X-rays as tools to identify and study stellar clusters in the era of GAIA

Chandra Science for the Next Decade, August 2016

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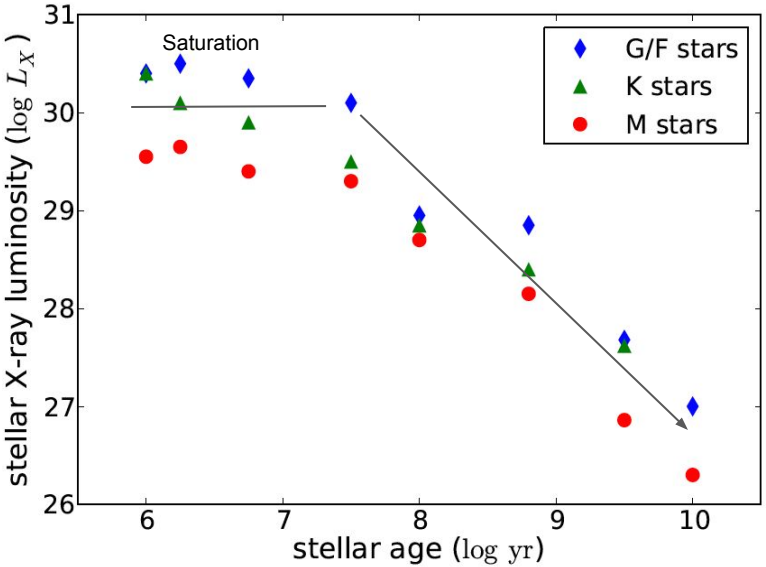
X-rays from Stars and stellar activity



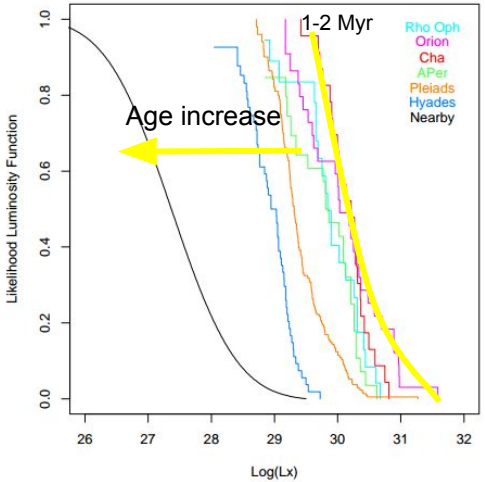
X-rays probe stellar activity since star formation.

Saturation of Lx and Lx/Lbol till ~50 Myr

Lx - rotation - relationship
Rotation - age relationship
Lx - age dependence

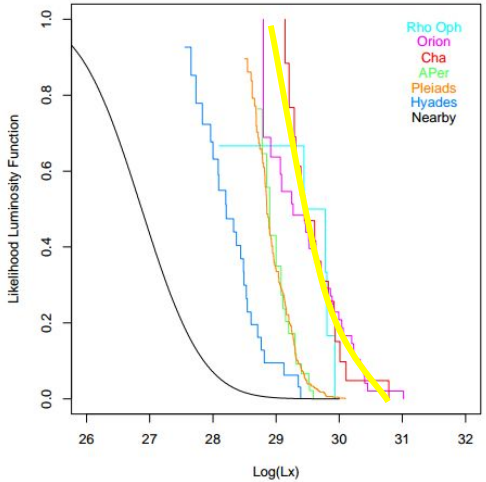
Clusters to study Suns in Time

G-K stars



Guedel 2004 & ref. therein

M stars



XLF = X-ray Luminosity function

Clusters of several ages

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, ~838 ksec)

Log-normal distribution, mean = 29.3, σ~1
Similar XLFs are found valid for other star forming regions (Wang et al. 2007)

GAIA http://sci.esa.int/gaia/

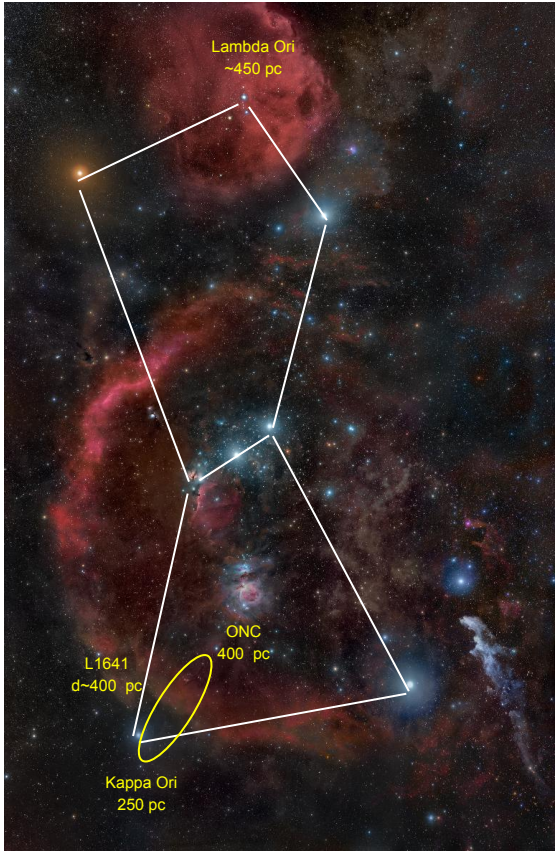
- Astrometry and proper motions of 1 billion of stars
- Galactic structure and stellar groups
- stellar structure and evolution, constraints to stellar models
- Exoplanets: transits, masses, orbit inclinations

Expected first release of data: September 2016

Status and on flight performances: Mora et al. 2016

https://arxiv.org/abs/1608.00045

X-rays and distances: Kappa Ori and Orion A



Av map (Gutermuth et al. 2009)

ONC
(400 pc)

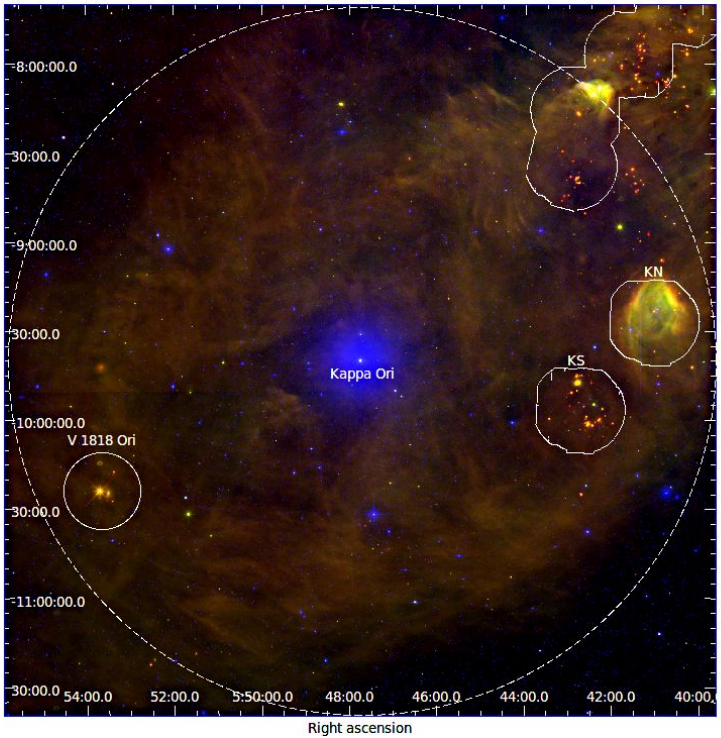
Spitzer + XMM: census of YSOs, disk and disk-less stars
Megeath et al. (2012)
Pillitteri et al. (2013)

L1641
(400 pc)

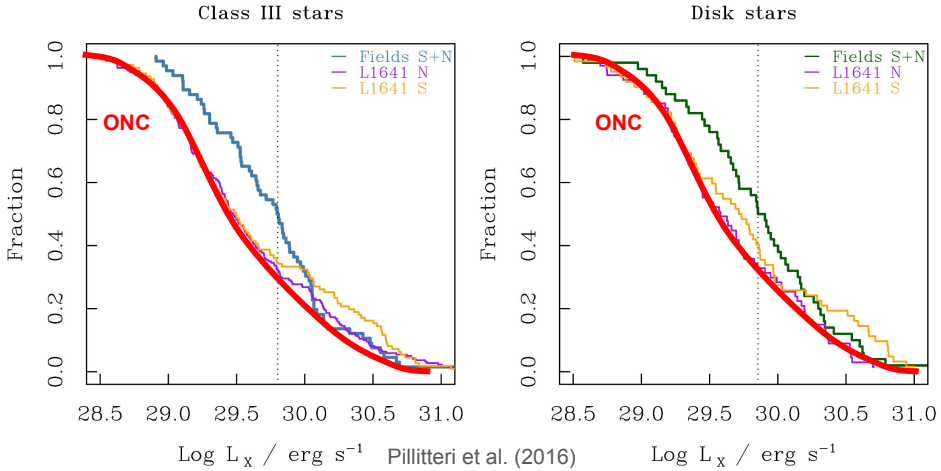
Kappa Ori
+
(250 pc)

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

X-rays and distances: Kappa Ori and Orion A

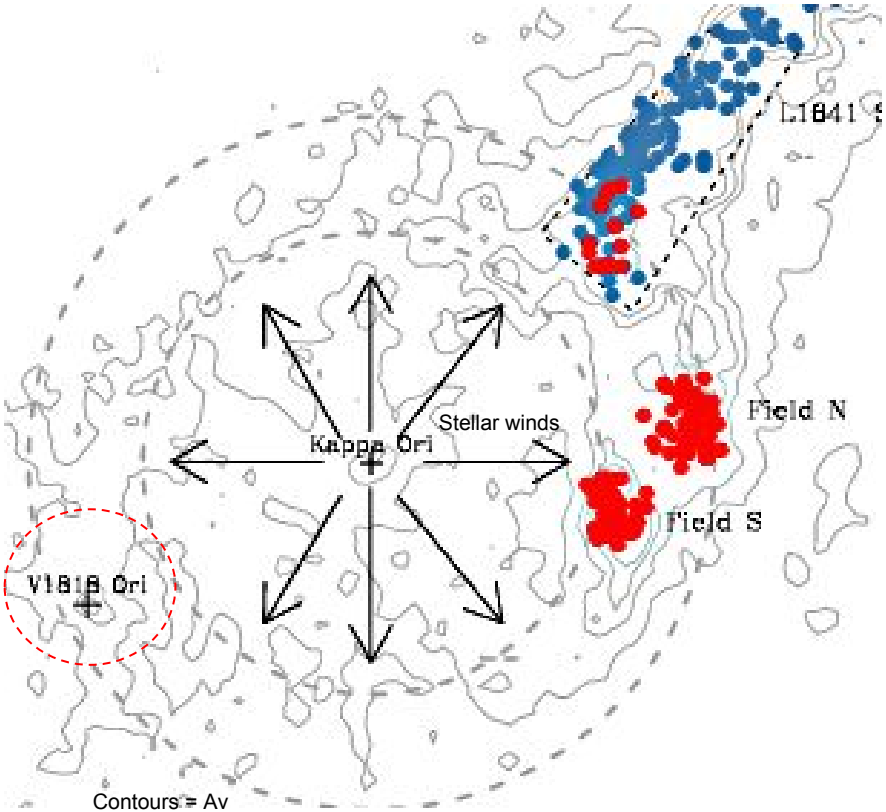


Optical + WISE 12μ +WISE 22μ



121 YSOs in the Field N & Field S, disks and disk-less stars
D = 400 pc not compatible with XLFs,
systematic difference about a factor 2 in fluxes
D = 250-280 pc, the distance to Kappa Ori!

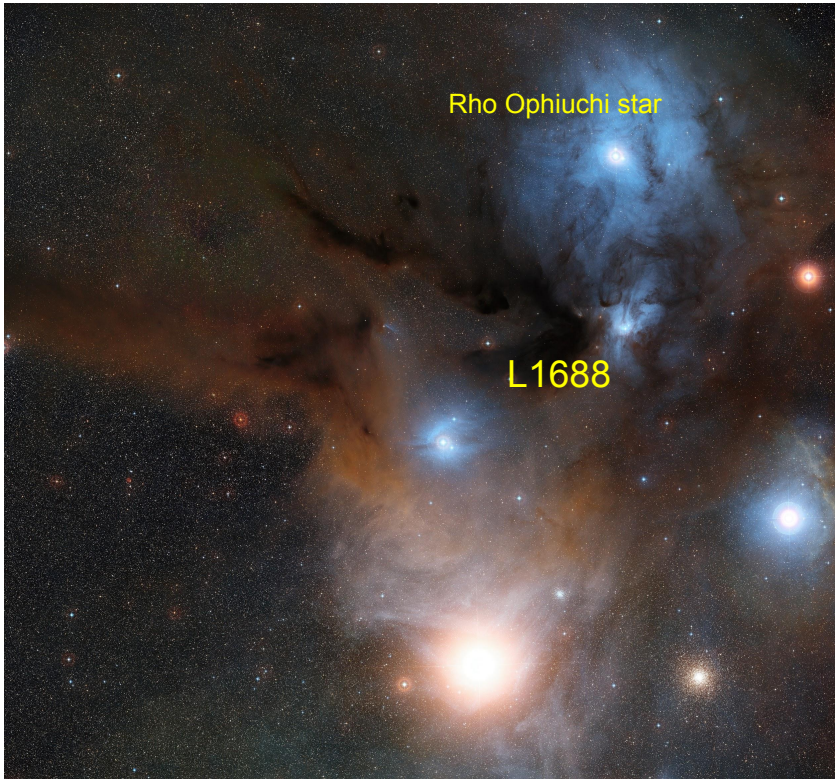
X-rays and distances: Kappa Ori and Orion A



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

V1818 Ori part of the same cluster?

X-rays and stellar ages: Rho Ophiuchi



Credit: ESO

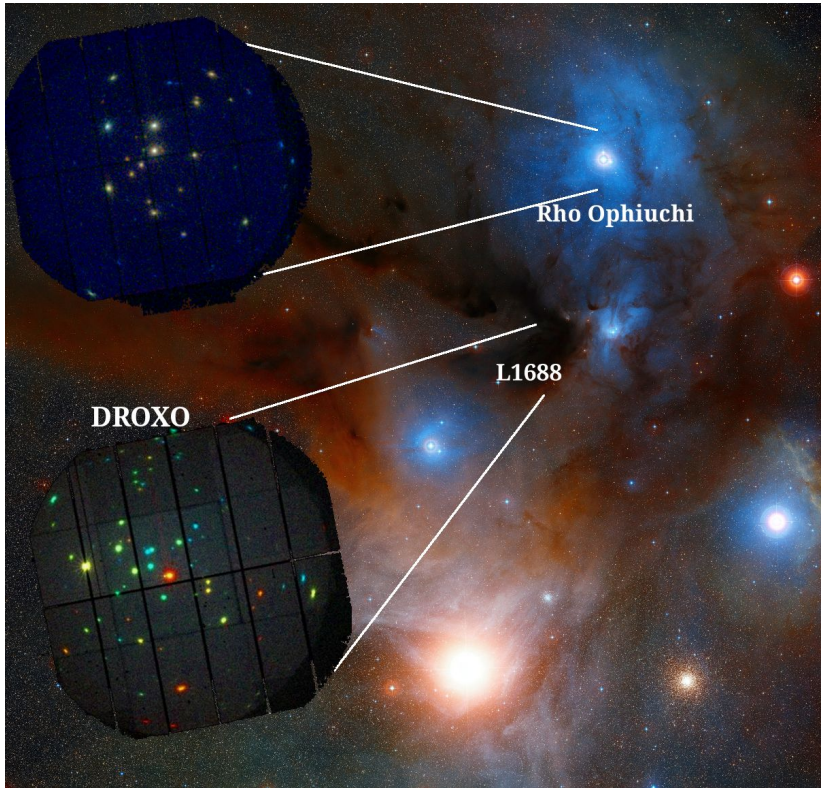
Multi patch **Youngest** and **Closest** Star forming region

About 300 protostars, stars with disks and disk-less stars embedded in L1688 (age ~ **1 Myr**)

Rho Ophiuchi A+B (B2IV+B2V)

Less absorption in a ring around Rho Ophiuchi

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. in prep.)

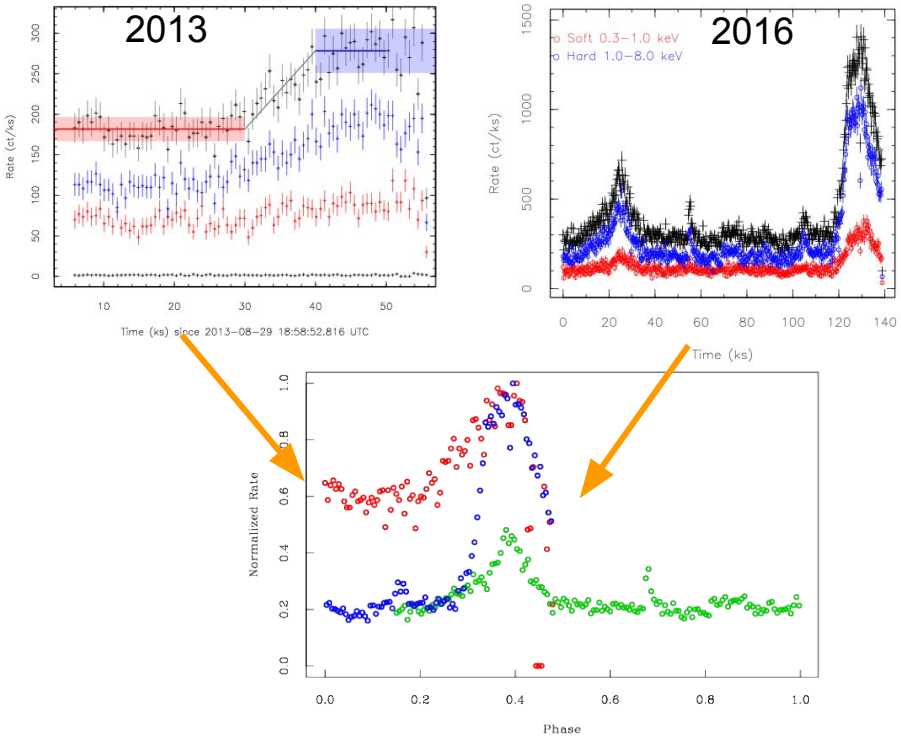
X-rays and stellar ages: Rho Ophiuchi

. 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: Lx ~ 5x10^{27} erg/s**
. **X-ray detection complete** down to substellar masses.
. Brown Dwarfs emit L_X < 5x10^{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. in prep.

Rho Ophiuchi A



Rho Ophiuchi A (B2IV) emits hard X-rays with periodic increase of X-ray flux and hardness

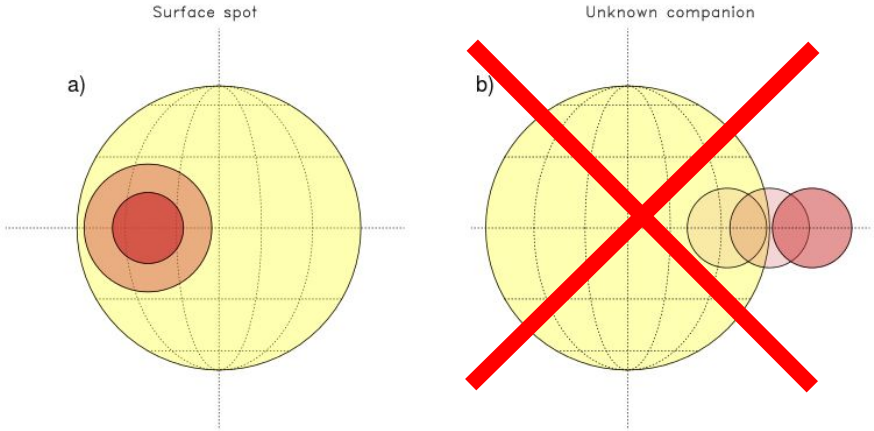
Period: ~1.2 days → stellar rotation

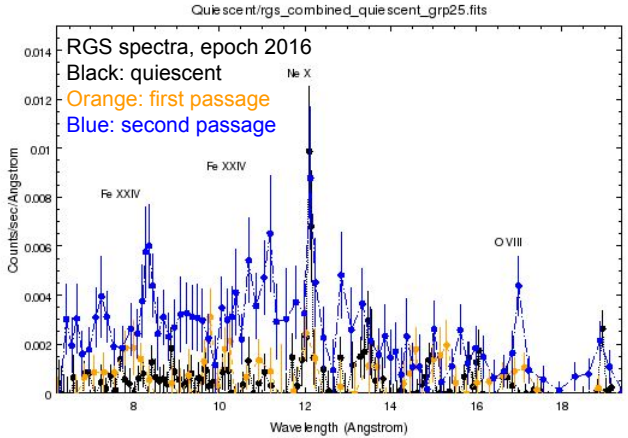
Red: rate observed in 2013

Green & Blue: rate observed in 2016

Pillitteri et al. (2014),Pillitteri et al in prep.

Rho Ophiuchi A





Hi-res spectroscopy can discriminate among the mechanisms of emission of X-rays

Conclusions

Test cases:

- X-rays from YSOs near Kappa Ori reveal a cluster unrelated to Orion at ~250 pc
- X-rays from disk-less YSOs around Rho Ophiuchi reveal a multi-epoch star formation history

X-ray observations will work in **synergy with GAIA** to understand the galactic structure and stellar evolution.