Sterrenkunde Practicum 2

Introduction

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General information

Sterrekunde Practicum 2 - SP2 - is a continuation of Praktische Sterrenkunde (PS).

What is different?

In PS the main emphasis is on learning to write reports (*verslaglegging*). That is still important! but in SP2 we will also start to work with the analysis and acquisition of astronomical data.

Weight: 5 EC
Website: http://www.strw.leidenuniv.nl/~jarle/Teaching/Practicum2

Who to ask when you run into problems

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What is the course all about?

Three main tasks:

Task 1: **Photometry and the colours of stars**

The goal of this is to get experience with data manipulation and calibration of data.

Task 2: **The exo-planet 51 Peg-b**

Practical experience with fitting data to a model

Task 3: **The observing proposal**

The preparation, execution and analysis of an observing proposal.

Observing proposal

For this you will need to form teams of ~four people each.
At least one person per team should go to La Palma

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How do we decide what to do?

You can come up with ideas yourself.
You can make use of a list of suggestions.

Flights:

Date: 01/05/2015
08:05-10:40 on IB3721 Amsterdam->Madrid
12:25-14:20 on IB3842 Madrid -> Santa Cruz de la Palma

Return:
Date: 08/05/2015
14:55-18:45 on IB3843 Santa Cruz de la Palma -> Madrid
19:50-22:25 on IB 3720 Madrid -> Amsterdam

The observing proposal

The main task of SP2 is the construction of the observing proposal, carrying out the observations and reducing the data.

The other two tasks help build towards this **and** towards your Bachelor Onderzoek.

- Choose the topic
- Give a scientific justification for what you want to do
- Provide a detailed technical justification for your proposed observations.
- Ranking of the proposals
- Acquire data
- Analyse data

What

Why

How

Deadlines

18/02 - Provide plan for observing proposal (by email!)
25/02 - Report for Task 1
11/03 - Scientific justification for observing proposal

Problem set 0

Main lessons:

a) Keep your code modular! (for instance use functions)

b) Add comments!

The shortest program is not always the best

c) topcat & ipython can make life easier for you!

Problem set 0

An example

```
def read_exoplanet_table():
    """
    Read in the exoplanet table from exoplanet.eu in FITS format.
    """

    # The name of the file
    file = 'exoplanet_catalog.fits'

    # Read in the FITS table
    t = pyfits.getdata(file, 1)

    # Return the result to the user.
    return t
```

Counting Kepler

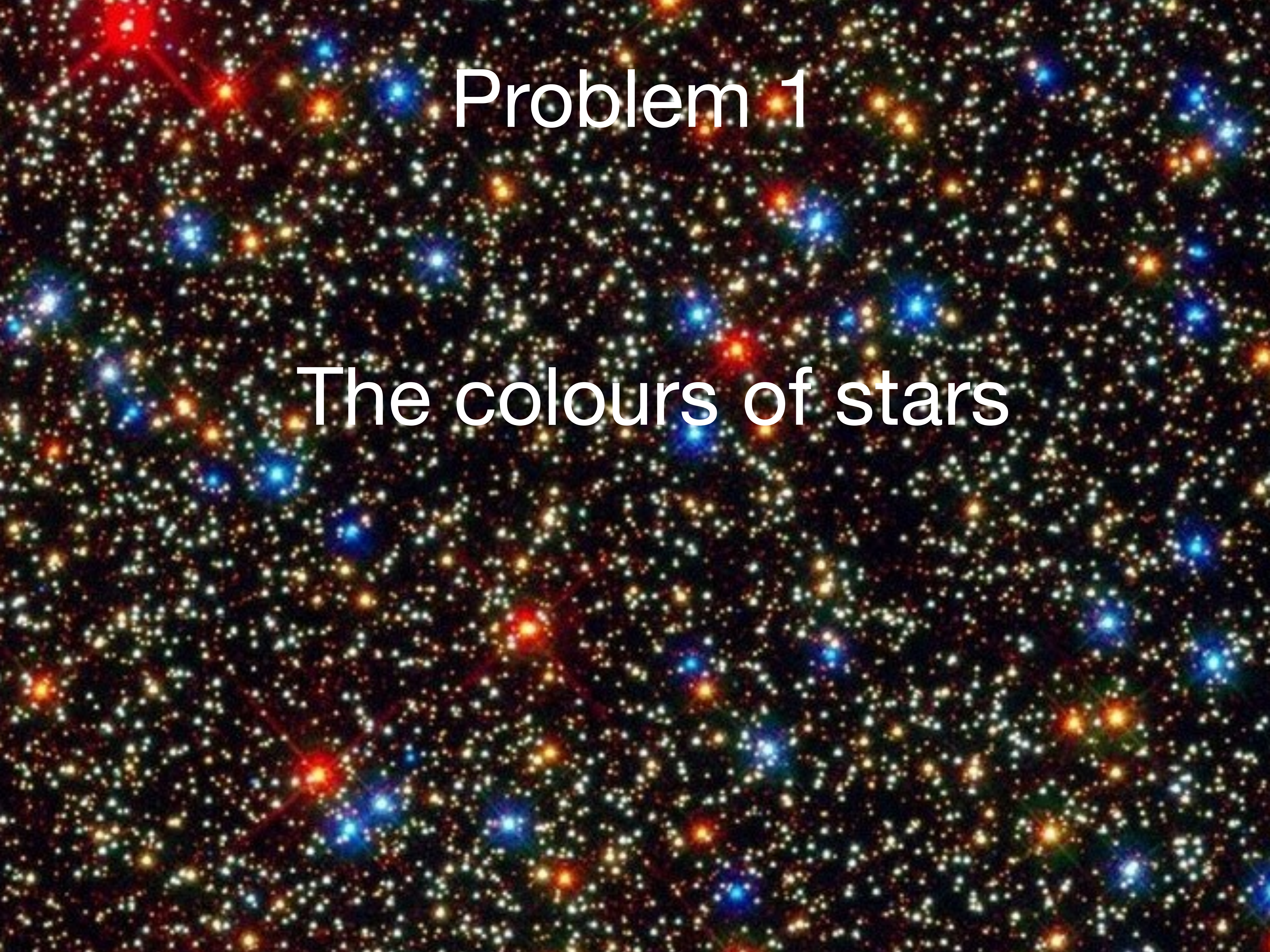
```
def count_Kepler(t):
    """
    Count the number of planets detected by Kepler assuming
    that if the name starts with Kepler it was detected
    by that satellite.
    """

    counter = 0
    for n in t['name']:
        if (n.startswith('Kepler')):
            counter = counter+1

    return counter
```

Problem 1

The colours of stars

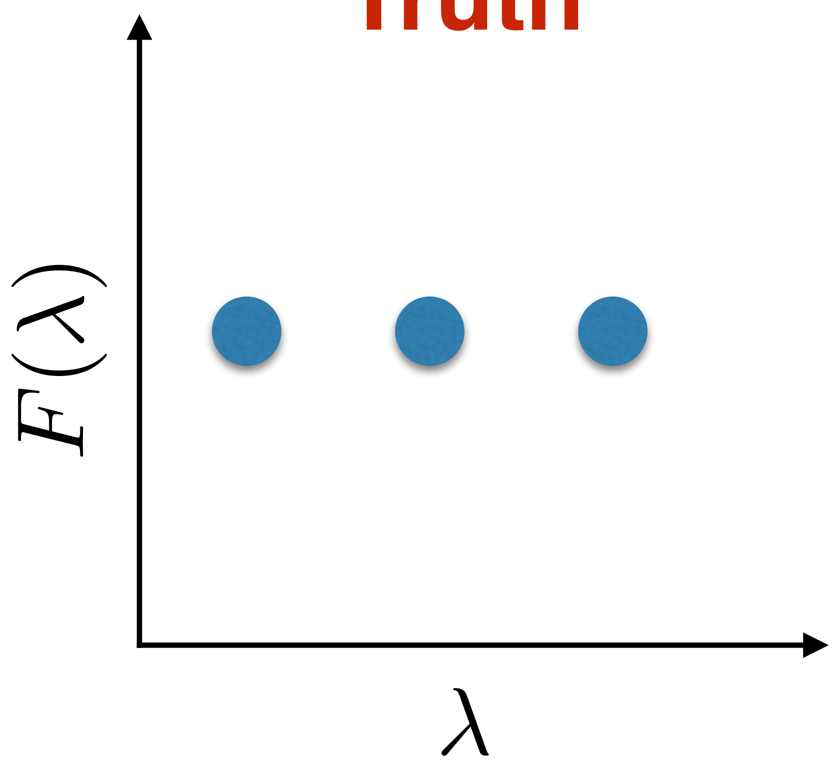


Photometry and the colours of stars

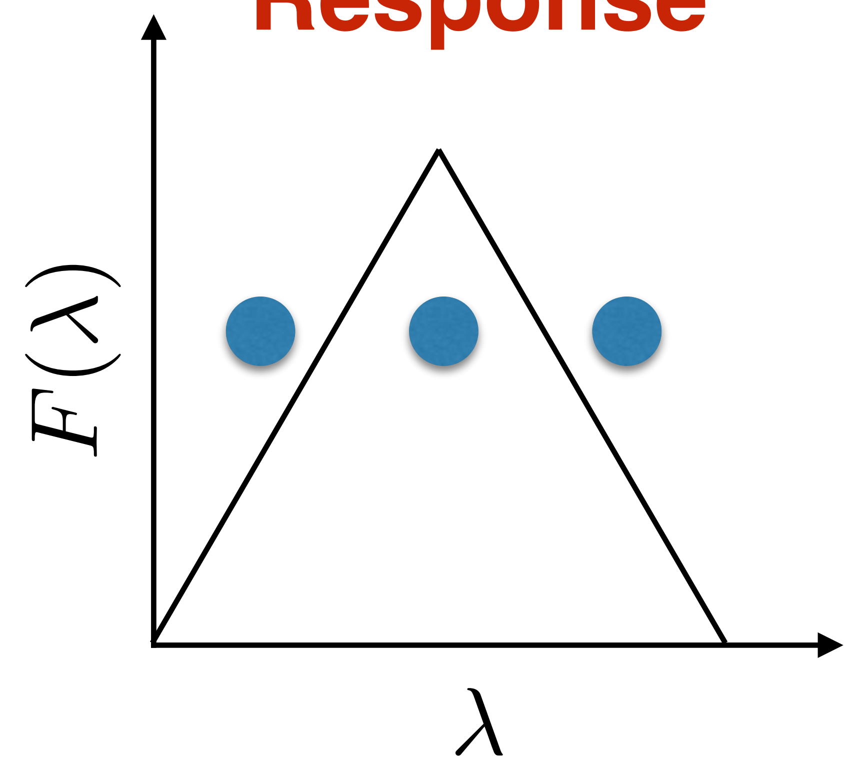
Aim:

Understand more deeply the definition of magnitude and how we use the colours of stars to calibrate our observations.

Truth



Response



Photometry and the colours of stars

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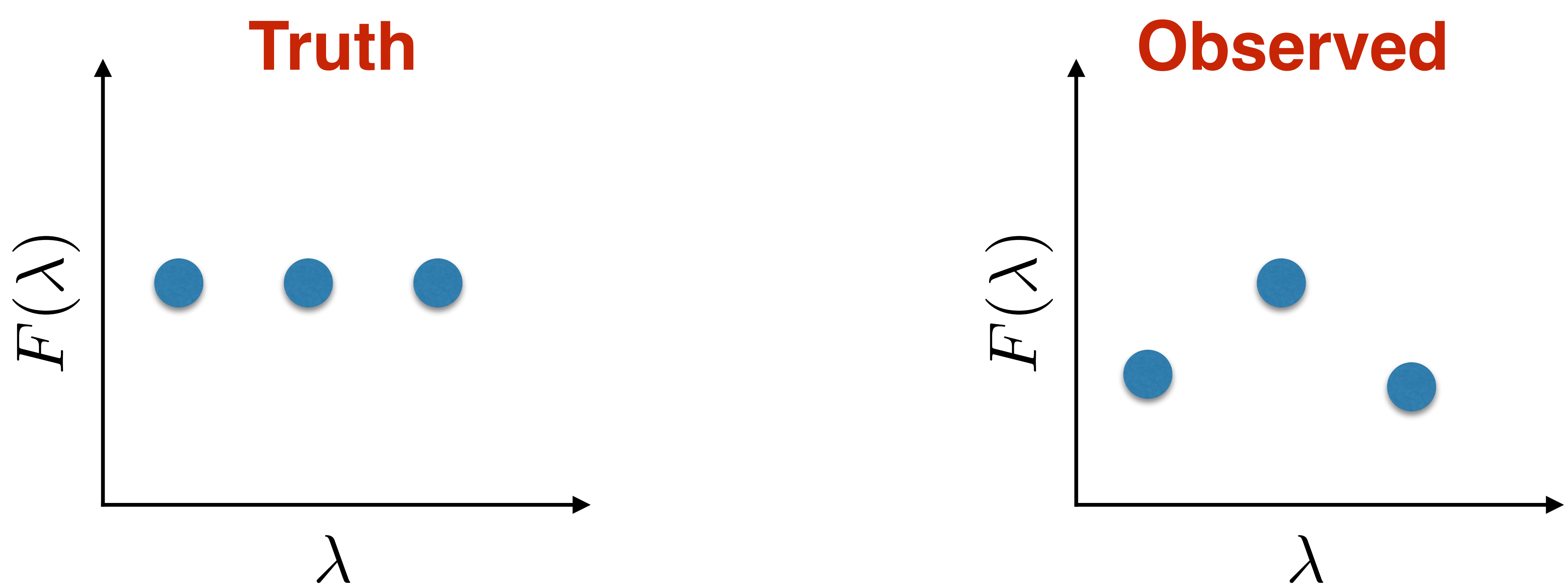


Photometry and the colours of stars

Aim:

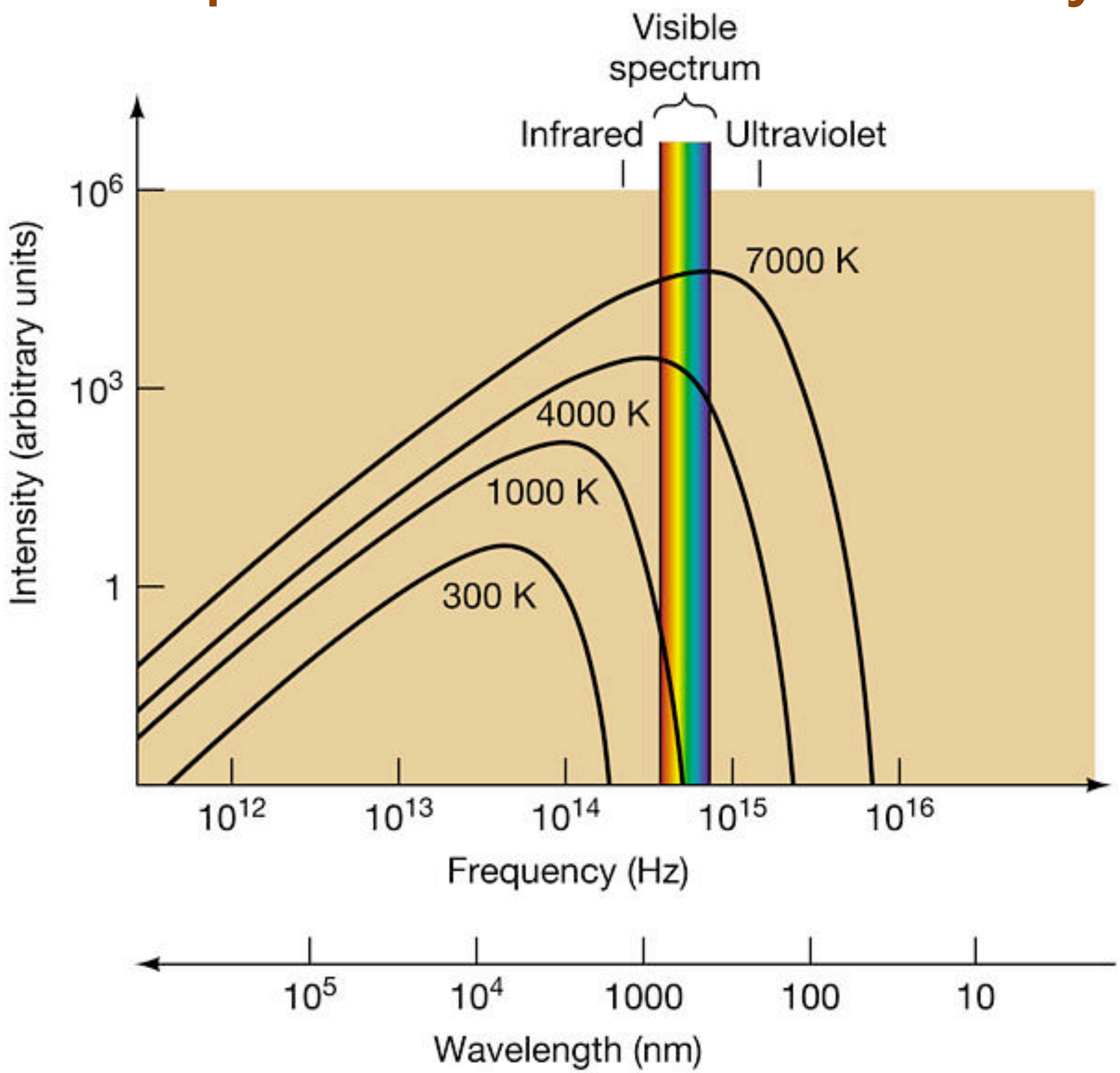
Understand more deeply the definition of magnitude and how we use the colours of stars to calibrate our observations.

The principle of what we learn here also applies to spectroscopy but we will focus on imaging.

Why do stars have a range of colours?

Omega Cen
Anderson, van der Marel

Spectral classification
Comparison to a black body

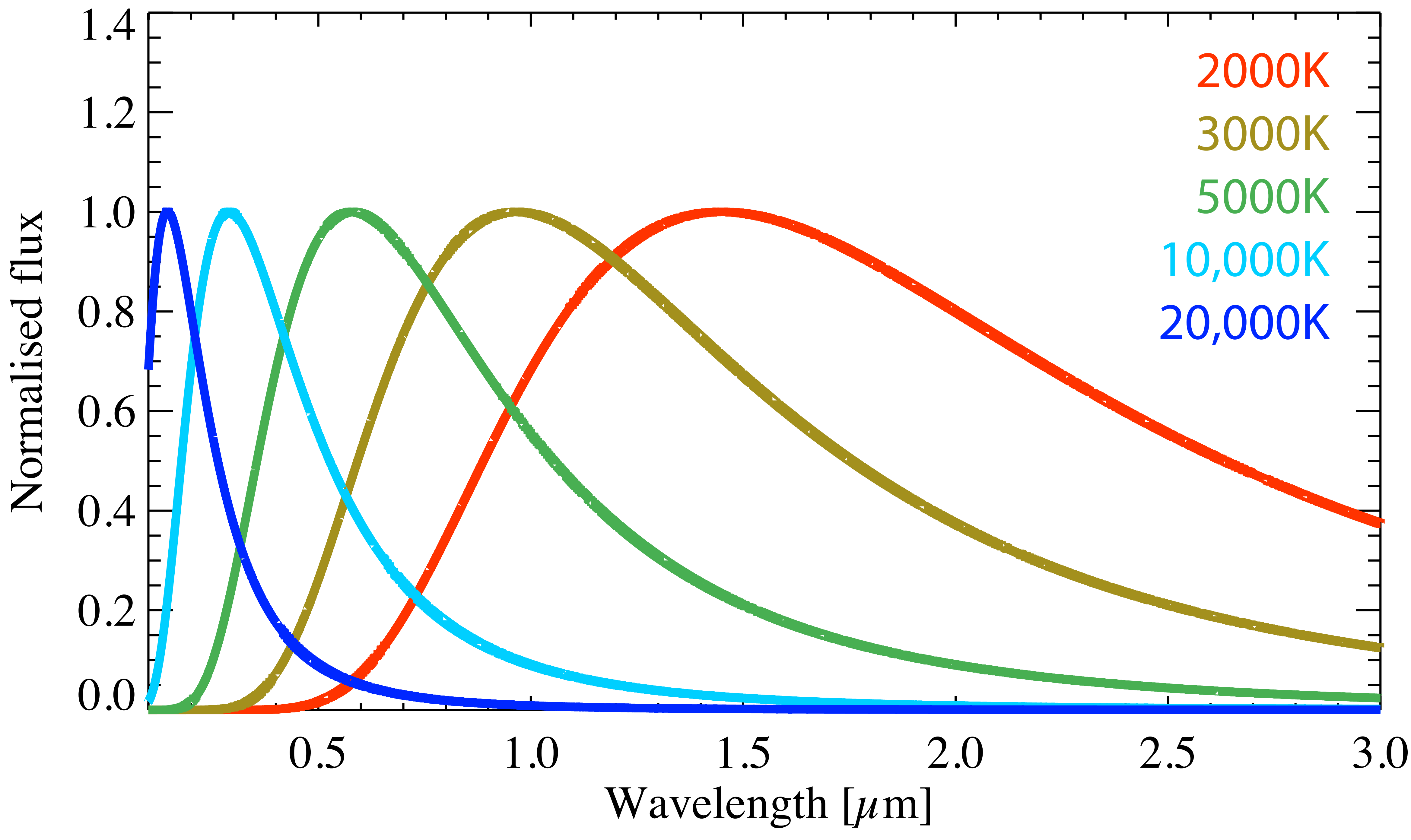


Stellar classification

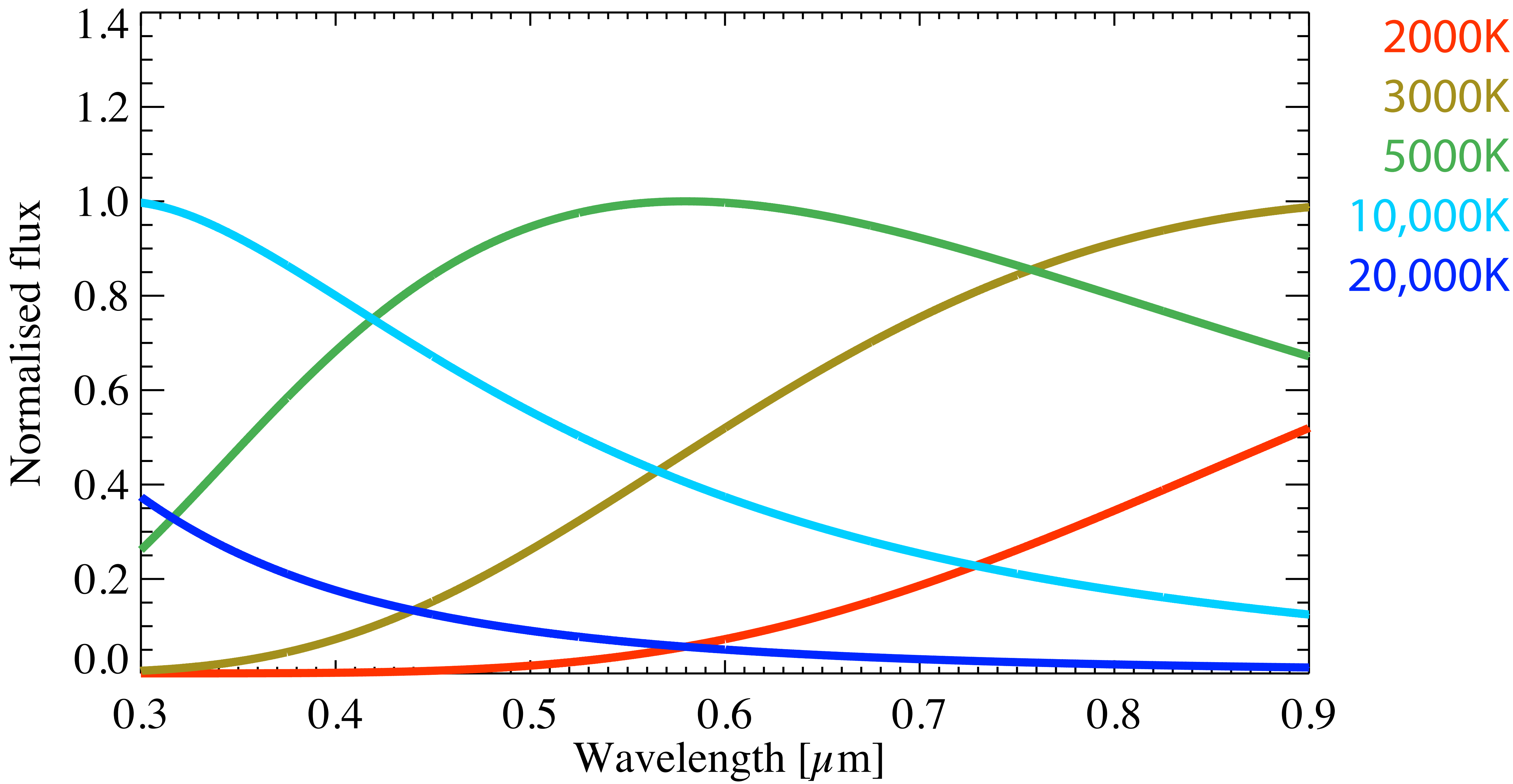
TABLE 17.1 Stellar Colors and Temperatures

B flux / V flux	Approximate Surface Temperature (K)	Color	Familiar Examples
1.3	30,000	blue-violet	Mintaka (δ Orionis)
1.2	20,000	blue	Rigel
1.00	10,000	white	Vega, Sirius
0.72	7000	yellow-white	Canopus
0.55	6000	yellow	Sun, Alpha Centauri
0.33	4000	orange	Arcturus, Aldebaran
0.21	3000	red	Betelgeuse, Barnard's Star

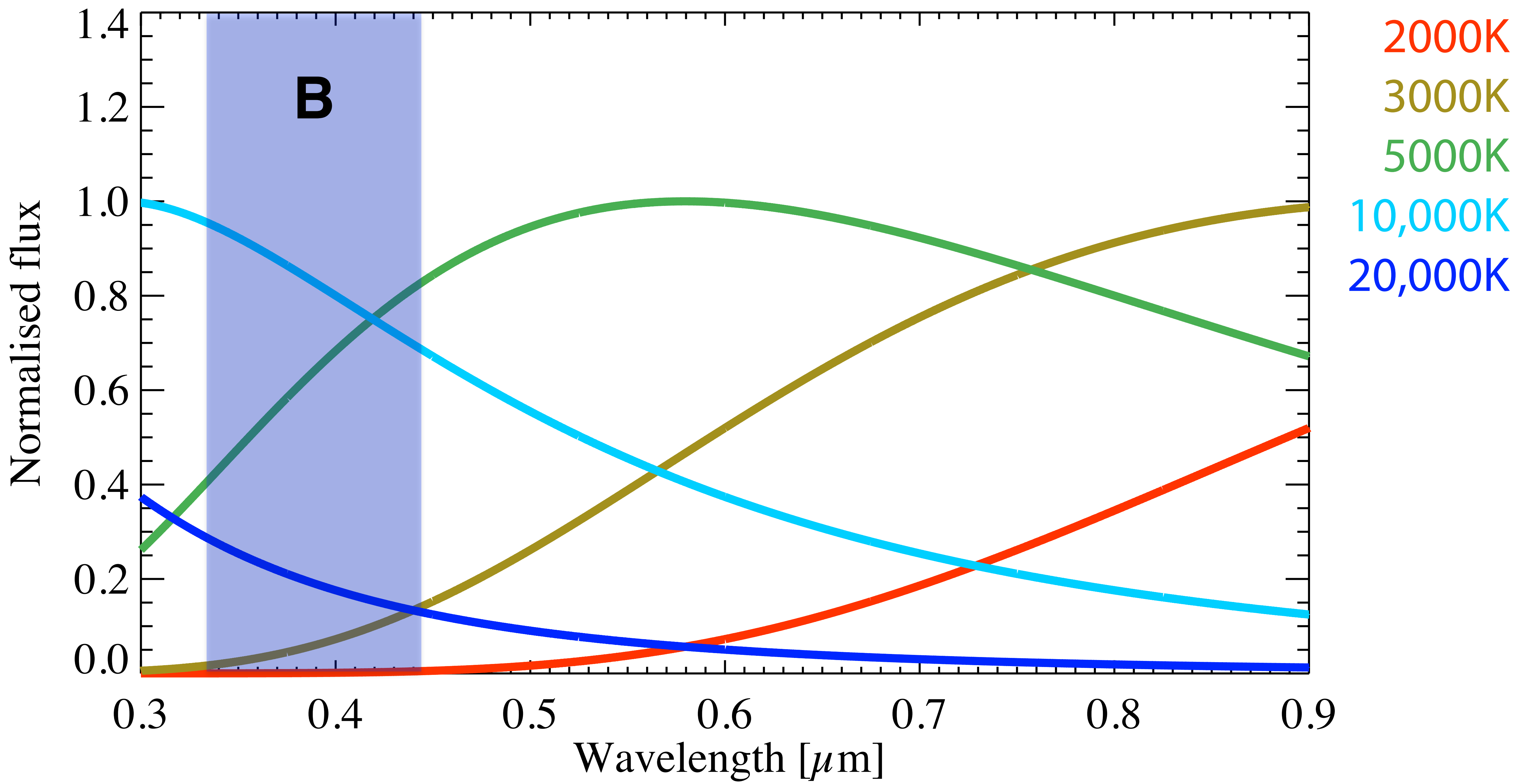
Zooming in on black bodies



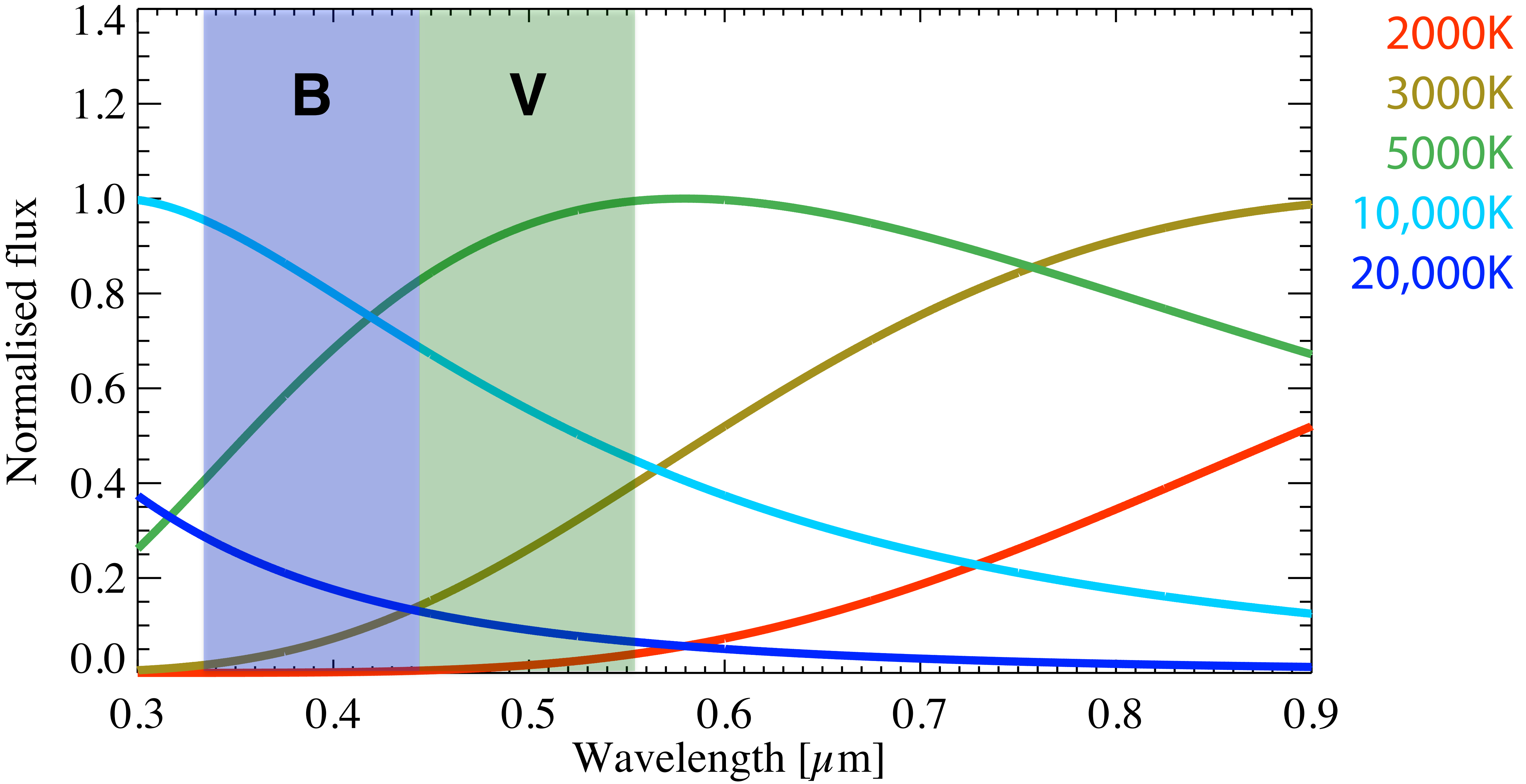
Zooming in on black bodies



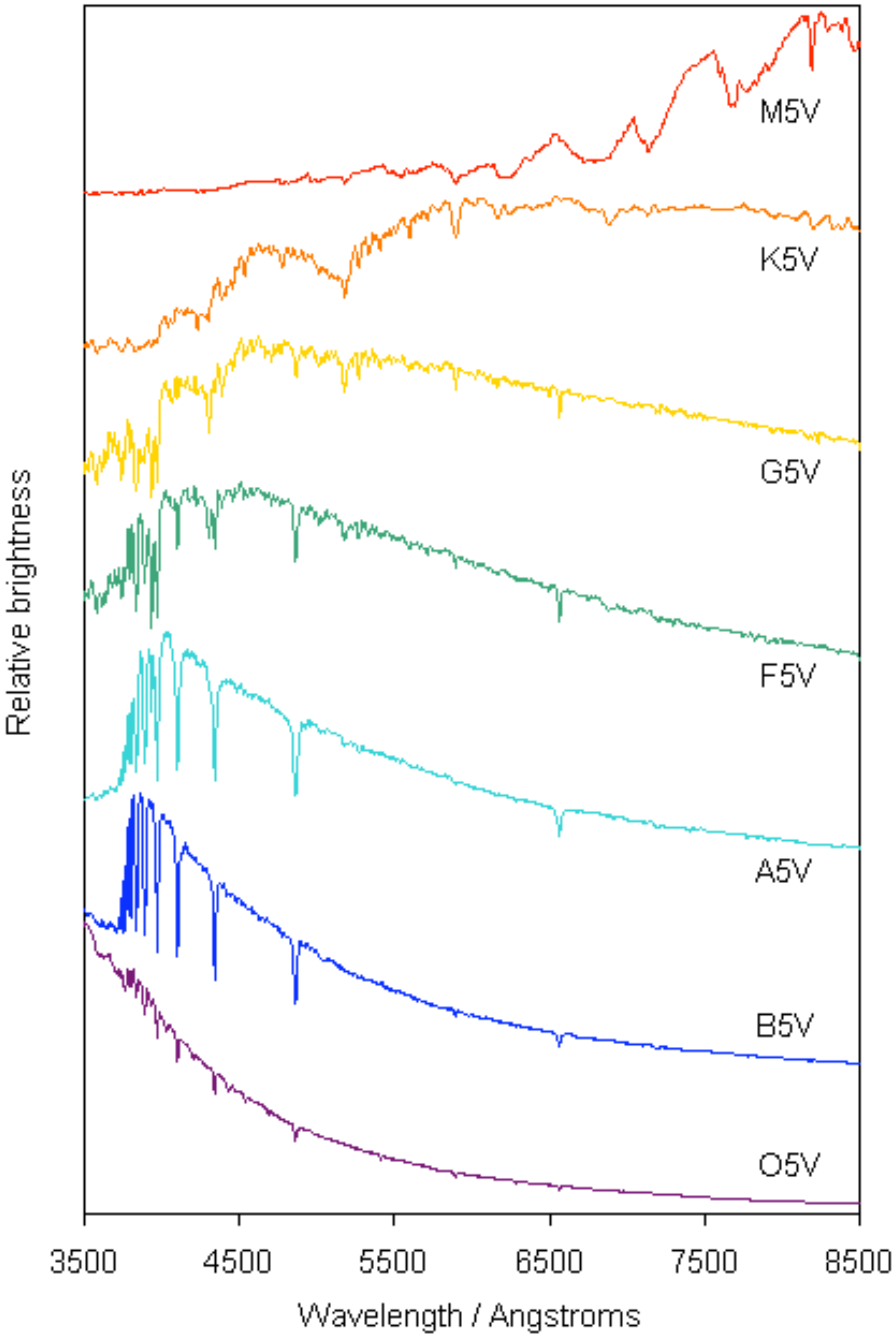
Zooming in on black bodies



Zooming in on black bodies



The spectra of stars of different types



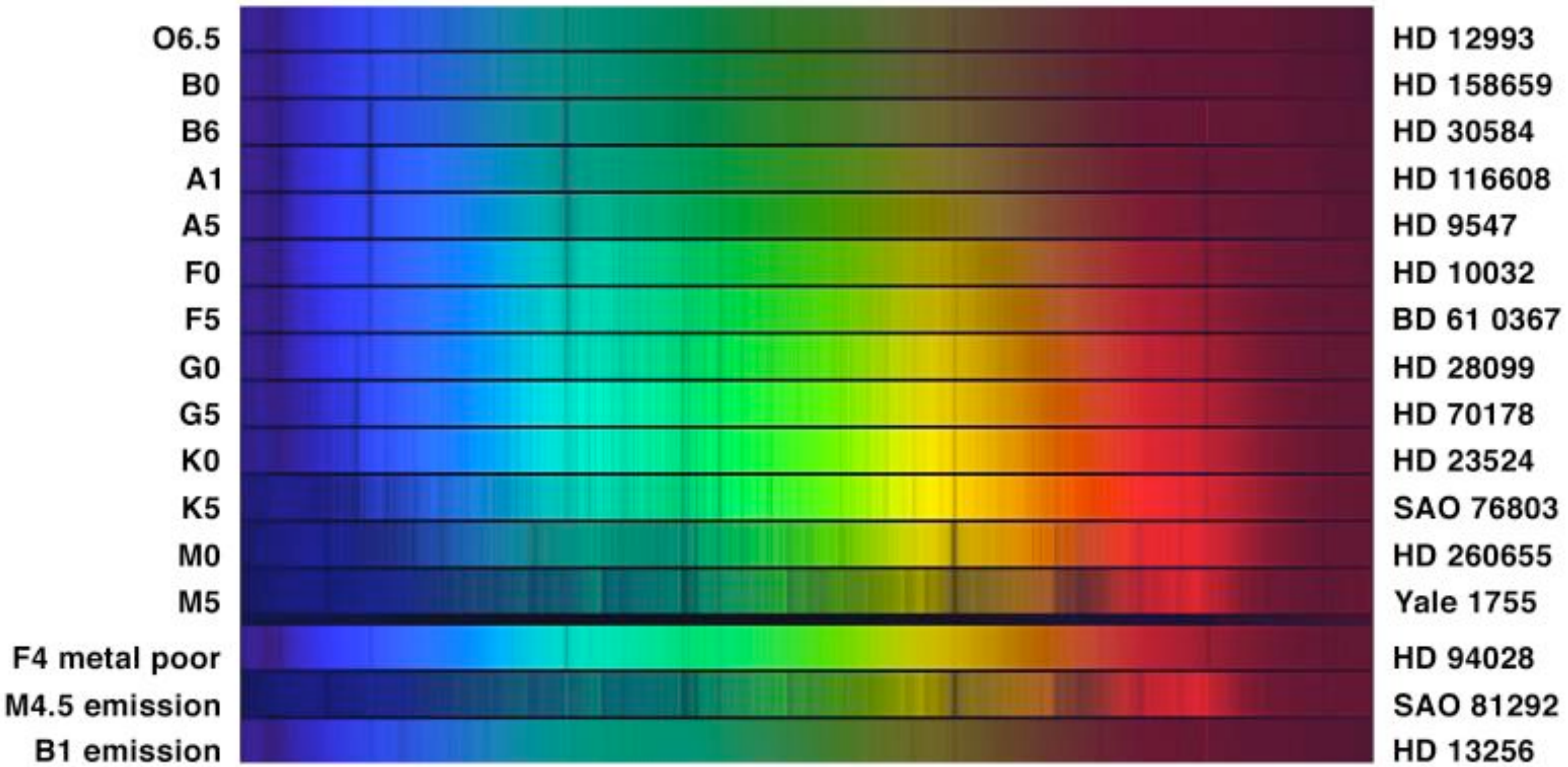
Harvard classification: OBAFGKM

Early on the prominence of hydrogen lines was important

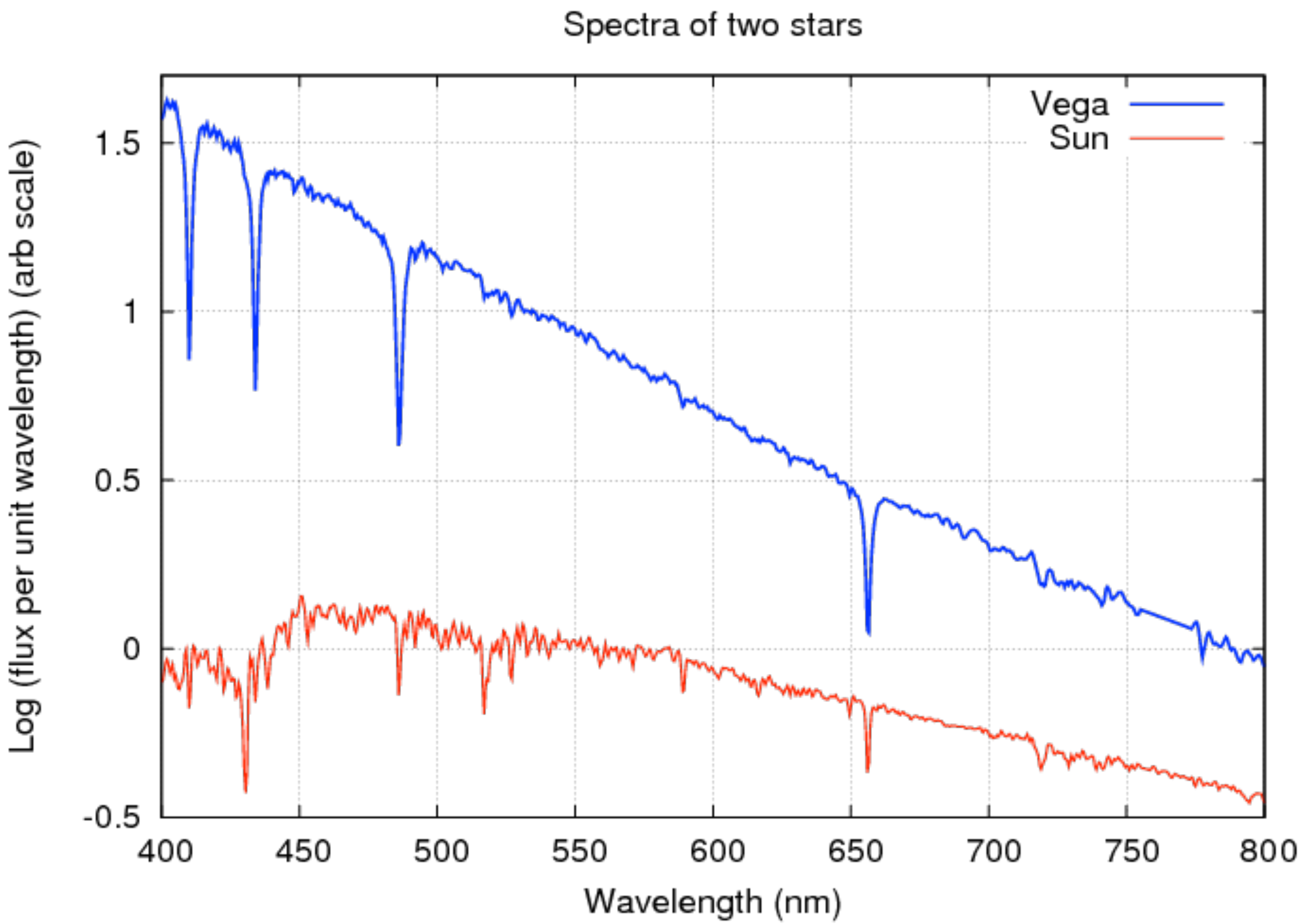
Morgan-Keenan classification

OBAFGKM - mostly a temperature sequence. MK classification in addition tracks surface gravity of the stars

Spectra of stars



Spectra of stars



Origin: http://spiff.rit.edu/classes/phys301/lectures/spec_lines/spec_lines.html

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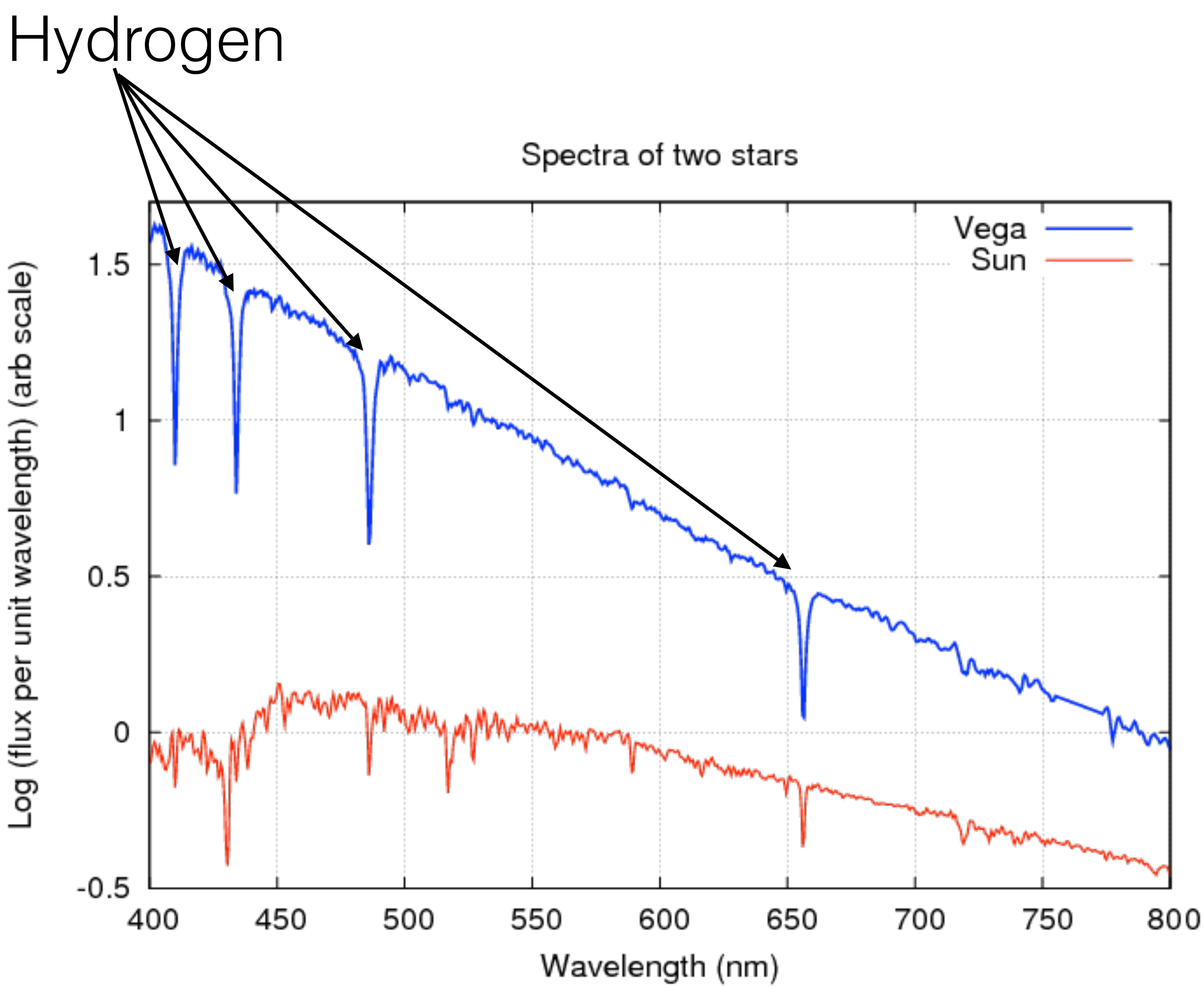

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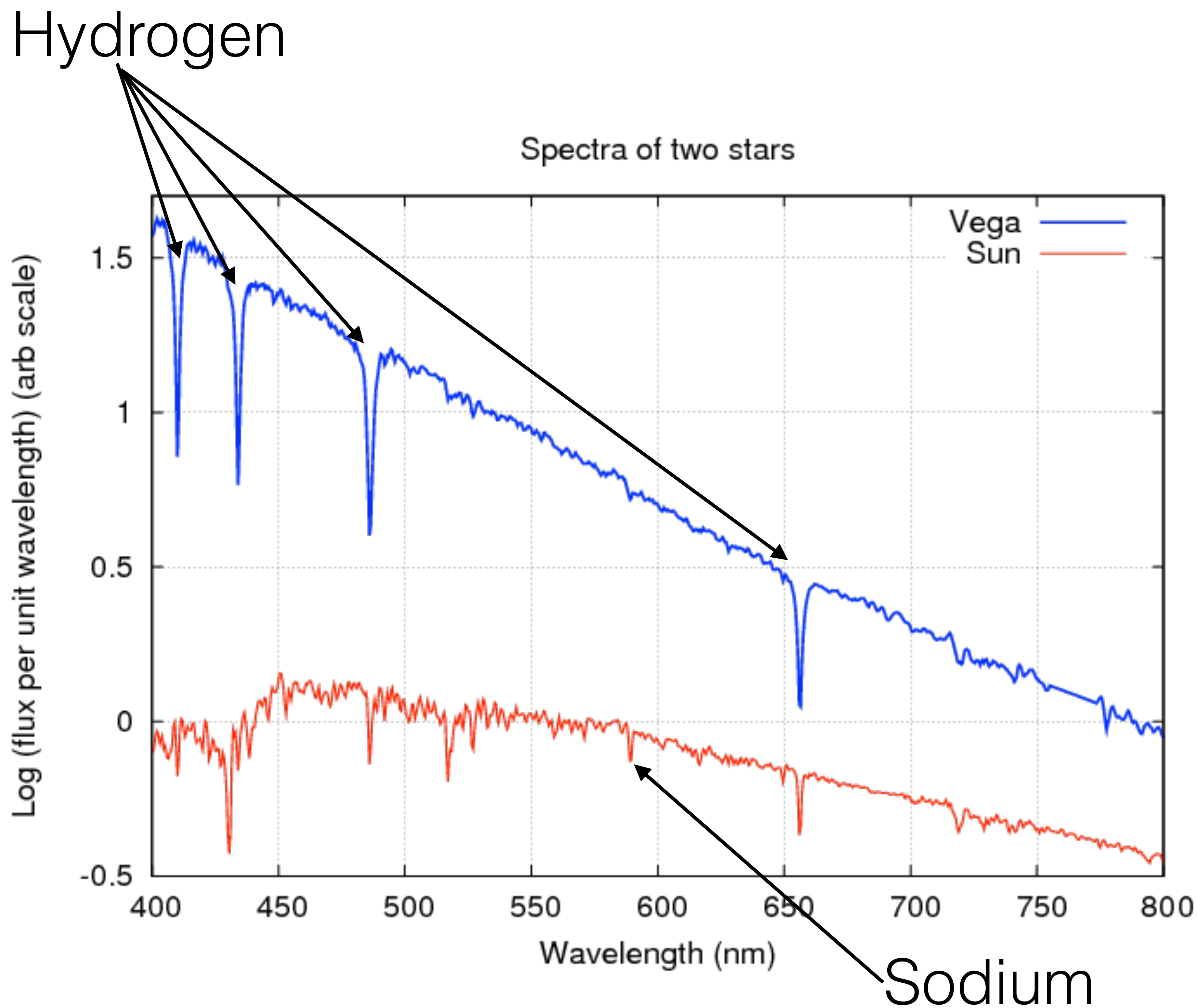

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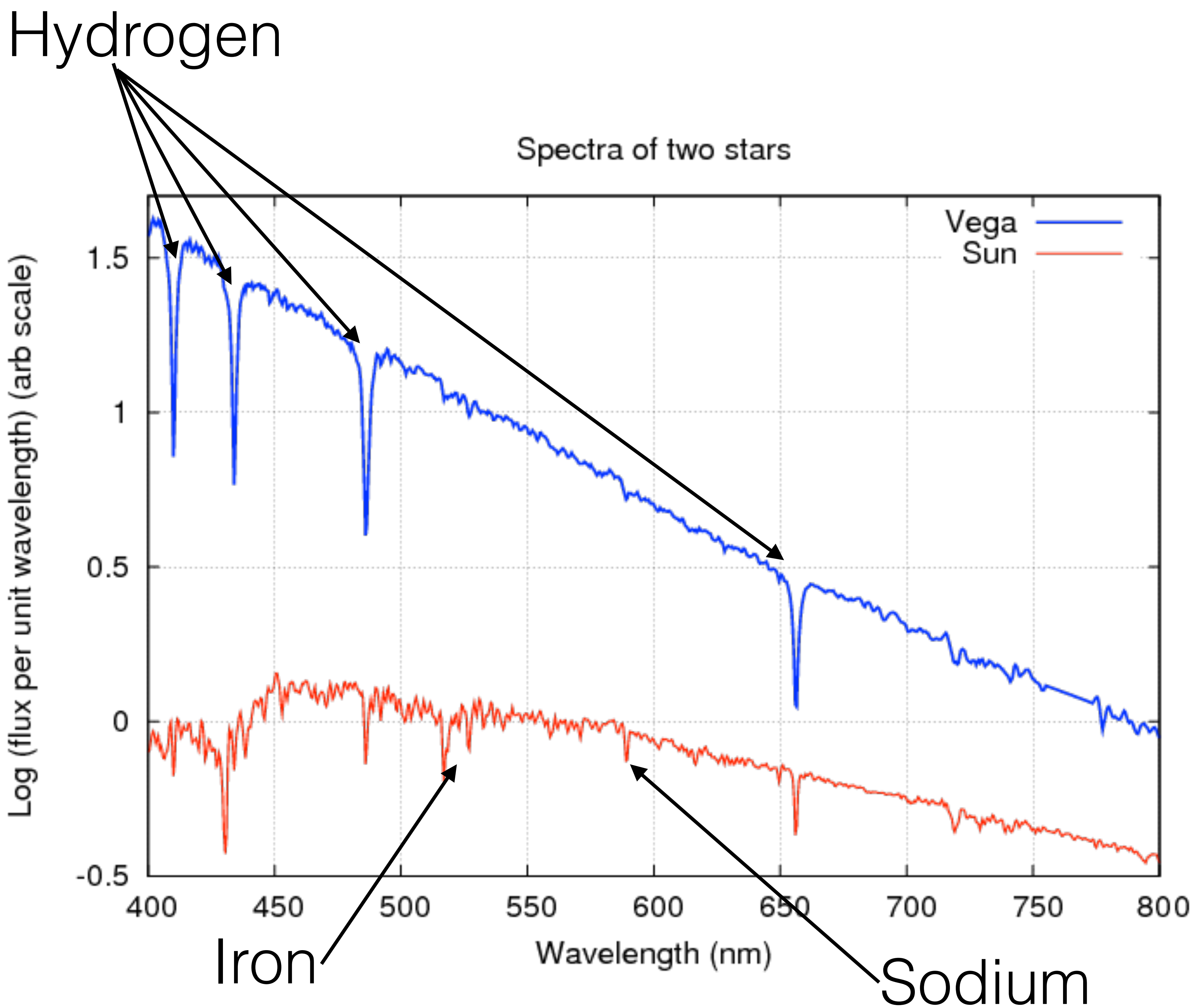
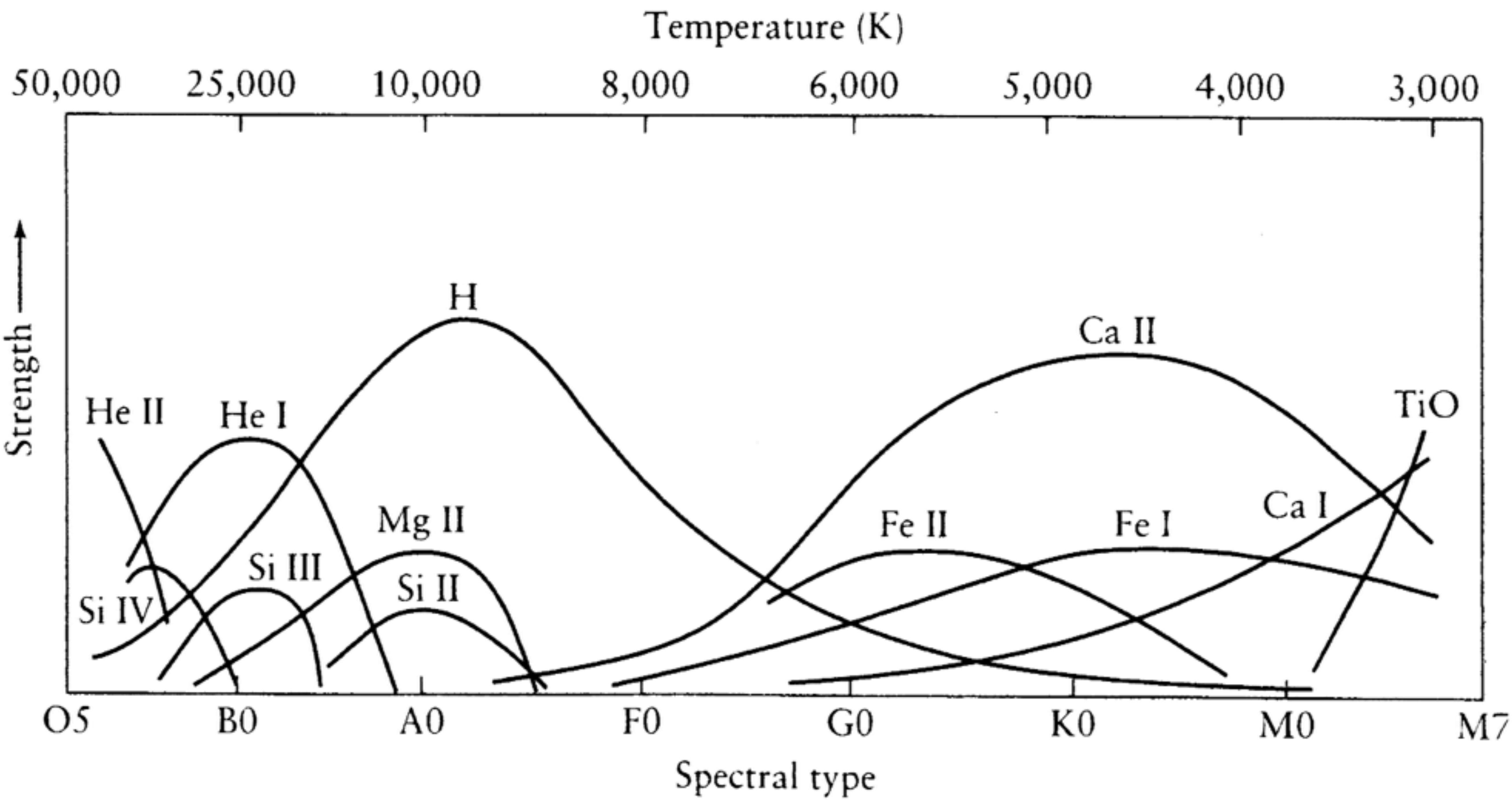


Origin: http://spiff.rit.edu/classes/phys301/lectures/spec_lines/spec_lines.html

When does what dominate?



From notes by Steve Majewski & Bob O'Donnell

An overview of spectral classes

TABLE 17.2 Stellar Spectral Classes

Spectral Class	Approximate Surface Temperature (K)	Noteworthy Absorption Lines	Familiar Examples
O	30,000	Ionized helium strong; multiply ionized heavy elements; hydrogen faint	Mintaka (O9)
B	20,000	Neutral helium moderate; singly ionized heavy elements; hydrogen moderate	Rigel (B8)
A	10,000	Neutral helium very faint; singly ionized heavy elements; hydrogen strong	Vega (A0), Sirius (A1)
F	7000	Singly ionized heavy elements; neutral metals; hydrogen moderate	Canopus (F0)
G	6000	Singly ionized heavy elements; neutral metals; hydrogen relatively faint	Sun (G2), Alpha Centauri (G2)
K	4000	Singly ionized heavy elements; neutral metals strong; hydrogen faint	Arcturus (K2), Aldebaran (K5)
M	3000	Neutral atoms strong; molecules moderate; hydrogen very faint	Betelgeuse (M2), Barnard's Star (M5)

Summarising

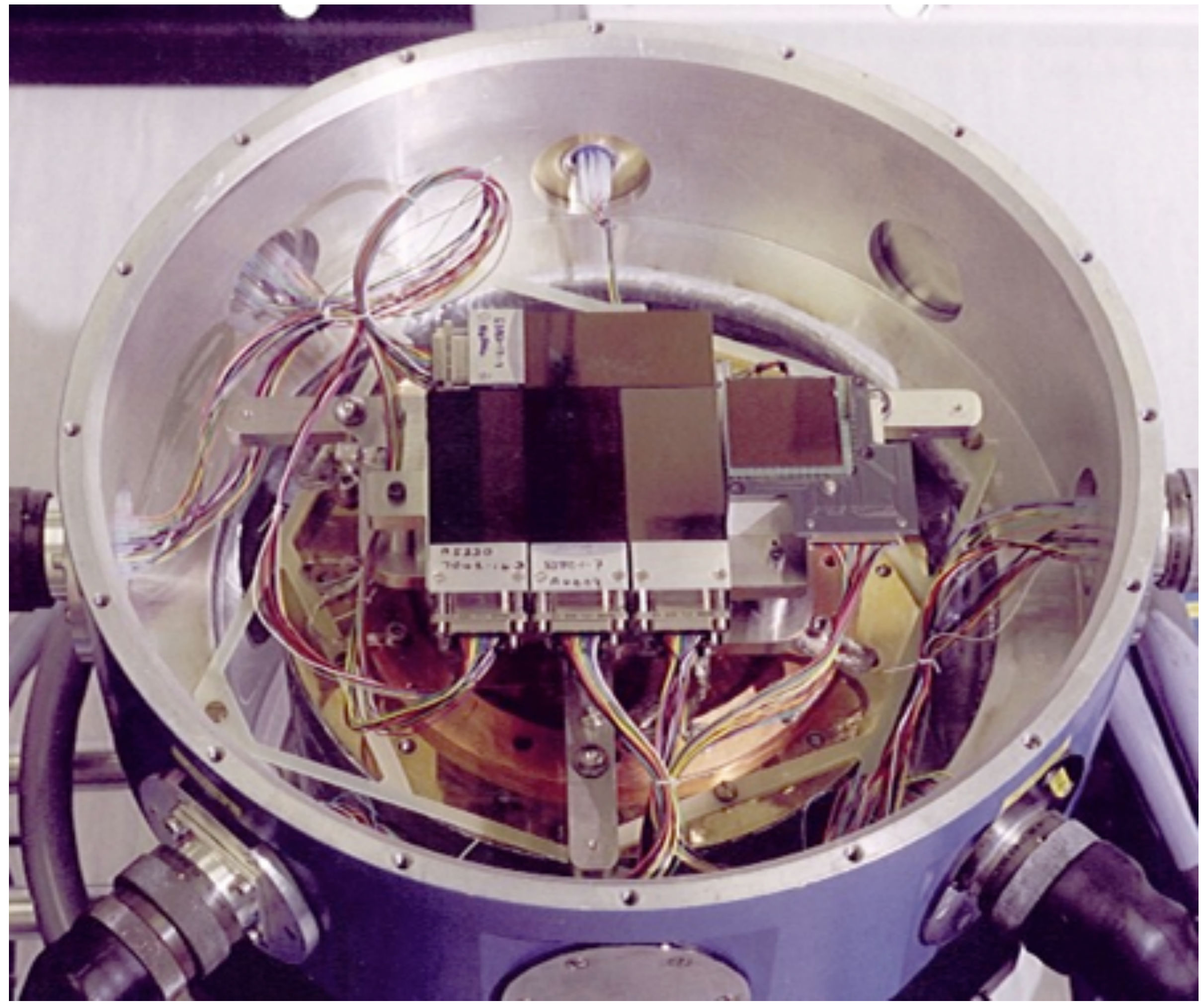
The colour of a star primarily reflects its temperature.

(the observed colour could be affected by dust between us and the star though)

The spectrum of a star contains absorption lines which reflect the presence of particular atoms/molecules. Their prominence is decided by temperature, surface gravity and the metal content of the stars.

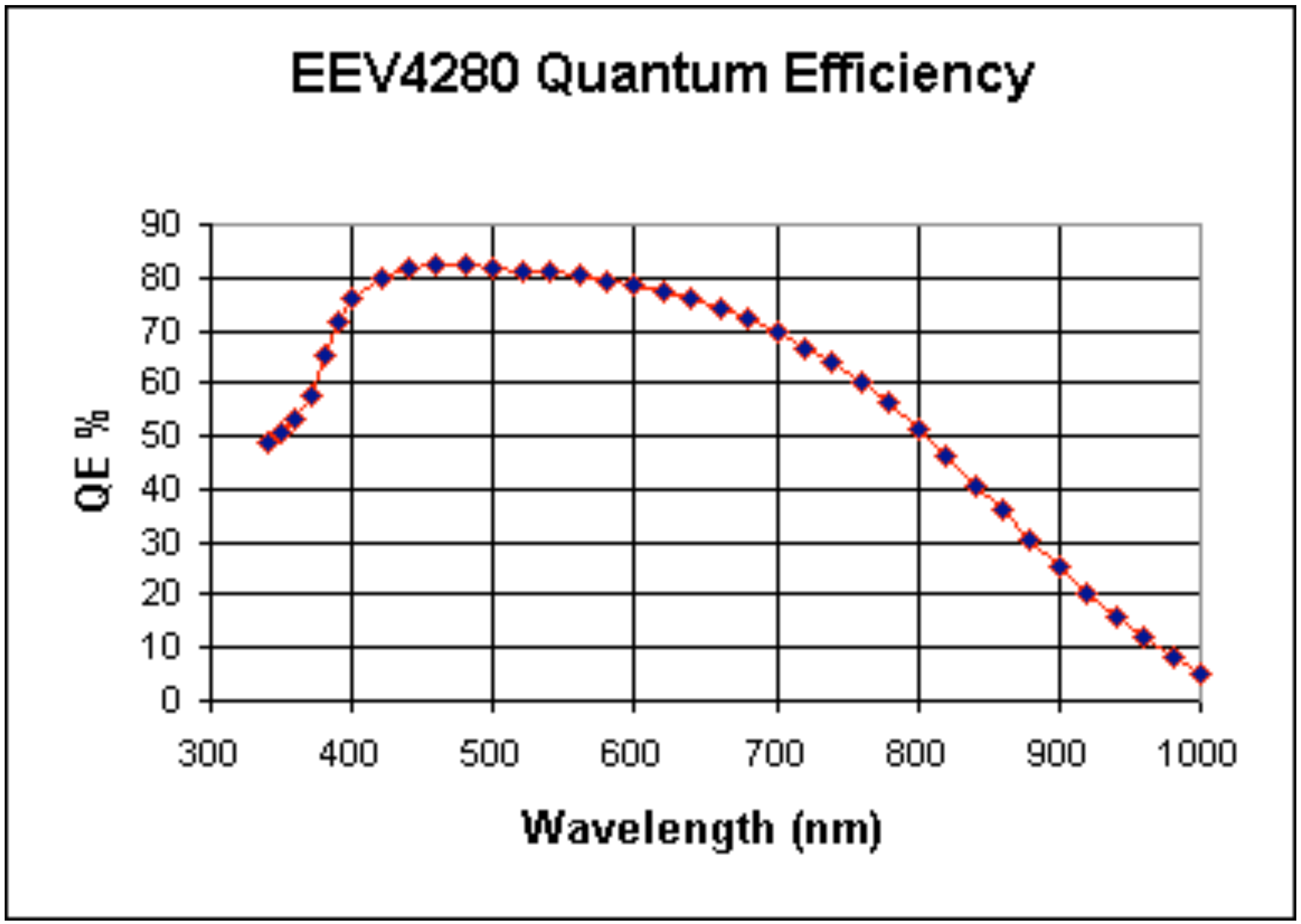
Our observing tool

The INT Wide Field Camera



The INT WFC consists of four CCDs. These collect photons and the resulting electrons are recorded and converted to numbers (counts).

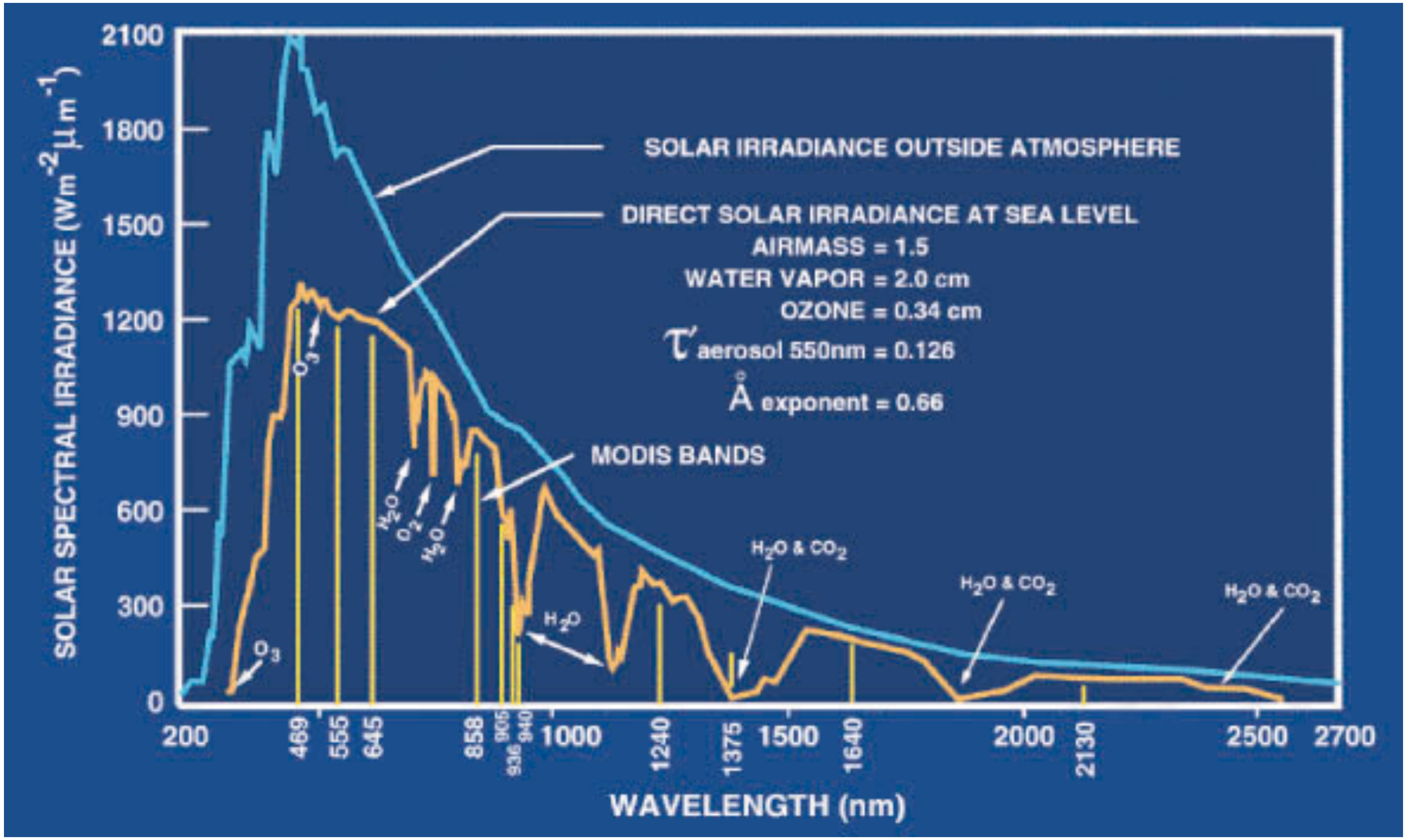
From counts to useful numbers



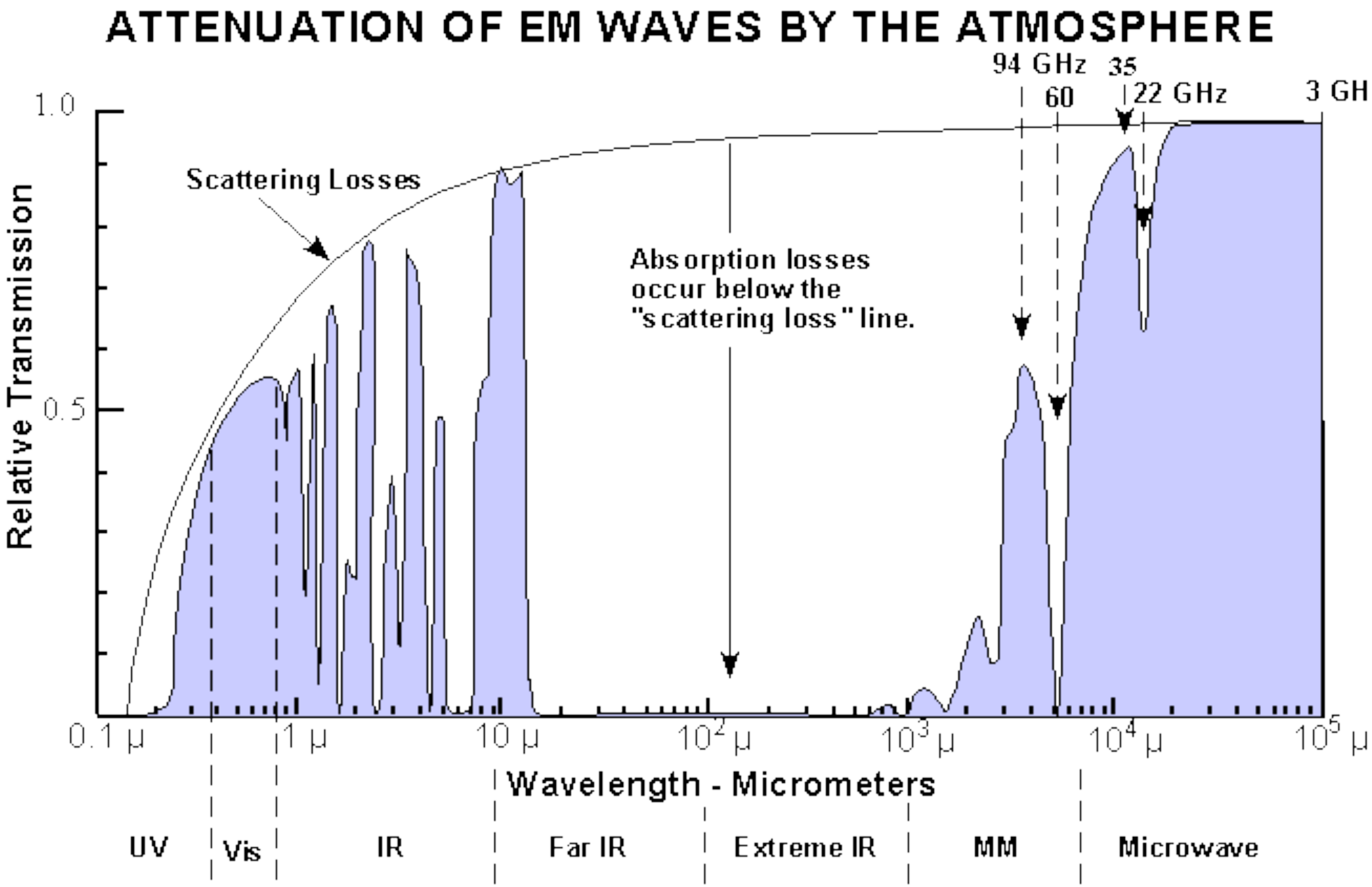
Any instrument has a variable sensitivity across wavelength space. This is the sensitivity of a CCD.

But that is not all!

The light that we observe has to travel through the Galaxy, then through our atmosphere and finally through our telescope. All of these steps can reduce the intensity of the light.



Atmospheric absorption

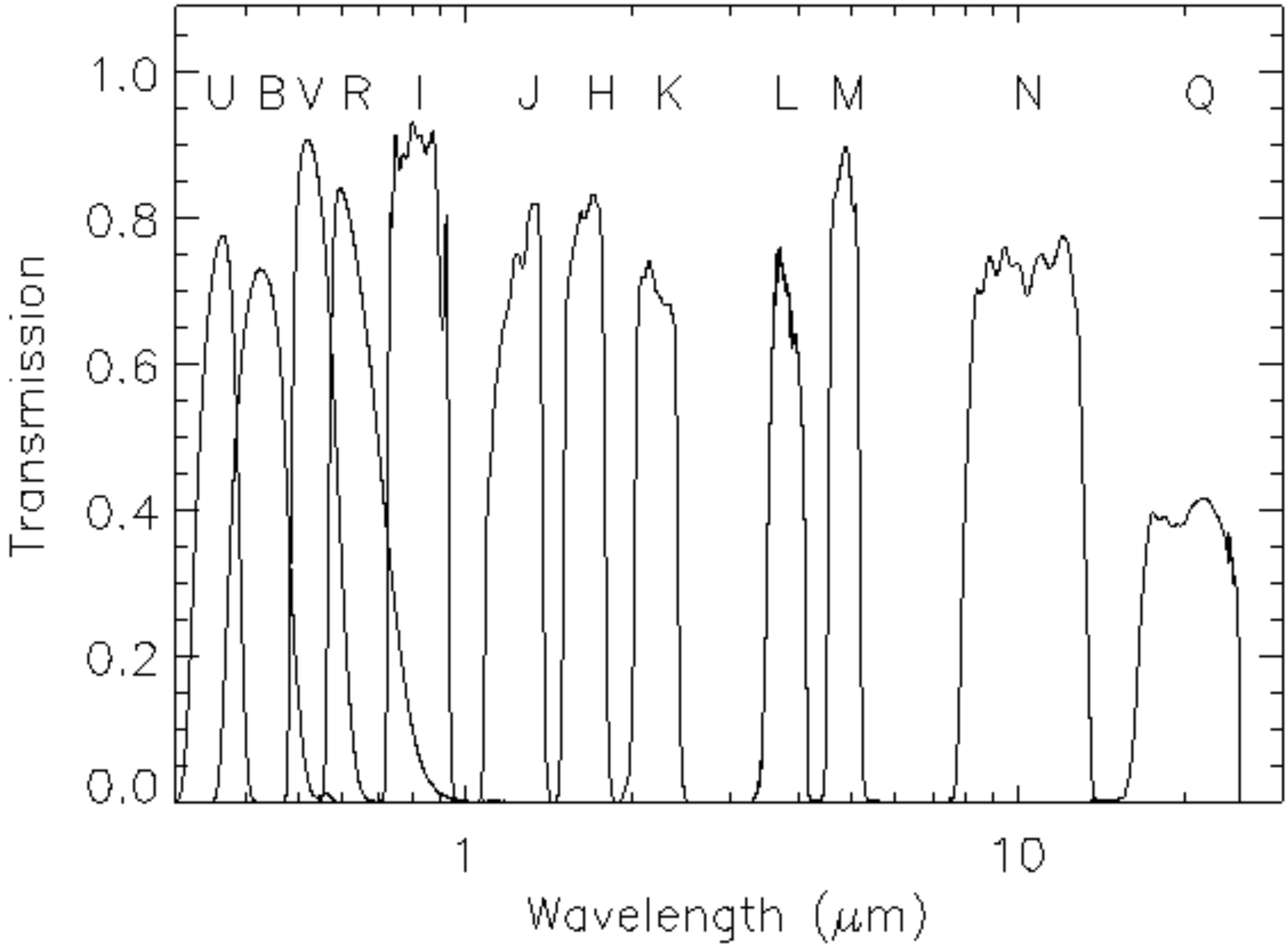


From spectrum to colours

A spectrum has a lot of information but it is time-consuming to acquire and it is difficult to observe faint objects with a spectrograph.

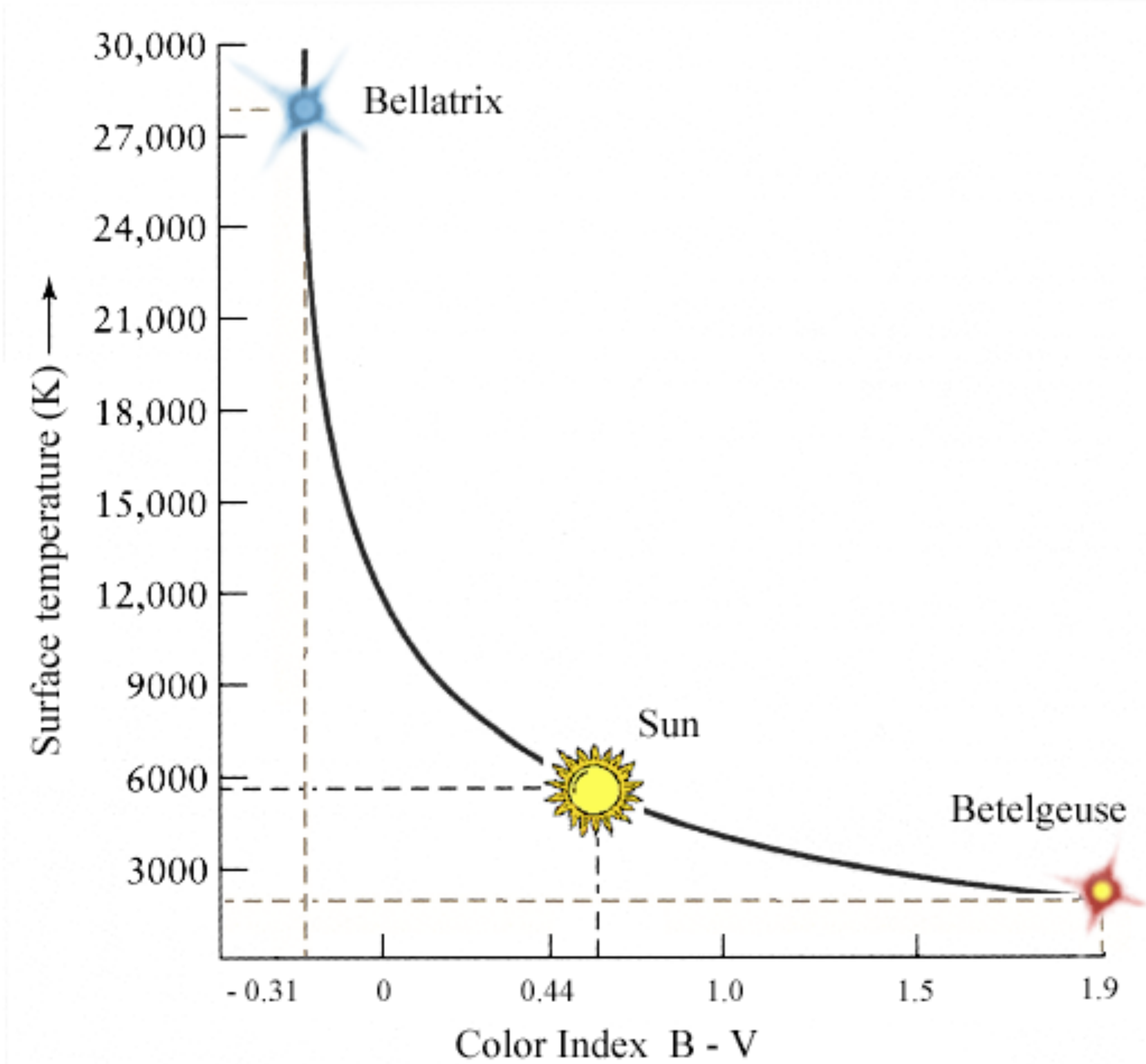
In imaging what we do is we sum a spectrum over a range of wavelengths.

From spectrum to colours



From spectrum to colours

Colour-temperature relationship



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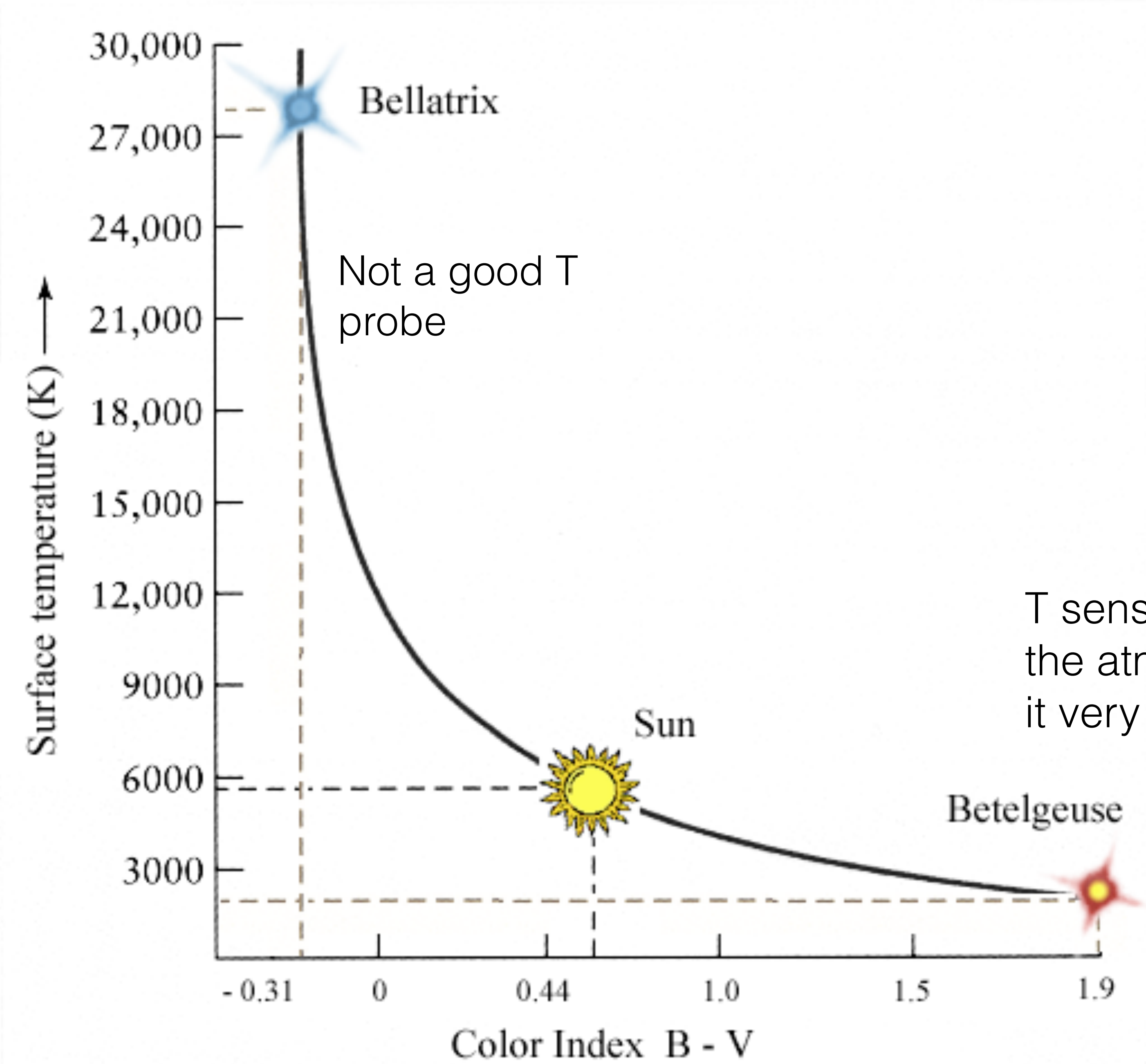
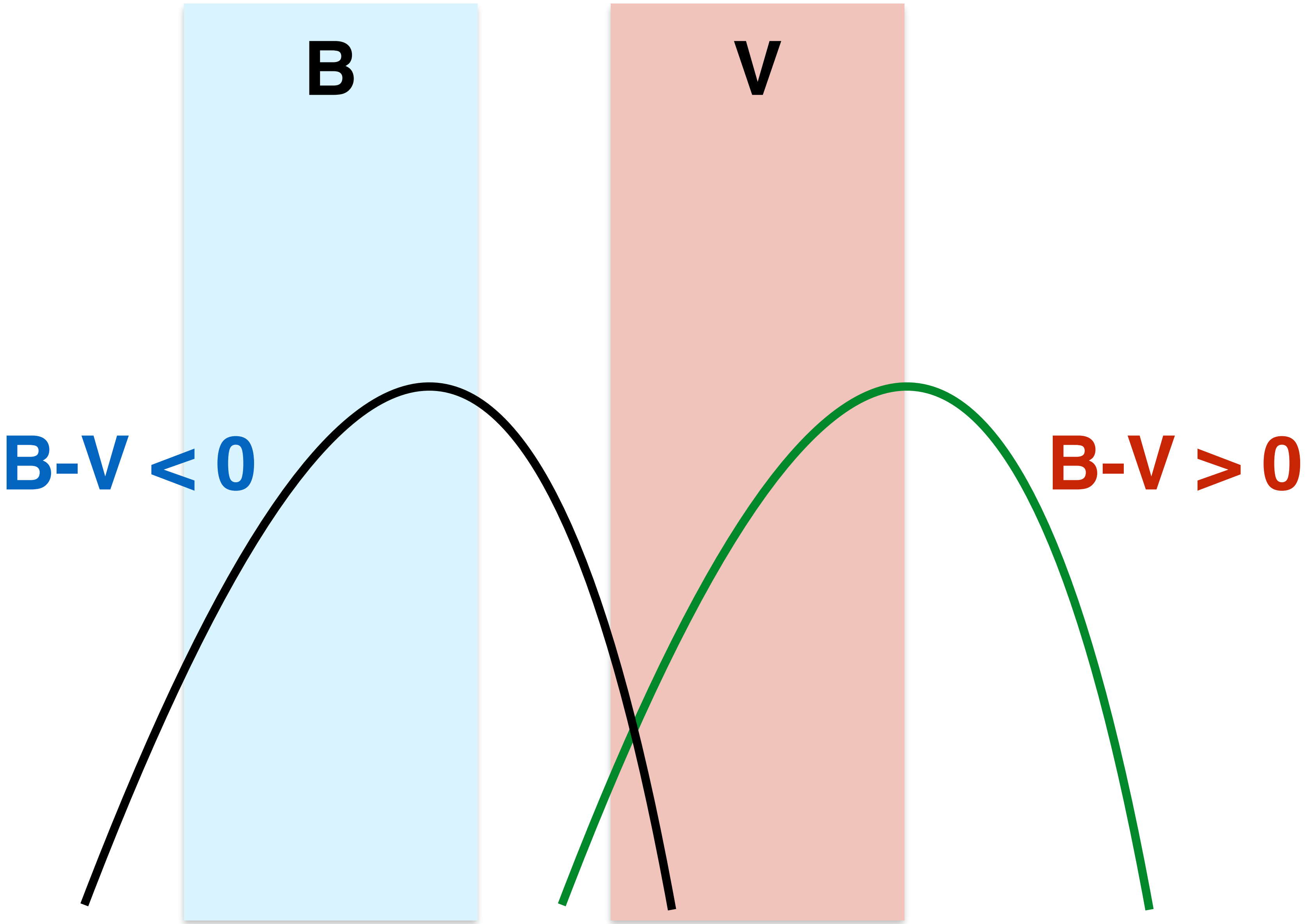


Not a good T probe

T sensitive but absorption in the atmosphere might make it very different from BB

Colour as simple photometry



Calibration of data

In order to calibrate our data we need to have some reference sources in the sky. For photometry in the optical/near-IR the classical comparison has been with Vega.

$$m_X = -2.5\log_{10}\frac{\int F(\lambda)R_X(\lambda)d\lambda}{\int R_X(\lambda)d\lambda} + C_X$$

C_X chosen so that m_X is zero in all bands for Vega.

(actually that equation is slightly incorrect - we will use it but see if you can spot what is wrong - think about how an imaging system collects data.)

The plethora of magnitude systems

Actually the world is more complex - today the most common is actually the AB magnitude system:

$$m_{\mathrm{AB}} = -2.5 \log_{10} f - 48.60$$

with f in erg/s/cm^2/Hz. In this system the formalism on the previous page can be used but now with a reference spectrum that has $F_\nu = \mathrm{const}$

Finally the Hubble Space Telescope data are often quoted in ST magnitudes which are done with a reference spectrum that has $F_\lambda = \mathrm{const}$

kalibratie

We moeten onze waarnemingen vergelijken met een referentiewaarde - standaard sterren.

De ultieme referentie: Wega (m=0 per definitie)

dit is inmiddels iets bijgesteld - handig voor het vergelijken van waarnemingen, maar niet handig voor vergelijking van modellen.

AB magnitudes$=-2.5\times\log_{10} f -48.60$

waarbij f de fluxdichtheid is. Dit is een fysische definitie, maar we hebben geen goede bronnen om te kalibreren.