SPIRE Calibration Strategy

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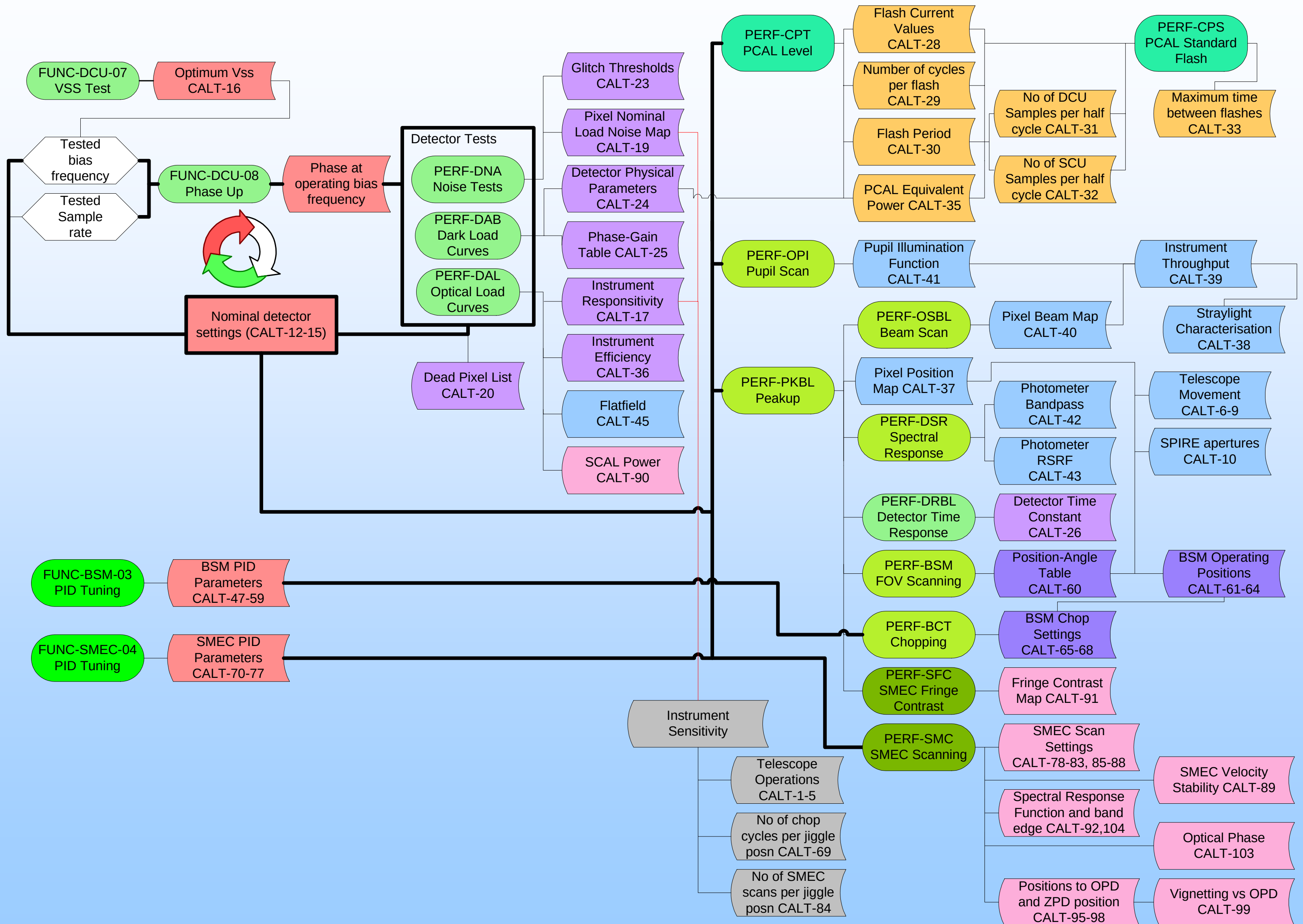
Strategy Summary

- Derive requirements
  - Science -> Cal Requirements
  - Pipeline Design
  - Operating Modes
- Robust ILT
  - 7 campaigns with 2 instrument models
  - Results used for initial population of cal files
- (Re) Calibration After Launch (PV Phase)
  - Establish parameters not possible from ILT
  - Confirm existing calibration
- Maintenance – Routine Calibration

Requirements - The SPIRE Calibration Scheme



Instrument Level Testing (ILT)

- Two test campaigns with the qualification model
- Five campaigns with the flight model
  - PFM1 – flight build phase 1 (Spec)
  - PFM2 – flight build phase 2 (Phot (part) + Spec)
  - PFM3 – Complete Phot + Spec
  - PFM4 – Main calibration campaign
  - PFM5 – Full instrument dark characterisation

ILT Summary

- Instrument came through vibration unscathed
- PFM4 provided a good set of optical calibration data
- PFM5 provided dark background to (re)calibrate detectors
- Anomalies
  - Initially non-functioning SSW o.k. but still high level of microphonic susceptibility
  - Some (~12-15) other pixels didn't function for various reasons (mostly test harness)
  - Room background (still) too high
  - PTC operation still not quite satisfactory
  - Photometer detector temperatures 25-30 mK higher than in PFM3 –reason unknown
  - L0 temperature could not be controlled for long periods –kept to 1.5 K

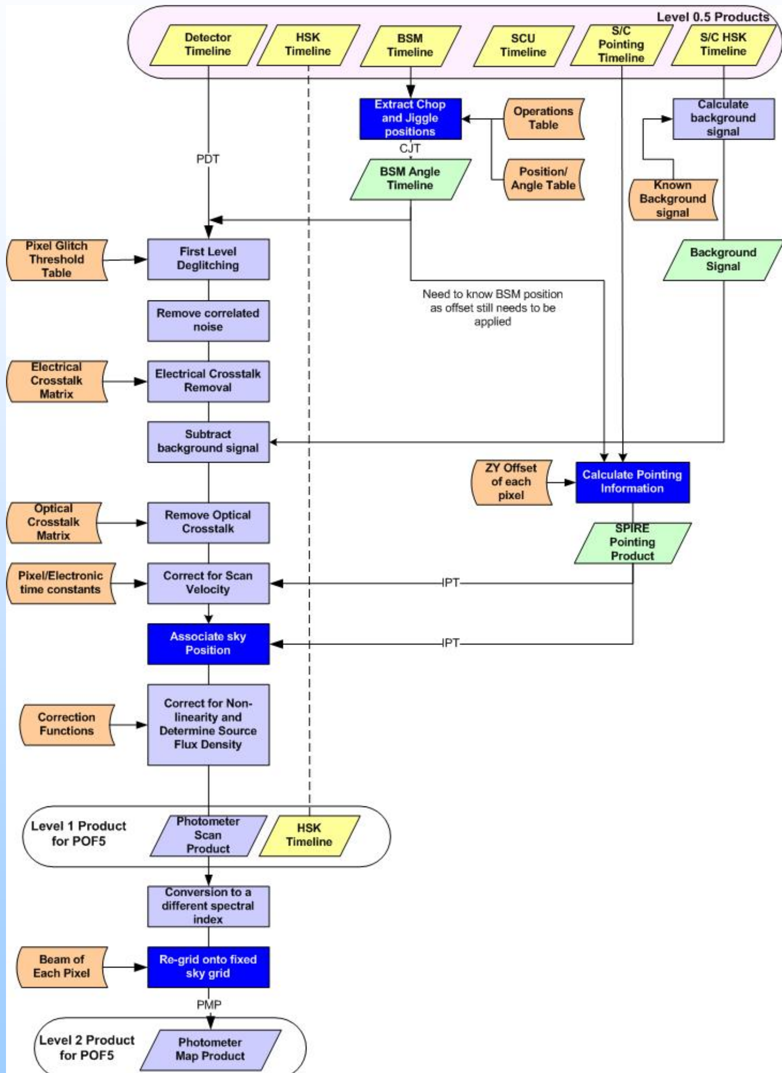
ILT Summary

- In one form or another SPIRE has been cold tested as for ~4 months
  - 2½ months of which as complete flight unit
- We have almost all the data we could have obtained for ground calibration – analysis on-going
- SPIRE meets or exceeds all performance specifications

Cal Files - Uplink

- BSM rest position, jiggle positions, chopping parameters
- SMEC parameters
- PCAL parameters
- Sensitivities
- Parameters to perform a cooler recycle
- PTC control parameters, based on ILT values, more work needed
- SCAL control parameters, based on modelled and ILT values
- Operations parameters, everything else needed for AOTs, slew rates, number of chop cycles etc

Cal Files - Data Processing Pipeline



Basic pipeline design has been in place for a few years

Used to set priorities in ILT

Currently evolving final design before flight

Most cal files now fully defined and populated

In Flight - Commissioning

- Top Level Plan Drafted
- Will start by carrying out standard Cold Functional Tests
- Then some basic engineering/characterisation tests
  - Mechanism tuning, PTC setup
  - Manual cooler recycle to setup automatic one
- While lid is still closed check out the cryostat ambient environment
  - Very useful to take spectra against lid
- Following lid opening – focal plane geometry
- More detailed planning currently being done

PV Phase Objectives

The main objectives of PV phase are:

- Verification of basic instrument performance by comparison with results from similar tests on the ground and model calculations
- Population, with initial values, of all calibration files which require in-flight data
- Verification of instrument operating modes
- Validation and optimisation of AOTs
- Generation of data sets required to update instrument sensitivity

Science Demonstration Objectives

The main objectives of Science Demonstration phase are:

- Some further optimisation of AOTs
- Verification of the scientific performance of each AOT, including verification of instrument sensitivity via observations of faint sources
- Assessment of capabilities of the observatory to carry out, and achieve the scientific goals of, the approved Key Programmes
- Generation of results for PR purposes

PV Planning - Key Assumptions

- PV phase will last 3 months
- It will be split equally between the three instruments
  - SPIRE would prefer a 2 day rotation
- The plan will be adaptable to ensure that PV is used effectively
- Pointing accuracy will be good enough (TBS - it is assumed this will evolve throughout PV phase and the SPIRE observations will have to be tailored accordingly)
- The spacecraft must be able to slew along a specified axis at a specified rate with good (TBS) pointing accuracy
- The straylight performance has been established. (This can only be finally established once the telescope has reached its operating temperature and the instruments have been operationally optimised.)

Priorities

The priority order is governed by the need to release AOTs. The following set of priorities is adopted (1 is higher priority than 5):

1. Point source photometry
2. Scan Map
3. Jiggle Map
4. FTS point source
5. FTS Map

Priorities

For each AOT, the following general priority order is adopted

1. Calibration files required for uplink of an AOT (e.g. BSM position vs. angle on sky)
2. Setup of an AOT (e.g. for point source photometry this would include optimum jiggle offset; for scan map it would include the scan speed)
3. Calibration files required for data processing but not needed for uplink (e.g. spectral response function)

Cal Files – Some Statistics

- **16 Uplink Files**
- **37 Pipeline Files**
- **168 parameters have been identified in these files**
- **87 Observations specified so far (50 phot, 37 spec)**
  - **But more to come…**

Sources - Introduction

- Investigation of potential targets is ongoing work
  - Summary in SPIRE-UCF-NOT-003016 “Astronomical calibration sources for Herschel-SPIRE”
- Prime calibrator for the photometer is likely to be Neptune and for the spectrometer, Uranus
- To cover the flux scale asteroids and a few stars will also be observed
  - For visibility reasons these observations are likely to extend into routine phase
- Bright isolated point sources is the only requirement for many observations
- Line sources are also required for the spectrometer

Source requirements

- Point-like in 18” beam
- Bright, well above confusion limit, >~100mJy
- Not too bright, <~200Jy
- Non-variable, or known variability
- Good sky distribution & Herschel visibility
- Well modelled/known SEDs, with in-band uncertainties <10%
- No line contamination is desirable (photometer)

Spectrometer source requirements

- Line fluxes accurately known or predicted
- Several observable lines
- Lines must be well isolated with good coverage of FTS dynamic range

Bright source observations

1. Detector non-linear response
   - Well-understood and can be corrected
2. Limited dynamic range for a single observation
   - Saturation of on-board ADC for source flux greater than some limit
   - Worst/best case dynamic range ~ 50/300 Jy
     - Neptune ~ (260, 120, 50) Jy
     - Asteroids: a few – a few x 10 Jy (high S/N; no saturation)

- Countermeasure: increase or decrease detector bias to reduce responsivity
  - Increasing bias by ~ 3 can double dynamic range
  - Significant fraction of PSW detectors will saturate for sources > 500 Jy
- Further analysis needed to clarify limiting source brightness for the FTS

Photometer calibration – wavelength definition & colour correction

- Photometer standard product will be flux densities at standard wavelengths of 250, 350, 500 μm
- Pipeline must make some standard assumption about source spectrum.
  - SVR3-25 proposes adoption of a power law with zero spectral index: α_S = 0 (S_ν flat across the band)
  - HST discussion concluded that the more usual convention of νS_ν flat across the band should be adopted (i.e., α_S = -1)
  - Document will be updated accordingly

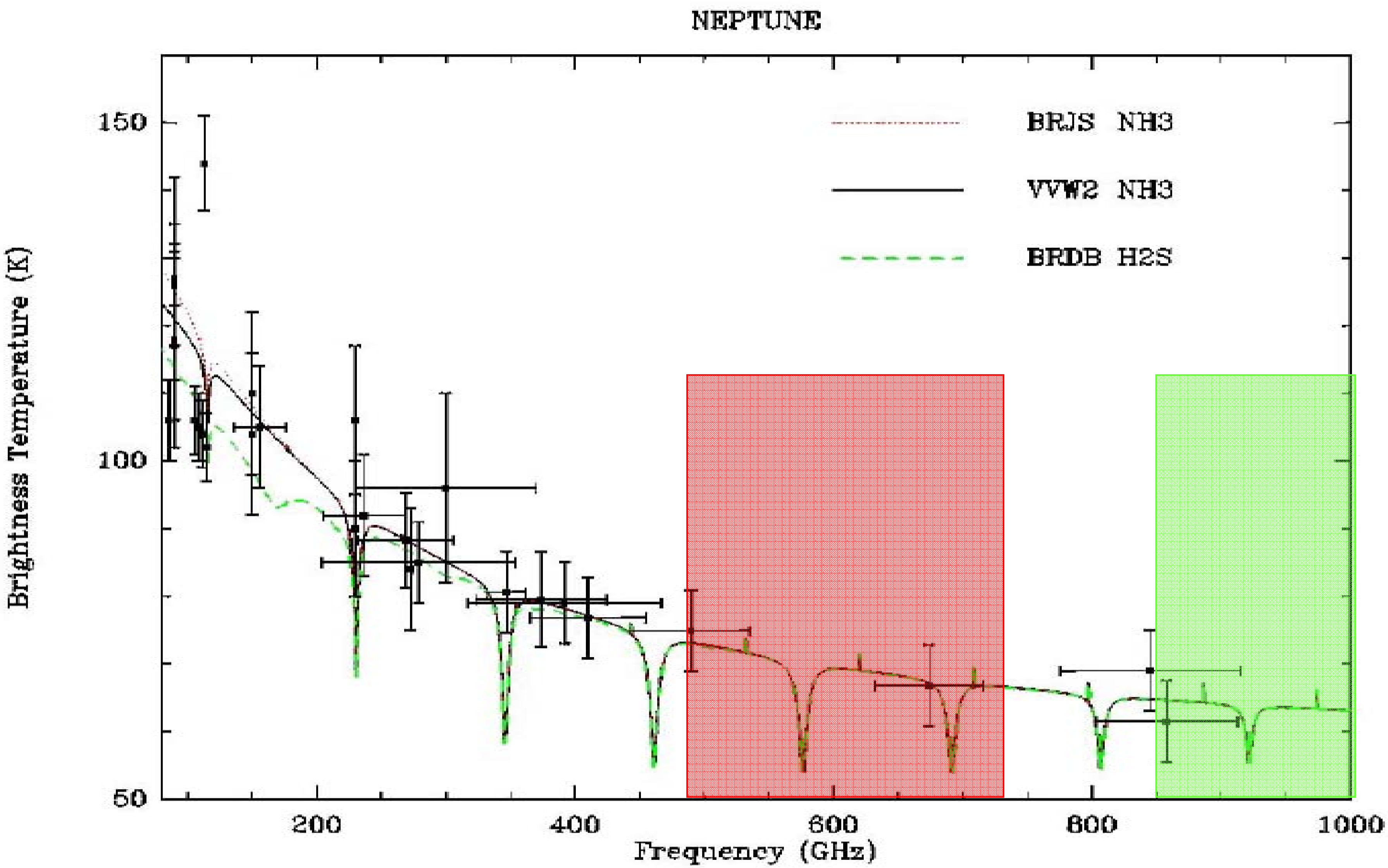
$$S_S(\nu) = S_S(\nu_o)\left(\frac{\nu}{\nu_o}\right)^{\alpha_S}$$

Routine Calibration Philosophy

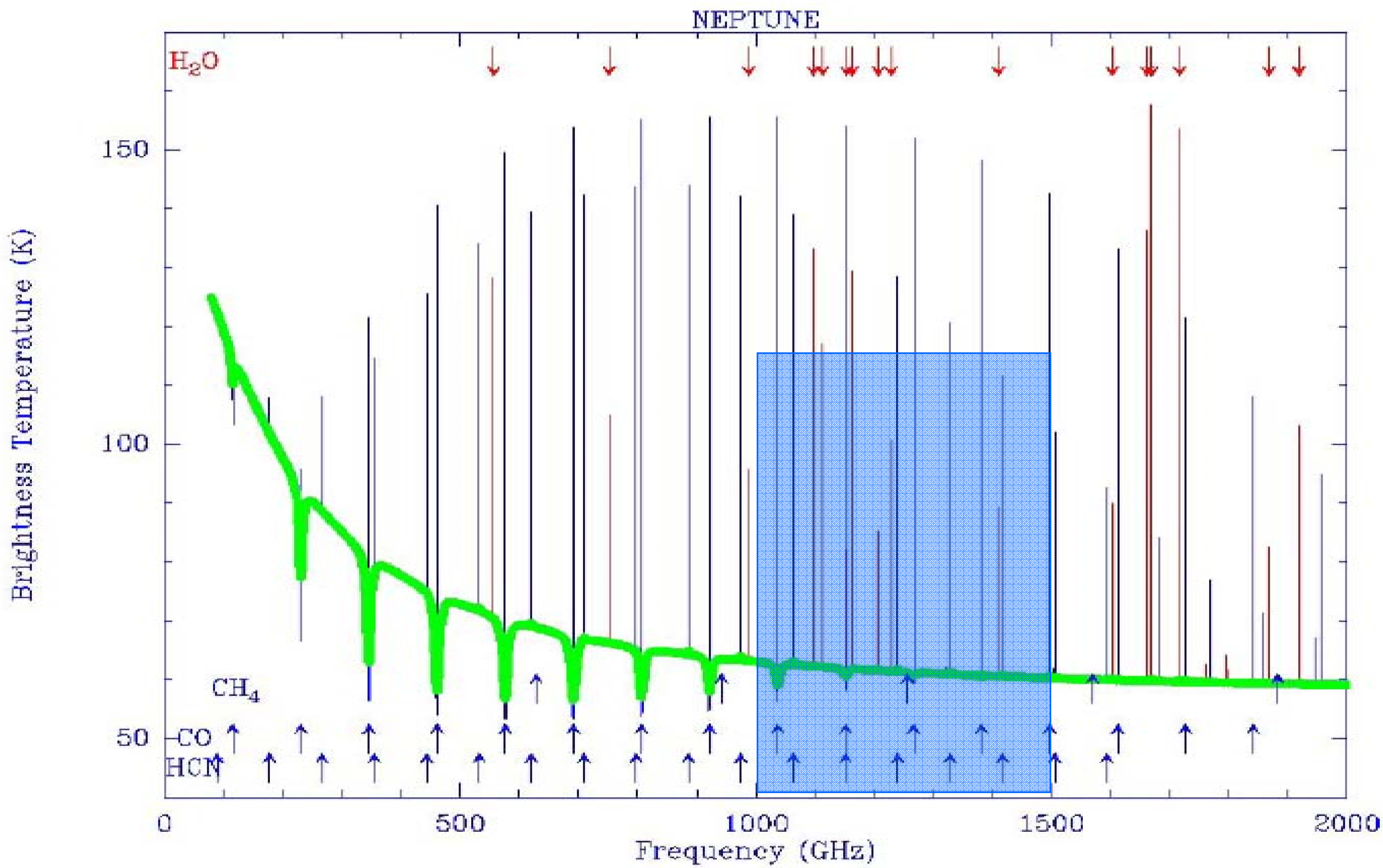
- Observe fewer, well-known sources many times, rather than many different sources
- Selected primary, secondary and tertiary sources
- Use PCal to transfer/monitor calibration

Standard Photometric Sources

- Primary
  - Neptune
    - Broad PH_3, CO and HCN lines, with contrast of 10-20K
    - Absorption features in all bands
    - Good flux level
  - Uranus
    - Shows few lines, some weak PH_3 lines with ~5K contrast at 538GHz and 802GHz
    - Very bright, especially at 250µm
      - Good for spectrometer



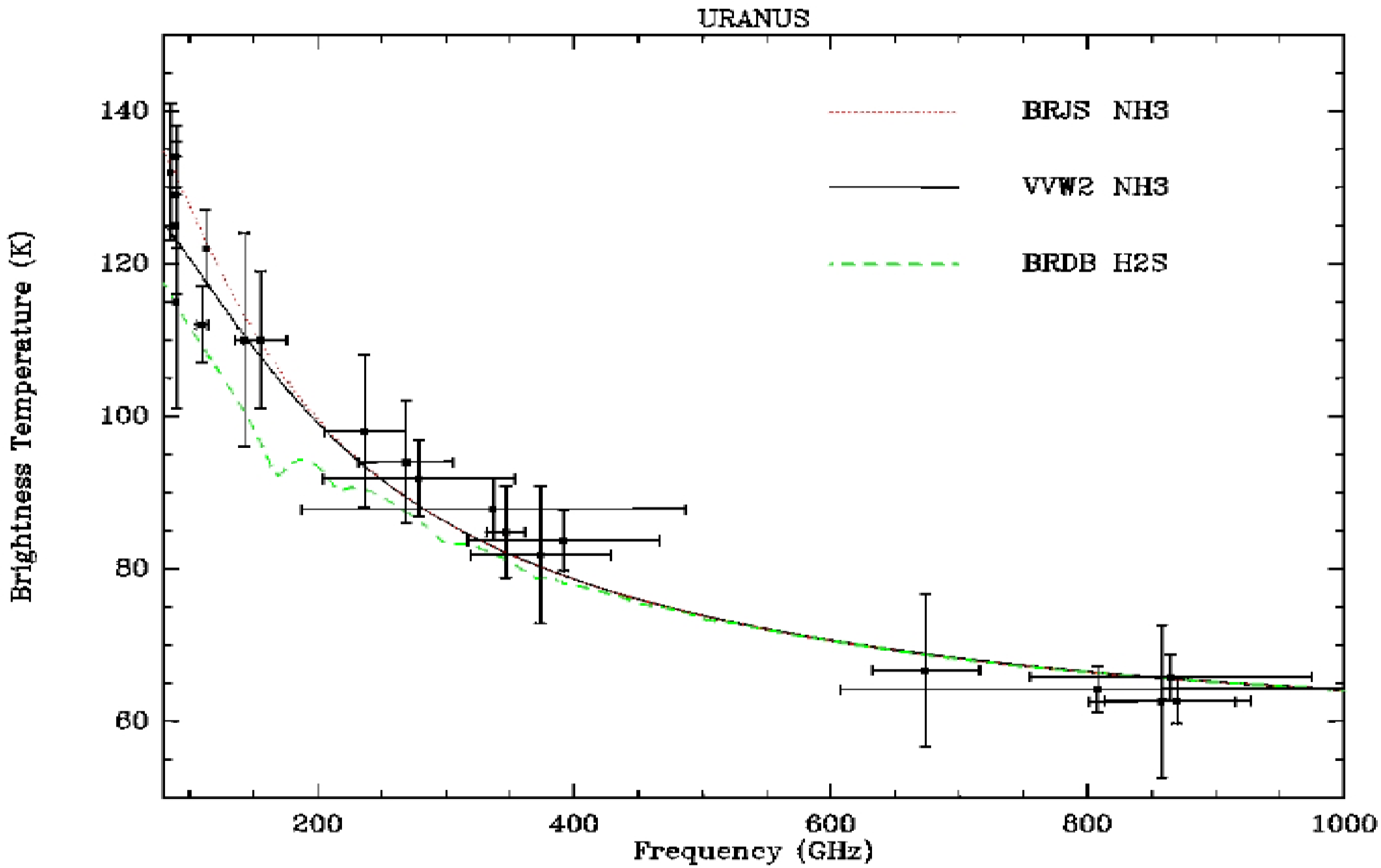
Encrenaz & Moreno



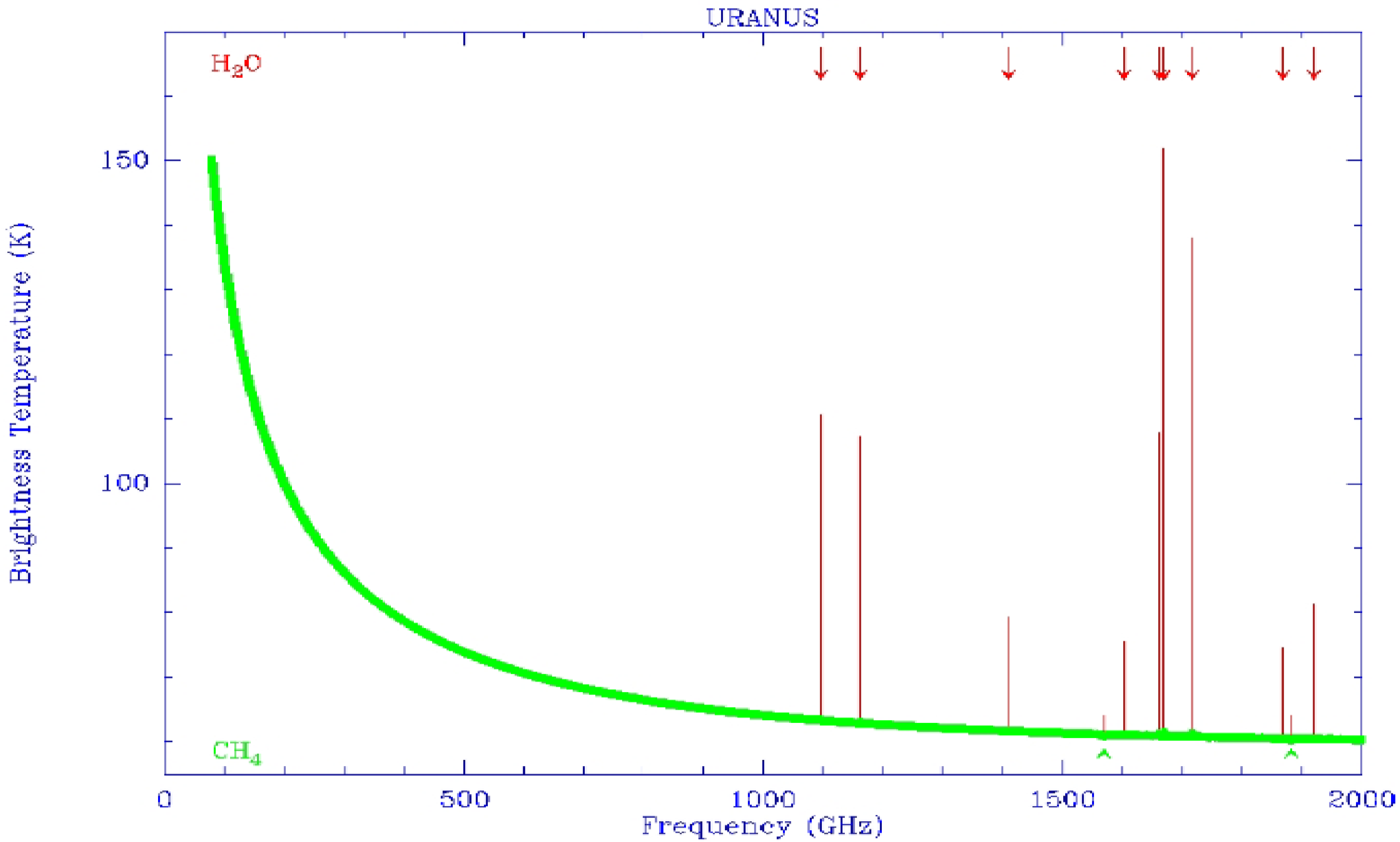
Encrenaz & Moreno

Neptune Flux Estimation

Band	PSW	PMW	PLW
T_B(K)	63	64	70
$S_\upsilon$max (Jy)	268	119	50
$S_\upsilon$min (Jy)	259	115	48



Encrenaz & Moreno



Encrenaz & Moreno

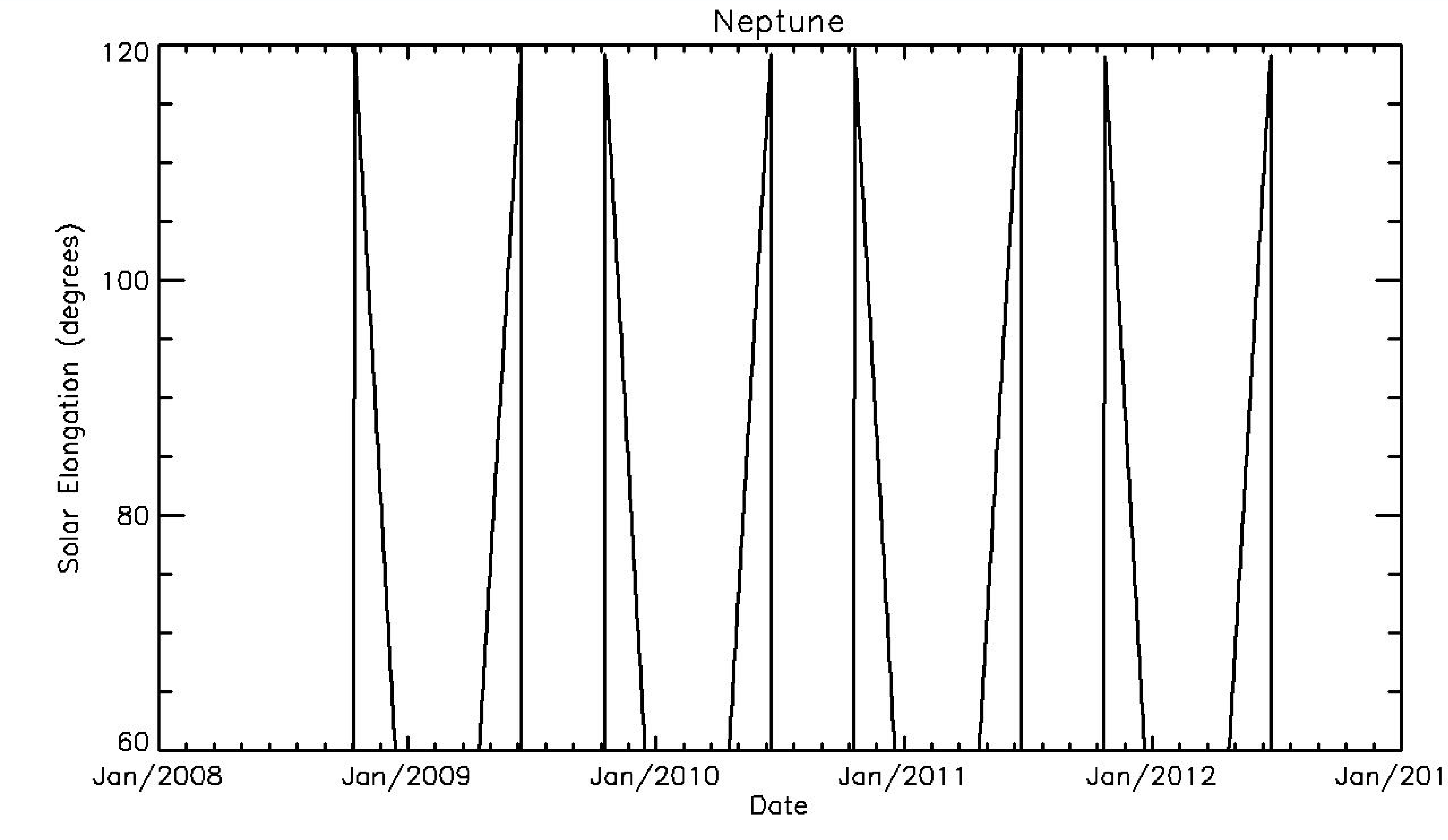
Uranus Flux Estimation

Band	PSW	PMW	PLW
T_B(K)	63	67	72
$S_\upsilon$max (Jy)	792	364	149
$S_\upsilon$min (Jy)	641	295	121

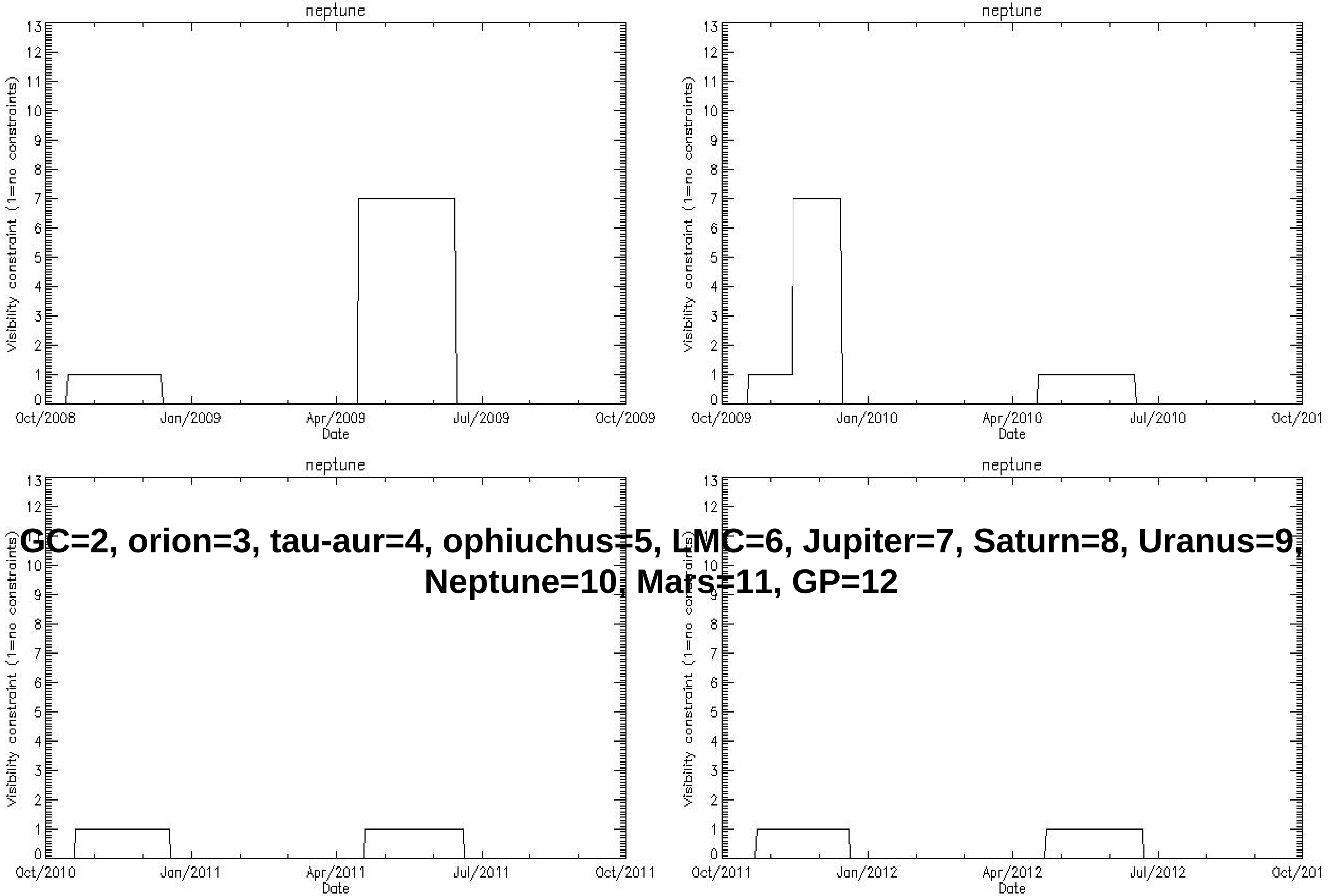
Flux Estimation

- Source fluxes vs mission timeline to be refined by modellers – advance at next HCal workshop.

Visibility – primary sources

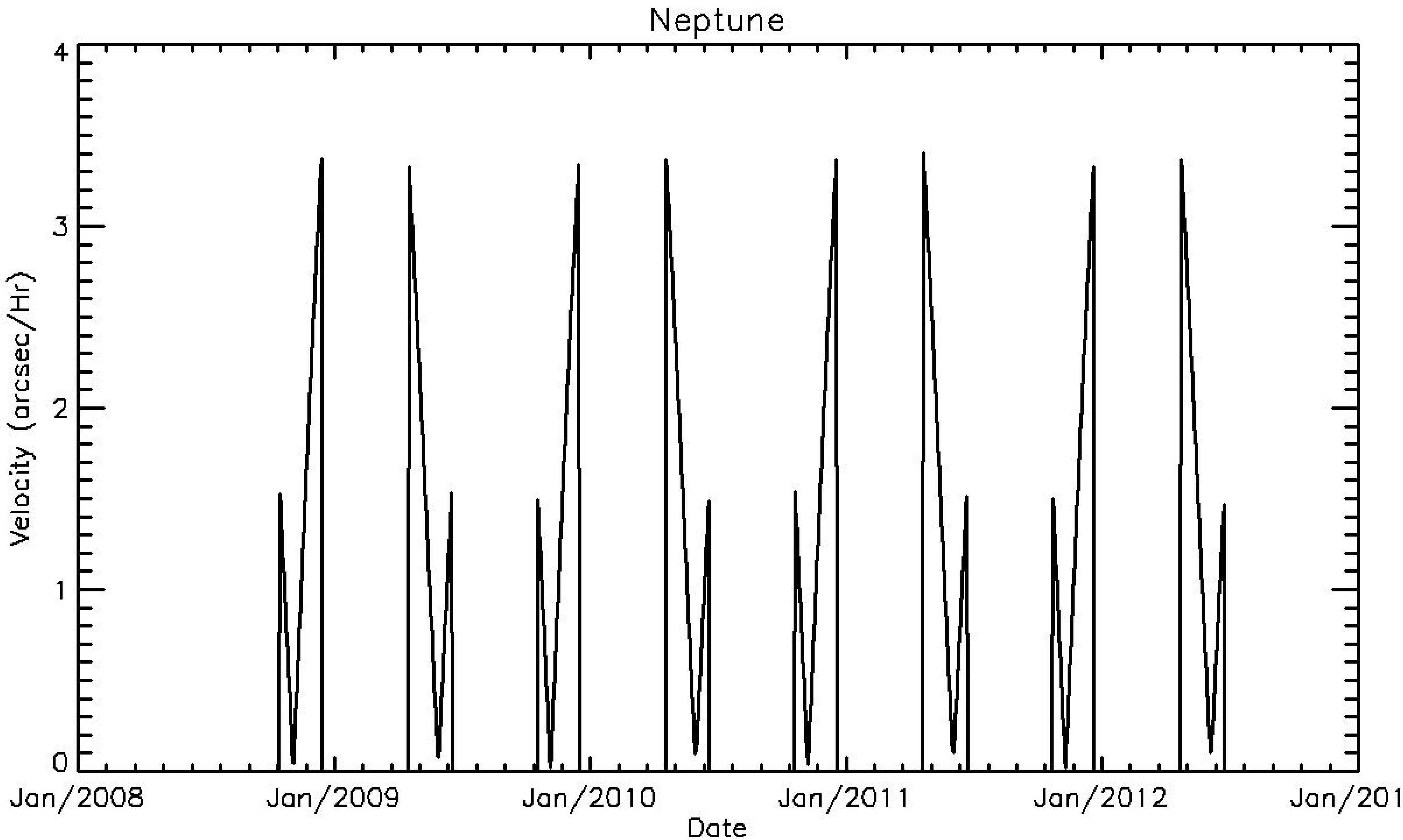


Visibility – primary sources

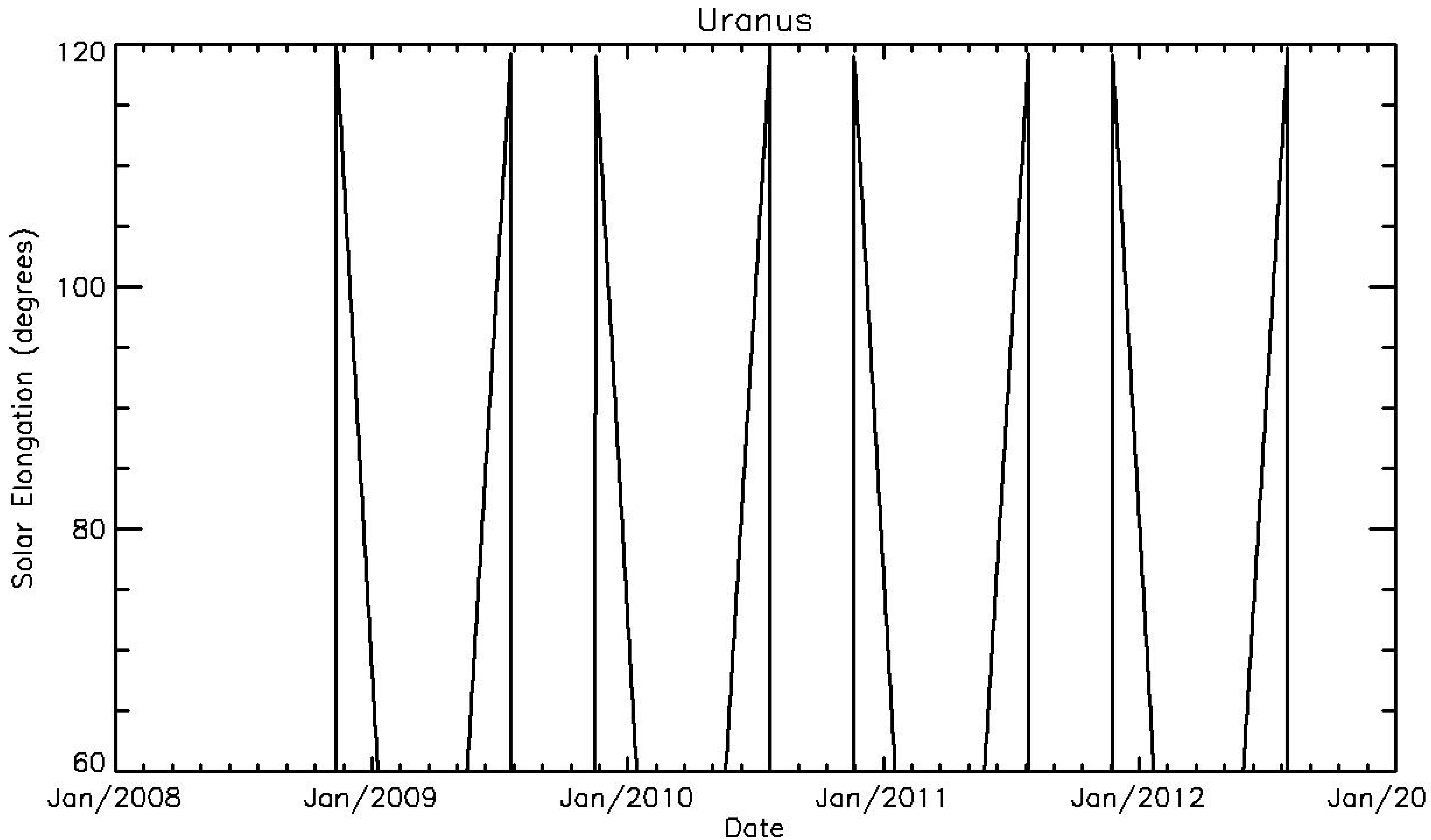


GC=2, orion=3, tau-aur=4, ophiuchus=5, LMC=6, Jupiter=7, Saturn=8, Uranus=9, Neptune=10, Mars=11, GP=12

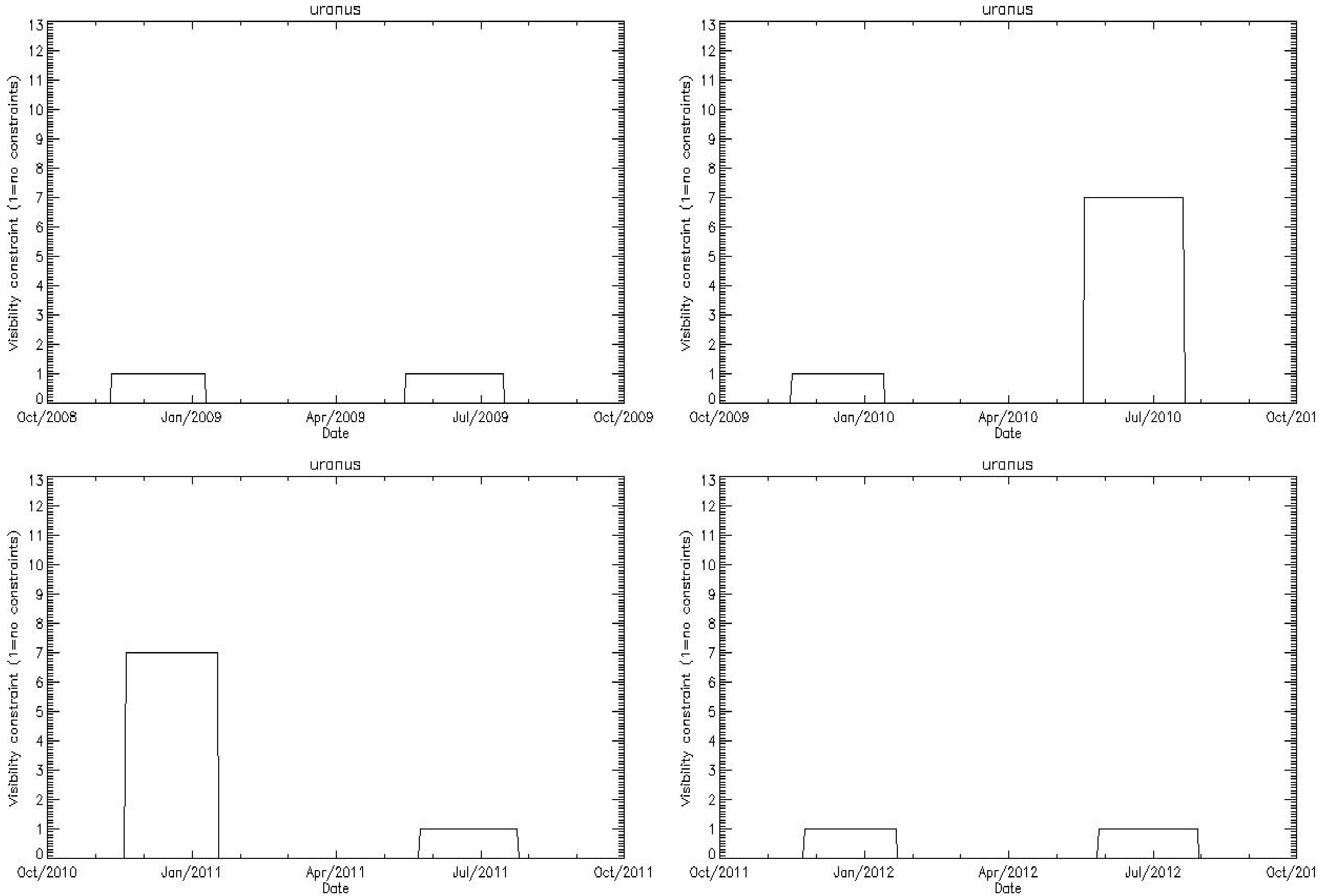
Visibility – primary sources



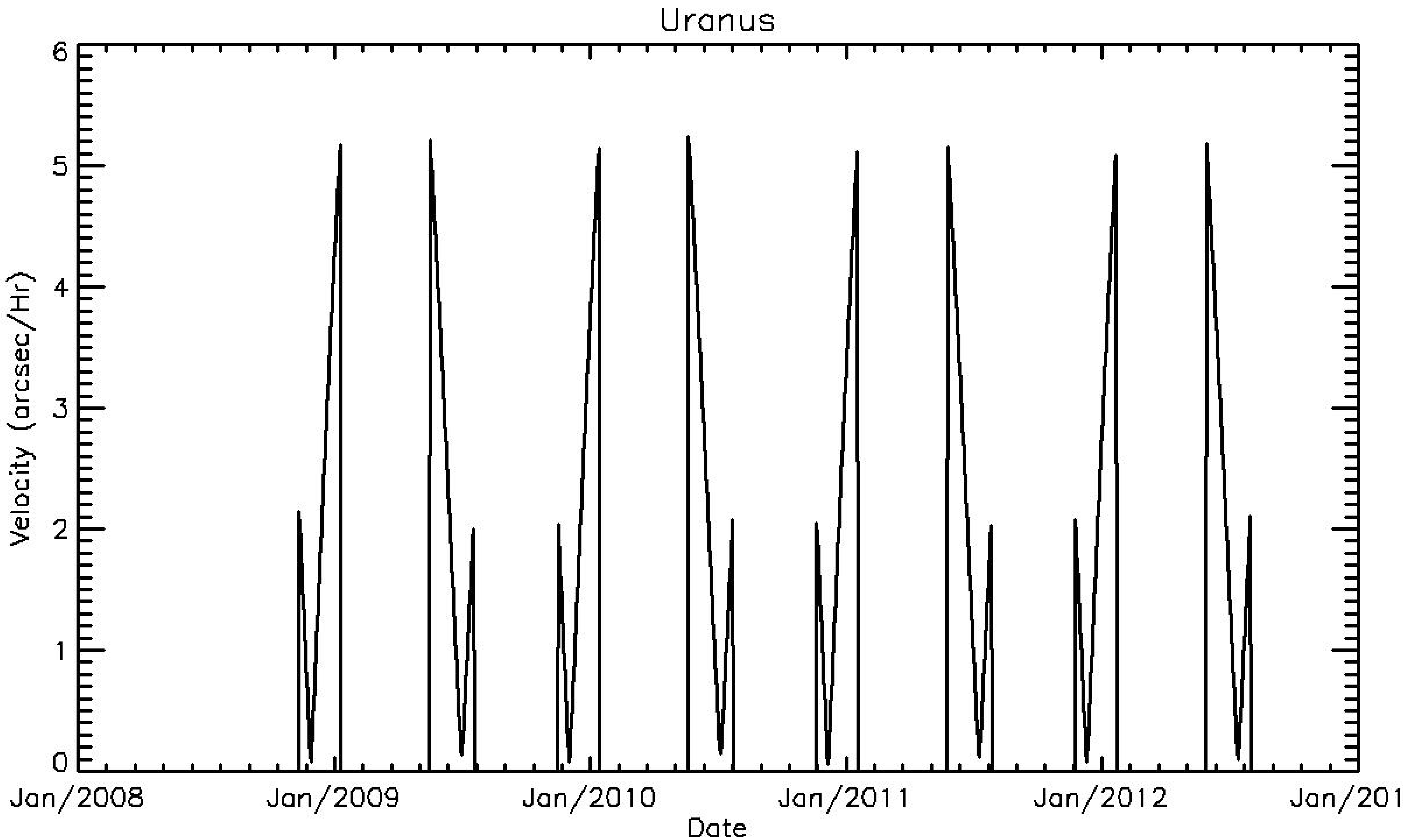
Visibility – primary sources



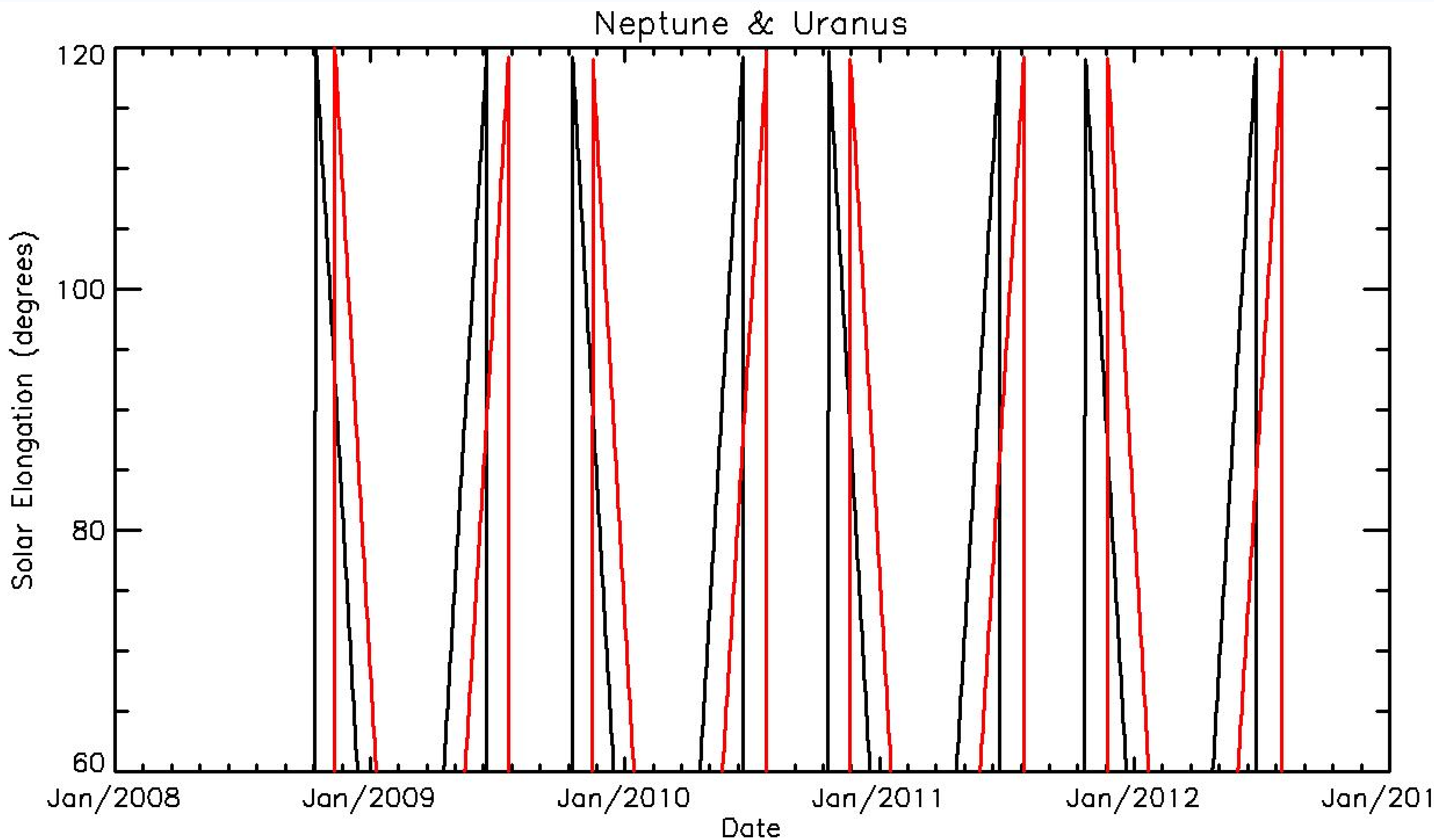
Visibility – primary sources



Visibility – primary sources



Visibility – primary sources

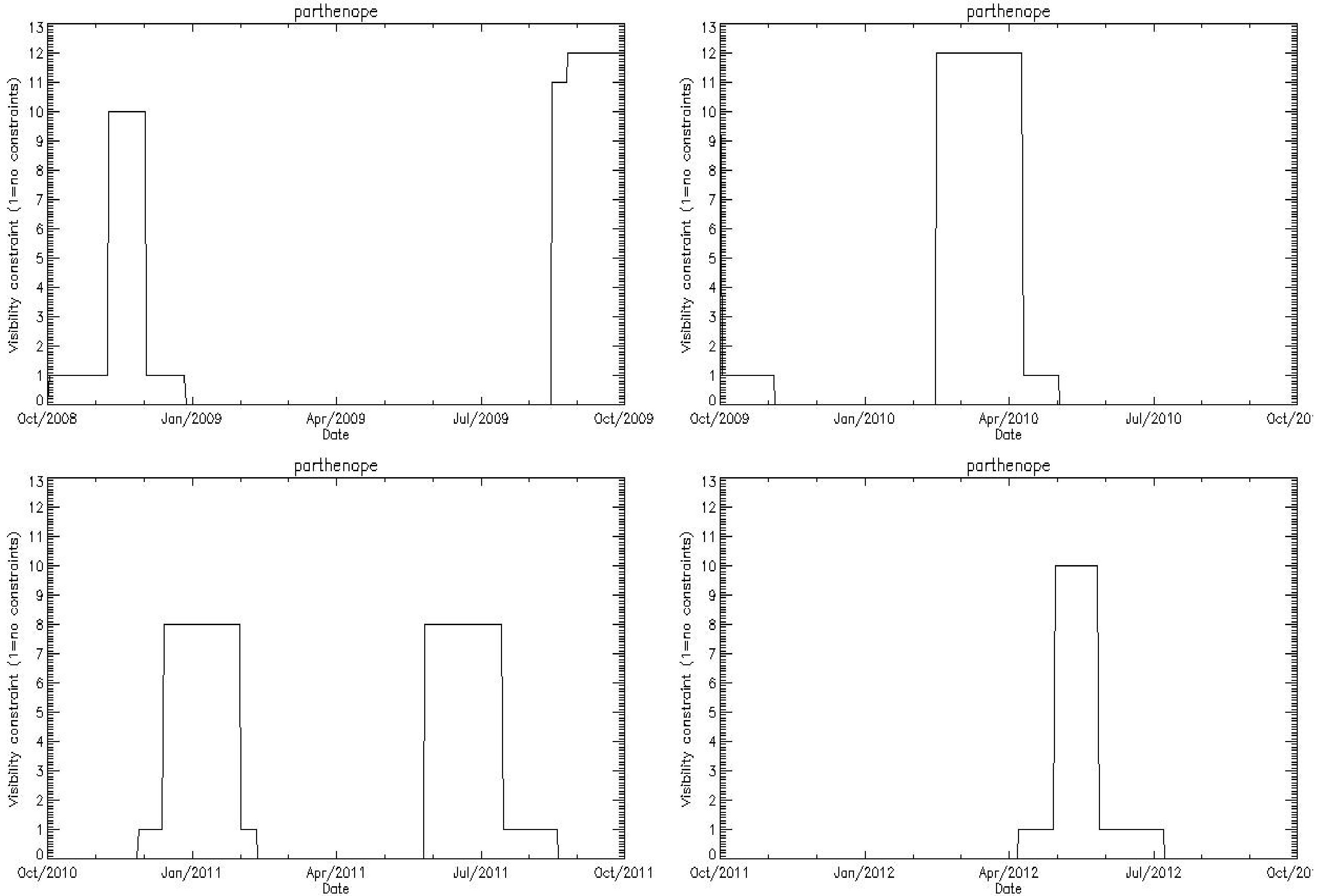


Sources

- Primary
  - Very well-known, with robust models – predicted flux errors <5%
  - Neptune, Uranus
- Secondary
  - Sufficient confidence that we can obtain photometric flux errors <10% now, or imminently with further modelling / observations
  - Asteroids
    - Ceres, Pallas, Juno, Vesta, Hygeiea, Cybele, Herculina
  - PNe
    - CRL2688, CRL618 – also good for spectrometer
  - Stellar sources – Brightest stars, selection in progress
    - Isophot list, M. Cohen, L. Decin, J. Blommaert etc. lists – subset of PACS list. Select sources with fluxes >~100mJy in all bands.
- Tertiary
  - Other asteroids
  - Other sources - ULIRGS, AGN, UCHII regions, Herbig Ae/Be, T-Tauri stars

Asteroids

- Selected 35 asteroids, following T.Mueller's recommendations (robustness of input parameters for TPM, other observations, shape etc)
- Of these, seven asteroids selected as secondary SPIRE calibrators (primary asteroids:- Ceres, Pallas, Juno, Vesta, Hygeiea, Cybele, Herculina)
- All others, tertiary sources (at present)
- Many of these will have been observed with AKARI – refinement of TPM

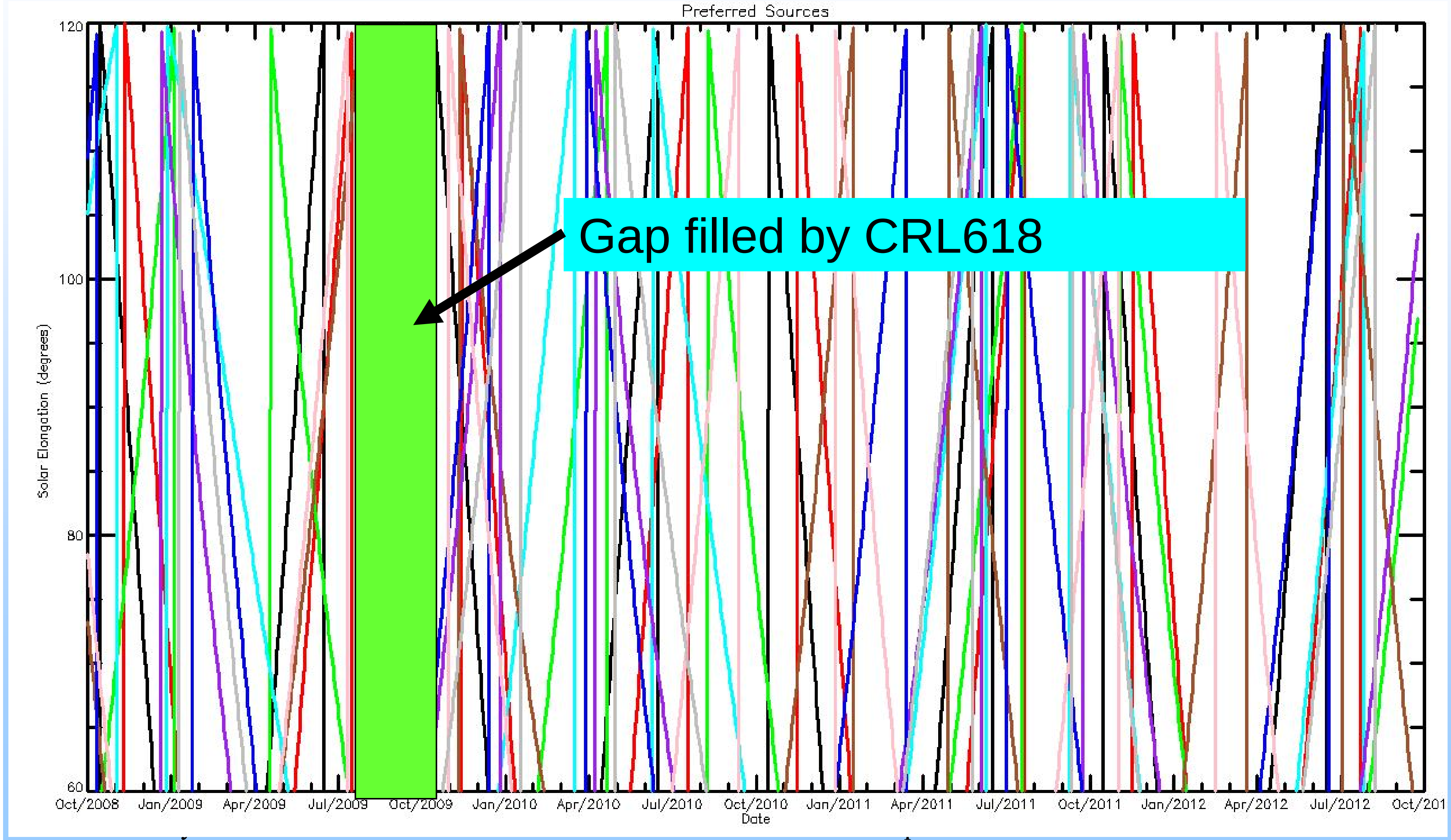


GC=2, orion=3, tau-aur=4, ophiuchus=5, LMC=6, Jupiter=7, Saturn=8, Uranus=9, Neptune=10, Mars=11, GP=12

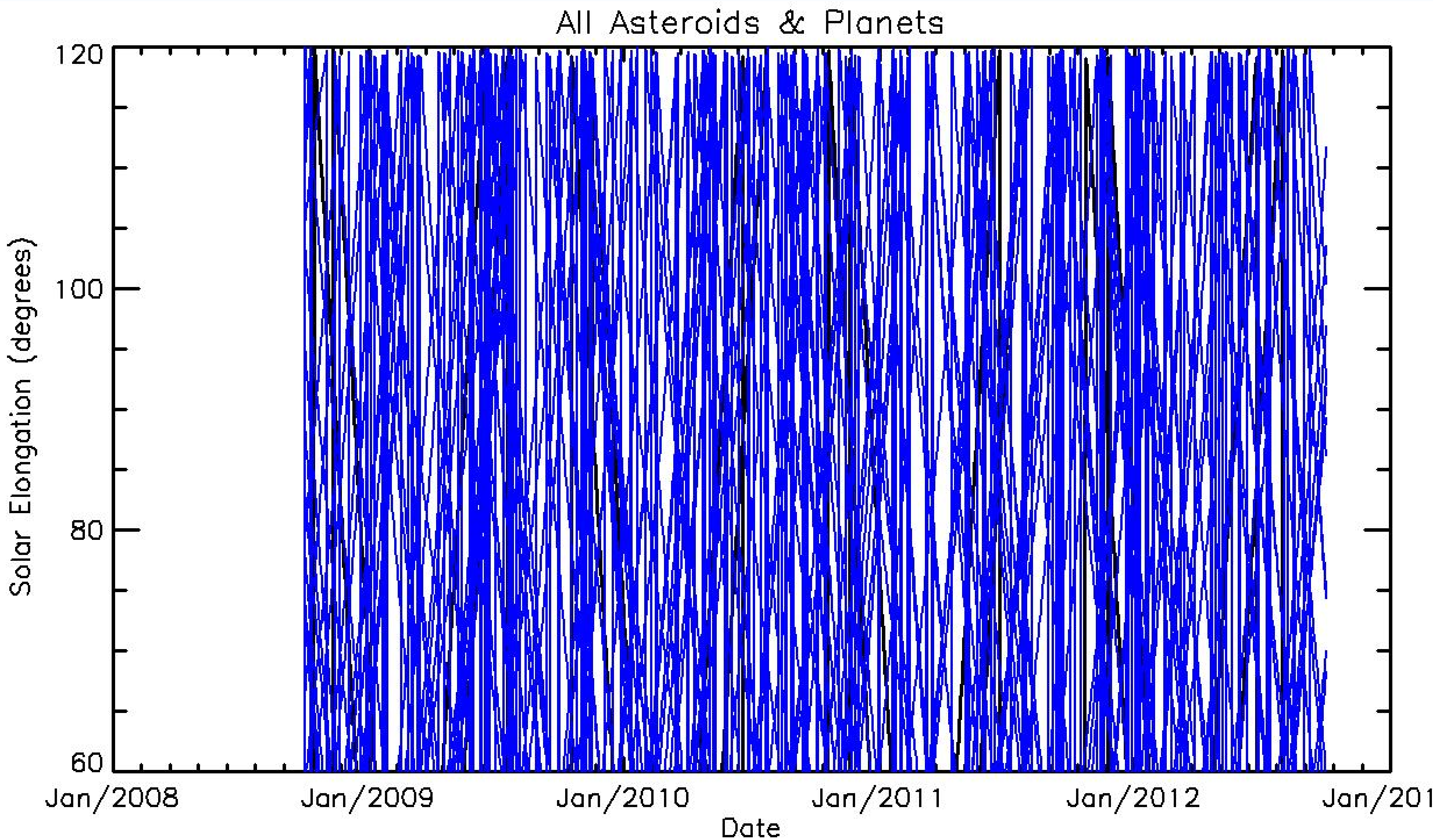
Planetary Nebulae

- CRL618
  - Secondary calibrator for JCMT
  - Flux = 10.9Jy @ 450μm
  - Point-like
- CRL2688
  - Secondary calibrator for JCMT
  - Flux = 22Jy @ 450μm
  - Extended
  - Observed by BLAST (with degraded resolution)

Visibility – primary planets & asteroids



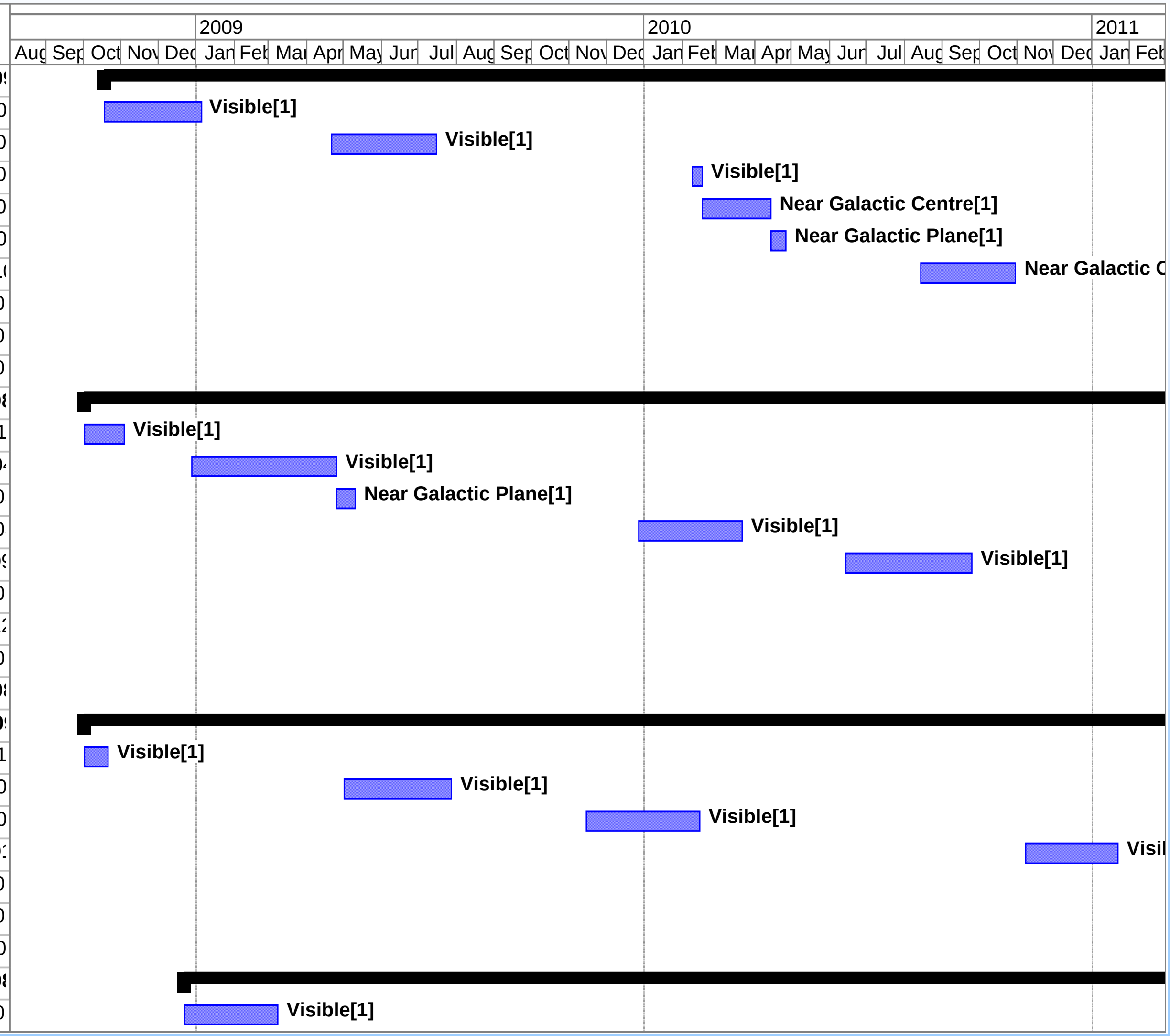
Visibility – all sources



Source visibility vs. mission

MS Project file with source details

ID		Task Name	Duration	Start	Finish
1		**Ceres**	**1423 da**	**Fri 17/1**	**Sun 09/0**
2		ceres	80 da	Fri 17/1	Mon 05/0
3		ceres	86 da	Mon 20/0	Wed 15/0
4		ceres	9 day	Mon 08/0	Wed 17/0
5		ceres	56 da	Wed 17/0	Wed 14/0
6		ceres	12 da	Wed 14/0	Mon 26/0
7		ceres	77 da	Sat 14/0	Sat 30/1
8		ceres	80 da	Sat 07/0	Tue 26/0
9		ceres	74 da	Wed 09/1	Sun 22/0
10		ceres	30 da	Fri 10/0	Sun 09/0
11		**Pallas**	**1403 da**	**Wed 01/1**	**Sat 04/0**
12		pallas	33 da	Wed 01/1	Mon 03/1
13		pallas	118 da	Sun 28/1	Sat 25/0
14		pallas	15 da	Sat 25/0	Sun 10/0
15		pallas	84 da	Sun 27/1	Sun 21/0
16		pallas	102 da	Mon 14/0	Fri 24/0
17		pallas	88 da	Sun 20/0	Thu 16/0
18		pallas	77 da	Fri 16/0	Fri 02/1
19		pallas	21 da	Tue 22/0	Tue 12/0
20		pallas	53 da	Tue 12/0	Sat 04/0
21		**Juno**	**1456 da**	**Wed 01/1**	**Wed 26/0**
22		juno	19 da	Wed 01/1	Mon 20/1
23		juno	87 da	Fri 01/0	Mon 27/0
24		juno	93 da	Sat 14/1	Mon 15/0
25		juno	75 da	Sun 07/1	Fri 21/0
26		juno	77 da	Thu 05/0	Thu 21/0
27		juno	71 da	Wed 18/0	Thu 29/0
28		juno	76 da	Thu 12/0	Wed 26/0
29		**Vesta**	**1341 da**	**Sun 21/1**	**Thu 23/0**
30		vesta	77 da	Sun 21/1	Sun 08/0

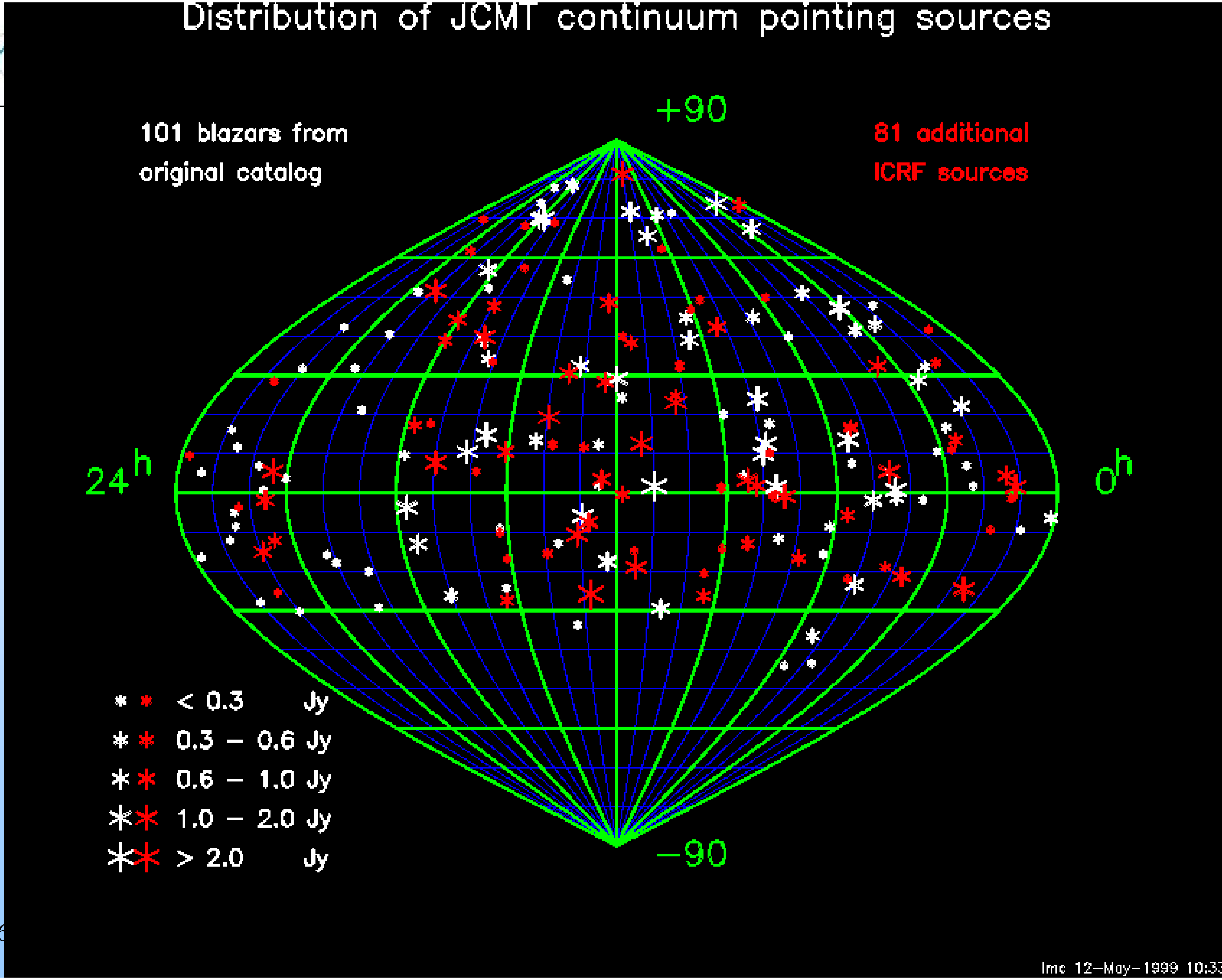


PV visibility

- Assuming October 2008 launch, & Dec/Jan PV…..
  - Uranus – visible mid-Nov – mid-Jan
  - Neptune – lose visibility mid-Dec
  - CRL2688 – visible until wk 2 Jan
  - Herculina – visible from wk 2 Jan
  - Vesta – visible from wk 3 Dec
  - Pallas – visible from late Dec
  - Ceres – visible until wk 1 Jan

Pointing Sources

- List compiled & added to visibility file
- Commonality with PACS requirements
- Using selection from JCMT, APEX, SEST catalogues (mainly blazars & BL Lac) – possibly bright stellar sources
- Flux range ~0.5 - several Jy @500µm
- Need to identify multiple sources….


Distribution of JCMT continuum pointing sources
+90
101 blazars from
original catalog
81 additional
ICRF sources
24h
0h
−90
< 0.3 Jy
0.3 − 0.6 Jy
0.6 − 1.0 Jy
1.0 − 2.0 Jy
> 2.0 Jy
lmc 12−May−1999 10:33

SEST – 130 sources