IRAM 1989

ANNUAL REPORT

ACKNOWLEDGEMENT

We thank the IRAM staff for their contributions to this report, and for all their help, enthusiasm and dedication during the 10 years we have been directors of IRAM. It is thanks to the considerable efforts of all of its staff members that IRAM has grown from its humble beginnings in 1979 to a well-known astronomical institute today.

M. de Jonge D. Downes

Annual Report
1989

Edited by the IRAM Directors

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Summary

In 1988, the 30-m telescope was scheduled for astronomical research during 77 per cent of the available time. Part of this time was used, as in the past, to continue key programs such as the mapping of molecular gas in the nearby spiral galaxy M51, and for new detections of galactic and extragalactic molecular lines. Some highlights are the discovery of strong millimeter water vapour masers at 183 GHz (a frequency which has up to now been inaccessible to ground-based observatories), and the detection of the CS molecule in the ultraluminous infrared galaxy Arp 220. This latter detection was quickly followed by complementary detections of HCN and HCO^+ in Arp 220 with the IRAM interferometer. As Arp 220 is twenty times more distant than other galaxies where these molecules have been found until now, these results impressively illustrate the sensitivity of both of the IRAM instruments.

In the Grenoble headquarters, the SIS laboratory was expanded and outfitted with new equipment for manufacturing niobium SIS junctions. On the Plateau de Bure, the first interferometer fringes on three simultaneous baselines were obtained shortly after the completion of the third antenna. The interferometer was officially inaugurated on the 6th of September by the French Minister of Research and Technology. Both IRAM observatories suffered damage during 1989 due to adverse weather conditions, including a blockage of the water line on Pico Veleta and damage to the antenna cladding on Plateau de Bure. Measures were undertaken to solve these problems, which will be completed in 1990.

Sumario

En 1989 el 30m fue programado para investigación astronómica durante el 77% del tiempo disponible. Parte de este tiempo se utilizó, como anteriormente, para continuar programas clave como el estudio de la distribución de gas molecular en la galaxia espiral M51, asi como nuevas detecciones de líneas moleculares dentro y fuera de nuestra Galaxia. Algunos resultados clave son el descubrimiento de un máser milimétrico intenso de H_2O a 183 GHz (frecuencia inaccesible hasta ahora a observatorios en tierra), y la detección de la molécula CS en la galaxia Arp 220, fuente infrarroja ultraluminosa. Esta ûltima detección se completó con la HCN y HCO^+ en Arp 220 con el interferómetro de IRAM. Dado que Arp 220 es veinte veces mas distante que cualquier otra galaxia en que estas moléculas se detectaron antes, estos resultados ilustran la impresionante sensibilidad de ambos instrumentos.

En la central de IRAM en Grenoble, el laboratorio SIS creció en su equipamiento para la manufactura de uniones SIS de niobio. En el Plateau de Bure las primeras franjas se obtuvieron en tres líneas de base poco después de la construcción de la tercera antena. El interferómetro fue oficialmente inaugurado el seis de septiembre por el ministro francés de investigación y tecnología. Ambos observatorios de IRAM sufrieron desperfectos de infraestructura durante 1989 por condiciones meteorológicas adversas, como lo fue el bloqueo del suministro de agua en Pico de Veleta y los daños en la estructura de las antenas de Bure. Para resolver estos problemas se iniciaron trabajos que se completarán en 1990.

Résumé

En 1989, 77% du temps programmé sur le télescope de 30 m était destiné à la recherche astronomique. Une partie de ce temps a été utilisé, comme par le passé, pour continuer certains programmes clés comme la cartographie du gaz moléculaire dans la galaxie spirale proche M51, et pour de nouvelles détections de raies moléculaires galactiques et extragalactiques. Parmi les réussites les plus marquantes, citons la découverte de masers millimétriques intenses de la vapeur d'eau, à 183 GHz (une fréquence jusqu'à présent inaccessible aux observatoires au sol), et la détection dxe la molécule CS dans la galaxie extrêmement brillante en infra-rouge Arp 220. Cette dernière détection a été rapidement suivie par les découvertes complémentaires à la précédente, de HCN et HCO^+ dans Arp 220, avec l'interféromètre de l'IRAM. Arp 220 est vingt fois plus distante que les autres galaxies où ces molécules avaient été trouvées jusqu'ici.

Dans les locaux de Grenoble, le laboratoire SIS a été agrandi et muni de nouveaux équipements pour fabriquer des jonctions SIS au Niobium. Sur le Plateau de Bure, les premières franges avec trois lignes de base simultanées ont été obtenues peu de temps après la fin de la construction de la troisième antenne. L'interféromètre a été officiellement inauguré le 6 septembre par le Ministre français de la Recherche et de la Technologie. Les deux observatoires de l'IRAM ont été endommagés en 1989, à cause des conditions météorologiques : blocage de l'approvisionnement en eau à Pico Veleta, et détérioration de la couverture arrière des antennes du Plateau de Bure. Des mesures ont été prises pour résoudre ces problèmes ; elles seront complètement effectuées en 1990.

Zusammenfassung

1989 wurde das 30-m Teleskop während 77 Prozent der verfügbaren Zeit für astronomische Forschungen eingesetzt. Wie bereits früher wurde ein Teil dieser Zeit zur Weiterführung von Key-Programmen benutzt, wie z.B. die Kartographierung von Molekül-Gas in der nahegelegenen Galaxis M51 und die Entdeckung neuer Moleküllinien in galaktischen und extragalaktischen Objekten. Einige Höhepunkte betreffen die Entdeckung von Wasserdampf-Masern bei 183 GHz (d.h. bei einer Frequenz, die erdgebundenen Beobachtungen bisher unzugänglich war) und die Entdeckung des Moleküls CS in der extrem infrarot-hellen Galaxis Arp 220. Dieser Entdeckung folgte kurz darauf die Entdeckung von HCN und HCO^+ in Arp 220 mit dem IRAM-Interferometer. Da Arp 220 zwanzigmal weiter entfernt ist als andere Galaxien, in denen diese Moleküle gefunden wurden, beweisen diese Resultate eindrucksvoll die hohe Empfindlichkeit der IRAM-Teleskope.

Im Institut Grenoble wurde das SIS-Labor erweitert und mit neuen Einrichtungen für die Herstellung von Niobium-SIS-Dioden ausgestattet. Auf Plateau de Bure wurden kurz nach Fertigstellung der dritten Antenne die ersten Fringes mit drei gleichzeitigen Basislinien erhalten. Das Interferometer wurde am 6. September von dem französischen Minister für Forschung und Technologie offiziell eingeweiht. 1989 erlitten die beiden IRAM-Observatorien einigen Schaden durch ungünstige Wetterbedingungen, einschliesslich eines Wasserversorgungsproblems des 30-m Teleskops sowie Schäden an der Verkleidung der Interferometer-Antennen. Es wurden Schritte zur Lösung dieser Probleme eingeleitet, und die Behebung der Schäden wird 1990 erwartet.

1979 - 1989 10 Years IRAM

On April 4, 1979, an agreement was signed between the Centre National de la Recherche Scientifique (CNRS) and the Max-Planck-Gesellschaft (MPG) to establish jointly the Institute for Millimeter Radio Astronomy (IRAM).

This agreement was the result of long and difficult negotiations between French, German, and initially also British astronomy groups and institutes, started in the early 70's, which all wished to exploit the considerable astronomical potential of the mm-wavelength spectrum.

Early in these discussions, the English groups decided to withdraw. The negotiations were continued between the French and German groups, and led, by the end of 1976, to a formal proposal, the "Joint Institute for Millimeter Astronomy (JIMA)" described in the so-called JIMA report. This JIMA report was the basis of the CNRS-MPG agreement to establish IRAM.

In parallel to the preparation of the JIMA proposal, surveys were made of various sites considered for the IRAM 30-m telescope and Interferometer. The Pico Veleta site in southern Spain was retained for the 30-m telescope, and for the Interferometer, the Plateau de Bure site in South-East France was selected. The final site selection was endorsed by a visiting committee which visited the sites during 1977.

Early 1977, a provisional Executive Council was created to discuss the organisational, financial, legal and operational aspects of the Institute to be created. This provisional Executive Council also initiated the discussions with the Spanish government for the establishment of the 30-m telescope observatory on Pico Veleta.

These discussions led to the Spanish-French and Spanish-German intergovernmental agreements and the scientific collaboration agreement between the Spanish "Instituto Geografico Nacional (IGN)" and IRAM, both signed May 16, 1980. The latter agreement allowed IRAM to obtain the site for the 30-m telescope on the Loma de Dilar, on the slope of Pico Veleta, and the office building in Granada as a gift. The change from the summit to the Loma de Dilar site for the 30-m telescope, which took place in 1978 as a result of ecological considerations, proved to be very beneficial for IRAM, since the climate at the summit of Pico Veleta would have made regular operations in winter very difficult.

To enhance the collaboration with the Spanish astronomers, the IGN-agreement foresaw that 10% of the available time would be granted to the Spanish astronomers. Early 1978, an interim director was nominated, who left the provisional IRAM organisation in 1979, and only by the end of October the IRAM institute started to function in a regular way. Site development on the Loma de Dilar started in 1979, and by the end of the year, an access road and provisional water and electricity supplies were available for the construction of the telescope foundation and tower in 1980.

During 1979, the contract of the 30-m telescope was awarded to German industry. The construction in industry, undertaken under the responsibility of the MPIfR, lasted until 1981 when assembly on the site started. The assembly and the bringing into operation of the telescope as well as the early commissioning lasted until August 1985. As of September 1985, the telescope was made available to the first visiting astronomers carrying out observing programs recommended at the first Program Committee Meeting held in March 1985. The telescope has been in continuous use for scientific research ever since. The observatory building with the control room, workshop and lodging facilities was constructed during 1982-1983 after an unsuccessful start of the building in 1981. In February 1986, the offices, laboratory space and lodging facilities in Granada offered by the IGN became available, which greatly facilitates operations in Spain.

The 30-m telescope was officially inaugurated by the Spanish Minister of Public Works on 12 September 1987. At this occasion, the Minister announced the Spanish wish to become full partner of IRAM. During 1988-1989, discussions were held among the French and German IRAM partners and representatives of IGN which resulted in a final partnership proposal submitted in July 1989. It is expected that Spain will officially become an IRAM partner in the course of 1990.

In 1979, the IRAM Headquarters were located in a wooden barack on the site of the Institute for Nuclear Research which very rapidly became too crowded. During 1980, the requirements for the IRAM Headquarters were defined, and a selection was made between various designs submitted by different architects. In its March 1981 meeting, the Executive Council authorised the construction of the Headquarters, which was started in April. As of May 1982, IRAM moved into its new Headquarters located on the University Campus, and since then, only small modifications (clean-room, printed circuit laboratory, photographic laboratory and partition of the workshop) were needed. The construction of receivers and backends, which were started as early as September 1979, was continued throughout the years and resulted in high quality receivers and backends for both IRAM facilities. In the beginning Schottky diodes delivered by the Cork University diode laboratory, sponsored by MPG, CNRS, and SERC, were used as detector elements in the receivers. The addition of an SIS junction manufacturing laboratory in June 1982 to the IRAM receiver group proved very positive for the development of the mm-mixers in IRAM, since IRAM receivers are now rated among the best in the world due to the use of SIS junctions.

Design work for the interferometer telescopes, infrastructure and buildings on the Bure site started in early 1980.

Work on the site could actually only start in February 1981 when the cable-car access to the Plateau became operational. The cable-car access, which limits the speed with which materials can be transported to the site, and the short summer seasons meant that the building of the assembly hall, observatory building and tracks could only be completed in 1986.

Initially, four interferometer telescopes of 10-m diameter and 100 µm r.m.s. surface accuracy were planned in the JIMA report. In view of the international competition, however, it was decided to construct three telescopes of 15-m with 50 µm r.m.s. surface accuracy. The inccreased diameter results in considerably higher sensitivity, and the increased surface accuracy allows interferometry at shorter wavelengths, thus making the IRAM interferometer a unique instrument, which can potentially carry out research that is inaccessible to other interferometers.

To obtain the high surface accuracy, the thermal deformation had to be eliminated, which led to the idea to use carbon fibers for the panels and reflector support structure. Since so far, carbon fibers had never been used in the construction of reflector support structures, extensive research to prove the feasibility was undertaken during the years 1981-1983. In parallel with this research, the steel mount and telescope transporter were designed with the help of an outside engineering company and ordered in 1983. The final order for the reflectors was placed in August 1984.

The mounts were assembled on the site in 1984-1985 and the first telescope completed in September 1986, followed by the second telescope in January 1988, and the third telescope in December 1988.

While the construction and assembly of the interferometer telescopes was going on, a copy of the telescope was constructed, delivered and erected at the La Silla Observatory, ordered by ESO and the Onsala Space Observatory. This telescope was completed in January 1987 and has been operated successfully ever since.

On the 5th of September 1989, the interferometer was officially inaugurated by the French Minister for Research and Technology.

IRAM Scientific Research

In 1989, the 30 m telescope was scheduled for astronomy during 77 per cent of the available time, the remaining 23 per cent going to new installations, repairs and maintenence. Unfortunately, bad weather made much of the scheduled time in December unusable. Since its opening for astronomy in 1985, the telescope has been used by more than 500 astronomers from around the world. The Table shows the percentages of telescope time scheduled for the main financial partners of IRAM, namely CNRS and MPG, as well as for their associate in Spain, IGN (French, German and Spanish universities are included in the CNRS, MPG and IGN time, respectively). The Table also shows the time scheduled for astronomers external to the IRAM countries. This time for external astronomers has steadily increased since the opening of the telescope, and in 1988 and 1989, about 20 per cent of the observing time was used by external astronomers, world-wide. Most of this research has been done in cooperative programs with scientists in France, Germany or Spain, but a significant fraction went to purely external programs.

Scheduled Time on the IRAM 30 m Telescope 1985-1989

Year		CNRS	MPG	IGN	External	Total
1985*	hours	714	645	384	0	1743
	per cent	41%	37%	22%	0%	100%
1986	hours	1906	2181	607	318	5012
	per cent	38%	44%	12%	6%	100%
1987	hours	1929	2355	277	686	5246
	per cent	37%	45%	5%	13%	100%
1988	hours	2153	2354	462	1208	6178
	per cent	35%	38%	7%	20%	100%
1989	hours	1951	3924	549	1320	6744
	per cent	29%	43%	8%	20%	100%
4.3-year Total*	hours	8653	10559	2279	3532	24923
	per cent	35%	42%	10%	14%	100%

* In 1985, the telescope was available for only four months.

Previous key programs with the 30-m telescope were continued in 1989. These programs were mainly extragalactic : further mapping of the spiral arms of the galaxy M51 in the CO(2-1) line at 230 GHz, with a resolution of 12.5", and the search for CO emission from starburst galaxies and quasars with high fluxes in the infrared. The latter search has continued to turn up numerous detections of cool CO in these relatively high redshift galaxies (cz = 15000 to 45000 km/s). Other highlights have been the detection of CS in the ultraluminous infrared galaxy Arp 220, at a distance of 73 Mpc, as well as the detection of more complex molecules, such as cyanoacetylene, HC_3N, and methyl acetylene, CH_3CCH, in nearby galaxies.

In our galaxy, the main highlights have been the first discovery of time variability in hydrogen recombination lines-the millimeter maser lines in MWC 349. A new strong HCN vibrational maser has been found in circumstellar envelopes at a frequency of 177 GHz. The most exciting maser discoveries have been those of the spectacularly strong millimeter water vapour masers at 183 GHz. The molecule CP has been discovered in circumstellar envelopes. The $H_2{}^{18}O$ isotope of water has been studied at 203 GHz, and vibrationally excited water masers have been found at 232 and 96 GHz. Comets Brosen-Metcalf and Macholz were detected in the millimeter continuum.

Deep CO.

As part of a key program by numerous investigators using the 30-m telescope for searching deep in space for CO in distant galaxies, many new detections have been made. The objects have been selected from ultraluminous ($\geq 10^{12}$ solar luminosities) infrared quasars and bright Seyfert galaxies. From the CO measurements, the mass of molecular gas in these objects is 0.7 to 6 10^{10} solar masses, more than 2 to 20 times the H_2 content of our Galaxy. The redshifts of these objects extend to 50000 km/s. For comparison, most of the catalogued galaxies with 21 cm HI line detections have redshifts < 30000 km/s, which suggests that it may be as easy to find CO millimeter lines in relatively high redshift galaxies (15000 to 50000 km/s) as it is to detect the 21 cm line of neutral hydrogen.

Further new detections of molecules in galaxies

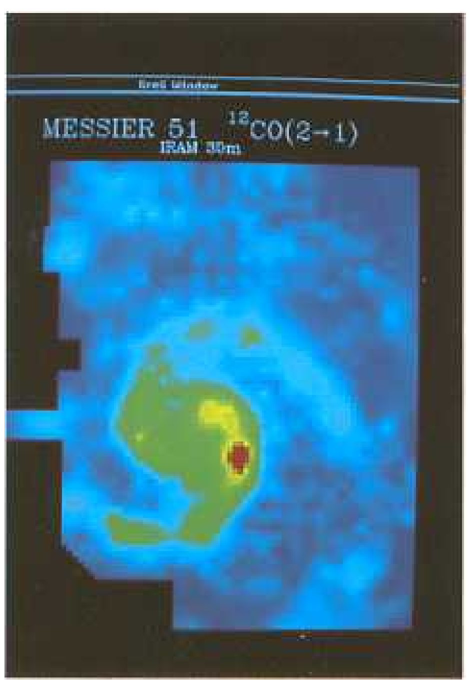
After the detection at the 30-m telescope of extragalactic methanol in 1987, and CN, C_2H, and HNC in 1988, further molecules were detected in 1989 for the first time in extragalactic sources with the 30-m telescope. These new extragalactic molecules include cyanoacetylene, HC_3N (confirmation of a tentative detection at Pico Veleta in 1988), N_2H^+ (the third molecular ion detected outside our Galaxy), and CH_3CCH. The latter molecule, methyl acetylene (propyne), is the most complex molecule known to date outside our Galaxy. The new detections have been made in the following lines :

HC_3N (J = 10-9 line at 91.0 GHz in M82 and IC342) ;
N_2H^+ (J = 1-0 line at 93 GHz in six galaxies) ;
CH_3CCH (J = 5-4, 6-5 and 8-7 lines in M82).

The CO(2-1) map of the spiral pattern in the galaxy M51.

During 1989, the 30 m telescope was used to map an additional 3.5 x 4 arc min quadrant of the nearly face-on galaxy M51 in the ^{12}CO(2-1) line, with full sampling. As M51 is both nearby and strong in CO, this map will be most useful for studies of spiral structure.

The map shows molecular gas in both the arm and interarm regions, with arm/interarm contrasts ranging from 3:1 to 7:1. There are also indications of strong streaming motions, of the order of 60 km/s. Observations have also been made of the ^{13}CO in some selected areas in both the (2-1) and (1-0) lines.



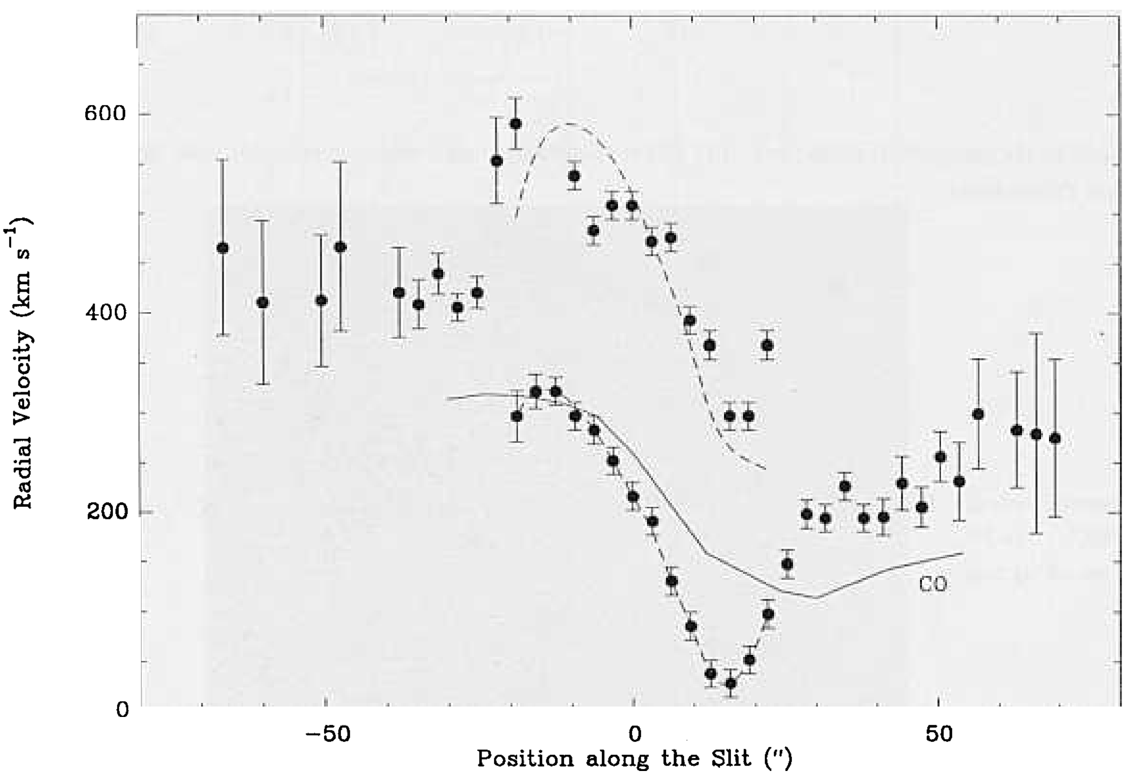
CO(2-1) in the spiral galaxy M51. Velocity range = 300 km/s, T_{max} = 0.7 K.

CO detected in an elliptical galaxy, NGC 3928.

As of 1988, CO had been detected in three elliptical galaxies, which have up to now been thought to be gas poor, containing mostly stars. In 1989, another detection has been made with the 30-m telescope in the blue elliptical galaxy NGC 3928 (Mrk 190), with strong emission in the far infrared. The averaged spectral profile is double peaked, as is typical of galactic disks, and the CO emission implies an H_2, mass of 5 10^8 solar masses, as compared to an H I mass of 3 10^7 $M_{\odot}$ from the same region. (*Astrophys. J.* **350**, L29).

The M82 Story.

In 1989, the nearby starburst galaxy M82 was intensively studied by astronomers from the IRAM community using the 30 m telescope and telescopes in other wavelength regions. In the current picture, the starburst zone in M82, as seen in the near and far infrared, lies in what was once a circumnuclear molecular disk. The numerous supernovae of the starburst have created a hot, 10^8 K gas, which breaks out of the galactic disk as a hot wind, giving rise to X rays and emission-line filaments above and below the plane of the galaxy. The blowout is channeled by what remains of the molecular disk, which is now a ring of radius 250 pc, and entrains a considerable mass of neutral gas in a cylinder around the hot superwind streaming out along the minor axis. New observations with the 30 m telescope at 115, 230 and 345 GHz of CO and its isotopes show the molecular ring in the disk, and also trace the molecular gas well above the galactic disk-presumably in the neutral cylinder surrounding the hot wind. Further observations with the 30 m telescope of the molecules CS (98 GHz) and para-formaldehyde (218 GHz) also show the molecular disk, indicating the presence of both low density (< 10^4 cm^{-3}) and high density (< 10^6 cm^{-3}) clouds. The 1.3 mm continuum radiation from the dust in the molecular disk has also been mapped at the 30 m telescope with the MPIfR bolometer. Supplementary optical observations parallel to the major axis of M82 show a split-emission line region, just outside of the molecular ring. The split lines are interpreted as coming from H II regions in the disk of the galaxy, and also from the rim of the blowout cone, where the ionized gas appears to have an outflow velocity of 600 km/s.



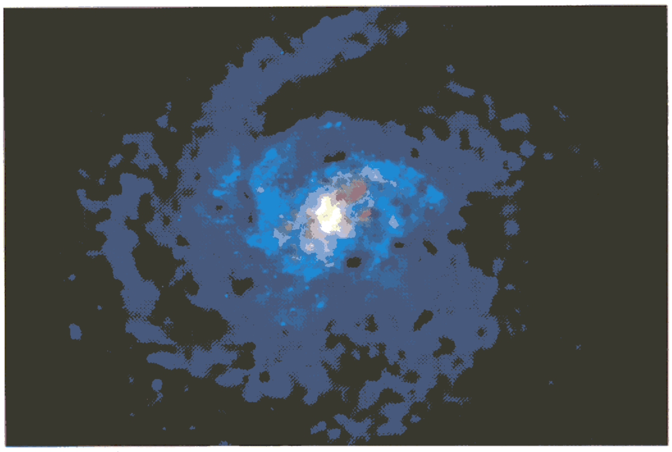
Radial velocities parallel to the major axis of the galaxy M82, as observed in the CO molecule at the 30 m telescope (solid line) and optical [N II] lines (dots with error bars). The CO curve corresponds to velocities expected from gas rotating in the disk of the galaxy ; the dashed curve indicates velocities expected from the blowout of the starburst wind, breaking out of the galactic disk.

Gas complexes in the galaxy NGC 6946.

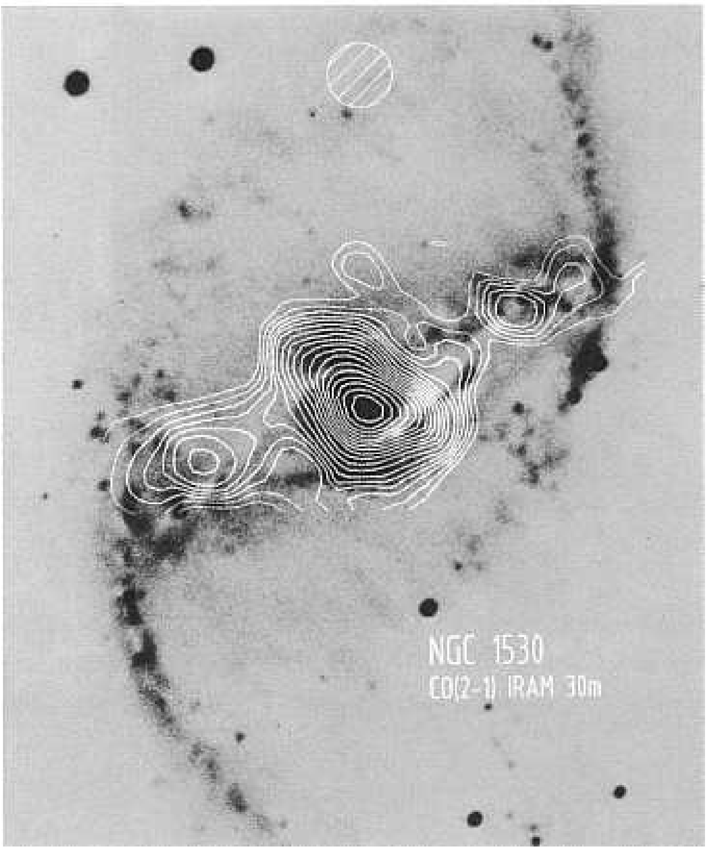
The disk of the spiral galaxy NGC 6946 has been mapped in the CO(2-1) and (1-0) transitions. The map shows the spiral structure, and the coincidence of the molecular concentrations with the spiral arms as defined by the H II regions and the maxima of H I and radio continuum emission. The CO arm-interarm contrast, averaged over a 2 kpc region, is 4 to 1 in both CO lines. The ratio CO (2-1)/(1-0) is 0.4, typical of low excitation.

CO in the bar of a barred spiral galaxy.

CO has been mapped in the barred spiral galaxy NGC 1530. The molecular gas is mainly in a nuclear concentration, but is also detected along the bar itself. The nuclear concentration is oriented 90° to the direction of the bar, and its rotational velocity vectors also appear to be perpendicular to the velocity variations in the bar.



Gas and starlight in the galaxy NGC 6946 ; red : CO (30 m telescope), green : optical continuum (Obs. de Haute Provence), blue : atomic hydrogen (Westerbork).



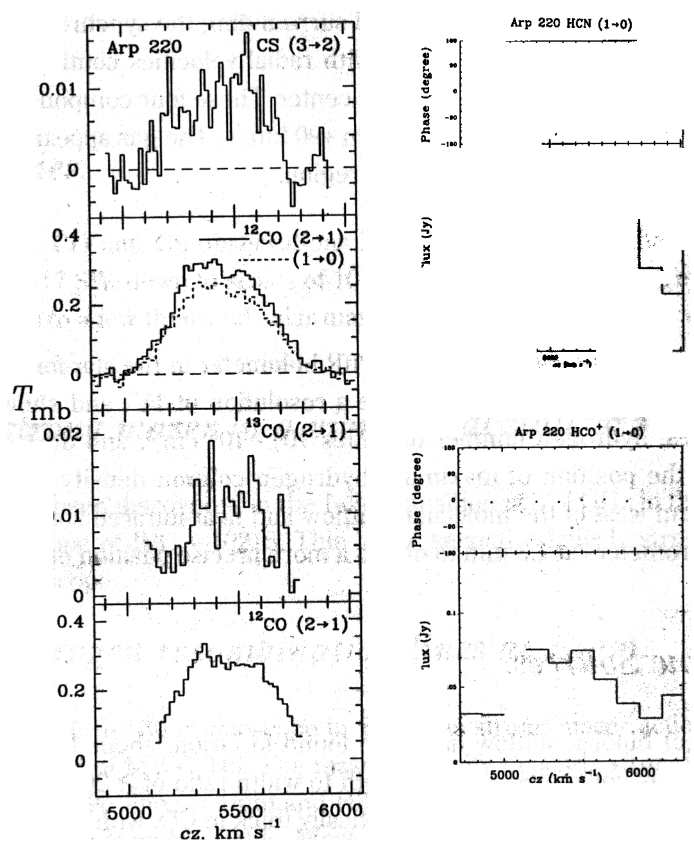
CO in the barred spiral galaxy NGC 1530, supermposed on an optical photograph.

CS in Arp 220 !!

At the 30 m telescope, CS(3-2) and ^{13}CO emission were detected in Arp 220, the prototype infrared luminous galaxy, at a distance of 73 Mpc. ***The CS luminosity of Arp 220 is half the ^{12}CO luminosity of the Milky Way.*** Since CS emission traces gas 100 times denser than that traced by CO emission, Arp 220 has much more molecular gas at high densities (10^5 hydrogen molecules per cm^3) than normal galaxies. This high gas density is characteristic of the cores of giant molecular clouds, the real sites of star formation. Since Arp 220 is the prototype ultraluminous infrared galaxy, the presence of this gas suggests that infrared galaxies are powered by star formation in very dense molecular clouds rather than by infall of material into a black hole. Detections of CS in other, more nearby galaxies with the 30 m telescope indicate that the CS/CO ratio is correlated with the far infrared luminosity, that is, the greater the amount of dense gas available, the higher the rate of star formation.

HCN and HCO⁺ in Arp 220 !!

After the detection of CS in Arp 220 at the 30 m telescope, it was evident that other molecules, like HCN and HCO^+, might also be detectable in this distant, infrared-bright galaxy. A search with the three antennas of the IRAM interferometer was then made, as a follow-up to the observations at Pico Veleta. The molecules HCN and HCO^+ were detected on all three interferometer baselines, along with the 30 mJy continuum radiation from the nucleus of the galaxy. The HCN emission appears to be coincident with the continuum nucleus, and to have a size of 4 arcsec. The HCO^+ emission appears to be slightly more extended.



CS, CO, HCN and HCO+ in the ultraluminous galaxy Arp 220 ; line profiles from the 30 m telescope (left column) and amplitudes and phases vs. frequency. from the IRAM interferometer (right column).

CO in the jets of NGC 4258 ?

The spiral galaxy NGC 4258 is known for its abnormal Hα and nonthermal radio arms perpendicular to the normal spiral arms. Observations with the 30 m telescope have now detected CO along the anomalous Hα arms up to distances of about 2 kpc from the nucleus of the galaxy. Cuts perpendicular to the southern anomalous arm indicate that the CO is concentrated along the Hα emission. This is a very intriguing result, as all previous models for the anomalous arms involved expulsion from the galactic nucleus. However, the mass in the CO clouds is ten times higher than predicted by any model, making ejection from the nucleus unlikely.

Map of the galaxy IC 342 at 345 GHz.

During the first sub-mm molecular line observations at the 30 m telescope, the central region of the galaxy IC 342 was mapped in the CO(3-2) line at 345 GHz with 8.4" resolution. The strongest emission arises in two peaks, 13" apart, and the ratio of the 3-2 and 2-1 lines is unity. The aperture of efficiency of the 30 m telescope at this frequency is 11 per cent, and the main beam efficiency is 20 per cent.

Extensive maps of galactic center clouds near Sgr A.

High resolution (11") observations have been made of dust continuum and isotopic CO and CS line emission of clouds in the central 50 pc of the galactic center. These new results show that the previously-known giant molecular clouds with radial velocities of 20 and 50 km/s are actually a superposition of several components : a massive star-forming cloud $\geq$ 50 pc in front of the galactic center ; another cloud surrounding the synchrotron source Sgr A East ; a curved streamer which also lies in front of the galactic center, with radial velocities continuously increasing from 25 to 65 km/s ; and an extended 50 km/s cloud behind the galactic center. These four components appear to be immersed in a highly turbulent gas with radial velocities in the range -40 to +90 km/s. The gas appears to have 1 per cent of the mass of the stars, even in the central 15 pc of the galactic center region.

Dust in Orion

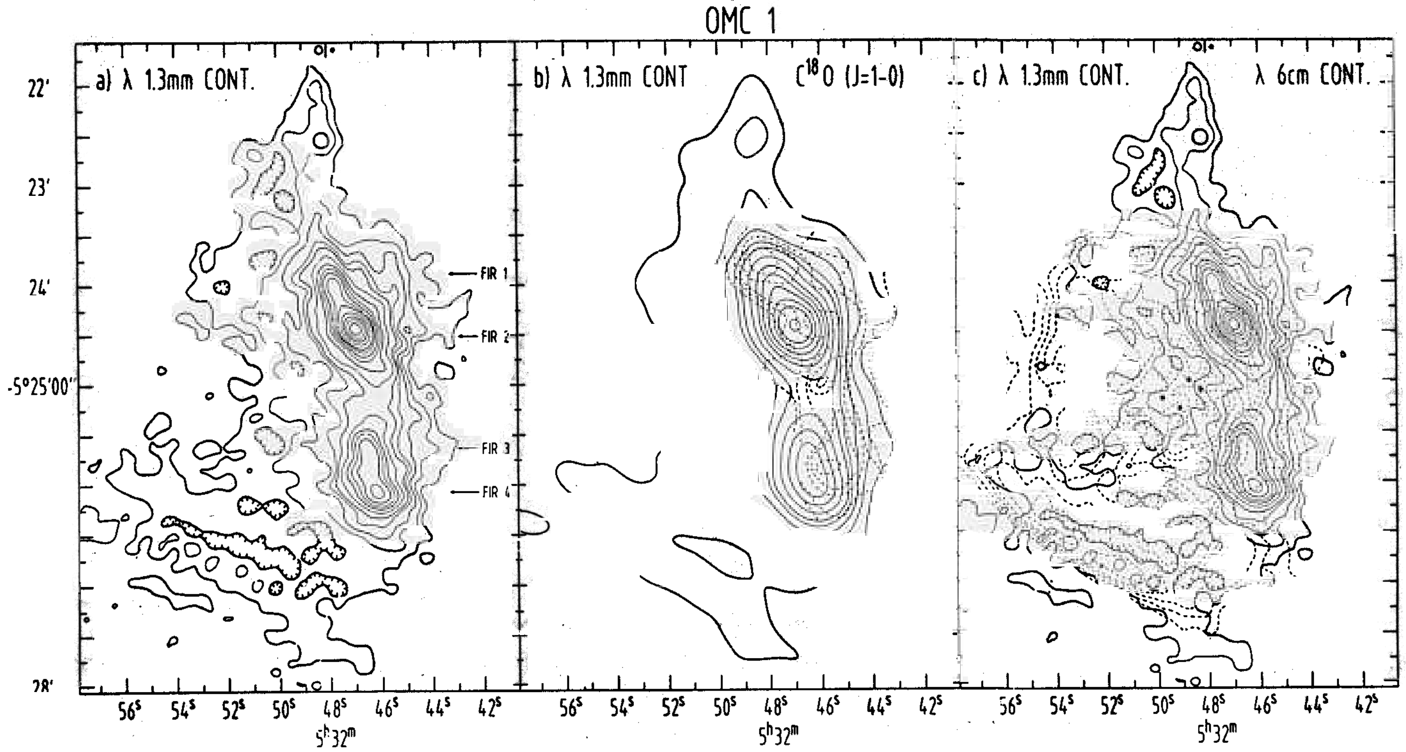
The 1.3 mm dust emission has been mapped with the MPIfR bolometer in the star-forming cloud cores OMC1 and 2 in Orion. The observations with the 30 m telescope have a resolution of 11", and show several condensations with masses of 5 to 50 solar masses, hydrogen number densities 10^5 - 10^8 cm^{-3}, and dust temperatures of 40 to 200 K. Averaged over an 11" beam, the position of maximum hydrogen column density of 10^{25} cm^{-2} appears to be at a projected distance of 2.4 10^{16} cm west of the molecular outflow and near-infrared source IRc2. It will be of interest to search this region with interferometers at 1.3 mm to obtain a more precise position of the continuum peak.

New Studies of Outflow Sources.

A new, large-scale (200 arc sec) bipolar outflow has been found in Orion, about 100" south of the well-known IRc2 outflow. The new outflow is highly collimated, with a length to width ratio of $\geq$ 20, with the maximal radial velocities increasing with distance from the origin. The outflow is optically thick in CO, with a kinetic temperature $\geq$ 50 K.

Observations with the 30 m telescope have also revealed evidence of an intermediate velocity outflow in the CS(3-2) transition in the Herbig-Haro objects HH 7-11.

A 200 km/s molecular outflow has been found in the protoplanetary nebula CRL 618. The flow is detected in the CO(1-0) and (2-1) lines, the J = 3-2 lines of HCN and HCO^+, and the J = 25-24 line of HC_3N. The blue and red-shifted flows are separated by 4" on the sky, and the mass loss rate is 10^{-5} solar masses per year. Formaldehyde has also been found in CRL 618, the first time H_2CO has been seen in a carbon-rich circumstellar envelope.



Maps of the central region of the Orion molecular cloud. left : Continuum emission of dust at 1.3 mm, as observed with the 30 m telescope ; middle : Smoothed map of 1.3 continuum emission superimposed on the $C^{18}O$ line emission, also mapped with the 30 m telescope ; right : Map of 1.3 mm dust emission superposed on the VLA map of free-free continuum emission at 6 cm.

Molecular Cloud Studies.

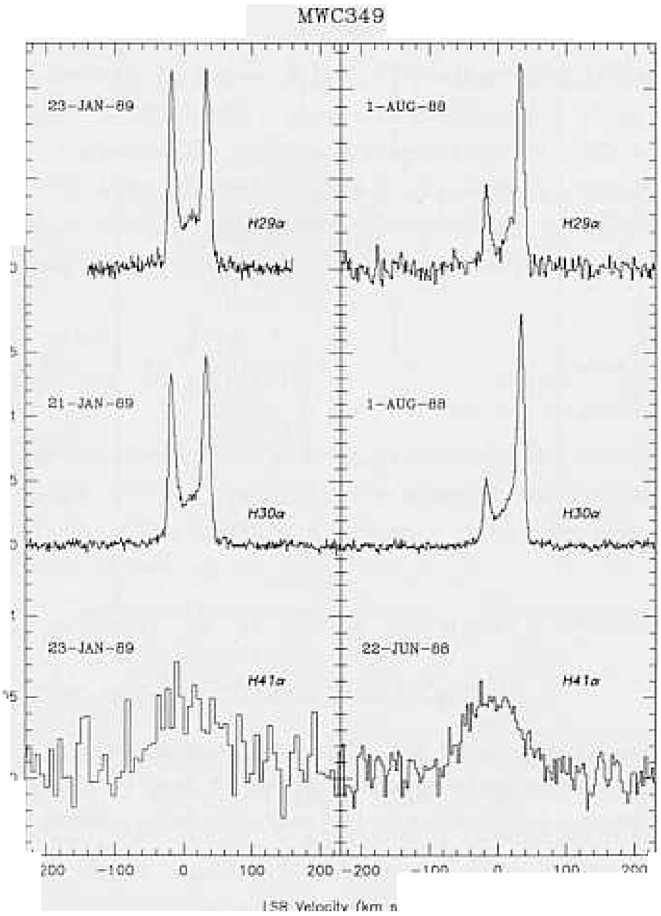
High spatial resolution isotopic CO and CS observations have been made with the 30 m telescope of the clumpy structure of the cloud core of M17 SW, down to scales of 10^{17}cm. Analysis of the data reveals 180 clumps with masses ranging from a few solar masses to a few thousand solar masses, and hydrogen number densities of 10^5 to 10^6 cm^{-3}.

Discovery of a new, strong maser in a vibrational state of HCN.

A strong (400 Jy) maser line has been discovered in the J=2-1 transition at 177 GHz in the $(0,1^{1c}, 0)$ vibrational state of HCN, in the circumstellar envelope of IRC + 10216. This is the second relatively strong maser found in vibrational states of HCN with the 30 m telescope.

Time variability of hydrogen recombination lines at 1 mm.

A spectacular discovery made with the 30 m telescope in 1988 was strong maser action in hydrogen recombination lines near 1 mm in the stellar wind of MWC 349. The maser intensity depends strongly on quantum number, and is present in the H31α, H30α, and H29α lines at 1mm and H34α at 2 mm. At a wavelength of 3 mm, the recombination line is thermal, and the maser action is undetectable. More recently, the H26α line at 354 GHz has also been detected at the 30 m telescope. Further monitoring of these lines during 1989 showed them to be variable, confirming the suspicion that the strong masering occurs at 4 10^{14} cm from the star, in a medium of electron density $\geq 10^7$ cm^{-3}. This means the intrinsic brightness temperature of the lines is greater than a million degrees, making them the strongest radio recombination lines known.



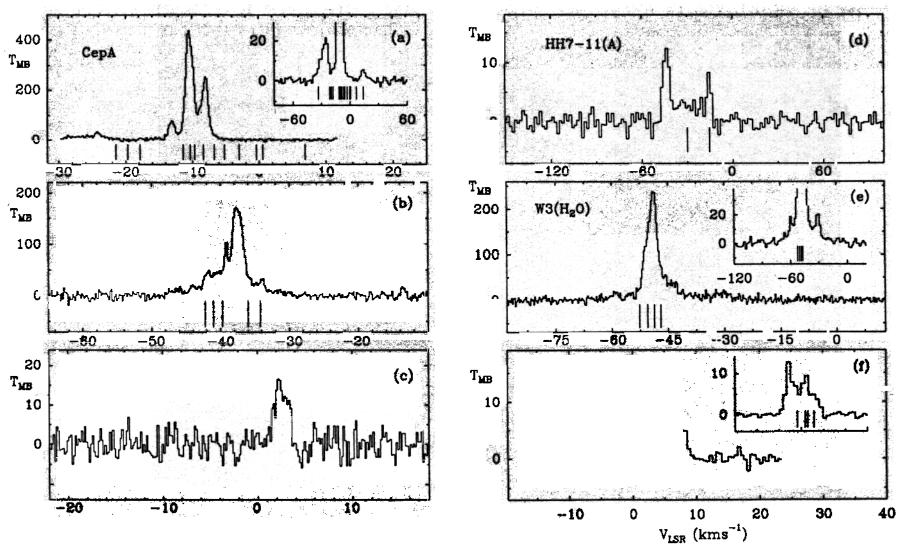
Millimeter recombination lines from the stellar wind of MWC 349 observed at two different epochs with the 30 m telescope. The H29α and H30 α lines, at wavelengths of 1.2 and 1.3 mm, are variable, while the H41α line at 3 mm is constant.

Water masers at 183 GHz observed from the ground !

Up to now, direct study of the millimeter and submillimeter lines of interstellar water vapour by ground based radio observatories has been blocked by tropospheric absorption lines, except for the maser lines at a wavelength of 1.35 cm. For this reason, previous detections of the water vapour line at 183 GHz have been limited to observations above the atmosphere, with the Kuiper Airborne Observatory. However, although the lowest millimeter and submillimeter water lines are completely absorbed by the troposphere at sea level, calculations of atmospheric transparency indicated a non-negligible transmission at the 2.9 km altitude of Pico Veleta. Consequently, a search was made at 183 GHz in the 3_{13}-2_{20} rotational line of H_2O, yielding the discovery of strong, narrow maser lines, comparable in intensity (1000 to 15000 Jy) to the strong H_20 masers at 22 GHz. These maser lines are seen in the same regions that have 22 GHz masers. In addition, broad line emission, perhaps of thermal origin, is found in sources with molecular outflows. Double peaked profiles are observed toward evolved stars. The maser emission at 183 GHz is also observed in more quiescent clouds, but at velocities different from the associated 22 GHz masers.

Hot Water !

The first astronomical detection has been made with the 30 m telescope of two millimeter-wave emission lines from vibrationally excited water vapour, at 96 and 232 GHz, toward the supergiant star VY CMa and the semiregular variable star W Hya. The energy levels where these lines occur are 2000 K above the ground state. The 96 GHz transition shows signs of maser action, while the 232 GHz transition may be nearly thermal. It appears that the vibrationally excited water lines arise in regions closer to the star than the part of the envelope where the 22 GHz masers are emitting.



Water masers at 183 GHz observed with the 30 m telescope. Vertical scale is main beam brightness temperature, horizontal scale is radial velocity. Vertical lines correspond to velocities of 22 GHz masers. The insets are lower-resolution spectra of the same lines, but covering a wider range in velocity.

Deuterated Water !

Because of the difficulties (up to now) of observing the millimeter and submillimeter lines of water vapour from the ground, there has been an active group of researchers using the 30 m telescope to study not water itself, but its isotopes, $H_2{}^{18}O$ at 203 GHz and HDO at 143.7, 225.9 and 255.1 GHz. Studies of these lines at Pico Veleta indicate that the abundance of water in hot core regions is about one-tenth of that of CO, and hence that water is not a major repository of interstellar oxygen in massive star forming regions.

New Methanol Maser.

A new methanol maser has been discovered at 145 GHz in the 9_0-8_1A^+ line. These masers appear to come from small (10^{16} cm), dense regions with about 0.1 solar masses. The masers appear to be collisionally excited, but, surprisingly, there are no infrared sources in these cloudlets.

Discovery of the molecule CP.

The radical CP has been detected in the envelope of the carbon star IRC+10216. Although this radical has been known since a long time in the laboratory, its rotational spectrum has only recently been measured with enough accuracy to allow a radio astronomical search. The results from the 30 m telescope indicate that CP is confined to the inner envelope, and is unlikely to result from photochemistry. Its abundance is surprisingly high : it is similar to or larger than that of HCP, and seems too high to result from thermoequilibrium reactions in the atmosphere of the star.

Survey for circumstellar disks around young stars.

Continuum observations at 1.3 mm with the MPIfR bolometer of 86 pre-main sequence stars in the Taurus-Auriga dark clouds show that 42% have detectable emission from small particles. A plausible interpretation is that the particles are in thin circumstellar disks, suggesting that disks more massive than the minimum mass of the proto-Solar System accompany the birth of solar-mass stars and that planetary systems are common in the Galaxy.

Solar system research.

Continuum observations of Comet Brorsen-Metcalf at 250 GHz on Pico Veleta showed a signal comparable to that from comet Halley in 1985/86. A study of observations of CO on Mars has been published (1989, Icarus, 77, 414), including the detection of ^{13}CO and monitoring of CO temporal variability. The (2-1) and (1-0) lines of ^{12}CO and ^{13}CO have been mapped in the Mars atmosphere, and SO_2 has been detected on Io. The CO(2-1) line has been detected in the upper stratosphere of Titan, confirming previous observations at the 30 m telescope in the CO(1-0) line, that CO is depleted in Titan's stratosphere, relative to its abundance in Titan's troposphere.

Pico Veleta Observatory

30-m Telescope Operation

Apart from some minor problems with the wobbler electronics, the 30-m telescope has functioned smoothly during the whole year.

During the first half of the year, the operation of the observatory was seriously hampered by the shortage of water due to the broken water supply-line, which limited the number of staff and visitors that could be housed in the observatory at any one time. Only in July, the water supply could be restored.

In February, the worst ice storm in the telescope's history resulted in severe damage of the cladding of the concrete base of the telescope. The damaged cladding plates were repaired later in the year.

Besides the normal preventive maintenance work on the telescope, the security of the telescope and the receiver equipment were significantly improved by a new window and all-weather protection shutter in the vertex tube. Furthermore, the deicing of the upper quadrupod legs was upgraded. It was planned to remeasure the surface accuracy of the telescope during the year, the weather conditions and the absence of a suitable 3-mm receiver, however, made these measurements impossible.

Receivers

The 3-mm SIS receiver installed in 1985 and since then in operation nearly without interruption, broke down in March, due to a cold leak in the cryostat. As a result, no 3-mm observations could be made until August, when a new 3-mm SIS receiver constructed in Grenoble was installed in the telescope. The old receiver is presently under repair and should be available again early next year.
During the summer, a second 1-mm SIS receiver was installed resulting in the availability of two polarisations at this wavelength.

After modification by the MPIfR in Bonn, whereby the lens was replaced by a paraboloid, and the L.O. system was improved, the 345 GHz Schottky receiver was reinstalled and brought into operation again on the telescope in October. The DSB receiver temperature at the band center is approximately 700 K.

The 2-mm SIS receiver operation continued without major problems throughout the year.

New L.O. systems based on Carlstrom Gunn oscillators and IRAM-built multipliers were installed in the new 1-mm and the 2-mm receiver, which eliminated the use of klystrons.

By year's end, five receivers are routinely available for observations, up to three receivers can be used in certain combinations simultaneously, remote control of the receivers, however, still presents a problem.

Backends

An additional 512 channel 1 MHz filter bank, sent from the Plateau de Bure, was brought into operation.

In total, six backends, as listed below, are now currently available for the observers on the 30-m telescope.

N°	Type	Resolution	Max. Bandw.	Channels
1	Continuum	500 MHz		2
2	Filterbank	100 kHz	25.6 MHz	256
3	Filterbank	1 MHz	512 MHz	512
4	Autocor. N° 1	variable	320 MHz	1024
5	Autocor. N° 2	variable	320 MHz	512
6	Filterbank	1 MHz	512 MHz	512

Not all the backends can be used simultaneously, due to limitations in the drive program's buffer size and the absence of an adequate backend distribution box. Both these problems should be overcome in the course of next year.

In October, the acousto-optical backend built in collaboration with Meudon Observatory, was tested successfully. All the specifications concerning power and frequency stability and the 1 MHz resolution were easily met. The bandwidth, at present 480 MHz, needs to be enlarged to 512 MHz.

Computer Hardware and Software

At present, two mVAX computers are installed at the telescope and two in the Granada office. Since the radio link between the observatory and the Granada office has become operational, the four computers are interconnected with Ethernet links.

The radio link allows remote control of the telescope from the Granada office.
Remote observations were first tested in October and demonstrated that virtually all observation modes, including the more complex ones, where three receivers and a number of backends were connected, can be handled without problems.

The remote observing from Granada will be extensively tested by the Granada astronomers and possibly made available to the observers in 1990, if additional funding can be raised to install a proper remote control station. During the year, OBS was improved in various ways and can now handle multiple frontends and backends.

The computer system was connected to the IBERPAC packet switching network. Furthermore, SPAN, BITNET or UUCP can be accessed from either the telescope or Granada.

Observatory Building and Infrastructure

The water problem encountered in the beginning of the year clearly showed the fragility of the observatory operations.

In order to overcome this fragility and to assure water and electric supply under all circumstances, an infrastructure improvement plan has been partially executed in 1989. This plan provides not only a second independent water supply but also a second high-voltage power supply-line.

Late in the year, the second water supply-line was completed inclusive pumps, controls, etc., and the high-voltage cables installed. The electric supply needs to be completed next year with switch gear in the observatory and an electricity distribution sub-station in order to allow supplying electricity from the present sub-station or from a second station.

Grenoble Institute

Receiver Group Activity

Much of the group activity was concentrated on the finishing, commissioning and installation of 3- and 1-mm SIS receivers for both Pico Veleta and the Plateau de Bure.

After the installation in March of the the 3-mm SIS receiver in the 3rd telescope of the interferometer, a start was made with the construction of a new 3-mm SIS receiver which can either be used to replace the Schottky receiver in telescope 1 or be kept as spare or be installed in the 4th telescope, when it becomes available.

Various visits to Spain were made by the Grenoble receiver group staff in order to repair the second 1-mm receiver and the YIG L. O. system.

In the laboratory, tests of the close cycle cryogenerator were continued, and the system proves so reliable that an order for the manufacturing of 6 cryogenerators could be placed with AIR LIQUIDE at the end of the year.

The design of the cryostat to be mounted on the cryogenerator is being developed. Also a series of designs have been planned for the best choice for the optics to be used with the cryostat when installed in the Plateau de Bure telescopes. The validity of these optics' designs is still to be determined by measurements part of which are under way.

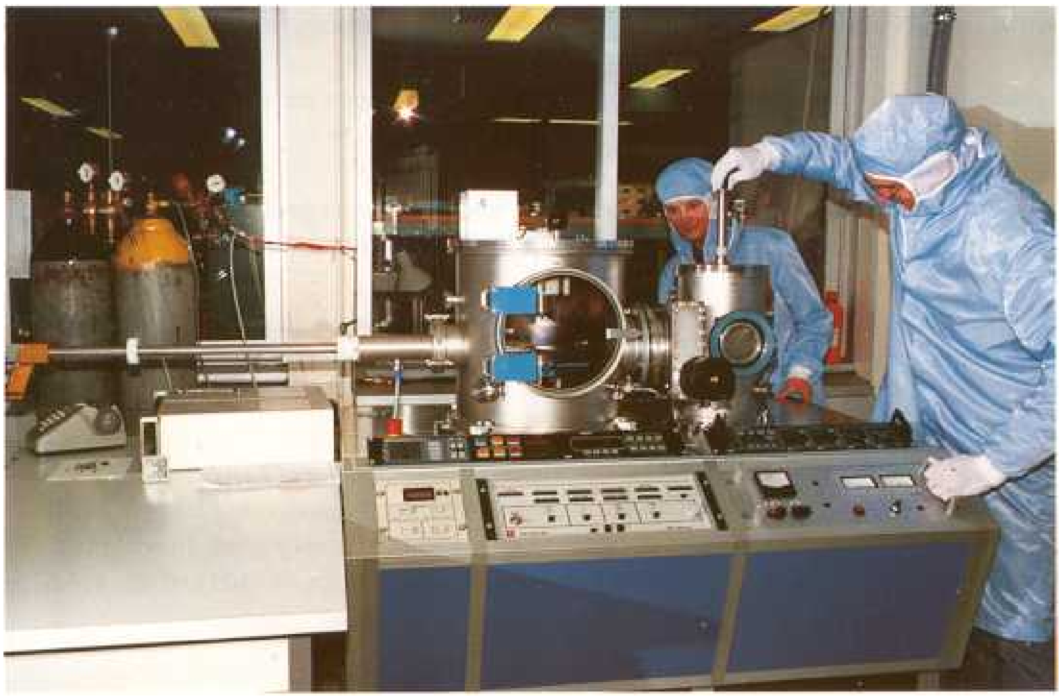
The design and industrial manufacturing of frequency doublers for the 2-mm receiver and frequency triplers for the 1-mm receivers has been successfully completed. The efficiency of ca. 3.5% of the triplers is very good. In order to have an alternative supply, the study of second harmonic Gunn oscillators for the frequency range 64 - 100 and 86 - 116 GHz has been started. Two oscillators using AsGa Thomson diodes have been completed so far.

230 GHz tripler

After completion of the detailed design using micro strip technology, seven HEMT amplifiers have been manufactured. The typical noise figure of the amplifiers is 9°K for a 600 MHz bandwidth at a centre frequency of 1.5 GHz.

Work on the ESA contract for SIN open structure mixers continued during the year. In particular the study and measurements of scaled antennae for these mixers required much attention.

SIS Laboratory



SIS laboratory, reactive ion etching equipment

Early in the year, the new sputter system ordered in 1988 was delivered, installed and brought into operation. Somewhat later, the reactive ion-etching system became operational. This new system allows IRAM not only to be fully competetive with other junction manufacturing facilities but also to fabricate Nb junctions, which are mecanically more robust and do not need to be stored at low temperature. To train the staff in the use of this sophisticated equipment, only junctions with relatively large areas have been manufactured up till now.

Besides this activity, many Pb/Bi junctions were manufactured in the SIS laboratory both for IRAM, MPIfR, and the MPI für Extraterrestrische Physik. The SIS laboratory staff participated in experiments in MPIfR to demonstrate that Pb/Bi junctions can be used for frequencies as high as 1000 GHz.

Backend-Group Activity

Past experience on both IRAM observatories has shown the need for reliable and high resolution spectrometers, with as much bandwidth as possible.

The availability of the NFRA 16-channel correlator chip, combined with the acquired expertise, has stimulated IRAM's decision to build a new generation of backends for the 90's.

Remote maintenance (at least diagnosis) and easy service (interchangeability of parts, spare part policy) have been included at an early design stage to insure permanent operation.

The system is of XF type (hardware correlation, software FFT). The FX approach has no particular advantage for a small number of baselines. The tradeoffs between IF and digital processing, for IRAM observatories, show that a subband width of 80 MHz is optimum. Subbands are digitized at 160 Megasamples/sec.

The correlators are organised in a number of totally independent units. One unit includes a correlator chassis and the relevant IF section so as to process a slice of frequency. If one unit fails, frequency coverage is reduced but operation is not stopped. Following units are planned:

for the 30-m
Two units, max BW = 2* (640 MHz, 512 channels)
min BW = 2* (20 MHz, 2048 channels)

for the Interferometer
Four units, max BW = 4* (160 MHz, 64 complex channels)
min BW = 4* (20 MHz, 256 complex channels)

A VME sampler board has been prototyped and behaved properly up to 290 Ms/s. In this board, great attention has to be paid in shielding, layout, etc. to prevent self-contamination.

The optimum board size for the IRAM correlators is a 4-by-4 chip array, which is best suited to support TMF-4 mode. Standard VME format is used. 71 of these boards are to be produced by subcontractors, so design has to feature a strong robustness against variation. A 4-chip prototype has been built and has demonstrated a 25% safety margin in speed. Tests on chips from different batches have shown fair consistency of chip parameters.

A control board delivering all service signals, including PLL clock has been built. It features a CRT display controller.

The correlator chassis is controlled by a commercial CPU under OS-9 operating system. Its flexibility allows quick writing of service programs to develop the correlator hardware. Power is enough to insure permanent readout of the correlation function and having its Fourier transform displayed at 10 pictures/sec.

Just before Christmas, a complete digital module consisting of sampler, correlator card and control board, was successfully tested.
Apart from this correlator development work, the group assured the maintenance of the backends and central L.O. system of the interferometer.

Computer and Software Group

The problems encountered on the Plateau de Bure with the data acquisition of the interferometer using PDP 11/44 computers led to the decision late in 1988 to change to μVAX computers.

Much of the effort of the computer and software group in 1989 was dedicated to the preparation of this change-over of computers on the Plateau. As a first step, the CAMAC controller needed up-grading to be compatible with the μVAX computer, and a new VMS CAMAC driver had to be written.

As the next step, all the existant interferometer software was made compatible with the new operating system and CAMAC interface. Extensive real-time simulations of the interferometer operation -inclusive the telescopes- were performed on a μVAX 2 and a VAX work station 3200 which demonstrated that a μVAX 3 is the right device for the real-time tasks.

Two identical VAX 3400, each equipped with two disks, were purchased and connected in such a way that all the 4 disks are equally accessible from either computer. One machine is used for the control and data acquisition of the interferometer and the other for the data reduction on the site. The system was fully tested in Grenoble before being installed on the Plateau de Bure.

The computer group furthermore assisted the users of the systems in Grenoble and was instrumental in the choice and purchase of the new VME interface system and the UNIX-type operating system as required for the new digital correlators.

Technical Group

During the year, the mechanical workshop and the design office were combined into one group, the technical group.

This was done in order to

- provide more and better planned services to the workshop users, the engineers from the receiver- and backend-group, etc.,

  increase the quality control of the workshop products,

  establish a clear interface between the workshop and its users,

  assure that correct drawings are made of all the prototype receiver components built in the workshop, and which might need to be manufactured in series by contractors so as to assure that IRAM is in a position to provide the large number of receiver channels as required in the future, in particular for the interferometer where several receiver channels are planned to be installed in one cryostat cooled by one cryogenerator.

The workshop area has been sub-divided into two areas, one for the precision tools and quality control, the other for general use.

mechanical workshop

In the 8 months the new group exists, it has clearly demonstrated to be functioning very well, since 104 requests for the manufacturing of components could be satisfied, and only very few jobs had to be contracted outdoors.

Collaboration with Other Institutes

A contract was concluded with ESO for the phase A design study of a 2-m class telescope. These telescopes are intended for the interferometer option in the ESO VLT project.

The feasibility study for the construction of SIN mixers for 350 GHz and possibly higher frequencies, contracted with ESA, continued during the year.

The SIS laboratory delivered junctions to a variety of institutes in Germany and France.

Assistance was given to the Onsala Space Observatory for the surface measurement of the 20-m millimeter telescope both with theodolite and holography measurements. Furthermore the deformations under gravity of this 20-m reflector were calculated as function of elevation.

Plateau de Bure Interferometer

Commissioning 3rd Telescope

Late in 1988, the assembly of the reflector of the 3rd telescope was completed, and shortly thereafter the surface accuracy was measured. The measurement yielded after one panel adjustment iteration an accuracy of 65μ m r.m.s.

In May, after the modification to increase the clearance between the tracks and the transporter was finished, the telescope was equipped with a 3-mm SIS receiver, and first pointing and efficiency measurements were performed. These measurements showed that telescope 3 has very similar efficiency -beam 85 %, aperture 65 %- and pointing performance as telescopes 1 and 2. By the end of May, the telescope was connected to the interferometer system, and search for fringes with three telescopes was started.

The Telescopes

A number of improvements of the telescopes were implemented during the year, among others

better sun-avoidance,
increased slewing rates,
remote control of the weather protection shutter in the central hub,
remote control of the diesel generators, etc.

In order to improve the quality of the pointing parameters, inclinometers were installed on the telescopes.

A first test was made with two inclinometers installed in one of the telescopes; they were placed in various locations, but gave identical results in all locations to within 1 arc. sec., which implies very good mechanical behaviour of the telescope. Then each telescope was equipped with one inclinometer. However, the inclinations measured could not be related reliably to the pointing parameters to better than 8 arc sec. The weekly variations of the inclinations measured by the inclinometers were typically 5 arcsec. Careful pointing measurements revealed also encoder variations of the same values, presumably due to thermal effects in the encoder coupling, a similar effect as observed at the 30-m telescope. The lack of better coincidence between inclinometer measurements and pointing parameters may be explained by these thermal effects, which limit the pointing accuracy to 5 arcsec.

During the year, some degrading of the telescope surface was observed, in particular telescope 2 showed a number of small black spots, which gave rise to a guarantee claim with the manufacturer, which is still under discussion.

A storm with windspeeds up to 150 km/h, in December, showed that the fixation of the back-cladding of the reflector is not up to survival wind specifications, since in particular from telescope 3, a number of back-panels were blown off.

A new fixation and possibly an improved cladding is in preparation. Awaiting these improvements, the telescopes cannot be submitted to the survival windspeed, which implies some limitation in the interferometer operation.

The Interferometer

After the detection of the first fringes on the 14th of December 1988, with two telescopes, the goal in 1989 has been to bring the Plateau de Bure array into full operation.

The beginning of the year was essentially devoted to tests of the control and acquisition software. Several small errors in the phase tracking were corrected. A first image, showing the radio jet of the galaxy VIRGO A (M87) was obtained at 86 GHz with the continuum correlator.

Interferometer tests were started with 3 telescopes end of May, and first fringes with 3 telescopes were detected in June. All the measurements obtained during the various interferometer tests were used to improve the knowledge of the array geometry.

In September, the change-over between the PDP 11/40 and mVAX 3400 computers was implemented on the site. After some initial hardware problems, the break-down of the CAMAC interface -which had performed well since months in Grenoble- and a failure of the continuum correlator, which could not be simulated in Grenoble, the interferometer became again fully operational during October.

The computer change suppressed all the limitations and problems experienced earlier in the year. In particular the interactions between the analysis program (CLIC) and the real-time parameters were simplified, and an easy switch-over between the various operation modes of the array (single-dish, Test, Multi-dish configuration and Interferometer) could be installed which greatly reduced errors and the need for interventions.

As the array progressed towards an operational stage, five full scale test programs were defined early November in order to

- assess the sensitivity of the array in continuum observations,
- investigate the high resolution mapping and narrow band (20 MHz) spectral correlator performance,
- test the spectral correlator in broad band (80 MHz) mode,
- evaluate the sensitivity for weak spectral lines and the simultaneous mapping of several transitions, and
- measure the performance in mapping spectral lines in the presence of a strong and complex continuum.

First attempts on base-lines from 40 to 60 meters of all these projects were made in November. In terms of sensitivity, all test projects proved to be feasible, and the theoretical sensitivity of the array is routinely met.

By the 18th of December, the tests had to be interrupted due to the storm damages, in particular of telescope 3.

Site and Building

The support of the cable car cabin was overhauled, which interrupted the cable car operations for two weeks. During this period, the personnel was transported to the site by helicopter.

Apart from the normal maintenance work on the buildings, no additional work was undertaken on the site, with the exception of some additional leveling of the tracks to assure better snow cleaning in winter.

Personnel and Finances

During 1989, the total number of persons employed by IRAM increased to 104, including the Spanish Co-director. Of these 104 persons, 89 are IRAM staff members, 4 are post docs -3 employed in Grenoble, 1 in Granada- and 10 are thesis students -4 in Grenoble and 6 in Granada. The geographical distribution of the staff over the various IRAM establishments did not change in 1989 as compared to 1988.

One of the staff positions in the SIS laboratory is for 50% financed by the MPIfR and the MPI für Extraterrestrische Physik, MPIfR furthermore finances one post doc in Spain. One of the students has a French/Spanish scholarship, and the Spanish Co-director is paid by IGN.

IRAM's financial situation in 1989 and the budget provisions for 1990 are summarised on the following pages.

Operations cost were higher in 1989 as a result of the water problem and the repair of the 30-m telescope cladding. The overhaul of the cable car with the associated helicopter transport further contributed to the increase.

The increase in personnel cost is partially due to the application, as of January 1989, of the new collective labour agreement with the Spanish staff.

During the year, 1.8 MF were invested in new equipment for the SIS laboratory, and 2.7 MF were paid to MAN at the partial delivery of reflector panels for the 4th interferometer telescope. No additional orders for this telescope were placed during the year.

Further investments were made both in France and Spain in computer hardware (1.0 MF), laboratory test equipment (1.1 MF), and receivers (1.1 MF). On the development of the new correlators and cryogenic equipment 0.8 MF were spent.

Income other than contributions was higher than foreseen due to larger project income, payment of services rendered to other organisations and reimbursement of salaries.

During the year, the problem of the reimbursement of Spanish Value Added Taxes could still not be resolved.

Budget 1989

Expenditure

Budget heading	Budget Mio FF	Actual Mio FF
Personnel	27.270	27.547
Operations	11.780	12.525
Investments	10.030	
Value-Added Taxes	3.260	
	52.340	53.138

Income

Budget heading	Budget Mio FF	Actual Mio FF
Contribution CNRS	23.775	24.096
Contribution MPG	23.775	24.050
Other Income	1.530	
Contribution CNRS for Value-added taxes	3.260	
	52.340	53.600

Budget Prevision 1990

Expenditure

Budget heading	Approved Budget (MF)
Personnel	28.860
Operations	13.060
Investments	8.000
Value-Added Taxes	3.830
	53.750

Income

Budget heading	Approved Budget (MF)
Contribution CNRS	24.600
Contribution MPG	24.600
Other Income	720
Contribution CNRS for Value-added taxes	3.830
	53.750

ANNEX I - Record of observing programs at the IRAM 30 m Telescope.

IRAM 30-M TELESCOPE — OBSERVING PROGRAMS — DEC 1988 - JAN 1989

Date	Title	Freq.(GHz)	People
Dec 1-5	Clouds in the molecular ring	90-115, 219-245	Depois, Pérault, Stark
Dec 1-2	mm lines of CH_3OH masers	84, 95, 132, 147, 229	Menten, Walmsley, Liechti
Dec 6-12	CO in NGC 4449	115 230	Henkel, Klein, Mebold
	Tidal arms + dwarf galaxies near M81	115 230	Becker, Henkel, Wilson et al.
	Envelopes of dwarf galaxies	115 230	Henkel, Becker, Appenzeller et al.
	Star formation in dwarf irregulars	115 230	Becker, Henkel, Wouterloot et al.
Dec 13-16	Mapping in Taurus + Molecular Disks	141 226 246	Lazareff, Monin, Pudritz
Dec 17-18	CO in ellipticals	113-115, 226-230	Lazareff et al.
Dec 17-19	Molecules near ultra-compact H II regions	98 110 220	Walmsley, Churchwell
Dec 18-19	Starburst galaxies	115 230	Moles, Gomez, Cernicharo, Masegosa
Dec 19-20	Starburst galaxies	115 230	Moles, Gomez, Cernicharo, Masegosa
Dec 20-23	Deuterated formaldehyde	111, 128-166, 221, 247	Mauersberger, Jacq, Henkel, Walmsley
Dec 21-23	Recomb. lines from compact H II regions	85.7 231.9	Churchwell, Walmsley
Dec 24-26	CS in ρ Oph cloud core	98 245	André, Martin-Pintado, Despois et al.
Dec 24-26	CO in Markarian galaxies	110 115 220 230	Chini, Krügel, Steppe
Dec 27-Jan 2	Maps of CO in galaxies	115 230	Radford, Solomon, Downes
Jan 3-9	CO in M33 and M101	115 230	Boulanger, Cox, Lequeux, Pérault et al.
Jan 10	Deuterated formaldehyde	111, 128-166, 221, 247	Mauersberger, Jacq, Henkel, Walmsley
Jan 11	CO and ^{13}CO maps toward Cas A	110 115 220 230	Wilson Przewodnik, Mauersberger et al.
Jan 12-14	Anomalous recombination line	98 147 245	Martin-Pintado, Bachiller, Thum
Jan 12-13	CO and SiO maps of NGC 7538-IRSI	86 115 217 230	Wilson, Johnston, Filges, Henkel
Jan 13-14	Maps of the Ring Nebula	90-115, 230	Bachiller, Planesas Bujarrabal, Martin, Gomez
Jan 14-16	CO from infrared quasars	210-230	Zylka, Wilson, Scoville, Zensus, Sanders
Jan 16	Vibrationally excited ammonia	140	Schilke, Mauersberger, Walmsley et al.
Jan17-19	CO from radio-quet quasars	88-113	Alloin, Gordon, Antonucci, Barvainis
Jan 19-20	Hydrogen level populations	99.0 99.2	Gordon, Walmsley, Wilson
Jan 20-21	$^{18}O/^{17}O$ ratios in galactic nuclei	110 220	Henkel, Mauersberger, Güsten, Wilson
Jan 21-23	Protostellar condensations	88 98 145 245 266	Güsten, Serabyn, Fiebig
Jan 22-23	Vibrationally excited H_2O in Orion	96 233	Menten, Melnick, Cernicharo, Walmsley
Jan 24-29	CO & HCN in circumstellar envelopes	88.6 230.5	Omont, Forveille et al.
Jan 24-29	Line maps of IRC+10216	88, 133-173, 226-272	Rieu, Kahane, Cernicharo, Omont et al.

Date	Title	Freq. (GHz)	People
Jan 29-Feb 2	Spiral galaxy survey	115 230	Casoli, Combes, Dupraz, Gerin Hummel et al
	Galaxy group Hickson 18	115 230	Dupraz, Casoli, Combes, Gérin
	Arm-interarm contrast in NGC 628	115 230	Casoli, Combes, Gérin
	O_2 in NGC 6240, Arp 220 and 3C84	115-116	Casoli, Gérin, Combes, Encrenaz, Pagani
	Galactic center clouds	86, 110, 115, 220, 236	Bel, Viala, Combes, Pagani
Feb 3-6	Arm-Interarm contrast in M51	115 230	Garcia-Burillo, Guélin, Cernicharo et al.
	HCS^+ Interstellar ion	86 96 110 128 145	Rist, Cernicharo, GuélinThaddeus, Valiron
	CO in nuclei of IRAS galaxies	115 230	M. Götz, Greve
Feb 7-13	Four-channel bolometer tests	250	Mezger, Haslam, Kreysa, Chini, Zylka and
Feb 14-20	0.87-mm bolometer tests	350	Wink, A.Götz, Steppe, Thum
Feb 21-27	CO in Markarian galaxies	110 115 220 230	Chini, Krügel, Steppe
	Maps of molecules near dust peaks	96, 109, 147, 218-235	Mezger, Wilson, Zylka, Mauersberger, Wink
	Disks around solar-mass stars	250	Beckwith, Chini, Güsten, Sargent
	Maps of dust continuum emission	250	
Feb 28-Mar 1	Circumstellar envelopes	250	Omont, Walmsley, Chini, Forveille, André
Mar 1	Dust in circumstellar disks	250	Lazareff, Monin, Pudritz
Mar 2-3	Protostars in DR 21 (OH)	250	Gear, Chandler, Moore
Mar 2-3	Dust column density in clouds	250	Puget, Pérault, Falgarone
Mar 3-4	Flux densities of quasars	250	Steppe, Gopal-Krishna
Mar 4	Cores of 6 lobe-dominant quasars	250	Alloin, Antonucci, Barvainis
Mar 5	IR sources in ρ Oph cloud	250	Montmerle, André
Mar 6	Quasar fields	250	Schultz, Kreysa, Steppe
Mar 7-10	Continuum emission from stars	250	Altenhoff, Thum, Wendker
Mar 11	Asteroids & cometary nuclei	250	Altenhoff
Mar 12-13	Fluxes of ultra-compact H II regions	250	Steppe, Mauersberger
Mar 12-13	Nova Vulpeculae	250	Greve, Steppe, Taylor
Mar 14-27	Quiescent regions in molecular clouds	145 219-230	Stutzki, Genzel, Graf, Güsten
	Star-forming regions	241 243 258 267	Harris, Stutzki, Graf, Genzel
	HCO^+ & HCN in IC342, N6946, M82	89 267	Jackson, Eckart, Downes, Harris
Mar 28-Apr 3	Line contribution to continuum fluxes	210 230 240	Mauersberger, Mezger, Thum, Zylka
Mar 29-31	CO (2-1) line from Titan	230.5	Marten, Lecacheux, Paubert, Courtin et al

Date	Title	Freq. (GHz)	People
Apr 4-10	CO in nucleus of NGC 3628	230	Wielebinski, Krause, Reuter, Casoli
	SiO masers toward W51-IRS2	86 214 215	Fuente, Alcolea, Martin-Pintado, Downes
	Molecular gas in NGC 1068	110 220	Planesas, Martin-Pintado, Gomez-Gonzales
	Lines from RV Tauri stars	89 110 115 220 230	Bujarrabal, Alcolea
	Molecules in globular clusters	115 230	Bachiller, Cernicharo, Bujarrabal, Gomez-Gonzales
Apr 11	Technical time		
Apr 12	Lunar occultation of IRC+10216	98 145 230	Cernicharo et al.
Apr 13-17	Jet + disk around young star in Orion	98 146 220	Castets, Duvert, Bally
Apr 14-17	J=3-2 HCN masers	87 264 266 267	Lucas, Cernicharo
Apr 18-20	HCN & HNC in the Orion hot core	86 87 91 145 153	Walmsley, Jacq, Harju
Apr18-22	H30α map of M82	231	Puxley, Moore, Nakai
Apr 19-23	Dynamics & dust/gas ratio of Sgr A ring	109 110 222 245	Wilson, Zylka, Mezger
Apr 21-22	Kinematics of the NGC 2024 flow	220 230	Hills, Richer
Apr 23-24	Masses of molecular gas in galaxies	230	Smith, Puxley, Mountain, Nakai, Brand
Apr 25-27	Spiral Galaxy survey	115 230	Casoli, Combes, Dupraz, Gérin, Hummel et al
	Galaxy group Hickson 18	115 230	Dupraz, Casoli, Combes, Gérin
	Arm-interarm contrast in NGC 628	115 230	Casoli, Combes, Gérin
	O_2 in NGC 6240, Arp 220 and 3C84	115-116	Casoli, Gérin, Combes, Encrenaz, Pagani
	Galactic center clouds	86, 110, 115, 220, 236	Bel, Viala, Combes, Pagani
	NGC 4314 and NGC 6946	115 230	Casoli, Combes, Gérin, Garcia-Barreto
Apr 28-29	Compressed, turbulent gas	110 115 220 230	Puget, Pérault, Falgarone
Apr 30	Search for H_2O^+	144	Ziurys, Wilson, Henkel, Mauersberger

Date	Title	Freq. (GHz)	People
May 2-9	Protostellar Condensations	145, 245, 266	Güsten, Serabyn, Fiebig
	Probing the birth sites of Massive Stars	145, 245, 266, 343	Güsten, Serabyn, Schulz, Downes
	Non-Thermal Filaments	145	Güsten, Serabyn
May 9-12	Tests		Granada staff
May 12-16	Lunar Occultation of IRC+10216	145, 230	Cernicharo et al.
	Envelope of R Aqr	220, 230	Alcolea, Bujarrabal, Omont
	Circumstellar envelopes	217, 230	Sahai, Bujarrabal, Claussen, Scott
	CO Ring in M104	230	Wielebinski, Krause, Dettmar
May 16-23	Dynamics + Dust-to-Gas Ratio in Sgr A	222, 245	Wilson, Zylka, Mezger
	Search for Interstellar H_2O^+		Ziurys, Wilson, Henkel, Mauersberger
	Hot clouds near the galactic center	147, 239, 96, 144, 241	Wilson, Hüttemeister, Henkel, Mauersberger
	Cyanoacetylene in NGC 253	137, 155, 227	Henkel, Walmsley, Mauersberger
	Extragalactic Methanol	several	Mauersberger, Henkel, Walmsley, Wilson et al.
May 23-30	CO in Early Type Galaxies	230	Wiklind, Henkel
	Extreme Mass Loss	220, 230, 140	Omont, Forveille, Guilloteau, Habing, Heske et al.
	CO in Planetary Nebulae	230	Forveille, Huggins
	Molecular Spiral Structure in M51	230	Guélin et al.
May 30-Jun 6	Detection of Interstellar CNCN	228	Stroh, Winnewisser, Walmsley, Churchwell, Jewell
	Molecular Spiral Structure in M51	230	Guélin et al.
	Silicon Chemistry in Clouds	217.1, 217.8	Martin-Pintado, Bachiller, Cernicharo, Fuente
	CO in Luminous FIR Galaxies	220, 230	Baan, Henkel
Jun 6-9	Tests		Granada staff
Jun 9-13	Molecular lines from RV Tau stars	220, 230	Bujarrabal, Alcolea
	Oval distortions in galaxies	230	Lazareff, Paubert
Jun 13-20	HCN Maser from CIT-6		Liechti, Guilloteau, Lucas, Omont
	Distant FIR Active Galaxies	230	Downes, Solomon, Radford
	Selected Milky Way Cloud Cores	98, 147, 230, 245	Solomon, Wilson, Walmsley, Rivolo
	M101 and Other Nearby Galaxies	230	Solomon, Downes, Sage
	Anomalous Refraction	226	Altenhoff, Downes
Jun 20-27	High velocities from young objects		Bachiller, Cernicharo, Martin-Pintado, Rodriguez
	Vibrationally Excited Ammonia	140	Mauersberger, Menten
	SiC, HSiC and HNSi	157, 162-170, 236	Guélin, Cernicharo, Paubert, Mauersberger
Jun 27-Jul 4	Dense Gas in the Circumnuclear Ring	268	Jackson, Genzel, Harris
	W3	147, 217, 237, 230	Gaume, Claussen, Johnston, Wilson
	Non-spherical Outflows	230	te Lintel, Heske, Maloney, Latter

Date	Title	Freq. (GHz)	People
	Tests		Granada staff, D. Morris
Jul 7-11	Lunar Occultation	145, 230	Cernicharo et al.
	Effects of Interaction in Galaxies	230	Braine, Casoli, Combes, Dupraz, Gélin et al
	Interacting Galaxies in Arp 118	230	Casoli, Combes, Gérin, Dupraz
Jul 11-18	Molecular Ring of NGC 7479	230	Combes, Gérin, Casoli, Kenney
	Molecular Spiral Arms in NGC 6946	230	Clausset, Casoli, Combes
	Nitrogen Chemistry : NO and N_2H^+	150, 250, 350	Gérin, Combes, Pauzet, Viala
Jul 18-25	Receiver installation	230	Blundell, Blondel, Chenu
	Radioquiet Quasars	226	Alloin, Antonucci, Barvainis, Gordon
Jul 25-28	Tests		Granada staff, D.Morris
Jul 28-Aug 1	Cygnus A	222	Mirabel, Planesas, Kazes, Sanders
	Vibrationally Excited Water in Stars		Menten, Melnick, Mauersberger, Walmsley
Aug 1-7	Molecular Line Maps of 1.3 mm Continuum Peaks	147, 218, 235, 239	Wilson, Mezger, Zylka, Mauersberger, Wink
	Cas A - Follow-up	220, 230	Wilson, Przewodnik, Mauersberger, Olano
	CO towards Infrared Quasars	200-220	Wilson, Zylka, Scoville, Sanders, Zensus
	CO and SiO Maps of NGC 7538 - IRS 1	217, 230	Wilson, Johnston, Filges, Henkel, Schilke
	Line Maps in Pseudo-Continuum Mode	230	Mauersberger, Brunswig, Mezger, Wilson
	Continuum Emission from ρ Oph Objects	130, 226	André, Montmerle, Steppe
Aug 8-14	Deep Survey of Planetary Nebulae	140, 230	Huggins, Forveille, Omont, de Muizon et al.
	Influence of Lyman Photons on H-Levels	140	Gordon, Walmsley, Wilson
	CO in Markarian Galaxies	220, 230	Chini, Krügel, Steppe
	CO in Elliptical Galaxies	220, 230	Gordon
Aug 15-22	Anomalous Refraction	140, 250	Altenhoff, Downes
	Comet Brorsen-Metcalf	250	Altenhoff, Kreysa, Schmidt, Thum
	Tidal Arms and Dwarf Galaxies of the M81 Group	230	Henkel, Becker, Wilson, Appenzeller
	NGC 4449	230	Henkel, Klein, Mebold, Becker
Aug 22-28	Insterstellar CH_2DOH	85-95, 134, 223, 264	Walmsley, Herbst, Mauersberger, Henkel
	Galactic Center OH/IR Stars	115, 230	Winnberg, Olofsson, Lindqvist, Henkel
	Circumstellar Chemistry of TX Cam	86, 145-150, 213-272	Olofsson, Lindqvist, Winnberg, Nyman, Rieu
	$H_2{}^{18}O$ in Compact Cores	203	Henkel, Wilson, Jacq, Walmsley, Baudry
	Excited Molecular Lines in Galaxies	147, 245, 266, 267	Rieu, D.Morris, Viala, Alberdi, Jackson et al.

Date	Title	Freq.(GHz)	People
	Giant Star Forming complexes in NGC 5446, 5471		Viallefond, Cox, Lequeux, Pérault, Boulanger
	Comet P/Brorsen-Metcalf	89, 266	Crovisier, Despois, Colom, Bockelée-Morvan, Gérard
	M33	115, 230	Boulanger, Cox, Lequeux, Goss
Sept 5-12	$H^{13}CN$ and $HC^{15}N$(3-2) Lines on Titan	89, 258, 259	Bézard, Marten, Paubert
	Molecules in Regions near Orion KL	129, 217, 230	Wilson, Mauersberger, Johnston, Henkel
	High-Luminosity Carbon Stars	88, 115, 147, 230	Zuckerman, Kastner, Forveille, Omont
Sep 12-19	^{13}CO J=2-1 Observations of Maffei	220	Smith, Mountain, Puxley, Brand, Nakai
	Search for a CO Ring in M104	230	Wielebinski, Krause, Dettmar
	Molecular Gas Content in NGC 1068	110-120	Planesas, Martin-Pintado, Gomez-Gonzales
	CO Observations in NGC 4258	115, 230	Krause, Cox, Downes
	Molecular envelopes around WR stars	115, 147, 220, 230, 266	Bujarrabal, Alcolea, Bachiller
Sep 19-26	Farinfrared Luminous Active Galaxies	115, 230	Downes, Solomon, Radford
	High Resolution CO Maps of Galaxies	115, 230	Solomon, Downes, Radford, Viallefond
	CO Excitation of Ultraluminous IR Galaxies	104-109, 209-217	Kazès, Solomon, Downes, Radford
Sep 26-Oct 3	Lunar occultations	98, 115, 230	IRAM staff
	CO(1-0) of Arp 118	115	Casoli, Combes, Gérin, Dupraz
	Ratio $I_{CO}/N(H_2)$ in M81	115, 230	Brouillet, Baudry, Combes, Kaufmann, Bush
	Observations of NO and N_2H^+	93, 150, 250, 350	Gérin, Combes, Pauzat, Viala
Oct 10-13	Tests		
Oct 13-17	CS Maps of Nearby Galaxies		Mauersberger, Henkel
	Nitrogen in regions obscured by dust	262	Mauersberger, Henkel, Liechti, Walmsley
Oct 17-24	Protonated methylcyanide+cyanoacetylene	85-268	Henkel, Mauersberger, Walmsley
	Cyanoacetylene in NGC 253	90, 100, 136, 154, 226	Henkel, Walmsley, Mauersberger
	Cooling Flows in Galaxies		Huchtmeier, Bregman, Roberts
	CO Emission in Hydra Cluster Galaxies	114, 228	Huchtmeier, Richter
	CO Emission from Arp 244	115, 229	Huchtmeier, Richter
	Protonated Hydrogen Cyanide	148, 222	Henkel, Mauersberger, Walmsley
	Extragalactic Methanol	95, 216-261	Mauersberger, Henkel, Walmsley, Wilson, Hüttemeister
Oct 24-31	Line Maser Emission MWC 349	92, 160, 231	Thum, Martin-Pintado, Bachiller
	Molecular Bullets near L1448/IRS3	109-155, 218, 245	Bachiller, Cernicharo, Martin-Pintado
	Cooling Flows in Galaxies		Huchtmeier, Bregman, Roberts
	CO Emission in Hydra Cluster Galaxies	114, 228	Huchtmeier, Richter
	CO Emission from Arp 244	115, 229	Huchtmeier, Richter
	CS Surrounding Compact HII Regions	98, 147, 245	Cesaroni, Walmsley, Churchwell
	NGC 2024	220, 230	Hills, Richer

Date	Title	Freq. (GHz)	People
	Tidal Interaction of Spiral Galaxies	115, 230	Braine, Casoli, Combes, Dupraz, Gérin et al.
	D/H in the Galactic Center		Walmsley, Baudry, Jacq
	Molecular Rings in NGC2841 + NGC7331	115, 230	Combes, Gérin, Casoli
Nov 13-21	Grain Mantle Evaporation	143, 230, 240	Jacq, Walmsley, Henkel
	Deuterated Hydrogen Sulfide in Orion	110-169, 213-258	Jacq, Walmsley, Henkel
	HCN and HNC Chemistry in Orion-KL	86, 144, 172, 217, 259	Schilke, Walmsley, Harjo, Mauersberger
Nov 21-24	Technical time		
Nov 24-28	Frequency Survey 328-348 GHz	328-348	Schulz, Güsten
	Probing the Birthsites of Massive Stars	88-145, 245, 266, 343	Güsten, Serabyn, Schulz, Downes
Nov 28-Dec 1	Technical time		
Dec 1-4	Response of Turbulent Molecular Gas	110-115, 220-231	Puget, Pérault, Falgarone
Dec 5-12	Gaseous Content of Circumstellar Matter	110-14, 220, 226	Montmerle, André, Despois, Martin-Pintado
	HCO^+ Observations of Herbig-Haro Objects	267	Rudolph, Rieu, Welch
	SiO Maser Emission towards WS1-IRS2	86, 214, 216	Fuente, Alcolea, Martin-Pintado, Downes
Dec 12-19	The Remarkable Young Star RE50N	97-145, 220-245	Cernicharo, Reipurth
	Interaction of the Optical Jet H111 with the Surrounding Molecular Gas	97, 115, 145, 230, 245	Cernicharo, Reipurth
	Search for Sulfur Compounds in Venus' Atmosphere	146-168, 216-221	Lellouch, Marten, Bézard, Paubert
Dec 19-24	Vibrationally Excited HCN Masers		Lucas, Cernicharo
	MM-Emission from Water Vapor		Cernicharo, Thum, Bachiller, Mauersberger
Dec 24-Jan 1	Extragalactic Radio Sources at 3 mm	86	Witzel, Quirrenbach, Krichbaum, Hummel et al.
	Gas Content in IRAS Galaxies	110-115, 220-230	Dennefeld, Bottinelli, Gouguenheim, Martin
Jan 9-14	CO Observations of Proto-Planetary Nebulae	115, 230	Pottasch, Manchado, Henkel, Sahu et al.
	Two OVRO Fields in M33	115, 231	C. Wilson, Scoville, Guélin
	CO and SiO Maps of NGC7538-IRSI	217, 230	T.Wilson, Johnston, Walmsley, Henkel, Schilke
	Dense gas in the galactic center ring	268	Jackson, Genzel, Harris
	HCN in circumstellar envelopes	89, 130, 231	Omont, Forveille, Loup, te Lintel, Hekkert et al

ANNEX II A - IRAM Publications

Warm gas and spatial variations of molecular excitation in the nuclear region of IC 342
A. Eckart, D. Downes, R. Genzel, A.I. Harris
D.T. Jaffe, W. Wild
1990, *Astrophys. J.*, **348**, 434.

The structure of the molecular gas in the young planetary nebula NGC 2346
R. Bachiller, P. Planesas, J. Martin-Pintado,
V.Bujarrabal, M.Tafalla
1989, *Astron. Astrophys.*, **210**, 366.

184 Continuously moving telescopes for optical interferometry
M. Vivekanand, D. Downes
1989, in *Diffraction-Limited Imaging with Very Large Telescopes,*
eds. D. Alloin, J.M. Mariotti, Kluwer, Dordrecht, p. 85.

185 Millimeter wave interferometry
D.Downes
1989, in *Highlights of Astronomy,* vol. 8,
ed. D. McNally, Kluwer, Dordrecht, p. 555

194 A search for radio recombination lines of positronium near the galactic center
K.R. Anantharamaiah, V. Radhakrishnan,
D. Morris,
M. Vivekanand, D. Downes, C.S. Shukre
1989, in *The Center of the Galaxy,* IAU Symp. 136,
ed. M. Morris, Kluwer, Dordrecht, p. 607

197 The molecular spiral structure in M51 derived from CO(J=2-1) line observations
M. Guélin, S. Garcia-Burillo, R. Blundell,
J. Cernicharo, D. Despois, H. Steppe
1989, in *Highlights of Astronomy,* Vol. 8,
ed. D. McNally, Kluwer, Dordrecht, p. 575

Radio astronomy techniques
D. Downes
1989, in *Evolution of Galaxies - Astronomical Observations,*
eds. I. Appenzeller, H.J. Habing, P. Léna
Springer Verlag, Heidelberg, p. 351

Radio telescopes : basic concepts
D. Downes
1989, in *Diffraction-Limited Imaging with Very Large Telescopes,*
eds. D. Alloin, J.M. Mariotti, Kluwer, Dordrecht, p. 53.

200 Observations at 90 and 142 GHz of nine extended galactic radio sources
C.J. Salter, D.T. Emerson, H. Steppe, C. Thum
1989, *Astron. Astrophys.*, 225, 167.

201 Dense gas in nearby galaxies : distribution, kinematics and multilevel studies of CS
R. Mauersberger and C. Henkel
1989, *Astron. Astrophys.*, **223**, 79.

202 Molecules in external galaxies
R. Mauersberger, C. Henkel, P. Schilke
1989, *Astrophys. Space Science* **156**, 263.

203 Strategies for 2-dimensional telescope motion in optical interferometry
M. Vivekanand, D. Morris, D. Downes
1989, *Astron. Astrophys.*, **213**, 516.

204 A radio recombination line maser in MWC349
J. Martin-Pintado, R. Bachiller, C. Thum,
M. Walmsley
1989, *Astron. Astrophys.*, **215**, L13.

205 230 GHz observations of the radio galaxies Cygnus A and Virgo A
C.J. Salter, R. Chini, C.G.T. Haslam, W. Junor,
E. Kreysa,
P.G. Mezger, R.E. Spencer, J.E. Wink, R. Zylka
1989, *Astron. Astrophys.*, **220**, 42.

206 Detection of CO(1 —> 0) emission from infrared quasars and luminous Seyfert galaxies
D.B. Sanders, N.Z. Scoville, A. Zensus,
B.T. Soifer,
T.L. Wilson, R. Zylka, H. Steppe
1989, *Astron. Astrophys.*, **213**, L5.

207 Extinction toward the Orion nebula derived from $P\gamma/H\delta$ and [SII] 1.04μm/4071 A line ratios
A. Greve, C.D. Mc Keith, E.W. Barnett, M. Götz
1989, *Astron. Astrophys.*, **215**, 113

208 Warm gas and spatial variations of molecular excitation in the nuclear region of IC 342
A. Eckart, D. Downes, R. Genzel, A.I. Harris,
D.T. Jaffe, W. Wild
1989, in *Highlights of Astronomy,* Vol. 8,
ed. D. McNally, Kluwer, Dordrecht, p. 589

209 Proper motions of H_2O masers in W49(N) and the distance to the galactic center
C.R. Gwinn, J.M. Moran, M.J. Reid,
M.H. Schneps, R. Genzel, D. Downes
1989, in *The Center of the Galaxy,* IAU Symp. 136,
ed. M. Morris, Kluwer, Dordrecht, p. 47

210 Continuum observations of Sgr A at mm/submm wavelengths
P.G. Mezger, R. Zylka, C.J. Salter, J.E. Wink,
R. Chini, E. Kreysa, R. Tuffs
1989, in *The Center of the Galaxy,* IAU Symp. 136,
ed. M. Morris, Kluwer, Dordrecht, p. 357

21 Laboratory microwave spectroscopy of the C_3N radical in the vibrationally excited state v5
H. Mikami, S. Yamamoto, S. Saito, M. Guélin
1989, *Astron. Astrophys.*, **217**, L5.

212 Discovery of strong maser emission from
HCN in IRC+10216
R. Lucas and J. Cernicharo
1989, *Astron. Astrophys.*, **218**, L20.

213 Line calibrators at 1.3, 2 and 3 mm
R. Mauersberger, M. Guélin, J. Martin-Pintado,
C. Thum,
J. Cernicharo, H. Hein, S. Navarro
1989, *Astron. Astrophys. Suppl. Series*, **79**, 217

214 VLA observations of the $^{15}NH_3$ maser
associated with NGC 7538 IRS 1
K.J. Johnston, S.R. Stolovy, T.L. Wilson,
C. Henkel, R. Mauersberger
1989, *Astrophys. J.*, **343**, L41.

215 The Swedish-ESO submillimetre telescope (SEST)
R.S. Booth, G. Delgado, M. Hagström,
L.E.B. Johansson,
D.C. Murphy, M. Olberg, N.D. Whyborn,
A. Greve, B. Hansson,
C.O. Lindström, A. Rydberg
1989, *Astron. Astrophys.*, **216**, 315.

216 Study of bubbles in the L.M.C.
A. Laval, M. Rosado, J. Boulesteix,
Y.P. and Y.M. Georgelin,
M. Marcelin, D. Cahalo, A. Greve, J. Larsen,
A. Viale
1989, in *Recent Developments of MC Research*,
eds. K.S. de Boer, F. Spite and G. Stasinska

217 Study of groove nonradiative
dielectric waveguide
C.E. Tong, R. Blundell
1989, in *Electronics Letters*, **25**, 14.

218 CCD spectroscopy of Pγ (10939), Pδ (10049)
and corresponding Balmer lines in 30 Doradus
A. Greve, C.D. McKeith, J. Castles
1989, *ESO Messenger* 57, p. 56.

219 Radio continuum observations of comet P/Halley
AT 250 GHz
W.J. Altenhoff, W.K. Huchtmeier, E. Kreysa,
J. Schmidt, J.B. Schraml, C. Thum
1989, *Astron. Astrophys.*, **222**, 323.

220 A 200 km s^{-1} molecular outflow in the
protoplanetary nebula CRL 618
J. Cernicharo, M. Guélin, J. Martin-Pintado,
J. Penalver, J. Mauersberger,
1989, *Astron. Astrophys.*, **222**, L1.

221 Time-variable recombination line emission
in MWC 349
J. Martin-Pintado, C. Thum, R. Bachiller
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222 Water fountains in molecular clouds
J. Cernicharo, C. Thum, H. Hein, D. Jonn,
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223 Millimetre interferometry
D. Downes
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224 Principles of direct and heterodyne detection
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K.H. Gundlach
1989, "Superconducting Electronics",
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Vol.F59, eds. H. Weinstock and M. Nisenoff,
Springer Verlag

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II. CS emission from spiral galaxies
R. Mauersberger, C. Henkel, T.L. Wilson,
J. Harju
1989, *Astron. Astrosphys.*, **226**, L5

226 Vibrationally excited ammonia in the galaxy
P. Schilke, R. Mauersberger, C.M. Walmsley,
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1990, *Astron. Astrophys.*, **227**, 220.

227 High resolution maps of CO(2-1)
emission from three contrasting galaxies
P.M. Solomon, D. Downes, S.J. Radford
1989, *Bull. Am. Astr. Soc.*, Vol. **21**, No. 4, p. 1165.

228 Dense molecular clouds and the Arp 220 starburst
S.J. Radford, D. Downes, P.M. Solomon
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231 Anomalous refraction at radio wavelengths
D. Downes, W.J. Altenhoff
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cloud cores OMC 1 and 2
P.G. Mezger, J.E. Wink, R. Zylka
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S.J.E. Radford, P.M. Solomon, D. Downes
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ANNEXE II B : Publications of the user community of the 30-m Telescope

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physical conditions of the molecular clouds
and star formation
P. Planesas, J. Gomez-Gonzales,
J. Martin-Pintado
1989, *Astron. Astrophys.*, **216**, 1.

72 Detection of strong carbon monoxide emission
from the host galaxy of the quasar I Zw 1
R. Barvainis, D. Alloin, R. Antonucci
1989, *Astrophys. J.*, **337**, L69.

73 Carbon monoxide emission from the
ring nebula in Lyra
R. Bachiller, V. Bujarrabal, J. Martin-Pintado,
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