# Warm Gas Cloud Detected Towards Star HD168941

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## Abstract

By using spectra measurements of HD168941, a gaseous cloud within the interstellar medium has been found to fit the warm cloud model. This gives the temperature to be about 6000k


## Introduction

Gas clouds are the building blocks for star formation. Thus measuring their elemental abundances gives important information about the condition, composition, and evolution of the gas in the Milky Way. Heavy elements regulate gas temperatures through a variety of interstellar heating and cooling processes. The formation rates of molecules through gas-phase chemistry or on grain surfaces depend on the abundances of the reacting species. A majority of heavy elements have gas phase abundances that are less than expected due to the particles forming dust and heavier components. The lack of abundance due to dust forming is also known as depletion. By measuring gas-phase abundances, more information about elemental depletion in different parts of the Galaxy can be obtained.

## Procedure

Using data provided by the HST, the spectrograph of the star HD168941 was analyzed. To obtain a column densities, unsaturated lines must be used. The relationship between the absorption intensity $I_{obs}(\lambda)$ and the optical depth $\tau(\lambda)$ is given by

$$I_{obs}(\lambda) = e^{-\tau(\lambda)} I_e(\lambda)$$

$$e^{-\tau(\lambda)} = \frac{I_{obs}(\lambda)}{I_e(\lambda)}$$

$$\tau(\lambda) = \ln\left(\frac{I_e(\lambda)}{I_{obs}(\lambda)}\right)$$

where $I_e(\lambda)$ is the continuum. The optical depth can then be related to the number density.

$$\tau(\lambda) = \frac{\pi e}{m_e c^2} f\lambda^2 N(\lambda)$$

$$N(\lambda) = \int N(\lambda) d\lambda$$

Changing to a function of velocity gives the following form.

$$N_a(v) = \frac{m_e c^2}{\pi e} (f\lambda)^{-1} \ln\left(\frac{I_e(v)}{I_{obs}(v)}\right)$$

$$N_a(v) = 3.768 \times 10^{14} (f\lambda)^{-1} \ln\left(\frac{I_e(v)}{I_{obs}(v)}\right)$$

The abundance of a particular element is given by the ratio between the density of said element to the density of Hydrogen in the cloud. However, only the column density has been measured. Fortunately, the ratio between the column densities is equivalent to the ratio between the volume densities.

$$T = \frac{mb^2}{2k} = A\left(\frac{b}{0.129}\right)^2$$

$$b = \frac{FWHM}{2\sqrt{\ln 2}} = 0.6006 FWHM$$

$$Abundance = \frac{n(element)dl}{n(H)dl} = \frac{N(element)}{N(H)}$$

Observations by Diplas & Savage (1994) gives us values for the Hydrogen column density. The resulting data is not useful until a comparison with our sun is done. The difference between the log abundance of the element in the cloud and the sun is the final product allowing for a complete analysis. Observations by Asplund et al. (2009) provides numerical values for the corresponding element's abundance within the sun. However 12 must be subtracted from the log to get the true abundance

$$Abundance = \log(\frac{N_{\odot}(element)}{N_{\odot}(H)}) - 12$$

Data

Looking at the absorption features, N I, S II, Cl II, Ge II, Mg II, Si II, Ni II, O I, Fe II and Cu II provided consistency among their species. However, Si II and S II indicated that they were very much saturated. Thus only a lower bound for the abundance can be estimated.

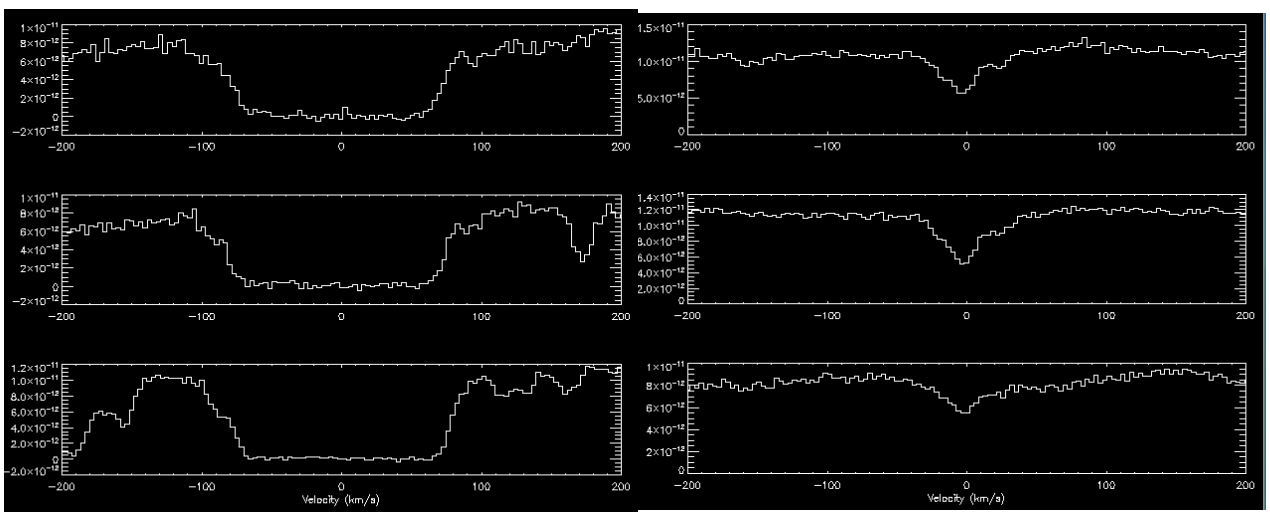


Figure 1: On the left are 3 species of Si II while on the right are 3 species of Ni II. This is a saturated vs. unsaturated case

To find make sure that the absorption lines in question are saturated, I compared the species of each element. Species that have differentiating peaks confirm the suspicion.

| Element | log(X/H)-log(X/H)$_{\odot}$ | Warm Model | Cool Model |
|---|---|---|---|
| Si II | -1.8814983 | -1.26 | -0.53 |

| | | | |
|---|---|---|---|
| Cu II | -0.95894398 | -1.53 | -0.82 |
| Mn II | -1.1531902 | -1.32 | -0.90 |
| Mg II | -0.77084716 | -1.24 | -0.89 |
| Fe II | -1.5094329 | -2.09 | -1.25 |
| Ni II | -1.4483633 | -2.46 | -1.51 |

Figure 2: metal abundances relative to the sun. Note how Silicon II looks like an outlier. This is due to the saturation in the absorption feature.

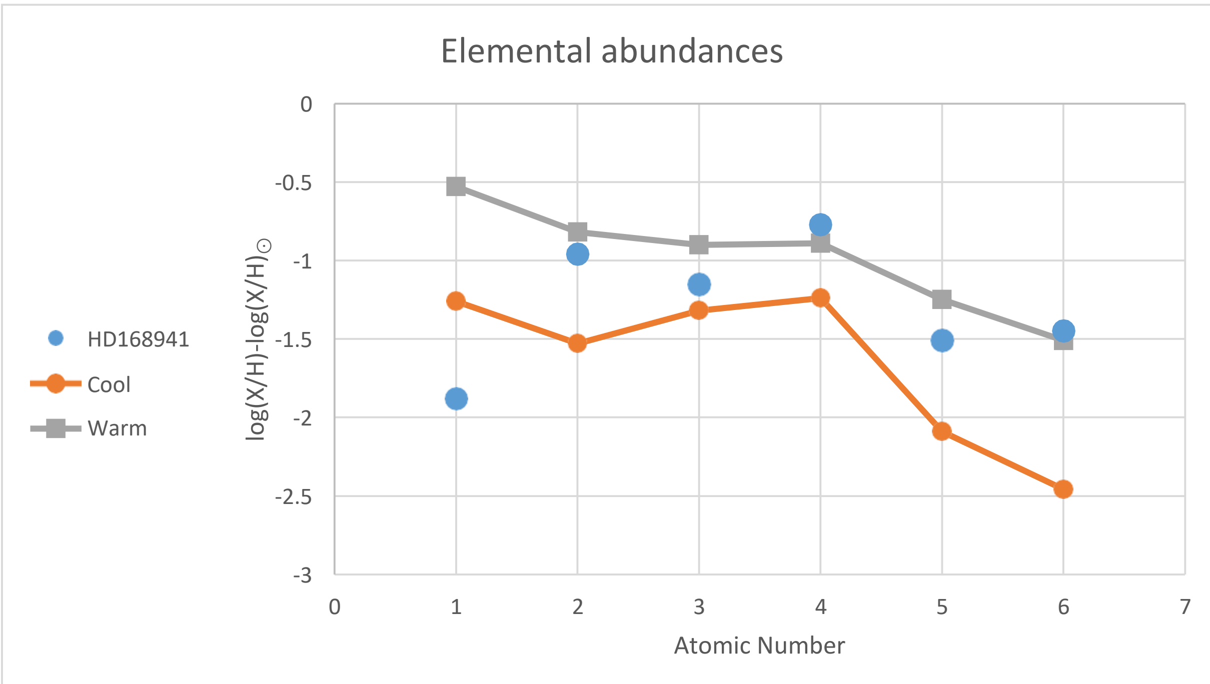


Figure 3: A plot of the elemental abundances in the cloud of interest and two model clouds: one warm and one cool. As one can see, if the saturated Si II is ignored, the cloud fits well with the warm model with a smaller chi squared.