A catalog of absolute spectral-flux calibrators for VLTI/MATISSE and future IR instruments

Violeta Gámez Rosas, Michiel Hogerheijde, József Varga,
Alexis Matter, Roy van Boekel, Leonard Burtscher, Walter Jaffe
Leiden Observatory, Leiden University
Nov 7 2024

Sterrewacht Leiden

European Interferometry Initiative

MATISSE

Project:

I. Script for calibrating in correlated flux mode for MATISSE

II. Catalog of calibrators

Motivation:

General:

- Observing faint sources with the MATISSE instrument at the VLTI (in Correlated Flux mode)
- To flux-calibrate observations of other IR instruments (E.g. JWST, ELT)

Personal:

- More Active Galactic Nuclei results with MATISSE!!

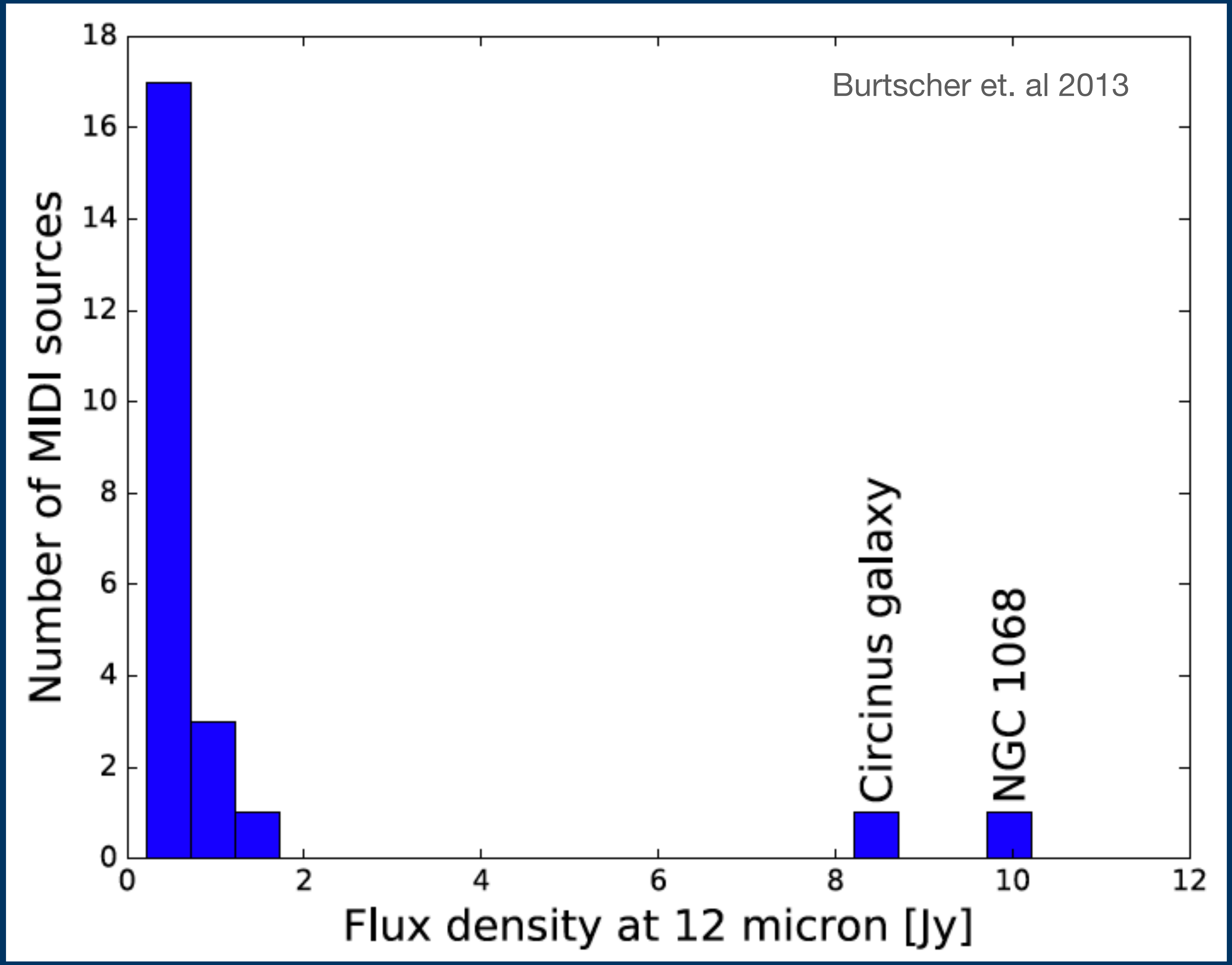
Other catalogs:

- Cohen et. al 1999 - 336 spectra
- van Boekel et. al 2004 - 482 spectra

→ 100,000s spectra

Why now?

- For MATISSE most AGNs are faint



Why now?

- **Difficult targets** for MATISSE -> faint

- For faint targets we have the option of using the Correlated Flux mode (If we avoid using visibilities: not dividing the correlated flux by the photometry which is more noisy for faint targets)

- But then we need the spectra of the stars used as a calibrators

Why now?

- GAIA DR3

Credit:ESA/ATG medialab; background image: ESO/S. Brunier

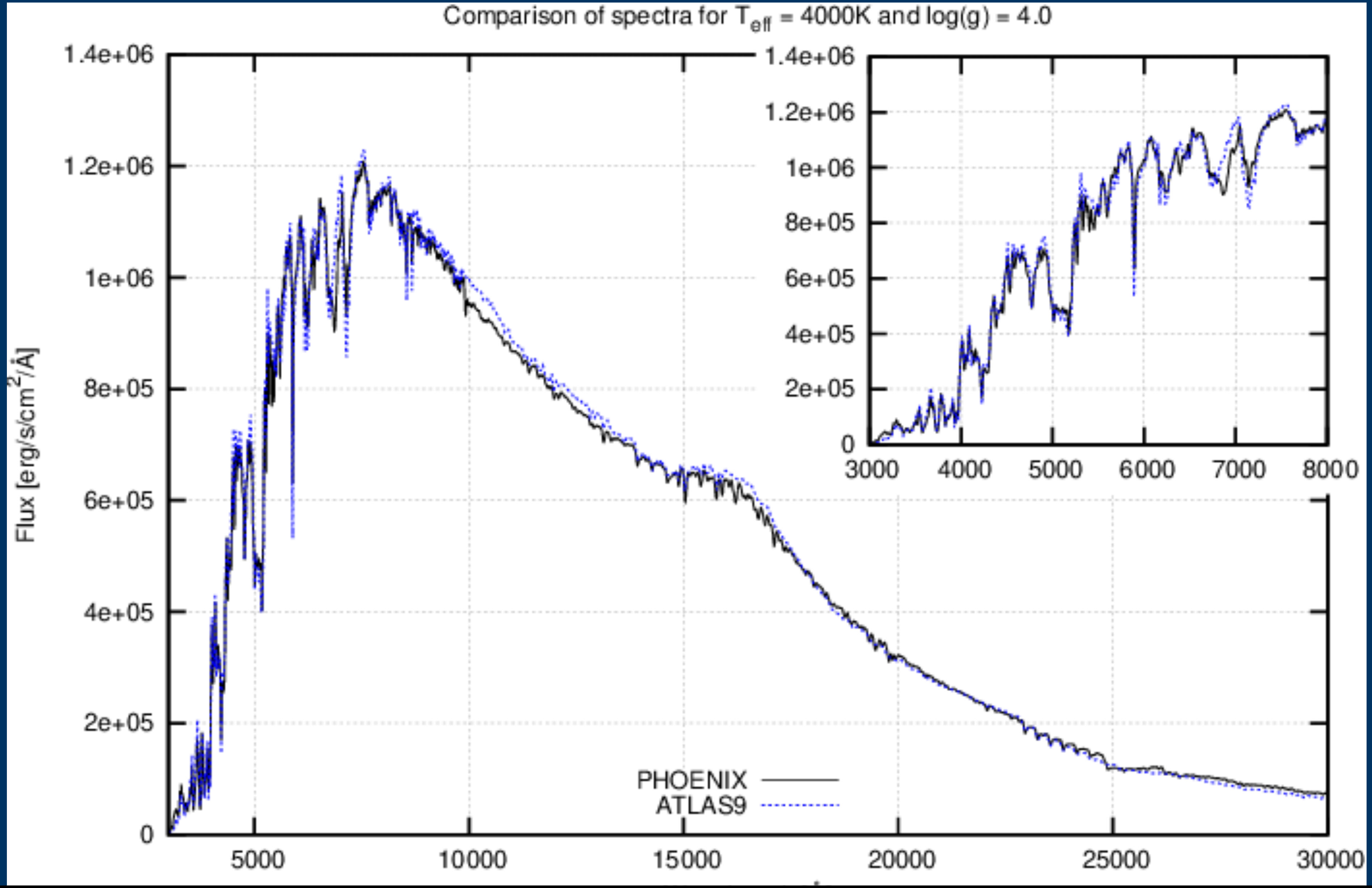
Radial Velocity Spectrometer (RVS) with the GSP spec module (purely spectroscopic treatment)
MatisseGauguin analysis workflow (based on projection and optimisation methods):

1. Parametrisation of the first 34 months of observations (multiple transits, selected to have S/N > 20)
2. The wavelength range is [846-870] nm
3. Mean resolving power is R = 11,500

Recio-Blanco et al. 2023

Why now?

- PHOENIX Models



Synthetic spectra:

1. Resolutions of R = 500,000 in the optical and near IR; R = 100,000 in the IR
2. The wavelength range is from 500 Å to 5.5 μm
3. The parameter space covers: $2{,}300\ K \leq T_{eff} \leq 12{,}000\ K$
   $0.0 \leq \log g \leq +6.0$
   $-4.0 \leq [Fe/H] \leq +1.0$

Husser et al. 2013

Building the Catalog

Four steps:

1. Cross-identification of catalogs (observed magnitudes)
2. Pre-selection of stars
3. Obtaining the magnitudes from the PHOENIX spectrum
4. Performing a fit to the observed magnitudes

Building the Catalog

Four steps:

1. Cross-identification of catalogs (observed magnitudes)
2. Pre-selection of stars
3. Obtaining the magnitudes from the PHOENIX spectrum
4. Performing a fit to the observed magnitudes

The current version (v 1.0) is based on:
The Mid-infrared stellar Diameters and Fluxes compilation Catalogue (MDFC Version 10: II/361, Cruzalèbes et al. 2019) Identifier: name of the star (465,857 stars)

"Good calibrator"

Building the Catalog

Step 1:

Cross match:

- GAIA data release 3 (Gaia DR3, Gaia Collaboration 2022) tables **“Main source”**, and the table **“astrophysical parameters”**
- The Two Micron All Sky Survey (2MASS All-Sky Catalog of Point Sources, Cutri et al. 2003)
- The Wide-field Infrared Survey Explorer (WISE All-Sky data Release, Cutri et al. 2012)

Catalog	Radius	Filters	$\lambda_{central}$ $[\mu m]$
MDFC	reference	N/A	N/A
GAIA DR3	0.1 arcsec	Gbp, G, Grp	0.51, 0.69, 0.84
2MASS	2 arcsec	J, H, K	1.24, 1.67, 2.16
WISE	2 arcsec	W1, W2, W3	3.37, 4.62, 12.08

Building the Catalog

Step 2:

Pre-selection:

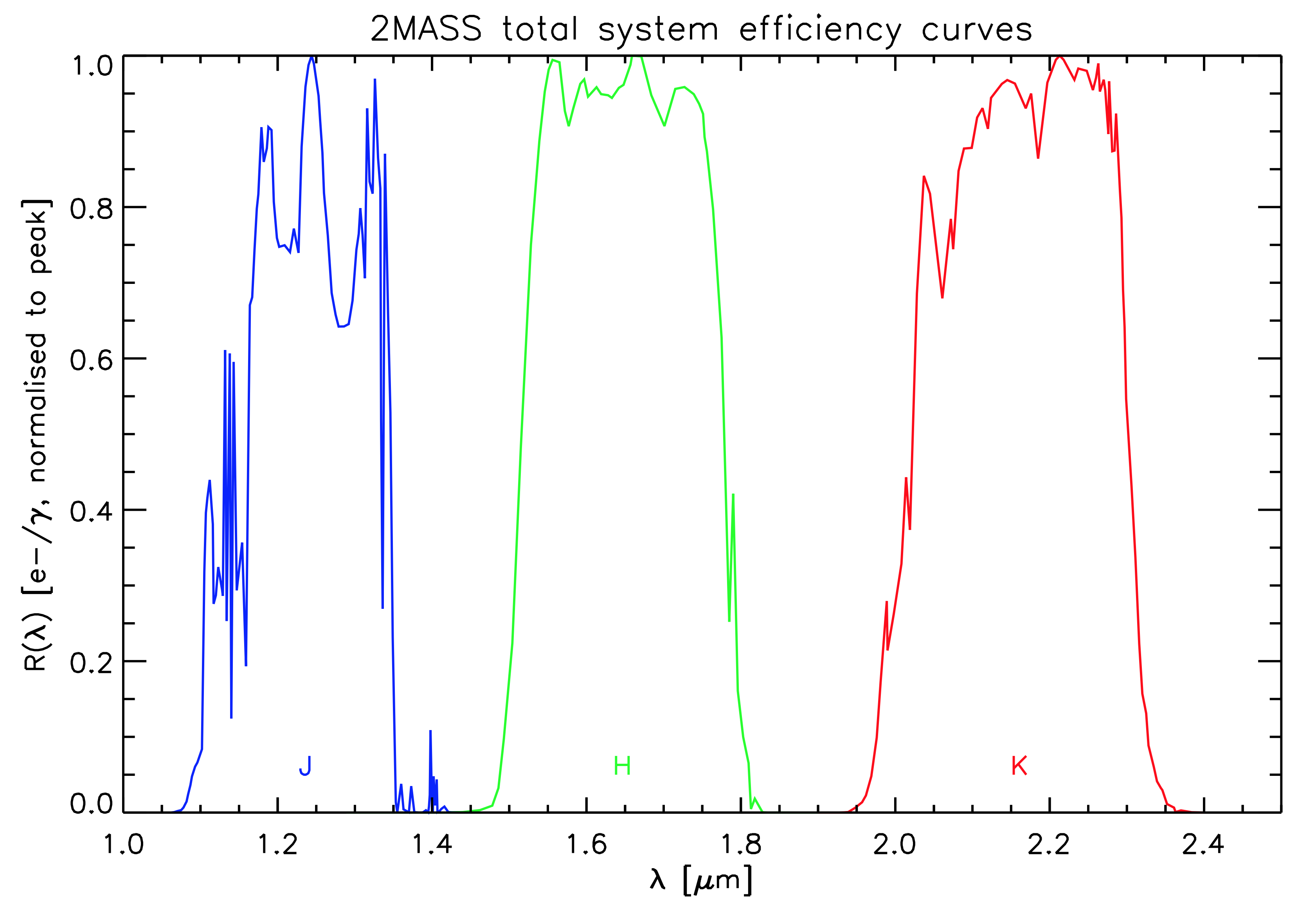
- First 13 GSP-Spec quality flags set to zero
- The sample was limited to stars with 3,500 K < Teff < 7,500 K
- WISE magnitudes that are not upper limits

Highly recommended to ensure the highest quality sample (Recio-Blanco et al. 2023).

Step 3:

Obtaining magnitudes from PHOENIX synthetic spectra (Husser et al. 2013):

- Select the spectrum with closest values to the GAIA DR3 GSP spec module T_eff and log(g)
- Calculate magnitudes using **Filter's response curves**



Building the Catalog

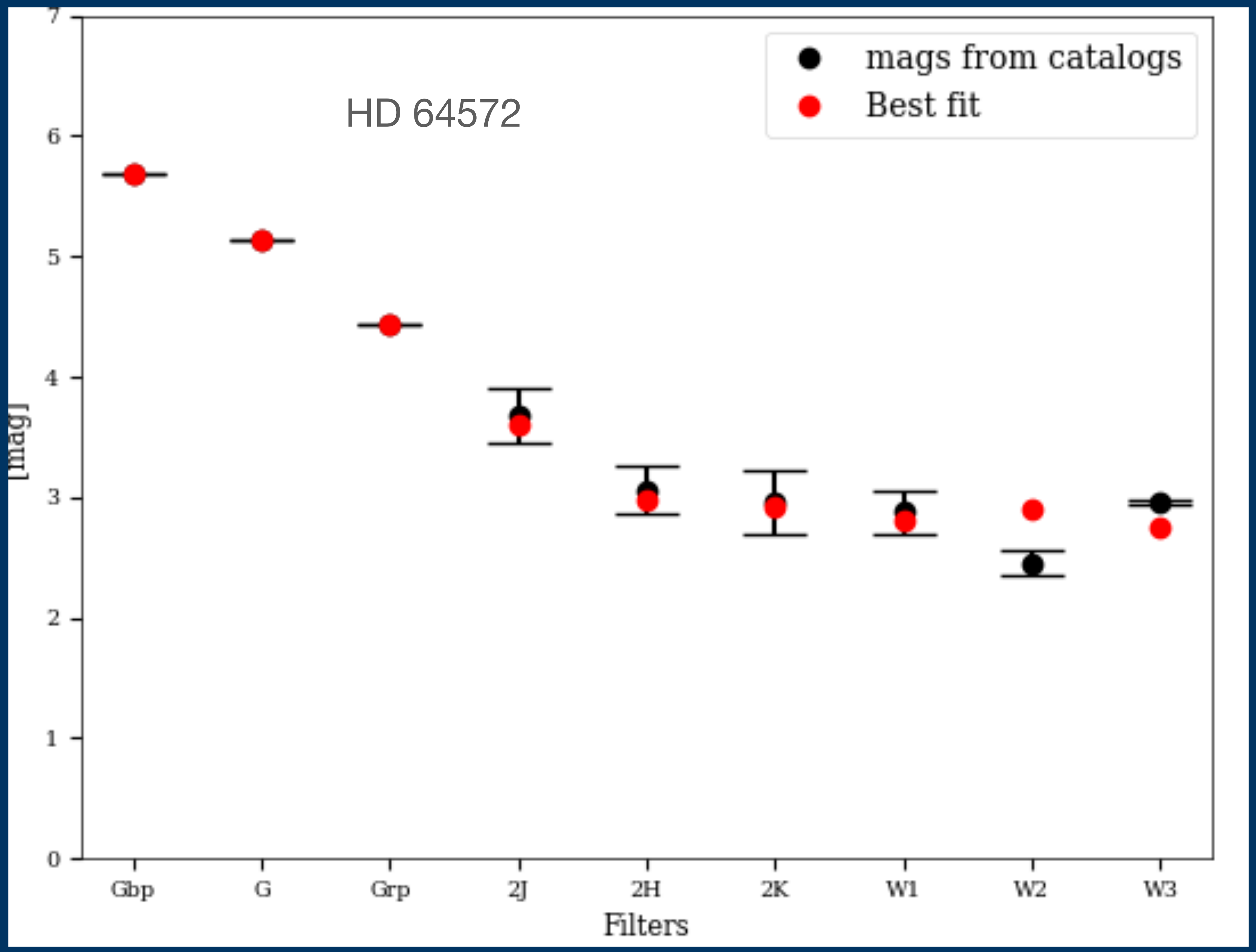
Step 4:

Fit:

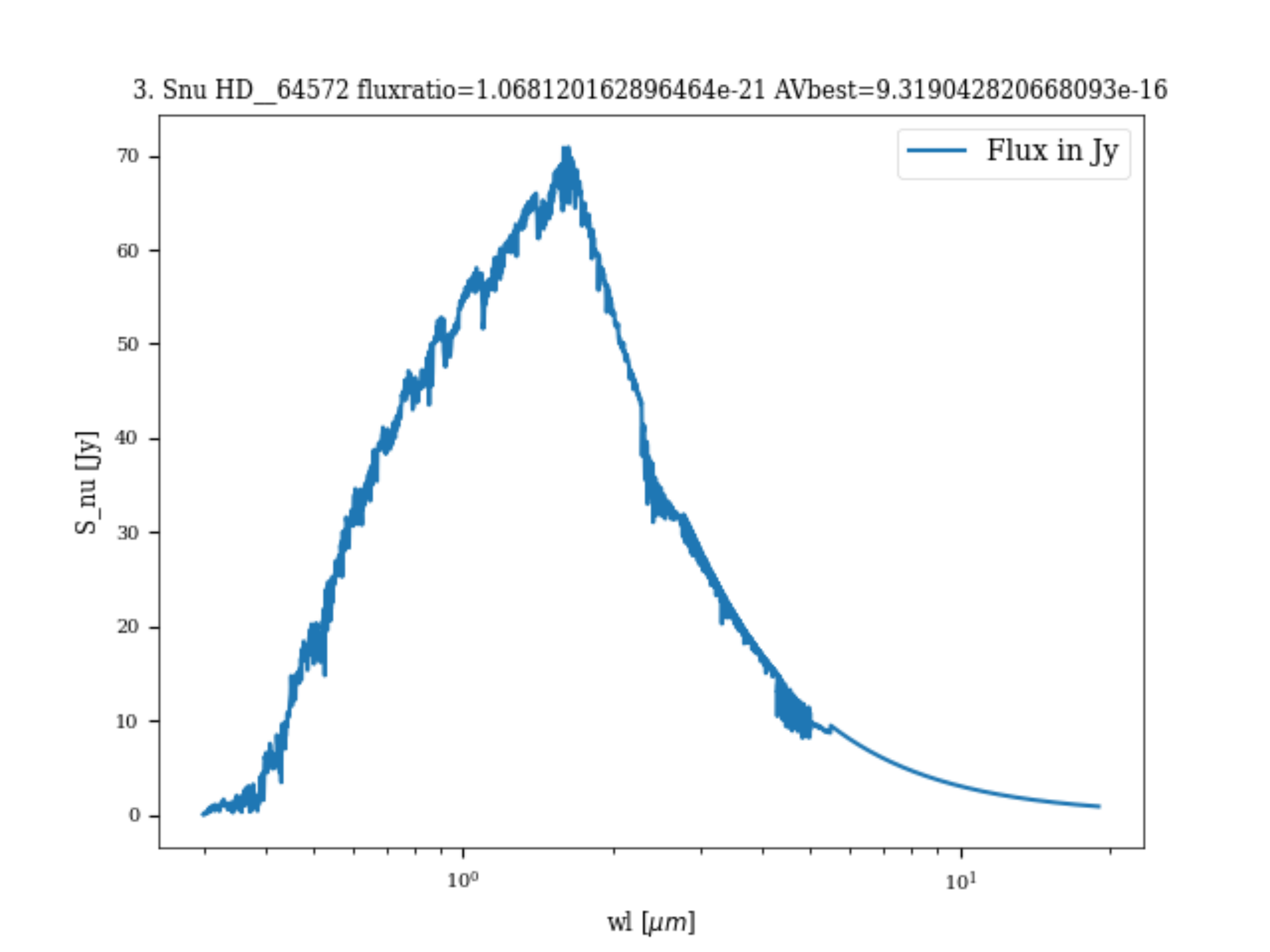
- Using the extinction curve by Jones et al. 2013
- Fixing RV (total-to-selective extinction or A(V)/E(B-V)) at 3.1
- Fit extinction AV & scaling of the fluxes -> stellar radii

Dust model consisting of a power-law distribution of small amorphous carbon (a-C) grains and log-normal distributions of large amorphous silicate grains, of olivine- and pyroxene-type composition with Fe nano-inclusions (Sil_{Fe}) and amorphous hydrocarbon (a-C(:H)) grains.

The standard value for the diffuse ISM in the Milky Way.



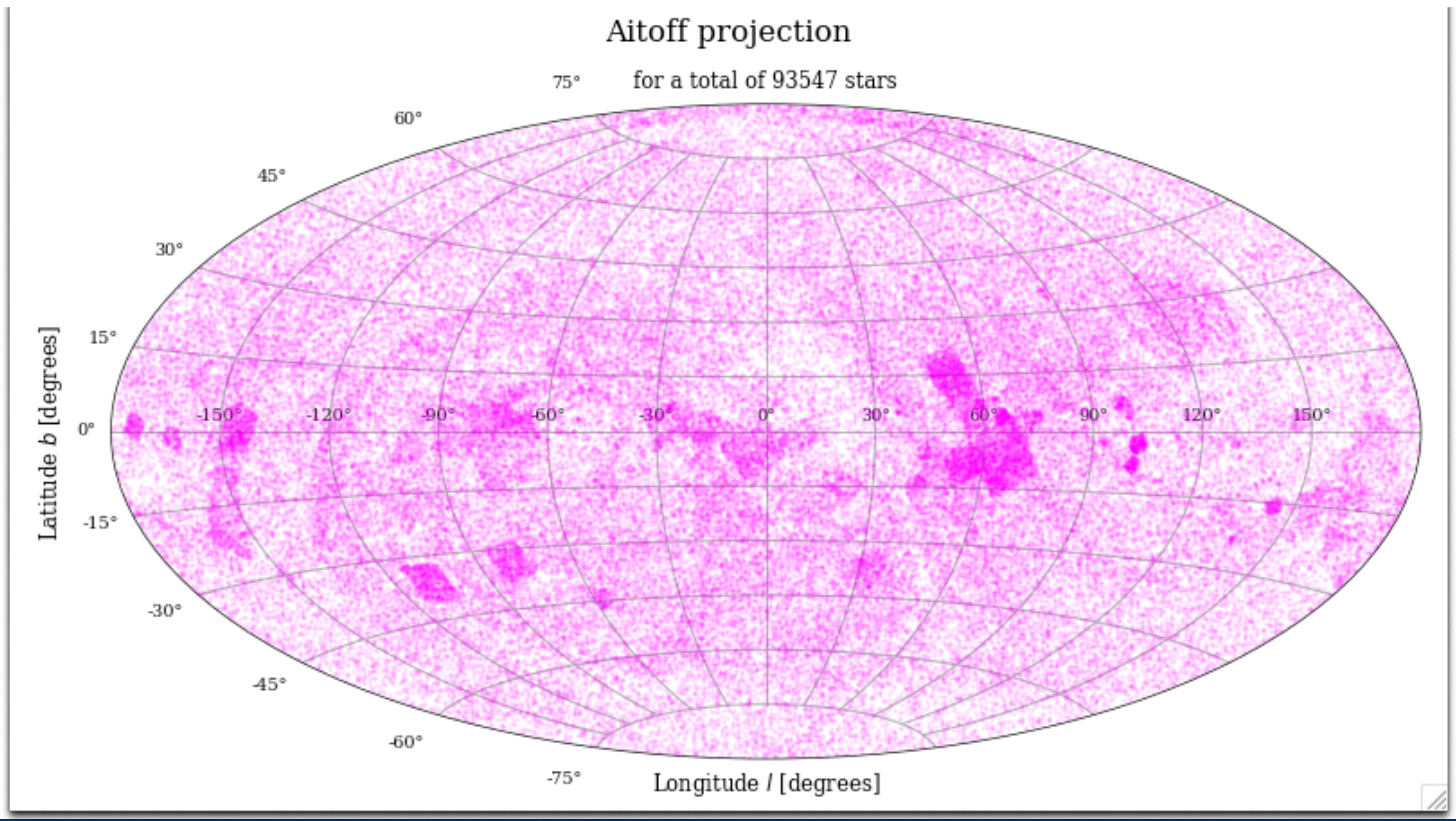
Final Spectrum



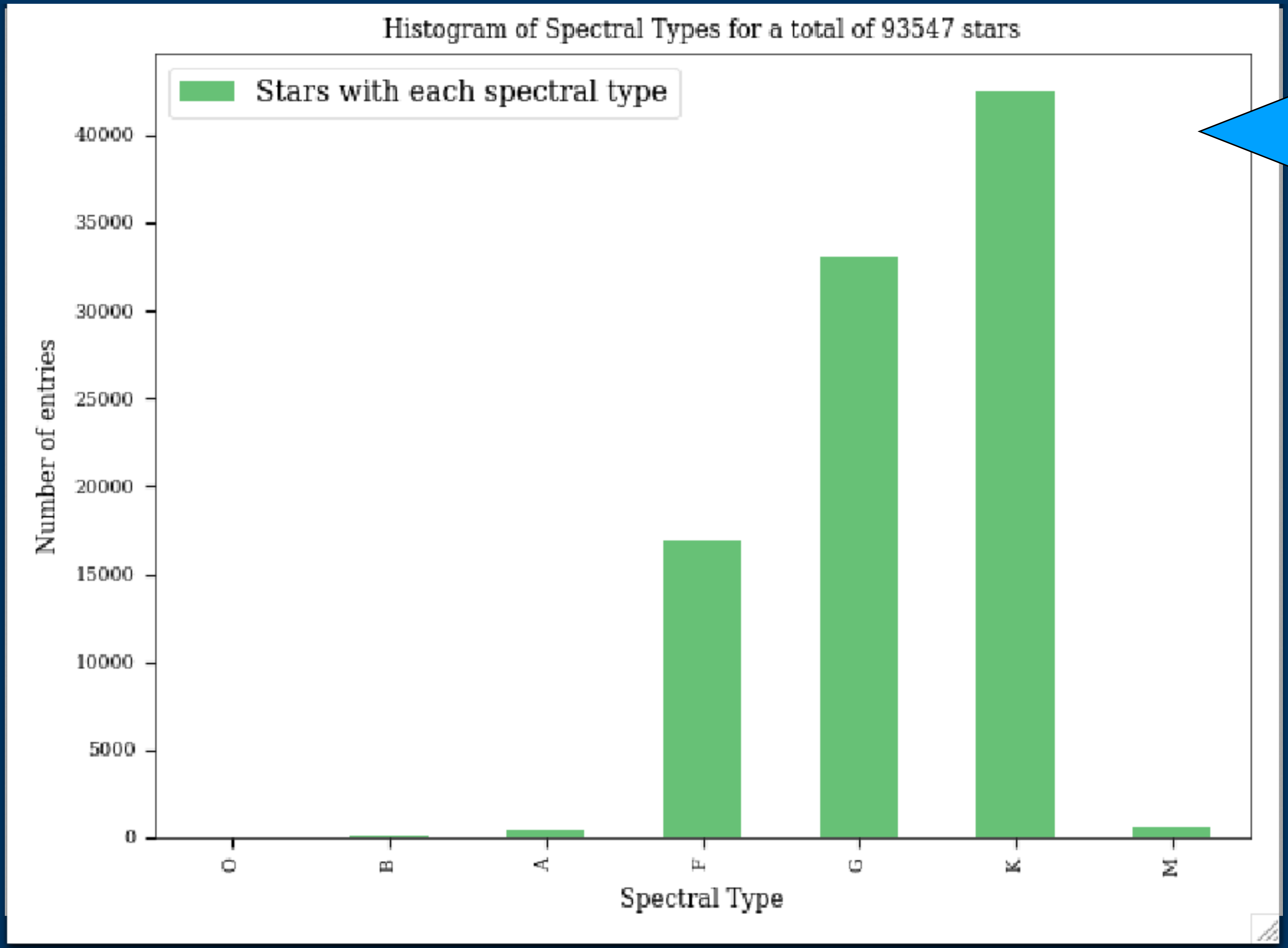
Properties of the Catalog
(V 1.0)

- The catalog is presented in FITS format
- Each calibrator star has its individual FITS file (file name = star name)
- The primary HDU contains the spectrum of the star to be used for the absolute flux calibration

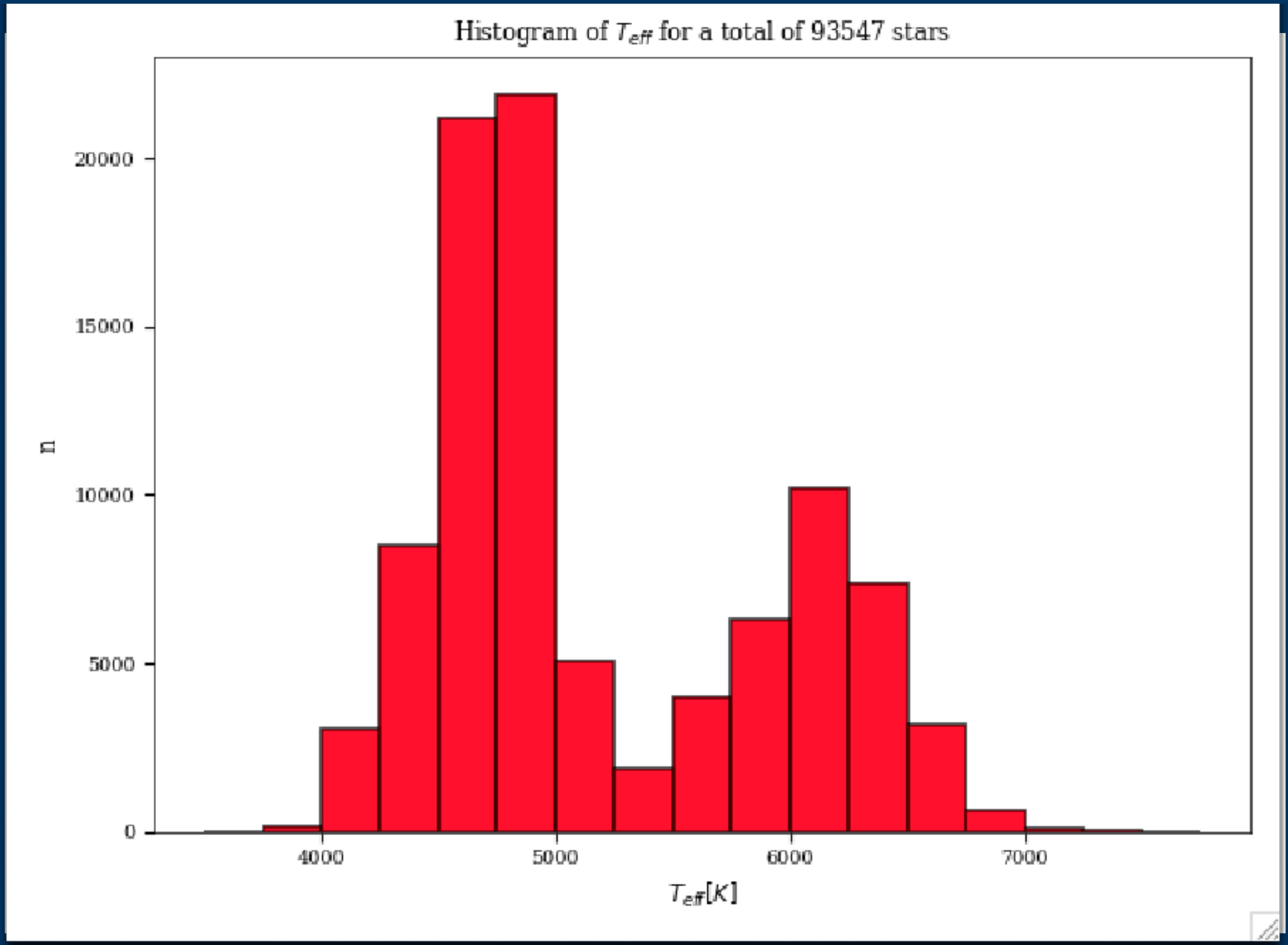
Distribution in the Sky



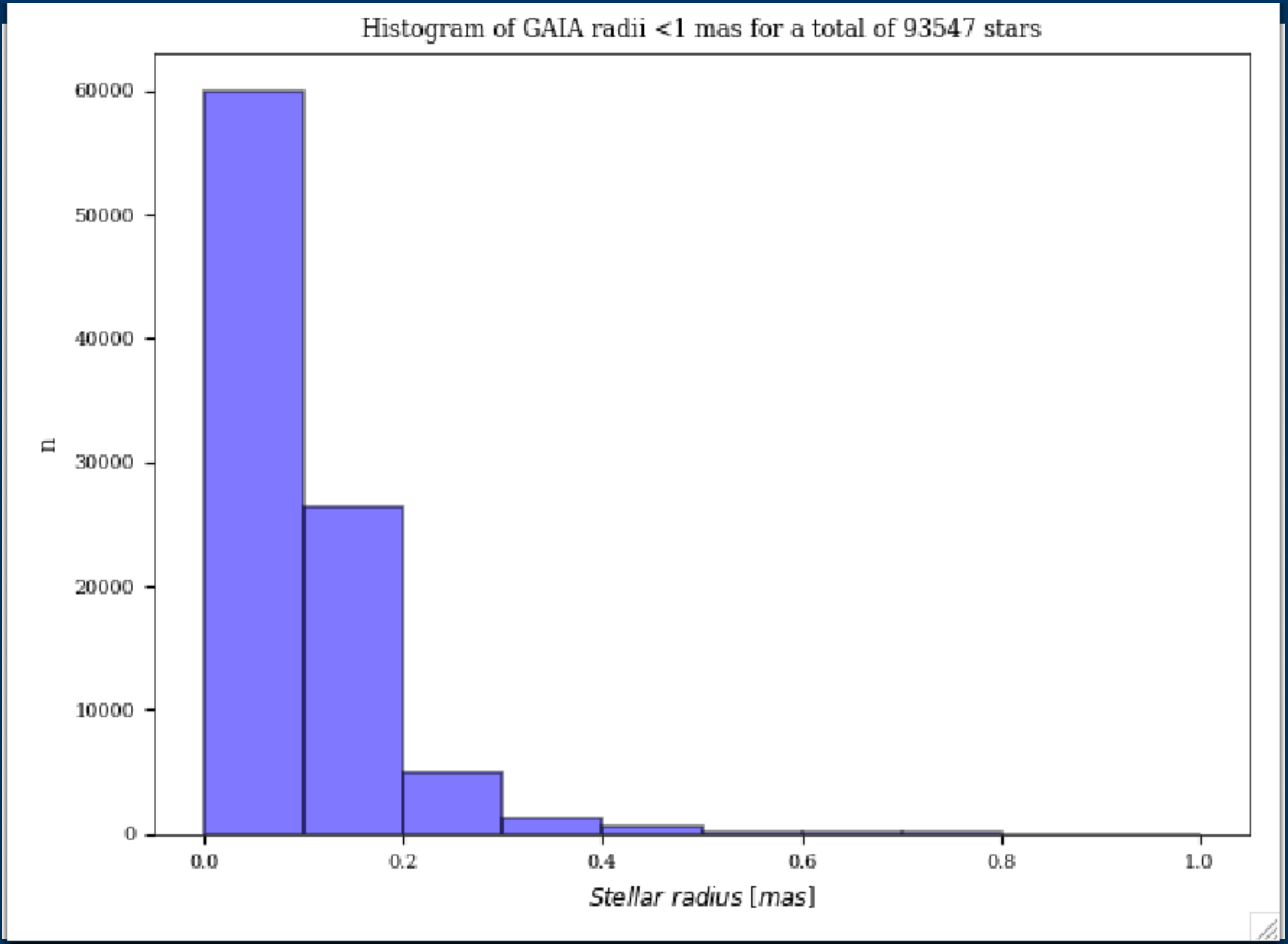
Distribution of Spectral Types and Teff



+ A few stars with spectral class:
N, R, S, C and D.



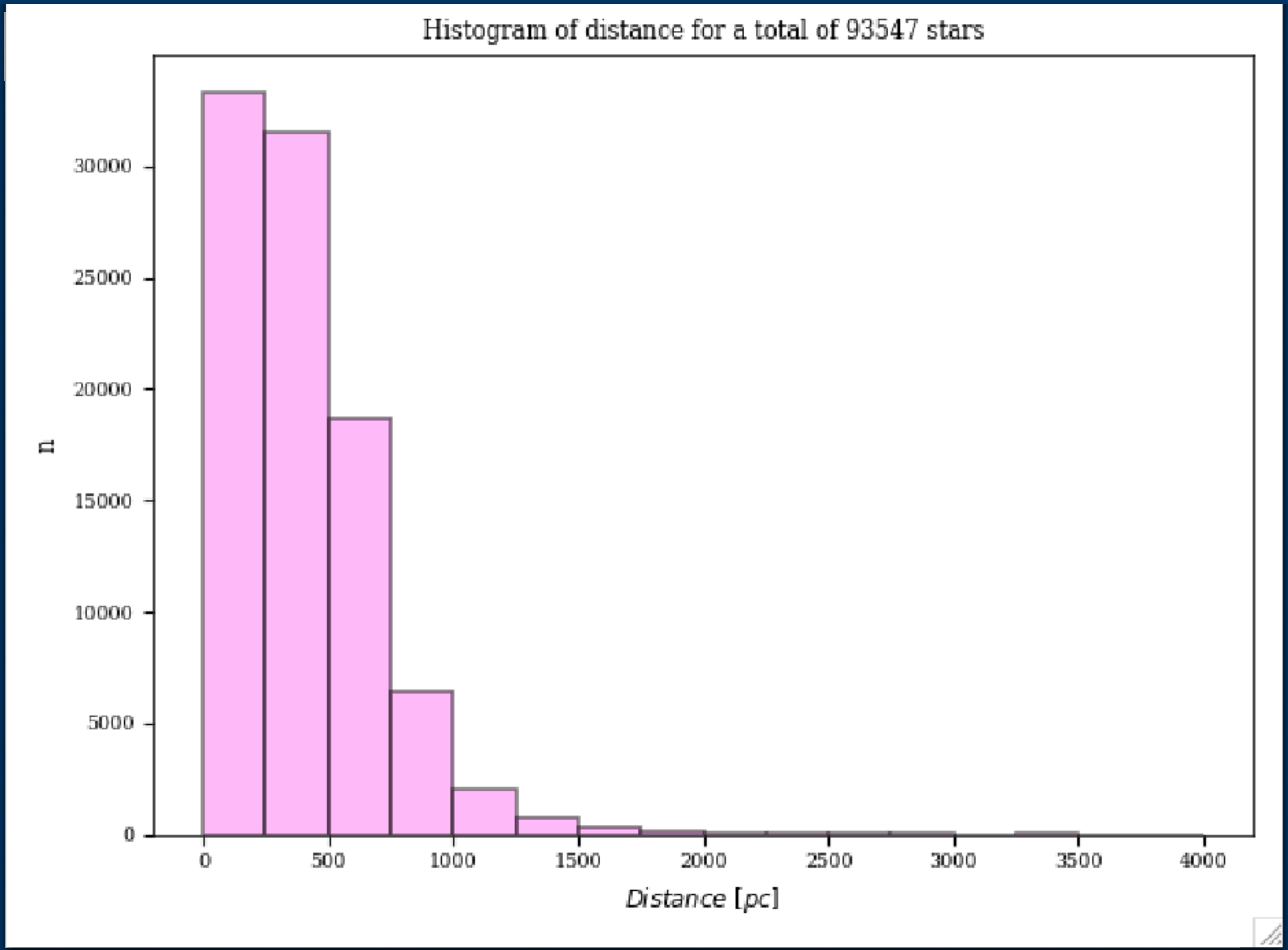
Distribution of Stellar radii



Number of stars with radius larger than 0.5 mas

Range of stellar radii [mas]	Number of stars
0.5 to 1.0	351
1.0 to 1.5	23
1.5 to 2.0	2
2.0 to 2.5	2
2.5 to 3.0	1
larger than 3.0	1

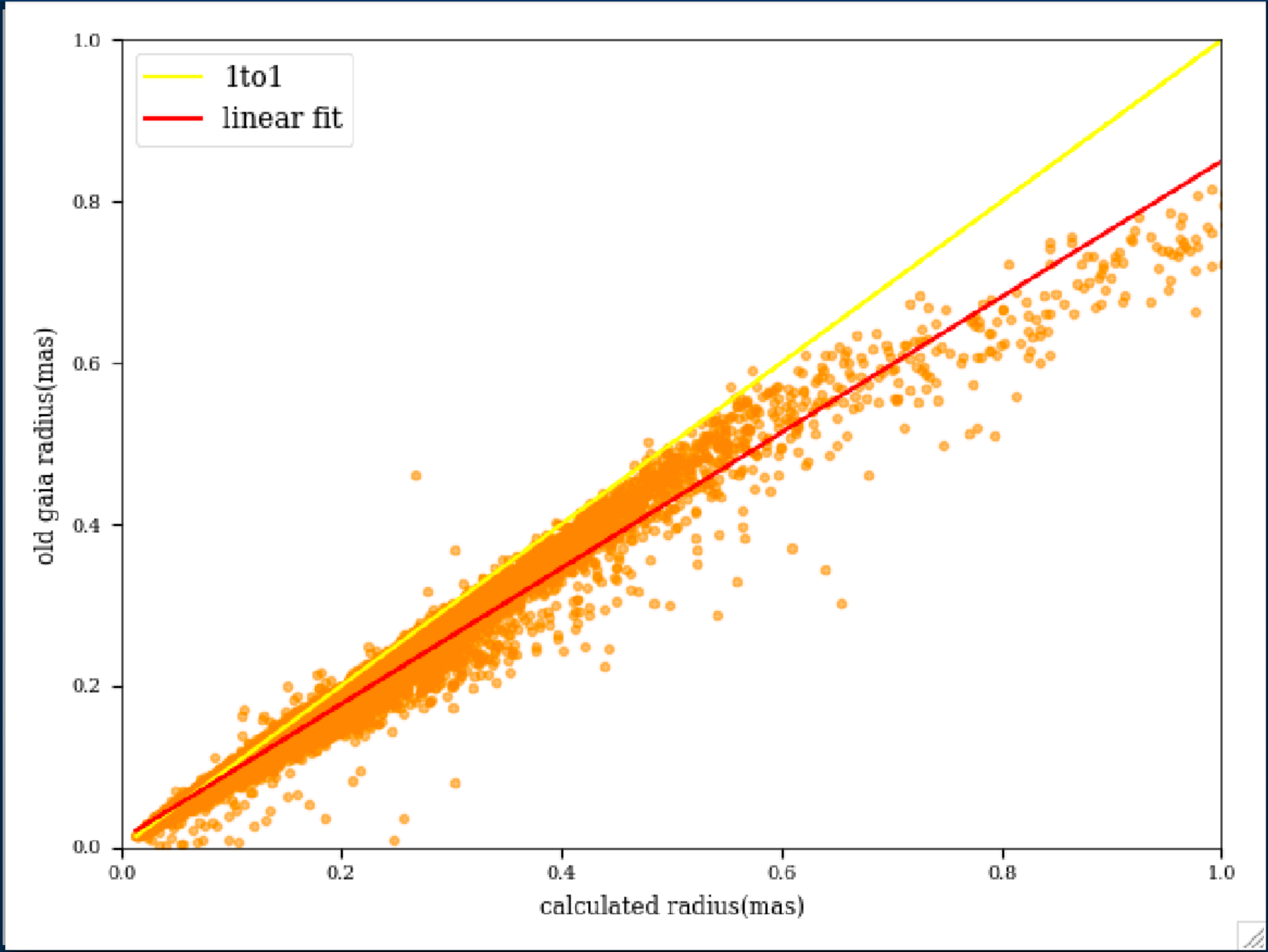
Distribution of Distances



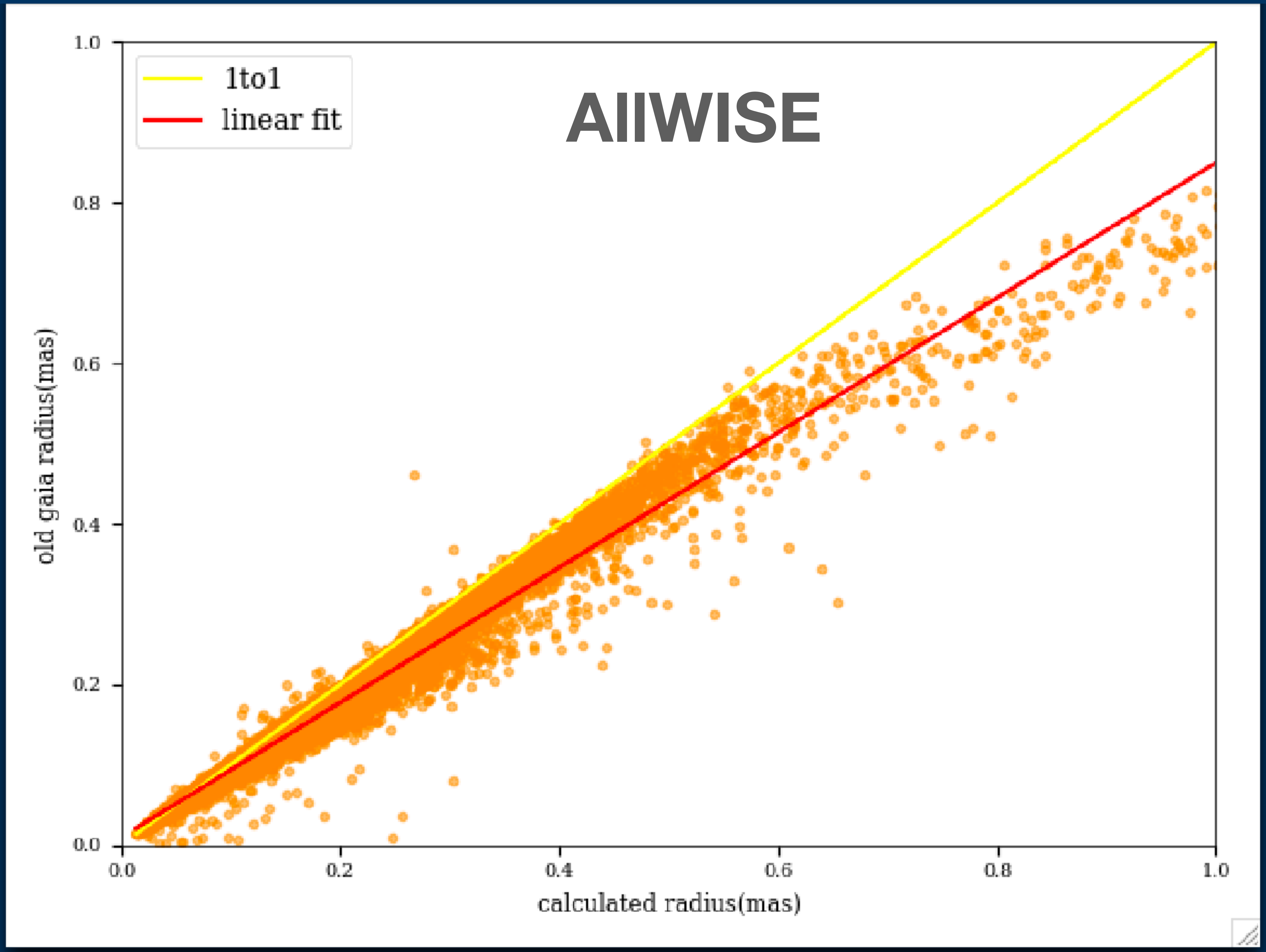
Number of stars with distance larger than 2,000 pc

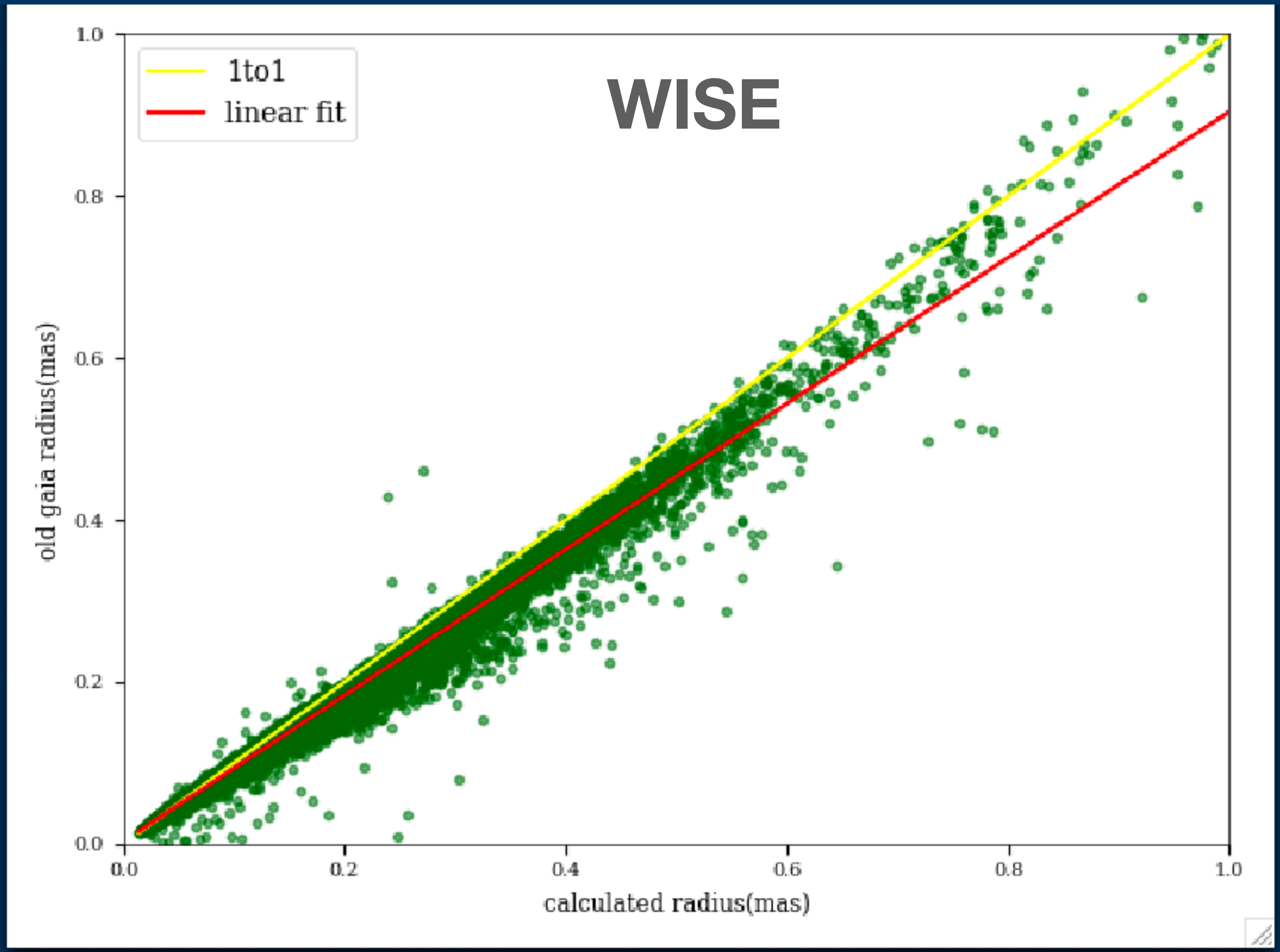
Range of distances [pc]	Number of stars
2,000 to 3,000	151
3,000 to 4,000	46
4,000 to 5,000	31
5,000 to 6,000	8
6,000 to 7,000	7
7,000 to 8,000	1
8,000 to 9,000	2
9,000 to 10,000	0
10,000 to 11,000	0
11,000 to 12,000	1
12,000 to 13,000	0
	0

Stellar Radii - comparison to GAIA DR2 radii

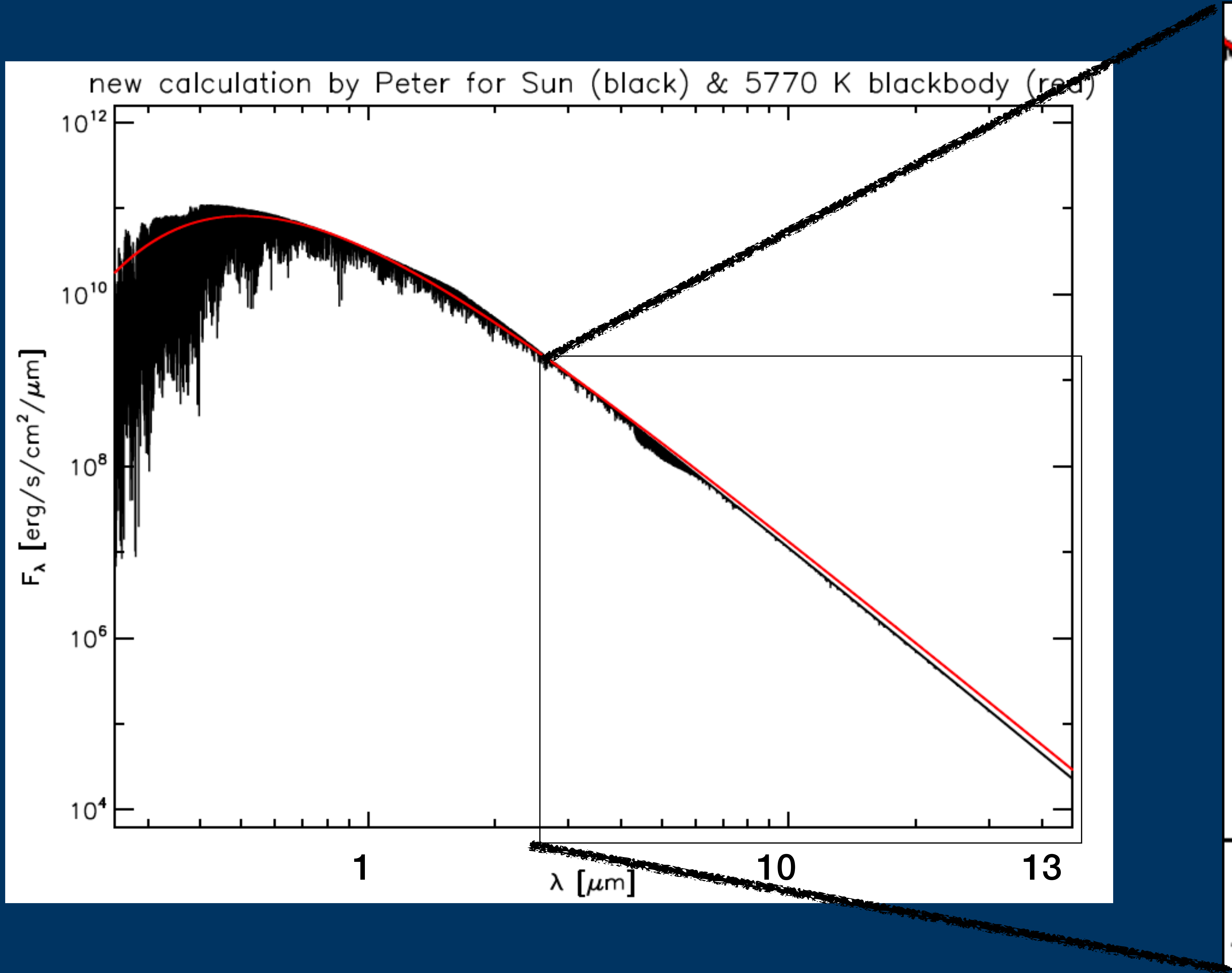


Stellar Radii - comparison to GAIA DR2 radii

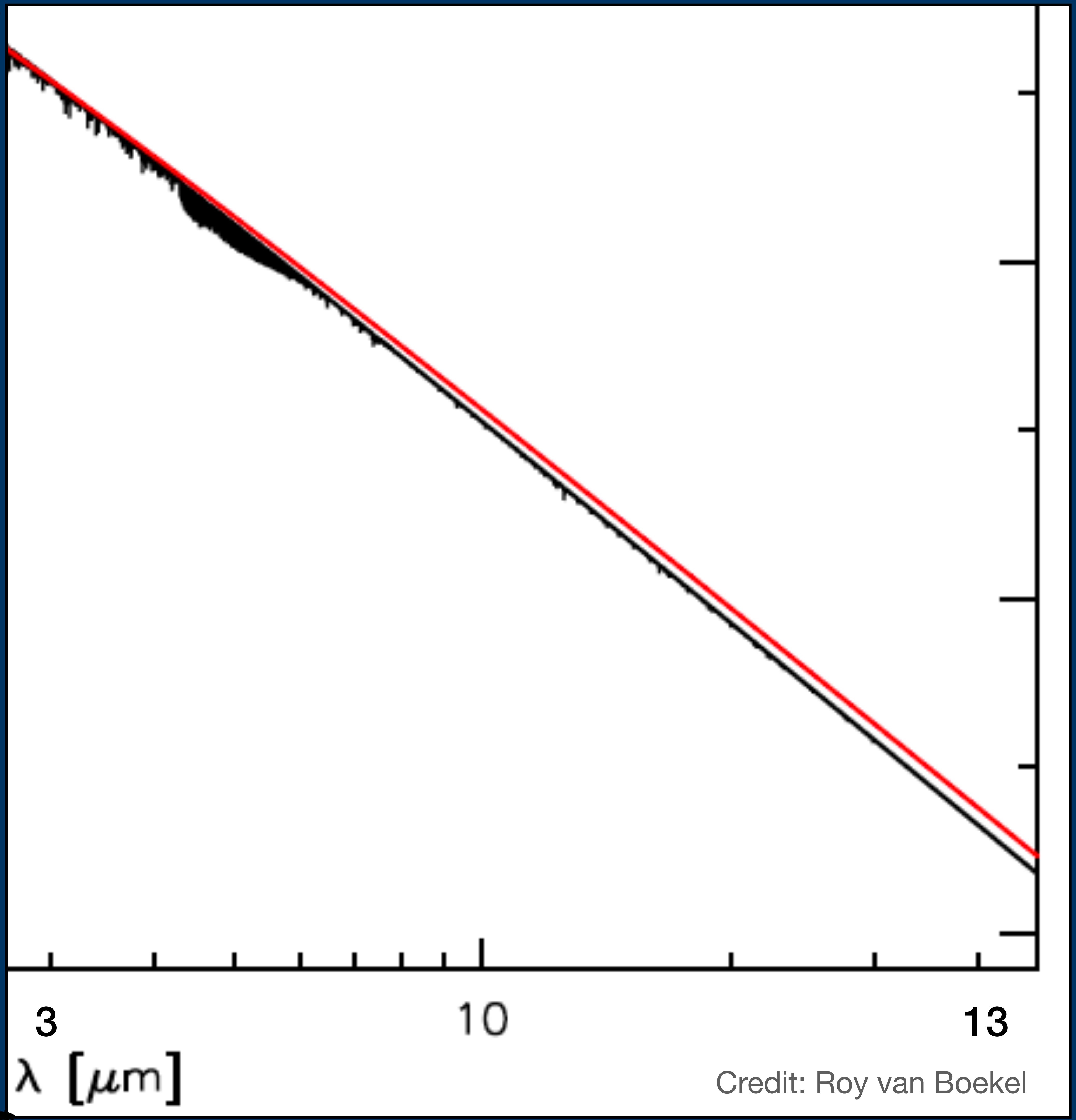




Future Work

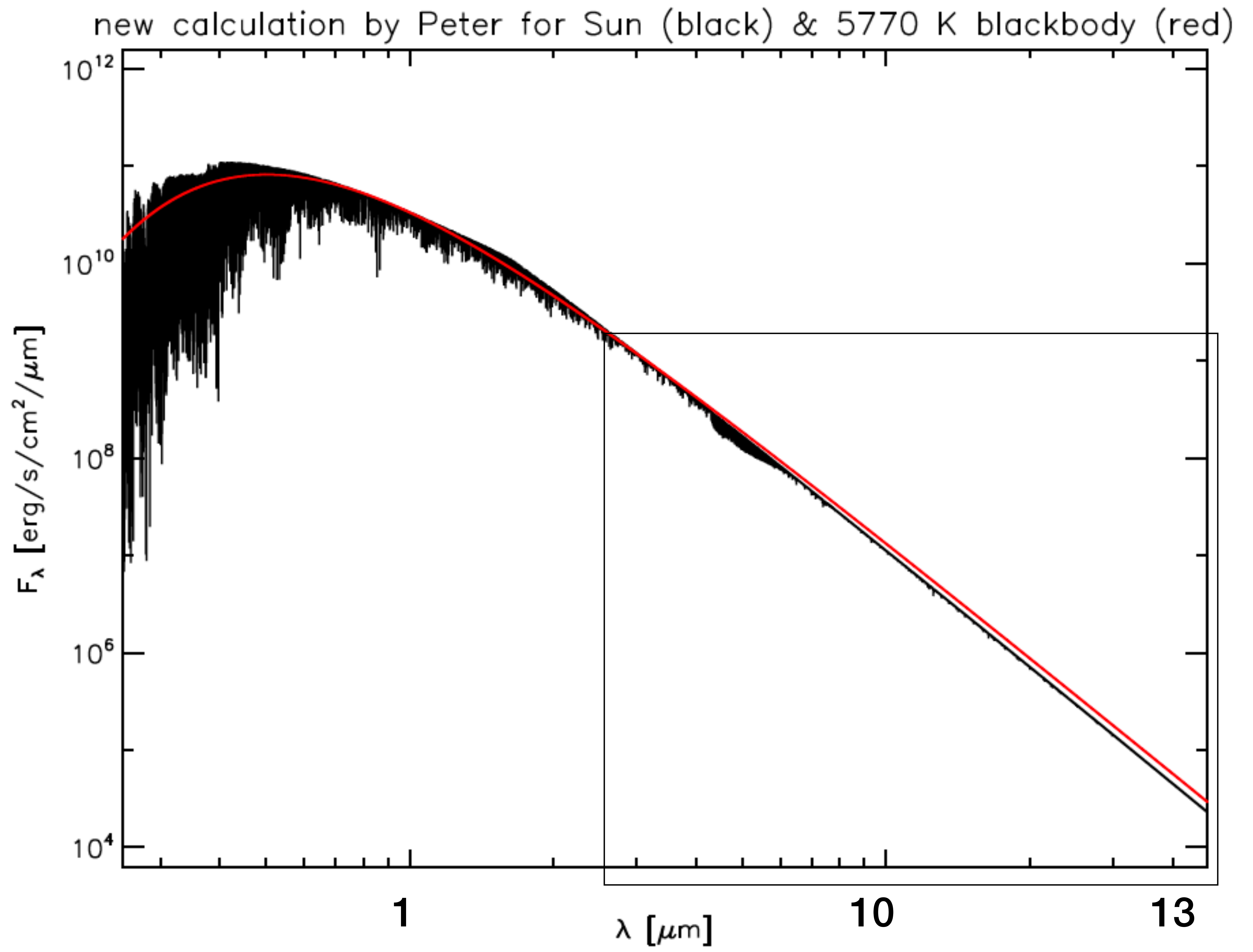


new calculation by Peter for Sun (black) & 5770 K blackbody (red)
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
F_λ [erg/s/cm^2/μm]
1
10
13
λ [μm]



3
10
13
λ [μm]
Credit: Roy van Boekel

Future Work



Objective:

- Extend the **number of sources** and provide **higher flux accuracy**.

Future releases:

- **MIR-PHOENIX** models to fine-tune the Rayleigh-Jeans tail of the spectra.
- **Gaia DR4**, while the number of parameterized stars will increase by a factor of ten, reaching approximately 50 million stars.
- Implementation of selecting the synthetic spectra with the closest value for the metallicity **[M/H]**, and the alpha-processed element abundances **[alpha/Fe]**.
- Use more observed magnitudes of other catalogs.

webpage:

https://home.strw.leidenuniv.nl/~gamez/

To be continued…