The Hot Star Triplet HD 206267A

P. S. Wojdowski, N. S. Schulz, K. Ishibashi, D. P. Huenemoerder [a]

[a]Center for Space Research, Massachusetts Institute of Technology, Cambridge, MA, 02139, USA

We have observed the triple O star system HD 206267 with Chandra HETGS for the purpose of studying the properties and dynamics of the system's stellar wind. The triple system includes a 3.7 day binary which was observed once at each of the two phases of quadrature. The spectrum contains emission lines from hydrogen and helium-like oxygen, neon, and magnesium, helium-like silicon and the iron L-shell ions XVII, XVIII, and XIX. We have fit this spectrum with a combination of emission-line spectra of the individual ions at the temperatures at which the populations of the ions peak. From this fit we derive a temperature differential emission measure distribution which is cut off at temperatures above ~10 MK. All lines are very broad with HWHM velocities of $\sim$ 1500–2000 km s^{-1}. The Lyman α lines from O, Ne, and Mg are blue shifted and asymmetric as would be expected from shocks within a line driven wind of considerable continuum opacity. The stellar triplet revealed the main orbital velocity of 320 km s^{-1} through shifts in the X-ray lines. So far, we have not found any indications for a colliding wind in the X-ray spectrum.

1. Introduction

Spectroscopic studies in the optical and UV indicate that HD206267A consists of two stars (A_1 & A_2) in a 3.7 day orbit as well as a third component (A_3) which may or may not be bound to the binary (Stickland 1995 and references therein). The system, as a whole, has type O6.5V. Though the various components are difficult to resolve, Stickland estimates of the type of A_1 to be O5V, the type of A_2 to be "earlier than about B1", and the type of A_3 to be O7V or O8V. Crampton & Redman (1975) estimate the type of A_2 to be O9.

HD 206267A also exhibits quite an exceptionally high wind velocity. A survey of terminal velocities of the stellar wind in early type stars (Prinja et al. 1990) showed that O-stars indicate a wide range of velocities from $\sim$ 1000 to over 3000 km/s, where O6-7 type stars in particular range from 1425 to 2420 km/s. HD 206267A with a maximum terminal velocity of 3225 km/s exceeds all the 181 O-stars investigated.

We are interested in HD 206267A for at least two reasons:

- Because it is a member of the young open cluster Trumpler 37, we know that it is ~3 Myr old and this observation can help us construct a sequence of the X-ray evolution of young, hot stars.
- The fact that the system consists of three O stars makes it a candidate system to look for evidence, such as gas at temperatures of order 10^7 K [Cherepashchuk(1976)], of colliding winds.

The spectra we obtained allow us to construct a differential emission measure (DEM) distribution. We do this by fitting the spectrum to an empirical continuum model plus line emission models for individual ions. From observed line profiles, we constrain the wind velocity and geometry.

2. Observations

The HD 206267 trapezium-like system is very complex. Like its more prominent cousin, the Orion Trapezium, it consists of several stars, most of which are probably high mass stars. Besides the bright main component, HD 206267A, it harbors three fainter stars: component B at 1".6 (nature unknown), component C at 11".7 (B1V), and component D at 19".9 (B2IV) angular distance (see Schulz, Berghöfer & Zinnecker 1997 and references therein). We observed the system with the *Chandra* High Energy Transmission Grating Spectrometer (HETGS) for 50 ks at the phases where the radial velocity of A_1 is most negative and most positive. In Fig. 1 we show the zero order image for of each of the two observations. The components of the HD206267A system are not resolved but the A, B, C, and D are all clearly resolved from each other. From these two images, it may be seen that the B, C, and D components are highly variable in X-rays. Such variability is not expected from stars of their spectral type. No such variability was seen in any of the main Orion

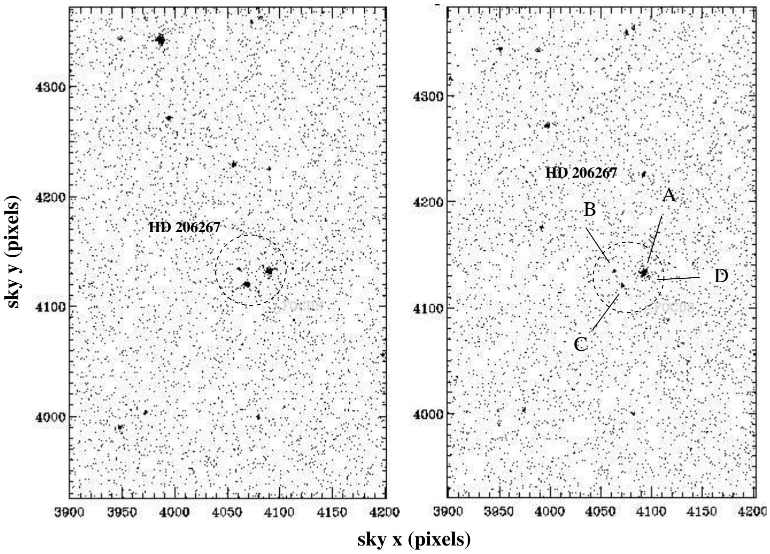

Figure 1. The zero-order image of the field for the two observations. In the second panel, the A, B, C, & D components of HD 206267 are indicated.

Trapezium stars in *Chandra* observations of that system.

3. Line Profiles

The HETGS consists of the High Energy Grating (HEG) and the Medium Energy Grating. The resolution of these two instruments are, respectively, 12 and 23 mÅ. At 12 Å(~1 keV) this corresponds to velocity widths of, respectively, 300 and 600 km s^{-1}.

In Fig. 2 we show line profiles for the Lyman α lines of two hydrogen-like ions for the two observations obtained by summing the HEG and MEG data. The lines appear blueshifted indicating that the continuum optical depth is sufficient to absorb the wind on the far side of the star. The width of the lines indicate Doppler wind velocities of ~1500–2000 km s^{-1}. The emission region must, therefore, be far enough away from the stellar surface that the wind has achived a significant fraction of its terminal velocity. The line shifts are simply those of the A$_1$ component, indicating that the X-ray line emission may be due entirely to that star. The X-ray luminosity of stars decreases rapidly with lateness beyond about B0 (Cohen, Cassinelli, & MacFarlane 1997) so the faintness of the A$_2$ and A$_3$ components is most

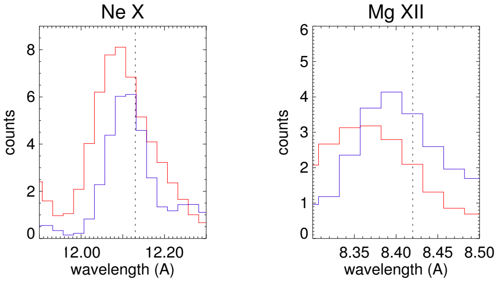

Figure 2. Line profiles for the Lyman α lines of the hydrogen-like ions Ne X and Mg XII. The data for the observations at the two different phases are shown in red and blue.

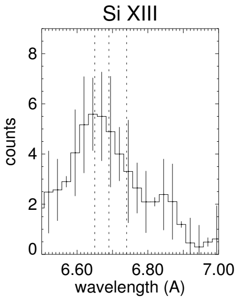

Figure 3. Line profiles for the Lyman α lines of the hydrogen-like ions Si XIII and Mg XI. The dashed lines indicate the rest wavelengts of, respectively, the resonance, intercombination, and forbidden lines.

easily explained if they are actually of type B1 or later, rather than O7/8 and O9 as previously estimated.

In Fig. 3 we show the triplets of two helium-like ions. Because of the large Doppler widths, it is difficult to obtain precise fluxes for the individual components of the triplets. However, it is clear that the forbidden lines of these triplets are weak. This indicates that the line emission occurs in a region of high density or high UV intensity, presumably the latter. For the emission to originate in a region of high UV intensity, the emission region must not be too far from the stellar surface.

4. Differential Emission Measure Distribution

Using the ISIS spectral fitting program, we fit the *Chandra* HETGS spectrum of HD20627A to determine the differential emission measure (DEM) distribution. The DEM is defined as follows:

$$\mathrm{DEM} = \frac{d \int n_e^2 dV}{d \log T} \tag{1}$$

That is, the integral of the DEM over a range in (log) temperature, gives the total emission measure ($\int n_e^2 dV$) in that temperature range.

We fit the spectrum using an empirical continuum consisting of two bremsstrahlung components with different temperatures plus several single-ion emission line components. A single-ion emission line component contains all emission lines for a given ion. The relative fluxes intensities for the lines of a given ion are those for collisional (coronal) equilibrium at the temperature at which the total line emission from that ion peaks. All line emission data is from the Astrophysical Plasma Emission Database (APED).

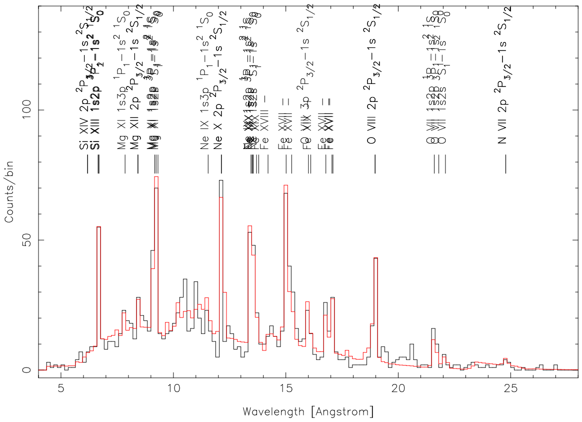

Figure 4. The summed spectrum for both observations (in black) and the best fit model (in red). A number of strong lines, as well as a few weaker ones, are indicated.

In Fig. 4 we show the obseverved spectrum and the best fit model spectrum. Since each ion emits over a limited range of temperatures ($\Delta \log T \lesssim 0.5$), the normalization parameter for a given ion gives a weighted average value of the DEM over the temperature range where the ion emits.

In Fig. 5 we plot the The implied DEM distribution for HD206267A. This plot of the DEM indicates that the gas in the system above $\sim 10^6$ K is dominated by temperatures just above 10^6 K with very small amounts of gas at temperatures as high as 10^7 K. This is consistent with standard wind shock models.

5. Summary & Discussion

We have resolved the HD206267 system spatially into its A, B, C, & D components. From the HETGS spectrum of the A component, we have determined that:

- the X-ray line emission from that component is dominated by emission from a single

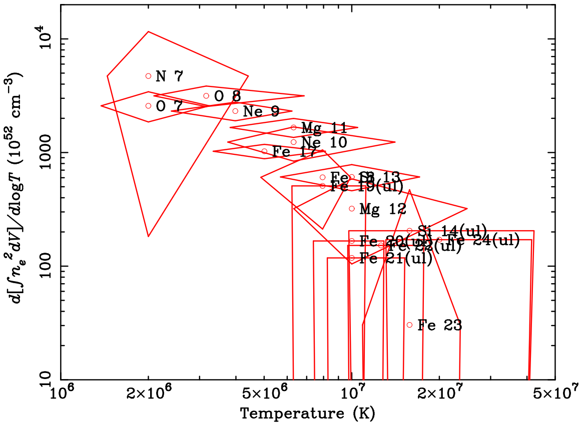

Figure 5. The implied DEM distribution implied from the fits with the single-ion models. The location of a point in the vertical direction indicates the implied weighted average value of the DEM distribution for that ion. Vertical error bars indicate statiscal errors for that value of the DEM distribution. The location of a point in the horizontal direction indicates the peak temperature of emission for that ion and horizontal error bars indicate, approximately, the temperature range over which that ion emits. The designation (ul) indicates an upper limit.

star — the A_1 component.

- the emission line profiles and helium-like triplet component flux ratios indicate emission from regions where the wind has achieved a significant fraction of its terminal velocity, as expected from models of wind shocks

- there is very little gas at temperatures above a few MK, also as expected from wind shock models

The spectrum and profiles we observe are similar to those found in recent observations of the O star prototype ζ Puppis by Kramer, Cohen, & Owocki (2002). Our results are consistent with the X-ray emission being due to heating of gas in wind shocks and we find no evidence for heating of gas by colliding winds.

REFERENCES

[Cherepashchuk(1976)] Cherepashchuk, A. M. 1976, Soviet Astronomy Letters, 2, 138

1. Cohen, D. H., Cassinelli, J. P., & MacFarlane, J. J. 1997 ApJ 487, 867.
2. Crampton, D., & Redman, R. O. 1975 AJ, 80, 454.
3. Kramer, R. H., Cohen, D. H., & Owocki, S. P. 2002 ApJ submitted (astro-ph/0211550).
4. Schulz, N. S., Berghöfer, T. W., & Zinnecker, H. 1997 A&A 325, 1001.
5. Schulz, N. S., Canizares, C., Huenemoerder, D., Kastner, J. H.; Taylor, S. C., & Bergstrom, E. J. 2001 ApJ 549, 441.
6. Stickland, D. J. 1995, The Observer, 115, 180.