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Optically-Thin Line-of-Sight Spectroscopy: What Are You Really Measuring?

Or: ***The Effect of Non-Equilibrium Ionization and the Solar Wind on the Broadening of Coronal Emission Lines***

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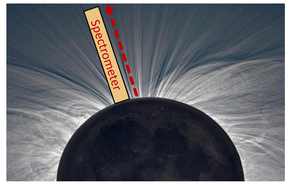
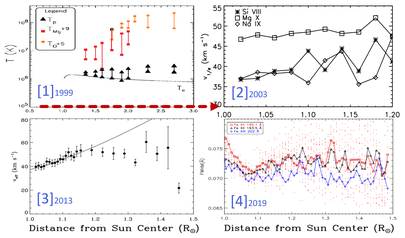
This research was performed in python using **GHOSTS**: the **G**lobal **H**eliospheric **O**ptically-thin **S**pectral **T**ransport **S**imulation, written by Chris R. Gilly.

Introduction + Background

Case Study: The Solar Corona

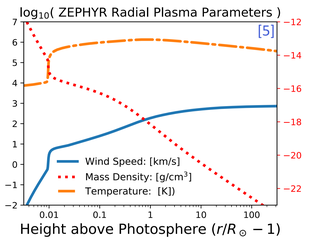


1. Slit spectrometers measure spectral lines vs position.



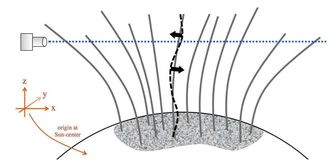
2. We have used them for decades to observe the Sun's atmosphere.

We study the both the intensity and the width of the spectral lines.



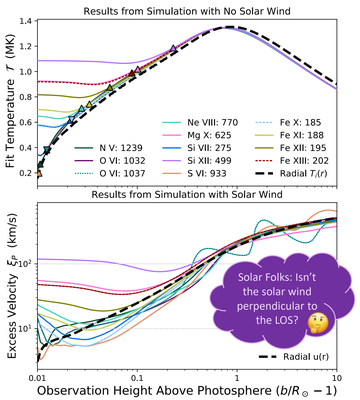
3. We want to measure radial variation of plasma.

How does the temperature, or the solar wind speed, change with height?



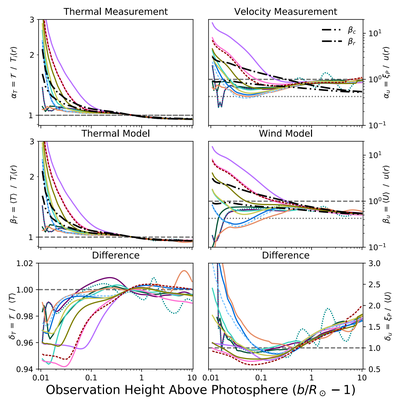
4. But there is a Line-of-Sight Problem.

In an optically thin system, observations contain light from the whole column. Commonly called a "Line-of-Sight Average."



5. Simulated measurements probe radial variation only for some regions and some ions.

Others show very strong departures.



6. Measurements probe an emissivity -weighted average of the quantities.

$$\langle T \rangle = \frac{\int_{-s}^{s} J\ T_i\ dx}{\int_{-s}^{s} J\ dx} \qquad \langle U \rangle = \frac{\int_{-s}^{s} J\ \vec{u} \cdot \hat{n}_{los}\ dx}{\int_{-s}^{s} J\ dx}$$

The **most dense plasma** in an optically-thin observation **isn't always the brightest** part of the line-of-sight.

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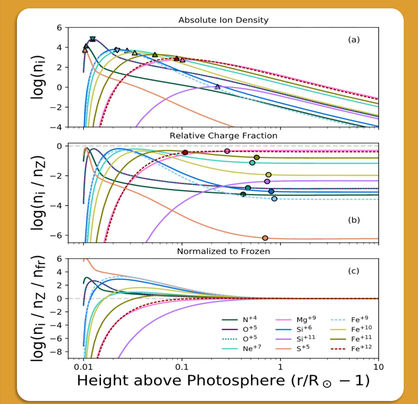
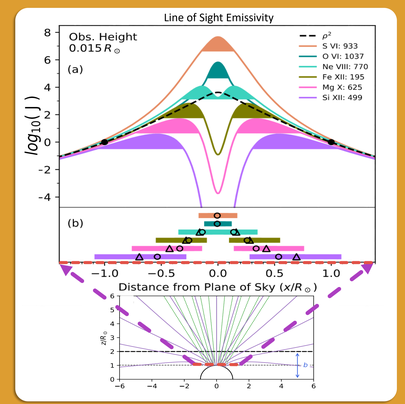
Position along a slit **is not** always **correlated with** measurement **location.**

Discovery: Measurement Floors

"Line-of-Sight Averaging" doesn't just skew the results, it *changes the effective measurement location*.



7. Temperature gradients cause strong population changes.



8. Measuring lower doesn't actually probe lower in the corona.

Lessons for Anyone

who studies spectral lines

When interpreting results of spectroscopy, be mindful of any effects that may change the population of the particle you are observing independently of total density variation. Make sure you understand what the **ion density** is doing, separately from the total density. **Ionization effects are often dominant** in regions where the temperature is varying rapidly.

Sometimes the properties of a measured line profile do NOT reflect the temperatures (and Doppler motions) in the regions of space that appear most responsible for forming the line.

References: [1] Esser et al. 1999, ApJ, 510, L63; [2] Moran 2003, ApJ, 598, 657; [3] Hahn & Savin 2013, ApJ, 763, 106; [4] Del Zanna 2019, A&A, 624; [5] Cranmer 2007, ApJs, 171, 520

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