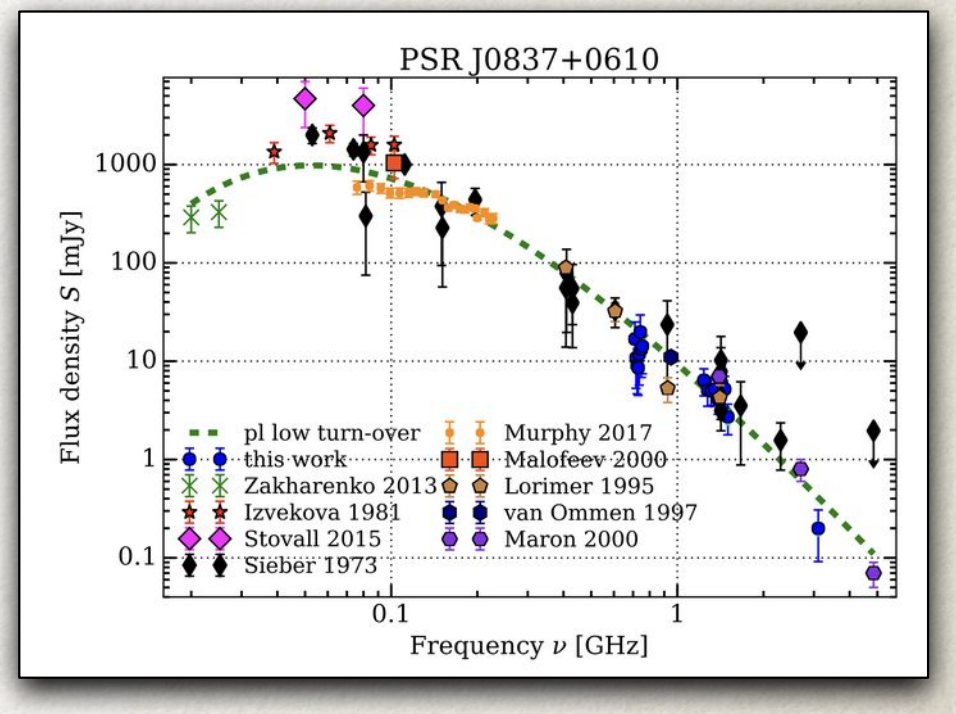
# Absolute Flux Density Calibration

## Motivation

- Absolute flux densities
- Radio spectra
- Absolute pulse energies, pulse-energy distributions
- Survey sensitivity
- Non-detection upper limits (FRBs, LPTs, other transients)




(Parkes & literature, FJ+ 2018)

Fabian Jankowski fabian.jankowski@cnrs-orleans.fr Paris Obs, LPC2E, CNRS

# General Approach

- Use the radiometer equation and known system parameters
- Dewey et al. 1985, Lorimer & Kramer 2012
- Work out counts to Jansky mapping

Folded

$$S_\nu = \mathrm{S/N}\,\beta\,\frac{T_{\mathrm{sys}} + T_{sky}}{G\sqrt{B N_{\mathrm{p}} t}}\sqrt{\frac{\delta}{1-\delta}},$$

(UTMOST, FJ+ 2019)

Single

$$S_{\mathrm{peak}}\left(\mathrm{S/N}, \mathrm{W_{eq}}, \vec{a}\right) = \mathrm{S/N}\,\beta\,\eta_{\mathrm{b}}\,\frac{T_{\mathrm{sys}} + T_{\mathrm{sky}}}{G\sqrt{b_{\mathrm{eff}} N_{\mathrm{p}} \mathrm{W_{eq}}}}\,a_{\mathrm{CB}}^{-1}\,a_{\mathrm{IB}}^{-1},$$

(MeerKAT, FJ+ 2023)

# Telescope Performance Parameters

1) SEFD: $S_{sys}(f) = T_{sys} / G$ (sensitivity vs frequency) – bandpass calibration

2) Telescope gain curve (sensitivity vs elevation) – temporal calibration

Example for UTMOST, fit to pulsar transit data.

$$\eta(m,n) = \left[\frac{a_{\mathrm{m}}}{\cos(m-m_0)} + b_{\mathrm{m}}\right]\left[a_{\mathrm{n}}(n-n_0)^2 + b_{\mathrm{n}}\right].$$

(UTMOST, FJ+ 2019)

m, n analogue to zenith and azimuth angles.

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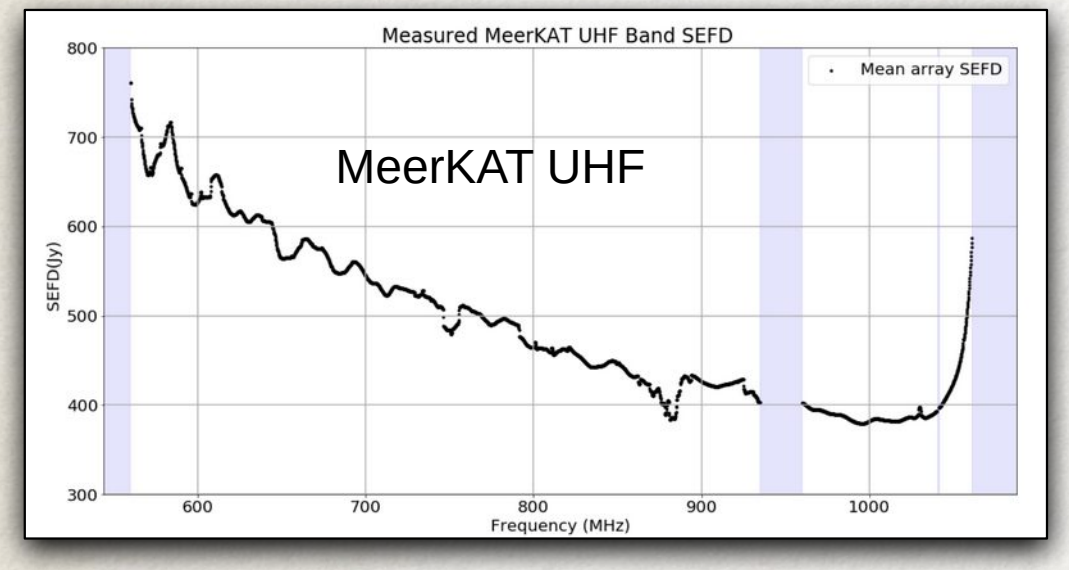
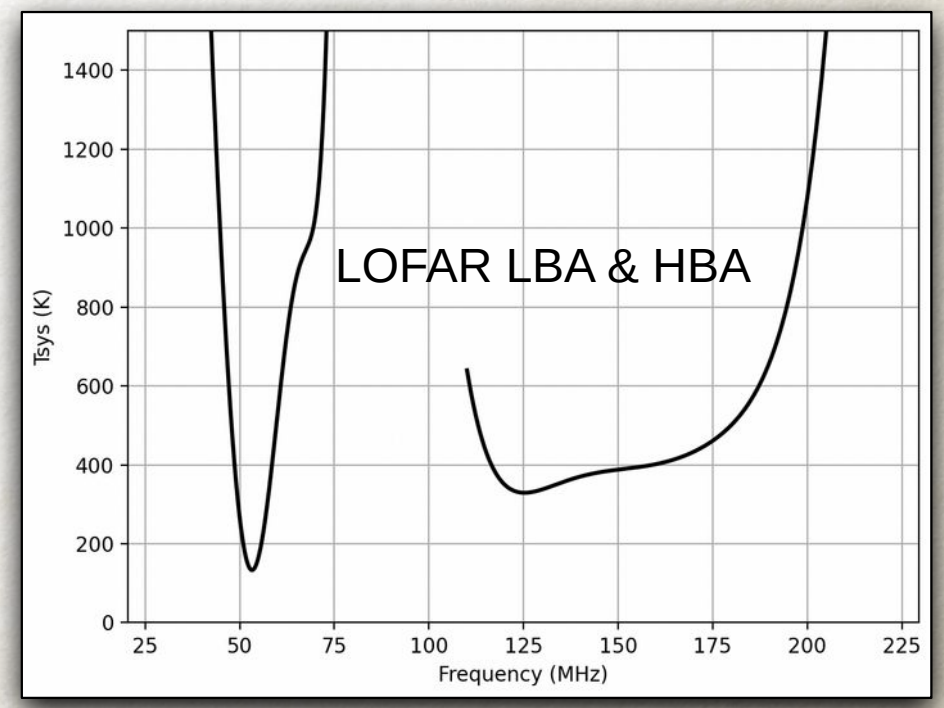
# Other Examples

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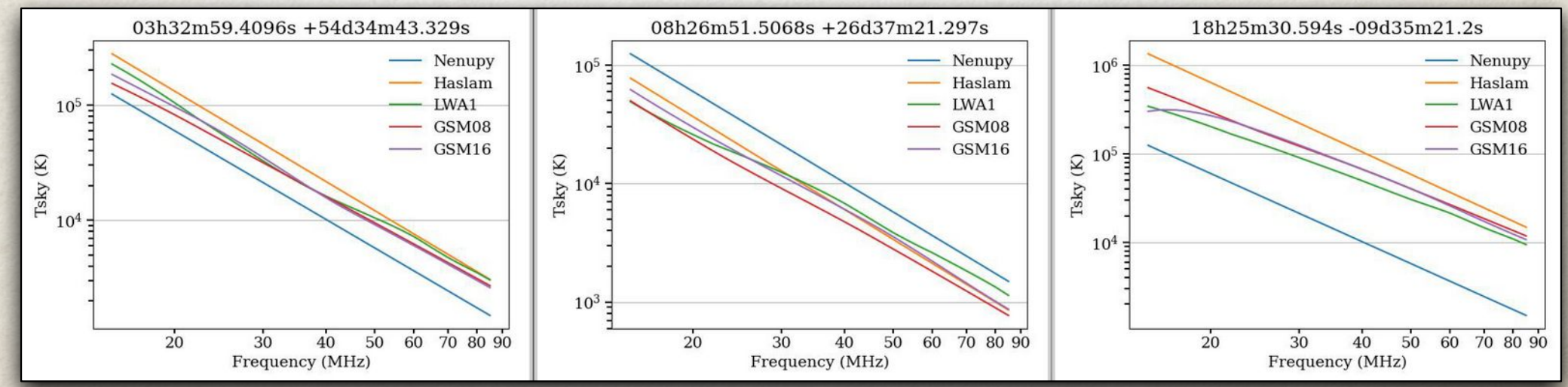
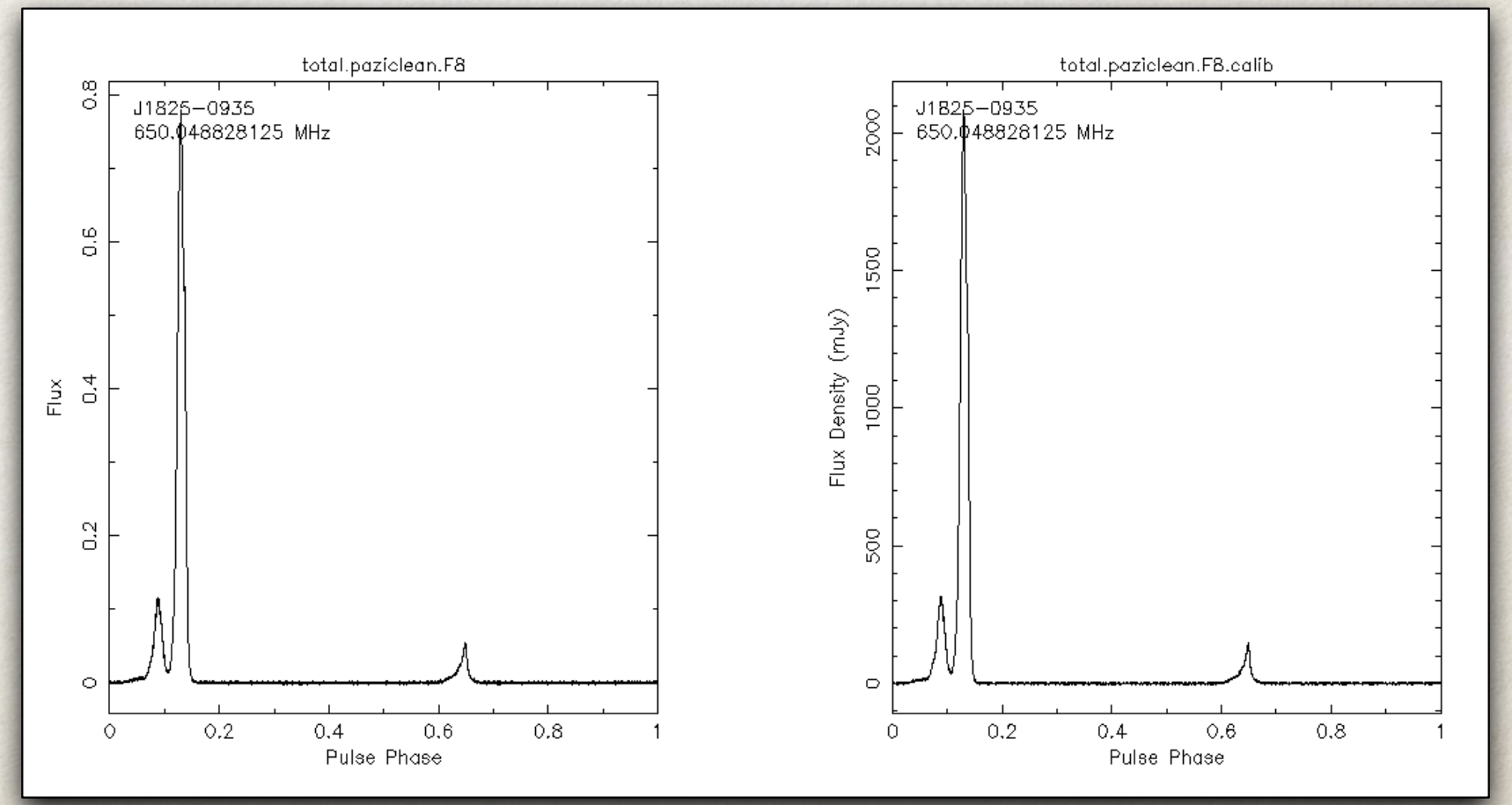
# Sky Temperatures

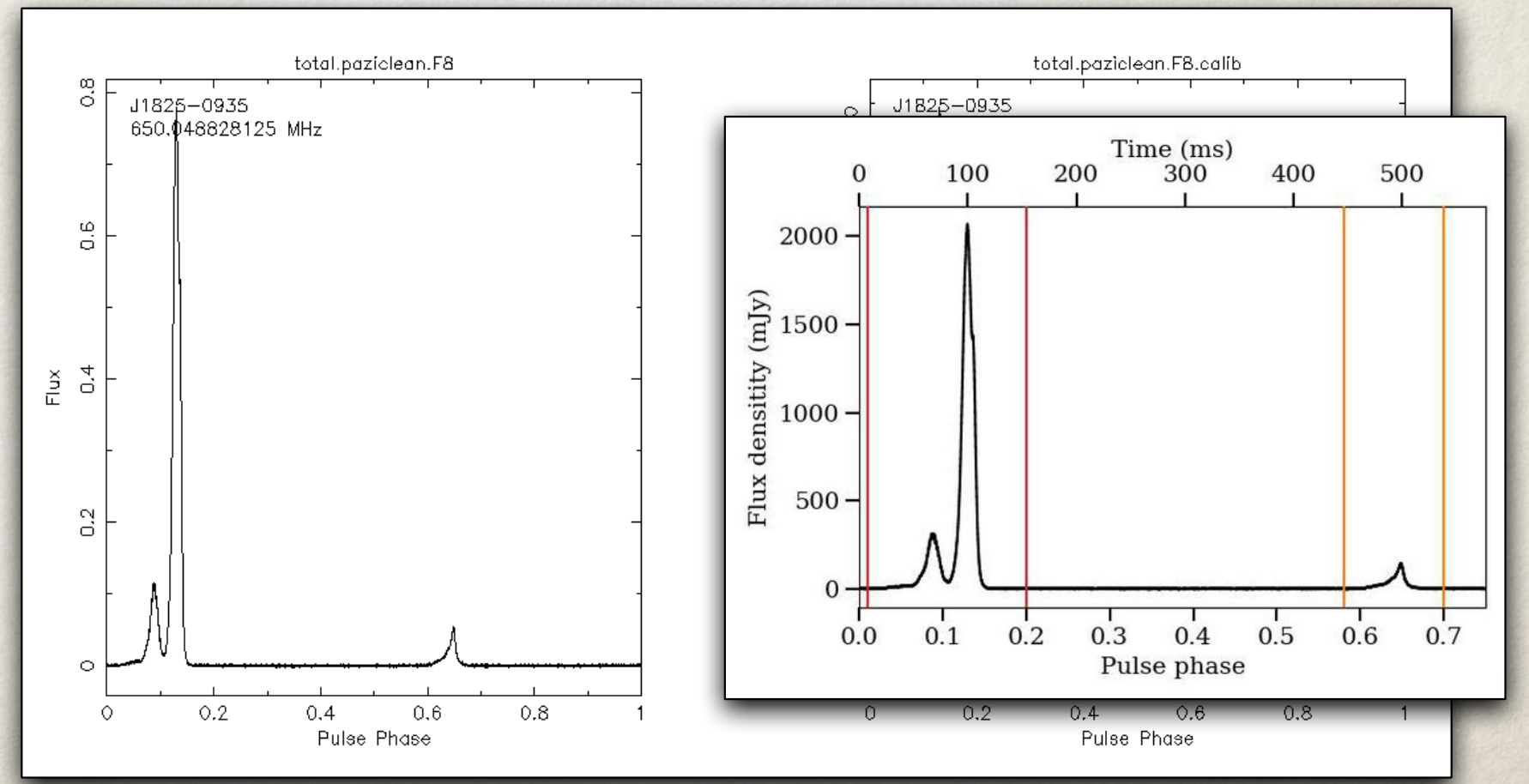
- Investigated several different diffuse sky models
- Haslam et al. map & spectral index is not too bad
- However, accurate model is much preferred at NenuFAR frequencies
  - $T_{sky}$ dominates in the $T_{sys}$ + $T_{sky}$ term



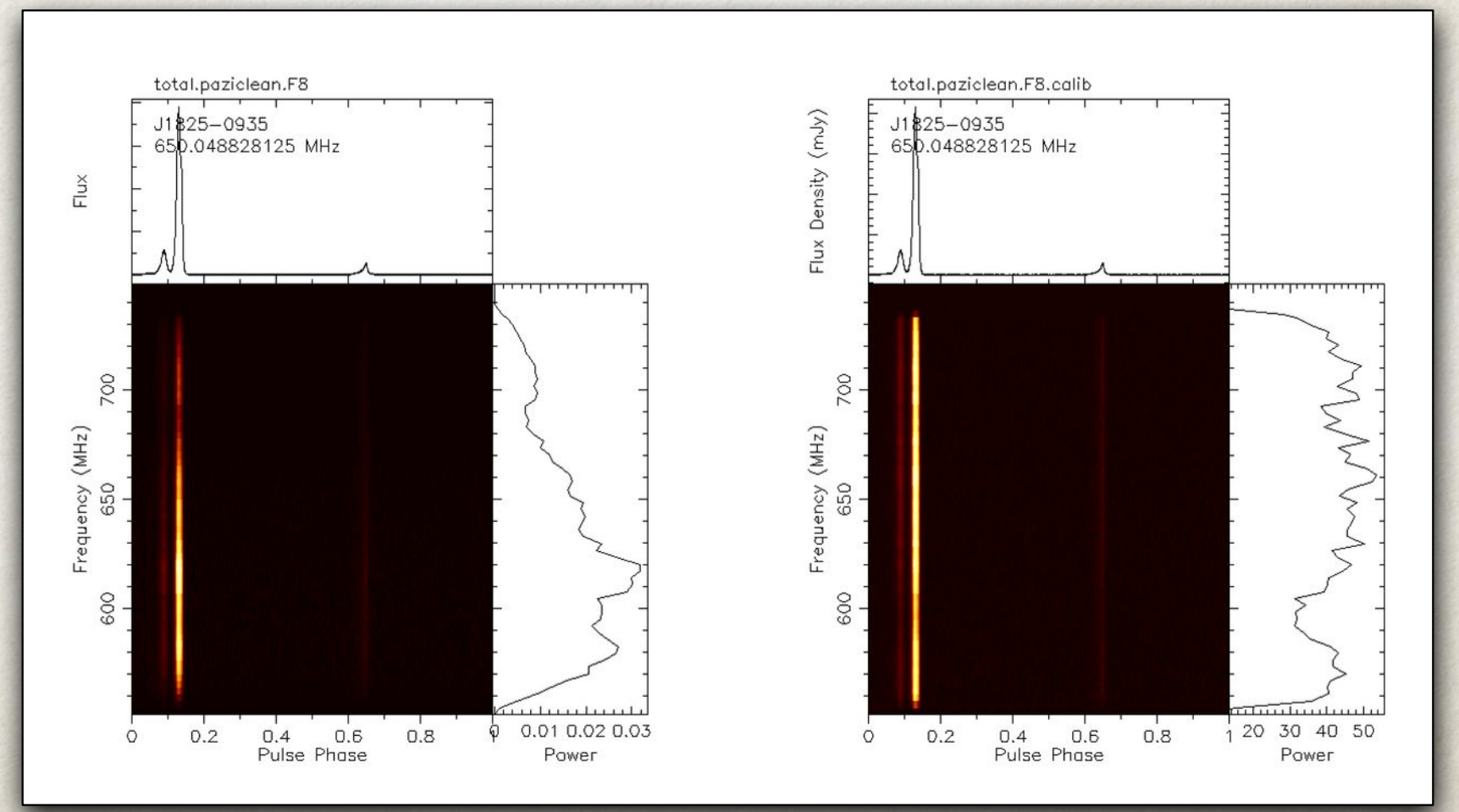
# uGMRT Pulsar Calibration



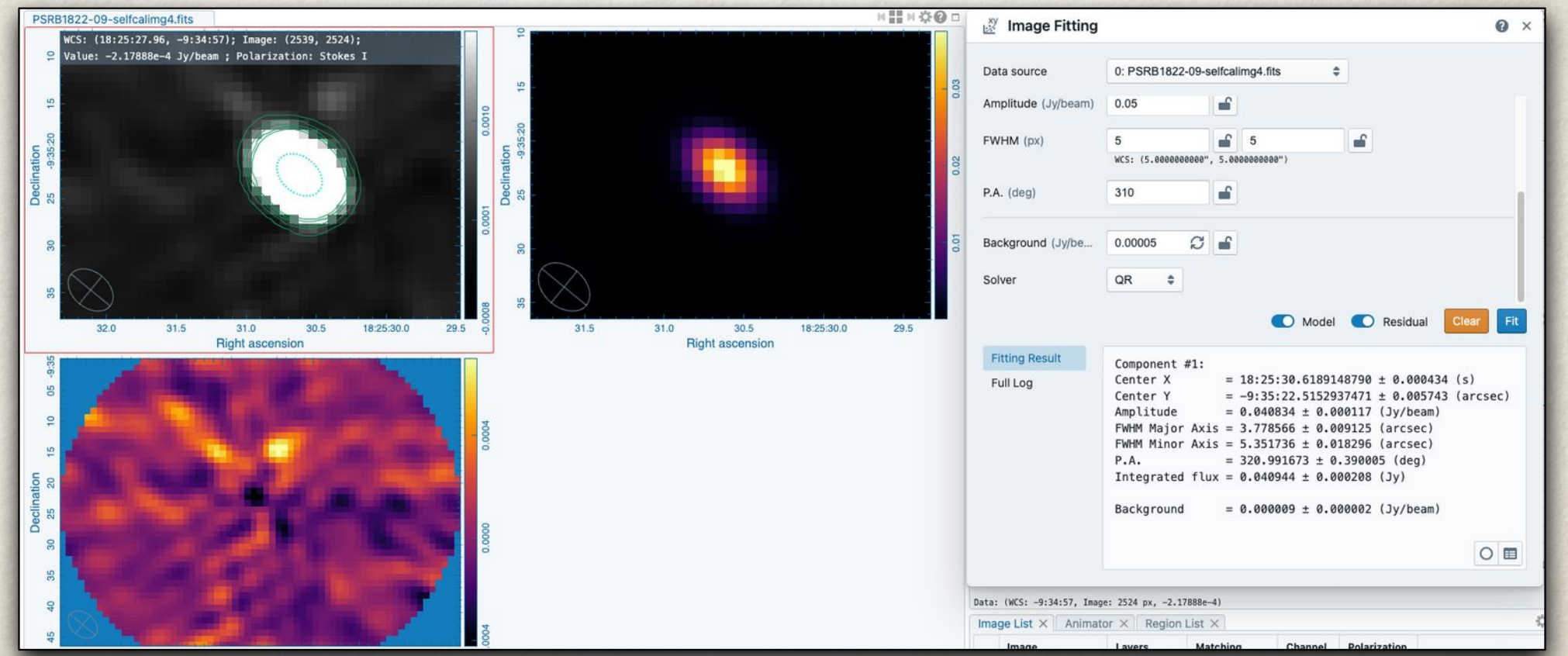
# uGMRT Pulsar Calibration



# uGMRT Bandpass Calibration



# Verification with uGMRT Synthesis Images

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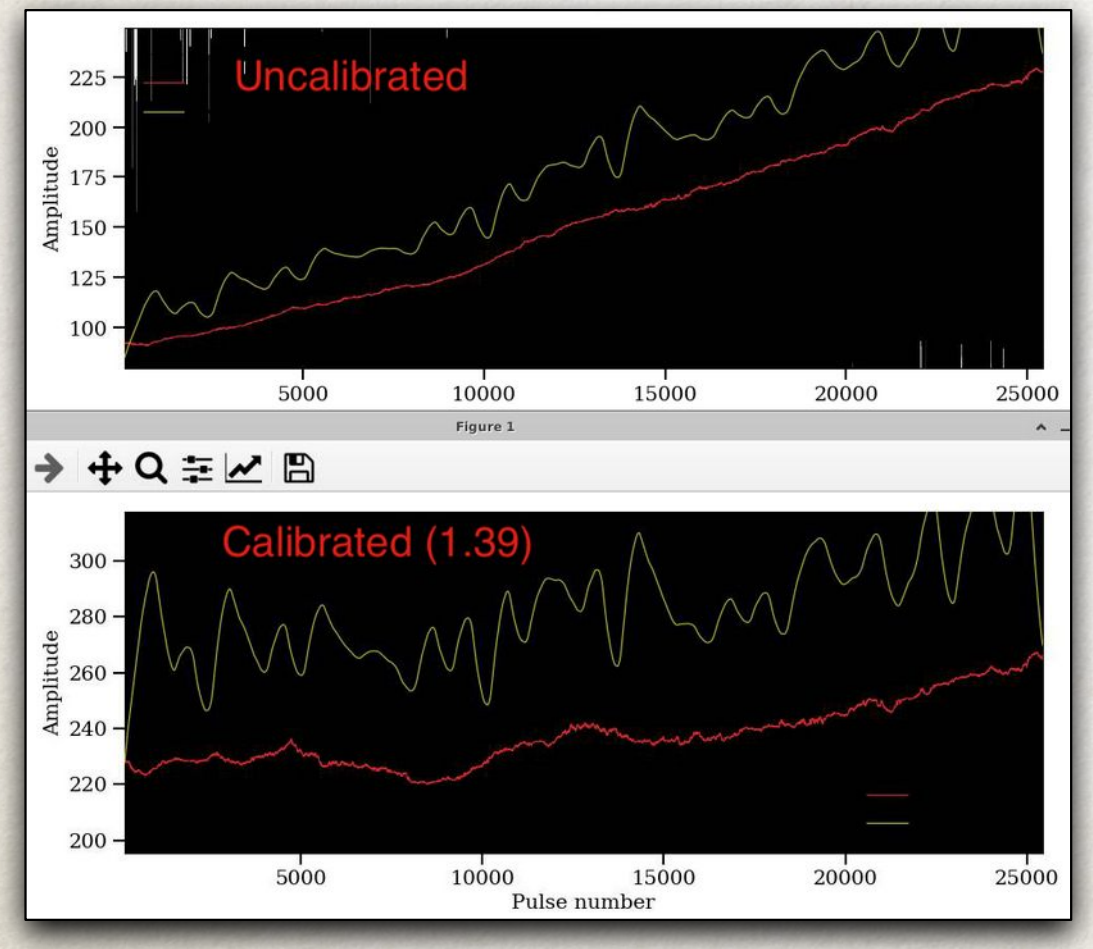
Almost perfect agreement so far.

# LOFAR Pulsar Calibration



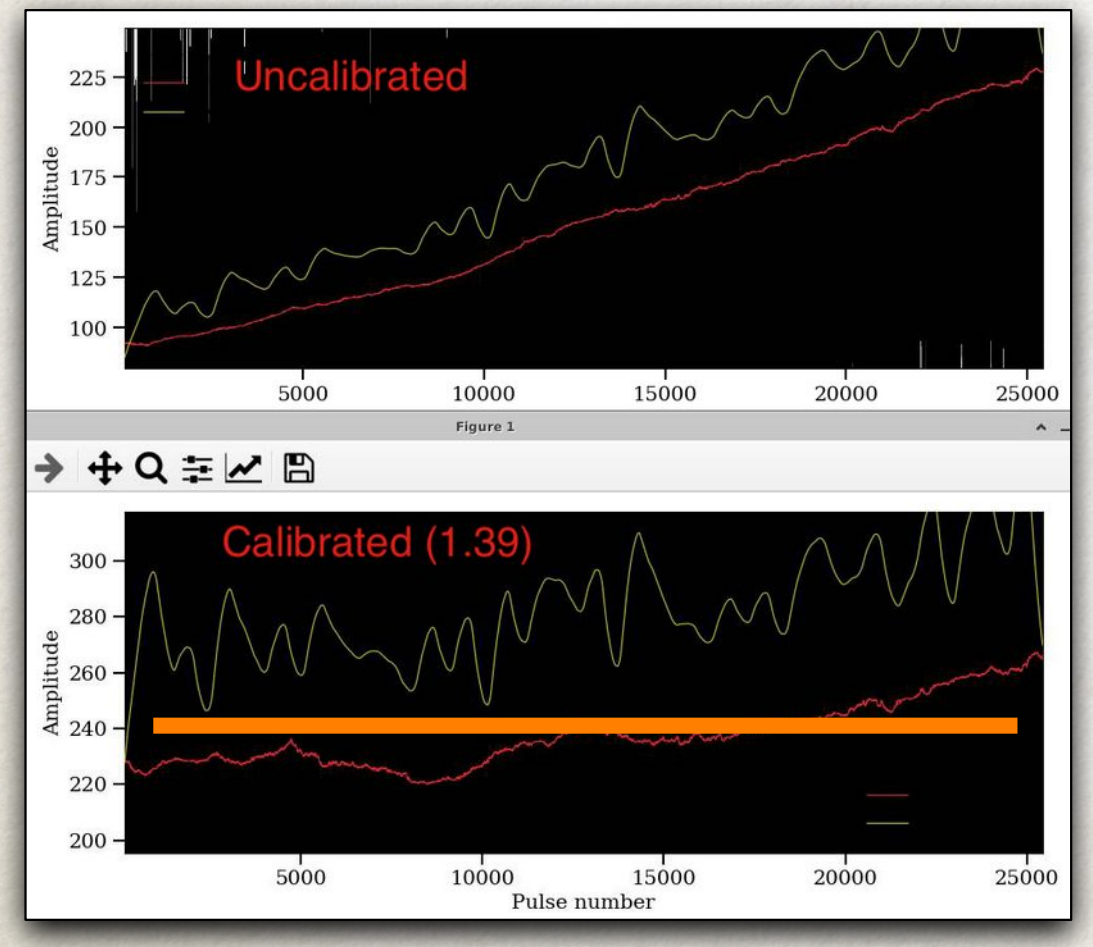

Fluence or pulse energy

Time or elevation

- LOFAR FR606 HBA
- PSR B2217+47 rising in elevation
- Large scatter in single-pulse fluences
- Running medians (red lines) smoothly rising
- Geometric projection effect
- Modelled as ~$\sin^b(\mathrm{el})$ with b = -1.39

# LOFAR Pulsar Calibration

Fluence or pulse energy

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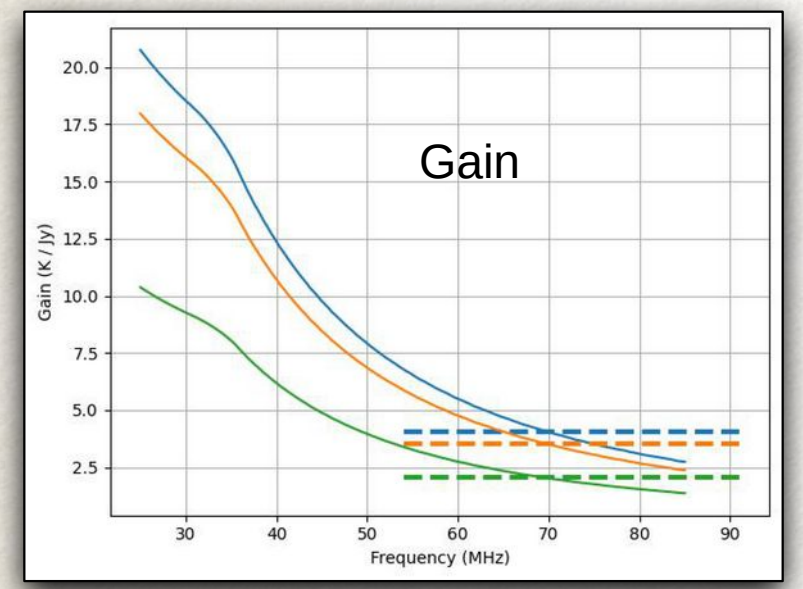
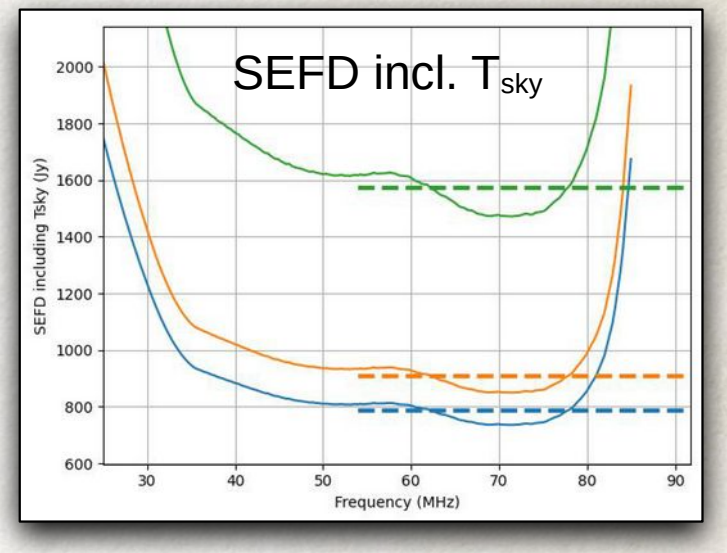
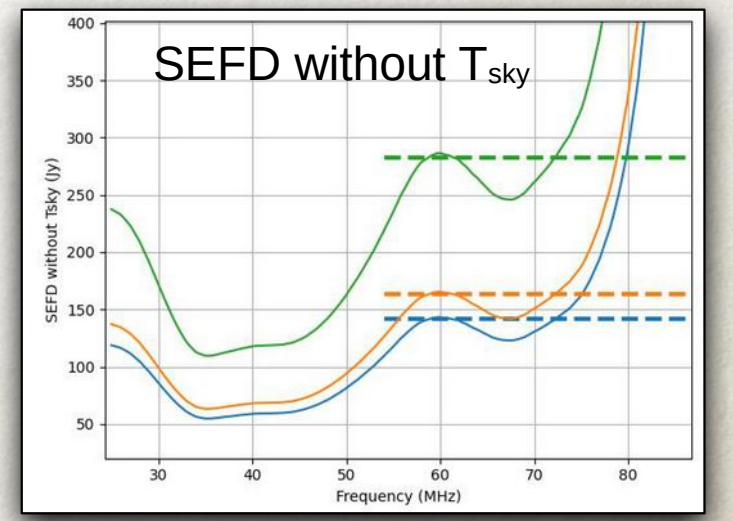
# NenuFAR



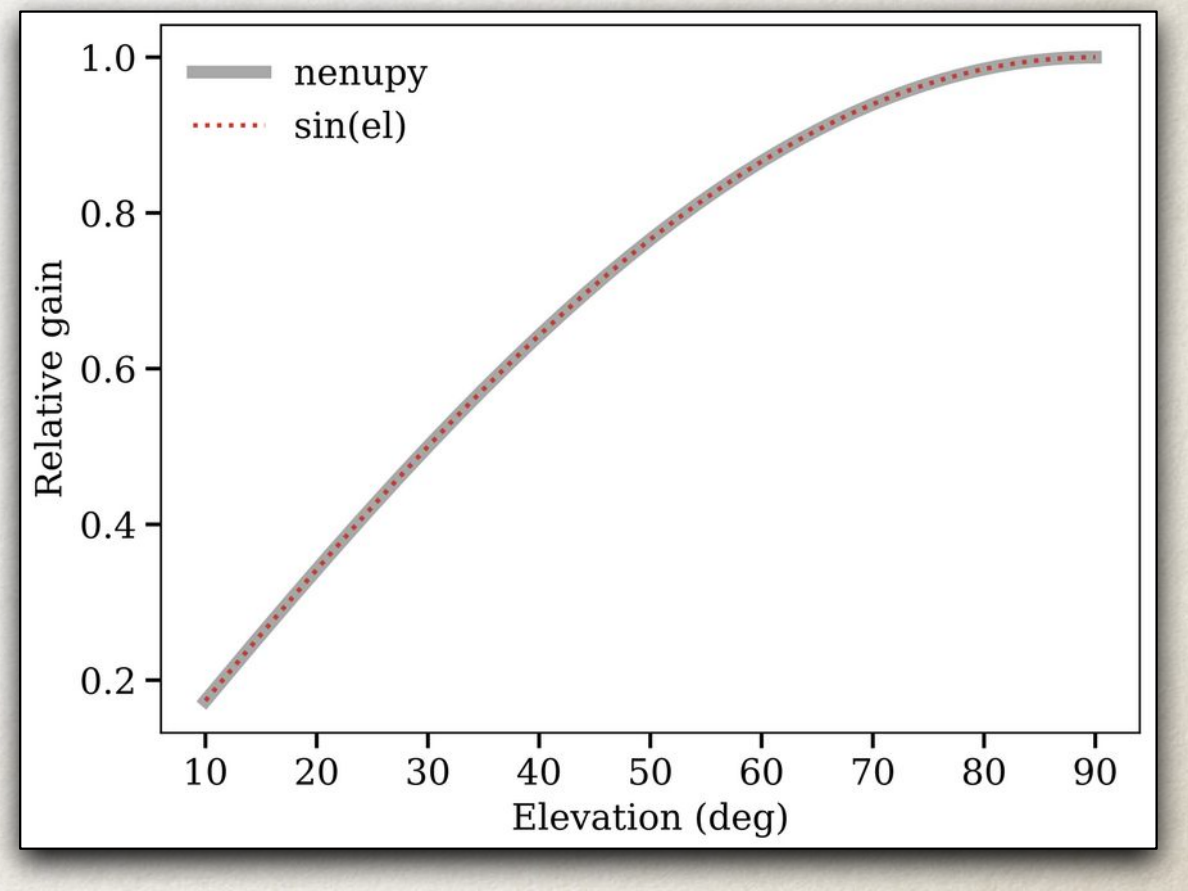




- All computed using nenupy software
- Colours map to elevations: 90, 60, 30 deg
- SEFD contains a location **independent** $T_{sky}$ by default
  - Would be better to add $T_{sky}$ later

# NenuFAR Gain Curve

- G(el, freq) / G(90 deg, freq)
- Computed using nenupy
- NenuFAR core (without remote MAs)
- Too simplistic?
- Can we measure it?
  - Quasars preferred, can use pulsars

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# NenuFAR Questions

- Need accurate **SEFD curve**
  - How are the parameters in nenupy measured?
  - Why do they include $T_{sky}$?
- Need measured **elevation-gain curve**
  - Best to use quasar transits
  - Can verify calibration using pulsar transits
- Need NenuFAR's phasing or **beam-forming efficiency**
  - Have we measured this?
  - Observe a source and iteratively increase the number of MAs included
- What about the (chromatic?) **telescope mis-pointing**?
  - Some pulsars vanished (>6 dB)