SARAH F GRAVES

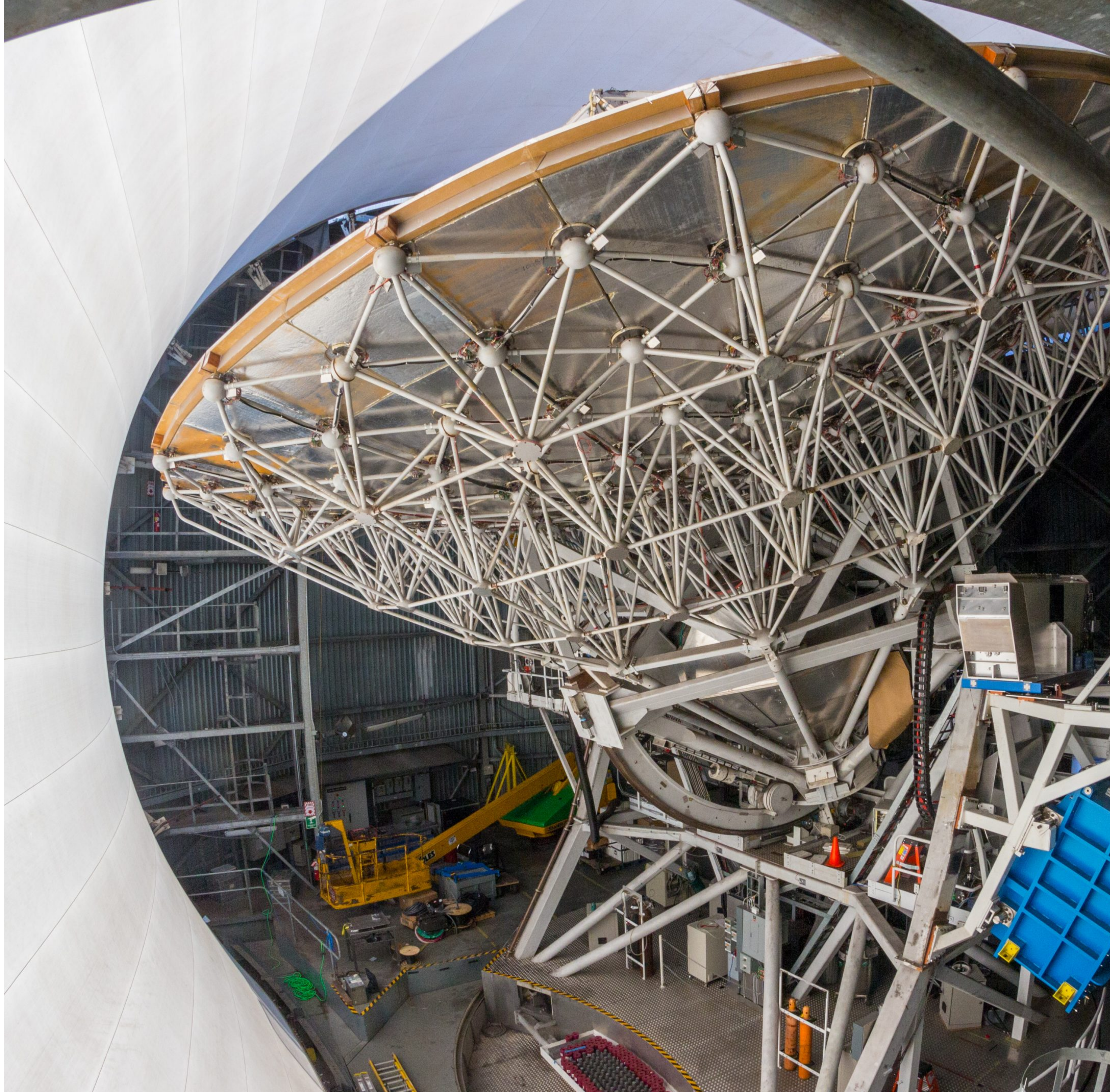
JCMT Calibration

JCMT Virtual Users' Meeting February 2022

General Telescope Calibration

Observatory Monitoring

- Pointing
  - Carried out by TSS as needed throughout night.
  - Normally 2” standard deviation in x and y, approx 3” absolute.
- Monitoring of standards
  - All instruments.
  - Routinely observe standard/s at night to check instrument is working within normal parameters
  - Follow up on longer time scales by staff.
- Monitoring of instrument performance (temperatures etc)
- Inclinometry carried out regularly

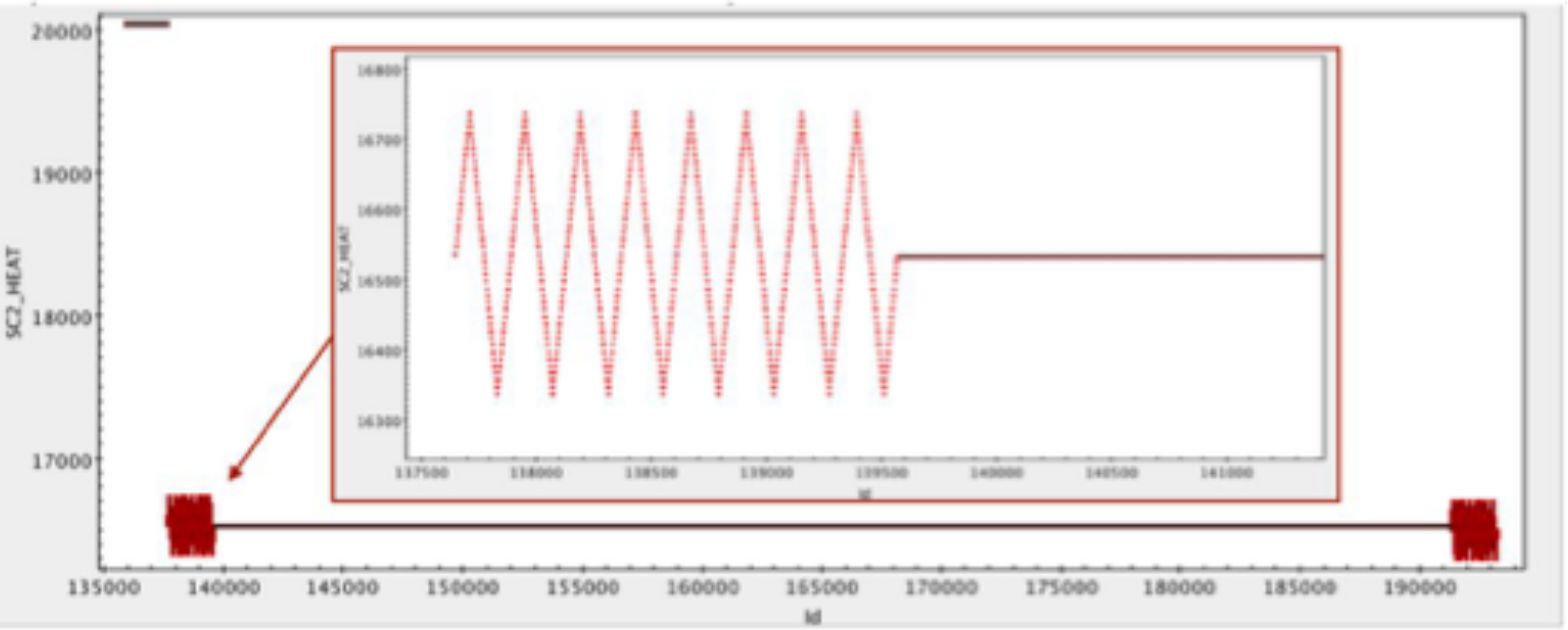


SCUBA-2 Calibration (and POL-2)

Applied by the Instrument Software

While the observations are being written, the instrumental values are calibrated into units of pW by using a “fast flat” observation.

The raw data you download has already applied this calibration.

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>> jcmtstate2cat s8a20120501_00068_*.sdf state.tst
>> topcat -f tst state.tst
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After Observing: Flux Conversion Factors

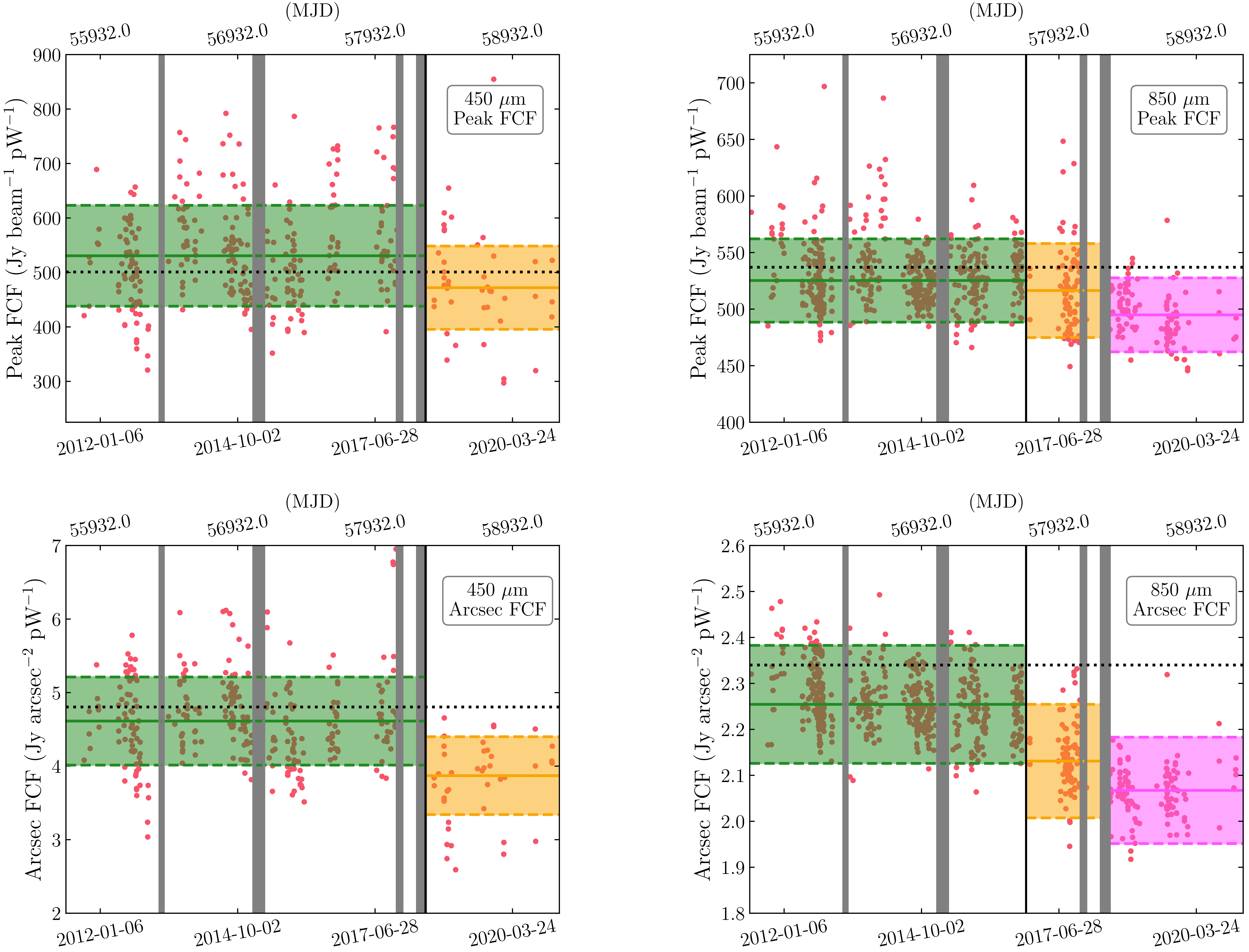
- Telescope regularly observes bright point sources with a known flux.
  Primary calibrator is Uranus, with CRL-618 and CRL-2688 being the next two most used sources.
- We derive the conversion from the instrumental units (pW) to mJy/arcsecond^2 or mJy/beam
  - Reduce the observation with the ‘BRIGHT POINT SOURCE’ ORAC-DR recipe.
  - Calculate the detected signal inside an aperture to get the Arcsecond FCF.
  - Calculate the fitted Gaussian peak of the source to get the Beam FCF .
- Requires large number of observations due to high intrinsic scatter of results.
- An absolutely uncertainty in the flux of Uranus of ~5% at these wavelengths.
- Original work done in Dempsey et al 2013, updated with many more years in Mairs et al 2021.
- Applied during/after data reduction process

Mairs Et Al 2021: Updated FCF Values

- Repeated and improved original Dempsey 2013 et al analysis with far more data.
- Derived improved extinction corrections, incorporated into SMURF ‘makemap’ software as of Starlink 2021A
- Checked for date variation in FCF based on known events that may have affected SCUBA-2 performance significantly enough to change FCF values.
- Identified 3 date ranges (450um) and 2 date ranges (850um) where we should be changing the default FCF used.

Uranus calculated FCFS in the different epochs from stable part of night.

- Grey areas indicate no data used for FCF calculation due to issues. (WVM, SMU, GoreTex)
- Colored regions indicate different time based FCF eras.
  - 2018 June 30th: Secondary mirror fixed
  - 2016 Nov 19th: Thermal filter stack updated (450 only)



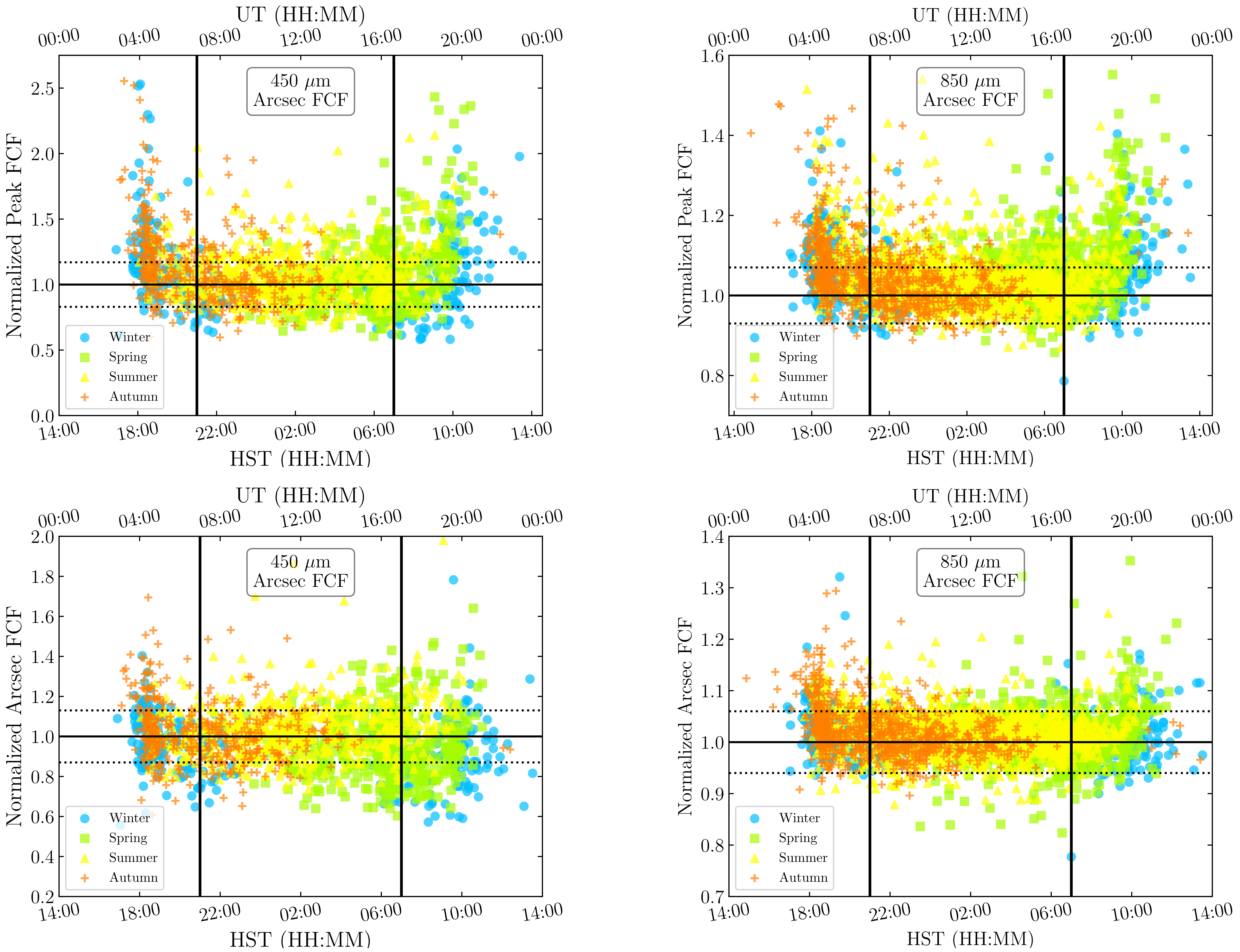
The New Standard FCFs

Table 4. Recommended FCFs for observations obtained between 07:00-17:00 (UTC).

Wavelength, Date Range	$\mathrm{FCF}_{\mathrm{peak}}$	$\mathrm{FCF}_{\mathrm{arcsec}}$
450 μm, Pre 2018 Jun 30	531 ± 93	4.61 ± 0.60
450 μm, Post 2018 Jun 30	472 ± 76	3.87 ± 0.53
850 μm, Pre 2016 Nov 19	525 ± 37	2.25 ± 0.13
850 μm, 2016 Nov 19 to 2018 Jun 30	516 ± 42	2.13 ± 0.12
850 μm, Post 2018 Jun 30	495 ± 32	2.07 ± 0.12

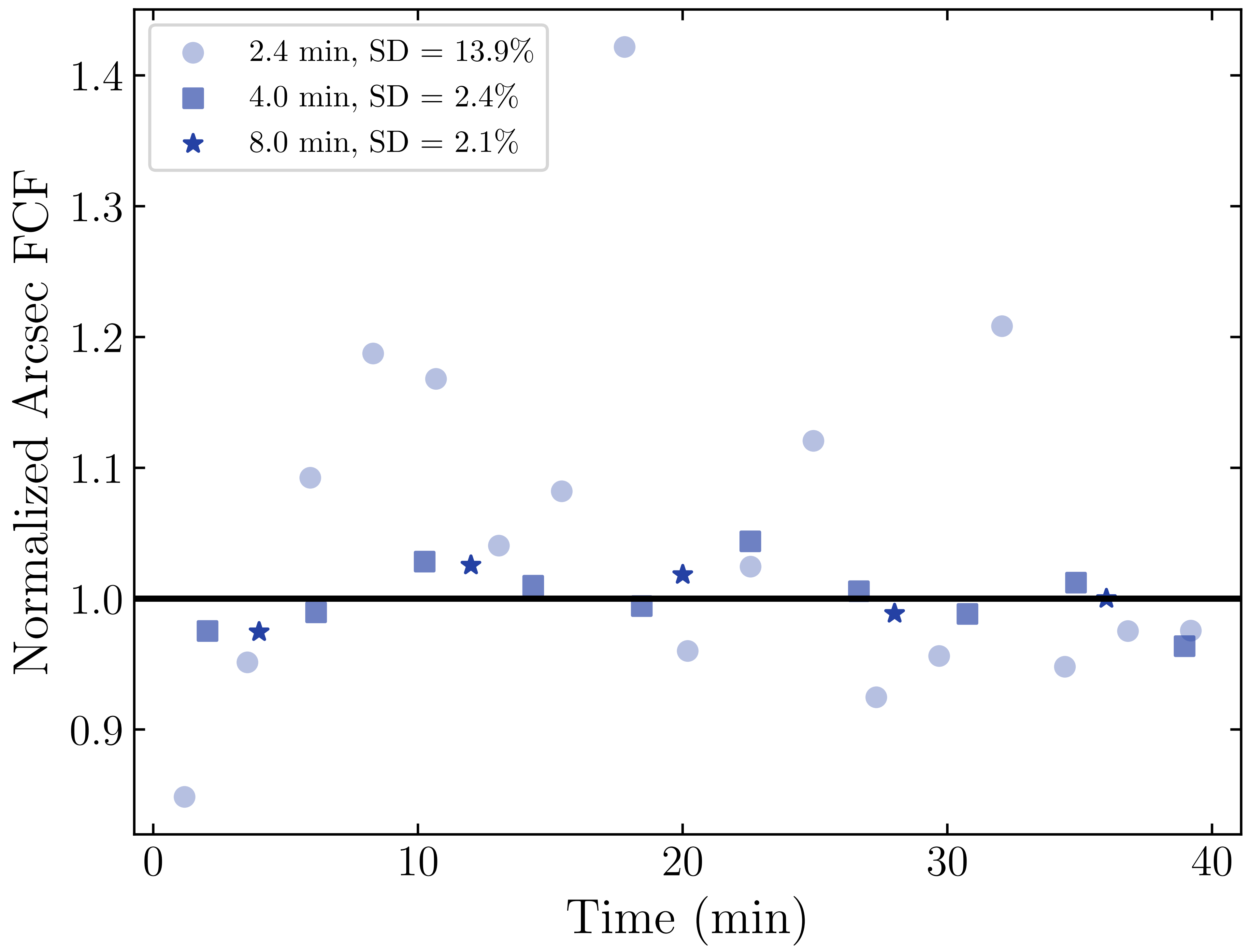
NOTE—These FCFs assume the opacity relations presented in Equation 6 and Table 1 were applied during the extinction correction. The same extinction correction must be used for a direct comparison with the FCF values presented by D13. The atmospheric transmission lower limits included in the FCF determination are 10% and 25% for 450 and 850 μm, respectively. The primary calibrator, Uranus was used to derive these FCFs.

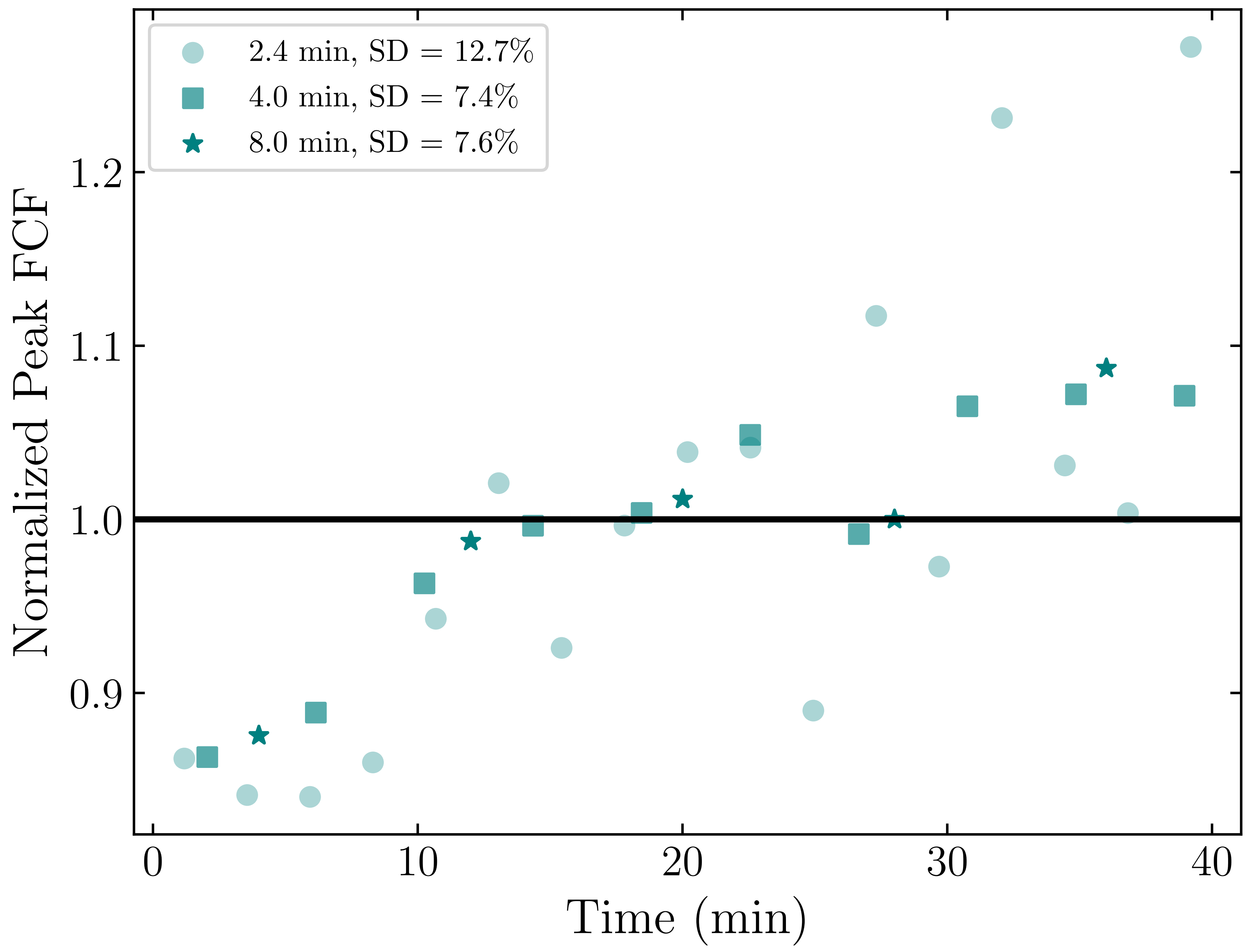
Variation Throughout Night



FCF Variation Within One Observation

- 40minute observation of CRL2688, subdivided into 2.4, 4minute and 8 minute integrations to check variation within one observation.





How To Apply to Your Data

- Use Starlink 2021A! This latest release should apply the correct date-dependent FCFs when you reduce your data with ORAC-DR, and will use the new updated opacity corrections.
- Generally, start with the newly updated standard FCFs, with their error range.
- Determine how accurate you need to know the FCF and its uncertainty for your science (within feasibility!)
- You can check FCFs on a given night to check telescope performance, but large scatter means we DO NOT recommend using the FCF from the closest-in-time calibrator observation(s).
- If you need to apply time-dependent (i.e. varying with time of night) FCFs you will currently have to apply these yourself; contact the observatory if you need help with this.
- Check the effect of your data reduction. Use simulated sources (similar to your science sources, and at similar positions in the map), and reducing calibrator data with your DR method.

Heterodyne Calibration (HARP & Nāmakanui)

Applied by the Instrument

- Raw heterodyne data are downloaded in units of T^*_A, corrected antenna temperature, in Kelvin
- This scale is calibrated using measurements of hot &/or cold loads with knowledge of sky & ambient temperatures (and for UU also the WVM data)
- Corrected for:
  - Atmospheric attenuation
  - Scattering
  - Rearward spillover (portion of beam not looking at source)

- Not corrected for: Basic telescope/instrument efficiency!

ʻŪʻū Instrument Calibration

- To convert the raw values to T^*_A we use the system temperature.
- To obtain the system temperature for ʻŪʻū the following method is used:
  - we apply chopper wheel calibration using blank sky, an ambient load and a measurement of the atmospheric opacity during the observation.
  - Opacity at 225 GHz is taken from the 186 GHz water vapor radiometer at JCMT
  - (assumes that the opacity does not significantly vary by frequency across ʻŪʻū frequency range.)

- See Mizuni et al 2020 from SPIE (https://ui.adsabs.harvard.edu/abs/2020SPIE11453E..3TM/abstract)

After Observing

- Normally you will need to convert from the telescope specific T^*_A temperature scale to a more scientifically useful: T_{MB} or T_R^*

- Main Beam Temperature: uses η_{MB}, the main beam efficiency
- Radiation Temperature (T_R^*): uses η_{FSS}

- Note that different telescopes/papers may use different nomenclature or slightly different definitions.
  - See e.g. Kutner & Ulich, 1981

Temperature Scales

- Main beam temperature: $T_{MB} = T^{*}_{A} \ / \ \eta_{MB}$.
  - η_{MB} is the efficiency of the main beam of the instrument/telescope combination, as found by measuring a source of similar size to the beam (Jupiter, Uranus or Mars).
  - Most appropriate for point sources.
- Radiation Temperature: $T_R^{*} = T^{*}_{A} / \ \eta_{FSS}$.
  - η_{FSS} is the efficiency of the entire telescope beam, including the sidelobes, as found by measuring the intensity from a source much larger than the beam (e.g. the moon).
  - Most appropriate for large sources filling the whole beam, otherwise a correction for source filling factor should be applied.
- Many sources are intermediate between these two extremes (e.g. clumpy molecular clouds), so the best choice of calibration is a decision by the scientist.

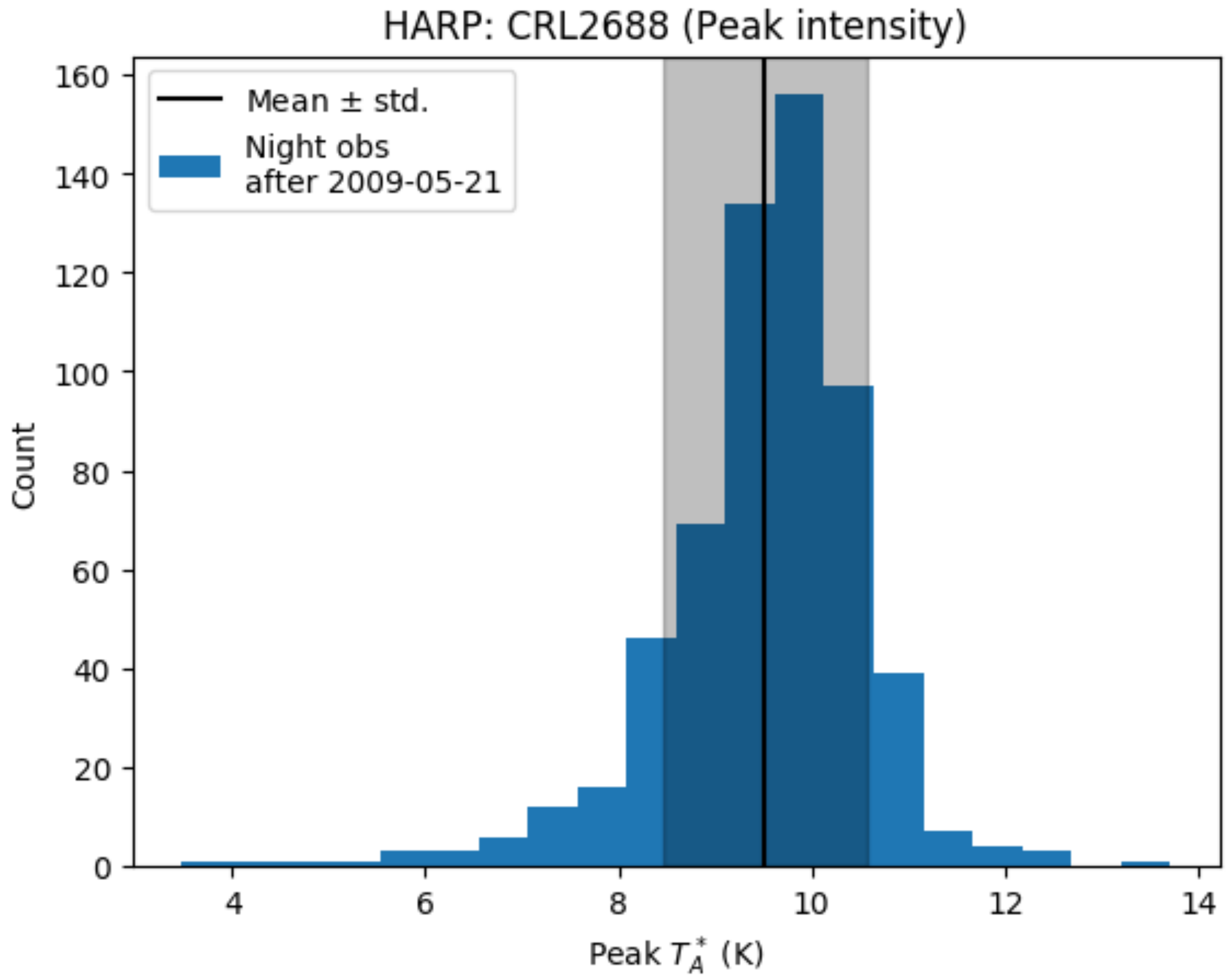
Flux Density

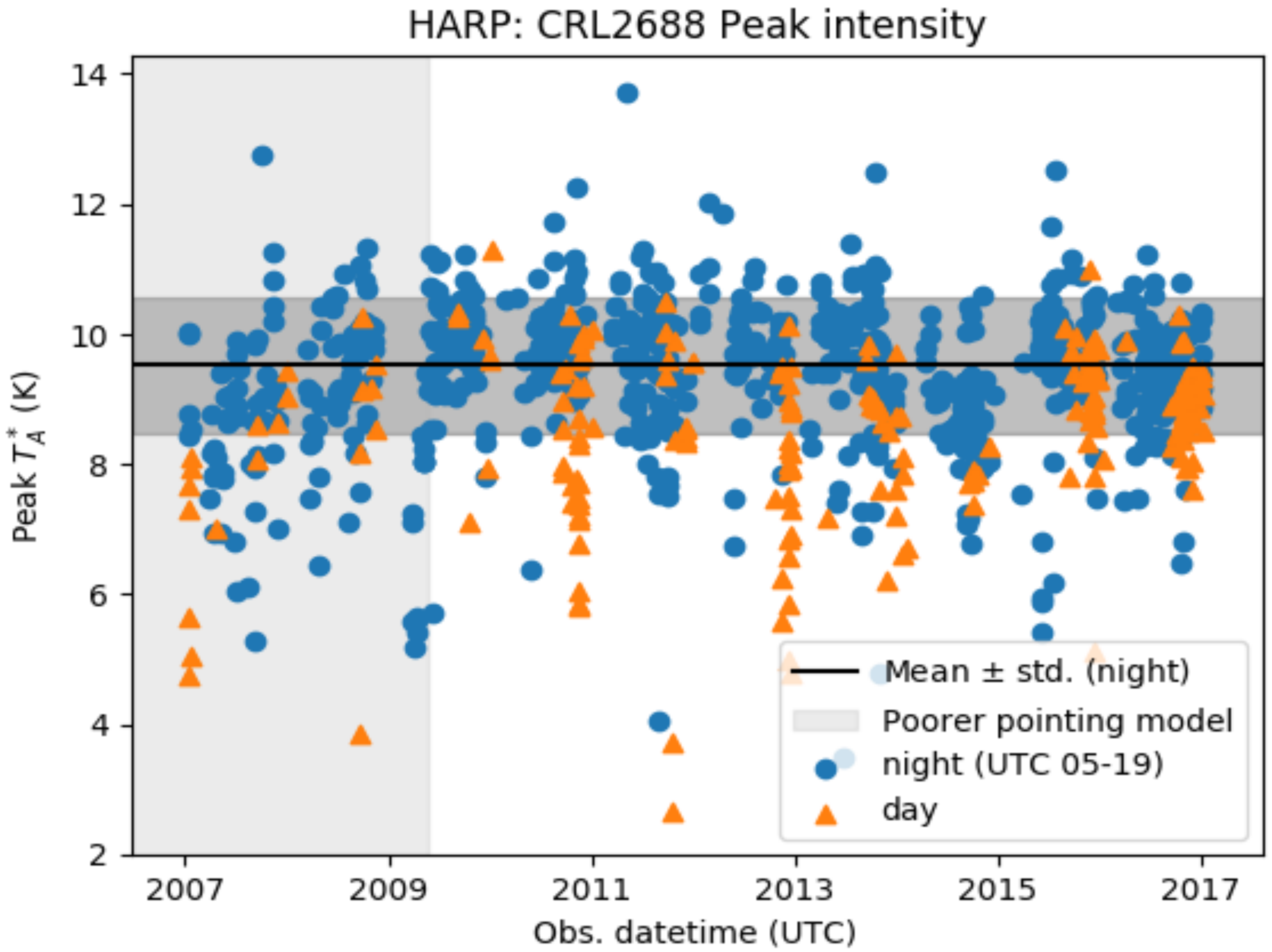
- To convert to point source flux density:
  - (e.g. flux density equivalent of T_{MB})
  - Conversion uses the aperture efficiency ηA .
  - ηA is calculated from the same data as η_{MB}.
- For a 15m dish, the conversion factor is: $S(Jy) = 15.6\ T^{*}_{A}(K) / \eta A$

Best Practices

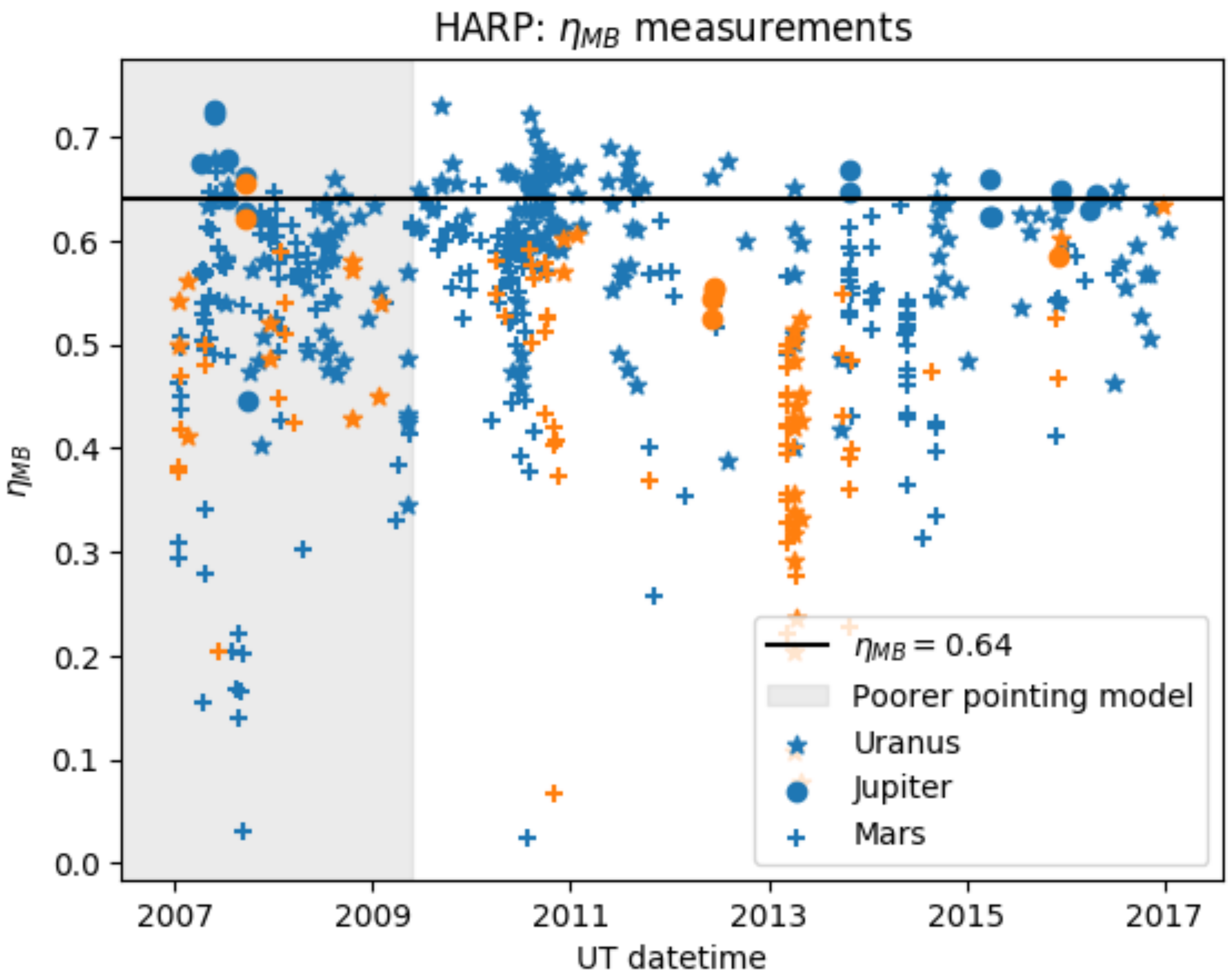
- 1)Get observations and calibrations, reduce all with ORACDR.
- 2)Check data quality & fix/consult as necessary.
  - (HARP rasters: check if flatfield fix required/possible.)
- 3)Check calibration result is within expected value +/ scatter.
  If answer is NO: read obslogs and consult observatory for further help!
- 4)Select final temperature/flux scale (T_{MB}, T_R^*, Flux density).
- 5)Look up and apply appropriate efficiency.
  - Remember to include calibration uncertainty to your overall uncertainty estimation, if required.

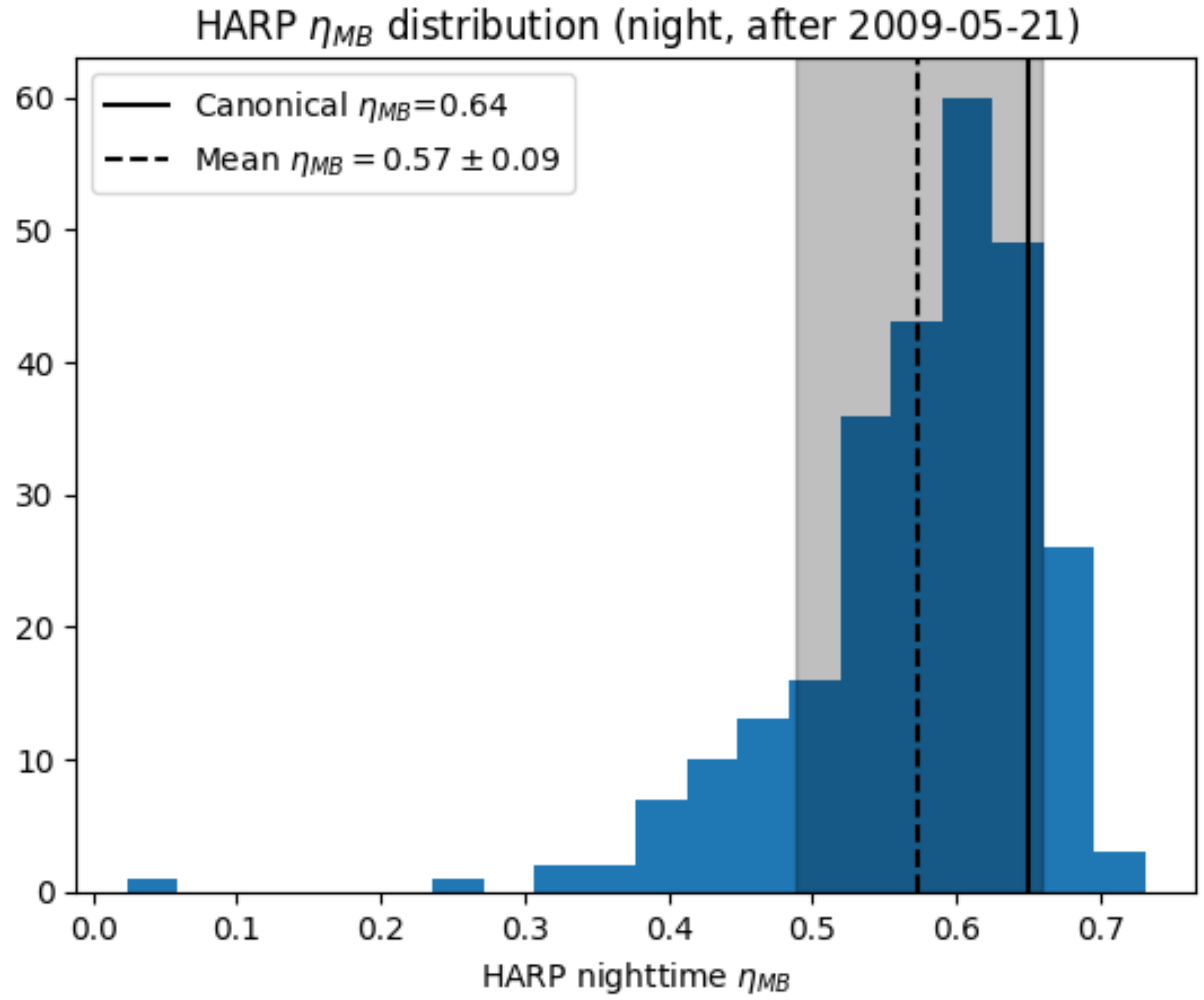
Example Variation (HARP Spectral Standard)





Example Variation: HARP η_{MB}





Best Practices: When There Are Issues

- We recommend checking the spectral standard and heterodyne planetary observations from the same night as your data to see if they are reasonable.
  - Look at shift comments and obslog comments on JCMTCAL observations, along with the ORACDR logs.
  - For archival data, you can download proposal=JCMTCAL observations from that night.
  - If you see issues please contact your support scientist directly, or the observatory via: helpdesk@eaobservatory.org