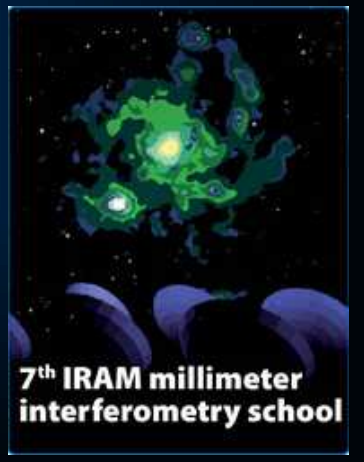
iram
Institut de
Radioastronomie
Millimétrique

Absolute Flux Calibration

Melanie Krips



Outline

I. Primary/Secondary Flux Calibrators

II. Practical Tips to Calibrate the Fluxes of your Sources

Motivation

What do we want in a flux calibrator?

- strong (>1Jy) emission at mm wavelengths
- compact (<<1”) emission at mm wavelengths
- emission should not be variable in time
- preferentially with long LST range
  (i.e., high declination source)
- no or only little sun-avoidance
- preferentially well known properties
  (such as SED, size)

Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
5. Antenna Efficiencies?

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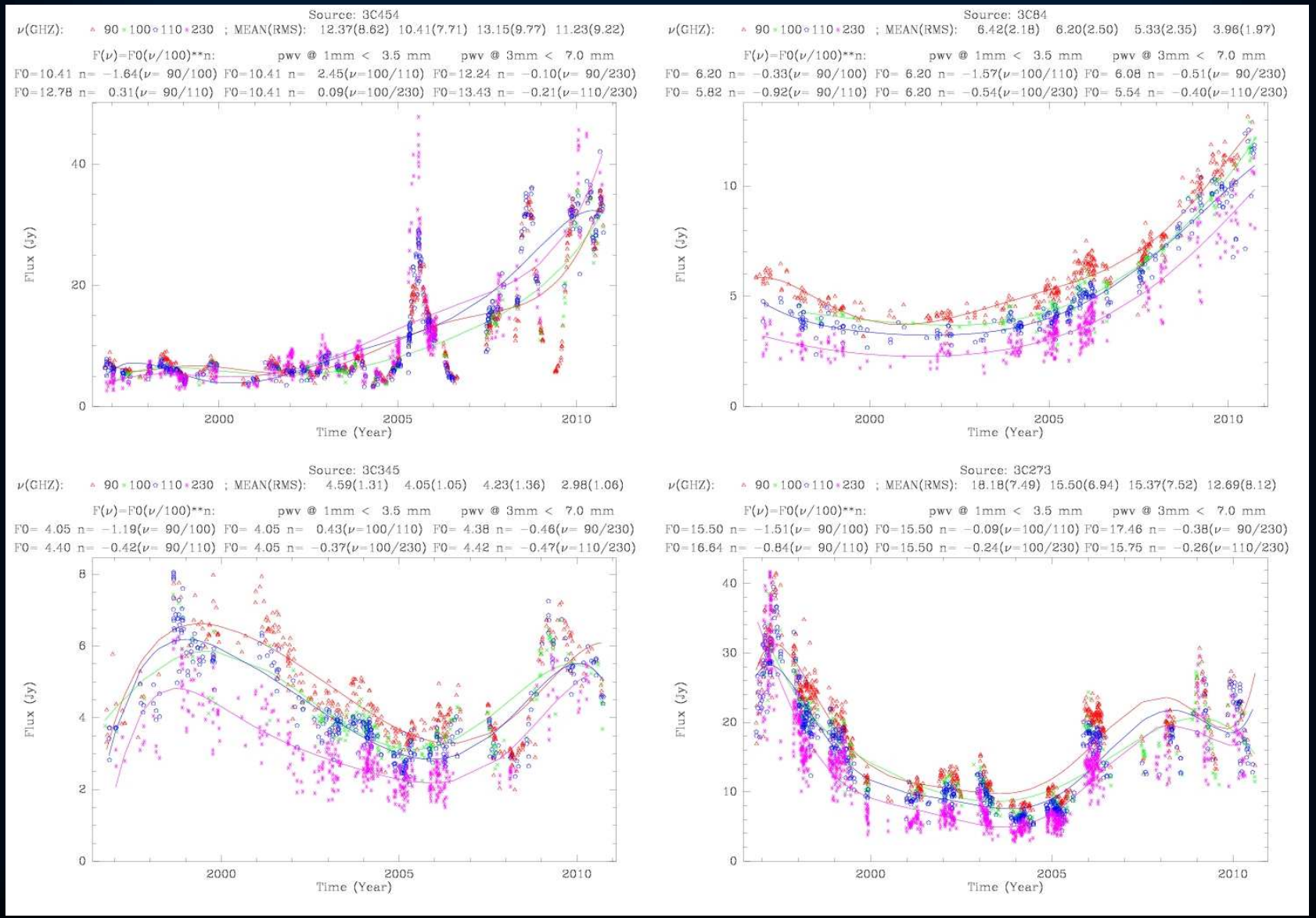

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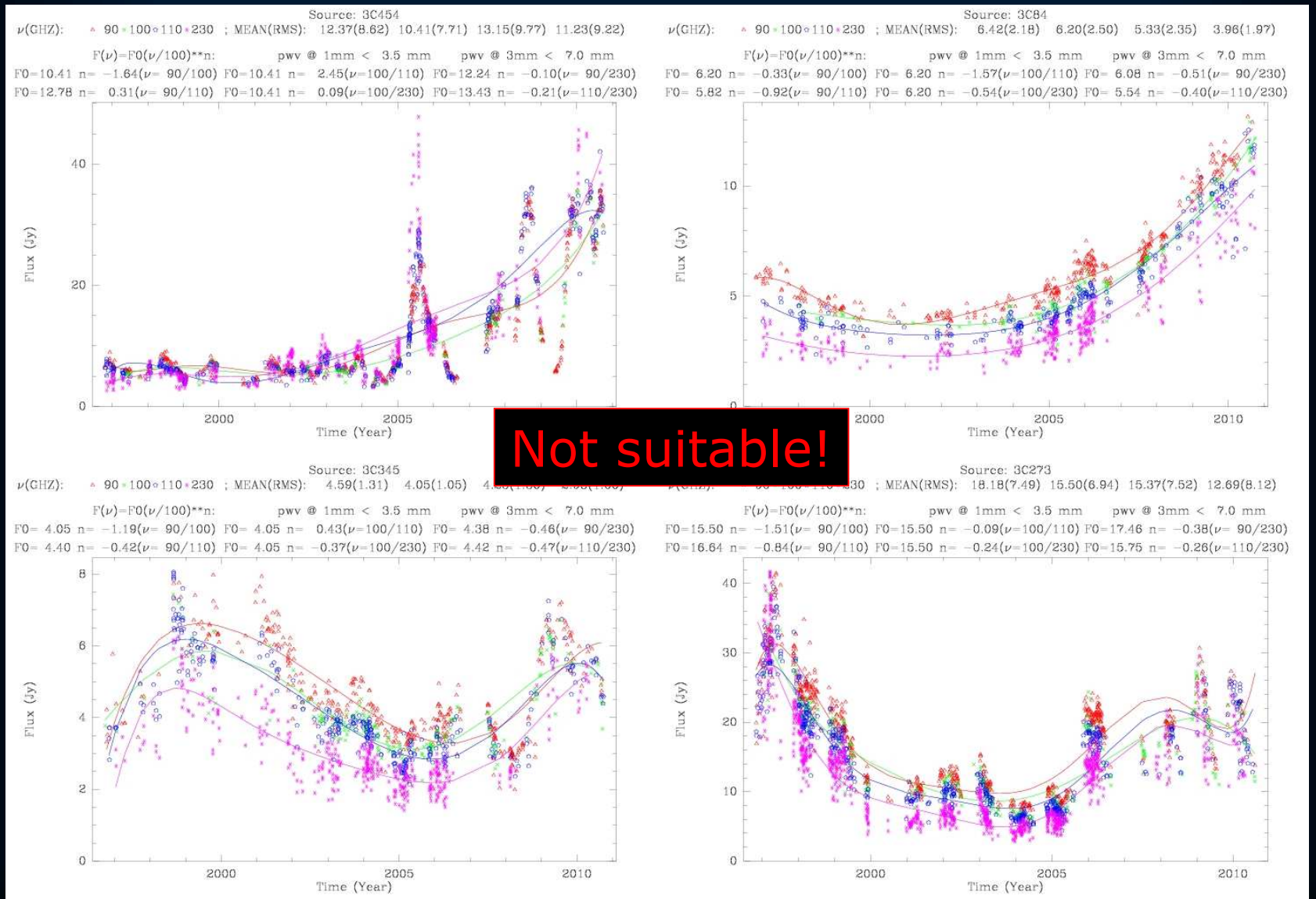

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Flux Calibrators: Planets

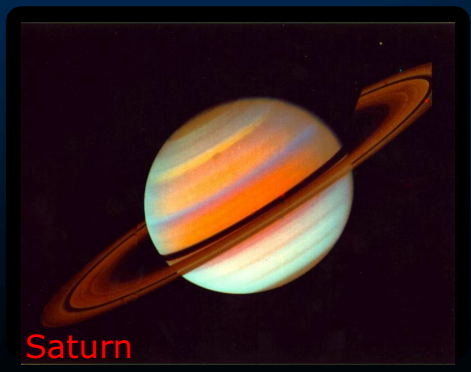
- Pro:
  most of the solar planets have strong mm-emission and reasonably well derived flux models

- Contra:
  1.) Fluxes not completely constant
  2.) They start to be resolved (≥3”) already at 3mm
  3.) Some of them have broad molecular line absorption (e.g., Mars, Jupiter, Saturn)
  4.) Not always visible, i.e., more constraints due to sun-avoidance, short LST ranges


Mars


Uranus


Jupiter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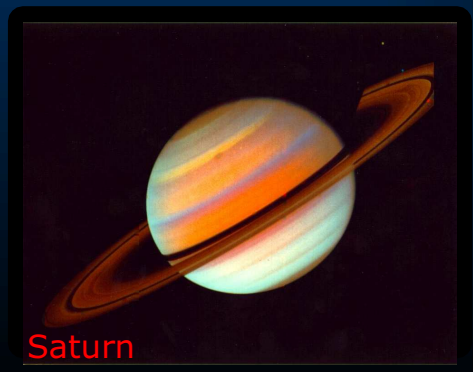
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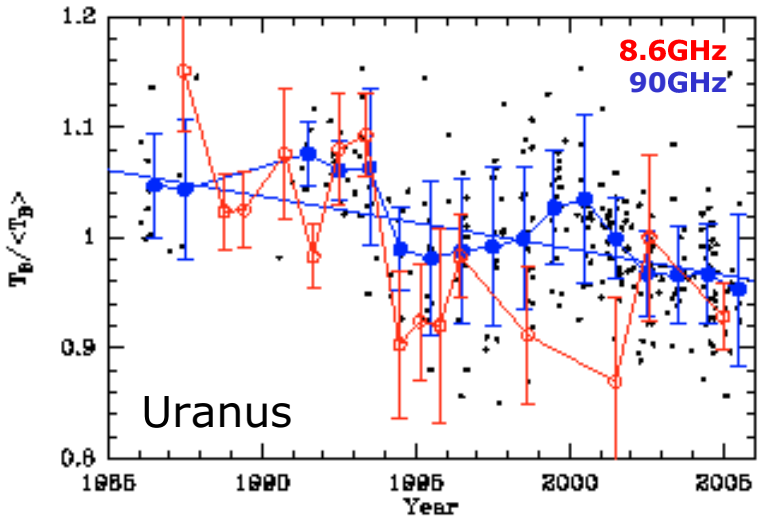
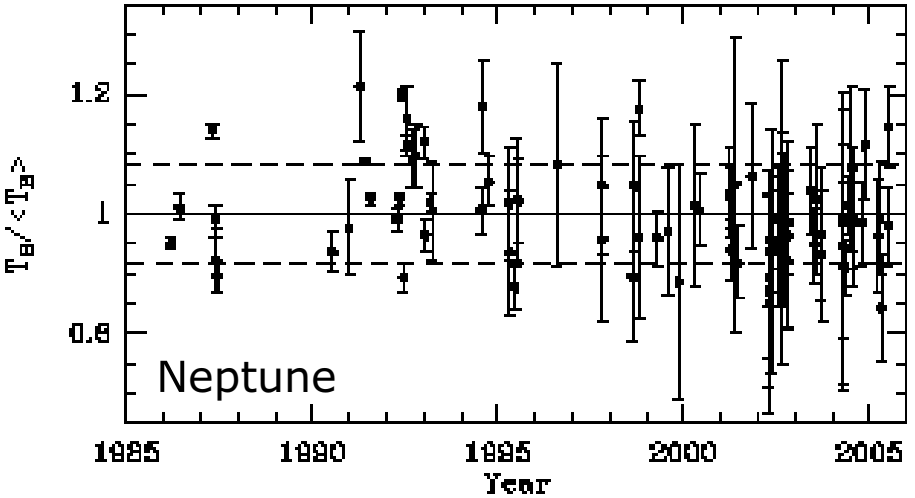
Flux Calibrators: Planets

Kramer et al. (2008)





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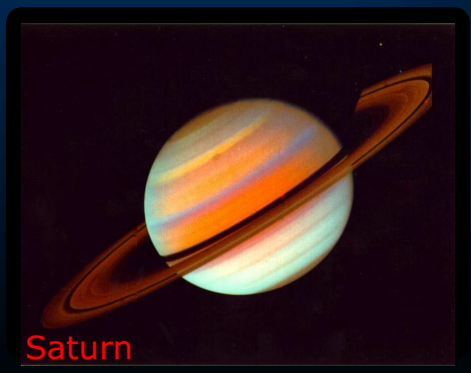

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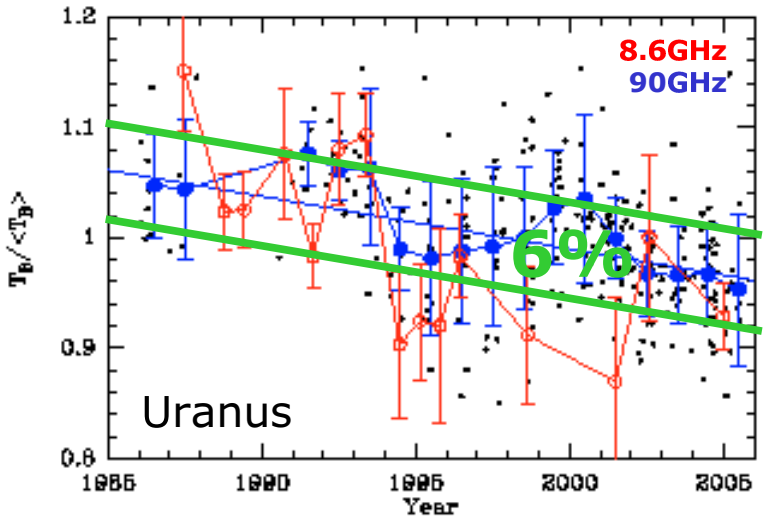

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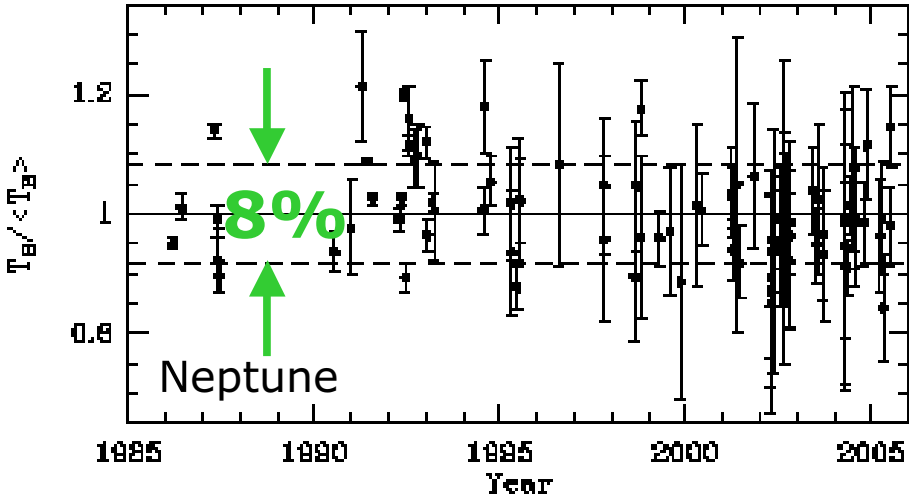

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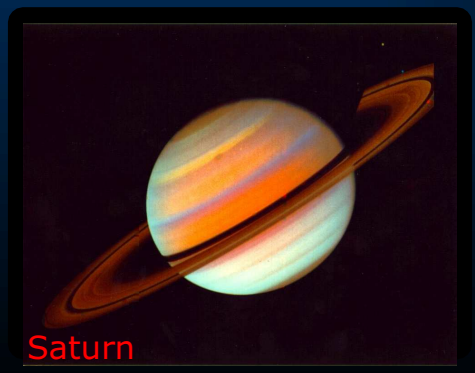

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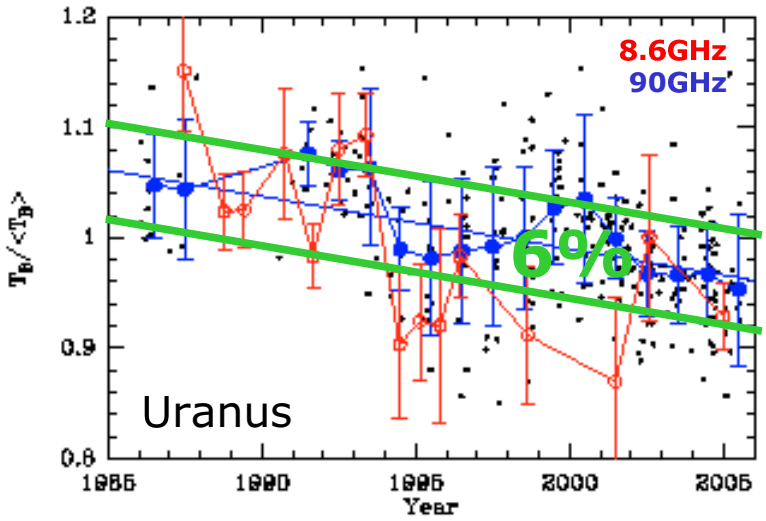

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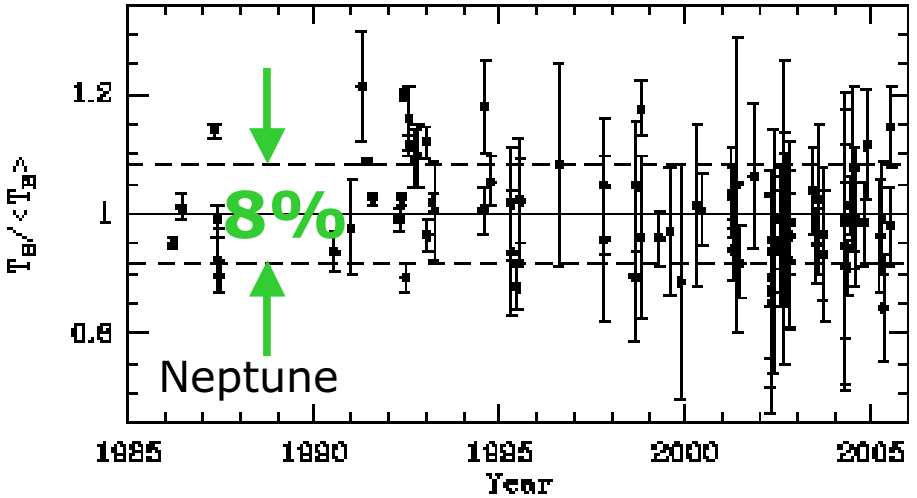

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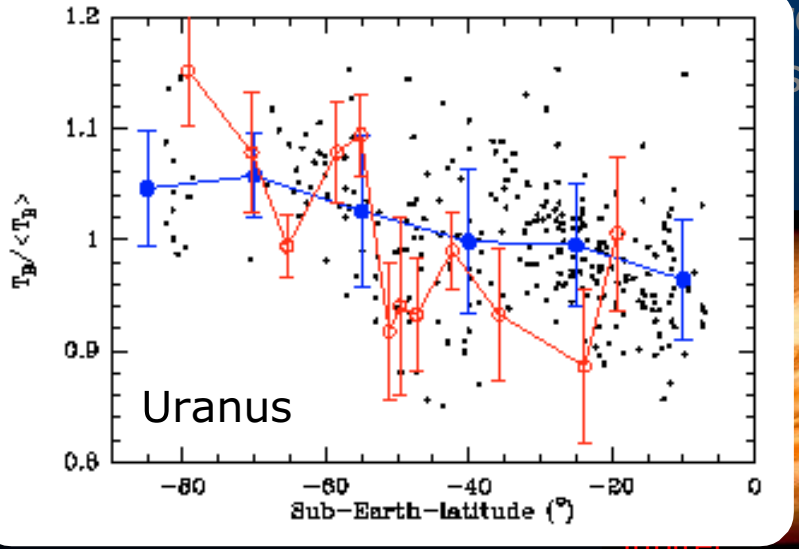

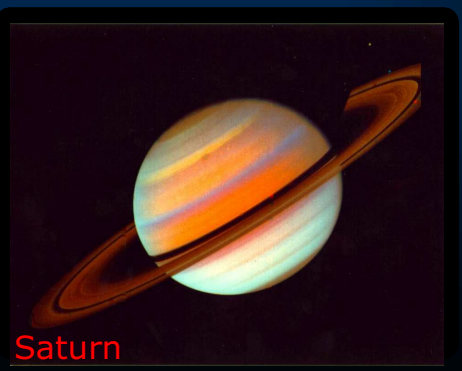

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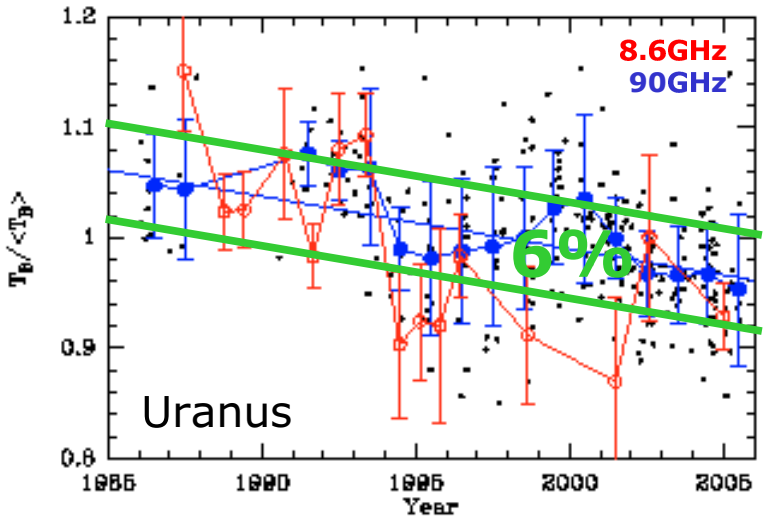

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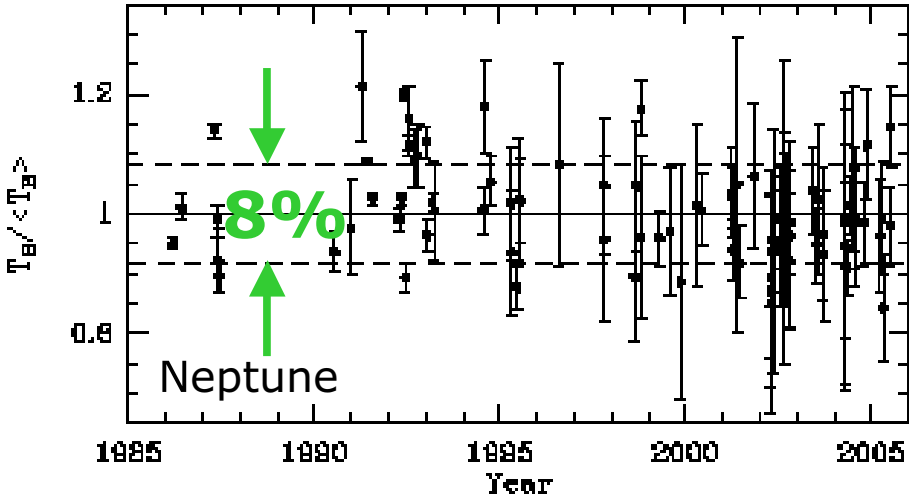

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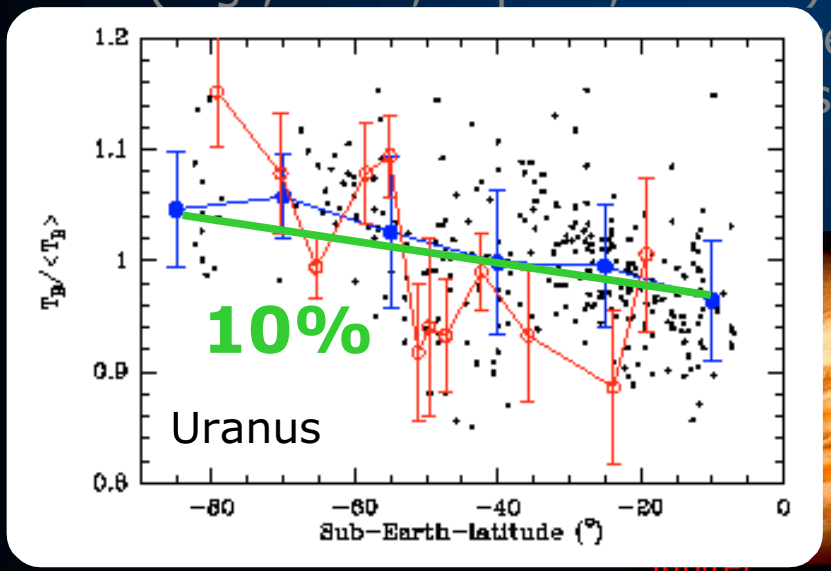

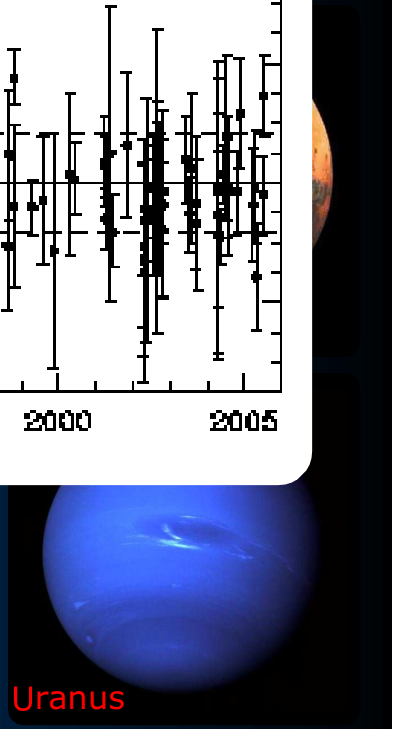

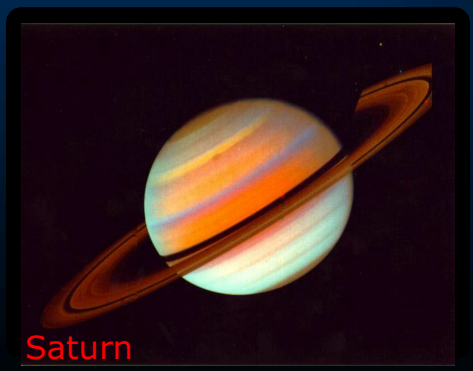

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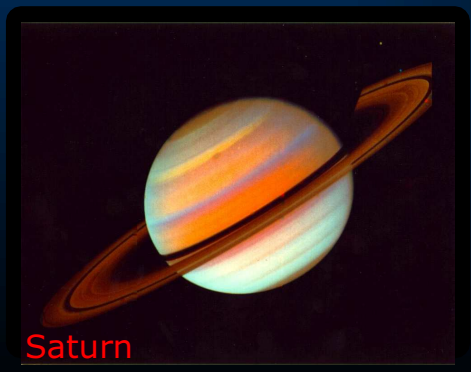
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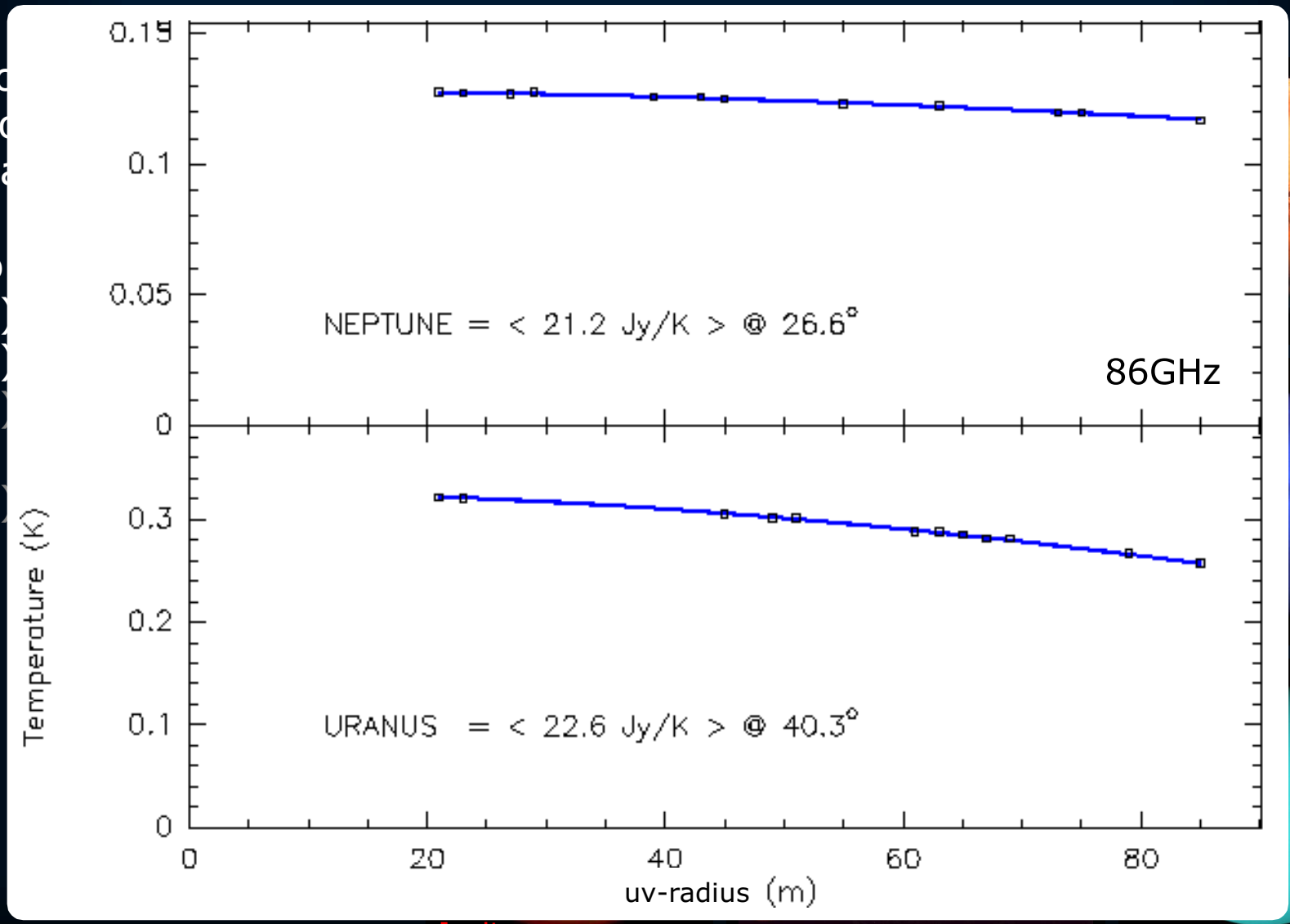

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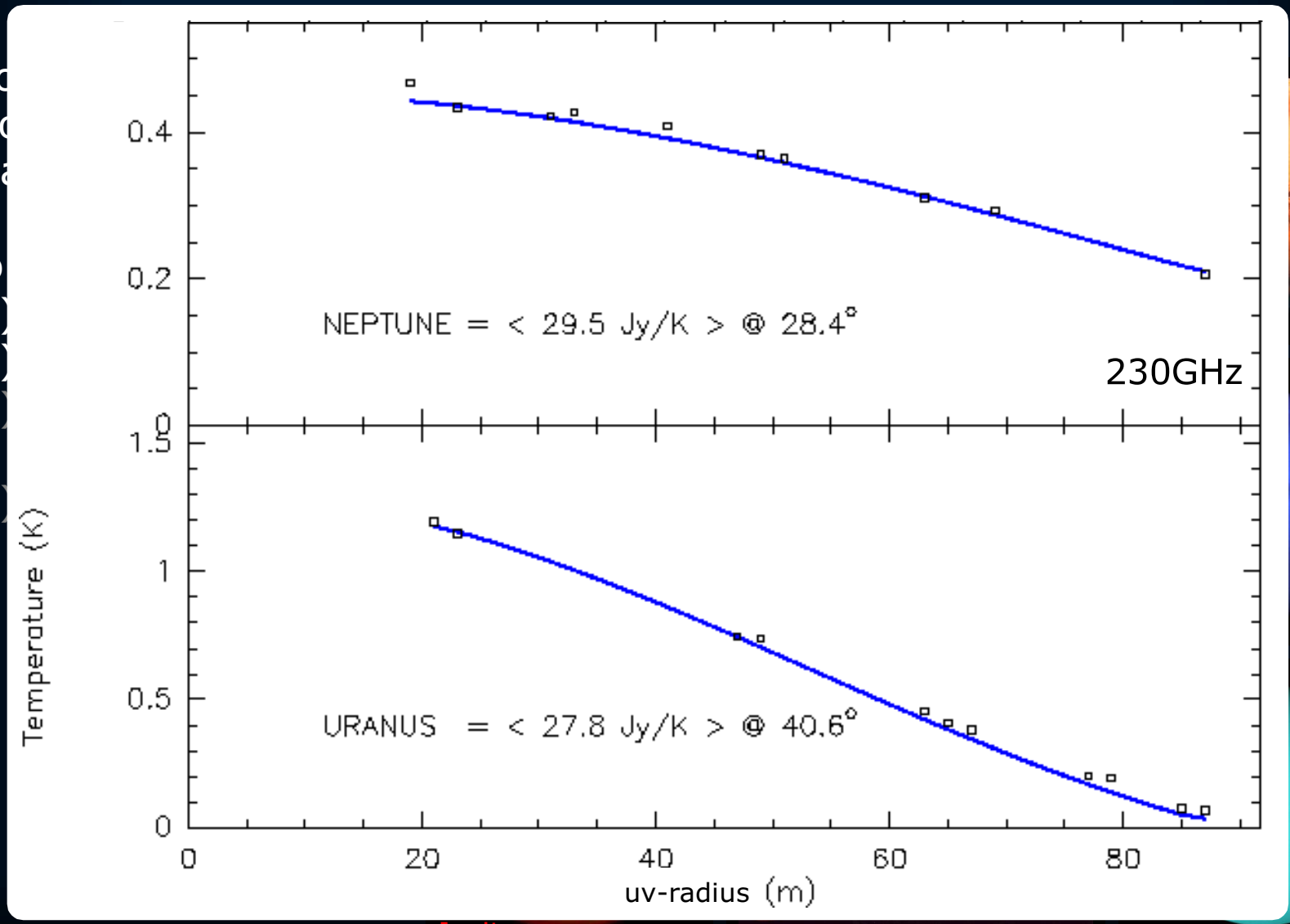

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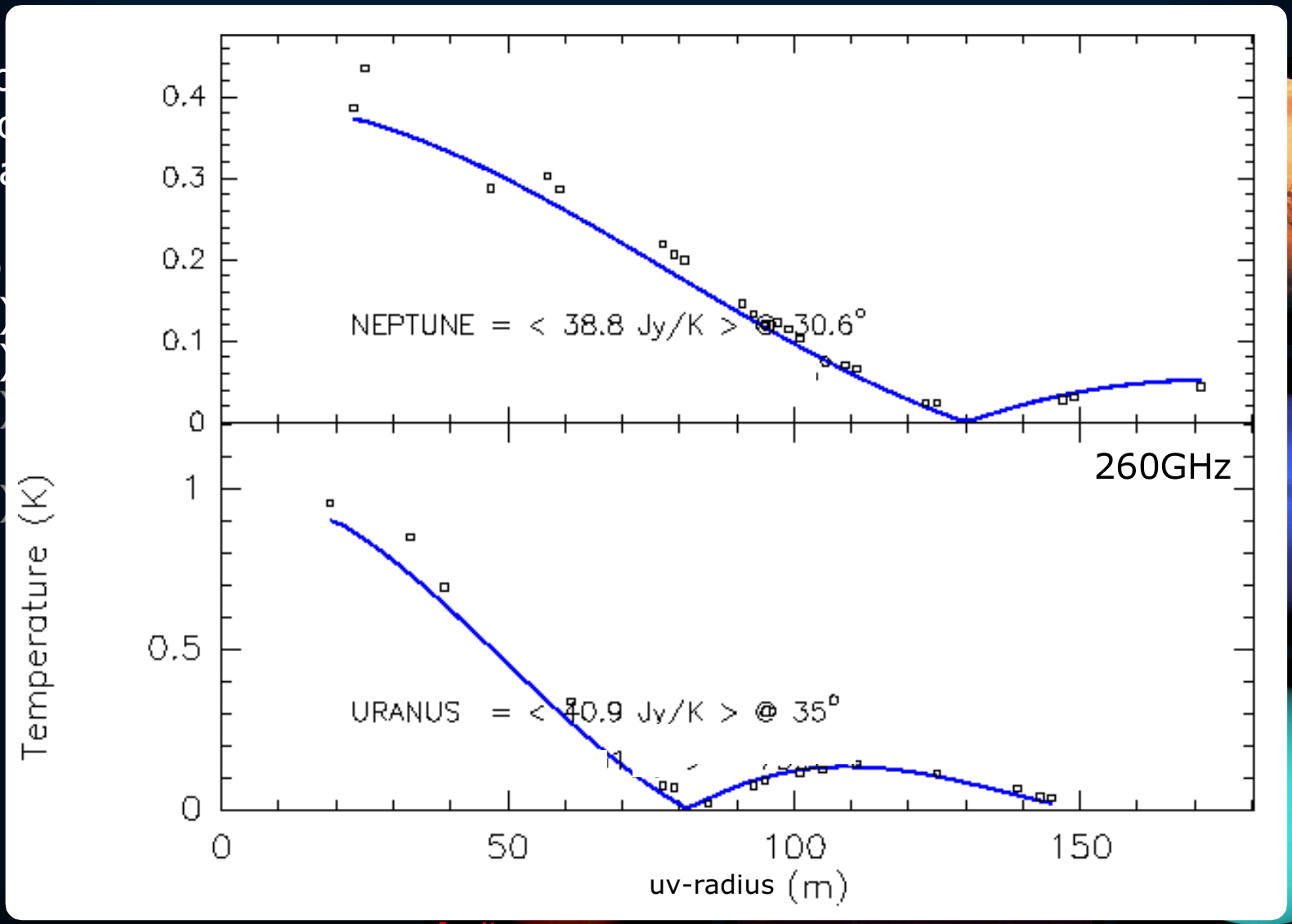

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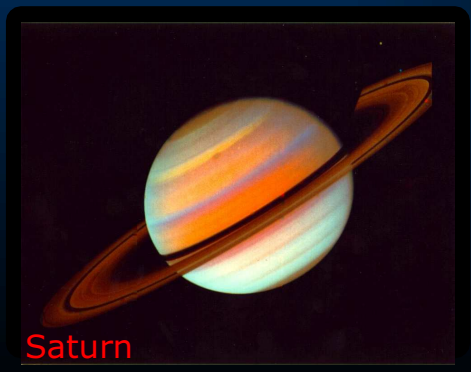
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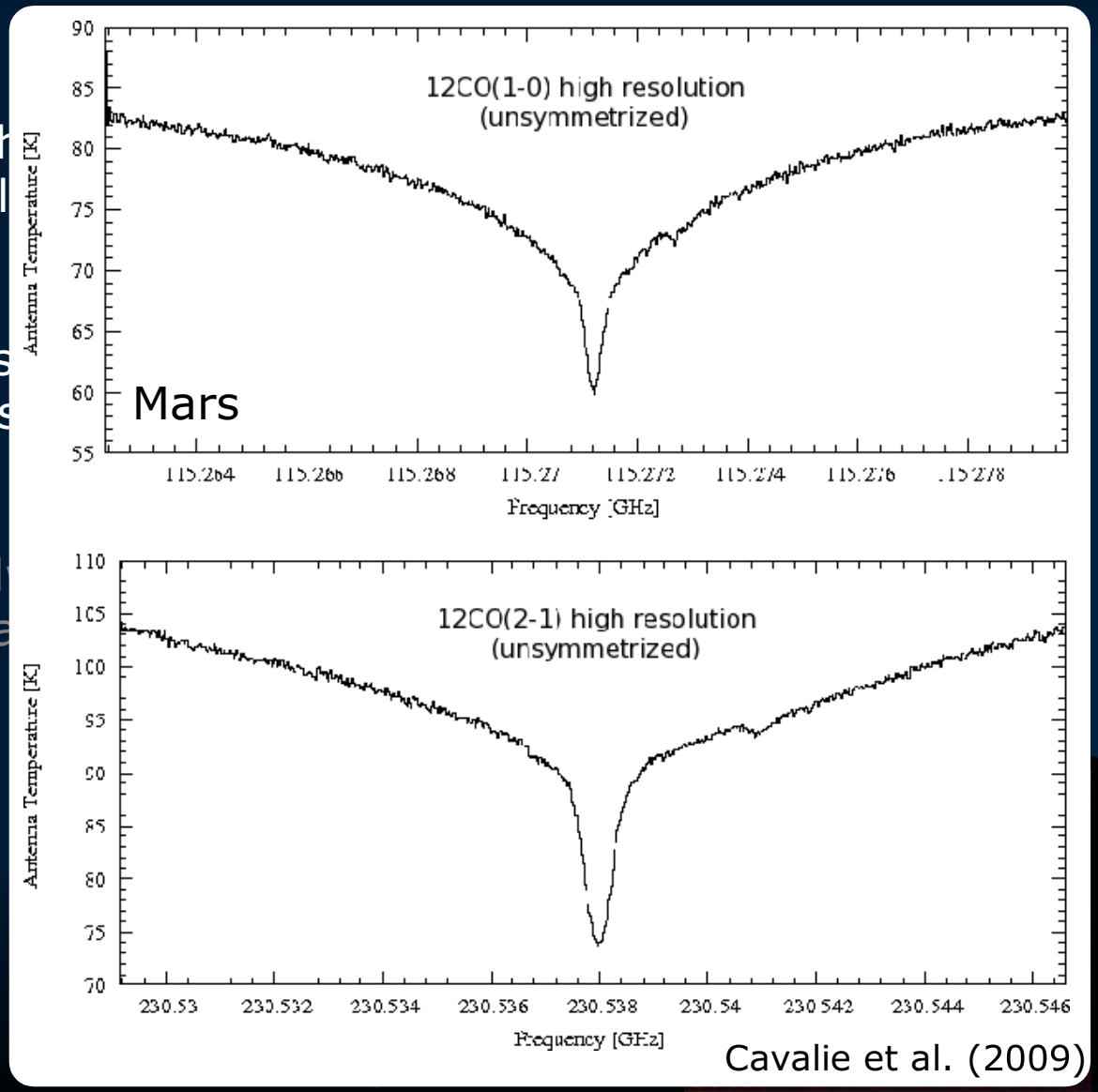

Cavalie et al. (2009)


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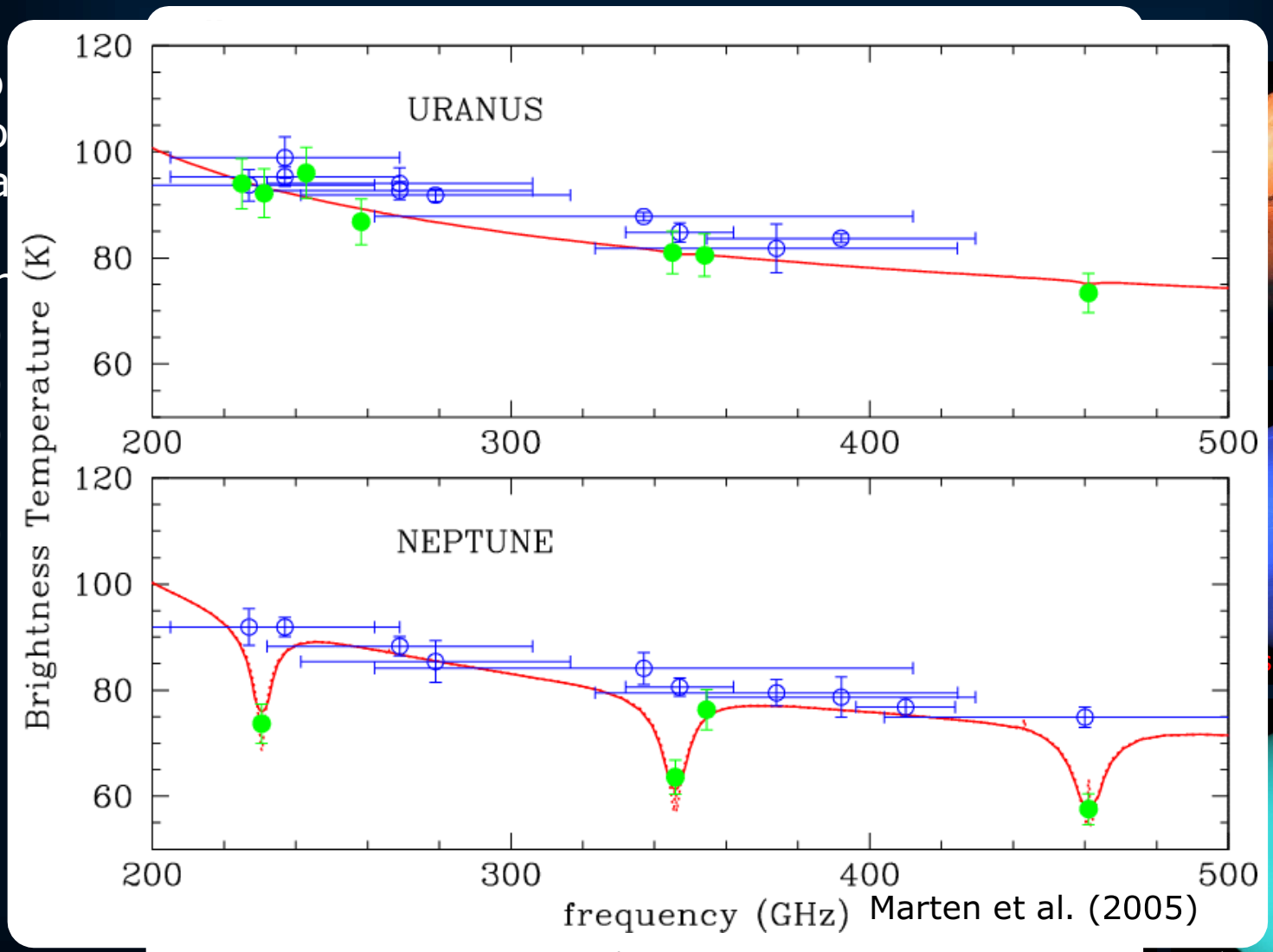

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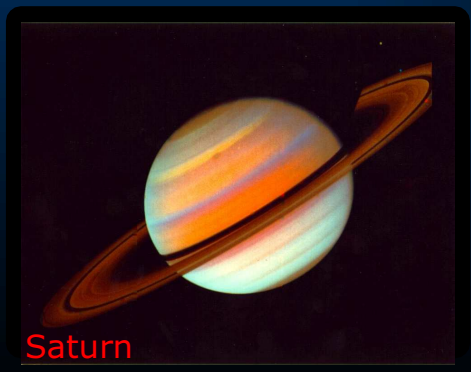
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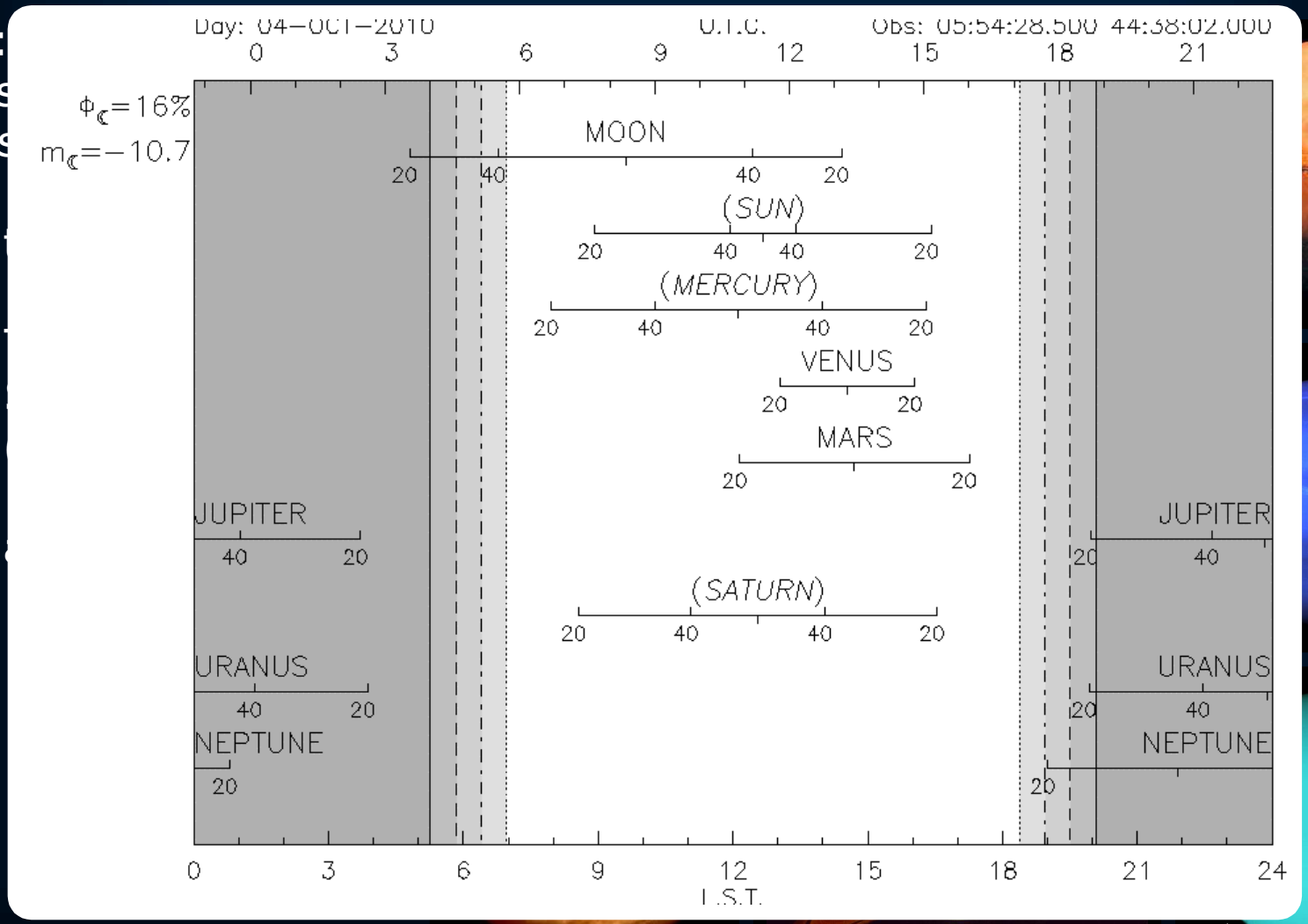


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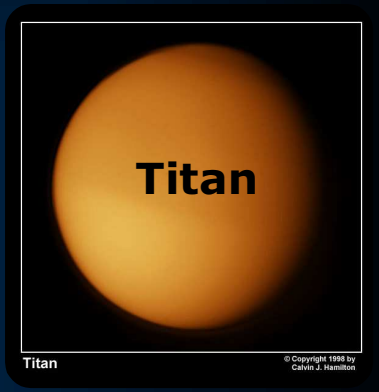
Flux Calibrators: Satellites

- Pro:
  - They are quite compact (hence better for extended configurations and/or higher frequencies than planets) and still sufficiently bright (>500mJy@3mm)

- Already regularly used at the SMA:
  Titan, Ganymede, Callisto

- Contra:
  - Titan also shows broad molecular lines
  - they are not always useable especially when they are too close to their 'mother'-planet (or each other); one needs at least 3xPB
  - flux models not as well constrained as for planets



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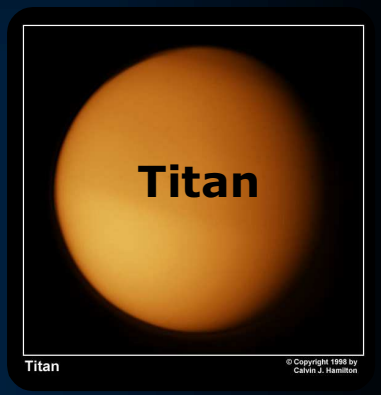

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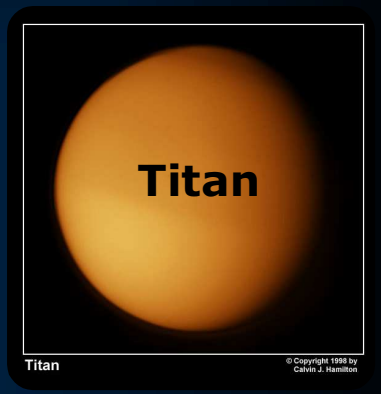
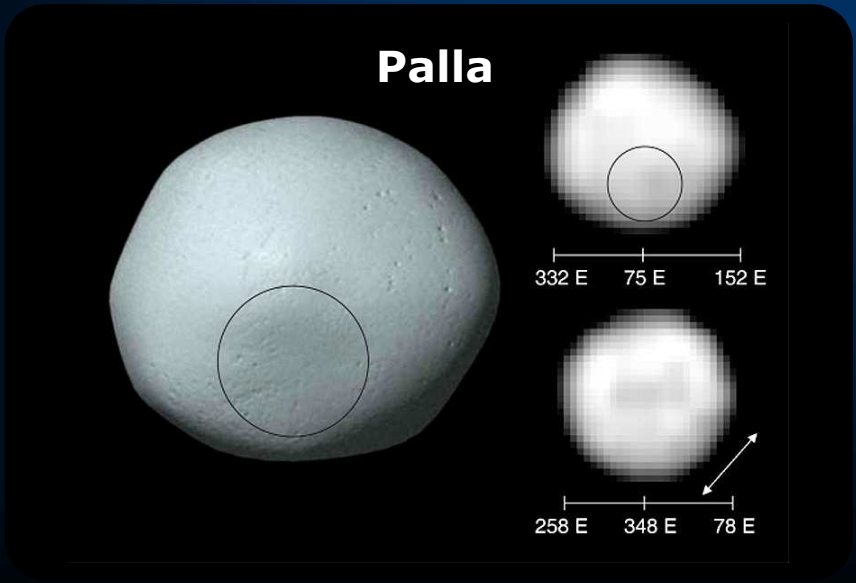
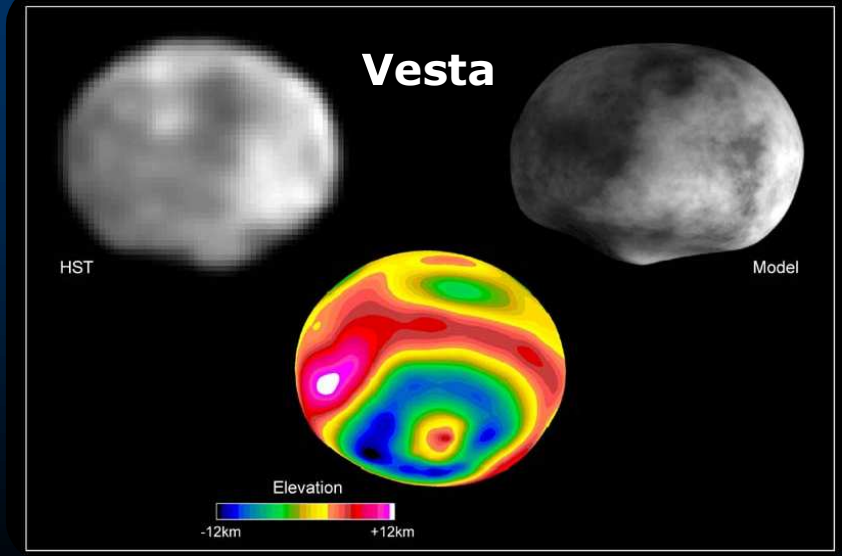


Flux Calibrators: Asteroids/Dwarf Planets

- Pro:
  - bright and relatively small solar bodies

- Contra:
  - Fluxes not (yet) well determined; some of them known to vary quite significantly within a day
  - irregular shapes





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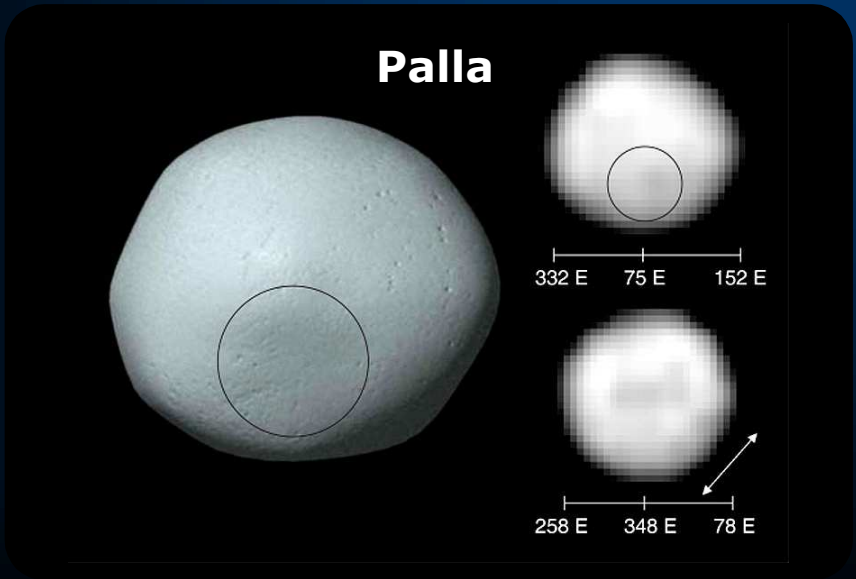

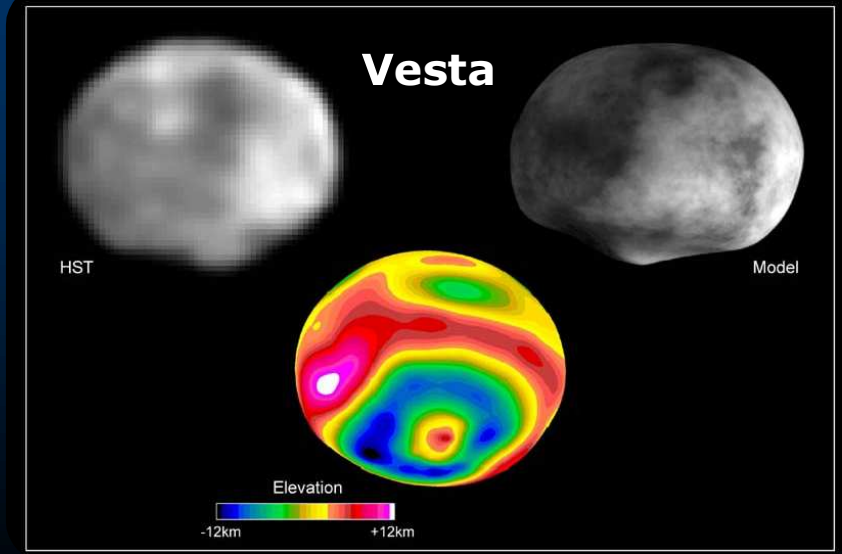

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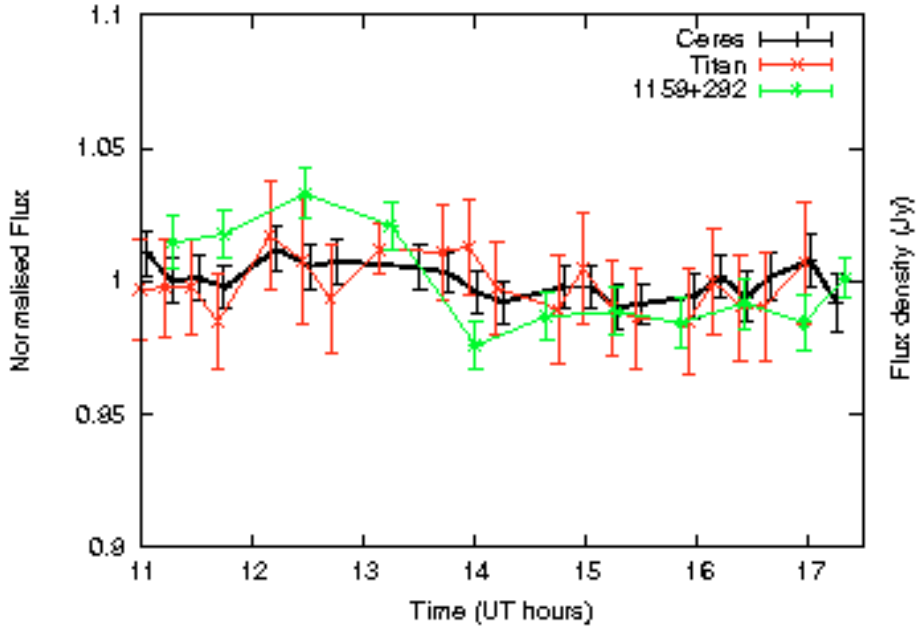
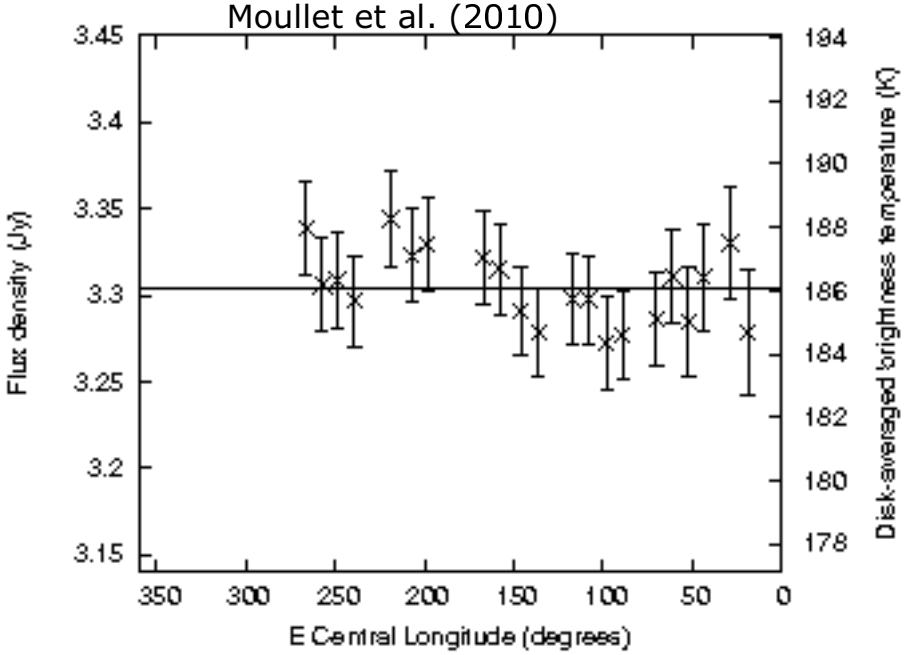
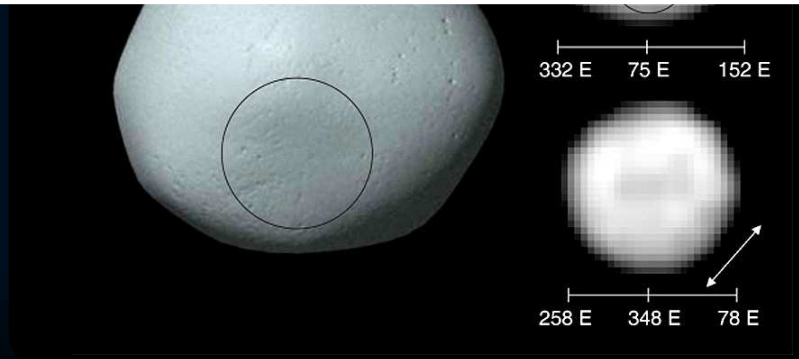
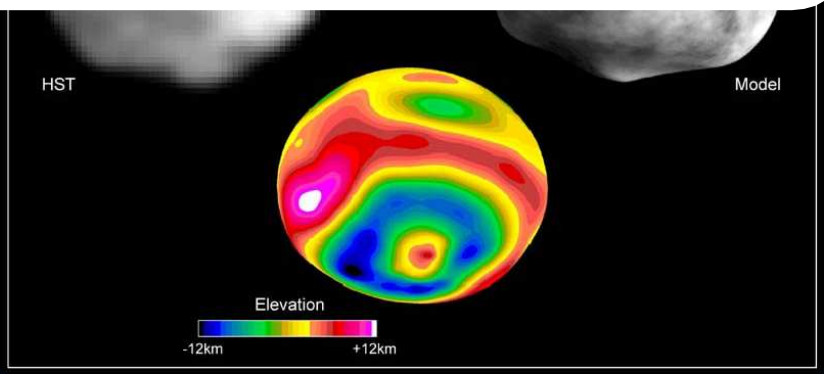


Moullet et al. (2010)







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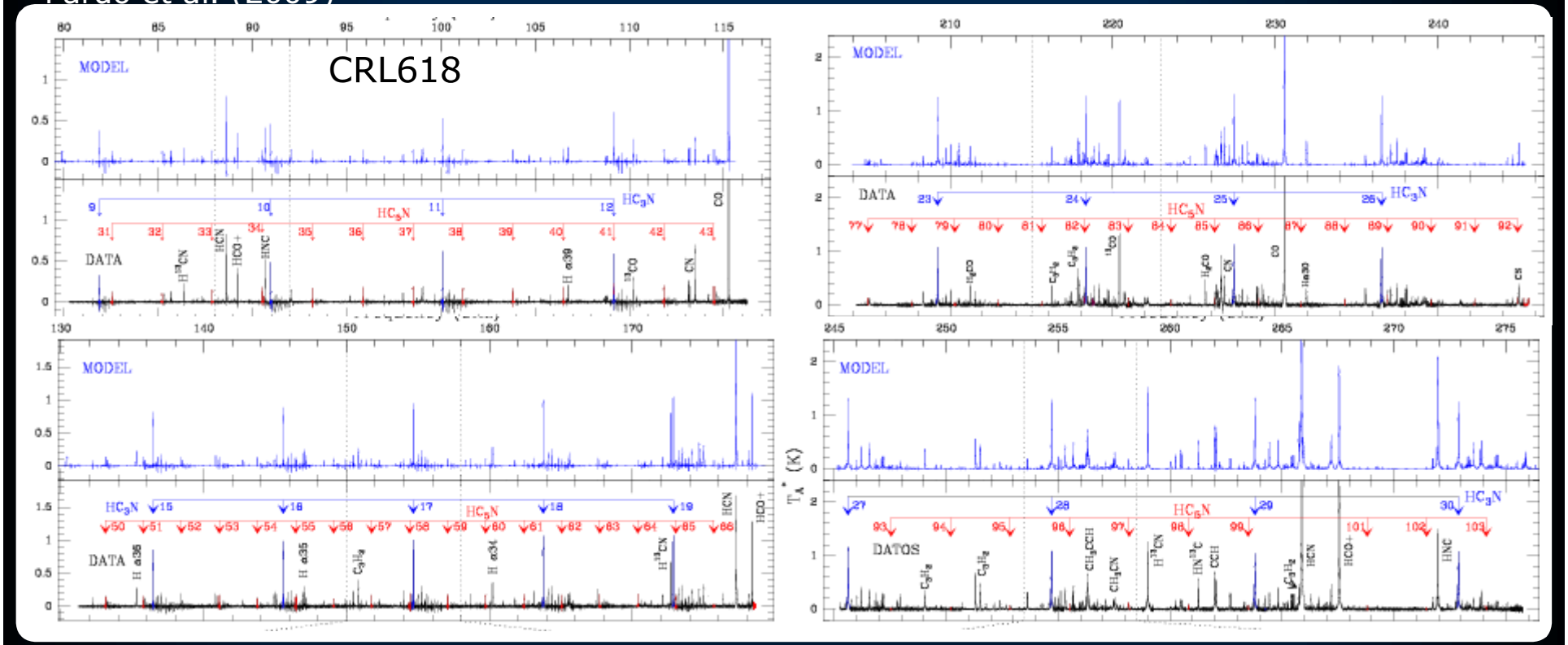
Flux Calibrators: Radio Stars

Number of radio bright stars:

- MWC349 (binary star)
- CRL618 (PPN)
- W3OH (HII region)
- NGC7072 (young PN)
- NGC7538 (HII region)
- K3-50A (HII-region)
- …..

Flux Calibrators: Radio Stars

Pardo et al. (2009)



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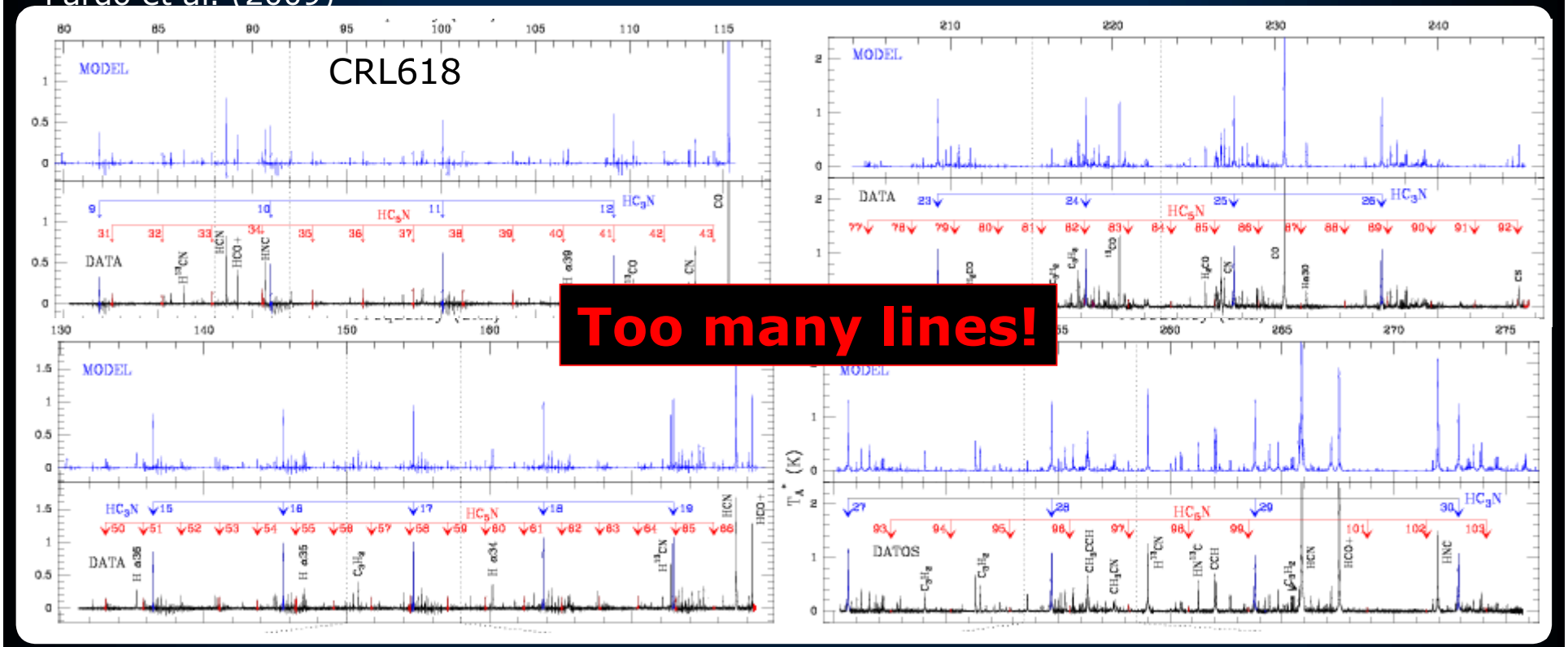

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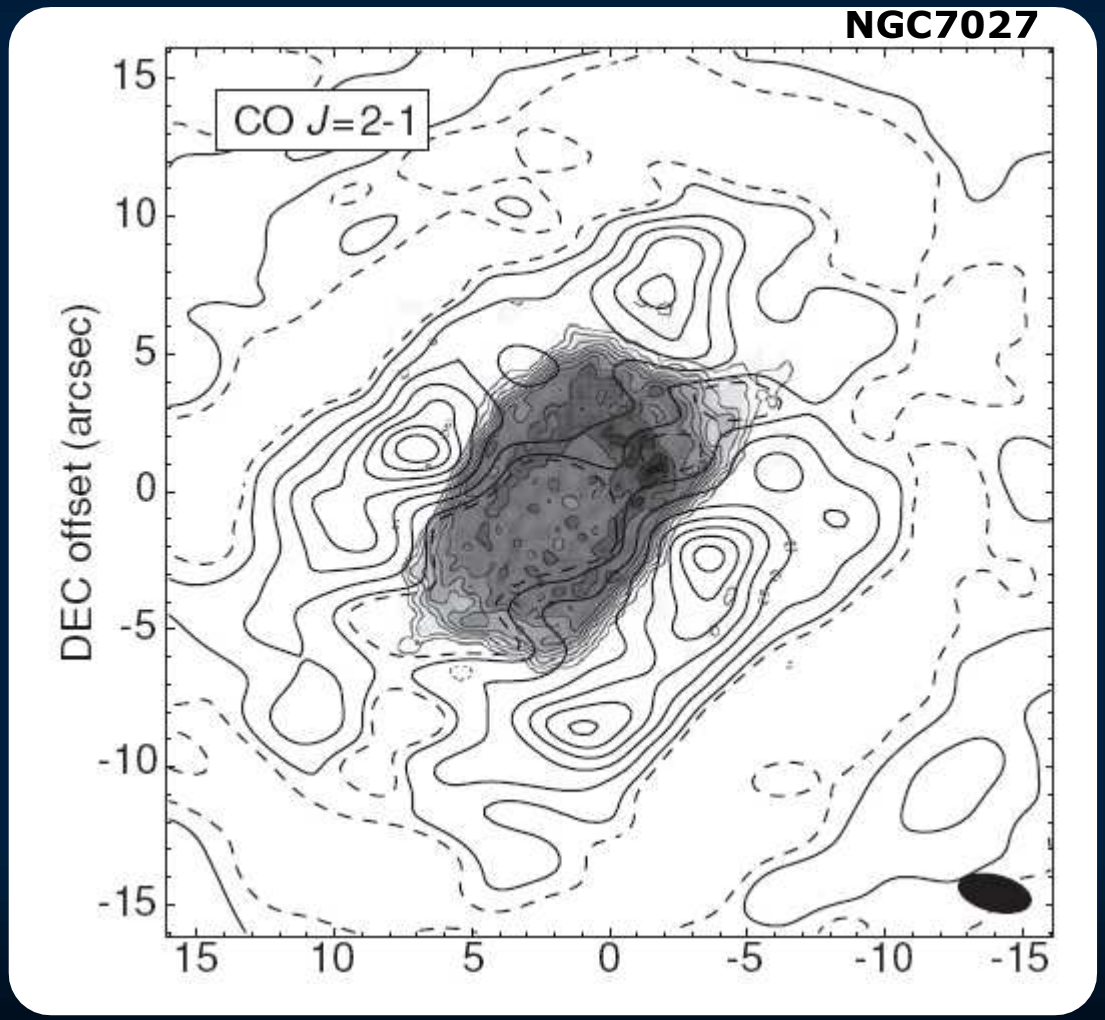
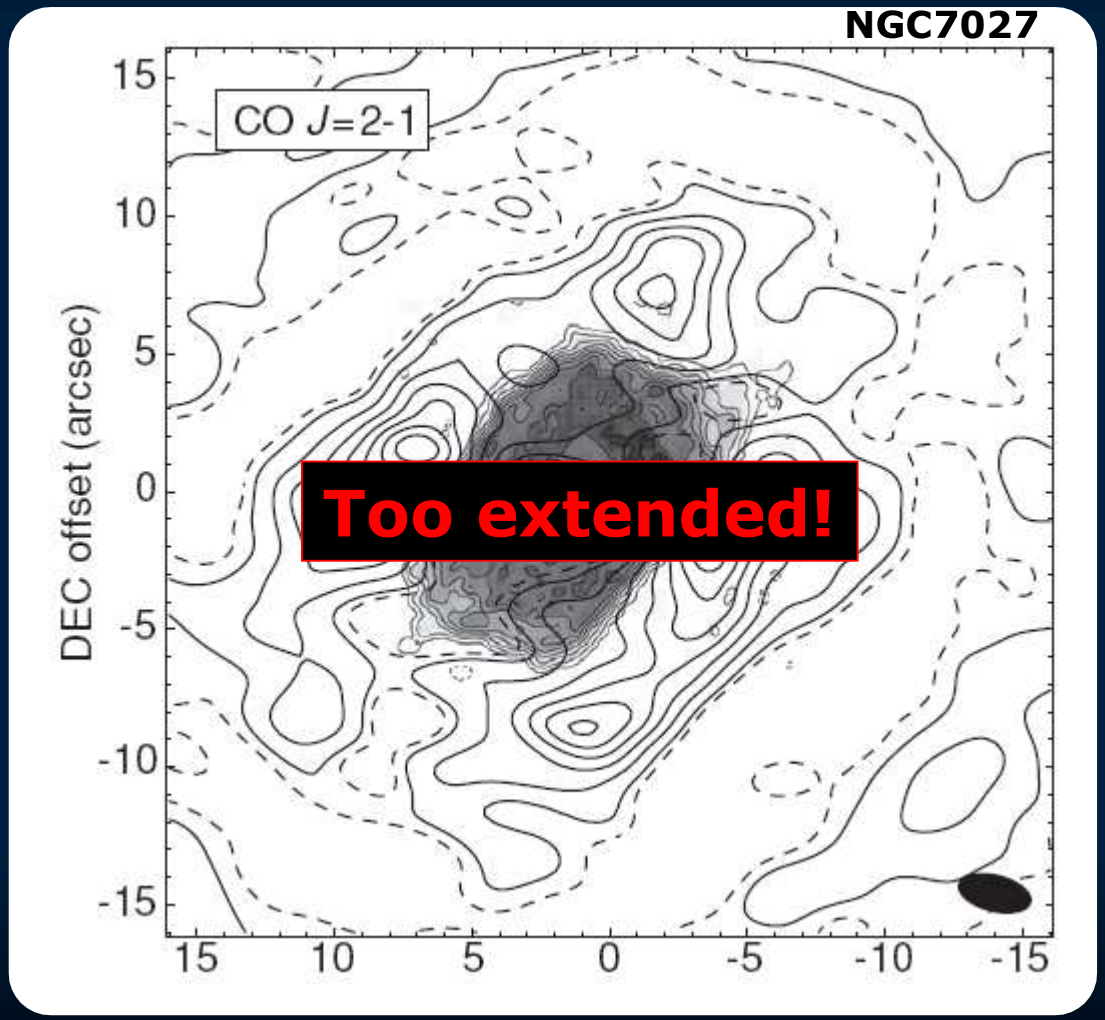


Nakashima et al. (2010)

Flux Calibrators: Radio Stars



Nakashima et al. (2010)

Flux Calibrators: Radio Stars

Number of radio bright stars:

- MWC349
- CRL618
- W3OH
- NGC7072
- NGC7538
- K3-50A

Flux Calibrators: MWC349

Some facts:

- binary stellar system:
  MWC349A (Be) & MWC349B (B0 type III)
- the two stars are separated by 2.4″±0.1″ and possibly interact
- MWC349A the brightest radio continuum star
- radio continuum produced by "ionised bipolar flow that photoevaporates from the surface of a neutral Keplerian disk"
- size of flow decreases with frequency
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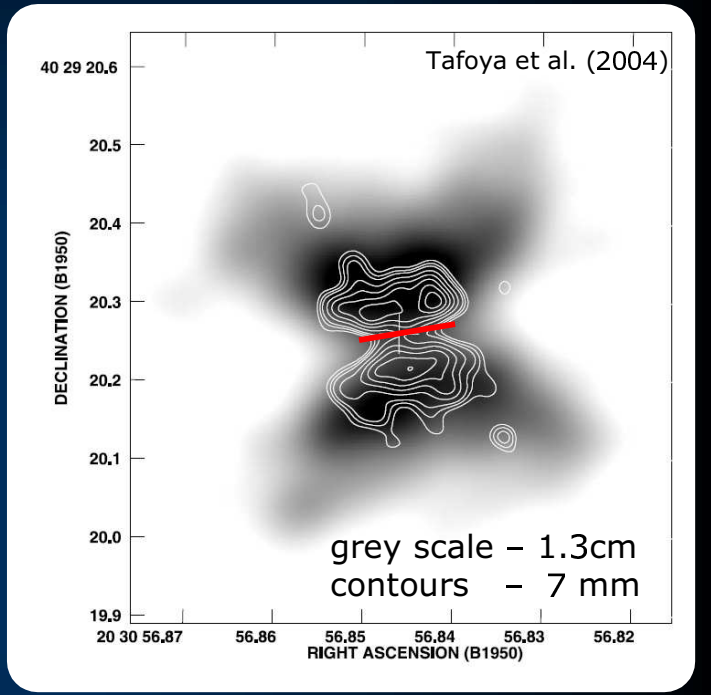
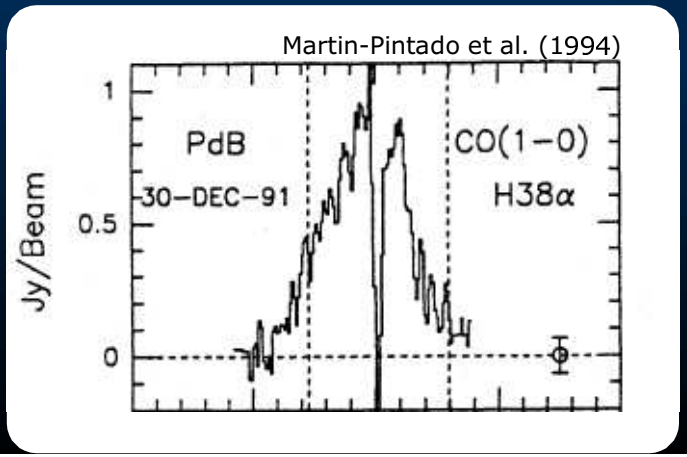
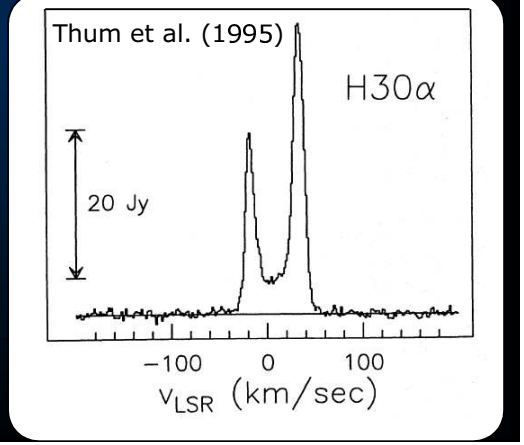
- at declination of >40deg -> visible for ~13h per day







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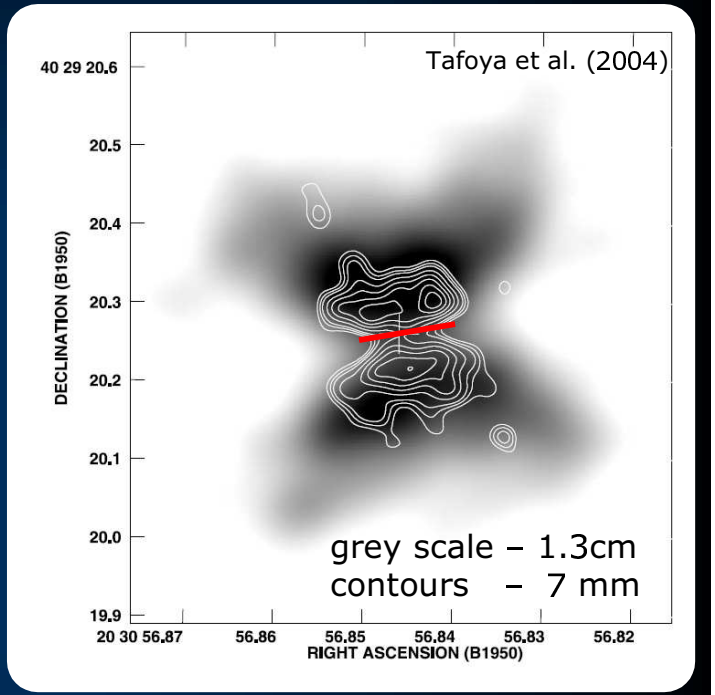

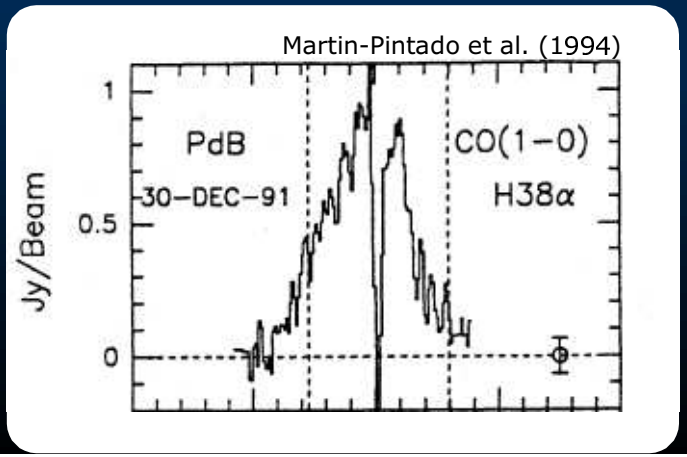

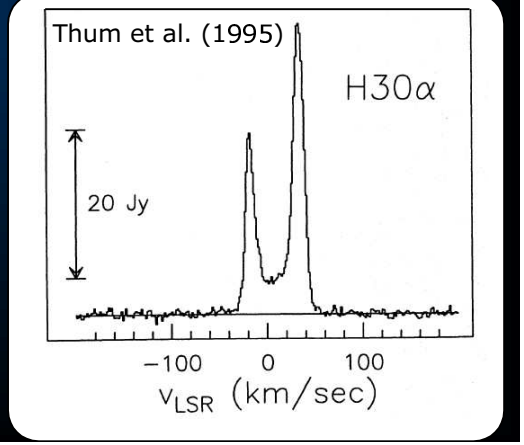

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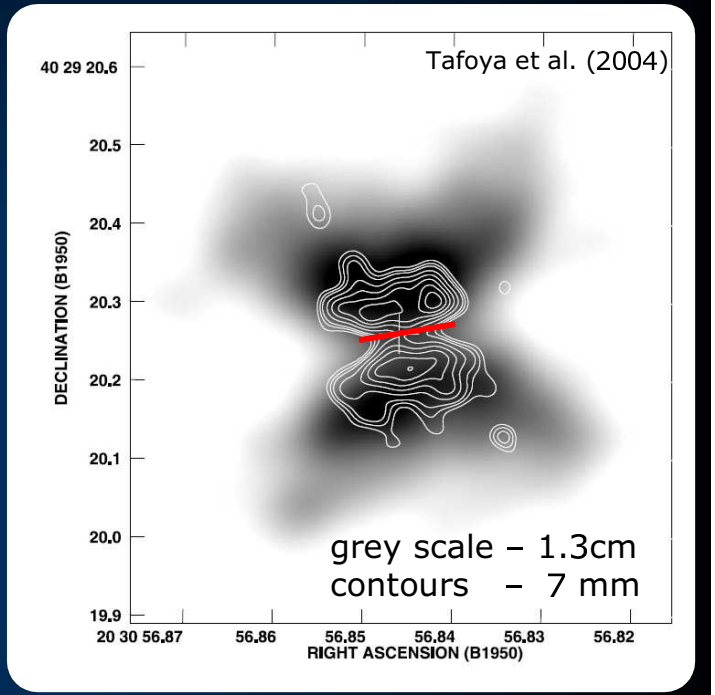

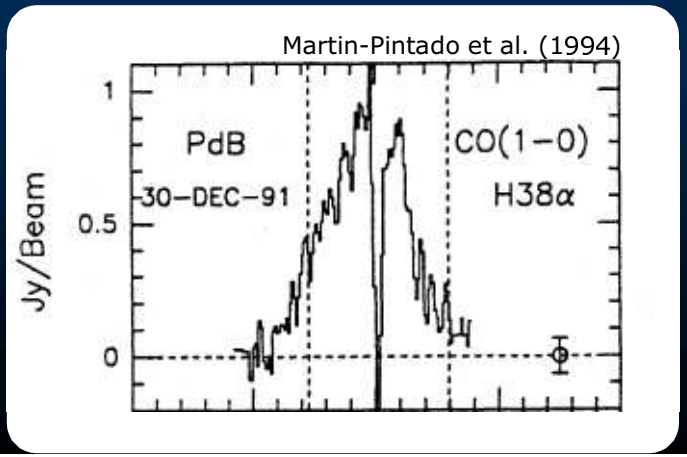

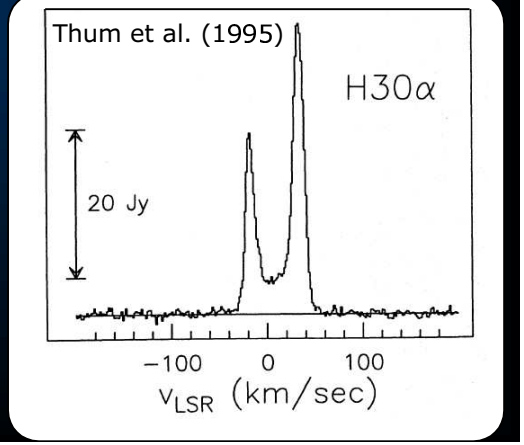

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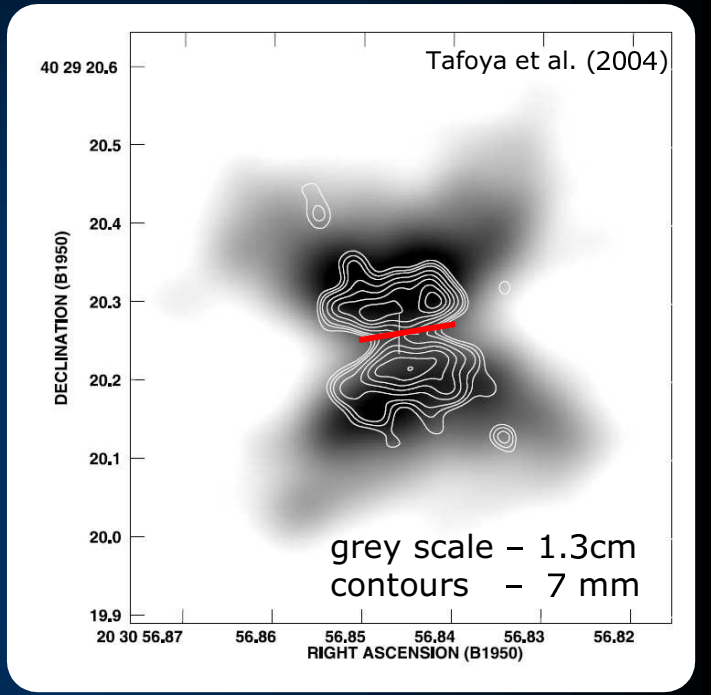

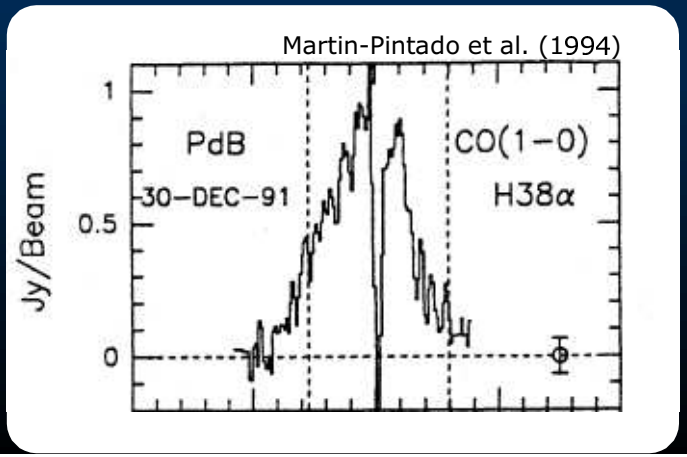

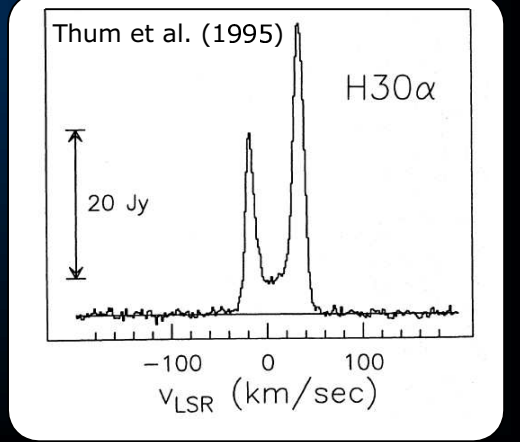

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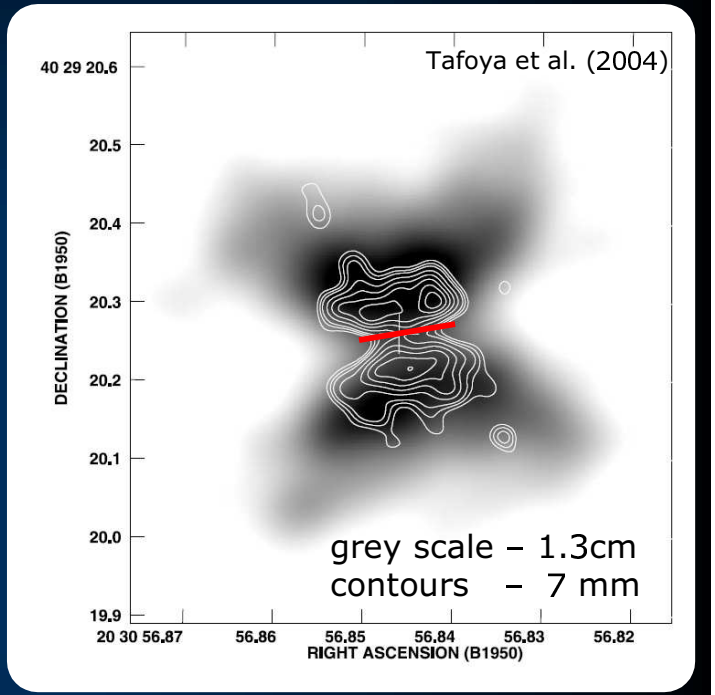

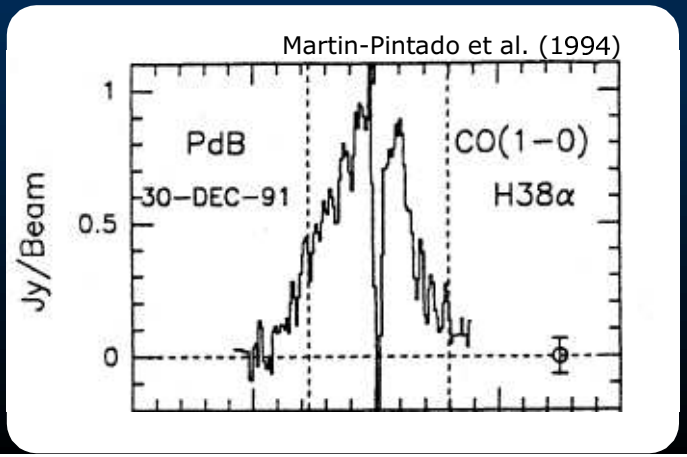

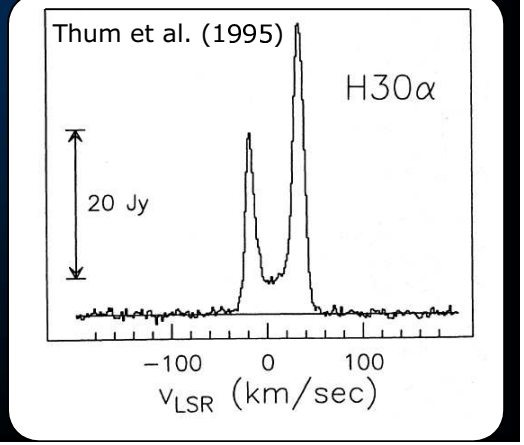

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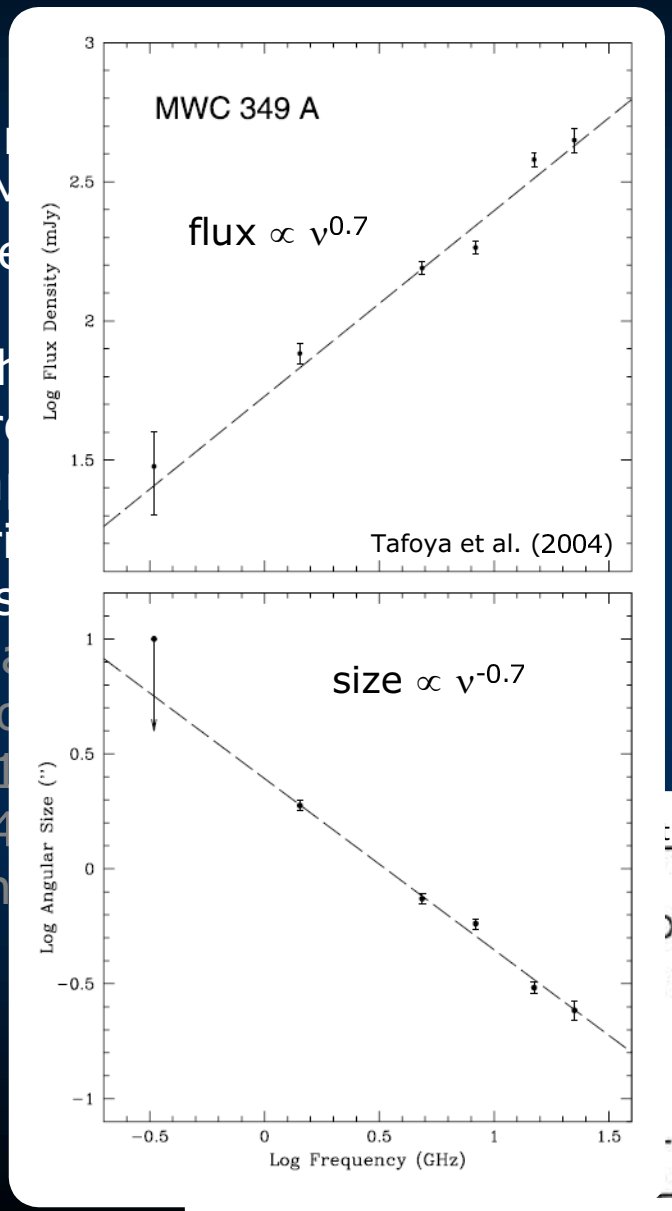

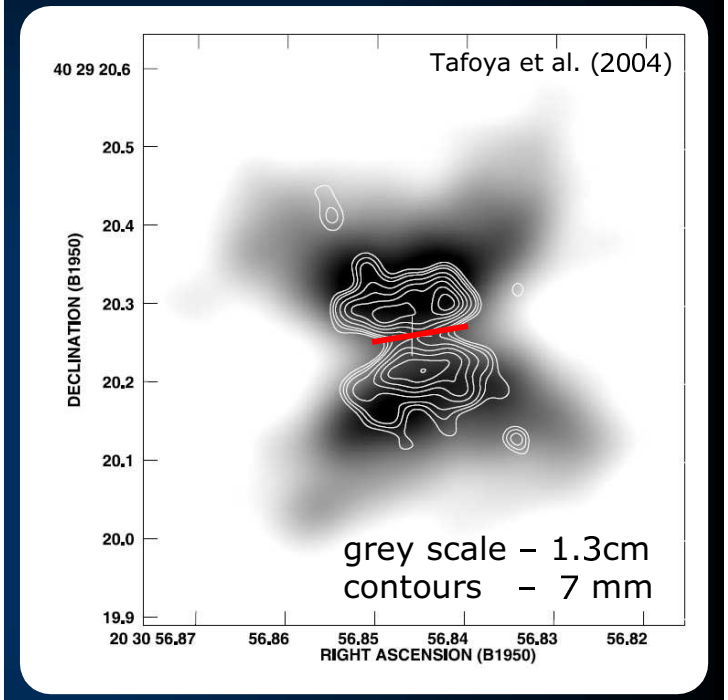

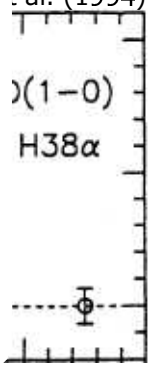

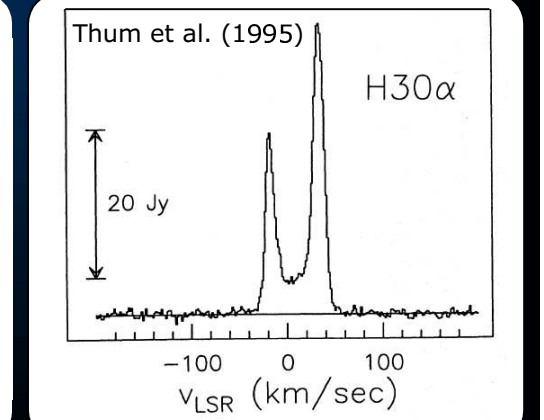

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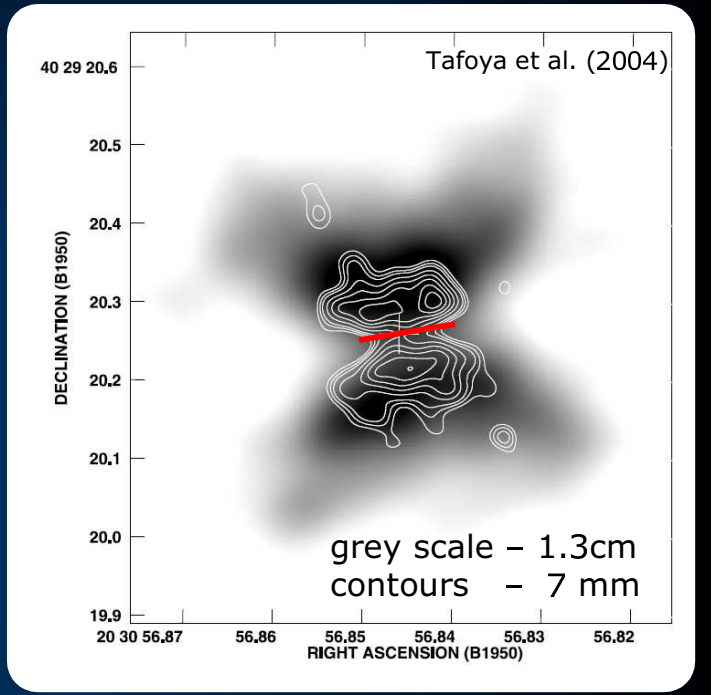

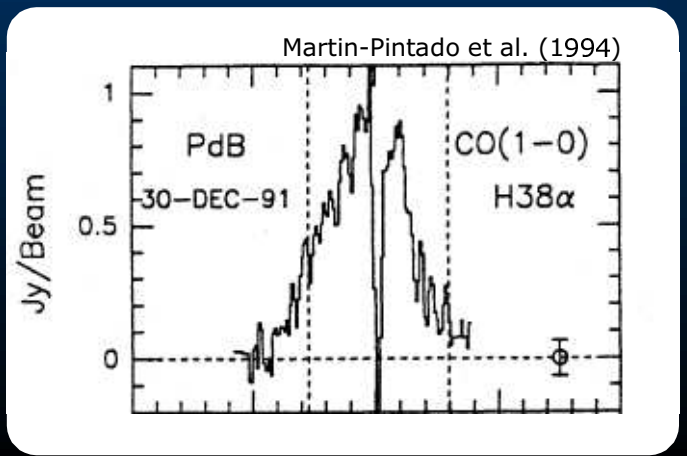

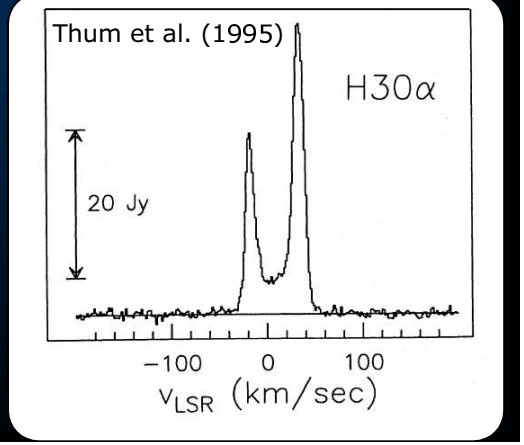

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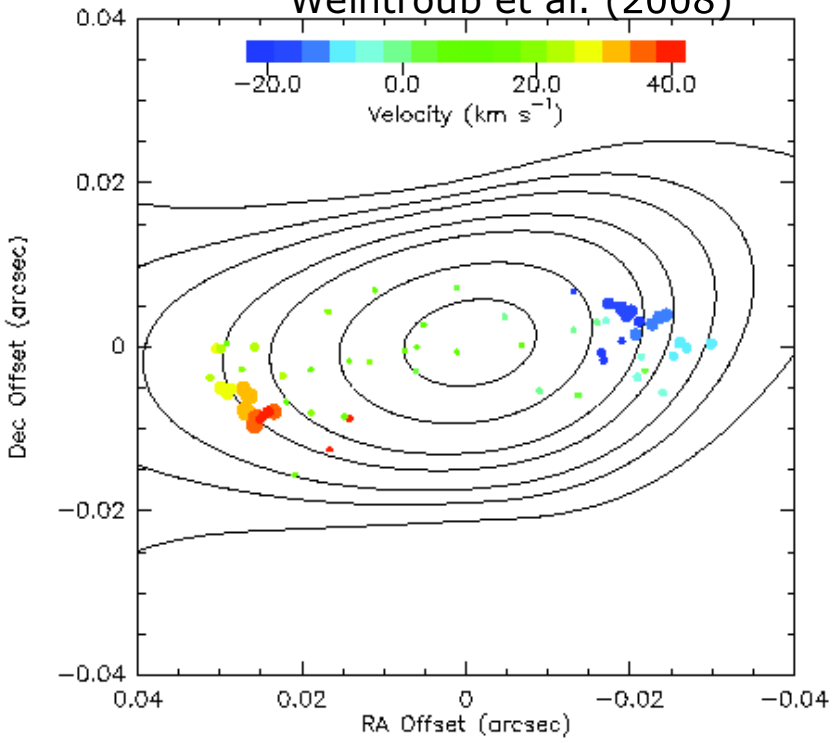
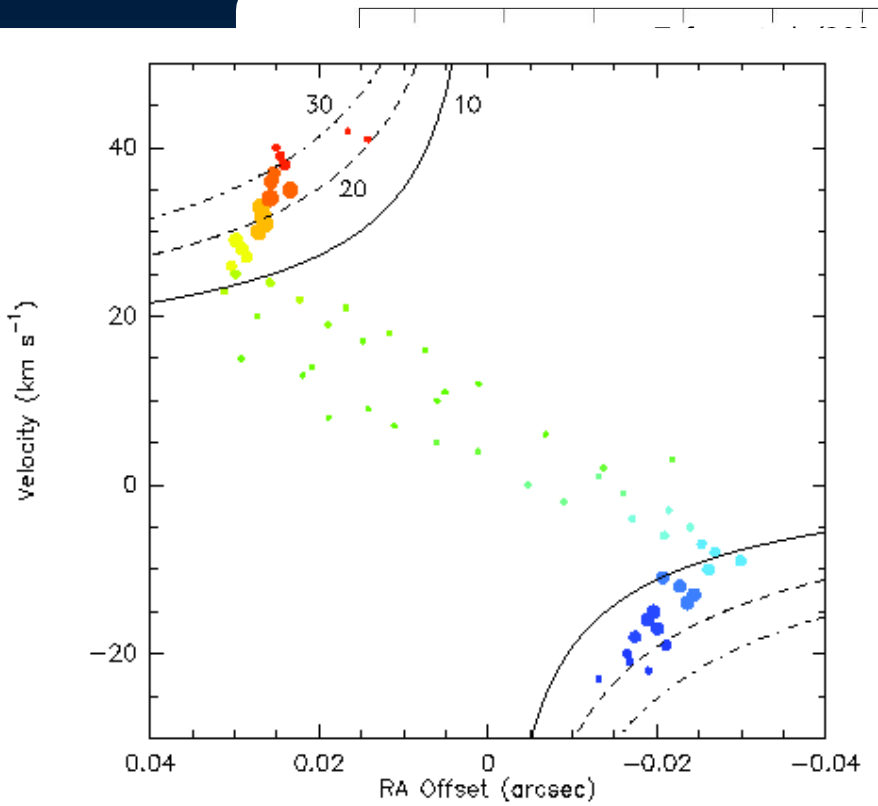
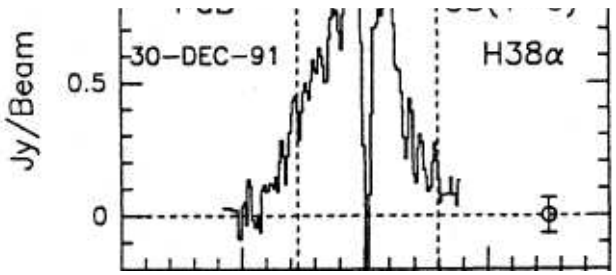
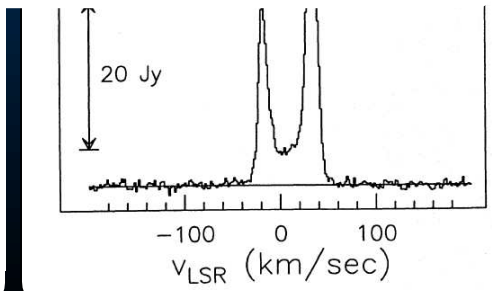
Weintroub et al. (2008)









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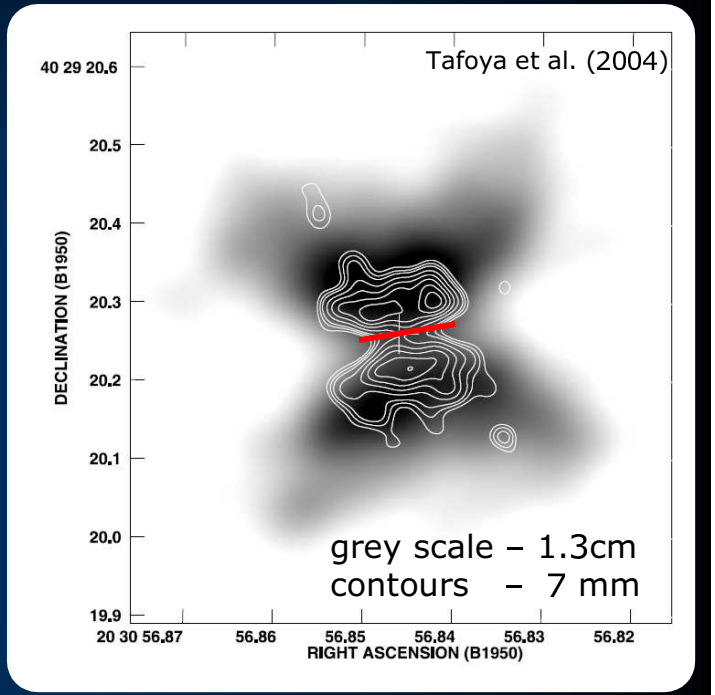

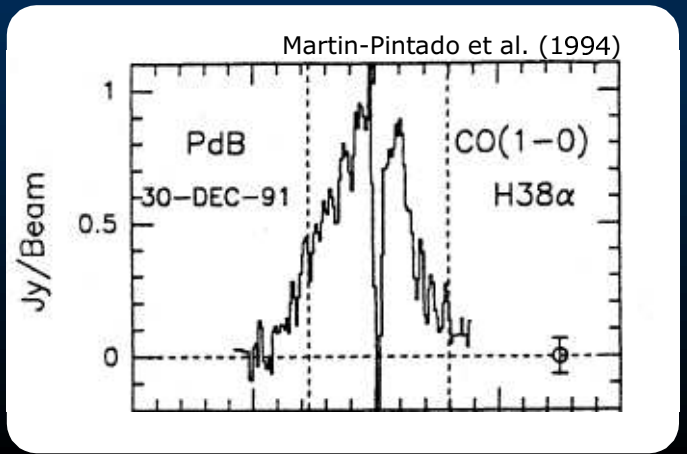

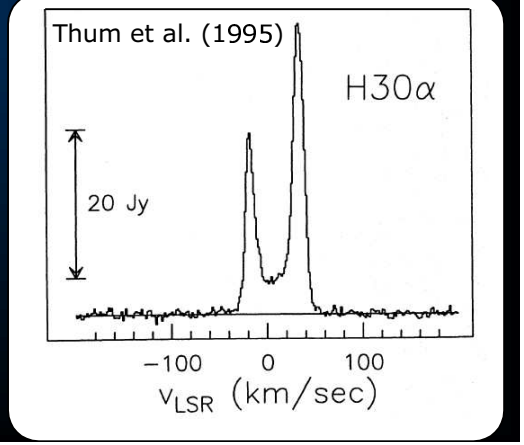

Flux Calibrators: MWC349

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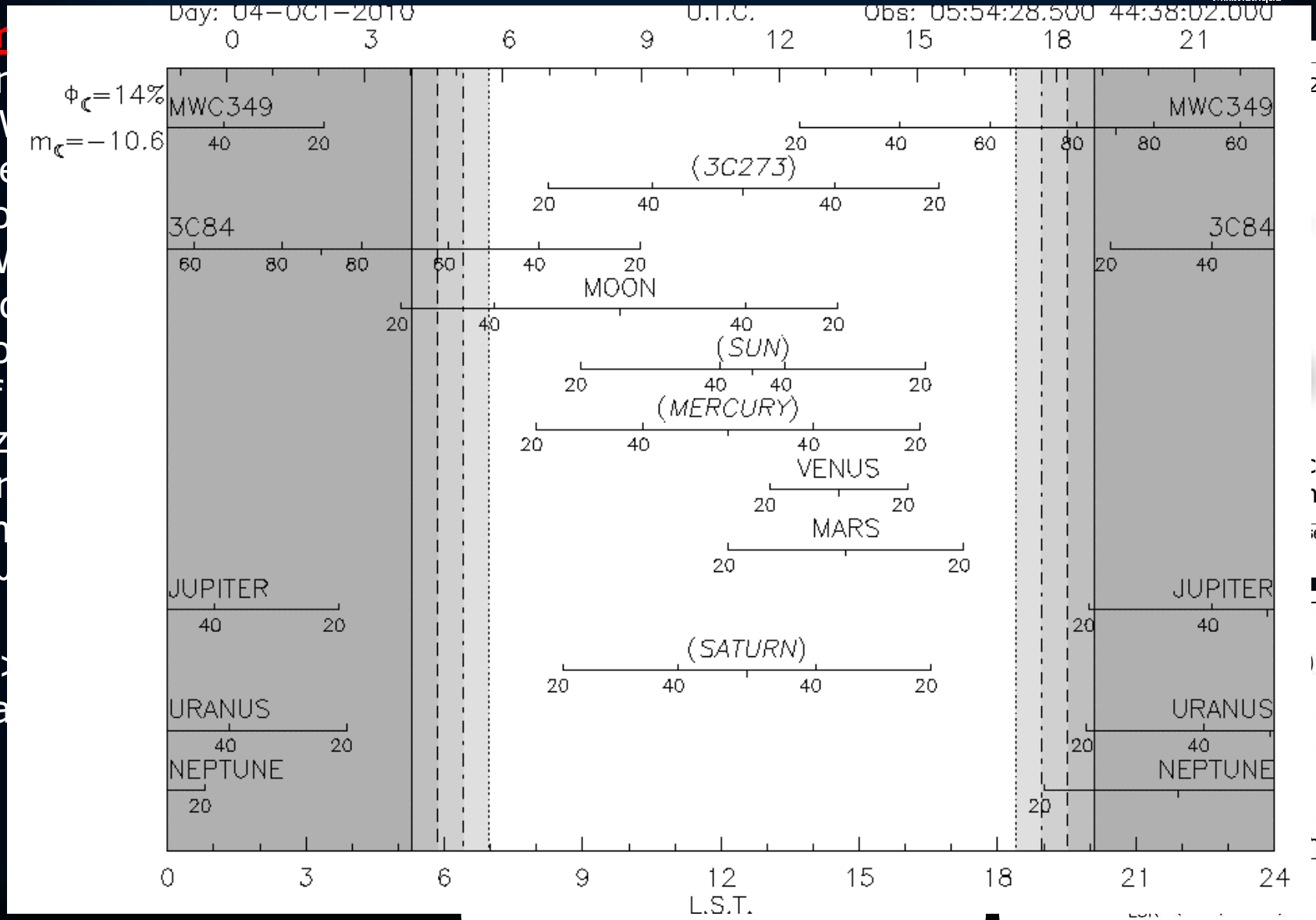
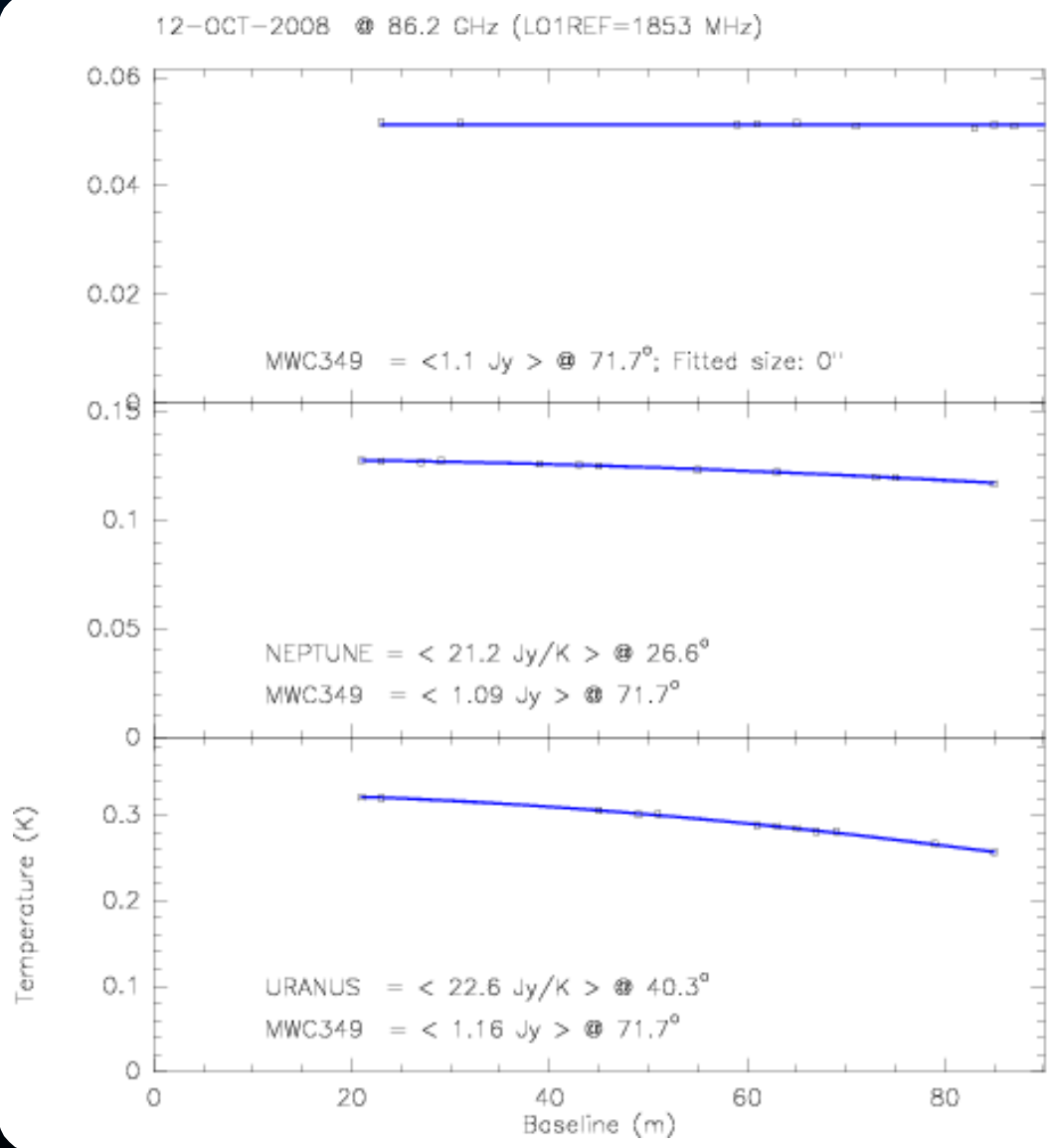


How to calibrate a calibrator?



ANTENNA	3c454.3@46°	mwc349@72°
1	21.5 Jy/K	21.3 Jy/K
2	22.3 Jy/K	22.5 Jy/K
3	21.7 Jy/K	22.1 Jy/K
5	22.1 Jy/K	22.4 Jy/K
6	22 Jy/K	21.9 Jy/K
Weighted Av.	21.8 Jy/K	21.9 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
URANUS	7.4	3.64	3.53	255
NEPTUNE	2.7	2.27	2.21	340

3c454.3 26.51 (Neptune)
3c454.3 28.16 (Uranus)

Flagged:
L02 C02 for Line Frequency:86243MHz
L03 C03 for Line Frequency:86243MHz
L06 C06 for Line Frequency:86243MHz
L07 C07 for Line Frequency:86243MHz

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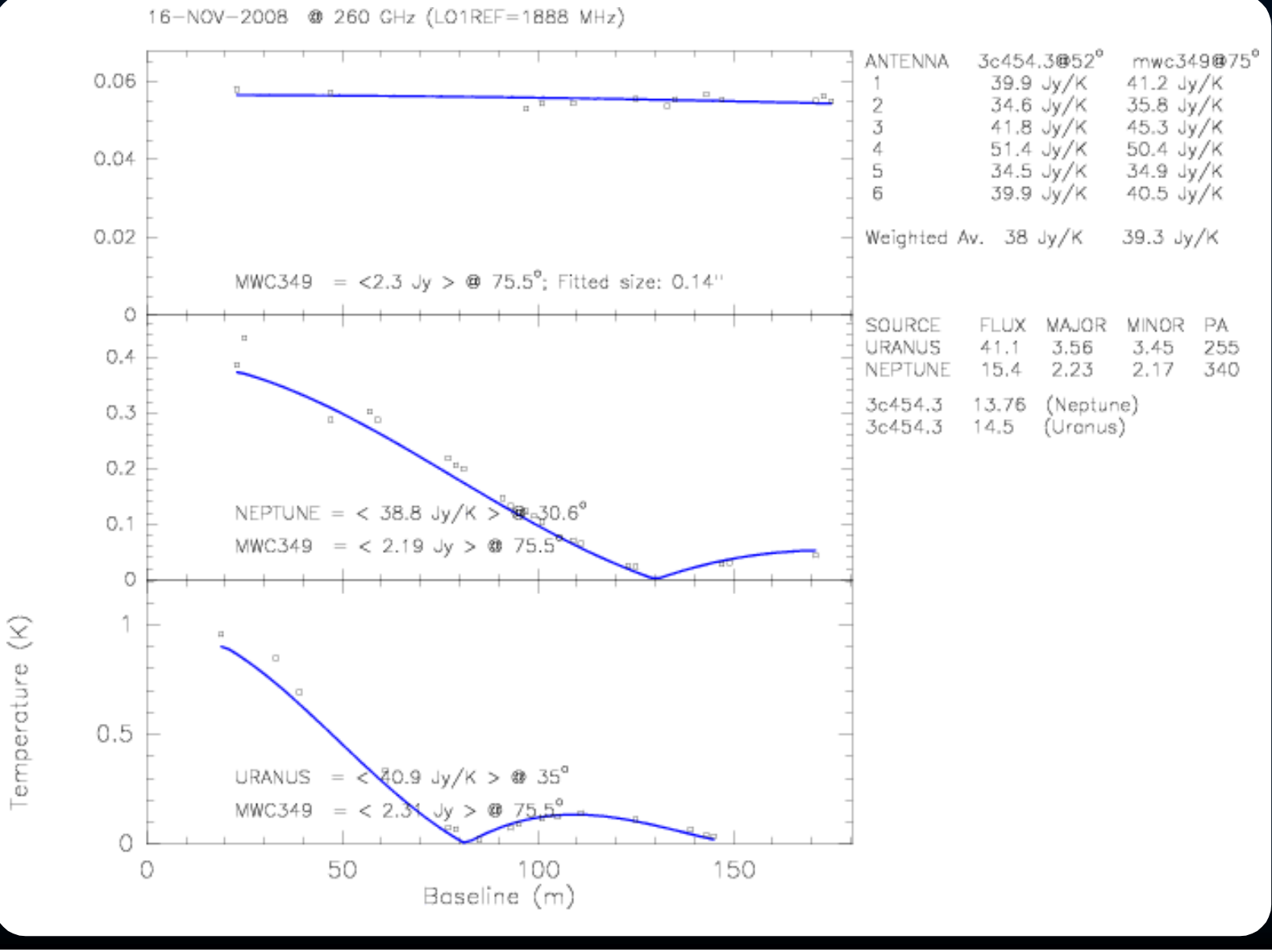
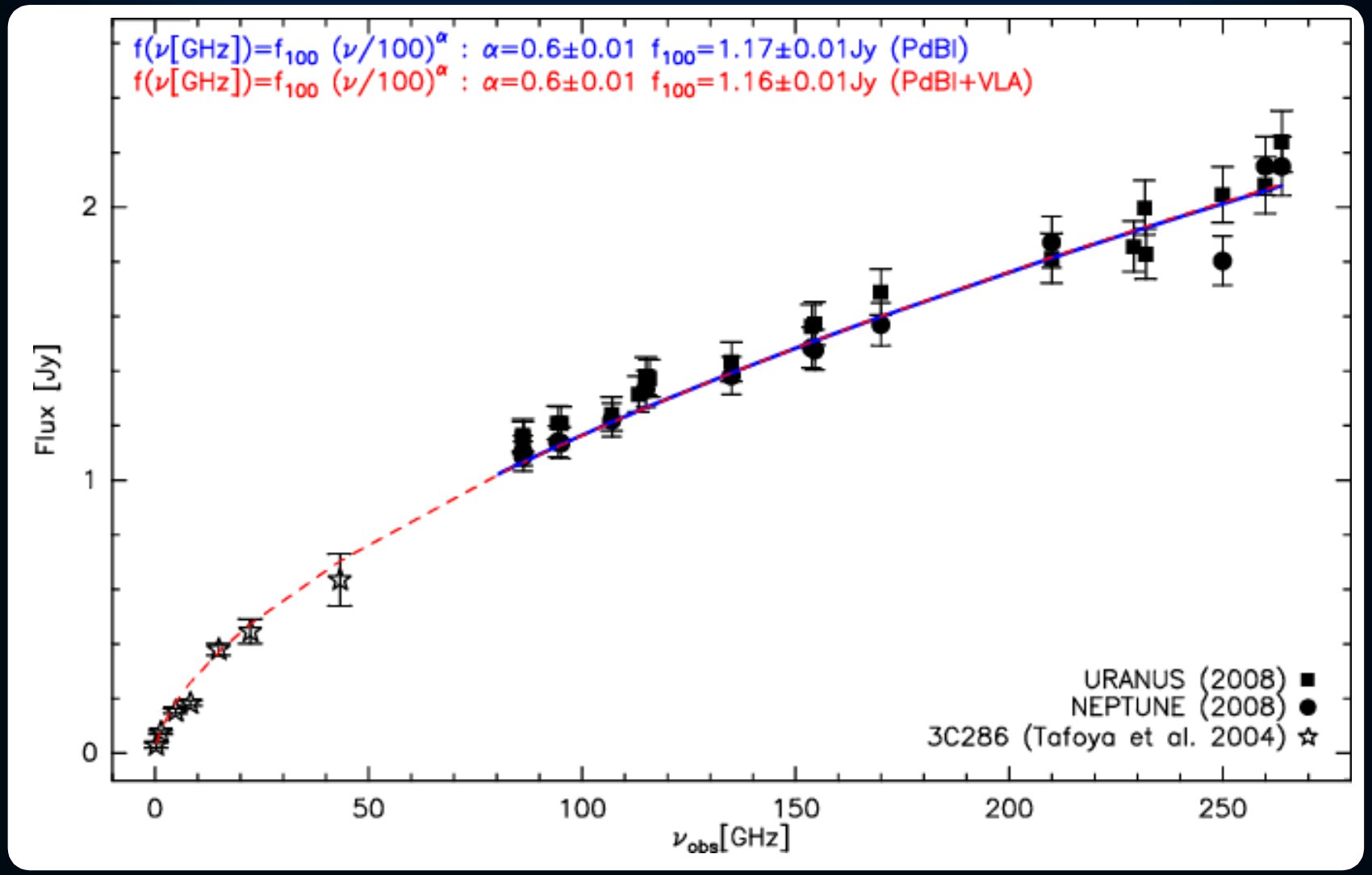


ANTENNA	3c454.3@52°	mwc349@75°
1	39.9 Jy/K	41.2 Jy/K
2	34.6 Jy/K	35.8 Jy/K
3	41.8 Jy/K	45.3 Jy/K
4	51.4 Jy/K	50.4 Jy/K
5	34.5 Jy/K	34.9 Jy/K
6	39.9 Jy/K	40.5 Jy/K
Weighted Av.	38 Jy/K	39.3 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
URANUS	41.1	3.56	3.45	255
NEPTUNE	15.4	2.23	2.17	340

3c454.3	13.76	(Neptune)
3c454.3	14.5	(Uranus)

Flux of MWC348: SED



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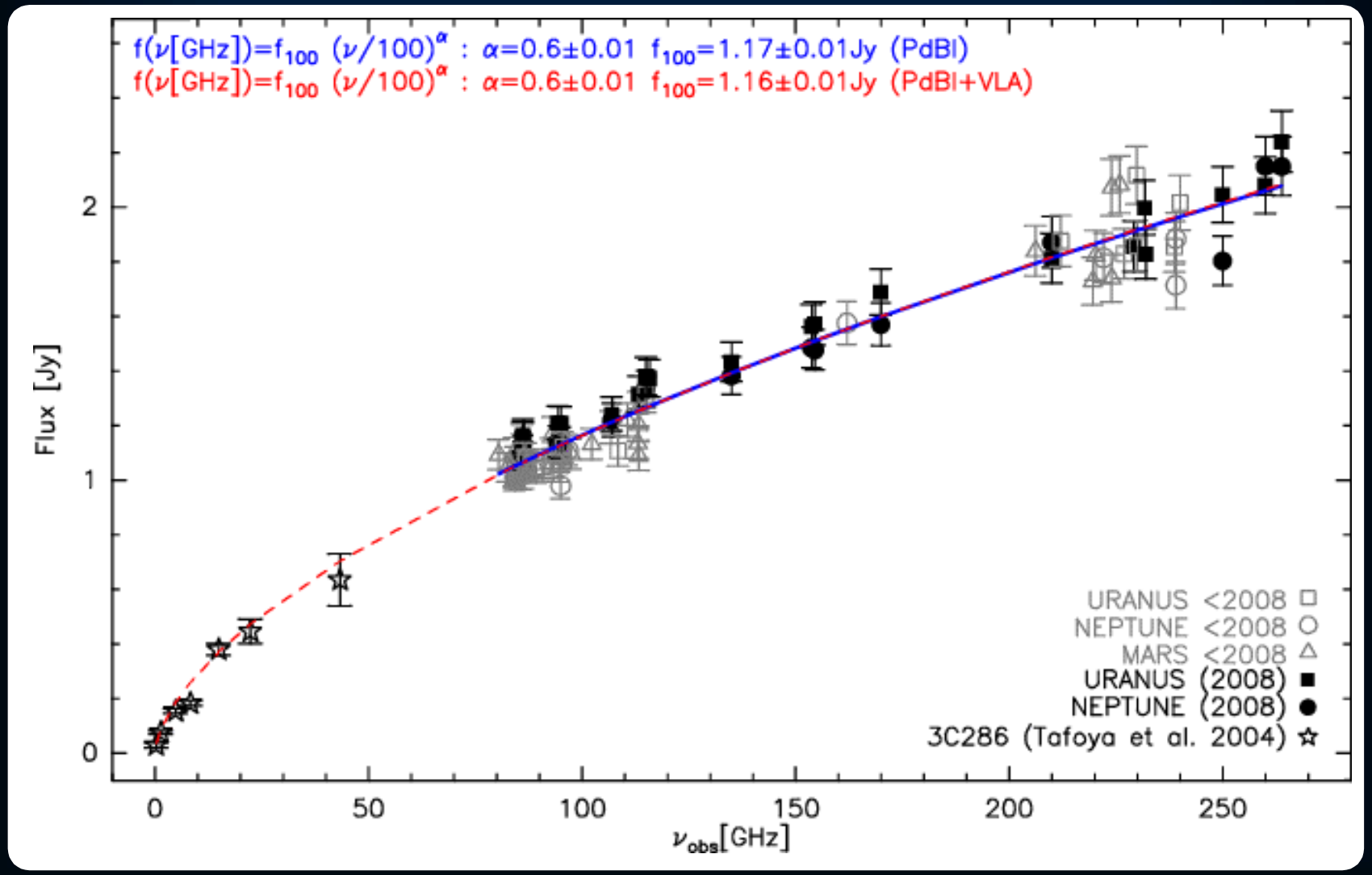
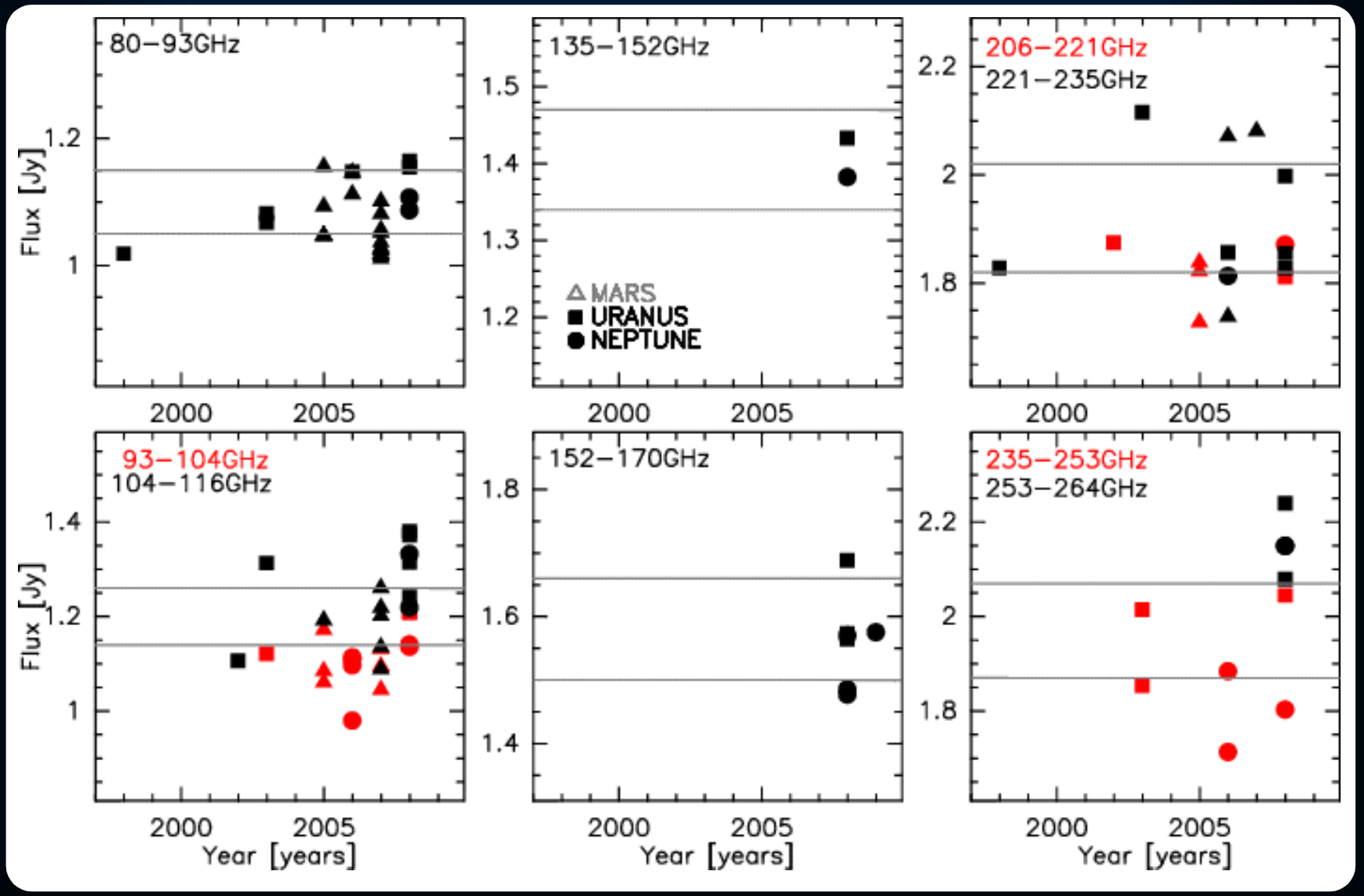
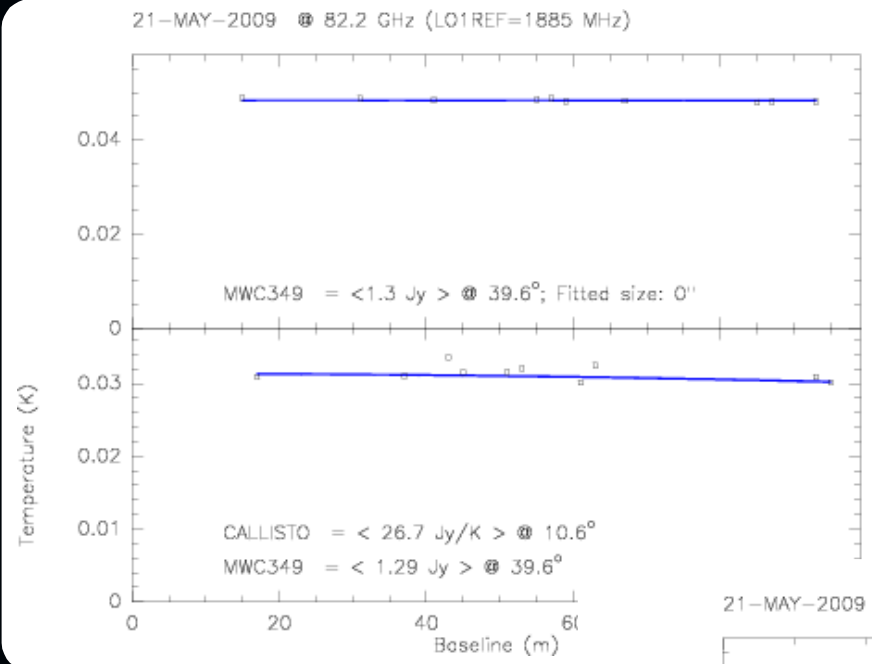


Flux of MWC348: Time variability?



Flux of MWC348: Using satellites?

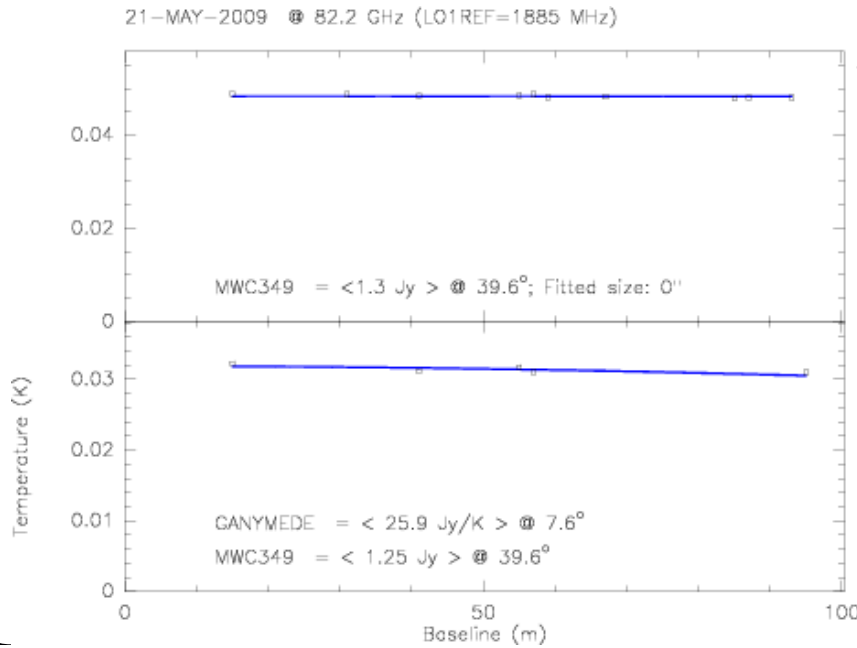


ANTENNA	3C454.3@52°	mwc349@40°
1	28.6 Jy/K	28.6 Jy/K
2	26.3 Jy/K	26.2 Jy/K
4	26.5 Jy/K	26.9 Jy/K
5	26.4 Jy/K	26.1 Jy/K
6	26.7 Jy/K	26.6 Jy/K
Weighted Av.	27 Jy/K	27.1 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
CALLISTO	0.8	1.36	1.36	0

3c454.3 6.37 (CALLISTO)

Using SMA model!



ANTENNA	3C454.3@52°	mwc349@40°
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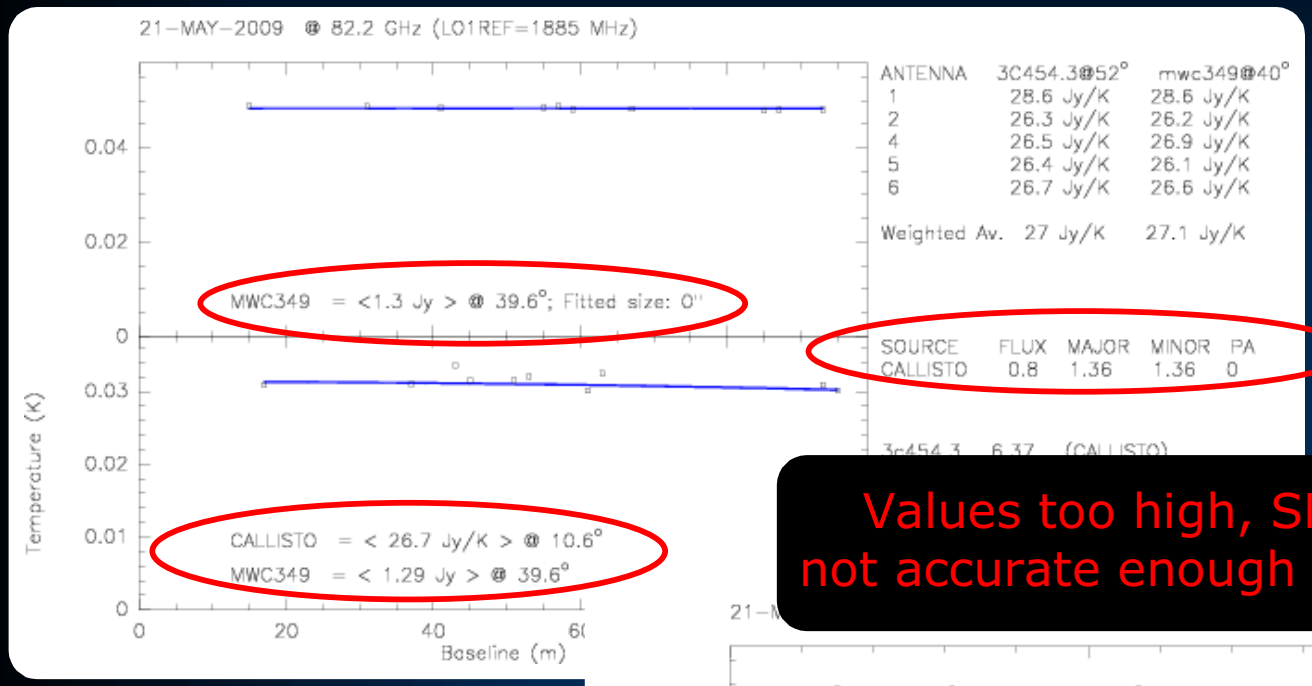
2	25.5 Jy/K	25.5 Jy/K
4	25.8 Jy/K	26.1 Jy/K
5	25.6 Jy/K	25.4 Jy/K
6	25.9 Jy/K	25.8 Jy/K
Weighted Av.	26.3 Jy/K	26.3 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
GANYMEDE	0.8	1.48	1.48	0

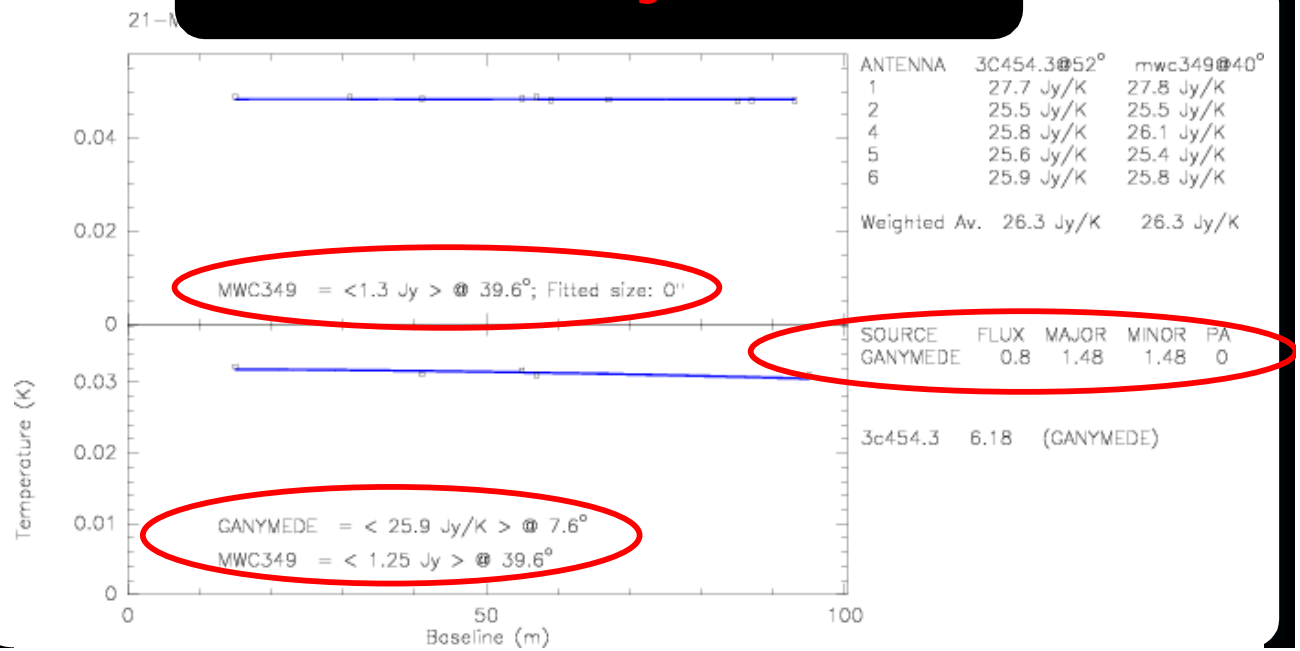
3c454.3 6.18 (GANYMEDE)

Flux of MWC348: Using satellites?



Using SMA model!

Values too high, SMA model not accurate enough for λ>1mm!



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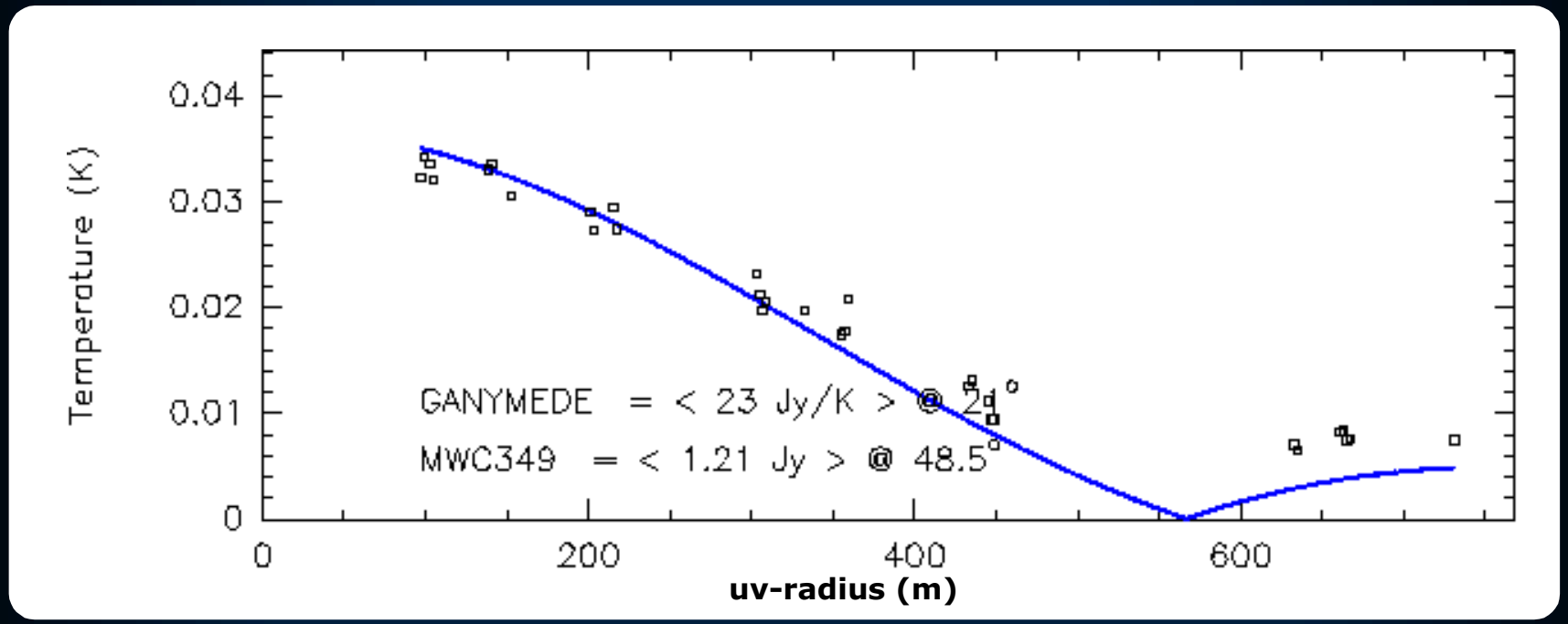

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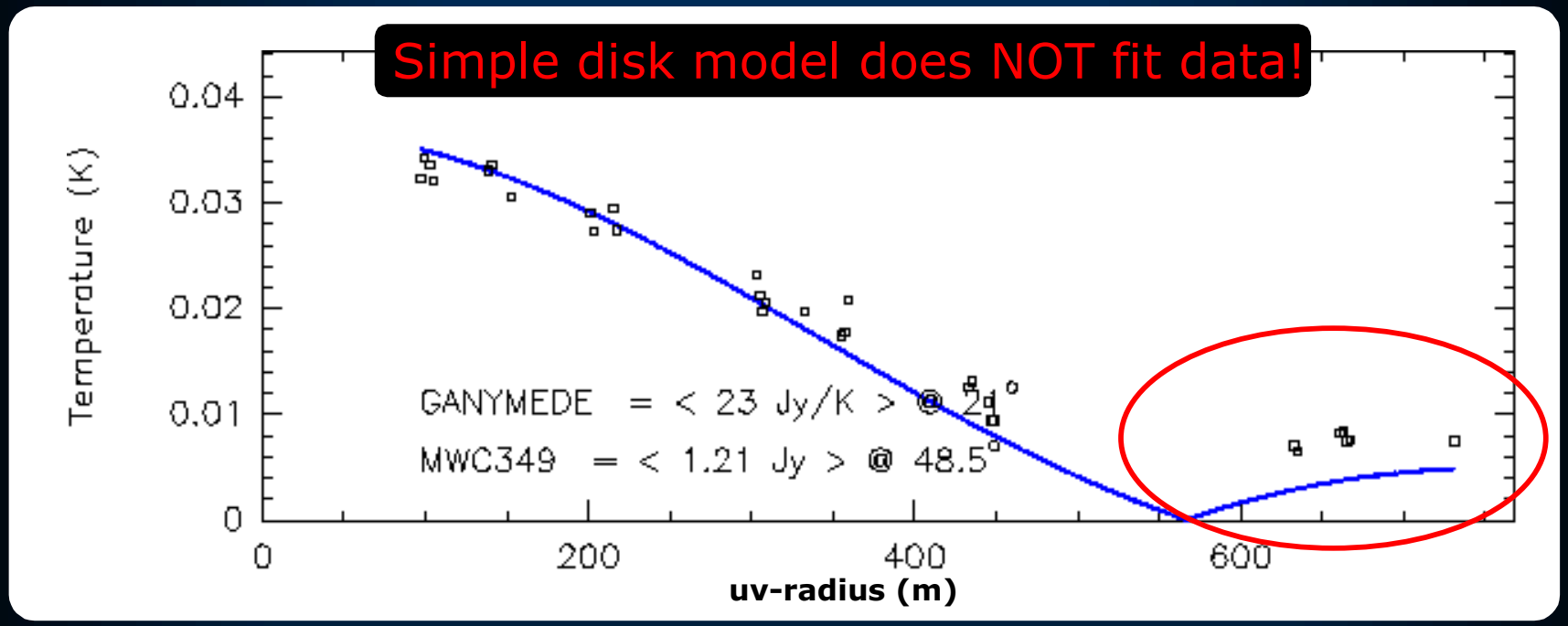

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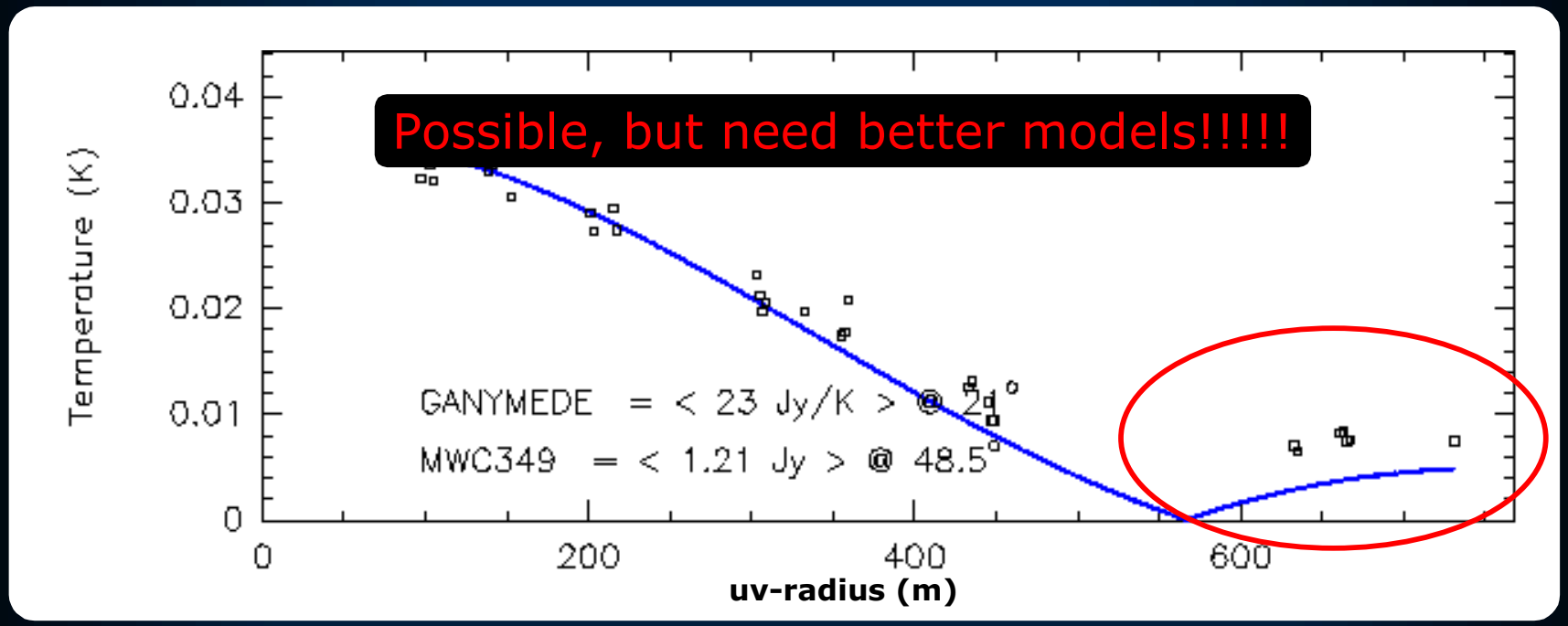
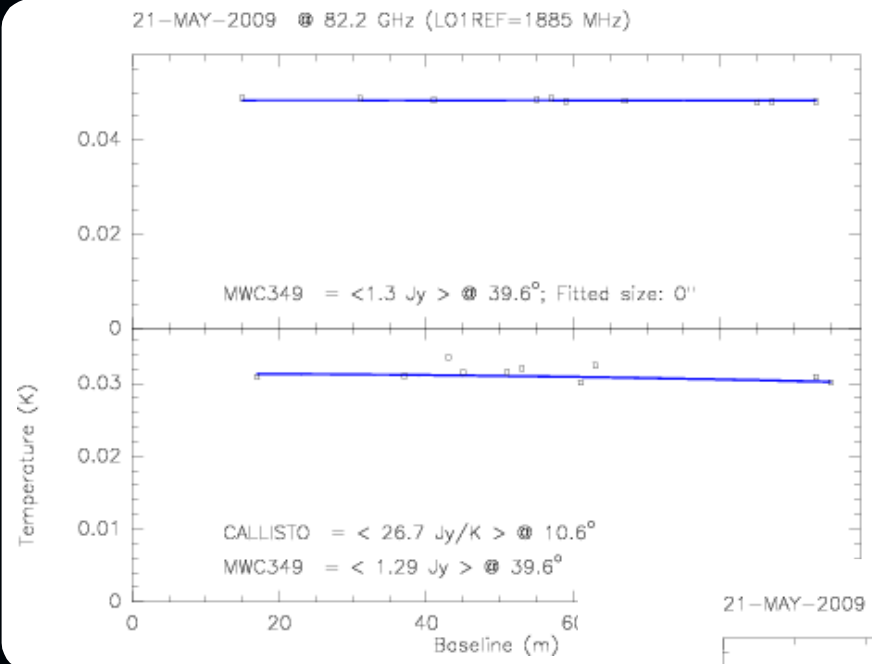


Flux of MWC348: Using satellites?

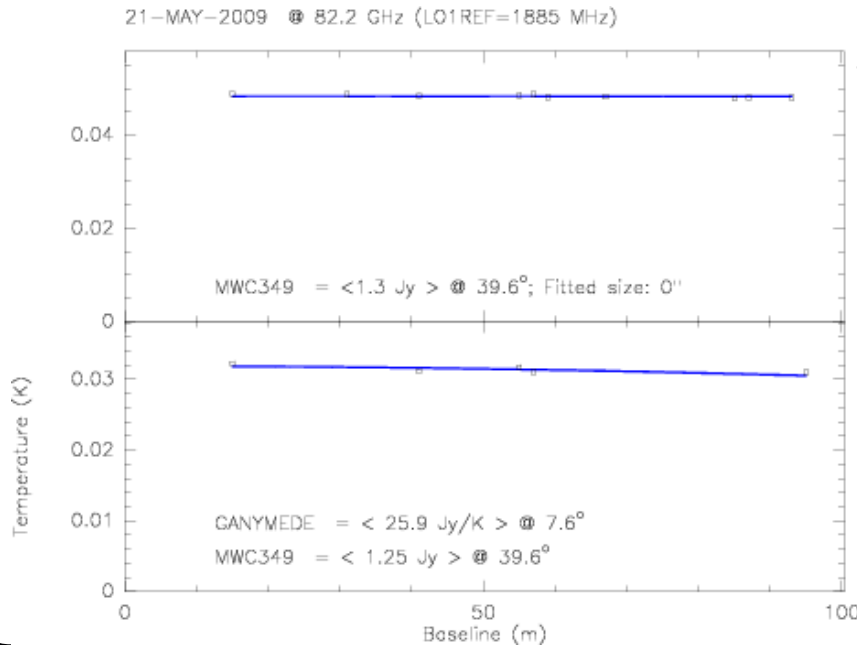


ANTENNA	3C454.3@52°	mwc349@40°
1	28.6 Jy/K	28.6 Jy/K
2	26.3 Jy/K	26.2 Jy/K
4	26.5 Jy/K	26.9 Jy/K
5	26.4 Jy/K	26.1 Jy/K
6	26.7 Jy/K	26.6 Jy/K
Weighted Av.	27 Jy/K	27.1 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
CALLISTO	0.8	1.36	1.36	0

3c454.3 6.37 (CALLISTO)

Using SMA model!

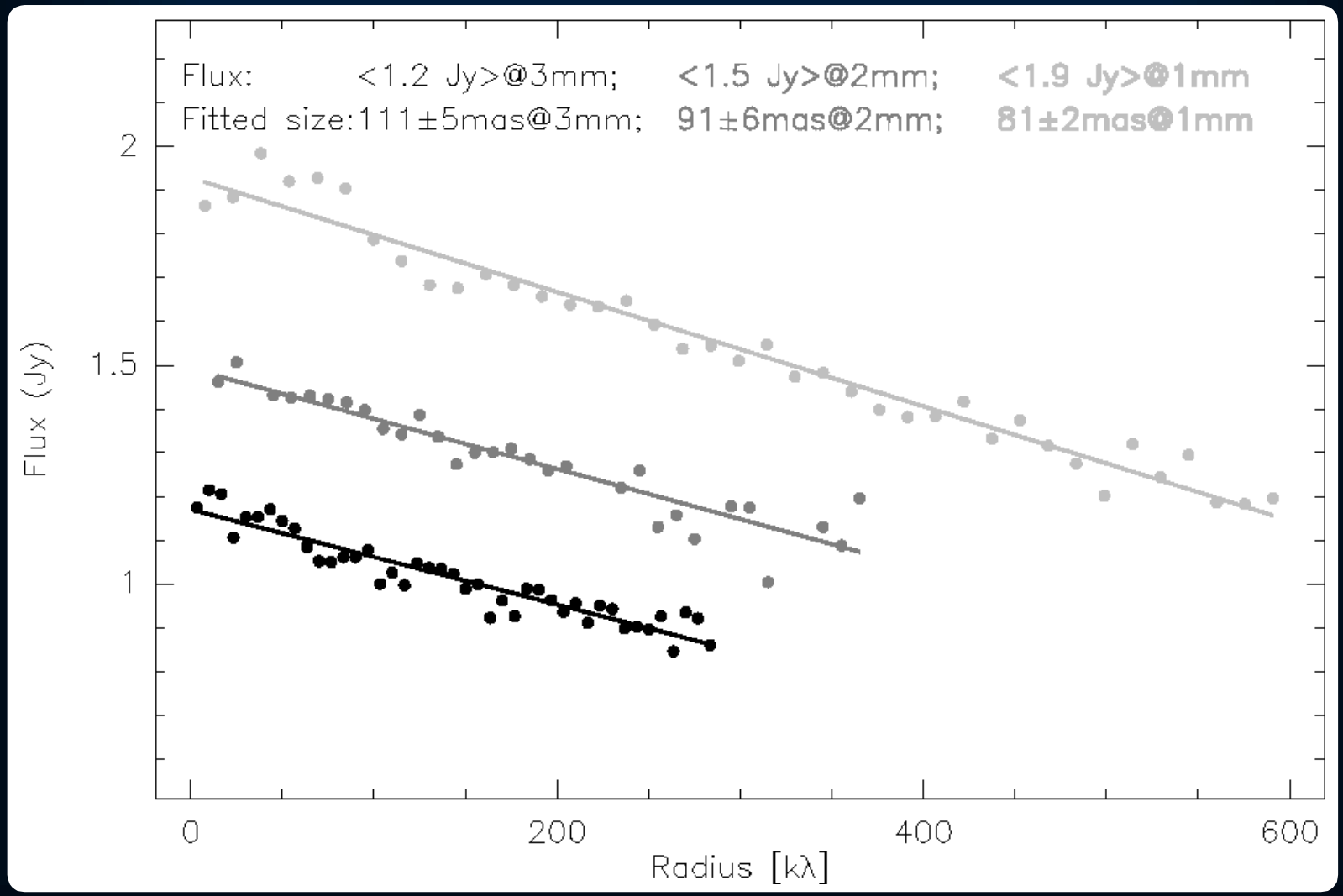


ANTENNA	3C454.3@52°	mwc349@40°
1	27.7 Jy/K	27.8 Jy/K
2	25.5 Jy/K	25.5 Jy/K
4	25.8 Jy/K	26.1 Jy/K
5	25.6 Jy/K	25.4 Jy/K
6	25.9 Jy/K	25.8 Jy/K
Weighted Av.	26.3 Jy/K	26.3 Jy/K

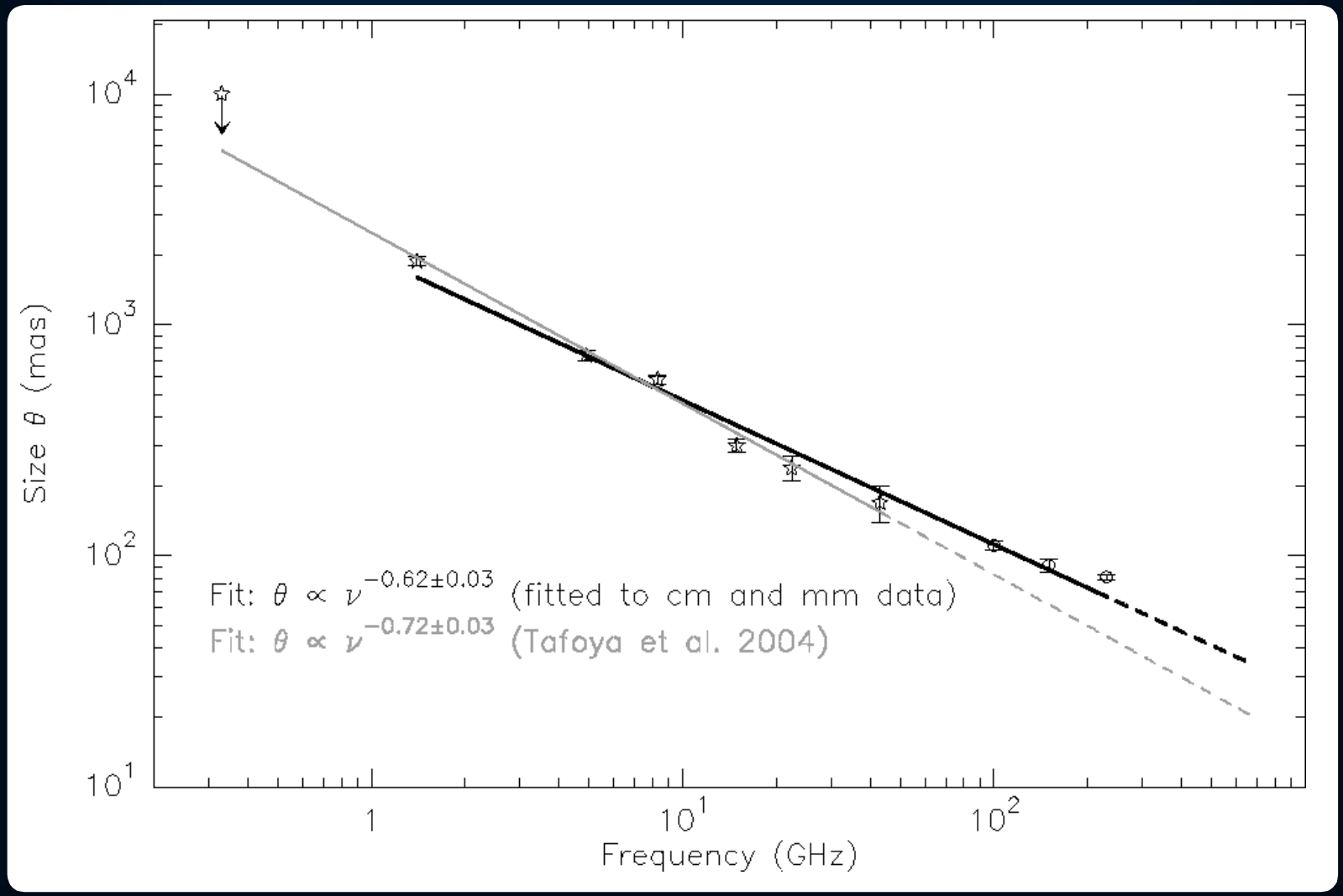
SOURCE	FLUX	MAJOR	MINOR	PA
GANYMEDE	0.8	1.48	1.48	0

3c454.3 6.18 (GANYMEDE)

Size of MWC348



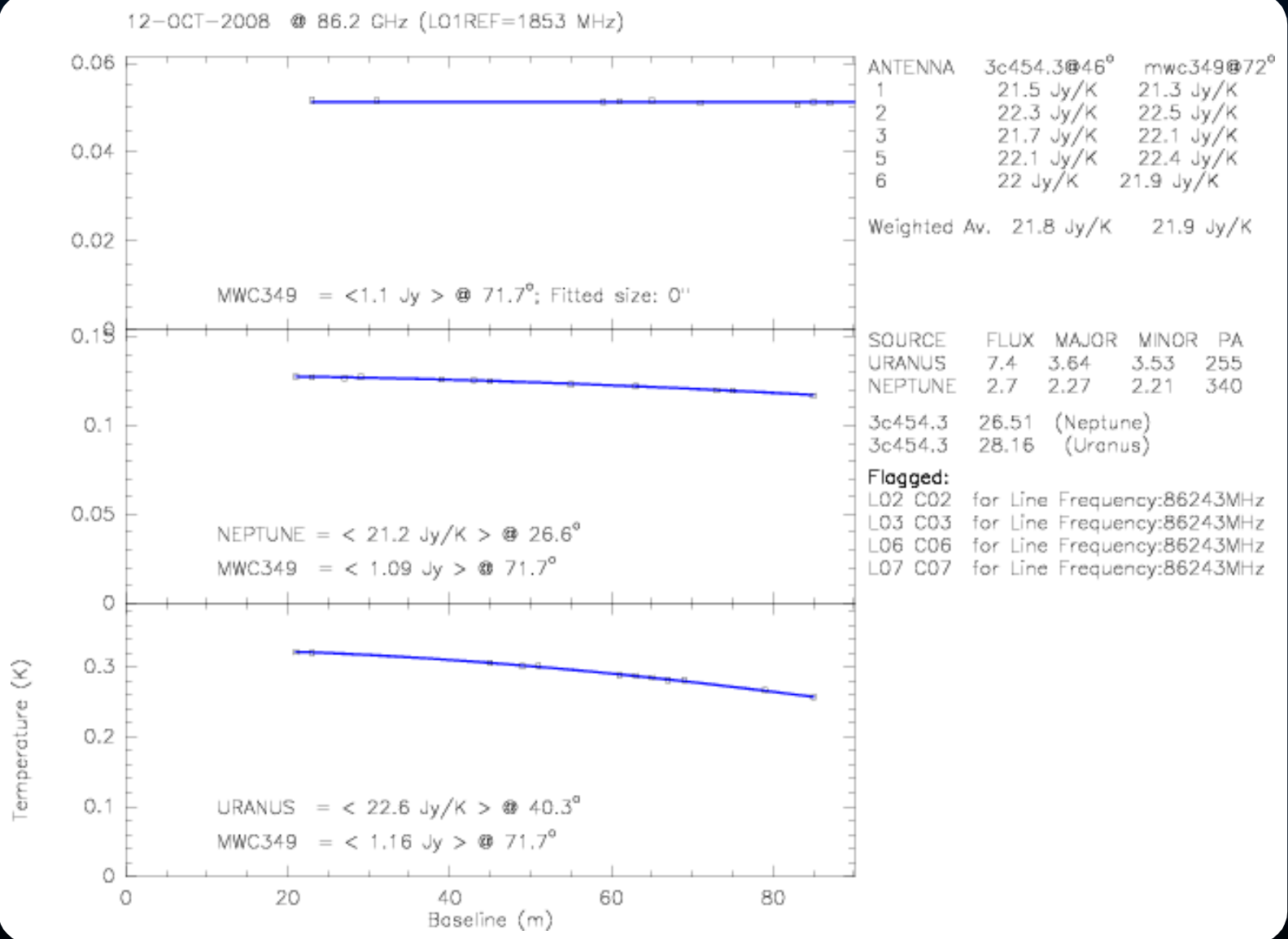
Size of MWC348



Primary Flux Calibrators

1. Quasars
2. Planets
3. Solar Bodies (Satellites, Asteroids, Dwarf Planets)
4. Radio Stars
5. Antenna Efficiencies?

"By-product" of calibration



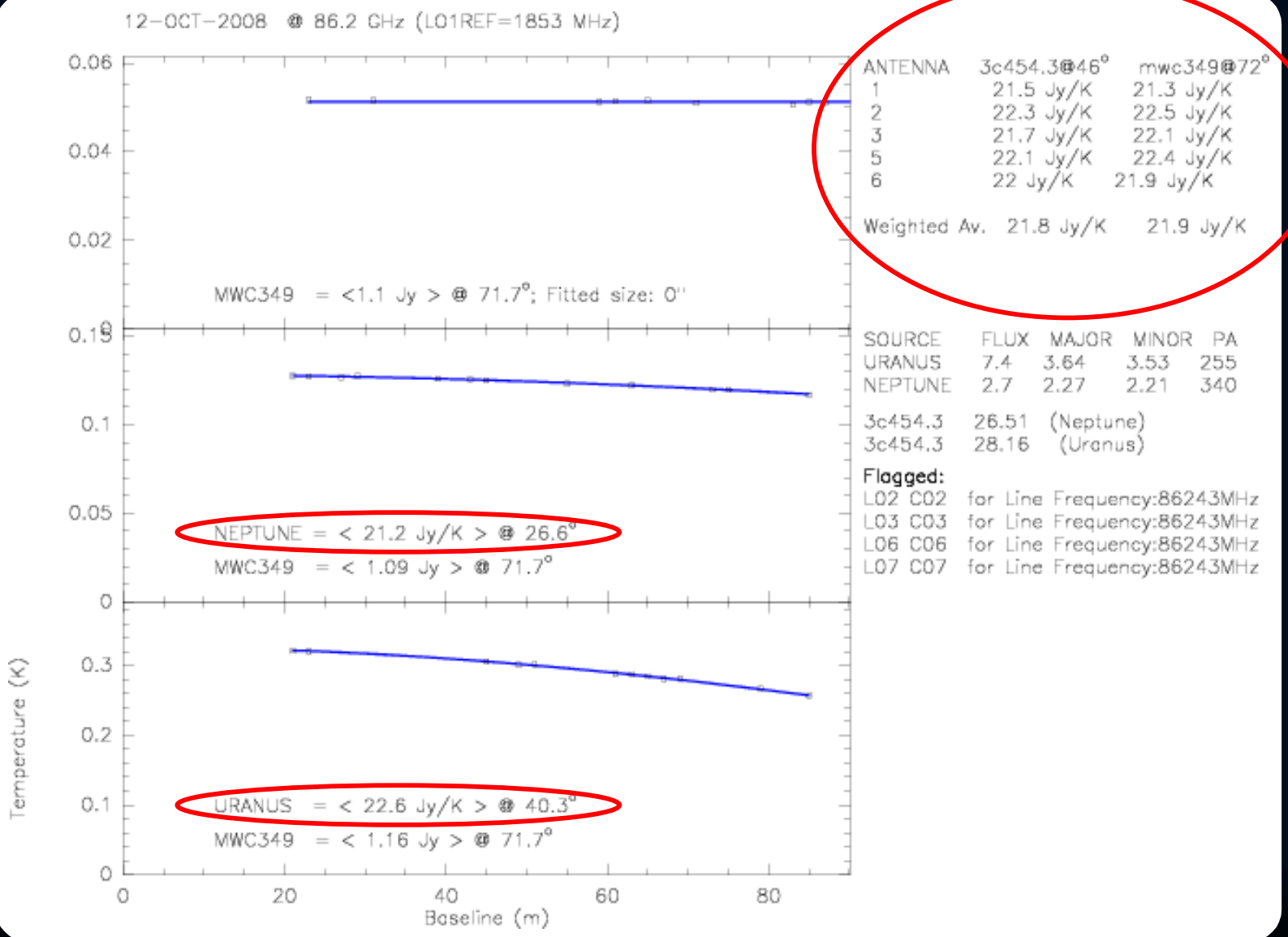
ANTENNA	3c454.3@46°	mwc349@72°
1	21.5 Jy/K	21.3 Jy/K
2	22.3 Jy/K	22.5 Jy/K
3	21.7 Jy/K	22.1 Jy/K
5	22.1 Jy/K	22.4 Jy/K
6	22 Jy/K	21.9 Jy/K
Weighted Av.	21.8 Jy/K	21.9 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
URANUS	7.4	3.64	3.53	255
NEPTUNE	2.7	2.27	2.21	340

3c454.3 26.51 (Neptune)
3c454.3 28.16 (Uranus)

Flagged:
L02 C02 for Line Frequency:86243MHz
L03 C03 for Line Frequency:86243MHz
L06 C06 for Line Frequency:86243MHz
L07 C07 for Line Frequency:86243MHz

"By-product" of calibration: getting antenna efficiencies!



ANTENNA	3c454.3@46°	mwc349@72°
1	21.5 Jy/K	21.3 Jy/K
2	22.3 Jy/K	22.5 Jy/K
3	21.7 Jy/K	22.1 Jy/K
5	22.1 Jy/K	22.4 Jy/K
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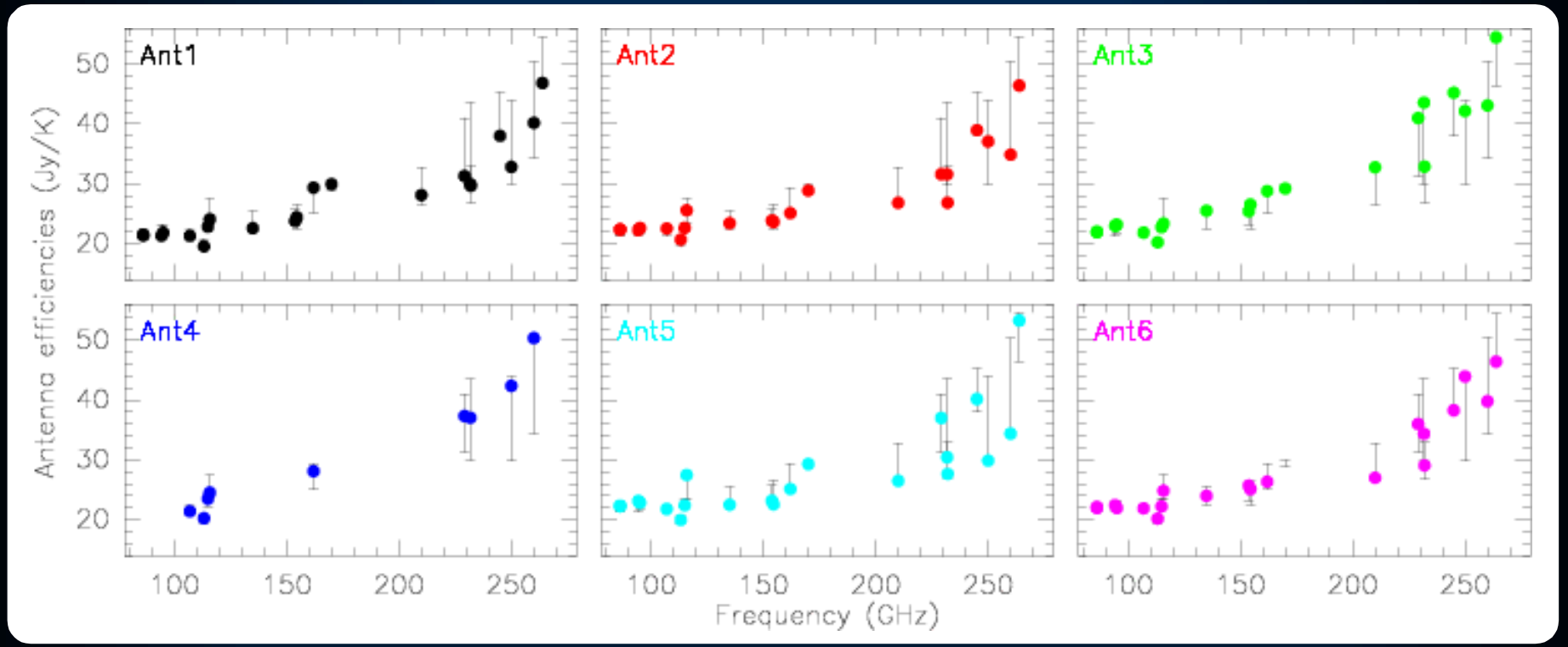
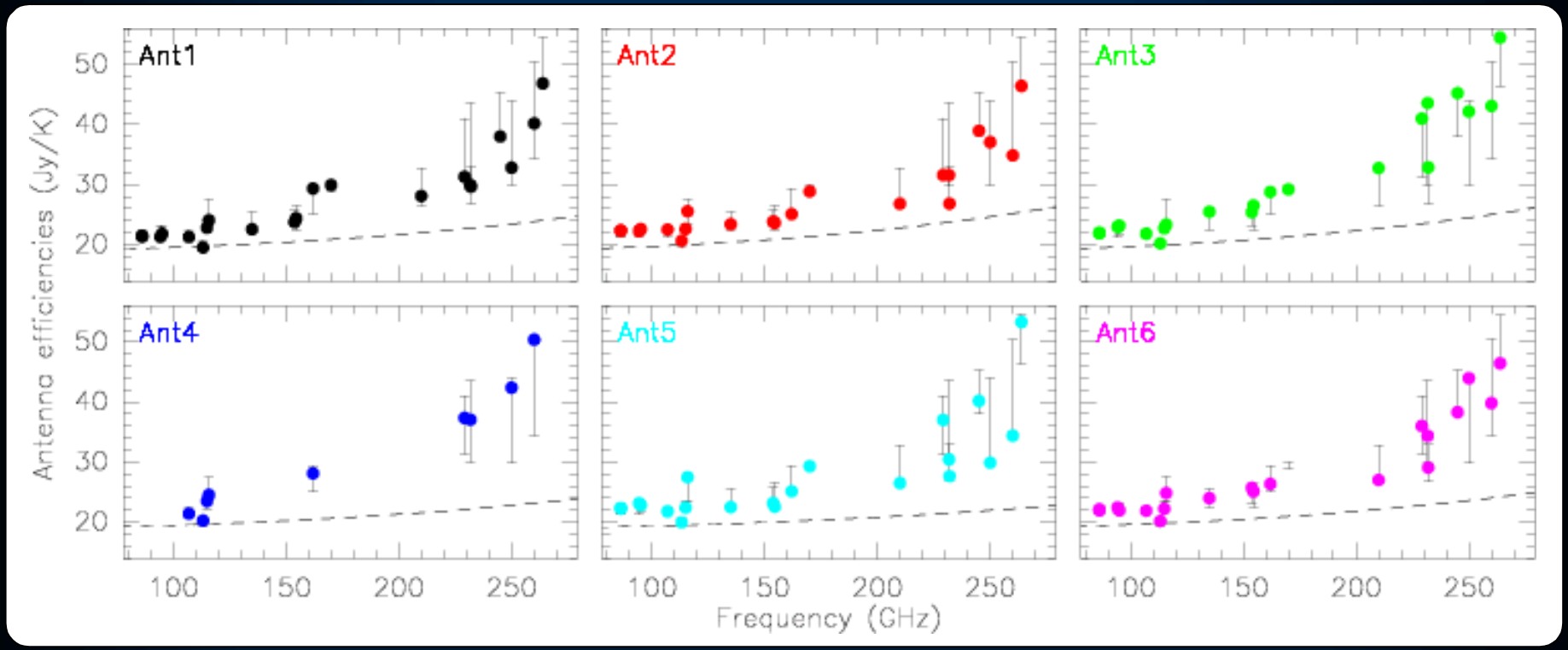
3c454.3 26.51 (Neptune)
3c454.3 28.16 (Uranus)

Flagged:
L02 C02 for Line Frequency:86243MHz
L03 C03 for Line Frequency:86243MHz
L06 C06 for Line Frequency:86243MHz
L07 C07 for Line Frequency:86243MHz

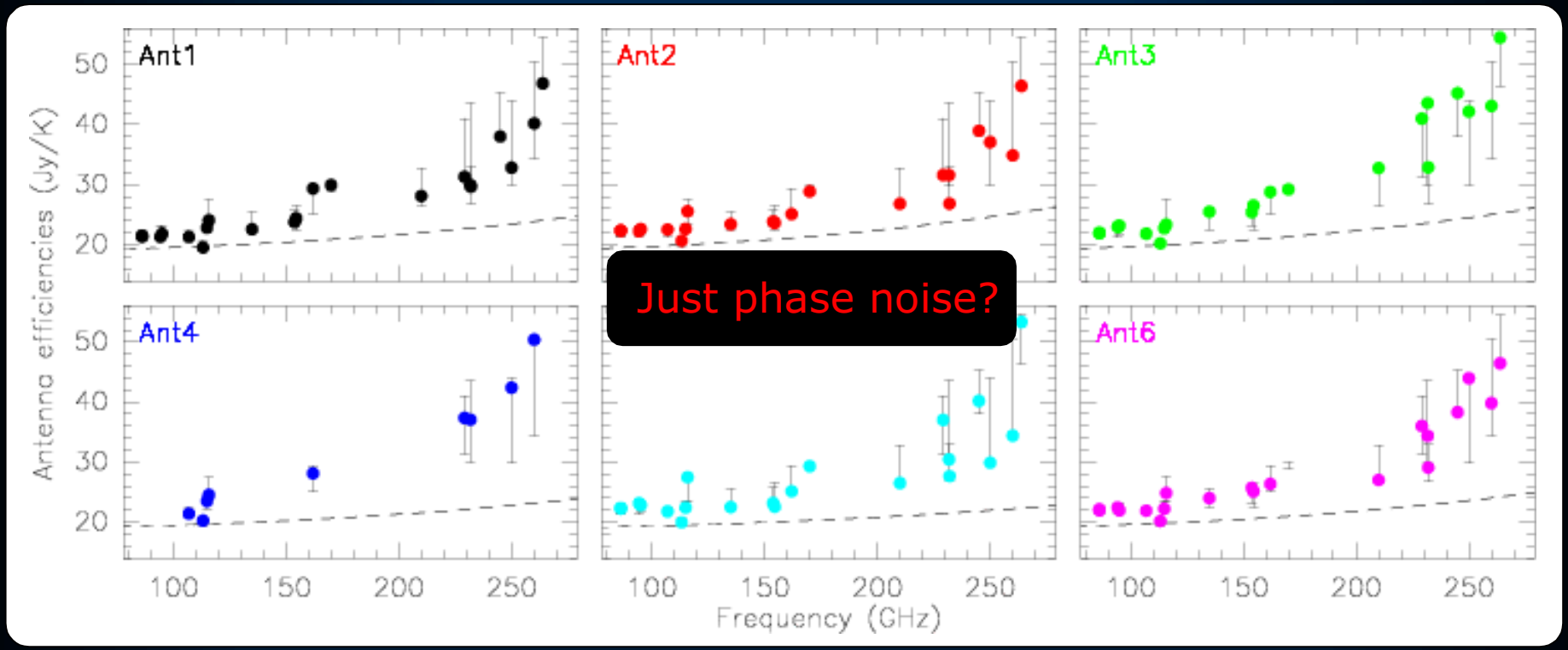
Antenna Efficiencies: Interferometrically



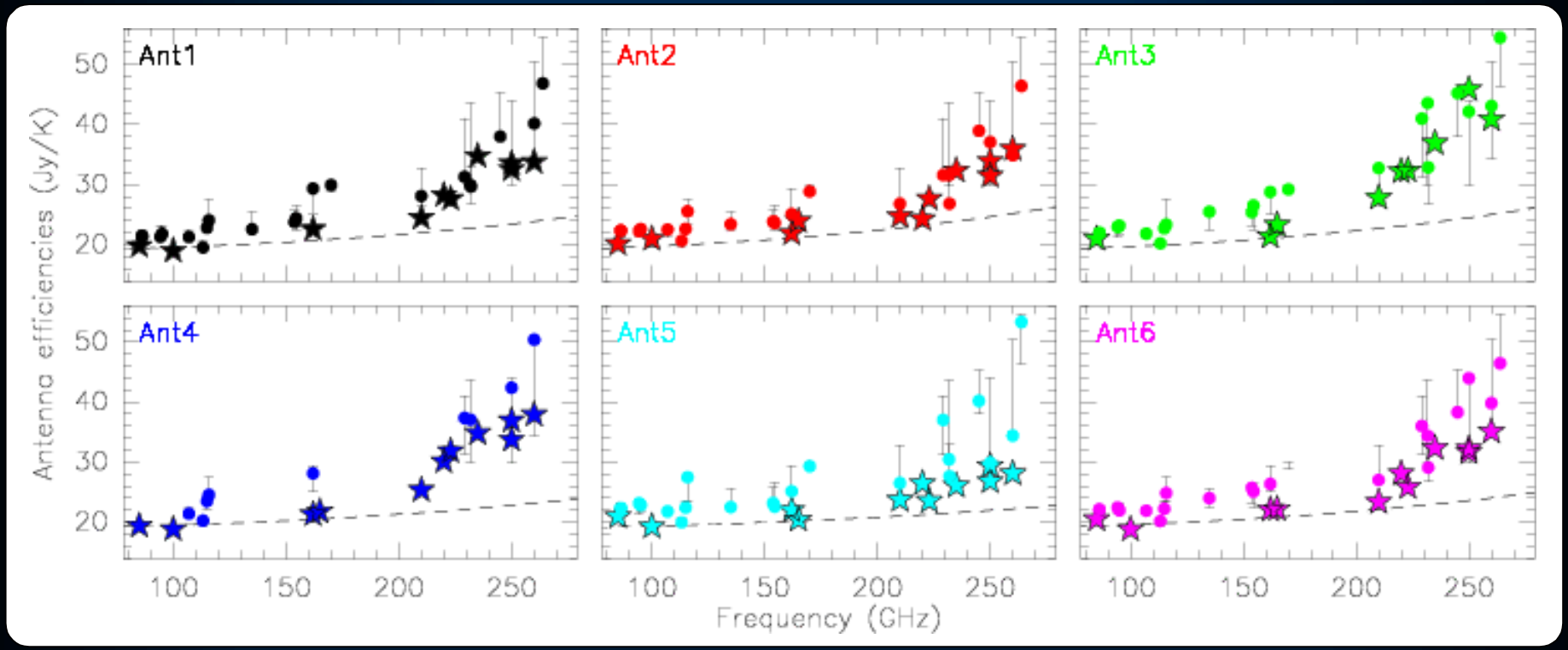
Antenna Efficiencies: Interferometrically + Holo



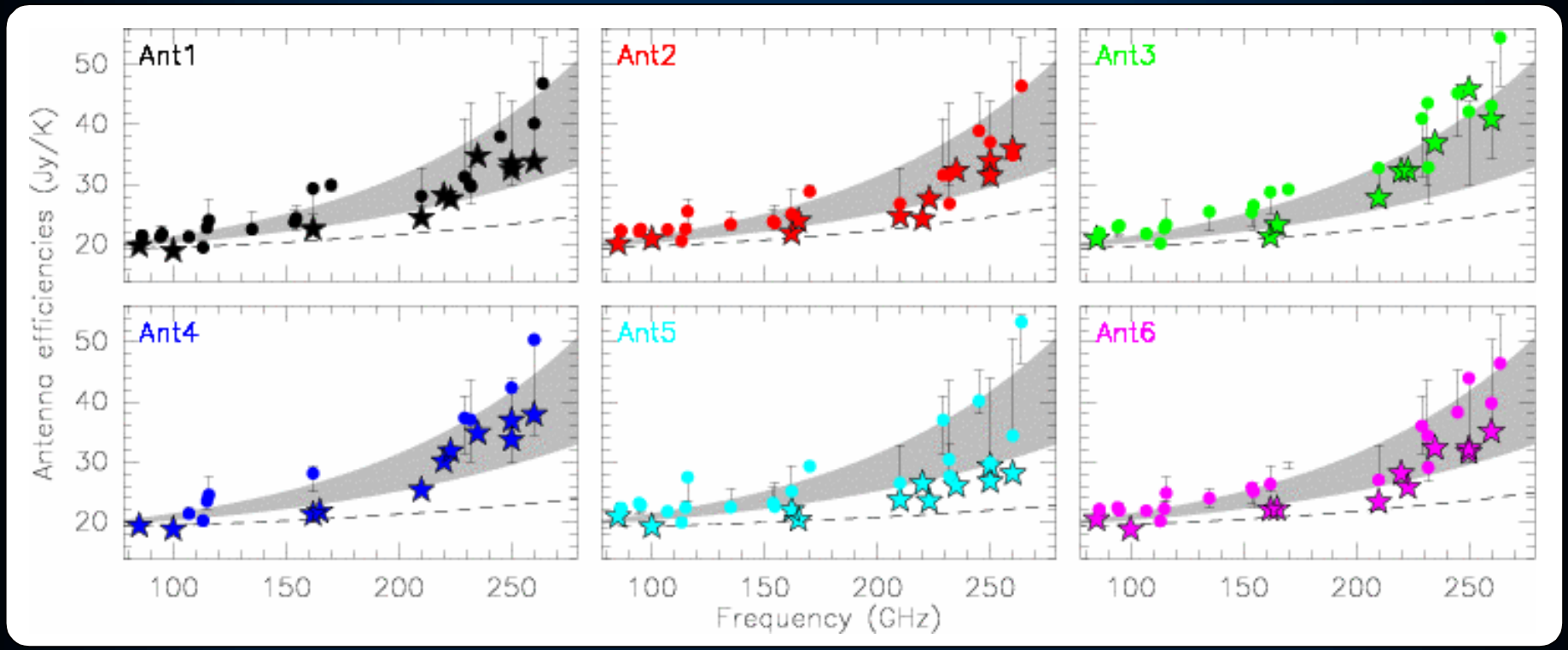
Antenna Efficiencies: Interferometrically + Holo



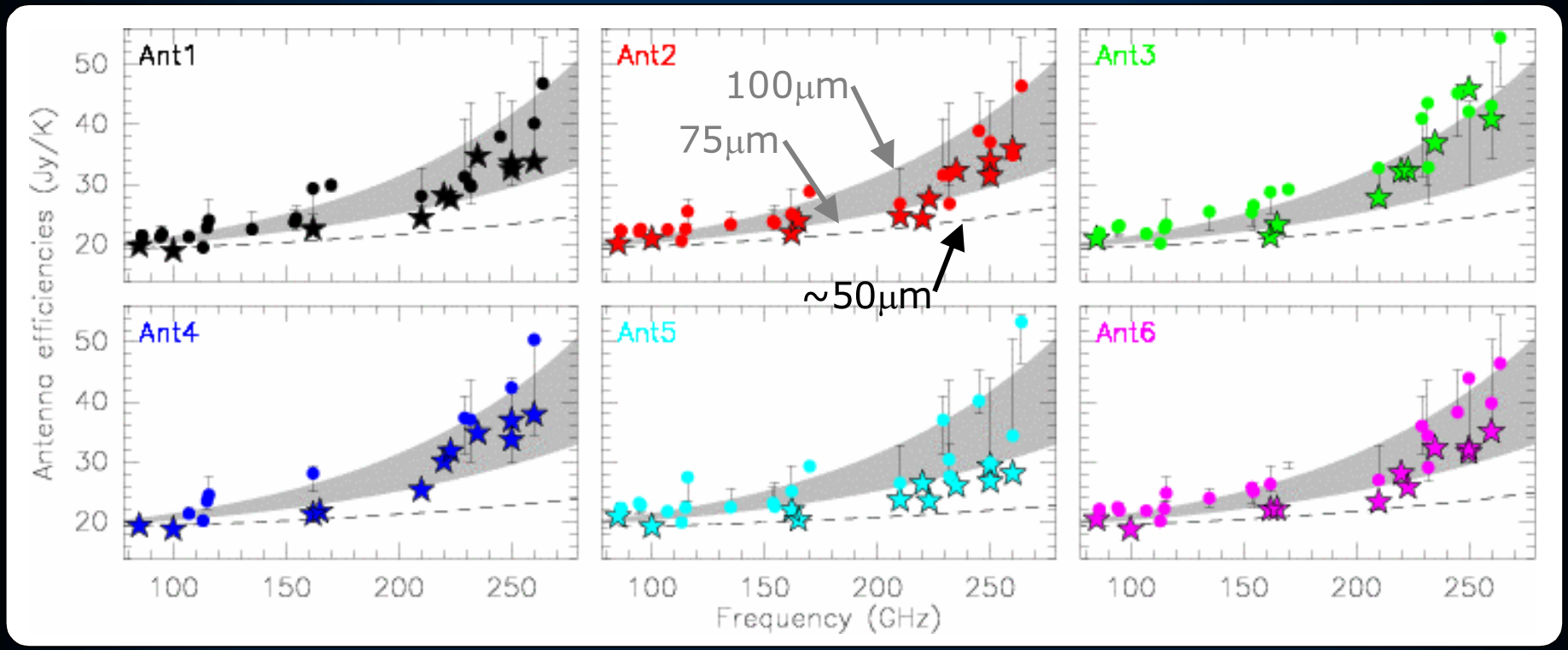
Antenna Efficiencies: Interferometrically + Holo + SD



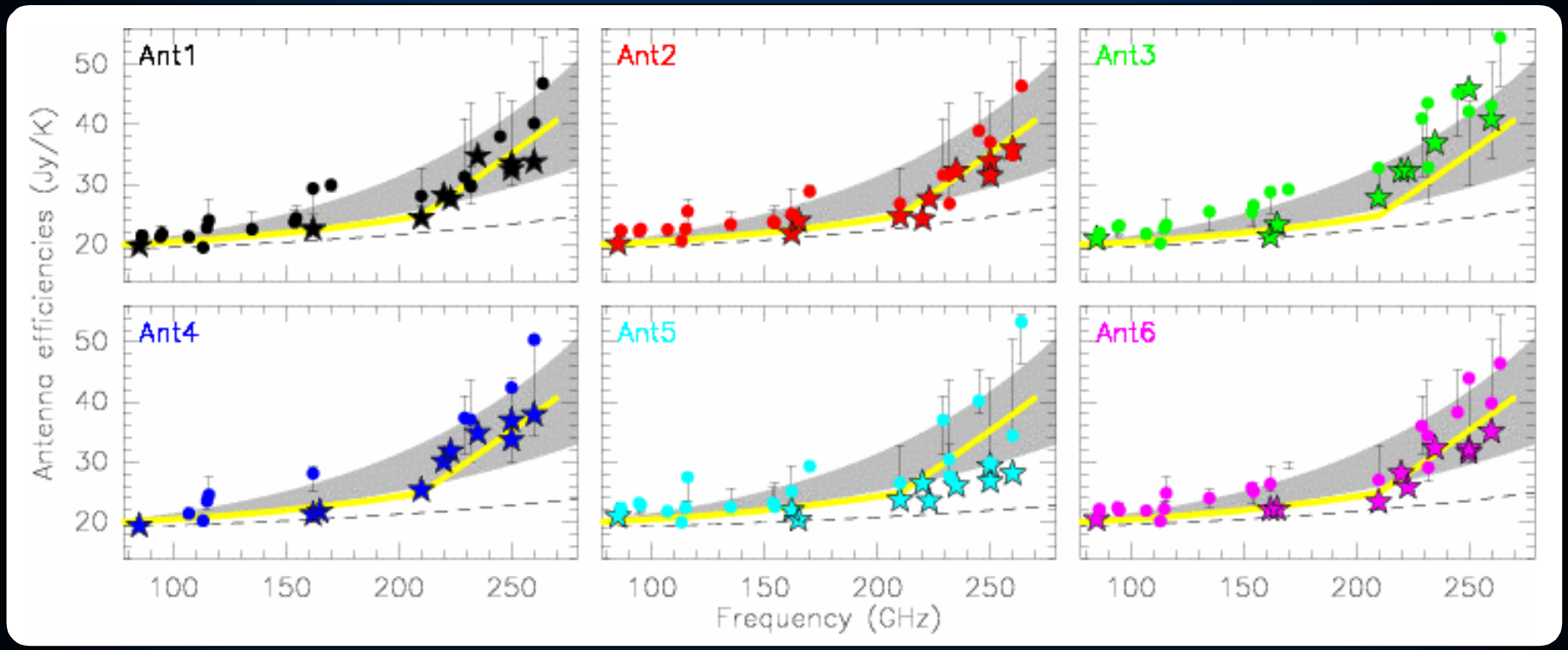
Antenna Efficiencies: Interferometrically + Holo + SD



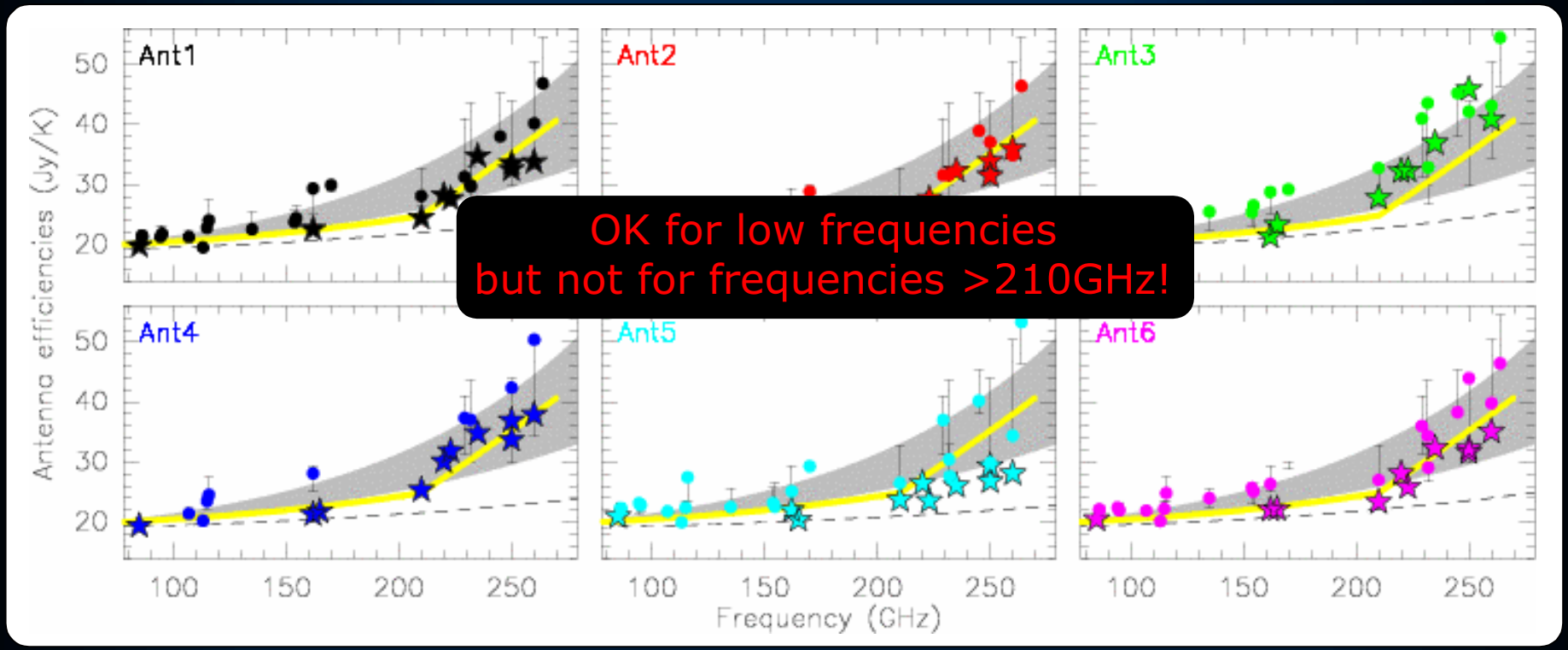
Antenna Efficiencies: Interferometrically + Holo + SD



Antenna Efficiencies: Interferometrically + Holo + SD



Antenna Efficiencies: Interferometrically + Holo + SD

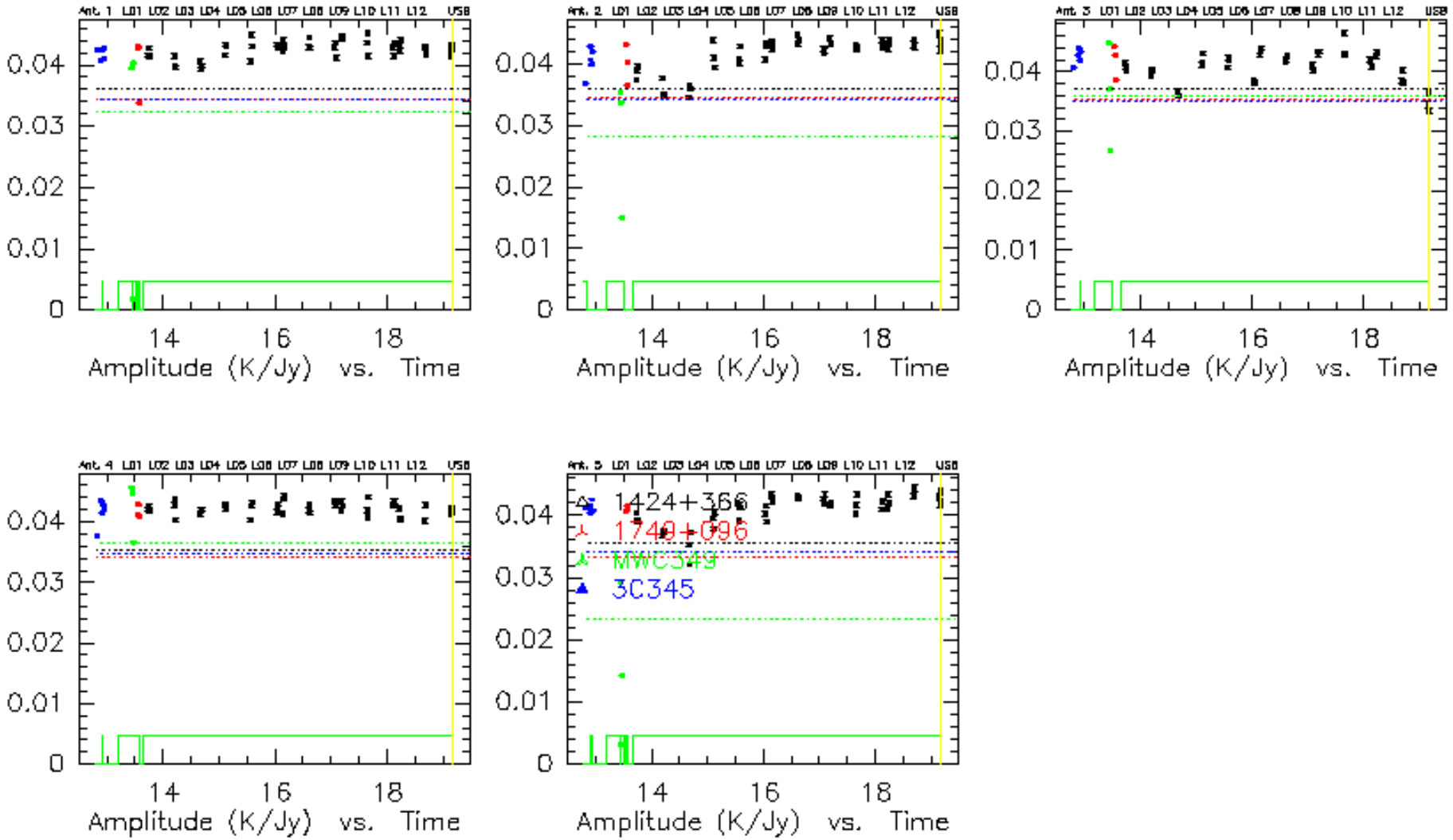


Practical Tips

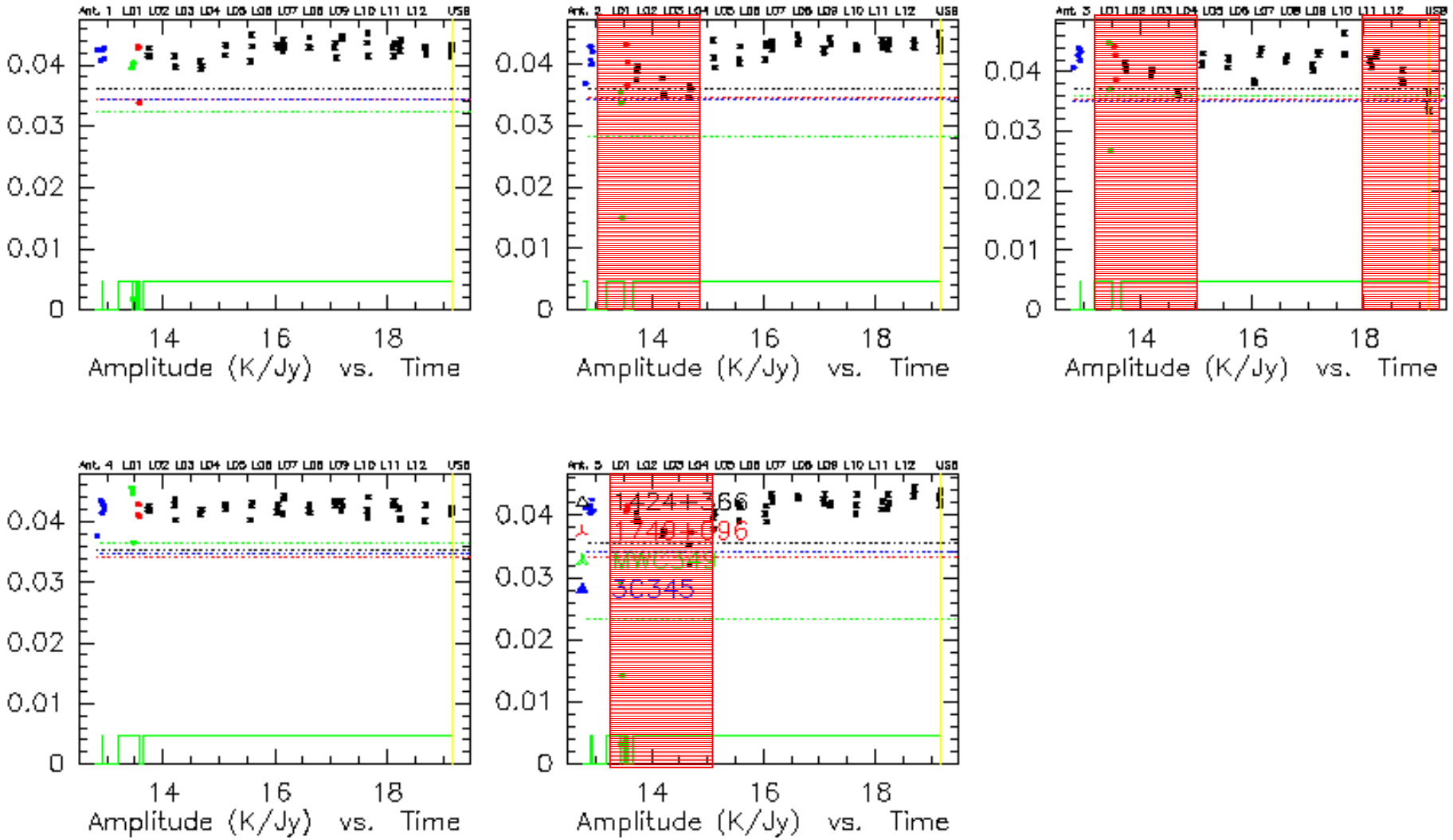
Checklist:

- Antenna Shadowing
- Pointing/Focus Problems
- Tracking Problems
- Do phases of different spectral windows overlap?
- Noisy data
- Has Flux Calibrator Lines?
- Is Flux Calibrator Extended?
- Check Elevation of your source
- Check whether source is polarised (only important when using NC with one polarisation)

Practical Tips

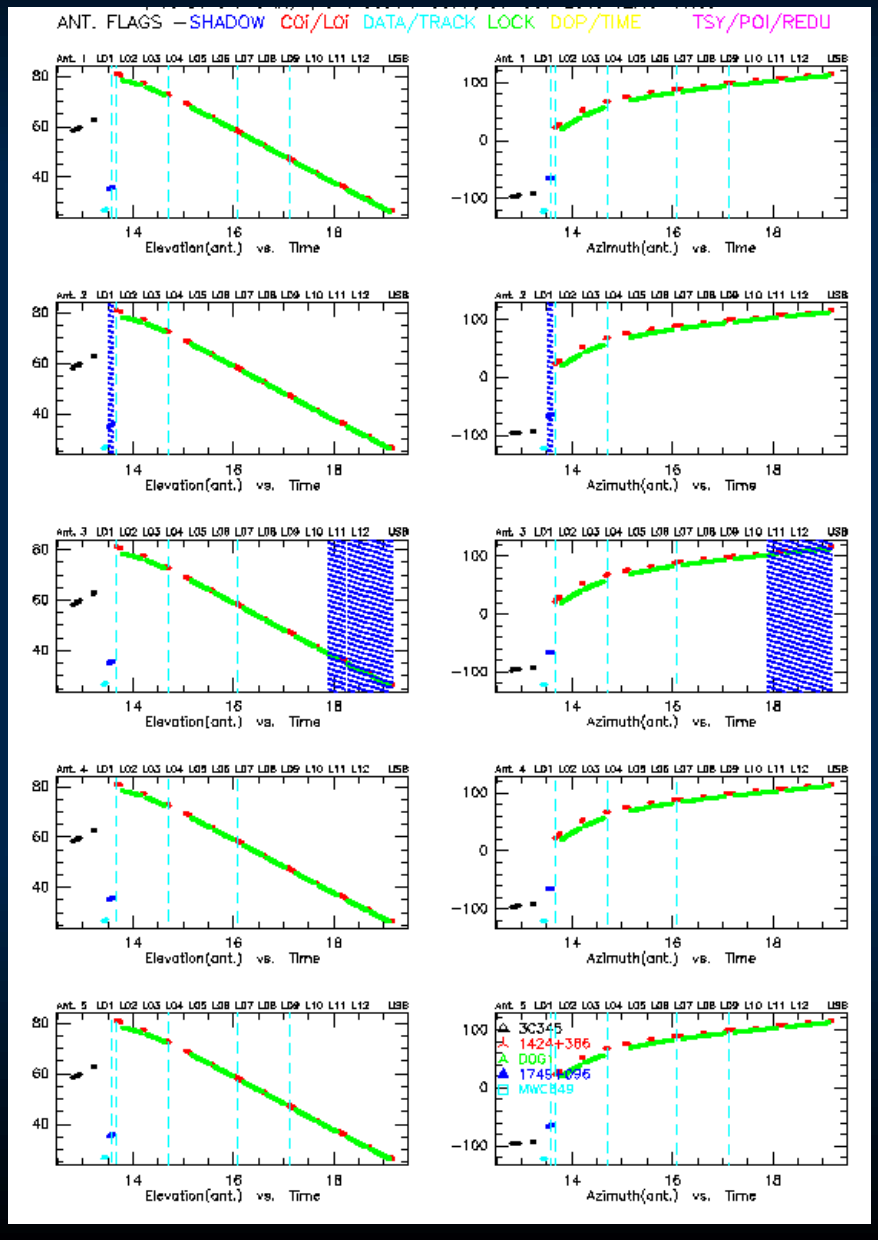


Practical Tips

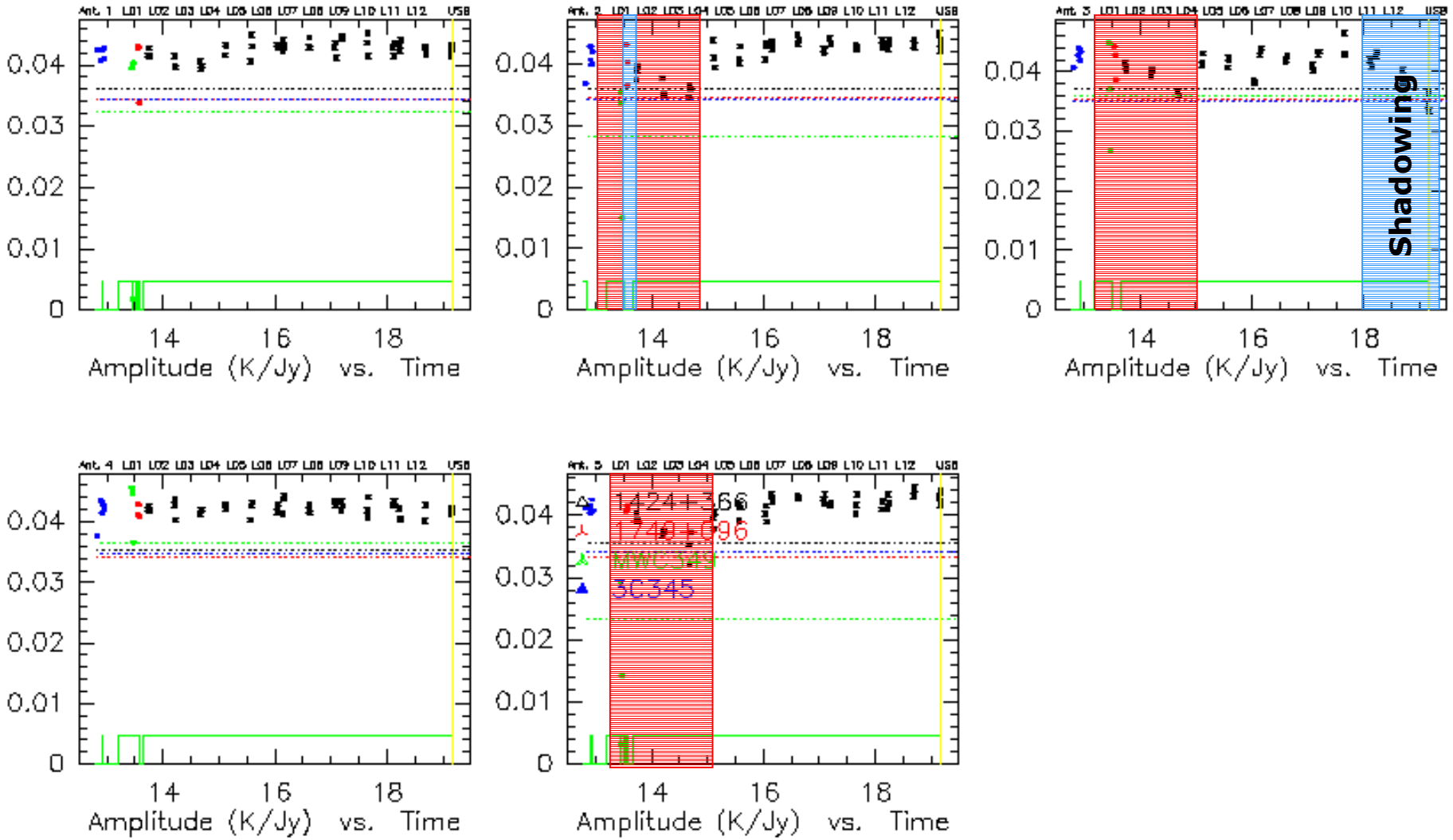


Practical Tips: Shadowing

First Look

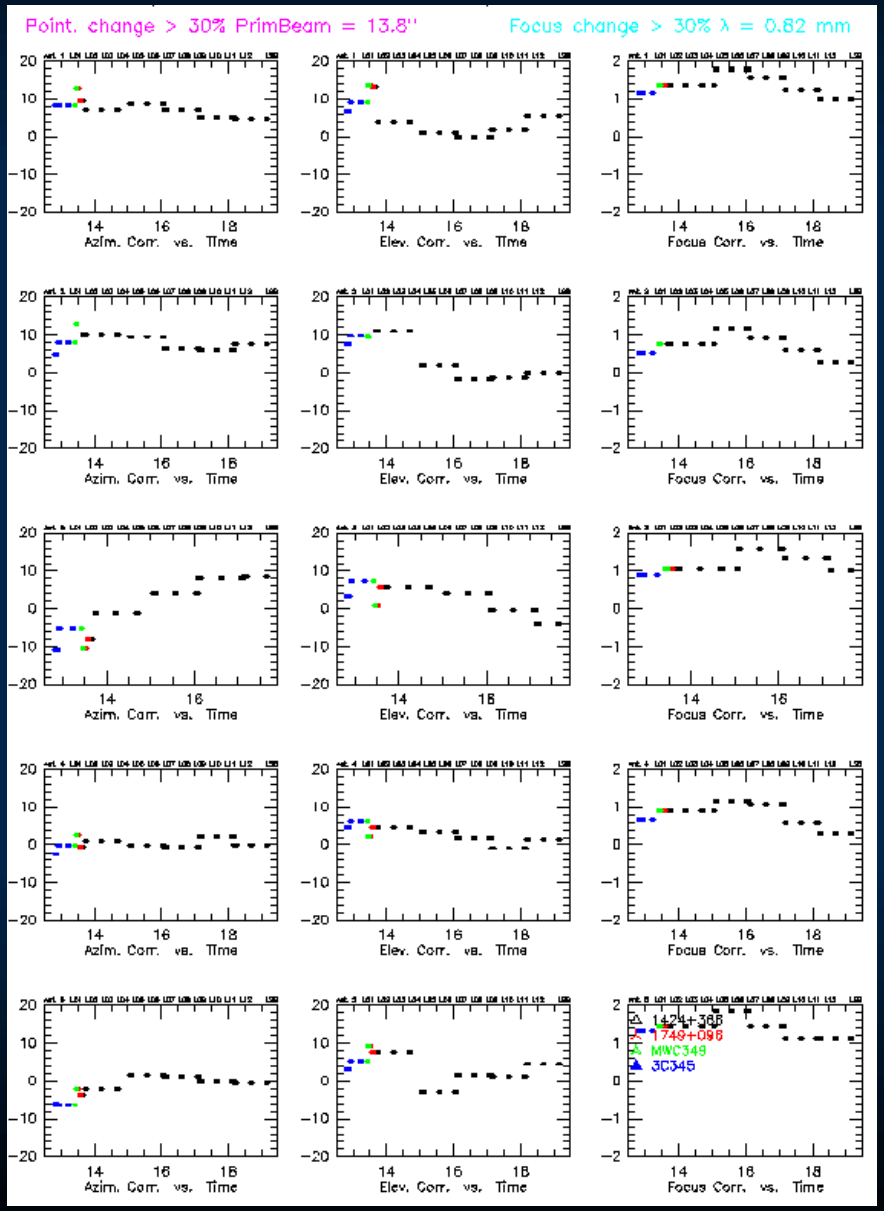


Practical Tips: Shadowing



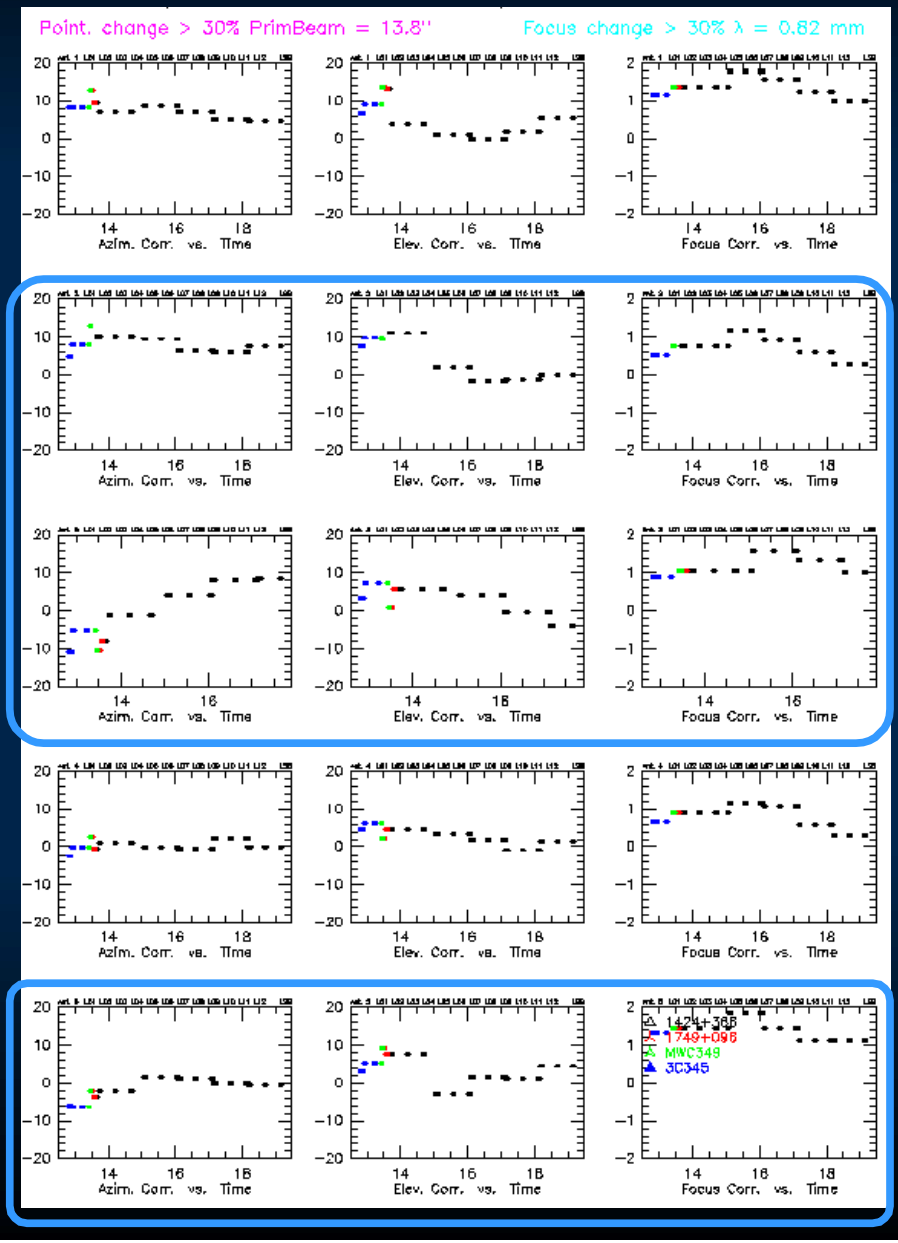
Practical Tips: Pointing/Focus

First Look



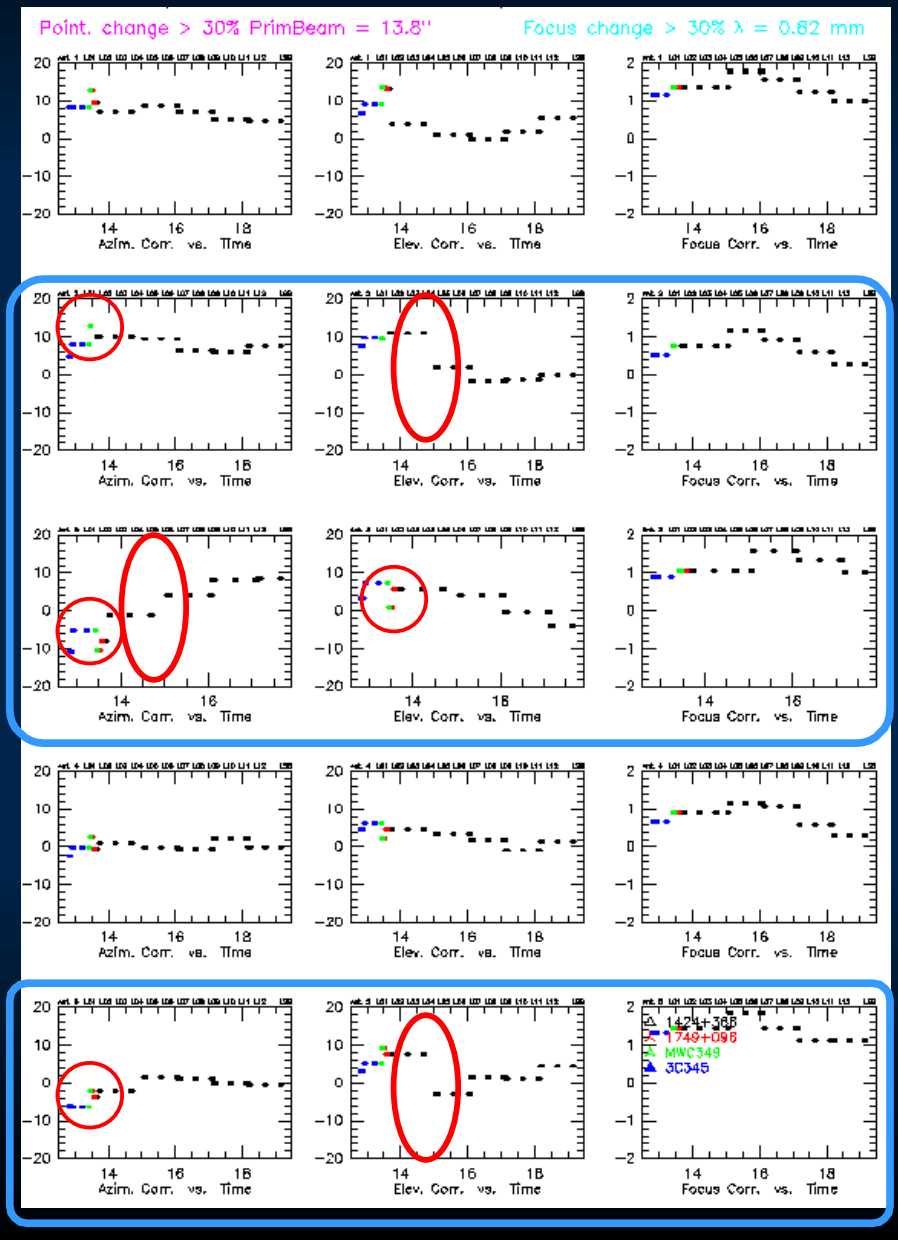
Practical Tips : Pointing/Focus

First Look



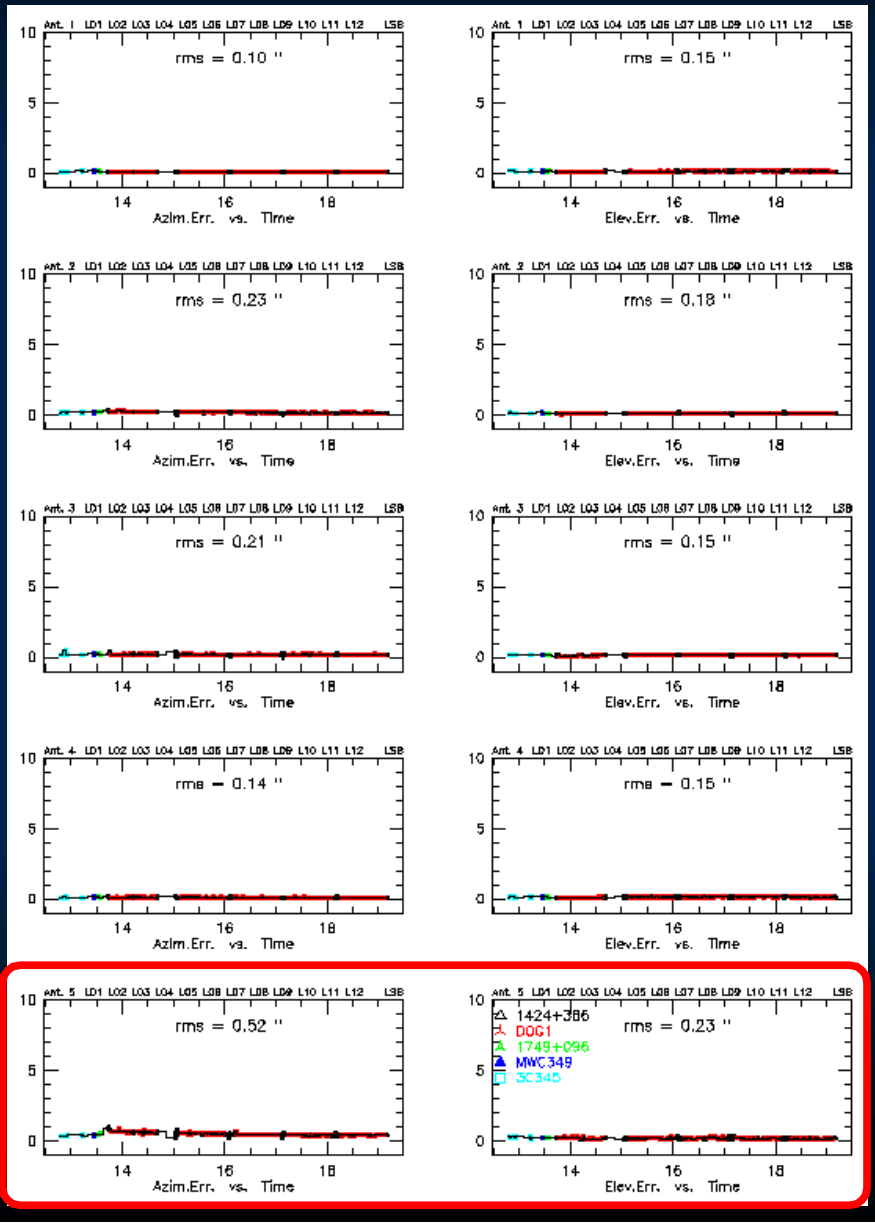
Practical Tips : Pointing/Focus

First Look

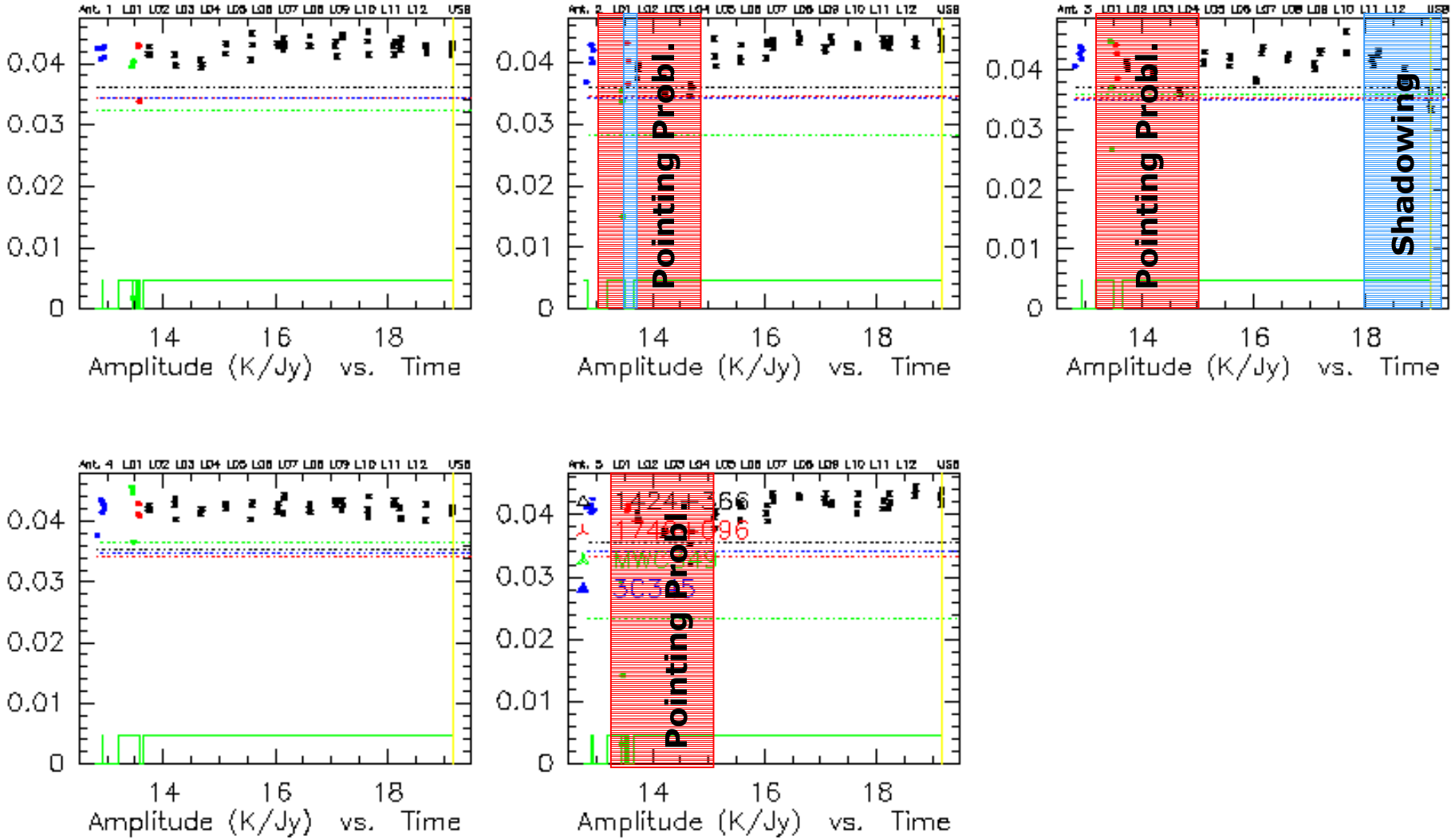


Practical Tips: Tracking

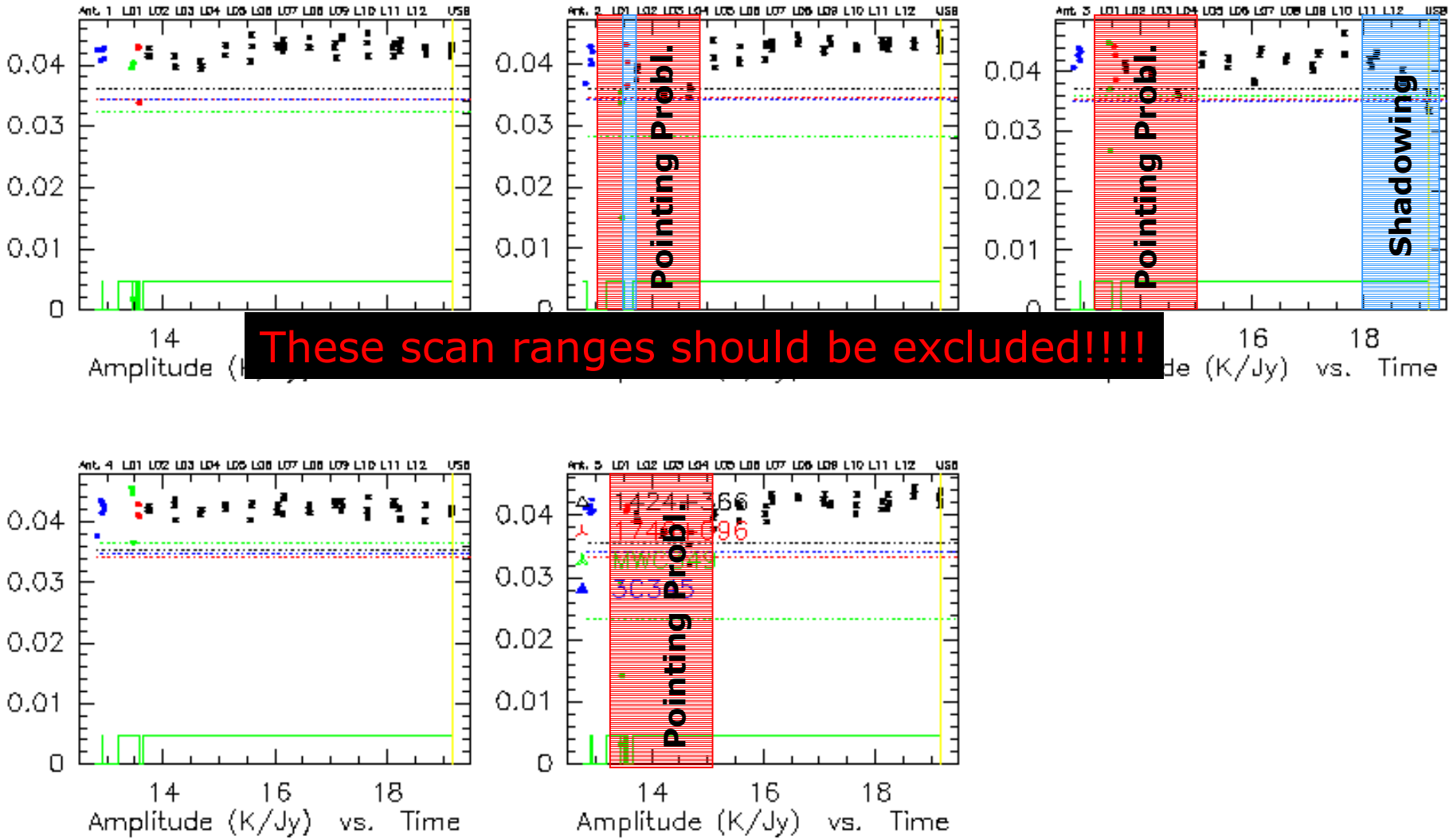
First Look



Practical Tips



Practical Tips



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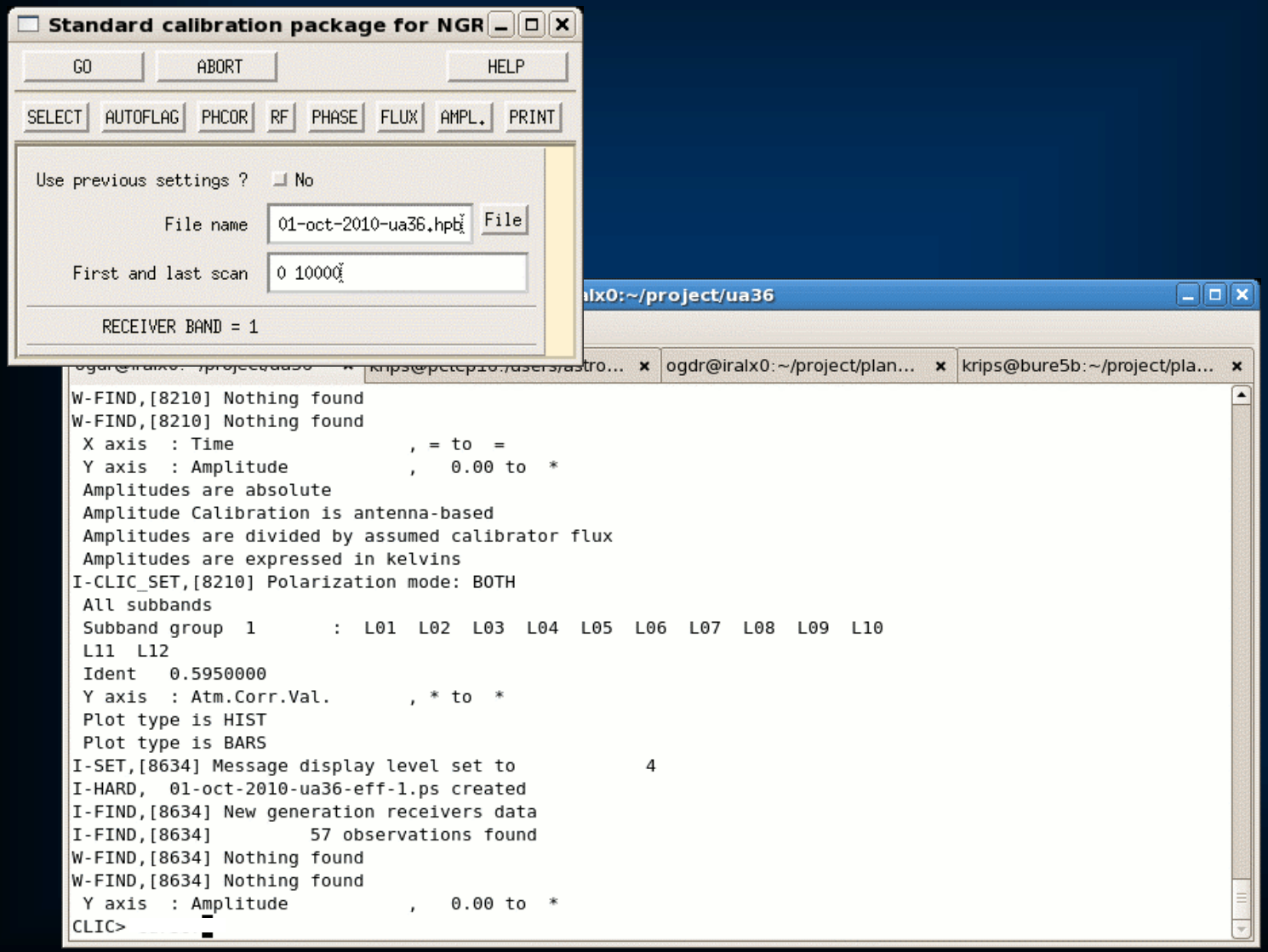

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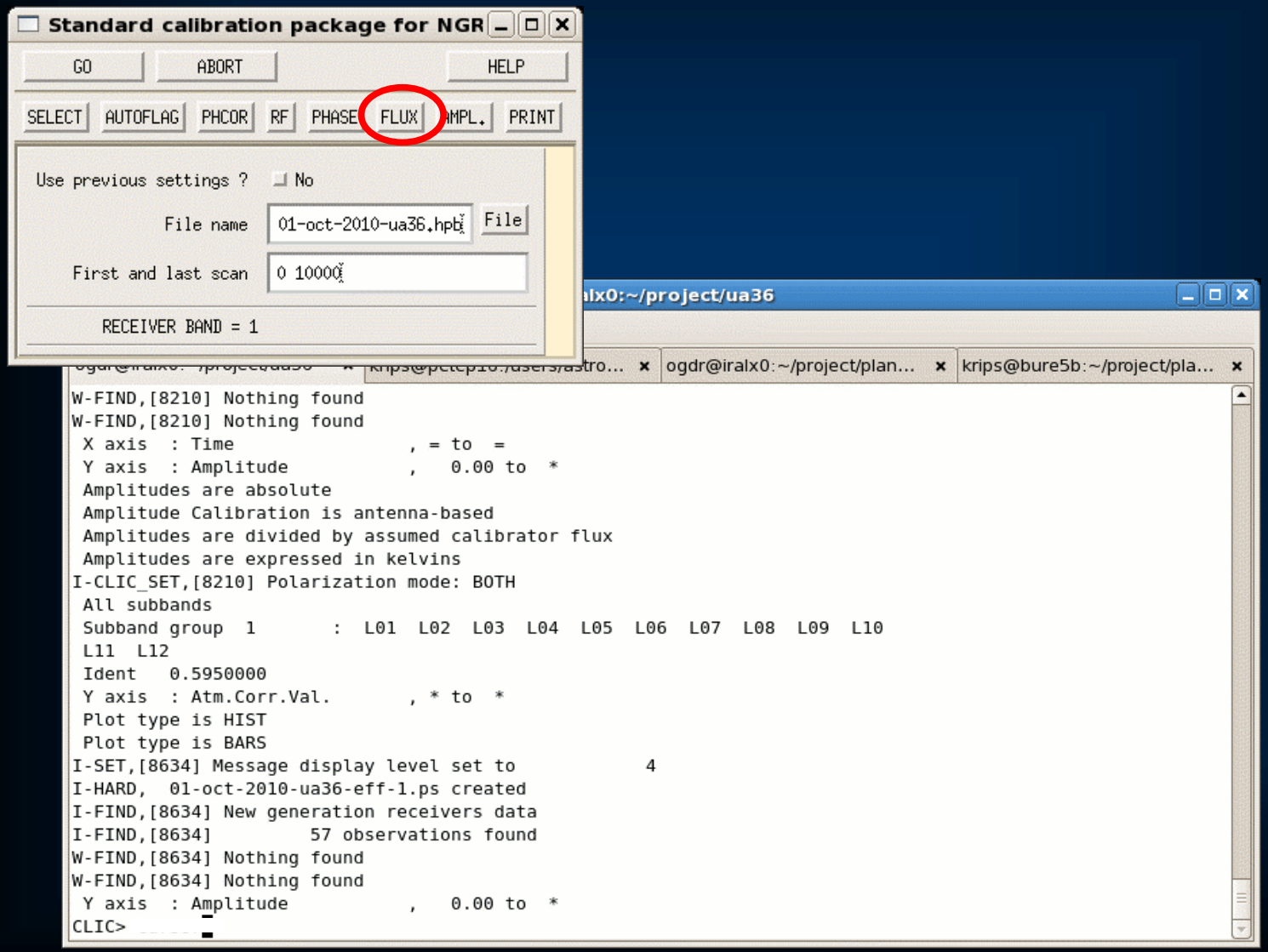
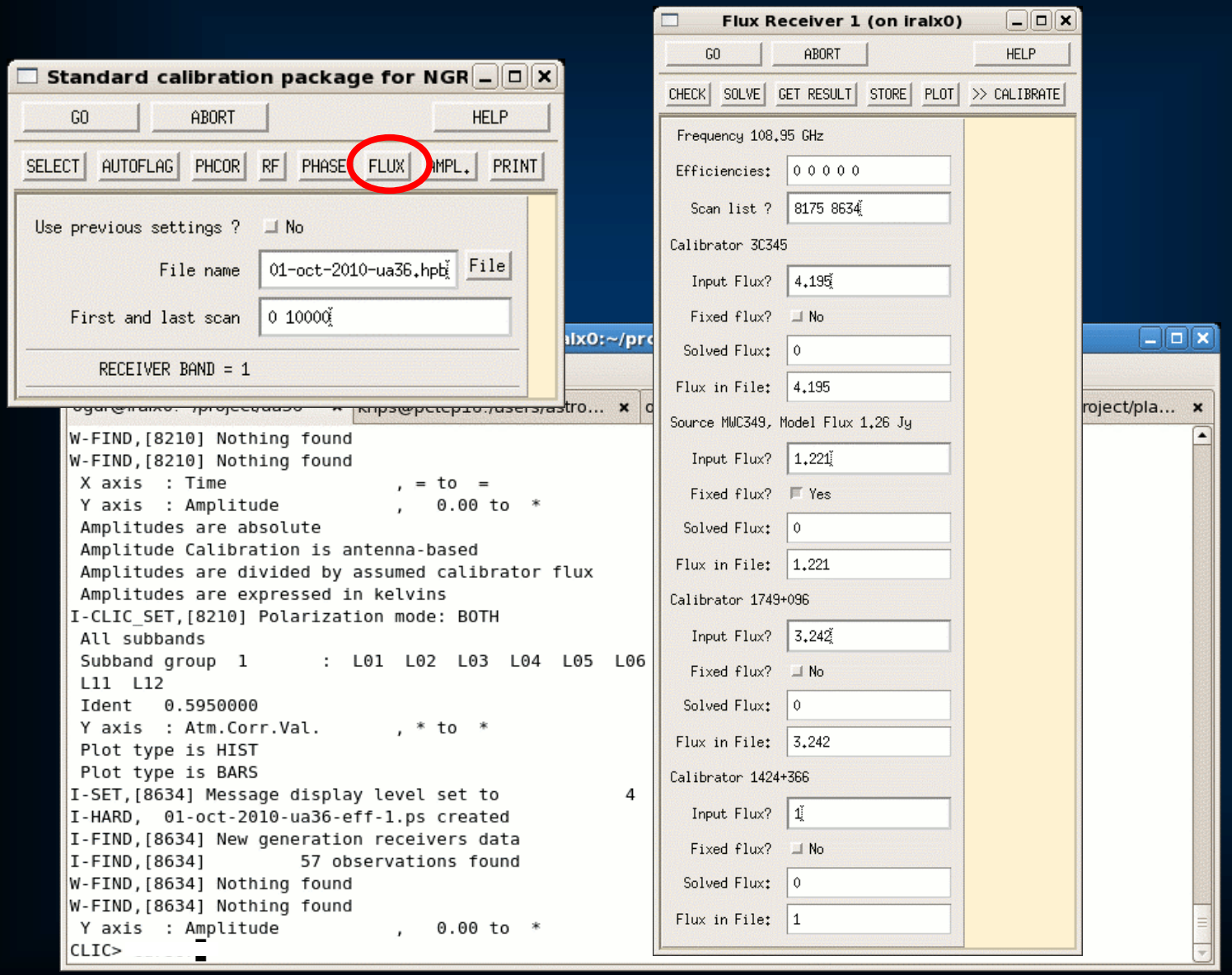
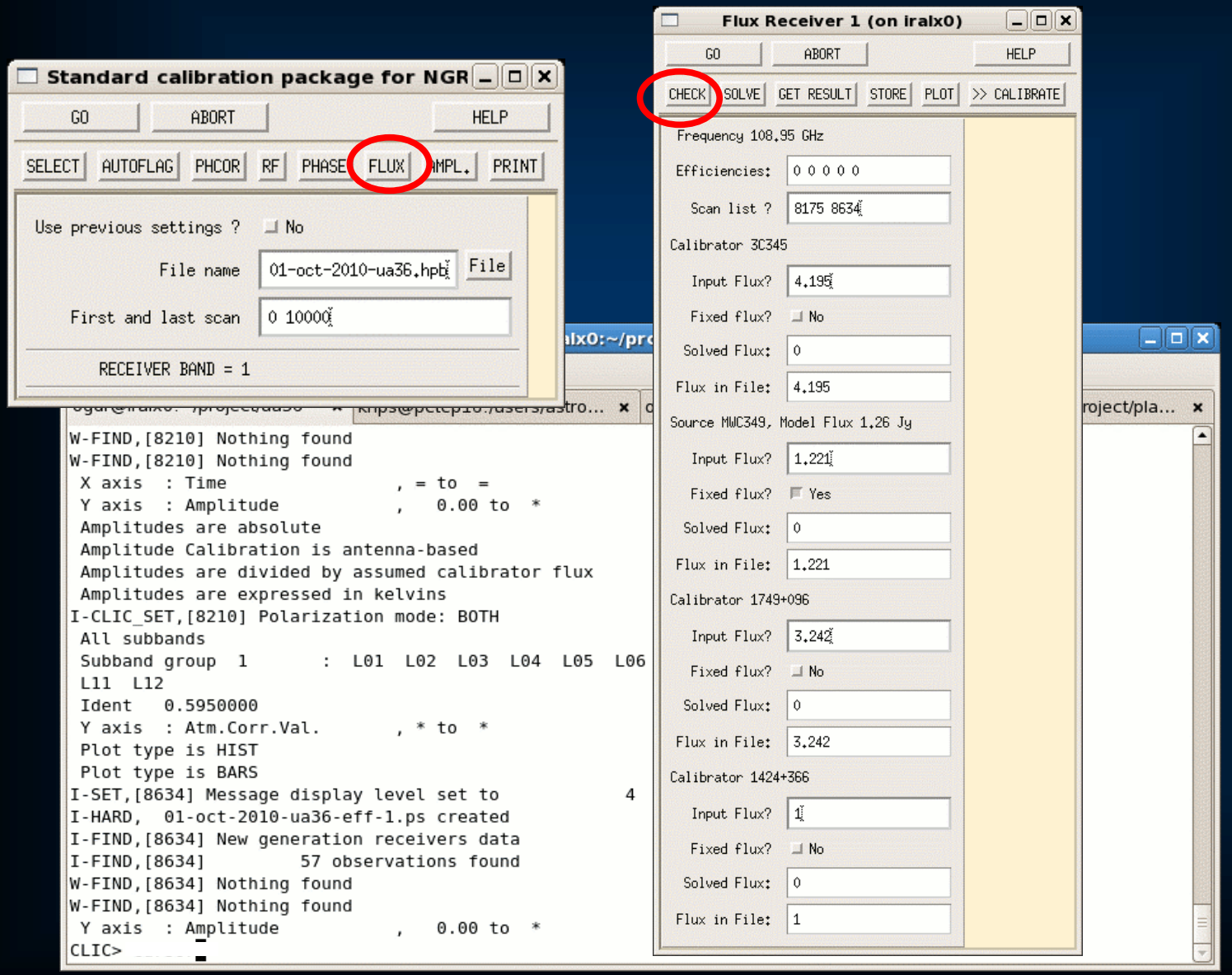


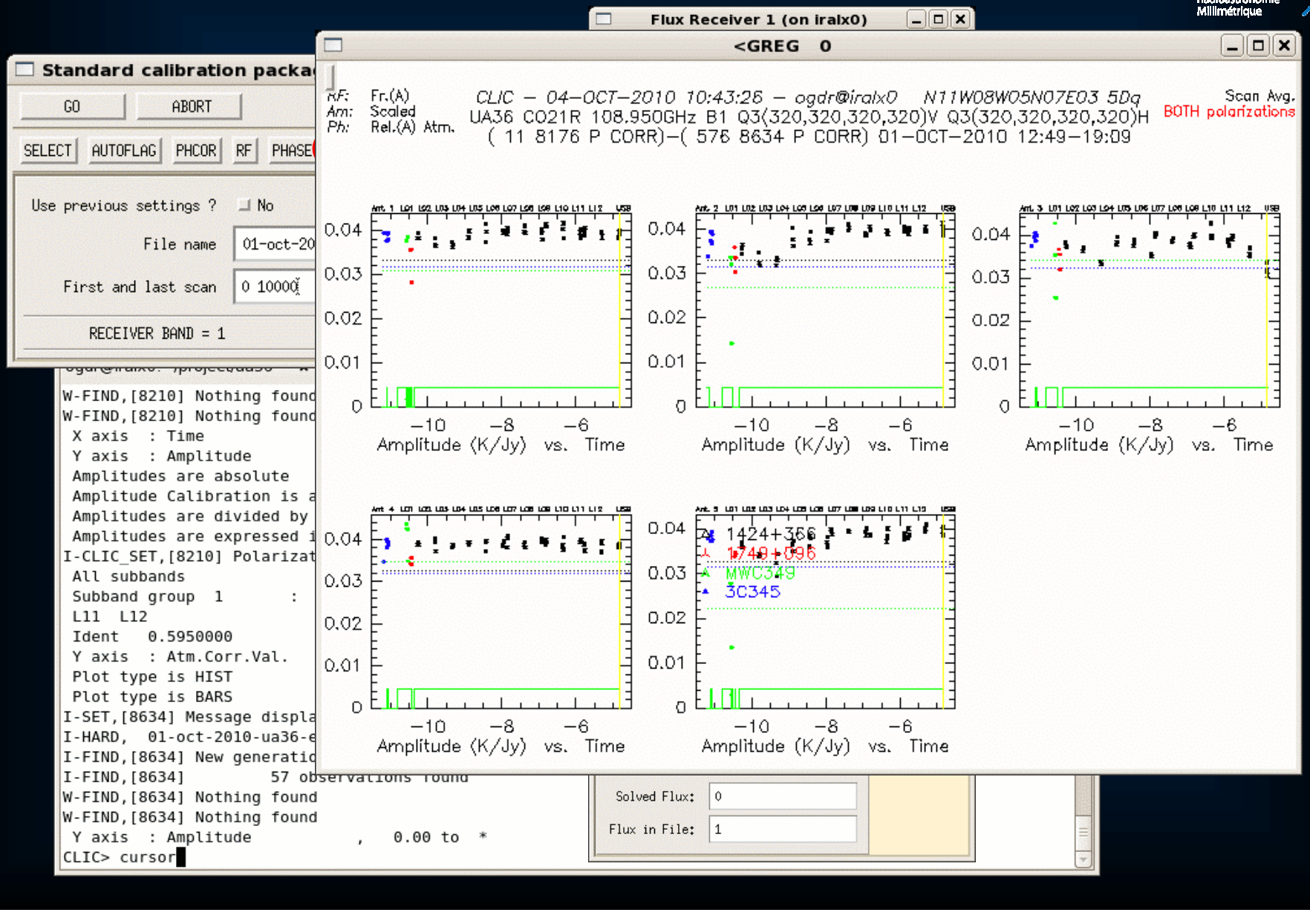
Practical Tips



Practical Tips



Practical Tips



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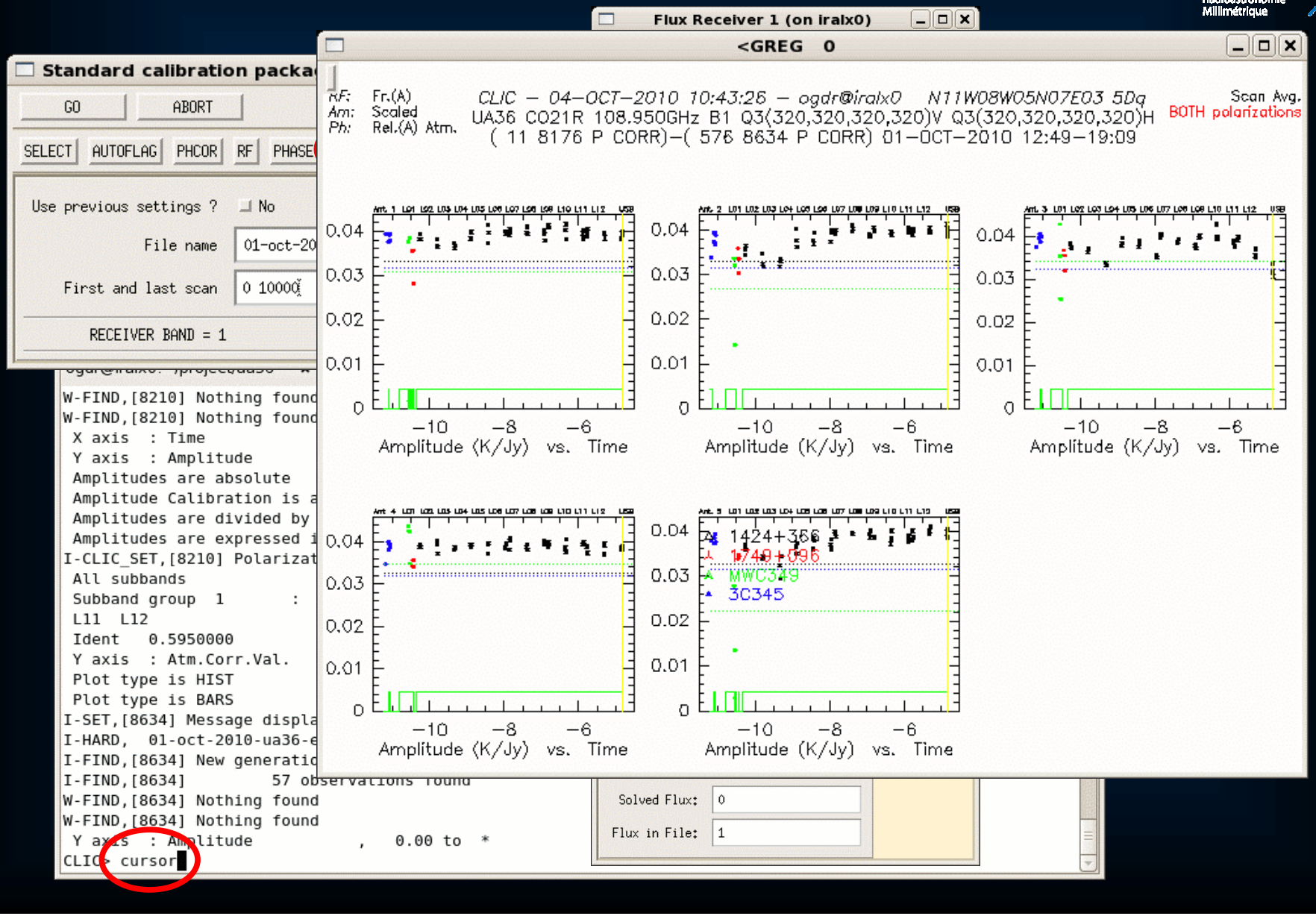

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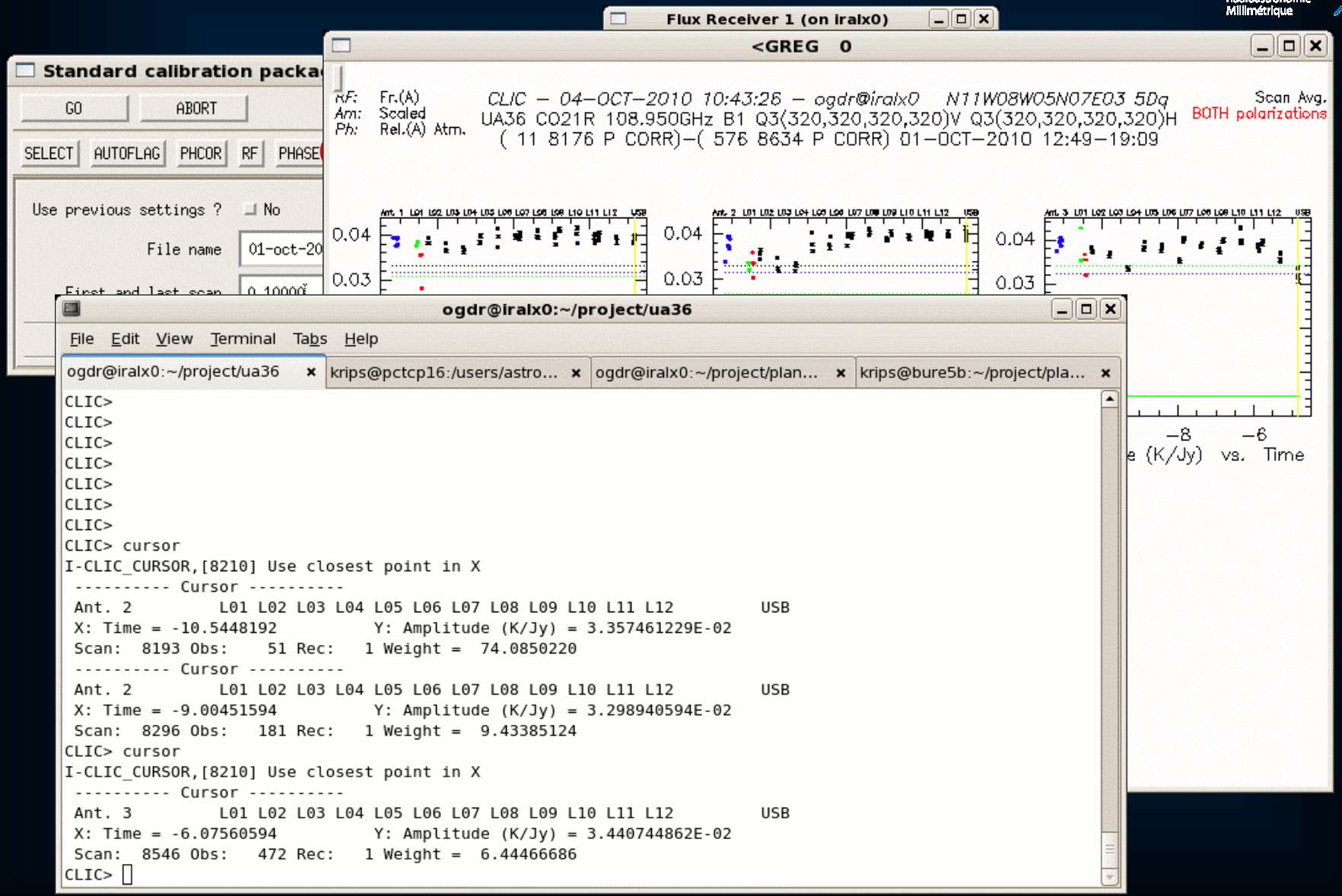

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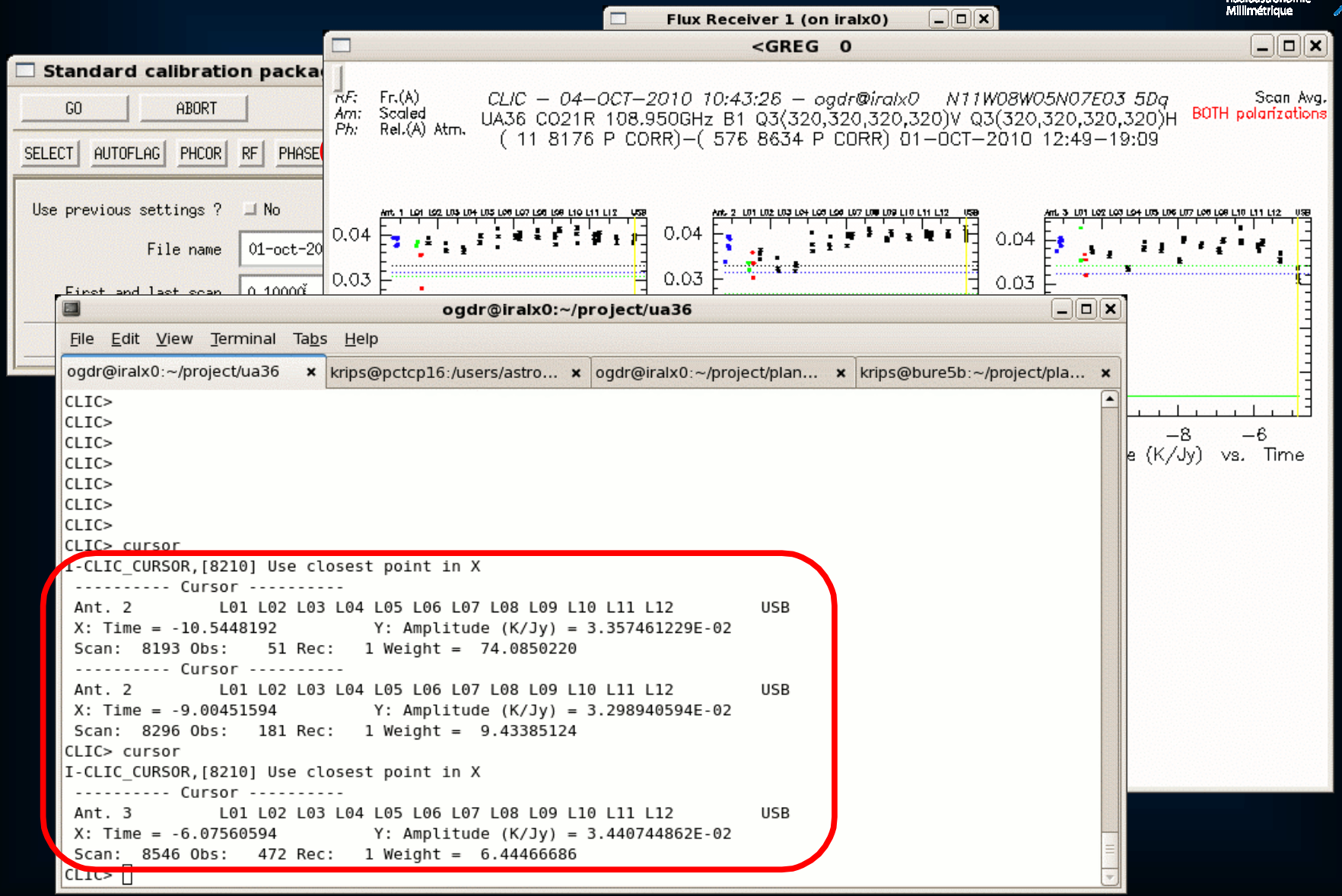

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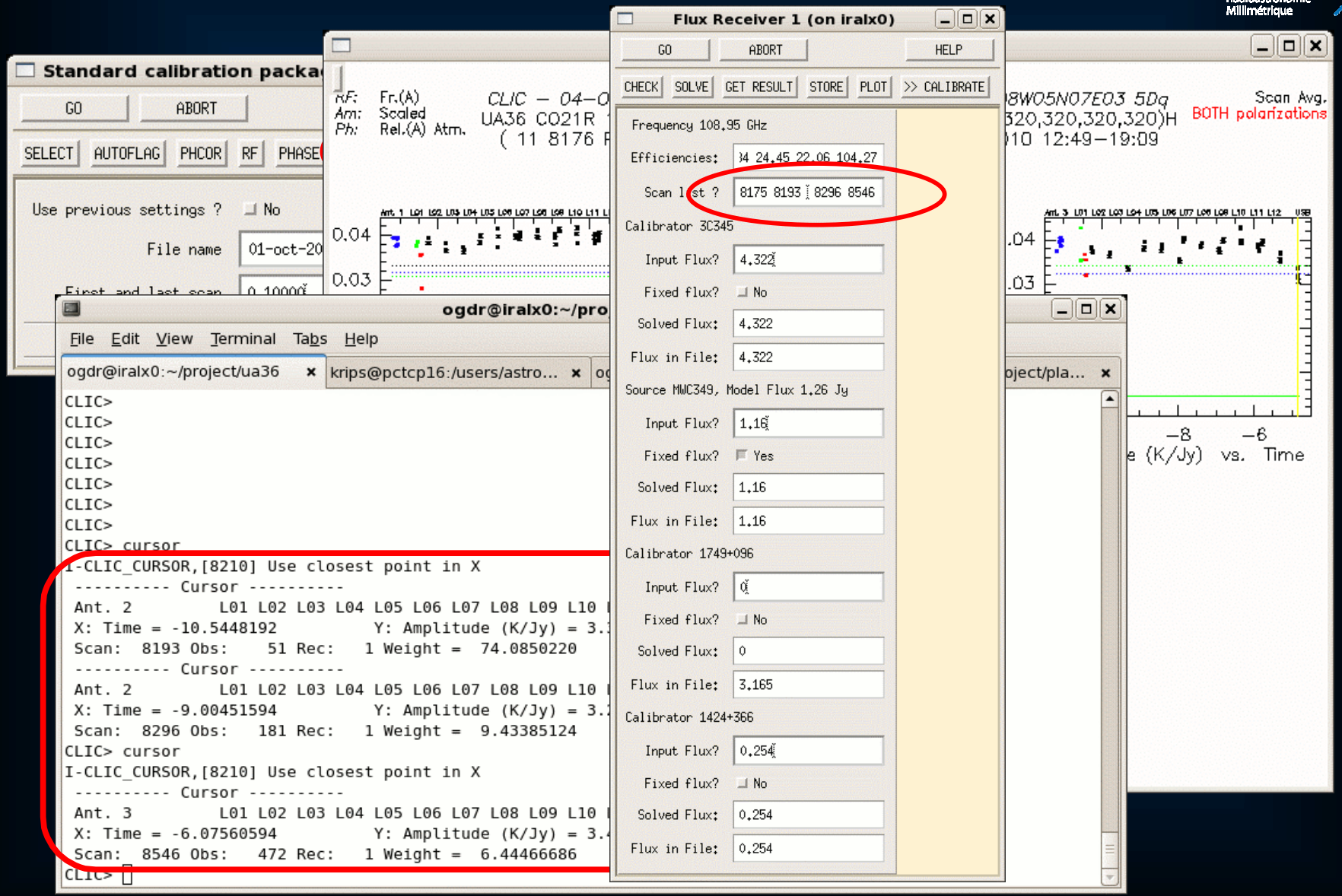
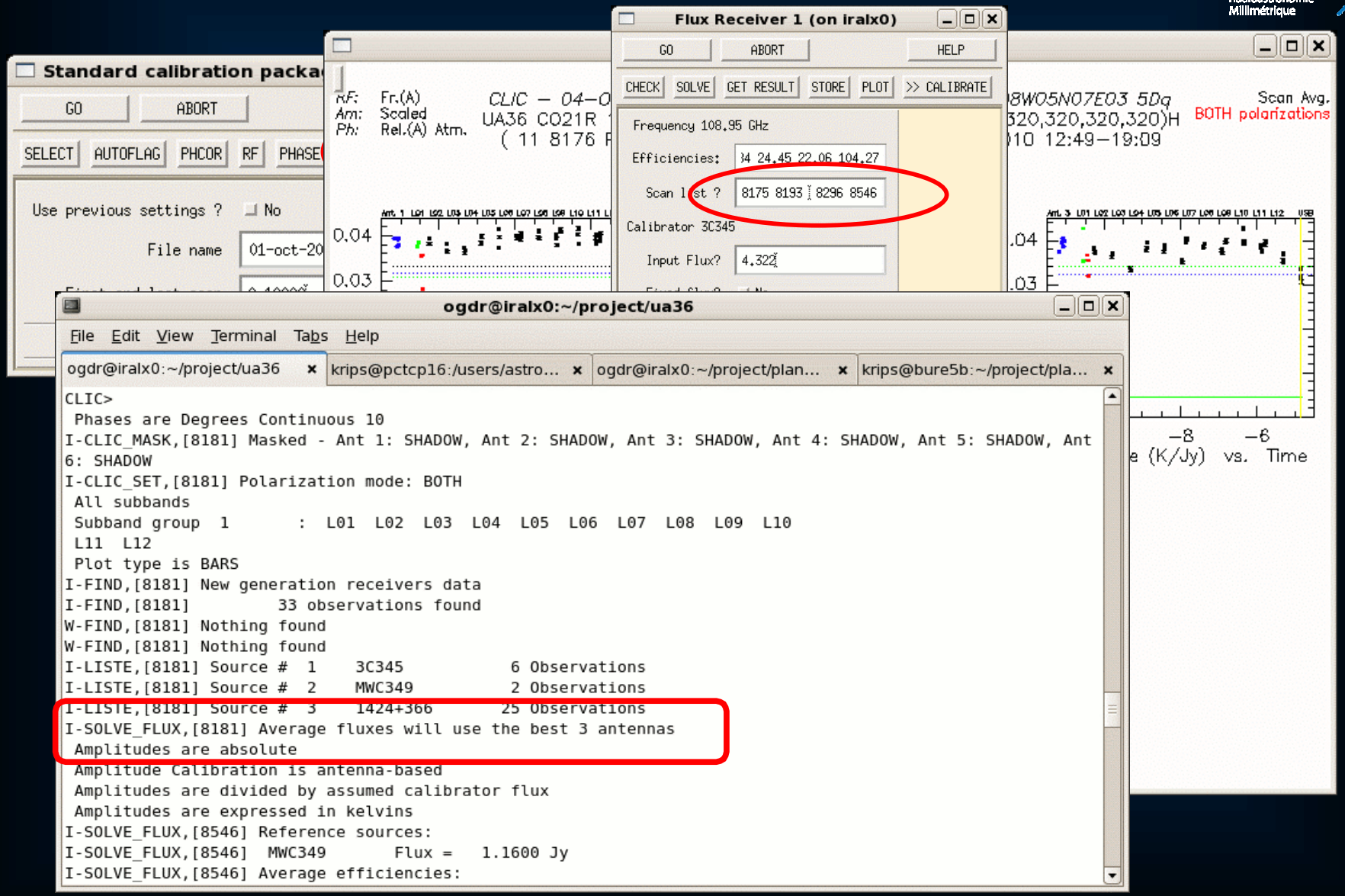
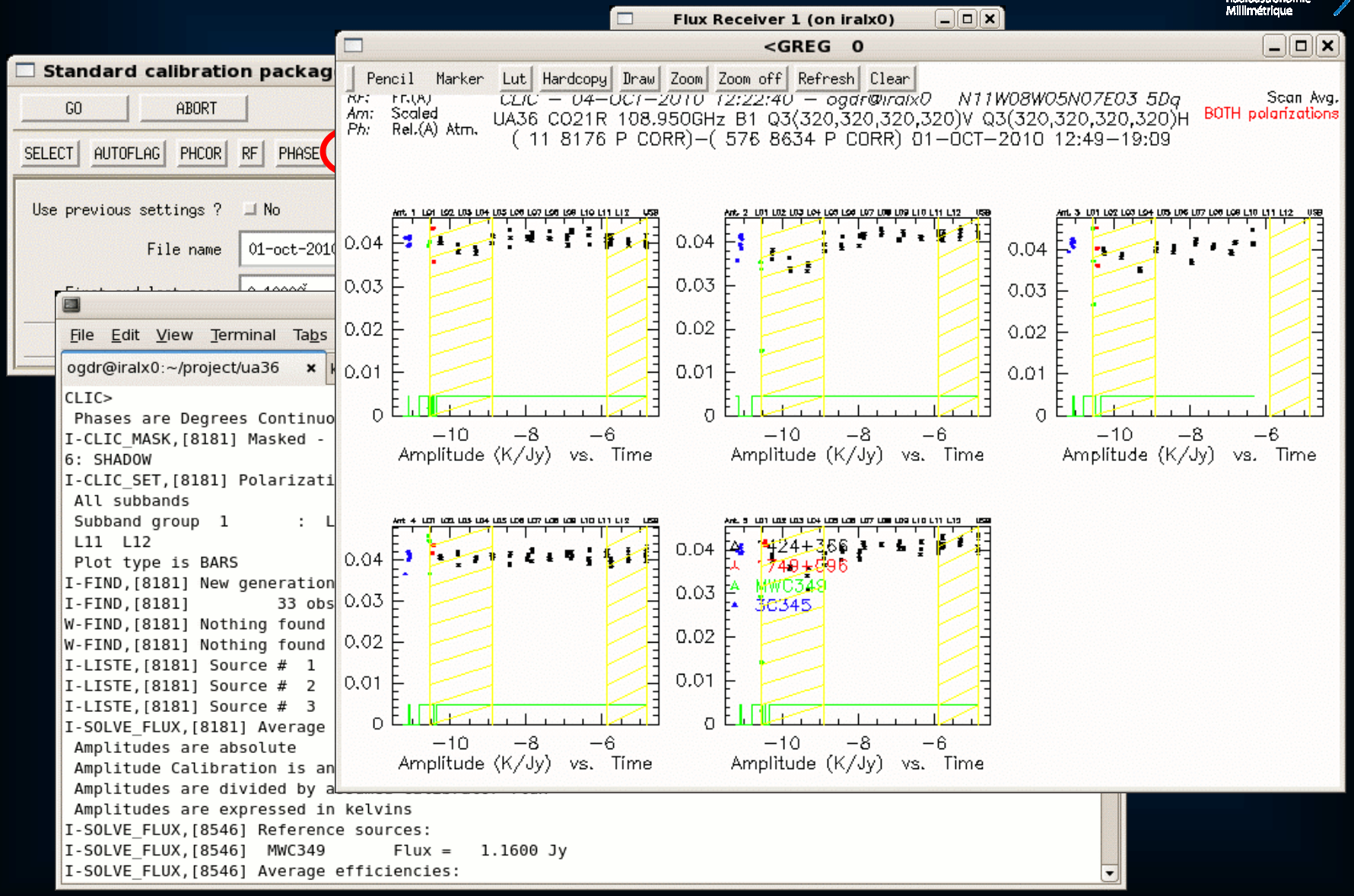


Practical Tips



Practical Tips



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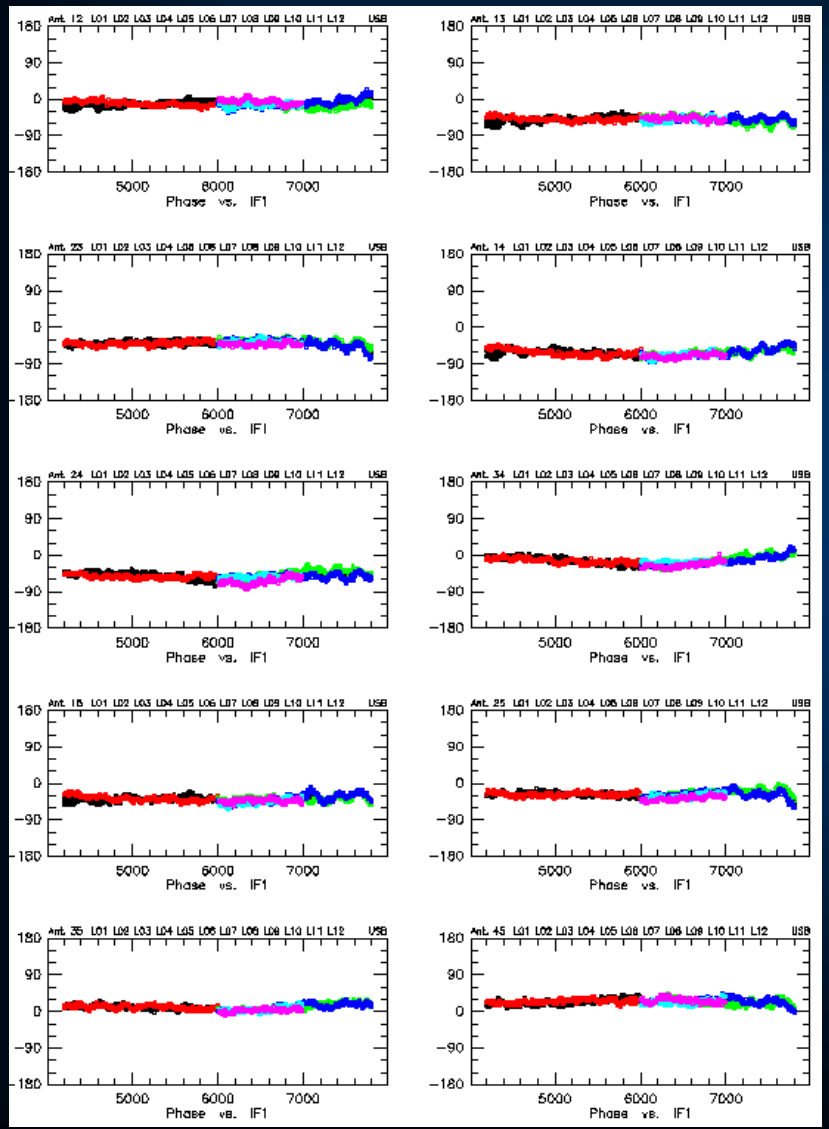

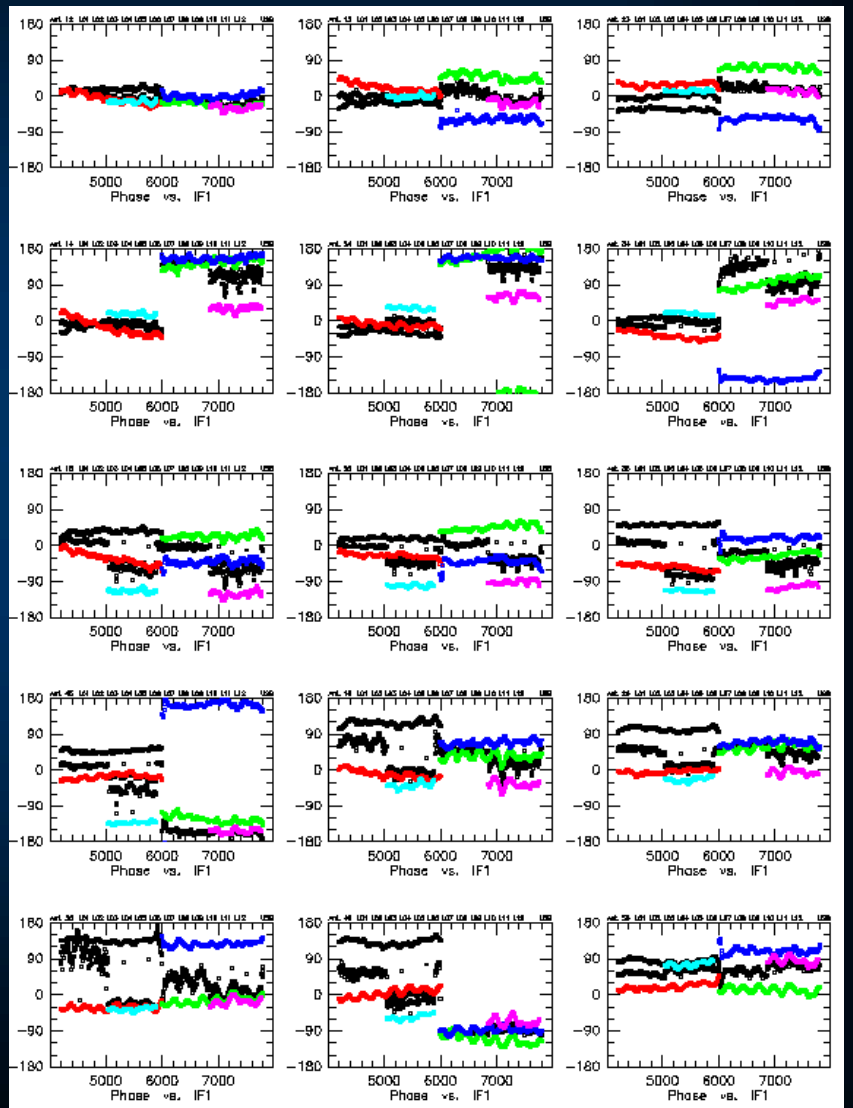

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Questions?

Summary

- SED of MWC349 follows $f \propto \nu^{0.6}$
- No time variability found above 10% during the past ~10years
- Satellites can be used as flux calibrators as well but need better models
- Antenna efficiencies ok for 3mm & 2mm but quickly degrade for 1mm

Motivation

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