Characterizing the X-ray Emission Properties of Intermediate-Mass, Pre-Main Sequence Stars

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X-rays from Young Stars

- **Pre-main-sequence (PMS) stars (Convection)**
  - Magnetic reconnection flares produce hard (>2 keV) X-rays (e.g. Preibisch et al. 2005).
  - X-ray emission tied to convective interior (Mayne et al. 2010, Gregory et al. 2016)

- **Massive stars (O and early B types) (Winds)**
  - “Microshocks” in strong stellar winds produce soft (<1 keV) X-rays (Lucy & White 1980).
  - More exotic mechanisms (Colliding wind binaries? Magnetically channeled wind shocks?) produce hard (>1 keV) X-rays (e.g. Gagné et al. 2011).

- **Intermediate-mass main-sequence stars (Companions)**
  - No known source of strong X-ray emission (no convection-driven dynamos to produce flares, winds are not strong enough).
  - X-ray emission associated with intermediate-mass stars is usually attributed to the presence of a lower-mass companion (e.g. Evans et al. 2011).
Motivation

- Potential as sensitive chronometers (Matt’s talk)
- Allow us to probe the $L_X$-Mass relation
- Further constrain stellar evolutionary models

COUP: Orion Nebula Cluster

Preibisch+ 2005
**Chandra Carina Complex Project**

- Wide-field, high resolution multiwavelength datasets to probe the young stellar population of Carina (Broos et al. 2011, Townsley et al. 2011)
  - IR: *Spitzer/IRAC, Spitzer/MIPS, 2MASS*
  - X-ray: *Chandra/ACIS-I*

**Why?**
- Large sample of IMPS (intermediate-mass pre-main-sequence stars)
- Nearby analog of a “starburst” region
The Great Nebula in Carina

*Spitzer 3.6 μm*

- Diskless PMS YSOs (disks)
- Contours: CCCP stellar density (Feigelson+11)

X-ray Bright Sample
Net Counts ≥ 50
> 5 sigma detection
371 sources
Source Classification (pHRD)

**R-IMPS** require $T_{\text{eff}}$ from spectroscopy.

Gaia-ESO Survey

Damiani et al. (2017)

Siess et al. (2000) Tracks
X-ray Modeling

Model (XSPEC)
Thermal Plasma Emission Model

Absorption Correction
$N_H$ Constrained from IR SED Parameters

or

$N_H$ free XSPEC parameter

($N_H \sim 1.6 \times 10^{21}$ cm$^2$mag$^{-1}$ A$^{-1}$ Vuong et al 2001)

~90% Agreement between independently derived IR $N_H$ and XSPEC $N_H$
The Great Nebula in Carina

*Spitzer* 3.6 μm

X-ray Bright Sample
Net Counts ≥ 50
> 5 sigma detection
371 sources
HRD w/ Intermediate Mass Birth line

Haemmerlé et al. (2019) Tracks
Isochrones: 0.1, 1, 3, 10 myr

log(Teff) [K]

log(Lbol/L⊙)
**L_X-L_{bol} Relation**

T Tauri $\log(L_X/L_{bol}) = -3.4$ - 

\[ \log(L_X/L_{bol}) = -2 \] 

\[ \log(L_X/L_{bol}) = -3 \] 

\[ \log(L_X/L_{bol}) = -4 \] 

\[ \log(L_X/L_{bol}) = -5 \] 

\[ \log(L_X/L_{bol}) = -6 \] 

\[ \log(L_X/L_{bol}) = -7 \]
Main Takeaways...

- IMPS powered by T Tauri dynamo, $\log(L_X/L_{bol}) \sim -4.4 - -3.4$

- R-IMPS X-ray emission decays with radiative interior development

- $2 - 8 \, M_\odot$ AB sources X-ray emission consistent with T Tauri X-ray emission suggesting unseen low mass companion.

- IMPS more luminous in $L_X$ than all other sub-classes with Mean $\log(L_X) \sim 31.3$

- Lx-Mass relation can be extrapolated further from $2 \, M_\odot$ to $4 \, M_\odot$ *for a certain amount of time*
$L_x - L_x$ Relation

![Graph showing the $L_x - L_x$ relation with data points and a trend line.](image-url)
Total Band $L_X$ CDF