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DOUBLE STARS AS TRACERS OF TINY STRUCTURES IN THE INTERSTELLAR MEDIUM

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ABSTRACT

Observed spectra of stars around the Sun have indicated that the Sun is located in a gas cavity, extending to 100pc. This gas cavity is called the "Local Bubble". The density of the interstellar medium (ISM) in the local bubble is about one tenth that of the average for the ISM in the Milky Way. Furthermore, some structures such as gas planes and strings in the local bubble are probably the result of supernovae. These, due to their low temperatures, can not be observed in the visible and infrared. The only way to do so is to measure the spectra of nearby stars so that the light of stars passing through the local bubble is absorbed by existing gas and the resulting spectral lines from absorption can be measured. In this study, we use binary stars to trace the local bubble structures through lines such as the Na I Doublet. First, we determined the observed spectral lines of stars by HARPS and FEROS echelle spectrographs. Then, we made synthetic spectra with the ATLAS9 code. Finally, the difference between the observational and synthetic spectra confirms the existence of the Na I Doublet in the local ISM.

Key words: ISM: tiny structures: Na I Doublet,Balmer Series, binary stars, Local Bubble , ATLAS 9, synthetic spectra

1. INTRODUCTION

Recent surveys have revealed a significant population of tiny structures in the Galactic Interstellar Medium (ISM). As the temperature ranges of low density ISM regions were derived to be about 10 K ∼ 300 K, it has provided the opportunity to discover various neutral and ionized structures, detected with narrow and optically thin spectral lines.

Discovery of the Orion Nebula (Messier 42, NGC 1976) fueled discussion about gas clouds. The first interstellar absorption lines were observed by Hartmann. The development of astronomical instruments strongly impacted this field in 1973 when Lyman Spitzer's UV satellite, Copernicus, allowed transitions of abundant species to be measured, such as H_2, HI Ly_α, Na I, and Ca II.

Furthermore, many observations report that the Sun is embedded in a small interstellar cloud, with $T = 7000$ K and n $\sim$0.1 cm^{-3}, itself located in a region of low density (n $\sim 5 \times 10^{-3}$) and high temperature, T $\sim 10^6$, called the local bubble. This extends in all directions to at least 50 pc and and up to about 300 pc away.

2. CATALOGUES

•**Hipparcos** : The Hipparcos Input Catalogue was constructed as the observing program for ESA's Hipparcos astrometry mission. This has resulted in a catalogue of stellar data including up-to-date and comprehensive information on positions, proper motions, magnitudes, colors, and when available, spectral types, radial velocities, multiplicity and variability. The catalogue is complete to well-defined magnitude limits, and includes a substantial sampling of the most important stellar categories present in the solar neighbourhood beyond these limits. 118000 stars are included in the Hipparcos Input Catalogue. The mean accuracies achieved, as demonstrated by comparison with the Hipparcos results (Turon et al. 1995, A&A, 304, 82T) are 0.3 arcsec for the positions and 0.25 mag for the Hp magnitude, with accuracies of 0.02 mag or better for more than a third of the catalogue[1].

•**WDS** : The Washington Visual Double Star Catalog (WDS)[2] is the successor to the Index Catalogue of Visual Double Stars, 1961.0 (IDS; Jeffers & van den Bos, Publ. Lick Obs. 21). The WDS covers the entire sky, and is intended to contain all known visual double stars for which at least one differential measure has been published. The WDS is continually updated as published data become available[3,4].

[1]http://cdsarc.u-strasbg.fr/viz-bin/Cat?I/239
[2]http://ad.usno.navy.mil/wds/
[3]http://cdsarc.u-strasbg.fr/viz-bin/Cat?B/wds
[4]"This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory."

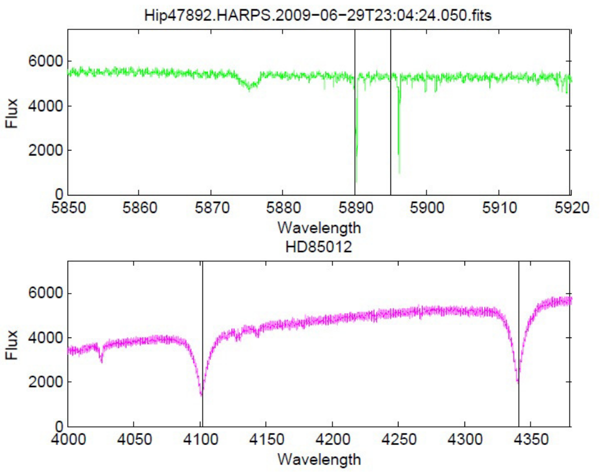

Figure 1. Top panel, Spectral lines in Na I Doublet, 589.0 nm and 589.5 nm. Bottom panel, Spectral lines in $H_\beta = 486.1$ nm & $H_\delta = 410.2$ nm; One of the 649 binary stars, HD 85012

3. DATA ANALYSIS

3.1. Selected Stars

WDS and Hipparcos provide us with complete information about different binaries parameters, from which we can select stars suitable for the goals of our study. First, we determined the stars with the following properties:

- Angular sepration of stars should be greater than 1 arcsec: $\delta > 1'$
- Spectrum classification of binaries should be O, B or A.
- Stars should be observable from the following echelle spectrographs: **HARPS** and **FEROS**[5].

3.2. Programming

Then, by running a well-defined python program, we are able to corrolate these two catalogues, resulting in 649 binary stars which satisfy the above conditions. Now we have the name of all stars in the WDS catalogue with Hipparcos ID and more comprehensive information such as distances and B-V index.

Taking FITS files from the database of the European Southern Observatory, we extract data and plot line spectra of binary stars in the Balmer Series[6] and Na I Doublet using MATLAB.

3.3. Comparision

In Figure 1, two narrow and optically thin spectral lines of Na I Doublet are clear, which is true for the most of the binary stars. Regarding the spectral classification of our stars, the hot stars in the O, B, A ranges possess neutral and ionized hydrogen lines, so the exsitence of absorption narrow lines of Na I Doublet in the stellar spectra indicate that the Na I Doublet does not belong to the binary stars. In additon, redshifts are observed between the Na I Doublet lines and H line spectra. Stars with high SNR spectra have been selected for producing synthetic spectra. In addition, H_δ was selected because it is the most obvious and nearest absorption line to compare with the Na I Doublet in our binary spectra. Using ATLAS9 code, running atlas and synthe files, by inserting the properties of stars such as temperature, gravity, and turbulence velocity, 72 outer layers of the stellar atmosphere were produced synthetically. Then, by calculation of Guassian line width and wavelength ranges[7], we obtain synthetic spectra of binary stars which are the nearest stars in the local interstellar to the Sun, with parallaxes in the range of 1.01 $\lesssim$ plx $\lesssim$ 7.72.

[5]HARPS and FEROS are belonged to European Southern Observatory (ESO) with high resolution 115000 and 48000, respectively

[6]H_α, H_β, H_γ, H_δ

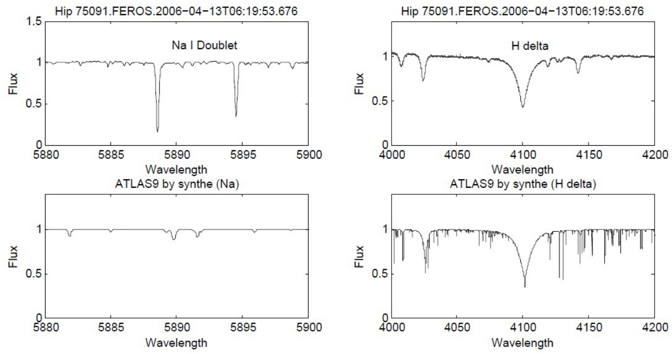

Figure 2. Top row: observational spectra at $\lambda = 589.0$ nm and 589.5 nm and $\lambda = 410.2$ nm. Bottom row: synthetic spectral lines in the stated wavelength, Hip 75091

4. CONCLUSION

Based on the comparison, as seen in Figure 2, we firmly revealed the differences between observational and synthetic spectra, and determine that there is no Na I Doublet absorption lines (or there is a too weak line absorption) in synthetic spectra. The H_δ absorption lines were obvious, while Na I is seen strongly in observational spectrum along with the absorption line of H_δ.

In conclusion, when we examine the light from binary stars from two different interstellar medium regions, discrepancies in binary star spectra confirm that there are cold, tiny structures located in the low density ISM local bubble, which has a temperature about of 1,000,000 K.

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[7]for both Na I Doublet and H_δ

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