Flux-Calibrating Your Spectra

Concept, Practice, and Discussion
for AAVSO Spectroscopy On-Line Meeting

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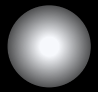
Reference: David Boyd (2020):
A method of calibrating spectra in absolute flux using V magnitudes
https://britastro.org/wp-content/uploads/2021/05/absfluxcalibration.pdf

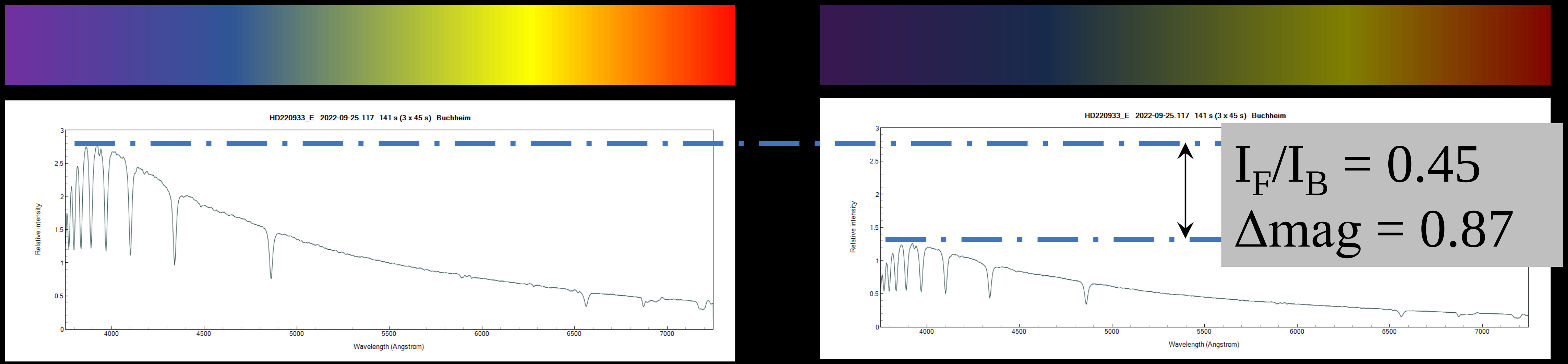
One way of looking at the relationship between spectrum and photometry

Brighter



Fainter

Identical
spectral profiles



Why flux-calibrate?

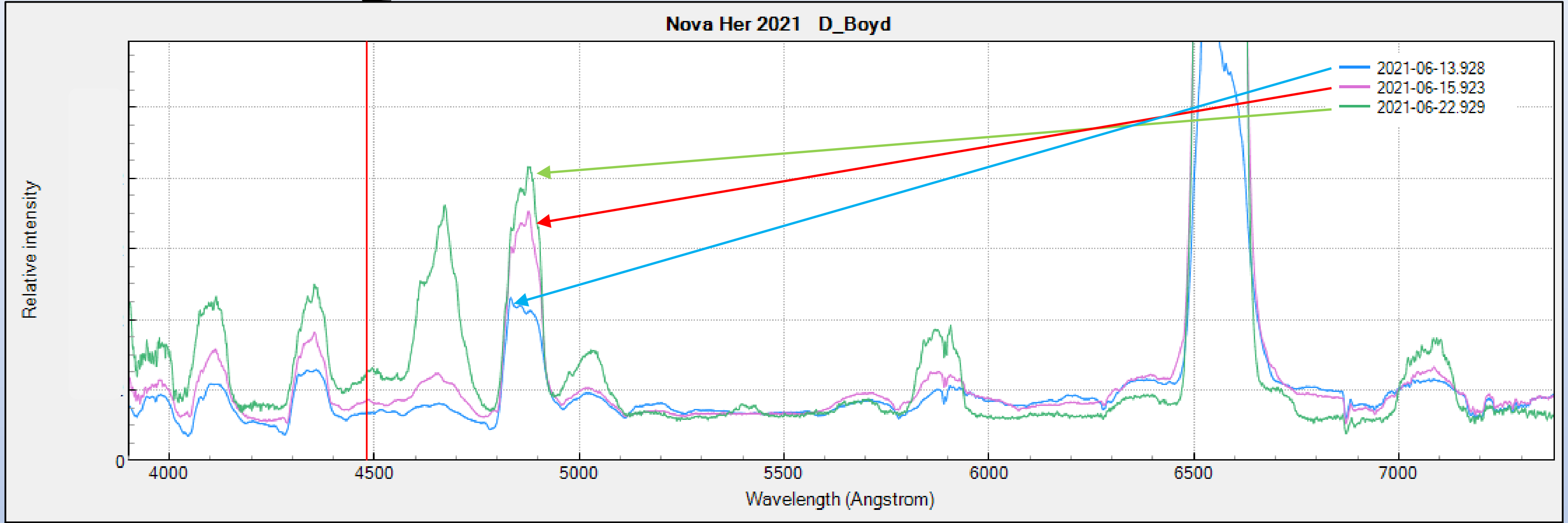
- Different view of changes
- Combine Spectra + Photometry

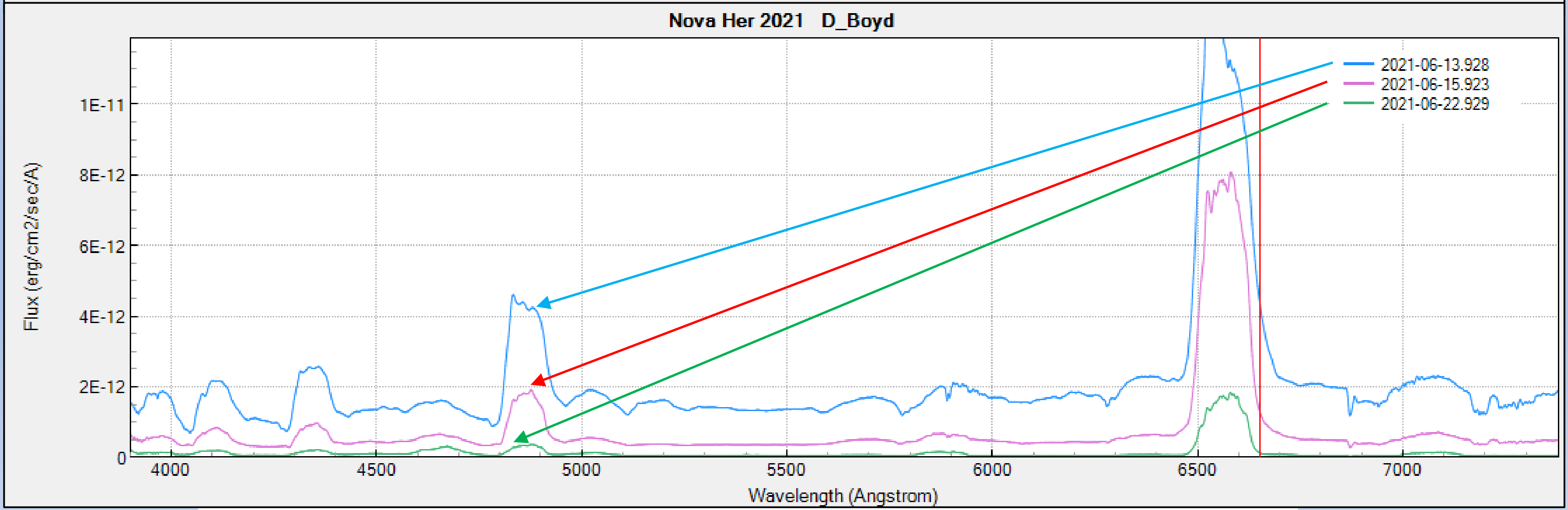
- Spectral profile:

Rel Intensity vs λ

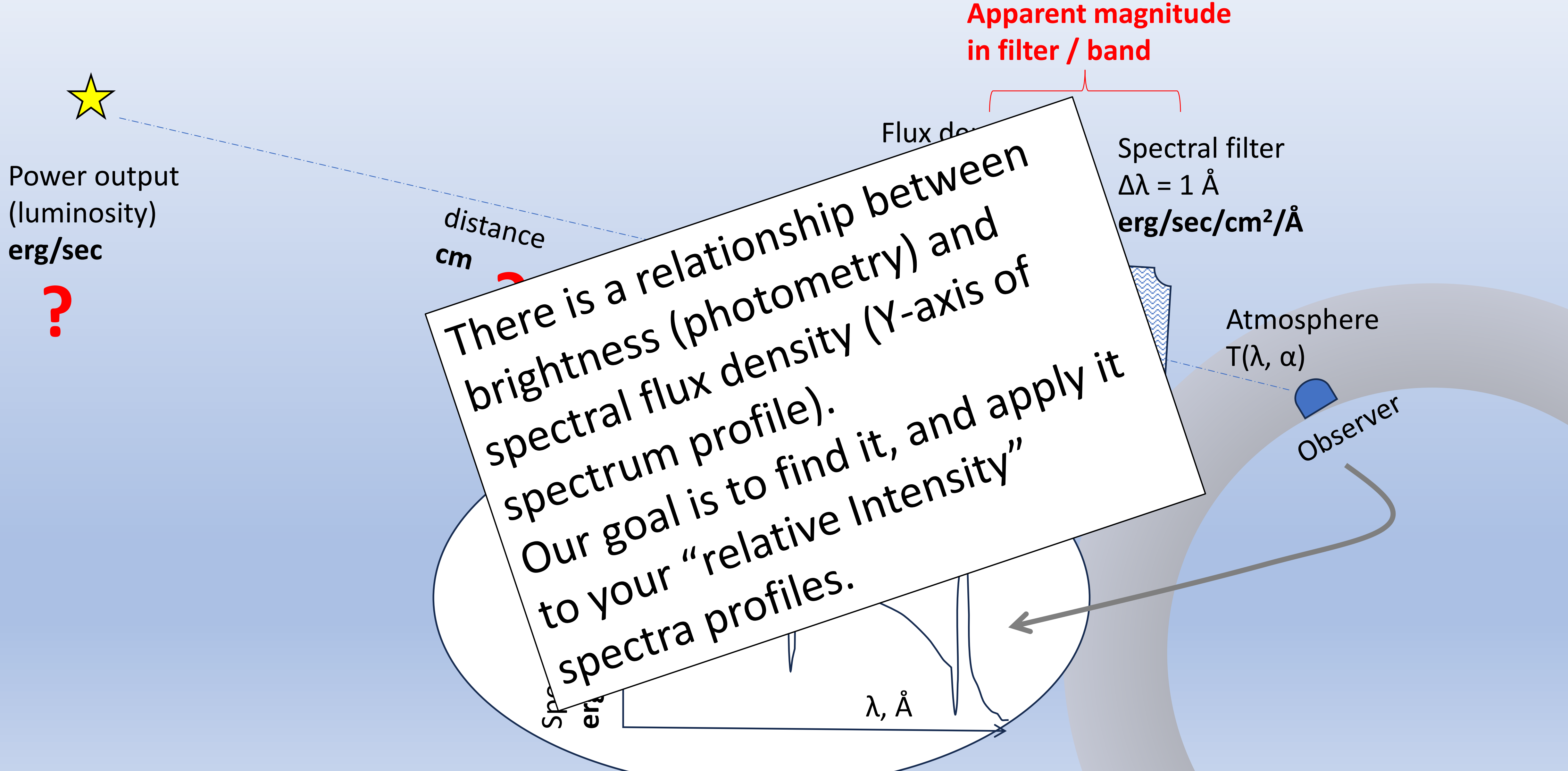
- Flux-Calibrated Spectra

erg/s/cm²/Å vs λ





“Flux”: What do the units mean?



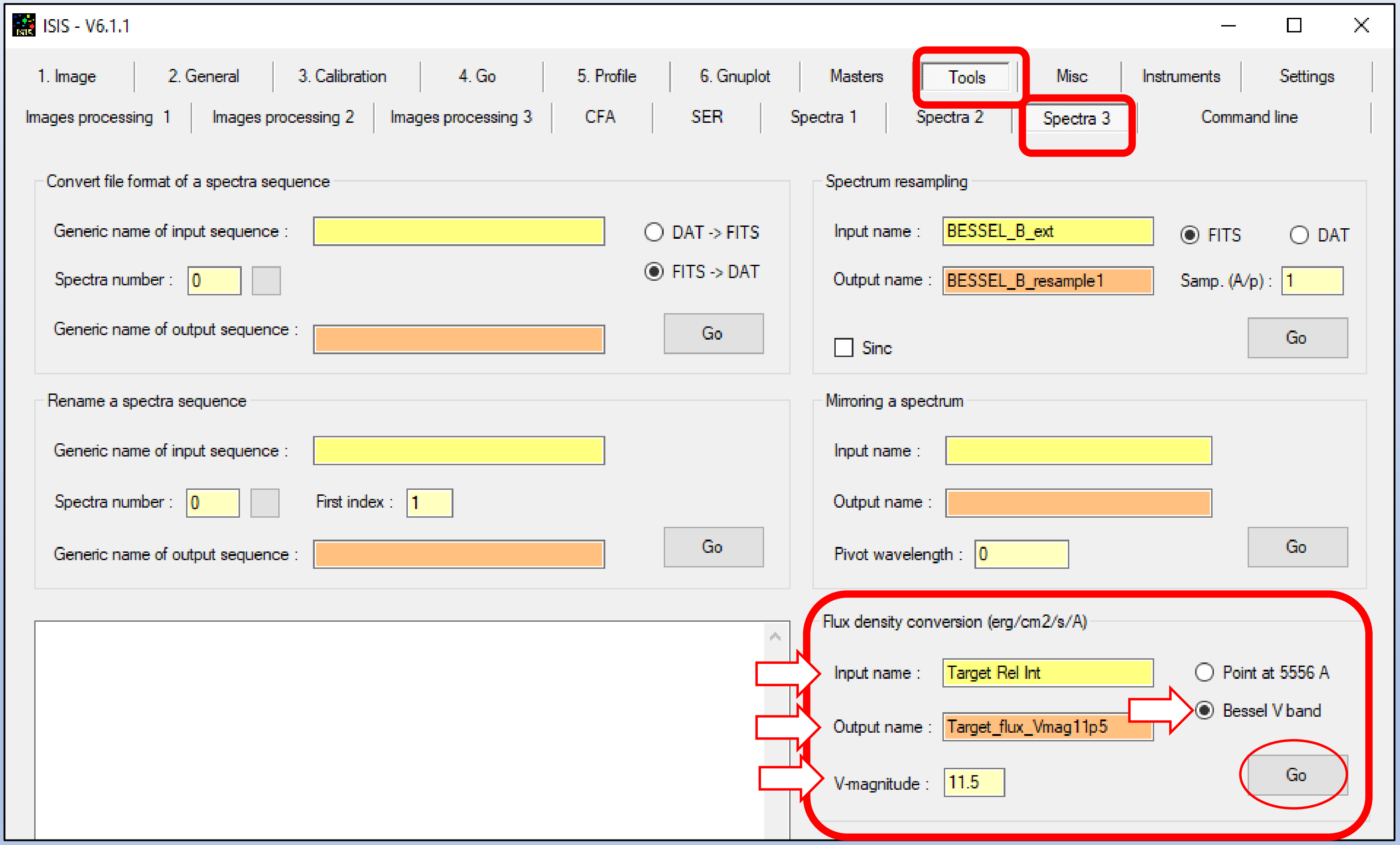
There is a relationship between brightness (photometry) and spectral flux density (Y-axis of spectrum profile).
Our goal is to find it, and apply it to your “relative Intensity” spectra profiles.

Simple: ISIS Command

- Process spectrum as usual, FITS profile of Rel Int vs λ
  - Saved into "working directory"

Then:

- ISIS > Tools
- > Spectra3 menu
- Enter:
  - Rel Int profile file name
  - File name for flux-cal'd file
  - V-mag
  - Select "Bessel V" and "GO"

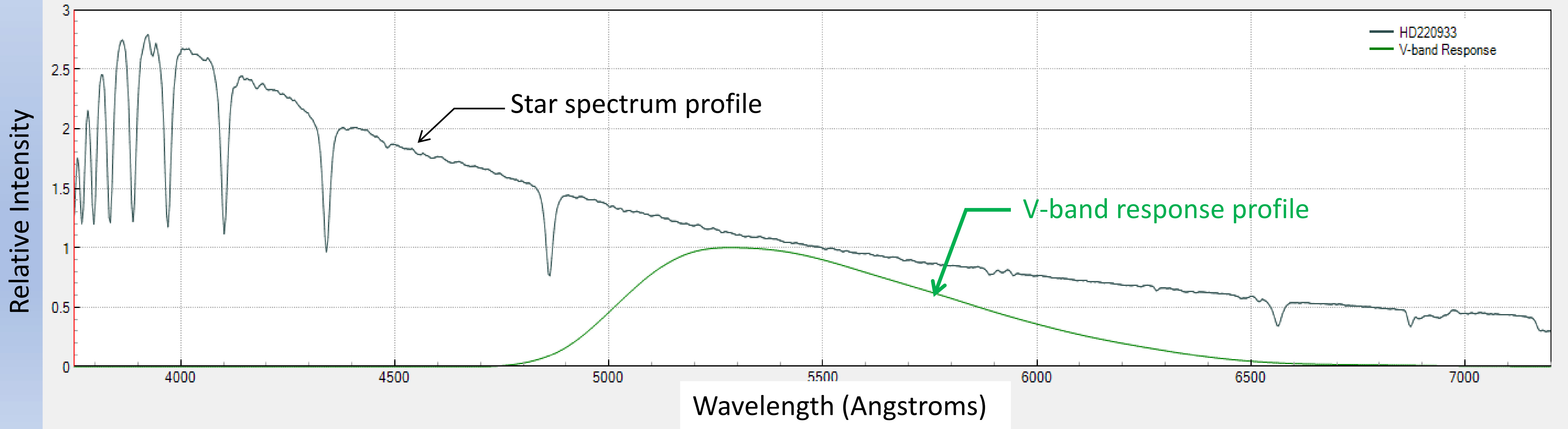


Writes flux-calibrated FITS profile to Working Directory

Assumptions hidden within ISIS tool

- Low- or medium-resolution spectrograph (e.g. ALPY, LISA)
  - R≈ 500 – 2000
  - Spectral range spans ≈ 4700 - 6700Å
- "Simultaneous" V-mag of target

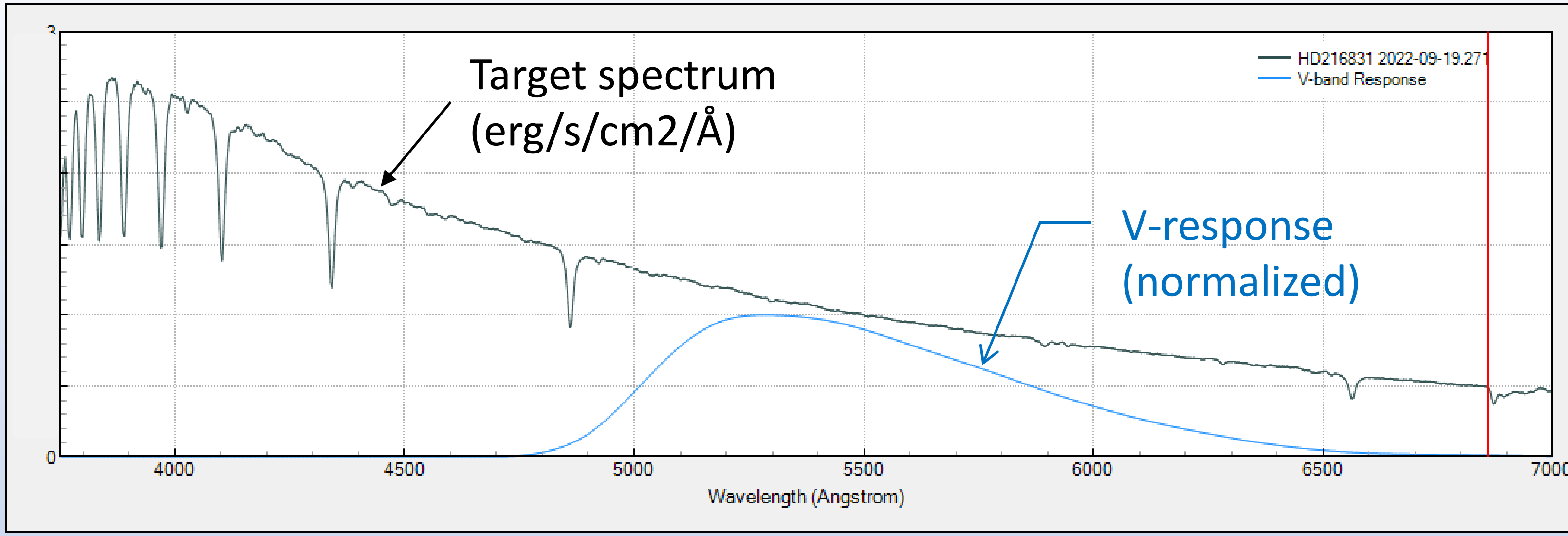
- Your spectrum profile has been corrected for:
  - Instrumental + atmospheric response
  - Rel Int (exo-atmospheric) vs wavelength
  - Normalized (I_{REL} = 1) at some wavelength range

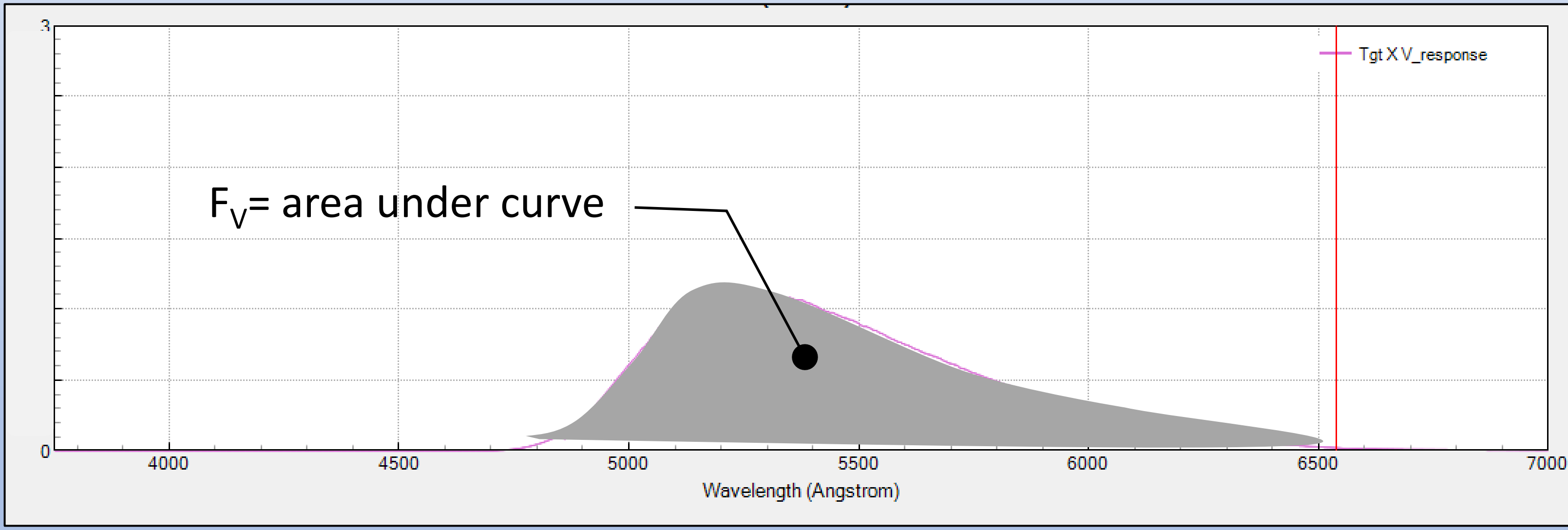


V-band flux from target:

- Multiply: received flux F(λ) times V-band Response function
- Integrate over all λ

= F_V, in erg/s/cm^2





Assume:

$Tgt_{Flux}(\lambda) = K * Tgt_{RelInt}(\lambda)$

$$I_{Tgt} = \int Tgt(\lambda) * Resp_V(\lambda) d\lambda$$

The Math …

$$I_{Tgt} = \boldsymbol{K} \int Tgt_{RelInt}(\lambda) * Resp_V(\lambda) d\lambda$$

Relative Intensity Tgt Spectrum

$$I_{Comp} = \int Comp_{FluxCal}(\lambda) * Resp_V(\lambda) d\lambda$$

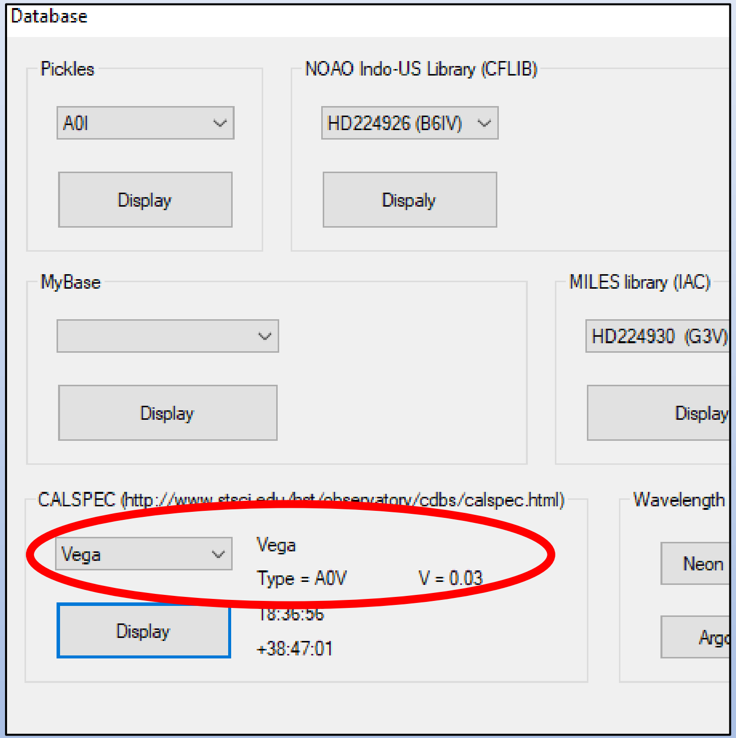
Flux-Calibrated Comp Star Spectrum
(e.g. CALSPEC Vega, Vmag= 0.03)

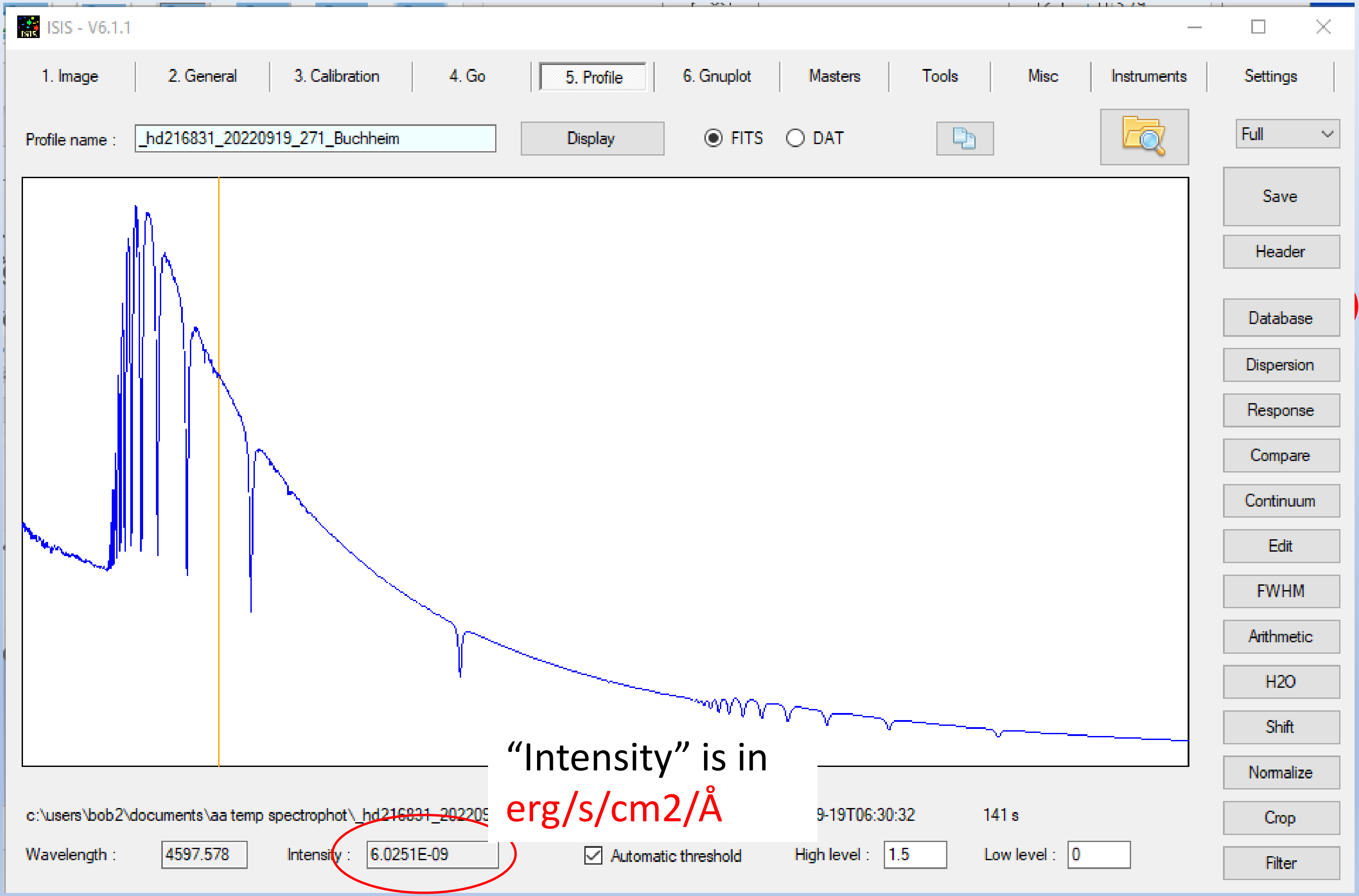
$$\Delta Vmag = V_{Tgt} - V_{Comp} = -2.5 log \left[\frac{I_{Tgt}}{I_{Comp}} \right]$$

$$\boxed{10^{\frac{V_{Tgt} - V_{Comp}}{-2.5}} * \frac{\int Comp_{FluxCal}(\lambda) * Resp_V(\lambda) d\lambda}{\int Tgt_{RelInt}(\lambda) * Resp_V(\lambda) d\lambda} = K}$$

Use ISIS "ARITHMETIC" and "FWHM" tools to solve for value of K

Flux-calibrated “Comp star” spectra: CalSpec





“Intensity” is in erg/s/cm2/Å

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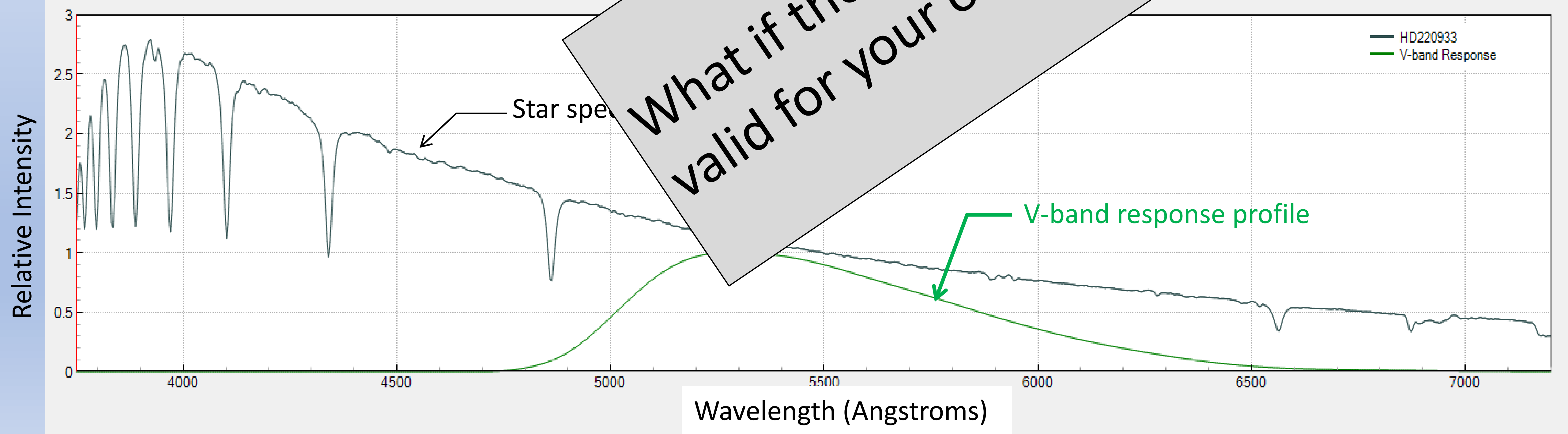
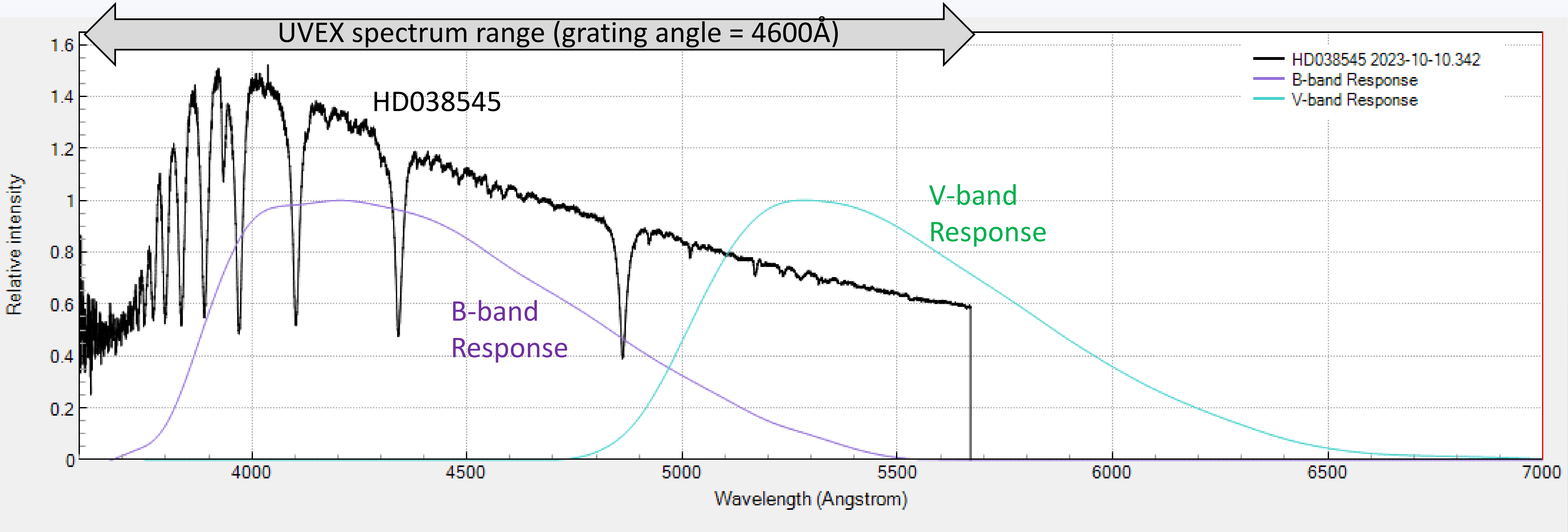
- Your spectru… …as been correcte…
  - I… …response
  - … …wavelength
  - … …some

What if the Assumptions aren’t valid for your observations?





The concept & equations are valid even if:

- Your spectra doesn’t span full wavelength range of V-band (e.g. my UVEX), or
- You do photometry in tri-color R-G-B, or …?

➢The equation for K still works (using “your” filter/band and magnitude)!

Summary

- Why flux-calibrated spectra?
- Relationship between Magnitude, Flux, and Spectrum Profile
- ISIS built-in Calculator
- Some Equations …
- Why V-magnitudes?
  - Purely matter of convenience, and generally good match to Shelyak spectrographs (ALPY, LISA)
  - Same concept/math works with B-band (e.g. my UVEX), or R-G-B tri-color
- **Questions? Discussion?**

Addendum: *David Boyd's equation and mine are actually identical … he uses the "Zero Point" concept (more astronomical than my equation).*

- David defines:

$$F = \int Comp_{FluxCal}(\lambda) * Resp_V(\lambda)d\lambda$$

$$ZP = -V_{Comp} - 2.5 * \log(F)$$

$$A = 10^{[-0.4*(V_{Tgt}+ZP)]}$$

$$R = \int Tgt_{RelInt}(\lambda) * Resp_V(\lambda)d\lambda$$

- So that

$$Tgt_{flux}(\lambda) = \left(\frac{A}{R}\right) Tgt_{RelInt}(\lambda)$$

- My equation is:

$$Tgt_{flux}(\lambda) = K * Tgt_{RelInt}(\lambda)$$

- where

$$K = 10^{\frac{V_{Tgt}-V_{Comp}}{-2.5}} * \frac{\int Comp_{FluxCal}(\lambda) * Resp_V(\lambda)d\lambda}{\int Tgt_{RelInt}(\lambda) * Resp_V(\lambda)d\lambda}$$

- Exercise for the student: show that

$$\left(\frac{A}{R}\right) = K$$

See next slide …

Hints:

$$A = 10^{[-0.4*(V_{Tgt}+ZP)]}$$

Put in the definition of ZP:

$$A = 10^{[-0.4*(V_{Tgt}-V_{Comp}\ -2.5*\log(F))]}$$

Use $10^{[a+b]} = 10^{a} * 10^{b}$

$$A = 10^{[-0.4*(V_{Tgt}-V_{Comp}\ )]} * 10^{\log(F)}$$

Use $10^{[\log F]} = F$

$$= 10^{\left[\frac{(V_{Tgt}-V_{Comp}\ )}{-2.5}\right]} * F$$

Put in the definition of F

$$= 10^{\left[\frac{(V_{Tgt}-V_{Comp}\ )}{-2.5}\right]} * \int Comp_{FluxCal}(\lambda) * Resp_{V}(\lambda)d\lambda$$

Then use the definition of R to show that David's (A/R) equals my (K). Q.E.D.