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FUSE Observations of Main-sequence A-type Stars' Circumstellar Gas

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Abstract.
Since the discovery of Vega's (A0 V) large thermal IR excess over the extrapolated stellar photospheric radiation, dust disks around a large fraction of main-sequence A-type stars have been found by IRAS and ISO. Subsequent visual and ultraviolet observations of two of these stars, Beta Pic (A5 V) and 51 Oph (A0 V), have revealed a dynamic circumstellar gas disk. Although the amount of gas around main sequence A-type stars is much less than around T Tauri stars, circumstellar gas plays a crucial role in planet system formation. Many circumstellar absorption lines in the far-ultraviolet wavelength range are excellent diagnostics of circumstellar gas properties. We have obtained and analyzed FUSE spectra of two main-sequence A-type stars (2 And and Del UMa) to study the origin of their circumstellar gas disks and the possible link between their circumstellar gas and dust.

1. Introduction

Several previous studies have shown that young stars with circumstellar material appear to be common, but their properties vary greatly. Recent models of the dynamics of gas-dust coupling in the presence of stellar radiation pressure in Vega-type circumstellar disks suggest that the structure of dust disks strongly depends on the properties of gas disks, especially the density profile of the gas disk (Takeuchi & Artymowicz 2001). Since the circumstellar material can provide important constraints on the process of planetary system formation, it is important for us to determine the physical properties of these disks and to understand the relationship between the circumstellar gas and dust.

We have been engaged in detailed studies of the circumstellar environments of all nearby A-type stars. We have studied not only the thermal emission from their circumstellar *dust*, but also the characteristics of their circumstellar *gas* through absorption line spectroscopy. With high-resolution and high signal-to-noise visible spectra (Ca II K), we have identified about a dozen main-sequence A-type stars with circumstellar gas through a volume-limited survey. Although high-resolution visual spectra can be used to confirm the existence of the circumstellar gas and to monitor the gas dynamics, they do not allow us to determine the gas density and temperature. Fortunately, there are many absorption lines in the UV and FUV range that are sensitive to the gas density and temperature.

One of the main-sequence A-type stars we identified with circumstellar gas is 2 And. Unlike β Pic (A5 V), this A3 V star has no detectable infrared

excess based the IRAS data (Cheng et al. 1992), which indicates very little or no circumstellar dust. However, we detected variable, redshifted Ca II K absorption features in the 2 And system, similar to those frequently seen in β Pic spectra. We also detected Fe II and Al III circumstellar absorption lines in our HST/GHRS spectra (Cheng et al. 1997), similar to those observed in the β Pic system. We were able to constrain both temperature and electron density in the circumstellar gas around 2 And using the relative populations of the ground state and excited fine-structure levels of Fe II. We found that the density must be $\geq 10^6$ cm^{-3} and the temperature must be between 3,000 K and 10,000 K to yield the observed Fe II relative populations. Using the circumstellar gas temperature range we derived from Fe II and adopting a solar abundance, we further derived the total hydrogen a total H I column density range of 1.48 to 1.53×10^{17} cm^{-2}, which further suggests that the circumstellar disks around main-sequence stars may be gas-poor.

2. FUSE Observations

We have been awarded FUSE time to observe 5 main-sequence A-type stars with circumstellar gas, which were identified by our ground-based and ultraviolet surveys. So far, only two of our targets (see Table 1) have been observed with FUSE. We present here a preliminary comparison of the new Del UMa observation with the FUSE results for 2 And (see Cheng & Neff 2003).

Our co-added spectra have a signal-to-noise ratio (per 0.032 Å bin) in the photospheric continuum near 1150 Å of about 20 for 2 And and 12 for Del UMa. To obtain an absolute wavelength calibration, we cross-correlated our observed spectra with a model spectrum to obtain the best fit for the photospheric C I lines. The far-ultraviolet spectral range covered by FUSE contains many absorption lines that are good diagnostics of circumstellar gas. Some examples are shown in Figures 1 and 2.

Table 1. FUSE Target Stars That Have Already Been Observed

Star Name	Sp. Type	m_v	Distance	Exp. Time and Date
Del UMa = HD106591	A3 V	3.30	25 pc	16.9 ksec on 1 May 2004
2 And = HD217782	A3 V	5.09	107 pc	21.3 ksec on 3-4 July 2001

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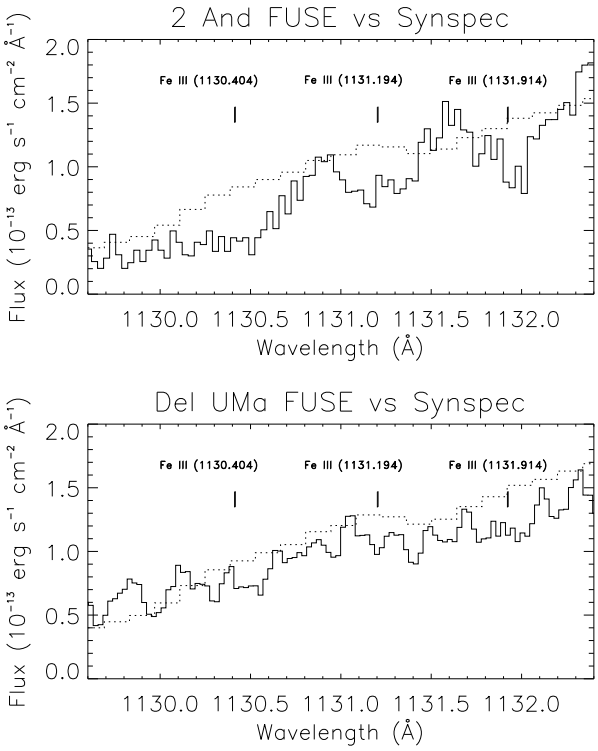

Figure 1. The purely circumstellar Fe III triplet near 1131 Å is clearly present in the 2 And spectrum (top panel) and possibly present in the Del UMa spectrum (bottom panel). The dashed line in each panel is a synthetic spectrum generated from a photospheric model.

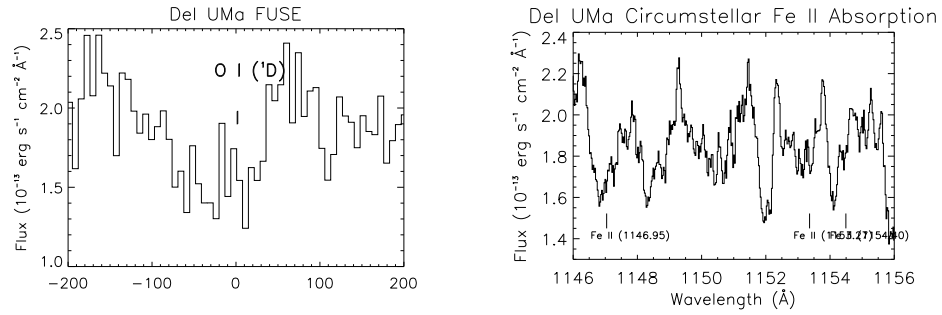

Figure 2. Examples of circumstellar features in the FUSE spectrum of Del UMa. The left panel shows the metastable O I (^{1}D) line in the rest frame of Del UMa (v_{rad} = 13.4 km s^{-1}). Three circumstellar Fe II lines are shown in the right panel.