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

Evan Haze Núñez

Cal Poly Pomona → Caltech

NSF GRFP Fellow

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Collaborators: Matthew Povich

Breanna Binder

Leisa Townsley

Patrick Broos

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)

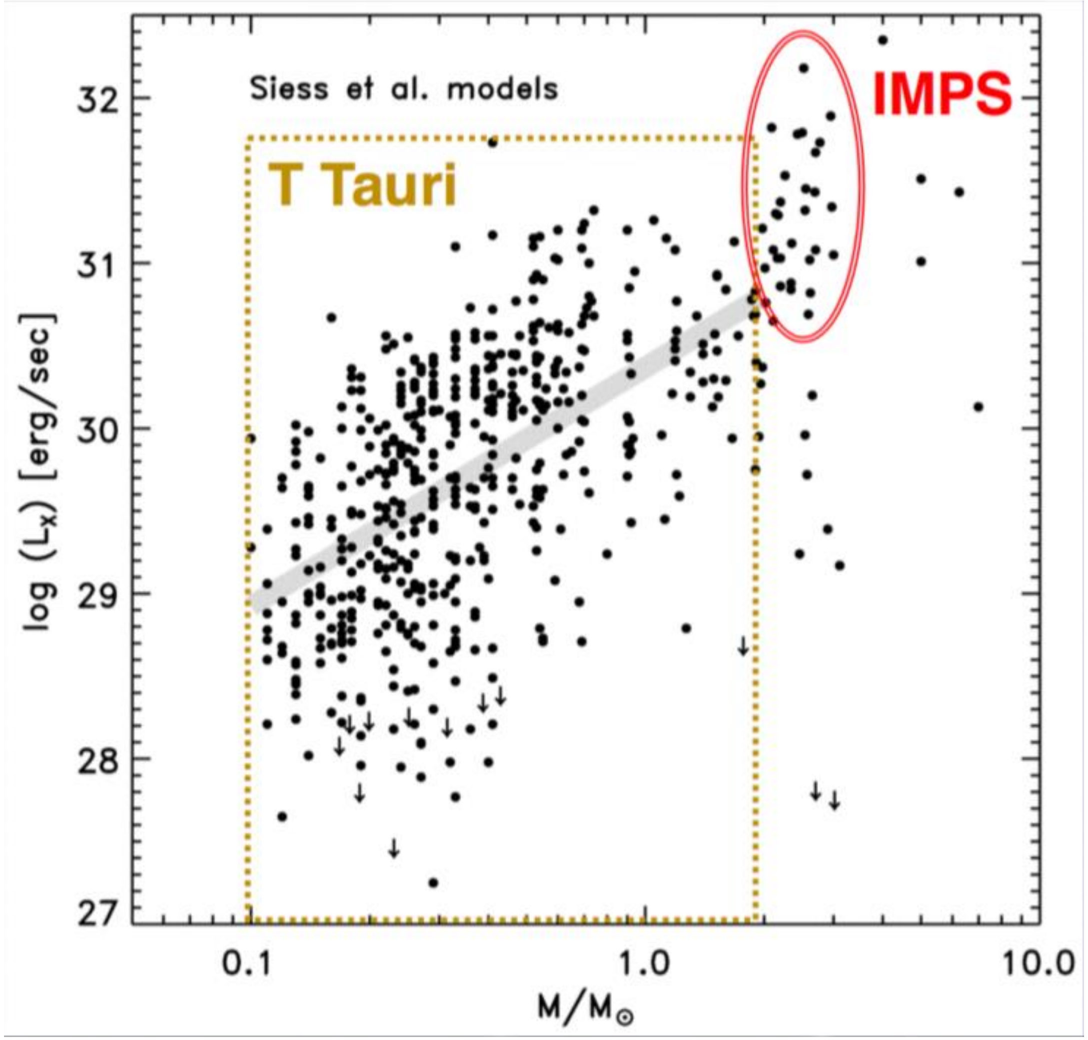
- **Massive stars (O and early B types) (Winds)**
  - "Microshocks" in strong stellar winds produce soft (<1 keV) X-rays (Lucy & White 1980).
  - More exotic mechanisms (Colliding wind binaries? Magnetically channeled wind shocks?) produce hard (>1 keV) X-rays (e.g. Gagné et al. 2011).

- **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



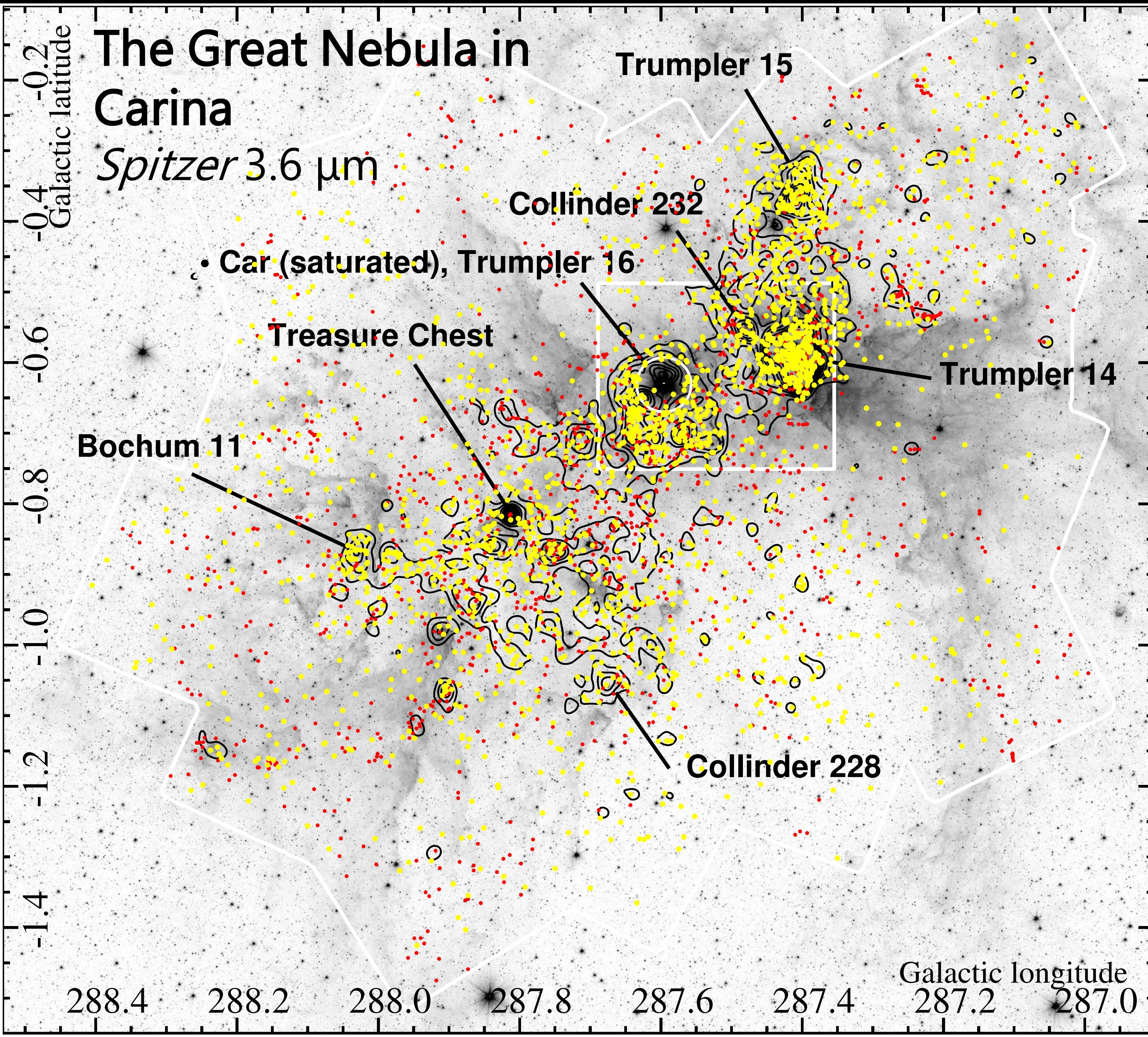
Preibisch+ 2005

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



Diskless PMS

YSOs (disks)

Contours: CCCP stellar density (Feigelson+11)

X-ray Bright Sample

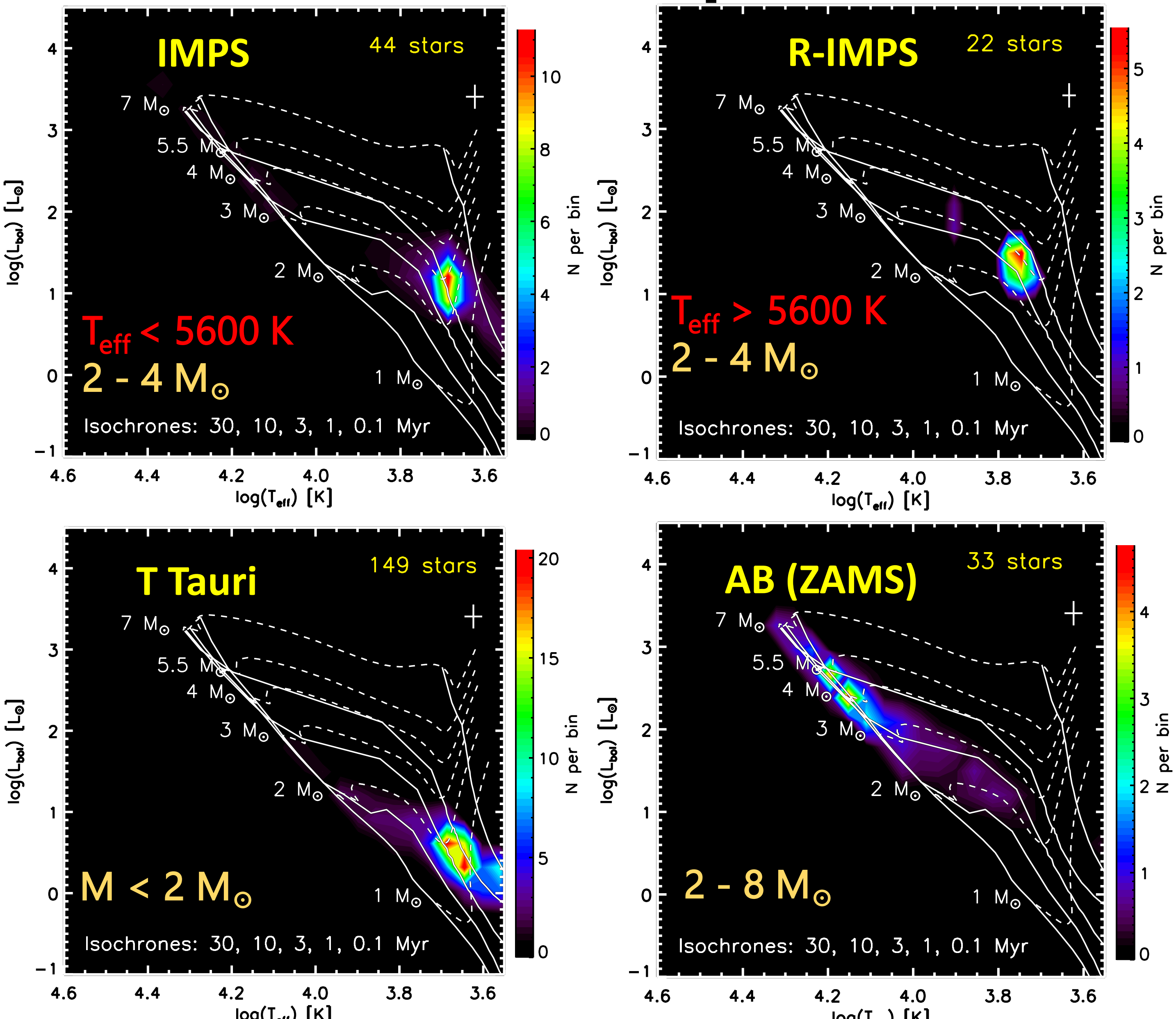
Net Counts ≥ 50

> 5 sigma detection

371 sources

Source Classification (pHRD)

R-IMPS require T_{eff} from spectroscopy. Gaia-ESO Survey Damiani et al. (2017)



Siess et al. (2000) Tracks

X-ray Modeling

Model (XSPEC)
Thermal Plasma Emission Model

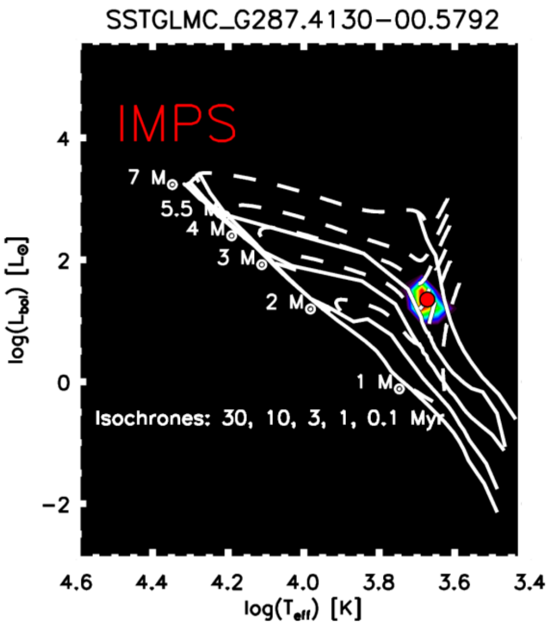
Absorption Correction
N_H Constrained from IR SED Parameters

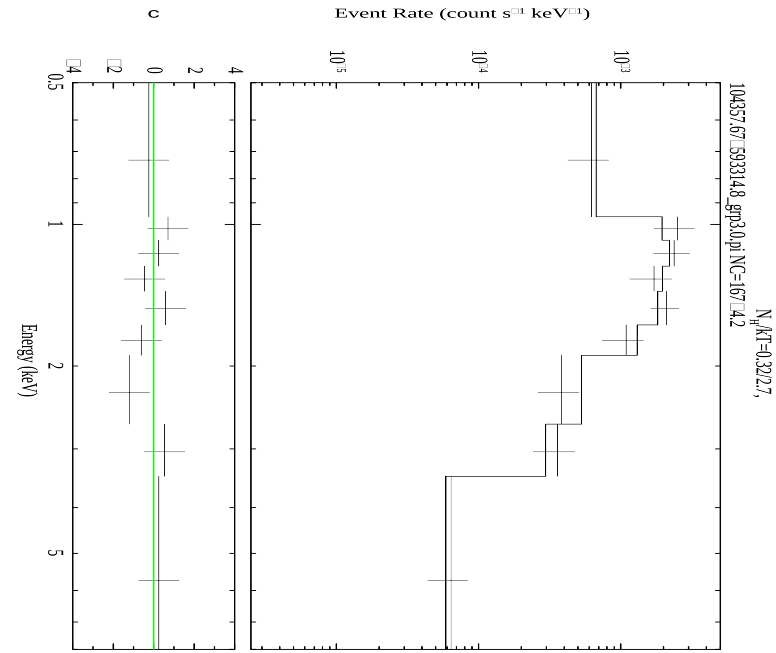
or

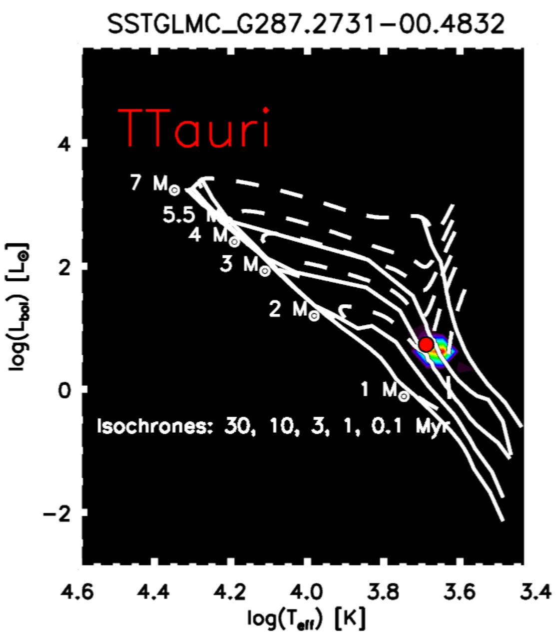
N_H free XSPEC parameter

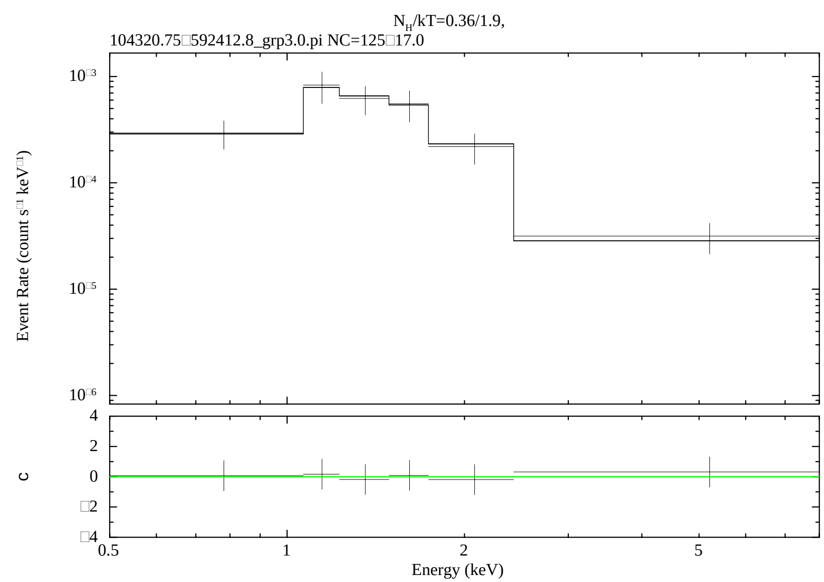
(N_H ~ 1.6x10^{21} cm^{2}mag^{-1} A$_V$ Vuong et al 2001)

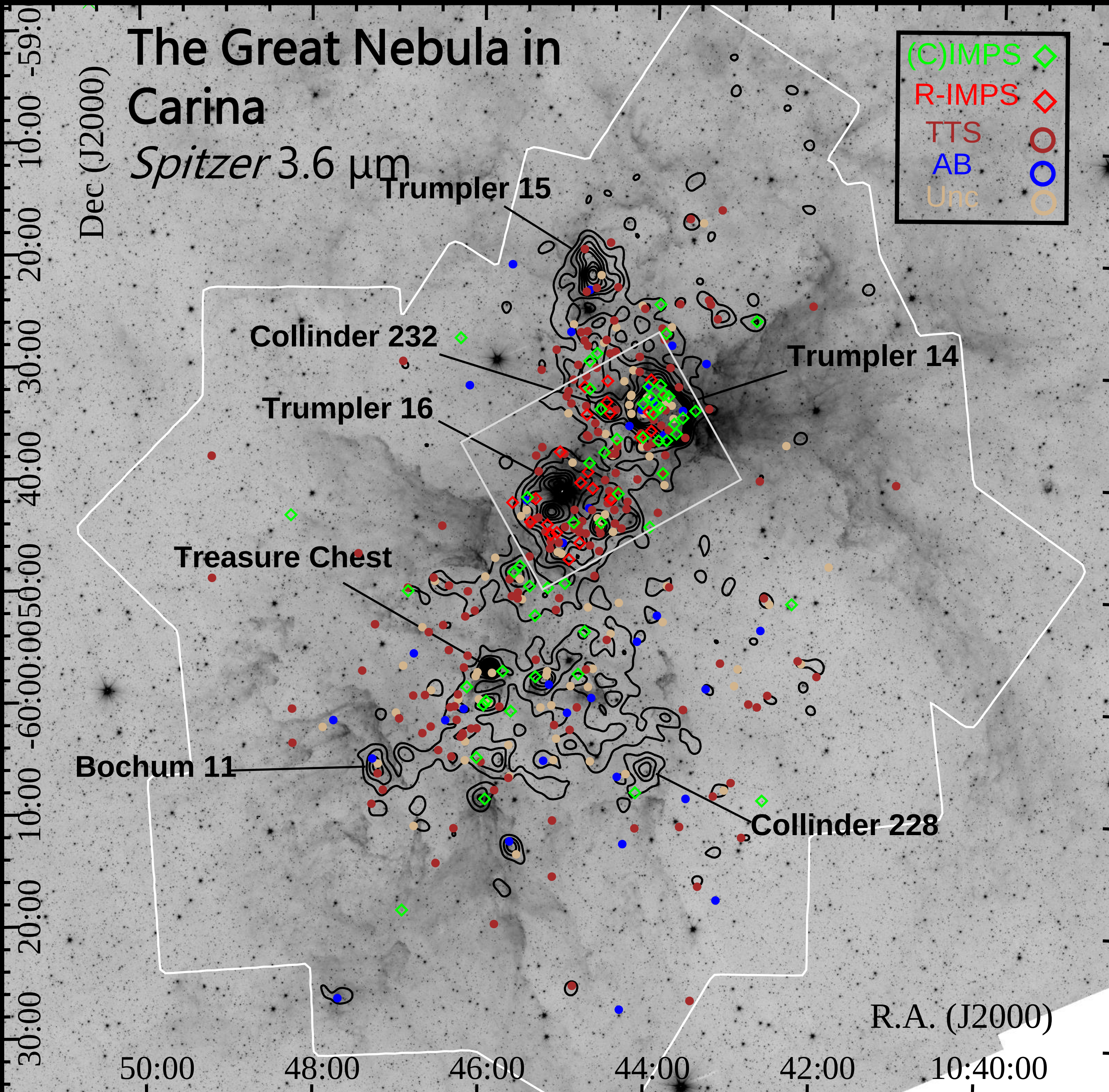
~90% Agreement between independently derived IR N_H and XSPEC N_H











X-ray Bright Sample

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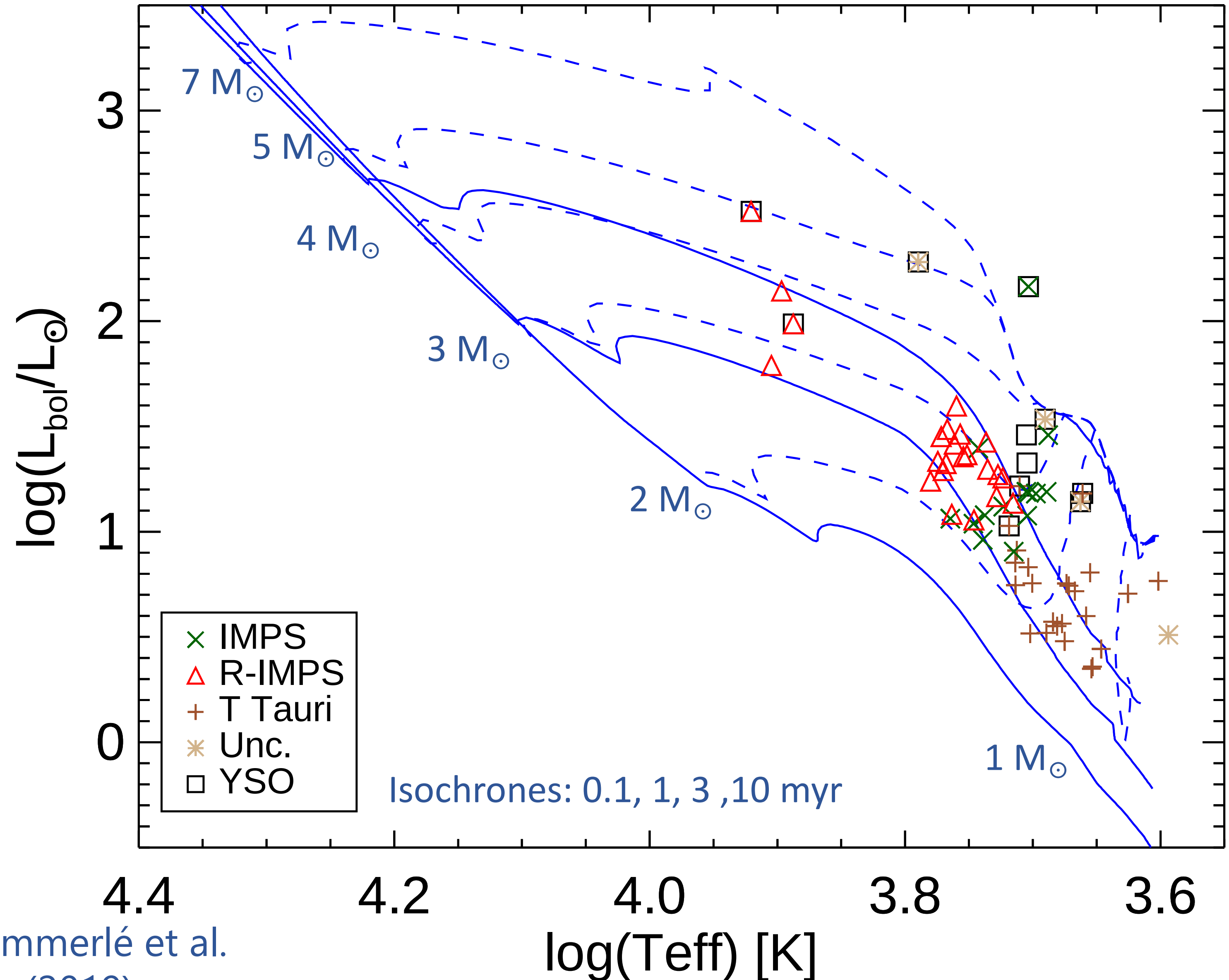
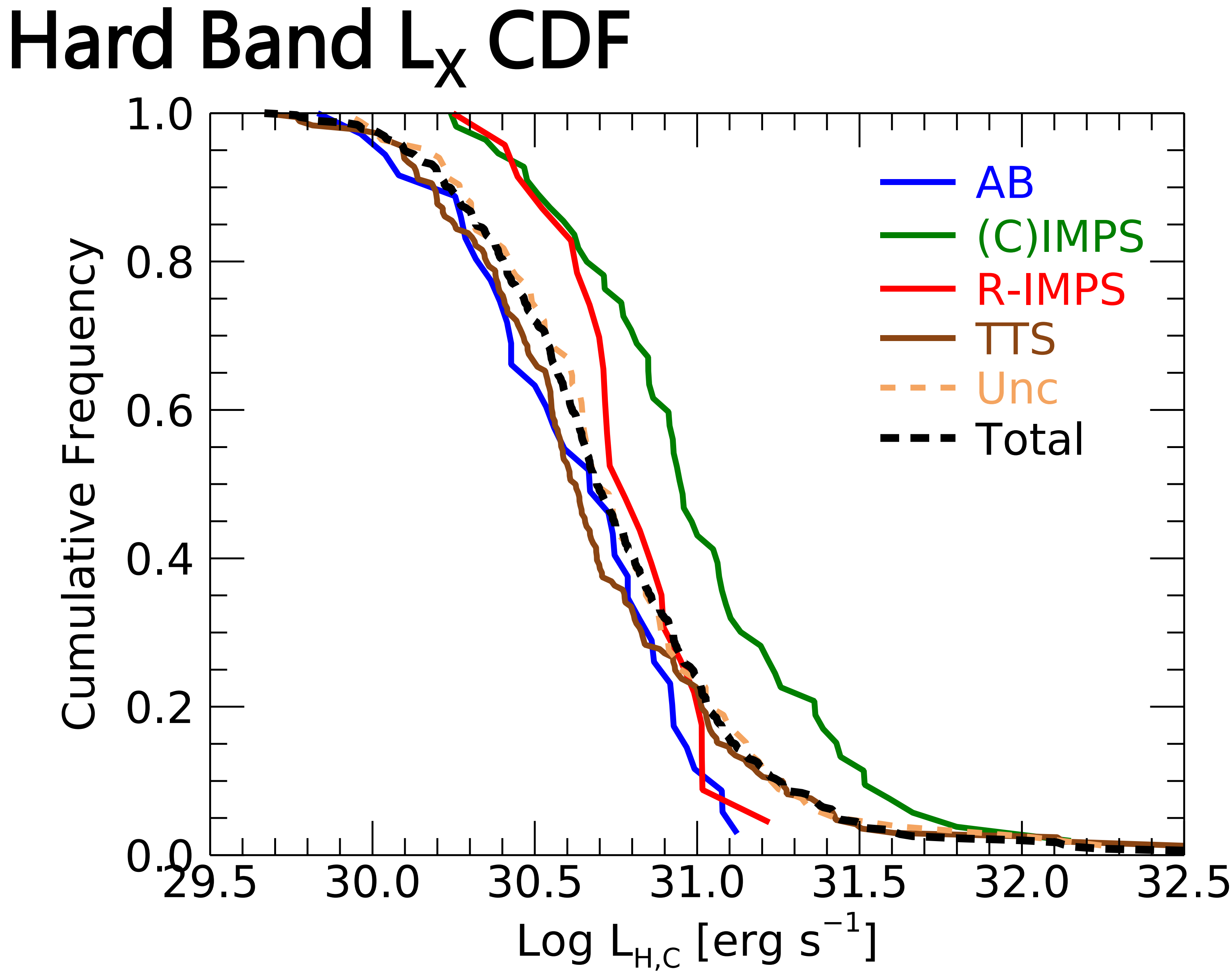
HRD w/ Intermediate Mass Birth line



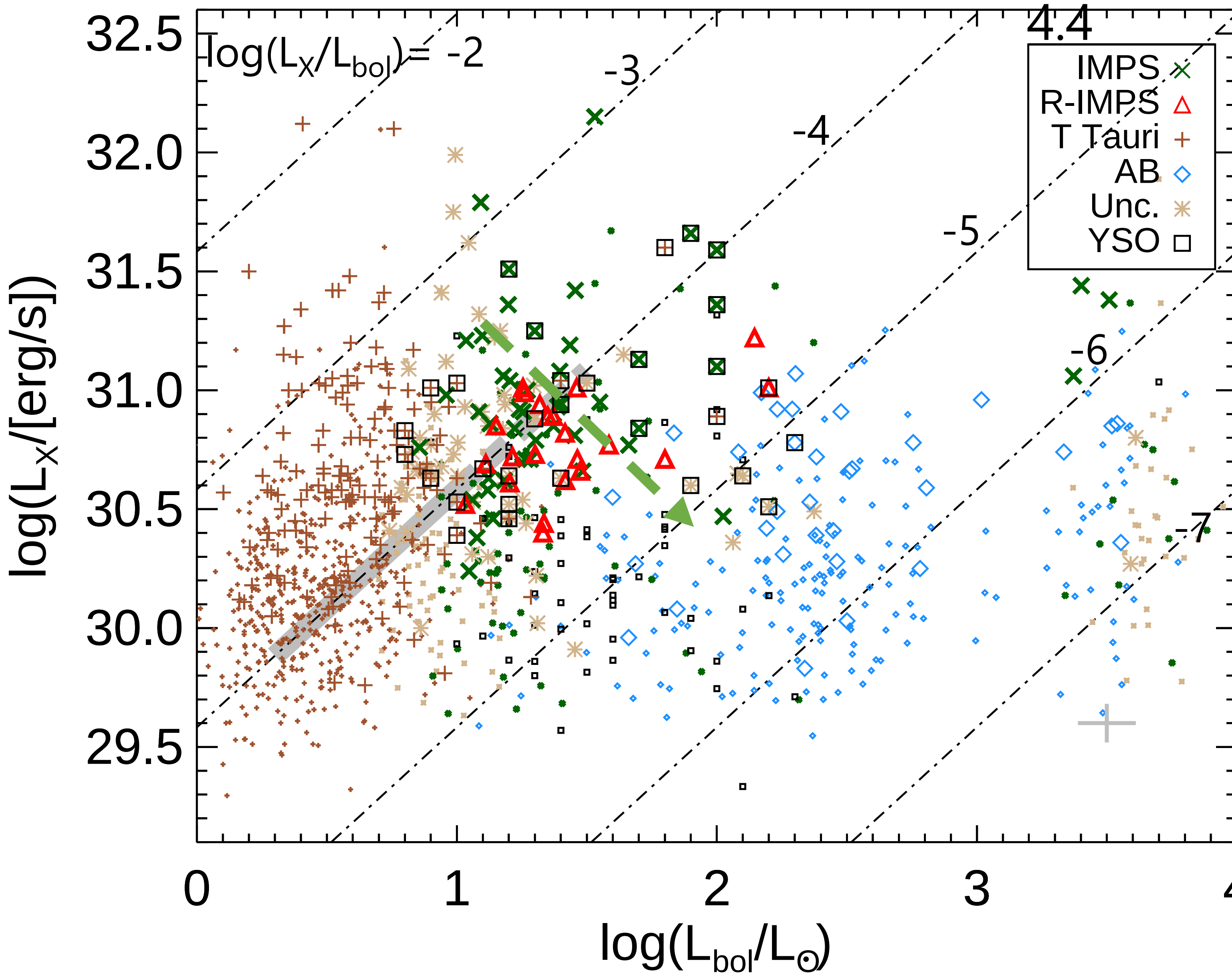
Haemmerlé et al. (2019)
Tracks



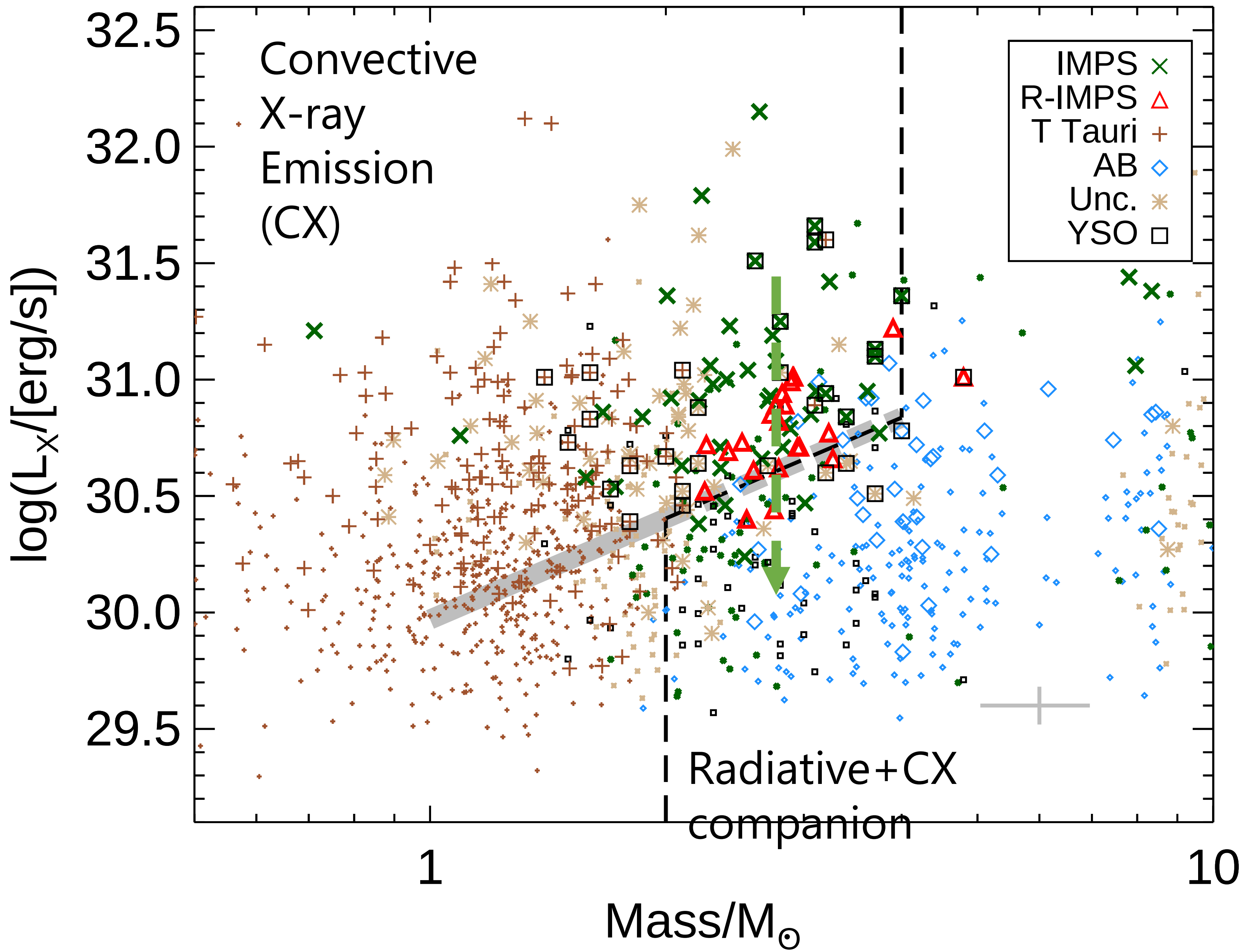
Hard Band L X CDF
1.0
0.8
0.6
0.4
0.2
0.0
29.5
30.0
30.5
31.0
31.5
32.0
32.5
Cumulative Frequency
Log L H,C [erg s −1]
AB
(C)IMPS
R-IMPS
TTS
Unc
Total

L_X-L_{bol} Relation

T Tauri $\log(L_X/L_{bol})$= -3.4 - -4.4



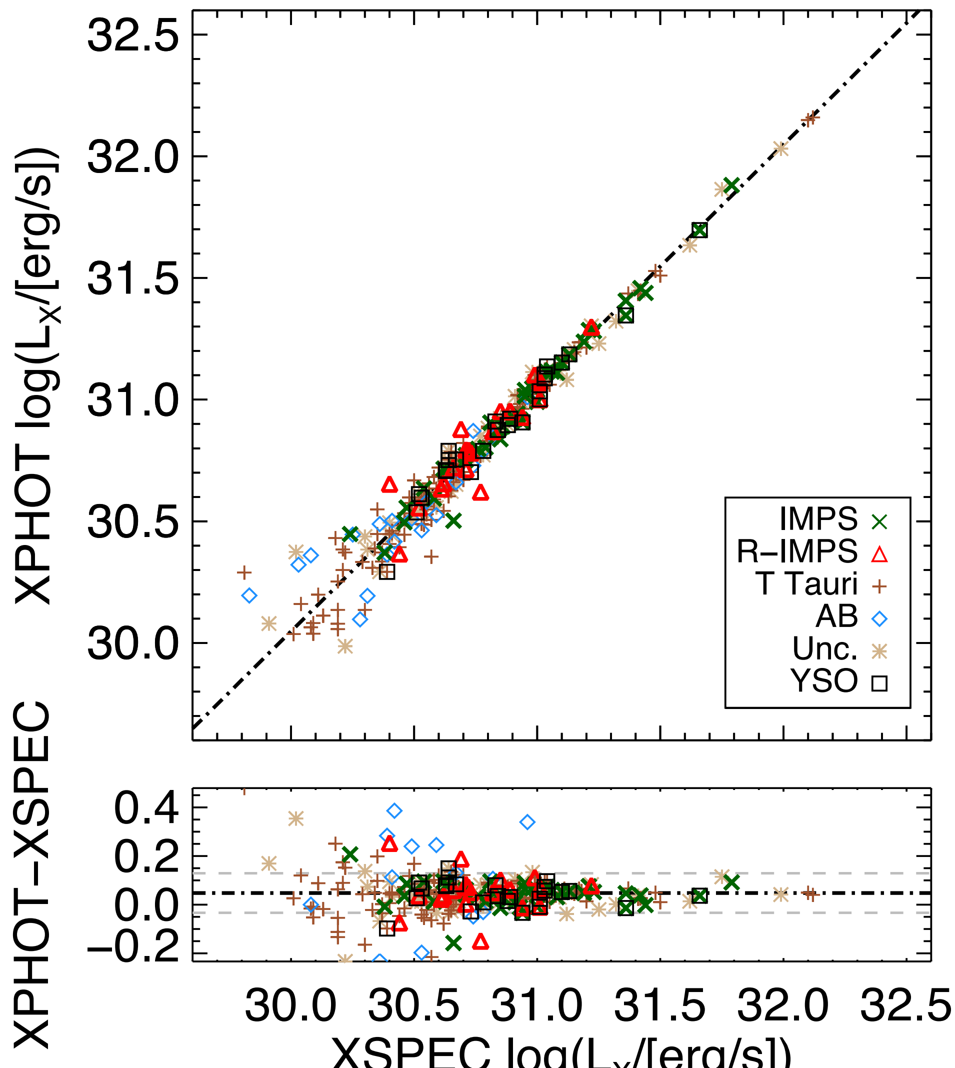
L_X-Mass Relation



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 $\mathrm{Log}(L_X) \sim 31.3$
- 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



Total Band L_X CDF