IRAM Newsletter

Number 19 March 9, 1995

Calendar

Observing proposals: Proposals for the period *May 15, 1995 to Nov. 15, 1995* should be submitted before *Tuesday, February 28th 1995*

Contents

1.3 mm and 3 mm VLBI between Plateau de Bure and Pico Veleta

In the IRAM Newsletter No.18 (November 1994) we reported that a first attempt had been made to use the 30m-telescope on Pico Veleta together with one antenna of the Plateau de Bure interferometer for a VLBI experiment. In this first experiment which focussed on 3mm observations, fringes were found from several sources, indicating that the equipment at both sites was fully functional. This prompted us to schedule a second 3mm plus 1.3mm test for early December, in conjunction with an international 3mm VLBI campaign (Europe, USA, Chile) in which the 30m-telescope participated most of the time.

Given the need for good weather conditions at both sites, we had defined a 'window' between December 2nd and 12th to carry out the 1.3mm test, using the same equipment (maser, terminal, tape unit) as in the earlier successful observing run. Our main goal was to demonstrate the feasibility of 1.3mm very-long-baseline interferometry on the baseline Bure(France) - Pico Veleta(Spain), corresponding to 1114 km. At 1.3mm this is equivalent to an angular resolution of 0.3 milli-arcseconds.

The observing procedure was the same as outlined in the earlier Newsletter. The log of the observations where both IRAM stations collected data reads as follows:

Date (Dec. 1994)	Project	λ (mm)	Observed Sources
3 - 4	Global VLBI	3	0528+134 2145+067 0420-014
6	Global VLBI	3	3C 111 BL Lac
8	Bure - Pico Veleta	1.3	3C 273B 3C 279 1823+568 2145+067
	Bure - Pico Veleta	3	2145+067
9	Bure - Pico Veleta	1.3	3C 273B 3C 279

We are happy to report that at 1.3mm fringes have been detected from 3C273B with S/N-ratios of 6.8 and 9.7, from 3C279 with a S/N-ratio of 10.2, and from 2145+067 with a S/N of 7.5 (Fig. 1).

1.3mm-VLBI observations with such S/N-ratios are unprecedented and are indeed a big encouragement to continue with such experiments. This is planned for the near future.

For completeness, we mention also that the 3mm observations yielded fringes (Fig. 2), in several cases with a S/N-ratio in excess of 100 !

We could not have been so successful without the substantial contributions from the engineers and technicians in the receiver and backend groups, the operators at the telescopes, the correlator group, and the astronomers who

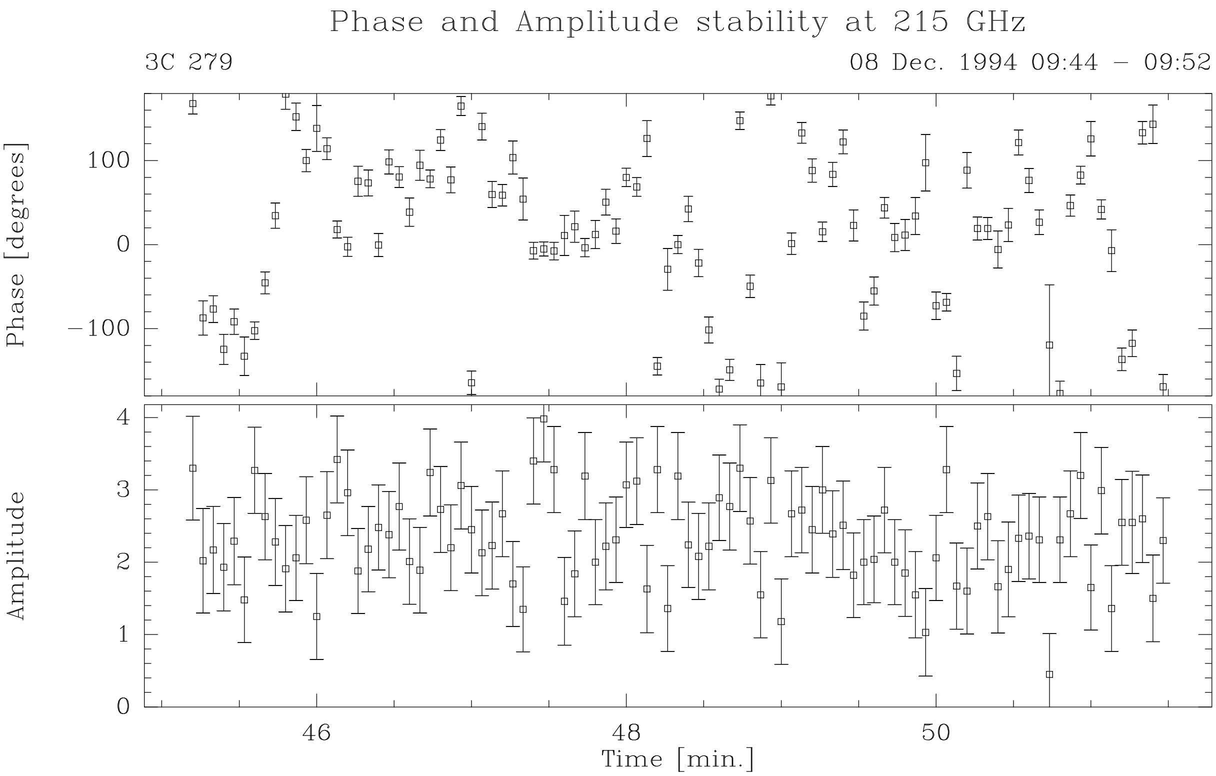

Figure 1: VLBI detection at 1mm between Plateau de Bure and Pico Veleta

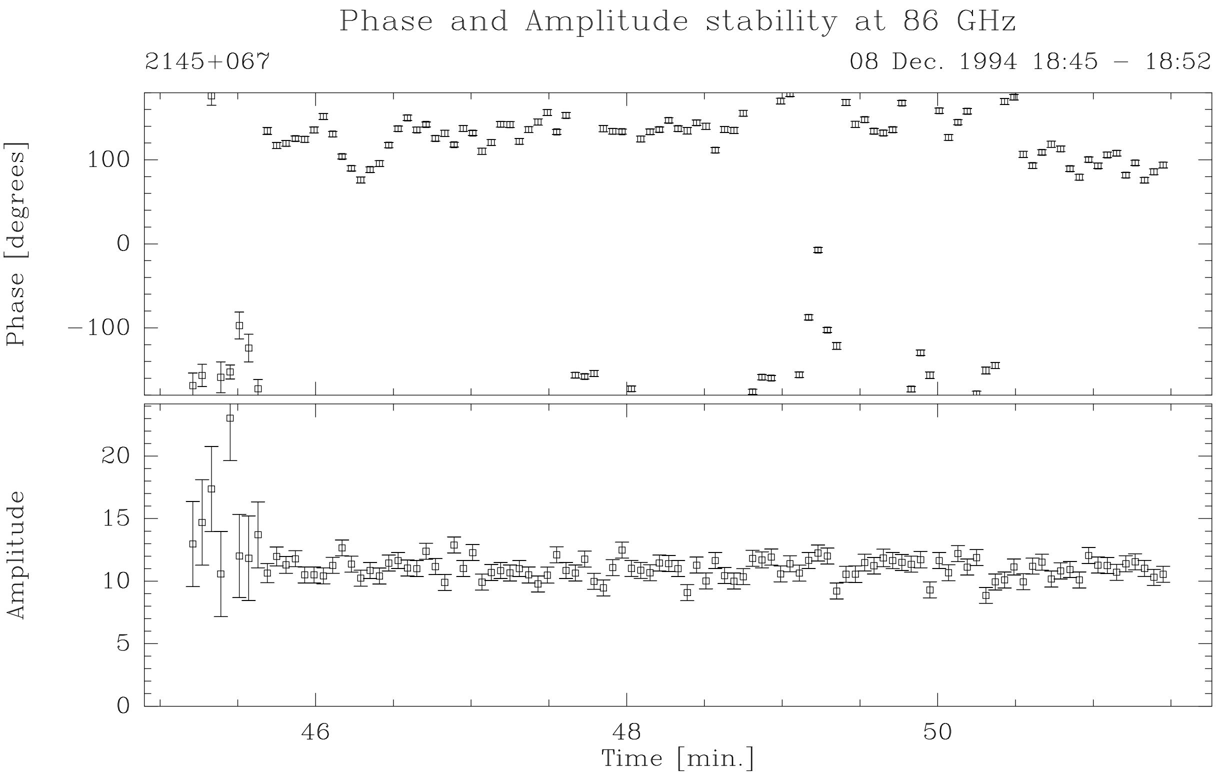

Figure 2: VLBI detection at 3mm between Plateau de Bure and Pico Veleta

participated in the preparation and execution of the observations and in the reduction of the data.

These 3mm- plus 1.3mm-VLBI experiments are a joint effort between IRAM and the Centro Astronomico de Yebes/Spain, the Max-Planck-Institute for Radioastronomy/Germany, and the Bordeaux and CERGA Observatories/France, coordinated by Albert Greve (IRAM).

Michael GREWING

Software

In the last IRAM newsletter, we issued a call for comments on a change of syntax for the SIC monitor. Since no comment has been received so far, we have implemented the modification as part of the JAN95 release of the GILDAS software. This release is now available.

This release contains a number of new functionalities for PdBI data reduction, in particular new programs to merge single-dish data with interferometer data, specially in the case of mosaics.

The GILDAS software has also been ported to PCs running the LinUX operating system. Performances are good on 486-Dx2 machines for all data reduction stages of 30-m data. The compiled version occupies about 30 MBytes of disk space (in addition to the LinUX system itself). Final checks are going on to implement this porting as part of the JAN95 source code release. However, since compile and link time is long (about a day), we also hope to provide an archive file of a compiled, ready to execute version of GILDAS under LinUX.

Interferometer

Baseline Extension

The East-West extension is complete up to W23. Station W27 could not be finished because of weather conditions. Tests of the "long" baseline E24-W23 are planned for early February.

Observations

Plateau de Bure has been involved in a global VLBI session and has performed a second 1.3mm VLBI experiment with Pico Veleta.

Standard observing projects are progressing on schedule. P.I.s can consult the *interferometer* item on the IRAM World Wide Web server to check the status of their project.

Telephone Numbers

The phone numbers for the Plateau de Bure changed on January 19th, 1995. The operator phone number is now 92 52 53 60; the fax number is 92 52 53 61. In addition the individual offices may be reached directly, according to the following list:

92 52 53 60	Operator's console
92 52 53 61	Fax
92 52 53 62	Thierry Crouzet
92 52 53 63	PC room
92 52 53 64	M. Dan - B. Aubeuf
92 52 53 65	D. Robert - A. Rambaud
92 52 53 66	B. Rossini - P. Chaudet
92 52 53 67	A. Grosz - S. Léonardon
92 52 53 68	Electronics Lab.
92 52 53 69	Astronomer
92 52 53 70	Computer Room
92 52 53 71	Workshop
92 52 53 72	Telepherique Upper Station
92 52 53 73	POM-2
92 52 53 74	Dining room - Kitchen

Frequency Switching at the 30m Telescope

The frequency switching technique is of great potential interest to the millimeter spectroscopist, since it combines important advantages over other observing modes. It is very efficient, since 100% of the observing time is spent on source, it can be used for very extended sources (no emission– free reference field needed), and it provides better cancellation of atmospheric emission fluctuations due to potentially higher switching speeds.

Despite these assets frequency switching (FSw) was not used much at the 30m telescope in the past, primarily because FSw spectra tended to have poor spectroscopic baselines. During 1994, motivated in part by the arrival of a new generation of SIS receivers, we have therefore made several test runs with the aim to bring the FSw equipment and its control software up to date, to find out what the limits are for the various FSw parameters, and last, but not least, investigate the quality of the spectroscopic baseline for FSw observations.

As the test results were quite encouraging, frequency switching will be offered now on a trial basis. During this initial trial period several restrictions will apply, the most important ones concern the availability of receivers (only the 3mm SIS and/or the 1mm SIS receiver No.1) and backends (only the 100kHz filter bank and the autocorrelator). Other limitations concerning the switching rates and frequency throw are described below. A Technical Report[1] on the FSw test results, including recommended observing procedures, technical implementation, and related items will be available soon. The trial period will hopefully tell us how strong the demand is for frequency switching, and what the remaining problems are. So, please, FSwitchers, report your findings, good and bad, to the undersigned.

RESULTS

At the 30m telescope frequency switching is done with the reference frequency (normally near 100 MHz) of the phase lock unit, thus switching the first local oscillator. Hardware and frontend software is in place to switch all 4 standard SIS receivers. The present limitation of the OBS frequency switching command to a maximum of 2 receivers and other considerations make it, though, that during the trial period only the 3mm SIS and/or the 1mm SIS receiver No.1 (commonly called "G1") can be used.

The quality of the spectroscopic baselines in FSw spectra was found to depend on a number of factors (see the Technical Report), most notably *(i)* the frequency throw Δf, *(ii)* the number and location of receivers used, and *(iii)* the stability of a receiver at a particular frequency.

In frequency switching on sources with little or no continuum, the baseline ripple is found to be strongly dominated by the path involving the subreflector, giving a dominant ripple period of 7.9 MHz. We found that this ripple can be suppressed to a large degree by making the frequency throw Δf equal to (or, to a lesser degree, twice) this period. Efficient simultaneous 1 and 3 mm observations are thus possible (Fig. 3). Thanks to the flexibility of the autocorrelator backend whose bandwidth should ideally be twice the frequency throw, it is even possible to have the same velocity scale at the two receivers.

Very good baselines can be obtained if only one receiver is used, the 3mm SIS or G1, by setting the Nasmyth beam distribution optics to a special mode (main polarization grid removed, dichroic set to $\lambda/8$) where the scattered wave is better rejected than with the standard optics. Usually still acceptable baselines are obtained when these two receivers are used in parallel as long as the dichroic is optimized for the 1 mm receiver.

All receivers have acceptable stability at most frequencies investigated (for details see the report) if SSB tuned with the recommended amount of USB rejection is used. We cannot exclude, however, that there might be a few bad frequencies where receiver stability is so poor that FSw observations are impractical. Best stability (often $< 10^{-3}$ on a 1 sec time scale) and best baselines were obtained at 3mm.

LIMITATIONS

frequency throw

In the frequency switching scheme implemented at the 30m–telescope, a frequency step Δf of the phase lock reference synthesizer (ref. 2) generates a frequency step of the same size at the level of the Gunn oscillator. At 3mm where no additional frequency multiplication is used, Δf is then directly the FSw throw in sky frequency. The 1mm receivers are equipped with triplers, so the FSw throw corresponds to $3\Delta f$. In the way the ref. 2 synthesizers are currently operated they permit a maximum throw of +20 MHz. The phase lock unit can, however, not handle such a large frequency step at all frequencies. Especially at 3mm, a practical maximum step seems to be 18 MHz. Our best estimates of these limits (positive and negative) are used by the OBS FSw command. For the observer it may usually be sufficient to remember that a throw of about 45 $\mathrm{km\,s^{-1}}$ should not be exceeded. In practice, we expect that the choice of Δf will usually be dictated, as outlined above, by the baseline ripple.

switching rate

The OBS FSw command also asks for the duration of one phase (default 1.5 sec). Although existing equipment permits phase durations in the range from 10 msec to 2.5 sec, not all of this range is actually usable. While

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[1] Thum, Sievers, Navarro, Brunswig, and Penalver 1995; IRAM Working report No. 228/95

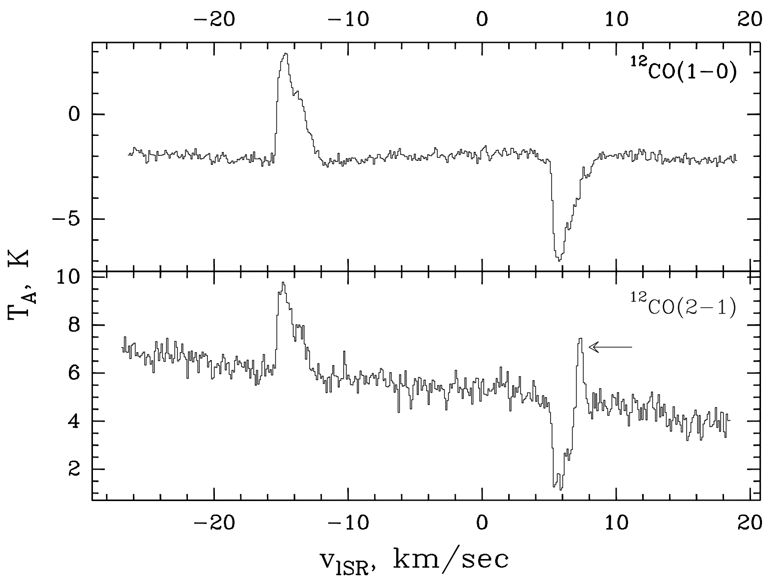

Figure 3: Frequency switched observation of CO transitions at a position in a dark cloud near the northern celestial pole. The spectra were observed with the 3 and 1 mm receivers in parallel, with frequency throws set to 7.9 and 15.8 MHz, respectively. The autocorrelator was used with 20 (40) MHz bandwidth and 20(40) kHz resolution for the 3 (1) mm transitions. Integration time is 15 min, the weather was poor (1mm opacity $\sim$ 0.6). Special optics (see text) was used to reduce the baseline ripple, but no baselines are removed. Note the presence of the mesospheric CO line (arrow) which is partially blended with the negative line from the source. Such interference can usually be avoided by changing the frequency throw.

the long phase durations do not suppress efficiently atmospheric and receiver gain variations, phase durations shorter than 1 sec are not possible with the autocorrelator. If only the 100 kHz filter spectrometer is connected, phase durations as short as 50 msec have been used successfully. At still shorter phase durations data transfer errors set in. The limits used by OBS take these problems into account, and the use of the default value (1.5 sec) is recommended. In view of the receiver instabilities which are pronounced near 1 sec, it would be desirable, however, to use significantly shorter phase durations. An upgrade of the autocorrelator microprocessor hard and/or software would make this possible.

Special Considerations

Like any other observing mode, frequency switching has its own set of special problems. Most importantly, this mode is sensitive to atmospheric line features which are efficiently canceled in other observing modes. The principal trouble maker for many observations is mesospheric CO, but other minor atmospheric constituents, like ozone, may also play a role. At 2.6 (1.3) mm, these CO lines were found to be about 0.5 (4) K strong and about 0.7 $\mathrm{km\,s^{-1}}$ wide, not unlike emission from a typical galactic dark cloud. These features can interfere either directly with the target line if the Doppler shift of the target is near zero, or interfere in other less obvious ways (see Fig. 3 for a simple example) We strongly recommend that the prospective observer checks such interference which can usually be avoided by chosing a suitable observing season. The Technical Report gives recipes on how to do this. In addition, it is planned to include in ASTRO a command which provides further help.

Another important boundary condition is that the frequency throw must be (considerably) larger than the velocity width of the target line if line cancellation is to be avoided. Since the maximum practical throw is currently about 45 $\mathrm{km\,s^{-1}}$, many potentially interesting FSw targets remain out of reach, like CO sources in the galactic plane, many circumstellar envelopes, or extragalactic lines.

A different problem arises if sources with a strong continuum are observed. On such sources, the spectroscopic baseline ripple is of more complex nature, since more than one scattering path tends to be involved. The simple trick of canceling the ripple by setting Δf equal to the ripple period does therefore not work as efficiently. But not much experience could be acquired yet on this matter.

Efficiency

Spending all time on source and avoiding the relatively long blanking times due to moving telescope components, frequency switching is the most efficient spectroscopic observing mode. A FSw scan consisting of 2 subscans of 150 sec each lasts about 320 seconds (> 90% efficiency) if the 100 kHz filter and the autocorrelator spectrometers are connected. This efficiency is more than a factor of 2 higher than that available when the main telescope or the subreflector has to be moved. Most of the overhead with FSw is due to the settling time of the ref. 2 synthesizer (blanked at 10 msec per phase) and to data transfer between backends and antenna computer.

In view of this enormous gain in observing efficiency we propose that the 30m users take frequency switching into serious consideration for their observations.

Wolfgang WILD and Clemens THUM

Call for Observing Proposals on the 30m Telescope

The *next deadline* for the submission of observing proposals for the IRAM 30 m telescope is *Tuesday, February 28th 1995.* The observing session will extend from *May 15, 1995 to Nov. 15, 1995* and cover roughly the 'summer' period at Pico Veleta. Only heterodyne receivers operating above λ1.1 mm will be available (neither the 0.8 mm SIS receiver, nor the bolometers will be installed during this session).

Roughly 3000 h of observing time will be available, which should allow scheduling of several time consuming (e.g. 90–150 h) programmes with an emphasis on 3 mm heterodyne observations (see below). No new call for 'key programmes' is issued for the session. Please, find below some relevant information as well as a copy of the proposal form.

NEWS

Recent improvements in hardware, software and mixers have made possible frequency-switching. In several test periods during 1994 the behaviour of the receivers (stability of phase lock, baseline quality, blanking time, efficiency etc.), the data acquisition, control software and system interfacing were investigated and improved. Several limitations exist e.g. in terms of frequency throw (max. 18 MHz), backends, phase times etc. For details see the report by Wild & Thum in this Newsletter. Frequency switching is now open for public use (at present, however, only with the 3 mm SIS and the 1.3 mm 230G1 receivers operating simultaneously).

The new 3mm SIS receiver can be tuned to a high rejection of the upper sideband (25-30 dB) and is much more stable for continuum observations. It is now used as the standard pointing receiver. Pointing sources with fluxes $\geq$ 0.5 Jy can generally be used. The 3 mm Continuum Schottky receiver remains in stand-by in case of a failure of the 3 mm SIS receiver.

A second 3 mm receiver is being built presently. When operational, it will be usable with the present 3 mm receiver and, with some extra losses, with receivers 230G1 and 230G2. Although simultaneous 4-receiver operation is expected to become possible before the end of the coming session, it should not be considered in the telescope time calculations.

Most proposals submitted for the 30 m telescope underestimate the observing time needed to carry out the programme, even during excellent weather. We ask you to pay special attention on this matter as time underestimation becomes a major criterium for proposal rejection. A technical report has been issued to help you (see below); you may also ask for IRAM's assistance (but only well ahead of the deadline!).

Finally, to help us keeping up a computerised source list, we ask you to fill in your 'list of objects' as explained below.

APPLICATIONS

Your applications should be addressed as usual to

IRAM Scientific Secretariat,
300 rue de la piscine,
F-38406 St Martin d'Hères, France.

All proposals should have *reached* the Secretariat by *Tuesday, February 28th 1995*, midnight. (Proposals sent by Fax will be accepted, provided they arrive by that time in a readable form; Fax (33) 76 42 54 69). Except for a duplicate of the source list (see below), no proposal should be sent by e-mail. You (i.e. the Principal Investigator) will receive by return mail an acknowledgement of reception and a proposal number.

To avoid the allocation of several numbers per proposal, send *only one* copy of your proposal, either by mail or by fax. In case your fax reaches us in time incomplete or unreadable, we will try our best to contact you (your responsibility, however).

Your proposal will only be evaluated if submitted in the correct format (these forms are available by anonymous ftp from `iraux2.grenet.fr` in directory `dist/proposal`, together with the Latex style file). Do not use characters smaller than 11pt, which would make your proposal unreadable if we had to fax it, e.g. to the members of the P.C.

On the title page, you must fill out the line 'special requirements' if you request the polarimeter, 'service observing', or specific dates for time dependent observations (if there are periods when you cannot observe for personal reasons, please specify them here; beware, however, that they could be a motive for proposal rejection!).

We *insist* upon receiving with proposals for heterodyne receivers a complete list of frequencies *corrected* for source redshift (to 0.1 GHz, unless your frequencies are confidential). You should specify which receivers you plan to use. *Note that the use of the 2 mm receiver prevents the use of the second 1.3 mm receiver 230G2, which, otherwise, can be used in parallel with receiver 230G1 (see below).*

In order to avoid useless duplication of observations and to protect already accepted proposals, we keep up a computerised list of observational targets. We ask you to fill up carefully your source list. This list must imperatively contain *all the sources you plan to observe during the coming session and only those* for which you actually request observing time. To allow optical recognition of your source parameters, your list must be typed or printed following the format indicated on the Proposal Form (please, do *not* write by hand). If your source list is long (e.g. more than 15 sources) you may print it on a separate page, *keeping the same format.*

The scientific aims of the proposed programme should be explained in 2 pages of text, maximum, plus one page of figures and tables. Proposals should be self-explanatory, clearly state these aims, and explain the need of the 30 m telescope. The amount of time requested should be carefully estimated and justified (see below); it should include pointing, focussing, and calibration checks and allow for receiver tunings (on average 20 min. per receiver).

A scientific project should not be artificially cut into several small projects but should rather be submitted as one bigger project, even if this means 100–150 hrs. This approach is all the more advisable now that we have switched to 6-month summer/6-month winter sessions.

If time has already been given to one project but turned out to be insufficient, explain the reasons, e.g. indicate the amount of time lost due to bad weather or equipment failure; if the fraction of time lost is close to 100%, don't rewrite the proposal, except for an introductory paragraph. For continuation of proposals having led to publications, please give references to the latter. *In all cases, indicate on the first page form whether your proposal is (or is not) the resubmission or the continuation of a previously submitted 30 m telescope proposal.*

OBSERVING TIME ESTIMATES

Observing time estimates must take into account:

- receiver tunings,
- pointing, focus, eventually necessary receiver alignment, continuum and line calibrations,
- telescope motions when changing sources as well as dead times due to telescope motion and/or data writing between ON and OFF subscans,
- integration time on source and comparison field(s). The total integration time should be derived using the standard formula:

$$\Delta T_{MB} = \frac{\eta_{\rm F}}{\eta_{\rm B}} \frac{2T_{\rm sys}}{\sqrt{Bt}}$$

  where $\eta_{\rm F}$ and $\eta_{\rm B}$ are the telescope forward and main beam efficiencies, $T_{\rm sys}$ is the system temperature above the atmosphere (in the antenna temperature scale), B the channel bandwidth, and t the total (ON + OFF) integration time. $T_{\rm sys}$ should be estimated for an 'average' summer humidity for 3mm, 2mm and 1.3mm observations (7 mm of precipitable water, or $\tau_{\rm zenith} = 0.5$ at 230 GHz).

A technical report explaining how to estimate the telescope time needed to reach a given sensitivity level in various modes of observation is published in this Newsletter (Guelin, Kramer & Wild). *You are asked to follow the guidelines given in this report* (or to justify particular requirements) in your proposal.

LONG PROGRAMMES

This observing session offers the opportunity to schedule a few bigger programmes (typically 90–120 h). These 'long' programmes should mostly be centered on 3 mm spectral observations and should use at least 10h/day; they should have a large astronomical interest and be well explained. Careful time estimates will be of crucial importance for their acceptance.

SERVICE OBSERVING

To facilitate the execution of short (≤8 h) programmes, we propose "service observing" for some easy to observe (e.g. single source) programmes *with only one set of tunings.* The observing will be made by the IRAM staff, according to a pre-submitted observing plan (forms will be given when proposals are accepted). Please, if you are interested by this mode of observing, specify it as a "special requirement" in the proposal form (IRAM will decide which proposals will actually go to that mode). If you are located in Spain, France, or Germany, we will try to e-mail you, via IBERPAC, TRANSPAC, etc..., the `spectra.30m` files in quasi real-time; this excludes any intervention in the execution of the programme (see below for more details, page 9).

PROGRAMMES FOR THE NOV. 94 – MAY 1995 PERIOD

A total of 149 30m telescope proposals were submitted for the deadline of October 1994. 39 proposals were rated "A", 47 "B", the others "C". About half of the proposals will actually get time on the telescope, some, however, with less time than requested. The telescope schedule until mid-March is made; the programme PIs have been or are being notified.

Principal Investigators of accepted proposals receive with the telescope schedule a *Confirmation of Observing Time* form which we ask you to return, properly filled, by Fax to IRAM Granada *and* IRAM Grenoble (Scientific Secretariat, Fax (33) 76 42 54 69, attention Mrs. C. Berjaud). The list of frequencies to be observed (normally, the same as in the proposal) should arrive in Granada at least two weeks in advance. It is also only after we receive your confirmation in Grenoble that we will send out duly signed travel forms to those of you entitled to travel reimbursement.

If you have questions, please contact Mrs. C. Berjaud at IRAM Grenoble.

RELEVANT INFORMATION ABOUT THE 30 M TELESCOPE

(Please, see additional information in the IRAM Newsletters and in the internal reports listed below).

Receivers

The IF bandwidth of all heterodyne receivers is 500 MHz. The following table lists the possible receiver combinations:

Receivers	3-Rx Combinations	
3mm-SIS	*	*
2mm		*
230G1	*	*
230G2	*	

3 mm Continuum Receiver

This receiver is not used at present since the 3 mm SIS receiver is more sensitive and stable enough for continuum pointing. The Schottky receiver is in stand-by and will be put into operation in case of a failure of the 3 mm SIS receiver.

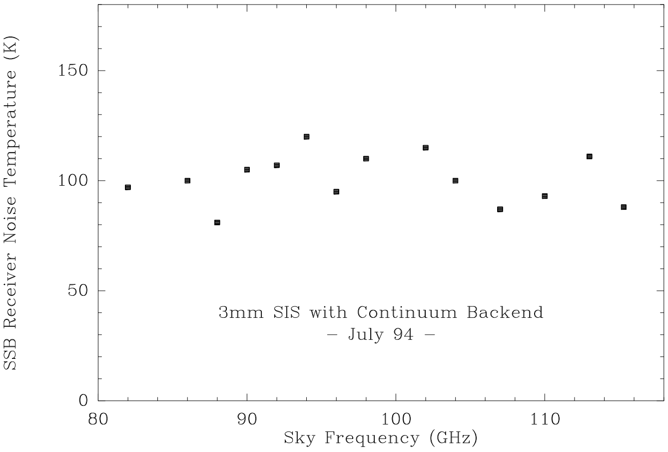

Figure 4: Performance of the 3mm SIS receiver

3 mm SIS receiver

(tuning band: 85 - 116 GHz).

This receiver is much more stable since its mixer has been exchanged in July 1994. Receiver temperatures are between 80 and 120 K (see Fig. 4), the image sideband rejection is between 25 dB and 30 dB.

The high rejection of the USB improves the system temperature and the calibration accuracy, particularly for 115 GHz observations, for which the receiver image sideband sees the bright oxygen 118.75 GHz atmospheric line.

It is important to check your calibration on strong reference sources (see IRAM line catalog and updates). Beware also of possible interference between the 'second' 1.3 mm receiver, 230G2, and this receiver when operating at harmonic frequencies (the two receivers receive the same polarization; the interference will be a strong and narrow line).

2 mm Receiver

Good and reliable performance over most of the band. Tunable from 130 GHz to 180 GHz with SSB receiver temperatures of 70 to 150 K (130 to 155 GHz), and 150 to 400 K (155 to 180 GHz).

1.3 mm heterodyne Receivers

- 230G1:

  Operating band: 203.4 – 250 GHz. Between 203 and 245 GHz, the SSB receiver temperature is 100 – 180 K in the standard reference plane.

- 230G2:

  This receiver has been equipped with a new mixer in February 1994. The SSB receiver temperature over the nominal tuning range (210–250 GHz) is 100–130 K in the standard reference plane. The upper side band can be rejected by typically $\gtrsim$ 16 dB over this range. This receiver can be tuned to 267 GHz, although with a higher noise temperature ($T_{\rm SSB} \sim$ 600 K). See the March 1994 Newsletter for more details.

The two 1.3 mm receivers and the 3 mm SIS receiver can be used simultaneously. Beware, however, of possible interference of the 230G2 LO into the 3 mm receiver. *The 230G2 receiver cannot be operated with the 2 mm receiver*, since both receivers use the same control box and polarization. Switching from one receiver to the other is not straightforward and will not be made upon request in real time. Please specify in the proposal form whether you choose to use the 2 mm receiver or 230G2.

At 1.3 mm (and *a fortiori* at shorter wavelengths) a large fraction of the receiver radiation pattern is distributed in an error beam (which can be approximated by two Gaussians of HPW $\simeq 170''$ and $800''$ — see A&A 274, p.144-146 for more details). Astronomers should take into account this error beam when converting antenna temperatures into brightness temperatures.

Polarimeter

A polarimeter has been constructed by IRAM for measurements of *circular* polarization. It has been tested on the telescope in February 1994. The results of the test are available in the March 1994 issue of this Newsletter. The main technical features of the polarimeter are briefly described below.

The polarimeter consists of a dielectric quarter-wave plate working in transmission. It is rotated between two positions at $\pm 45^o$ by a motor, the switching time is $\simeq 0.3s$, and the phase time is adjustable. From the point of view of data acquisition, it functions like other switching devices, i.e. the chopper or the wobbler, and the *difference* between the RCP and LCP intensities is acquired.

The present quarter-wave plate has been designed for 113.3 GHz. Its transmission loss is $\simeq 2\%$, and its cross-polarization below 20 dB. Similar plates could be fabricated for other frequencies if needed. Proposals for projects requiring the polarimeter can be submitted. They should state clearly the degree of performance that they demand from the technical side. Besides the scientific evaluation, the acceptance and scheduling of such proposals will depend on their feasibility as judged from their requirements.

General point about receiver operations

We urge observers to restrict their frequency lists as much as possible and to send them early to Granada and Grenoble. For late arrivals (less than 2 weeks in advance), or a large number of frequencies, there is no guarantee for a prior test of the requested tunings.

Service observing

"Service observing", with the PI staying at his home institute, is possible upon request for some programmes (of less than 8 hours, with only one set of tunings and few sources or positions to be observed). Observations are made by the local staff (operators helped by the astronomer-on-duty or by a member of the investigator's institute present at the telescope for his/her own observations). We will try to send you the `spectra.30m` data-files and the two pages of the OBS monitor if your computer allows it (Spain, France or Germany only, so far). This is a passive way of observing, no direct interaction with the telescope through OBS being possible. For this type of observation, we request an acknowledgement of the IRAM staff member's help in the forthcoming publication.

Backends

There are 6 backends which can be individually connected to any receiver.

- The *1_1MHz* filter bank, consisting of 512 channels of 1 MHz (can be split into two halves and connected to two different receivers);
- The *2_1MHz* filter bank, consisting of 512 channels of 1 MHz (not splittable);
- The *100kHz* filter bank, consisting of 256 channels of 100 kHz (splittable into two halves movable inside the 500 MHz instantaneous bandwidth, and connectable to two different receivers)
- The 500 channel *AOS*: [*currently the AOS is out of operation because of a hardware failure. Waiting for spare parts.*]
  Bandwidth 500 MHz; actual spectral resolution 1.5 MHz. Using the AOS with the 3 mm SIS receiver results in higher noise at the band edges, so the combination 3 mm SIS + AOS is not recommended.

- The *AUTO* autocorrelator: The software treats the autocorrelator as one unit although physically it consists of two identical machines. The following numbers are to be understood for the complete autocorrelator setup. Available resolutions are 10, 20, 40, 80, 320 and 1250 kHz. The bandwidth is between 20 MHz and 2 × 512 MHz, depending on resolution. The correlator can be split into 8 independent subbands, each of which can be configured individually and connected to the same or different receivers. For the larger bandwidths (i.e. more than one subband of 80 MHz) a problem of platforming may exist (i.e. baselines from the different subbands have slightly different levels).

Pointing / Focussing

Pointing sessions are made every one to two weeks; at present, the fitted pointing parameters yield an absolute pointing accuracy better than $3''$ (r.m.s.). We also try to keep the receivers as closely aligned as possible (to about $2''$, however, alignment can be lost occasionally). Checking the pointing, focus, and receiver alignment is the responsibility of the observers (use a planet for alignment checks). Note that 230 G2 and 230 G1 have foci differing by 0.4 mm. Using both receivers, you should carefully monitor the focus and choose a compromise value. Not doing so may result in broadened beams (e.g. HPW $15''$ and non-gaussian beams on one receiver [2]).

Wobbler

- Beam-throw: from 0 to $240''$ on either side of the source (avoid small amplitudes for line work).
- Standard phase duration: 2 s for spectral line observations.

Calibrated spectral lines

We are continuing a number of line calibrations at the higher frequencies (2 mm and 1.3 mm, similar to the Mauersberger et al. catalog) and calibrations for redshifted CO lines. These calibrations are made with precisely known rejections.

REFERENCES

1 Receiver tests during the August 1992 period
M. Carter, J.Y. Chenu, H. Hein, S. Navarro, A. Greve, M. Guélin (Sept 92)

2 Appendix I: Error beam and side lobes of the 30 m telescope at 1.3 mm, 2 mm and 3 mm wavelength
in: Molecular Spiral Structure in Messier 51, S. Garcia-Burillo, M. Guélin, J. Cernicharo 1993 Astron. Astrophys. **274**, 144-146.

3 A Small Users' Guide to NOD2 at the 30m telescope
A. Sievers (Feb. 1993)

4 Thermal behaviour of mm-wavelength radio telescopes
A. Greve, M. Dan, J. Penalver 1992 (IRAM report 233)

5 Interferometric measurement of tropospheric phase fluctuations at 86 GHz
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6 Thermal design and thermal behaviour of Radio Telescope structures
A. Greve 1992 (IRAM report 253)

7 Astigmatism in reflector antennas: measurement and correction
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8 Design parameters and measured performance of the IRAM 30-m millimeter radio telescope
J. Baars, A. Greve, H. Hein, D. Morris, J. Penalver, C. Thum 1993 (IRAM report 298).

9 Frequency switching at the 30m telescope
W. Wild, C. Thum (IRAM newsletter Jan. 1995)

10 Cookbook formulae for estimating observing times at the 30m telescope
M. Guélin, C. Kramer, W. Wild (IRAM Newsletter Jan 1995)

These reports are available upon request (see also previous Newsletters). Please write to Mrs. C. Berjaud, IRAM Grenoble.

Michel GUÉLIN, Wolfgang WILD

Call for Observing Proposals on the Plateau de Bure Interferometer

Observing proposals are invited for the IRAM Plateau de Bure Interferometer (PdBI), for the period *May 15, 1995 to Nov. 15, 1995.* The deadline for applications is *Tuesday, February 28th 1995.* The available frequency range will be 82 GHz to 116 GHz.

Details of the PdBI and operations are given in the document "An Introduction to the IRAM Plateau de Bure Interferometer" (copies can be obtained from the address below, or from Internet via the World-Wide-Web and NCSA-Mosaic software; use IRAM homepage `http://iram.fr/www/iram.html`). Proposers should read this document carefully before submitting any proposal.

Proposals should be sent to

IRAM Scientific Secretariat
Interferometer Observing Proposal
300 Rue de la Piscine
F-38406 Saint Martin d'Hères Cedex
FRANCE

IRAM expects to schedule and complete between 20 to 30 projects in this period, with an elapsed time of at least two months between start and end of any given project. Selection will be based on scientific merit, technical feasibility, and adequacy to the instrument.

For this call for proposal, please note the following specificities:

Very long baselines Phase stability precludes the use of the longest East-West baselines. Standard "high resolution" (BC configuration) may be feasible at night time, but cannot be guaranteed. Moreover, work is required this summer to complete the West and North track extension. This may render station N20 unavailable for some time.

230 GHz receivers Average precipitable water vapor in this period normally precludes 230 GHz observations during the summer period. Accordingly, 230 GHz proposals will not be considered for this period.

However, as an exception, dual-frequency proposals (i.e. proposals in which both the 3mm and 1.3 mm receivers are used) will be considered, under the following restrictions:

- The source should be observable at night during the September to November months.
- 1.3 mm data should not be critical to the success of the project (i.e. the 3mm project should be self-sufficient)
- IRAM will not provide any guarantee of results for the 1.3 mm project.

3 Antenna time As usual in summer time, major maintenance will be carried out, leaving the array with only 3 antennas for one to two months. Projects which can make use of this 3 antenna time, such as detection experiments, are encouraged.

Other relevant information is also given below:

Change of scheduling periods: IRAM has changed to issuing 2 calls for proposal per year, instead of 3. The two scheduling periods are 15-May to 15-Nov ("Summer Period") and 15-Nov to 15-May ("Winter Period").

Configurations: Two sets of configurations will be available. The "CD" (compact) array is obtained with 3 configurations, and the "BC" (high resolution) array with 4 configurations, with two configurations in common.

We insist that authors specify and *carefully* justify the requested configuration choice.

Many proposals have been received with insufficient noise estimates. In many cases, a better result can be obtained using lower angular resolution. Combination of all configurations (BCD, 5 configurations in total), is possible, but must be even more justified.

Coordinates and Velocities: The interferometer now operates in the J2000.0 system. For best positioning accuracy, source coordinates *must* be in the J2000.0 system; position errors up to $0.3''$ may occur otherwise.

Please do not forget to specify LSR velocities for the sources. For pure continuum projects, the "special" velocity `NULL` (no Doppler tracking) can be used.

Correlator: The correlator has 6 independent units, each being tunable anywhere in the 130-610 MHz band, and providing 4 choices of bandwidth/channel configuration: 160 MHz/64, 80 MHz/128, 40 MHz/256 and 20 MHz/256. For the 40, 80 and 160 MHz bandwidth, the two central channels may be perturbed by the Gibbs phenomenon (depending on continuum strength): it is recommended to avoid centering the most important part of the lines in the middle of the band of the correlator unit.

Receivers: In the 3 mm band, receivers offer best performances in Lower sideband, with high rejection (10 to 20 dB). Below 100 GHz, expected system temperatures are (T_r^*) 150 K to 200 K for the summer period. DSB tuning is possible also below 100 GHz, but not guaranteed above 100 GHz.

The 1.3 mm receivers are expected to give $T_{\rm rec}$ = 80K, with DSB tuning.

Sun Avoidance: For safety reasons, the sun avoidance circle has been extended to 45 degrees. Please take this into account for your sources AND for the calibrators.

Mosaics: The PdBI has mosaicing capabilities, but the pointing accuracy may be a limiting factor at the highest frequencies. Please contact S.Guilloteau in case of doubts.

Data reduction: Proposers should be aware of constraints for data reduction:

- In general, data will be reduced **in Grenoble**. Proposers will not come for the observations, but will have to come for the reduction.
- We keep the data reduction schedule very flexible, but wish to avoid the presence of more than 2 groups at the same time in Grenoble. Please contact us in advance.
- IRAM may consider splitting the data reduction in two phases: intermediate calibration and final mapping. Such a splitting is often absolutely necessary for the high resolution images. In such a case, the proposers must be ready to come at IRAM for fast data reduction of the "compact" configurations.
- CLIC is still evolving fast to cope with the evolution of the PdBI array. The newer versions are upward compatible with the previous releases, but the reverse is not true. Observers wanting to finish data reduction at their home institute should obtain an updated version of CLIC, which is now available. Since CLIC maintenance is a heavy and tricky task, we insist that observers having a copy of CLIC take special care in maintaining it up-to-date.

Data reduction will be carried out on the dedicated HP workstation.

Local contact: Depending upon the program complexity, IRAM may require an in-house collaborator instead of the normal local contact.

Technical pre-screening: All proposals will be reviewed for technical feasibility in parallel to being sent to the members of the program committee. Please help in this task by submitting technically precise proposals. Scientific justification should be kept within 2 pages. Note that your proposal must be complete and exact: velocities, position and frequency setup must be exactly specified.

Non-standard observations:
Please contact S.Guilloteau in case of doubt about non-standard program feasibility.

The documentation for the IRAM Plateau de Bure interferometer includes documents of general interest to potential users:

- An Introduction to the IRAM Plateau de Bure Interferometer.
- IRAM Plateau de Bure Interferometer: Calibration CookBook.
- IRAM Plateau de Bure Interferometer: Mapping CookBook.
- IRAM Plateau de Bure Interferometer: Frequency Setup.
- CLIC: Continuum and Line Interferometer Calibration.

More specialized documents are also available; they are intended to observers on the site (IRAM on-duty astronomers, operators, or observers with non-standard programs):

- IRAM Plateau de Bure Interferometer: OBS Users Guide.
- IRAM Plateau de Bure Interferometer: Amplitude Calibration.
- IRAM Plateau de Bure Interferometer: Flux Measurements.
- IRAM Plateau de Bure Interferometer: Pointing Parameters.
- IRAM Plateau de Bure Interferometer: Trouble Shooting Guide.

All documents can be retrieved on Internet via the World-Wide-Web and NCSA-Mosaic softwares. IRAM homepage is `http://iram.fr/www/iram.html`

Finally, we would like to stress again the importance of the quality of the observing proposal. The technical preparation of observing proposals is unfortunately often insufficient. In the past, proposals were received which did not even include exact observing frequencies or even source coordinates, or worse, with coordinates with the wrong epoch !... The IRAM interferometer is a powerful, but complex and unique instrument, and proposal preparation requires special care. Information is available in the documentation, and the IRAM staff can help in case of doubts if contacted well before the deadline. Note that the proposal should not only justify the scientific interest, but also demonstrate how the Plateau de Bure interferometer will bring new information.

Stéphane GUILLOTEAU

Scientific Results

DENSE GAS IN NEARBY GALAXIES IX. A SURVEY FOR HNC

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(3) Observatoire de Bordeaux, BP 89, F-33270 Floirac, France
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(5) DEMIRM, Observatoire de Paris, Section de Meudon, F-92195 Meudon, France
(6) Mathematics Department, UMIST, PO Box 88, Manchester M60 1QD, UK

Abstract: Ten detections and five tentative detections of hydrogen isocyanide) $J = 1 - 0$ emission are reported from a survey including sixteen galaxies. Full maps are presented for the nuclear regions of NGC 253 and IC 342, partial maps for Maffei 2, M82, and M83. Toward IC342, the HNC and HCO^+ distributions differ from those observed in ^{12}CO, ^{13}CO, HCN, CS, and NH_3. This is likely a consequence of the density structure. Relative HNC abundances are with $10^{-1} - 10^{-9}$ much smaller than those measured in nearby dark clouds and appear to be slightly smaller than those in regions of massive star formation of the Galactic disk. This is consistent with the presence of dense warm gas or a frequent occurrence of shocks in the nuclear regions of the galaxies observed. As in prominent Galactic star forming regions, 3 mm HNC line emission tends to be weaker than the corresponding emission from HCN and HCO^+. Toward Arp 220, however, the 3 mm HNC/HCN line intensity ratio is > 1. HNC/HCO^+, HNC/CO, and HNC to 20 cm radio continuum luminosity ratios are also particularly large. A possible interpretation is the presence of cool quiescent gas outside the central region which contains the starburst. In the other ultraluminous galaxy observed, NGC6240, $X(\mathrm{HNC}) < 10^{-10}$. This is a factor of > 10 smaller than in Arp 220, demonstrating that the molecular composition in ultraluminous galaxies is far from being uniform. HNC/CN and HNC/CS abundance ratios are of order 0.1. The CN abundances are smaller than expected for an interstellar medium which is often considered to be 'chemically young'.

CO, HCO^+ AND HCN ABSORPTION IN THE GRAVITATIONAL LENS CANDIDATE B0218+357 AT $z = 0.685$

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Abstract: Absorption lines of CO(1–2), CO(2–3), HCO^+(1–2) and HCN(1–2) have been detected at a redshift of $z_\mathrm{a} = 0.68466$ towards the background BL Lac object B0218+357. The CO and HCN lines are strongly saturated, while the HCO^+ line is mildly saturated (Fig 5). Lower limits to the column densities are $(7.0 \pm 0.3) \times 10^{16}\,\mathrm{cm}^2$ for CO, $(7.4 \pm 0.2) \times 10^{13}\,\mathrm{cm}^2$ for HCO^+ and $(1.4 \pm 0.1) \times 10^{14}\,\mathrm{cm}^2$ for HCN. The filling factor for the background source is larger than 0.7–0.8. The absorption line profile is asymmetric with a width of $\sim 30\,\mathrm{km\,s}^{-1}$. B0218+357 is a gravitational lens candidate with two compact continuum sources separated by 335 mas (1.8 kpc). The small linewidth of the molecular absorption puts constraints on the inclination and position angle of the lensing galaxy. We also report a search for QSOs molecular absorption lines in 12 other redshifted systems; none were detected.

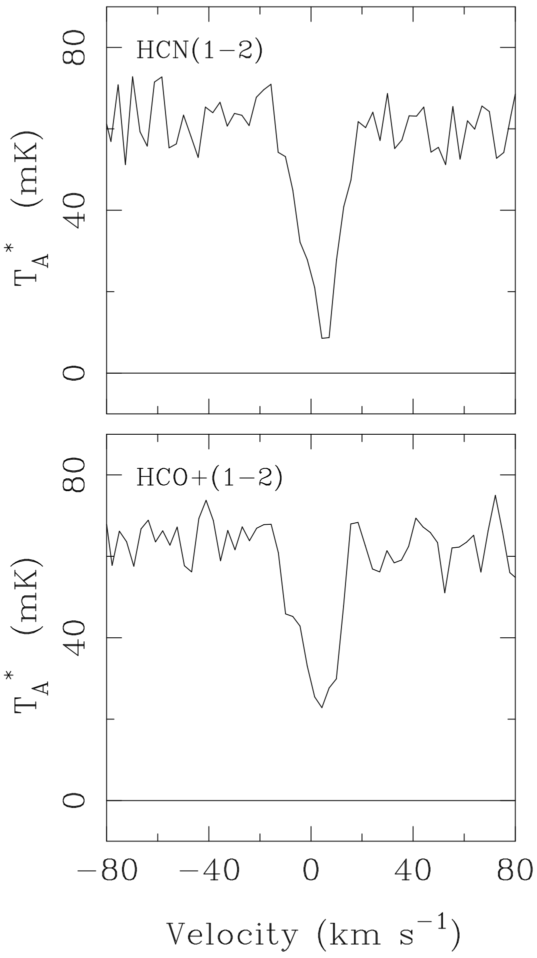

Figure 5: Low resolution spectra of a) HCN ($J = 1-2$), $\Delta v = 2.83$ km s^{-1}, and b) HCO^+, $\Delta v = 2.85$km s^{-1}, towards B0218+357. The velocity scale in heliocentric and centered at $z_a = 0.68466$

λ6cm and λ2mm H_2CO Absorption Toward Compact Extragalactic mm-wave Continuum Sources

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Abstract: We have observed galactic λ6cm and λ2mm ortho- and para-H_2CO absorption along lines of sight toward and around compact extragalactic mm-wave continuum sources (Fig. 6). From comparison of on and off-source λ6cm profiles it is possible to derive the anomalous excitation temperature, which is surprisingly close to the temperature of the cosmic microwave background in several cases. The λ2mm absorption profiles show that the ortho/para ratio is 3-4, which (taken alone) favors formation either on grains at $T_{\rm K} > 20$ K or at comparable temperatures in the gas phase. However the abundance of H_2CO, as with other species, is probably too high at low extinction to be explained by any known process; we find $N(H_2CO)/N(^{13}CO) \sim 10^{-2}$ for $N(^{13}CO) \sim 10^{14}{\rm cm}^{-2}$.

The distorted kinematics of Molecular Gas in the center of NGC 891

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(2) IRAM, Grenoble (France)

Abstract: The center of the edge-on spiral galaxy NGC891 has been mapped in the J=2–1 and J=1–0 transitions of ^{12}CO using the IRAM 30m telescope, with spatial resolutions of 13" and 21" respectively. The kinematics of molecular gas in the inner regions of the galaxy is particularly distorted. The position-velocity diagram (p-v) taken along the kinematical major axis of NGC891 is strikingly similar to the Galaxy's longitude-velocity plot (l-v). As in our Galaxy, we have detected in NGC891 molecular gas circulating at velocities 'forbidden' by a law based only on circular rotation.

Following the work of Binney et al. (1991) on the interpretation of our Galaxy's CO l-v diagram, we have developed a model on the gas kinematics of the inner regions of NGC891 that explains satisfactorily the major features of the CO p-v diagram. In our model, the flow of molecular gas is driven by a bar that has corotation at r$\sim$3 kpc and that is viewed at an angle $\alpha \sim 45\,^{\circ}$ from its major axis. Molecular clouds circulate along x_2 orbits (elliptical orbits perpendicular to the bar) between the two Inner Linblad Resonances (ILR), and partly populate x_1 orbits (ellipses parallel to the bar) in the outer regions (from the outer ILR up to the corotation circle). We can also explain the radial distribution of molecular gas: the great ring of molecular material at r$\sim$4.5–6 kpc might be associated with the Outer Linblad Resonance of the bar (OLR) and the adjacent hole of molecular gas inside this radius, with the corotation circle.

The observed kinematics of molecular gas in the center of the edge-on spiral NGC5907, as well as a number of other galaxies, could be also interpreted in terms of highly elliptical orbits driven by bars or triaxial potentials.

Carbon Monoxide Outgassing from Comet P/Schwassmann-Wachmann 1.

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(3) Observatoire de Bordeaux, BP 89, F-33270 Floirac, France

Abstract: P/Schwassmann-Wachmann 1 is a peculiar comet on a nearly circular orbit at $\simeq$ 6 AU from the Sun. It undergoes strong, unpredictable outbursts which cannot be explained by water sublimation at this large heliocentric distance. The recent detection of the $J(2-1)$ line of CO at the JCMT (Senay & Jewitt 1994, *Nature* **371**, 229) suggested that carbon monoxide may be responsible for this activity.

We observed the $J(2-1)$ and $(1-0)$ lines of CO in comet P/Schwassmann-Wachmann 1 at IRAM 30-m with high spectral resolution at four different epochs. The line profile is dominated by a very narrow (0.14 km sec^{-1} FWHM) component blueshifted by 0.48 km sec^{-1}, with a fainter component redshifted at 0.30 km sec^{-1} (Fig. 7). We infer that CO is preferentially outgassed from the day side of the nucleus, percolating through a porous mantle of ice or dust rather than sublimating from pure exposed ice. From the line width of the narrow component and from the line intensity ratio of the two lines we estimate cold ($\simeq$ 10 K) kinetic and rotational temperatures. The CO production rate, $\simeq 5 \times 10^{28}$ sec^{-1} in this distant comet and comparable to that of P/Halley near the Sun, is high enough to explain the release of dust and its activity observed in the visible.

(To be published in ICARUS)

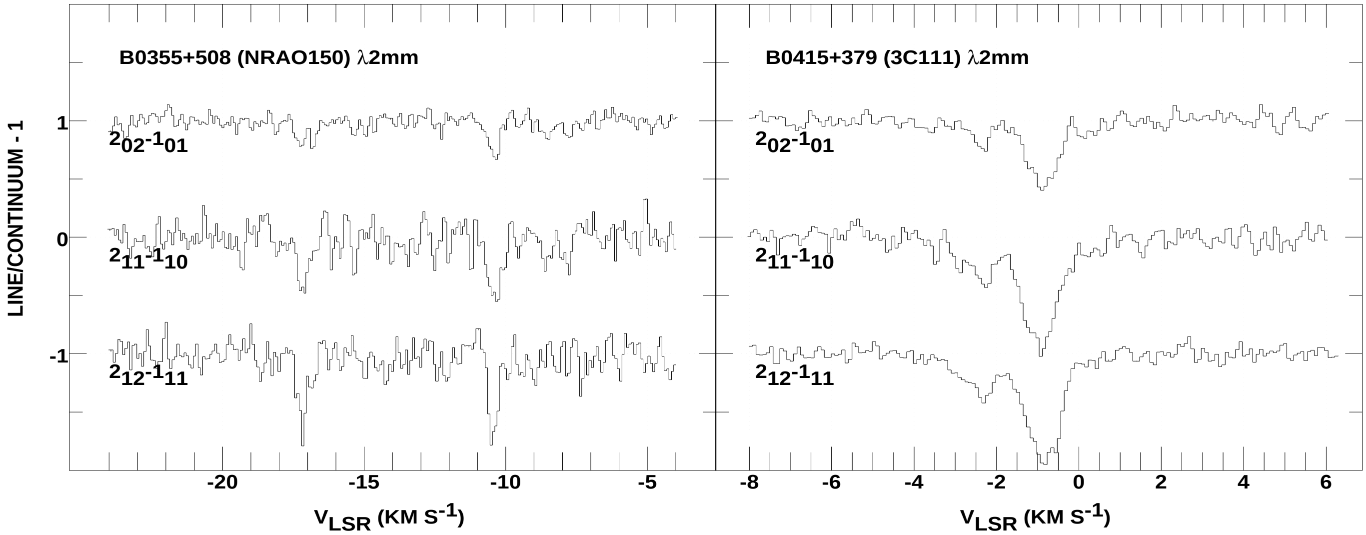

Figure 6: λ2mm para $(2_{02}-1_{01})$ and ortho absorption line profiles toward two sources.

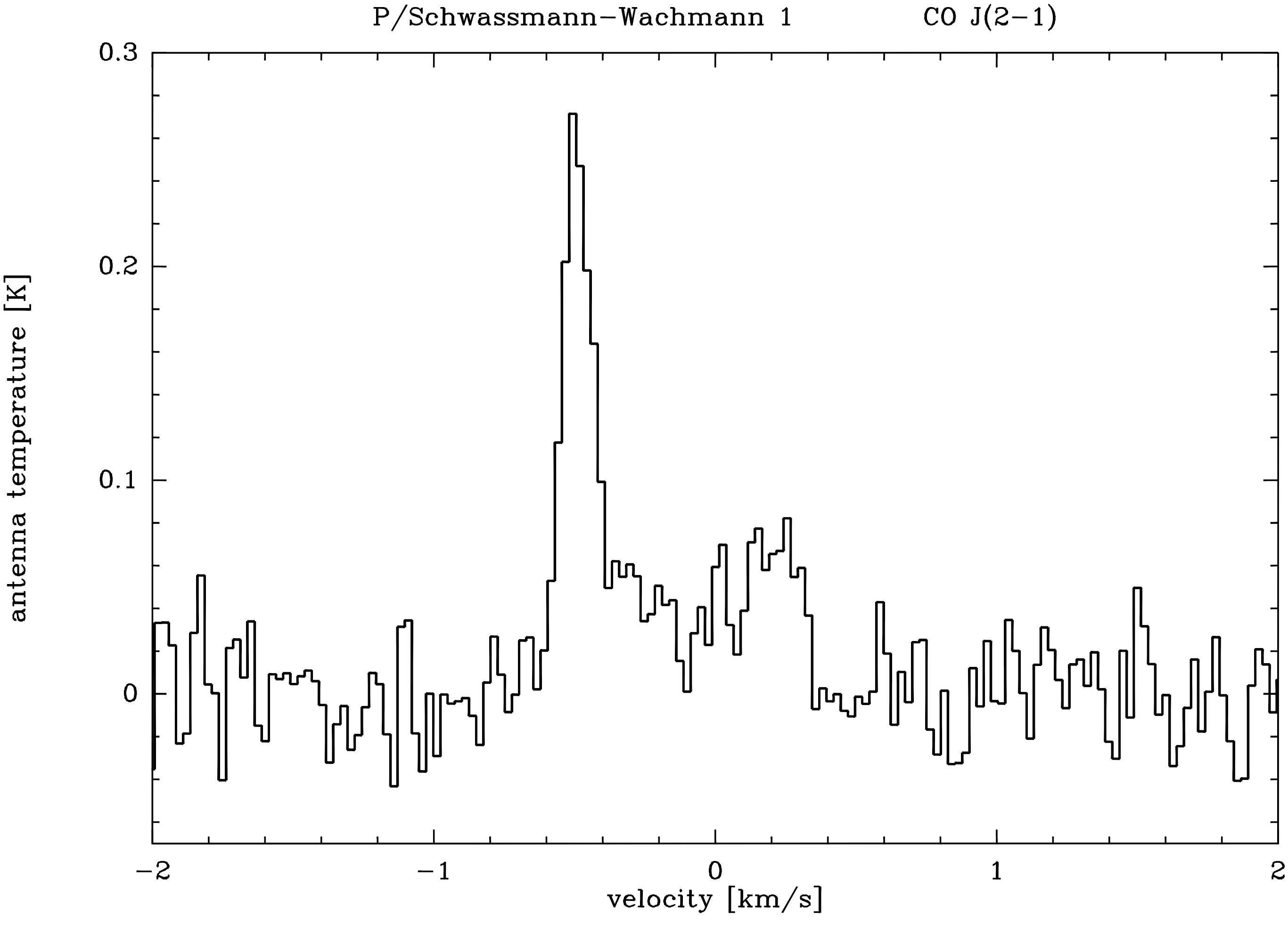

Figure 7: The CO $J(2-1)$ observed at the IRAM 30-m telescope in comet P/Schwassmann-Wachmann 1 (average of Sept. 3-4 and Oct. 4-5 1994). The velocity scale is with respect to the comet frame of rest.

New Preprints

The following preprints are available from IRAM:

340. Plateau de Bure Observations of IRC+10216 : High sensitivity observations of SiC_2, CSiS, and CS
R. Lucas, M. Guélin, C. Kahane, P. Audinos, J. Cernicharo
1994, presented at the Conference on Circumstellar Matter, Edinburgh, Aug 29th - Sep. 2nd.

341. Dense gas in nearby galaxies IX. A survey of HNC
S. Huettemeister, C. Henkel, R. Mauersberger, N. Brouillet, T. Wiklind, T.J. Millar
1994, to be published in Astronomy and Astrophysics.

342. Disk-like structures around young stars
P. André
to appear in the proceedings of the 10th IAP Meeting, Circumstellar Dust Disks and Planet Formation, July 4-8, 1994.

343. Low-mass protostars and protostellar stages
P. André
1994, presented at the Conference on Circumstellar Matter, Edinburgh, Aug 29th - Sep. 2nd.

344. CO, HCO^+ and HCN absorption in the gravitational lens candidate B0218+357 at $z = 0.685$
T. Wiklind, F. Combes
1994, to be published in Astronomy and Astrophysics.

Cookbook Formulae for Estimating Observing Times at the 30m Telescope

FOREWORD

Estimating the telescope time needed for a scientific programme is obviously the task and responsibility of the investigators. There are no absolute rules for such an estimation, as it depends, besides the expected signal strength and S/N ratio, on the line width, the requested baseline quality, the pointing and calibration accuracies, etc... Experience, however, shows that many observers grossly underestimate even the time needed for standard quality observations during good weather. Since time underestimates may result in 6-12 month delays in the derivation of usable results (or, worse, in the publication of inconclusive results), as well as in an increased bureaucracy, everyone's interest is to prevent them as much as possible. The following gives some simple examples and formulas aimed at helping you to make realistic time estimates. They are in no way, however, rules, and should not curtail your own personal experience. Note that IRAM and the IRAM Programme Committee realize fully that a (slight) overestimation of the time needed to carry out a programme is preferable to the reverse. The rating of programmes is done accordingly.

TELESCOPE EFFICIENCIES

In order to estimate the observing time needed to detect a signal of a given intensity, its flux density S_d (or 'beam averaged brightness temperature' $T_{\rm mb}$) has to be converted in antenna temperature units. This is done e.g. by multiplying S_d or $T_{\rm mb}$ by the telescope efficiency. Different efficiencies should be used, depending on the size of the source relative to the telescope beam: the aperture efficiency $A_{\rm eff}$, the main-beam efficiency $B_{\rm eff}$, the 'Moon' efficiency $M_{\rm eff}$. Another relevant efficiency is the 'telescope forward efficiency' $F_{\rm eff}$, which depends on the coupling of the 'receiver' with the cold sky, and which can be measured during excellent weather conditions by tipping the antenna (SKYDIP –beware however that your $T_{\rm cold}$ is correct!).

The various efficiencies are listed in columns 4–6 of Table 1. The aperture efficiencies were derived from continuum cross scans of Mars and Uranus carried out between March, 17th and August, 15th, 1994. The planetary diameters during this period ranged between $3.5''$ and $5.5''$. A (theoretical) correction was made for the antenna gain-elevation dependence. This correction was at most 7% for this data set.

The third and last columns of Table 1 give the telescope half-power beamwidth and the flux density to antenna temperature ratio for a point source, S_ν/T_A^* (in Jy/K). This latter is calculated from the formula $S_\nu/T_A^* = 3.91 \times F_{\rm eff}/A_{\rm eff}$, where the numerical factor stands for $2k/Area$. Values for the Moon efficiency $M_{\rm eff}$ are in preparation. Note that in order to convert the 'antenna' temperatures T_A^* given by OBS into main-beam averaged 'Raleigh-Jeans brightness temperatures' (or 'radiation' temperatures), $T_{\rm mb}$, the former have to be to be multiplied by $B_{\rm eff}/F_{\rm eff}$ (assuming the source does not extend outside the telescope main beam).

Table 1: 30m Telescope efficiencies

Receiver	Freq. [GHz]	HPBW θ_b [$''$]	Aperture eff. $A_{\rm eff}$	Main beam eff. $B_{\rm eff}$	Forward eff. $F_{\rm eff}$	Jy/K
3mm SIS	90	27	0.60	0.75	0.92	6.0
	100	24	0.58	0.70	0.92	6.2
	110	22	0.57	0.68	0.92	6.3
2mm SIS	130	18	0.47	0.58	0.90	7.5
	150	16	0.43	0.52	0.90	8.2
	160	15	0.41	0.50	0.90	8.6
1.3mm G1 SIS	220	10.9	0.35	0.41	0.86	9.6
	230	10.4	0.32	0.39	0.86	10.5
	240	10.0	0.29	0.37	0.86	11.6
0.87mm SIS	340	9	0.11	0.18	0.75	26.6

Note: The conversion from T_A^* to T_{mb} is done via $T_{\rm mb} = (F_{\rm eff}/B_{\rm eff}) \times T_A^*$.

RECEIVER CHARACTERISTICS

The 'receiver' includes the cryostat (windows, horn, mixer,...) and some optics (LO injection system, dichroic diplexer allowing to separate rays of different wavelengths, polarisation grids,..). The telescope also consists of optical parts (primary and secondary mirrors, Nasmyth mirrors). In the following, we will include in the 'receiver' all the optics between the cryostat and a 'standard reference plane' located just outside the first polarization grid (i.e. located between this grid and the telescope vertex) and 'telescope' all the optics beyond this plane. Receiver temperatures are normally measured by holding HOT/COLD loads in this plane.

As of today (Oct 1994) the receiver characteristics shown in Table 2 apply (or are expected for next winter).

Table 2: Receiver characteristics

Freq(GHz):	86	95	110	115	140	150	165	175
Rx(SIS):	3mm	3mm	3mm	3mm	2mm	2mm	2mm	2mm
Inst. BdW (GHz)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
USB Rjn: (dB)	> 20	> 20	> 20	> 20	6	6	> 10	> 10
T_{rec} (K):	110	110	110	110	110	120	300	500

Freq(GHz):	205	220	230	245	265	320	345	360
Rx(SIS):	230G1 -	230G1 230G2	230G1 230G2	230G1 230G2	- 230G2	345	345	345
Inst. BdW (GHz)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
USB Rjn(dB):	10 -	10 > 10	10 > 10	10 > 10	- > 10	0	0	0
T_{rec} (K)	140 -	120 100	140 120	200 240	- 400	80	95	150

Note: The receiver temperatures quoted here include the losses and noise introduced by the LO injection diplexer, the dichroic mirror and the polarization splitter.

The above receiver temperatures are relative to the 'standard reference plane', just outside the first polarisation splitter. They include the cross polarisation losses, as well as the ohmic and spillover losses between the receiver window and this plane, but assume that the 'dichroic mirror' (which allows the simultaneous operation of 3 receivers) is optimized for this particular receiver. It is possible to optimize correctly the 3mm and 230G1 receivers simultaneously when their operating frequencies are the double (or the triple) of each other. The usual rule is then to optimize 230G1 (which is more critical). The losses in the dichroic diplexer are then $L_{\text{dic}} = 0.05$; their contribution is already included in the T_{rec} above. If both frequencies are not exact multiples, typically 5-10 K (an extra $L_{\text{dic}} = 0.02 - 0.03$) should then be added to the T_{rec} of the 3mm receiver.

When the frequencies of the 3mm and 230G1 receivers are neither double or triple of each other, high losses (L_{dic}) may occur. When optimizing 230G1, the 3mm receiver temperature can be increased (for some unfavorable cases, like 90/230 GHz) by 30-40 K (L_{dic}=0.1-0.13). When optimizing the 3mm receiver, T_{rec} of 230G1 can be increased by more than 200 K and this receiver may become practically useless. The reader is referred to IRAM internal report [1] for details.

Note that the receiver temperatures calculated by 'OBS' and plotted on the 'RED' screen can be somewhat larger (e.g. 10 K) for some backends (e.g. 1_1M) than the actual values, due to *i*) bad channels and interferences, and *ii*) a slight offset of the channels' zeros. The continuum backends and the autocorrelators gives usually the best estimations of the receiver temperatures.

Simultaneous observations with 2 or 3 receivers may result in interferences (e.g. beatings of the LO of receiver A coming into the band of receiver B). To avoid spurious signals, it is advisable to make long integrations with at least 2 different LO settings.

RECEIVER TUNINGS

The time needed to tune a receiver varies from 15 min to 30 min, depending on whether one wants to check the USB rejection by injecting a line, whether the tuning has been prepared, etc... To be on the safe side, count 20min (0.33h) for tunings and 12min (0.2h) for slight retunings.

BACKEND CHARACTERISTICS

The versatility of the IF distribution box allows a large flexibility in the use of the 30-m telescope backends (splittable 100 kHz and 1 MHz filterbanks, autocorrelators, AOS). This allows an optimum frequency resolution for most programmes.

Normally, the filter banks add very little noise to the receivers. The filters have rectangular shapes with widths very close to 1 MHz. Their spacing is also close to 1 MHz.

In the case of the autocorrelators, a number of bandwidths (20-520 MHz) and channel resolutions (from 10 kHz up) can be achieved. It should be noted however that the bandwidths larger than 80 MHz are made up of several subbands the baselines of which can be slightly offset from one another after a long integration (mostly when position switching against a continuum source). It is often advisable to make the observations with different centering of the autocorrelators to monitor these effects. The autocorrelators samplers have 2 bits. The limited number of sampling levels results in an increase of the recorded noise by $f_{\rm auto}$= 15%.

For the AOS, the resolution bandwidth is 1.1 MHz, and the noise bandwidth about 1.7 MHz.

DEAD TIMES

Telescope motions are either in the 'slew' mode (when moving toward a new pointing position, or from the source to a reference field), or in the 'tracking' mode. Data acquisition is not allowed during 'slews'. Similarly, when wobbling the subreflector (WSW mode), there are blanking intervals during the subreflector motions. These dead times have to be included in the telescope time evaluation. They can be estimated with the following formulas:

1. Telescope slew: $$\begin{array}{lcll} t_{\rm slew}\ ({\rm s}) & = & 7 + D/v_{\rm max} & \text{for } D > 1 \text{ deg} \\ t_{\rm onoff}({\rm s}) & = & 7 & \text{for } D < 1 \text{ deg,} \end{array}$$
   where D is the AZ or EL angle (whichever is the largest) between the two positions, expressed in degrees, and $v_{\rm max}$ is 0.75 deg/sec.
2. In the standard wobbling mode (WSW= $2'$ or $4'$, Phase= 2s), the blanking time is $t_{\rm wobb}(s) = f_{\rm blank} * N$, where N is the number of 2s integration phases and $f_{\rm blank} = 0.4$ s.

To these times, one must add the deadtimes between subscans, $t_{\rm sub}$ = 2s (but only when the telescope does not move, otherwise this time is included into $t_{\rm slew}$), and the time needed to initiate and close a scan ($t_{\rm scan}$ = 8s).

EXAMPLES OF CALCULATION OF TIME EFFICIENCY RATIOS

- A) **PSW scan:** The time needed for a position switch scan (8 subscans with integration time $t_{\rm int}$= 30s ON source or on OFF position at $15'$ from the source, `set subs 8, psw /t 30 /sym`) is thus roughly:

  $$t_{\rm psw} = t_{\rm scan} + 4 \times \left(2 \times t_{\rm int} + t_{\rm onoff} + t_{\rm sub}\right) = 284 \text{ s}$$

  the efficiency ratio (integration time/observing time) is $R = 240/284 = 0.85$.
- B)**WSW scan:** The time needed for a wobbler switch scan (8 subscans with $t_{\rm int}$ = 40s, `set subs 8, wsw 240 /t 40 /p 2`) is:

  $$t_{\rm wsw} = t_{\rm scan} + 4 \times \left(t_{\rm sub} + t_{\rm onoff} + 2 \times t_{\rm int} + 20 \times f_{\rm blank}\right) = 396 \text{ s}, \quad \text{and R} = 0.81 \ .$$
- C)**RASTER scan:** The time needed for a **'Raster' scan** (i.e. several ONs for one OFF by using the OBS command 'RASTER') can be estimated from the values of $t_{\rm scan}, t_{\rm onoff}$, and $t_{\rm slew}$ given above. For a raster scan consisting of 15 ONs of 30 s and 8 OFFs of 45 s, such as:

  `RASTER 84 6 0 6/REF 3600 0/ON 2/T 30 45,` the calculation gives:

$t_{\text{raster}} = t_{\text{scan}} + 15 \times t_{\text{int-ON}} + 14 \times t_{\text{slew}} + 7 \times t_{\text{onoff}} + 8 \times t_{\text{int-OFF}}$,

$t_{\text{raster}} = 8 + 15 \times 30 + 14 \times 9 + 7 \times 8 + 8 \times 45 = 1000s$

and R= 0.78.

Note that the measured average time for such a raster scan was actually 1050 s and R= 0.74.

- D)For a **3-hour observation on one object**, one must add 3 pointings and one focussing, and at least 10 calibrations:

$$\begin{aligned} t_{\text{point}} &= 2 \times t_{\text{slew}} + 180\text{s} + t_{\text{scan}} = \text{e.g. } 440\text{s (per pointing on a strong source, } \texttt{subs 4}) && (1)\\ t_{\text{focus}} &= 180\text{s} + t_{\text{scan}} && (2)\\ t_{\text{point}} &= 2 \times t'_{\text{slew}} + 360\text{s} + t_{\text{scan}} = \text{e.g. } 400\text{s (on weak nearby source ,} \texttt{subs 8}) && (3)\\ t_{\text{cal}} &= 150\text{s}, && (4) \end{aligned}$$

  i.e. $440 + 180 + 400 + 10 \times 150$, or 2500s (0.7h), to which you may add your own reaction time, typing time, etc...

  In total, in this typical PSW mode, you can expect to observe in 3 hours (10800 s) about (10800-2500)/$t_{\text{psw}} \simeq 29.2$ scans (total $t_{\text{int-ON+OFF}} = 7000$s (∼2h)). The observing 'efficiency' is thus only $R = 0.65$.

  In the Wobbling mode, these numbers would drop to 21 scans, $t_{\text{int}} = 6700$s and $R = 0.62$. (You could increase them somewhat by setting `set subs 12`).

- E) For a **'complete' 8-hour long PSW or WSW observation** on the same object, with one single tuning (plus one retuning) per receiver, you have (3 receivers operating simultaneously):

  Receiver tunings: 3 x 0.33 h = 1.0 h
  Retunings: 3 x 0.2 h = 0.6 h

  The following preparation costs about 0.4 hours:

  First slew to the source: 5 min
  Skydip: 5 min
  Observation of a Line Calibrator: 15 min (with slew)

  Observations: 6 h (including 3.7 to 3.9 h of integration ON+OFF source, see example C above).

in total:	`set subs 8` `psw /t 30`	`set subs 8` `wsw 240 /t 40 /p 2`	percentage of total time
total time	8 h	8 h	100%
RX tunings	1.6 h	1.6 h	∼20%
Preparation	0.4 h	0.4 h	∼5%
point.+focus+calib.+dead times	2.1 h	2.3 h	∼30%
ON+OFF integration time	3.9 h	3.7 h	∼45%
efficiency ratio R	49%	46%	

EXAMPLE OF CALCULATION OF INTEGRATION TIMES

Applying the radiometer formula

Since we use the chopper wheel method for calibration, it is convenient to write the radiometer equation in units of T_A^*, the 'antenna temperature corrected for rear spillover losses and atmospheric attenuation'. The r.m.s. noise fluctuation is then:

$$\Delta T^*_{\text{A,rms}} = \frac{K\ \ f\ f'\ \ T^*_{\text{sys}}}{\sqrt{B}\ \ t_{\text{int}}}. \quad (5)$$

- We call integration time t_{int} (in seconds) the **sum** of the integration times ON the source and on the OFF position. This time does not take into account additional times due to telescope movement and data handling. For standard observations, the same amount of time is spent on the source and on a reference field (the `raster` mode can be different).

- B is the channel width (Hz) of an individual backend channel. Note that this is not the same as the channel spacing. The 'channel' width should be taken at maximum *i*) equal to half the linewidth, or *ii*) equal to 50 MHz, whichever is the smallest (weak lines broader than 50 MHz, in fact, are more difficult to detect than 50 MHz-wide lines).
- $T^*_{\rm sys}$ is the system temperature (K) (see below)
- For position- or beam- switched observations the factor K equals 2 and takes into account that half of $t_{\rm int}$ is spent on the source itself and that a substraction ON-OFF will be made. For frequency switched observations K equals $\sqrt{2}$ since all the time is spent on the source. The factor f is 1.15 for the autocorrelator, 1.0 for the filterbank (see above). The factor $f' = 1/(1 - L_{\rm dic})$ is due to losses in the dichroic mirror.

The system temperature $T^*_{\rm sys}$ (in the T^*_A scale) is calculated by `OBS` via

$$T^*_{\rm sys} = \frac{\exp(\tau_s A)(1+G_{\rm im})}{F_{\rm eff}}[F_{\rm eff}T_{\rm sky} + (1-F_{\rm eff})T_{\rm cab} + T_{\rm rec}] \tag{6}$$

with	the zenith opacity in the signal sideband	τ_s,
	the airmass	$A = 1/\sin(\text{elevation})$,
	the sideband gain ratio (see Table 2)	$G_{\rm im} = 10^{-({\rm USBRjn}/10)}$
	the sky brightness temperature	$T_{\rm sky} \approx T_{\rm ATM}(1-\exp(-\tau_s A))$,
	the mean physical atmospheric temperature (see [2])	$T_{\rm ATM} \simeq 250K$,
	the ambient temperature	$T_{\rm cab} = 290K$, and
	the receiver temperature (see Table 2)	$T_{\rm rec}$.

Zenith opacities are strongly correlated with the most important atmospheric absorbant, water; the relevant parameter is the amount of precipitable water vapour (pwv –see [2],[3]). For 20% of the time during winter (summer) the pwv is below 2 mm (4 mm). The 'average' pwv is below 4 mm during the winter regime and below 7 mm during the summer regime (see e.g. IRAM technical reports [2],[4]). Zenith opacities for typical winter and summer conditions are given in Table 3.

Table 3: Zenith opacities for typical weather conditions at selected frequencies

Condition	pwv [mm]	Frequency [GHz]					
		90	115	145	230	266	345
good winter conditions	2	0.06	0.26	0.08	0.16	0.21	0.53
'average' winter conditions/ good summer conditions	4	0.08	0.29	0.13	0.31	0.42	1.05
'average' summer conditions	7	0.11	0.35	0.22	0.53	0.73	1.83

Note that January and February are dedicated in principle to 0.8 mm and bolometer observations. Especially during this period the night-time opacities are better than the day-time opacities.

Table 4 gives examples of the rms noise $T^*_{\rm A,rms}$ after 10 minutes of total integration time (ON + OFF position). To calculate the system temperature some typical values were chosen: Elevation = 50°, gain ratio $G_{\rm im}$ between 0.001 and 1 (depending on receiver and frequency), forward efficiency $F_{\rm eff} = 0.90$, cabin temperature $T_{\rm cab} = 290$ K, mean atmospheric temperature $T_{\rm ATM} = 250$ K.

Application of the formulae: one practical example

Assume that one wishes to detect with a S/N of 10 the ^{12}CO(2-1) line from an extended envelope covering about the telescope main beam (11″). The expected line width and strengths are 6 MHz (7.8 km/s) and $T_{\rm mb}$= 0.06 K (note that we assume in these crude calculations that we are still in the Rayleigh-Jeans regime). The line is assumed flat-topped.

- *i*) let us calculate the line strength in the T^*_A scale:

$$T^*_A = \frac{B_{\rm eff}}{F_{\rm eff}} \times T_{\rm mb} = \frac{0.40}{0.86} \times 0.06{\rm K} = 0.028{\rm K} \tag{7}$$

  we need then $\Delta T^*_A = T^*_A/10 = 3$ mK in a 6 MHz/2= 3 MHz band.

Table 4: Examples of rms noise values after 10 minutes of integration (assuming $f = f' = 1$)

Frequency [GHz]	Receiver	$T_{\rm rec}$ [K]	$B_{\rm res}$ [MHz]	pwv [mm]	τ_ν	$T^*_{\rm sys}$ [K]	$T^*_{\rm A,rms}$ [K]
90	3mm-SIS	110	1	2	0.06	188	0.015
				4	0.08	199	0.016
				7	0.11	217	0.018
115	3mm-SIS	110	1	2	0.26	318	0.026
				4	0.29	340	0.028
				7	0.35	389	0.032
145	2mm-SIS	110	1	2	0.08	239	0.019
				4	0.13	275	0.022
				7	0.22	347	0.028
230	230G1	140	1	2	0.16	347	0.028
				4	0.31	487	0.040
				7	0.53	749	0.061
266	230G1	400	1	2	0.21	1412	0.115
				4	0.42	2015	0.164
				7	0.73	3269	0.267
345	0.8mm-SIS	95	1	2	0.53	1049	0.086
				4	1.05	2554	0.209
				7	1.83	7955	0.649

- *ii*) now, $T^*_{\rm sys}$:

  If we use the 230G1 alone with a 10 dB rejection ($G_{\rm im}$=0.1), $T_{\rm rec}$ = 140 K, zenith opacity $\tau_s = 0.2$, elevation = 42^o applying the above formula lead to $T_{\rm sky}$ = 65 K and $T^*_{\rm sys} \sim 410$ K.

- *iii*) the r.m.s. noise in a 3 MHz channel for $t_{\rm int}$= 1 h.

  Assume we use 230G1 alone with the 1_1M filterbank. Then $f = 1$, $f' = 1$. After 1h of ON+OFF integration, the r.m.s. noise in a 3 MHz band will be
  $\Delta T^*_A = 820/\sqrt{(3600 \times 3 \times 10^6)} = 7.9$ mK.

We thus need theoretically to integrate during $1{\rm h}\times(7.9/3.0)^2 \sim 7{\rm h}$ to reach the requested sensitivity. (If we wished to use the autocorrelator, this time would increase by a factor $f^2 = 1.15^2 = 1.3$ and would be 9 h.)

If we use the wobbling subreflector for these observations, the theoretical observing time will be 7h/R= 7/0.62= 11.3 h, to which we should add the receiver tuning (20min for 1 tuning, but one retuning after shifting the LO would be advised, so 30min) and the preparation steps (25min if this is the first observation).

OVERHEADS

Note that for longer integration times (> 5h), the factor f is expected to increase slowly (e.g. $f = 1.1$ for $t_{\rm int}$= 5h). For broad weak lines, because of baseline problems, it is advisable to multiply the observing times by 1.6 or so, so that 2 independent sets of data can be obtained.

If we had used the PSW mode instead of the WSW one, although theoretically R decreases, poorer baselines would probably lead to an increase of the total observing time. The corresponding factor is difficult to figure out as it depends on the atmospheric conditions. A factor of $1.2 - 1.3$ on $t_{\rm int}$ would however be recommended for **weak** signals.

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