GHRS OBSERVATIONS OF THE B_p STAR, chi Lupi

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ABSTRACT. High resolution, high S/N ultraviolet observations of the ultra-sharp-lined B_p star chi Lupi, obtained with the Goddard High Resolution Spectrograph, reveal an unprecedented level of spectroscopic detail. Spectral synthesis of the Hg II λ1942 resonance line confirms the extreme isotope abundance anomaly of mercury in this star. The data also provide the first positive detections of Ru II and Zr III, and tentative detections of As I and Ge II.

1. INTRODUCTION

The chemically peculiar B star, chi Lupi, is ideally suited as a target with which to assess the resolving power and effective S/N ratio of GHRS data. It is bright. It possesses an exceedingly sharp-lined photospheric spectrum ($v \sin i < 1.2$ km s^{-1}), containing a complex assortment of weak and strong lines. It is a double-lined binary, but the secondary contributes only weakly to the observed UV spectrum.

Chi Lupi is an extreme member of the non-magnetic sequence of B_p stars of the "HgMn" class. It's photosphere is enriched in mercury by a factor of 100,000 with respect to the solar system abundance. The shape and position of Hg II λ3984 suggest that Hg in the line-forming region is dominantly in the form of ^{204}Hg (White, et al. 1976). For comparison, ^{204}Hg constitutes only 7% of the terrestrial isotope blend. One objective of our GHRS observation was to independently verify the Hg isotope anomaly in chi Lupi, based on the profile of the Hg II resonance line at 1942 A, prior to a more general study of low excitation UV lines of Hg I, Hg II and Hg III aimed at testing the radiatively-driven diffusion models of Michaud, et al. 1974.

Only a small sample of the periodic table is represented in abundance analyses which rely solely on optical-wavelength spectra. At UV wavelengths we can observe numerous intrinsically strong transitions of low-abundance elements and lines of ionization states that are not observable from the ground. In this way we can more thoroughly "fill in" the periodic table in order to systematically study the patterns of

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abundance anomalies from element to element as well as from star to star. This was also a key objective of our observations.

The data were obtained in February, 1991, with the Echelle-B, small-aperture mode of the GHRS. In this mode throughput is reduced by a factor of four due to the reduced central intensity of the aberrated PSF, but spectral resolution is unaffected by spherical aberration. The resolving power is $\lambda/\delta\lambda \simeq 87,000$ and the S/N ratio per data point is $\simeq$ 100 near the continuum. The observation spanned 10.4 A, centered on the 1942 A line of Hg II.

2. DEMONSTRATION OF A NEW CAPABILITY

In Figure 1 we illustrate the comparison of a 2 A segment of the spectrum of chi Lupi obtained with the IUE in high dispersion, and that obtained with the GHRS. Our purpose is not to denigrate the very important capabilities of the IUE, but rather to illustrate as clearly as possible an important new capability now available to spectroscopists. We believe this is the most detailed ultraviolet spectrum ever obtained of a star other than the sun. We see here for the first time lines of Ge II, As I, Zr III and Ru II.

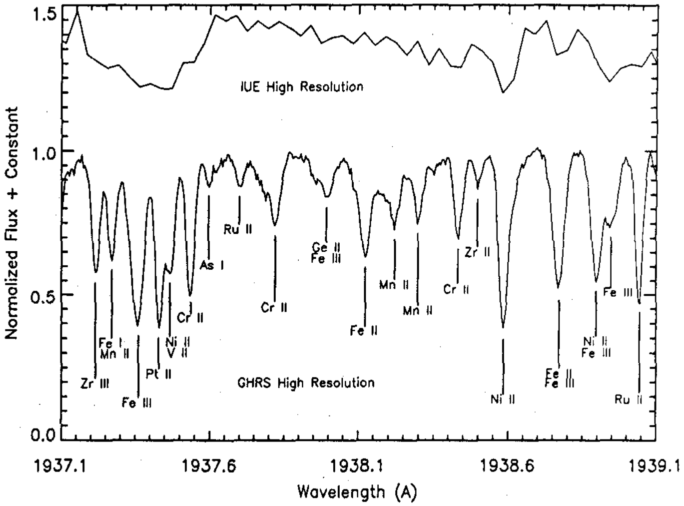

Figure 1. Comparison of IUE and GHRS Echelle observations of chi Lupi

3. THE Hg ISOTOPE ANOMALY

Figure 2 shows the result of our investigation of the Hg isotopic abundance distribution, using λ1942. Details may be found in Leckrone, Wahlgren and Johansson (1991). The observed profile of the Hg II resonance line is compared here to two computed profiles, one corresponding to the terrestrial isotope abundance mix, and the other corresponding to nearly pure ^{204}Hg. The observed profile is well matched in the latter case.

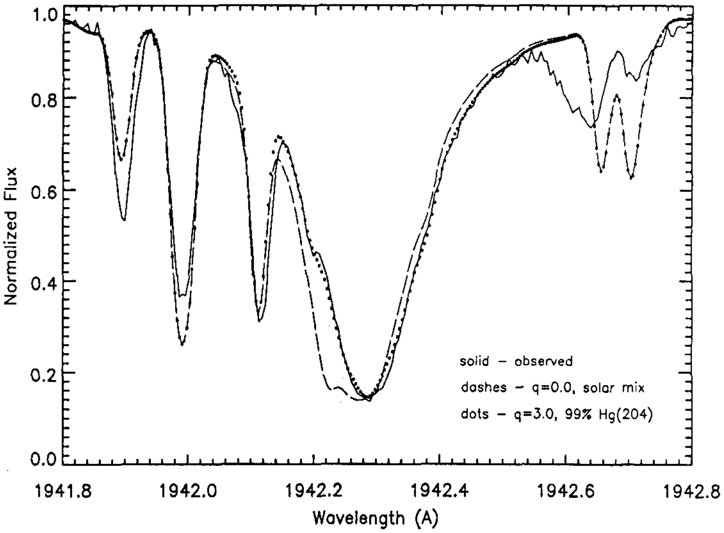

Figure 2. Observed and theoretical profiles of Hg II λ1942.3.

4. "FILLING IN" THE PERIODIC TABLE AND THE ATOMIC DATA PROBLEM

The atomic data base needed to accurately synthesize UV spectra currently lags well behind our present observational capabilities both in comprehensiveness and in accuracy. This is well illustrated in Figure 3, where we have superimposed the observed chi Lupi spectrum in a 1.2 A interval and our initial computation, using Kurucz's latest semi-empirical transition probabilities for the iron group ions and other species. The match is unsatisfactory, both because of transitions which are not included in the data base, and because of large systematic errors for particular transitions of common ions, such as Fe II and Cr II. Further discussion may be found in Leckrone, Johansson and Wahlgren (1991).

In Figure 4 we show the same interval, but here we have substantially improved the completeness and accuracy of the atomic data, by means of detailed (Cowen code) calculations where possible, or by other means (such as by comparison with corresponding transitions in homologous ions, or by extensions of isoelectronic sequences). The most interesting result is the first measurement of the abundance of the important s-process element, Ruthenium, in an early-type star. We find it to be approximately 2 dex overabundant relative to the sun.

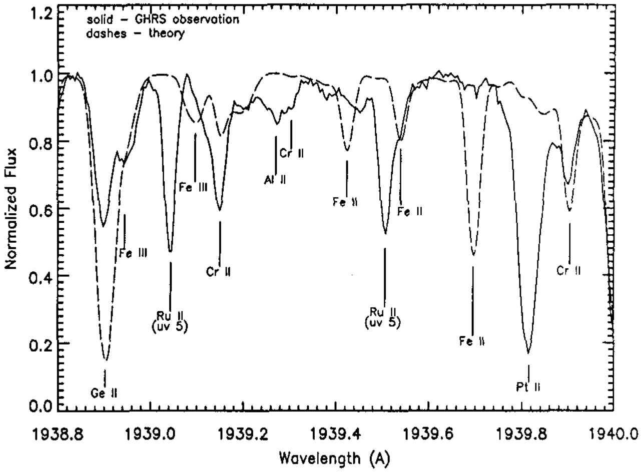

Figure 3. Initial synthesis using readily available atomic data.

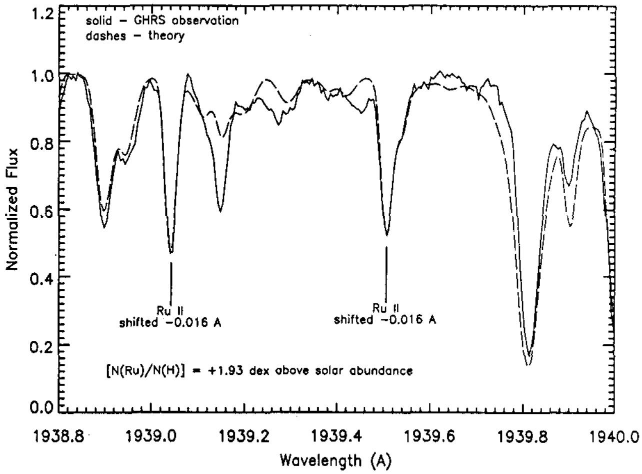

Figure 4. Improved spectrum synthesis with estimated transition probabilities for Ge II, Ru II, Pt II and Fe II. All observed Ru II lines were displaced from published laboratory wavelengths by 16 mA.

REFERENCES

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