webSME
"Spectroscopy made Easy"

(ChINOS Summer School, 25 July, 2023)

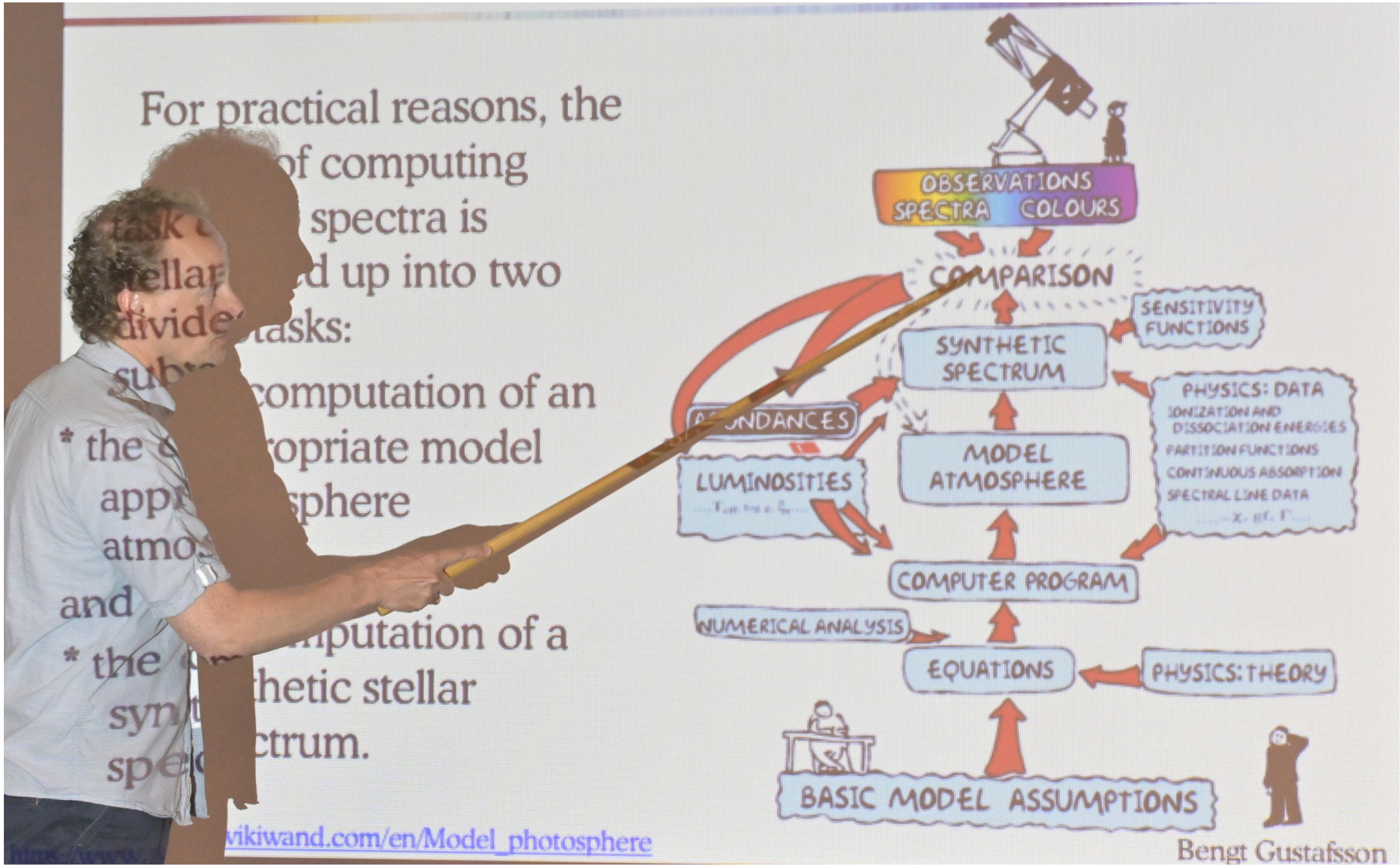
Johannes Puschnig

post-doc

Uppsala University, Sweden

UPPSALA
UNIVERSITET

webSME
”Spectroscopy made Easy”



Who I am

* Salzburg, Austria (1980)

Who am I

* Salzburg, Austria

Who am I

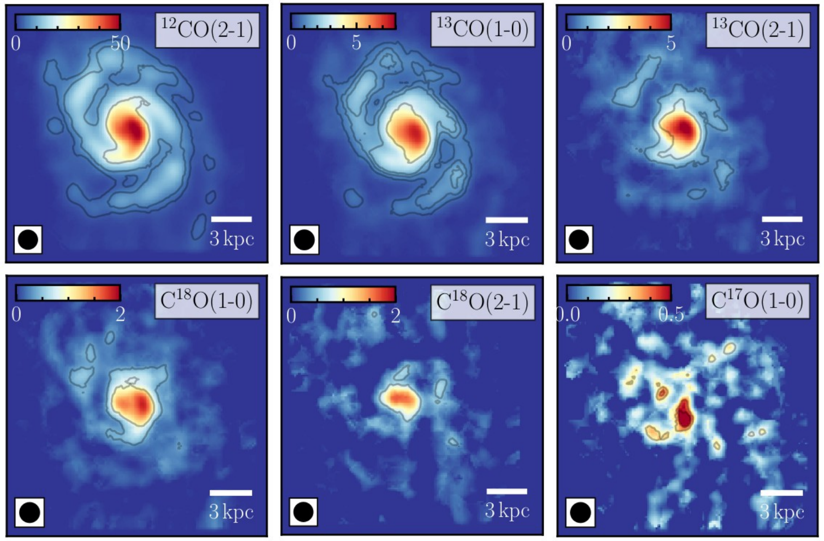
- 2000 – 2009: running an IT company in Vienna

- BSc (2012) and MSc in Astrophysics (2014) in Vienna:
  Census of the Molecular Gas in Nearby Galaxies Selected from the CALIFA Survey

- 2015-2019: PhD student at Stockholm University
  Molecular gas and ionizing radiation in star-forming galaxies

Who am I

- 2020-2022: post-doc at ITA Heidelberg and AifA Bonn
  (working on molecular gas radiative transfer, Dense Gas Toolbox)



- 2022-present: post-doc at Uppsala University (Andreas Korn)
  Stellar Analysis Pipeline Development in frameworks of ChETEC-INFRA and ANDES

Outline

1) Motivation and aim

2) Relevant stellar parameters

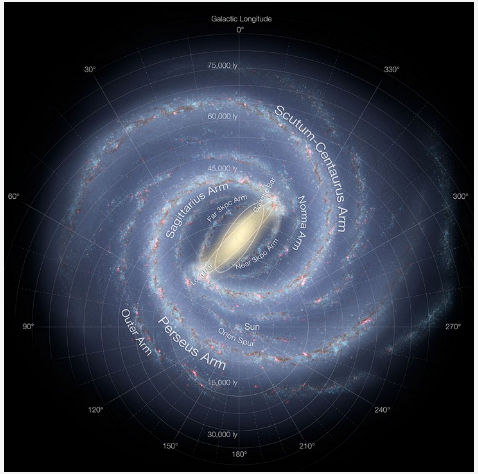
3) Live Pipeline Presentation

1) Motivation and aim

- In the context of **Galactic archaeology** we want to understand the formation of stellar populations in the Milky Way, e.g.: How did the prominent bar in the Milky Way form?

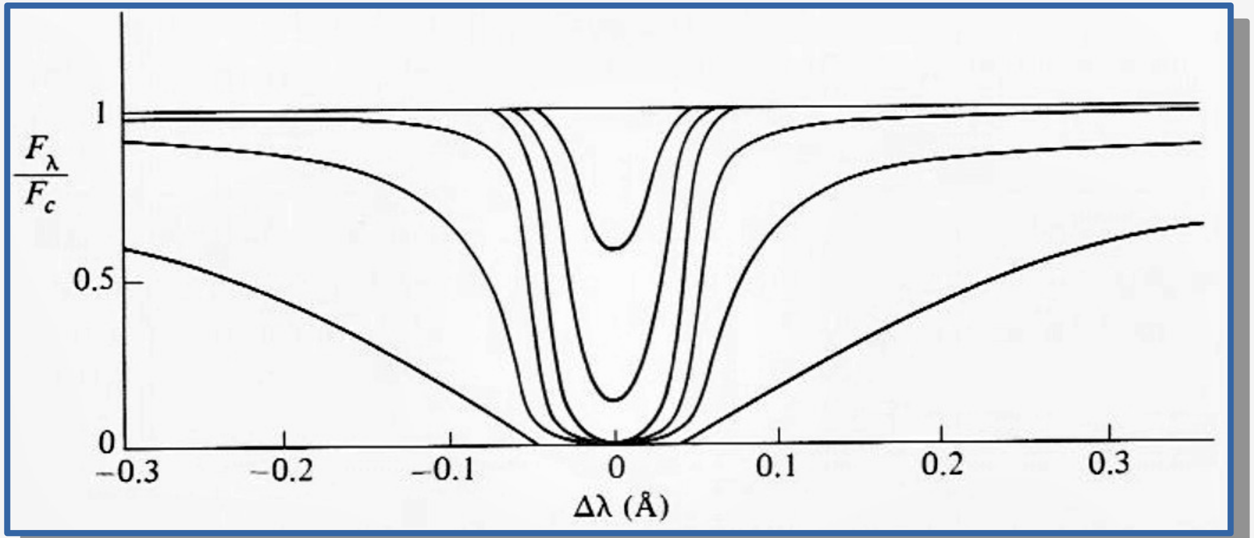
- The stars are our fossils that provide insight into the formation history and evolution of the Milky Way.

→ We need to measure accurately the **chemical composition** (and dynamics) of the stars.



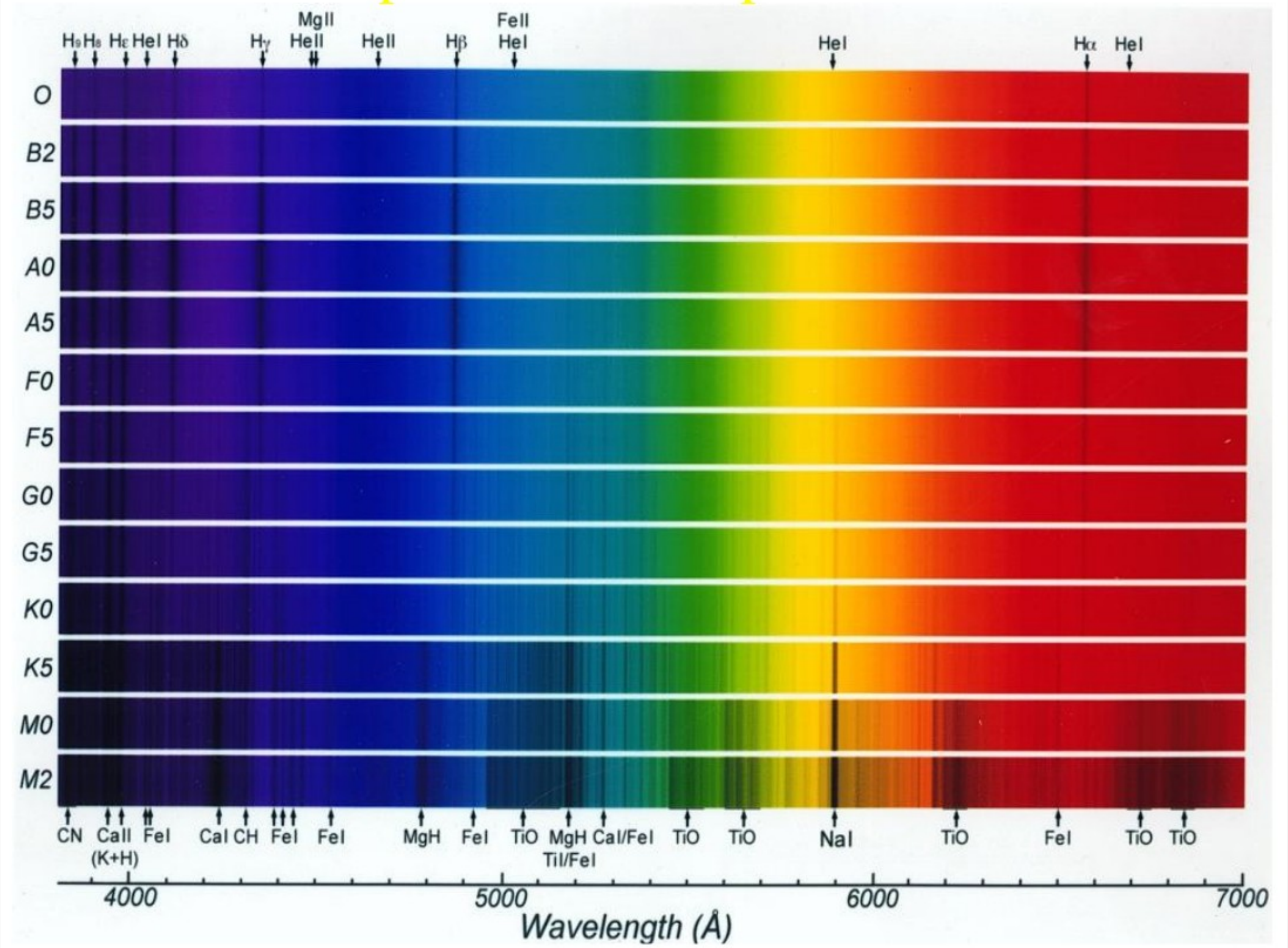
1) Motivation and aim

Principle: Spectral line shapes contain information about the number of absorbing atoms/ions along line of sight → column density N_a (of element in observed state)

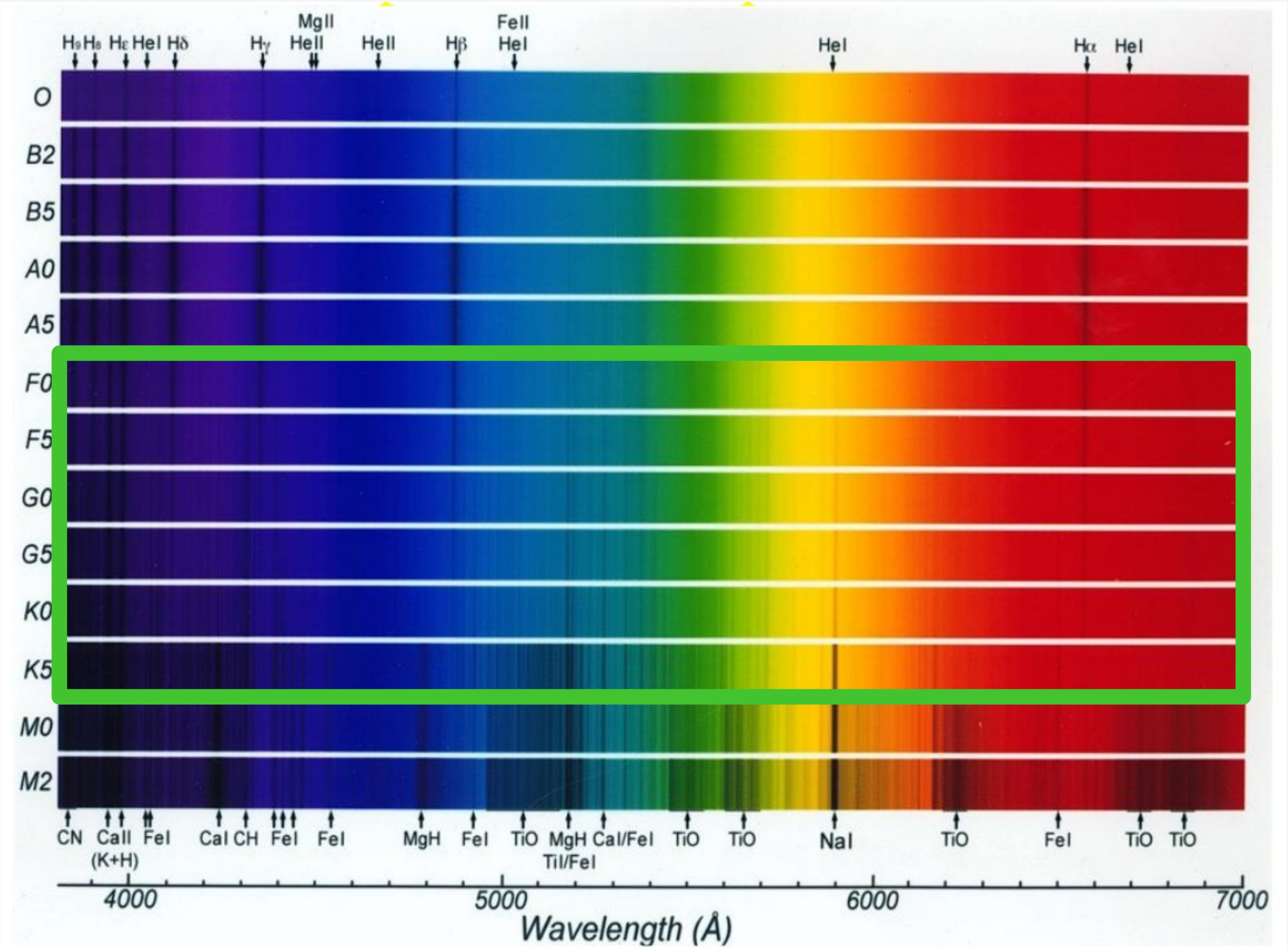


Example: Voigt profiles of Ca II K lines produced by N_a~10^{11} cm^{-2} in the shallowest case up to ~10^{16} cm^{-2} (change by factor 10 per line).

1) Motivation and aim



1) Motivation and aim



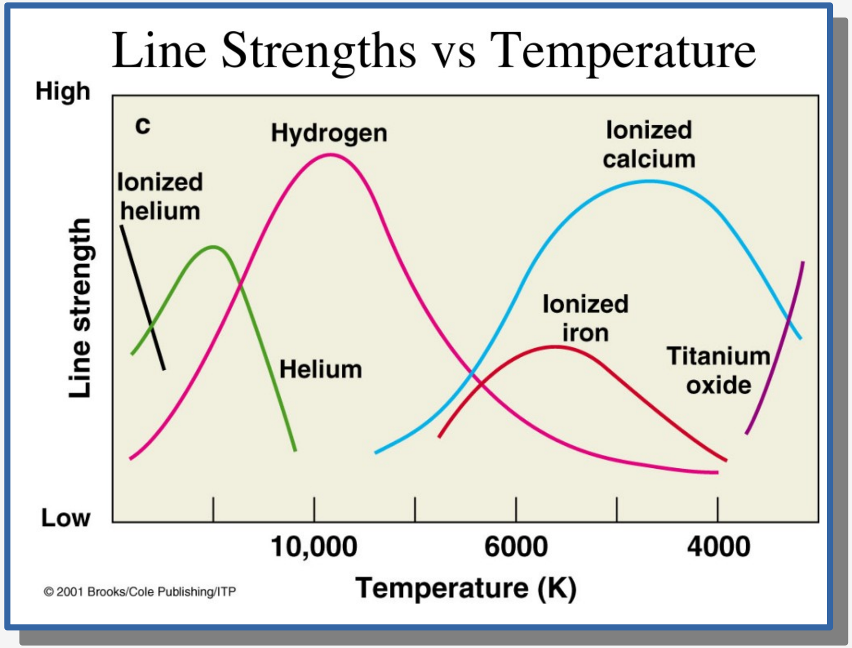
2) Stellar parameters

Stellar photospheres can be characterized by a handful of parameters:

→ Effective temperature (Teff)

temperature of a black body with the same integrated flux as star

$$\int F \, d\lambda = \sigma_B T_{eff}^4$$



2) Stellar parameters

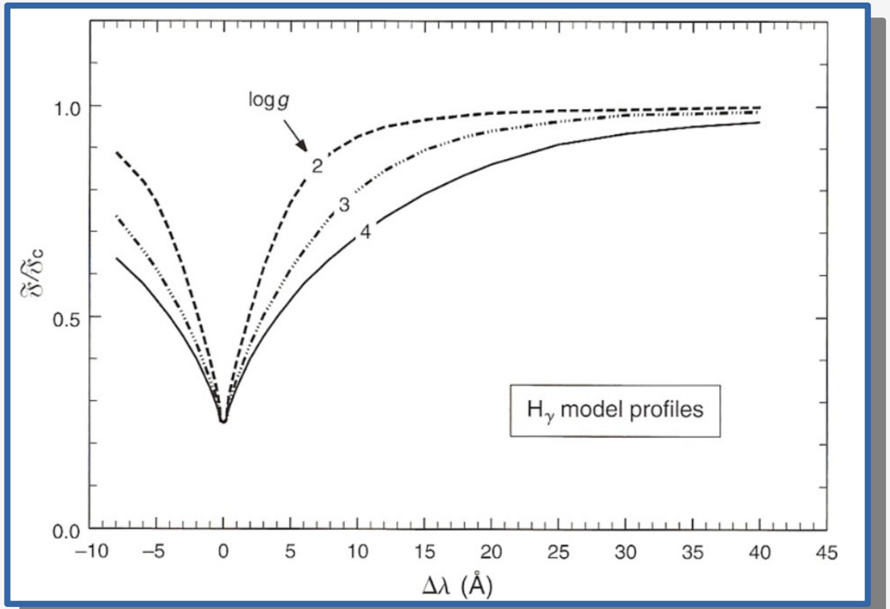
Stellar photospheres can be characterized by a handful of parameters:

→ **Surface gravity log g**

logarithm of the gravitational acceleration at the surface of the star

$g \propto M/R^2$

In the outer layers of the star, where the spectrum is created and mass is essentially independent of the radius, log g determines gas density!



Gray 2005, Stellar Photospheres, CUP

2) Stellar parameters

Stellar photospheres can be characterized by a handful of parameters:

→ **Metallicity [M/H]**

the star mostly consists of hydrogen and helium, but other elements are important too. We define metallcity relative to solar values:

$$[M/H] = \log_{10}\left(\frac{M}{H}\right) - \log_{10}\left(\frac{M_\odot}{H_\odot}\right)$$

M…number of particles of all metals
H… number of hydrogen particles

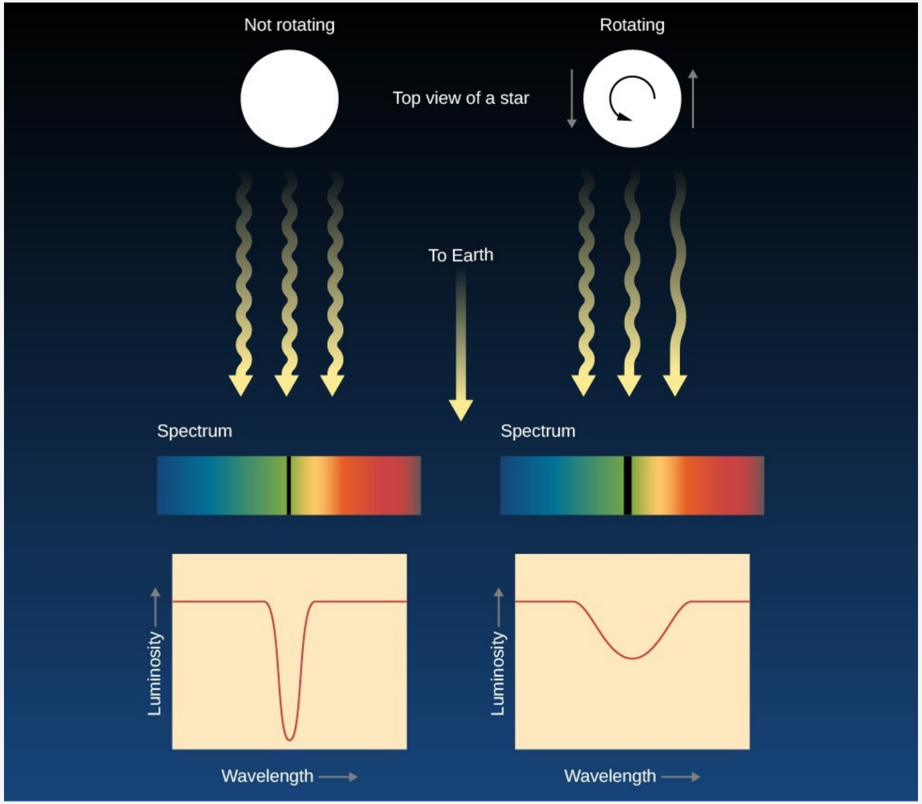
(sun has [M/H]=0 by definition)

2) Stellar parameters

Stellar photospheres can be characterized by a handful of parameters:

→ Projected rotational velocity
v sin(i)

stellar rotation as seen from Earth, with i being the inclination of the rotation axis relative to line of sight



https://openstax.org/books/astronomy/pages/1-introduction

2) Stellar parameters

- Stellar photospheres can be characterized by a handful of parameters:

  → microturbulence v_{mic} and macroturbulence v_{mac}

  high-order pulsations, turbulence, convection and stellar activity cannot be spatially resolved → v_{mic} and v_{mac} are used to describe effects on line

motions on scales < mean free path length
→ increased line opacity

motions on scales > mean free path length
→ change line shape, not strength

2) Stellar parameters

Note: A star has more characteristics, e.g. age, evolutionary status, or binarity, but those are not relevant for the measured stellar flux. The pipeline only includes parameters, that we need to measure with high precision, in order to accurately model the stellar spectrum.

3) webSME

Evolution of "Spectroscopy Made Easy":

- SME: Original version published by Valenti & Piskunov (1996)
  `C++` and `FORTRAN` library
  complemented by IDL framework

- Library has undergone significant development (Piskunov & Valenti 2017)

- pySME: Wehrhahn et al. (2022) translated IDL part of code to `python`

- webSME: based on pySME, with some updates...

3) webSME

- **New features:**
  i) a web interface that allows users to upload and visualize observed spectra

  ii) implementation of (parallel tempered) MCMC routines to infer uncertainties of the derived parameters

- **Update** of intrisic features to produce results based on the latest developments in the field:

  i) we make use of the Gaia-ESO line list of Heiter et al. (2021)

  ii) inclusion of the most recent solar reference abundances of Asplund, Amarsi and Grevesse (2021) to allow for accurate metallicity derivations.

3) webSME

http://pipeline.chetec-infra.eu

MCMC

Thanks for Listening

Questions?

Pipeline
preview available at
http://pipeline.chetec-infra.eu/

3) Pipeline Development