, Gordon
46-47	Nov 12 - Nov 26	153-91	Multi molecular mapping of the circumstellar envelope of IRC+10216	90,113,232, 341	Kahane, Cernicharo, Guélin, Forveille Lucas, Omont, Guilloteau
		166-91	Short spacings for the Bure interferometer maps of SiCC and C4H(2v7) in IRC+10216	34, 94	Lucas, Guélin, Cernicharo
		168-91	Chemical processes and their localisation in CRL 2688	95,93,145,244	Omont, Lucas, Kahane
		154-91	The $^{18}O/^{17}O$ ratio in oxygen-rich dusty envelopes	36, 219, 224	Kahane, Forveille, Cernicharo, Guélin
		123-91	N3310:a more extreme starburst than M82?	115,230,88,89	Braine, Combes
		121-91	CO observations of M87	115, 230	Braine, Combes, Wiklind
		122-91	NGC 3187: little FIR, little blue light, but lots of CO ?	115, 230	Braine
		162-91	Nature of the molecular halo in NGC891		Garcia-Burillo, Guélin, Cernicharo

Week	Date	Ident.	Title	Freq.(GHz)	People
8–49	Nov 26 – Dec 10		A study of shock chemistry SN the protoplanetary nebula CRL 618		Garcia–Burillo, Tejero, Cernicharo, Guélin, Neri, Martin–Pintado
		112–91	Density wave induced star formation in the arms of NGC3631:CO J=2–1	230	Knapen, Beckman, Van der Kruit, Cepa
		128–91	A search for molecular oxygen in dark clouds	109, 233, 219	Cernicharo, Fuente, Garcia–Burillo, Hein
		48–91	The origin of broad line wing emission in MBM16		Gotting, Stutzki
		117–91	CO rotation in selected edge–on galaxies		Wielebinski, Reuter, Krause, Ott, Grewing
		165–91	HCO+(J=3–2) observations of Herbig–Haro objects	267	Rudolph, Rieu, Welch, Bachiller
		145–91	CO in infrared luminous QSO's	96, 101,108	Wilson, Mauersberger, Kompe, Scoville, Sanders
50–51	Nov 10 – Dec 24	90–91	Gas response at the resonances in the Grand design spiral NGC 4321	114, 229	Elmegreen, Casoli, Combes, Guélin Garcia–Burillo, Beckman
		266–91	Distribution and kinematics of molecular clouds in elliptical galaxies	15, 230	Wiklind, Combes, Lees, Henkel, Rupen
		85–91	Oxygen isotope ratios in galàxies	115, 230	Sage, Salzer, Loose, Henkel
		135–91	CO observations of the edge–on galaxy NGC 100	115, 230	Bosma
52–01	Dec 24 – Jan 7	37–91	The kinematics and physical conditions of molecular gas near the center of M81	115, 230	Sage, Brouillet, Westpfahl
		156–91	CO observations in NGC595 and star forming regions in M33		Viallefond, Boulanger, Cox, Guélin, Lequeux
		71–91	Search for $^{13}CO(J=3-2)$ and CI emission emission in IRAS 10214+4724	00, 149, 246	Brown, Vanden Bout
		217–91	Observations of HCN(J=1–0)in Maffei 2. Complementary mapping for emission at low spatial frequencies for PdB observations	38, 131, 265	Rieu, Viallefond, Combes, Jackson Lequeux, Truong–Bach
		19–91	High density slakk scale structure in the edges of molecular clouds	10,115,220,230	Falgarone, Philips
		120–91	Internal motions and density structure in dense cores: High resolution observations of C3H2	32, 85, 145	Fuller, Falgarone, Puget
		100–91	Circumstellar molecular emission : From IRAS sources to T Tauris star	109,146,244	Fuller, Myers, Masson, Falgarone
		270–91	Comparison of the small scale structure in dense cores with and without stars	98,146,109,219	Fuller, Myers, Falgarone, Puget

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

Project	Conf.	Title	Authors	Molecules	Object	Type
A032 A033 A035	BC	Dense Cores in Star Forming Regions	R.Gusten R.Cesaroni D.Fiebig C.Henkel K.M.Menten R.Mauersberger P.Schilke J.Schmid-Burgk C.M.Walmsley T.L.Wilson J.Wink	CH_3OH,$C^{34}S$ CH_3CN, HCO^+ H41α	NGC 2024 Orion A W3(OH)	YSO
A042	C1,C2	A Neutral Circumstellar Disk around MWC 349	J.Martin-Pintado C.Thum R.Bachiller	CO	MWC 349	CSE
A043	C2	Cold Condensations in a Molecular Cloud	F.Pajot, J.L.Puget M.Perrault J.P.Bernard	Continuum	TCDa-b	Mol
A045	CD	Snapshots of circumstellar material in Young Stellar Objects	D.Despois P.André T.Montmerle A.Baudry S.Cabrit	^{13}CO	AS205, L1719B, S68, L723-MM, B335, LkHa234, Elias 1, RY Tau, DL Tau, CI Tau, L1527, GM Aur	YSO
A049	BC	HCO^+ in IC342	J.Lequeux Nguyen-Q-Rieu F.Casoli F.Combes M.Gérin C.Henkel J.Jackson F.Viallefond Truong-Bach	HCO^+	IC 342	Gal
A050	C2	Fine scale isotropy of cosmic background radiation	S.Radford	Continuum	Empty field	Oth
A051 A052	CD	Mapping of the high velocity bullets in L1448 outflow	R.Bachiller A.Fuente J.Martin-Pintado P.Planesas S.Guilloteau B.Lazareff	CO	L1448	YSO
A054	BC	Morphology and Kinematics of Circumstellar Disks around Outflow sources	S.Cabrit C.Bertout P.André A.Baudry D.Despois S.Guilloteau	^{13}CO	HL-Tau	YSO
A057	CD mosaic + 30-m	CO observations of the Spiral Structure of NGC6946	F.Boulanger F.Casoli F.Combes S.Guilloteau J.Lequeux Nguyen-Q-Rieu F.Viallefond	CO	NGC 6946	Gal
A059	BC	A search for rotating proto-stellar disks: the dense gas around W3(OH)	S.Guilloteau A.Castets G.Duvert	$C^{18}O$	W3(OH)	YSO
A065	BC	Bipolarity around AGB Stars CO in IRAS09371+1212	M.Morris T.Forveille R.Lucas S.Guilloteau A.Omont	CO	Frosty Leo nebula	CSE

Project	Conf.	Title	Authors	Molecules	Object	Type
A068	BC	Molecular Disks in HH 1-2 and HH 34	J.Cernicharo B.Lazareff J.L.Monin R.Pudritz	$H^{13}CO^+$	HH34, HH1-2	YSO
A069	D B2 C2	High resolution observations of CO emission in the envelopes of evolved stars: A key to the ultimate evolution of stars with high mass loss	R.Lucas S.Guilloteau M.Guélin R.Neri J.Cernicharo T.Forveille C.Loup M.Morris A.Omont V.Bujarrabal J.Martin-Pintado Nguyen-Q-Rieu (open list)	CO	50 Circumstellar Envelopes of O C or S types at high declinations	CSE
A070	CD	CO observations of a sample of molecular clouds in the nearby spiral M 33 : A test of the $W(CO)/N(H_2)$ conversion factor	F.Boulanger F.Casoli F.Combes P.Cox S.Garcia-Burillo M.Guélin J.Lequeux Nguyen-Q-Rieu N.Scoville F.Viallefond	CO	M 33	Gal
A072	CD	The spatial distribution of Metal Halides in IRC+10216	M.Guélin J.Cernicharo P.Chaudet	NaCl, SiC_2	IRC+10216	CSE
A077	B2	Astrometry and Kinematics of the v=1, J=2-1 SiO Masers	A.Baudry G.Daigne R.Lucas S.Guilloteau T.Krichbaum D.Graham A.Witzel P.Colomer P.DeVicente B.Ronnang	SiO	Stars including Mira and R Cas	CSE Oth
A079	CD	The bipolar nebula M2-9: A 3-d spatiokinematical model	R.Neri M.Baasgen C.Diesh M.Grewing	CO	M2-9	CSE
A081	Any	Stellar flares on AD Leo Multiband observations	A.Lecacheux G.A.Dulk T.S.Bastian J.Bookbinder L.Belkora	Cont.	AD Leo	Oth
B001	B2	Astrometry of the HCN v=2 emission in IRC+10216	R.Lucas S.Guilloteau	HCN v=2	IRC+10216	CSE
B007	BC or CD	Dense and Schocked Gas in the inner part of M 82	N.Brouillet P.Schilke G.Pineau-des-Forêts A.Baudry	HCN	M 82	Gal
B014	Any	The positron annihilation radiation source 1E 1740.7-2942	I.F.Mirabel J.Wink B.Cordier J.Paul F.Lebrun	CS Cont.	Galactic center	Oth
B023	BC	Protostars in W 51	R.Gusten D.Fiebig	$C^{34}S$	W 51	YSO
B040	BC	The CO emission of the z=2.286 protogalaxy IRAS10214+4724	R.L.Brown P.A.VandenBout	CO	IRAS10214+4724	Gal.

8. ANNEX II : PUBLICATIONS / 8.1 IRAM Publications

. MOLECULAR SPIRAL STRUCTURE IN M51 FROM $^{12}CO(2-1)$ AND (1–0) SINGLE DISH OBSERVATIONS
S. Garcia-Burillo, M. Guélin
1991, in Dynamics of Galaxies and their Molecular Cloud Distributions, IAU Symp. 146, ed. F. Combes, F. Casoli, Kluwer, Dordrecht, p. 67

274. CO EMISSION ALONG THE ANOMALOUS ARMS OF NGC 4258
M. Krause, P. Cox, J.A. Garcia-Barreto, D. Downes
1991, in Dynamics of Galaxies and their Molecular Cloud Distributions, IAU Symp. 146, ed. F. Combes, F. Casoli, Kluwer, Dordrecht, p. 166

CO IN DISTANT GALAXIES
D. Downes, S.J.E. Radford, P.M. Solomon
1991, in Dynamics of Galaxies and their Molecular Cloud Distributions, IAU Symp. 146, ed. F. Combes, F. Casoli, Kluwer, Dordrecht, p. 295

THE DENSE MOLECULAR CORE OF ARP 220
S.J.E. Radford, J. Delannoy, D. Downes, M. Guélin, S. Guilloteau, A. Greve, R. Lucas, D. Morris, J. Wink
1991, in Dynamics of Galaxies and their Molecular Cloud Distributions, IAU Symp. 146, ed. F. Combes, F. Casoli, Kluwer, Dordrecht, p. 303

277. SIMULATIONS OF MOLECULAR CLOUDS IN M51
S. Garcia-Burillo, F. Combes, M. Gerin
1991, in Dynamics of Galaxies and their Molecular Cloud Distributions, IAU Symp. 146, ed. F. Combes, F. Casoli, Kluwer, Dordrecht, p. 351

278. HIGH–VELOCITY MOLECULAR BULLETS IN BIPOLAR OUTFLOWS: L1448 AND HH 7–11
R. Bachiller, J. Cernicharo, J. Martin-Pintado, M. Tafalla, B. Lazareff
1991, in Fragmentation of Molecular Clouds and Star Formation, IAU Symp. 147, ed. E. Falgarone, F. Boulanger, G. Duvert, Kluwer, Dordrecht, p. 389

279. EFFECTS OF THE UV RADIATION ON THE SURROUNDING GAS AND DUST
A. Fuente, J. Martin-Pintado, J. Cernicharo, N. Brouillet, G. Duvert
1991, in Fragmentation of Molecular Clouds and Star Formation, IAU Symp. 147, ed. E. Falgarone, F. Boulanger, G. Duvert, Kluwer, Dordrecht, p. 409

280. PHYSICAL CONDITIONS OF STAR FORMING SITES IN THE S247/252 MOLECULAR COMPLEX
C. Koempe, G. Joncas, J.G.A. Wouterloot, H. Meyerdierks
1991, in Fragmentation of Molecular Clouds and Star Formation, IAU Symp. 147, ed. E. Falgarone, F. Boulanger, G. Duvert, Kluwer, Dordrecht, p. 443

281. AN 8″ RESOLUTION CO(3–2) MAP OF IC 342
R. Mauersberger, A. Schulz, J.W.M. Baars, H. Steppe
1991, in Fragmentation of Molecular Clouds and Star Formation, IAU Symp. 147, ed. E. Falgarone, F. Boulanger, G. Duvert, Kluwer, Dordrecht, p. 460

282. OPEN STRUCTURE SIS RECEIVER FOR SUB-MM RADIO ASTRONOMY BETWEEN 350 & 700 GHz
H. Rothermal, A. Eckart, K.H. Gundlach, M. Lucius
1991, in Int. Conf. MM Wave & Far Infrared Technology, ICMWFT'90, Beijing, p. 4

283. INVESTIGATION OF THE TUNNEL BARRIER IN Nb–BASED JUNCTIONS PREPARED BY SPUTTERING AND ELECTRON BEAM EVAPORATION
H. Kohlstedt, K.H. Gundlach, A. Schneider
1991, IEEE Trans. Magnetics 27, 3149

284. EXTENSION MILLIMÈTRIQUE d'un ANALYSEUR de RESEAUX 20 MHz
F. Mattiocco, M. Carter
1991, in Résumés des Conférences 7èmes Journées Nationales Microondes, JNM–LEMO–ENSERG, Grenoble, p. 213

285. CO EXCITATION AND H_2 MASSES OF INFRARED–LUMINOUS GALAXIES
S.J.E. Radford, P.M. Solomon, D. Downes
1991, ApJ 368, L15

286. ASTRONOMICAL DETECTION OF H_2CCC
J. Cernicharo, C.A. Gottlieb, M. Guélin, T.C. Killian, G. Paubert, P. Thaddeus, J.M. Vrtilek
1991, ApJ 368, L39

287. ASTRONOMICAL DETECTION OF H_2CCCC
J. Cernicharo, C.A. Gottlieb, M. Guélin, T.C. Killian, P. Thaddeus, J.M. Vrtilek
1991, ApJ 368, L43

288. MICROWAVE DETECTION OF HYDROGEN SULFIDE & METHANOL IN COMET AUSTIN (1989c1)
D. Bockelée-Morvan, P. Colom, J. Crovisier, D. Despois, G. Paubert
1991, Nature 350, 318

289. ASTRONOMICAL DETECTION OF THE HCCN RADICAL. TOWARD A NEW FAMILY OF CARBON-CHAIN MOLECULES ?
M. Guélin, J. Cernicharo
1991, A&A 244, L21

290. THE NUCLEAR RING OF THE BARRED GALAXY NGC 4314
J.A. Garcia-Barreto, D. Downes, F. Combes, M. Gerin, C. Magri, L. Carrasco, I. Cruz-Gonzalez
1991, A&A 244, 257

291 DENSE GAS IN NEARBY GALAXIES IV. DETECTION OF N_2H^+, SiO, $H^{13}CO^+$, $H^{13}CN$ AND $HN^{13}C$
R. Mauersberger, C. Henkel
1991, A&A 245, 457

292. FIRST DETECTION OF HDO IN THE ATMOSPHERE OF VENUS AT RADIO WAVELENGTHS: AN ESTIMATE OF THE H_2O VERTICAL DISTRIBUTION
T. Encrenaz, E. Lellouch, G. Paubert, S. Gulkis
1991, A&A 246, L63

293. ASTRONOMICAL AND LABORATORY STUDY OF $Si^{13}CC$
J. Cernicharo, M. Guélin, C. Kahane, M. Bogey, C. Demuynck, J. Destombes
1991, A&A 246, 213

294. DENSE GAS IN NEARBY GALAXIES V. MULTILEVEL STUDIES OF CH_3CCH AND CH_3CN
R. Mauersberger, C. Henkel, C.M. Walmsley, L.J. Sage, T. Wiklind
1991, A&A 247, 307

295. 1.3 MM CONTINUUM EMISSION FROM CIRCUMSTELLAR ENVELOPES
C.M. Walmsley, R. Chini, E. Kreysa, H. Steppe, T. Forveille, A. Omont
1991, A&A 248, 555

296. ^{29}SiO v=1 MASER EMISSION FROM EVOLVED STARS: PUMPING OF ^{29}SiO BY ^{28}SiO THROUGH INFRARED LINE OVERLAPS
J. Cernicharo, V. Bujarrabal, R. Lucas
1991, A&A 249, L27

297. EXTRAGALACTIC $^{18}O/^{17}O$ RATIOS AND STAR FORMATION: HIGH MASS STARS PREFERRED IN STARBURST SYSTEMS ?
L.J. Sage, R. Mauersberger, C. Henkel
1991, A&A 249, 31

298. CO(J=1-0 AND 2-1) MAPPING OF IRC+10216: A HOT CORE MODEL FOR THE GAS KINETIC TEMPERATURE DISTRIBUTION AND THE MASS-LOSS RATE
Truong-Bach, D. Morris, Nguyen-Q-Rieu
1991, A&A 249 435

299. 1E 1740.7-2942: A BLACK HOLE IN A MOLECULAR CLOUD ?
I.F. Mirabel, M. Morris, J. Wink, J. Paul, B. Cordier
1991, A&A 251, L46

300. THE INTERNAL STRUCTURE OF MOLECULAR CLOUDS: II. THE W3(OH)/W3(H_2O) REGION.
T.L. Wilson, K.J. Johnston, R. Mauersberger
1991, A&A 251, 220

301. ^{13}CO EMISSION IN THE IRREGULAR GALAXY NGC 55 AND THE IR-LUMINOUS GALAXY NGC 3256
R. Becker, W. Freudling
1991, A&A 251, 454

302. EXTINCTION TOWARDS 30 DORADUS DERIVED FROM COMMON UPPER LEVEL P_γ/H_δ AND P_δ/H_ϵ LINE RATIOS
A. Greve, J. Castles, C.D. McKeith
1991, A&A 251, 575

303. CIRCUMNUCLEAR STAR FORMATION IN THE BARRED GALAXY NGC 1022
J.A. Garcia-Barreto, D. Downes, F. Combes, L. Carrasco, M. Gerin, I. Cruz-Gonzalez
1991, A&A 252, 19

304. MOLECULAR CLUMPS ASSOCIATED WITH ULTRA COMPACT H II REGIONS
R. Cesaroni, C.M. Walmsley, C. Kömpe, E. Churchwell
1991, A&A 252, 278

305. ANATOMY OF THE BARNARD 5 CORE
G.A. Fuller, P.C. Myers, W.J. Welch, P.F. Goldsmith, W.D. Langer, B.G. Campbell, S. Guilloteau, R.W. Wilson
1991, ApJ 376, 135

306 MM WAVE OBSERVATIONS OF INTERSTELLAR MOLECULES
M. Guélin, C. Rist, J. Cernicharo
1991, in Molecular Clouds, ed. R.A. James, T.J. Millar, Cambridge Univ. Press, p. 97

307. A CO SURVEY OF THE HALO OF NGC 891
S. Garcia-Burillo, M. Dahlem, M. Guélin
1991, in The Interstellar Disk-Halo Connection in Galaxies, IAU Symp. 144, ed. H. Bloemen, Kluwer, Dordrecht, p. 299

308. PHYSICAL CONDITIONS OF LOW MASS STAR FORMING REGIONS
J. Cernicharo
1991, in Physics of Star Formation and Early Stellar Evolution, ed. C.J. Lada, N.D. Kylafis, Kluwer, Dordrecht, p. 287

309. GALAXY KINEMATICS FROM ISIS SPECTRA
J. Castles, C.D. McKeith, A. Greve
1991, Vistas in Astronomy 34, 187

310. SPECKLE–INTERFEROMETRY AND PROVISIONAL ORBIT OF BU 738
M. Scardiam, R. Neri, M. Grewing
1991, Astron. Nachr. 312, 6, 351

311. MOLECULAR SPIRAL STRUCTURE IN MESSIER 51 FROM $^{12}CO(2–1)$ AND (1–0) SINGLE DISH OBSERVATIONS
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9. ANNEXE III - IRAM Executive Council and Committee Members, January 1991

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