# HIGH PRECISION ABUNDANCES IN THE 16 CYG BINARY SYSTEM: A SIGNATURE OF THE ROCKY CORE IN THE GIANT PLANET

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## INTRODUCTION

We study the stars of the binary system 16 Cygni to determine with high precision their chemical composition. Knowing that the component B has a detected planet with minimum of 1.5 Jupiter masses, we investigate if there are chemical peculiarities that could be attributed to planet formation around this star.

## OBSERVATIONS

We have obtained high resolution (R=81,000) and high S/N (700 at 600nm) spectra of 16 Cyg A, 16 Cyg B and the Sun (Ceres) with ESPaDOnS on CFHT, using the same instrumental configuration for all stars, wich is vital for our differential analysis.

## ABUNDANCE ANALYSIS

We used the line-by-line differential method to obtain stellar parameters and chemical abundances. The abundances were determined using the 2002 version of the LTE code MOOG (Sneden 1973) with Kurucz ODFNEW model atmospheres (Castelli & Kurucz 2004).
The adopted line list in this work is a updated version of that presented in Meléndez et al. (2012) and the equivalent width measurements were made manually with IRAF.
The stellar parameters were obtained by differential excitation equilibrium and differential ionization equilibrium (Table 1 and Table 2).
We obtained the abundance of 18 elements: C, O, Na, Mg, Al, Si, S, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, and Zn. All abundances were differentially determined line-by-line using the Sun as standard in a first approach and then using 16 Cyg B as reference to obtain the 16 Cyg A-B ratios.

**Table 1**
Stellar Parameters of 16 Cyg A and B Obtained using the Sun as Reference for our Differential Analysis.

| Estrela | Teff(K) | [Fe/H] (dex) | Log g (dex) | Vt (km/s) |
|---|---|---|---|---|
| 16 Cyg A | 5830±11 | 0.101±0.008 | 4.30±0.02 | 0.98±0.02 |
| 16 Cyg B | 5751±11 | 0.054±0.008 | 4.35±0.02 | 0.90±0.02 |

**Table 2**
Stellar Parameters of 16 Cyg A and B Obtained using 16 Cyg B as Reference for our Differential Analysis.

| Estrela | Teff(K) | [Fe/H] (dex) | Log g (dex) | Vt (km/s) |
|---|---|---|---|---|
| 16 Cyg A | 5830±7 | 0.047±0.005 | 4.30±0.02 | 0.98±0.01 |
| 16 Cyg B | 5751±6 | | 4.35±0.02 | 0.90±0.01 |

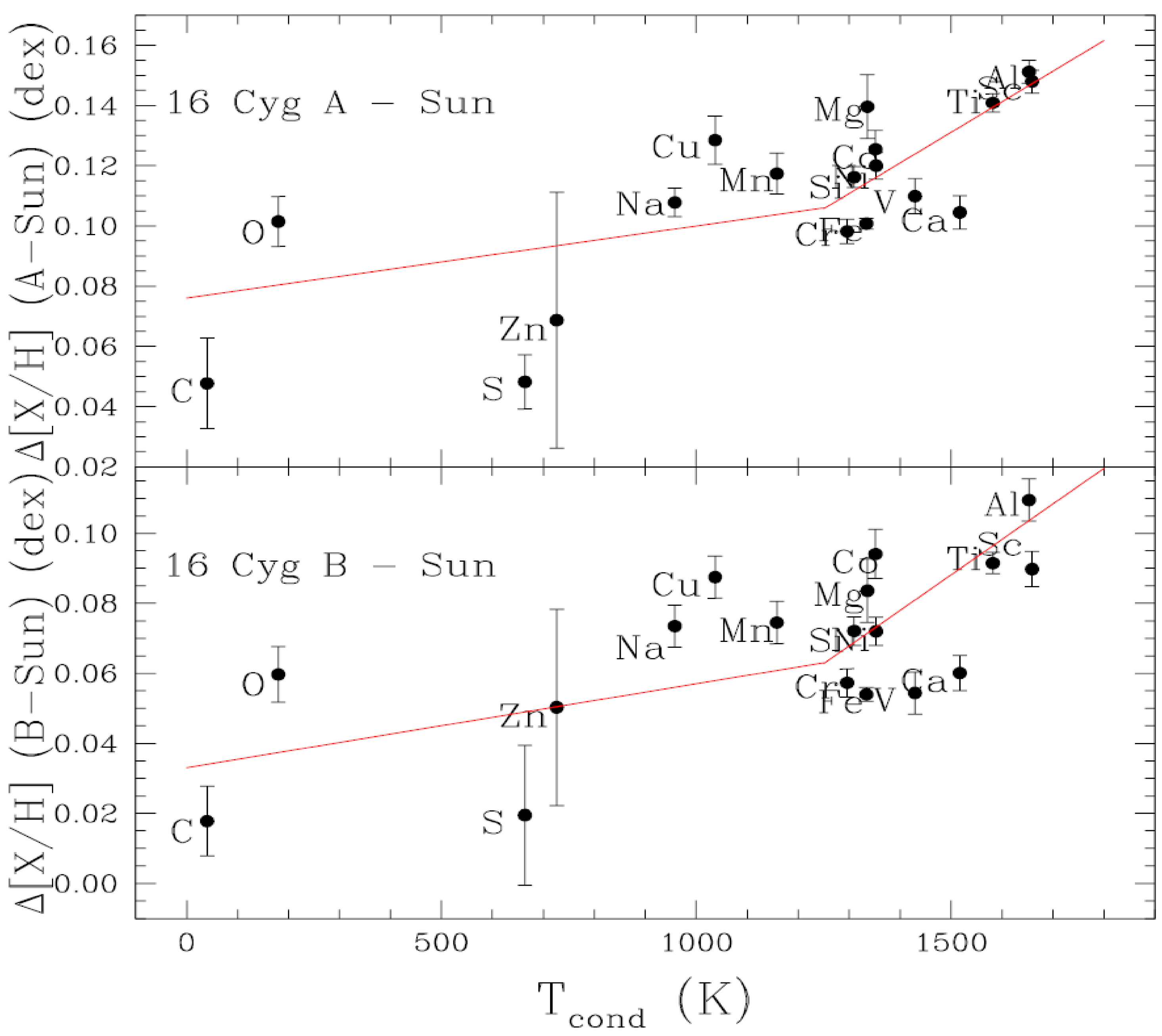


**Figure 1** – Differential abundance of 16 Cyg A – Sun (top panel) and 16 Cyg B – Sun (bottom panel) vs. condensation temperature.

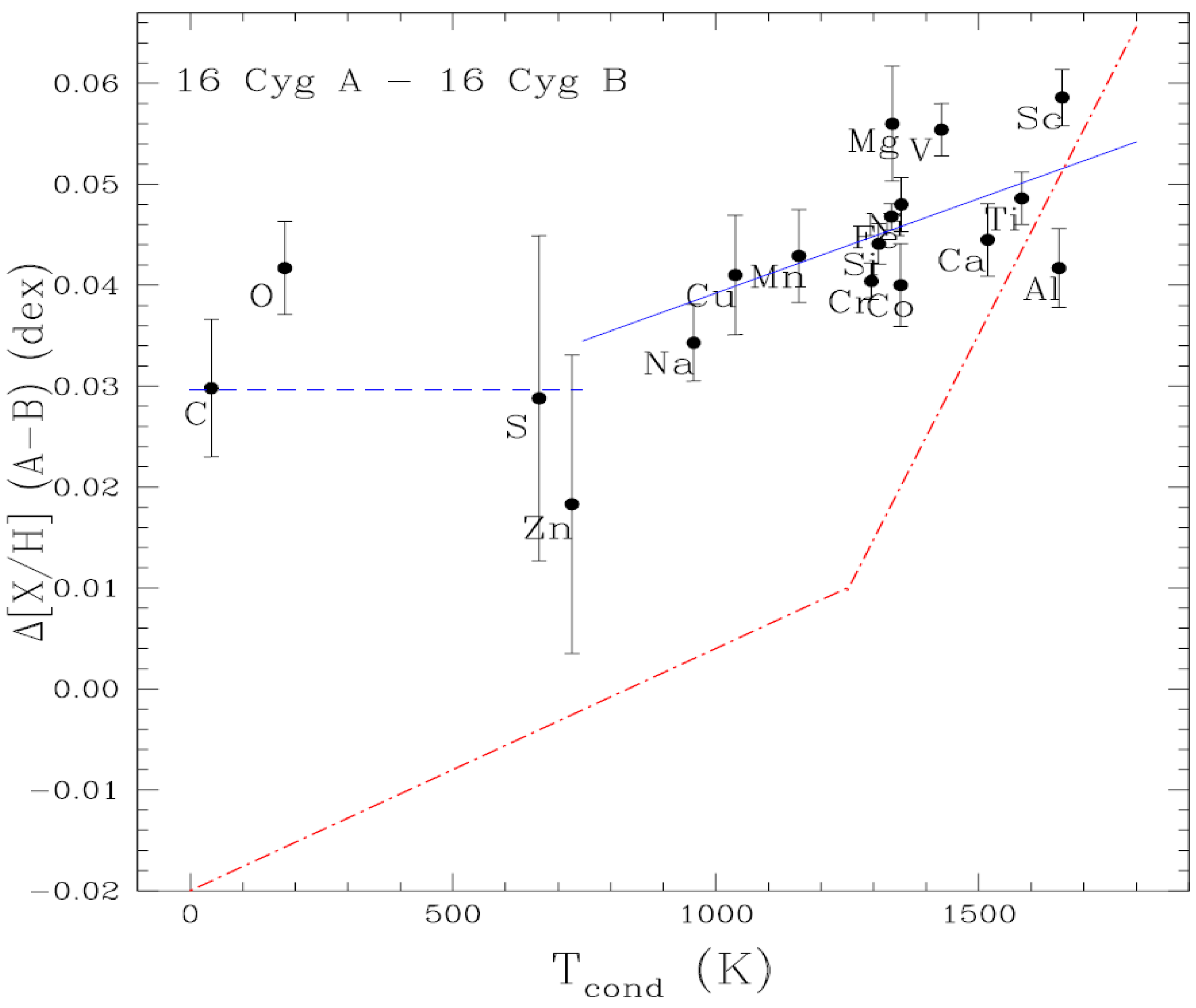


**Figure 2** – Differential abundances of 16 Cyg A – 16 Cyg B versus condensation temperature. The dashed line is the average of the volatiles and the solid line the trend of the refractories. The dot-dashed line is the mean trend obtained by Melendez et al. (2009) for 11 solar twins compared to the Sun, after a vertical shift is applied to match the highly refractory elements in A-B.

## DISCUTION AND RESULTS

The differential abundances of the 16 Cyg pair relative to the Sun are shown in Figure 1. Both 16 Cyg A and B show abundances that have a clear trend with condensation temperature. There is a reasonable agreement with the mean trend of 11 solar twins relative to the Sun (solid lines) by Melendez et al. (2009).
Figure 3 shows the differential abundances of 16 Cyg A relative to 16 Cyg B. All elements seem enhanced in 16 Cyg A, with the volatiles showing a difference of about 0.03 dex and the refractories show larger differences (about 0.06 dex) with a slope of $1.88 \pm 0.79 \times 10^{-5}$.
The overall deficiency in the abundances of 16 Cyg B (compared to 16 Cyg A), could be attributed to the formation of its giant planet, as the metals missing in 16 Cyg B could have been taken from the proto-planetary disk to form its gaseous giant. The higher deficiency of refractories in 16 Cyg B, means that the giant planet 16 CygBb may have an excess of refractories, which could be due to its rocky accretion core.
We estimate the mass of this rocky core, following Chambers (2010), by adding a mixture of the composition of the Earth and CM chondrites to the convective zone of 16 Cyg B. The estimated mass is 1.5 – 6 Earth masses that is consistent with Jupiter's core mass of 5±5 Earth masses (Guillot 2005).

## REFERENCES

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