Contrib. Astron. Obs. Skalnaté Pleso **38**, 439 – 440, (2008)

X-ray emission and incidence of magnetic fields in massive stars of the Orion Nebula Cluster

V. Petit[1], G.A. Wade[2], L. Drissen[1] and T. Montmerle[3]

[1] *Département de Physique, de Génie Physique et d'Optique and Centre de recherche en astrophysique du Québec, Université Laval, Canada*

[2] *Department of Physics, Royal Military College of Canada, Canada*

[3] *Laboratoire d'Astrophysique de Grenoble, Université Joseph-Fourier, France*

Received: November 30, 2007; Accepted: December 8, 2007

Abstract. Magnetic fields have been frequently proposed as a likely source of variability and confinement of the winds of massive stars. We have carried out ESPaDOnS observations to search for direct evidence of such fields in the massive stars of the Orion Nebula Cluster, detecting unambiguous Zeeman signatures in three objects. These results bring forth new challenges in understanding the processes leading to X-ray emission in massive stars.

Key words: stars: early-type – stars: magnetic fields – X-rays: stars

Stellar magnetic fields are well known to produce X-rays in late-type convective stars like the Sun. However, X-ray emission coming from OB stars is often explained by radiative instabilities resulting in a multitude of shocks in their winds. The Chandra Orion Ultradeep Project (COUP) was dedicated to observe the Orion Nebula Cluster (ONC) in X-rays. The COUP OBA sample (20 stars) was studied by Stelzer et al. (2005) with the goal of disentangling the respective roles of winds and magnetic fields in producing X-rays. The production of X-rays by radiative shocks should be the dominant mechanism for the subsample of 9 O to early-B stars, which have strong winds. However, aside from 2 of those stars, all targets showed X-ray intensity and/or variability which were inconsistent with the small shock model predictions. We have undertaken a study with ESPaDOnS to explore the role of magnetic fields in producing this diversity of X-ray behaviours.

We observed 8 stars of the COUP "strong winds" OB subsample with the spectropolarimeter ESPaDOnS at CFHT. High resolution ($R = 65\,000$) measurements of Stokes I and V were obtained in January 2006 and March 2007, with an appreciable signal-to-noise ratio. The mean Stokes I and V profiles were extracted with the Least Squares Deconvolution (LSD) procedure of Donati *et al.* (1997), which allows the use of many lines to increase the level of detection of a magnetic Stokes V signature. We detected magnetic field signatures in three stars: θ^1 OriC (for which a field has already been previously detected), Par 1772 (HD 36982) and NU Ori (HD 37061).

The modeling of the LSD Stokes V profile can constrain the surface field strength and geometry in a detection case, and provide upper limits for a non-detection. We sampled the 4-dimensional parameter space which describes a

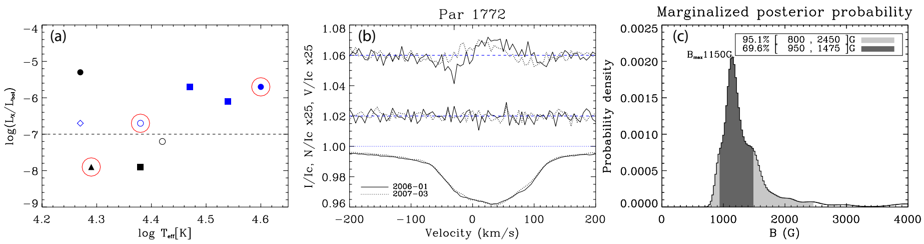

Figure 1. (a) X-ray efficiency of COUP "strong wind" OB stars as a function of effective temperature. The detected stars are circled. Filled symbols are for stars with indirect indications of the presence of a magnetic field. The diamond star was not observed. The dotted line indicates the typical efficiency for massive stars. (b) LSD profiles for Par 1772. The curves are the mean Stokes I profiles (bottom), the mean Stokes V profiles (top) and the N diagnostic null profiles (middle), from 2006 and 2007. (c) Marginalized posterior probability densitiy for the surface dipole field strength of Par 1772. The 95% credible region (filled) is [800, 2425] G.

centered dipolar magnetic configuration. For each configuration, we expressed the goodness-of-fit in term of Bayesian probabilities. With the marginalized probability density of the field strength, we can extract a credible region for the field strength of each star. This yields inferred surface dipole field strength values (with 1σ error bars) for the new detected stars of 1150^{+325}_{-200} G for Par 1772 and 620^{+220}_{-170} G for NU Ori.

This study of the Orion stellar cluster represents a *complete* magnetic survey of a *co-evolved* and *co-environmental* population of massive stars. The role of magnetic fields in X-ray production remains poorly understood. As shown in Fig. 1(a), X-ray variability is not necessarily correlated with the presence of a field. Furthermore, magnetic fields are observed even in the absence of X-ray indications.

Acknowledgements. VP acknowledges support from FQRNT. GAW and LD (Canada Research Chair) acknowledge support from NSERC. Based on observations obtained at the CFHT which is operated by the NRC, the INSU and the University of Hawaii. The ESPaDOnS data were reduced using the data reduction software Libre-ESpRIT (Donati *et al.*, 1997), made available to observers at CFHT.

References

Donati, J.-F., Babel, J., Harries, T.J., Howarth, I.D., Petit, P., Semel, M.: 1997, *Mon. Not. R. Astron. Soc.* **291**, 658

Stelzer, B., Flaccomio, E., Montmerle, T., Micela, G., Sciortino, S., Favata, F., Preibisch, T., Feigelson, E.D.: 2005, *Astrophys. J., Suppl. Ser.* **160**, 557