

Ages and Distances to Star Forming Regions from the synergy of X-rays and IR observations

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X-ray Universe 2017 Rome



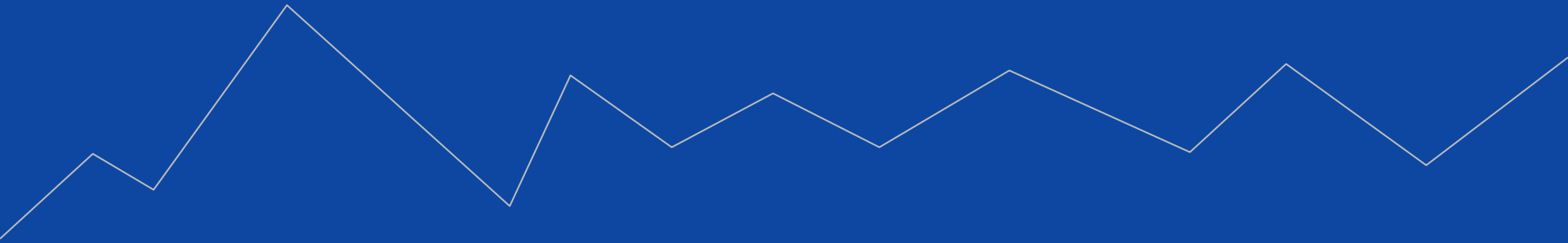
Outline

Context: Modes of Star formation

Where: Orion A/Kappa Ori and Rho Ophiuchi

How: X-rays+IR to infer distances and ages of young stars

X-rays and Distances



X-rays from Young Suns

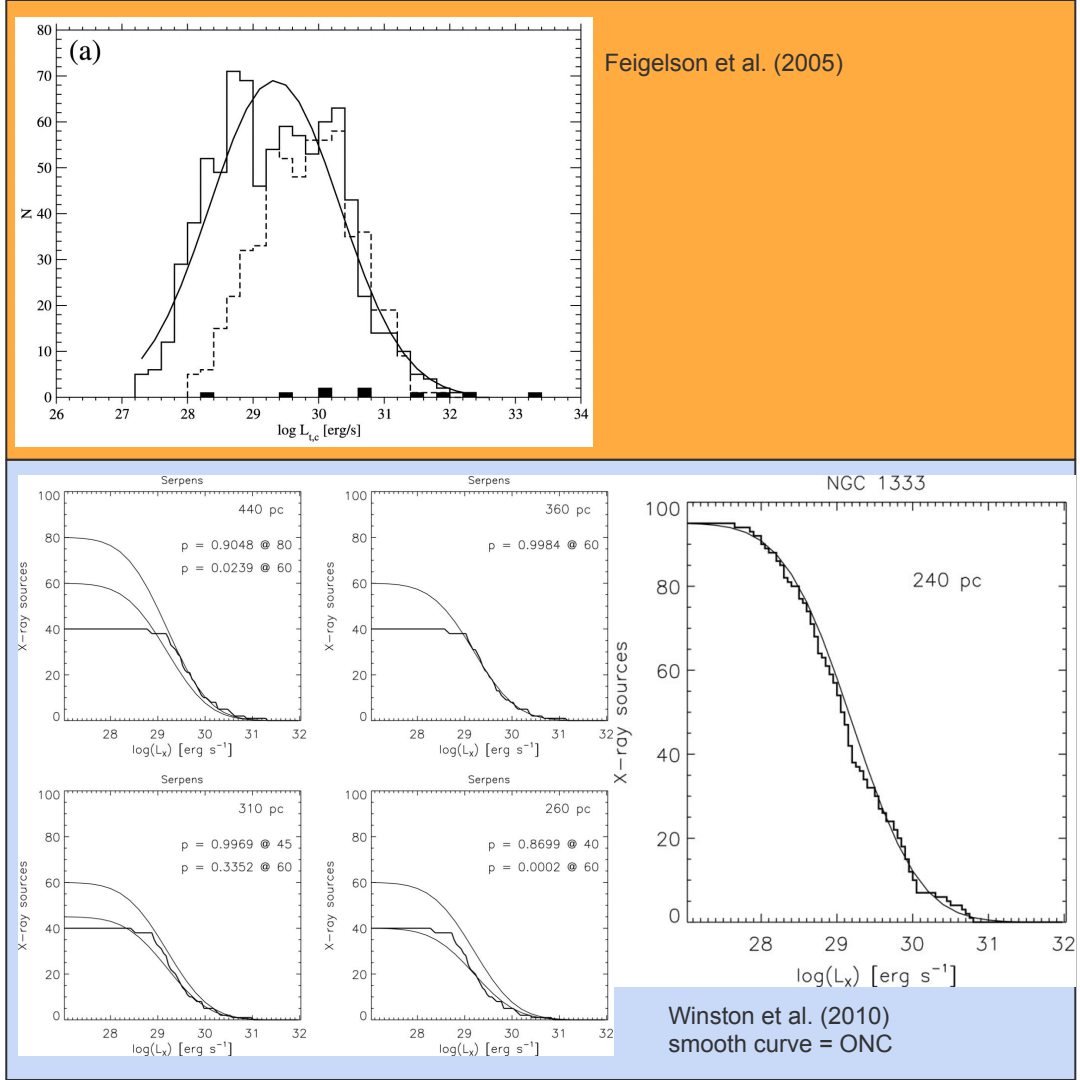
XLF = X-ray Luminosity function

Ingredients for a XLF: accurate cluster membership, X-ray fluxes, and distance

YSOs = Young stellar objects

“Universal” XLF from COUP survey of ONC in 2003 (Feigelson et al., 2005, Getman et al. 2005)

Log-normal distribution, mean = 29.3, $\sigma \sim 1$
 Similar XLFs are found valid for other star forming regions (e.g., Winston et al., 2010)



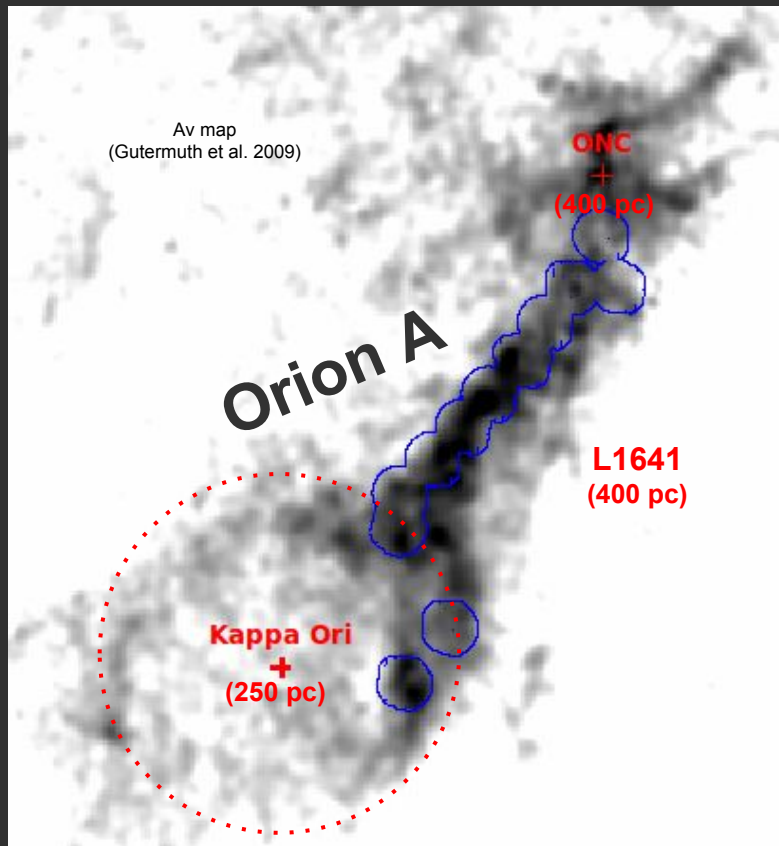
X-rays and distances: Kappa Ori and Orion A

L1641: “SOXS” Spitzer + XMM:
census of YSOs with and without
disks

Megeath et al. (2012)

Pillitteri et al. (2013)

A ring of dust around
Kappa Ori, with YSOs in
it, how these YSOs are
related to Orion?



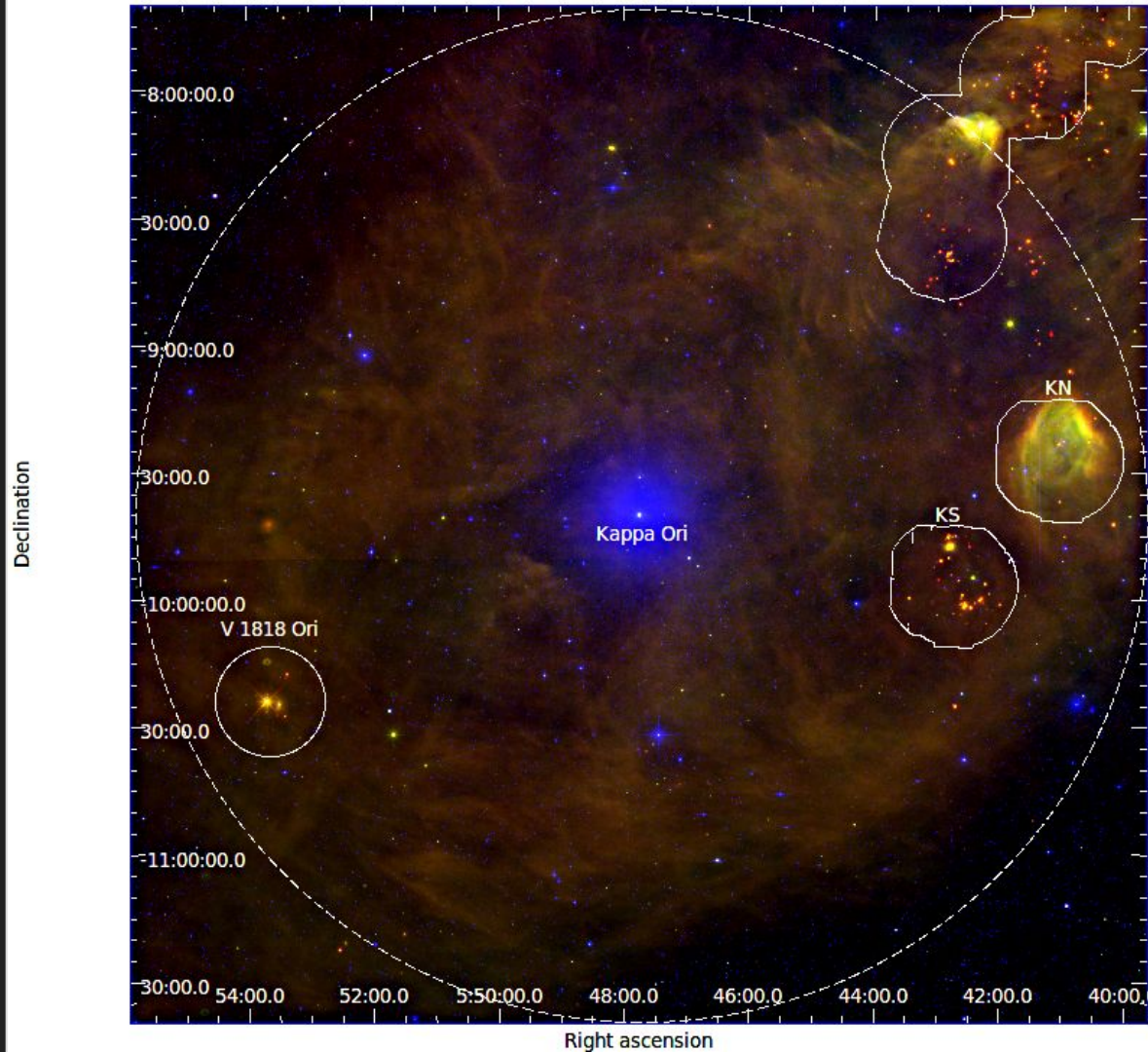
X-rays and distances: Kappa Ori and Orion A

Optical + WISE 12 μ + WISE 22 μ

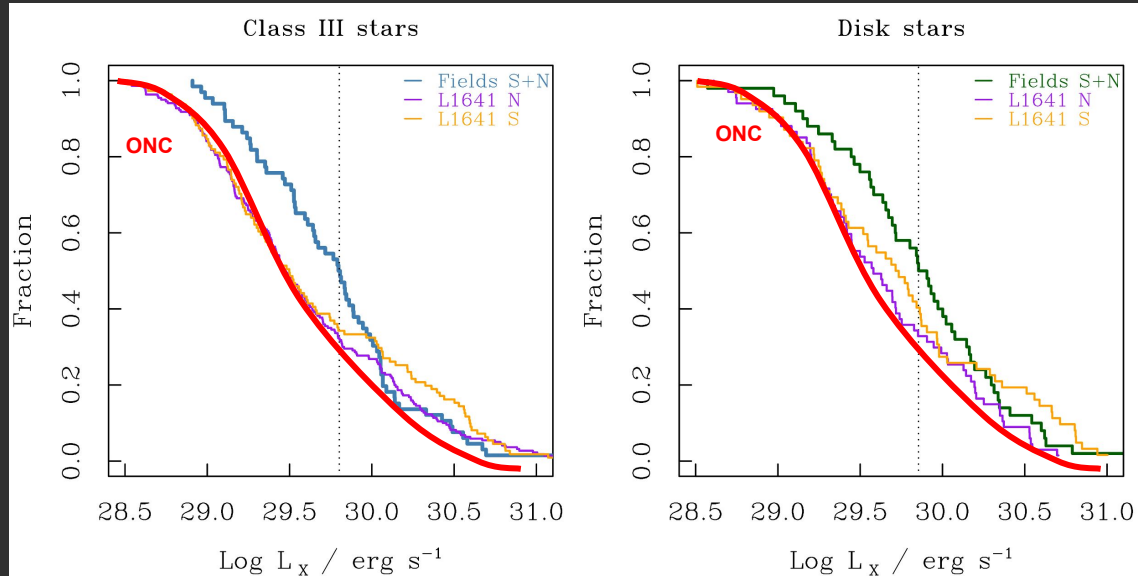
Bubble shaped cloud around Kappa Ori

XMM observations:

- 121 YSOs in fields KN & KS
- Stars with disks and without disks



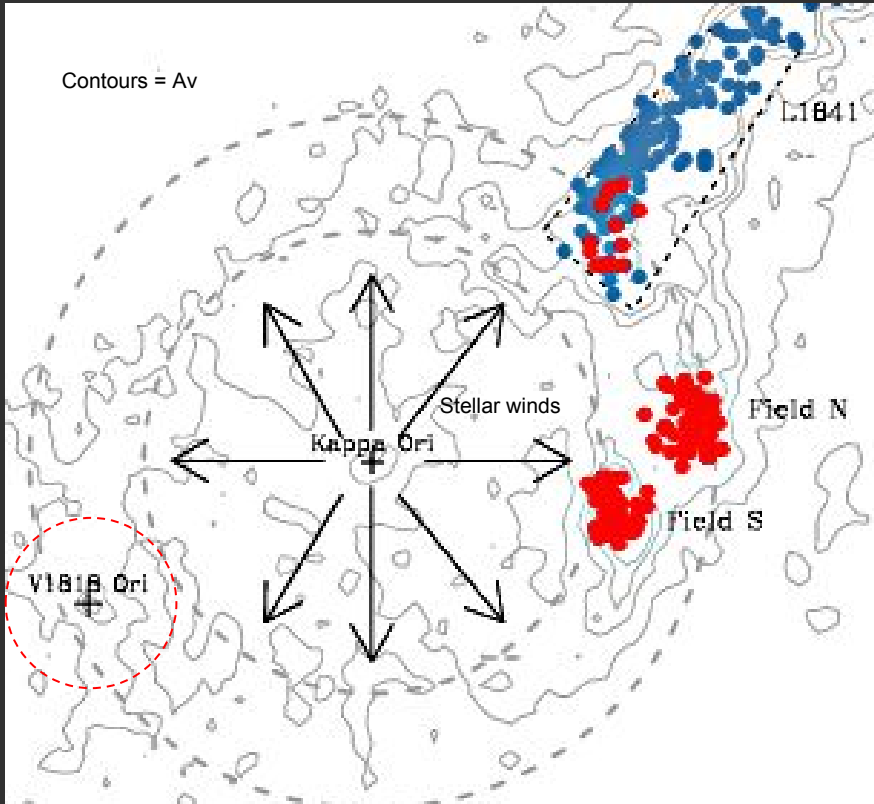
West to Kappa Ori: YSOs at 250 pc



D = 400 pc not compatible with XLFs,
systematic difference about a factor 2 in fluxes
D = 250-280 pc, as the distance to Kappa Ori

Pillitteri et al. (2016)

The Kappa Ori Cluster



A young association unrelated to Orion.
Star formation perhaps triggered by winds from
Kappa Ori (B0V)

Pillitteri et al. (2016)

Question: Is V1818 Ori part of the same
cluster?

Chiang et al. (2015) associate V1818 Ori and its group
of YSOs to Mon R2 at **900 pc**, they used the scheme by
Koenig et al. (2012) IR classification based on WISE.

However

An improved scheme by **Koenig & Leisawitz (2014)**
based on *AllWISE* gives a different YSOs selection

V1818 Ori: XMM observation

Observation date: April 6 2017

Duration: about 40 ks

PI: I. Pillitteri

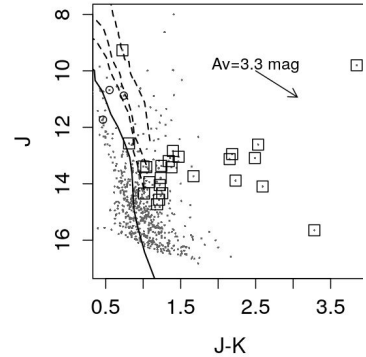
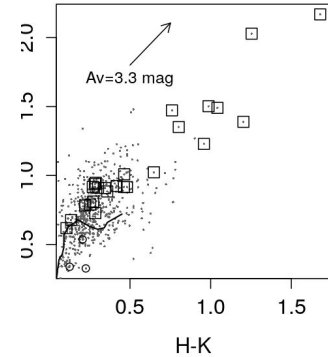
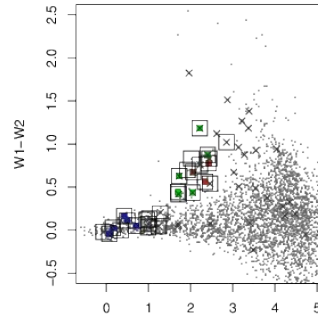
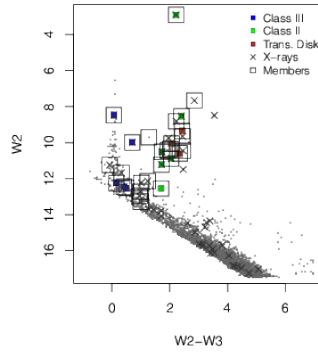
GTI: 25 ks (bad space weather)

91 point like sources and one faint
extended source (top left)



A/WISE and 2MASS photometry

About 20 YSOs detected in X-rays



Identifying YSOs

Koenig & Leisawitz (2014)

XLF and distance to the V1818 Ori's clump

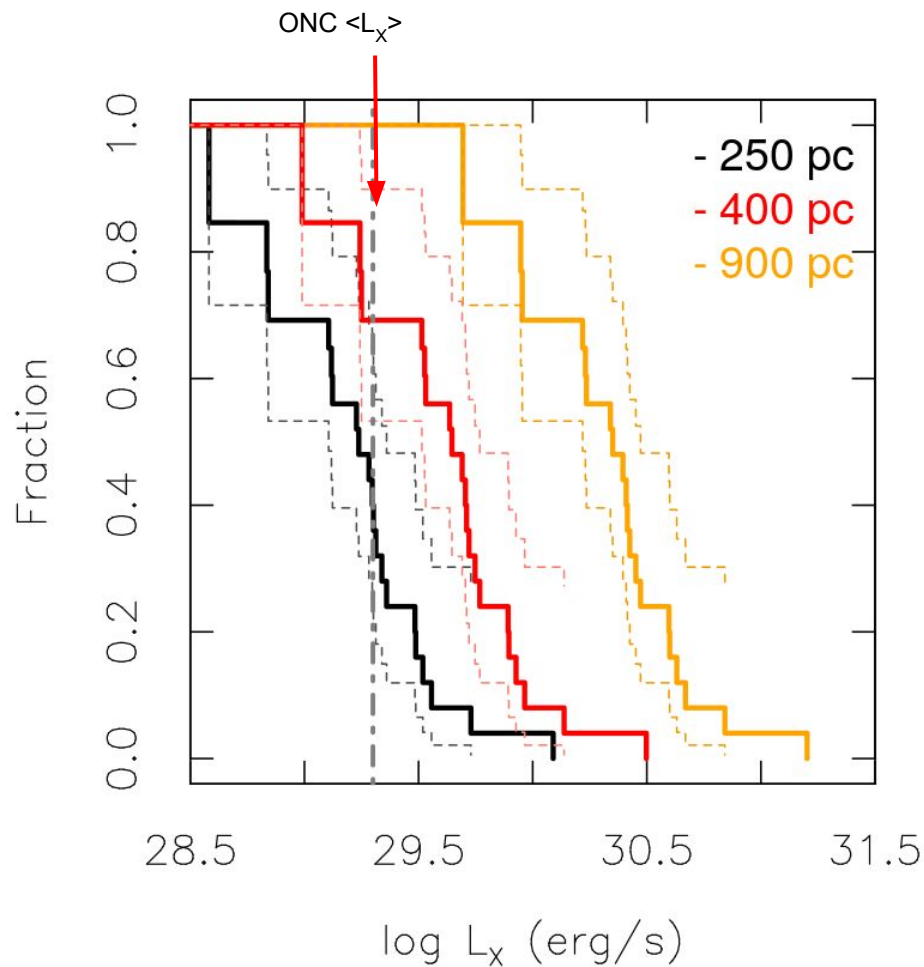
900 pc: not realistic

400 pc: still too offset

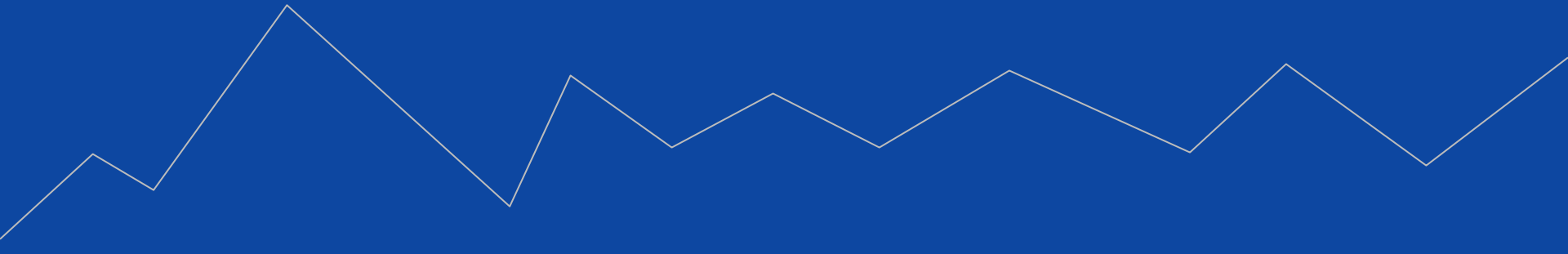
250 pc: better fit

The group of V1818 Ori is part of the Kappa Ori cluster

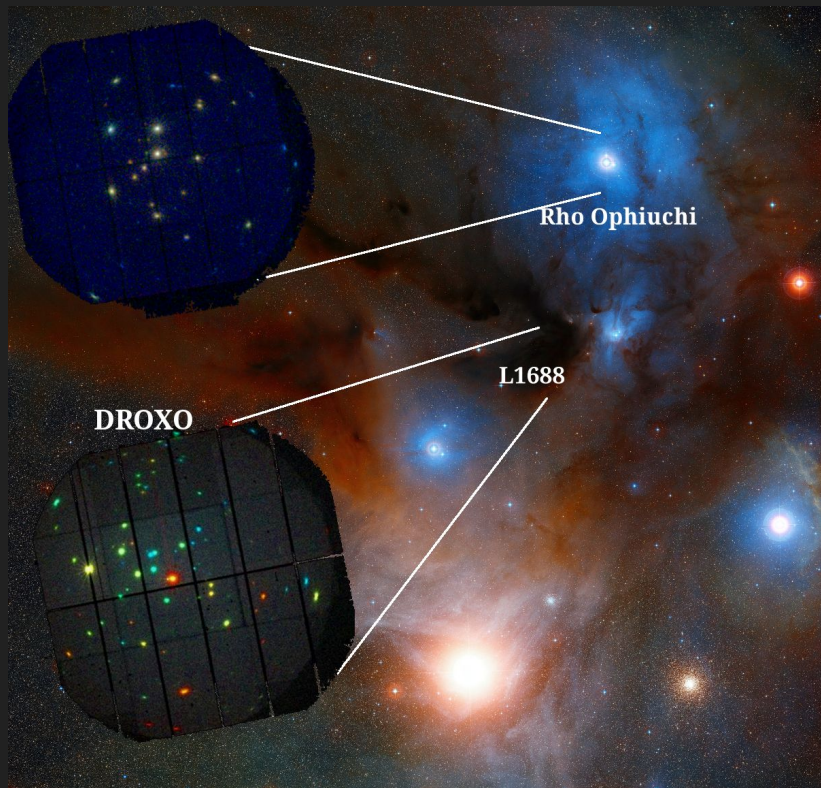
Pillitteri et al. A&A submitted



X-rays and Ages of Stars



X-rays and stellar ages: Rho Ophiuchi



Multi patch youngest and closest Star forming Region

About 300 Classical T-Tauri stars and Weak T-Tauri stars embedded in L1688

Rho Ophiuchi A+B (B2IV+B2V)

Less absorption in a ring around Rho Ophiuchi

Einstein/ROSAT/XMM/Chandra observations

XMM observed with DROXO L1688 Core F for 500 ks (Sciortino et al. 2005, Giardino et al. 2007, Flaccomio et al. 2009, Pillitteri et al. 2010)

... and Rho Oph in 2013 and 2016 for 50+140 ks (Pillitteri et al. 2014, Pillitteri et al. 2016, Pillitteri et al. 2017)

X-rays and stellar ages: Rho Ophiuchi

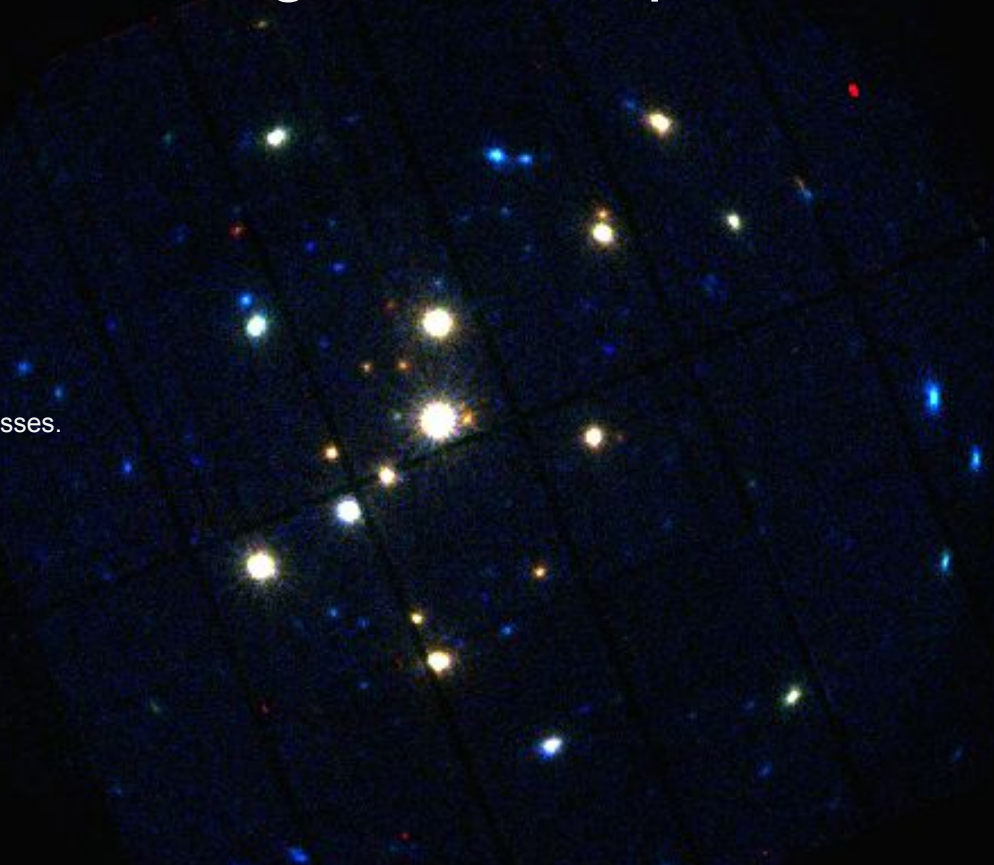
- . About 140 sources
- . **Two different types of sources**
- . **Stellar coronae (yellow/white)**
- . **Background objects (blue)**
- . **28 young stars, including Rho Oph,**
almost all disk-less stars
- . Ratio disk-less to disk stars 8:1 -> **age~5 Myr**
- . **Sensitivity: $L_x \sim 5 \times 10^{27}$ erg/s**
- . **X-ray detection complete** down to substellar masses.
- . Brown Dwarfs emit $L_x < 5 \times 10^{27}$ erg/s at 5-10 Myr

Red=0.3-1.0 keV

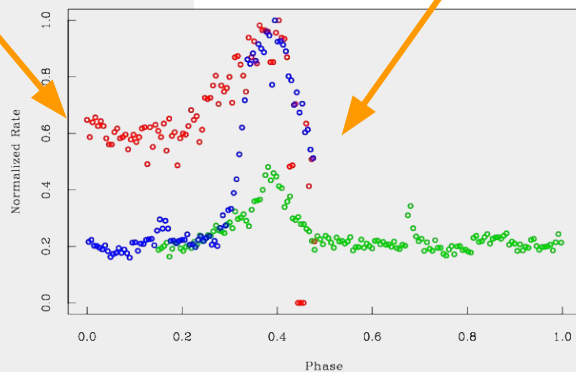
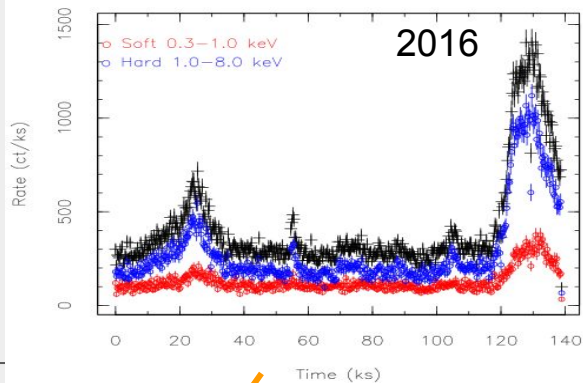
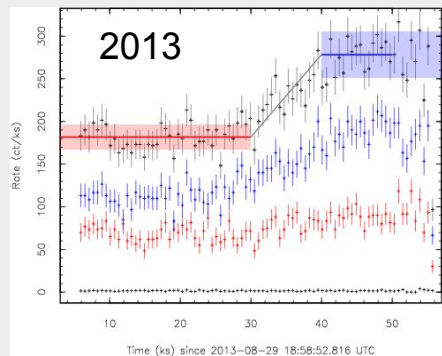
Green=1.0-2.5 keV

Blue=2.5-8.0 keV

Pillitteri et al. (2016),
Pillitteri et al. 2017 in prep.



Rho Ophiuchi A



Rho Ophiuchi A (B2IV) emits hard X-rays with periodic increase of X-ray flux and hardness
Period: ~ 1.2 days \rightarrow stellar rotation
Red: rate observed in 2013
Green & Blue: rate observed in 2016

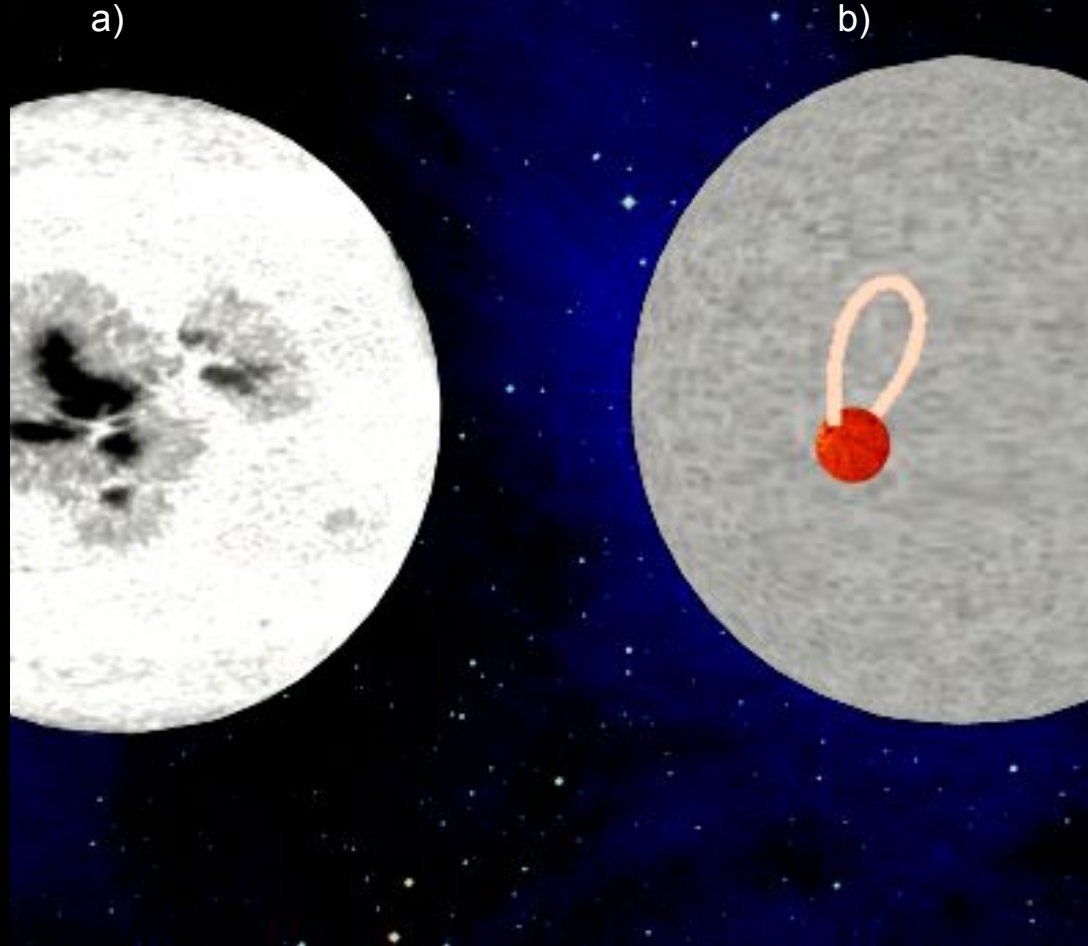
Pillitteri et al. (2014), Pillitteri et al (2017)

Rho Ophiuchi A

An X-ray lighthouse

- a) A large surface spot and intrinsic magnetism
- b) An unseen low mass companion in a very tight orbit

Pillitteri et al. (2017)





Conclusions

X-rays can be used for estimating distances and ages of very young clusters.

Powerful synergy with IR photometry to characterize YSOs

Can complement GAIA in dense SFRs

The Kappa Ori cluster and V1818 Ori

Rho Oph A is an X-ray lighthouse