High resolution near-IR spectroscopy of FGK stars

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To Linnea, Henriette, and Rico
For always supporting me

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Chapter 1

Introduction

1.1 Planet host stars

With the present diversity of exoplanets ot becomes increasingly important to get an accurate and precise characterization of the planets in order to study them in samples and on an individual level. An accurate and precise characterization can give us an idea wether the planet is rocky, composed of water or gaseous.

1.2 Atmospheric parameters

CHAPTER 2

THEORY

To encompass all theory regarding stellar structure, evolution, and their atmosphere is far beyond the scope of this thesis. Rather the theory needed is presented below with highlights on the most important aspects.

2.1 Stellar structure

The structure of a non-rotating spherical stars can be described by five rather simple differential equations (see e.g. Kippenhahn and Weigert, 1994) presented below:

1. **Equation of Continuity**

   Relation between the mass, m, the density, ρ, at a symmetric shell at radius r

$$\boxed{\frac{\partial r}{\partial m} = \frac{1}{4\pi r^2 \rho}.} \tag{2.1}$$

2. **Equation of Hydrostatic Equilibrium**

   The equation of hydrostatic equilibrium shows how a star in equilibrium is balanced between two forces. The inward force from gravity and the outward force from pressure, P,

$$\boxed{\frac{\partial P}{\partial m} = -\frac{Gm}{4\pi r^4}.} \tag{2.2}$$

When working with asteroseismilogy a time dependent pertubation to this equation is added (see e.g. Aerts et al., 2010, for a thorough discussion). However, this term is neglected here.

3. **Equation of Energy Conservation**

   The equation of energy conservation shows how the energy is produced and lost throughout the star.

   $$\boxed{\frac{\partial l}{\partial m} = \varepsilon - \varepsilon_{\nu} + \varepsilon_{g},} \tag{2.3}$$

   where ε is the energy production in the center of the star, ε_{ν} is the energy lost by neutrinos which is always positive, ε_{g} is a source function of time-dependent terms, and l is the luminosity at m. ε_{g} comes from the fact that non-stationary shells can change its internal energy, and thus exchange mechanical energy with neighboring shells.

4. **Equation of Energy Transport**

   Energy transportation throughout the star is described with the following equation

   $$\boxed{\frac{\partial T}{\partial m} = -\frac{GmT}{4\pi r^4 P}\nabla_{\text{rad}},} \tag{2.4}$$

   where ∇_{rad} is the radiative temperature gradient, and T is the temperature. The value of the temperature gradient compared to the radiative temperature gradient tells if the energy is transported by convection or radiation. In our Sun the outer layer are convective while the inner layer are radiative.

5. **Equation of Chemical Composition**

   In this last equation we see the evolution of an element, X_i, when it reacts with other elements with reaction rates r_{ji} and r_{ik}

   $$\boxed{\frac{\partial X_i}{\partial t} = \frac{m_i}{\rho}\Big(\sum_j r_{ji} - \sum_k r_{ik}\Big).} \tag{2.5}$$

   Note that this is the only time-dependent equation of the five presented.

These five fundamental equations are implemented in stellar evolutionary codes, which we will use in later chapters. The many different codes that exist take other things into account, e.g the star can rotate, and it may not always be in hydrostatic equilibrium (this is important if we want our star to pulsate). For simplicity we have only presented time-dependence in the Equation of Chemical Composition since timescales of rotation, pulsations, and activity are much shorter than the long timescale found in chemical composition changes.

2.2 Stellar atmosphere

Bibliography

Aerts, C., Christensen-Dalsgaard, J., and Kurtz, D. W.: 2010, *Asteroseismology*

Kippenhahn, R. and Weigert, A.: 1994, *Stellar Structure and Evolution*, Springer-Verlag