Mem. S.A.It. Vol. 88, 840

Memorie della

Ages and distances to star forming regions from the synergy of X-rays and IR observations

I. Pillitteri[1], S. J. Wolk[2], and S. T. Megeath[3]

[1] Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, I-9-134 Palermo, Italy, e-mail: `pilli@astropa.inaf.it`
[2] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, USA
[3] University of Toledo, Toledo, OH, USA

Abstract. We present two studies based on XMM-Newton observations aimed at inferring the distances and the ages of young groups of stars around Kappa Ori, south to the Orion Nebula, and Rho Ophiuchi. By leveraging on the characteristics levels of X-ray luminosities of very young stars we determined that around Kappa Ori a group of stars has formed at a distance of 250 pc from the Sun, and thus it is unrelated to the Orion complex at 400 pc. To the same group belong V1818 Ori and the surrounding young stars, and we exclude that these stars belong to the Mon R2 region at 900 pc as suggested before. Around Rho Ophiuchi we found X-ray active and disk-less stars with ages estimated in 5-10 Myr, thus older than the young stellar objects in the main core of the cloud, L1688. Rho Ophiuchi itself is a strong, periodic emitter of X-rays, and we ascribe this behavior to an intrinsic magnetism or an unknown low mass companion.

1. Introduction

Young stellar objects (YSOs) are strong emitters of X-rays. At ages $\leq$ 20 Myr the X-ray luminosities are well described by a log-normal distribution with median 29.3 dex and $\sigma = 1$ dex (Feigelson et al. 2005). Together, these properties can be used to infer ages and distances of groups of very young stars. We present two case studies based on XMM-Newton observations of YSO around Kappa Ori (B0V) and Rho Ophiuchi stars (B2V+B2IV).

2. Inferring distances to SFRs: Kappa Ori and V1818 Ori

South to ONC and L1641, Kappa Ori (a B0V star at 250 pc) is at the center of a ring of dust that embeds groups of YSOs. We used Spitzer and WISE to classify them in Class I, Class II, Class III objects. We wanted to understand whether these YSOs related to Orion or constitute a foreground young association.

With XMM-Newton we observed two fields west to Kappa Ori containing about 120 YSOs (Pillitteri et al. 2016a). These are divided in few protostars, and an equal number of stars with and without disks. Their X-ray luminosity function (XLF) is systematically offset to high X-ray luminosities when using $d = 400$ pc. Rather, with a distance of 250 pc, same as Kappa Ori, we can match the XLF with the one of ONC and L1641. We conclude that the YSOs around Kappa Ori form a spherical sub-group not related to ONC and Orion.

V1818 Ori is a Herbig Be star surrounded by a few YSOs. Chiang et al. (2015) associ-

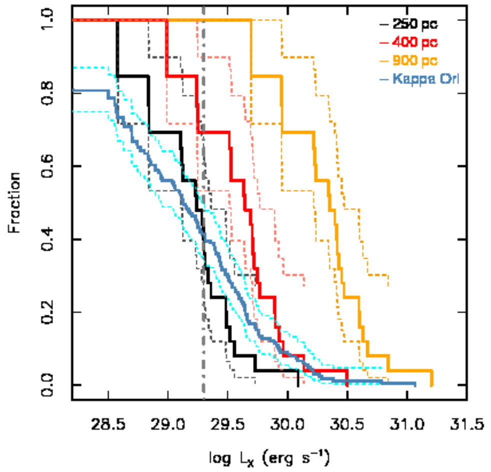

Fig. 1. X-ray luminosity function (XLF) of the stars around V1818 Ori calculated at three distances: 250 pc, 400 pc and 900 pc. For comparison we plot the XLF of the YSOs west to Kappa Ori (Pillitteri et al. 2016a).

ated this group to Mon R2 at 900 pc. We observed V1818 Ori with XMM-Newton to infer their distances from their XLF and determine whether they truly belong to Mon R2 or are rather part of Orion A or the Kappa Ori group.

The XLF calculated at three different distances (250, 400, 900 pc, fig. 1) shows that they are likely part of the Kappa Ori group and not associated with Mon R2 or Orion A (Pillitteri et al. 2017b).

3. Inferring the ages of young stars: Rho Ophiuchi

At 120 pc the Rho Ophiuchi Dark Cloud contains ~ 300 YSOs in the dense core of L1688. This part has been extensively studied in IR and X-ray surveys (e.g. DROXO). The YSOs in L1688 are ~ 1 Myr old. However, Rho Ophiuchi star sits 1 degree north of L1688 at the center of a low extinction ring. We investigated the stellar population around Rho Ophiuchi with two XMM-Newton observations in 2014 (50 ks) and 2016 (140 ks) for a total of 190 ks.

About 140 sources are detected in X-rays around Rho Ophiuchi. We identify about 28 YSOs with half of them being PMS stars without disks. From a fit to isochrones of L_{bol}/T_{eff} we infer that their ages are between 5 and 10 Myr, significantly older than YSOs in L1688. A burst of star formation formed this group of stars about 5-10 Myr ago around Rho Ophiuchi. This challenges the previous hypothesis of a sequential star formation through Upper Sco Cen and Lupus regions about 5-10 Myr ago and then in the Rho Ophiuchi Dark Cloud 1 Myr ago (Pillitteri et al. 2016b, 2017a).

We also discovered a periodic increase of X-ray flux in Rho Ophiuchi every 1.2 days (its rotational stellar period). We interpreted this as due to: a) an intrinsic magnetism and the presence of a surface active spot, or b) an unseen low mass companion orbiting very close to Rho Oph (Pillitteri et al. 2014, 2017c).

Acknowledgements. IP acknowledges support from INAF, ASI and the ARIEL consortium. S.J.W. was supported by NASA contract NAS8-03060.

References

Chiang, H.-F., Reipurth, B., & Hillenbrand, L. 2015, AJ, 149, 108

Feigelson, E. D., Getman, K., Townsley, L., et al. 2005, ApJS, 160, 379

Pillitteri, I., Wolk, S. J., Goodman, A., & Sciortino, S. 2014, A&A, 567, L4

Pillitteri, I., Wolk, S. J., & Megeath, S. T. 2016a, ApJ, 820, L28

Pillitteri, I., Wolk, S. J., Chen, H. H., & Goodman, A. 2016b, A&A, 592, A88

Pillitteri, et al. 2017a, A&A, in preparation

Pillitteri, et al. 2017b, A&A, submitted

Pillitteri, I., Wolk, S. J., Reale, F., & Oskinova, L. 2017c, A&A, 602, A92