Determining stellar properties with FORCAST

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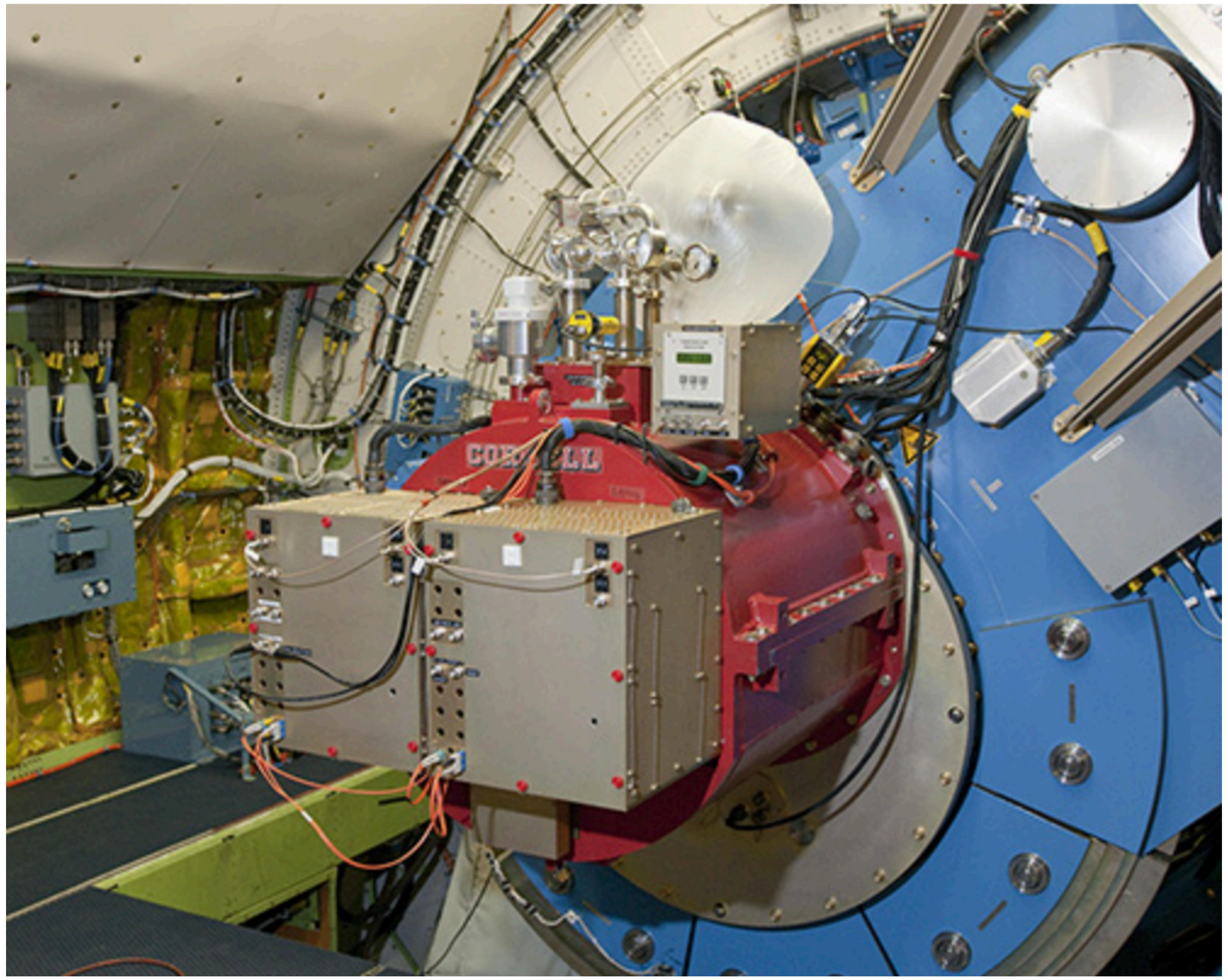
NSF's NOIRLab

SOFIA SCHOOL

1. FORCAST: Faint Object infraRed CamerA for the SOFIA Telescope



Camera Details

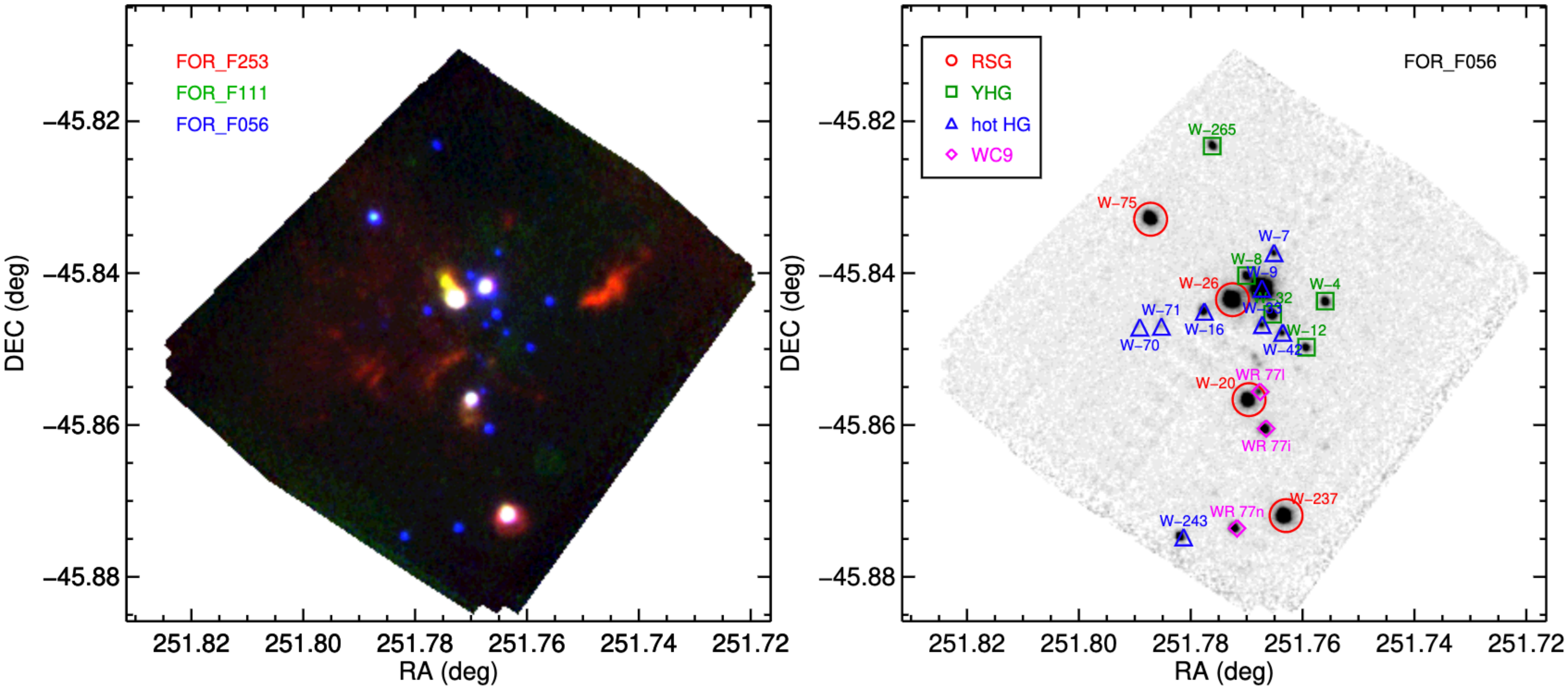
Camera	Wavelength Range	Detector
SWC	5–25 µm	Si:As (BIB)
LWC	25–40 µm	Si:Sb (BIB)
Each channel consists of a 256x256 pixel array that yields a 3.4'x3.2' instantaneous field-of-view with 0.768" pixels		

Filter Parameters

SWC Filters		LWC Filters	
λ_{eff} (µm)	$\Delta\lambda$ (µm)	λ_{eff} (µm)	$\Delta\lambda$ (µm)
5.4	0.16	11.3	0.24
5.6	0.08	11.8	0.74
6.4	0.14	24.2	2.9
6.6	0.24	31.5	5.7
7.7	0.47	33.6	1.9
8.8	0.41	34.8	3.8
11.1	0.95	37.1	3.3
11.2	2.7	A subset of these will be chosen each cycle as the nominal set.	
19.7	5.5		
25.3	1.86		

2. Handling the data

The data generally comes fully reduced, including flux calibration (hurray!) but you can find an excellent guide and tutorials for data reduction here: https://www.sofia.usra.edu/data/data-pipelines



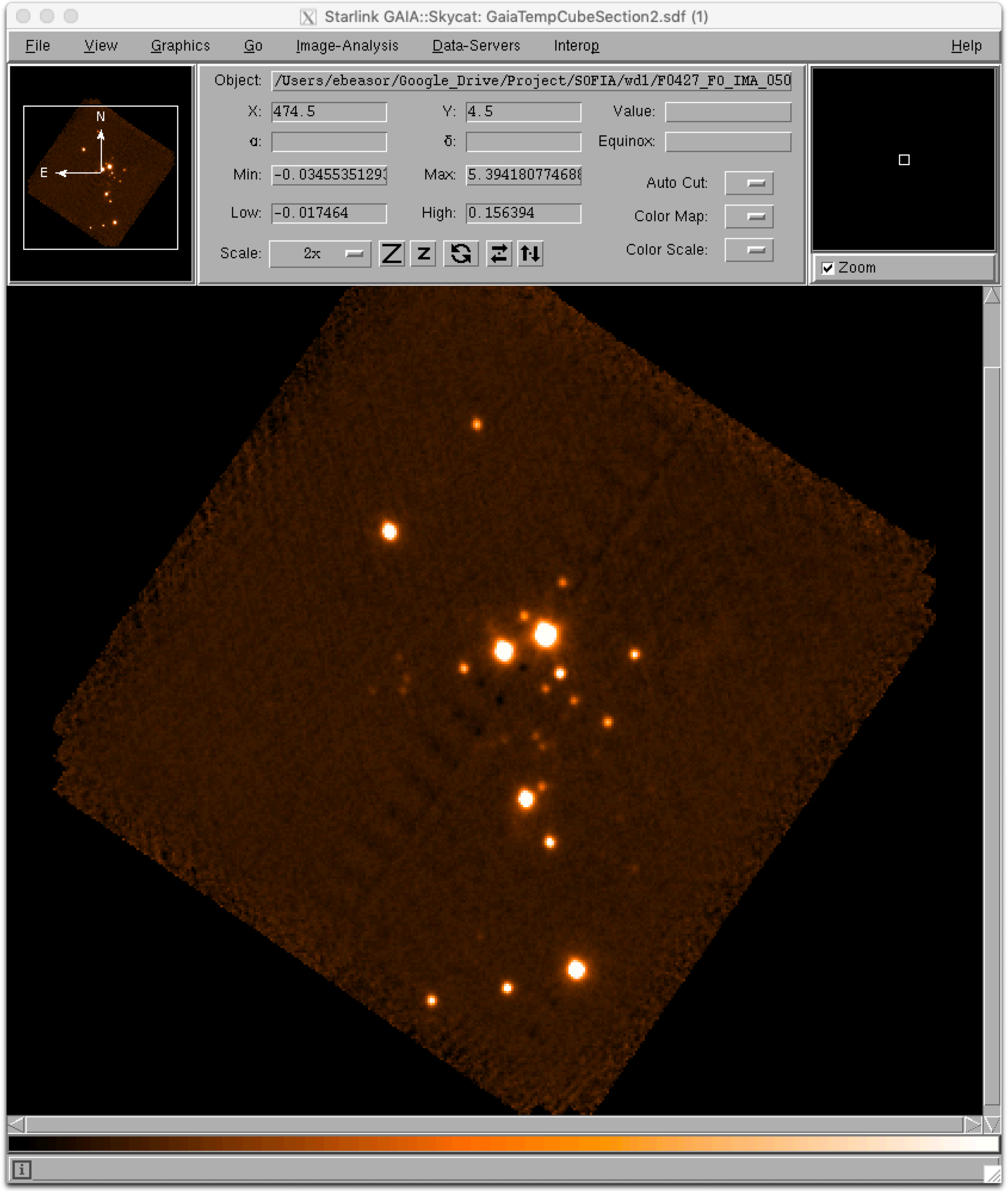
Beasor et al. 2021

2. Handling the data

In this case, the stars are well separated.
So we can use aperture photometry.

Software: GAIA Starlink

Could also use e.g. DAOPHOT, Starfinder (IDL), various Python packages



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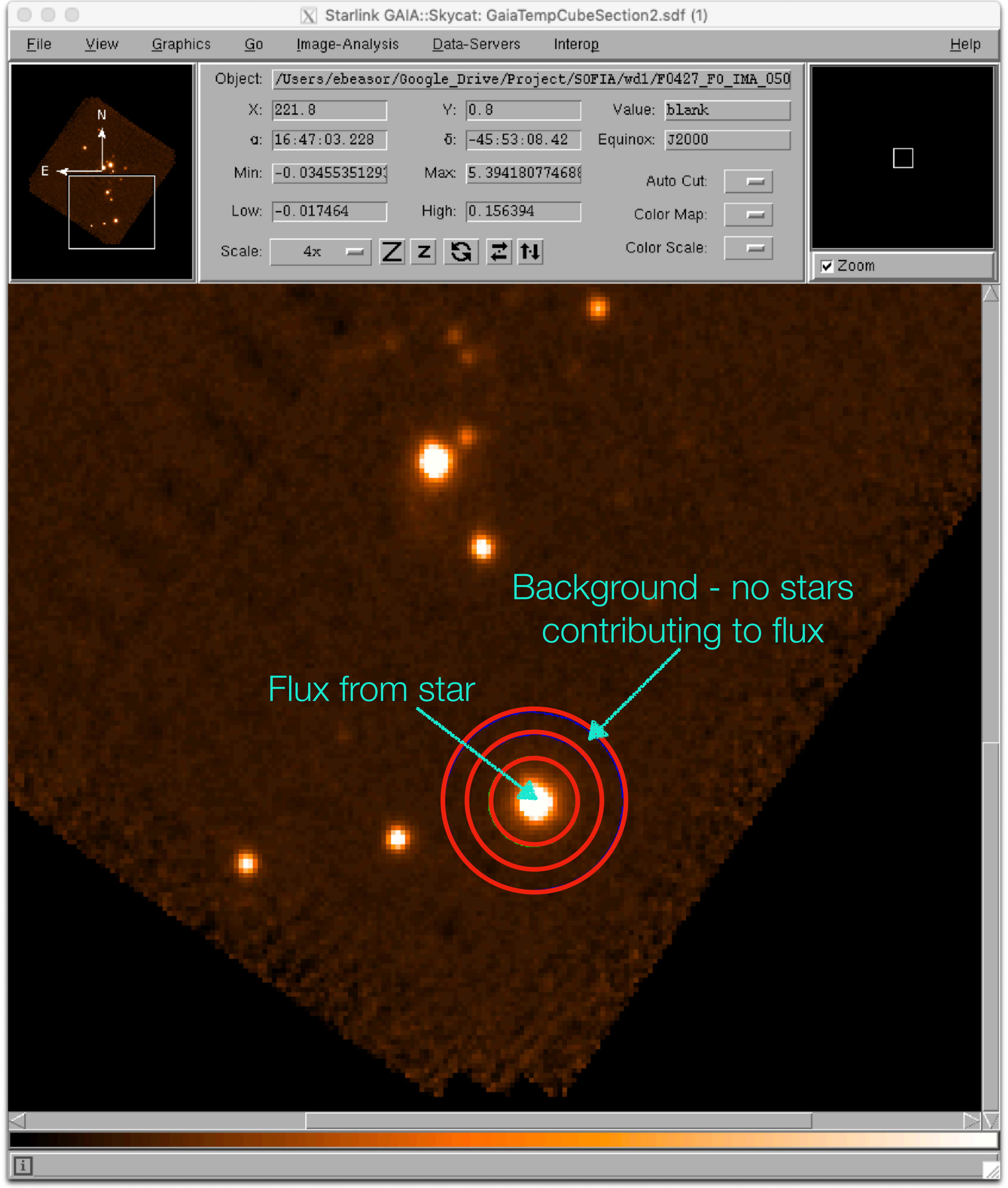
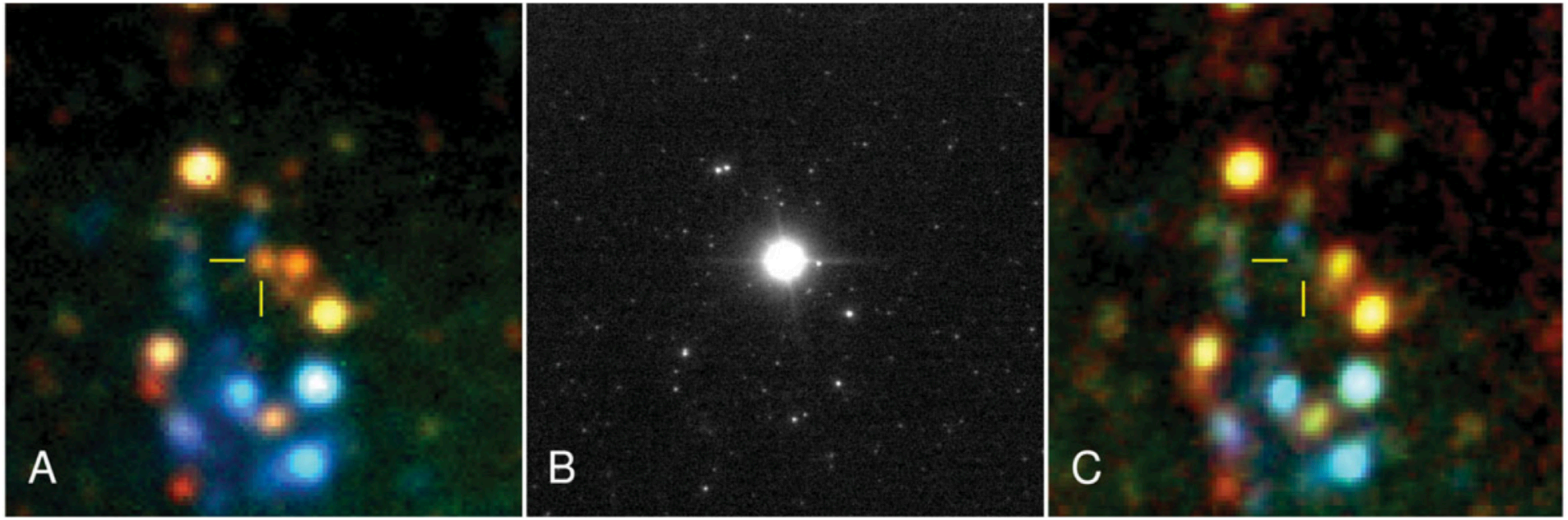


3.Determining stellar properties

- Stellar luminosities are essential properties for stellar evolution
- For massive stars - helps us understand which stars explode, and which do not



3.Determining stellar properties

- Let's assume we only have 1 photometric point… how do we get luminosity?

$$m_{\rm bol} = m_\lambda + BC_\lambda$$
$$m_{\rm bol} = 4.8 - 2.5log(L/L_\odot)$$

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Bolometric magnitude

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Magnitude at a given wavelength

$$m_{\rm bol} = m_\lambda + BC_\lambda$$
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Bolometric correction

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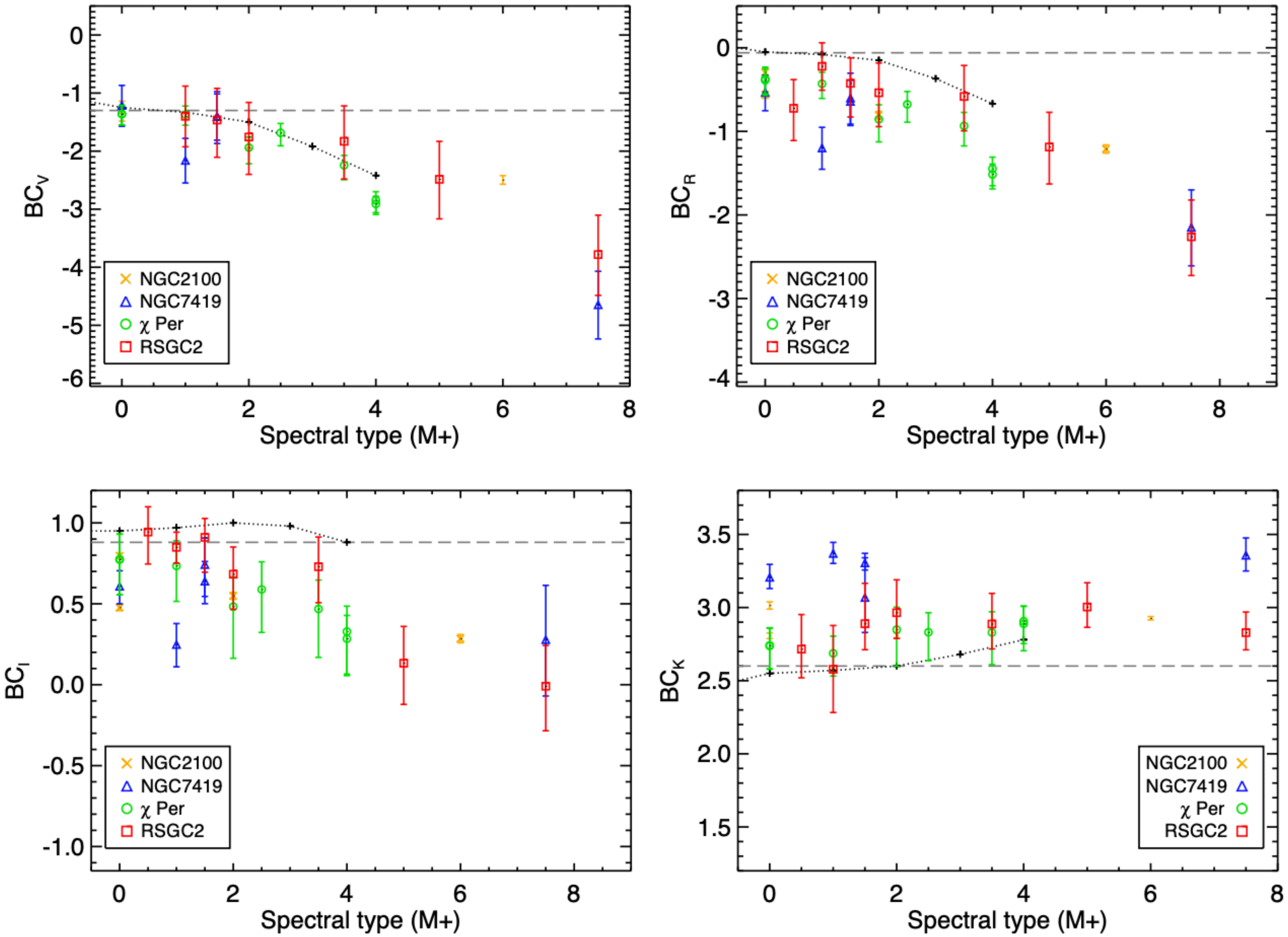

Davies & Beasor 2018

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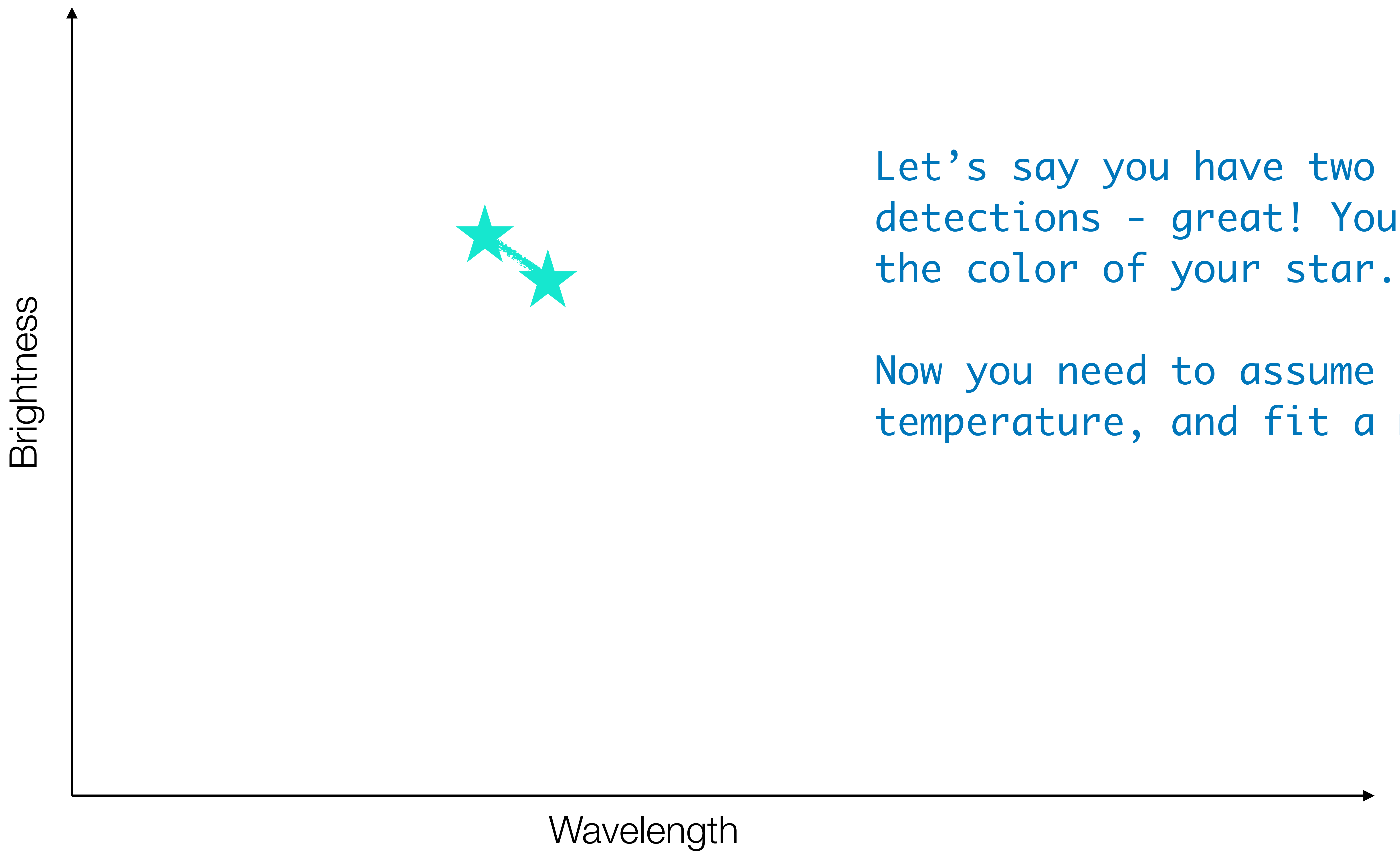

Let’s say you have two detections - great! You know the color of your star.

Now you need to assume a temperature, and fit a model…

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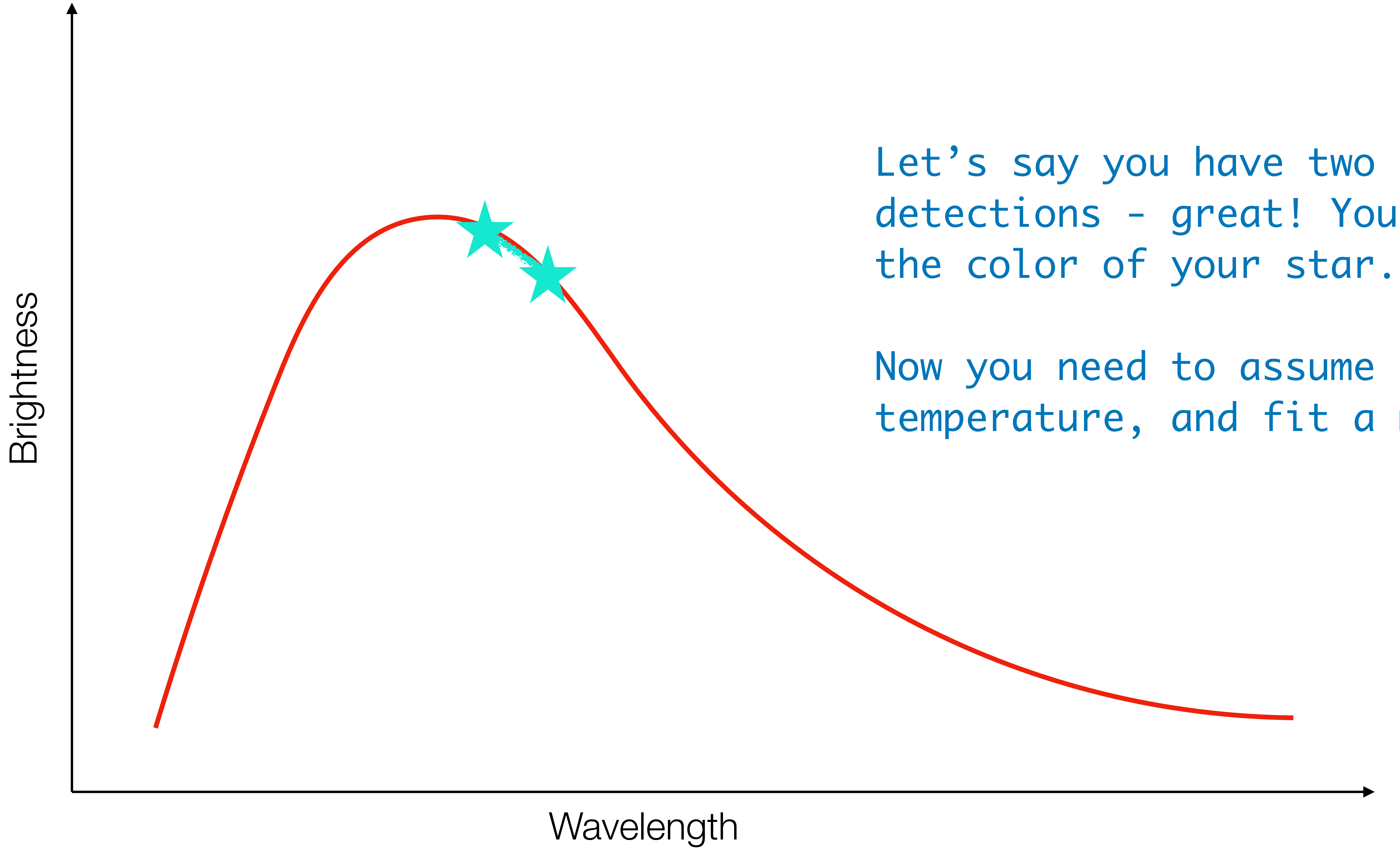

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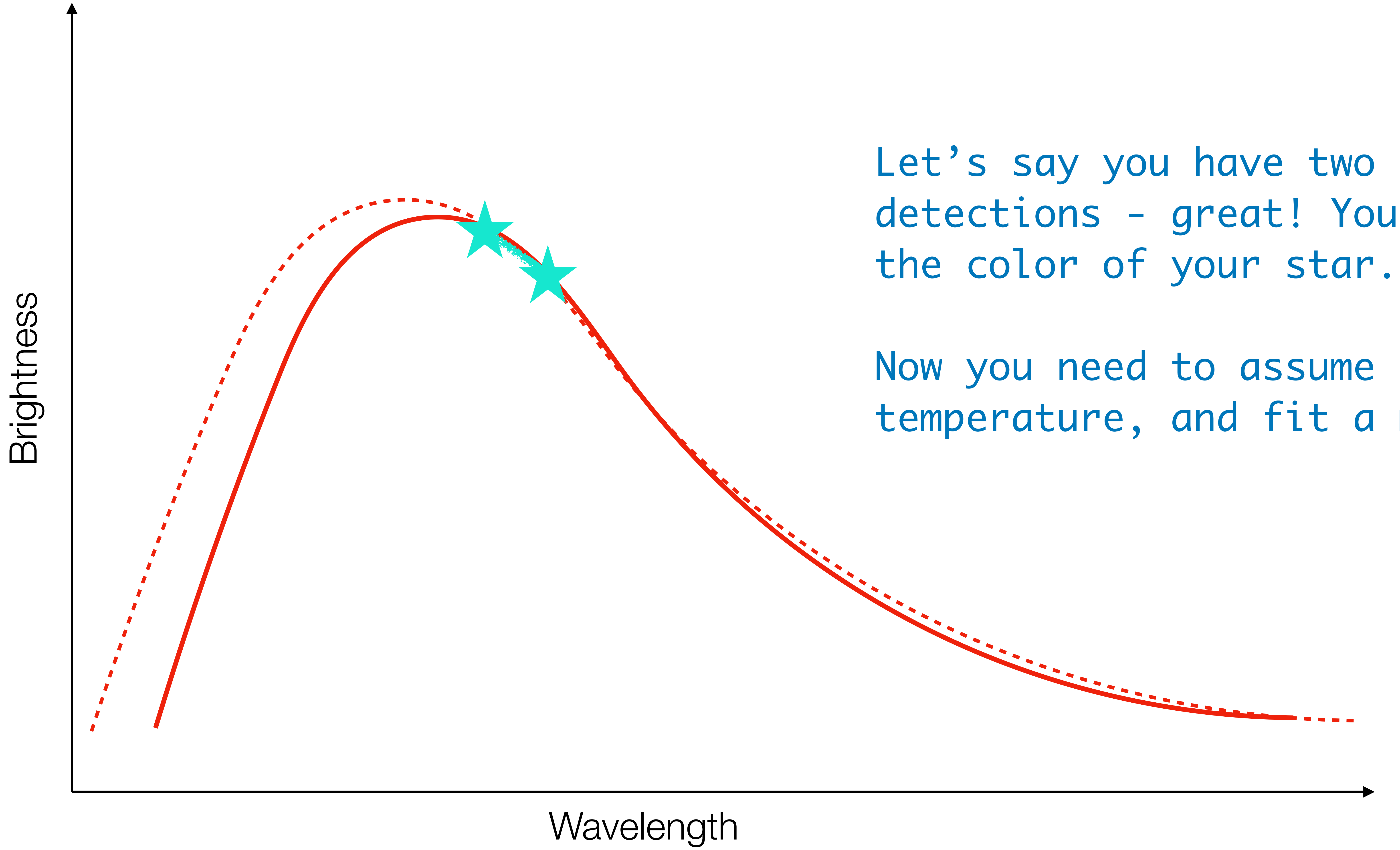

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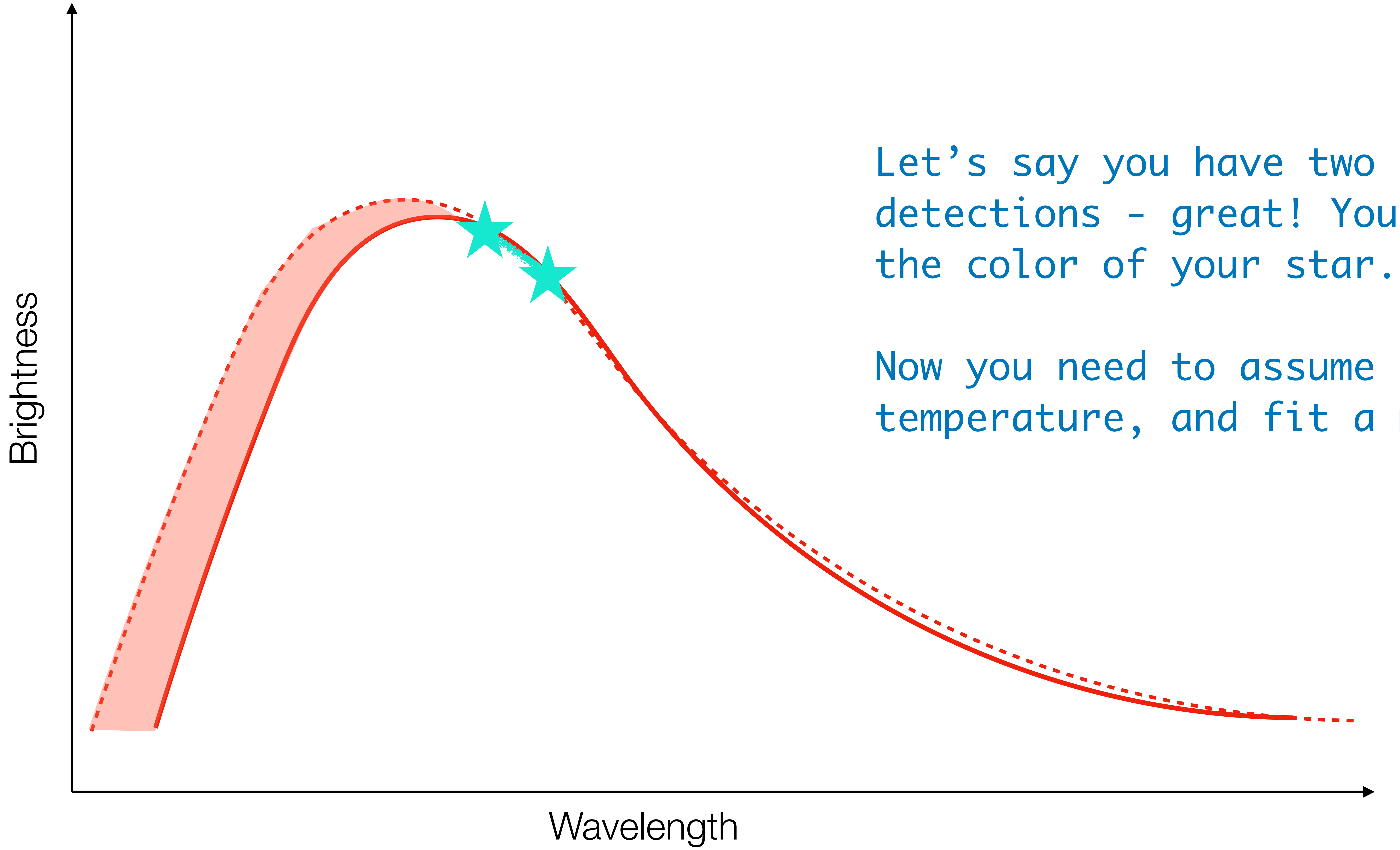

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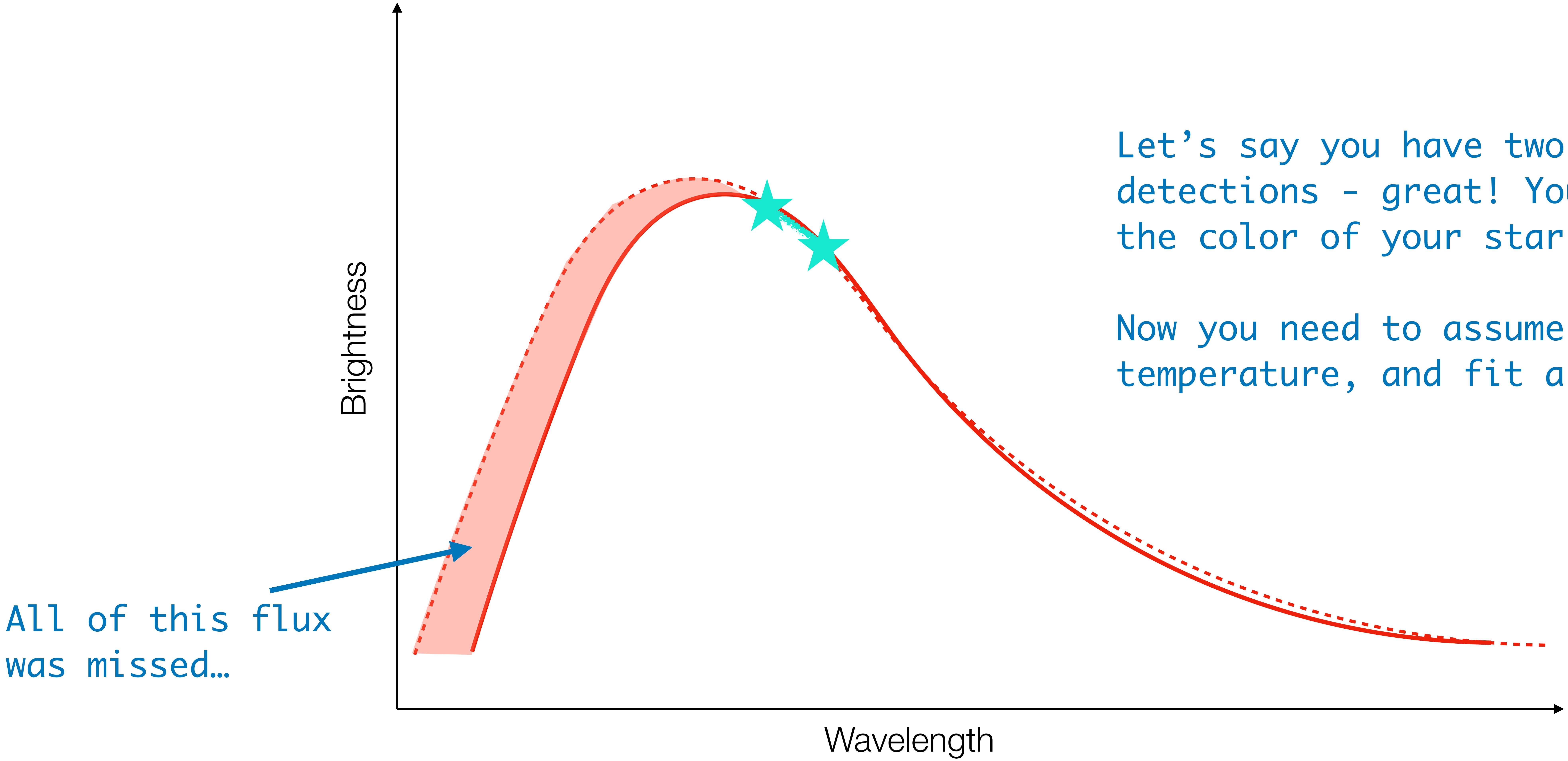

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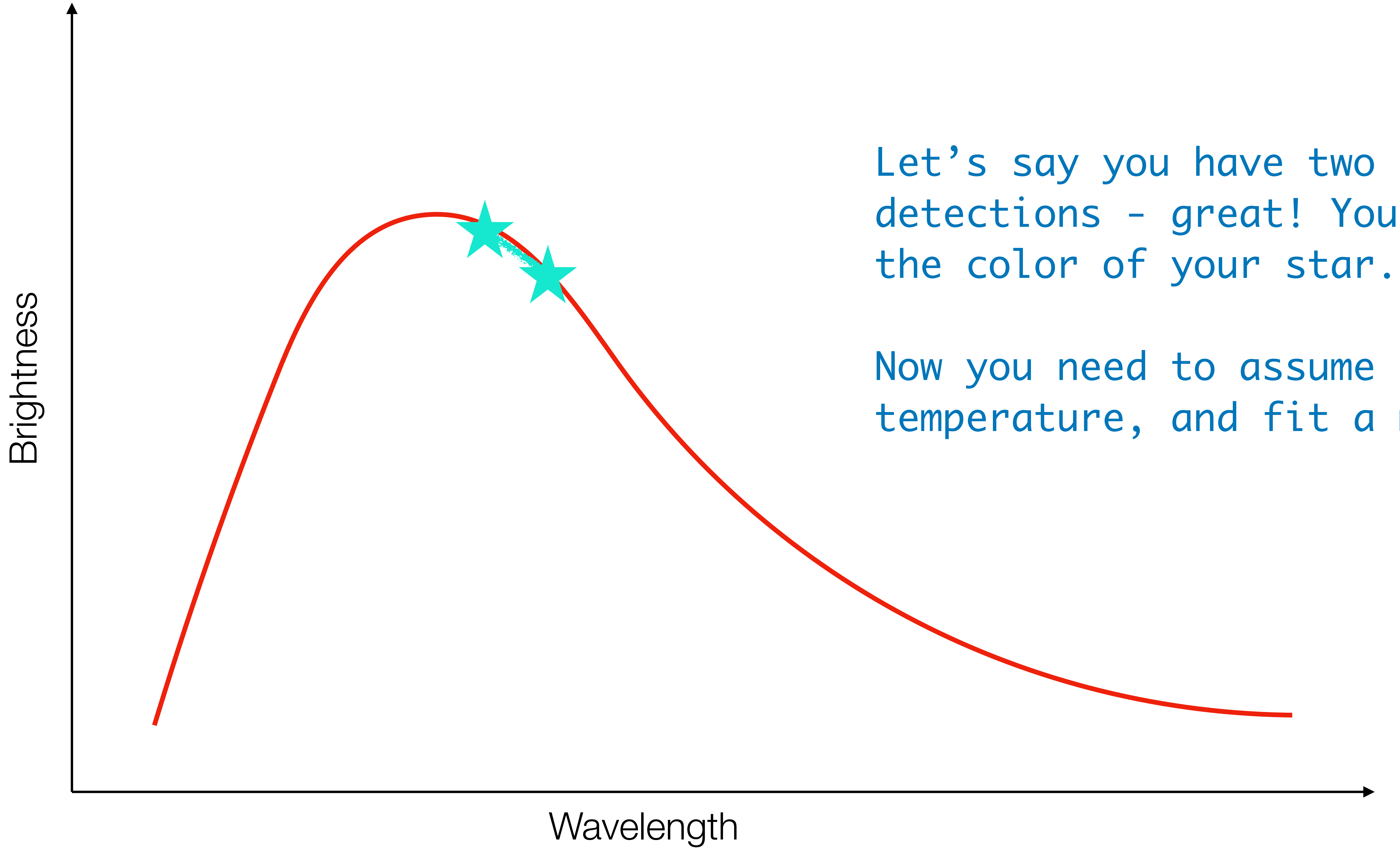

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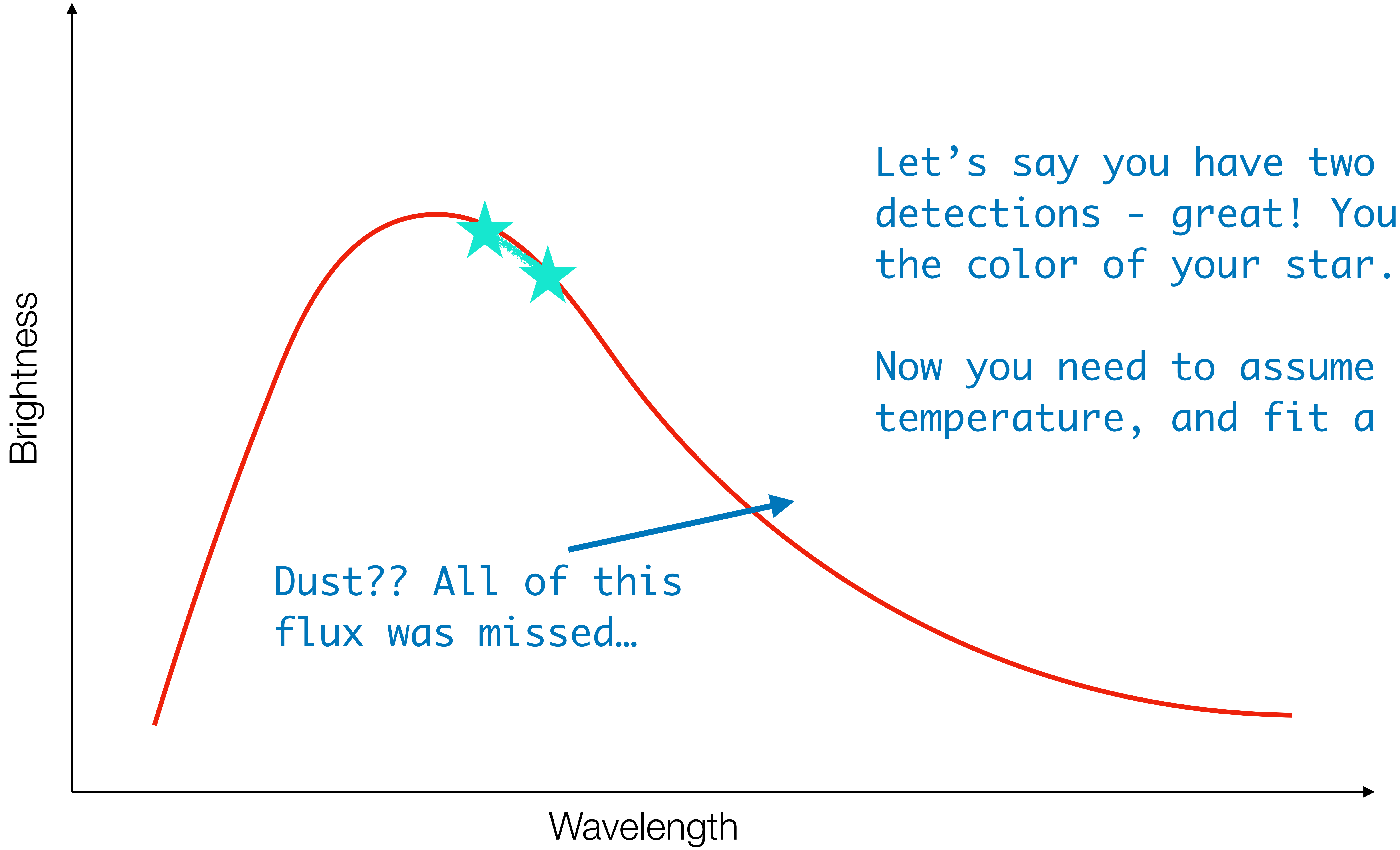

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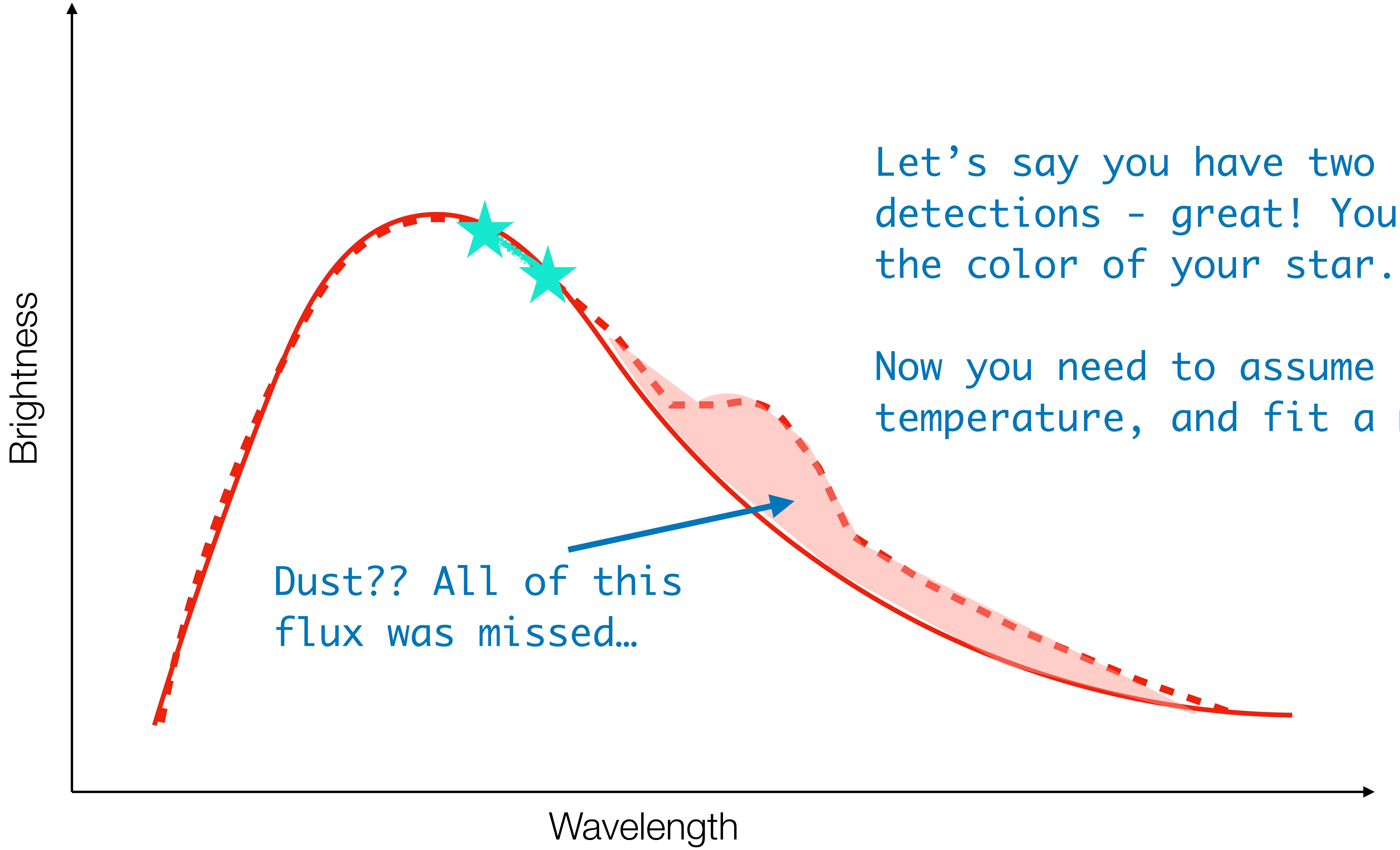

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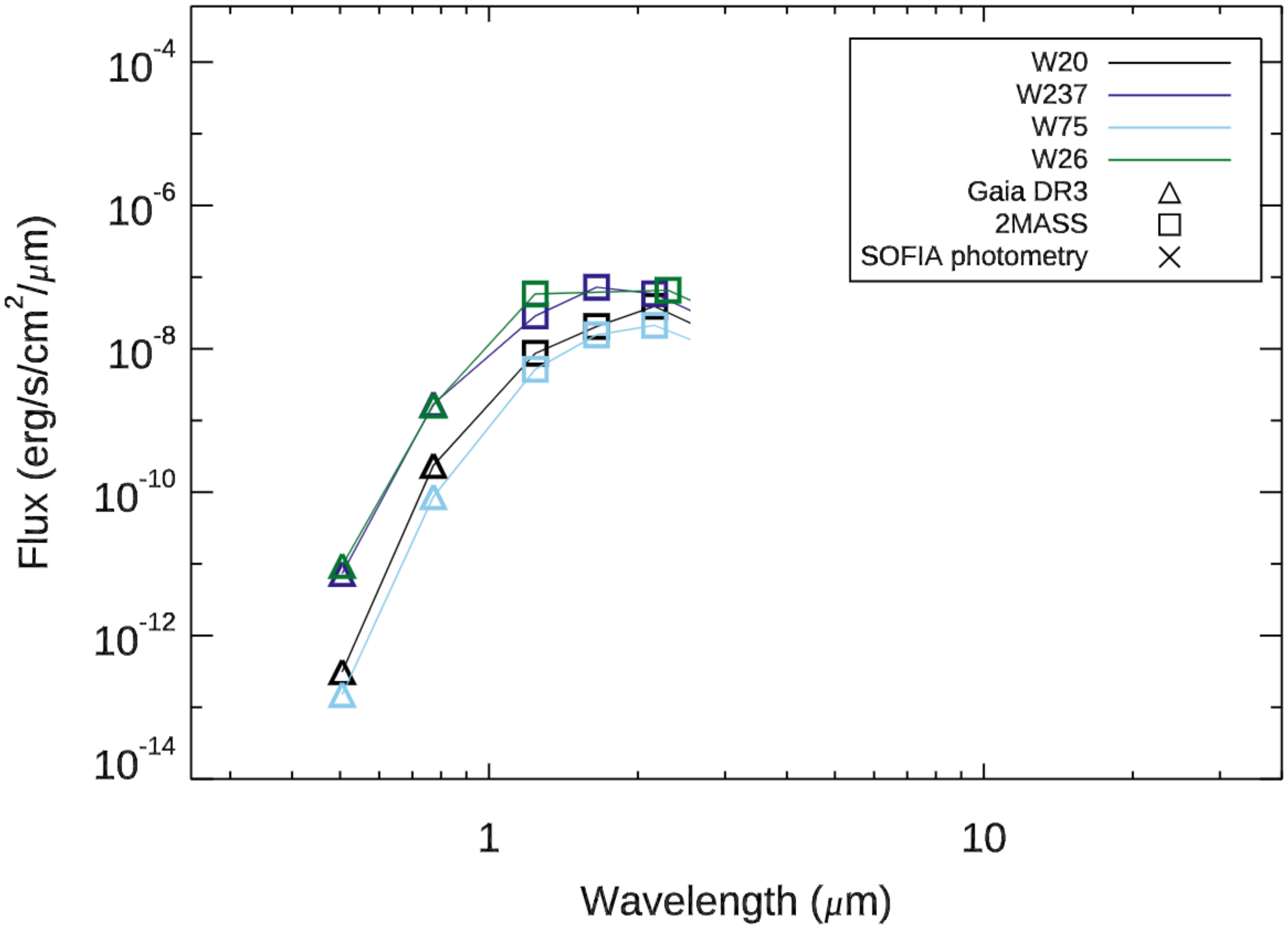
The more complete your SED… the better!



Beasor et al. 2021

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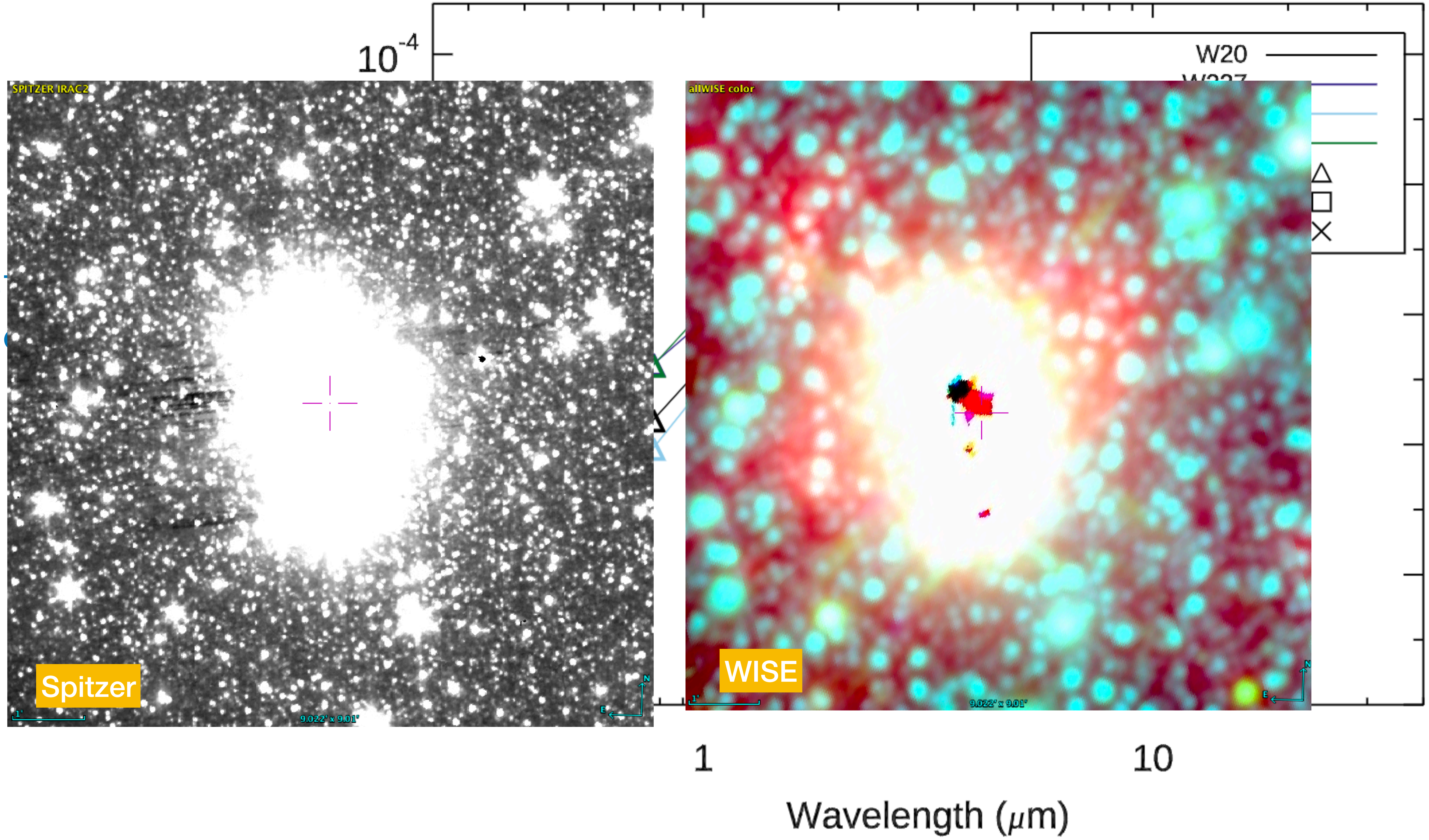

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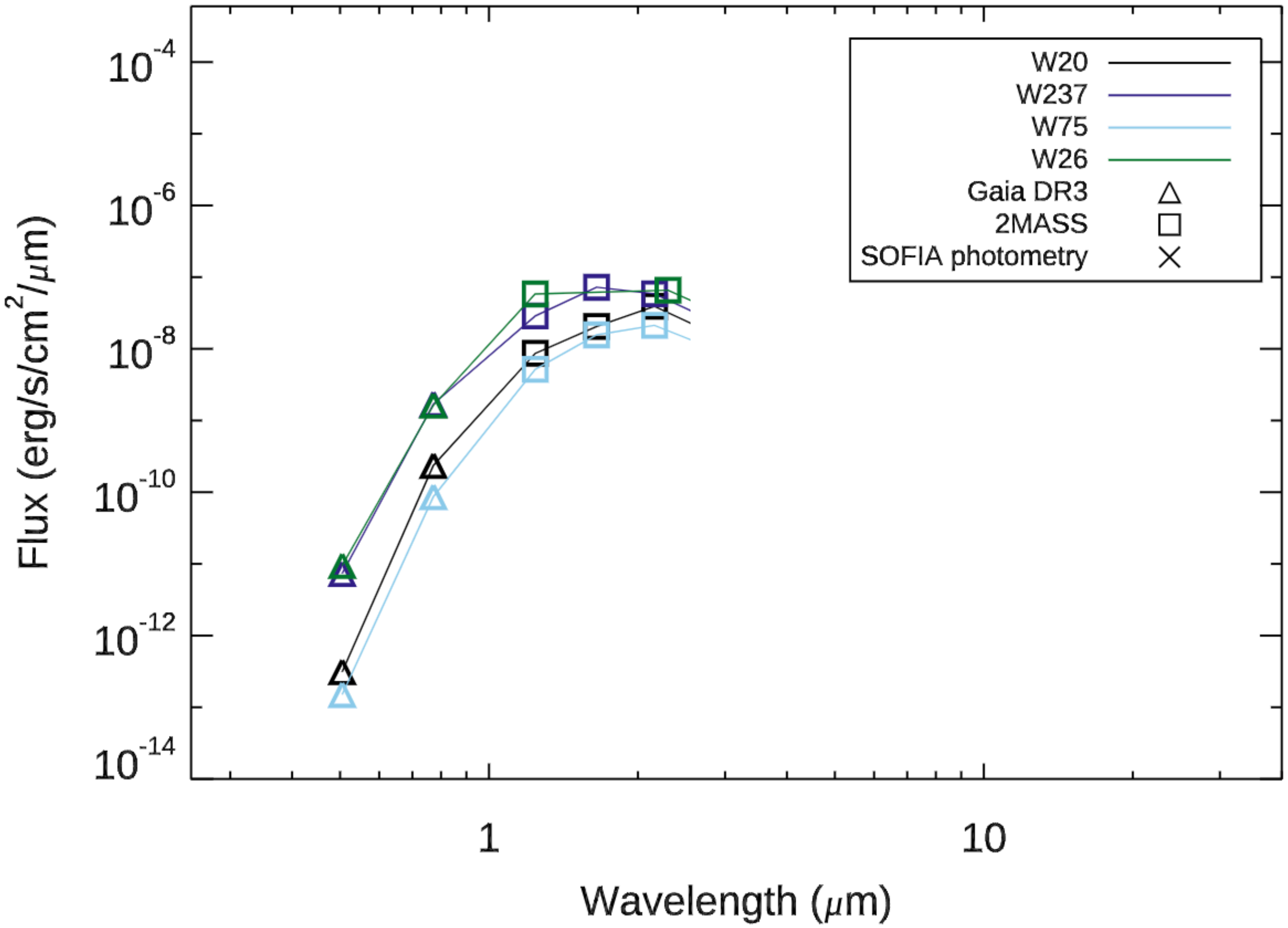

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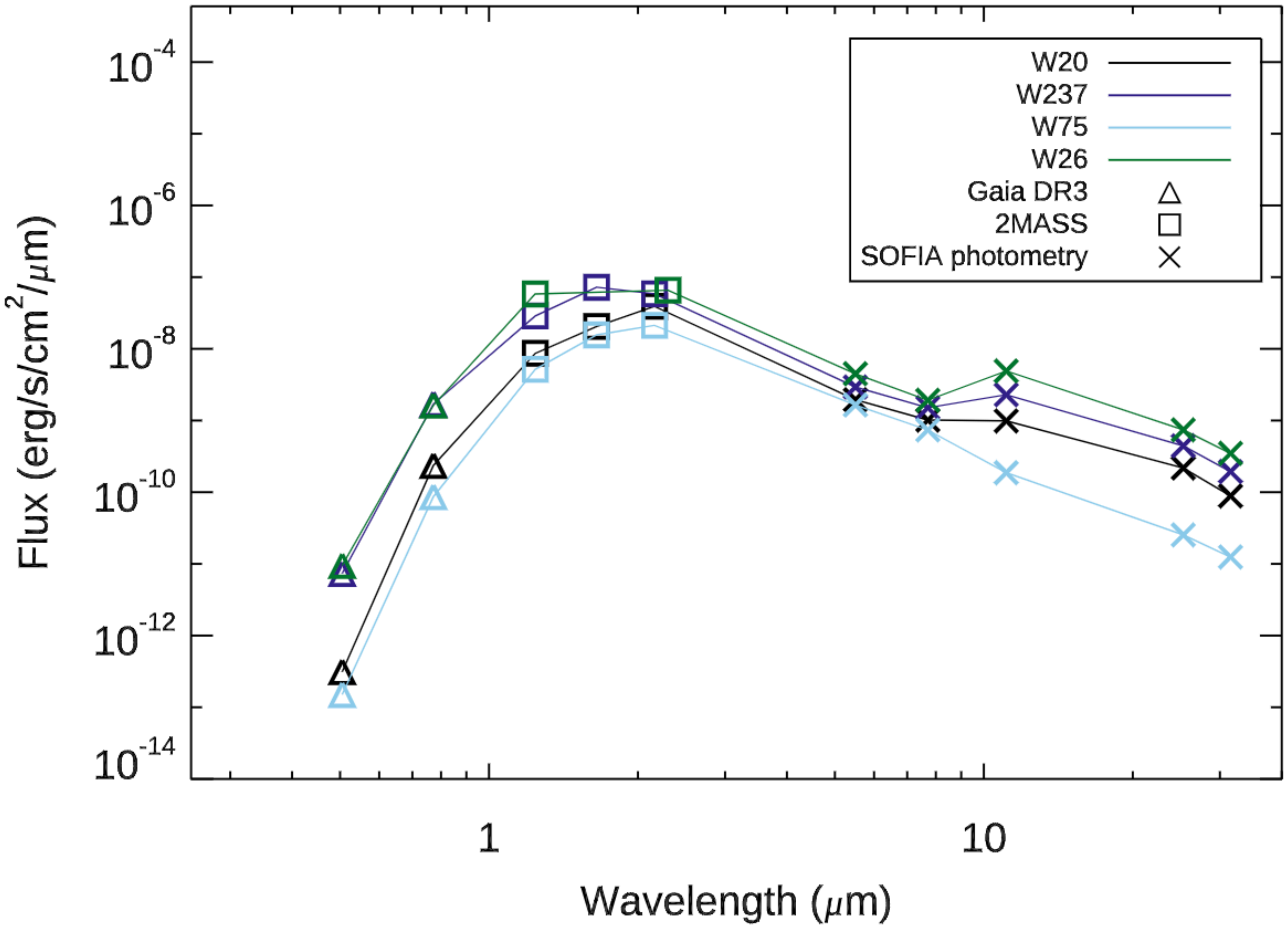

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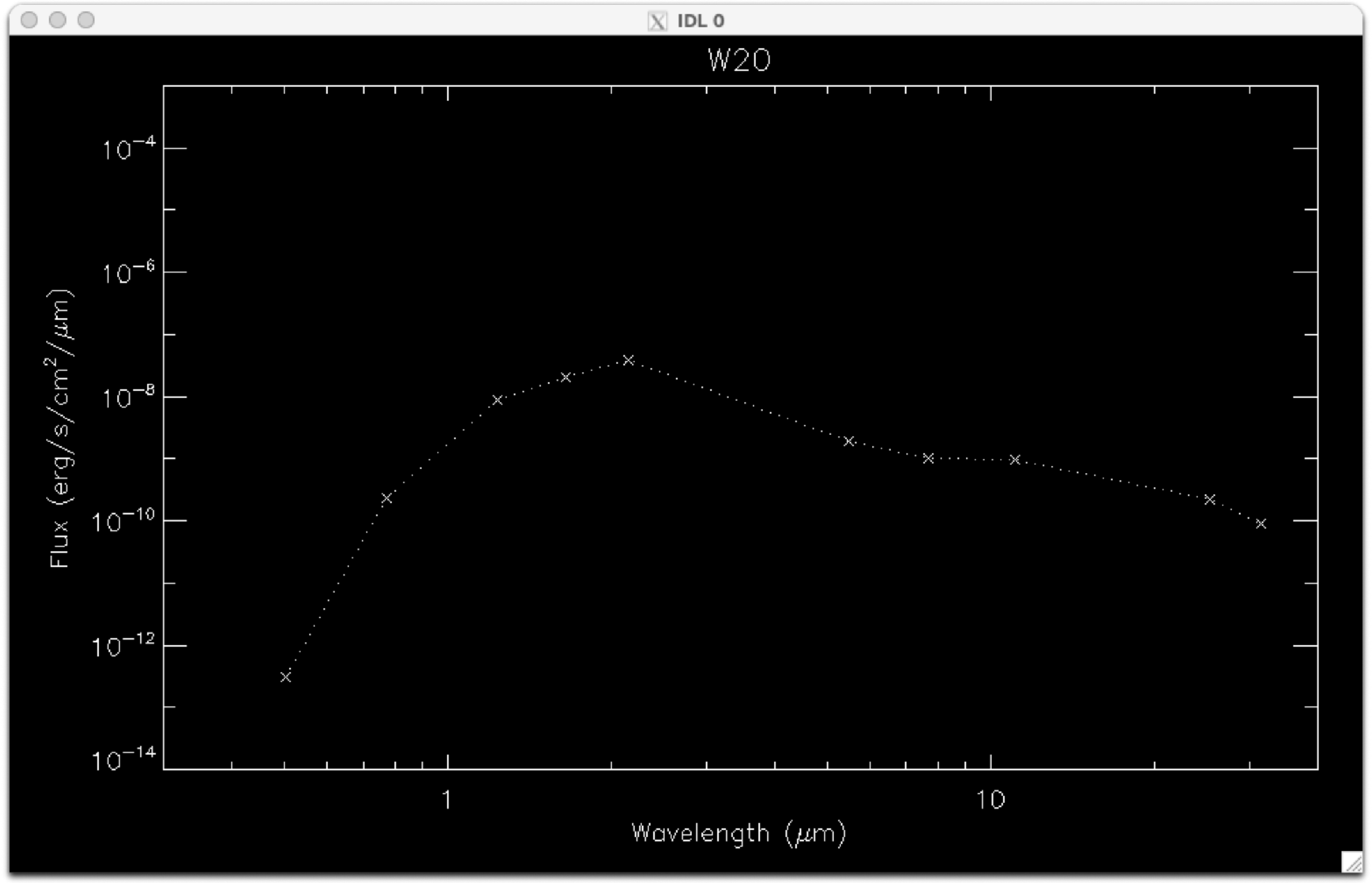

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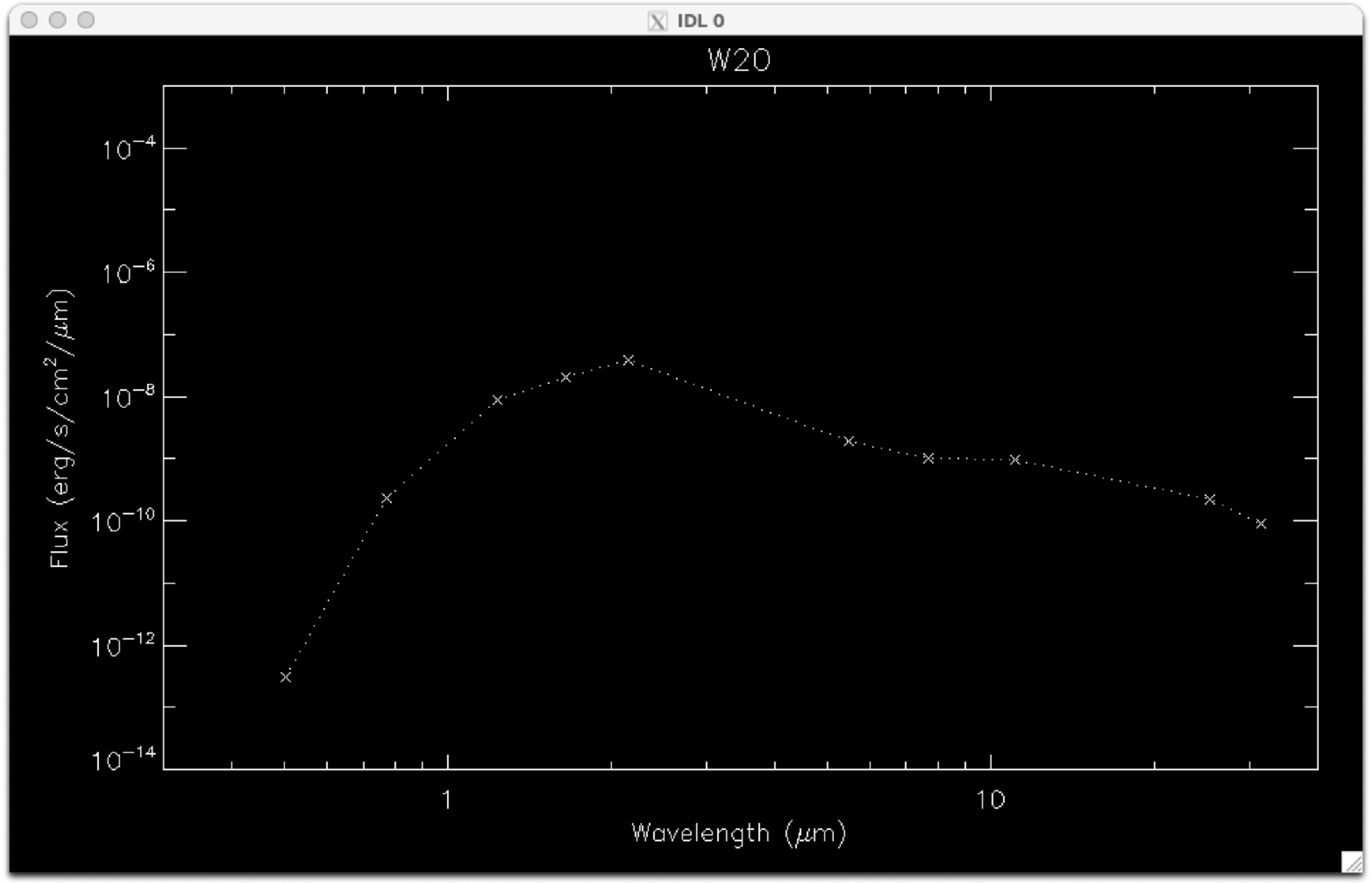

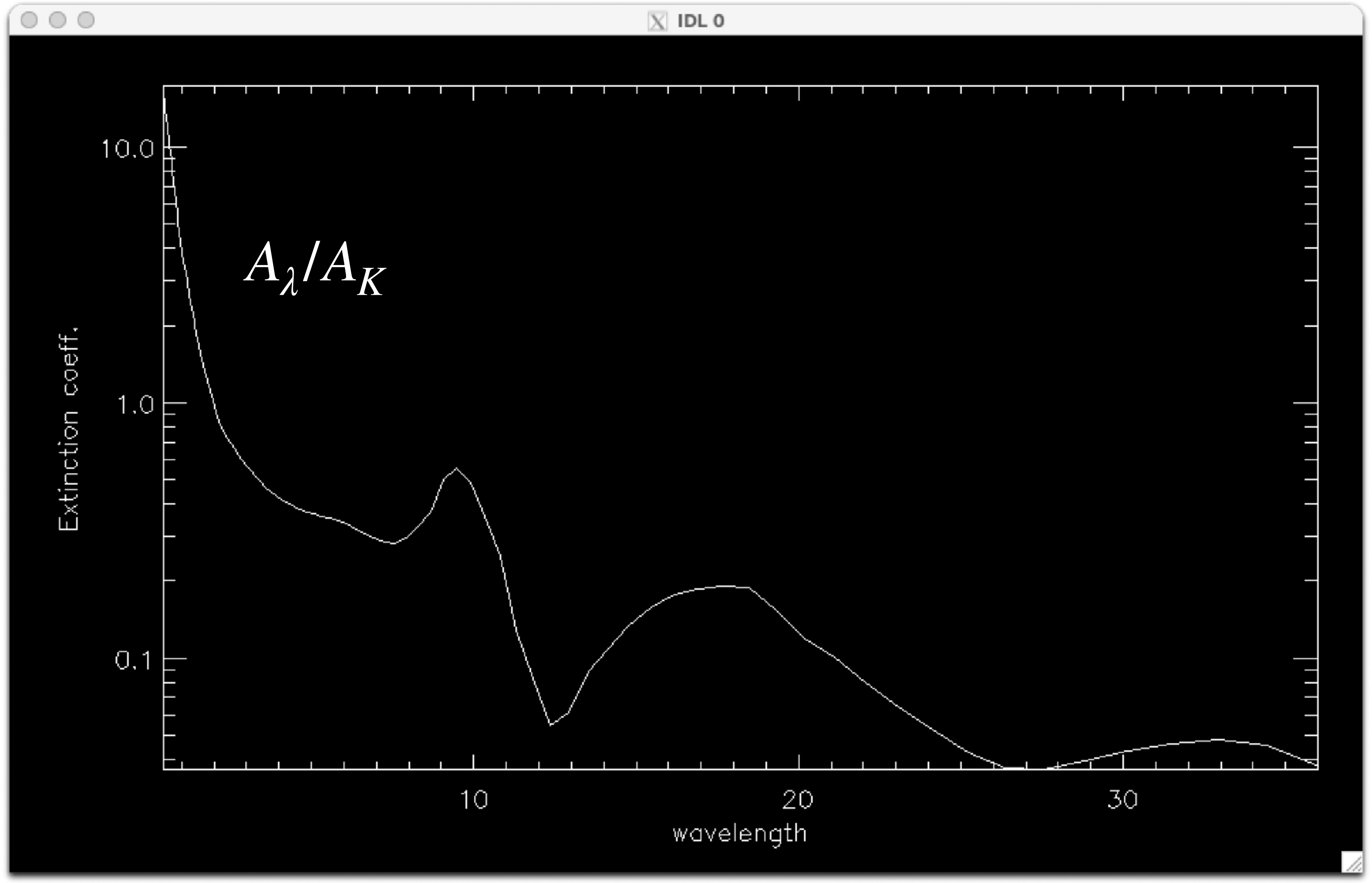

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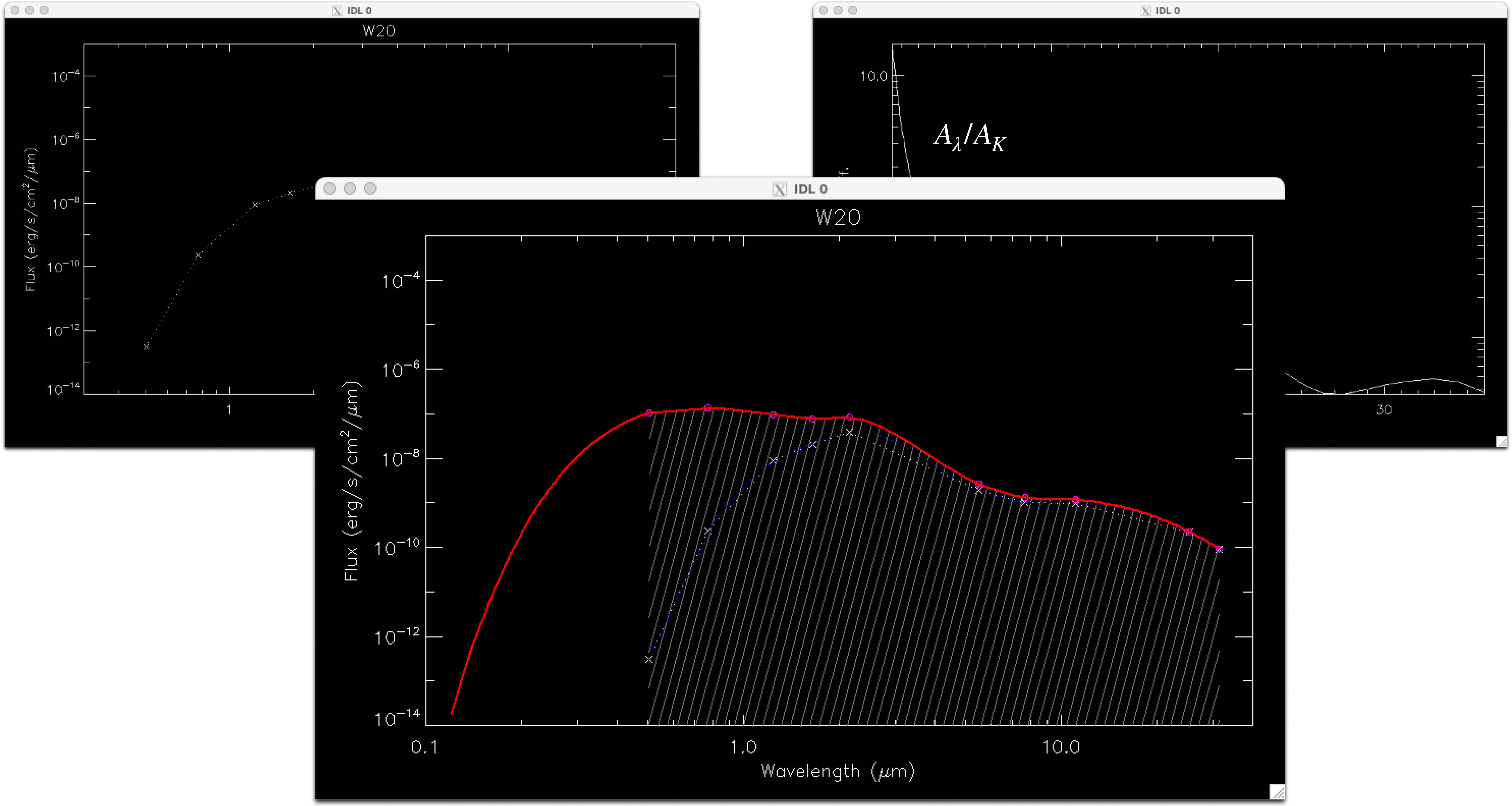

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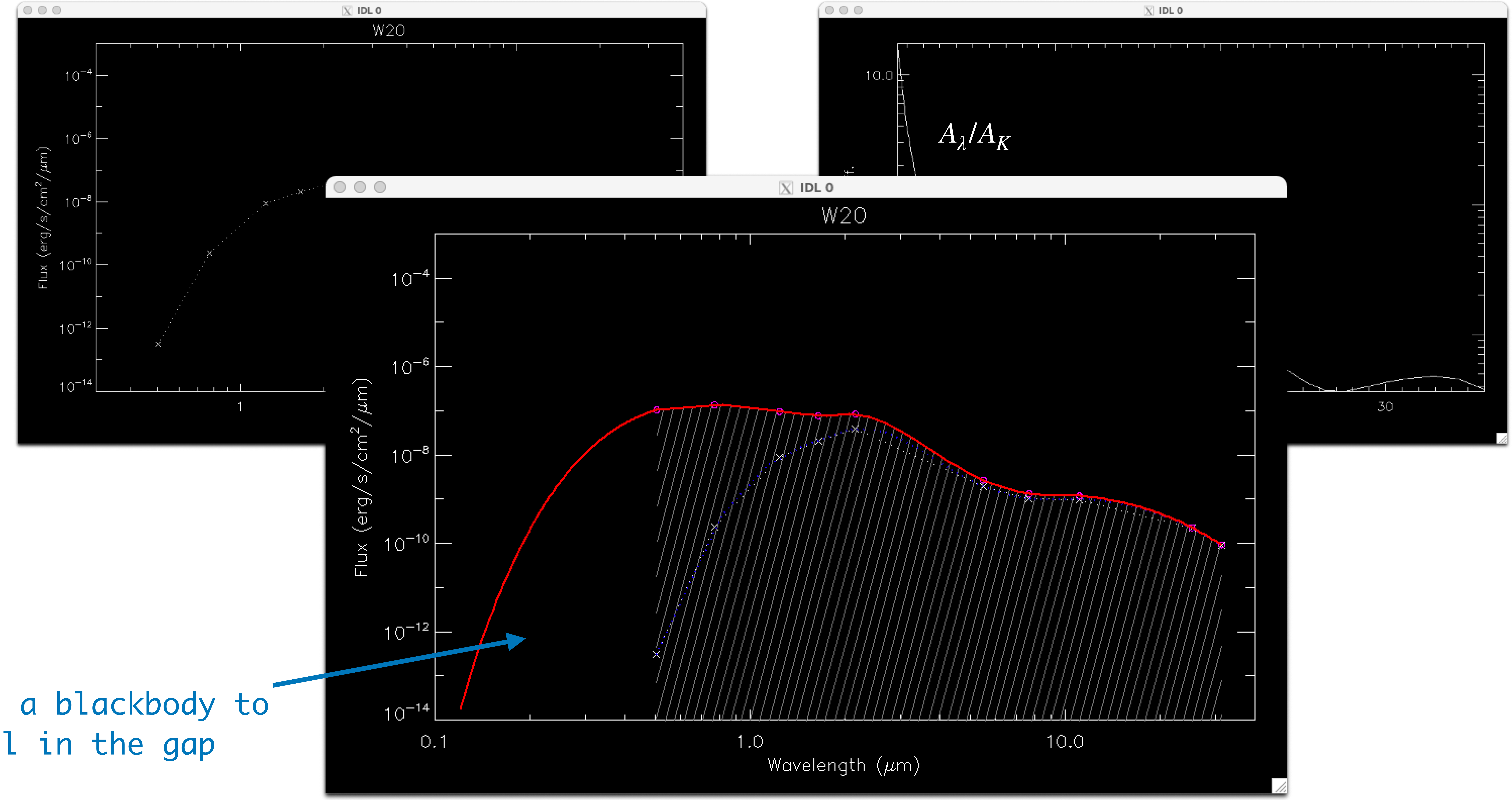


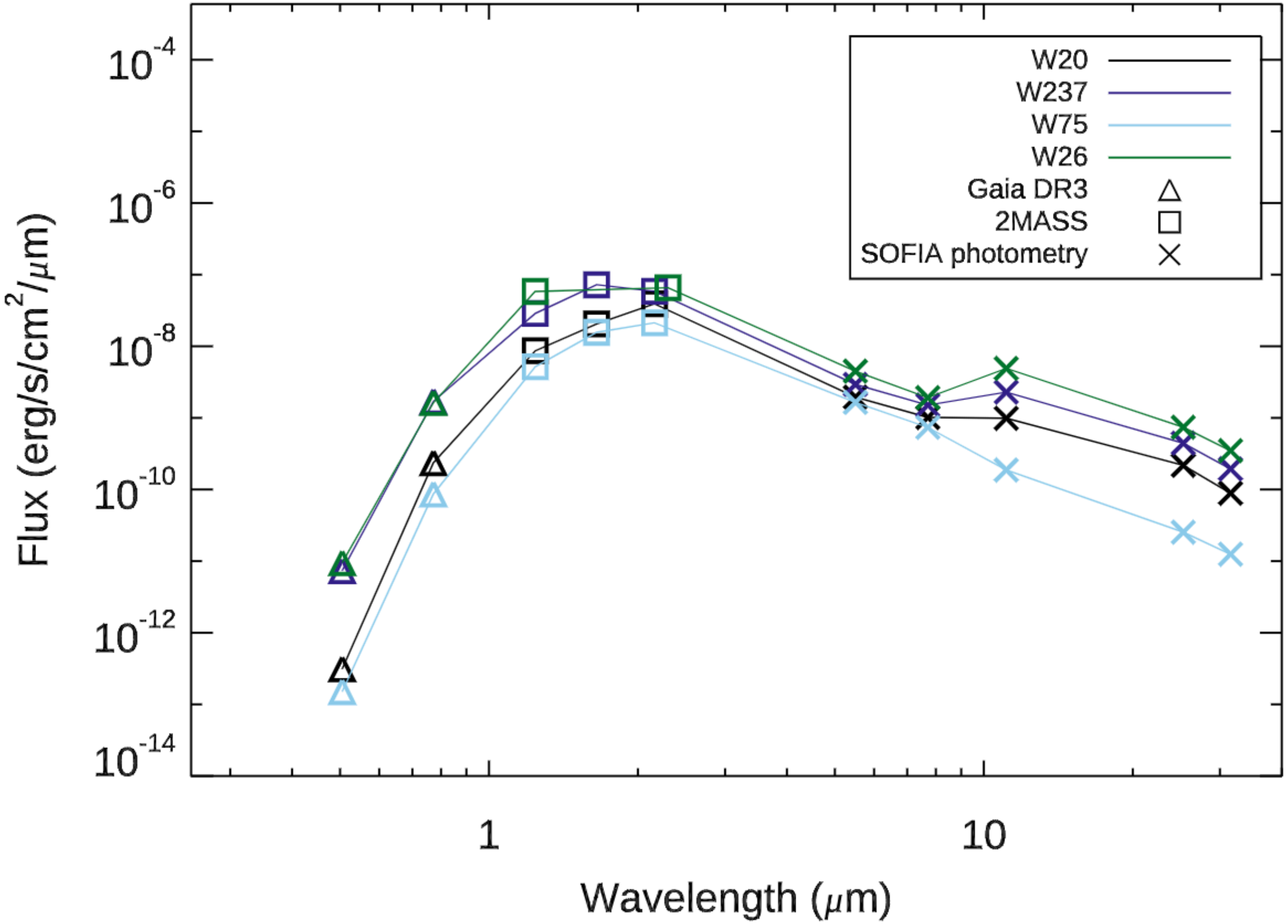
Use a blackbody to fill in the gap

3.Determining stellar properties

Now it's simple

We can integrate under the observed SED and derive a luminosity!

For this, I use IDL function `int_tabulated` and scale for the distance of the star (can of course also be done in Python)



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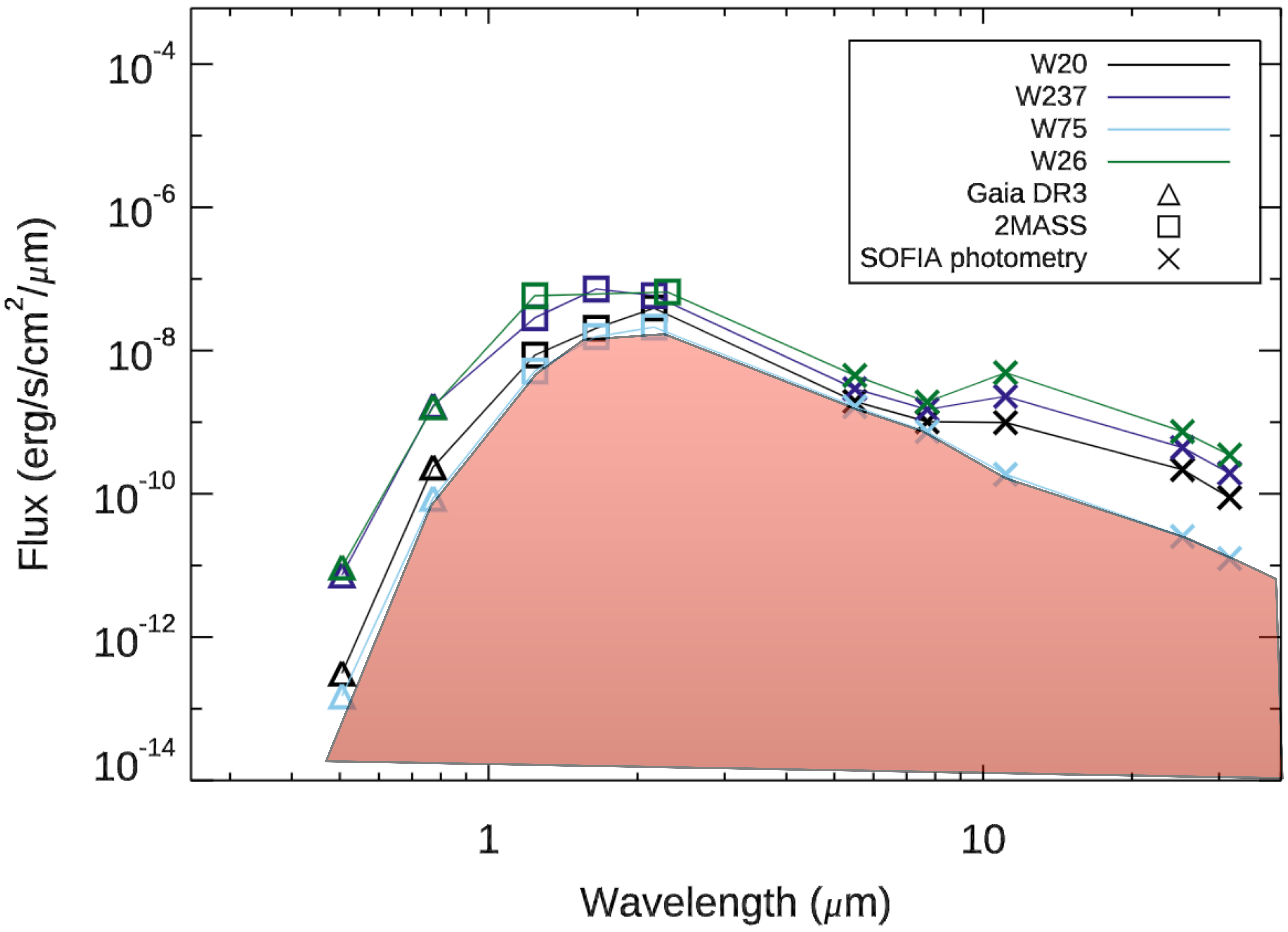

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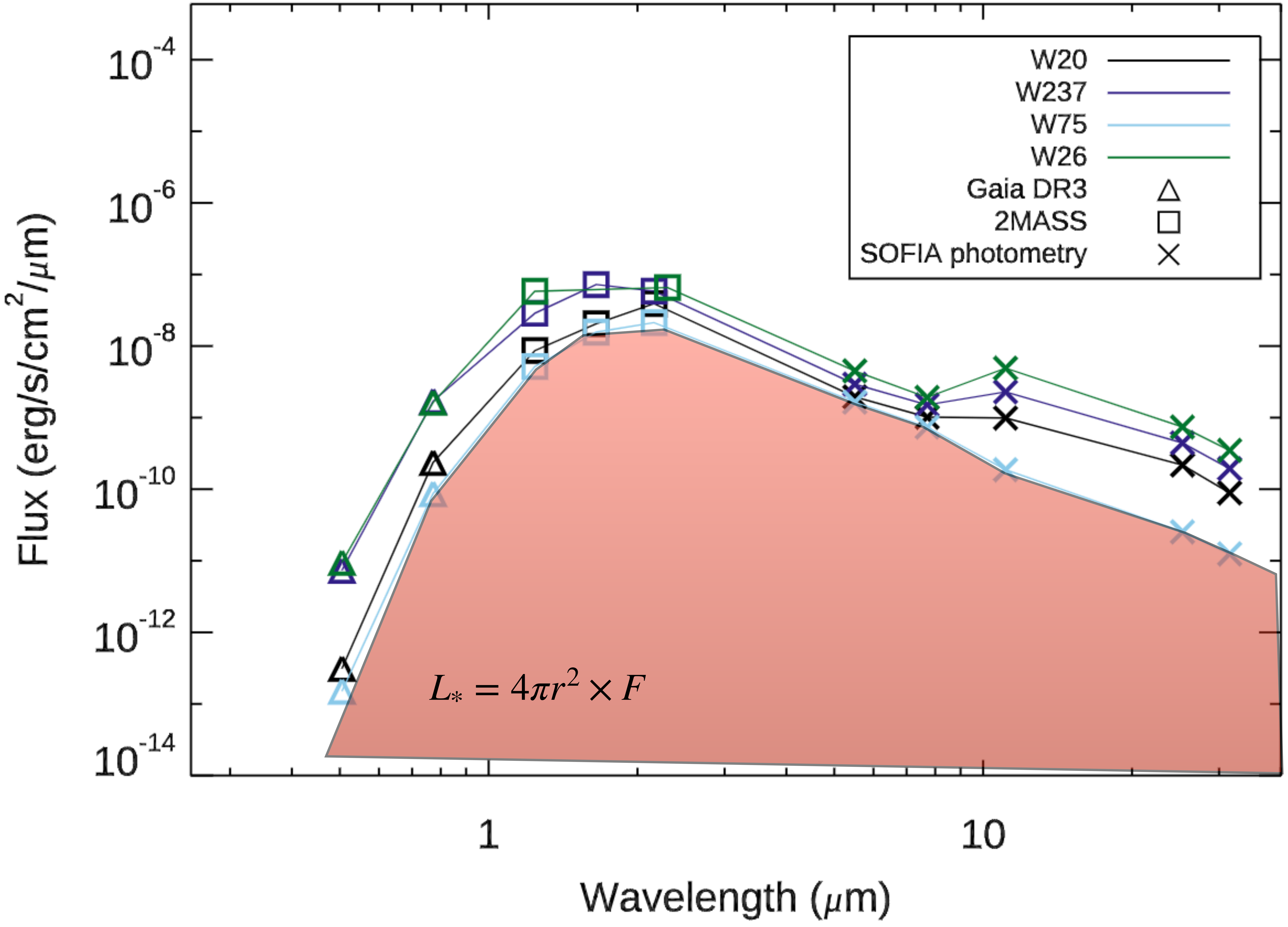

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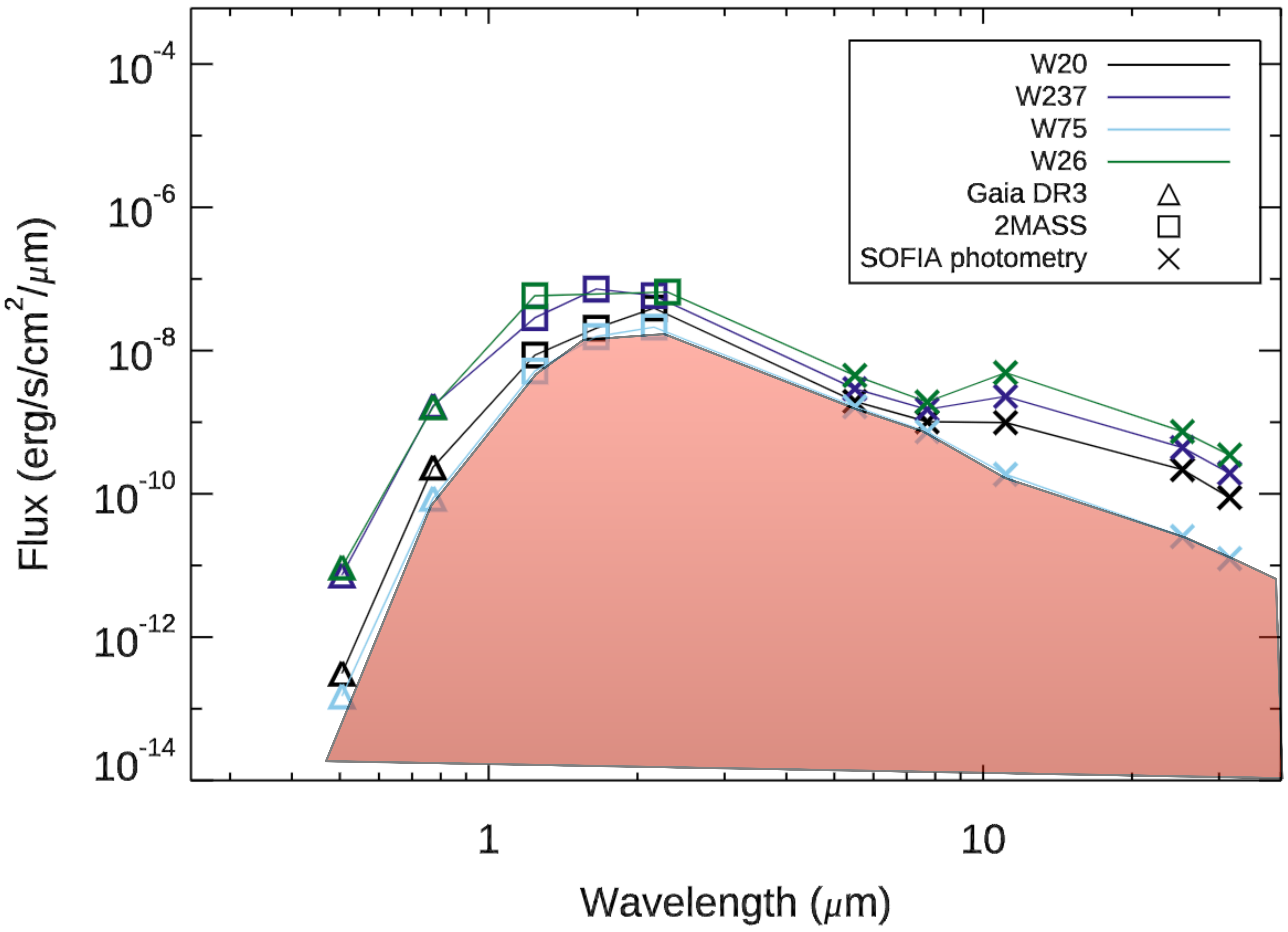
Main sources of error:

- Distance
- Extinction



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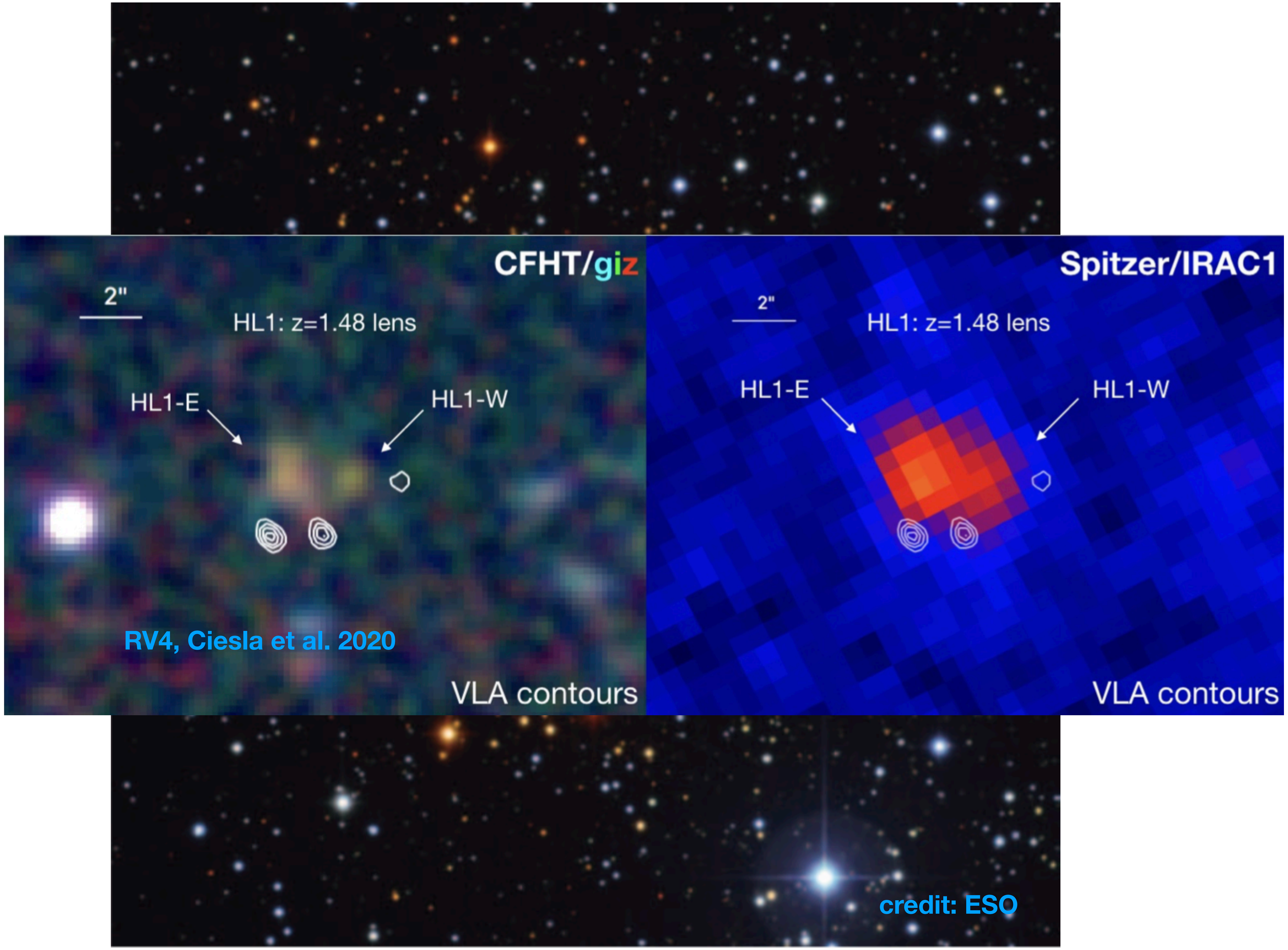

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Extreme stellar diversity…
BSGs, WRs, RSGs, YSGs, LBV
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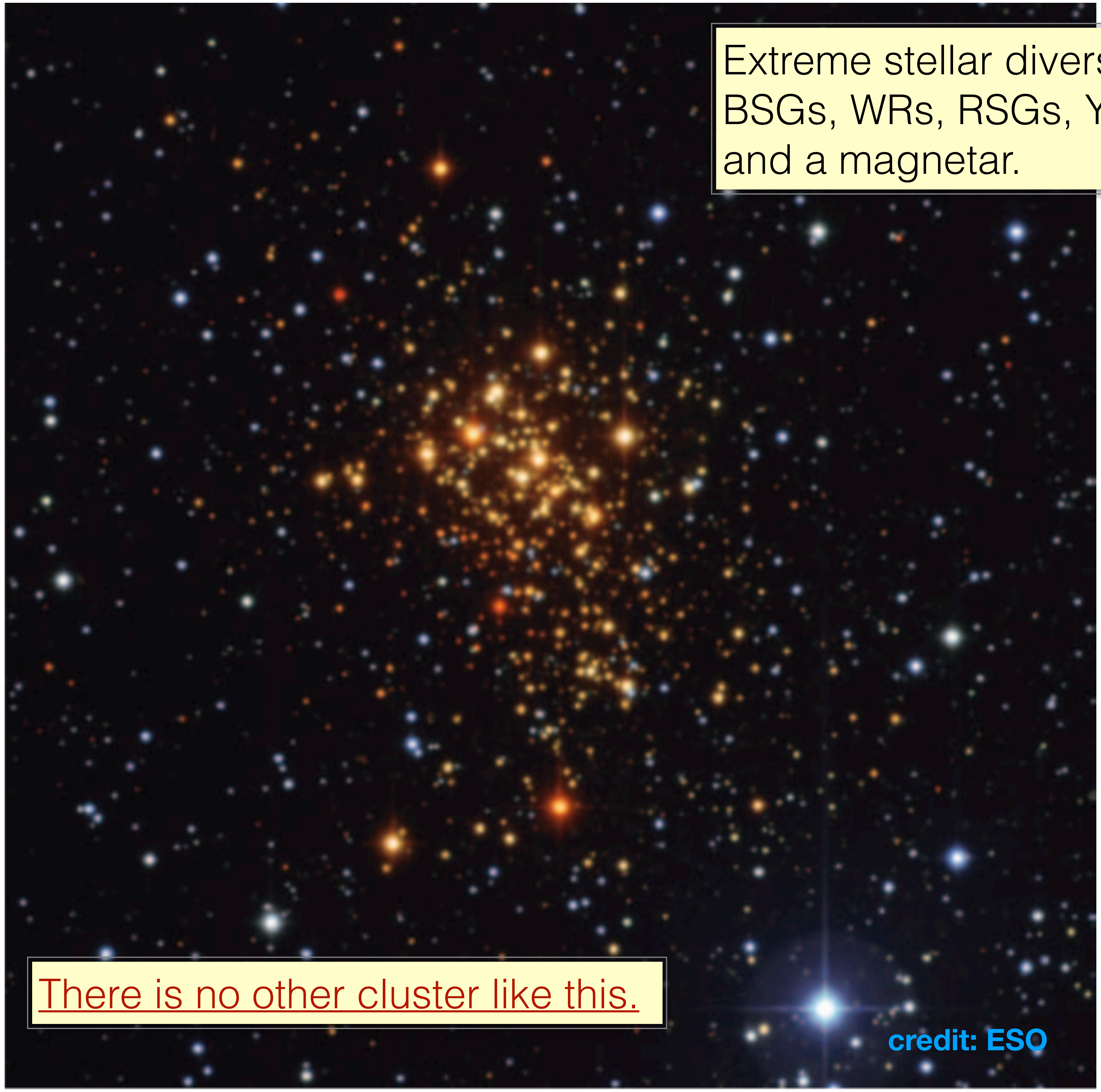


Extreme stellar diversity…
BSGs, WRs, RSGs, YSGs, LBV
and a magnetar.

There is no other cluster like this.

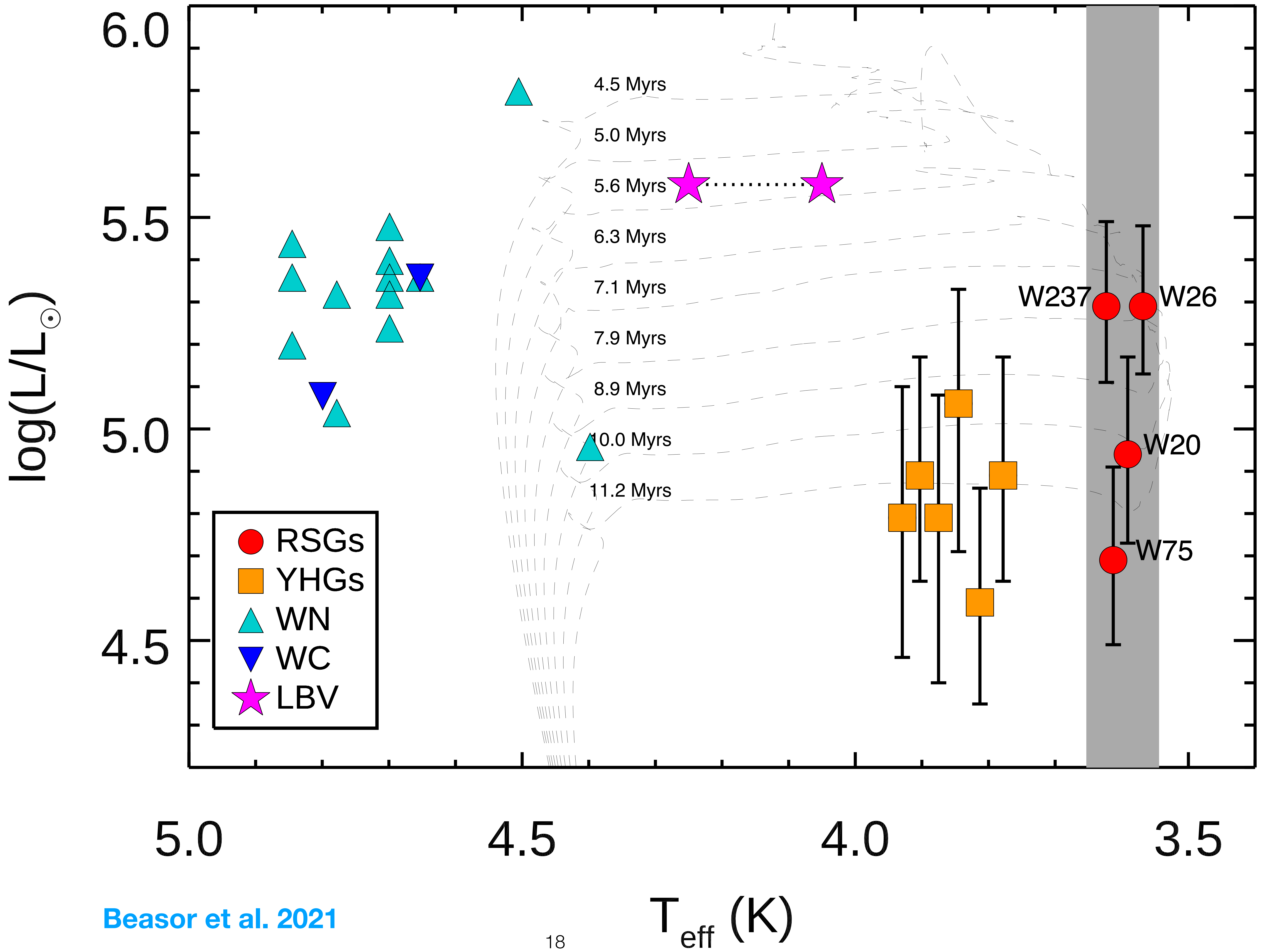
4. Westerlund 1

- Under the single star paradigm, only a very specific age could explain the existence of both RSGs and the WRs

- Clark et al. (2005) first used the stellar diversity to suggest an age of ~ 5 Myr, implying a progenitor population with masses > 30 Msun

- First example of a super star cluster in the MW - total mass of ~ 10^5 Msun - the most massive Galactic cluster yet discovered

4. Westerlund 1



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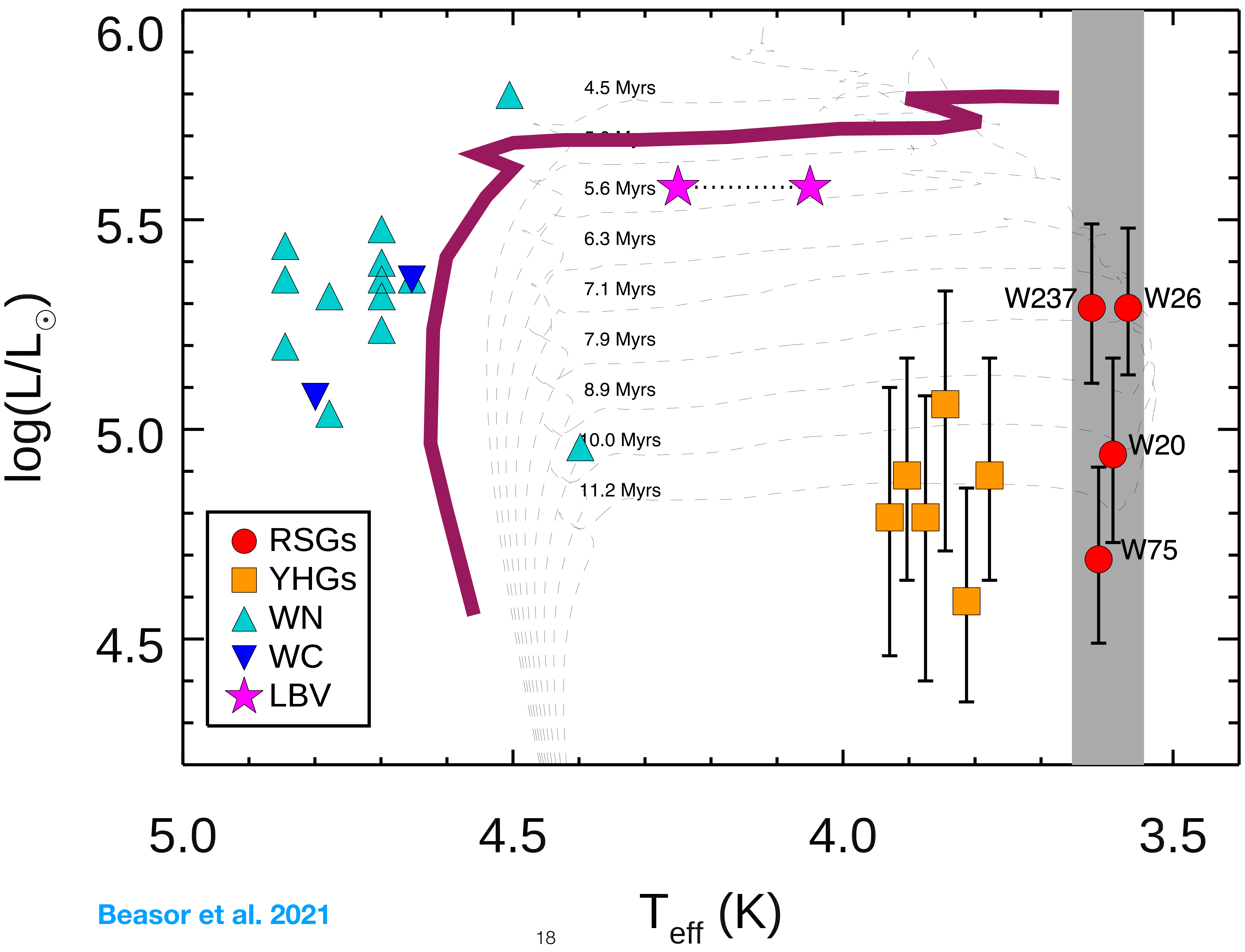

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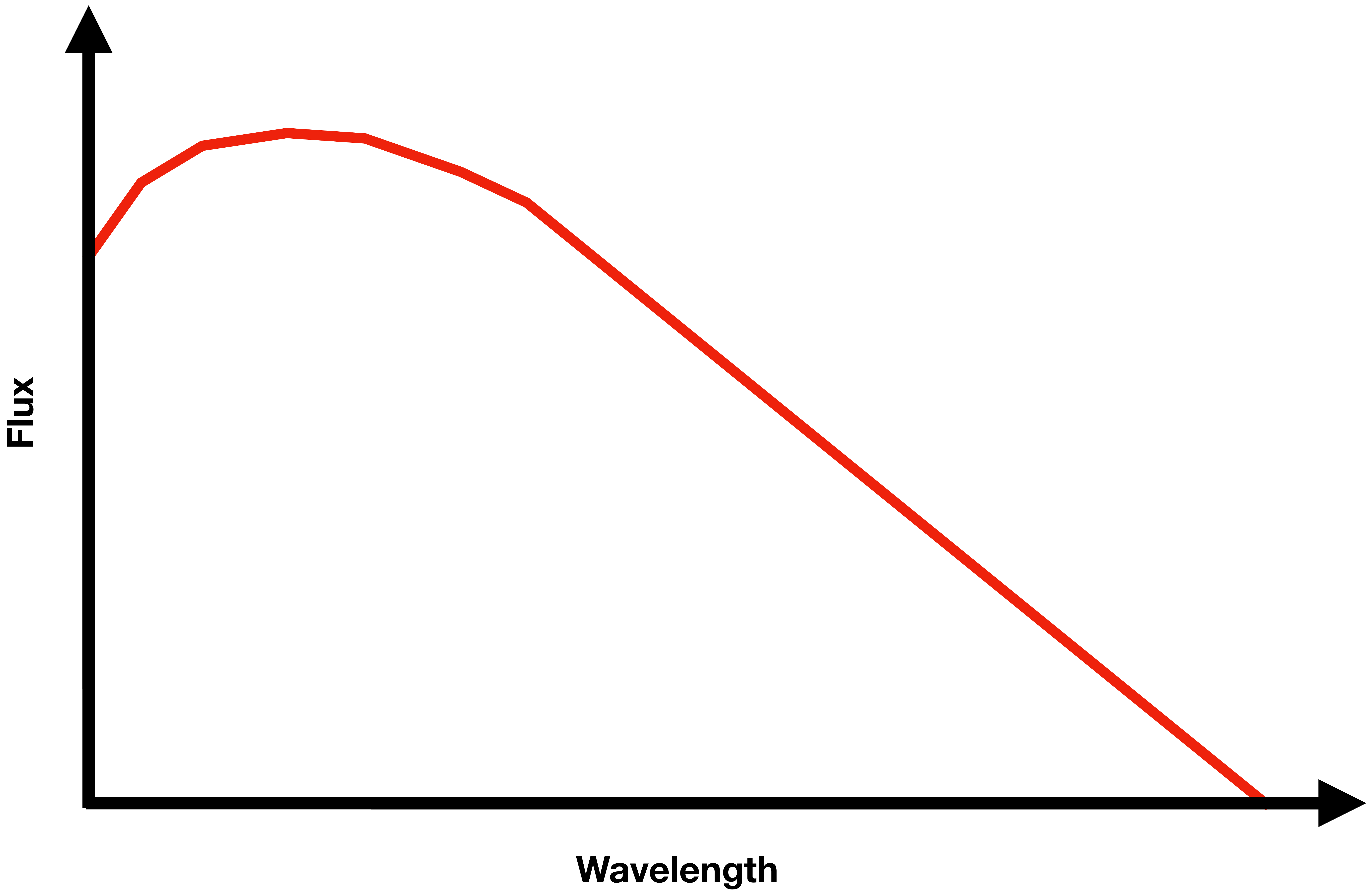
4.Other applications: mass-loss rates



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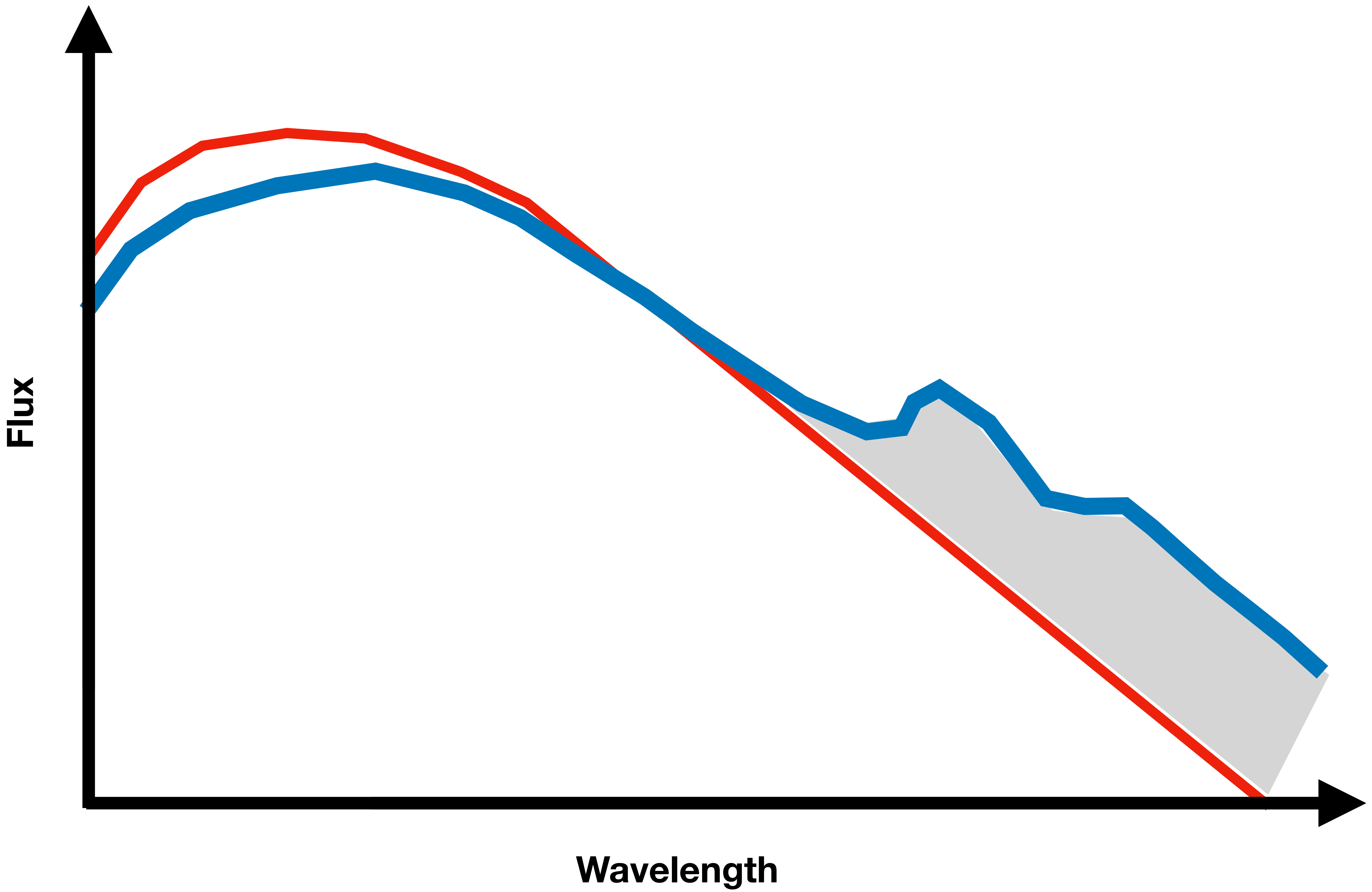

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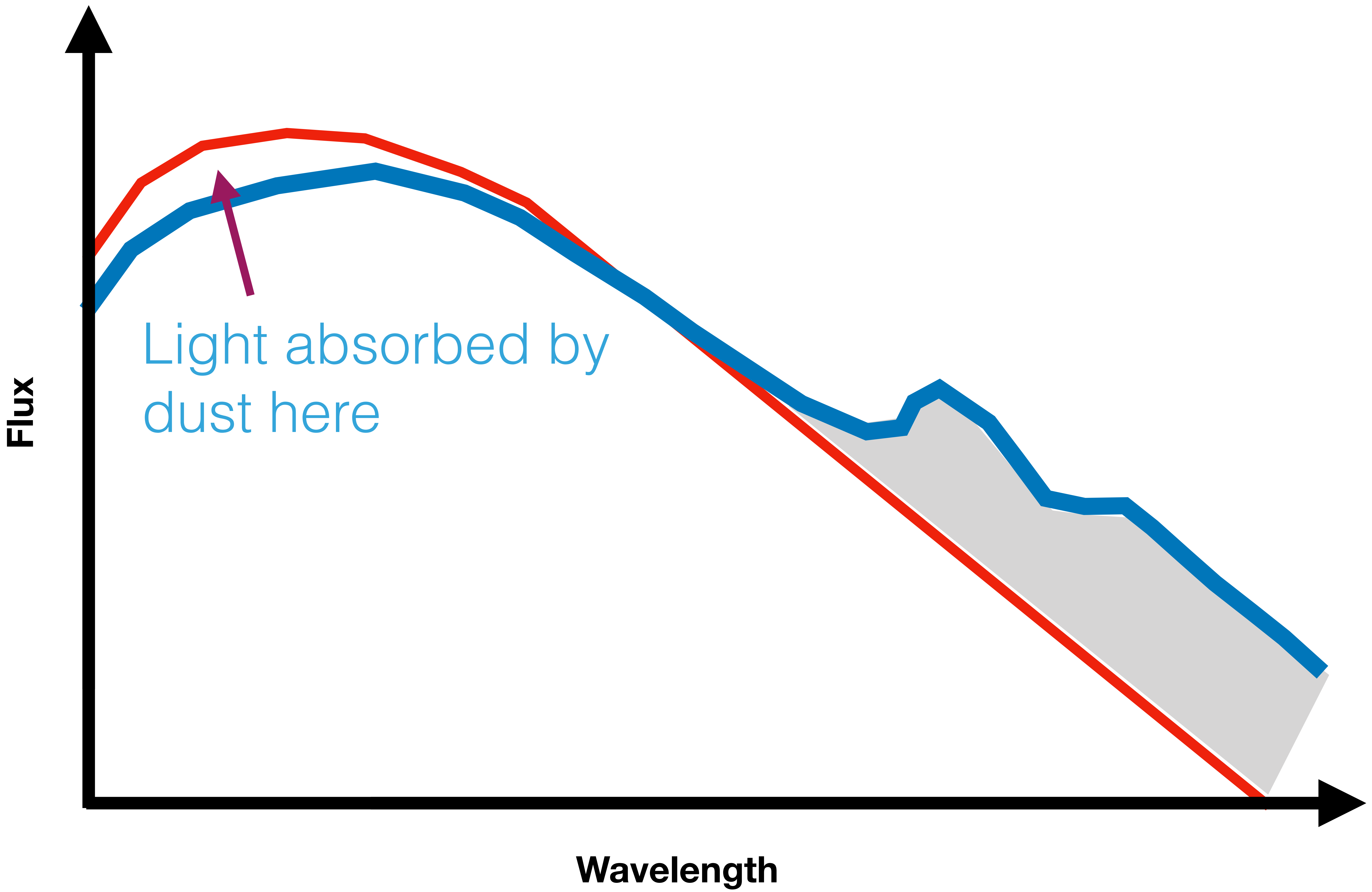

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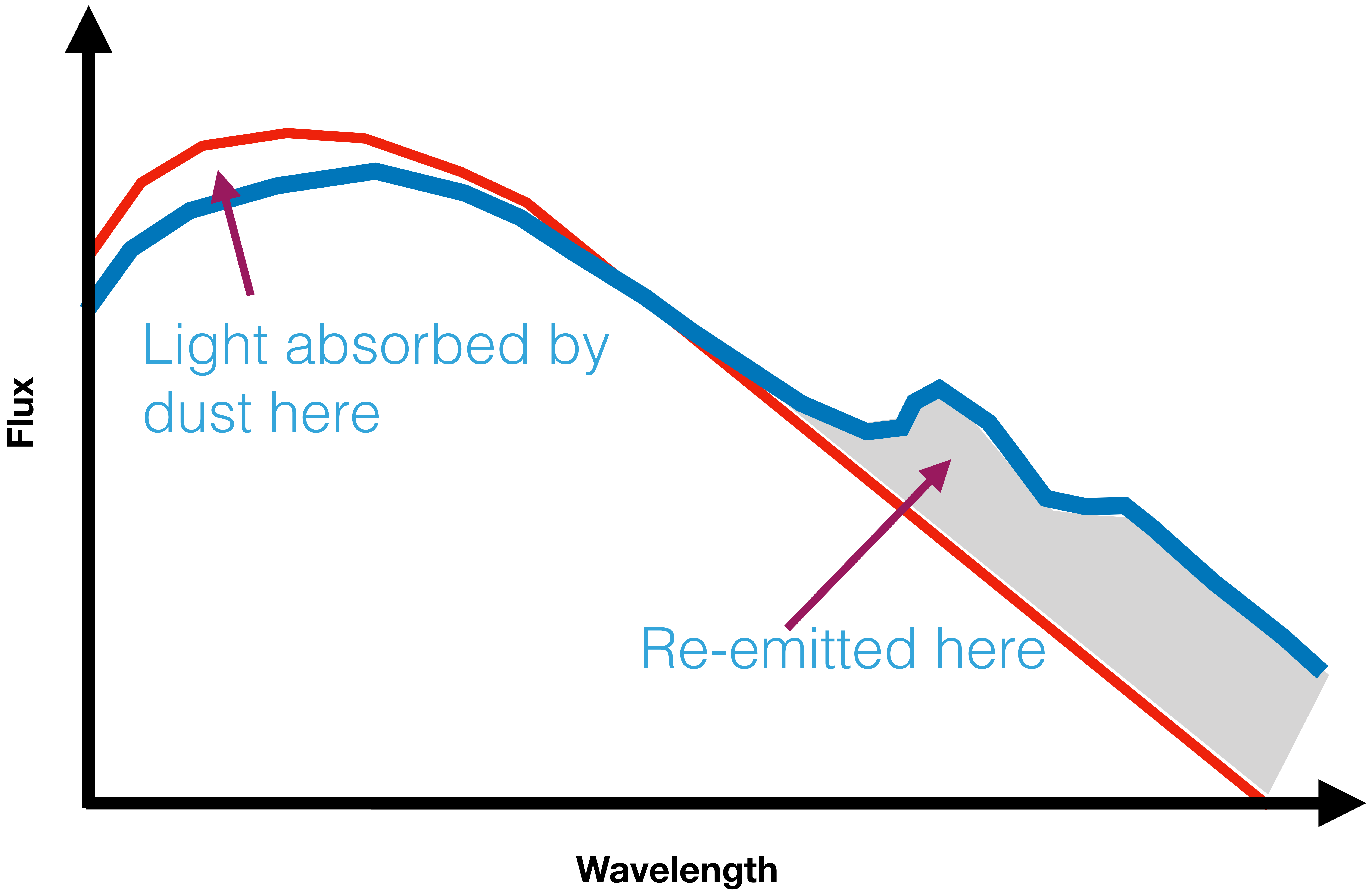

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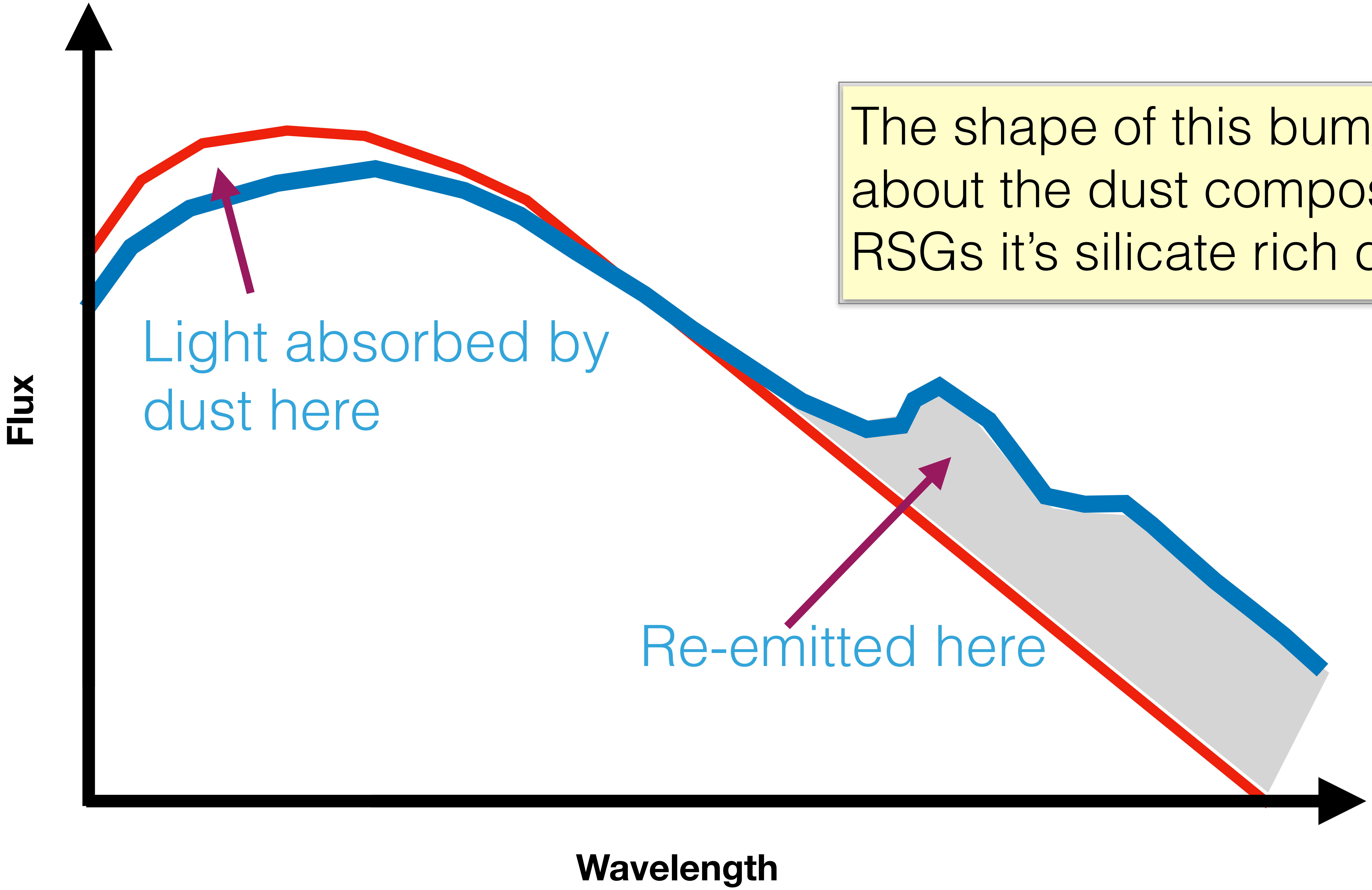

The shape of this bump tells us about the dust composition, for RSGs it's silicate rich dust

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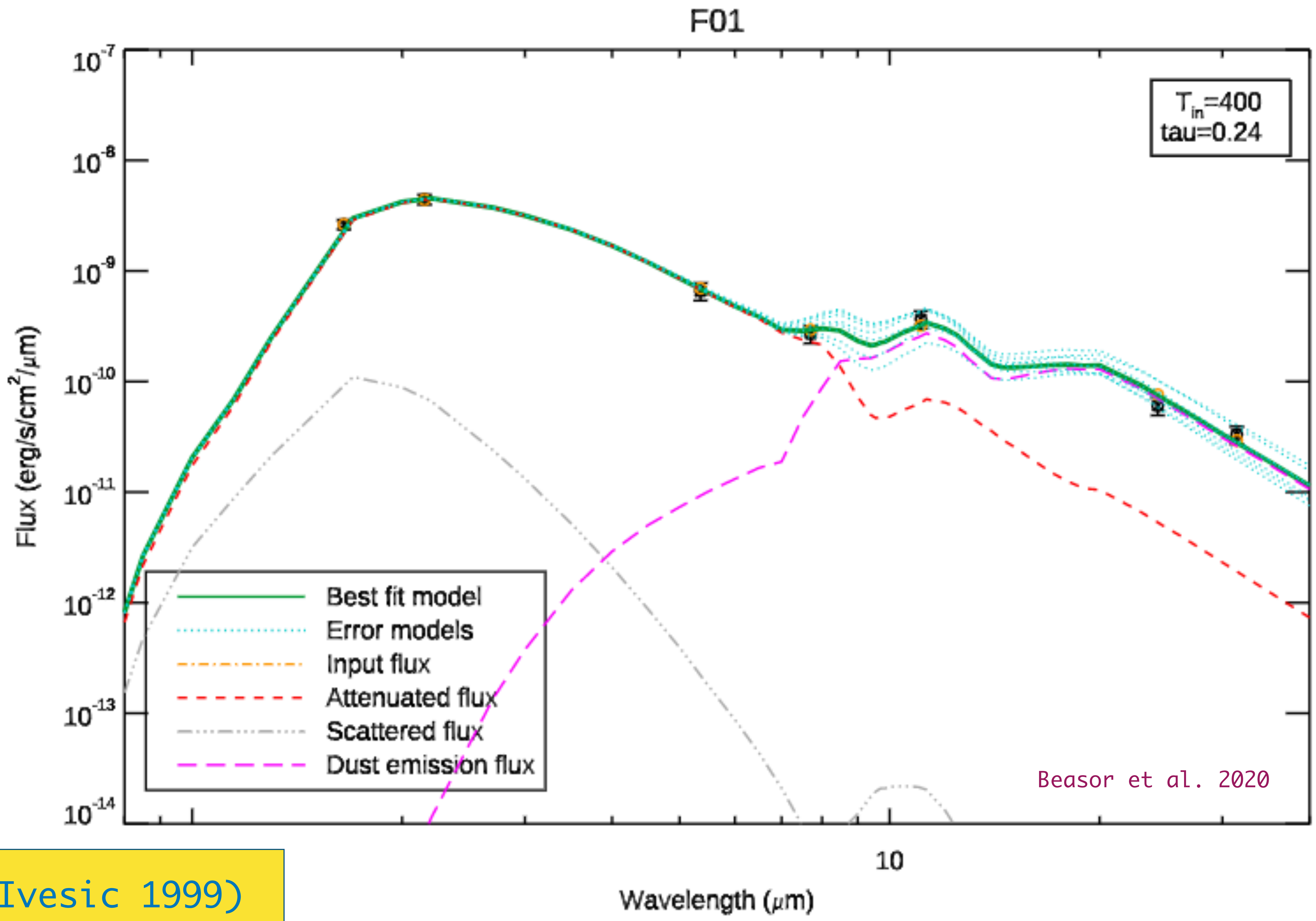

Software: DUSTY (Ivesic 1999)

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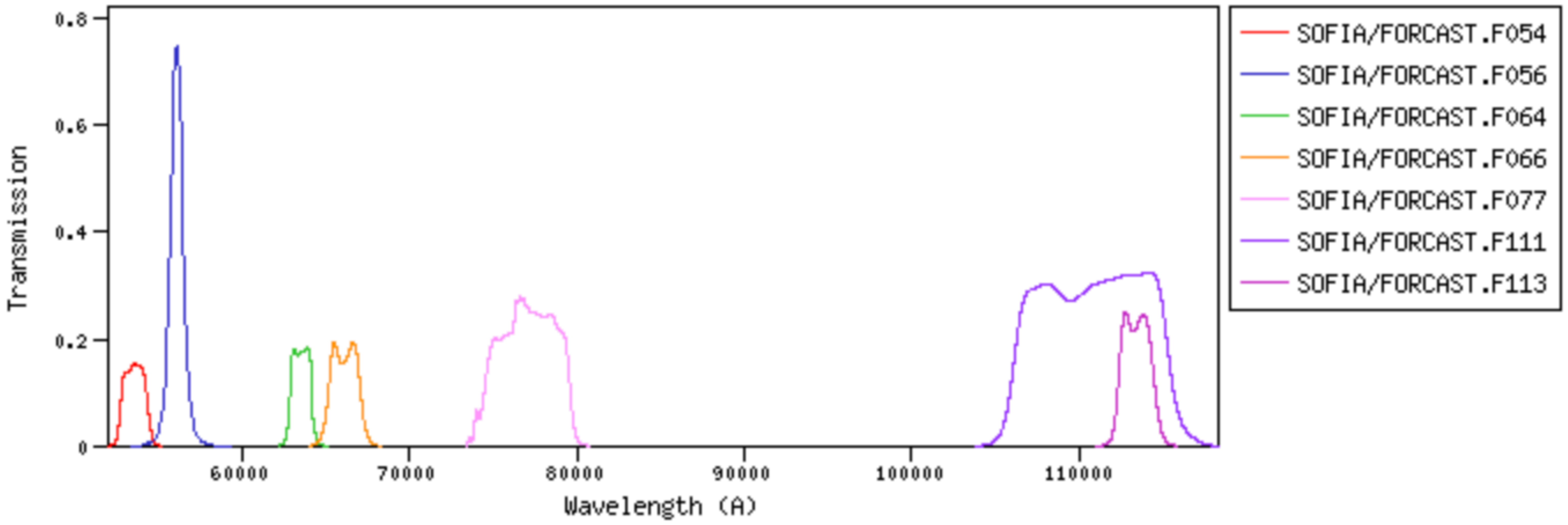

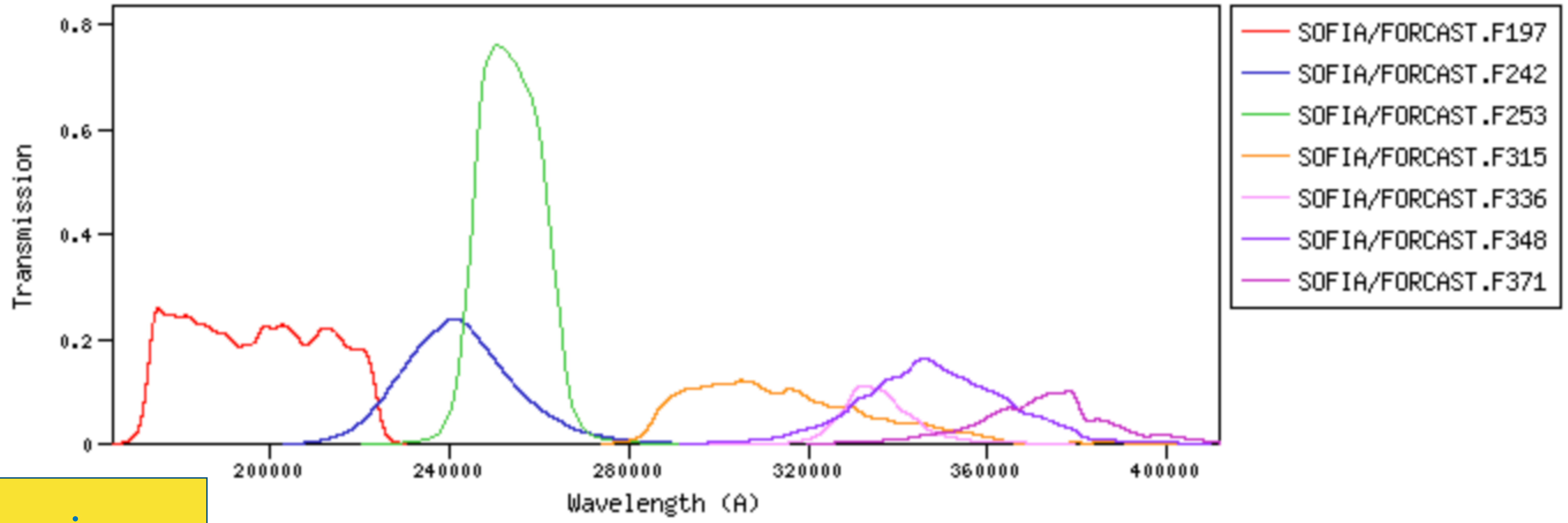

SVO Filter Profile Service

5. Advice for infrared astronomers

- When proposing for telescope time… start with the science
- Ask people to read your proposals. Most postdocs/faculty have served on some sort of panel, you learn what makes a strong proposal
- Don’t be put off by negative referee reports - use them to make your work stronger!
- Remember how cool our job is!