Absolute Flux Calibration

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Institut de
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Millimétrique

Outline

I. Why?

II. Primary/Secondary Flux Calibrators

III. Practical Tips to Calibrate the Fluxes of your Sources

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Why?

Need to go from Temperatures (K) to Fluxes (Jy):

$$S(Jy) = \eta_{eff} \times T(K)$$

$$\eta_A = \frac{2k}{A_{geom}} \frac{T_A'}{S_\nu}$$

Point source sensitivity or aperture efficiency

(remember also talk by C.Kramer!)

Why?

Need to go from Temperatures (K) to Fluxes (Jy):

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Antenna Efficiencies
Phase noise
Decorrelation
Pointing/Focus

$$\eta_A = \frac{2k}{A_{geom}} \frac{T_A'}{S_\nu}$$

Point source sensitivity or aperture efficiency

(remember also talk by M.Bremer!)

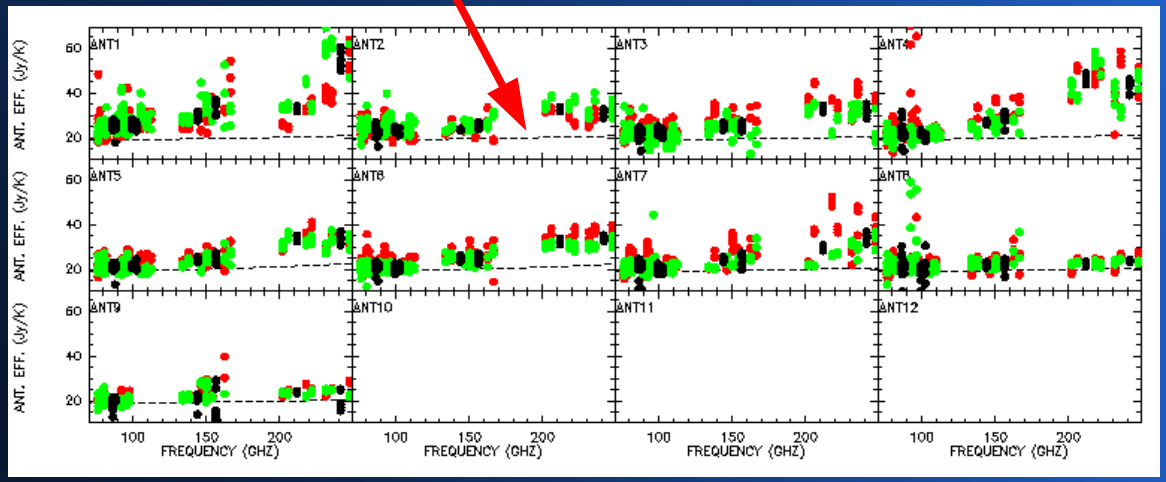
Why?

Antenna Efficiencies:

Mainly defined by Ruze formula, i.e., via antenna surface accuracy σ (which can be measured with holographies, usually 30-40μm):

$$A_{eff} \sim \exp(-(4\pi\sigma/\lambda)^2)$$

(remember also talk by C. Kramer!)



TP measurements on Mars and/or Saturn

Why?

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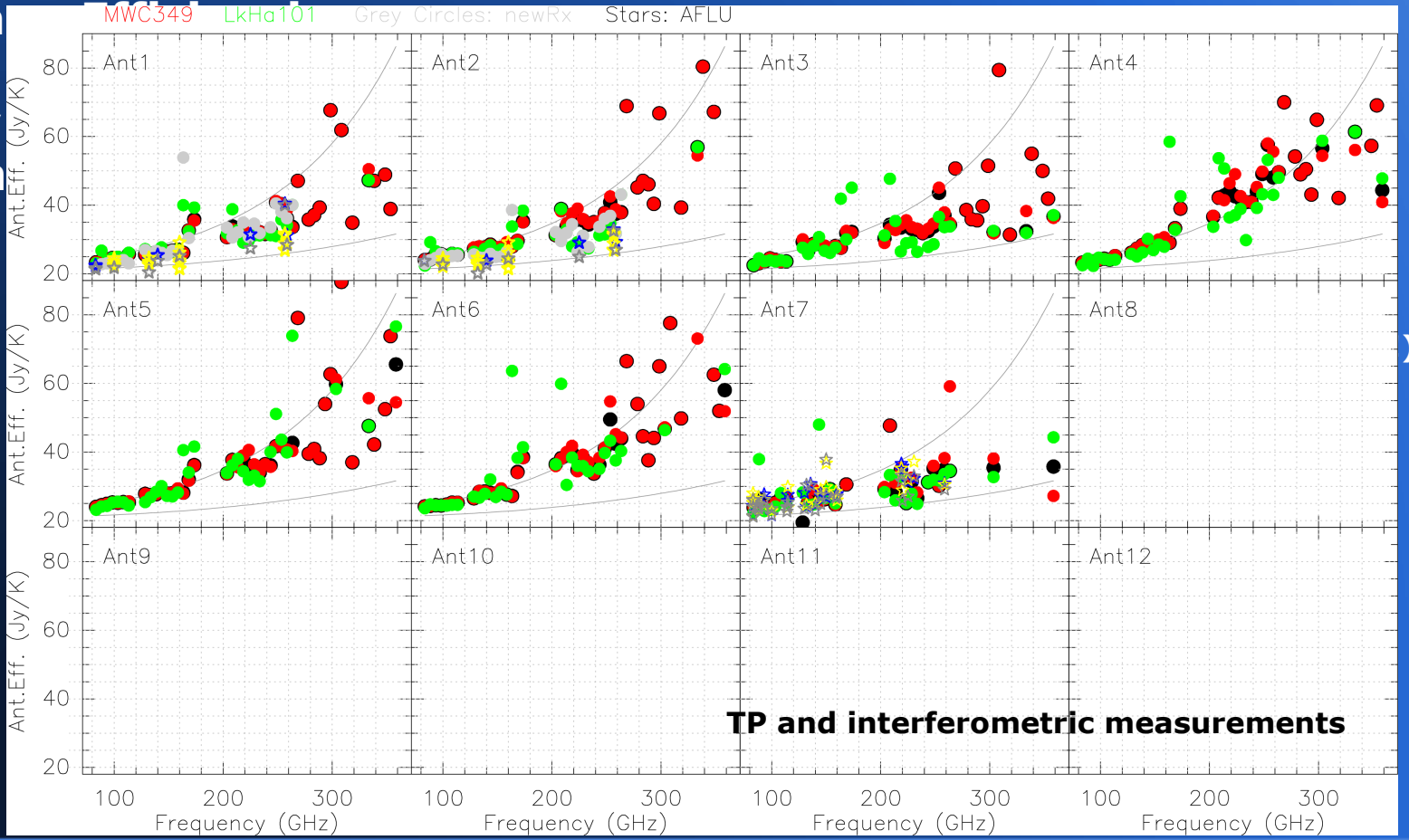

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Why?

Need to go from Temperatures (K) to Fluxes (Jy):

$$S(Jy) = \eta_{eff} \times T(K)$$

η_{eff} can vary from observation to observation (also frequency dependent)!!

Antenna Efficiencies
Phase noise
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Why?

Need to go from Temperatures (K) to Fluxes (Jy):

$$S(Jy) = \eta_{eff} \times T(K)$$

Do an absolute Flux Calibration:

We measure T(K) and if we know S(Jy) on one source in the track, we can derive η_{eff} and apply it to all other sources!

-> Need an Absolute Flux calibrator!!!!

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II. Primary/Secondary Flux Calibrators

III. Practical Tips to Calibrate the Fluxes of your Sources

Flux Calibrators

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What do we want in a flux calibrator?

- **preferentially well known properties (such as flux SED, size if not pointlike)**
- **strong (>100mJy) 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**

Flux Calibrators

1.) Quasars

2.) Planets

3.) Solar Bodies
(Satellites, Asteroids,
Dwarf Planets)

4.) Radio Stars

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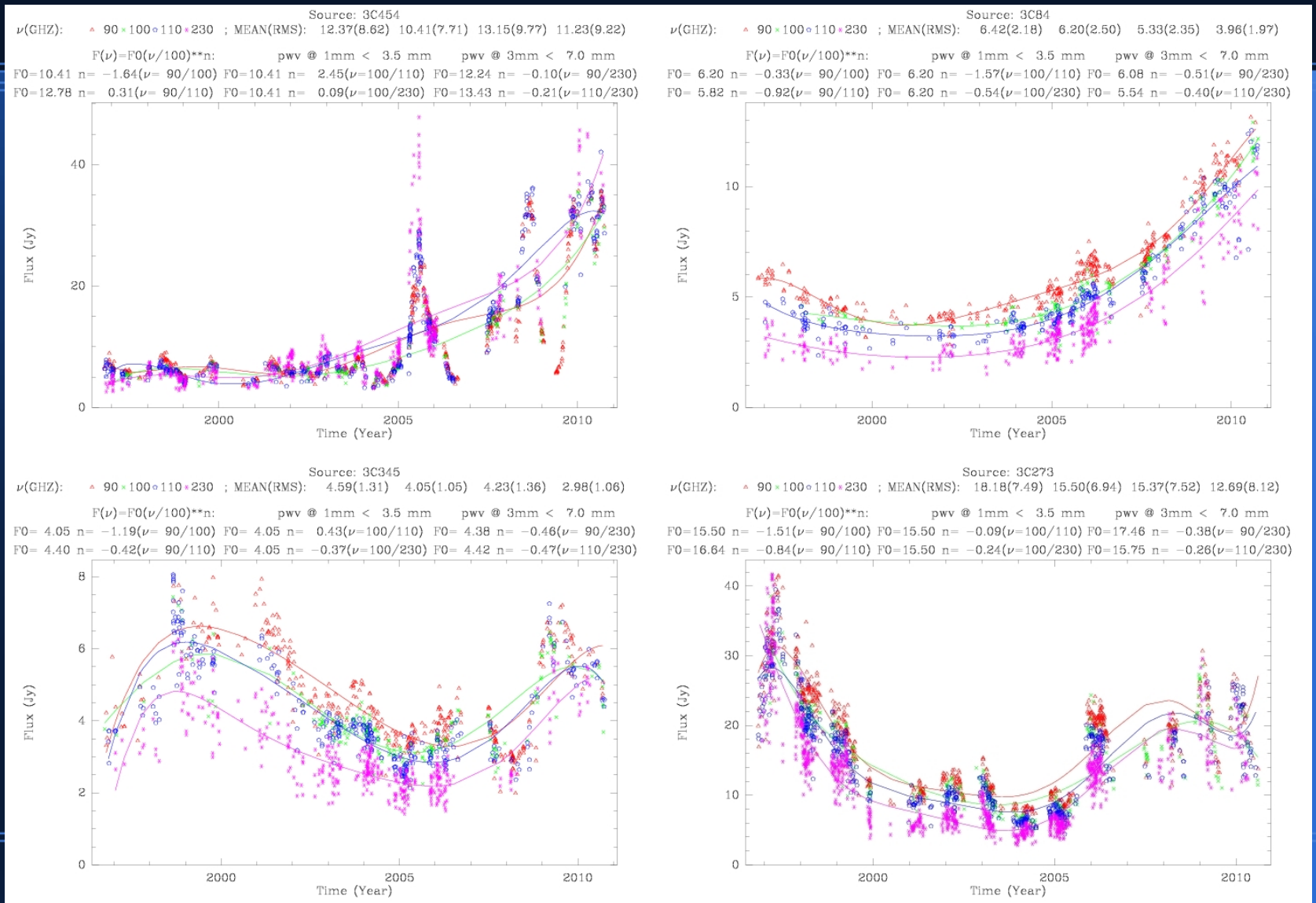
Flux Calibrators: Quasars



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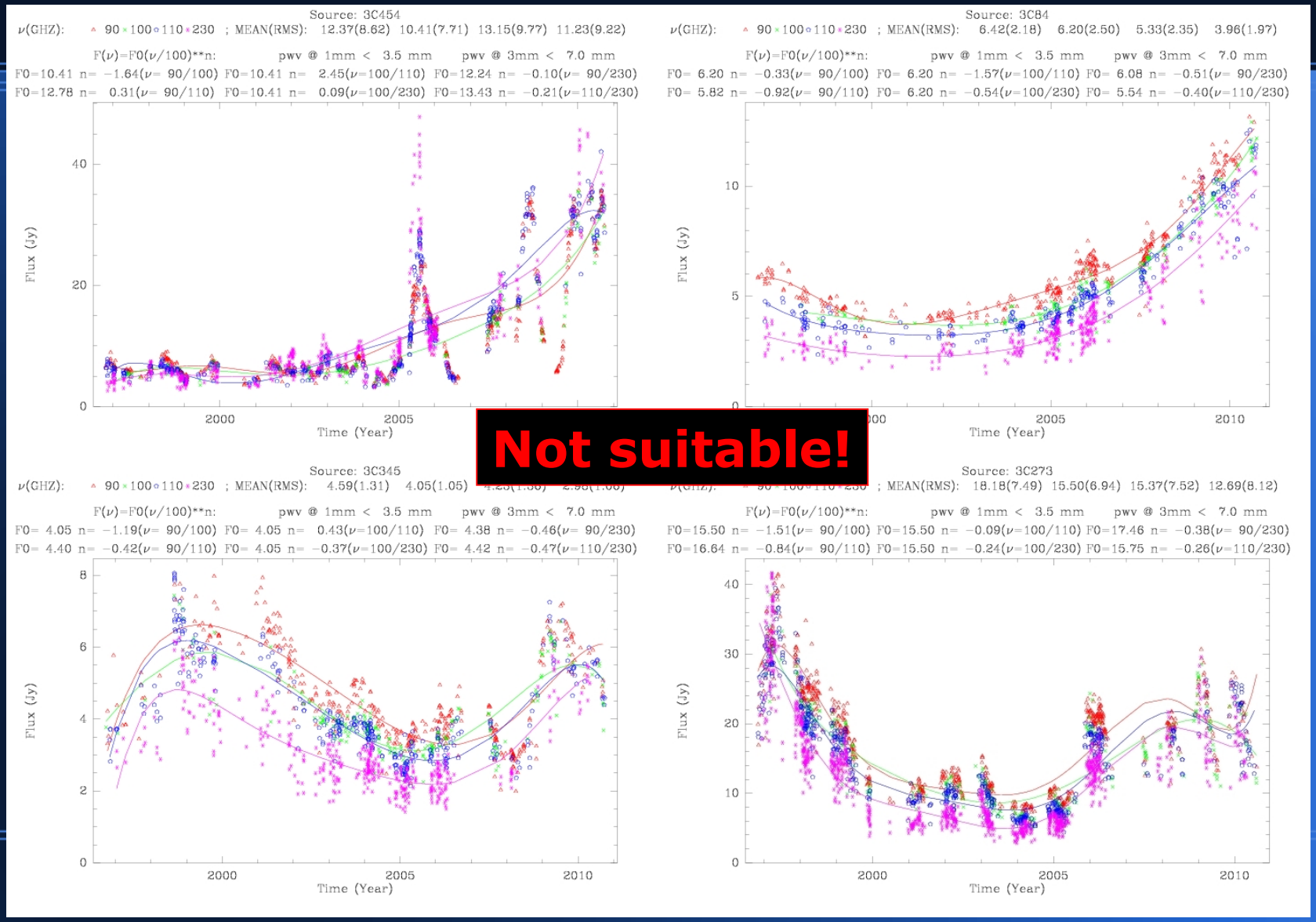

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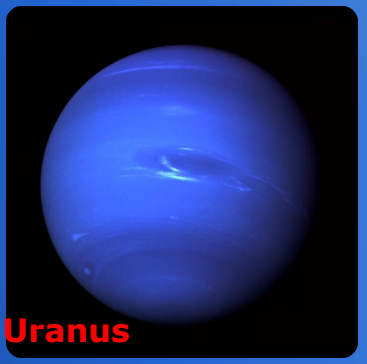
Flux Calibrators: Planets

- 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



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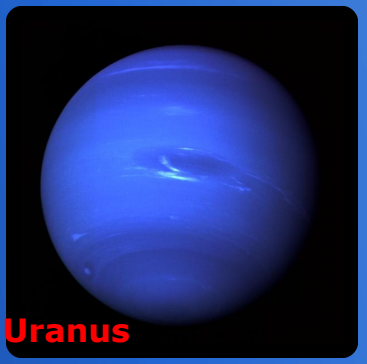
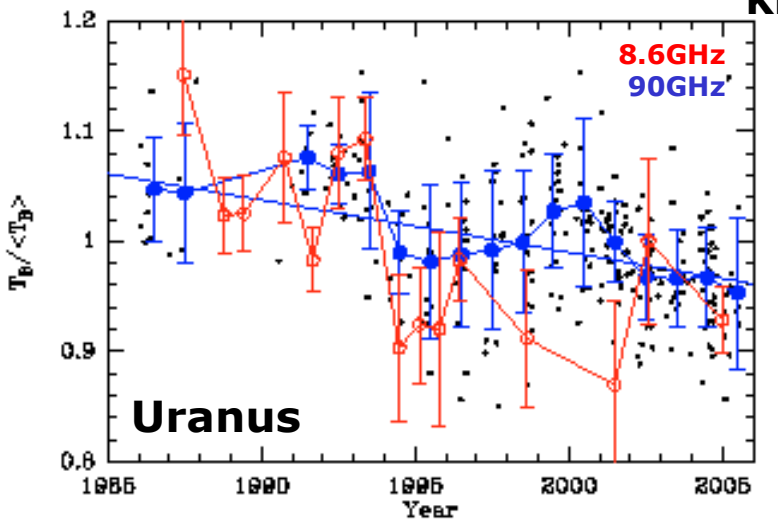
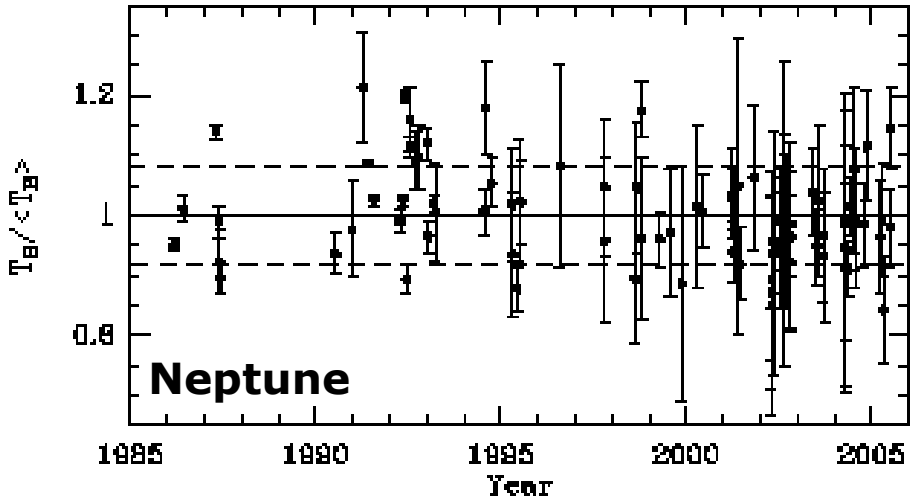


Flux Calibrators: Planets

Kramer et al. (2008)





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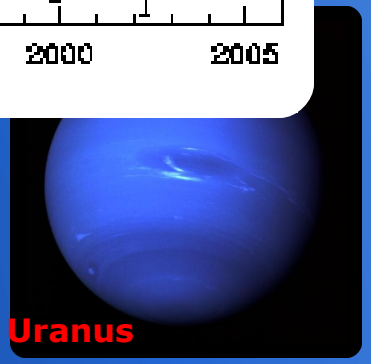

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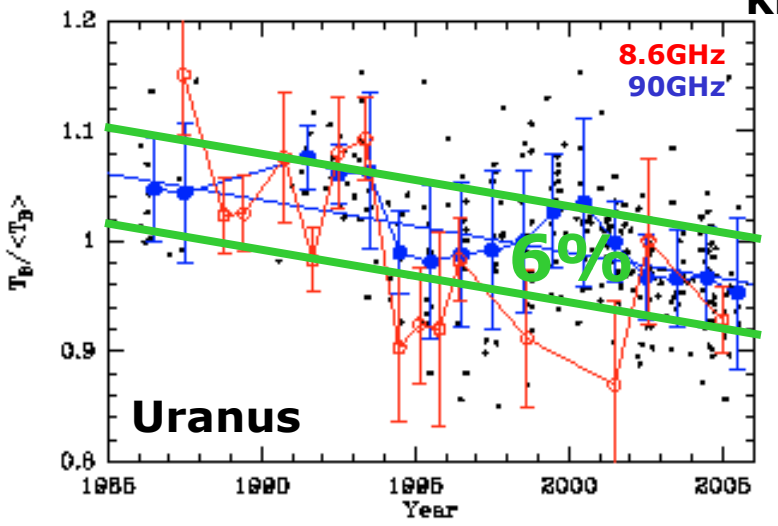

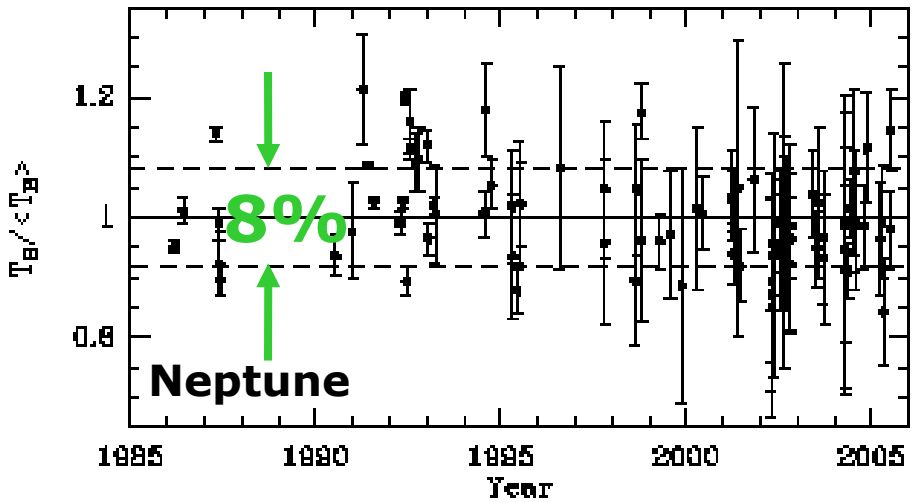

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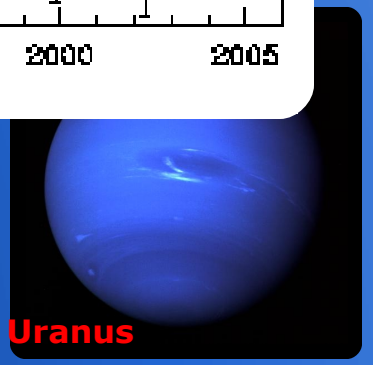

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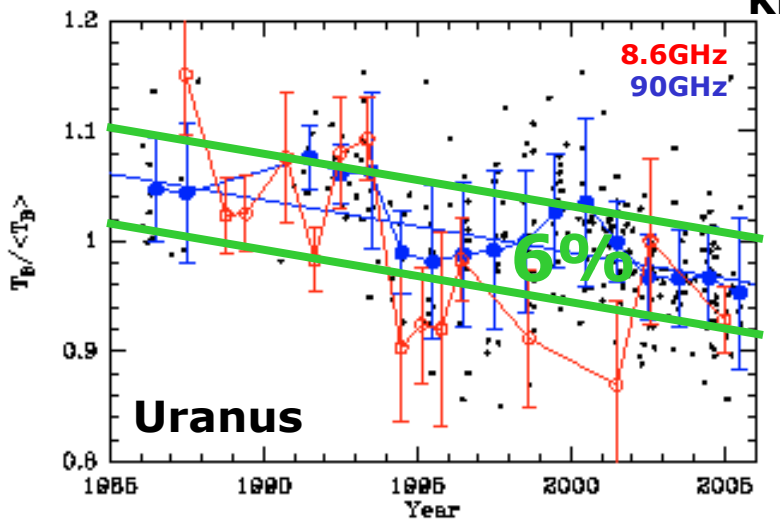

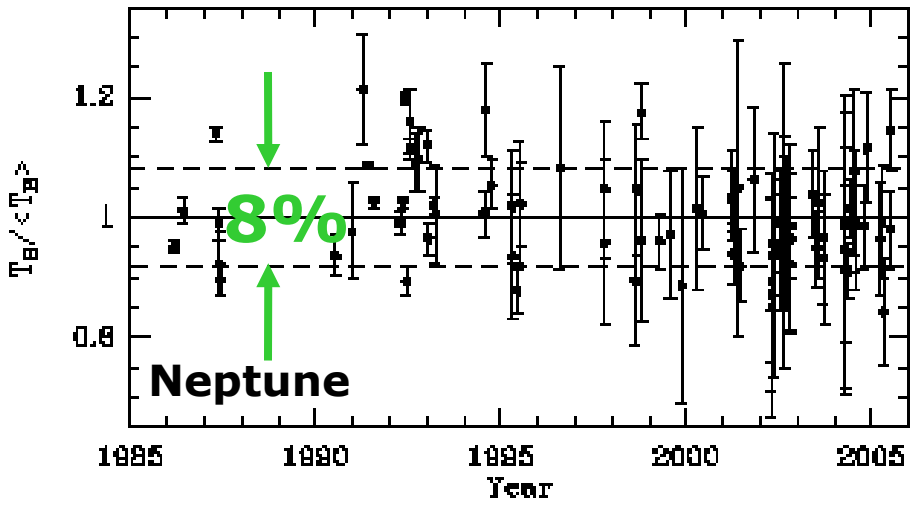

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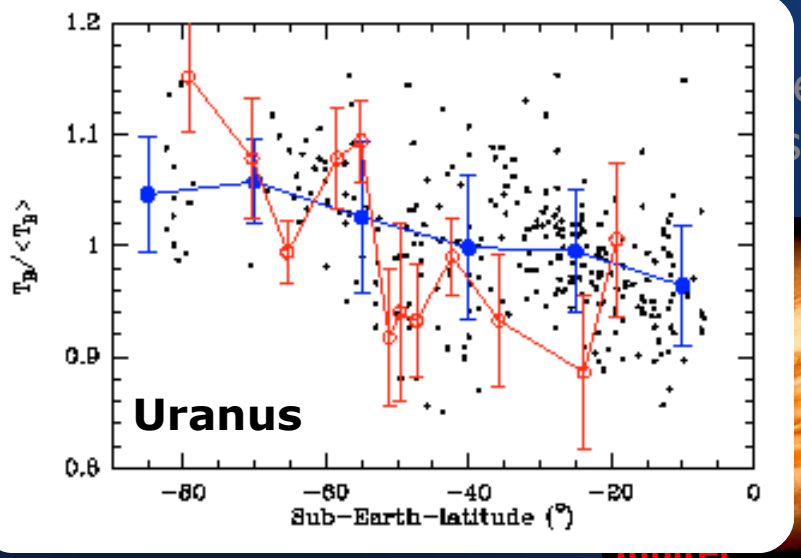

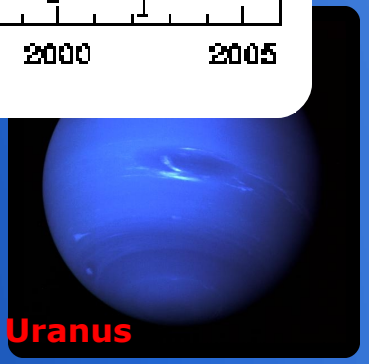

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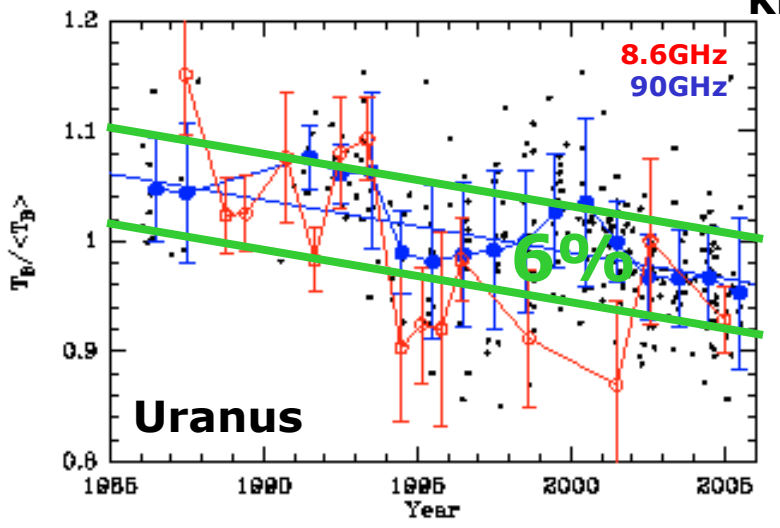

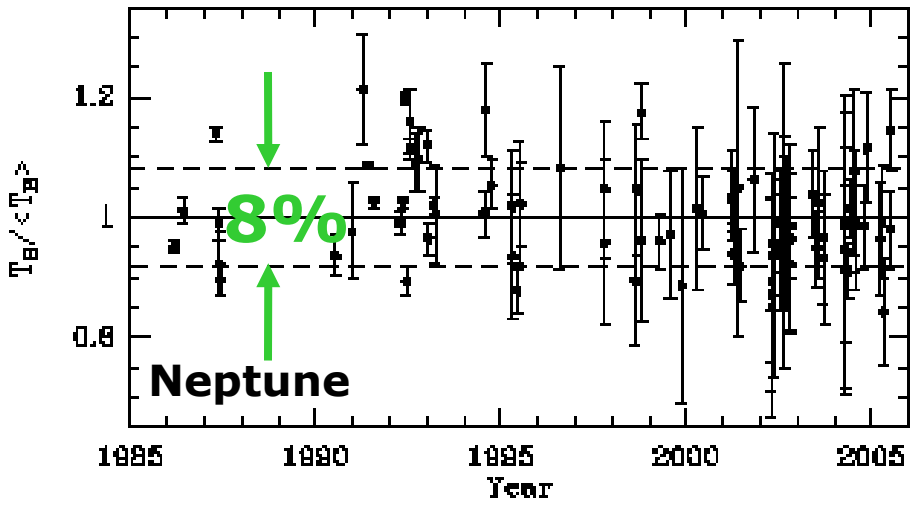

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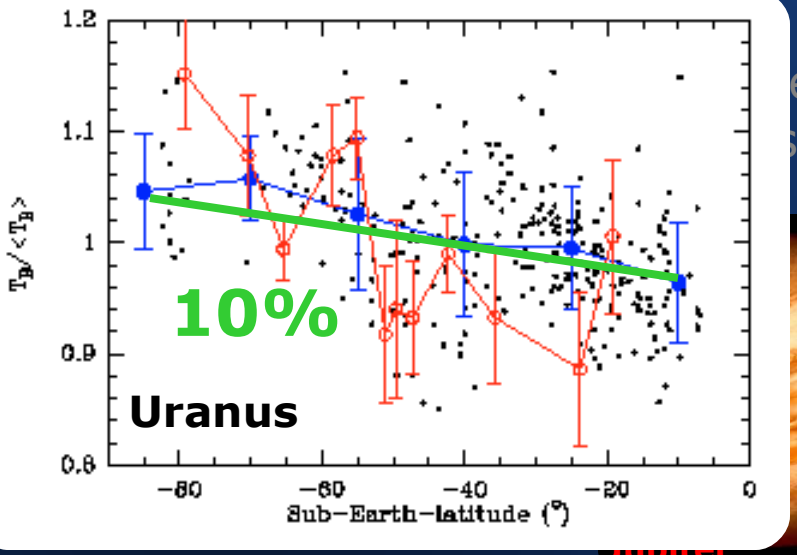

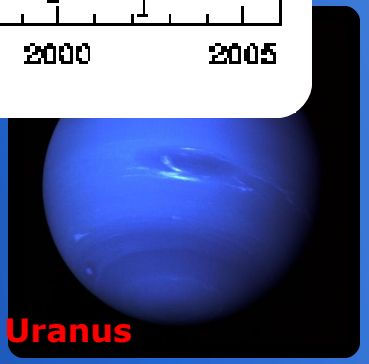

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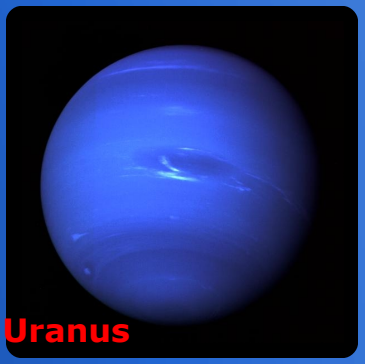

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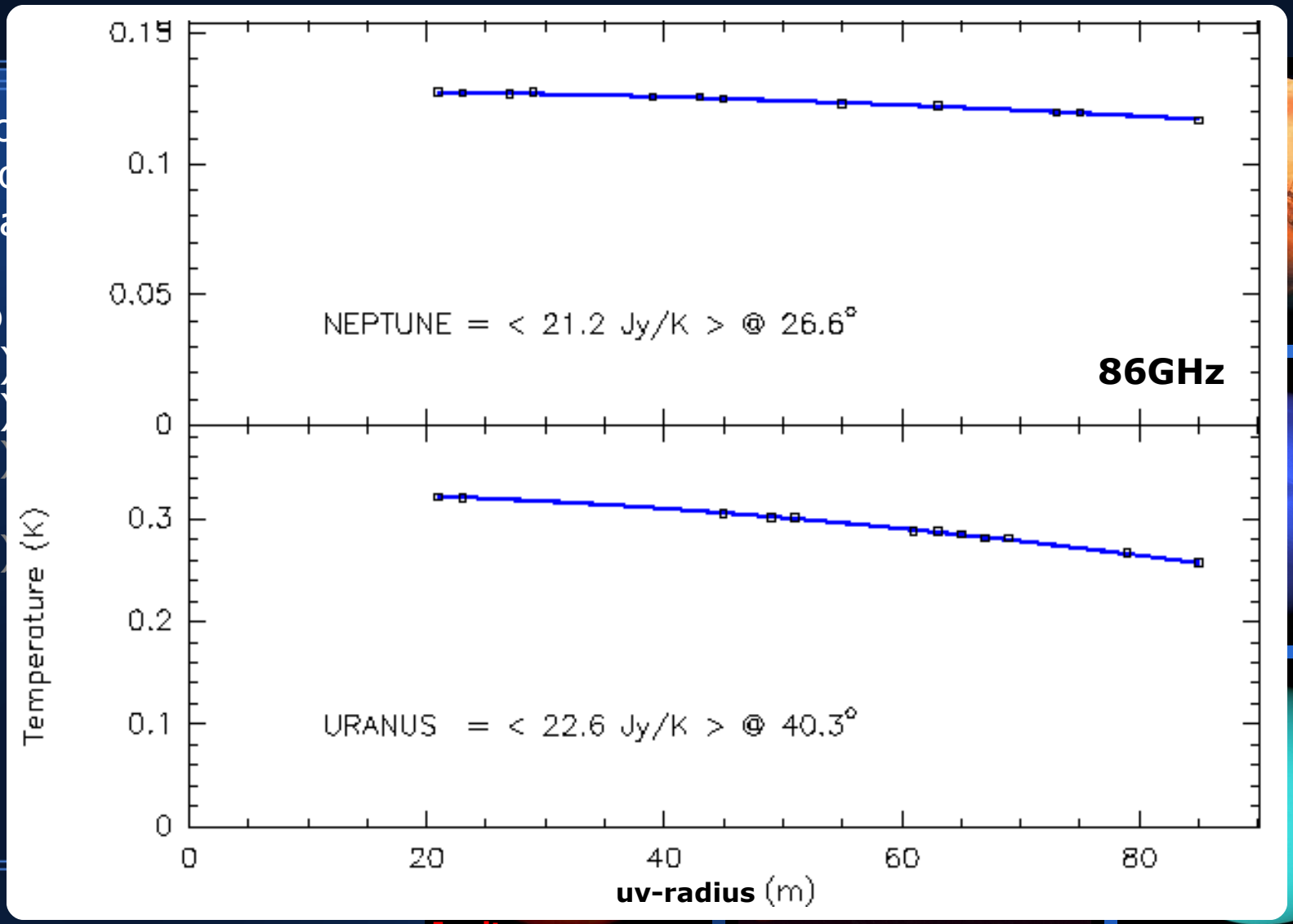

Jupiter Saturn Neptune

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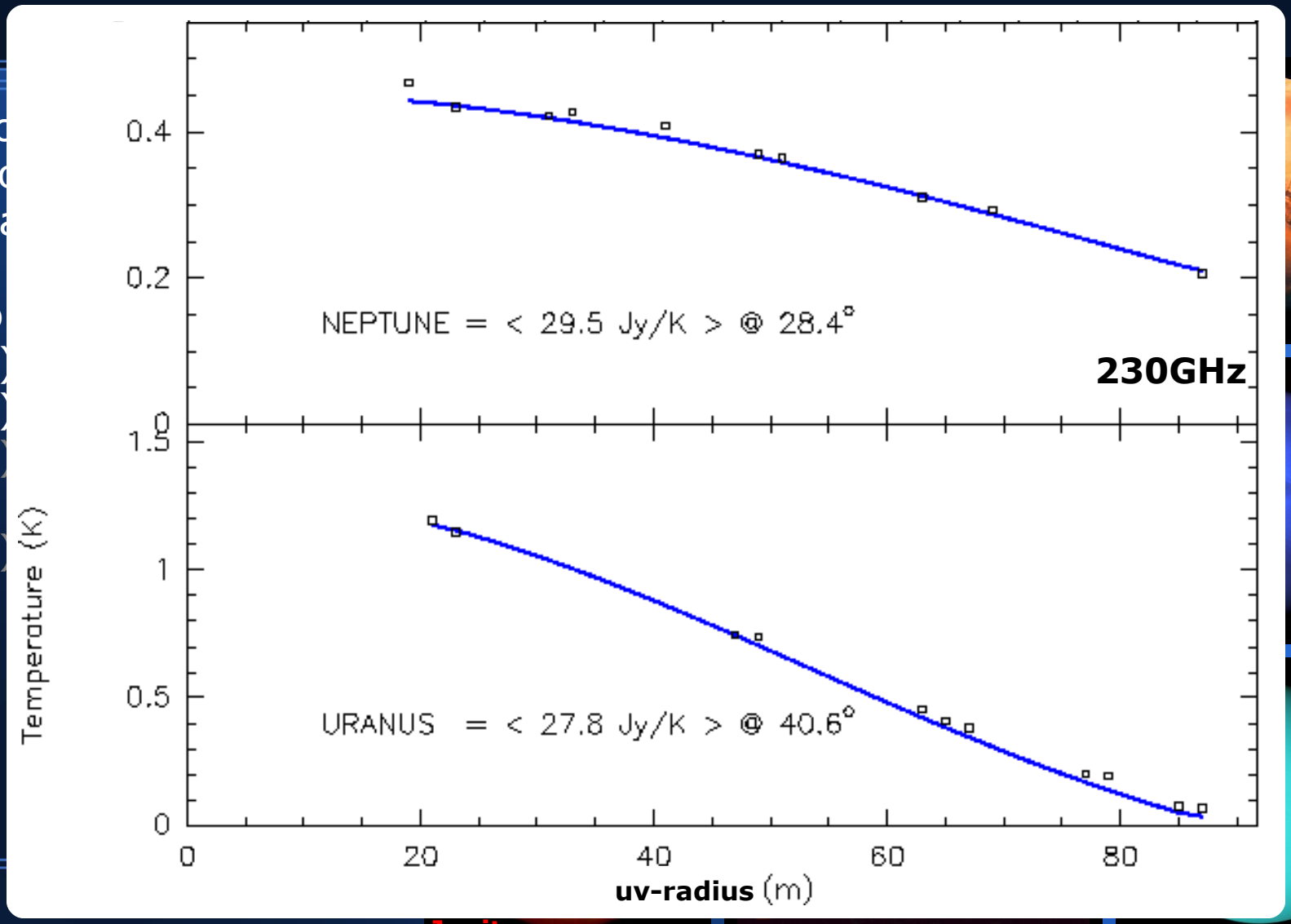

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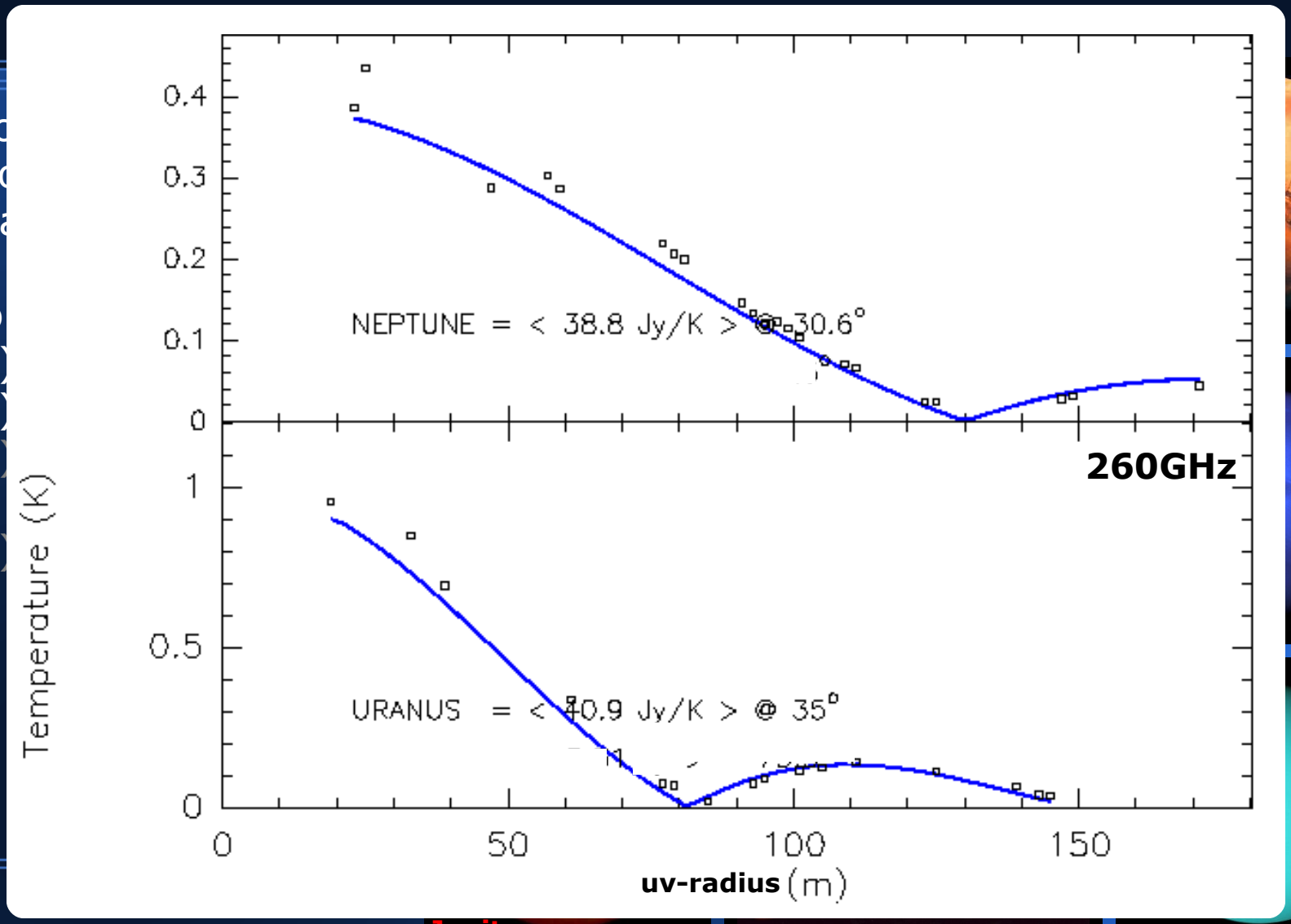

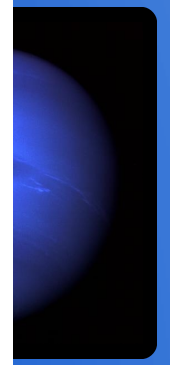

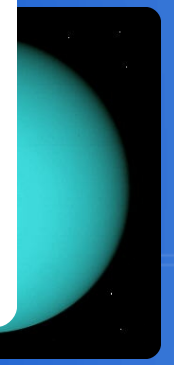

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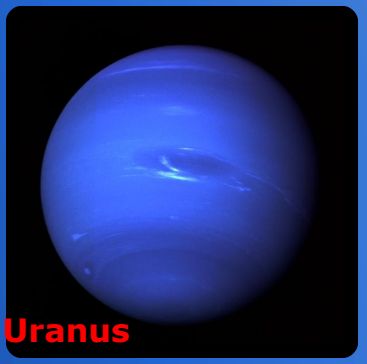

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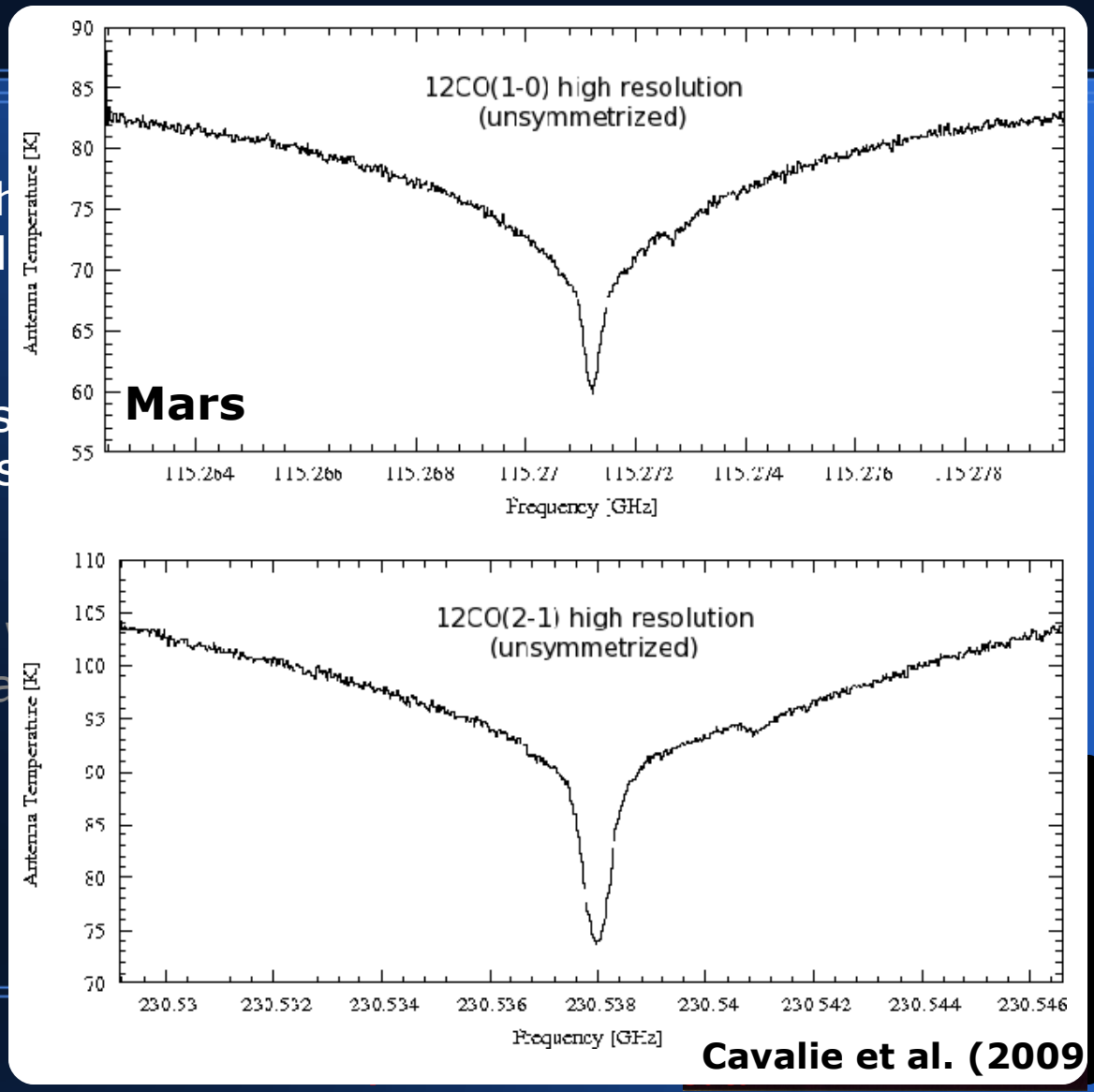
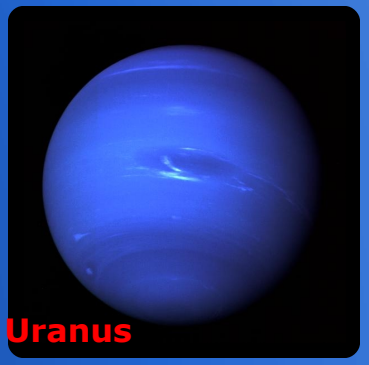


Cavalie et al. (2009



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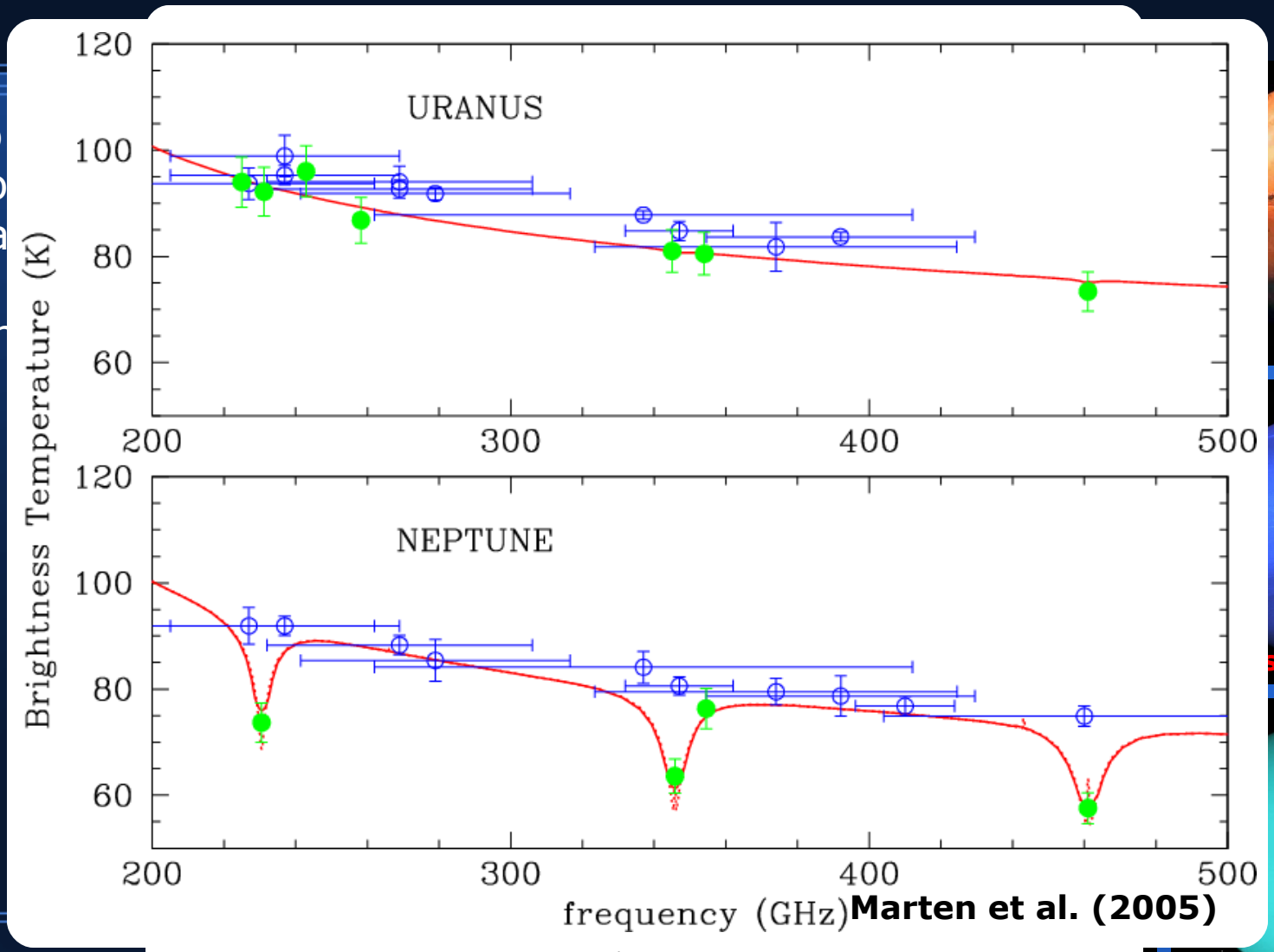
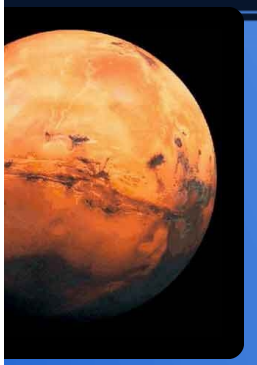
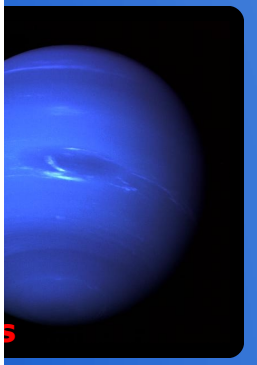


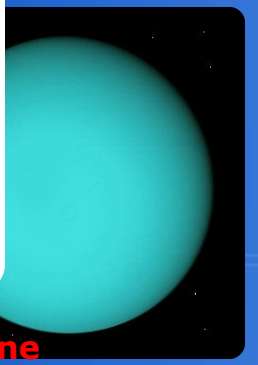
Marten et al. (2005)

Frequency [GHz]

Cavalie et al. (2009







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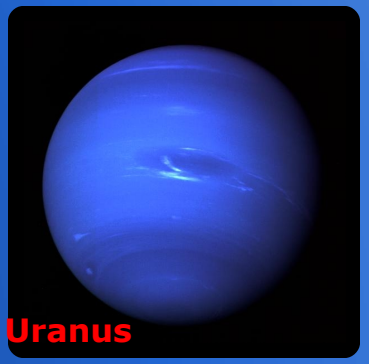
Uranus


Jupiter


Saturn


Neptune

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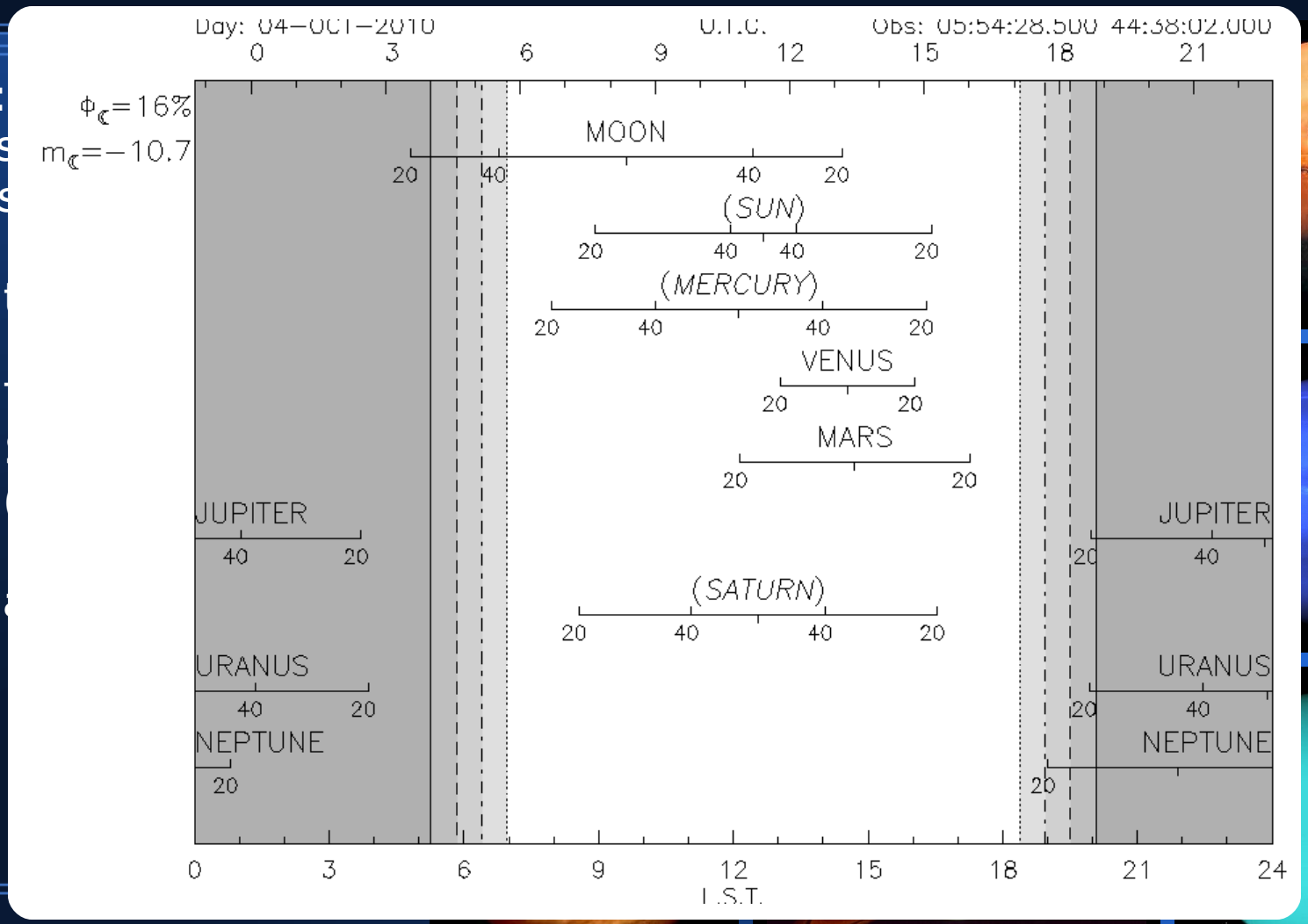

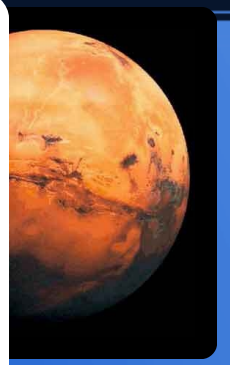

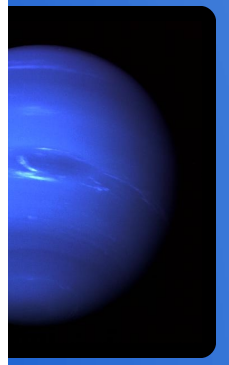

Jupiter Saturn Neptune

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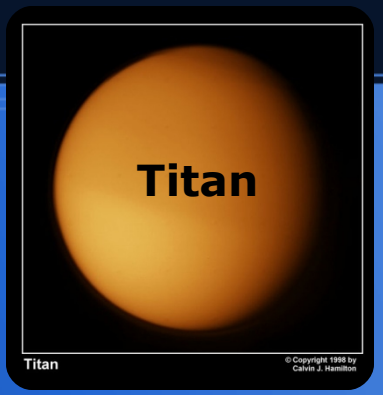
- Pro:
  - They are quite compact (hence better for extended configurations and/or higher frequencies than planets) and still sufficiently bright (>500mJy@3mm)

- Already regularly used at the SMA & ALMA: 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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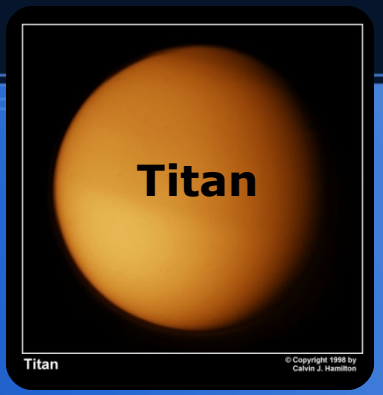

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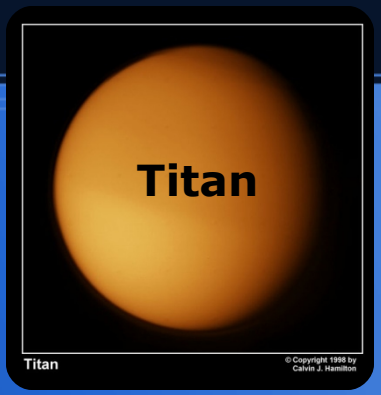
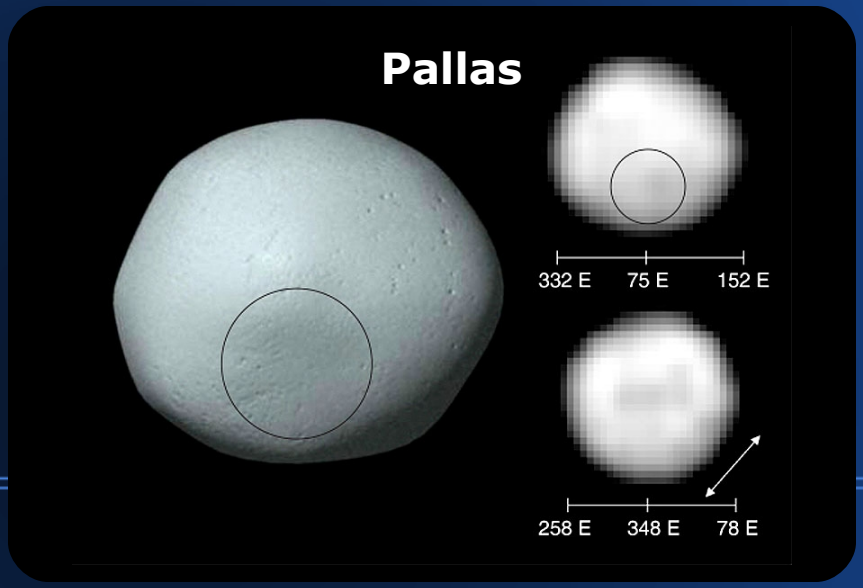
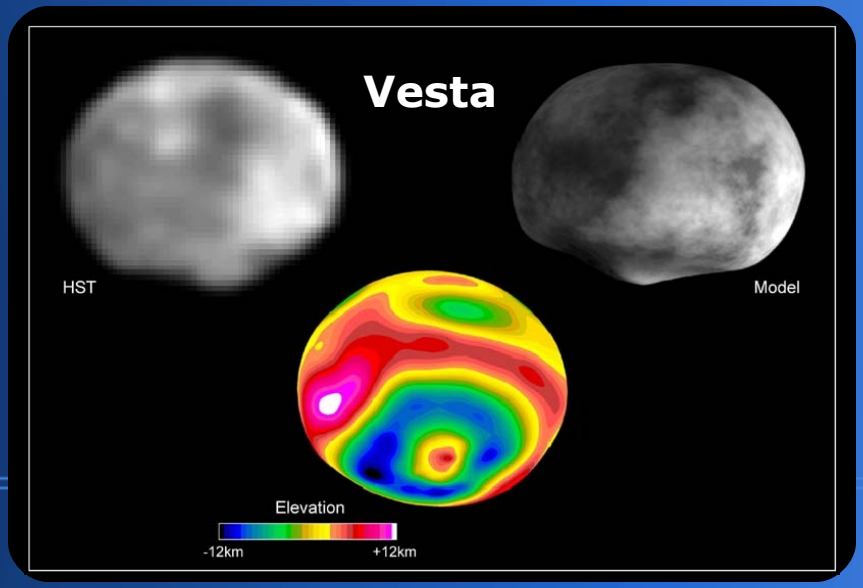


Flux Calibrators: Asteroids/Dwarf Planets

- Pro:
  - bright and relatively small solar bodies

- Contra:
  - Still uncertainties in their flux; some of them known to vary quite significantly within a day
  - irregular shapes

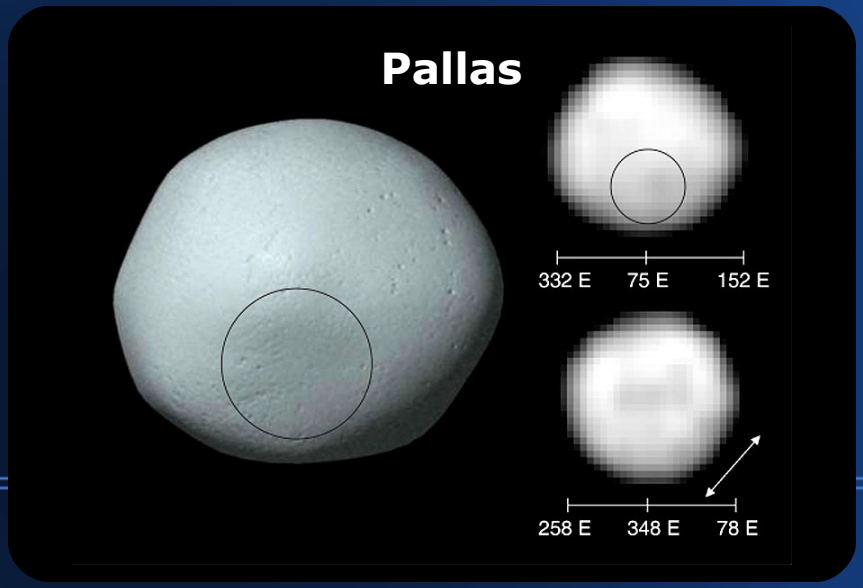


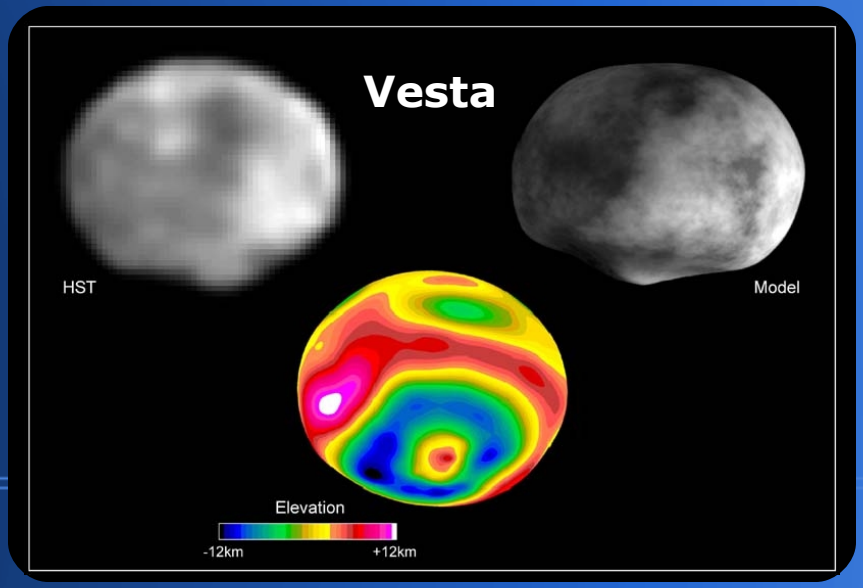


Flux Calibrators: Asteroids/Dwarf Planets

- Pro:
  - bright and relatively small solar bodies

- Contra:
  - Still uncertainties in their flux; some of them known to vary quite significantly within a day
  - irregular shapes





Flux Calibrators

1.) Quasars

2.) Planets

3.) Solar Bodies
(Satellites, Asteroids,
Dwarf Planets)

4.) Radio Stars

Flux Calibrators: Radio Stars

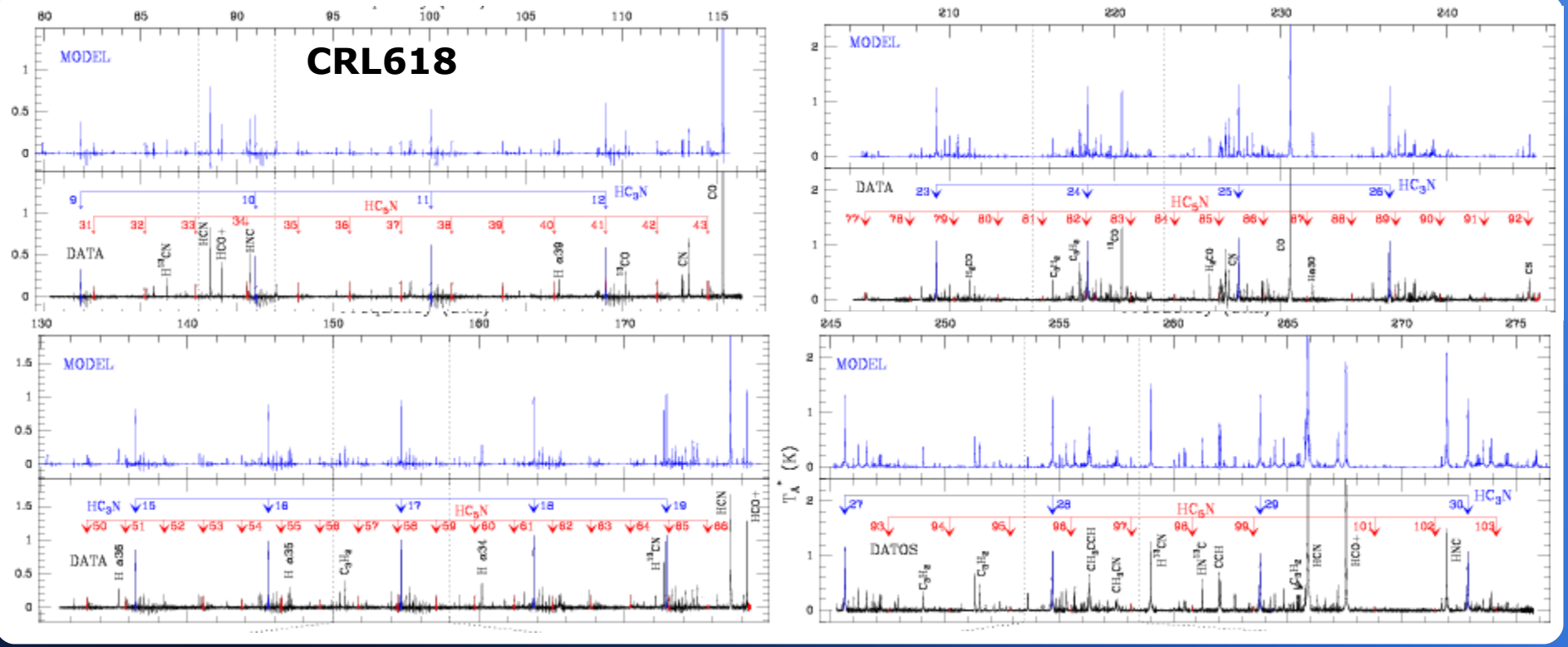
Radio bright stars:

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

Flux Calibrators: Radio Stars

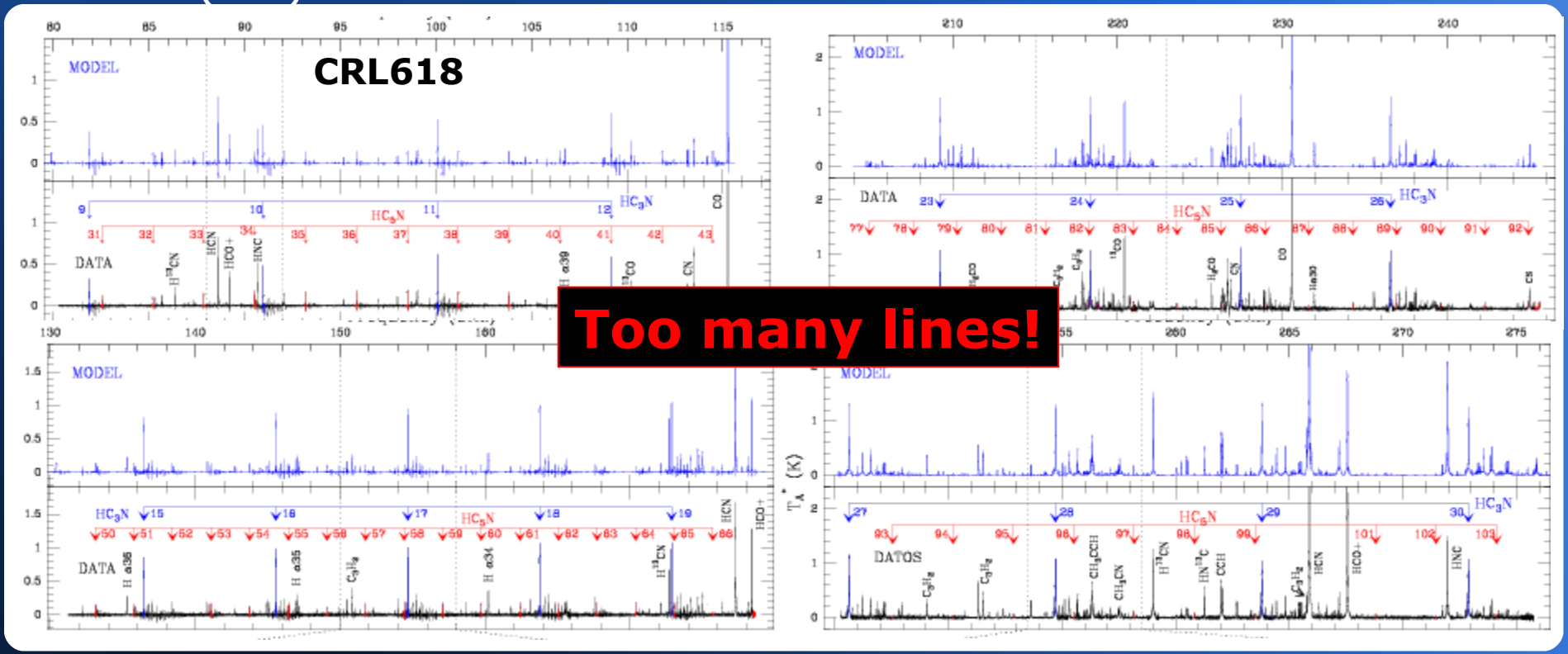
iram
Institut de Radioastronomie Millimétrique

Pardo et al. (2009)

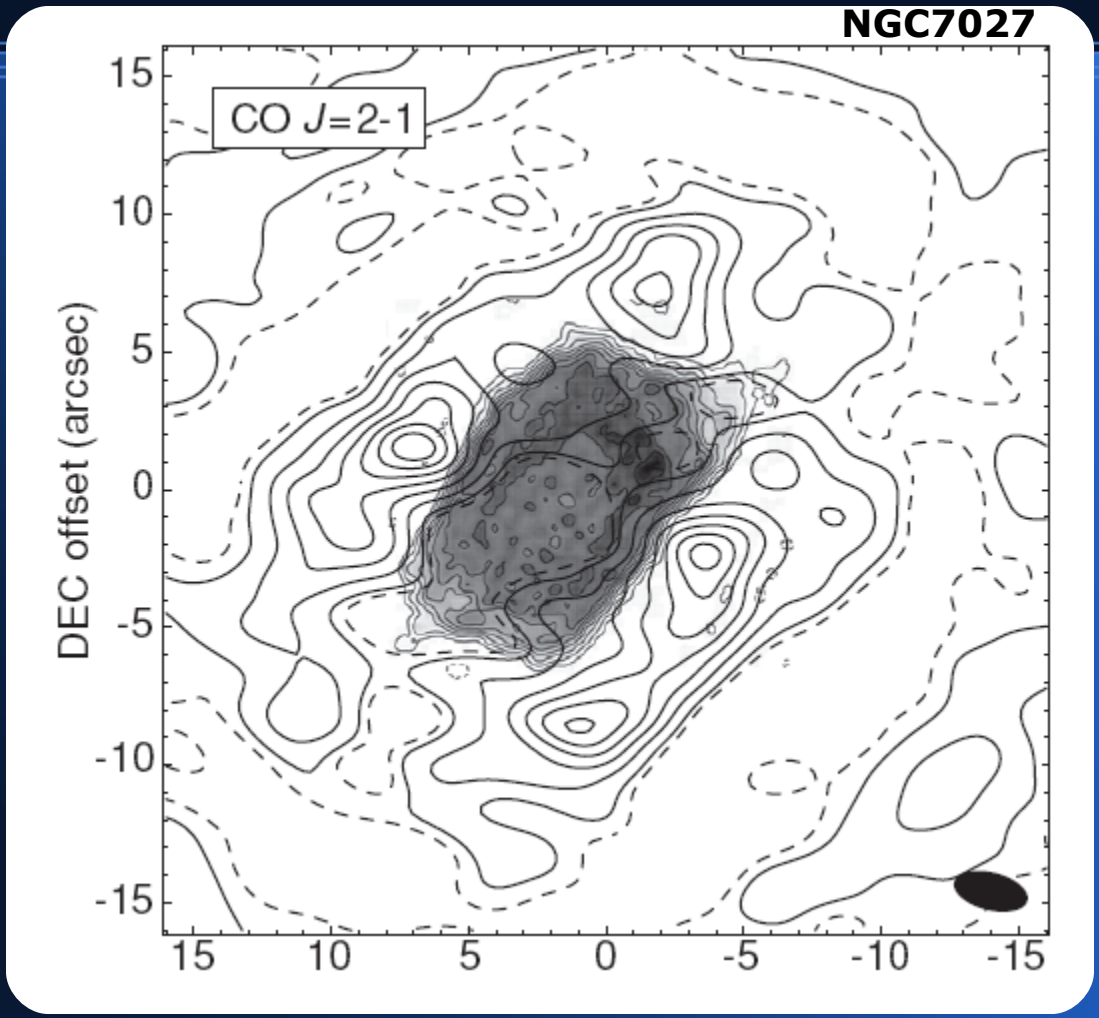


Flux Calibrators: Radio Stars

Pardo et al. (2009)

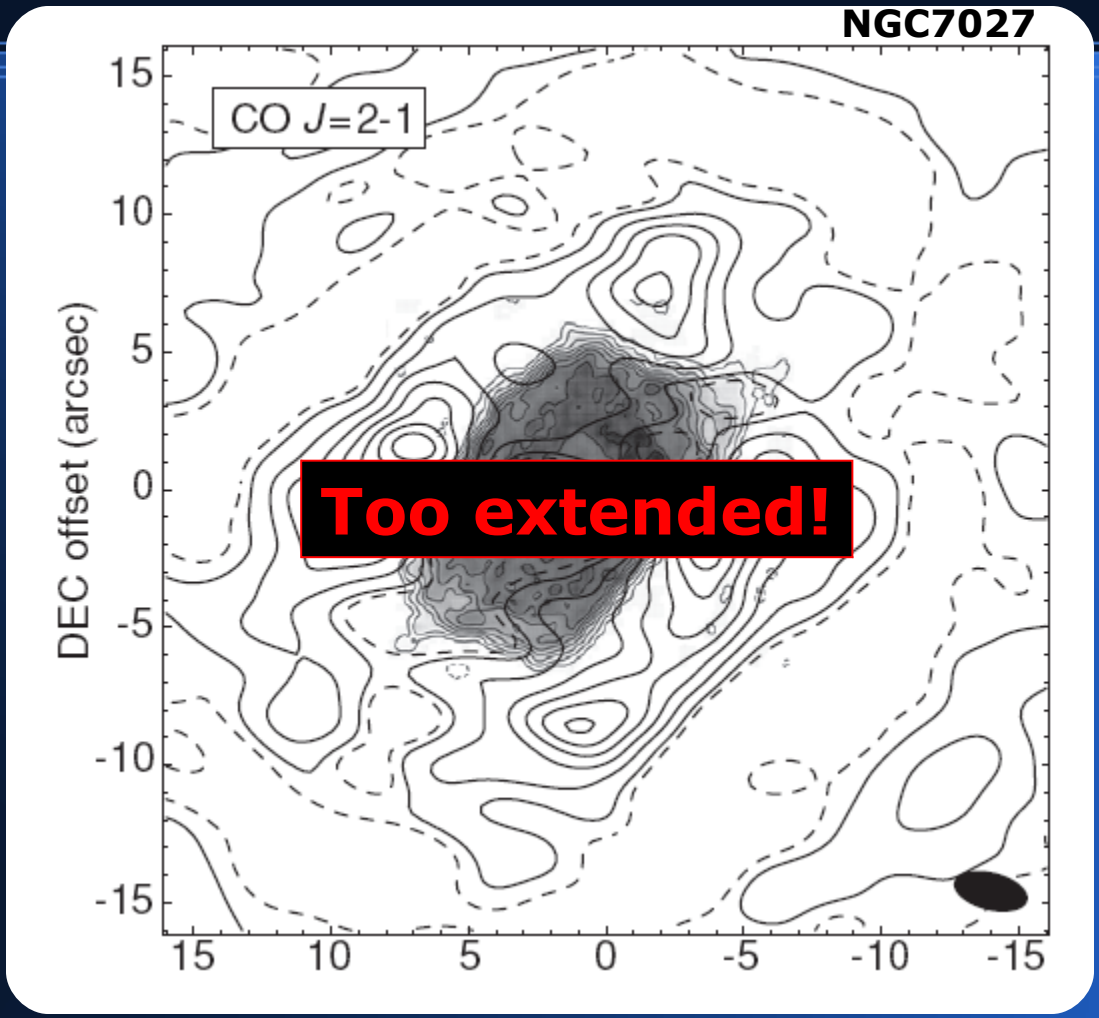


Flux Calibrators: Radio Stars



Nakashima et al. (2010)

Flux Calibrators: Radio Stars



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Radio bright stars:

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

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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
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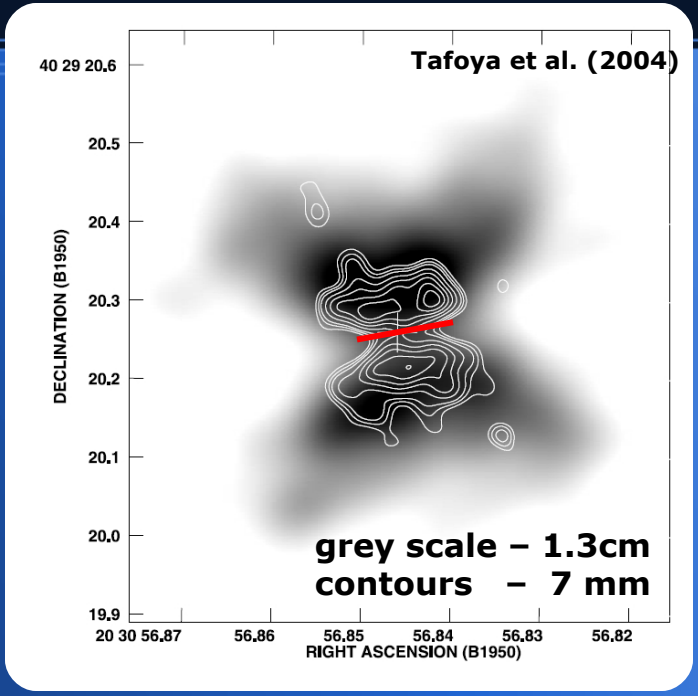
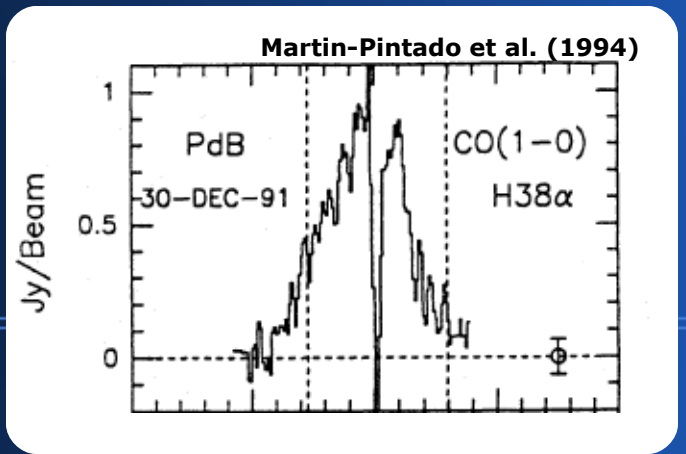
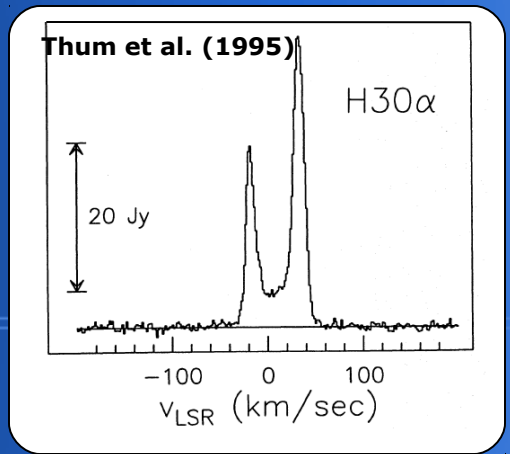
- at declination of >40deg -> visible for ~13h per day







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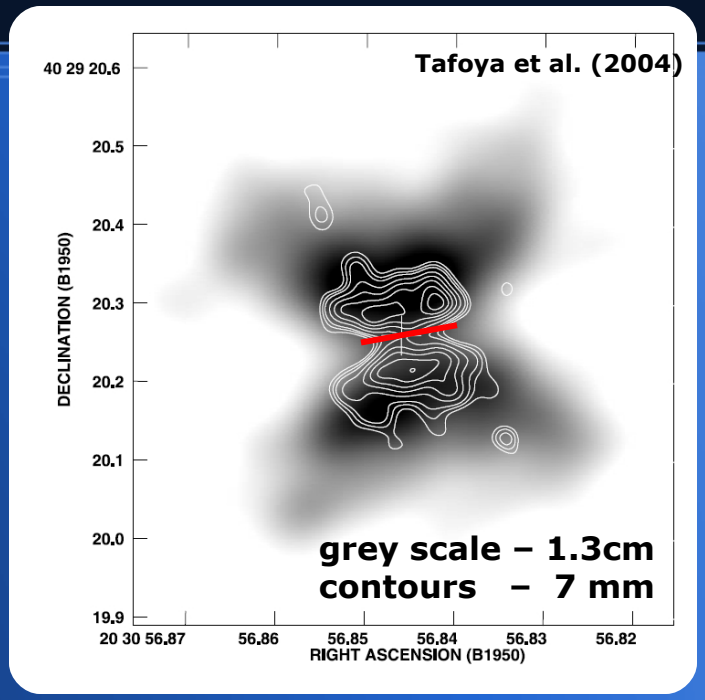

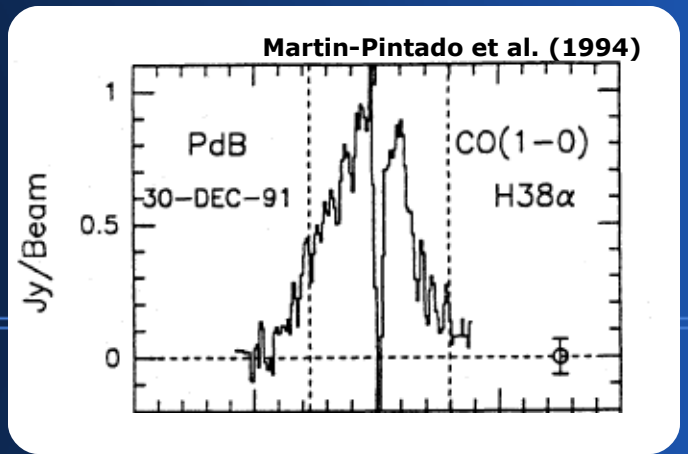

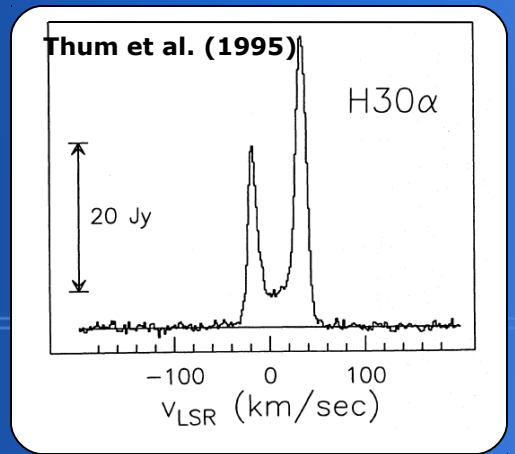

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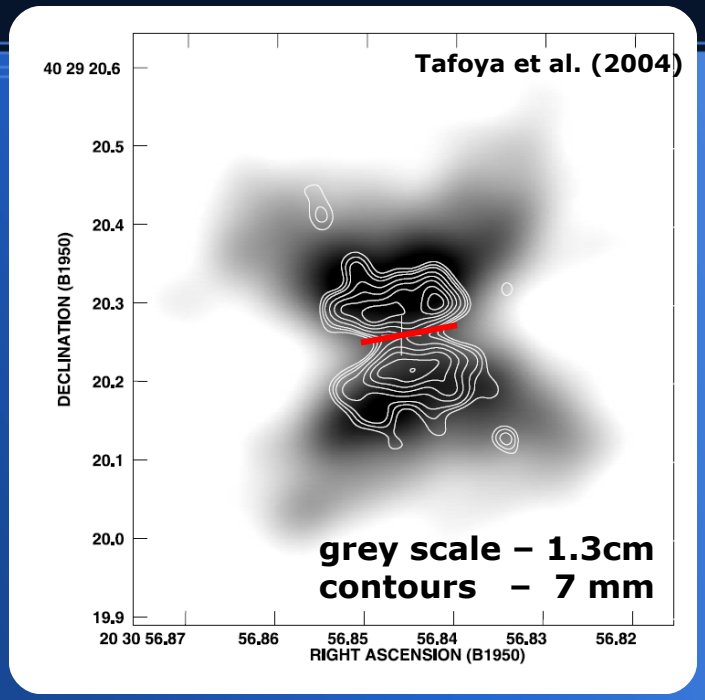

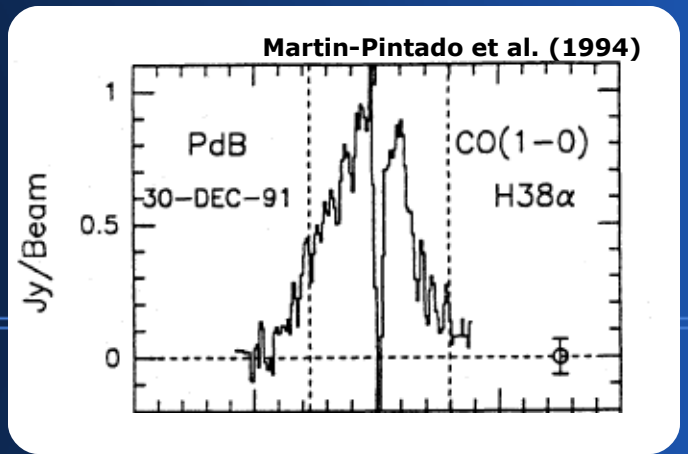

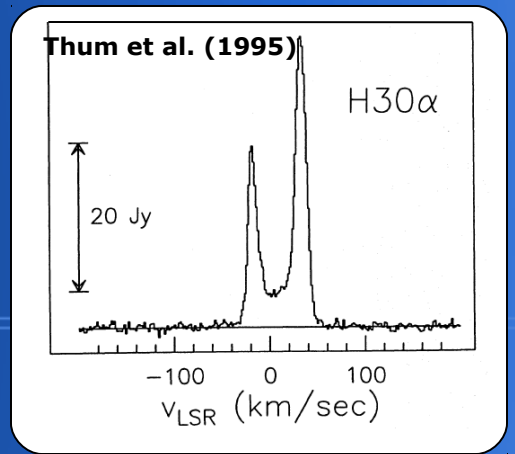

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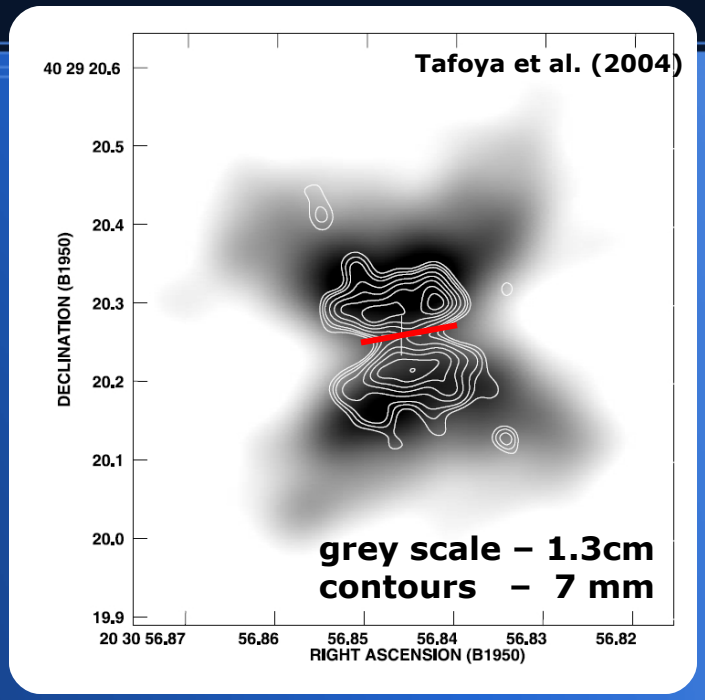

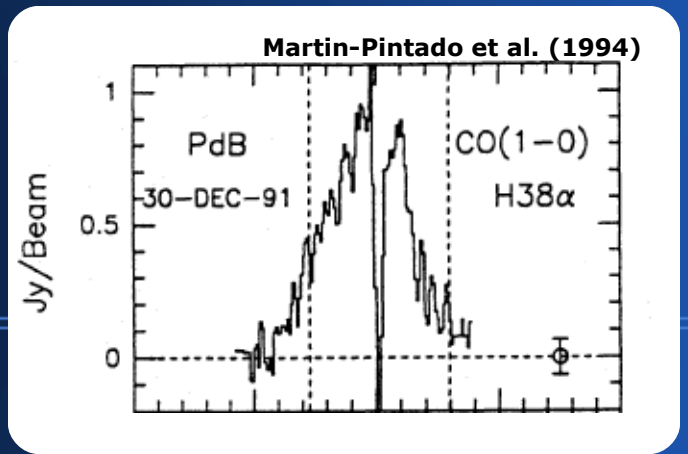

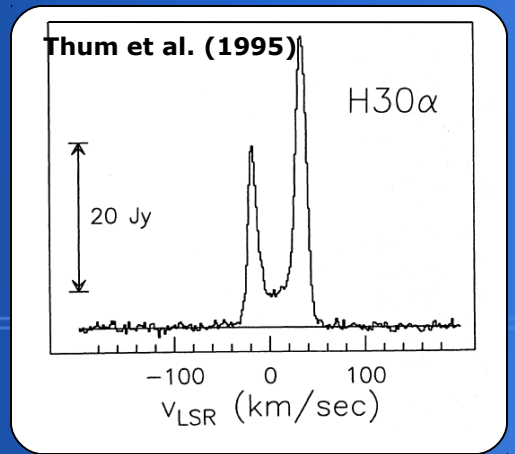

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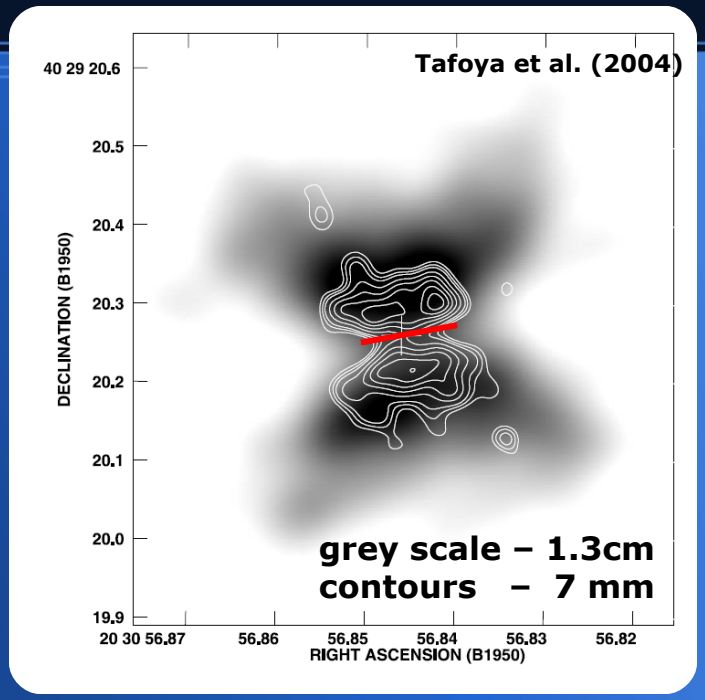

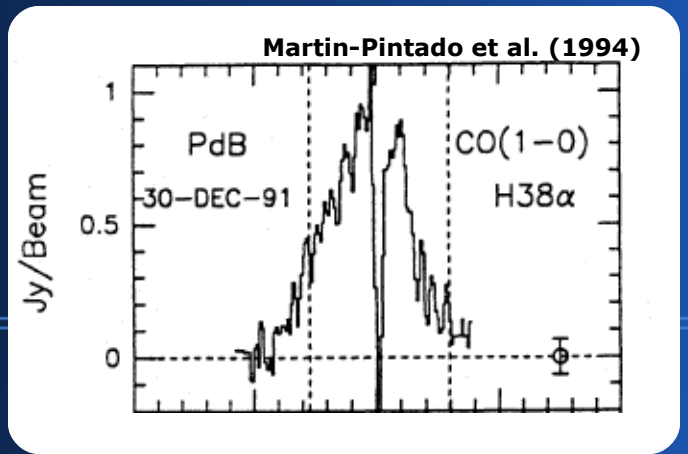

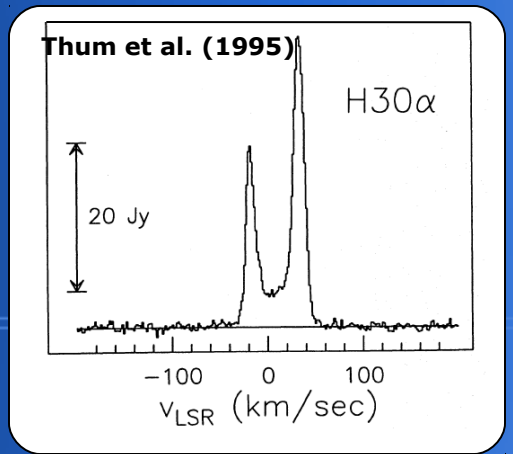

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  (~0.065”=80AU@1
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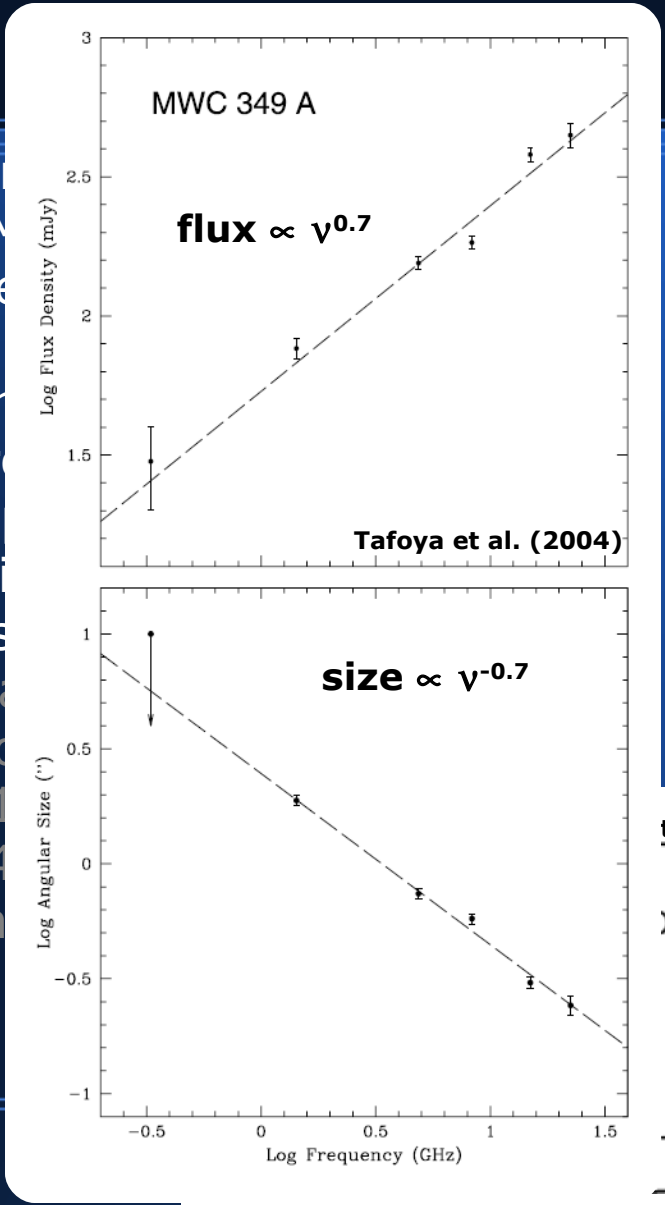
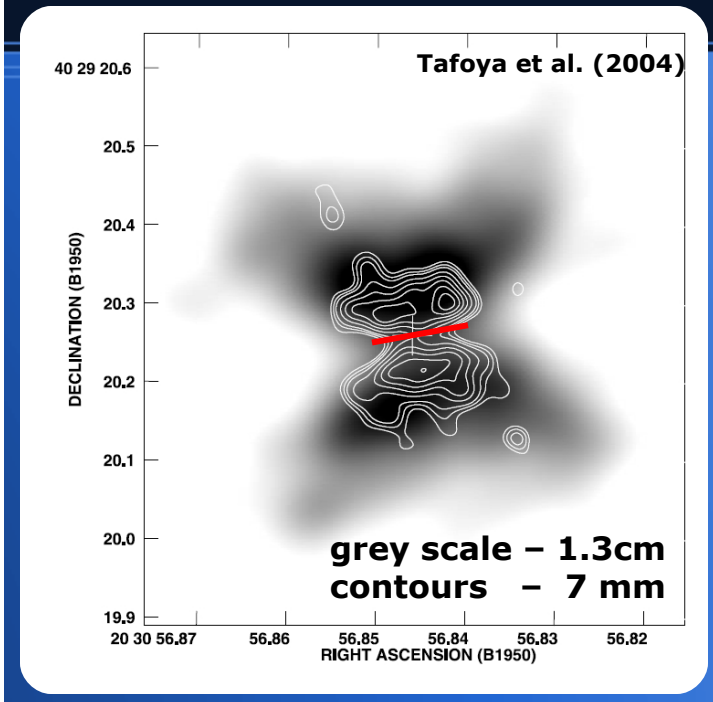
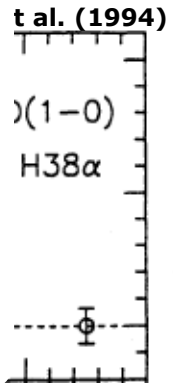
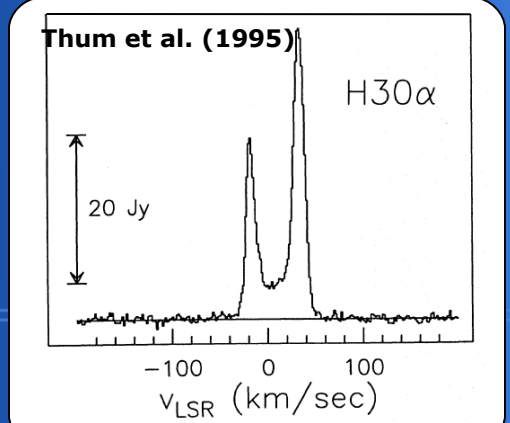
  day









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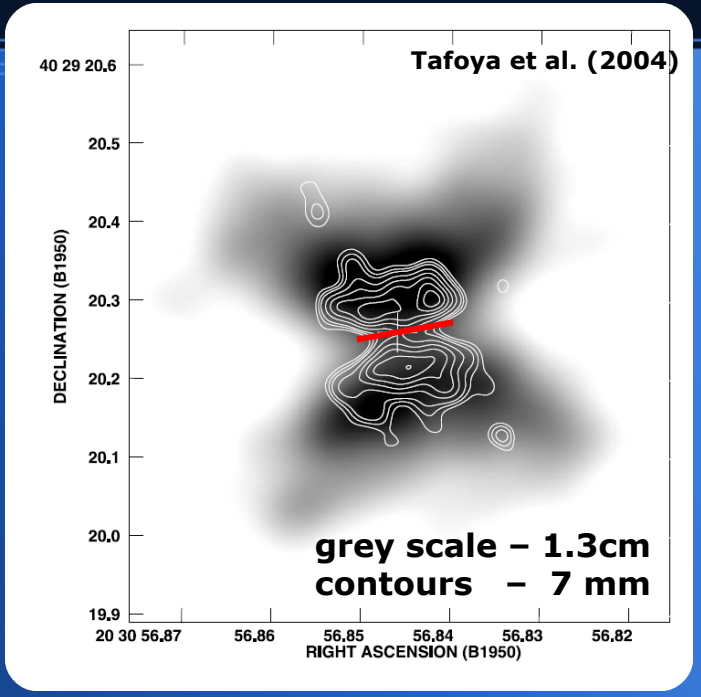

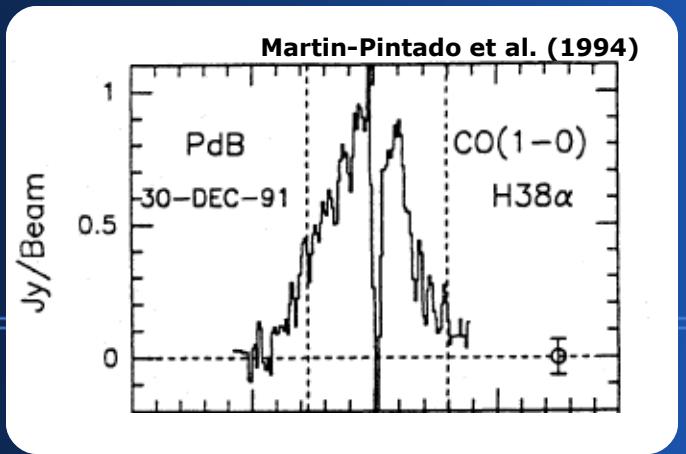

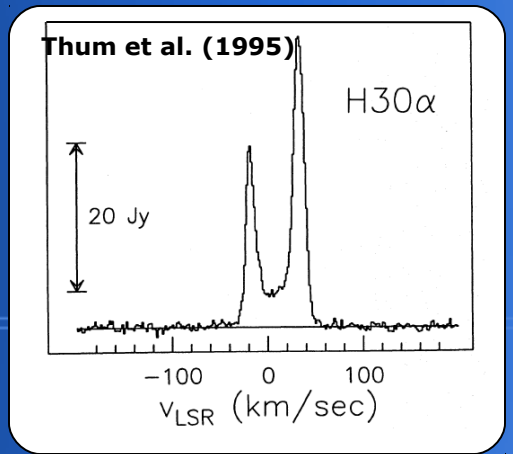

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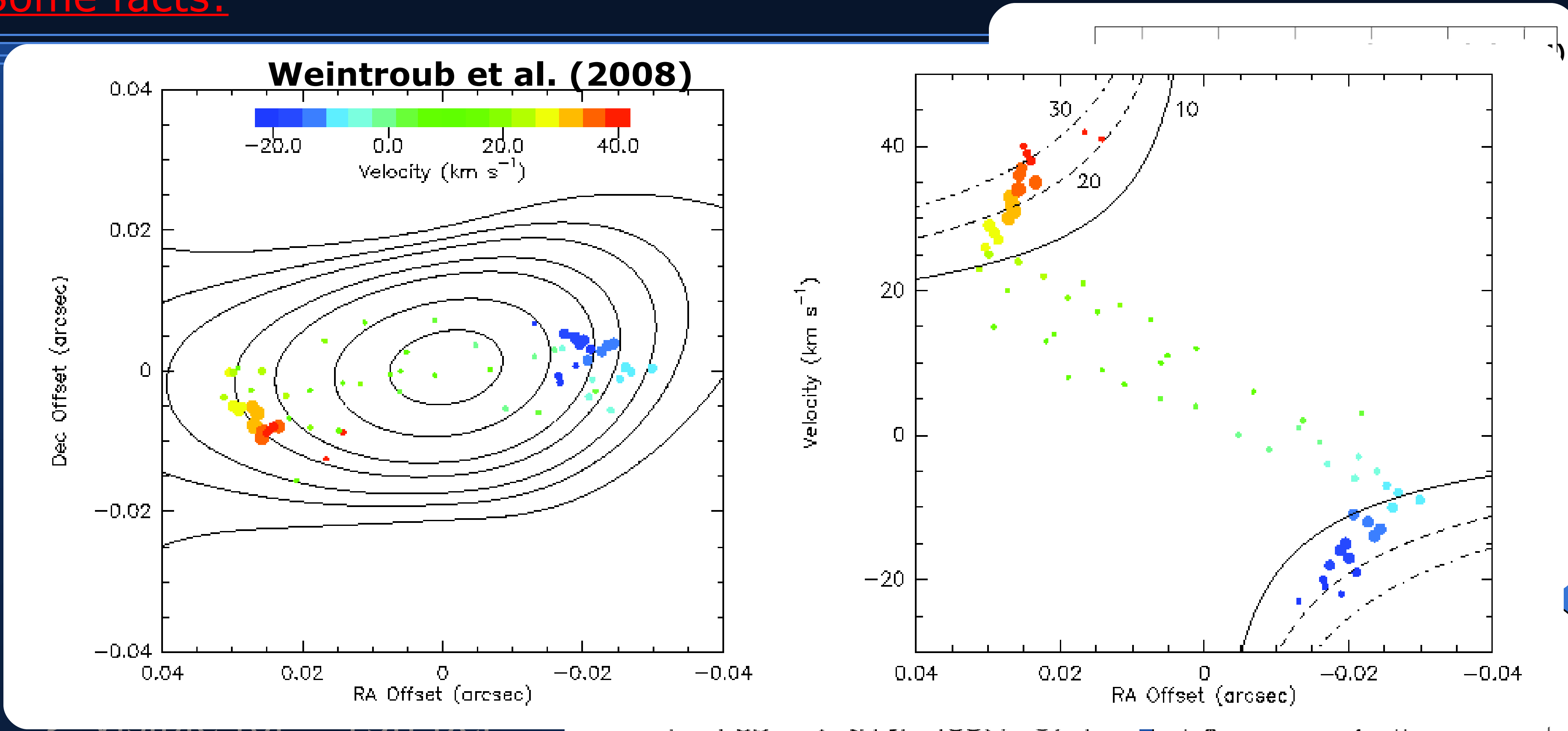

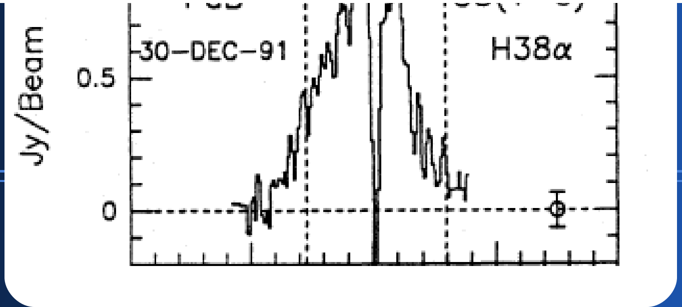

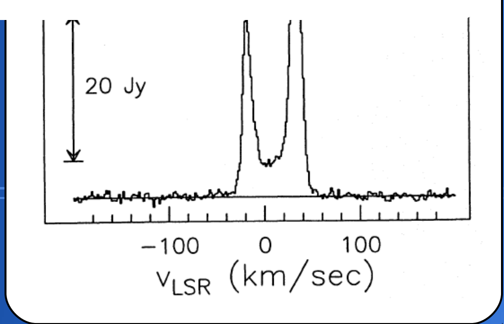

day

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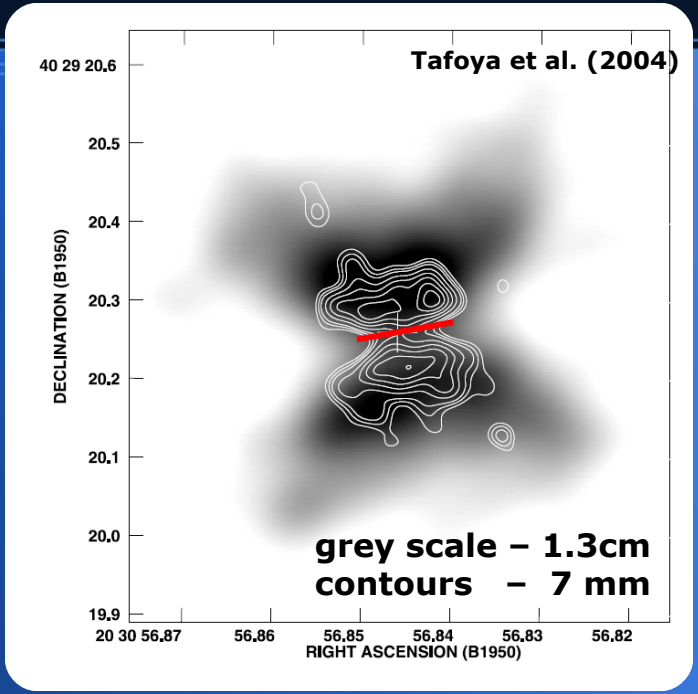
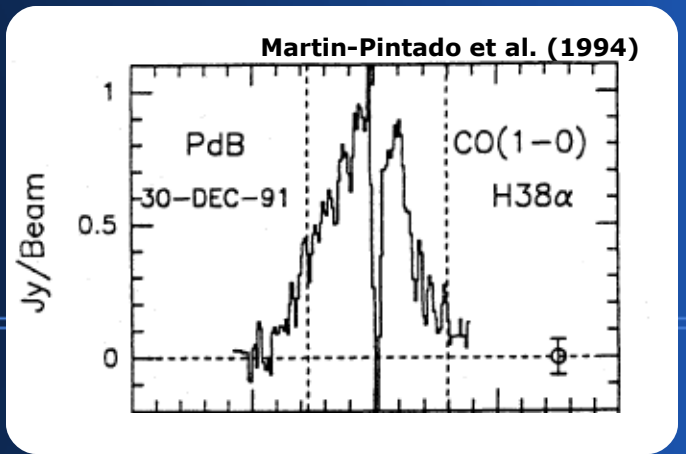
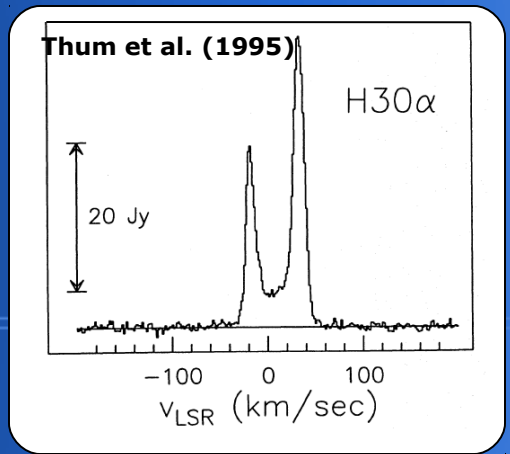
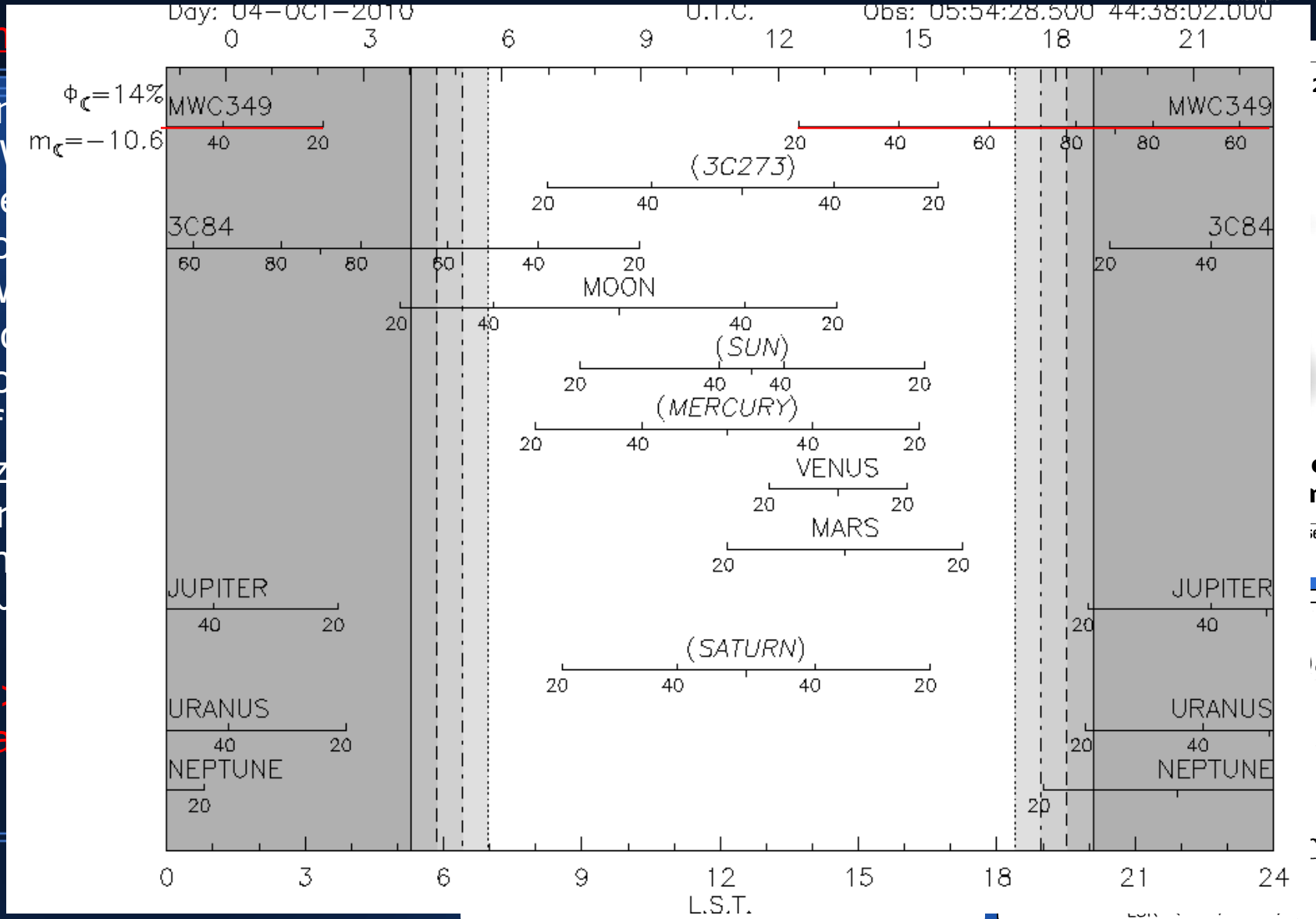






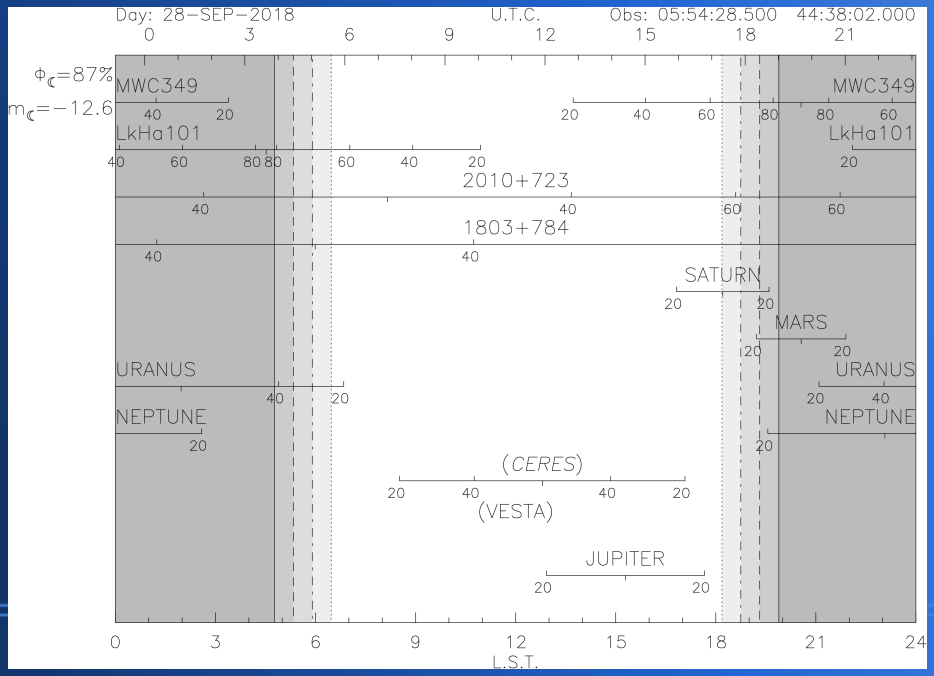
Flux Calibrators: MWC349



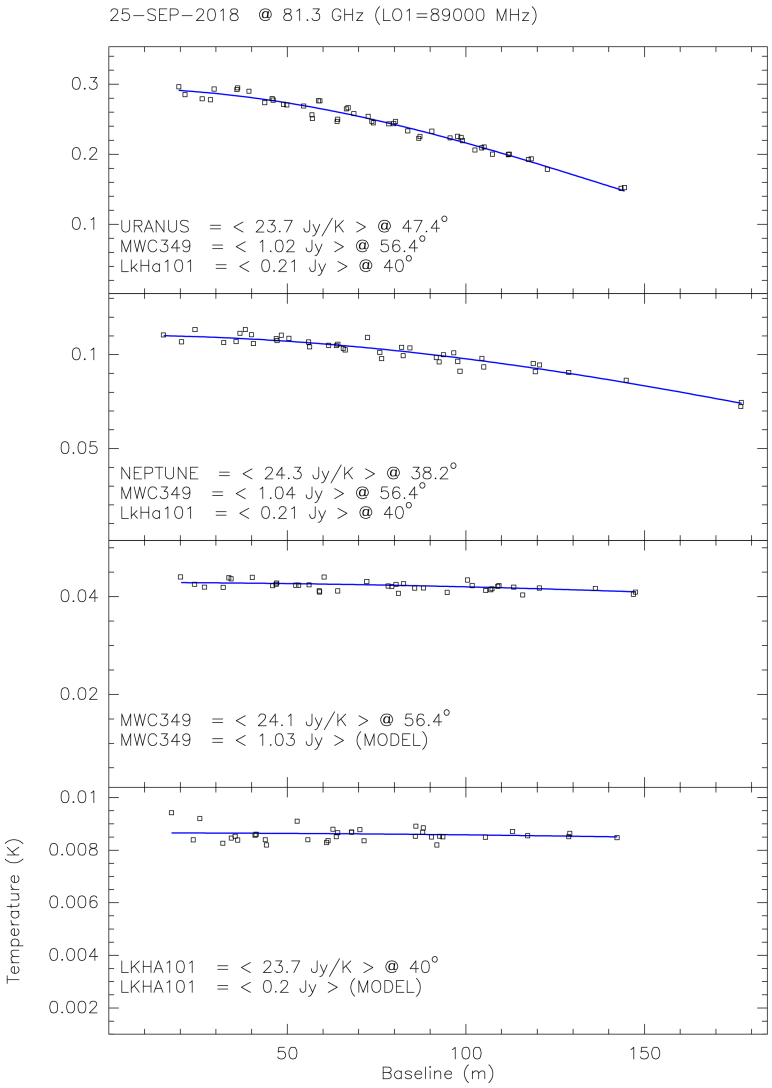
Flux Calibrators: Radio Stars

Reference radio bright stars:

- **MWC349**
- **Since ~ 2013 we also use LkHa101**
- **LkHa101 covers the complementary observable LST**
- **24h LST coverage with FLUX reference**



How to calibrate a calibrator?



ANTENNA	3C454.3@61°	mwc349@56°
1	39.9 Jy/K	40 Jy/K
2	54.1 Jy/K	54.2 Jy/K
3	76.7 Jy/K	77 Jy/K
4	52.6 Jy/K	52.8 Jy/K
5	66 Jy/K	66.2 Jy/K
6	40.6 Jy/K	40.7 Jy/K
7	48.6 Jy/K	48.7 Jy/K
8	66.9 Jy/K	67.1 Jy/K
10	35.2 Jy/K	35.3 Jy/K
Weighted Av.	53.5 Jy/K	53.8 Jy/K

SOURCE	FLUX	MAJOR	MINOR	PA
URANUS	7	3.71	3.63	260
NEPTUNE	2.7	2.36	2.32	324
3C454.3	12.71	(URANUS)		
3C454.3	12.99	(NEPTUNE)		

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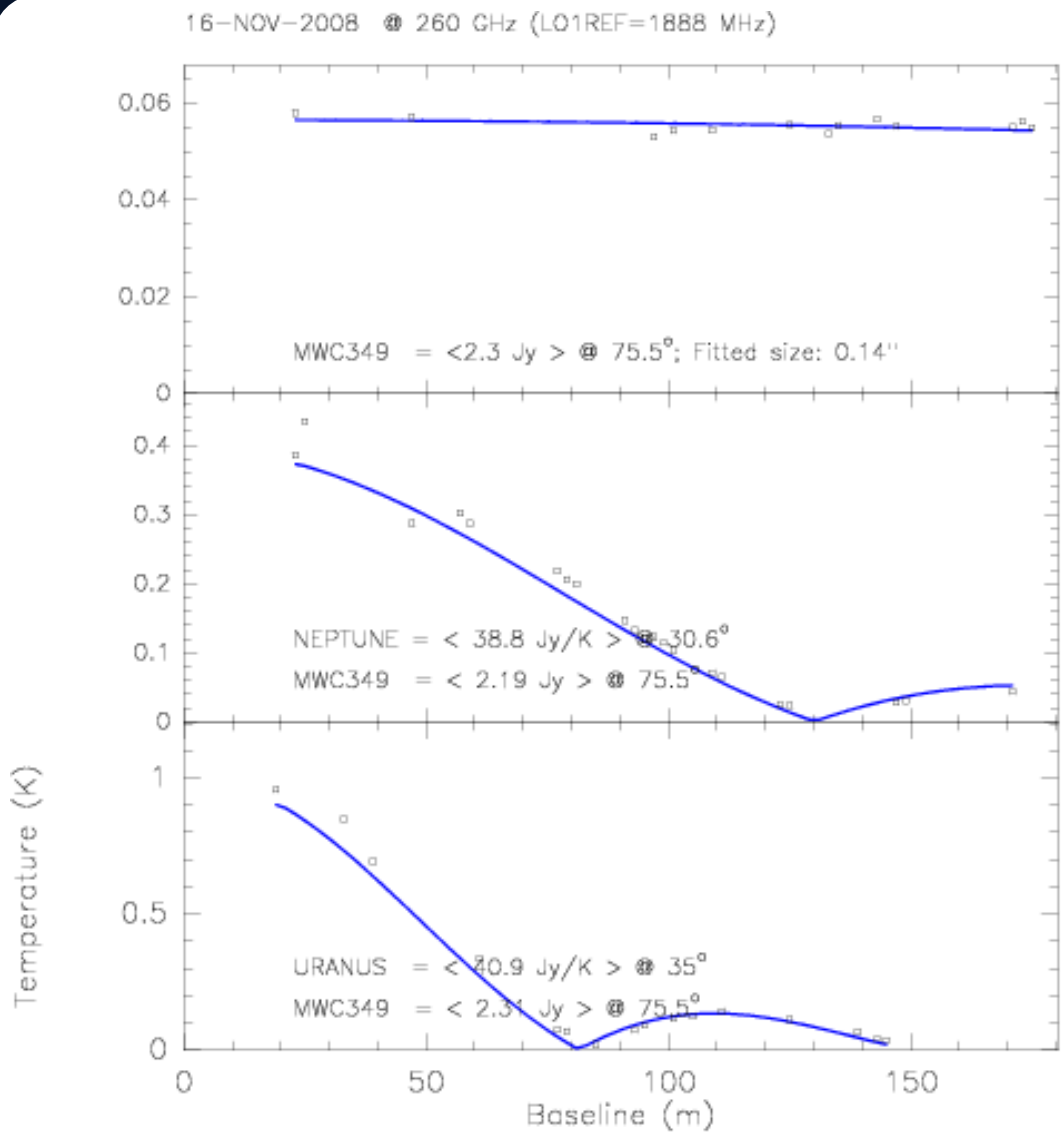
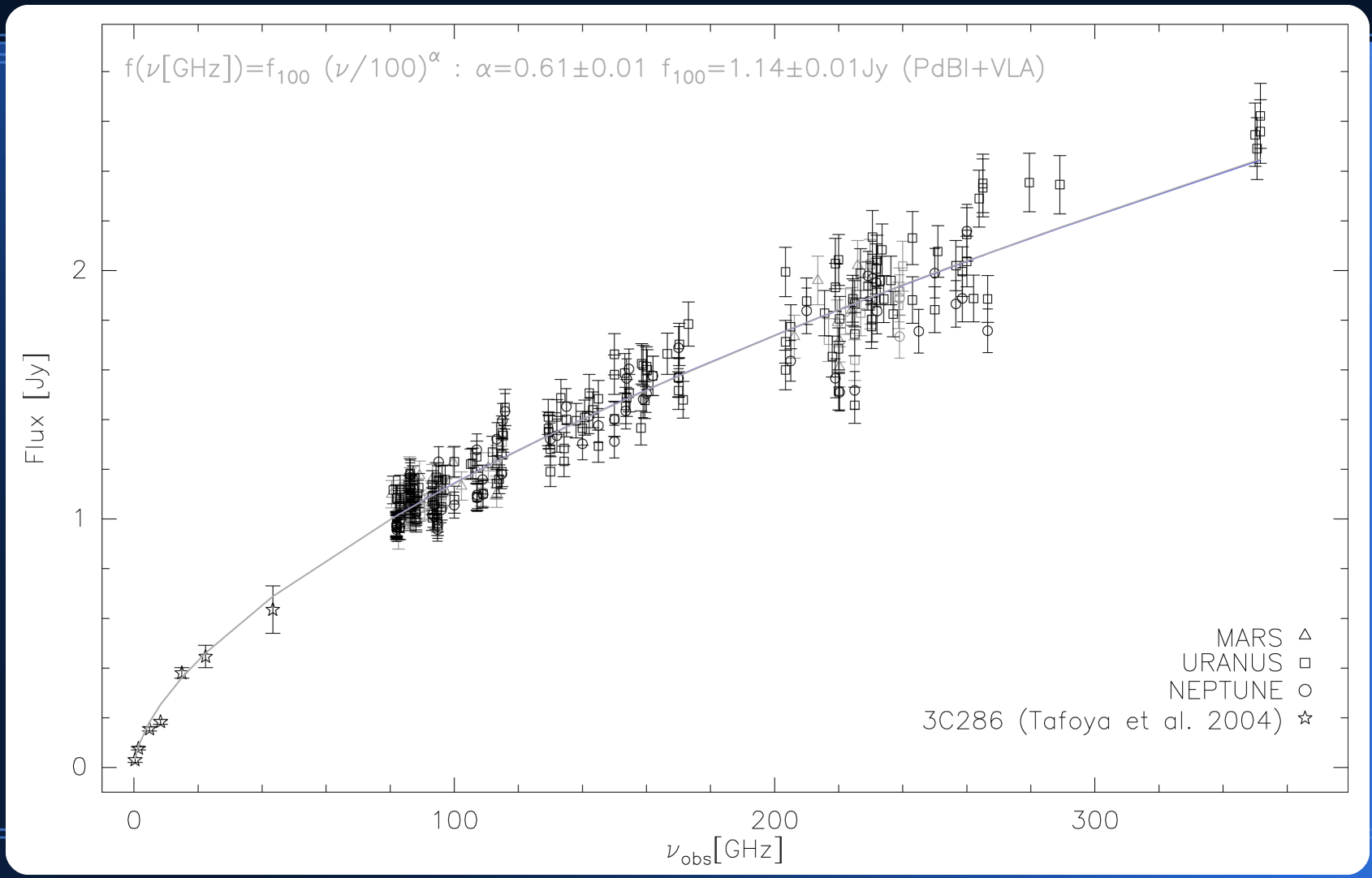


ANTENNA	3c454.3@52°	mwc349@75°
1	39.9 Jy/K	41.2 Jy/K
2	34.6 Jy/K	35.8 Jy/K
3	41.8 Jy/K	45.3 Jy/K
4	51.4 Jy/K	50.4 Jy/K
5	34.5 Jy/K	34.9 Jy/K
6	39.9 Jy/K	40.5 Jy/K
Weighted Av.	38 Jy/K	39.3 Jy/K

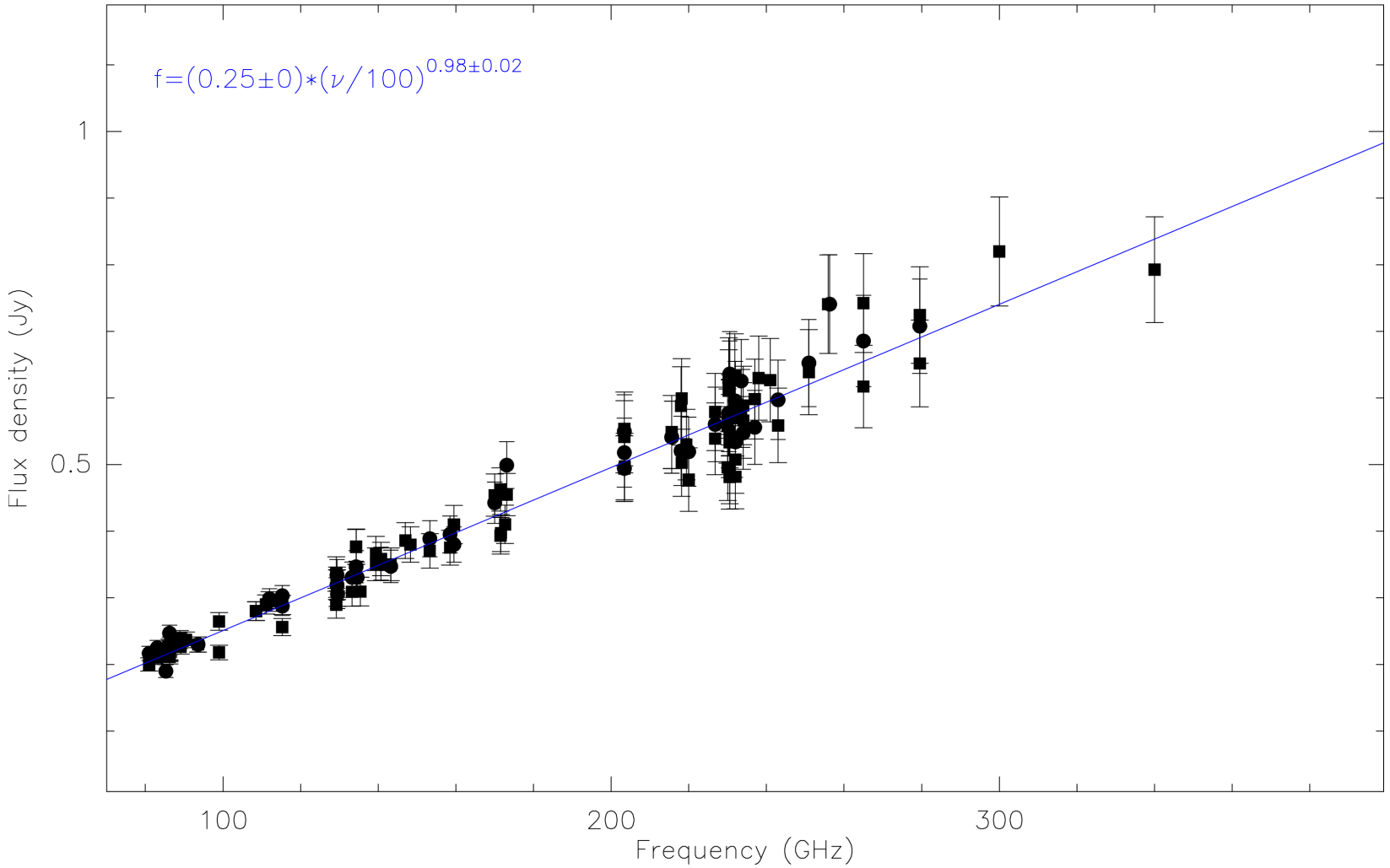
SOURCE	FLUX	MAJOR	MINOR	PA
URANUS	41.1	3.56	3.45	255
NEPTUNE	15.4	2.23	2.17	340

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

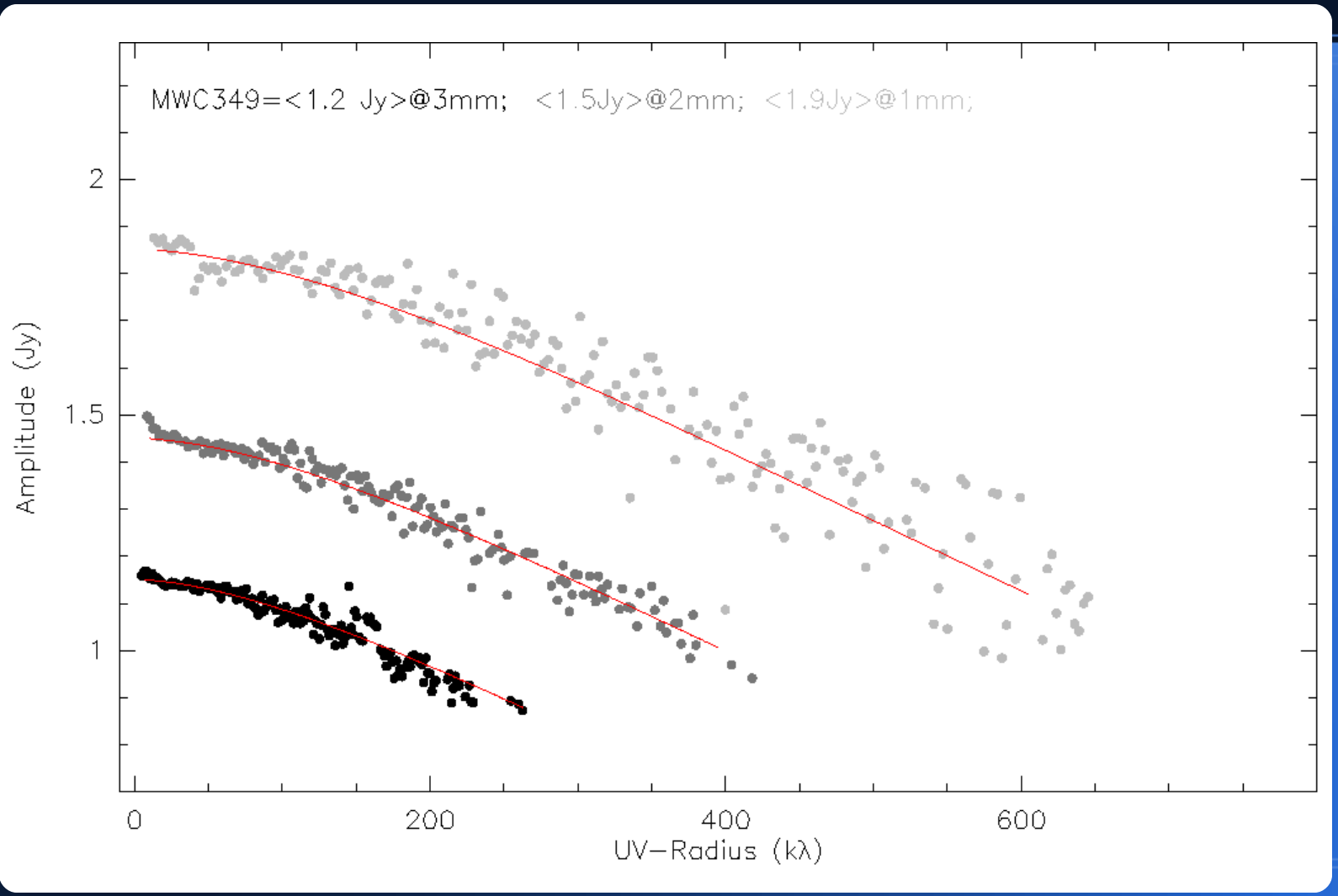
Flux of MWC349: SED



Flux of LkHa101: SED



Size of MWC349



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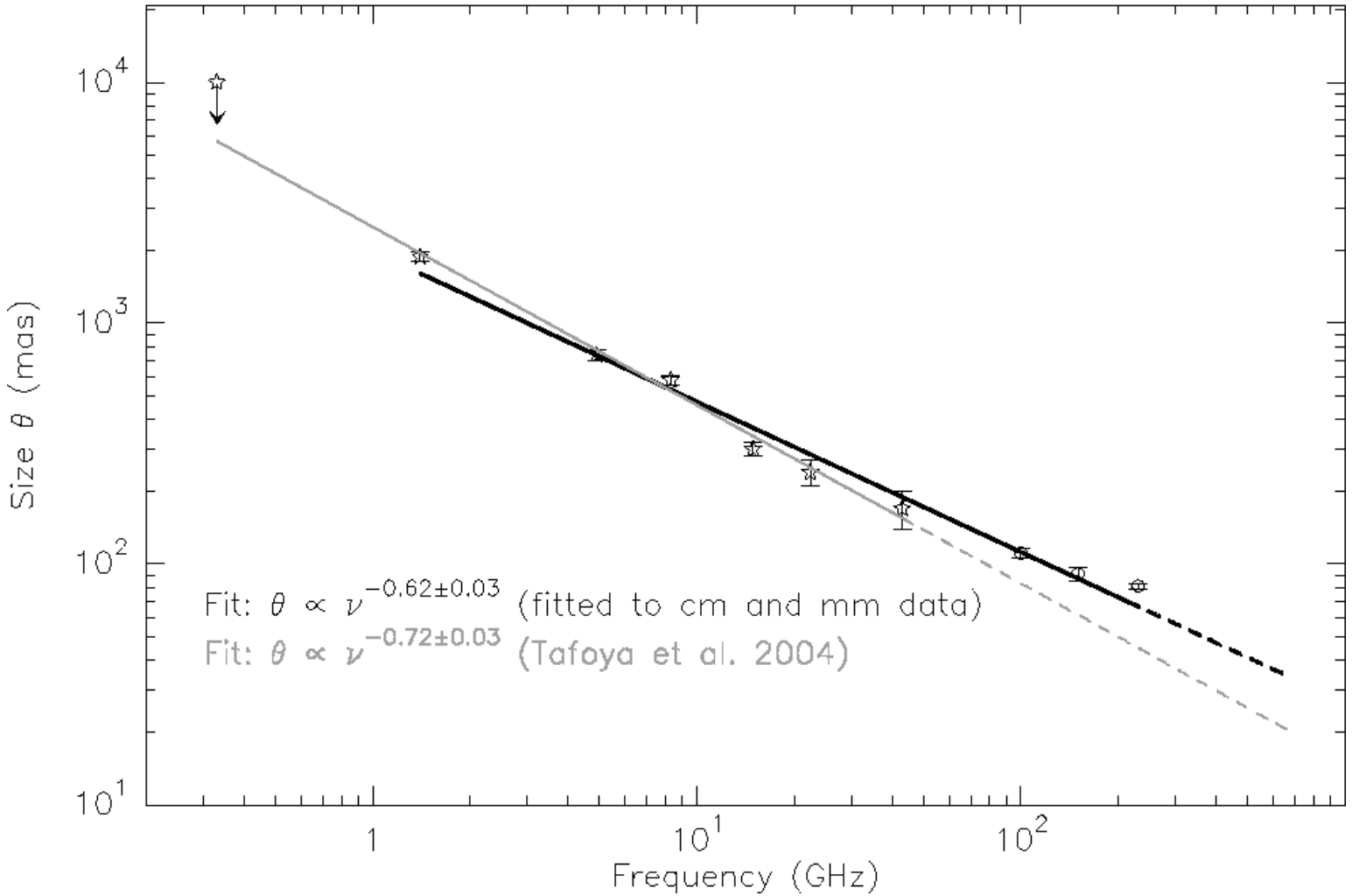
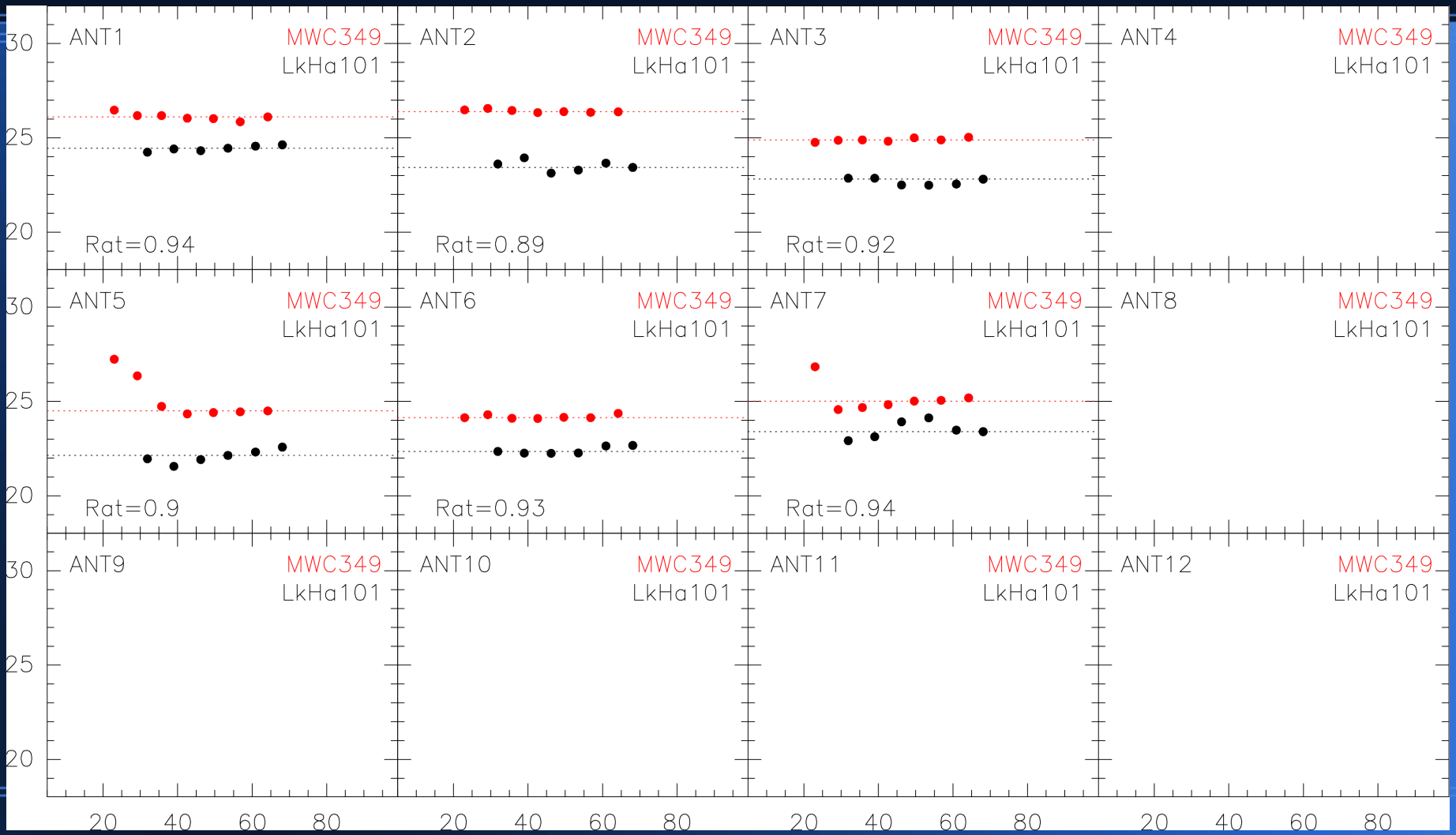
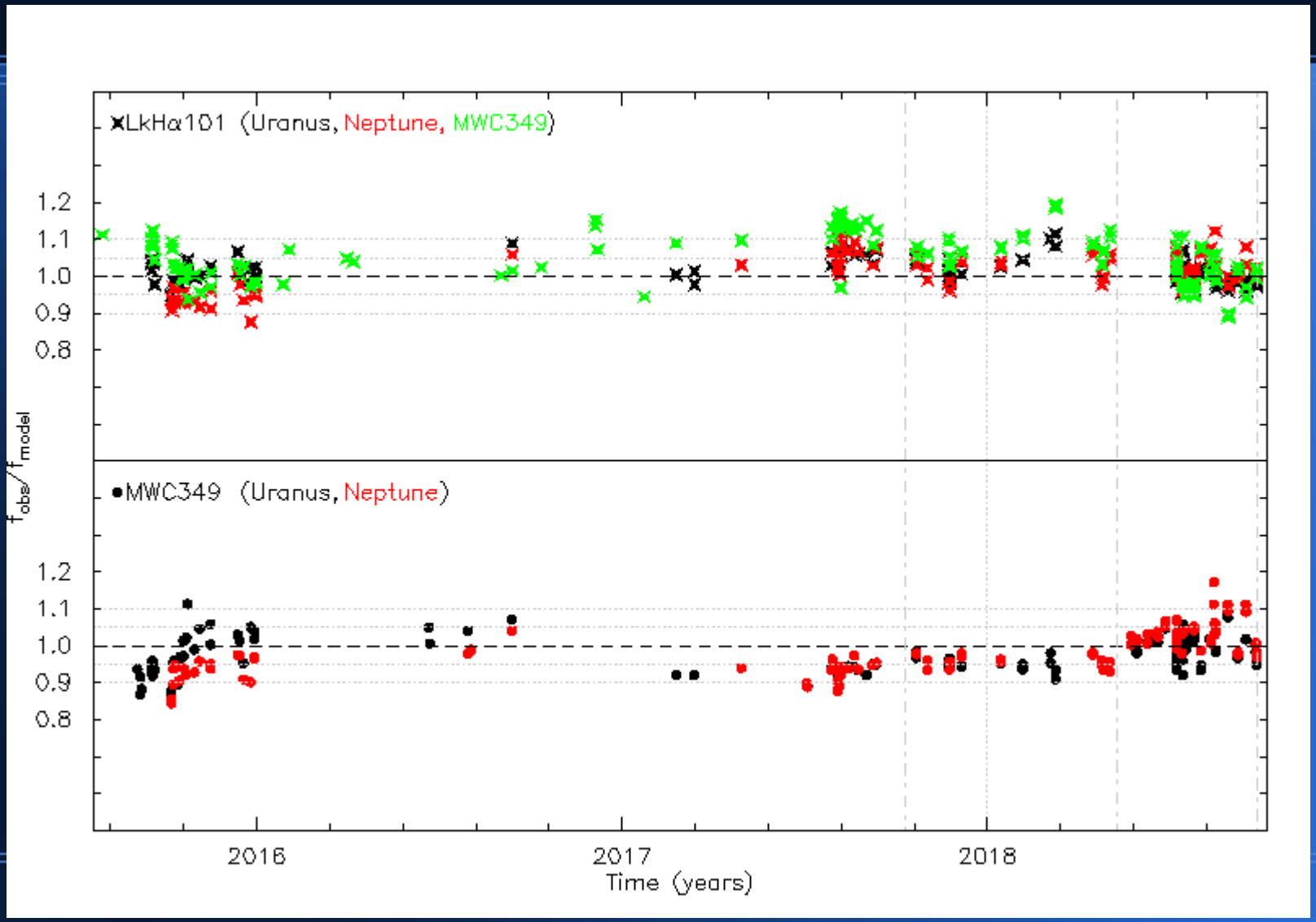


Flux of MWC349 & LkHa101: Variability



Flux of MWC349 & LkHa101: Variability



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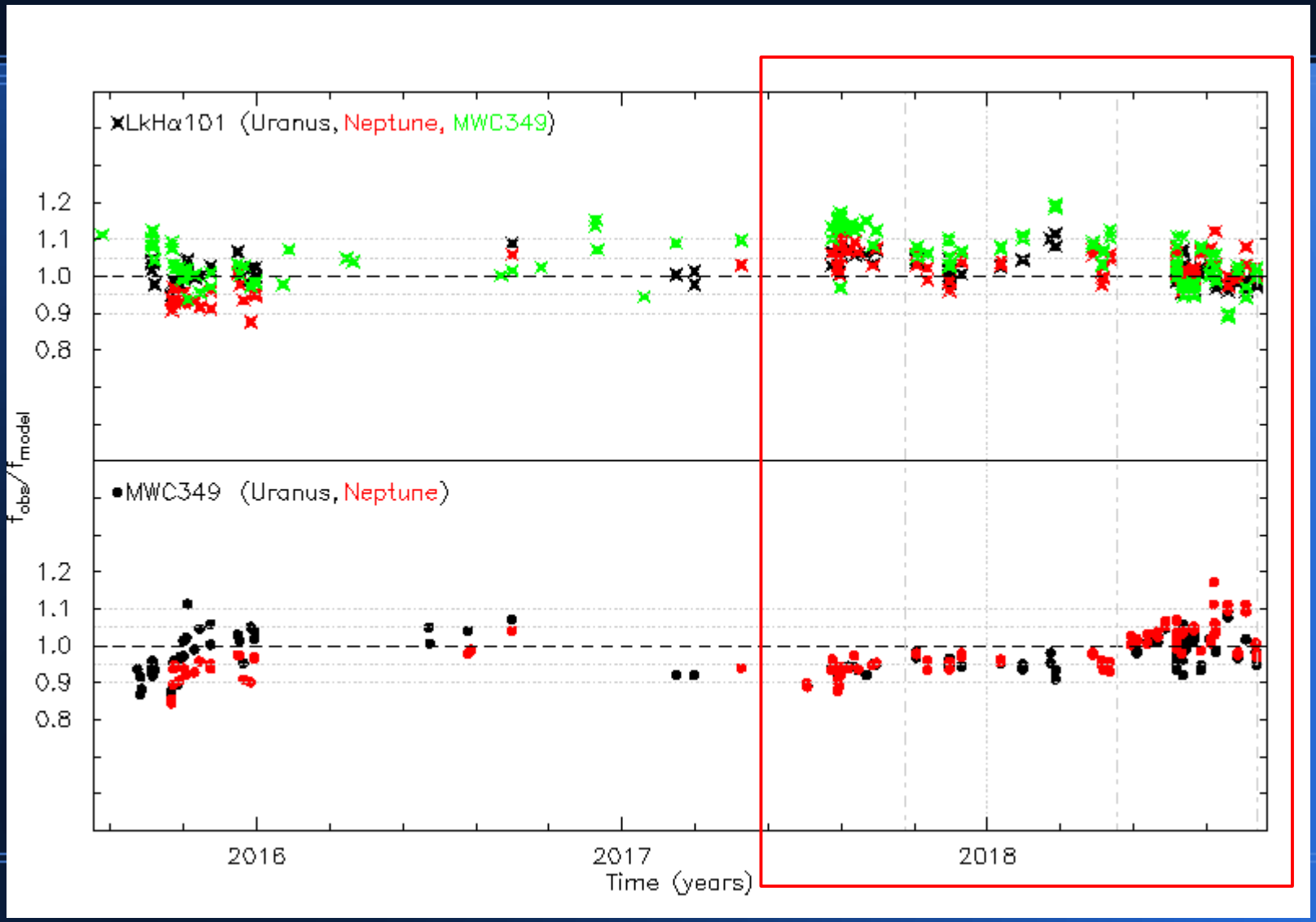

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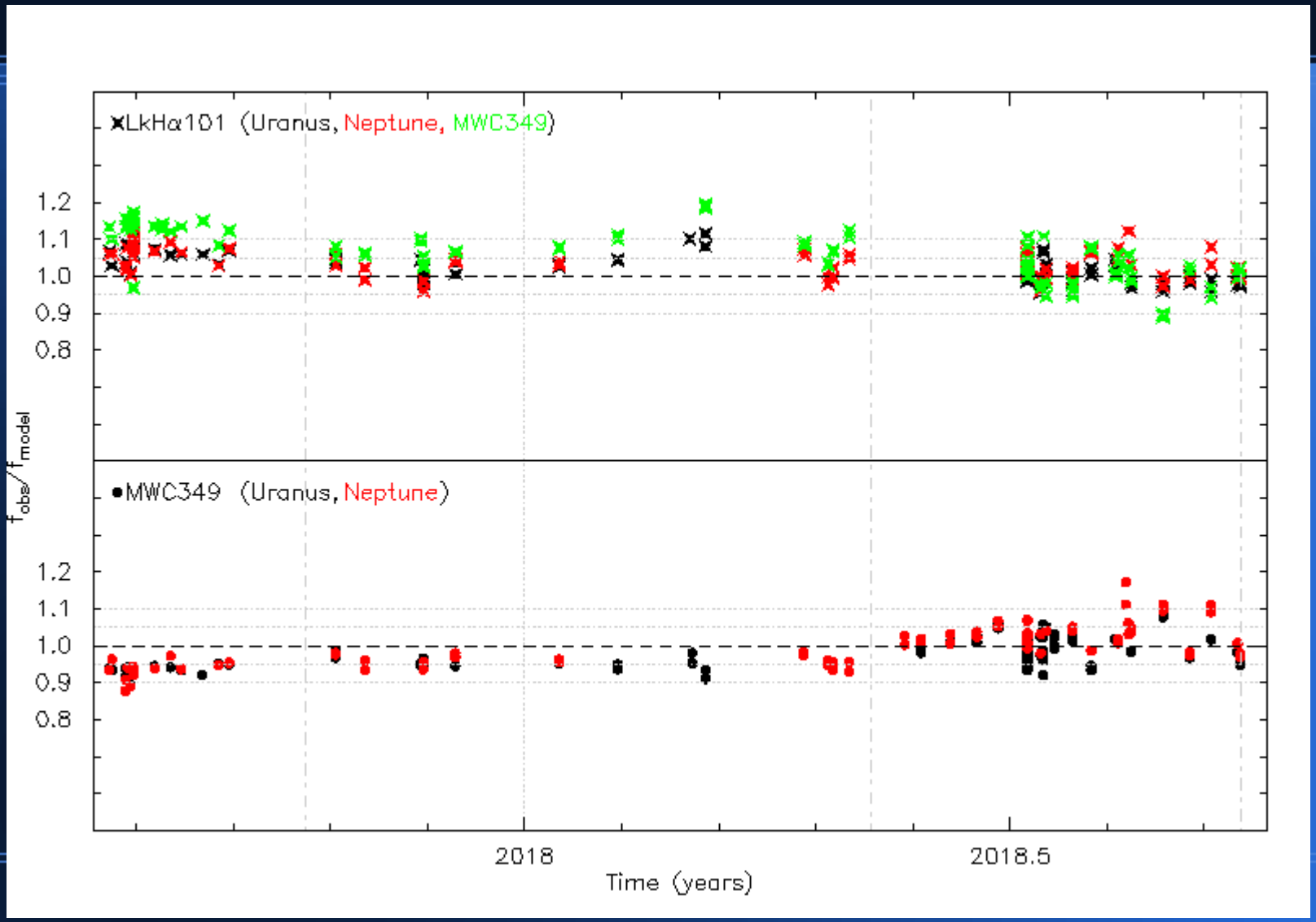

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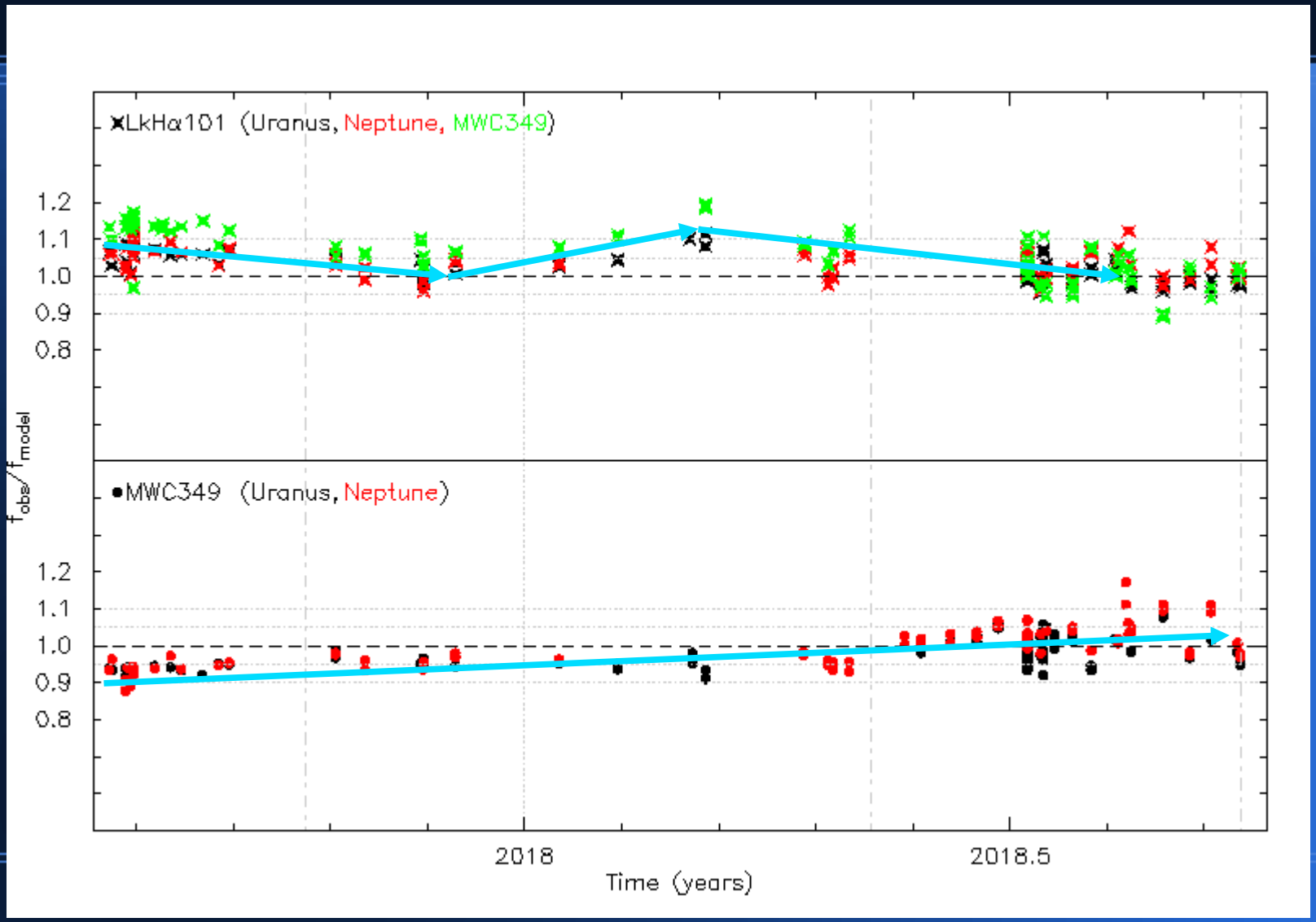


Outline

I. Why?

II. Primary/Secondary Flux Calibrators

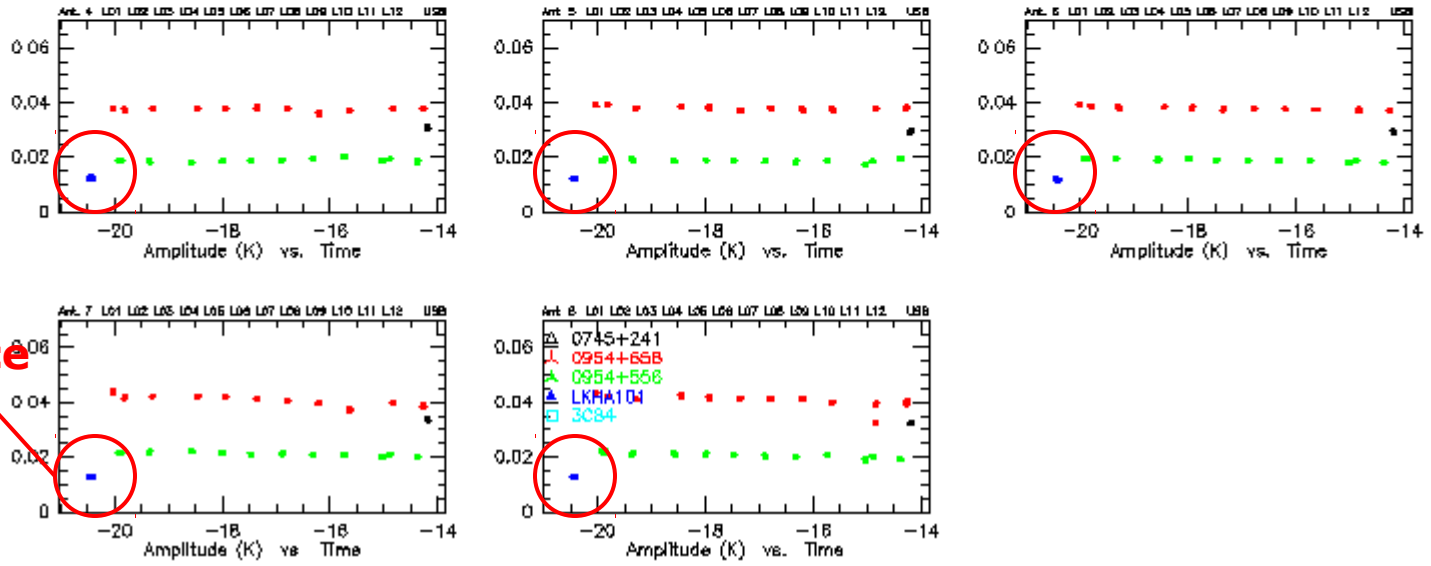
III. Practical Tips to Calibrate the Fluxes of your Sources

Practical Tips

Steps in flux calibration:

1) Fix the flux (Jy) of the reference calibrator
2) Estimate K/Jy factor (antenna efficiency)
3) Derive flux for other calibrators

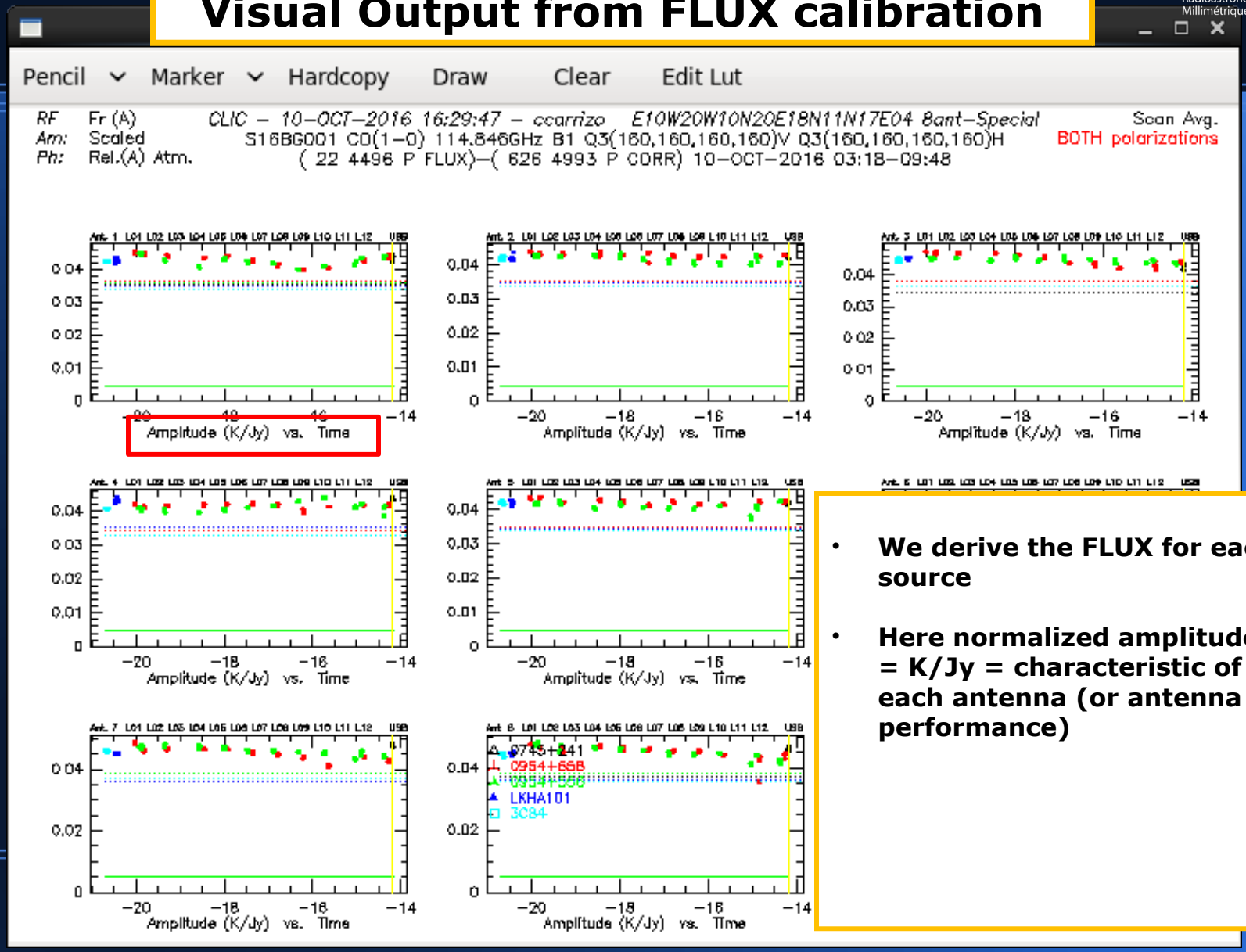
Final representation = normalized amplitudes = antenna efficiencies (Jy/K or K/Jy)



Flux reference

Practical Tips

Visual Output from FLUX calibration



- **We derive the FLUX for each source**
- **Here normalized amplitudes = K/Jy = characteristic of each antenna (or antenna performance)**

Practical Tips

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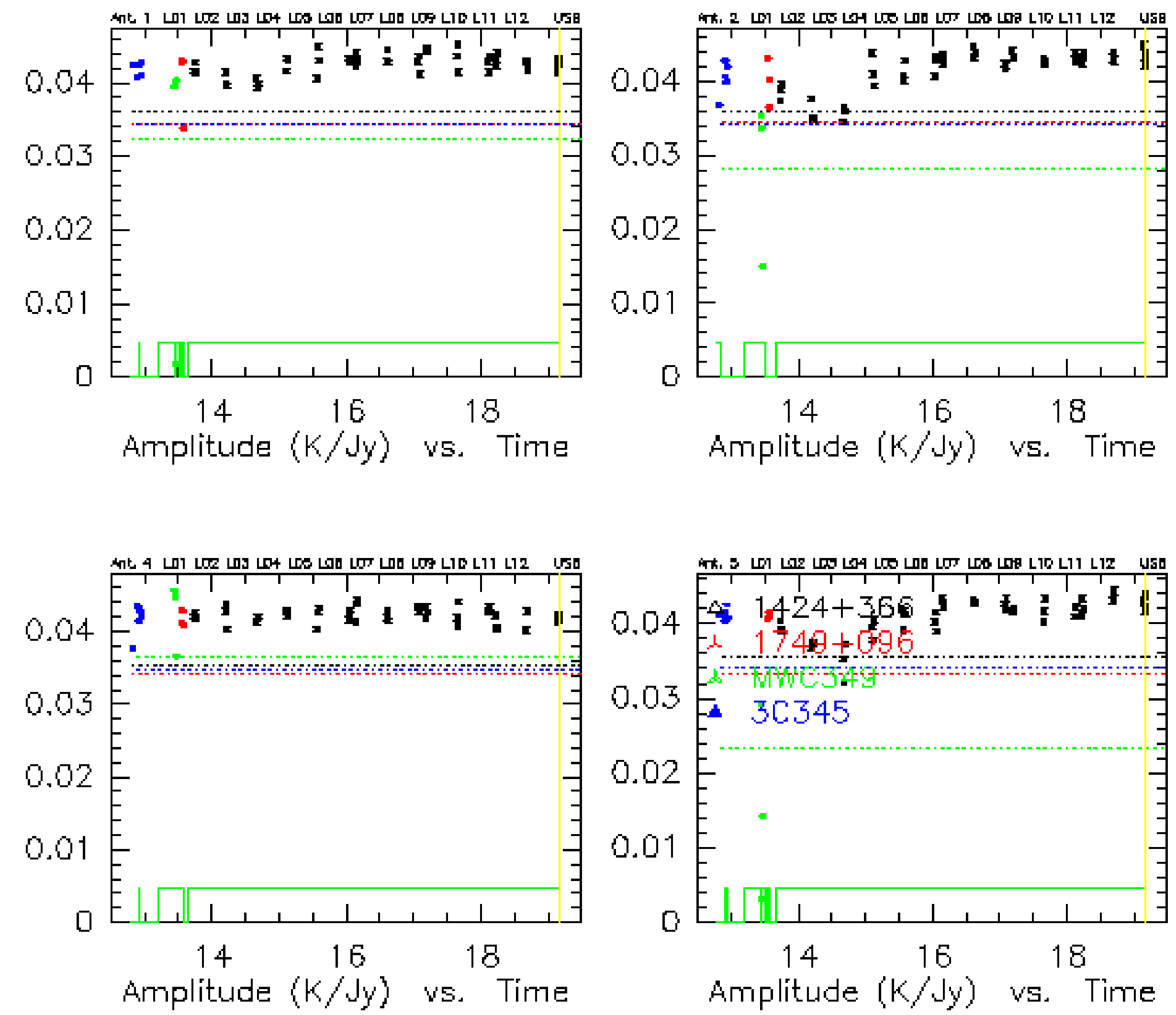

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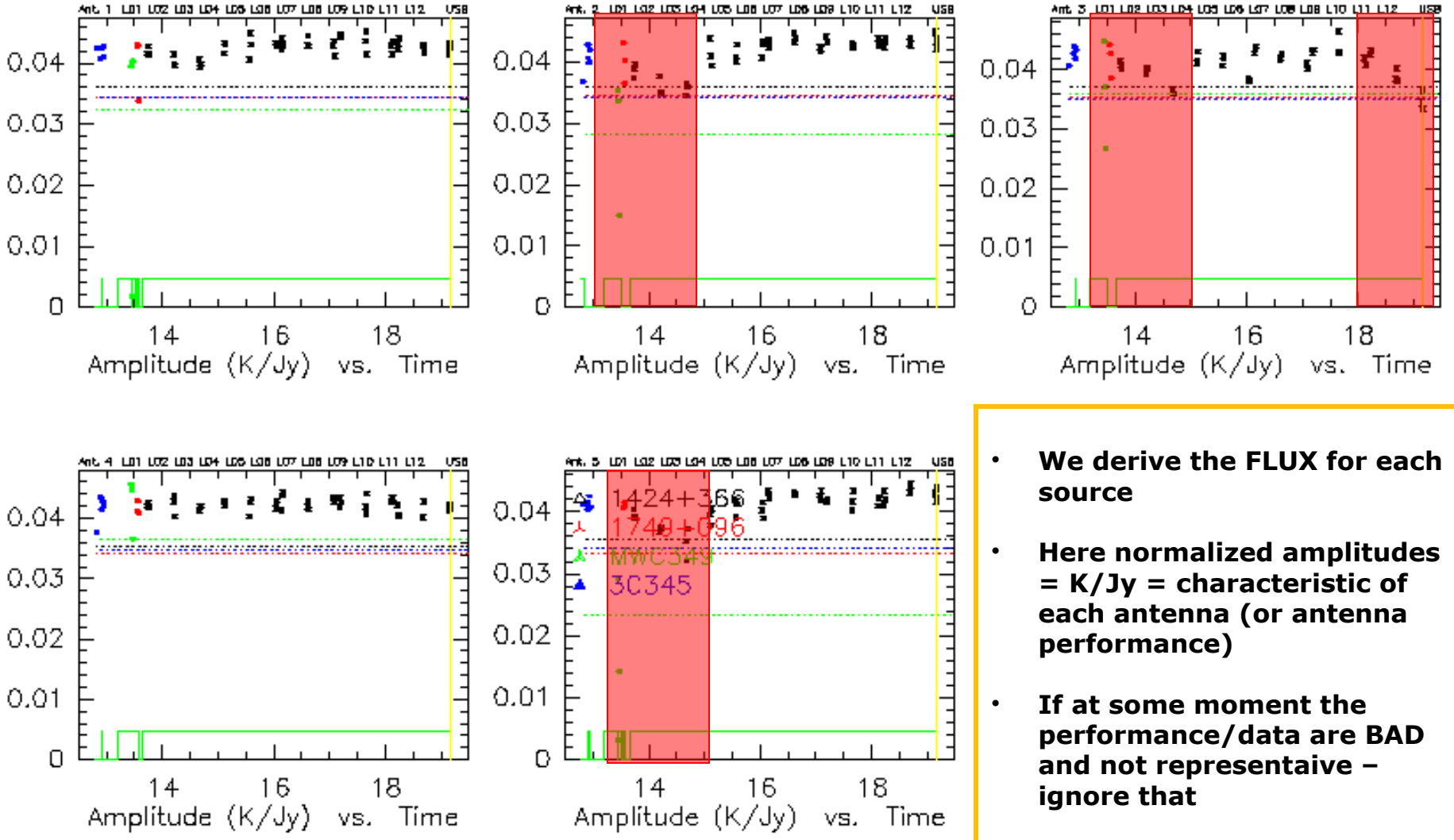

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Practical Tips

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Which are the issues to consider?

Checklist:

- **Antenna Shadowing**
- **Pointing/Focus Problems**
- **Tracking Problems**
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- **Has Flux Calibrator Lines?**
- **Is Flux Calibrator Extended?**
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- **Do phases of different spectral windows overlap?**

Practical Tips: Shadowing

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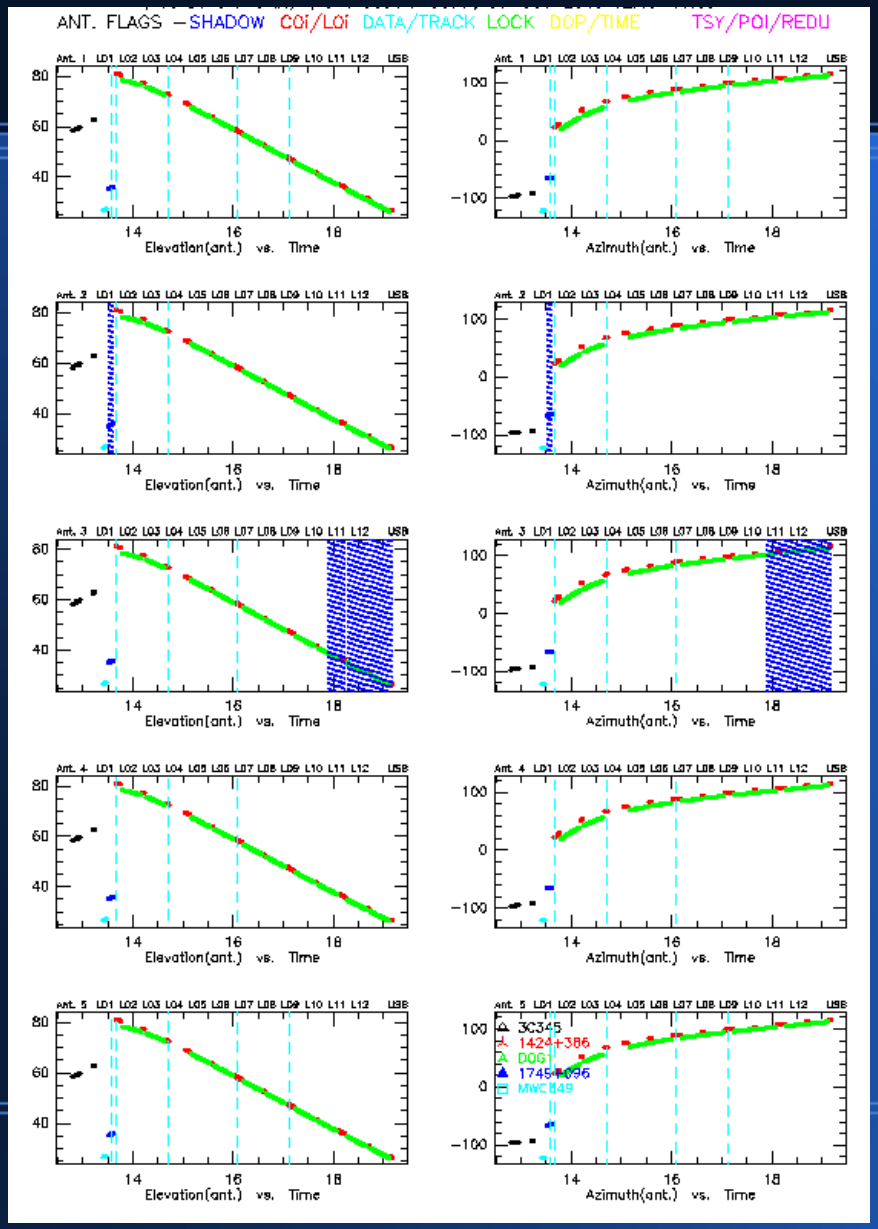
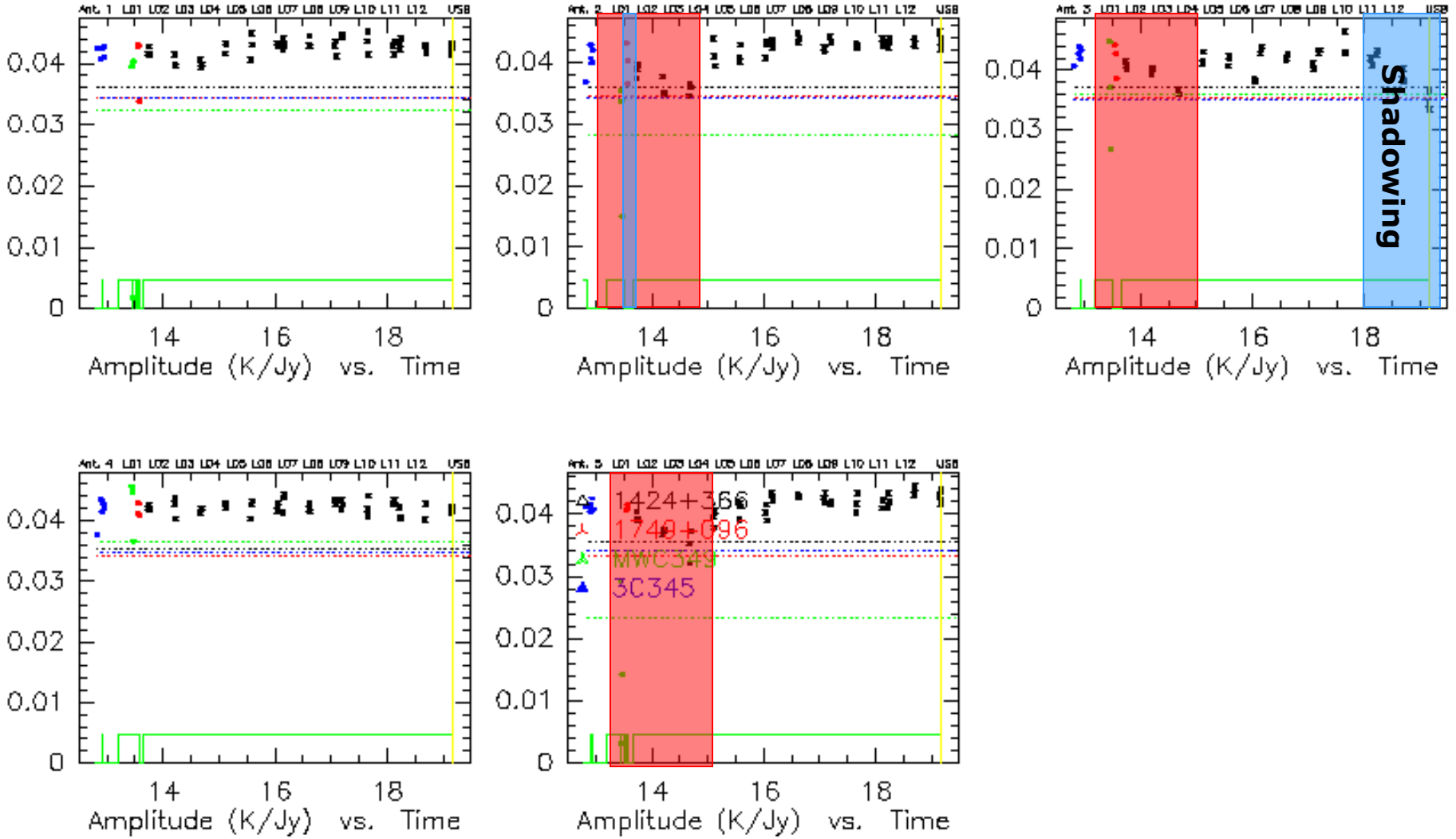


Practical Tips: Shadowing



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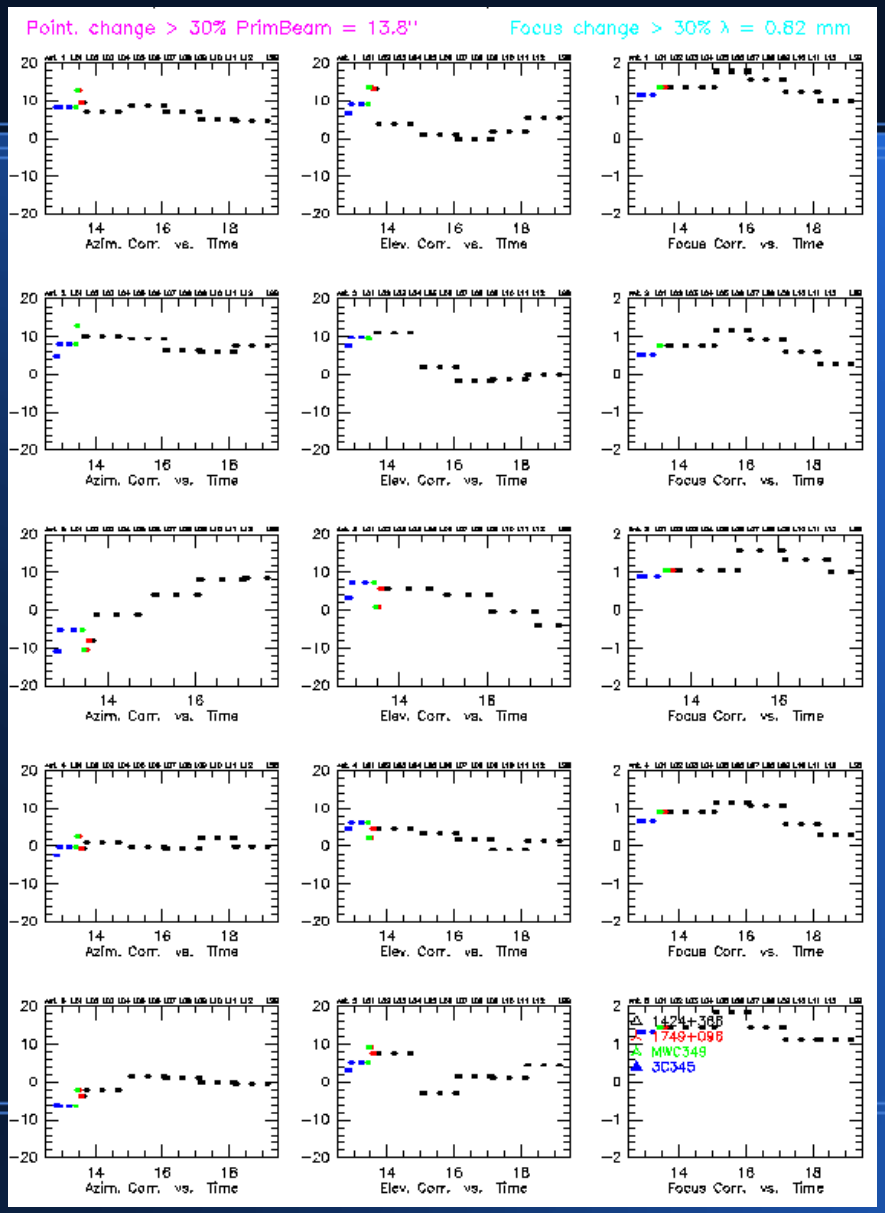

Practical Tips: Pointing/Focus

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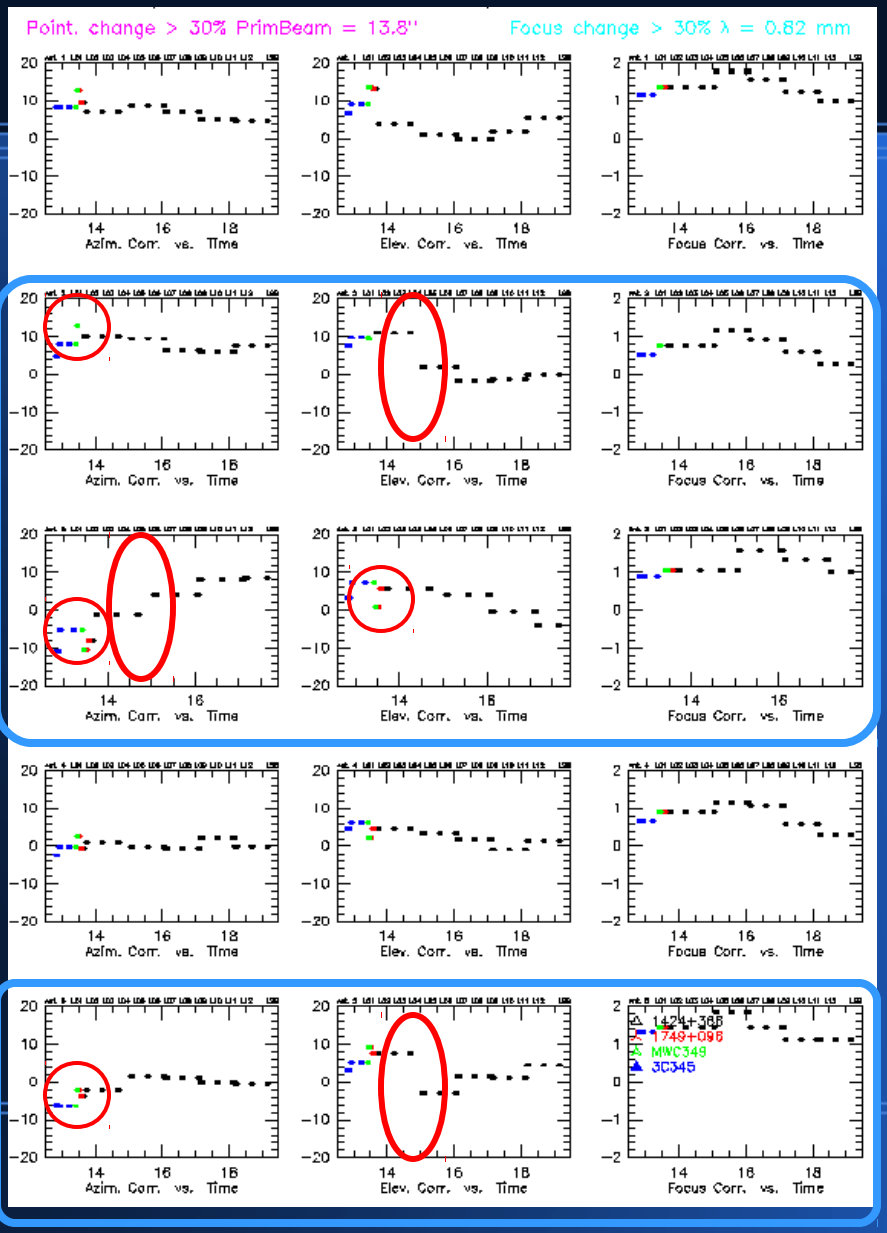
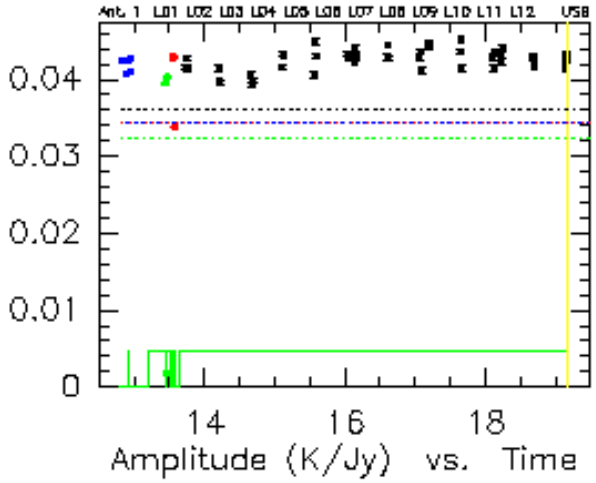
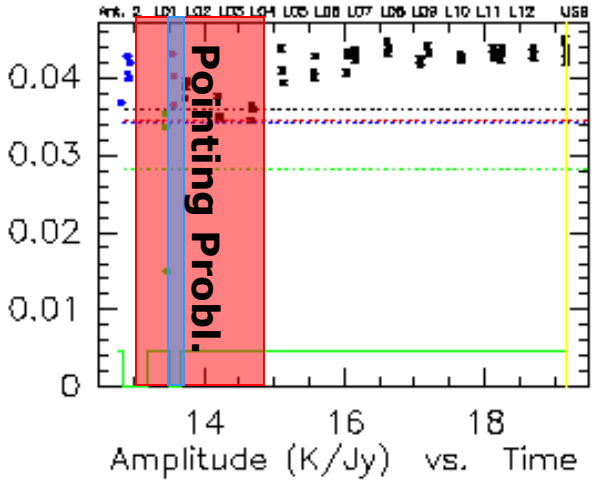
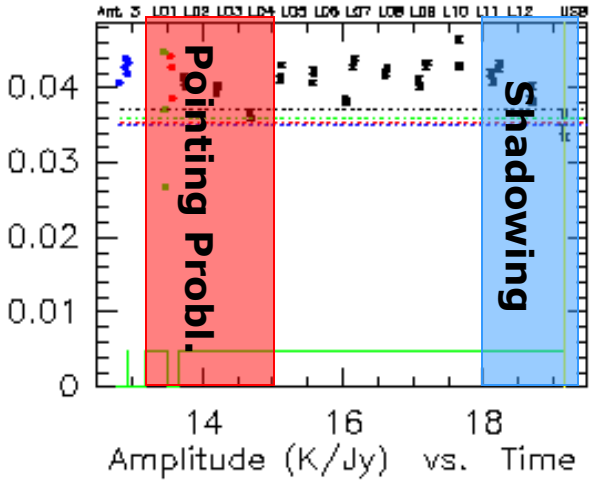
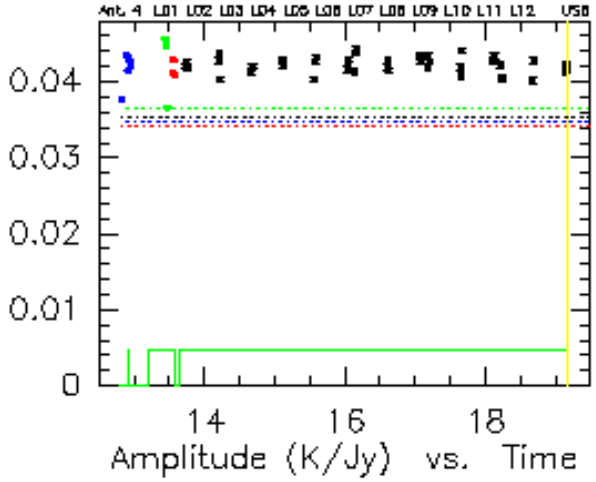


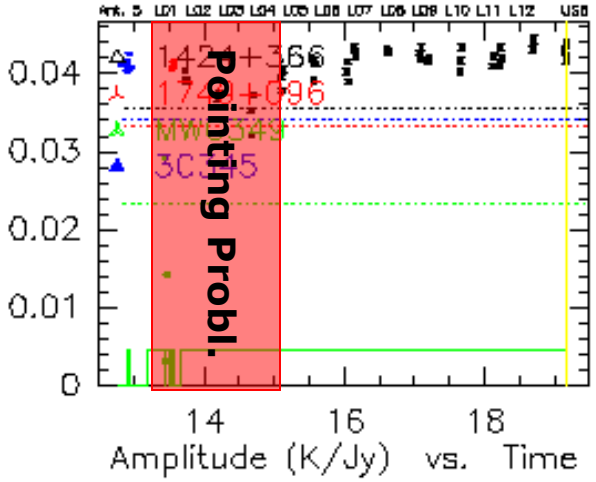
Practical Tips



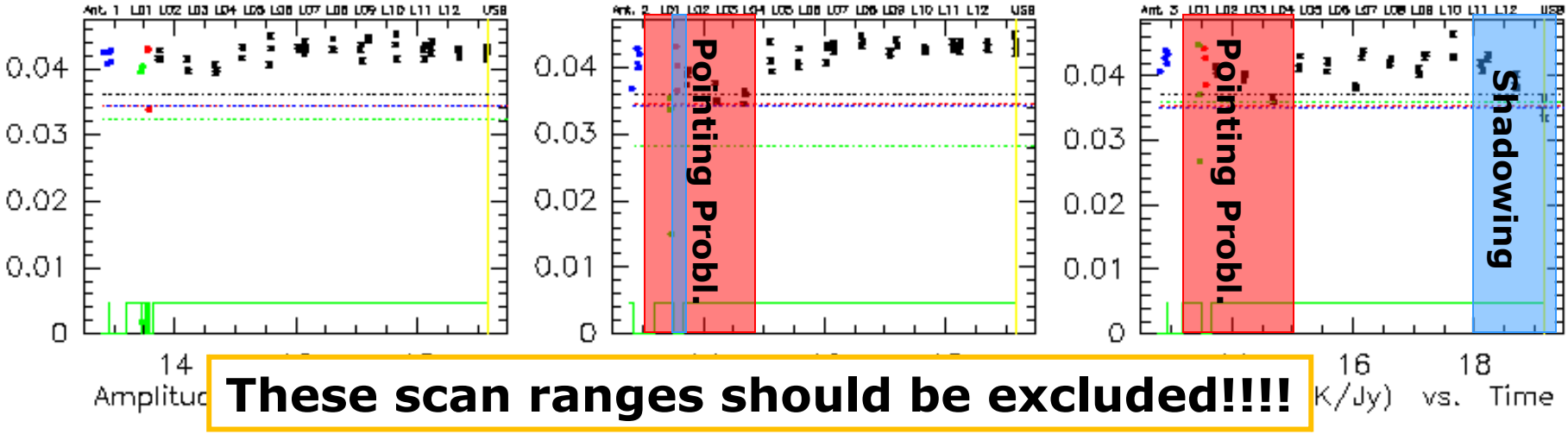




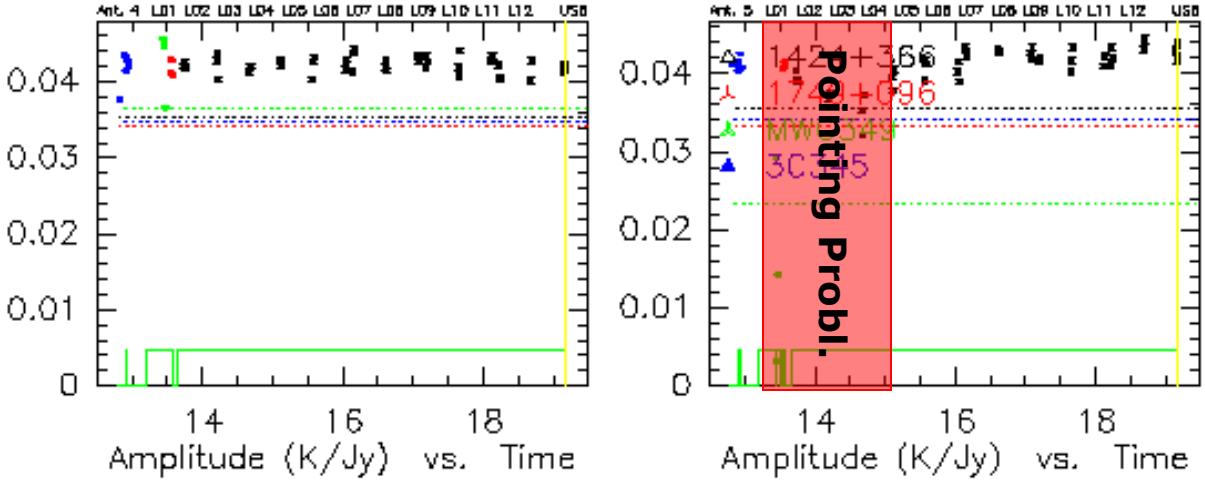




Practical Tips



These scan ranges should be excluded!!!!



Practical Tips

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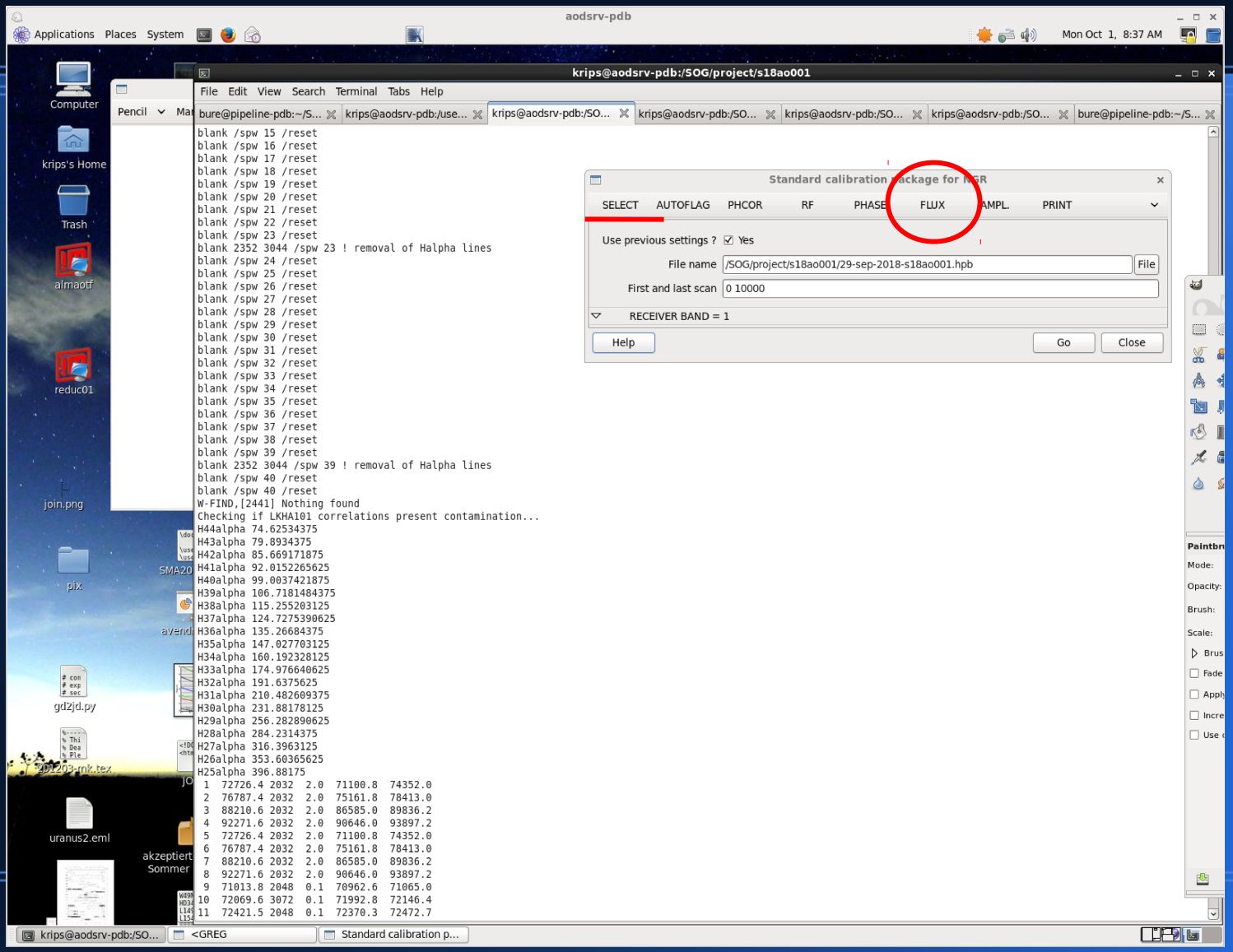
Practical Tips: CLIC software tools



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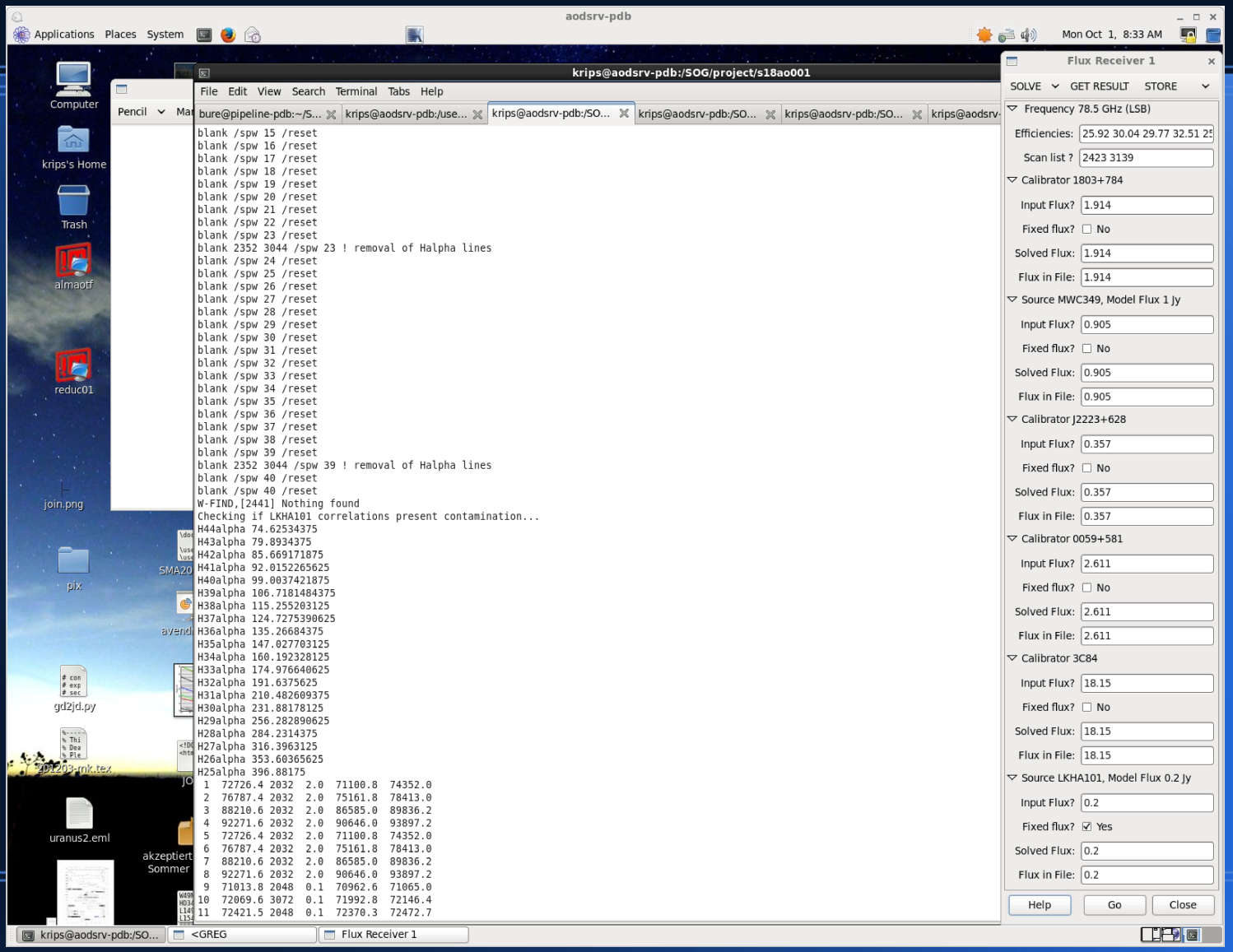

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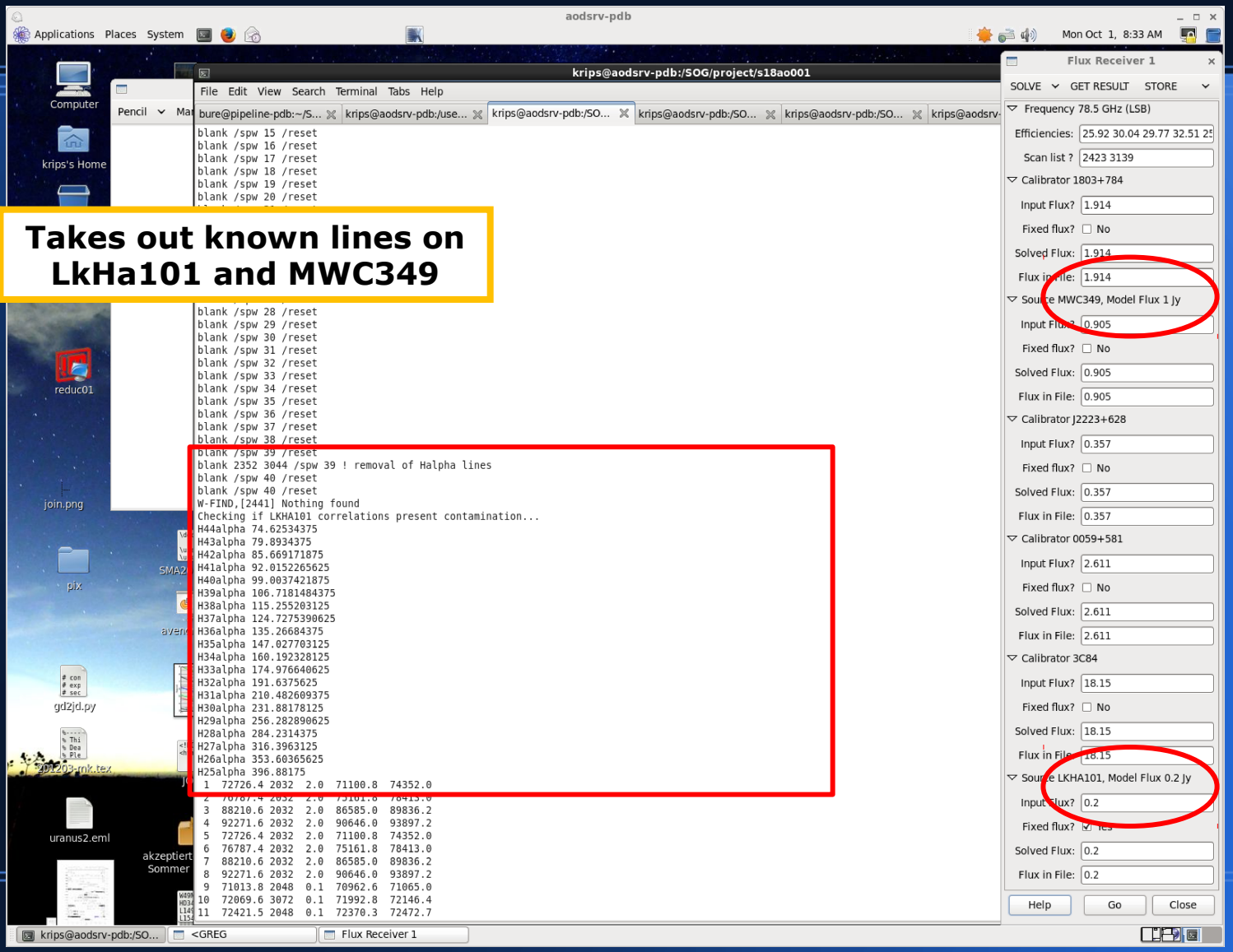

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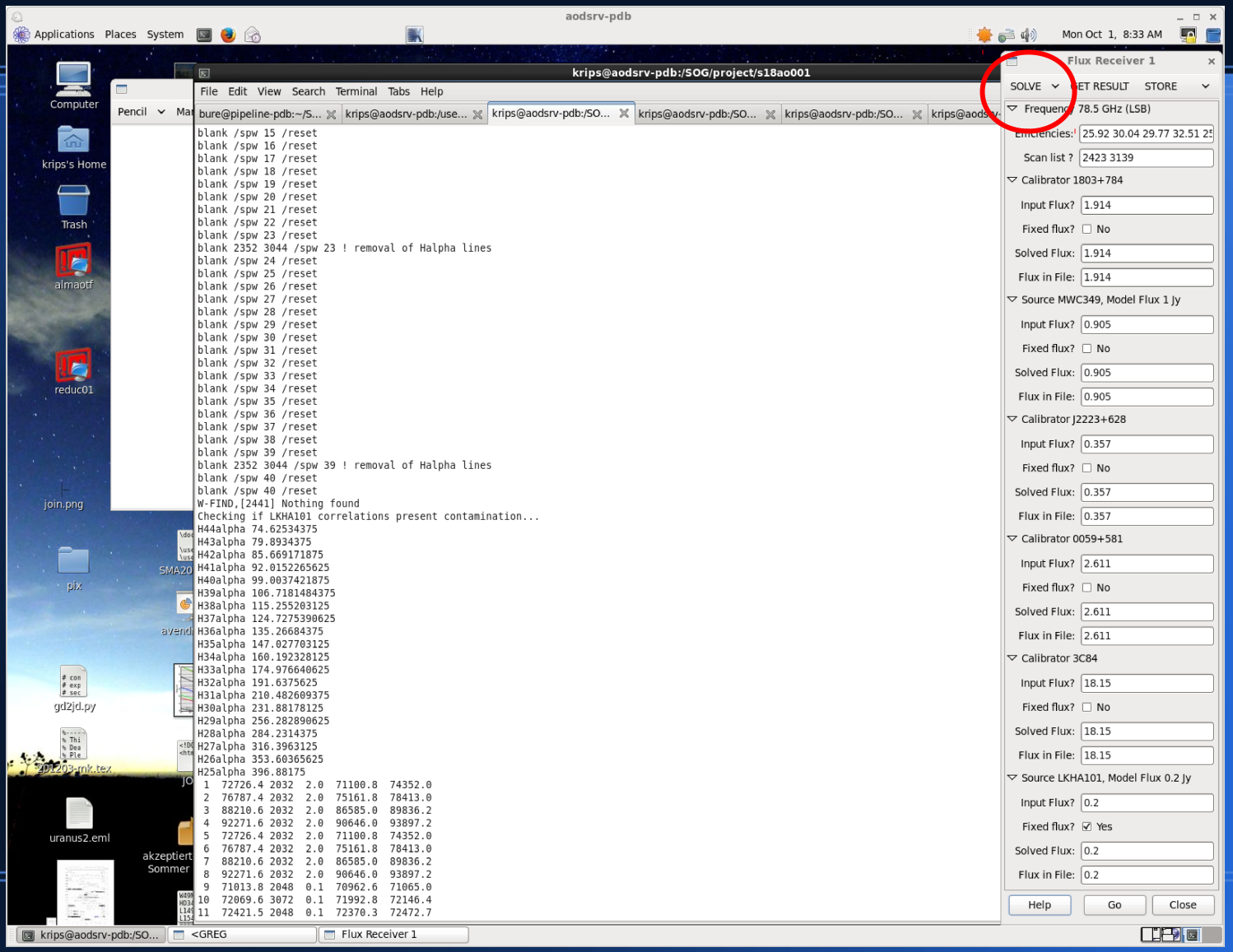

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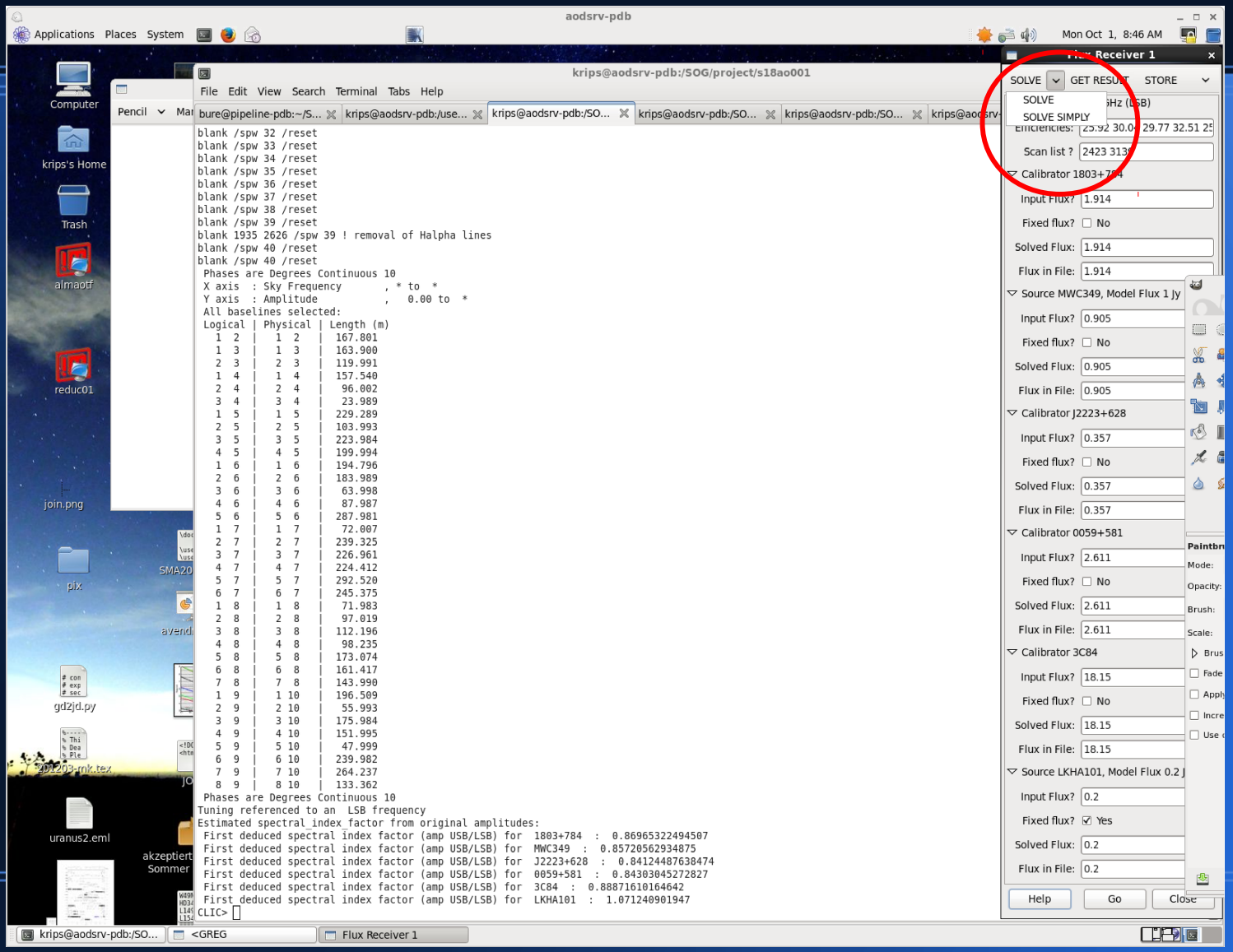

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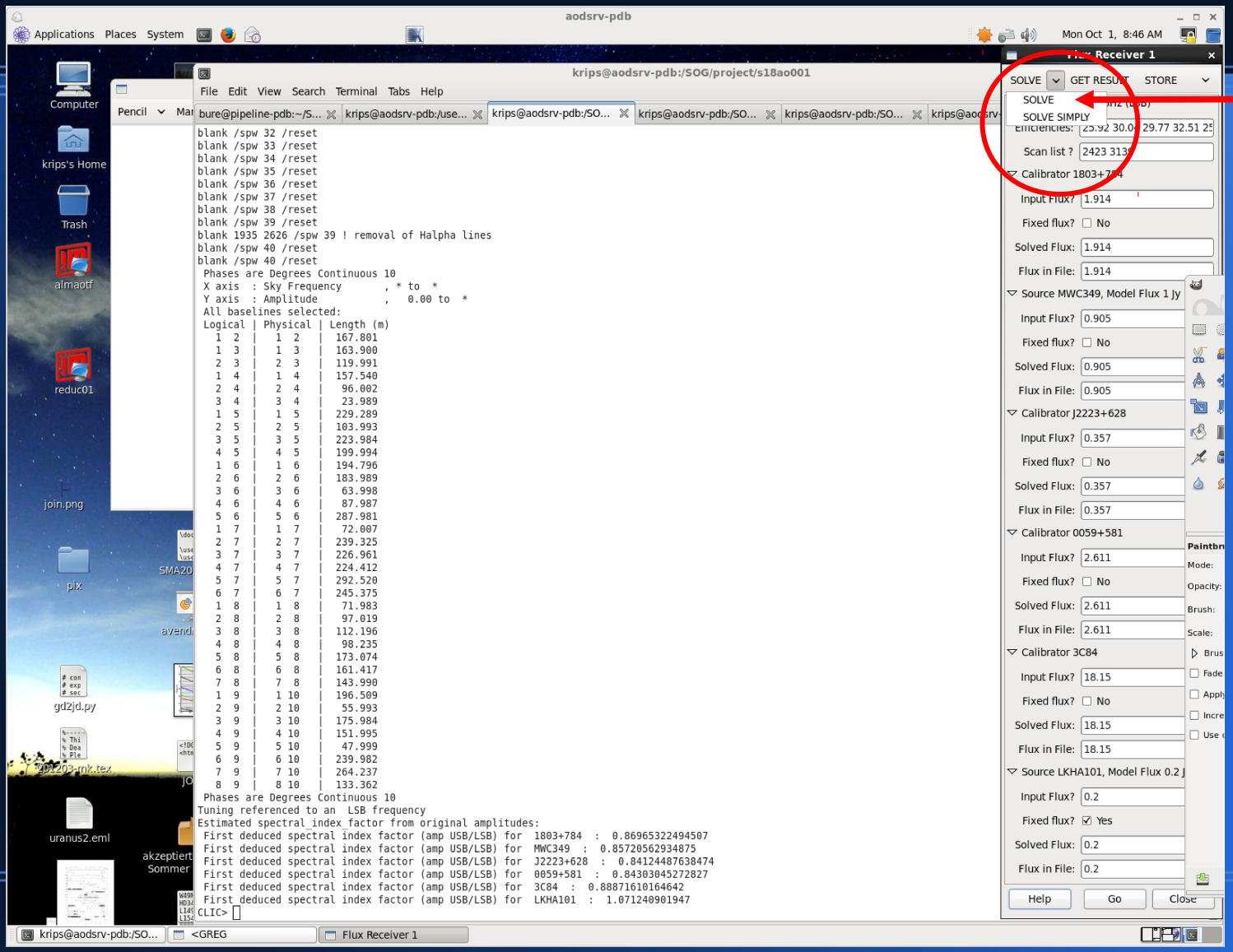

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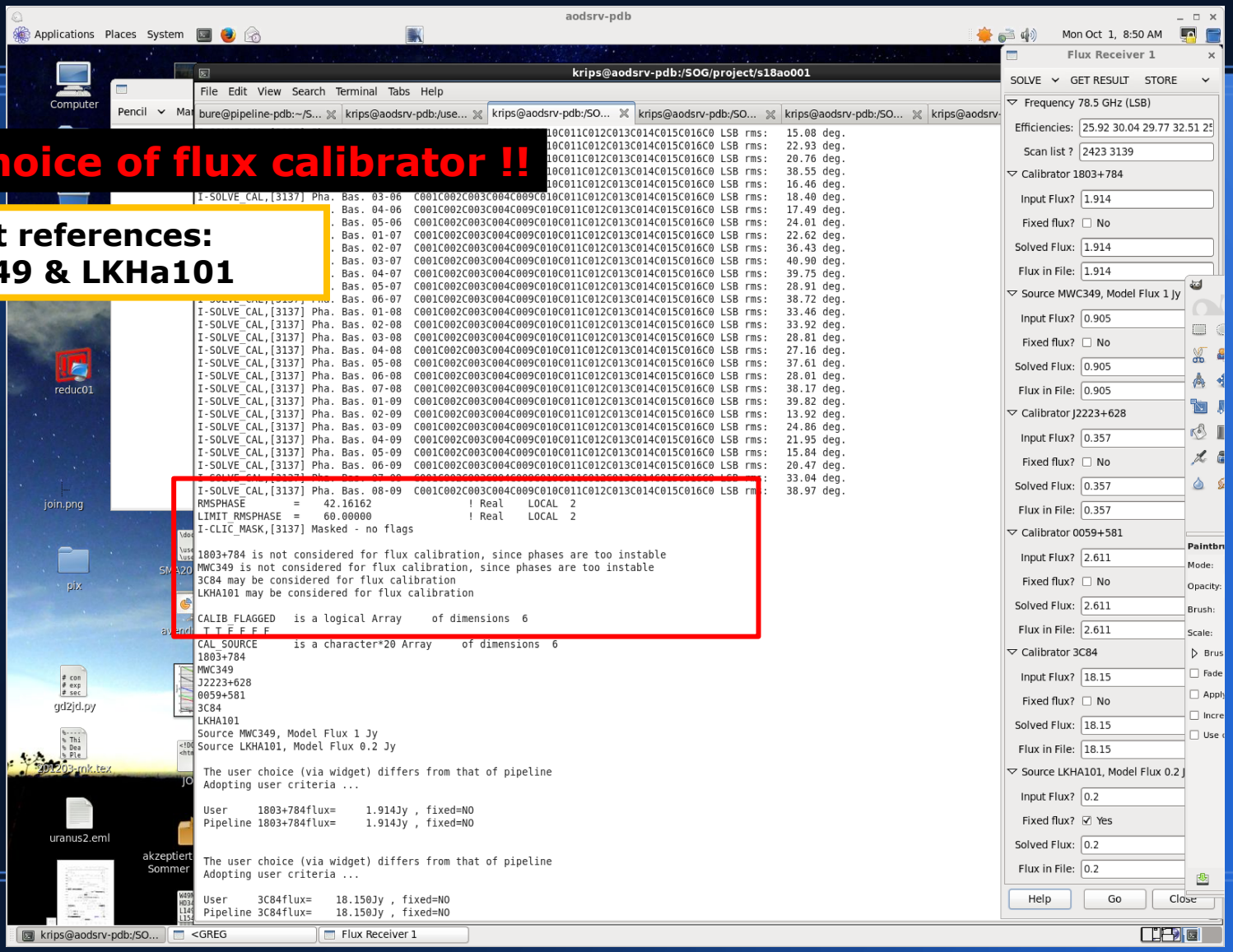

1.) Choice of flux calibrator !!

Default references:
MWC349 & LKHa101

Practical Tips: CLIC software tools

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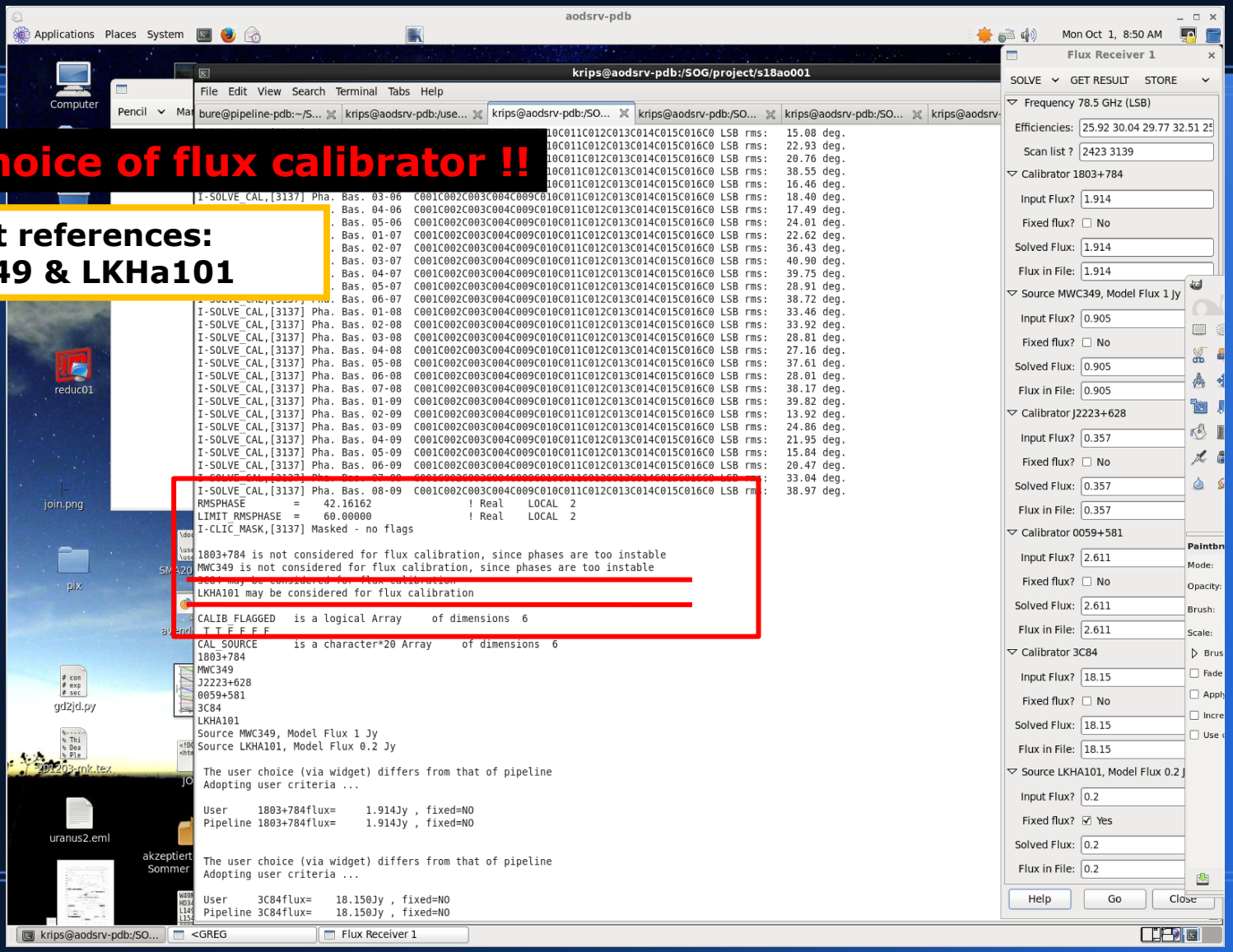

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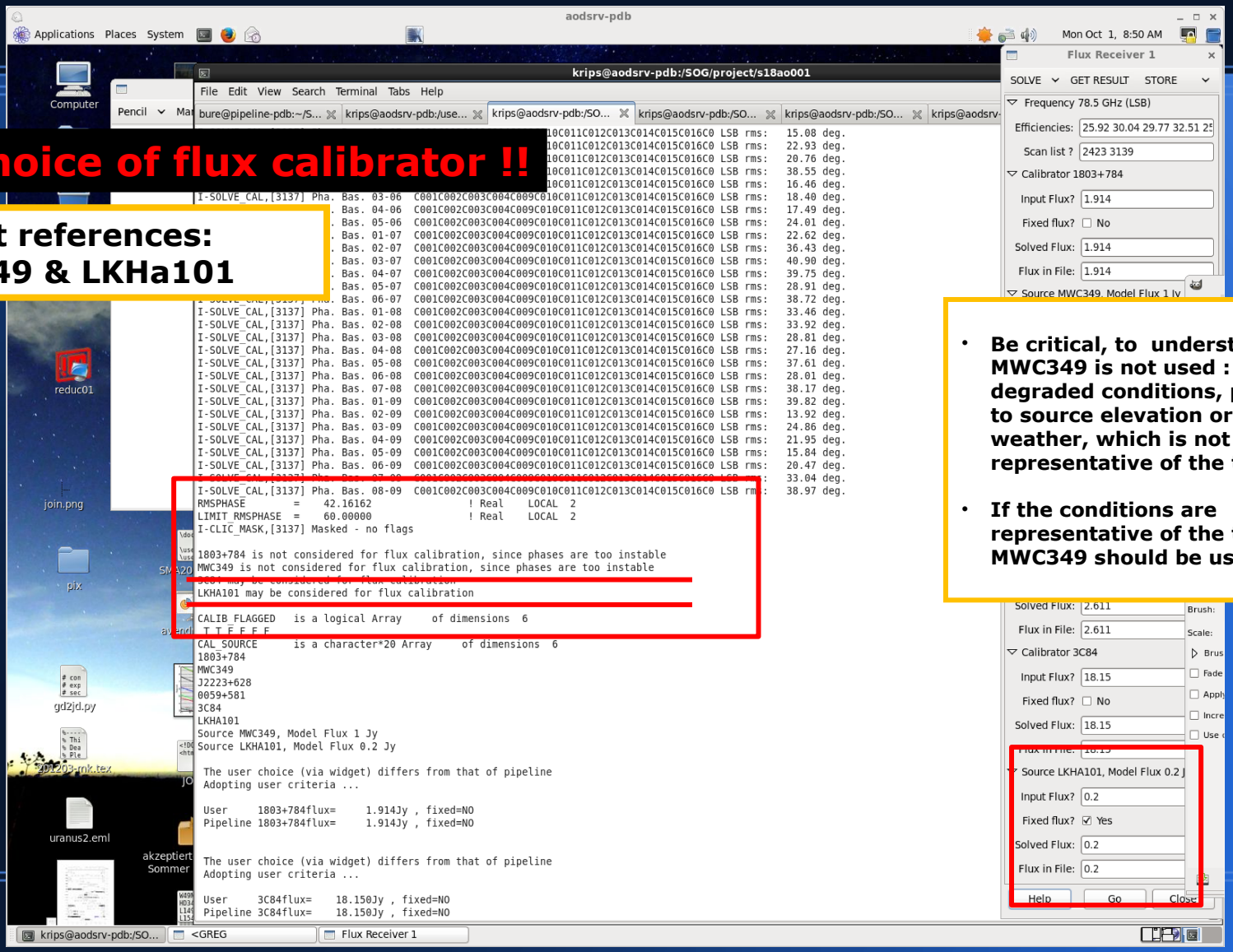

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Practical Tips: CLIC software tools

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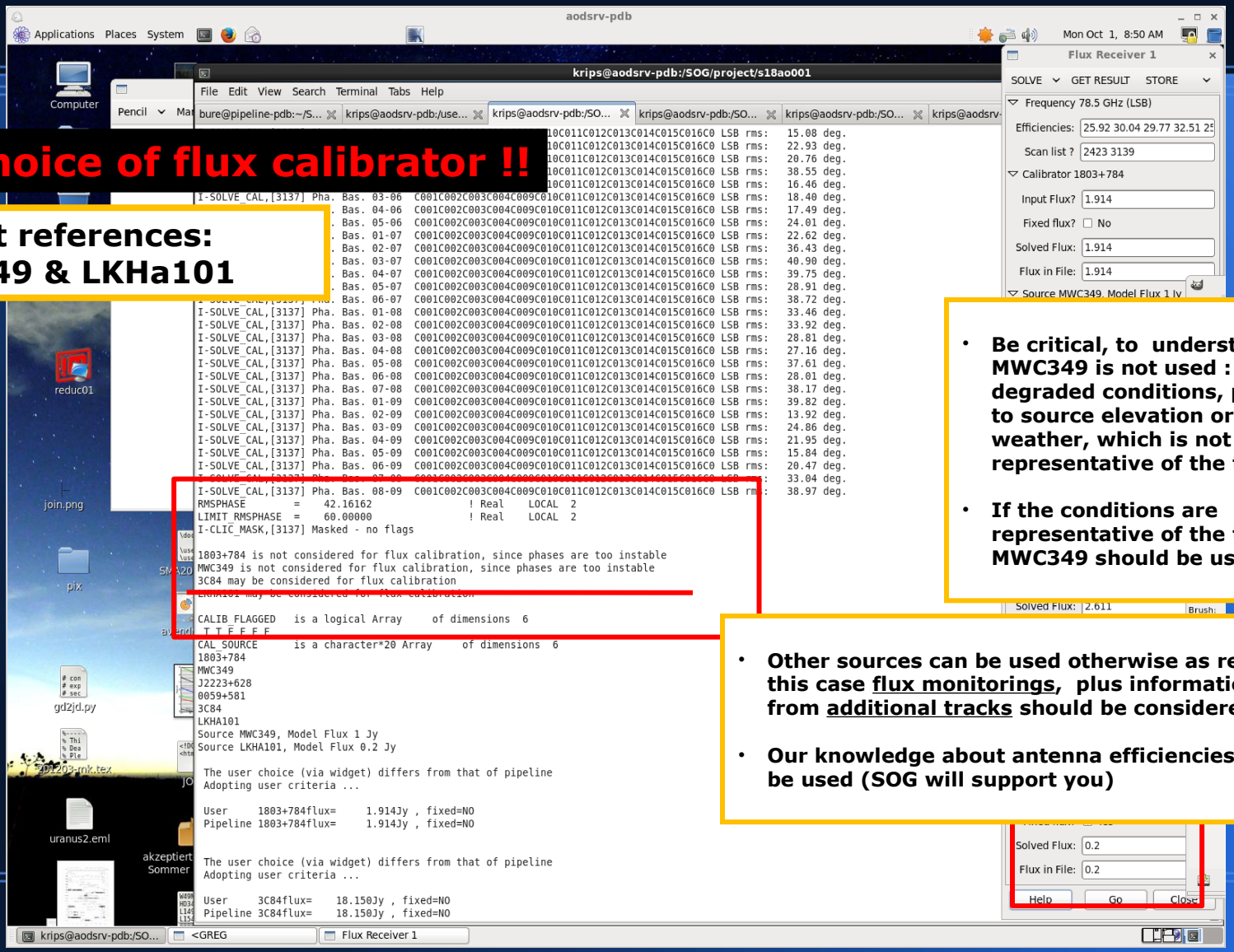

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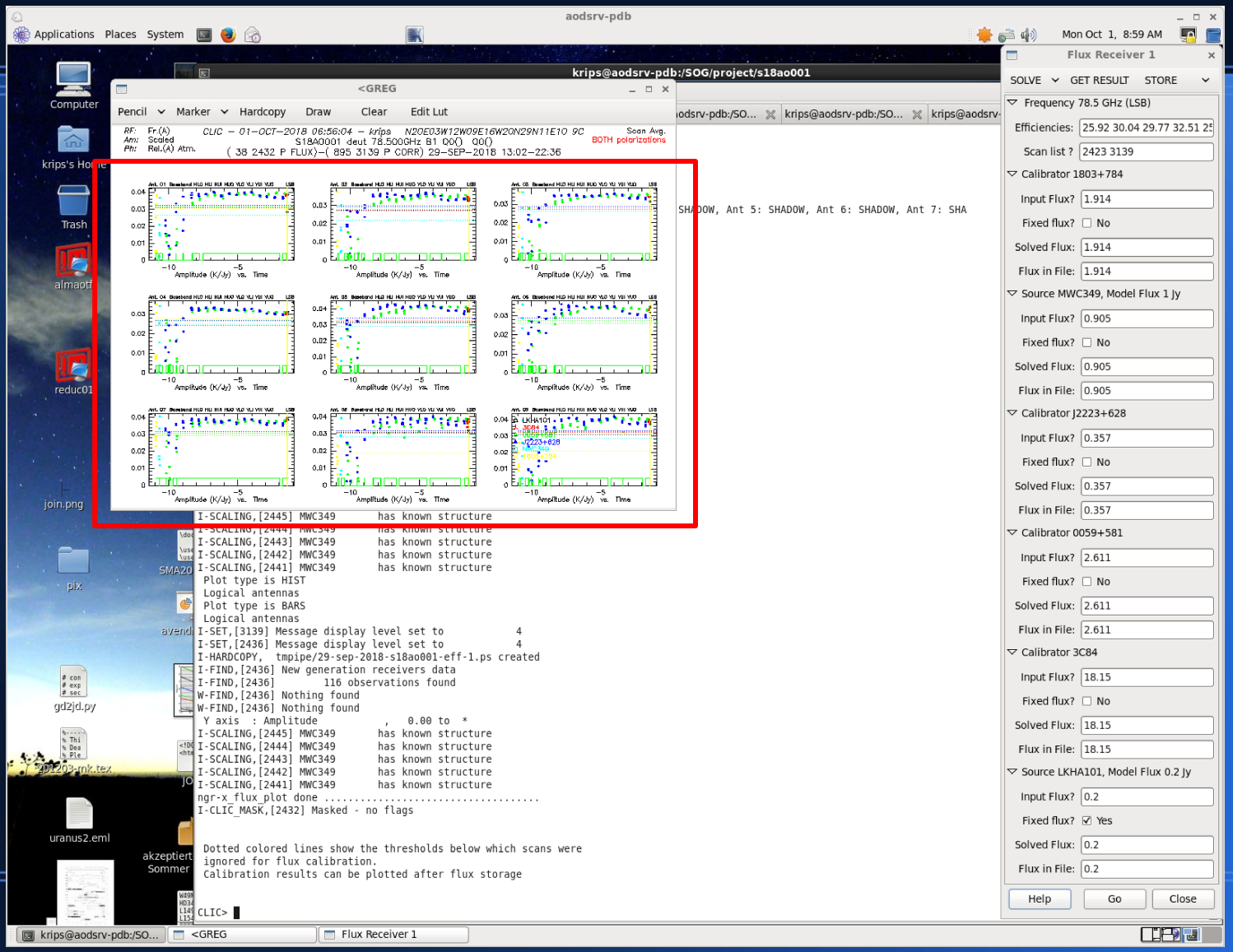
- **Other sources can be used otherwise as reference: in this case flux monitorings, plus information coming from additional tracks should be considered**
- **Our knowledge about antenna efficiencies should also be used (SOG will support you)**

Practical Tips: CLIC software tools



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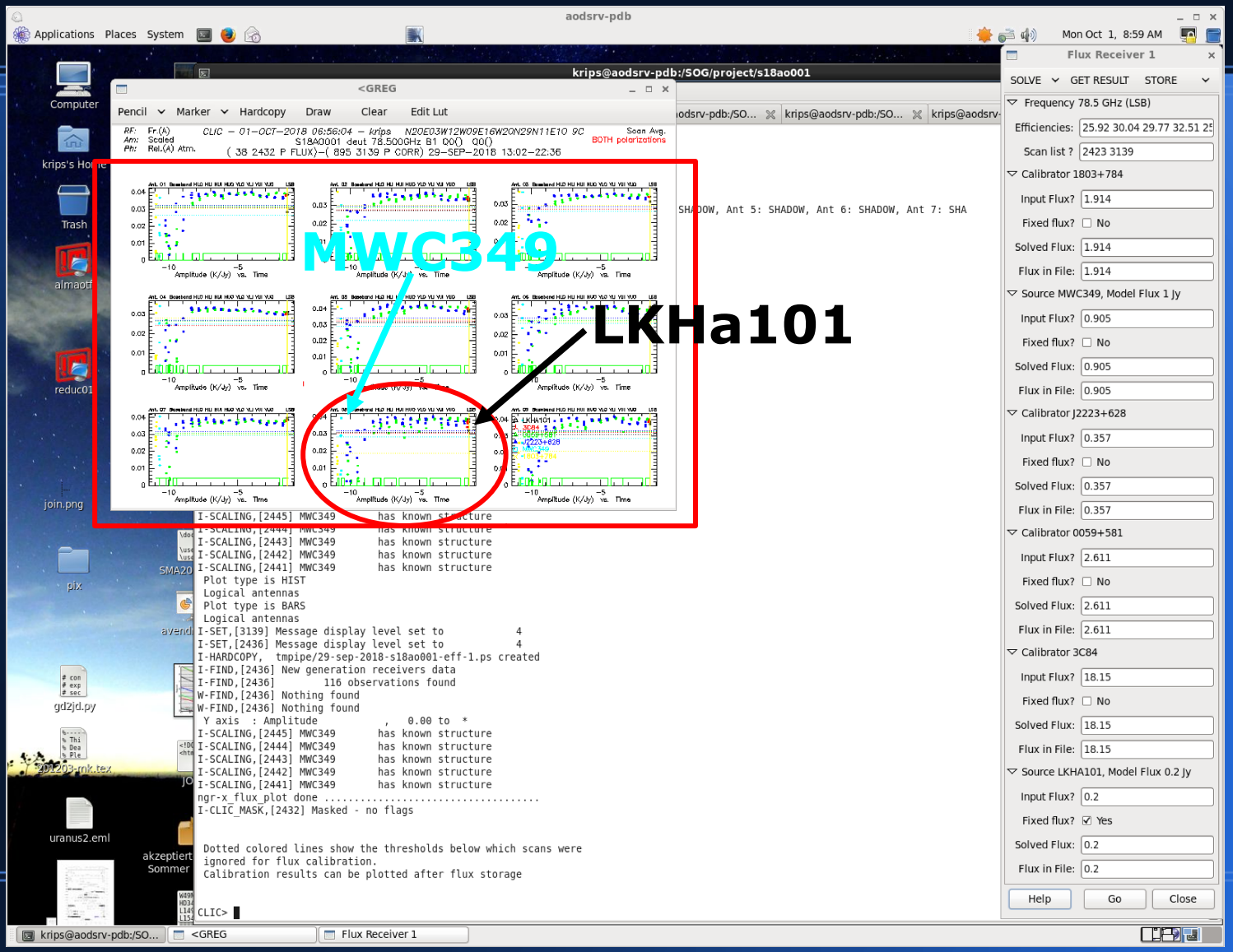

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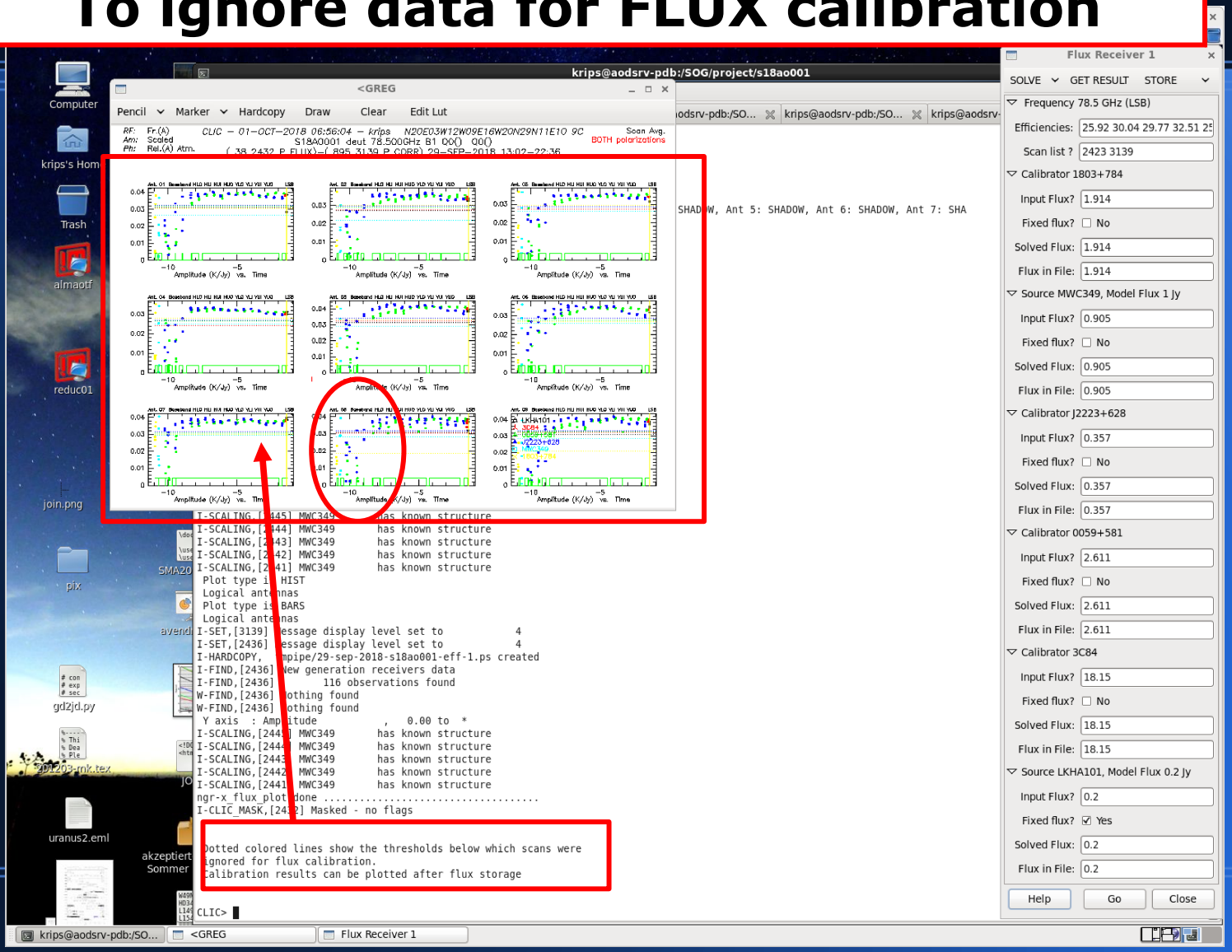
To ignore data for FLUX calibration



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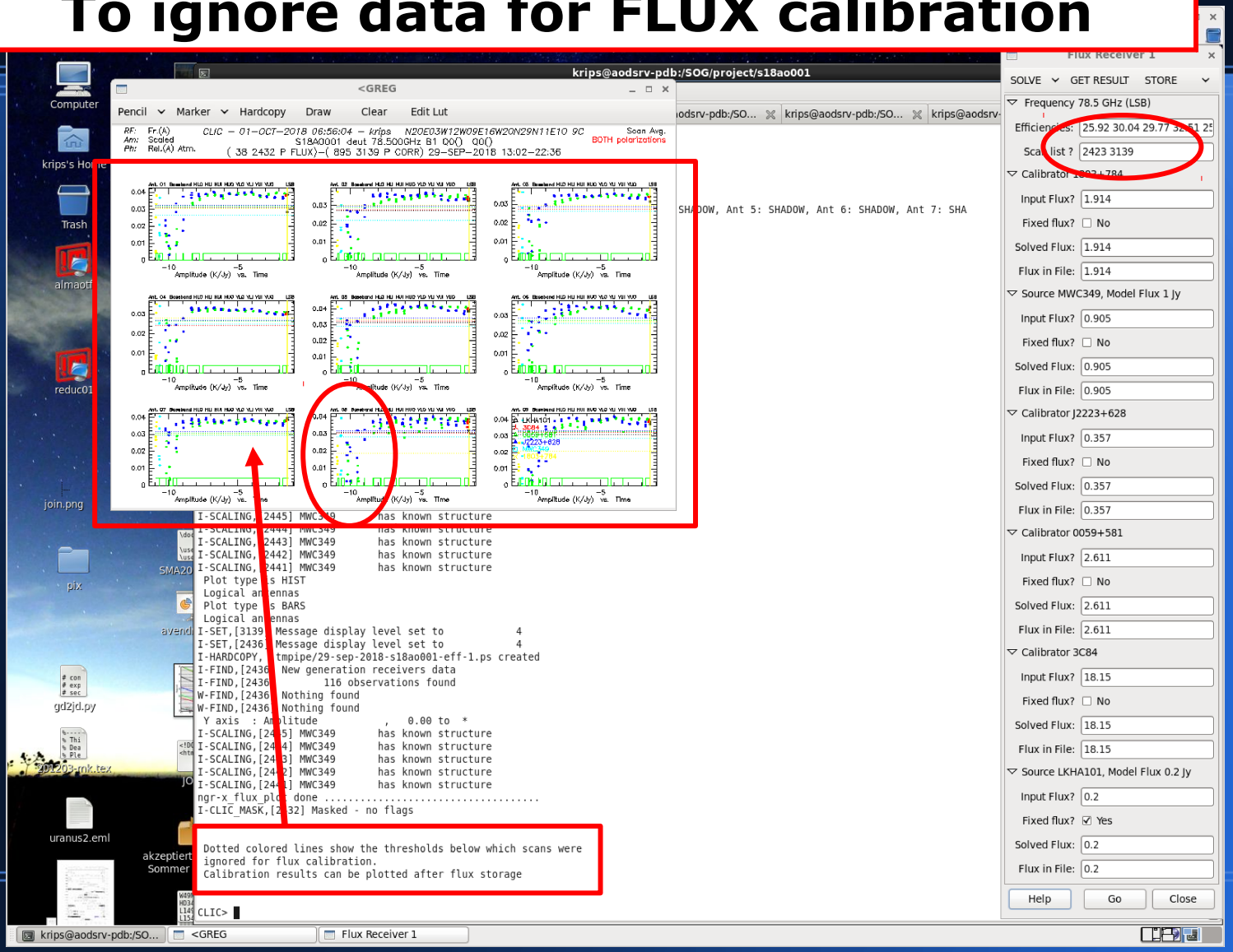

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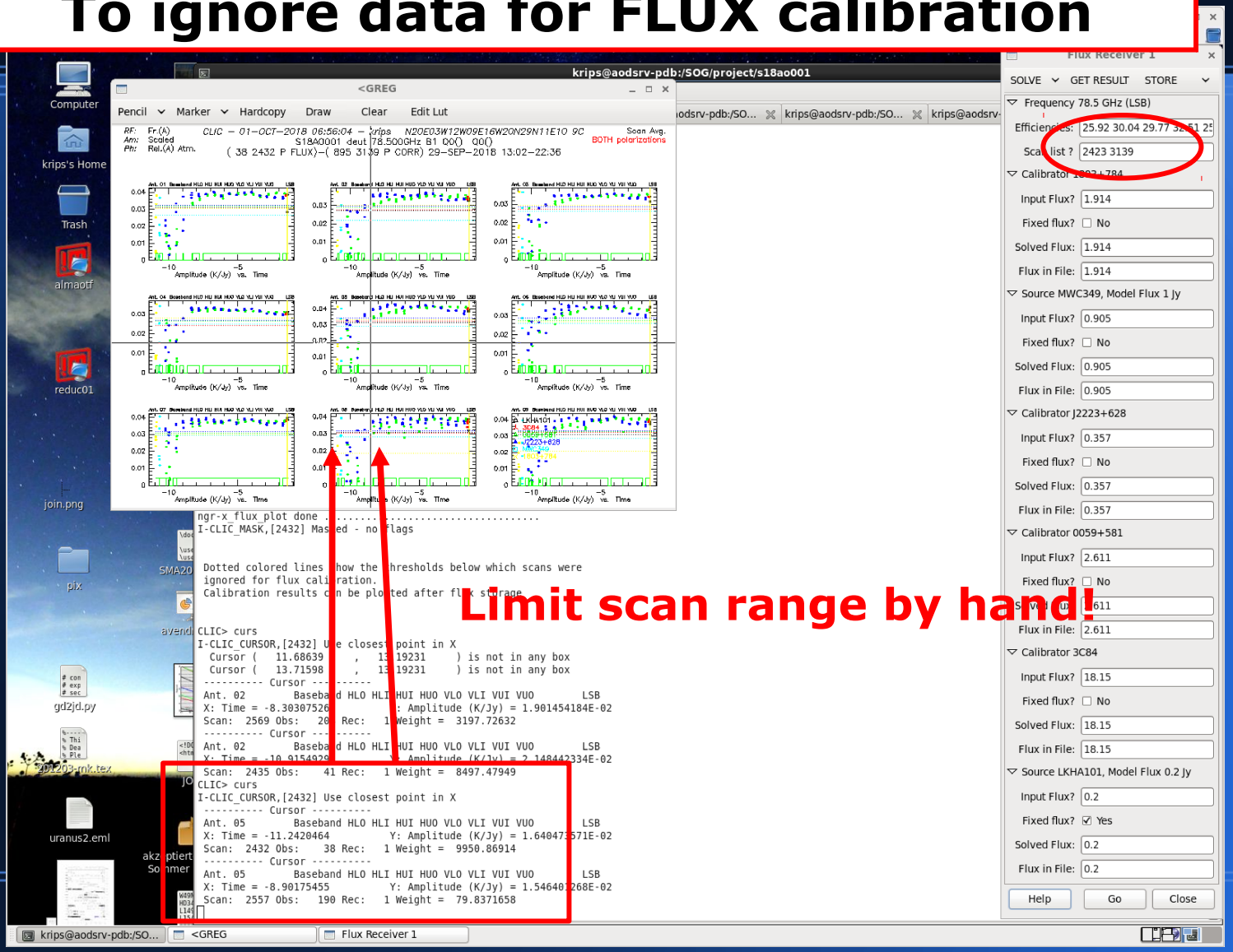

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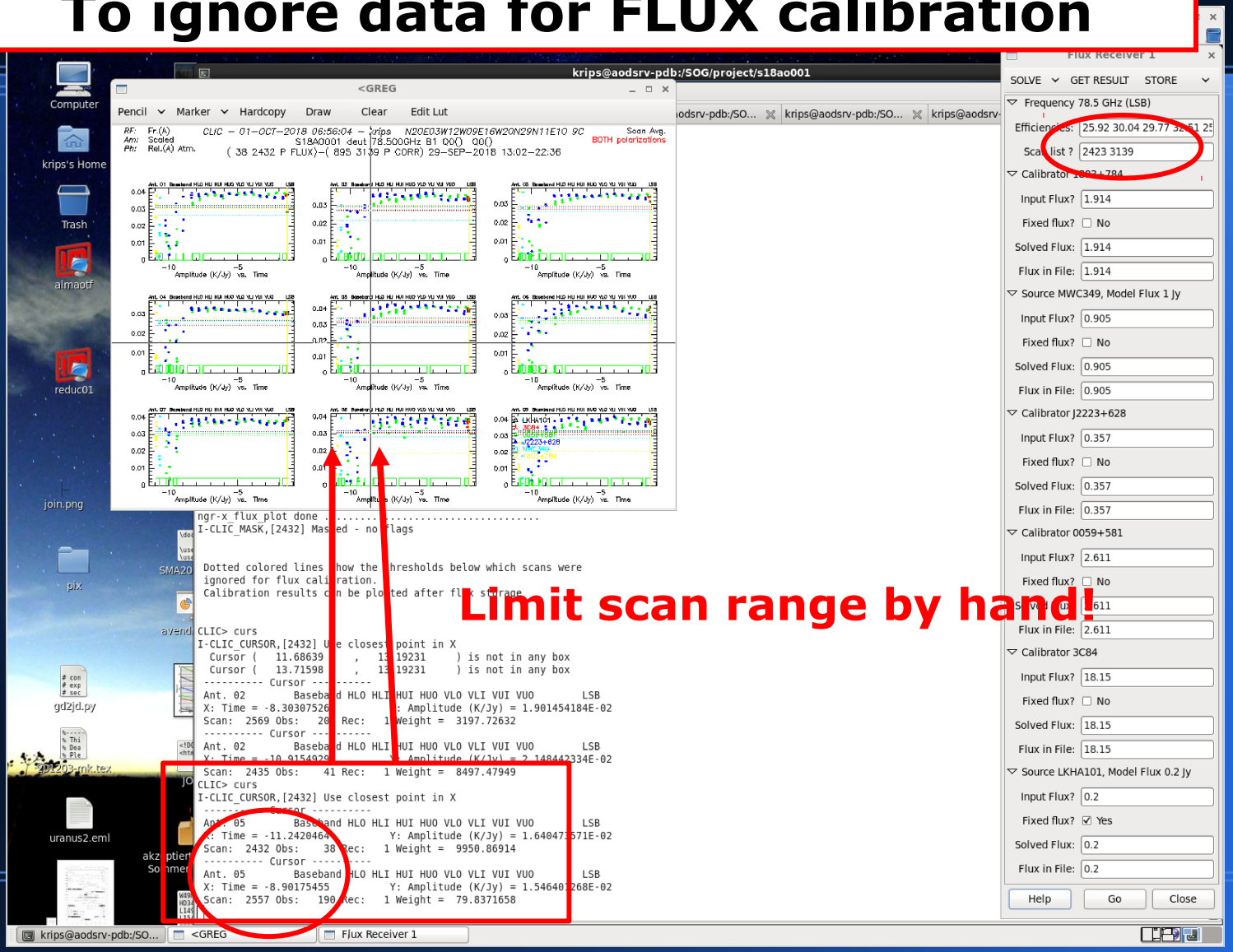

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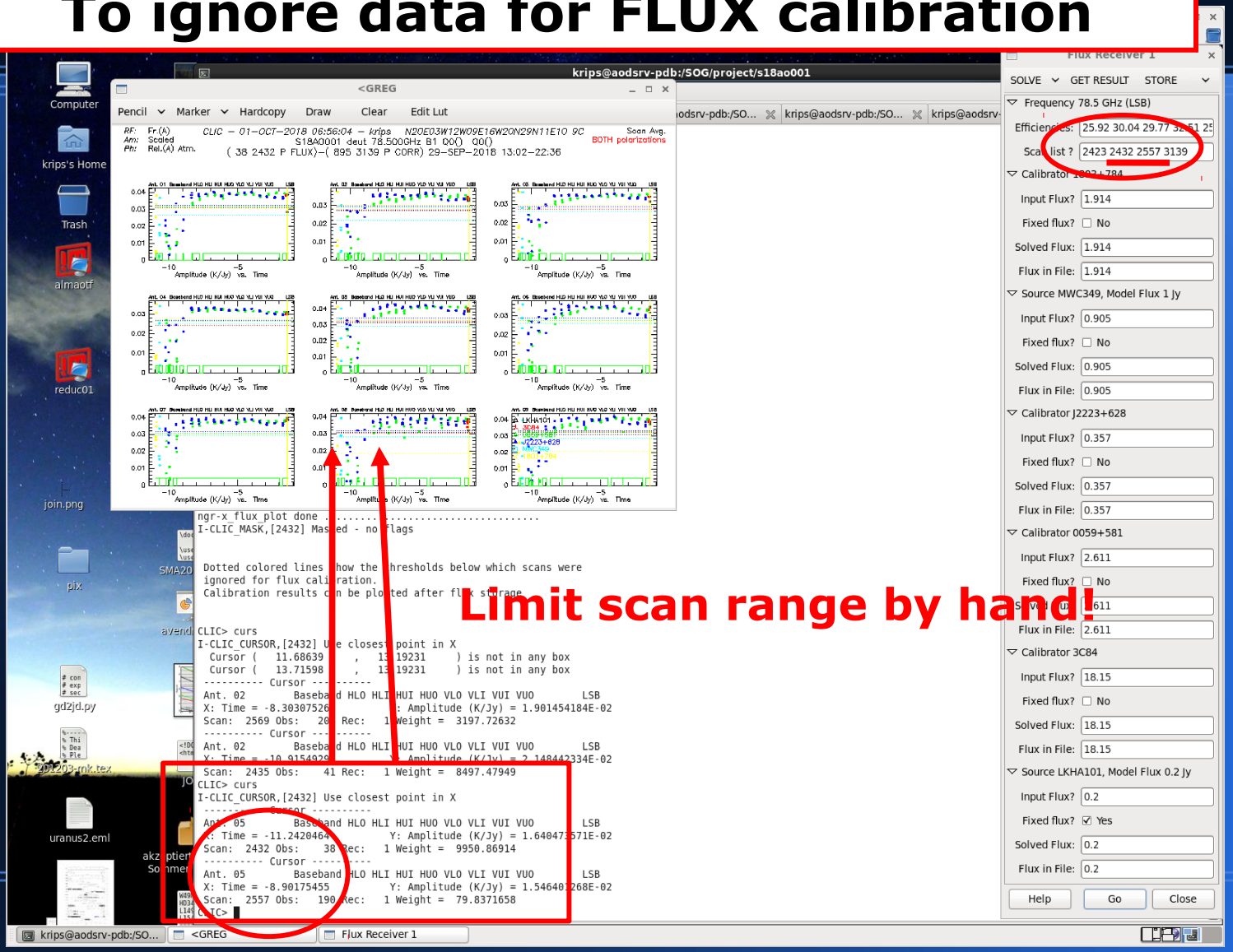

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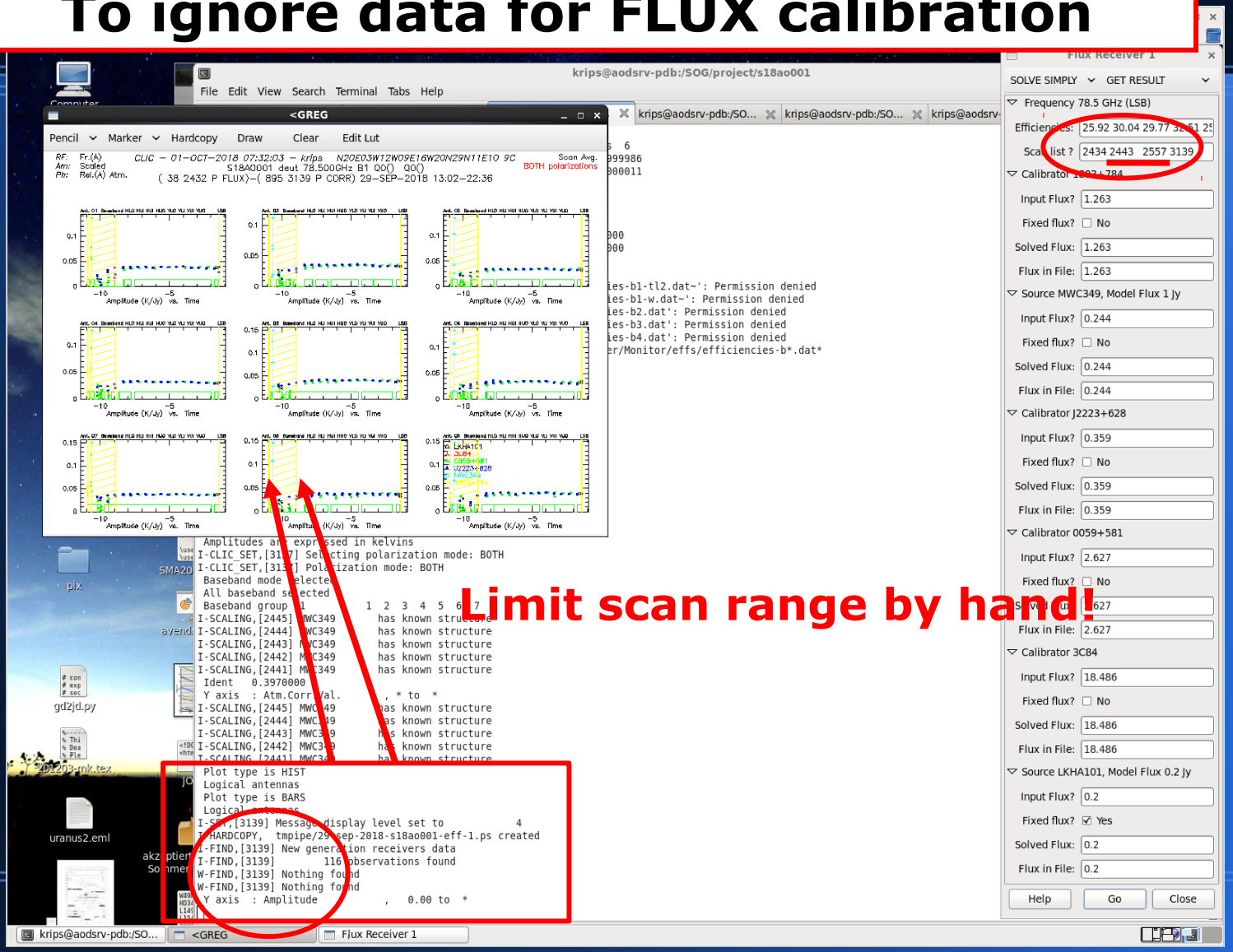

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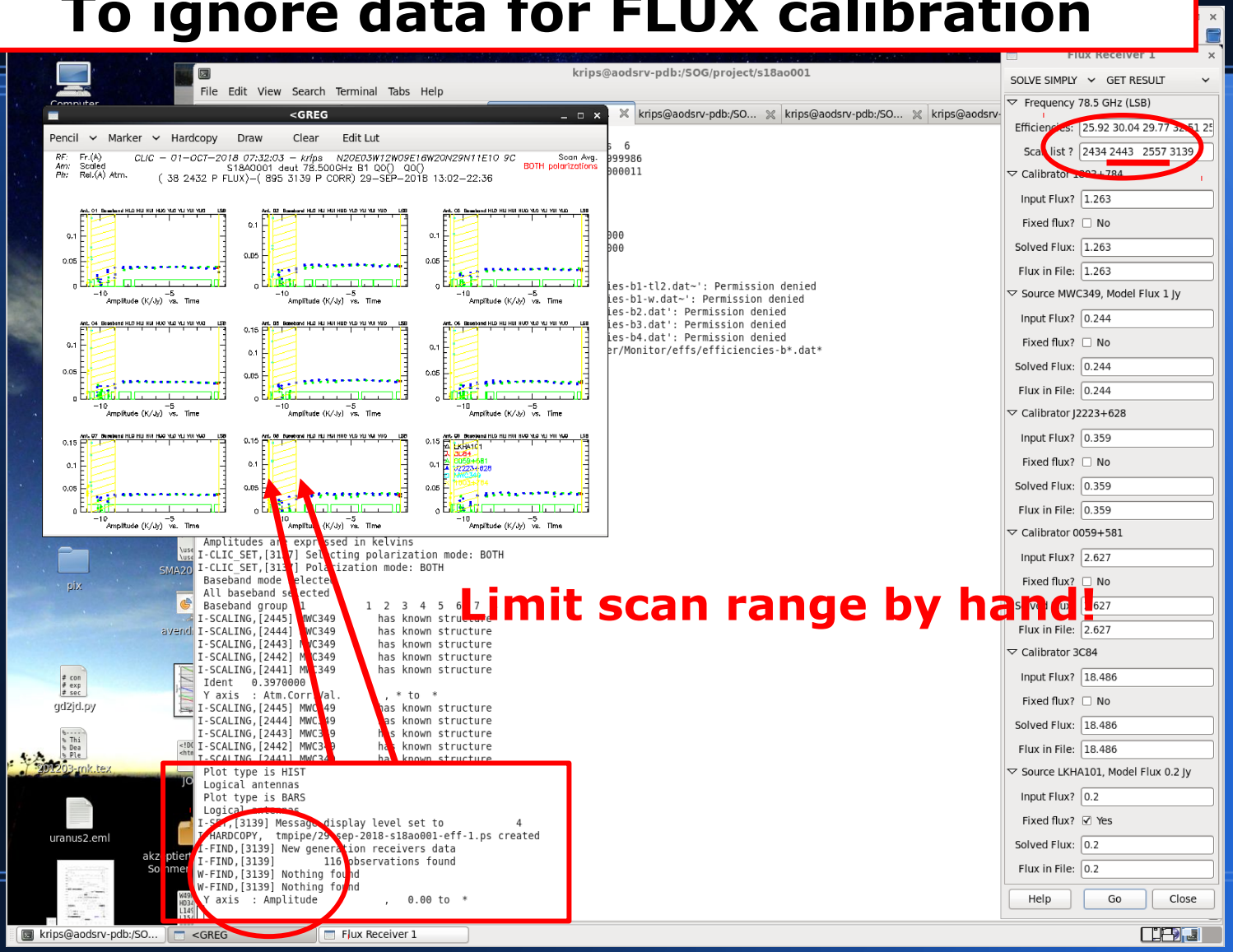

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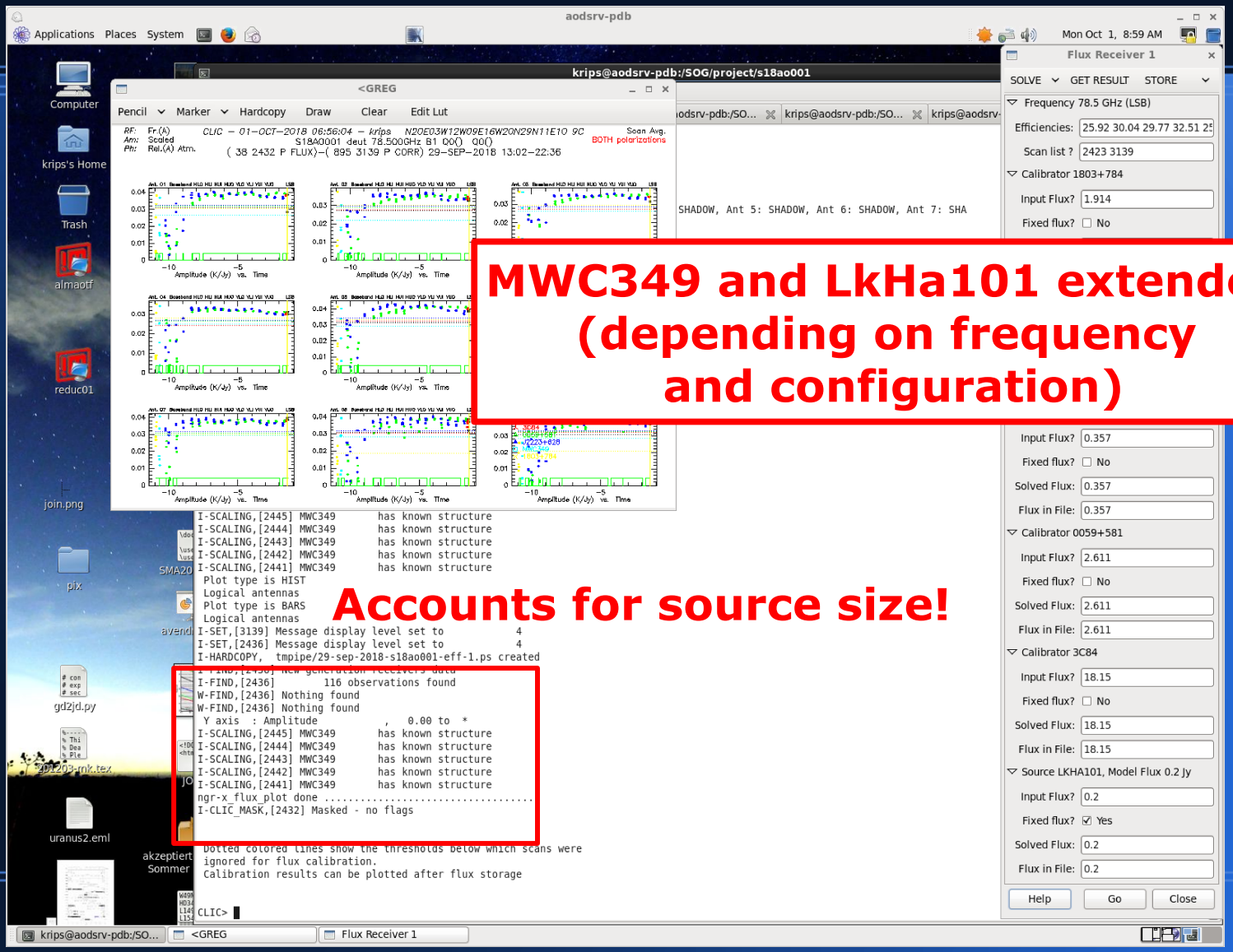

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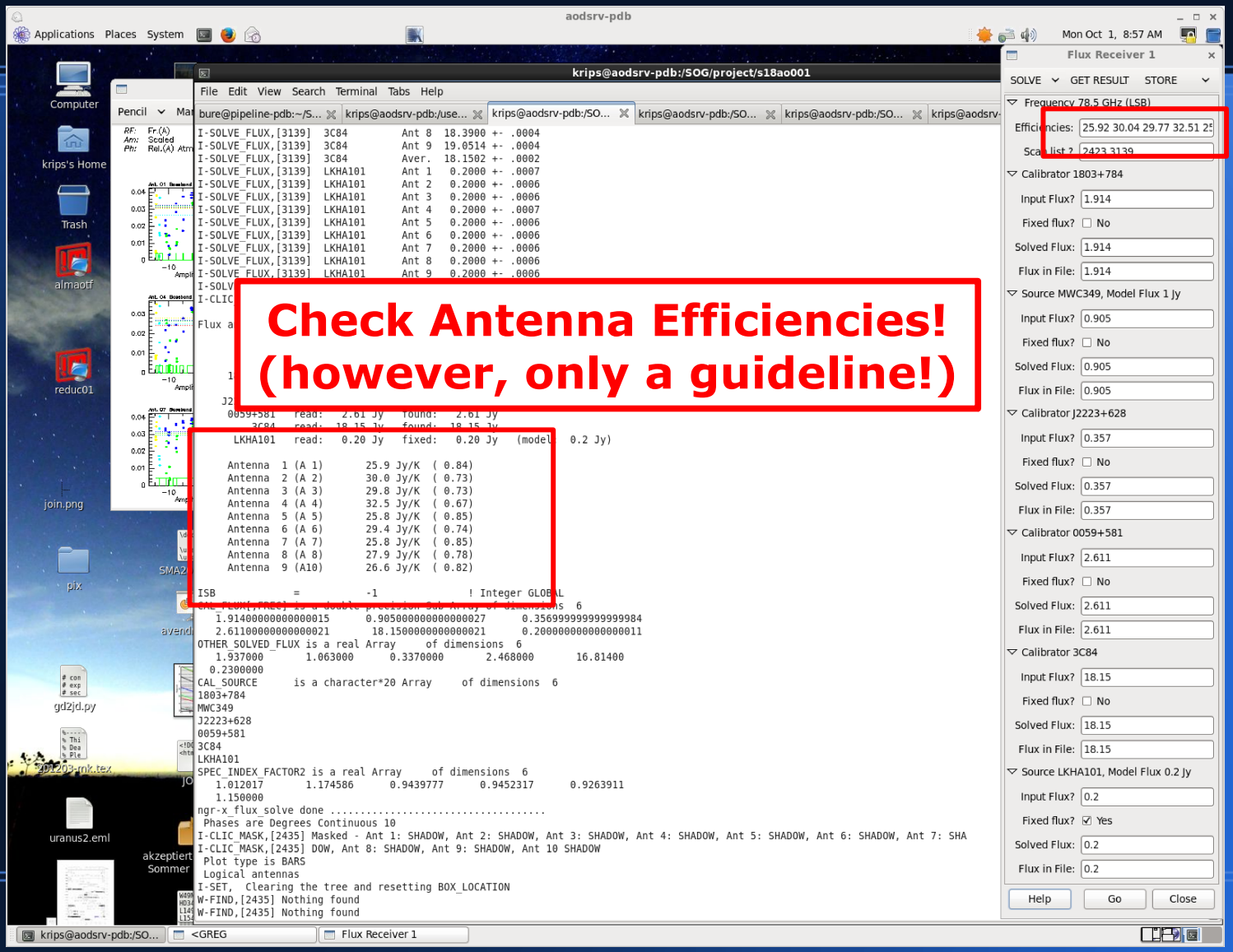

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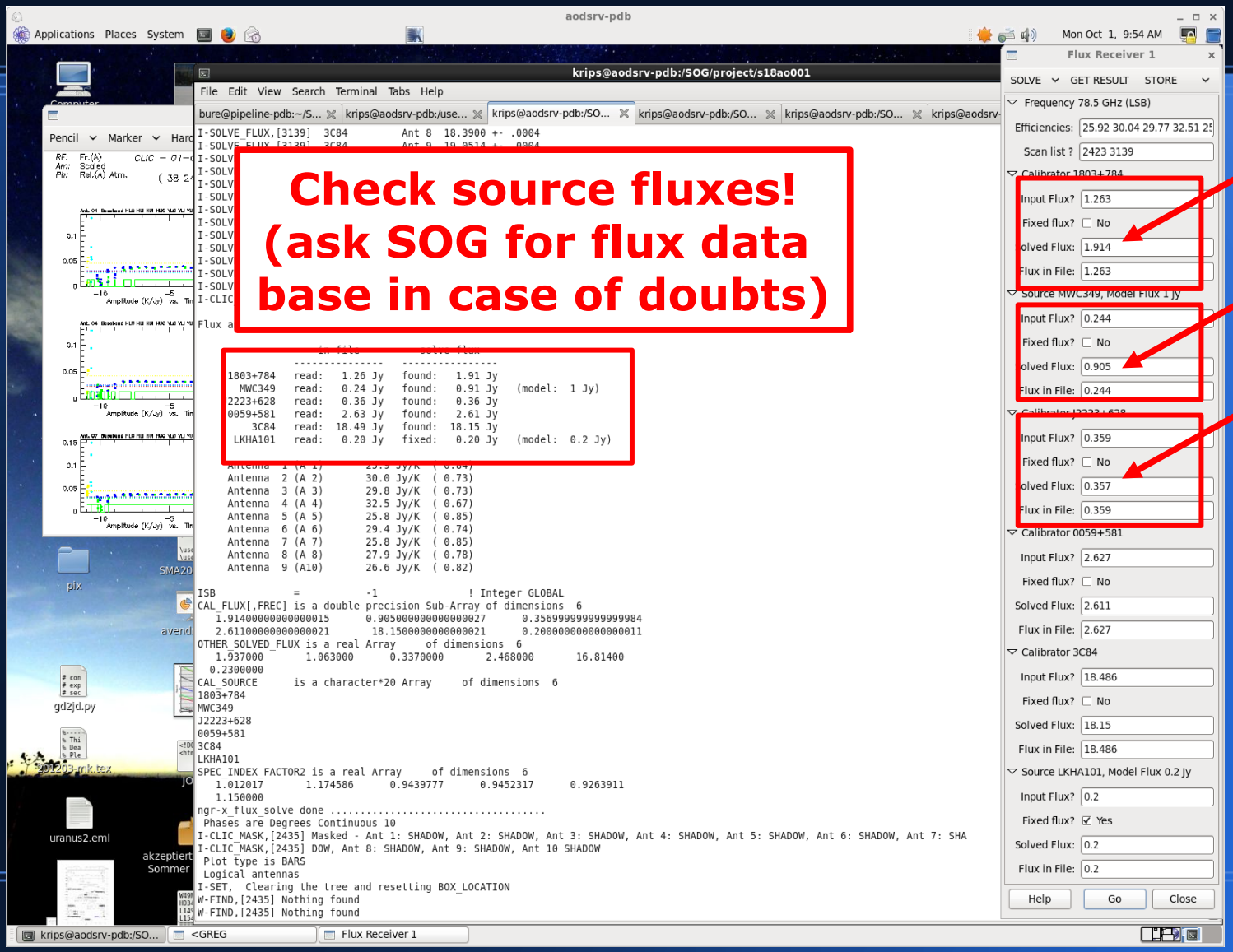

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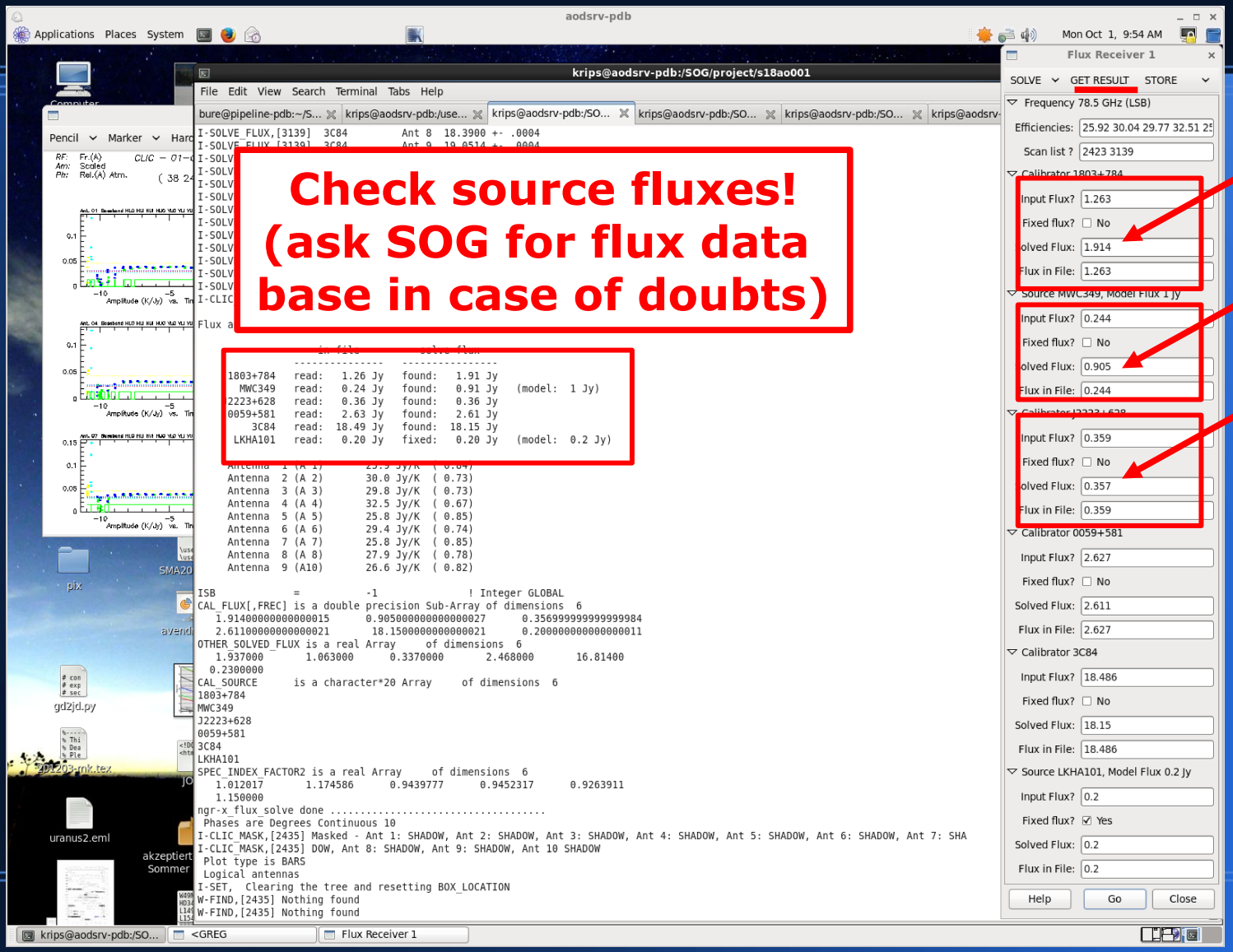

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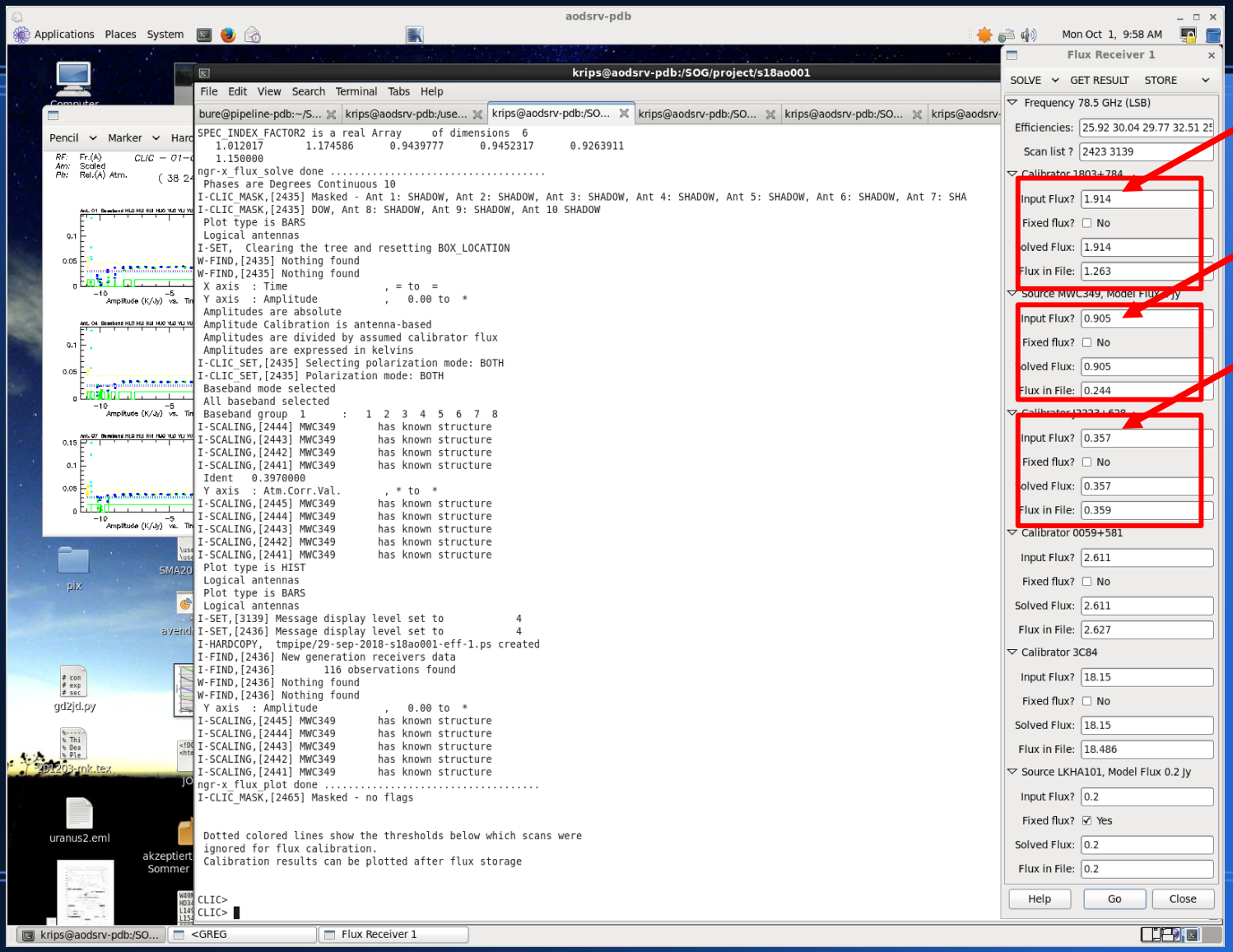

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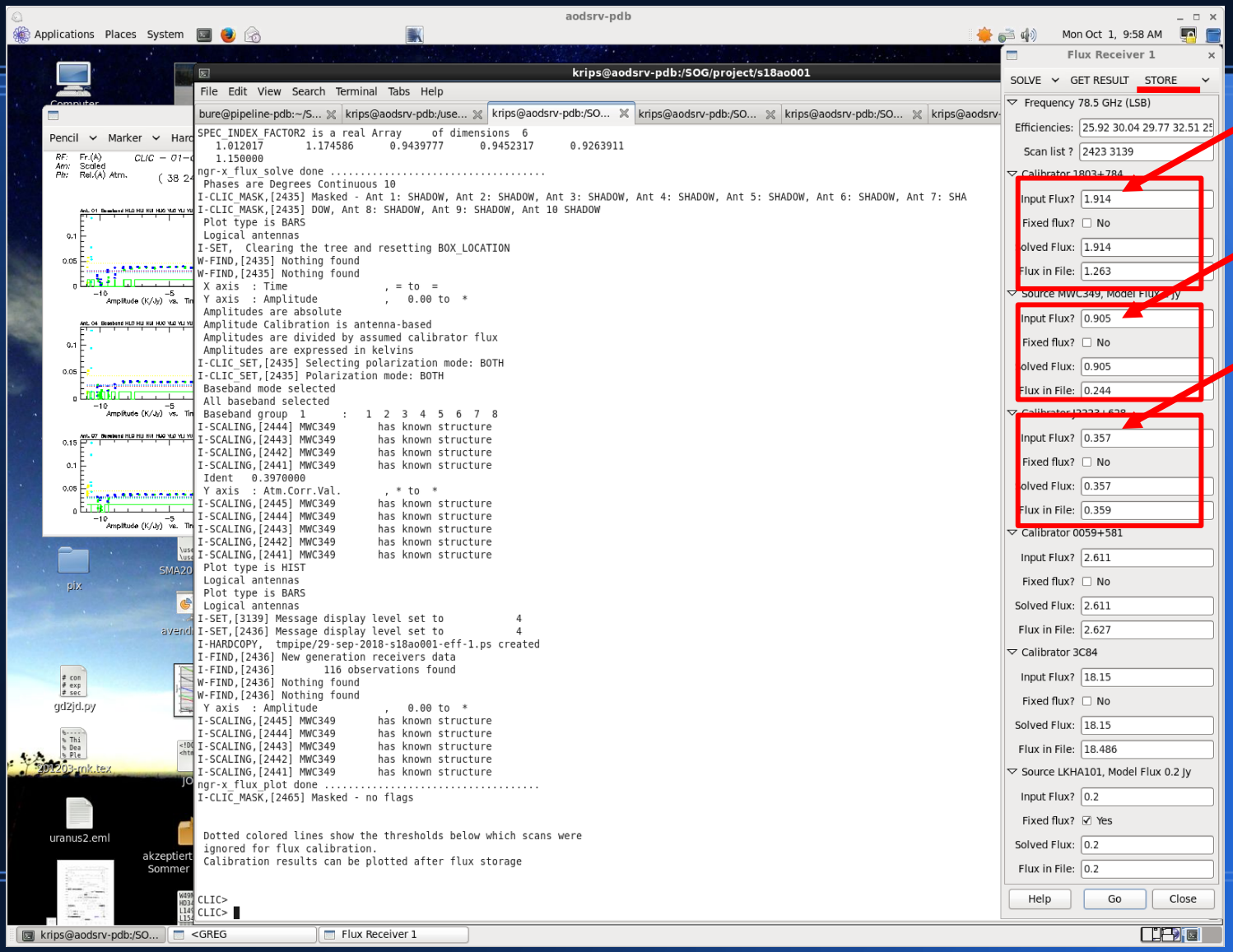

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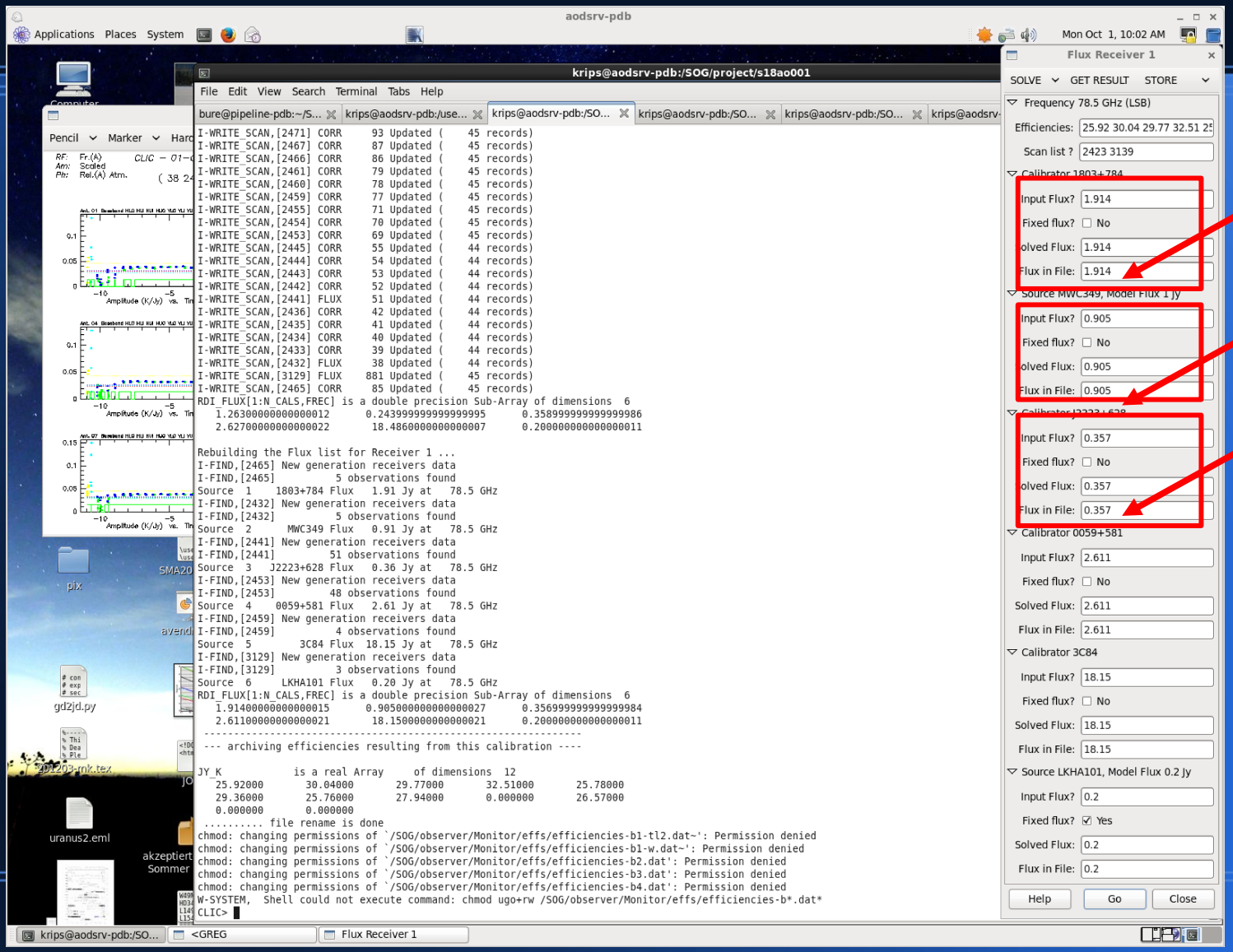

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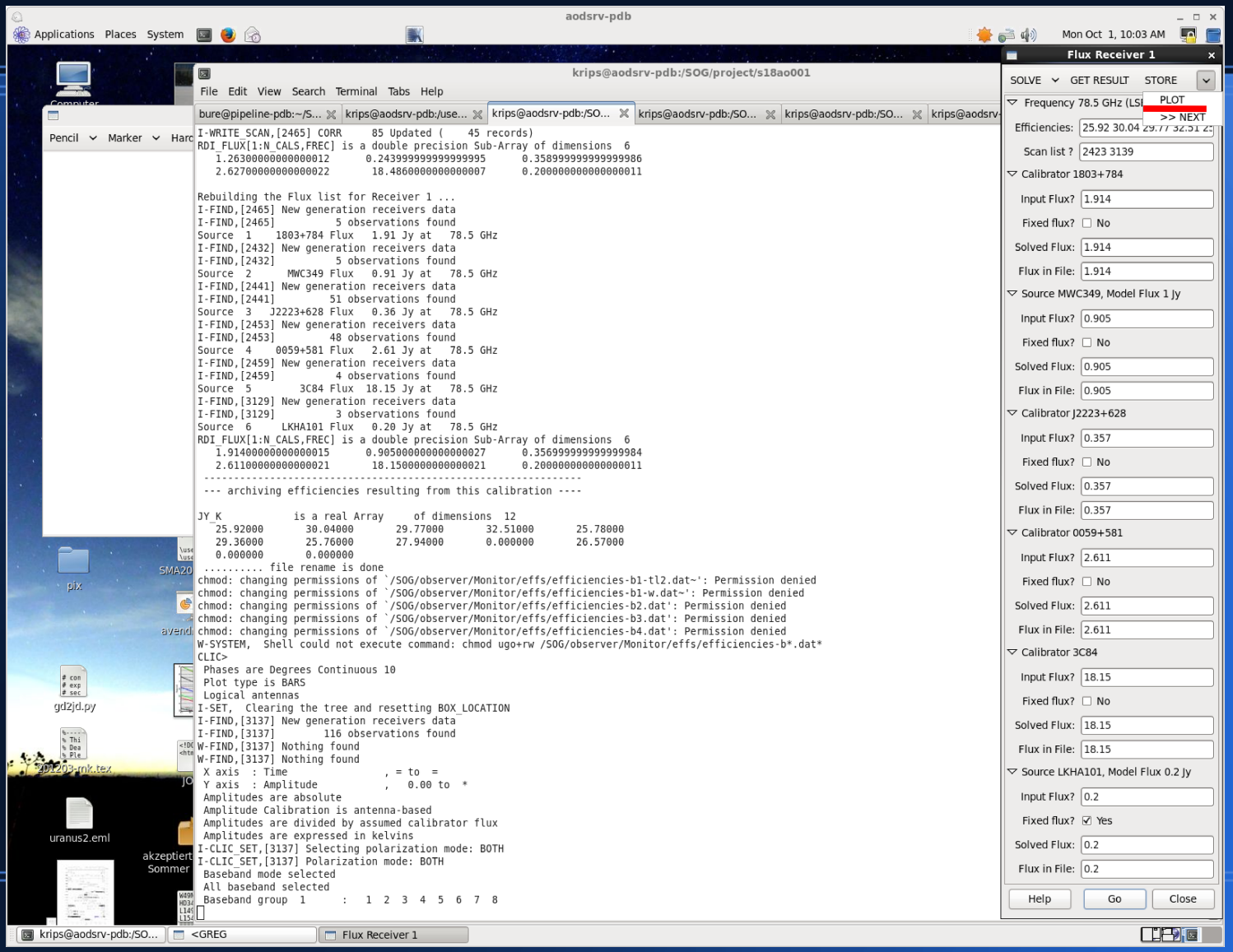

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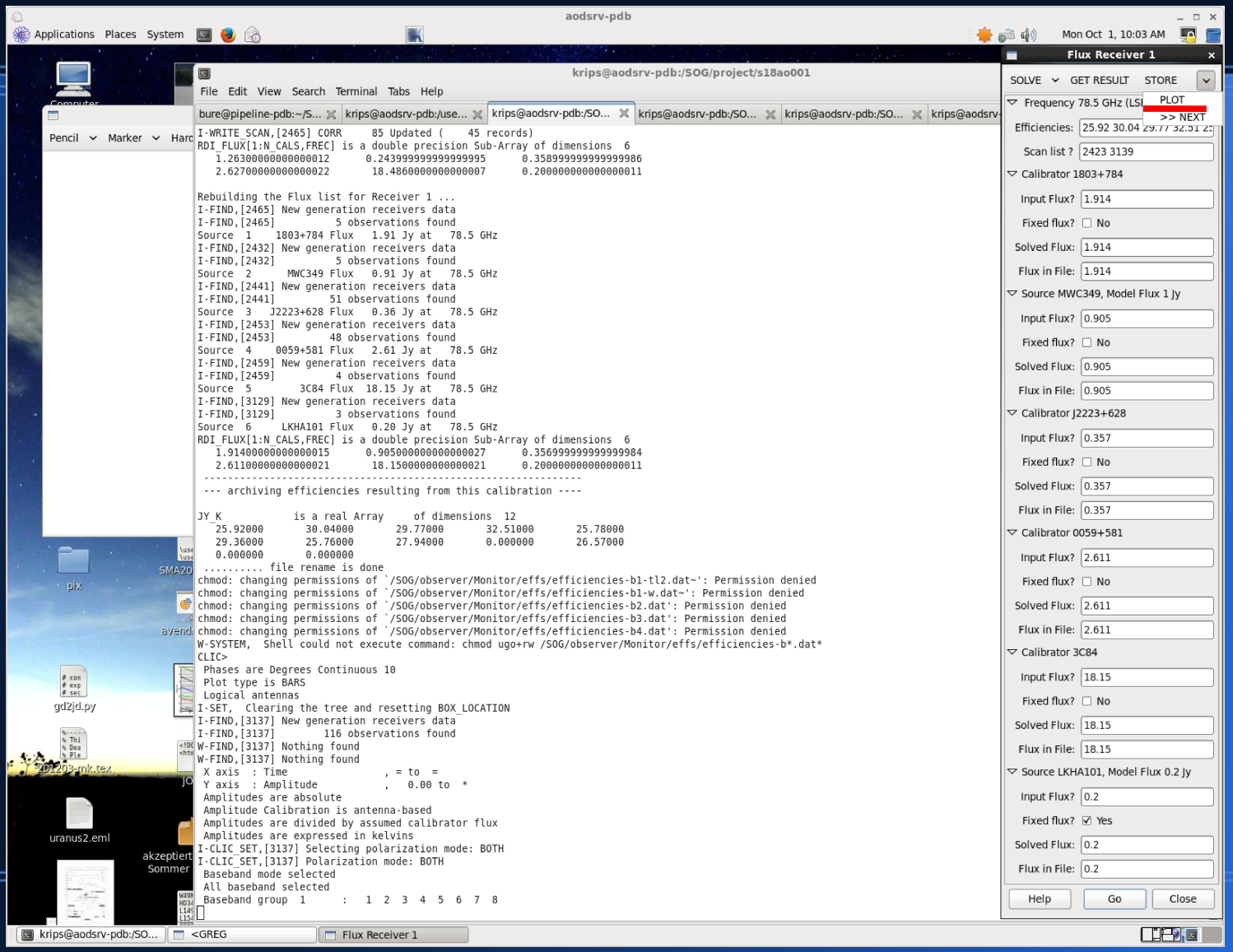

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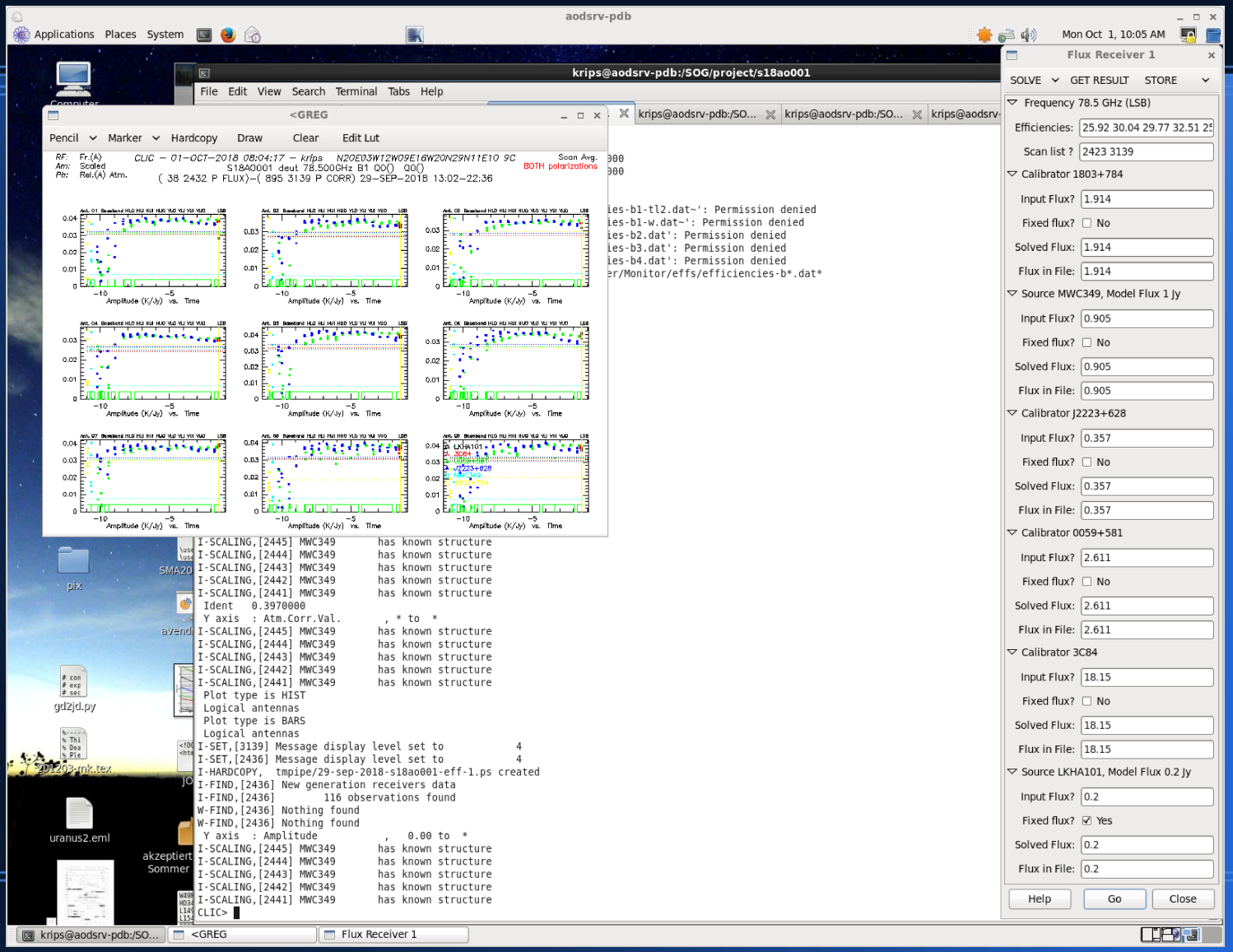

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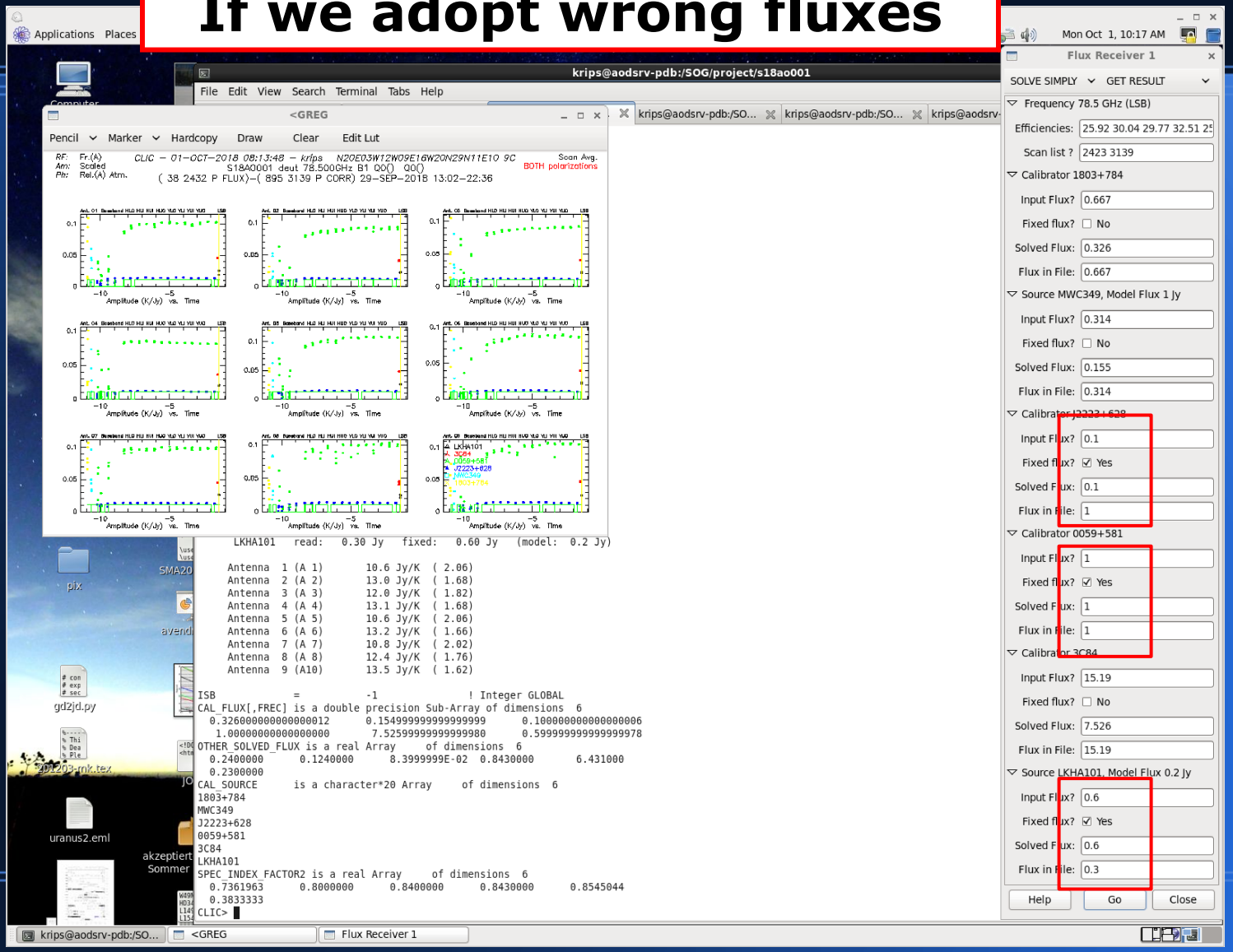
If we adopt wrong fluxes



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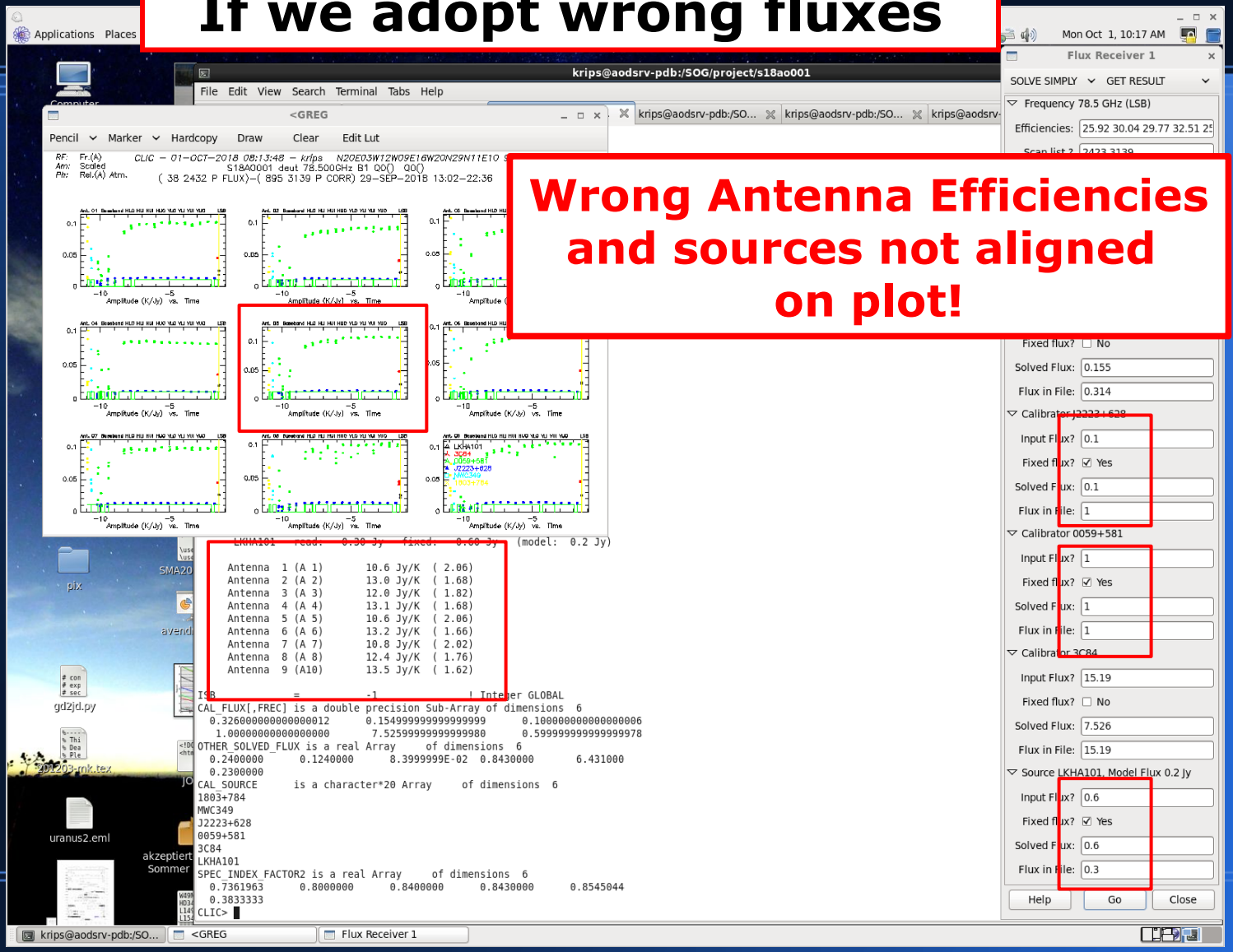

Wrong Antenna Efficiencies and sources not aligned on plot!

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Questions?