P142
8/5/2019

Interpreting Off-Limb Emission Lines in Polar Coronal Holes

Chris "Gilly" Gilbert
Steven Cranmer
Chris.Gilbert@Colorado.edu, Steven.Cranmer@lasp.Colorado.edu

Summary

We generate synthetic spectral lines from the solar corona and explore how line-of-sight plasma properties affect the observations. This will help us interpret real observations of the Sun better.

In this work, a semi-empirical forward model (GHOSTS) is developed and used to generate simulated spectral observations of the solar corona. The widths of these spectral lines are often used to infer thermal and non-thermal velocities in the corona as a function of height. However, because the corona is optically thin, a variety of line-of-sight (LOS) effects keep these raw measurements from representing the values in the plane of the sky (POS). We explore the dependence of these observations on LOS plasma properties, with physical data for the model drawn from models (e.g., ZEPHYR, CHIANTI) and observations (e.g., the SUMER spectral atlas).

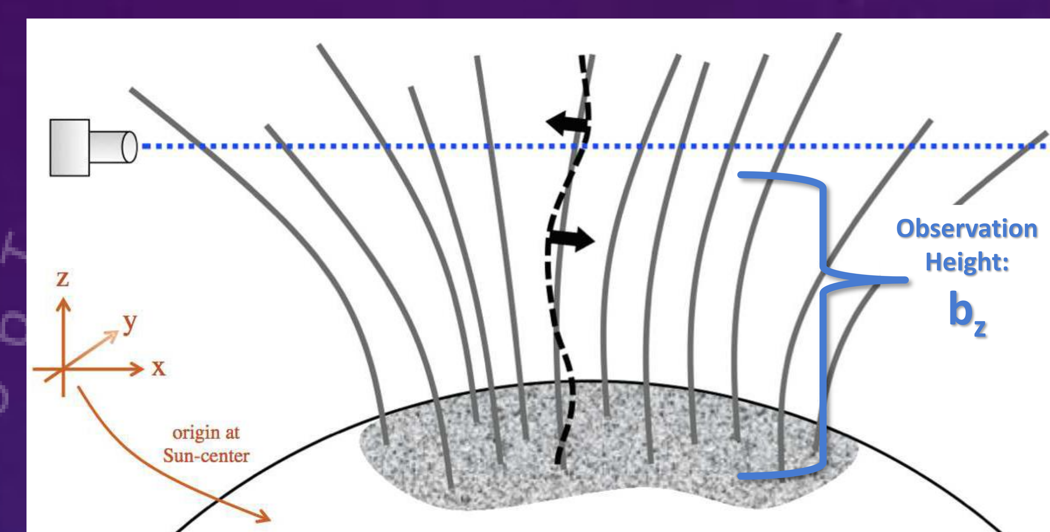
Non-equilibrium ionization effects cause different ions to have very different relative emissivities along the LOS, which leads to some notable effects on the observations. Line-fit temperatures only seem to match the POS value when the POS is the densest part of the line of sight, which is often not the case below heights of a few tenths of a solar radius. The spectral lines seem to be significantly broadened by the presence of the solar wind, even when the POS wind velocity is negligible. The resonantly scattered component of the line is significantly broadened if the surrounding continuum is included in the incident line profile. Work in preparation will also address the effects of Alfvén waves, preferential ion heating, and fine magnetic structure on the spectral profiles.

Basics of the Model

GHOSTS is the **G**lobal **H**eliospheric **O**ptically-thin **S**pectral **T**ransport **S**imulation. This is a semi-empirical forward model which draws data from other models and then illuminates them.

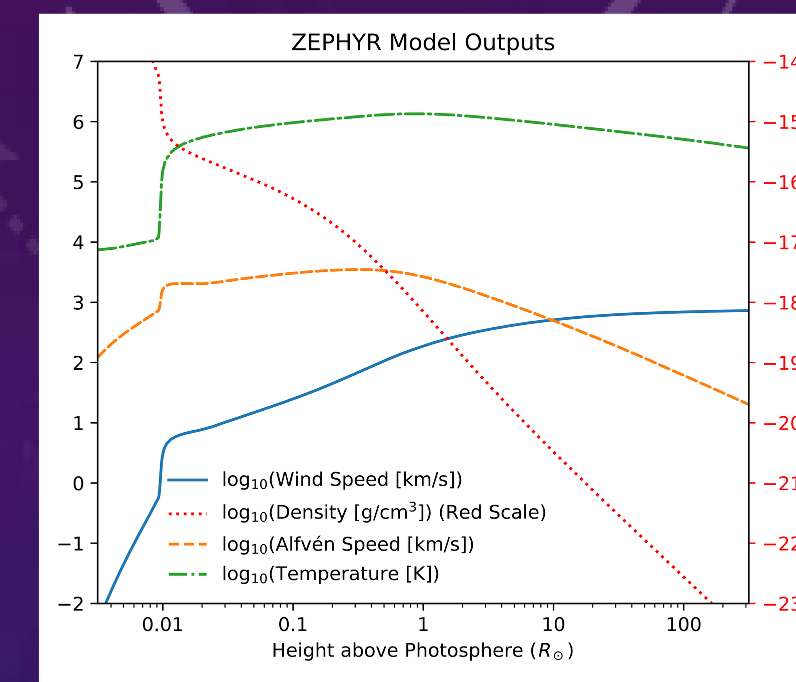
Simulated Geometry

We draw lines of sight through an idealized axisymmetric open magnetic polar coronal hole with superradial expansion.



Time-Steady Background Plasma

The **ZEPHYR** code produces tabulated average background plasma parameters inside the polar coronal hole which are read into the GHOSTS model.



Main Takeaway

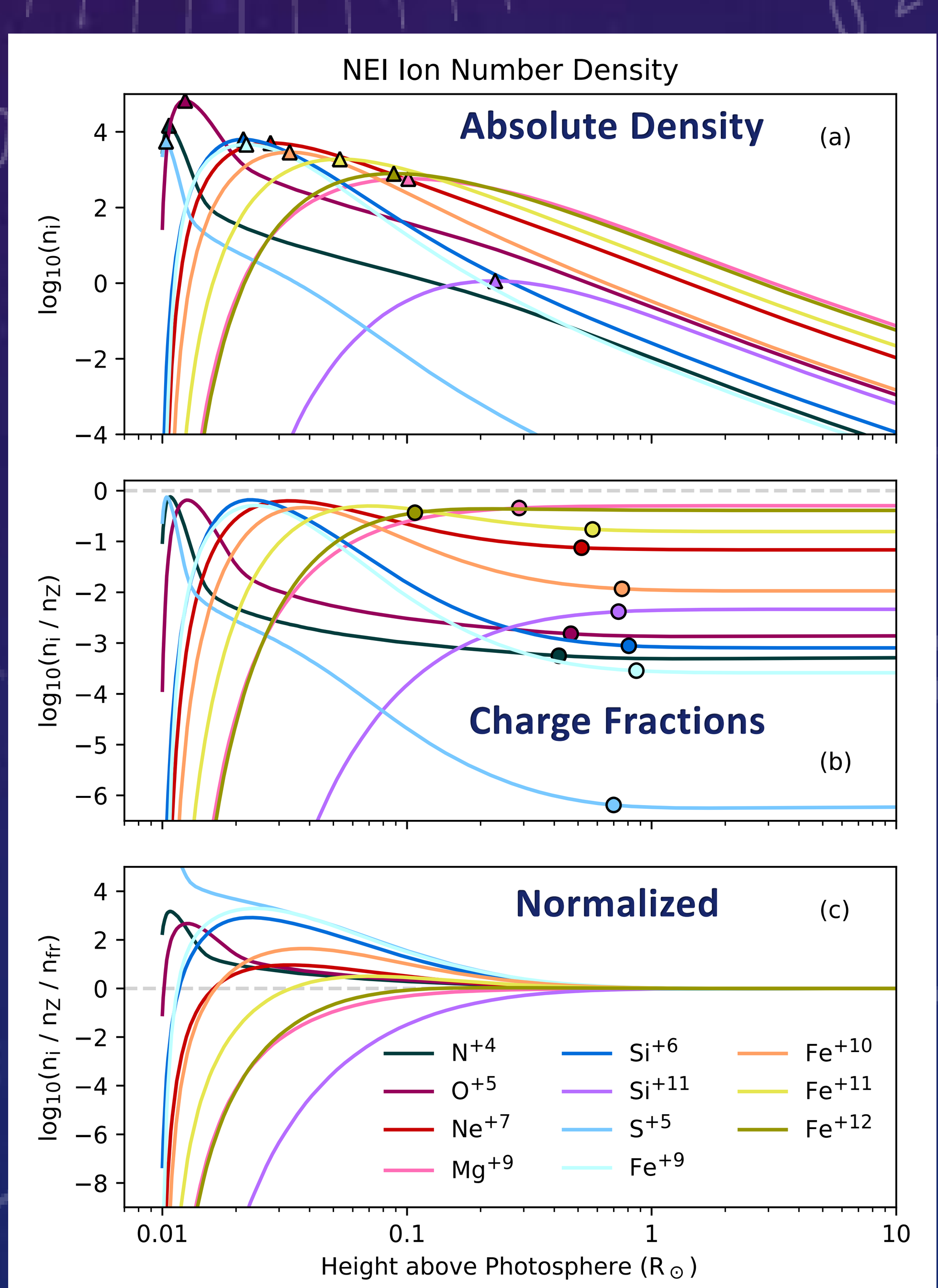
The plane of the sky is not always the dominant part of the LOS

Because ionization states are free to vary with temperature, sometimes even when the total density is high, the density of a given ion might be low. For many ions, their absolute density drops sharply in the lower corona, causing the POS to not be a significant source of photons. Measurements are not good probes of the POS below an ion's altitude of maximum density. This means these measurements aren't actually giving linear data vs height. This affects both thermal and non-thermal measurements.

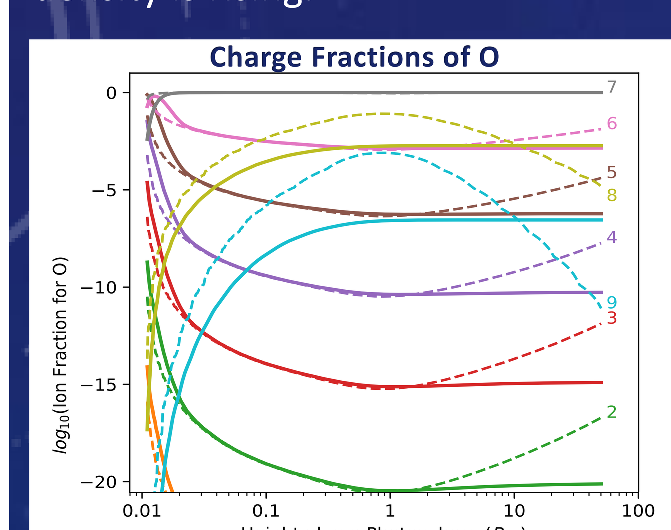
LOS: The Line of Sight along which we are looking. "LOS Effects" describe the fact that the POS is not always the only/dominant contributor of photons to the LOS measurement.
POS: The Plane of the Sky, or the x = 0 plane. Along a polar LOS (like the dashed line), it is the point with the lowest heliocentric altitude (and highest density).

The densest part of an optically-thin observation isn't always the brightest part of the line-of-sight.

Non-Equilibrium Ionization (NEI)



We use ZEPHYR data and the CHIANTI database to integrate the equation below to find self-consistent non-equilibrium ionization states for each ion of each element, which show "freezing-in" behavior due to the solar wind becoming collisionless at large distances. Freezing heights are marked by circles, and heights of maximum absolute density are marked by triangles. Below this height, the ion density drops rapidly, even though the total density is rising.

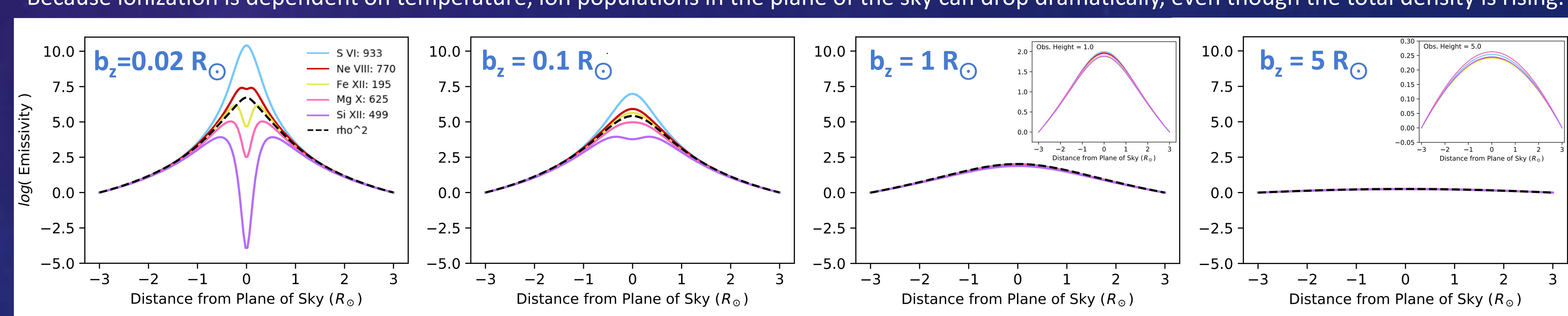


$$\frac{1}{fr^2}\frac{\partial}{\partial r}(fr^2 n_i u_i) = n_{i-1}C_{i-1} + n_{i+1}R_{i+1} - n_i(C_i + R_i)$$

Results

Line of Sight Emissivity at Different Observation Heights

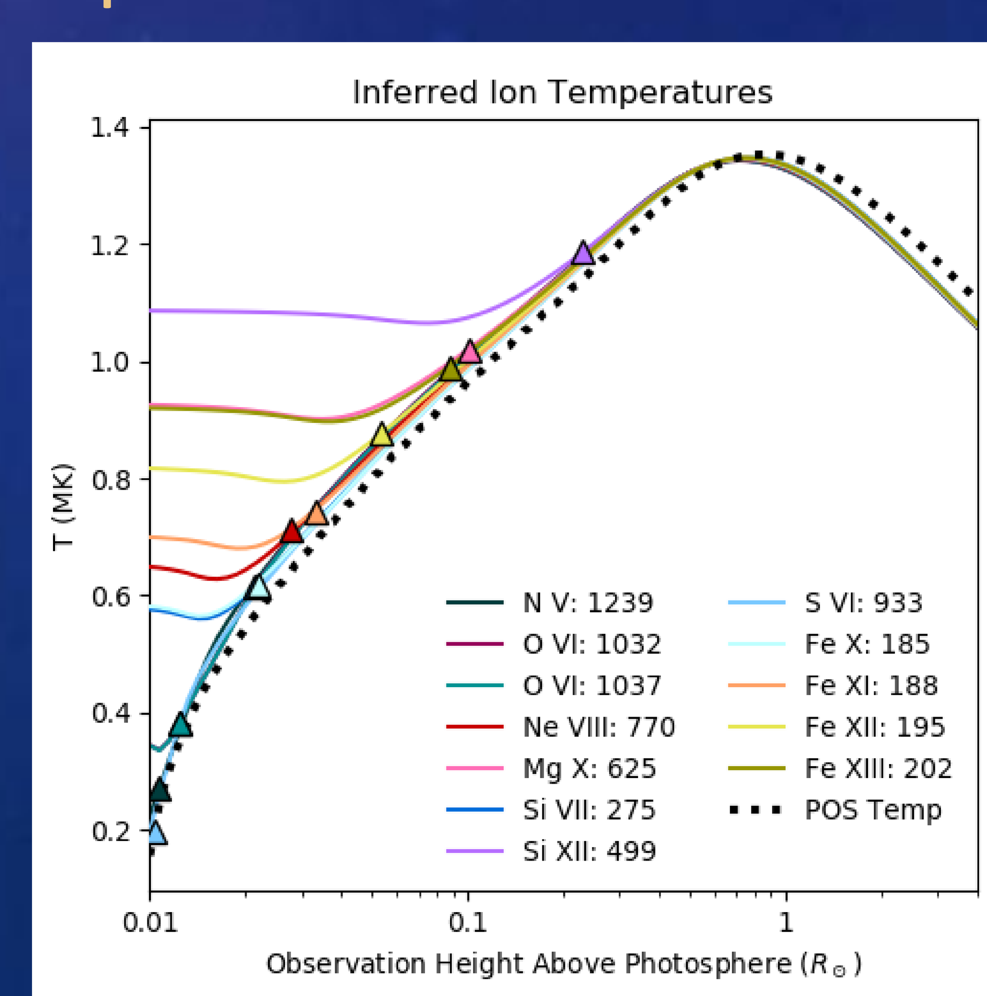
Because ionization is dependent on temperature, ion populations in the plane of the sky can drop dramatically, even though the total density is rising.



Flow-Free Case: Temperature Measurement Floors

When lines are simulated with no macroscopic velocities present in the system, the line widths only depend on temperature. The measurements follow the POS values quite well in the upper regions of the corona, but below the height of their maximum density (the "floor height", marked by triangles), the measurements plateau.

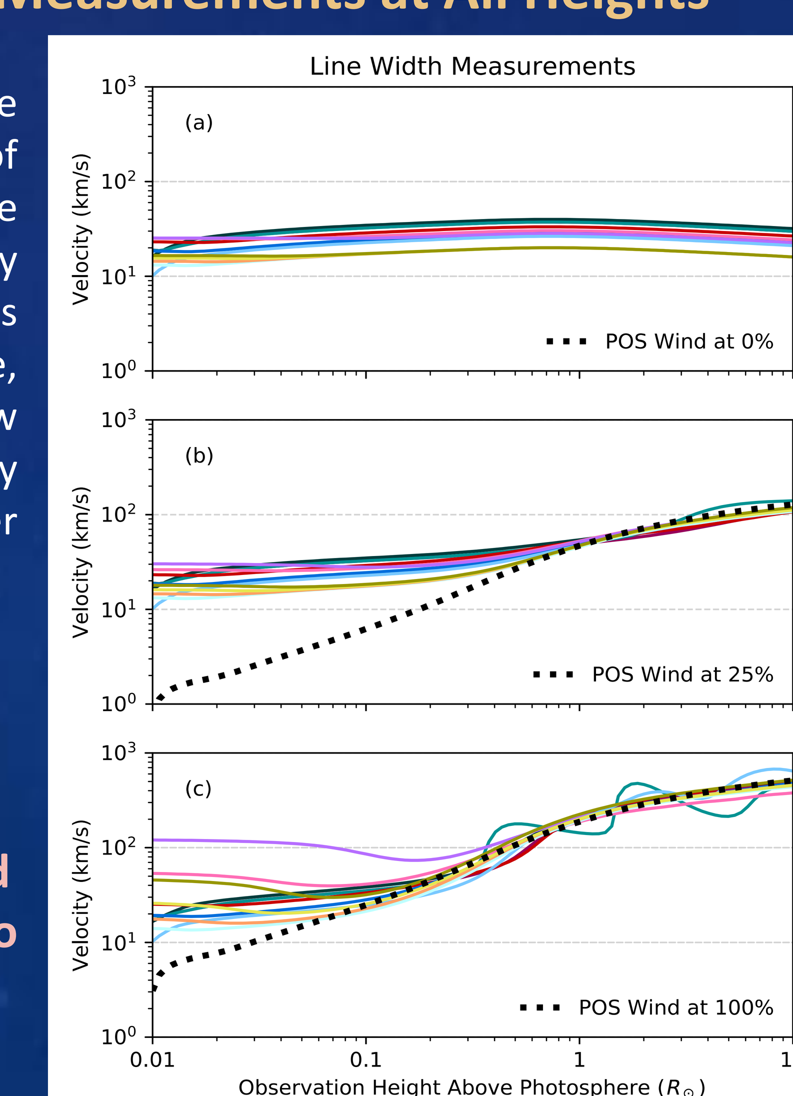
Ion lines are not good probes of temperature vs height, as they do not give information from the evacuated regions below their floor height.



Solar Wind Affects Measurements at All Heights

We simulated lines with the several different strengths of solar wind, with the relative velocity vs height provided by ZEPHYR. In the same way as in the flow-free case, measurements at low observation heights actually sample the corona at a higher altitude.

The solar wind affects measurements that are taken very low in the corona, where one would usually expect the wind to be negligible.



References

[1] Cranmer, S. R., et al. 2007, ApJS, 171, 520; [2] Del Zanna et al. 2015, A&A, 582, A56. [3] Owocki, S., et al. 1983, ApJ, 275, 354-366. [4] Curdt et al. 1997, A&A Supp, 126, 281.

Poster presented at the SHINE Conference in Boulder CO in August 2019.