ASTRO
A Software To pRepare Observations

a GILDAS working group software

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Version 2.0

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Contents

1 Introduction

This document gives a description of the **ASTRO** software, developed to aid astronomers in preparing their observations with the IRAM telescopes. While some commands are very specific to the IRAM instruments (particularly the Plateau de Bure Interferometer), most commands are quite general and may be used with any radiotelescope to plan observations for maximum efficiency. This program is interactive and uses **GreG** for graphic output.

ASTRO also includes a language named FLUX which allows the user to bootstrap flux densities from quasars and planet measurements made by **CLASS** or **CLIC**. Please refer to the FLUX documentation for details.

2 Catalogs of Sources

ASTRO uses as default the catalog format for Plateau de Bure. The catalog is selected by command `CATALOG name`, where `name` is the file specification for the catalog. File extension may be omitted, default is `.SOU`. Catalogs in the **OBSINP** input format, in use at Pico Veleta for the IRAM 30-m telescope, may also be used; the command is then `CATALOG /VELETA`. In that case, the input file (default extension `.CAT`) is read and converted to the standard Plateau de Bure format; a file with the same name and extension `.SOU` is created in the current directory.

In the Plateau de Bure 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 explicitely, 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.

- 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 like hh:mm:ss.sss or dd.ddd or hh:mm.mmm ...

- Latitude-like coordinate: in degrees, same format as above.

- Velocity type: alphabetic code , such as `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) The flux can be followed by a spectral index.

A second catalog (known as the "ALTERNATE"catalog) may also be defined: 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 your project sources in the main catalog, and pointing sources, or phase calibrators, in the ALTERNATE catalog.

3 Setting the Observatory

The results of most commands of **ASTRO** depend on the observer's location on Earth [1]. This information is input via the OBSERVATORY command. You should type:
`OBSERVATORY longitude latitude altitude`
where the longitude and latitude are in degrees and the altitude in kilometers. You may also type `OBSERVATORY name`
Known names are "BURE", "VELETA", "KITT_PEAK", "VLA", "MAUNA_KEA" and "LASILLA". You will have to reset the time if you change the observatory.

4 Setting the Time

Further commands need the time to be set. For this use command TIME. Its format is
`TIME hour date`
The defaults are the current system time and date. Formats are "hh:mm:ss.ss" and "jj-mmm-yyyy" ; the hour must be given if the date is present. By default time and date are supposed to be in UTC (Universal Time Coordinated). You may use local time instead if you enter the option /ZONE z where z is the number of hours to be substracted to the local time to convert it to UTC (example: /ZONE 2 to use Summer Time in Western Europe).

Other possible options are: /UT1 to use UT1 instead of UTC (otherwise, the value of DUT1, input by SET DUT1, is added to UTC to get UT1); /TDT to use the input value as TDT, the argument of the ephemeris for solar system objects (otherwise, the value of DTDT, input by SET DTDT, is added to UTC to get TDT); and /NODRAW, to suppress the plotting of the Sun avoidance circle, which is plotted by default (radius 35 degrees at Plateau de Bure).

5 Computing and Plotting Object Positions

This done with the two commands SOURCE and PLANET. They work in the same way, except that SOURCE uses objects from the catalogs, while PLANET takes Solar System objects.

`SOURCE name` will compute the apparent coordinates of an object from the current catalog. The epoch 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 coordinates are printed on the screen, together with the line–of–sight components of the velocities

[1] this restriction to Earth-based observatories has not been so far a real limitation for potential users

of the Solar System barycenter G, relative to the observatory, and of the Local Standard of Rest (relative to G). All velocities are in km/s, counted positively for increasing distance (redshift).

`SOURCE` with no arguments will compute positions and optionally draw all sources from the current catalog; `/ALTERNATE` will direct the search to the alternate catalog.

`PLANET name` will do the same thing, but the object must be a known Solar System object: the Sun, the Moon, and planets from Mercury through Neptune. Pluto is not yet available. With no `name`, all Solar System Objects are used. In addition information is given on the planet's apparent size and osition angle, its brightness temperature and flux at millimeter wavelengths, at the current frequency. The current frequency (in GHz) is updated either through command `LINE` or by modifying the value of the variable `FREQUENCY`.

With option `/DRAW arguments` the position of the object are plotted in the current plotting frame. Arguments to `/DRAW` 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 flux or magnitude in the catalog), `SYMBOL` (to draw the source name in capitals), or `FULL` (to get both the marker and name; for planets, `FULL` gives the symbol, centered on the object's position).

The coordinates (in radians) of the last computed position are stored in the SIC variables `RA`, `DEC`, `AZ`, `EL`.

The plotting frame is defined by command `FRAME`. The frame may be in Equatorial coordinates or in Horizontal coordinates. The plotting may be done in rectangular coordinates (using `FRAME HO` or `FRAME EQ`, with no other argument); or in a stereographic projection, 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 12:00 45 20
```

will use a projection centered in the direction of 12 hours, 45 degrees in 1950 equatorial coordinates, and of size 20 degrees. The size defaults to 180 degrees (a half hemisphere). A few abbreviations exist, like `FRAME HO ZENITH`, which gives the whole sky above the horizon, or `FRAME HO SOUTH`, for the visible sky above the southern horizon.

Use of SIC variables permits 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.

Command `HEADER` will label the frame with the times (LST, UTC) and date.

6 Constellations Drawing

The `CONSTELLATION` command will plot the constellations stars using the current `pen` and `symbol` to plot the stars in the `FRAME` area. See the corresponding section of language internal help for details.

7 Observability Bar Charts

A convenient mean of planning observations of sources in a given list is to prepare a diagram, using time as x–coordinate, where a bar is drawn at the times for which a given source is up. One may do this under **ASTRO**, with command `HORIZON`. Optionally 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 `/SOURCE name1 name2 ...`), or a limited number of objects may be used at the same time (`/SOURCE NEXT n`, used repetitively to obtain pages with `n` objects at a time).

A source in the sun avoidance circle is within brackets ([]) and in italics (e.g. [*IRC+10216*])

8 Plotting tracks in the UV plane

This command `UV_TRACK` is quite specific to Plateau de Bure, though it might in principle be used for other interferometers.

Give the names of the stations (e.g. `N05 W12 E24`) occupied by the antennas for a given configuration as arguments; the option `/FRAME` must be given for the first configuration. Also give the option `/TABLE name` to open a table of UV data, if you want to compute later a synthesised beam using **GILDAS** task `UV_MAP`. A plot of UV tracks is made in a square box, labelled in meters. A sketch of the interferometer with the stations used is also drawn.

9 Preparing Line Observations for Plateau de Bure

ASTRO enables to prepare the line observations with the Plateau de Bure interferometer by plotting the frequency coverage of the line correlator for a given rest frequency. The `LINE` command should be entered as in **OBS** on Plateau de Bure. The syntax is:
`LINE name frequency band Lock Center Harm`
(only the first four arguments are mandatory). The coverage of the line backend for both upper and lower sidebands is drawn if option `/SPECTRAL` is present. Markers may be drawn for a few by giving the option `/MOLECULES file` with the specification for a text file containing, in the first column, the frequencies in GHz, and in the second column, the line names to be used by **GreG** (between single quotes; use of **GreG** control codes is possible). The default file name for `/MOLECULES` is `GAG_MOLECULES`.

The Doppler correction for the last used object is used in the calculations. This is of some importance since Doppler tracking is correct only in the signal side band. The Doppler scale is exact in the image side band when the frequency is loaded in **OBS**, 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 (see the document on Frequency Setup, by S. Guilloteau).

10 A Few Examples

10.1 A sample catalog

This is the contents of the catalog `sample.cat`

```
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
```

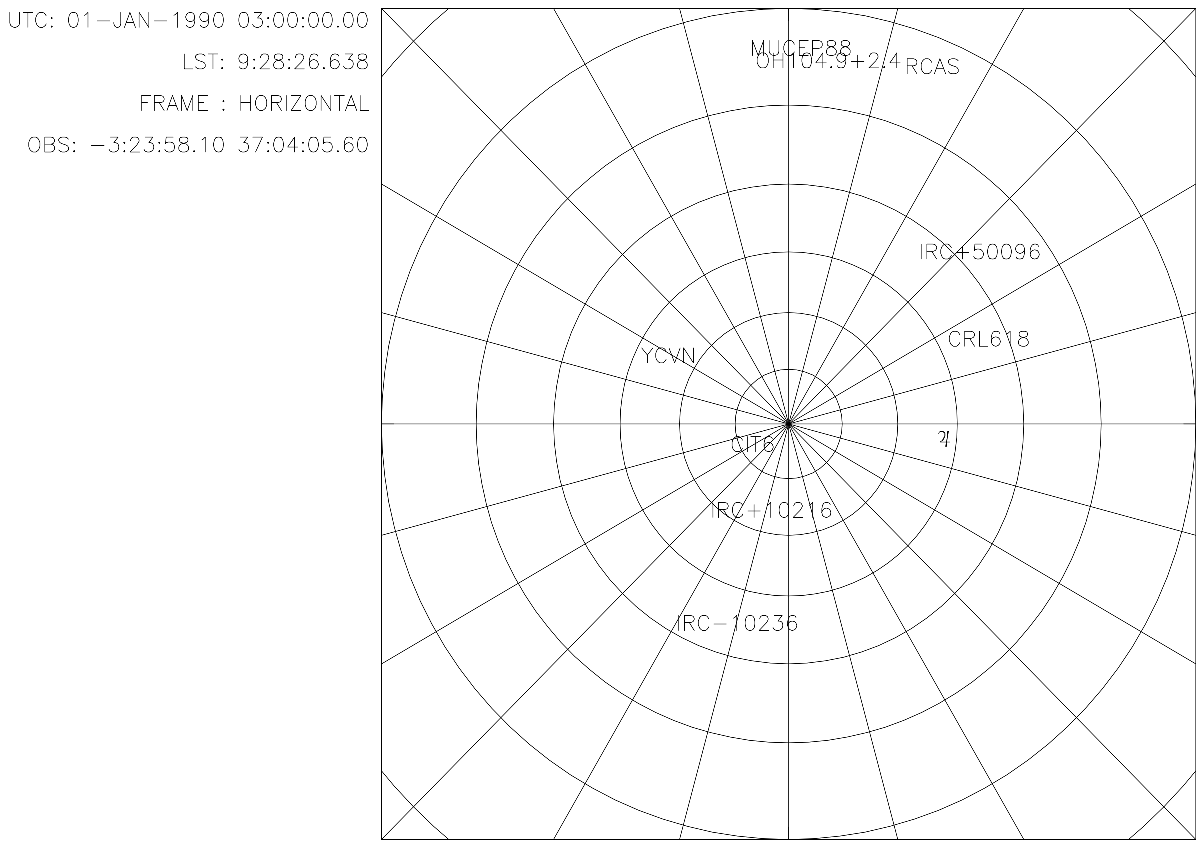

Figure 1: Plotting source positions

```
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.
```

10.2 Plotting the current position of the sources

The following commands will plot the position of the sources in the sky at 03:00 UT on January 1^{st}, 1990, together with the position of planets:

```
CATALOG SAMPLE                       ! First define the catalog
OBSERVATORY VELETA                   ! and the observatory
TIME 03:00 01-JAN-1990               ! the time and date
FRAME HORIZON ZENITH                 ! The whole visible sky
SOURCE/DRAW                          ! draw all sources from catalog
PLANET /DRAW                         ! and planets (only Jupiter is up)
HEADER                               ! label the plot.
```

The output will look like Figure 1.

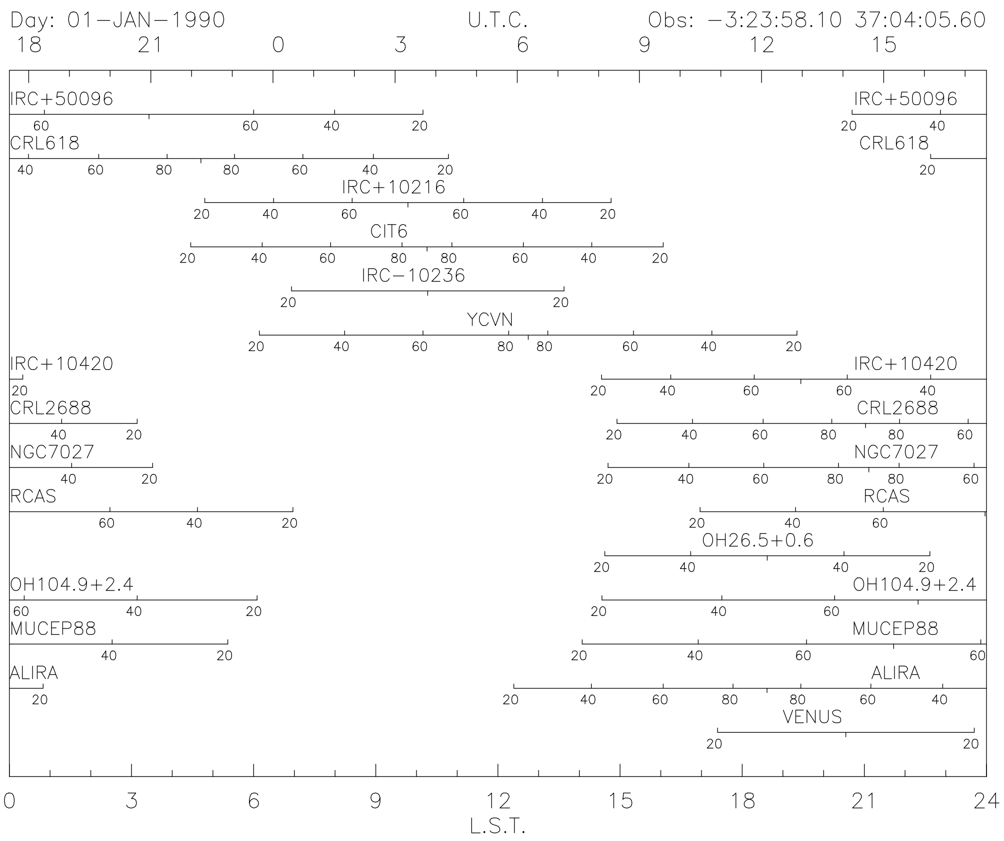

Figure 2: Plotting an observability chart

10.3 Plotting Observability Charts

The following commands will plot the position of the observability hours for sources on on January 1^{st}, 1990, together with planet Venus:

```
CATALOG SAMPLE                        ! First define the catalog
OBSERVATORY VELETA                    ! and the observatory
TIME 03:00 01-JAN-1990                ! the time and date
HORIZON /SOURCE /PLANET VENUS
```

The output will look like Figure 2.

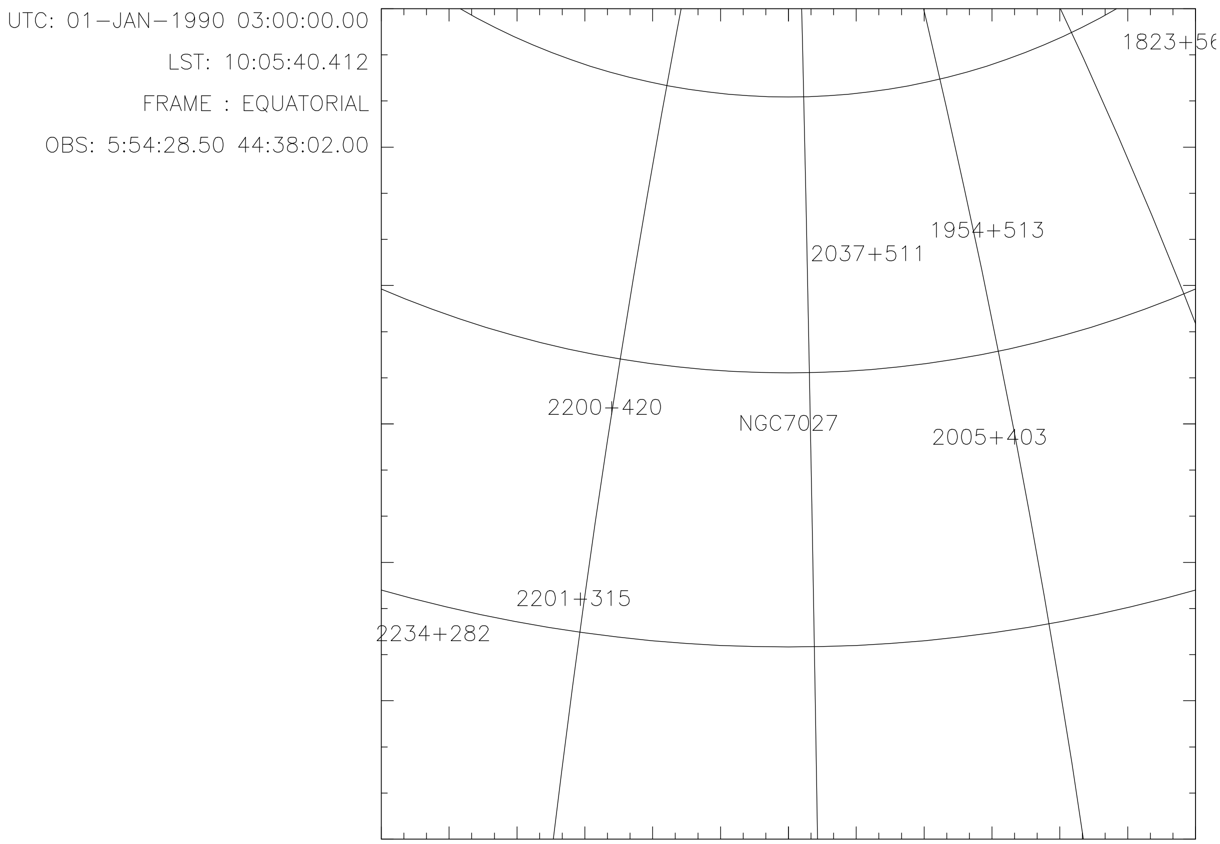

Figure 3: Finding phase calibrators

10.4 Finding Phase Calibrators

The following commands will plot the phase calibrators close to NGC 7027.

```
CATALOG SAMPLE                        ! First define the catalog
CATALOG GAG_ASTRO:PHASE /ALTERNATE    ! Phase Calibrators
OBSERVATORY BURE                      ! The observatory
TIME 03:00 01-JAN-1990                ! the time and date
SOURCE NGC7027                        ! Get source position
FRAME EQ RA|PI*12 DEC|PI*180 45       ! Frame Eq., centered on Source,
      ! 45 degrees in total size
SOURCE NGC7027/DRAW                   ! Plot source position
SOURCE /DRAW /ALTERNATE               ! Draw Phase calibrators
HEADER                                ! label the plot.
```

The output will look like Figure 3.

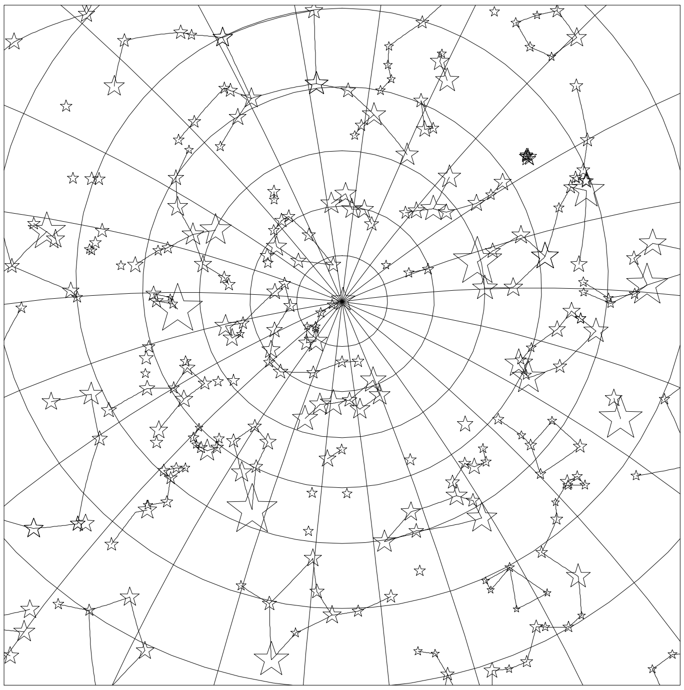

Figure 4: Plotting Northern constellations

10.5 Plotting the Constellations

This example show the use of the `CONSTELLATION` command to plot constellation charts. The output will look like Figure 4.

```
TIME                               !The current time (not useful but necessary)
FRAME EQ 12:32:54 75:30:33 180.0 !an equatorial frame
GREG\SET MAR 5 2 1                 !number of sides, type and size of marker
CONSTELL/DRAW M L                  !draws the stars and the lines
```

11 ASTRO Language Internal Help

We give here a *fac simile* of the internal HELP file for ASTRO. Please consult the internal help itself, which is normally kept up to date.

11.1 ATMOSPHERE

```
    [ASTRO\]ATMOSPHERE [INTERPOLATE|MAKE]

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.

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)
   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).
```

11.2 CATALOG

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

Open the catalog file specified by 'name'.  Default  file  extension  is
".SOU".  The  catalog  is  of  the format used at Plateau de Bure.  Some
standard catalogs are available in the directory GAG_ASTRO :
    SIO.SOU contains SiO masers used for pointing.
    CONTINUUM_1.SOU contains "strong" continuum sources (Flux > 8 Jy)
    CONTINUUM_2.SOU contains weaker sources, still useable for  pointing
    (Flux > 3 Jy).
    PHASE-2000.SOU contains the phase calibrators  of  Plateau  de  Bure
    (Flux > 0.1 Jy)
The catalog format is described in the ASTRO manual  and  summarized  in
the subtopic FORMAT".

/VELETA option will  open  the  catalog  file  'name'.CAT,  assuming  it
follows  the format of OBSINP catalogs in use on the 30 meter telescope.
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.

/ALTERNATE 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 with no arguments will display the catalogs currently opened.
```

11.2.1 CATALOG FORMAT

```
    In the Plateau de Bure 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 explicitely,
                            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 like hh:mm:ss.sss or dd.ddd or hh:mm.mmm
 5) Latitude-like coordinate: in degrees, same format as above.
 6) Velocity type: alphabetic code , such as "LSR", "HELIO" or "EARTH".
      HELIO actually means: referred to the Solar System barycenter.
 7) Velocity: in km/second, in the corresponding reference frame (LSR,
    HELIOcentric, or EARTH=local). Default is zero.
 8) Intensity type: Either "FLUX" or "MAGNITUDE" (optional)
 9) Intensity: Either the Flux in Jansky or the magnitude (optional)
    The flux can be followed by a spectral index.
```

11.3 CONSTEL

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

Plots in the current FRAME with the current FONT, MARKER  and  PEN,  the
constellations,  i.e.,  the  main stars of all the 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)
 /NAME will draw the constellation's names
 /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 VERY slow. Use with caution.
This command makes use of the logical name GAG_CONSTELL which points  to
a  GILDAS  Table  containing  the stars positions and drawing codes, and
GAG_CONST_BOUND which defines the constellation boundaries.
```

11.4 CONVERT

```
    [ASTRO\]CONVERT  [Catalog_Name]  [/ALTERNATE]  [/J2000  [Obs_epoch]]
[/PRECESS  [New_epoch]]  [/GALACTIC] [/FLUX fmin] [/NAME ncname [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.

11.5 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
      (ex 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.
```

11.6 HEADER

```
    [ASTRO\]HEADER

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

11.7 HORIZON

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

This command is used to produce plots of LST ranges of visibility, above
specified  elevations,  of  sources and planets. A line is drawn for all
hours when the object is 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. UTC axis
is drawn on  top  of  the  plot.  A  label  with  date  and  observatory
coordinates is plotted.
    /SOURCE                 will plot on one page all sources
                            of the Current (by default) or Alternate
                            (optionally) 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)
    /PLANET                 will plot on one page all solar-system bodies
    /PLANET name1 name2 ...  will be restricted to the specified bodies
    /ALTERNATE              with /SOURCE, will use the Alternate catalog.
    /FLUX Fmin Fmax         restrict the search to sources with flux in
                            the specified range.
    /PROJECT                add the project name (for Plateau de Bure
                            bookkeeping
```

11.8 Language

```
                    ASTRO\ Language summary

The  ASTRO\  language  contains  commands  to  compute  apparent  source
positions on the sky at any time(*) for any place on earth.
ATMOSPHERE          : Compute atmospheric parameters
CATALOG name        : opens a standard source catalog
CONVERT             : convert .SOU catalogs to .CAT or J2000 system
FRAME               : define plotting reference system
LINE                : plot frequency coverage for Plateau de Bure
HORIZON             : plot visibility hours of sources and planets
```

```
HEADER               : write time parameters on top of plot
OBSERVATORY name     : load observatory coordinates
PLANET [name]        : compute planet coordinates
SOURCE [name]        : compute source coordinates
SET parameter value  : enter some parameter value
TIME [time [date]]   : set computation time
UV_TRACKS            : plot interferometer UV tracks

* Ephemerides must be available for the planets at this time.
```

11.9 LINE

```
    [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.   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 6)
    Bandwidth is the bandwidth in MHz (10, 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.Ers/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
setup 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.
```

11.10 OBSERVATORY

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

Specify an  observatory  whose  coordinates  are  known,  or  Enter  the
observatory 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.   Known
observatories are  "BURE",  "VELETA",  "LASILLA",  "SEST",  "MAUNA_KEA",
"JCMT",  "CSO",  "VLA",  "KITT_PEAK",  "EFFELSBERG",  "PARANAL"  (or its
equivalent "VLT").

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

A reasonable  system  default  should  be  introduced  in  command  file
"GAG_UTIL:ASTRO_LOCAL.ASTRO".   For   "PARANAL"/"VLT",   the   variable
FREQUENCY is changed to 300 THz, i.e, a reasonable 1  micron  value  for
the VISA interferometer.
```

11.11 PLANET

```
    [ASTRO\]PLANET [name] [/DRAW [...]]
```

Compute the coordinates of a Solar System object. Known objects are: SUN, MOON, MERCURY, VENUS, MARS, JUPITER, SATURN, URANUS, NEPTUNE. By default, all known objects are plotted if visible. The Option /DRAW is used to plot the object symbol on the screen. The planet coordinates (apparent RA, apparent DEC, Azimuth and Elevation at time of computation) are typed on the screen.

PLANET outputs also the geocentric and heliocentric distances of the object (in A.U.), the apparent minor and major diameters (in arc.sec.), the position angle of the central meridian (east from north, in degrees), the brightness temperature (in K), and the flux (in Jy) at the current frequency. The frequency may be entered either through command LINE or by updating variable FREQUENCY (in GHz).

```
Arguments to /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).
If several arguments are given they will be used in sequence.
```

11.12 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.)
  - DTDT
    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).
  - FLUX Name Value
    Attribute the flux value Flux to the source Name (only  for  quasars
    or  continuum  sources  which are not planets). This command is used
    when no planet measurement is available and/or as a  redundant  flux
    check  on  strong and well known quasars or W3OH for example. A * as
    flux value frees the source as reference source.
  - 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
```

```
              names of the source
```

Reasonable system defaults may be introduced in the command procedure "GAG_UTIL:ASTRO_LOCAL.ASTRO".

11.13 SOURCE

```
    [ASTRO\]SOURCE [name [...]] [/DRAW [m] [l] [s] [f]] [/ALTERNATE]
[/SUN] [/FLUX Fmin Fmax]
```

Compute the coordinates of a Source from the Current catalog. If no name is specified, all sources of the catalog are selected. Source coordinates may also be 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 (RA, DEC, Azimuth and Elevation at time of computation) are printed on the screen, as well as the line-of-sight components of the following velocities:
increasing.

Arguments to /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).
```

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

/ALTERNATE will direct the search to the Alternate catalog.

/SUN will also list the sun avoidance limits

/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.

/PRINT option will suppress the printing of Az and El, and print the source characteristics as in catalog instead.

11.14 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 default to current system time. Local civil time may be input instead, in conjunction with the option /ZONE z, where z is the difference in hours between UT and local civil time (use /ZONE 2 on Plateau de Bure in summer, 1 in winter).

By default, if the sun is visible, a sun avoidance circle is plotted. It can be suppressed using the /NODRAW option.

The radius of the sun avoidance circle is now 30 degrees on Plateau de Bure.

11.15 UV_TRACKS

```
[ASTRO\]UV_TRACKS station1 station2 [station3 [...]] [/FRAME [size]]
[/HOUR_ANGLE Hmin [Hmax]] [/TABLE [Name]] [/HORIZON Elmin]
```

Plot interferometer UV tracks for the most recently called source. Station coordinates are searched for in the file ASTRO_STATIONS. Stations should be referred to by a mnemonic (e.g. E03, W00 ...). A sketch of the interferometer described by ASTRO_STATIONS is also drawn.

Option /FRAME 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.

Option /HORIZON specify 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 decimal hours.

Option /TABLE can be used to write the sampling function (UV coverage) on 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 set.

The box labelling is in meters. A double labelling in kilo wavelengths is drawn if variable FREQUENCY (observing frequency in GHz) is defined. Switching to the VLT by the command "OBSERVATORY VLT" defines FREQUENCY to some 1 micron (300 THz). Some labellings are then in wavelengths (microns). Switching between files describing interferometer stations can be done inside ASTRO by redefing 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:astro_stations.dat)
The VLT stations are described in the file ephemeris/vlt_stations.dat
(and accessed by

```
SIC LOG ASTRO_STATIONS GAG_ASTRO:vlt_stations.dat)
The IOTA stations are described in the file  ephemeris/iota_stations.dat
(and accessed by
SIC LOG ASTRO_STATIONS GAG_ASTRO:iota_stations.dat)
```

12 FLUX Language Internal Help

12.1 FILE

```
    [FLUX\]FILE Name

    Define the entry file name. The entry file  can  be  produced  using
CLASS command
    ANALYZE\PRINT FLUX/OUTPUT Name
or using CLIC command
    CLIC\SOLVE POINTING /FLUX Name
```

12.2 INDEX

```
    [FLUX\]INDEX Filei Name/OUTPUT Fileo [NEW]

Compute the spectral index (with errors bars) of the  source  Name  from
all  the  data  available on that source in the input file Filei (result
from FLUX\PRINT).  Write the results on the output file Fileo.

If NEW is present, the output file is created, otherwise it is appended.
```

12.3 PRINT

```
    [FLUX\]PRINT [/OUTPUT File [New]]

Print the date and information lines on the meaning of each column, then
the  fluxes  with  error bars, the frequency, the antenna number and the
average antenna efficiency (Jy/K), with error bars.   The  command  asks
for  atmospheric conditions and quality of the data and writes it in the
header of the output file.

If NEW is present, the output file is created, otherwise it is appended.
```

12.4 READ

```
    [FLUX\]READ Iant Freq

    Read the gaussian fits data from the antenna  number  Iant  and  the
```

```
frequency  Freq. The frequency must be the LSB frequency tuning given at
+- 0.5 GHz.
```

12.5 SOLVE

```
    [FLUX\]SOLVE [Name1 [Name2 [...]]]

Use the sources Name1, Name2, etc... as flux references.  For a  planet,
the  flux  is derived using the gain USB/LSB and the frequency
informations. For other sources, the flux specified by command SET  FLUX
is  used.  Without  argument, all the planets included in the input file
are used to calculate the antenna efficiency.

The fluxes of all sources is computed as described below at  the  ``gain
corrected'' frequency:
    F = ( F(LSB) + G x F(USB) ) / (1+G)
where G is the USB to LSB receiver gain ratio.

The computation steps are
   + Correct Azimuth subscan for elevation pointing error
   + Correct Elevation subscan for azimuth pointing error
   + Average both subscans to derive the source intensity
        (with proper weighting using standard deviations)
   + Average all independant scans on the same source
        (with proper weighting)
   + Determine the  average antenna efficiency from the list of
        sources of known flux, with error estimate
   + Determine the unknown fluxes, giving the error estimates:
        Relative, including only errors on the source intensity, and
        Absolute which also includes the error on antenna efficiency.
```

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