UPPSALA UNIVERSITET

Modelling Stars from Observations

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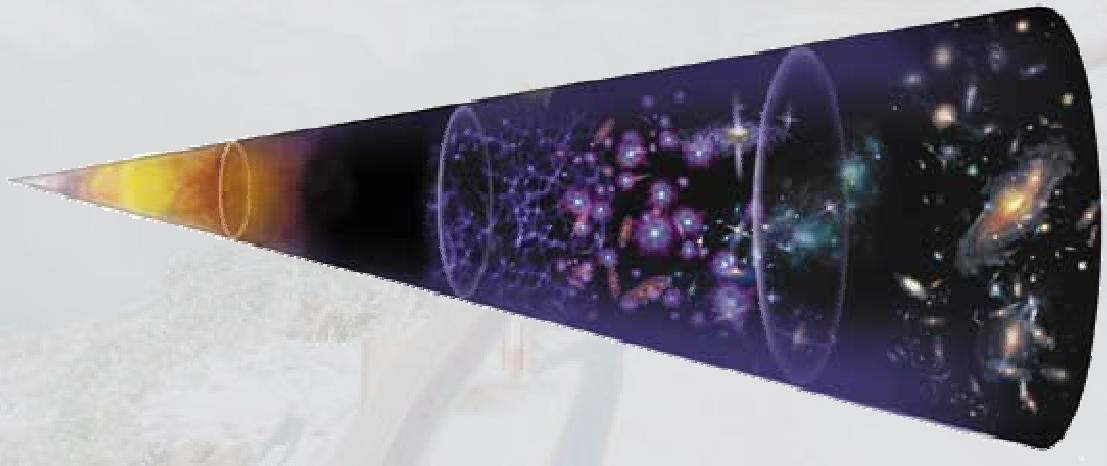
Why stars?

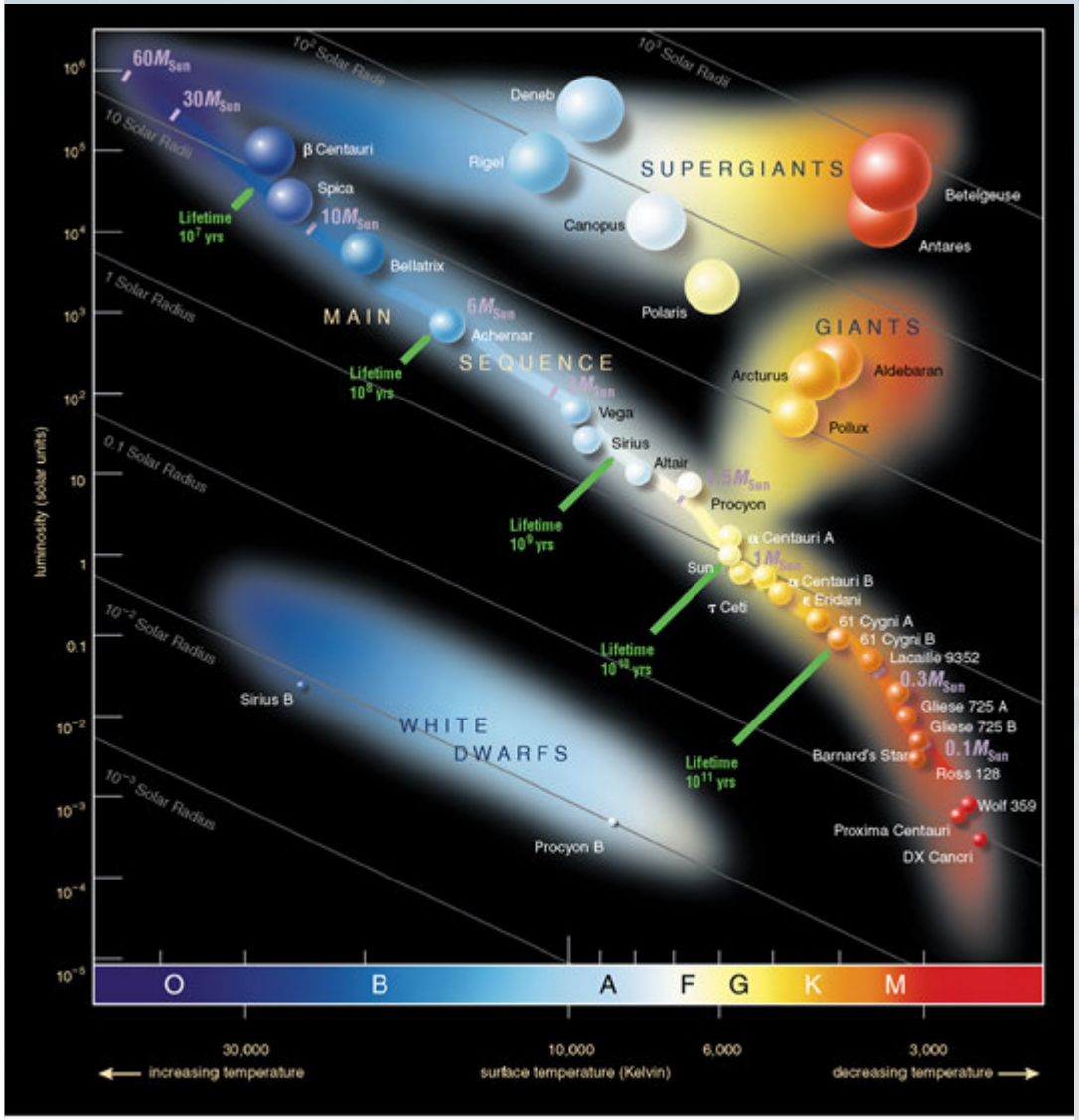
Time-line of our Universe:

Big Bang → Separation of matter and radiation → Recombination/Dark ages → Re-ionization

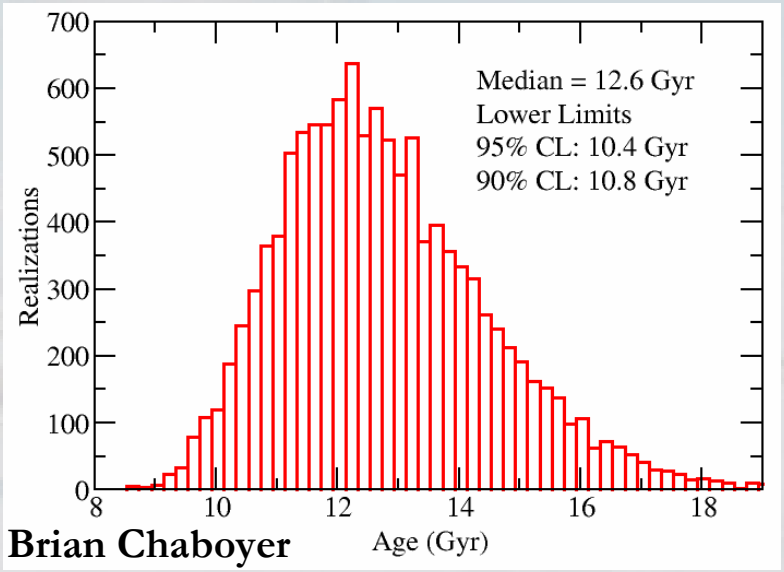


Stars are the source of most of EM radiation

Why stars??



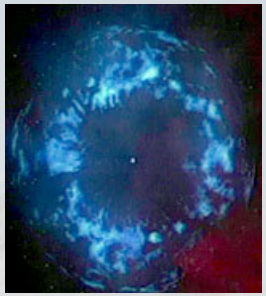
Stars come in various ages:



… and thus they witnessed the history of the Universe except for the 1st million year

Why stars???

Stars produce heavy chemical elements and in the end of life spread them in the interstellar medium (ISM)

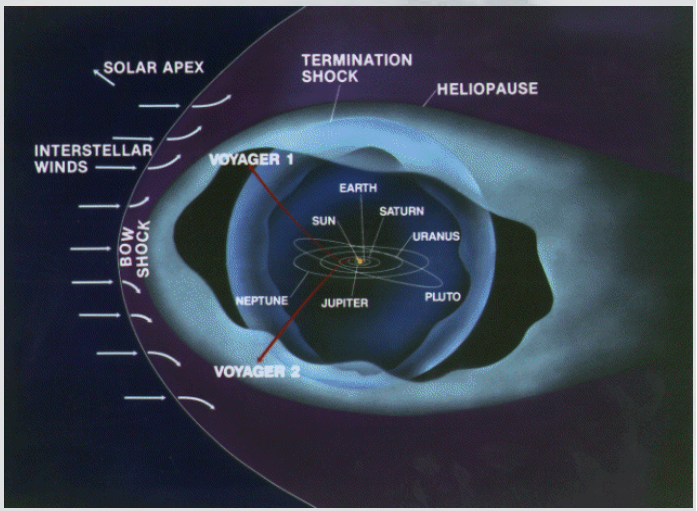


Oldest stars have almost pristine chemical composition from the Big Bang (H, He, Li)

Stars "amplify" magnetic fields and fields are important

What is happening inside stars?

Any other reasons why we my be interested in stars?



How do we study stars?

Observations

Models

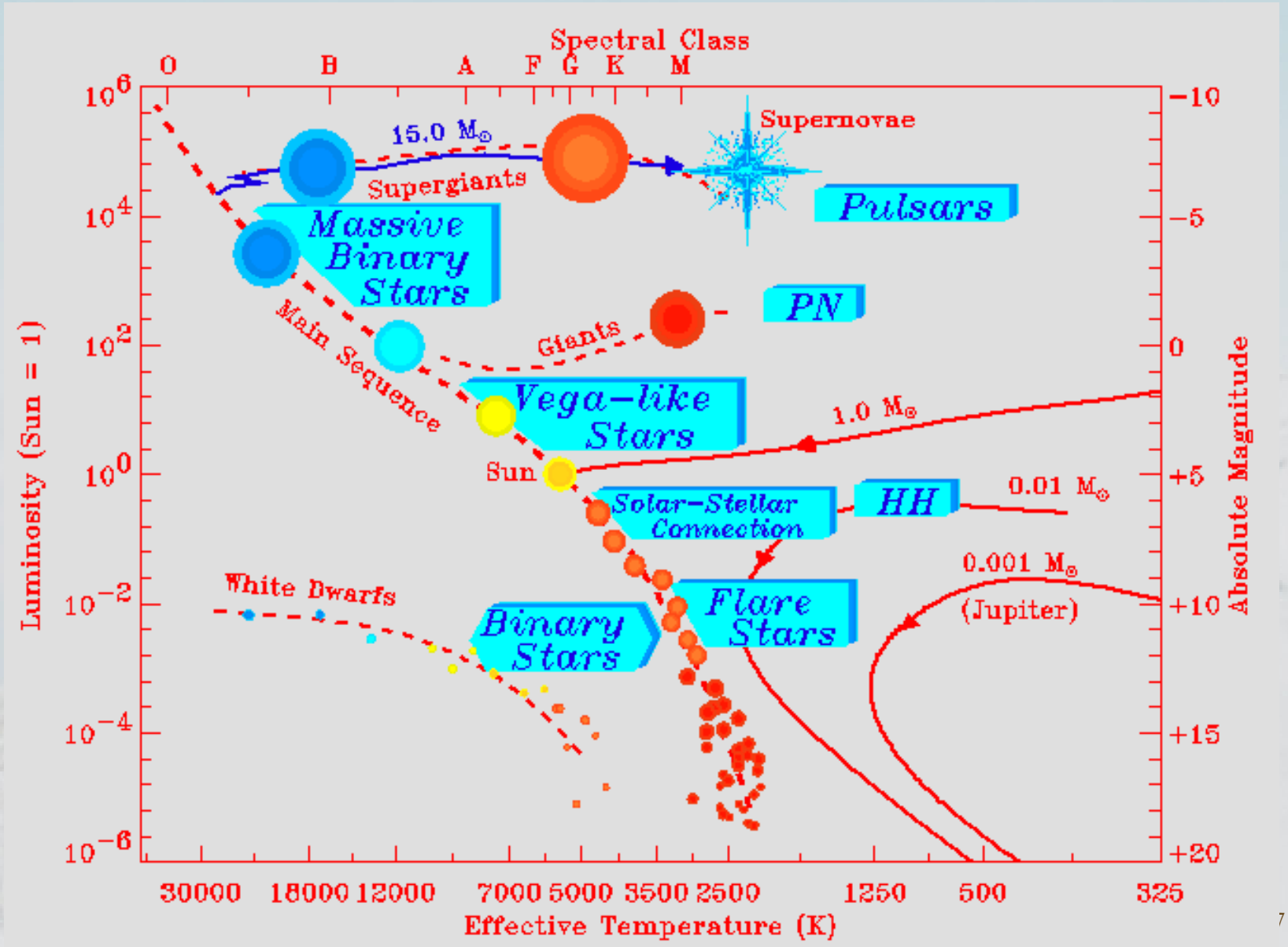
Layout of the course

- Stellar observables (colors, spectra, polarization, time series) and astronomical instrumentation
- "Theoretical" models of stars
- The importance of confronting models and observations
- Inverse models of stars

Discussion sessions:

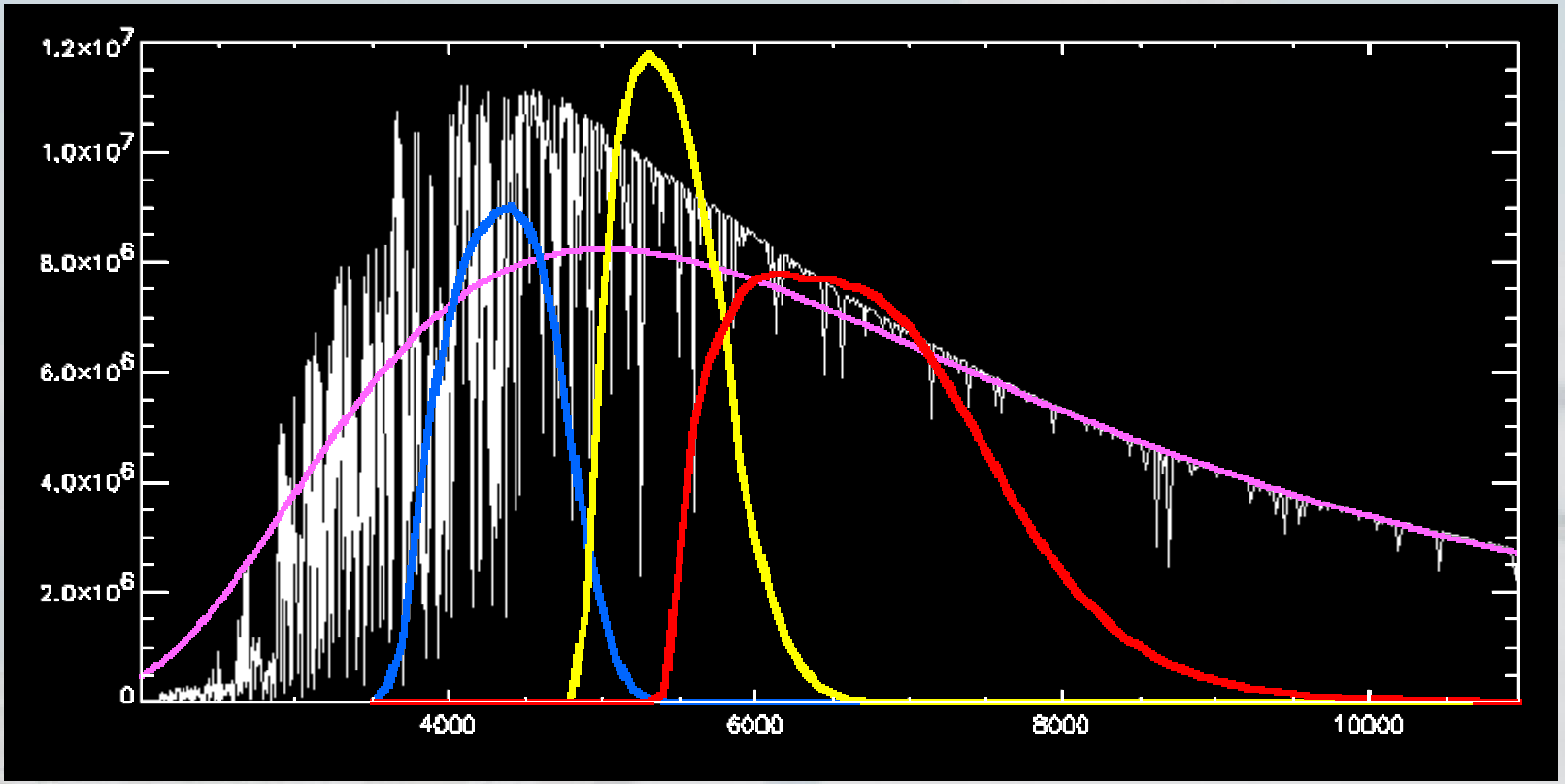
the topic will be announced in the lecture and there are a few questions in the lectures to think about.

Stellar Classification



Stellar radiation

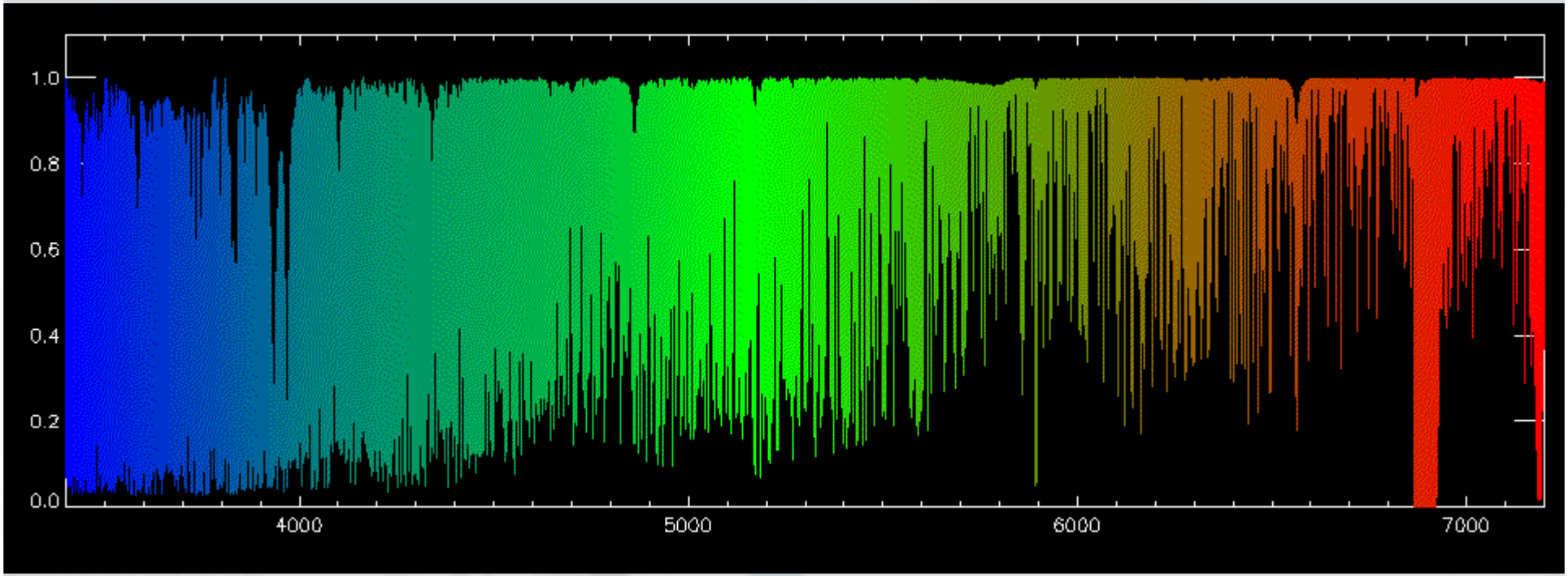
Spectral Energy Distribution and Colors



$$\Delta m_V = -2.5 \lg \left(a \int_V f^V(\lambda) I_\lambda d\lambda \Big/ b \int_V f^V(\lambda) I_\lambda^{ref} d\lambda \right)$$

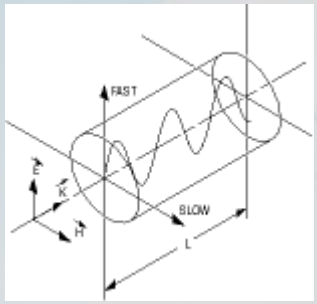
High-resolution spectra

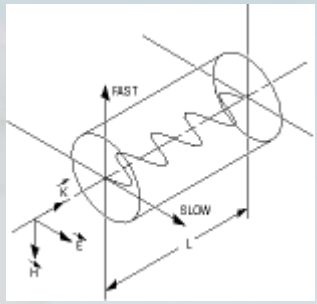
Astronomers normalize spectra to the envelope which they call “continuum”



Polarization

- Polarized EM radiation:





- Polarization is described by Stokes parameters:

I — total intensity

$V = 1/2 \cdot (I_{\odot}^{right} - I_{\odot}^{left})$ — circular polarization

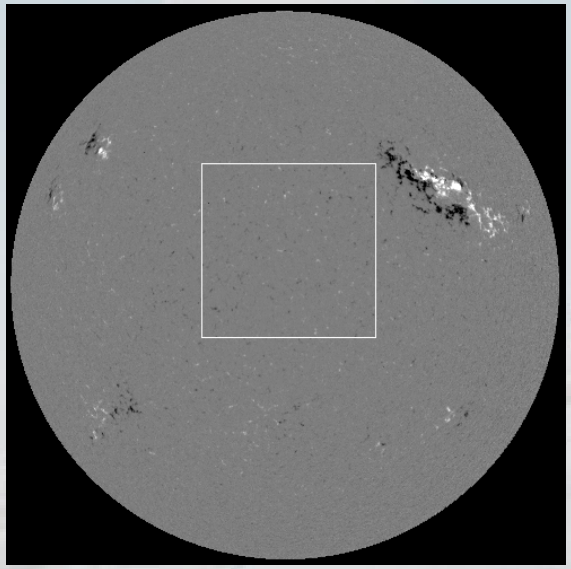
$Q = 1/2 \cdot (I_{|}^{0^\circ} - I_{|}^{90^\circ})$

$U = 1/2 \cdot (I_{|}^{45^\circ} - I_{|}^{135^\circ})$

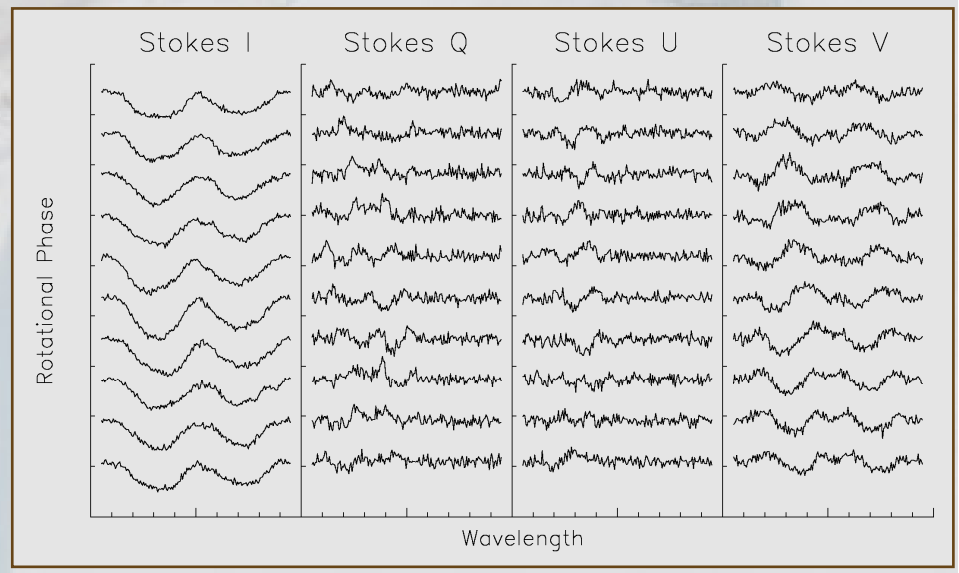
} linear polarization

Polarization (observations)

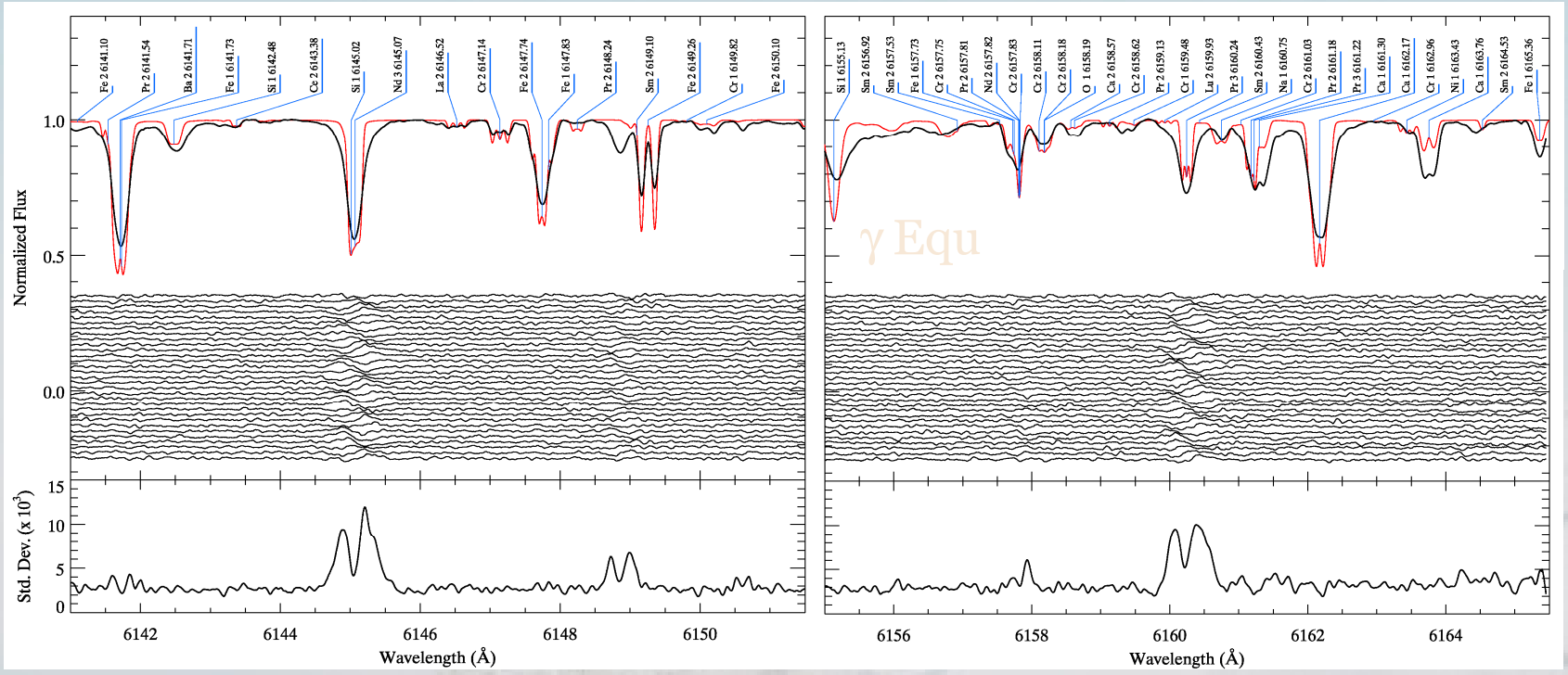
- Broad-band polarization (e.g. produced by scattering)



- Spectral line polarization (Zeeman effect)



Time series



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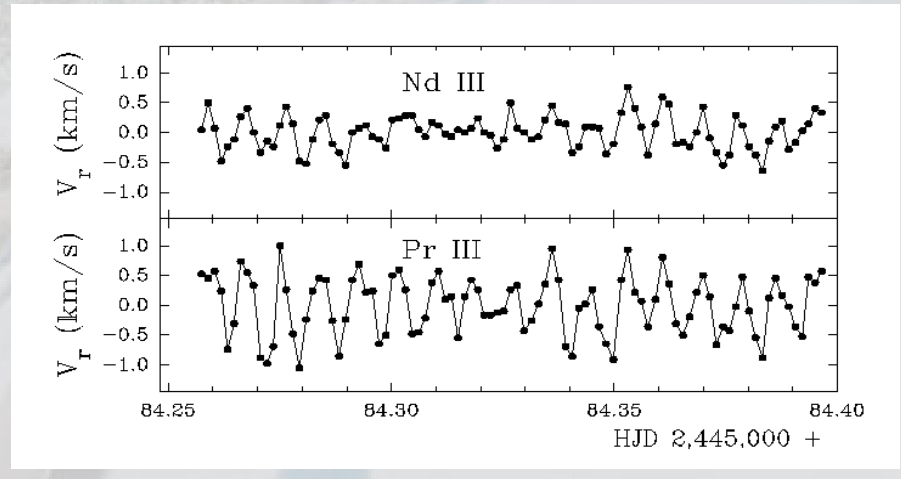
Line profiles

Radial velocities →



How do we observe?

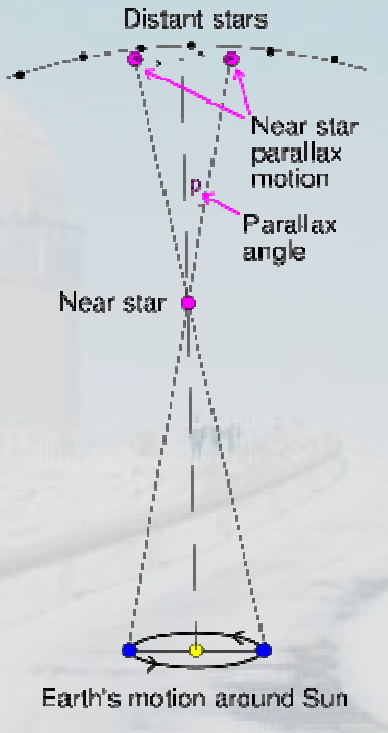
Writing an observing time application:

- **Science goals**
- **Why this telescope and this instrument?**
- **How will we do it?**

Time allocating committee meets once every 6 months

Useful numbers

- **Distances:** $R_\oplus$ 6.4×10^{8}cm
  $R_\odot$ 7×10^{10}cm
  AU 1.5×10^{13}cm
  pc 3×10^{18}cm
- **Times:** 1 year 3.16×10^{7}s
- **Velocities:** 1-1000 m/s
- **Densities:** 10^{16}-10^{18} cm^{-3} (10^{-6}-10^{-8} g/cm^3)
- **Masses:** $M_\odot$ 2×10^{33}g
- **Temperatures:** 10^2 – 10^6 K



Next lecture: Theoretical stellar models

1D hydrostatic models

Discussion subject:

How do we decide what experimental facility/equipment to build/use?