X-ray spectral variability of the colliding wind binary WR140

– the origin of the cool plasma component –

Yasuharu Sugawara,[1] Yoshitomo Maeda,[1,2] Kenji Hamaguchi[3,4] and Yohko Tsuboi[5]

[1] Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 229-8510, Japan
[2] Department of Space and Astronautical Science, SOKENDAI (The Graduate University for Advanced Studies), 3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, Japan
[3] CRESST and X-ray Astrophysics Laboratory NASA/GSFC, Greenbelt, MD 20771, USA
[4] Department of Physics, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250, USA
[5] Department of Physics, Faculty of Science & Engineering, Chuo University, 1-13-27 Kasuga, Bunkyo, Tokyo 112-8551, Japan
E-mail(YS): sugawara.yasuharu@jaxa.jp

Abstract

We report the results from the X-ray spectral analysis of the colliding wind binary WR140 (WC7pd+O5.5fc) using archival XMM-Newton, Suzaku and Chandra data. Recently, we reported that a cool plasma component in a recombining phase was discovered from the WR140 X-ray spectrum at near periastron. In order to uncover the origin of the cool plasma component, we performed the spectral analysis using XMM-Newton, Suzaku and Chandra data at near periastron. These observations cover four different epochs from 2008 December 26 to 2009 January 25 for a total exposure of about 184 ks. The spectra of the cool plasma component were well-fitted by a single-absorbed non-equilibrium ionization collisional plasma model. It is found that the emission measure of the cool plasma component decreased at approximately fifty percent per month. This variation indicates that the plasma was cooled down by radiation and/or was expanded. As one interpretation, the cool component may be a relic of the wind-wind collision plasma, and may represent a transitional phase from the compressed hot gas to dust formation.

Key words: stars: Wolf-Rayet — binaries: general — stars: winds, outflows — X-rays: individual (WR140)

1. Introduction

Massive binaries composed by a Wolf-Rayet star and a OB star have the highest temperature plasma, produced by the collision of the winds. Colliding wind binary is the best testing ground for plasma shock physics, because plasma properties vary with binary separations. Long period binary WR140 (WC7pd+O5.5fc, P=7.94 yr) is considered as the textbook example of an episodic dust-making colliding wind binary and a good natural laboratory for the study of shock physics, because the orbital parameters have well determined.

The cool plasma component was discovered for the first time by WR140 Suzaku observations around 2009 periastron (Sugawara et al. 2015). The simple analysis of one-temperature collisional equilibrium plasma emission (APEC: Smith et al. 2001) for the cool component failed to reproduce the observed spectra with the residuals at 1.21 keV and other energies remaining in the spectral fitting. On the other hand, the spectrum of the cool plasma component is reproduced well with the recombining collisional plasma model (vrnei[1] in *Xspec*).

In order to uncover the origin of the cool plasma component, we performed the spectral analysis using XMM-Newton, Suzaku and Chandra data at near periastron.

2. Analysis and Results

We used archived XMM-Newton/EPICs, Suzaku/XISs, and Chandra/ACIS-I datasets around 2009 periastron passage. The observations of WR140 were conducted with XMM-Newton on 2008 December 26 (ObsID 0555471001), with Suzaku on 2009 January 04–05 and

*1 See http://heasarc.gsfc.nasa.gov/xanadu/xspec/manual/XSmodelRnei.html

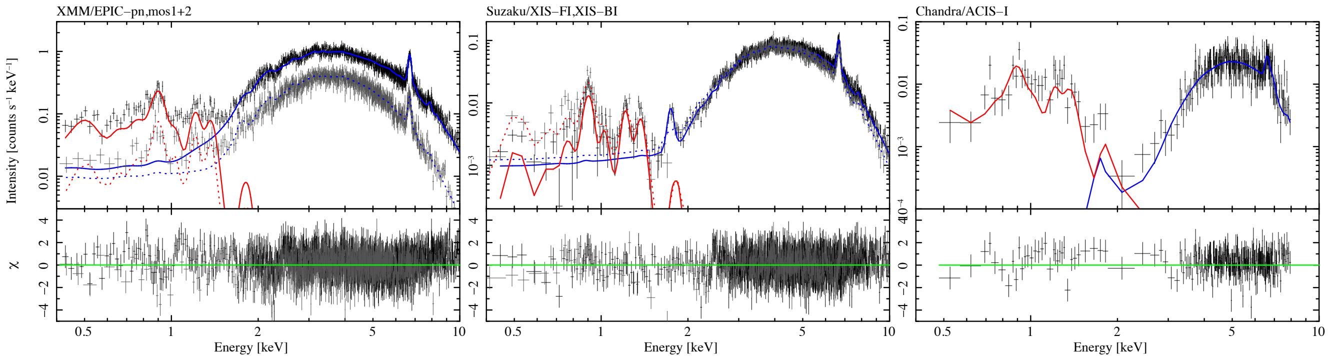

Fig. 1. The background subtracted spectra of WR140 for each phase and the fitting models. The left, center and bottom panels show the spectra of XMM-Newton/EPICs, Suzaku/XISs, and Chandra/ACIS-I, respectively. The red and blue lines in the upper panels show the cool and hot components, respectively. The lower panels show the residuals of the data from the model.

13–15 (Sequence number 403032010 and 403033010), and with Chandra on 2009 January 25 (ObsID 9918), respectively. The total exposure time was about 184 ks. The Suzaku datasets were summed up for two observations in order to get the good photon-statistic spectrum.

In all spectra, we found a soft emission component below 2 keV reported as cool component. We fitted the spectra for each phase with a two-temperature plasma model with independent absorption components (figure 1). One plasma model is the dominant hot component above 2 keV is derived from the wind-wind collision (model: TBabs*varabs*vAPEC)[2], and the other model is the cool component below 2 keV (model: TBabs*vrnei). As for the hot plasma, the elemental abundance were fixed at the reported values (table 3 in Sugawara et al. 2015). On the other hand, as for the cool plasma, the plasma parameters were fixed at reported values (table 2 in Sugawara et al. 2015) except for the emission measure and the absorption column density.

Figure 2 shows the variation of the emission measure and the column density for the cool component. The emission measure decreased at approximately fifty percent per month. The absorption column density of Suzaku spectrum was decreased at approximately thirty percent relative to that for XMM-Newton spectrum.

3. Discussion

We found for the first time that the emission measure and the absorption column density for the cool component decreased. A potential origin of the cool plasma is as follows. The plasma was heated in the past by a wind-wind collision shock. The heated plasma then escaped from the dense wind region, and is recombining

*2 We adopted two absorption components. One is the absorption component (varabs) for the W-R wind. Another is an interstellar absorption component, with elemental abundances fixed at ISM abundances (TBabs: Wilms et al. 2000).

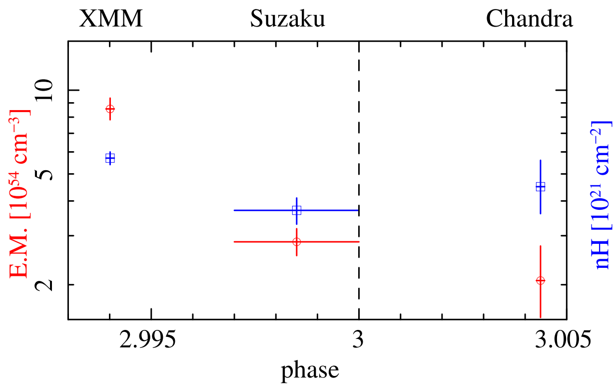

Fig. 2. The variation of the emission measure (red circle) and the absorption column density (blue square) for cool component with orbital phase. Orbital phases were derived using parameters given in Monnier et al. (2011) The dashed line shows a periastron phase.

electrons and emitting the radiative recombination continuum along with the collisional plasma emission. In this case, the cool plasma component may represent a transitional phase from the compressed hot gas to dust formation.

This research has made use of data and/or software provided by the High Energy Astrophysics Science Archive Research Center (HEASARC), which is a service of the Astrophysics Science Division at NASA/GSFC and the High Energy Astrophysics Division of the Smithsonian Astrophysical Observatory This work was supported by JSPS KAKENHI Grant Number JP16K17667.

References

Monnier, J. D., et al. 2011, ApJ, 742, L1
Smith, R. K., et al. 2001, ApJL, 556, L91
Sugawara, Y., et al. 2015, PASJ, 67, 121
Wilms, J., Allen, A., & McCray, R. 2000, ApJ, 542, 914