Astronomical Calibration Sources for HIFI

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In-flight calibrators

Two types of astronomical calibrators

- Absolute photometric calibrators
  - they drive the absolute intensity scale (efficiencies, coupling)
  - distinction between *primary,* and *secondary* calibrators, which need to be tied to the primary references
- Instrument calibrators
  - check and monitor the various instrument performances in the course of the mission
  - validate the HIFI observing modes on template targets

➔ the work of the calibrator consists in building lists of adequate calibration sources to fulfill these purposes

Identification of the calibrators

Approach to fulfill this task

- Analyze the calibration Use Cases against source needs
  - ➢ build the calibration source requirements (LRM-ENS/HIFI/SP/2001-01)
  - ➢ the considered topics include
    - ➔ beam properties (efficiency, PSF measurement)
    - ➔ sensitivity properties (e.g. long integrations, baseline quality)
    - ➔ spectral properties (check spectral profiles, assess platforming,..)
    - ➔ photometry properties (primary and secondary calibrators)
- Identify the required source properties
  - ➢ selection criteria based on variability, intensity, size (need for compact/extended targets), spectral profile, and distribution on the sky (telescope slow in slewing)

Identification of the calibrators

Identification of the source categories

- they span most of the future HIFI core targets
  - solar system bodies: serve as primary photometric references and compact strong emitters to map the PSF
  - evolved stars (AGB, PNe/PPNe): serve as compact emitters in a number of submm lines + secondary calibrator
  - starburst galaxies: provide broad lines for various sensitivity and baseline checks
  - ISM sources (UCHII regions, hot cores, PDRs): provide a range of spectral properties (narrow lines, rich spectrum) in compact-to-extended regions

Building the calibrator lists

The questions we need to answer are

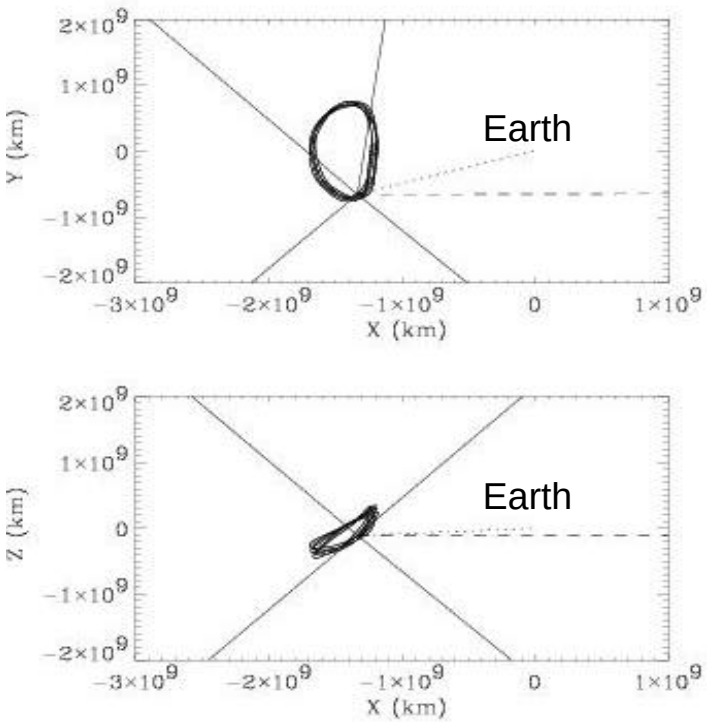
- how many sources are required ?
- what is already available / what is missing ?
- what needs to be observed before launch / what can be obtained from other observatories ?

➔ the driving criteria are related to the source visibility constraints + the expected frequency of occurrence of calibration measurements

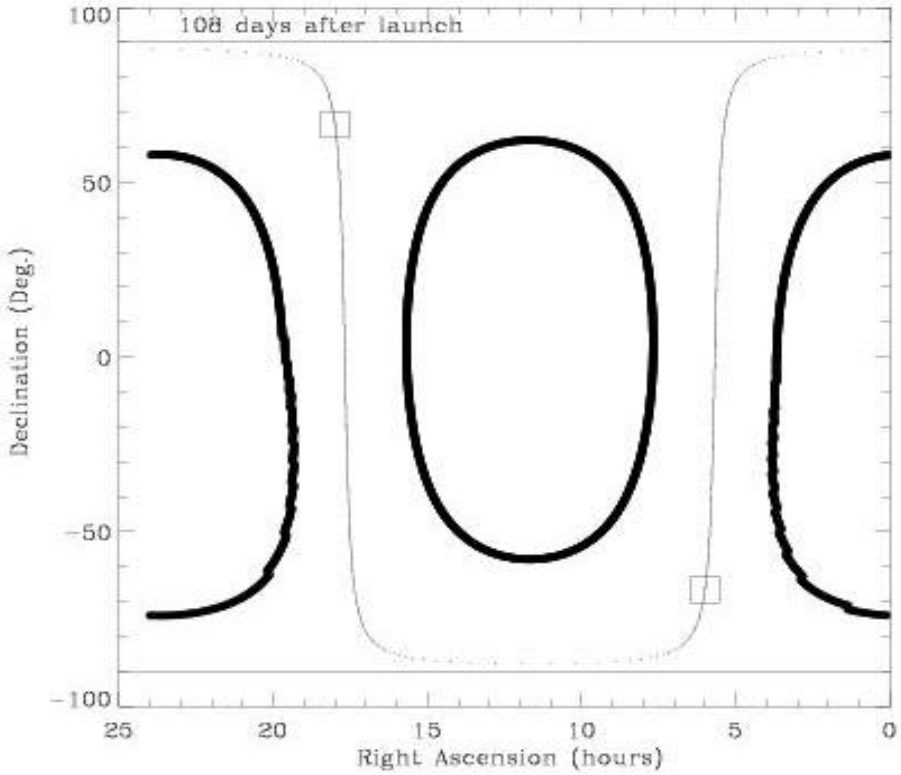
- ➢ the likely suitable planets are not often available (need for secondary calibrators !)
- ➢ galaxy sample *a priori* more often visible (high decl.) but scarser
- ➢ some checks only expected during science demo. phase

Sky visibilities over the mission

Visibility constraints

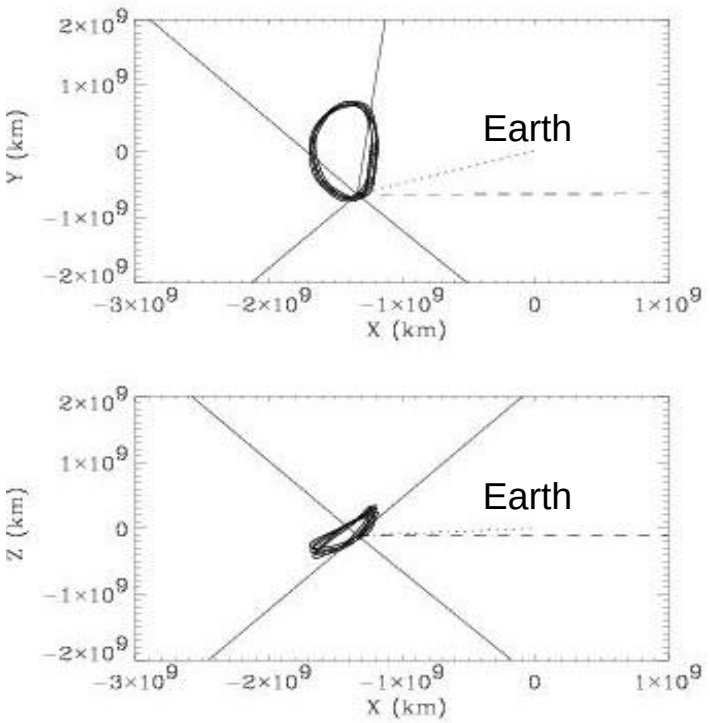


Visibility on a given day

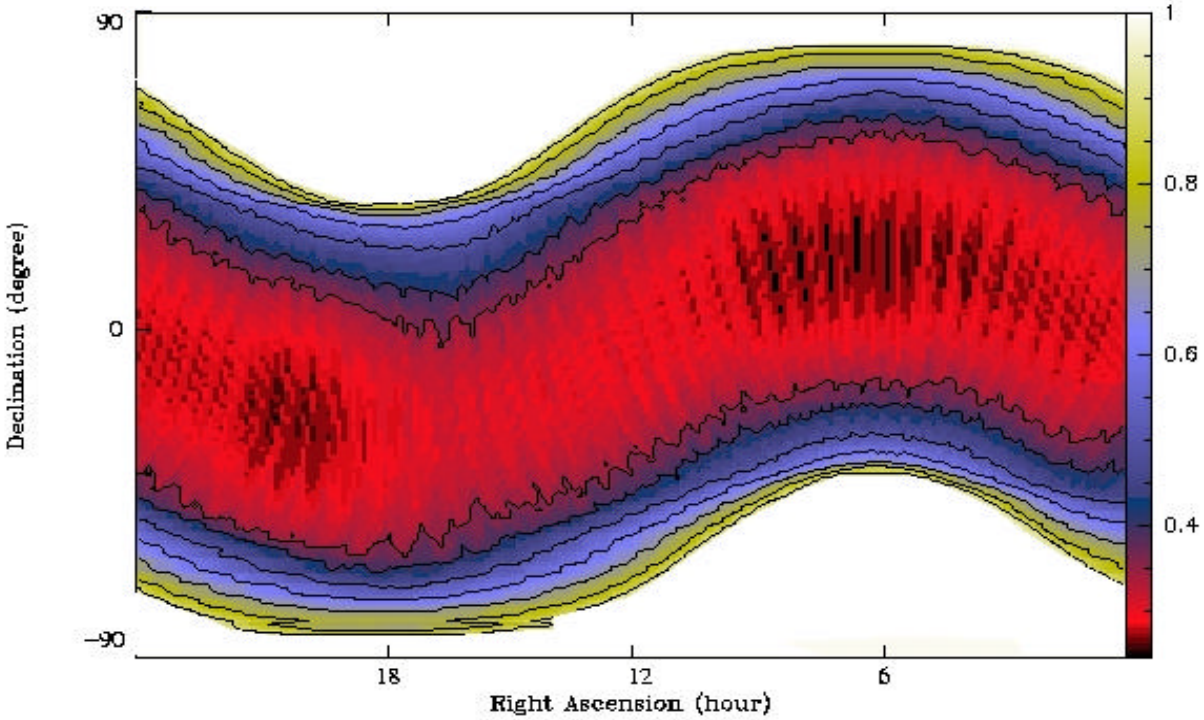


Sky visibilities over the mission

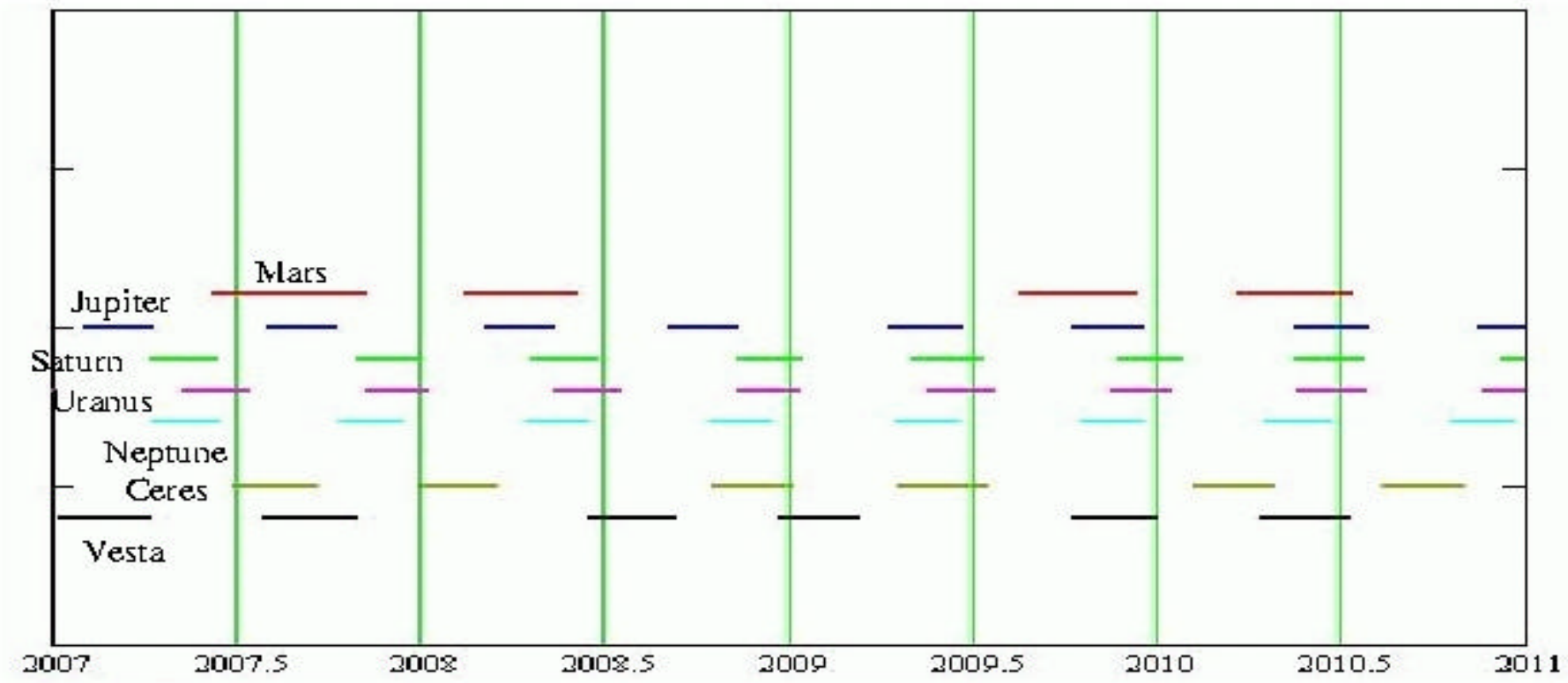
Visibility constraints



Visibility percentages



Source visibilities: solar system bodies



Building the calibrator lists

How many sources ? Tentative numbers…

- assuming an optimum observing scheduling
  - for monthly-to-trimestrial checks, 6x2 (north/south) sources per category *a priori* sufficient ➔ can we find as many adequate galaxies ?
  - for more frequent calibration measurements/checks, redundancy very likely required: 12x2 (north/south) enough ? ➔ critical issue for secondary calibrators
- first guess:
  - 24 evolved stars (compact strong emitters+secondary calibrators)
  - >12 ISM objects (extended and/or with narrow lines)
  - 6 galaxies (broad lines)
  - 2 planets (Mars and Uranus) at least (primary calibrators)

Building the calibrator lists

Existing data

- solar system bodies: rely on most recent models
  - planets: Mars (Griffin, Lellouch), Uranus (Moreno)
  - asteroids: work of T. Müller + SPIRE preparatory program
- evolved stars:
  - extensive lists exist in the mm windows (e.g. Loup et al. 1993) and IR (ISO heritage)
  - much scarser in the submm (mainly CO(3-2), CO(4-3), C[I])
- galaxies: few candidates reported in the submm (CO(3-2), C[I])
- ISM objects:
  - many data reported in a wide range of frequency range
  - submm observations on-going at KOSMA (CO(4-3),(7-6),C[I])
  - preliminary list of suitable candidates still underway

Building the calibrator lists

What is missing (calibration viewpoint) ?

- high-J CO data
- spatial structure information for assessment of beam dilution
- variability knowledge (and understanding)
- data from the southern sky

Need for a ground-based preparatory program

- Goal: ensure that all selected targets are suitable for the calibration purposes
  - ➢ preparatory modelling to “predict” expected intensities at the highest frequencies (very related to science preparation)
  - ➢ preparatory observations of candidates from the ground

Ground-based preparatory observations

Philosophy of the campaign

- needs are defined according to **specific** calibration requirements
- connection/commonality with science program is to be considered as much as possible
- insist on valuable by-products for the community
  - ➢ feed models with unprecedented data (unexplored freq. windows)
  - ➢ address scientific questions which affect the calibration issues (e.g. variability)
  - ➢ benefit to other observatories (ALMA, APEX, SMA, CSO, JCMT)

    ➔ high quality submm database

    ➔ cross-calibration

    ➔ the need for carefully calibrated data from these observatories implies a better understanding of the observatory parameters themselves

Ground-based preparatory observations

Preparatory campaign: planned activities

- intensity and spatial distribution of strong submm lines (e.g. CO) in freq. windows available from the ground
  - check the suitability of a candidate to be used as a calibrator at the frequencies of interest.
  - assess the beam dilution by the HSO + optimize observing mode
  - get inputs to the models required to predict the line strengths
- variability study (monitoring) on a sample of evolved stars
  - essential for e.g. secondary calibrators
- search for suitable calibrators (all categories) in the southern hemisphere
  - critical if telescope slewing time remains an issue

Ground-based preparatory observations

What have we done so far ?

- Pioneering CSO campaign started one year ago
- sample of evolved stars mapped (or cross-mapped) in CO(6-5)
- 19 candidates probed
  - ➢ 15 exhibit non-negligible emission as seen in a 10-m dish (T_{mb} > 1.5 K, S/N > 3)
  - ➢ 13 correspond to a first detection at this frequency
- 9 candidates mapped, 5 appear as non point-like

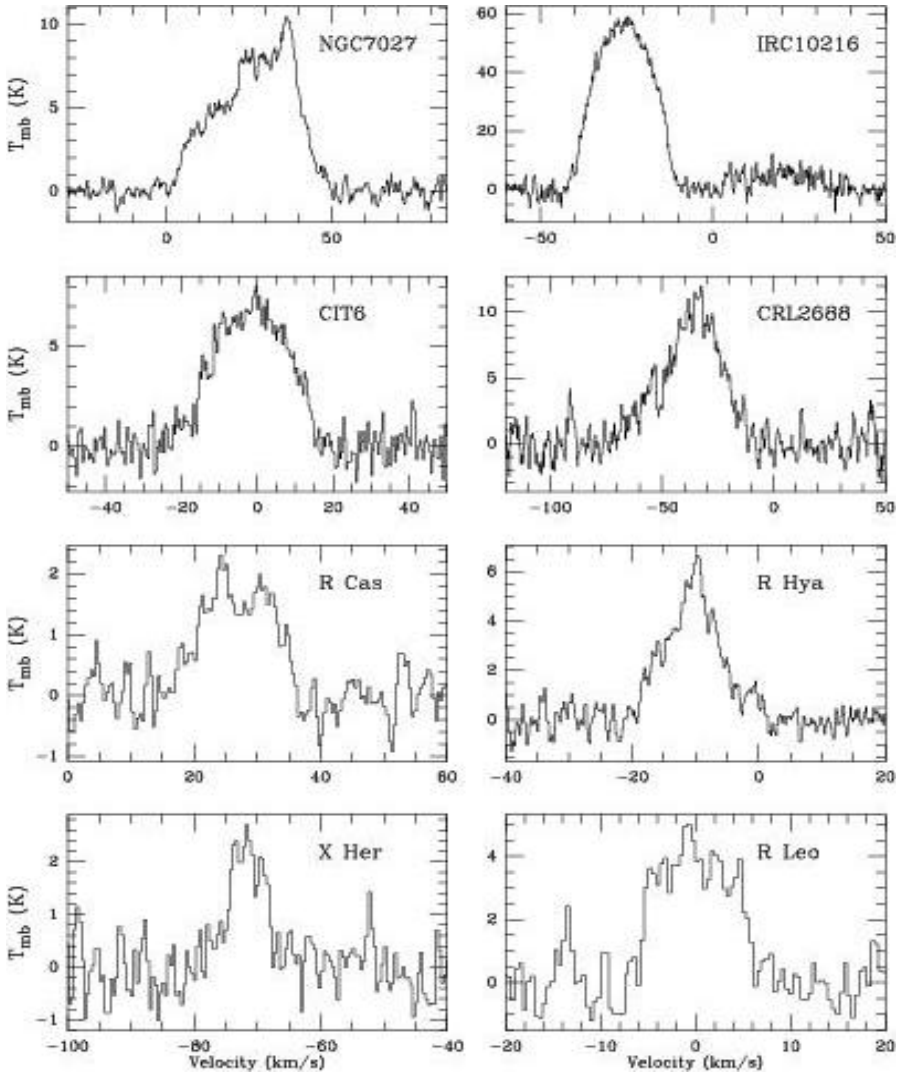
➔ significant growth of emitter list at this frequency

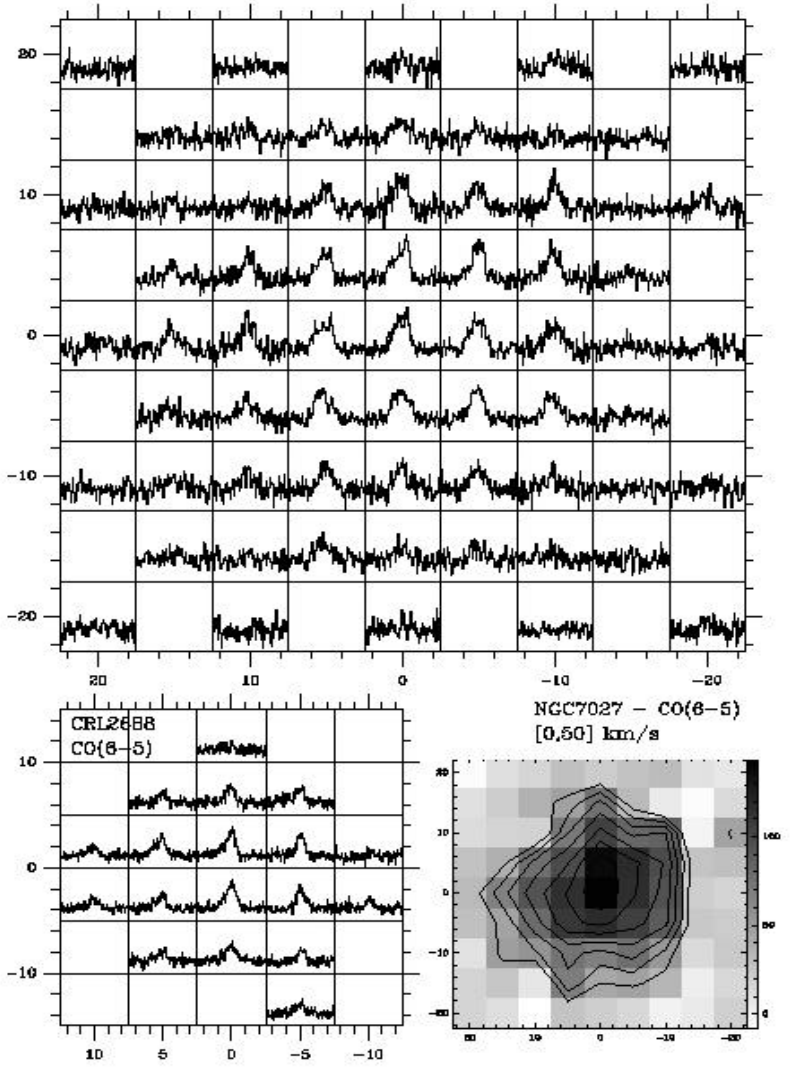
➔ selection criteria are validated

➔ proved the suitability of about of dozen of them as in-flight calibrators

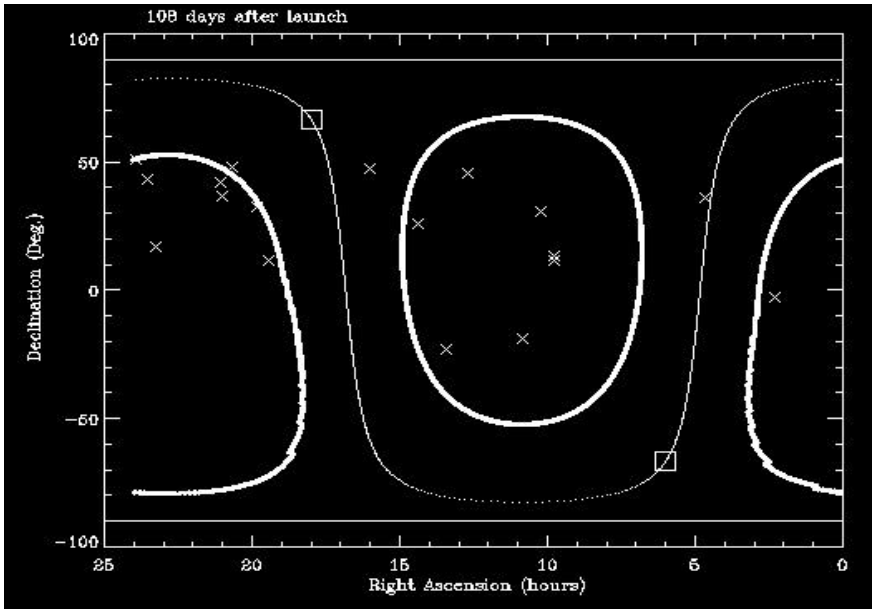
➔ scientific exploitation on-going

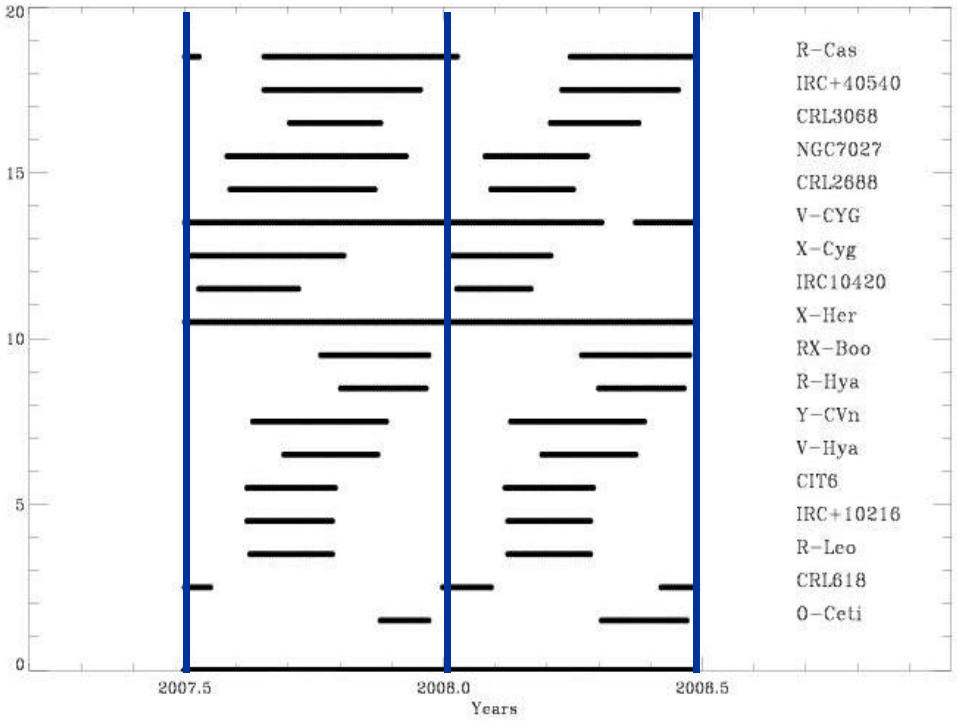
Pioneering CSO campaign: examples





Source visibilities: evolved star sample





Preparatory observations

Next steps: tentative mid-term plans, proposals ?

- other strong submm lines
  - CO(7-6) at CSO/JCMT ?
  - usefulness for further modelling to be discussed
- variability study (likely ^{13}CO(3-2) monitoring at JCMT) on a sample of AGB/PPNe candidates (4-6 targets ?)
- probe submm emitters in the southern sky
  - AST/RO probably too small, need to wait for the facilities in Chile (e,g, APEX, ASTE)