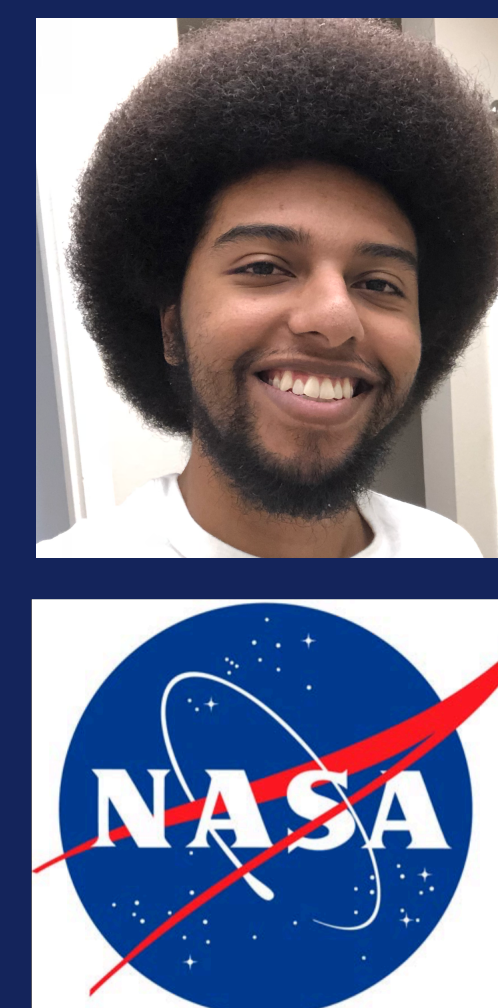# Characterizing Intermediate-Mass Pre-Main-Sequence Stars Via X-Ray Emission

Evan H. Nuñez, Matthew S. Povich, and **Breanna A. Binder** • *California State Polytechnic University, Pomona*
Leisa K. Townsley and **Patrick S. Broos** • *The Pennsylvania State University*

Background on IMPS

Intermediate-Mass Pre-Main-Sequence Stars (IMPS):

- Masses between 2 $M_\odot$ and 8 $M_\odot$

- Spectral types G or later, fully or partially convective structure

- Characterized by absorption-corrected L_X >10^{31} erg s^{-1}

- Higher-mass analogs of coronal T Tauri X-ray emission (Povich et al. 2011, Gregory et al. 2016)?

- Potentially sensitive chronometers for very young (<10 Myr) star-forming regions since their X-ray emission is highly time-dependent (Gregory et al. 2016)
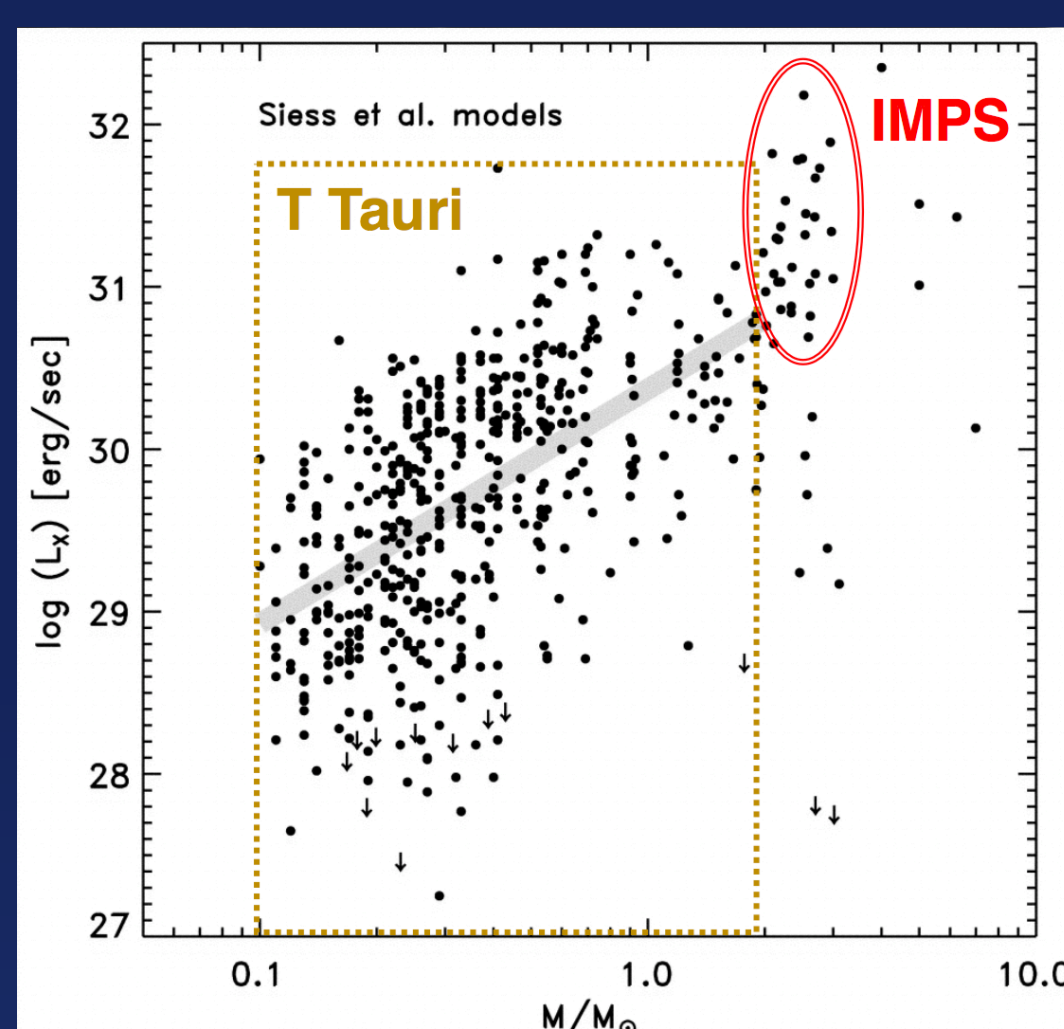

Fig. 3 from Preibisch et al. (2005), L_X versus mass for stars in the Orion Nebula Cluster
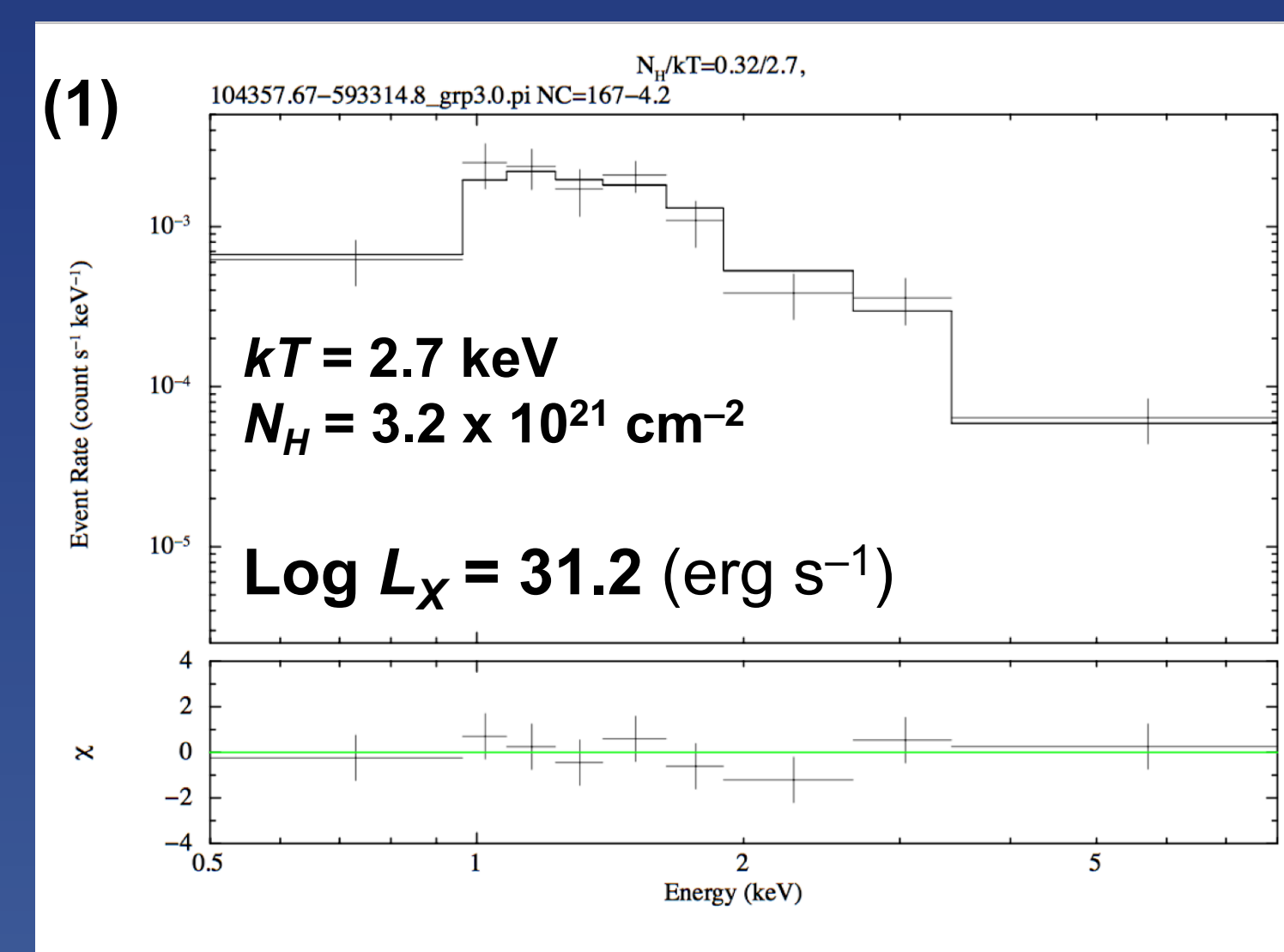
IR SED Classification

- ***Probabilistic HR Diagrams (pHRDs)*** are "heat maps" showing (L, T_{eff}) parameter distributions from SED model fits to 1–8 µm IR photometry.

- We classify each source by "dividing" its pHRD into regions separated by temperature and mass. This is summarized below in the pHRD showcasing the fit of our best IMPS source (3) (Povich et al. 2011).
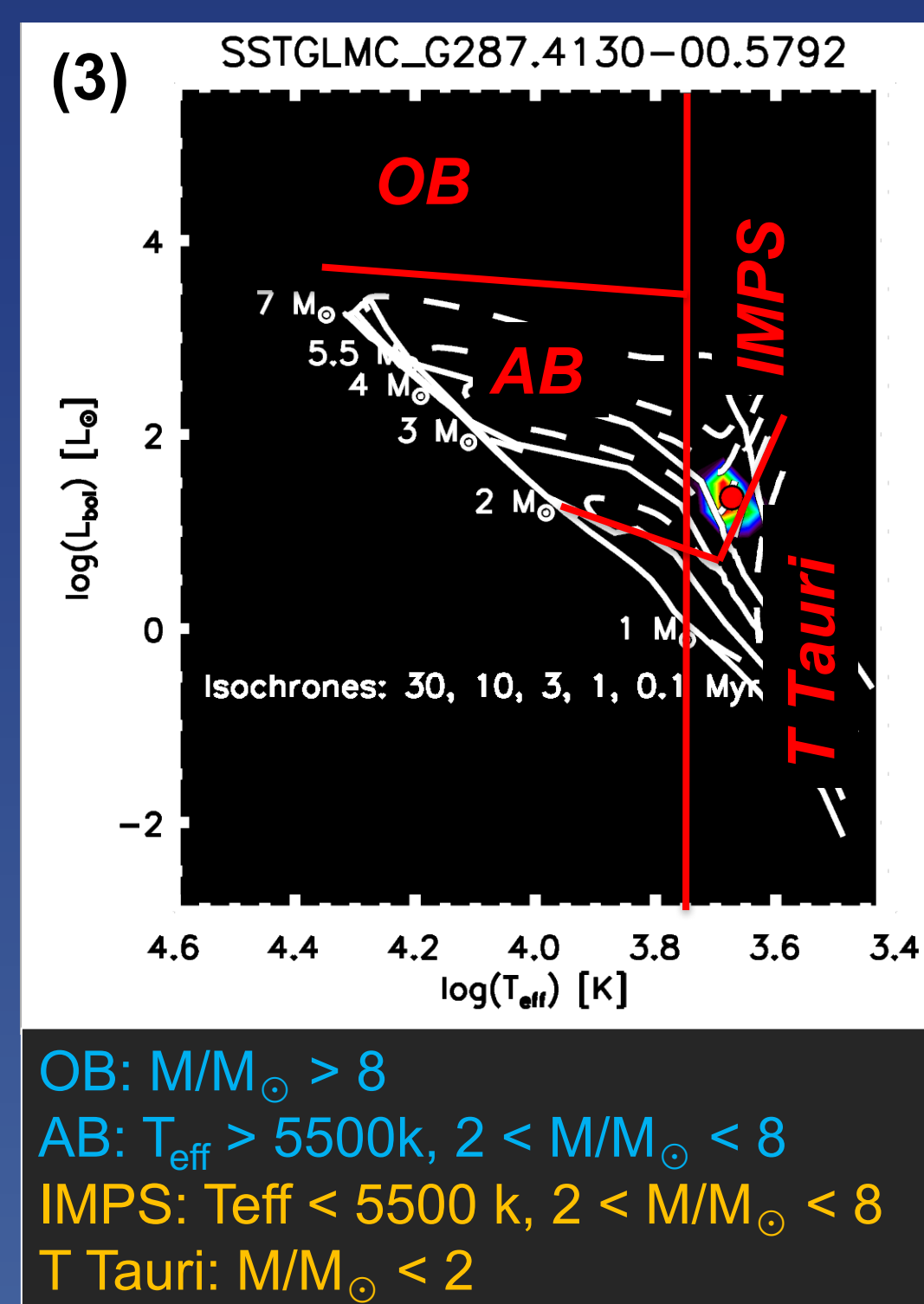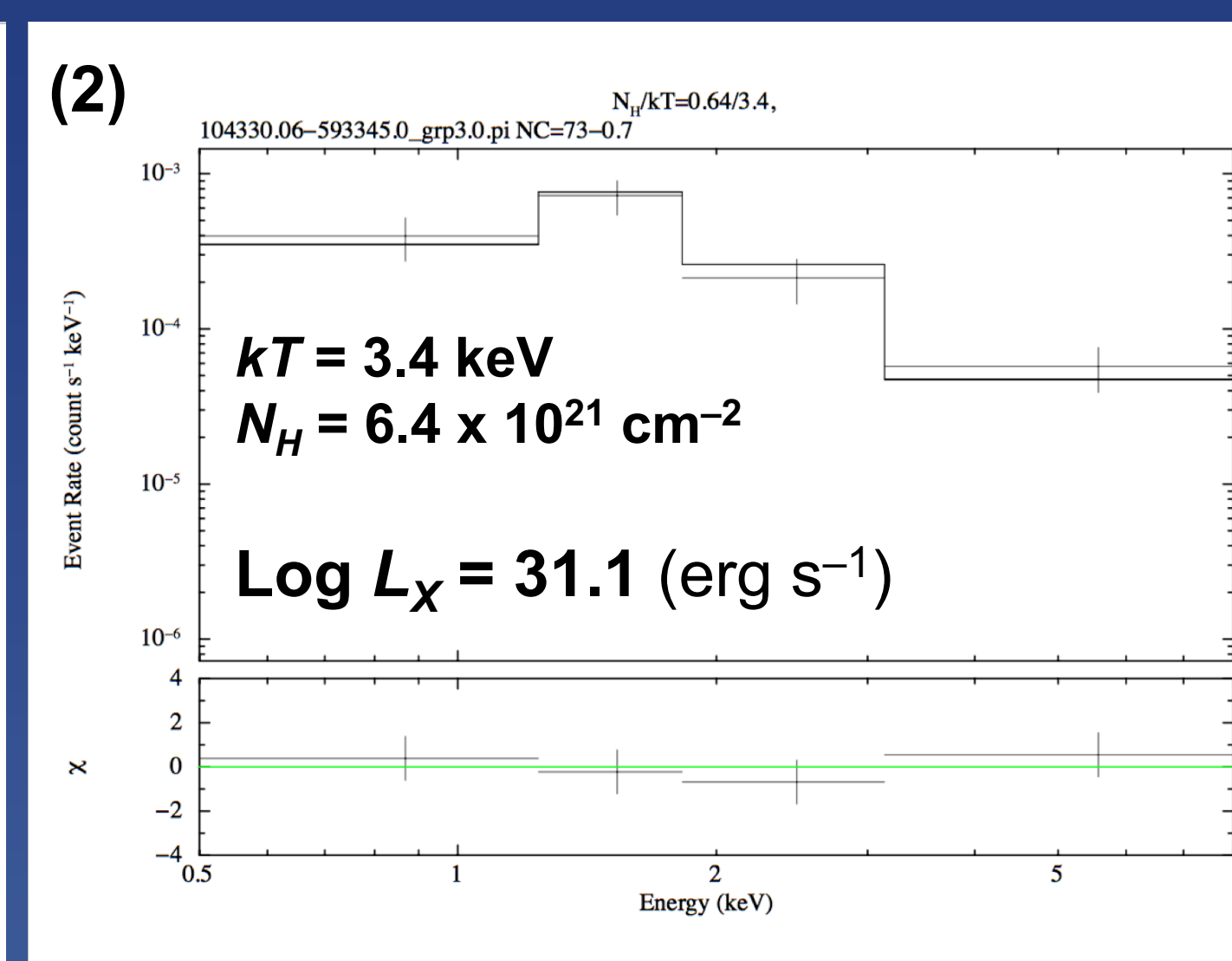

OB: M/M$_\odot$ > 8
AB: T$_{eff}$ > 5500k, 2 < M/M$_\odot$ < 8
IMPS: Teff < 5500 k, 2 < M/M$_\odot$ < 8
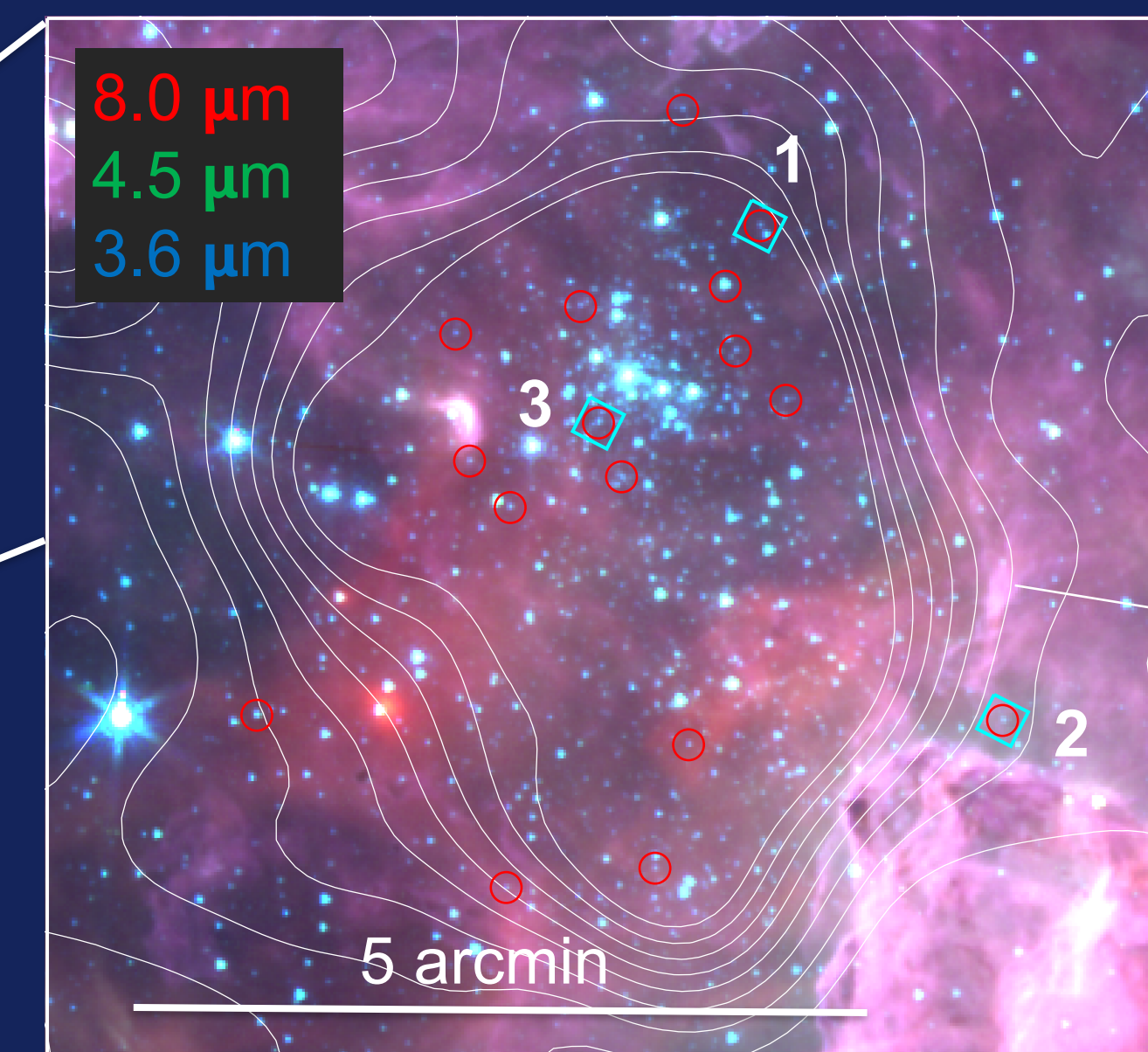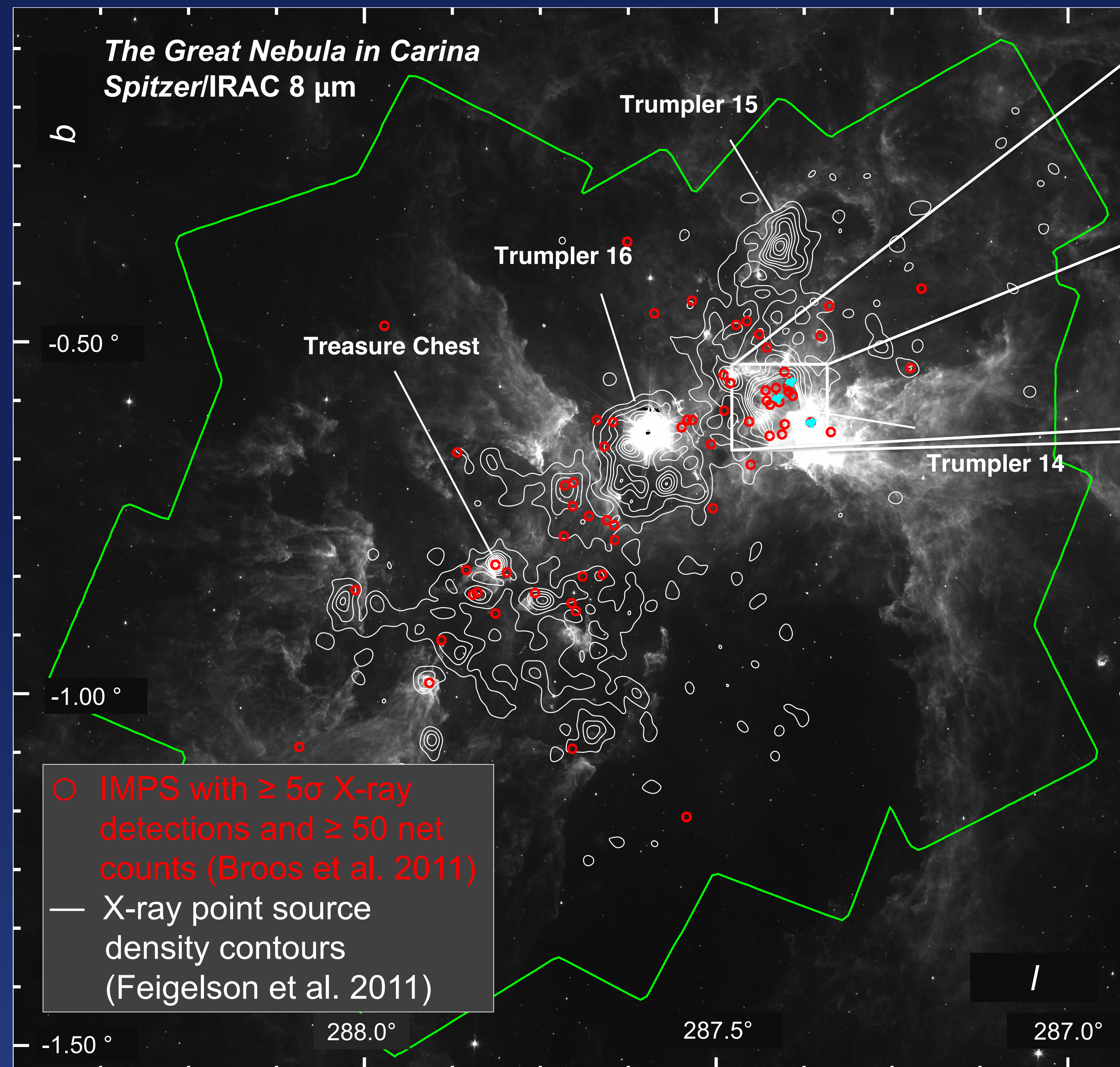T Tauri: M/M$_\odot$ < 2

X-Ray Spectral Fits

- We used Xspec (Arnaud 1996) to fit 1 component thermal plasma models to ACIS-I spectral data from the Chandra Carina Complex Project (CCCP; Broos et al. 2011; Townsley et al. 2011).

- Where possible, absorption was constrained using the IR extinction.

- Total-band (0.5-8 keV) absorption-corrected model fluxes were converted to luminosities assuming a distance of 2.3 kpc to the Carina Complex.

The Great Nebula in Carina
Spitzer/IRAC 8 µm

Trumpler 15

Trumpler 16

Treasure Chest

Trumpler 14

○ IMPS with ≥ 5σ X-ray detections and ≥ 50 net counts (Broos et al. 2011)
— X-ray point source density contours (Feigelson et al. 2011)

8.0 µm
4.5 µm
3.6 µm

5 arcmin

Zoom in on the Trumpler 14 cluster. This is a rich, young cluster containing a high density of X-ray emitting stars depicted by the white contours on the plot (Feigelson et al. 2011). It has the largest concentration of X-ray bright IMPS candidates, including the three sources highlighted in this poster **(numbered).**

Among our examples, Source (3) has the highest X-ray luminosity and mass (~3-4 M$_\odot$). Located near the dense core of Trumpler 14; ~1 Myr pHRD age of this star is consistent with the youth of the parent cluster (e.g. Getman et al. 2014).

(3)
kT = 2.9 keV
N_H = 3.2 x 10^{21} cm^{-2}
Log L_X = 31.4 (erg s^{-1})

(1)
kT = 2.7 keV
N_H = 3.2 x 10^{21} cm^{-2}
Log L_X = 31.2 (erg s^{-1})

(2)
kT = 3.4 keV
N_H = 6.4 x 10^{21} cm^{-2}
Log L_X = 31.1 (erg s^{-1})

Example source (1) with mass ~2-3 M$_\odot$ and age ~1 Myr. This and the other two example sources show no signs of variability and were well-fit with a *single* thermal plasma component using absorption constrained by the IR extinction.
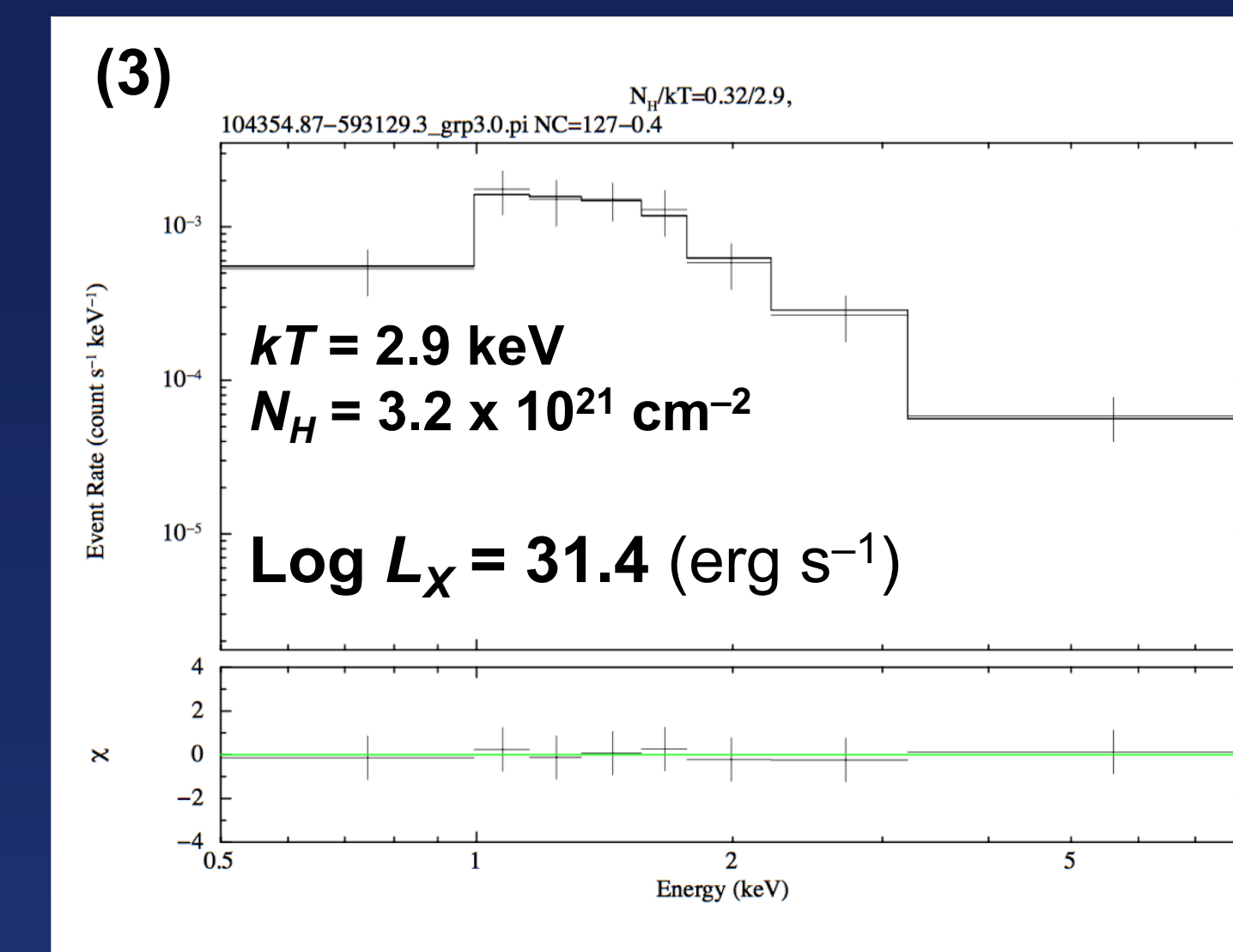
Source (2) with mass ~3 M$_\odot$ and age <1.5 Myr. The higher absorption (=IR extinction) of this source compared to the other two is consistent with its location near the molecular cloud bordering Trumpler 14 (cutout figure, top right).

Next Steps

- Comparative analysis of IMPS X-ray spectra and those of other source classifications (AB stars, TTauri stars, OB stars and unclassified)

- Explore using the fraction of X-ray bright IMPS in a stellar population for age-sensitive science, such as measuring the star formation rate of the entire Carina region

Acknowledgements

References

Arnaud 1996, *ASP Conf. Series*, **101**, 17
Broos et al. 2011, *ApJS*, **194**, 2
Feigelson et al. 2011, *ApJS*, **194**, 14
Getman et al. 2014, *ApJ*, **787**, 108
Gregory et. al 2016, *MNRAS*, **457**, 3836
Povich et al. 2011, *ApJS*, **194**, 14
Preibisch et al. 2005, *ApJS*, **160**, 401
Siess, Dufour, & Forestini 2000 *A&A*, **358**, 593
Townsley et al. 2011, *ApJS*, **194**, 1

Download a copy of this poster!

Cal-Bridge
A California State University–University of California PhD Bridge Program