Modeling Circumstellar Gas around Polluted White Dwarfs

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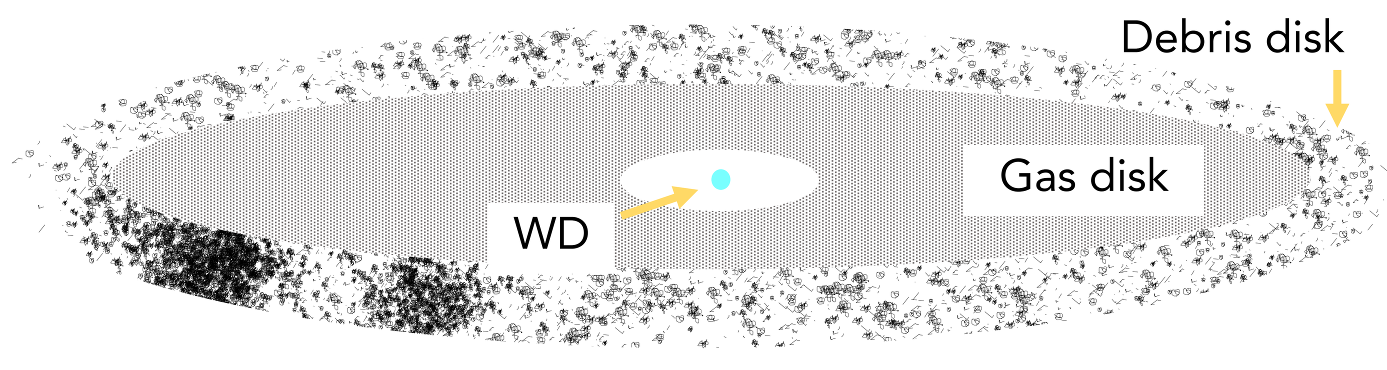
Introduction

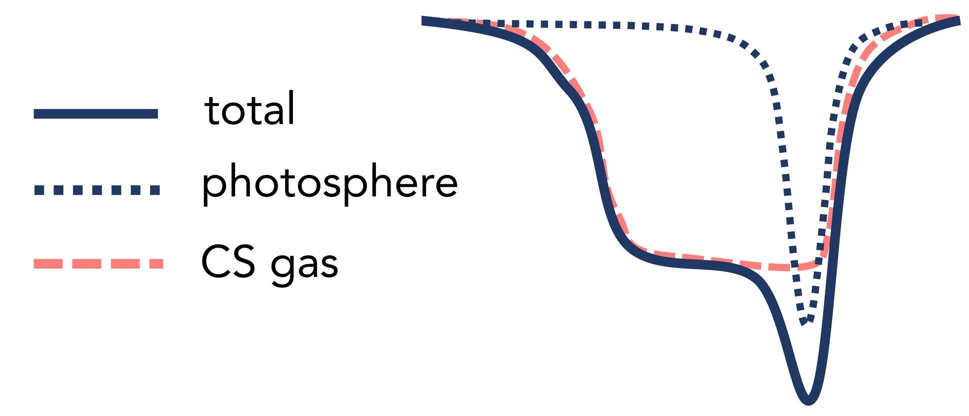
At least 30% of white dwarfs (WDs) show heavy elements in their atmospheres. This "pollution" likely arises from the accretion of planetesimals that were perturbed by outer planet(s) into the white dwarf's tidal radius. A small fraction of these WDs show either emission or absorption from circumstellar (CS) gas. The CS component arises from a gas disk produced through the sublimation of a transiting, disintegrating planetesimal. For WD114+017, the **photospheric abundances** have been measured and ***are similar to the bulk composition of the Earth.***



Observations

- Rapid changes of circumstellar gas
- Accretion from differentiated rocky material.

However, models (to date) have not yet been able to link the CS species to the total atomic abundance in gas.



Here we present a method of modeling CS gas to determine its elemental abundances.

Determining Characteristics of Two Polluted WDs with Cloudy

Cloudy is a microphysics code designed to simulate the physical conditions in 'clouds' of various densities and temperatures. It predicts the thermal, ionization, and chemical structure of the cloud, and predicts its output spectrum. Our calculations were performed with version 17.06.dd of Cloudy, last described by Ferland et al. (2017).

Input

- Continuum shape and intensity
- Absorber geometry
- Hydrogen density
- Abundances

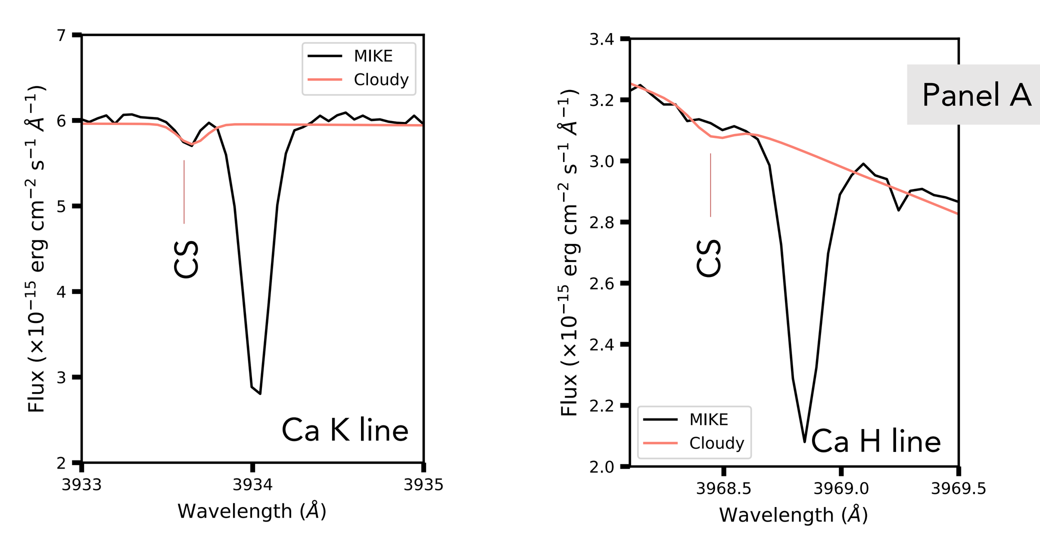
Output

- Temperature with depth
- Optical depths
- Column densities

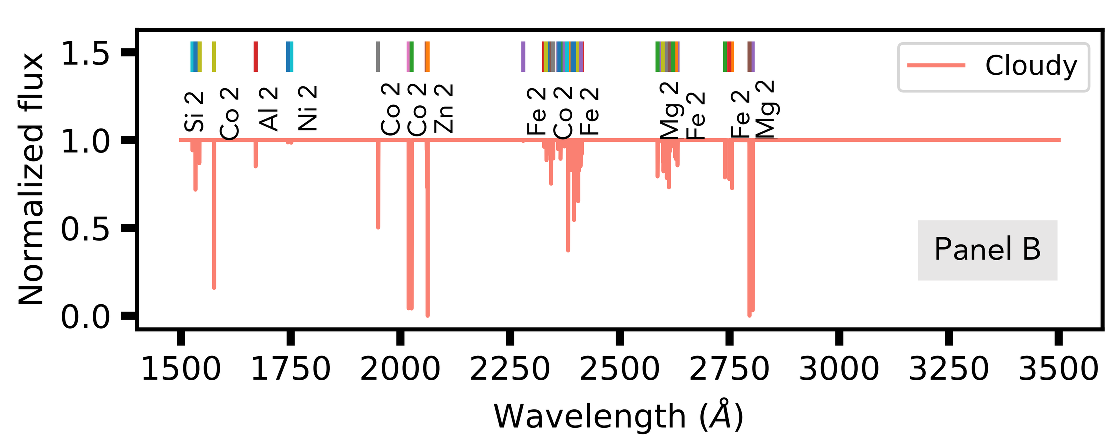
Method:

① n(Z) photosphere ~ n(Z) CS
② Run Cloudy with n(Z)
③ Build spectrum using Voigt profiles
④ Compare to data
⑤ Repeat if necessary

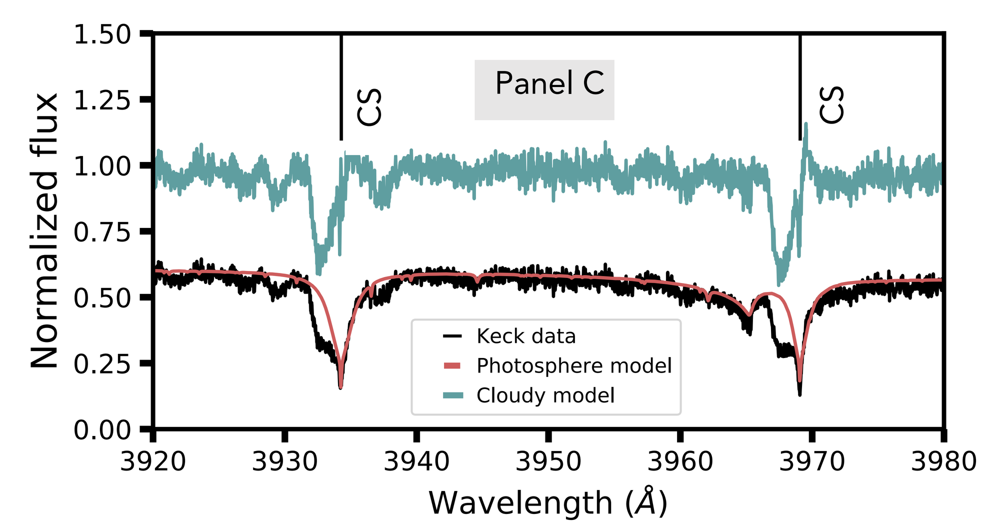
WD 1124-293



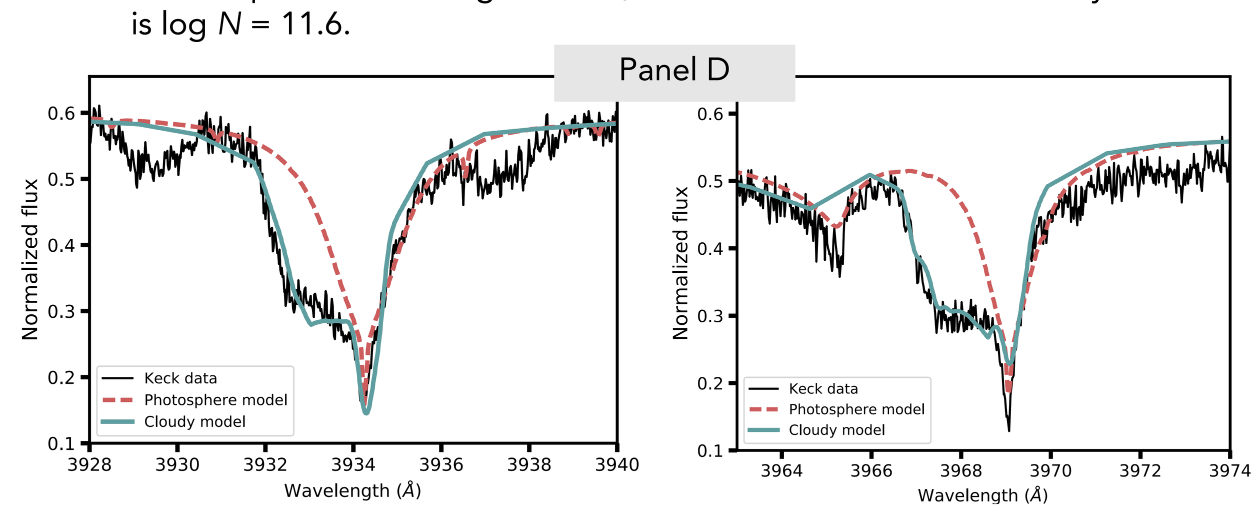
Panel A: Comparison of Cloudy model to MIKE Magellan observations of WD1124. Right, CS absorption seen blue-shifted relative to the photospheric component is well-fit by salmon-colored Cloudy model. The temperature of the gas is ~4450K and the Ca column density N is log N = 10.3.



WD 1145+017



Panel C: We divide the data by a high resolution model to highlight the CS absorption features of calcium. Panel D: Using Voigt profiles, we fit the features with 10 components with velocities -160 km/s to +20 km/s. The temperature of the gas is ~10,000 K and the Ca column density N is log N = 11.6.



	WD 1124-293	WD 1145+017
Mass ($M_\odot$)	0.66	0.68
Radius ($R_\oplus$)	1.4	1.26
Temp (K)	9367	15 000
Log (g)	7.99	8.15
Distance (pc)	33.6	141.7

Table 1. Stellar parameters. The log g, T_{eff}, mass, and radius are based on photometric SED fits to WD cooling models.

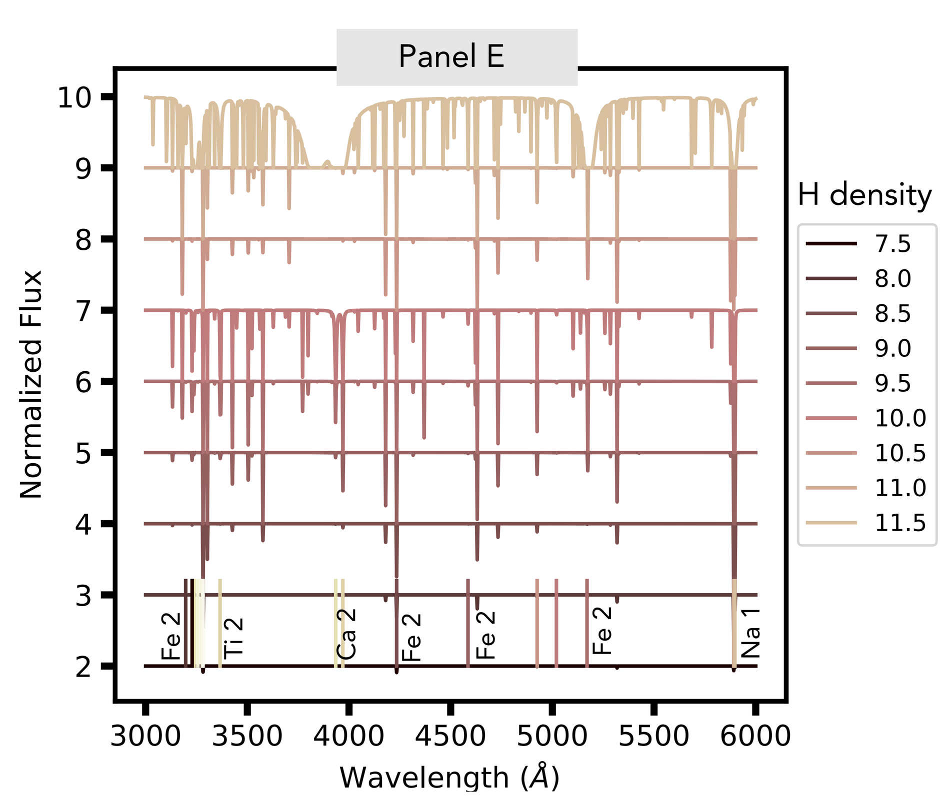
Results in Figures:

Panels A – D show our preliminary fits to two WDs with CS gas. For WD1145, we find a preliminary Ca CS abundance consistent with the photospheric abundance in Xu et al. 2016. For WD1124, we can test the models with future observations. If successful, we will predict the observability of CS gas around WDs.

Predicting the Observability of CS gas around WDs

We build a grid of models and place constraints on the gas masses needed for detection with current observatories, which can be used to constrain the frequency of CS gas around statistical samples of WDs. These models of CS gas around polluted white dwarfs will provide a key to understanding the instantaneous composition of the material flowing from the planetesimals, will guide modeling of the transits and of the dust in these polluted systems, and will help constrain the radial locations of different gas components.

- Temps: 9000 K to 25000 K
- Log g: 6.5 to 9.5
- Input: Blackbodies and Koester WD models



Panel E: An example of our grid for a WD with: T = 15000K, log g = 8 and hydrogen densities (log): 7.5 - 11.5

Overall Results

- We determined the preliminary abundances of CS lines arising from planetesimals using Cloudy code
- Created a grid of self-consistent models of CS gas in orbit around various types of DA WDs

What's next?

- Continue to refine fits to polluted WDs to better constrain these systems in a self-consistent manner
- Incorporate the velocity structure into our fits

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References: 1. Koester et al. 2014, 2. Vanderburg et al. 2015, 3. Holberg, & Bergeron 2006, 4. Kowalski, & Saumon 2006, 5. Tremblay et al. 2011, 6. Bergeron et al. 2011, 7. Xu et al. 2016, 5. Croll et al. 2017, 6. Bonsor et al. 2017, 7. Jura & Young 2014, 8. Kral, Clarke, & Wyatt 2017