

ASTRO

A GILDAS software

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Questions? Comments? Bug reports? Mail to: gildas@iram.fr

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using GILDAS software to reduce and/or analyze data.
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<http://www.iram.fr/IRAMFR/GILDAS>

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1. IRAM
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Related information is available from:

- CLIC: Continuum and Line Interferometric Calibration
- CLASS: Continuum and Line Analysis Single-dish Software
- GREG: Graphical Possibilities
- SIC: Command Line Interpreter
- IRAM Plateau de Bure Interferometer: Flux Measurements

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Chapter 1

Introduction

This document gives a description of the ASTRO software, developed to help astronomers to prepare their observations with the IRAM telescopes. ASTRO stands for “A Software To pRepare Observations”.

ASTRO includes a series of tools to compute **ephemeris**, typically the position of sources as seen at a given time from a given location. These commands are described in Chapter 2. Although they are slightly biased towards (sub)millimeter astronomy, specially in the terminology used for input and output parameters, these commands are generic enough to be used to plan observations with any instrument.

A number of tools are available to **prepare millimeter-wave observations** (Chapter 3). Especially, ASTRO provides an interface to the **ATM** library, that can be used to model the atmospheric absorption and emission at millimeter wavelengths.

ASTRO also includes a number of tools that are **specific to the IRAM instruments**, and are aimed at helping astronomers to prepare observing procedures for the Pico Veleta 30m antenna and the Plateau de Bure interferometer. These tools are described in Chapters 4 and 5.

Chapter 2

Ephemeris

2.1 Setting observatory and time

2.1.1 Setting the observatory

The results of most commands of ASTRO depend on the observer's location on Earth. This information is input to the software using the `OBSERVATORY` command:

```
OBSERVATORY longitude latitude altitude [sunlimit]
```

where the longitude and latitude are in degrees (with the usual convention of positive values towards North and East respectively) and the altitude is in kilometers. The fourth parameter is the radius of the sun avoidance circle (default is 30 degrees), used to indicate in plots the sky area that cannot be observed. A number of observatories are pre-defined and can be selected directly by typing:

```
OBSERVATORY name
```

Known observatories are given in Table 2.1. Note, that the Plateau de Bure sun avoidance limit used to be 45 degrees, but has been decreased to 35 degrees in July 2009. For the submillimeter and millimeter facilities within this list, ASTRO also assumes an antenna diameter, that is used to compute the beam size and thereby the main beam brightness temperatures of planets (see `PLANET` command).

When entering only `OBSERVATORY` (without argument), ASTRO will select the default observatory. The latter is defined by the `GAG_ASTRO_OBS` logical:

```
SIC LOG GAG_ASTRO_OBS PICO      ! define PICO as default observatory
OBSERVATORY ALMA                ! select ALMA as observatory
OBSERVATORY                     ! select PICO as observatory
```

Note for experts – The logical `GAG_ASTRO_OBS` is defined in the `gag.dico.gbl` file in the GILDAS distribution. By default, it is set to `BURE`. To override this default, users have to "export `GAG_OBSERVATORY=ObservatoryName`" just before sourcing `gildas-env.sh` at the beginning of the compilation procedure. Another possibility to permanently modify the value of `GAG_ASTRO_OBS` is to edit the `astro-site.astro` procedure (see section 2.1.3).

Name	Longitude	Latitude	Altitude (m)	Sun avoidance limit (deg.)	Antenna diameter (m)
BURE (or PDBI)	05:54:28.5	44:38:02.0	2560	35	15
PICOVELETA	-03:23:58.1	37:04:05.6	2850	2	30
ALMA	-67:45:11.6	-23:01:11.7	5000	0	12
APEX	-67:45:33.0	-23:00:20.8	5104	0	12
ATF	-107:37:10.02	34:04:29.8	2135	0	12
CSO	-155:28:18	19:46:36	4200	30	10
FCRAO	-72:21:00.0	42:23:24.0	0	0	14
JCMT	-155:28:18	19:46:36	4200	30	15
KITTPEAK	-111:36:54	31:57:12	1938	30	12
KOSMA	07:47:02.4	45:59:02.4	3089	30	3
SEST	-70:43:48	-29:15:24	2347	60	15
SMA	-155:28:18	19:46:36	4200	30	6
SMT (or HHT)	-109:53:28.48	32:42:05.8	3186	30	10
EFFELSBERG	06:53:02	50:31:29	360	20	
GBT	-79:50:23.41	38:25:59	807	0	
VLA	-107:37:06	34:04:42	2124	0	
LASILLA	-70:43:48	-29:15:24	2347	60	
MAUNAKEA	-155:28:18	19:46:36	4200	60	
PARANAL (or VLT)	-70:24:11.642	-24:37:33.117	2636	60	
IOTA	-110:53:05	31:14:11	2608	60	
PTI	-116:51:47.88	33:21:24.12	1687	60	
GI2T	06:55:36	43:44:56	1270	60	

Table 2.1: Observatories known by the `OBSERVATORY` command. For interferometer, the coordinates correspond to the array center. The first part of this table lists the millimeter instruments: an antenna diameter is defined, to be used to compute angular resolution and planet brightness temperatures.

2.1.2 Setting the time

After having set the observatory, it is necessary to define the time at which ephemeris must be calculated, using the command:

```
TIME hour date
```

Formats are “hh:mm:ss.ss” and “jj-mmm-yyyy”. Entering only `TIME` will use the current system time and date. By default, time and date are supposed to be in UTC (Universal Time Coordinated). However, time may also be entered in:

- local time, using the option `/ZONE z` where `z` is the number of hours to be subtracted to the local time to convert it to UTC (example: `/ZONE 2` corresponds to Summer Time in Western Europe).
- UT1, using the option `/UT1`. The difference between UTC and UT1 can be modified using the `SET DUT1 dUT1_value` command. As of January 2008, dUT1 is -0.3 sec (Bulletin D 98 of IERS). By construction of UTC, the value of dUT1 is always lower than 1 sec. The difference is therefore very small for all usual ephemeris computations.
- TDT (Terrestrial Dynamical Time), using the option `/TDT`. The difference between UTC and TDT can be modified using the `SET DTDT dTDT_value` command. Since January 2006, dTDT1 is 65.184 sec (last introduction of a leap second, Bulletin C 30 of IERS).

Definitions – The definition of the various times used in astronomy is given in a number of excellent textbooks. To make a quite complex story short: time standard is the TAI (International Atomic Time), which is not defined by an astronomical measurement. The TDT (Terrestrial Dynamic Time) is defined as $TDT = TAI + 32.1284$, the offset being introduced to allow for a continuity with older definitions. UT1 is defined by astronomical measurements of the Earth rotation, corrected for various effects. UT1 differs from TAI, because of the irregularity of the Earth rotation period at the millisecond level, and drifts slowly with time, because of the overall slowing down of the Earth rotation. UTC is defined as $TAI + \text{a certain offset}$, such that $|UTC - UT1| < 1$ sec, i.e. UTC is an atomic-based time that is tracking the astronomical-based time within one second. Since UT1 drifts compared to TAI (and thus UTC), a leap second in UTC may be introduced on the 1st of January or 1st of June. Hence, the difference $UTC - UT1$ is kept < 1 sec.

2.1.3 Setting defaults

ASTRO comes with a short procedure named `astro-site.astro`, located in the `pro` directory of your GILDAS installation. This file is executed at the beginning of each ASTRO session, and is used to set default values for the time and observatory parameters.

```
!
! Observatory and time initialization
!
astro\set dut1 -0.3      ! November 2007 Bulletin D 98 of IERS
astro\set dtdt 65.184    ! January 2006 Bulletin C 30 of IERS
!
astro\observatory        ! Select default observatory
```

```

astro\time          ! Use current system time
!
if (observatory.eq."BURE") then
  astro\set azimuth south
  astro\catalog gag_data:phase-pdb
  sic\message i site "Plateau de Bure defaults selected"
else if (observatory.eq."PICOVELETA") then
  astro\set azimuth north
  sic\message i site "Pico Veleta defaults selected"
else
  sic\message i site "No known defaults for this observatory"
endif

```

Note the SET AZIMUTH NORTH|SOUTH command, which is used to define the azimuth to be zero in the North or South directions, to conform to local conventions.

2.1.4 HEADER command

At any time during an ASTRO session, the HEADER command can be used to check the current time and observatory that have been selected. The output of the command also give sun-related information (sun rise, sun set, twilight times).

```

UTC :    19-SEP-2007    02:18:59.998
UT1 :    19-SEP-2007    02:18:59.698    D_UT1 :    -0.300
TDT :    19-SEP-2007    02:20:05.182    D_TDT :    65.184
Julian date :          2454362.60
LST :          02:33:06.1453

```

```

OBS :    BURE    05:54:28.500    44:38:02.000
Alt.:    2.560 km    Sun Avoidance:    45.0 deg.

```

```

SunRise/Set :    05:23:47.980    17:37:02.472
Twilight          Start          End
Civil :          18:10:55.799    04:49:54.653
Nautical :       18:45:21.460    04:15:28.992
Astronomical :   19:20:49.604    03:40:00.848

```

2.2 Computing source positions

2.2.1 Source catalogs

ASTRO uses source catalogs, that are selected by the CATALOG **name** command. File extension may be omitted when specifying the file name, the default is **.sou**. The catalog format is that used at the Plateau de Bure and Pico Veleta telescopes.

Catalogs in the old OBSINP input format, used at the IRAM 30-m Pico Veleta telescope until 2006, may also be read. The command is then CATALOG /VELETA. In that case, the input file (default extension **.cat**) is read and converted to the standard format; a file with the same name but extension **.sou** is created in the current directory.

In the ASTRO catalog format, each source uses one line of the catalog file. Each line should contain the following consecutive keywords (some may be omitted):

- Source name field:
The source name field is a composite item which can accomodate several names for a single source. Names should be separated by a vertical bar | with no embedded spaces, e.g.:

B0415+379|3C111

Each name must have at most 12 characters.
- Coordinate system: 2 characters, optional. May be:
 - EQ for equatorial coordinates. If EQ is given explicitly, then the next keyword (epoch) is mandatory.
 - GA for Galactic II coordinates.
 - EC for J2000 Ecliptic coordinates
 - HO for horizontal coordinates
 - DA for equatorial, present-day coordinates.
- Epoch: needed for equatorial coordinates after EQ keyword.
- Longitude-like coordinate: in degrees, except for EQ and DA where it should be in hours. Format is hh:mm:ss.sss or dd.ddd or hh:mm.mmm.
- Latitude-like coordinate: in degrees, or hours for EQ and DA (same format as above).
- Velocity type: alphabetic code, can be LSR, HELIO or EARTH.
- Velocity: in km/second, in the corresponding reference frame (LSR, Heliocentric, or local. Default is zero.
- Intensity type: Either FLUX or MAGNITUDE (optional)
- Intensity: Either the Flux in Jansky or the magnitude (optional).
- Spectral index (optional).

A second catalog (known as the “ALTERNATE” catalog) may also be defined, using CATALOG Name /ALTERNATE. Commands SOURCE, HORIZON and CONVERT will take sources from this alternate catalog if used with the /ALTERNATE option. This enables easy switching between two classes of objects: for instance the project sources in the main catalog, and pointing sources or phase calibrators in the ALTERNATE catalog.

Example of catalog:

IRC+50096	3:22:59.000	47:21:19.00	LS -17.2
CRL618	4:39:34.000	36:01:16.00	LS -21.3
IRC+10216	9:45:14.800	13:30:40.50	LS -27.0
CIT6	10:13:11.000	30:49:17.00	LS -1.8
IRC-10236	10:14:35.000	-14:24:31.00	LS 3.3

YCVN	12:42:47.000	45:42:48.00	LS 21.7
IRC+10420	19:24:26.700	11:15:11.00	LS 75.0
CRL2688	21:00:19.900	36:29:45.00	LS -36.0
NGC7027	21:05:09.400	42:02:03.00	LS 24.8
RCAS	23:55:51.700	51:06:36.00	LS 22.0
OH26.5+0.6	18:34:52.500	-5:26:37.00	LS 27.0
OH104.9+2.4	22:17:42.500	59:36:16.00	LS -28.0
MUCEP88	EQ 1988.5 21:43:09.300	58:43:37.00	LS 0
ALIRA	EQ 2000.0 18:36:56.200	38:47:01.00	LS 0.

2.2.2 Source selection

Once a catalog has been defined, a source within this list can be selected using the **SOURCE name** command. The **/ALTERNATE** option will direct the search to the alternate catalog.

The source coordinates are reduced to current epoch (as defined by the last **TIME** command), and converted to horizontal coordinates azimuth and elevation relative to the observatory (as defined by the last **OBSERVATORY** command). Precession, nutation, aberration are taken into account. The motion of the Earth uses the ephemerides from the Bureau des Longitudes (BDL82). The source horizontal coordinates are printed on the screen, together with the line-of-sight components of the velocities of:

- the source relative to the observer (S/OBS)
- the source relative to the standard of rest (S/LSR)
- the standard of rest relative to the Solar System barycenter (LSR/G)
- and the Solar System barycenter relative to the observer (G/OBS)

All velocities are in km/s, counted positively for outwards motions. After running the **SOURCE** command, a number of **SIC** global variables are updated and contain the source right ascension (variable **RA**), declination (**DEC**), azimuth (**AZIMUTH**) or elevation (**ELEVATION**). These are global **ASTRO** variables, used or modified by other commands. In addition, a structure called **astro%source%** is created, and contains all output values of the **SOURCE** command.

SOURCE with no arguments will compute positions of all sources from the current (or alternate) catalog in a row. The **SIC** variables will contain the position of the last source.

2.2.3 Solar system bodies

The **PLANET name** command is similar to the **SOURCE** command, but the object must be a Solar System body. No catalog is used. Known objects are: **SUN**, **MOON**, **MERCURY**, **VENUS**, **MARS**, **JUPITER**, **SATURN**, **URANUS**, **NEPTUNE**. **PLANET** with no argument compute positions for all these objects.

Just like **SOURCE**, the **PLANET** command updated a number of **ASTRO** global variables (**RA**), **DEC**, **AZIMUTH**, **ELEVATION**). A structure called **astro%planet%** is also created, and contains all output values of the **PLANET** command.

In addition to the position, information is given on the planet's apparent size and position angle, its brightness temperature and flux at (sub)millimeter wavelengths, at the current frequency.

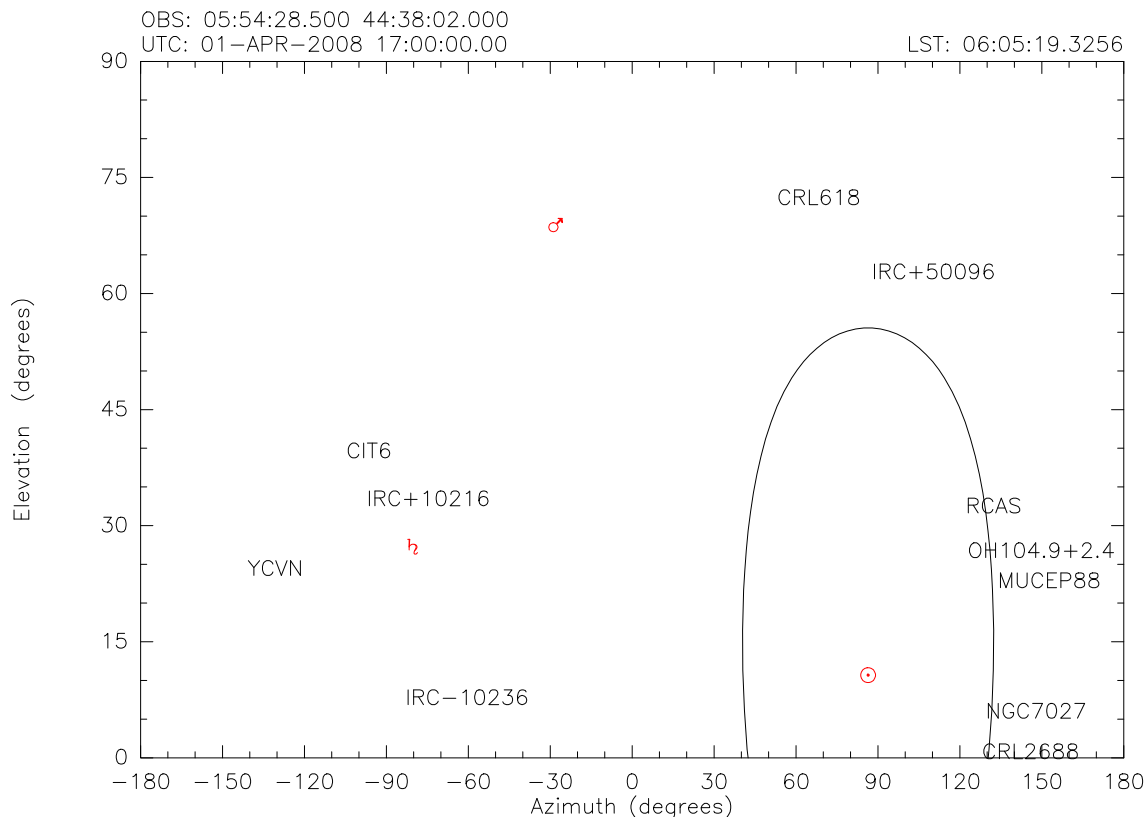


Figure 2.1: Example of plot produced by ASTRO: plotting source positions and sun avoidance circle in an horizontal frame.

- The observing frequency (in GHz) is updated by modifying the value of the variable **FREQUENCY**. Default is 100 GHz.
- The beam of the telescope is computed by ASTRO, using the antenna diameter associated to the selected observatory (Table 2.1). This can however be modified by the user, by setting the **BEAM** variable to a non-zero value. The read-only **PRIMBEAM** variable contains the value actually used in the computation.

2.2.4 Precession

... CONVERT command ...

2.3 Plotting object positions

In addition to computing positions of sources or planets, ASTRO can also produce plots of sky areas with the requested source positions being indicated.

2.3.1 FRAME definition

The plotting frame is defined by the command **FRAME**. The frame may be in Equatorial coordinates (Right Ascension–Declination) or in Horizontal coordinates (Azimuth–Elevation, as seen from the

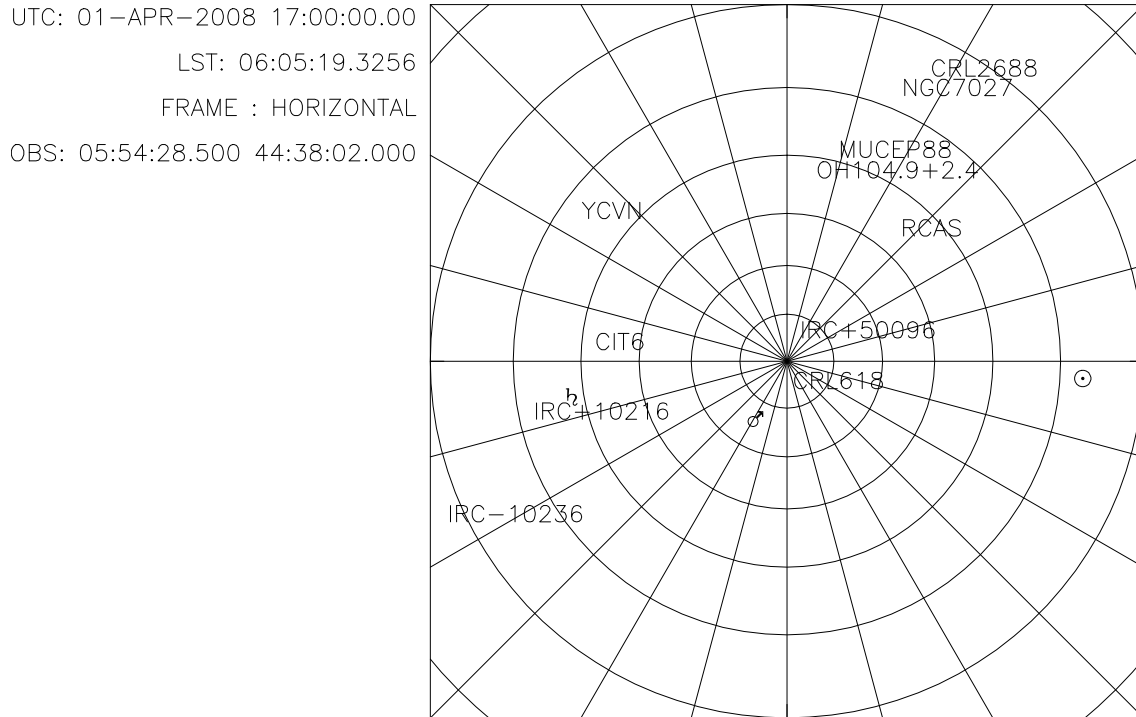


Figure 2.2: Example of plot produced by ASTRO: plotting source positions in an horizontal frame centered on zenith position.

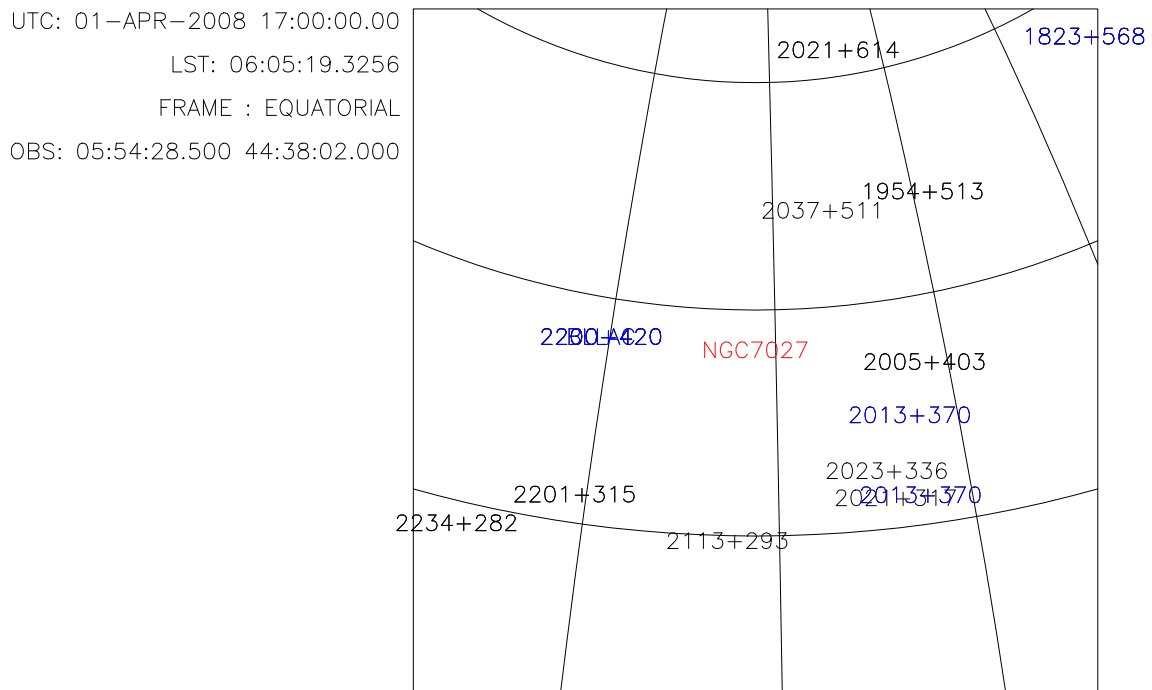


Figure 2.3: Example of plot produced by ASTRO: finding phase calibrators in the vicinity of NGC7027.

selected observatory and at the time defined by the `TIME` command). These two modes are selected by `FRAME EQ` or `FRAME HO` respectively.

The plotting may be done in rectangular coordinates using `FRAME HO` or `FRAME EQ`, with no other argument. If other arguments are given, a stereographic projection is used, which gives a better representation of the sky (distorsion of shapes is not too serious, but the scale of the map changes from the center of the projection to the edges). The projection is defined by its center coordinates and its size: for instance

```
FRAME EQ ra dec size
```

will use a projection centered in the requested direction, while the size parameter, in degrees, specify the plotting range (default is 180 degrees, i.e. a whole hemisphere). Similarly,

```
FRAME HO az el size
```

will produce a plot centered at the requested Azimuth and Elevation (in degrees). Caution: there are two possible azimuth definitions, depending on whether the azimuth is set to zero in the North or South direction. The `SET AZIMUTH NORTH|SOUTH` command allows one to select one or the other convention.

Use of SIC variables is allowed to select frames such as

```
FRAME EQ RA*12/PI DEC*180/PI 45
```

which selects a frame of size 45 degrees, in equatorial coordinates, centered on the last computed object position. A few short cuts are available to produce a number of useful, classical plots:

- `FRAME HO ZENITH` gives the whole sky above the horizon, centered on the zenith position. It is equivalent to `FRAME HO 0 90 180` in the `SET AZIMUTH SOUTH` convention, or `FRAME HO 180 90 180` in the `SET AZIMUTH NORTH` convention.
- `FRAME HO SOUTH` gives the visible sky above the southern horizon. It is equivalent to `FRAME HO 0 60 120` in the `SET AZIMUTH SOUTH` convention, or `FRAME HO 180 60 120` in the `SET AZIMUTH NORTH` convention.
- `FRAME HO NORTH|EAST|WEST` are also possible, to plot the visible sky above the north, east, and west horizon respectively.

2.3.2 Plotting sun avoidance region

The `TIME` command already described above also plots the sun avoidance region. This is not done automatically by `FRAME`, so that the user can produce time-independant plots. Alternatively, entering several `TIME` commands in a row allows to produce plots with different sun avoidance regions being plotted. `TIME /NODRAW` can be used to suppress the plotting of the sun avoidance circle.

Finally, the command `HEADER` will label the plot with the times (LST, UTC) and dates. Again, this is independant from `FRAME` and `TIME`, so that the user can have a full flexibility to define the plot and labels.

2.3.3 Plotting source or planet position

In addition to computing the coordinates, the commands `SOURCE /DRAW` and `PLANET /DRAW` will also indicate the position of the requested source in the current plot (as defined by `FRAME`). Arguments to the `/DRAW` option may be:

- `LINE`, to plot a line from the previously computed position
- `MARKER`, to plot the current GREG marker at the computed position (with a size corresponding to the source flux in the catalog, for the `SOURCE` command).
- `SYMBOL` to plot the source name (`SOURCE` command) or the usual planet symbol (`PLANET` command)
- `FULL`, to combine `MARKER` and `SYMBOL` (the source name or planet symbol will be offset one marker size above the computed position).

The default argument of `/DRAW` is `SYMBOL`. Another very useful option of the `SOURCE` command is `SOURCE /FLUX min_flux`, that selects only the sources whose flux is larger than the `min_flux` value.

Examples — Below are a few examples of plots produced by the commands described in this section. A large variety of plots can be produced, depending on the user's purposes.

The following commands plot the position of the sources in the sky at 03:00 UT on April 1st 2008, together with the position of planets (Fig. 2.1, only Jupiter is up):

```
CATALOG GAG_DEMO:SAMPLE.SOU      ! define the catalog
OBSERVATORY BURE                  ! define the observatory
FRAME HORIZON                    ! plots the whole visible sky
TIME 03:00 01-APR-2008           ! define the time & plot sun avoidance
SOURCE /DRAW                     ! draw all sources from catalog
PEN 1                            ! select pen 1 (red)
PLANET /DRAW                     ! draw all planets
PEN 0                            ! select pen 0 (black)
HEADER                          ! label the plot.
```

The same plot, but seen in a different projection (from zenith position, see Fig. 2.2), is produced by:

```
CATALOG GAG_DEMO:SAMPLE.SOU      ! define the catalog
OBSERVATORY BURE                  ! define the observatory
TIME 03:00 01-APR-2008           ! define the time
FRAME HORIZON ZENITH             ! plots the whole visible sky
SOURCE /DRAW                     ! draw all sources from catalog
PLANET /DRAW                     ! and planets (only Jupiter is up)
HEADER                          ! label the plot.
```

The following commands sequence plots the phase calibrators close to NGC 7027 (Fig. 2.3):

```
CATALOG GAG_DEMO:SAMPLE.SOU      ! selects the source catalog
CATALOG GAG_DEMO:PHASE /ALTERNATE ! selects the calibrators catalog
OBSERVATORY BURE                  ! define the observatory
```

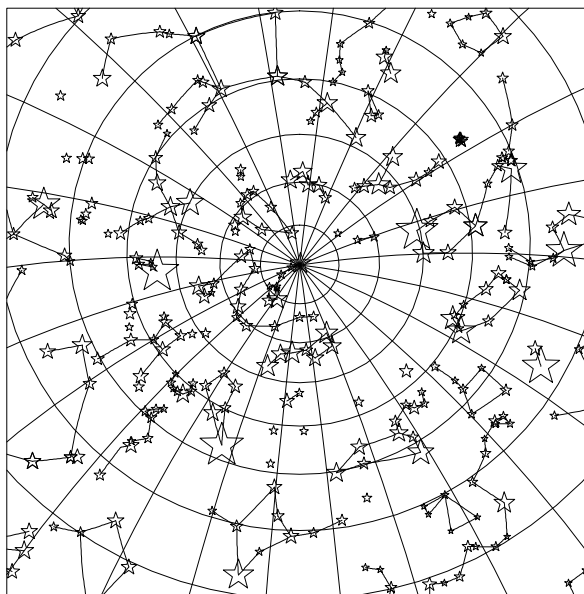



Figure 2.4: Plotting northern sky constellations.

```

TIME 03:00 01-JAN-1990      ! define the time
SOURCE NGC7027              ! get source position
FRAME EQ RA|PI*12 DEC|PI*180 45 ! frame EQ, centered on source,
                                ! 45 degrees in total size
PEN 1                        ! red pen
SOURCE NGC7027 /DRAW        ! plot source position
PEN 0                        ! black pen
SOURCE /DRAW /ALTERNATE     ! draw phase calibrators
HEADER                       ! label the plot

```

2.3.4 Constellations drawing

The `CONSTELLATION` command plots the main constellations stars in the `FRAME` area, using the current pen and marker. The marker size will scale according to the star magnitude. Options are available to draw lines between stars (to form classical constellation outlines) or plot the star names. See the corresponding section of language internal help for details.

Example – Figure 2.4 shows the plot resulting from the commands:

```

FRAME EQ 12:32:54 75:30:33 180.0 ! an equatorial frame
GREG\SET MARKER 5 2 1
CONSTELLATION /DRAW M L           ! draws the stars and the lines

```

2.4 Observability bar charts

A extremely convenient mean of planning observations is to produce a diagram in which time is used as x-coordinate, and in which an horizontal bar is drawn for each selected source to indicate the time period during which the source is up. Such a plot is produced using the

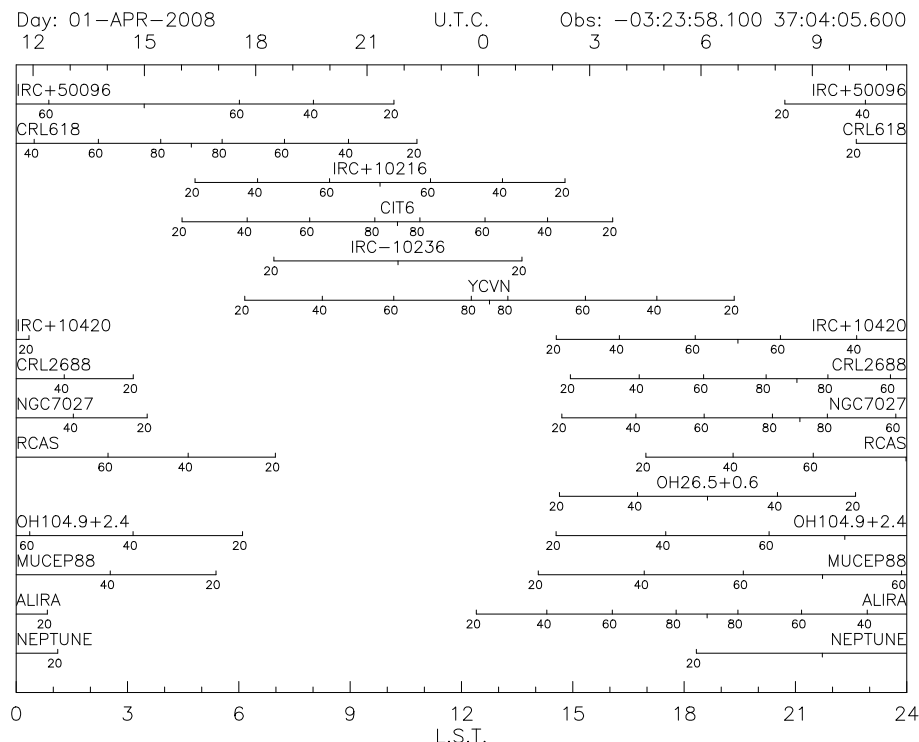


Figure 2.5: Plotting an observability chart.

command `HORIZON`. One may use all sources in the current catalog (`HORIZON /SOURCE`), all planets (`HORIZON /PLANET`), or both. Specific objects may be called by their names using `HORIZON /SOURCE name1 name2 ...` or `HORIZON /PLANET name1 name2 ...`. A source that is presently in the sun avoidance circle is written within brackets (`[]`) and in italics (e.g. [*NGC 2264*]). When a quite long catalog is used, the command `HORIZON /SOURCE NEXT n` can be used repetitively to obtain plots with only `n` objects at a time.

Example – The following commands will plot the observability hours for the sources of the `sample.sou` catalog on April 1stst 2008, together with planet Neptune. The output is presented in Fig. 2.5.

```
CATALOG GAG_DEMO:SAMPLE.SOU      ! define the catalog
OBSERVATORY PICOVELETA            ! ... the observatory
TIME 12:00 01-APR-2008            ! ... and the time
HORIZON /SOURCE /PLANET NEPTUN    ! produce the plot
```

Chapter 3

Millimeter-wave observations

3.1 Atmospheric effects

... ATMOSPHERE command ...

Chapter 4

Planning observations with the Pico Veleta antenna

Chapter 5

Planning observations with the Plateau de Bure interferometer

5.1 Receiver and correlator setup

The current generation of receivers at the Plateau de Bure is composed of **four receivers bands**, tuned **SSB**, each of them including **two polarization channels**. At any given time, only one receiver is used, but with the two polarizations. Each polarization delivers 4 GHz. The **narrow-band correlator** accepts as input two signals of 1 GHz bandwidth, that can be selected within the 2×4 GHz delivered by the receiver. A **wide-band correlator**, processing the whole 2×4 GHz is currently being built. The receivers bands are as follows:

Band 1	80–117 GHz	(3 mm window)
Band 2	129–174 GHz	(2 mm window)
Band 3	200–267 GHz	(1.3 mm window)
Band 4	277–371 GHz	(0.8 mm window)

To prepare Plateau de Bure observations, ASTRO includes a series of commands to simulate the receivers tuning and backend setup.

5.1.1 Receiver setup

The receiver tuning is selected by the `LINE` command, which has the same syntax as the corresponding command in the `OBS` software on Plateau de Bure:

```
LINE name frequency band lock center harm /RECEIVER.BAND irec
```

`name` is a line name, only used to label the plot; `frequency` is the rest frequency in GHz; `band` should be USB or LSB; `lock` is LOW or HIGH [optional, default LOW]; `center` is the IF1 frequency (in MHz) that must correspond to the required rest frequency [optional, default 6500]; `harm` is the harmonic number [optional, reserved for experts]. The `/RECEIVER.BAND` option is optional, the software will automatically find the appropriate receiver band, depending on the rest frequency.

It is highly recommended *not* to center the line at 6 GHz. This is because the correlator will analyse four 1 GHz-wide slices of the 4 GHz bandwidths, and 6 GHz is very precisely at the limit between two such adjacents quarters (see below).

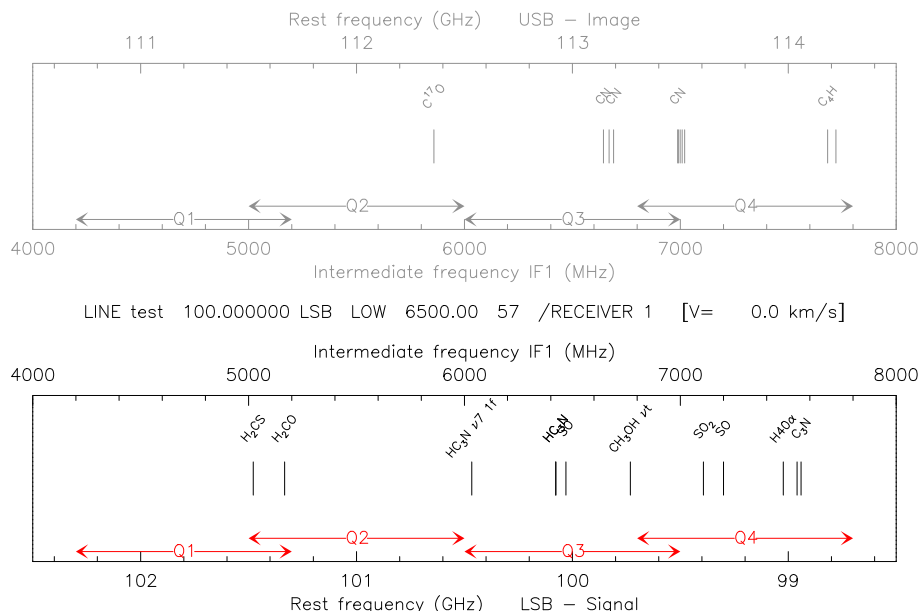


Figure 5.1: Plateau de Bure frequency coverage: output of `LINE test 100 LSB`. Both the LSB and USB frequency coverages are displayed.

The `LINE` command produces a plot of both the LSB and USB frequency coverage (the non-selected band being in light grey). The four quarters that are analyzed by the IF/correlator system are indicated by horizontal arrows (see Fig. 5.1). Vertical lines indicate the positions of the main molecular lines.

5.1.2 Correlator setup

The details of the IF processor and narrow-band correlator frequency plan is presented in another document. In short: the input 4–8 GHz band is split by the IF processor in four 1 GHz parts, labeled **Q1**, **Q2**, **Q3**, **Q4**. This processing is done in parallel for both polarizations. Since the narrow-band correlator accepts only two 1 GHz input signals, one has to define which part (=which quarter of which polarization) of the signal is to be sent to the correlator. The system allows the following choices:

- first correlator input can only be Q1 HOR, Q2 HOR, Q3 VER, or Q4 VER
- second correlator input can only be Q1 VER, Q2 VER, Q3 HOR, or Q4 HOR

where HOR and VER refers to the two polarizations and Q1...Q4 to the four quarters of the input 4 GHz signal. Note, that these quarters are 1 GHz wide but are covering only 3.6 GHz in total (due to filters' edges), hence an overlap between Q1 and Q2 on one side, and Q3 and Q4 on the other side:

$$\begin{aligned} \text{Q1} &= 4.2\text{--}5.2 \text{ GHz} \\ \text{Q2} &= 5.0\text{--}6.0 \text{ GHz} \\ \text{Q3} &= 6.0\text{--}7.0 \text{ GHz} \\ \text{Q4} &= 6.8\text{--}7.8 \text{ GHz.} \end{aligned}$$

The command

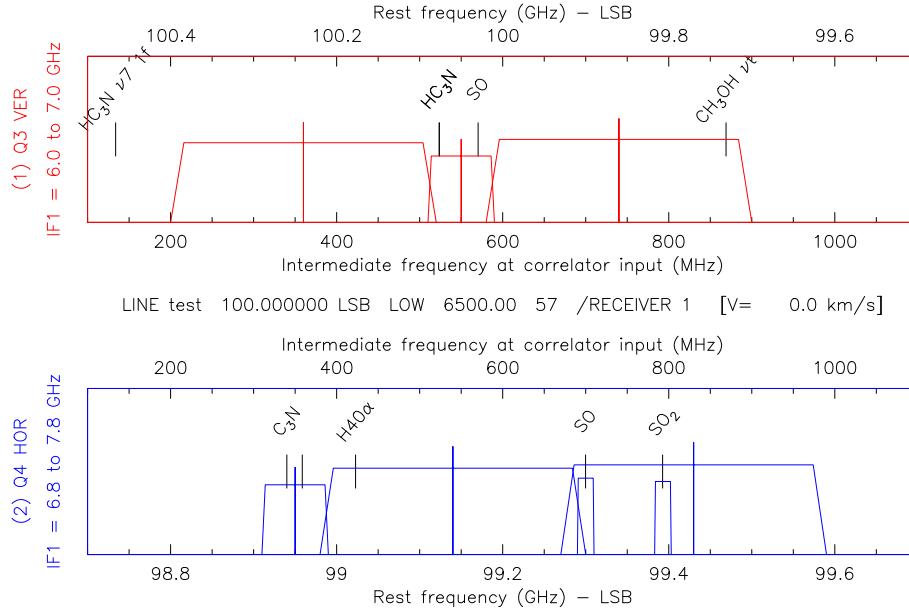


Figure 5.2: Plateau de Bure frequency coverage: output of LINE; NARROW; SPECTRAL commands.

NARROW_INPUT Q1|Q2|Q3|Q4 Q1|Q2|Q3|Q4

allows one to select the two entries of the narrow-band correlator. The polarization is determined from the above list. For instance, NARROW_INPUT Q1 Q2 selects Q1 as the first correlator entry – this can only be Q1 HORIZONTAL – and Q2 as the second correlator entry – this can only be Q2 VERTICAL. Selecting two times the same quarter (e.g. NARROW Q2 Q2) results in both polarization being observed simultaneously, in the same frequency range.

NARROW_INPUT produces a new plot, where the frequency coverage of the two selected quarters are displayed. After that step, the SPECTRAL command is used to define and plot the positions and widths of each of the 8 units of the correlator. The syntax is:

SPECTRAL iunit bandwidth fcenter /NARROW 1|2

where:

- **iunit** is the correlator unit number (1 to 8);
- **bandwidth** is the bandwidth in MHz (20, 40, 80, 160, or 320);
- **fcenter** is the center frequency (in MHz) of the unit in the second IF (in the range 100 to 1100 MHz);
- the option /NARROW is mandatory, to select which entry of the correlator the unit is connected to.

Example – Figure 5.2 presents the plot produced by the command sequence:

```
LINE test 100 LSB
NARROW Q3 Q4
```

```

SPECTRAL 1 80 550 /NARROW 1
SPECTRAL 2 80 350 /NARROW 1
SPECTRAL 3 20 793 /NARROW 1
SPECTRAL 4 20 700 /NARROW 1
SPECTRAL 5 320 360 /NARROW 1
SPECTRAL 6 320 740 /NARROW 1
SPECTRAL 7 320 540 /NARROW 1
SPECTRAL 8 320 830 /NARROW 1

```

5.1.3 Fine-tuning the plot

The `LINE`, `NARROW`, and `SPECTRAL` commands produce plots that display the receiver and correlator setup of the instrument. Those plots can be further modified using the `PLOT` command, to e.g.:

- swap from a DSB-like plot (LSB and DSB represented) to a NARROW-like plot (two selected quarters are displayed), using `PLOT DSB|NARROW`;
- zoom on a particular IF region, typically if many lines are present, using `PLOT /LIMITS min max`;
- introduce a width for the molecular lines displayed (`PLOT /WIDTH width`);
- plot the location of possible spurious lines (`PLOT /SPURIOUS`).

See the on-line help for more details on the input parameters.

5.1.4 Producing setups

Once the `LINE`, `NARROW`, and `SPECTRAL` commands have been used to define the tuning of the receiver and backend, the command `PRINT filename` allows one to write in an output file the corresponding OBS commands. This file can directly be included in the observing procedure (“setup” file) to be run at the Plateau de Bure.

```

!
! Plateau de Bure receiver and backend setup
! Written by ASTRO command PRINT on 11-FEB-2008
!
! ----- Receiver -----
!
LET RECEIVER 1
LINE LINE test 100.000000 LSB LOW 6500.00 57 /RECEIVER 1
!
! ----- IF processor -----
! Selected quarters are Q3 VER and Q4 HOR
!
NARROW Q3 Q4 /RECEIVER 1
!
! ----- Narrow-band correlator -----
!
SPECTRAL 1 80 550.00 /NARROW 1 /RECEIVER 1

```

```

SPECTRAL 2 80 350.00 /NARROW 2 /RECEIVER 1
SPECTRAL 3 20 793.00 /NARROW 2 /RECEIVER 1
SPECTRAL 4 20 700.00 /NARROW 2 /RECEIVER 1
SPECTRAL 5 320 360.00 /NARROW 1 /RECEIVER 1
SPECTRAL 6 320 740.00 /NARROW 1 /RECEIVER 1
SPECTRAL 7 320 540.00 /NARROW 2 /RECEIVER 1
SPECTRAL 8 320 830.00 /NARROW 2 /RECEIVER 1

```

5.1.5 Old receiver systems

The above description refers to the “new generation” receivers installed during the winter 2006–2007 (3 and 1.3 mm bands) together with the new IF processor. The system was completed in 2007–2008 with the 2 mm band, and should be further developed in the next years (0.8 mm band, new wide-band correlator). The **LINE** command allows one to produce plots using the old receiver and backend system, to be able to check old Plateau de Bure data. The command **SET PDBI 1995|2000|2006** is used to select the status of the instrumentation in the year:

- 1995: 3 and 1.3 mm receivers, 500 MHz bandwidth (from IF 100 to 600 MHz).
- 2000: 3 and 1.3 mm receivers, 580 MHz bandwidth (from IF 100 to 680 MHz).
- 2006: new generation receivers and new IF processor (this is the default)

For the old receivers (1995 and 2000), the **NARROW**, **SPECTRAL**, and **PLOT** commands are not relevant. Instead, the **LINE** command has a series of options, the most important one being **LINE /SPECTRAL iunit bandwidth fcenter** to plot the position and width of the correlator spectral units (see on-line help for all options). The plots that are produced are always DSB-like. Note that the doppler correction is of some importance for the old receivers, because these receivers were (or could be tuned) DSB. Indeed, doppler tracking is correct only in the signal sideband. The doppler correction is correct in the image sideband when the frequency is loaded by **OBS** at the Plateau de Bure, but subsequent tracking is computed for the signal side band only. The tracking error in the image side band is 0.04 km/s at 86 GHz, in the worst case. This is now irrelevant for the current Plateau de Bure receivers, which are SSB.

5.2 Predicting uv coverage

.... UV_TRACK...

5.3 GUI wizards

The **ASTRO** window interface includes a submenu “Plateau de Bure” that give acces to a few procedures specific to the Plateau de Bure interferometer.

5.3.1 Sensitivity estimate

5.3.2 Finding calibrators

Chapter 6

ASTRO language internal help

6.0.1 ATMOSPHERE

```
[ASTRO\]ATMOSPHERE [INTERPOLATE|MAKE|SAVE] [/PRINT]
```

Compute atmospheric emission, opacity, system temperatures, etc..., using input parameters provided by the user. Input parameters are the following SIC variables:

TEMPERATURE	Outside temperature
ZERO_PRESSURE	Pressure at sea level.
AIRMASS	Number of air masses
WATER	Precipitable water vapor
FORWARD_EFF	Forward efficiency
GAIN_IMAGE	Receiver gain ratio
TREC	Receiver temperature
FREQ_SIG	Signal frequency (in GHz)
FREQ_IMA	Image frequency (in GHz)

These variables can be assigned using the SIC command LET. The additional input variables

ALTITUDE	Site altitude
FREQ_SIG	Signal frequency (in GHz)
FREQ_IMA	Image frequency (in GHz)

are modified by the ASTRO OBSERVATORY and LINE commands.

Option /PRINT displays all these inputs.

The output of the command consists in the following variables

TRUE_PRESSURE	Local pressure, derived from the site altitude and the sea level pressure by the scale height of 5.5 km.
TSYS	The system temperature in the signal sideband
TAU_H2O	The water vapor opacity
TAU_O2	The dry atmosphere opacity (mostly due to Oxygen, but minor constituents like Ozone may also play a role)
TAU_TOT	The total opacity: H2O + O2 (+ minor components for new ATM versions)
EMIS_SIG	The atmospheric emission (Kelvin) in the signal sideband
EMIS_IMA	The atmospheric emission (Kelvin) in the image sideband
PATH_SIG	The atmospheric excess optical path length (mm) in the signal sideband
PATH_IMA	The atmospheric excess optical path length (mm) in the image sideband

These variables can then be used to produce plots of atmospheric transparency, system temperatures, etc...

ATMOSPHERE INTERPOLATE

will do the same calculations, but interpolating the data from the binary table (logical name GAG_ATMOSPHERE).

ATMOSPHERE MAKE filename nf freqmin freqmax

will create the binary table filename.bin for nf frequencies between

freqmin and freqmax (in GHz).

ATMOSPHERE SAVE filename

will save inside filename.bin the binary table currently in memory. This is useful to save with the current machine byte order a table previously computed on a different machine with a different byte order.

6.0.2 CATALOG

[ASTRO\]CATALOG name [/VELETA] [/ALTERNATE]

Open the catalog file specified by 'name'. Default file extension is sample.sou and phase.sou (an incomplete list of Plateau de Bure phase calibrators). The file GAG_DATA:phase-pdb.sou contains a more complete list of Plateau de Bure phase calibrators.

CATALOG with no arguments will display the catalogs currently opened. Please enter HELP CATALOG FORMAT for a description of the catalogs content.

CATALOG /VELETA

This option will open the catalog file 'name'.CAT, assuming it follows the format of OBSINP catalogs in use on the 30m Radiotelescope of IRAM. A file ?name'.SOU will be created in the current directory in the Plateau de Bure format, so that this option needs to be specified ONLY ONCE for each catalog. Fancy options such as SLOP, SBOP ... are not supported.

CATALOG /ALTERNATE

This option will open the specified catalog as a second catalog, only accessible through the "/ALTERNATE" options of commands SOURCE, HORIZON, and CONVERT. For instance, a catalog containing calibration or pointing sources may be opened as an Alternate catalog, while the objects to study are kept in the Current catalog, enabling easy switching between the two kinds of objects.

CATALOG FORMAT

In the ASTRO catalog format each source uses one line of the catalog file. Each line should contain the following consecutive keywords (some may be omitted):

- 1) Source name field:

The source name field is a composite item which can accomodate several names for a single source. Names should be separated by a vertical bar (|) with no embedded spaces, e.g.: B0415+379|3C111. Each name must have at most 12 characters.

- 2) Coordinate system: 2 characters, optional, may be:
 - EQ for equatorial coordinates. If "EQ" is given explicitly, then the Epoch keyword is mandatory.
 - GA for Galactic II coordinates.
 - EC for J2000 Ecliptic coordinates
 - HO for horizontal coordinates
 - DA for equatorial, present-day coordinates.
- 3) Epoch: needed for equatorial coordinates after "EQ" keyword.
- 4) Longitude-like coordinate: in degrees, except for EQ and DA where it should be in hours. Format is


```
hh:mm:ss.sss[,first[,second]]
```

 where
 - "hh:mm:ss.sss" is a generalized sexagesimal format (hh:mm:ss.sss or dd.ddd or hh:mm.mmm)
 - "first" is an (optional) first order time derivative
 - "second" is an (optional) second order time derivative
- 5) Latitude-like coordinate: in degrees, same format as above.

The following OPTIONAL KEYWORD can also be included, and may be listed in any order:

- A) a "Velocity" keyword
 - Velocity Value
 - where "Velocity" is an alphabetic code, equal to "LSR", "HELIO" or "EARTH". HELIO actually means: referred to the Solar System barycenter. Value is the velocity in km/second, in the corresponding reference frame. Default is zero.
- B) an "Intensity" keyword
 - FLUX Value [Index]
 - Value is the flux in Jy. Index is an optional spectral index
 - Mx Value
 - Value is the magnitude, Unknown values can be coded 99.99
 - Mx can be MAGNITUDE, or x is one of V,R,I,J,H,K,L,M,N to indicate the visual band
- C) a "Project" keyword
 - PROJECT ProjectID
 - to specify a project identification (a string without spaces)
- D) an "hour" keyword to indicate the validation hour for the coordinates (which is useful when time derivatives are given), specified by
 - HOOR Value
- E) A "Parallax" keyword
 - PARALLAX Value
 - Value is in arcsec.

Any other keyword will be ignored.

6.0.3 CONSTELL

```
[ASTRO\]CONSTELL [/DRAW [m] [l] [s]] [/BOUNDARIES]
```

Plots in the current FRAME with the current FONT, MARKER and PEN, the constellations, i.e., the main stars of all constellations with a marker size adequately depending on the magnitude. The options are:

```
/DRAW [m] [l] [s]
```

"m" will cause markers at the star's positions to be plotted

"l" will cause the constellations outlines to be plotted

"s" will cause the star's names to be plotted (using current centering and character size)

/BOUNDARIES will draw the constellation boundaries (originally constant RA and DEC at 1875 epoch, they are precessed to the current epoch).

The current code is quite slow.

The default is CONSTELL /DRAW m l. This command makes use of the logical name GAG_CONSTELL which points to a GILDAS Table containing the stars positions (constellation.bin by default) and drawing codes, and GAG_CONST_BOUND which defines the constellation boundaries (file sky.bin by default).

6.0.4 CONVERT

```
[ASTRO\]CONVERT [Catalog_Name] [/ALTERNATE] [/J2000 [Obs_epoch]]
[/PRECESS [New_epoch]] [/GALACTIC] [/FLUX fmin] [/NAME nname [iname]]
[/INPUT POS|FLUX filename pos]
```

Change catalog format or epoch.

Without any option (or with option /ALTERNATE) and without argument, this command creates an OBSINP-compatible copy of the 'name'.SOU catalog (or Alternate catalog if /ALTERNATE is specified) under the name 'name'.CAT.

With the /J2000 and/or /PRECESS option, the command will precess the current SOU catalog to J2000 system, using the specified epochs for observation (Obs_epoch, default 1950) and final result (New_epoch, default 2000). The output catalog is 'Catalog_name'.SOU, and has the standard format.

/FLUX create a copy of the current catalog with only sources of flux larger than fmin

/NAME ncname [iname]: reserve ncname characters for names field. With iname.gt.0, a standard name (Jhhmmmsddmmm) is created and put in inameth positions in the list of names.

/INPUT FLUX filename : will take fluxes from filename, which has itself the format of a catalog (both input catalog and filename are assumed alphabetically sorted)

/INPUT POSITION filename dpos : will take positions from filename, if different by more than dpos arc seconds. Filename has itself the format of a catalog (both input catalog and filename are assumed alphabetically sorted)

/ALTERNATE option : do the same operation with the Alternate catalog.

6.0.5 FRAME

[ASTRO\]FRAME System [...]

This command specifies the reference frame to be used for plots. System may be HORIZONTAL or EQUATORIAL (at epoch defined by TIME command) If no other argument is given, plotting is done in rectangular coordinates representing Azimuth-Elevation or Right Ascension-Declination. If other arguments are given, a Stereographic projection is used:

- FRAME EQUATORIAL Ra Dec Size
the projection will be centered on Ra and Dec (hours - degrees); Size in degrees specify the plotting range (e.g. 180 for a whole hemisphere = the default).
- FRAME HORIZONTAL Az El Size
same thing, but Az and El are in degrees.
- FRAME HORIZONTAL Center
will plot a hemisphere in horizontal system, where Center may be ZENITH, NORTH, EAST, SOUTH or WEST.

6.0.6 HEADER

[ASTRO\]HEADER

Write the UTC and LST times on top of the FRAME plot, as well as the observatory coordinates.

The same information, as well as a couple of other parameters (.eg. twilight start and end), are listed in the ASTRO terminal. Output is something like:

```
UTC :    19-SEP-2007    02:18:59.998
```

```

UT1 :    19-SEP-2007    02:18:59.698    DUT1 :    -0.300
TDT :    19-SEP-2007    02:20:05.182    DTDT :    65.184
Julian date :          2454362.60
LST :          02:33:06.1453

```

```

OBS :    BURE    05:54:28.500    44:38:02.000
Alt.:    2.560 km    Sun Avoidance:    45.0 deg.

```

```

SunRise/Set :    05:23:47.980    17:37:02.472
Twilight          Start          End
Civil :          18:10:55.799    04:49:54.653
Nautical :       18:45:21.460    04:15:28.992
Astronomical :   19:20:49.604    03:40:00.848

```

6.0.7 HORIZON

```

[ASTRO\]HORIZON h1 h2 ... [/AIRMASS] [/SOURCE ... ] [/PLANET ... ]
[/FLUX Fmin Fmax] [/NIGHT_MARKS] [/ALTERNATE] [/PROJECT] [/ELEVATION]

```

This command is used to produce plots of LST ranges of observability, above specified elevations, of sources and planets. An OBSERVATORY and a TIME must have been selected. The LST axis is drawn on the bottom of the plot, and UTC on the top. An horizontal line is drawn for the time period during which the object(s) is(are) visible above elevation h1; tick marks and labels are provided for elevations h1, h2, ... (in degrees), or corresponding air masses values (with /AIRMASS option). Elevation values must be in increasing order, or airmasses in decreasing order.

Various options are available to control the plot:

```

/SOURCE          will plot all sources
                  of the current (by default) or alternate
                  (if /ALTERNATE is used) catalog.

/SOURCE name1 name2 ... will be restricted to the specified sources
/SOURCE NEXT n      will plot the next n sources in the current
                  catalog (repeat this command to avoid over-
                  crowded pages)

/ALTERNATE         with /SOURCE, will use the Alternate catalog
/FLUX Fmin Fmax    restrict the search to sources with flux in
                  the specified range.

/PLANET            will plot on one page all solar-system bodies
/PLANET name1 name2 ... will be restricted to the specified bodies

/NIGHT_MARKS       Plots also the beginning and end of astronomical
                  nautical and civil twilights, and an estimate of
                  the moon phase and the moon bolometric magnitude

```

For specific Plateau de Bure scheduling purposes, the options /PROJECT and /ELEVATION can be used to further restrict the search of the sources in the catalog. In that case, the source catalog must have a number of additional parameters available for each source (project name, frequency, priority, minimal elevation,...).

6.0.8 Language

ASTRO\ Language summary

ATMOSPHERE	: compute atmospheric parameters
CATALOG	: opens a standard source catalog
CONVERT	: precess coordinates from an input catalog
CONSTELL	: draws constellation on current plot
FRAME	: define plotting reference system
HORIZON	: plot observability hours of sources and planets
HEADER	: write time parameters on top of plot
OBSERVATORY	: define observatory coordinates
PLANET	: compute planet coordinates
SET parameter value	: enter some parameter value
SOURCE	: compute source coordinates
TIME	: set computation time
UV_TRACKS	: plot interferometer UV tracks

6.0.9 OBSERVATORY

```
[ASTRO\]OBSERVATORY [longitude latitude altitude [radius]]
or
[ASTRO\]OBSERVATORY [Name]
```

Specify an observatory by giving its geographic coordinates in degrees, and elevation in km above sea level. Caution: east longitudes are positive. The fourth argument is the radius of the Sun avoidance circle, in degrees (default is 30 degrees).

Example: OBSERVATORY 44:23:12.0 +45:09:57.9 3.987 30.

A number of observatories are pre-defined and can be selected directly by typing "OBSERVATORY Name". The known names are: BURE (or PDBI), PICOVELETA (or VELETA) ALMA, APEX, ATF, CSO, FCRAO, JCMT, KITTPEAK, KOSMA, SEST, SMA, SMT EFFELSBERG, VLA LASILLA, MAUNAKEA, PARANAL (or VLT), IOTA, PTI, GI2T

Without argument, the observatory name is translated from the GAG_ASTRO_OBS logical name.

6.0.10 PLANET

```
[ASTRO\]PLANET [name] [/DRAW [argument]] [/QUIET]
```

Compute the coordinates of a Solar System object. Known objects are: MOON, SUN, MERCURY, VENUS, MARS, JUPITER, SATURN, URANUS, NEPTUNE. If no name is entered, all objects are selected. The Option /DRAW is used to plot the object symbol on the screen.

The PLANET command output the planet coordinates (apparent RA, apparent DEC, Azimuth and Elevation at time of computation) and the sun distance (with a warning message if this distance is lower than the telescope limit). PLANET also indicates the geocentric (DE) and heliocentric (DS) distances of the object (in AU), the apparent minor and major diameters (Min and Maj in arcsec), the position angle of the central meridian (PA, east from north, in degrees), the brightness temperature (TB in K), the flux (S in Jy) at the current frequency, the frequency (in GHz), the beam (in arcsec), the main beam temperature (Tmb in K), the associated flux (in Jy) and the planet size convolved with the telescope beam (size in arcsec). The frequency can be entered by updating the variable FREQUENCY (in GHz). The beam used in computation is available through the READONLY variable PRIMBEAM (in arcsec). User may override the default used beam size by setting the BEAM variable to a non-zero value (in arcsec).

All these parameters are also written in SIC variables, in the ASTRO%PLANET% structure. Just enter EXAMINE ASTRO%PLANET% to get a complete list of these variables. PLANET /QUIET suppresses all the printouts on the screen.

Arguments to PLANET /DRAW may be LINE, MARKER, SYMBOL, or FULL:

```
LINE    will draw a line from the previously computed position
MARKER  will draw a marker (GreG style defined by GREG\SET MARKER)
         at the computed position
SYMBOL  will draw the planet's symbol at the computed position
FULL    will combine MARKER and SYMBOL (the symbol will be offset
         one marker size above the computed position).
```

Default is SYMBOL. If several arguments are given they will be used in sequence.

6.0.11 SET

```
[ASTRO\]SET parameter value
```

Enter a value for a parameter. Valid parameters are :

```
- DUT1
  which is (UT1-UTC) in seconds of time (from I.E.R.S.)
```

- DTDI
which is (TDT-UTC) in seconds of time (from I.E.R.S.)
- AZIMUTH_REFERENCE
which is either NORTH or SOUTH, and defines the azimuth to be zero in the North or South direction (to conform to local conventions).
- SET NAME Argument
Define the naming convention for listing sources from the catalog. Sources in the catalog may have several names. This command define which name should be printed in commands SOURCE and HORIZON. Argument can be
 - * to print the name of the source which has been searched for
 - ALL to print all the possible names of the source
 - 1,2,3 etc... to print the first, second, third, etc.. possible names of the source

6.0.12 SOURCE

```
[ASTRO\]SOURCE [name [...]] [/DRAW [argument]] [/ALTERNATE] [/SUN]
[/FLUX Fmin Fmax]
```

Compute the coordinates of a source from the current catalog (or the alternate catalog, if the option /ALTERNATE is used). If no name is specified, all sources of the catalog are selected. Source coordinates may also be directly specified in the command line, in the same format as the catalog file. The /DRAW option is used to draw the source name on the plot at its current position (Azimuth, Elevation).

The source coordinates (azimuth and elevation at time of computation) are printed on the screen, as well as the line-of-sight components of the following velocities:

- V(S/OBS)
Source (S) relative to Observatory
- V(S/LSR)
Source (S) relative to Local Standard of Rest. This is the LSR velocity furnished by the observer as part of the source coordinates.
- V(LSR/G)
Local Standard of Rest relative to Solar System Barycenter (G)
- V(G/OBS)
Solar System Barycenter (G) relative to the Observatory

All velocities are in km/s, positive if the distance is increasing. With the above convention, $V(S/OBS) = V(S/LSR) + V(LSR/G) + V(G/OBS)$. Coordinates and velocities are written in SIC variables, in the ASTRO%SOURCE% structure (just type EXAMINE ASTRO%SOURCE% to get the complete list).

The output of the SOURCE command can be modified with the following options: SOURCE /SUN will also list the sun avoidance limits; SOURCE /PRINT suppresses the printing of Azimuth, Elevation, and the velocities

and prints the source properties as in catalog; SOURCE /QUIET suppresses all printout (useful to avoid too many messages on the screen in e.g. a loop on many sources).

SOURCE /FLUX Fmin Fmax will select only sources with flux densities in the specified range. Marker sizes will be proportional to the (logarithm of the) flux. This is useful to, e.g., filter a list of potential calibrators.

Arguments to SOURCE /DRAW may be LINE, MARKER, SYMBOL, or FULL, as for command PLANET:

LINE will draw a line from the previously computed position (SOURCE or PLANET)

MARKER will draw a marker (GreG style defined by GREG\SET MARKER) at the computed position

SYMBOL will draw the source name in capitals at the computed position

FULL will combine MARKER and SYMBOL (the name will be offset one marker size above the computed position).

Default is SYMBOL. If several arguments are given they will be used in sequence.

6.0.13 TIME

[ASTRO\]TIME [time [date]] [/ZONE Z] [/UT1] [/TDT] [/NODRAW]

Specify the time-date of computation. Time is normally understood as UTC; options /UT1 and /TDT may be used to change this to UT1 or TDT. The time format is HH:MM:SS.SSS, and the date format is DD-MMM-YYYY. Time and date may be absent or replaced by an asterisk (*), which defaults to current system time. Local civil time may be input instead of UTC, with the option /ZONE z, where z is the difference in hours between UTC and local civil time (use /ZONE 2 in western Europe in Summer, 1 in winter).

By default, if the sun is visible, a Sun Avoidance Circle (see HELP OBSERVATORY) is plotted. It can be suppressed using the /NODRAW option. Use HEADER to examine the value of the Sun Avoidance Circle.

6.0.14 UV_TRACKS

[ASTRO\]UV_TRACKS station1 station2 [station3 [...]] [/FRAME [size]] [/HOUR_ANGLE Hmin [Hmax]] [/TABLE [Name]] [/HORIZON Elmin] [/INTEGRATION t] [/STATIONS ALL|list] [/WEIGHT Mode]

Plot interferometer UV tracks as observed with the Plateau de Bure interferometer (but the command is in fact more general and can be used with any array).

Station coordinates are searched for in the file defined by the ASTRO_STATIONS logical variable. Stations should be referred to by a mnemonic (e.g. E03, W00 ...) given as arguments of UV_TRACKS.

The coordinates of the most recently selected SOURCE or PLANET are considered. Option /HORIZON specifies a minimum elevation (in degrees) for the source. Option /HOUR_ANGLE can be used to limit the hour angle coverage. Default is from source rise (above the minimum elevation) to source setup; Hmin and Hmax are in hours. The frequency of the simulated observation is read in the FREQUENCY SIC variable (which is also used by several other commands in ASTRO).

UV_TRACKS can be used iteratively, to simulate the observations of several configurations. Option /FRAME [size] should be used to start a new UV coverage. It clears the plot, draws the box, and open a new table if /TABLE is present. 'size' is the maximum UV spacing plotted, in meters (default 800 m). Subsequent call to the command (without /FRAME) adds the new configurations. The user may select another color pen to distinguish between the various coverages. A sketch of the interferometer described by ASTRO_STATIONS is also drawn, and the selected stations/antennas are highlighted.

Option /TABLE can be used to write the sampling function (UV coverage) in a UV table for further processing such as producing beams using the task UV_MAP. Name should be specified only if option /FRAME has been used, to initialize the table. Subsequent call to the UV_TRACK command will append the new observation to this table. The visibilities written in the UV table are constant, as if a point source were observed (real part = 1, imaginary part = 0). The weight is by default constant, equal to 1. This can be modified using the /WEIGHT Mode option. Mode can be UNIFORM (constant weight) or AIRMASS (weight proportional to airmass^{-2} , i.e. to $\sin(\text{elevation})^2$).

Option /INTEGRATION t [min] is used to change the time interval between points in the UV plane (currently there is a max of 3000 points between HA_MIN and HA_MAX). Default is 15 minutes per point.

---- Notes for experts ----

Option /STATIONS enable to access stations by their rank number in the ASTRO_STATIONS file, rather by their mnemonic. ALL means 'take all stations'. Switching between files describing interferometer stations can be done inside ASTRO by redefining the ASTRO_STATIONS logical variable using the command

```
SIC LOG ASTRO_STATIONS "path/to/the/desired/file"
```

The BURE stations are described in the file ephemeris/astro_stations.dat

(and accessed by default on most ASTRO installs, or otherwise by
SIC LOG ASTRO_STATIONS GAG_ASTRO_DATA:astro_stations.dat)

Chapter 7

PDBI language internal help

7.0.1 Language

PDBI\ Language summary

LINE	: define receiver setup
NARROW_INPUT	: define the input of the narrow-band correlator
SPECTRAL	: define the configuration of the spectral units of the narrow-band correlator
PLOT	: plot the resulting frequency coverage
PRINT	: print the corresponding observing procedure
FREQUENCY	: define receiver setup (ALMA)
BASEBAND	: define position of correlator basebands (ALMA)
SPWINDOW	: define spectral windows (ALMA)

7.0.2 BASEBAND

[PDBI\] BASEBAND i frequency [sideband]

The ALMA correlator is composed of four quadrants, each of them being able to process 2 GHz (x 2 polarization) of the receiver output. This is called a baseband, and this 2 GHz slice can be placed at any position in the receiver bandwidth. The BASEBAND command is used to define the *i*-th baseband, by selecting the frequency of its center. This can be done either in the RF or the IF domains

- if the frequency is < 1000, it is interpreted as a rest frequency in GHz.
- if the frequency is > 4000, it is interpreted as an intermediate frequency in MHz; a second parameter giving the sideband (LSB/USB) is then necessary.

Example: Receiver band 7 is tuned at 220 GHz LSB. It outputs 4-8 GHz signals in USB (corresponding to 234 to 238 GHz) and LSB (218 to 222 GHz). Baseband 1 can e.g. be placed at IF = 6.2 GHz in LSB, which corresponds to 220.8 GHz. The commands "BASEBAND 1 220.8" and "BASEBAND 1 6200 LSB" are therefore equivalent.

Entering "BASEBAND i" with no further arguments calls an interactive mode in which the baseband is defined with the cursor on the plot produced by the FREQUENCY command. Clicking in the plot defines the frequency/sideband of the center of the baseband.

7.0.3 FREQUENCY

[PDBI\]FREQUENCY Name Frequency Band Center

Define and plot the receiver frequency coverage of ALMA. The command syntax is similar to that of the LINE command for the Plateau de Bure:

```
Name      is a line name to label the plot
Frequency is the rest frequency in GHz
Band      should be USB or LSB
Center    is the IF1 frequency in MHz [optional]
```

The command produces a plot of the USB and LSB frequency band. It is then necessary to define the position of the four correlator basebands (command BASEBAND) and then the spectral windows within each basebands (command SPWINDOW).

A typical session to define an ALMA setup would be:

```
freq something 220 lsb ! define receiver tuning
base 1 220.8          ! define baseband #1
plot base 1          ! plot baseband #1
spw 1                ! define spectral windows on baseband 1
spw 2                ! using the cursor
```

7.0.4 LINE

```
[PDBI\]LINE Name Frequency Band [Lock [Center [Harm]]]
```

Define and plot the receiver frequency coverage of the Plateau de Bure Interferometer (with the receivers installed in winter 2006/2007). The command syntax is identical to that of the corresponding command in OBS:

```
Name      is a line name to label the plot
Frequency is the rest frequency in GHz
Band      should be USB or LSB
Lock      is LOW or HIGH [optional, default LOW]
Center    is the IF1 frequency in MHz [optional, default 6500]
Harm      is the harmonic number [optional]
```

- o The receiver band to be used (1 to 4) will be determined by the software.

- o The center frequency is expressed in the first IF (4-8 GHz = 4000-8000 MHz). WARNING: it is highly not recommended to center the line frequency at 6 GHz. This is because the correlator analyses quarters of the 4 GHz bandwidths, and 6 GHz is very precisely at the limit between two such adjacents quarters.

- o The plot displays the four "quarters" Q1...Q4 that can be selected as input for the correlator (see NARROW_INPUT command):

```
Q1 = 4.2-5.2 GHz, Q2 = 5.0-6.0 GHz
```

Q3 = 6.0-7.0 GHz, Q4 = 6.8-7.8 GHz

o Commands NARROW and SPECTRAL are available to setup the IF processor and the spectral units of the narrow-band correlator (see the corresponding help). A typical ASTRO session would look like:

```
line toto 100 usb          ! choice of rx tuning
narrow q1 q3              ! choice of the correlator windows
spectral 1 20 320 /nar 1   ! correlator unit 1
spectral 2 320 200 /nar 2   ! correlator unit 2
spectral 2 320 210 /nar 2   ! new def. of unit 2 --> plot is updated
```

o Command PLOT can be used to plot the full receiver coverage, that of the NARROW band correlator, or that of the WIDEX correlator.

o LINE can also be used to produce plots of the frequency coverage of the old receivers (replaced in 2006/2007). The command SET PDBI year allows one to select the instrument as of the selected year:

- 1995: 3 and 1.3 mm receivers, 500 MHz bandwidth
- 2000: 3 and 1.3 mm receivers, 580 MHz bandwidth
- 2006: new generation receivers (4 GHz bandwidth, 2 polar.) [default]

For the OLD receivers (years 1995 & 2000), the commands NARROW, SPECTRAL, PLOT are not active. Please enter HELP LINE OLD for a description of the behaviour of the LINE command in that case.

LINE OLD

```
[ASTRO\]LINE Name Frequency Band [Lock [Center [Harm]]] [/MOLECULES
File] [/SPECTRAL Unit Bandwidth IF_2] /WIDTH width
[ASTRO\]LINE /SPECTRAL Unit Bandwidth IF_2
[ASTRO\]LINE /AUTO
```

Plot rest frequency coverage of Plateau de Bure Interferometer using the OLD receiver system (replaced in 2006/2007). The command syntax is identical to that of the corresponding command in OBS.

Name is a line name to label the plot

Frequency is the center frequency in GHz

Band should be USB or LSB

Lock (optional) is LOW or HIGH

Center (optional), the center IF2 frequency in MHz, default 350.

Harm (optional), the harmonic number.

The option /MOLECULES enables to plot the rest frequencies of several transitions, found in file File. This is a text file with entries:

```
Freq      'chain'
```

where Freq is the rest frequency in GHz and 'chain' the line name to

be plotted by GreG, between single quotes. Example:

88.632 'HCN'

89.081 'HCO\u+'

The option /WIDTH width is used to introduce a finite width (in km/s) for the molecular lines displayed.

The option /SPECTRAL is used to overlay the desired spectral correlator configuration.

Unit is the correlator unit number (1 to 8)

Bandwidth is the bandwidth in MHz (20, 40, 80 or 160)

IF_2 is the center frequency (in MHz) of the unit in the second IF (in the range 110 to 590 MHz).

With only the /SPECTRAL option, the corresponding unit overlay will be drawn on an existing LINE plot.

Because only one synthesizer is used to generate the 1st and 2nd LOs, the IF frequency is slightly variable (between 1.500 and 1.550 GHz), and the Doppler tracking is correct only for the specified band (USB or LSB). The last specified source is used to get the Doppler shift. The image frequency doppler shift is wrong by at most $2 \cdot \text{Ers} / \text{Harm}$, where Ers is the Earth rotation speed, or about 0.9 km/s, roughly 0.04 km/s at 86 GHz.

The option /AUTO is used to guess the line frequencies and spectral set-up for Bure, given a set of variables:

N_LINE int number of line frequencies

N_CONT int number of continuum frequencies

for each of N_LINE:

LINENAME_i char line name of line table

LINEVELO_i char velocity range (2 values: min, max in km/s)

LINEFREQ_i dble line frequency (MHz)

LINEVRES_i dble velocity resolution (km/s)

for each of N_CONT:

CONTTABLE_i char name of continuum table

CONTBANDS_i char range of frequency bands for the continuum
(min1 max1 min2 max2 ...)

Output is also in a set of variables, used by setup writing procedures. look into LINE_* and SPEC_* variables.

7.0.5 NARROW_INPUT

[PDBI\]NARROW_INPUT Q1|Q2|Q3|Q4 Q1|Q2|Q3|Q4

Select the two entries of the PdBI narrow-band correlator. The PdBI receivers have 4 GHz bandwidth (for each polarization), from IF=4 GHz to

IF=8 GHz. The WIDEX correlator is able to analyse the whole bandwidth, but the narrow-band correlator can process only two 1 GHz wide bands.

The receiver 4 GHz bandwidth is split into four "quarters":

Q1 = 4.2-5.2 GHz Q2 = 5.0-6.0 GHz

Q3 = 6.0-7.0 GHz Q4 = 6.8-7.8 GHz

and two of them must be selected as inputs to the narrow-band correlator. Any combination is possible. The polarization that is selected depends on the selected quarter:

- the correlator input 1 can only be Q1 HOR, Q2 HOR, Q3 VER, Q4 VER
- the correlator input 2 can only be Q1 VER, Q2 VER, Q3 HOR, Q4 HOR

Example: NARROW_INPUT Q1 Q2 selects Q1 HOR as first input, and Q2 VER as second input. Simultaneous measurements of the two HOR and VER polarizations is obtained with e.g. NARROW_INPUT Q1 Q1.

7.0.6 PLOT

```
[PDBI\]PLOT [LINE|NARROW|WIDEX] [FREQUENCY!BASEBAND i]
[/LIMITS min max]
[/MOLECULES FileName [Mol1 Mol2 ... Moln]]
[/WIDTH width]
[/SPURIOUS [NO]]
[/ATMOSPHERE [water]]
```

The PLOT command is used to change the plot options and update the plot accordingly. Three types of plots can be produced for the Plateau de Bure:

- o LINE mode = plot of the LSB and USB (as produced by the LINE command). Note that the new generation receivers at PdBI are single-side band: the image sideband appears in light grey. Windex and Narrow-band units are indicated.

- o NARROW mode = SSB plot of the two selected entries of the narrow-band correlator. This plot is aimed at zooming on the two 1 GHz inputs of the correlator, as selected by the NARROW_INPUT command. The position and width of the 8 spectral units are drawn.

- o WIDEX mode = plot of the WIDEX frequency coverage.

After each of the LINE, NARROW_BAND, SPECTRAL or WIDEX commands, the plot is updated.

Similar plots can be produced for the ALMA correlator:

o FREQUENCY mode = plot of the LSB and USB output of the receiver band (as produced by the FREQUENCY command).

o BASEBAND mode = plot of the baseband #i. The position and width of the spectral windows defined with SPWINDOW are also drawn.

Various options are available to fine-tune the plot:

PLOT /LIMITS min max (in MHz) selects the IF range to be plotted (in the LINE mode only). This is to zoom on a specific part of the 4 GHz receiver bandwidth.

PLOT /MOLECULES FileName [Mol1 Mol2 ... Moln] enables to plot the rest frequencies of several transitions, found in file FileName. Default is to use the molecule.dat file, distributed with ASTRO. These file must be a text file with entries:

```

Freq   'chain'
where Freq is the rest frequency in GHz and 'chain' the line name to
be plotted by GreG, between single quotes. Example:
88.632  'HCN'
89.081  'HCO\u+'

```

PLOT /WIDTH width is used to introduce a finite width (in km/s) for the molecular lines displayed.

PLOT /SPURIOUS plots the location of possible spurious lines (Plateau deBure), at IF1=4500 MHz, 6300 MHz, and at 3 and 4 times the LO1REF frequency. This is now the default, it can be deactivated with PLOT /SPURIOUS NO

PLOT /ATMOSPHERE water plots the atmospheric transmission curve (vertical scale is from 0 to 1) as a function of the frequency. The amount of precipitable water can be given, default is 1 mm. The transmission is computed on-the-fly using the ATMOSPHERE command (see corresponding help). The command ATMOSPHERE /PRINT can be used to list the input parameters that were used. The ATM model version can be changed using the SET ATM OLD|NEW command (the NEW version is recommended).

7.0.7 PRINT

[PDBI\]PRINT [filename]

Write in an output file (default is setup.obs) the OBS command lines that correspond to the receiver and backend tuning selected with the

LINE, NARROW, and SPECTRAL commands. This file can directly be included in the observing procedure (''setup'' file) to be run at the Plateau de Bure. It can also be executed in ASTRO to (re)produce the the frequency coverage plot.

Example of output:

```

!
! Plateau de Bure receiver and backend setup
! Written by ASTRO command PRINT on 11-FEB-2008
!
! ----- Receiver -----
!
LET RECEIVER 1
LINE test 100.000000 LSB LOW 6500.00 57 /RECEIVER 1
!
! ----- IF processor -----
! Selected quarters are Q3 VER and Q4 HOR
!
NARROW Q3 Q4 /RECEIVER 1
!
! ----- Narrow-band correlator -----
!
SPECTRAL 1 80 550.00 /NARROW 1 /BAND LSB /RECEIVER 1
SPECTRAL 2 320 360.00 /NARROW 1 /BAND DSB /RECEIVER 1
SPECTRAL 3 320 740.00 /NARROW 1 /BAND DSB /RECEIVER 1
SPECTRAL 4 80 350.00 /NARROW 2 /BAND LSB /RECEIVER 1
SPECTRAL 5 20 793.00 /NARROW 2 /BAND LSB /RECEIVER 1
SPECTRAL 6 20 700.00 /NARROW 2 /BAND LSB /RECEIVER 1
SPECTRAL 7 320 540.00 /NARROW 2 /BAND DSB /RECEIVER 1
SPECTRAL 8 320 830.00 /NARROW 2 /BAND DSB /RECEIVER 1

```

7.0.8 SPECTRAL

[PDBI\]SPECTRAL iunit bandwidth fcent /NARROW 1|2 [/BAND LSB|USB|DSB]

Select the width and position of each spectral unit of the narrow-band correlator.

- 'iunit' is the correlator unit number (1 to 8)
- 'bandwidth' is the bandwidth in MHz (20, 40, 80, 160, or 320)
- 'fcent' is the center frequency (in MHz) of the unit in the third IF, i.e. the IF at the entry of the narrow-band correlator (in the range 100 to 1100 MHz).

The option /NARROW is mandatory, and is used to select which entry of the correlator the unit is connected to. The SPECTRAL command updates the current plot by drawing the position and width of the selected correlator unit. The list of the current correlator setup, including the

number of channels and resolution, is printed out.

Alternatively, the command "SPECTRAL iunit" with no other arguments calls the cursor and allows one to define interactively the spectral unit:

- Left hand click defines the central frequency and the narrow band unit
- +/- increases/decreases the bandwidth
- < and > shifts the position of the unit by 5 MHz
- E is used to Exit this mode

The plot is updated after each action.

Option /BAND LSB|USB|DSB can be used to define the processing mode of the selected correlator unit. There is no practical difference between LSB and USB tunings. The DSB mode provides twice as many channels than the LSB or USB modes for the same bandwidth, but the central channels suffer from the Gibbs effect. This mode is therefore not optimized for spectroscopic studies. Choosing between an SSB or DSB mode is possible only if a bandwidth of 160 or 80 MHz has been selected (320 MHz is only available in DSB mode; 40 and 20 MHz are only available in SSB). Default is DSB for 320 MHz wide units, LSB for the other bandwidth. The /BAND option has no consequences on the plot produced by ASTRO, but affects the printout (number of channels and resolution) and the setup file produced by the PRINT command.

7.0.9 SPWINDOW

```
[PDBI\] SPWINDOW ispw width frequency [/BASEBAND i]
      [/POLAR p] [USE u] [/RESET]
```

This command is used to define a spectral window in the i-th baseband. The /BASEBAND option is mandatory, unless a PLOT BASEBAND command has been run, in which case the plotted baseband is selected.

The parameters of the spectral window are then defined as follows:

- 'ispw' is the correlator window number (each baseband has its own list)
- 'width' is the bandwidth in MHz: 31.25, 62.5, 125, 250, 500, 1000, or 2000. NB: the software accepts and corrects 32, 60, 64, 120, 128, 256.
- 'frequency' is the center frequency (in MHz) of the unit in IF domain, as displayed in the plot produced by PLOT BASE.
- The /POLAR option is used to define how many polarization products must be computed (1,2, or 4). Default is 1.
- The /USE option defines which fraction of the correlator is to be used. This modifies the number of output channels, and therefore

the spectral resolution. Default is 100. Valid values are 3.125%, 6.25%, 12.5%, 25%, 50%, and 100%. Entries < 1 are accepted (e.g. 0.5 instead of 50).

Depending on all these input parameters, the software checks whether one or several correlator modes are available (not all combinations are possible). Obviously, defining several windows on one baseband is possible only if each window uses < 100% of the correlator resources.

The command "SPWINDOW ispw" with no additional parameters calls an interactive mode in which the spectral window can be defined with the cursor:

- Left hand click defines the central frequency.
- +/- increases/decreases the bandwidth
- < and > shifts the position of the unit by 5 MHz
- P changes the number of polarization products (1-2-4)
- U and I decrease/increase the fraction of the correlator to be used for that spectral window.
- E is used to Exit this mode

The plot is updated after each action.

7.0.10 WIDEX

[PDBI\]WIDEX

This command is foreseen to provide tuning parameters of the WIDEX correlator. None of them is currently open to the users, so the command only plots the frequency coverage of WIDEX.

The WIDEX command is therefore equivalent to PLOT WIDEX.