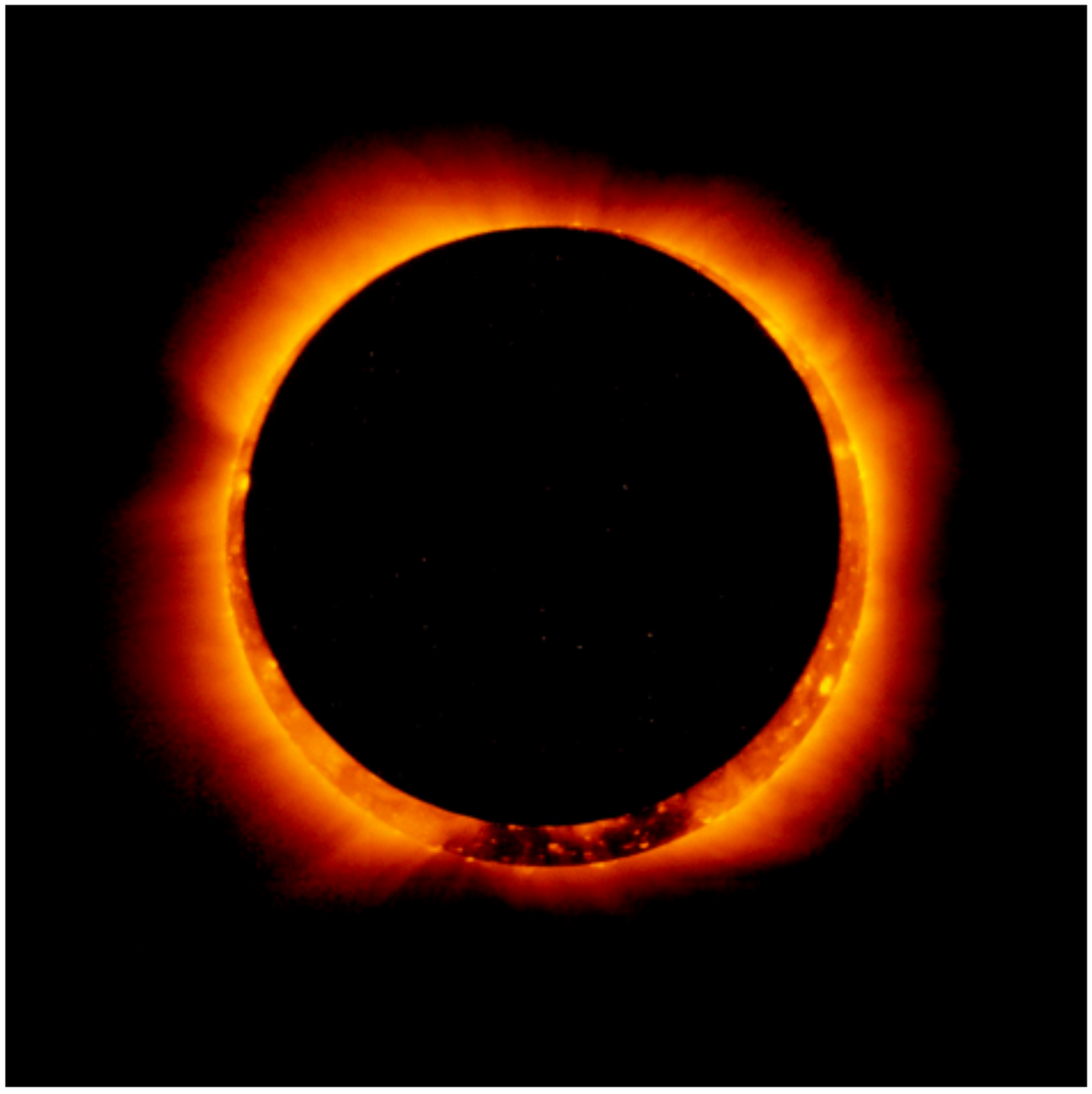
High Resolution X-ray Spectroscopy and Star Formation: HETG Observations of the Pre-Main Sequence Stellar Cluster IC 348

Massachusetts Institute of Technology

David Principe

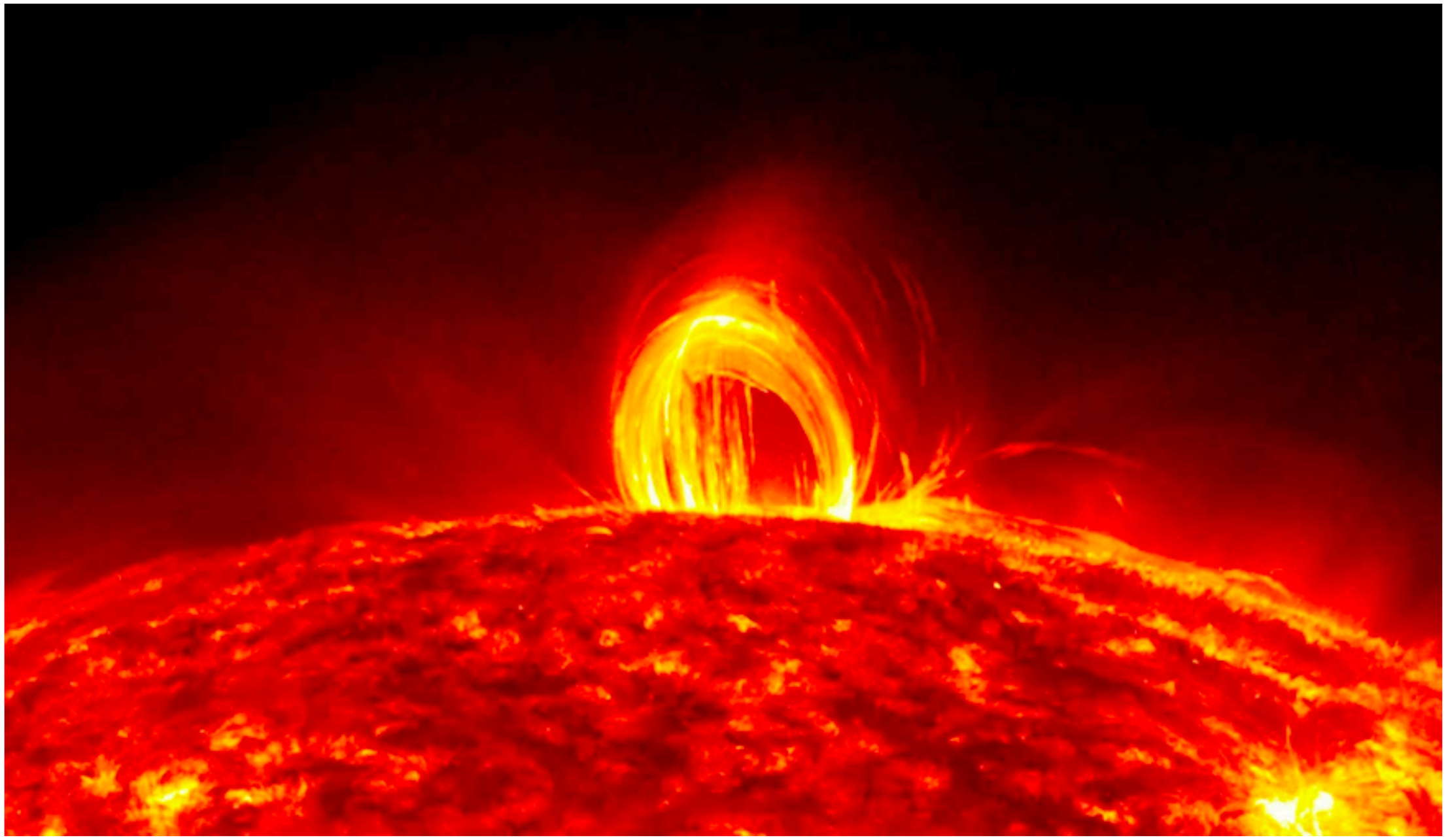
MIT KAVLI INSTITUTE

David Huenemoerder (MIT), N. Schulz (MIT), J. H. Kastner (RIT), D. Weintraub (Vanderbilt U.), T. Preibisch (U. Sternwarte Muenchen)



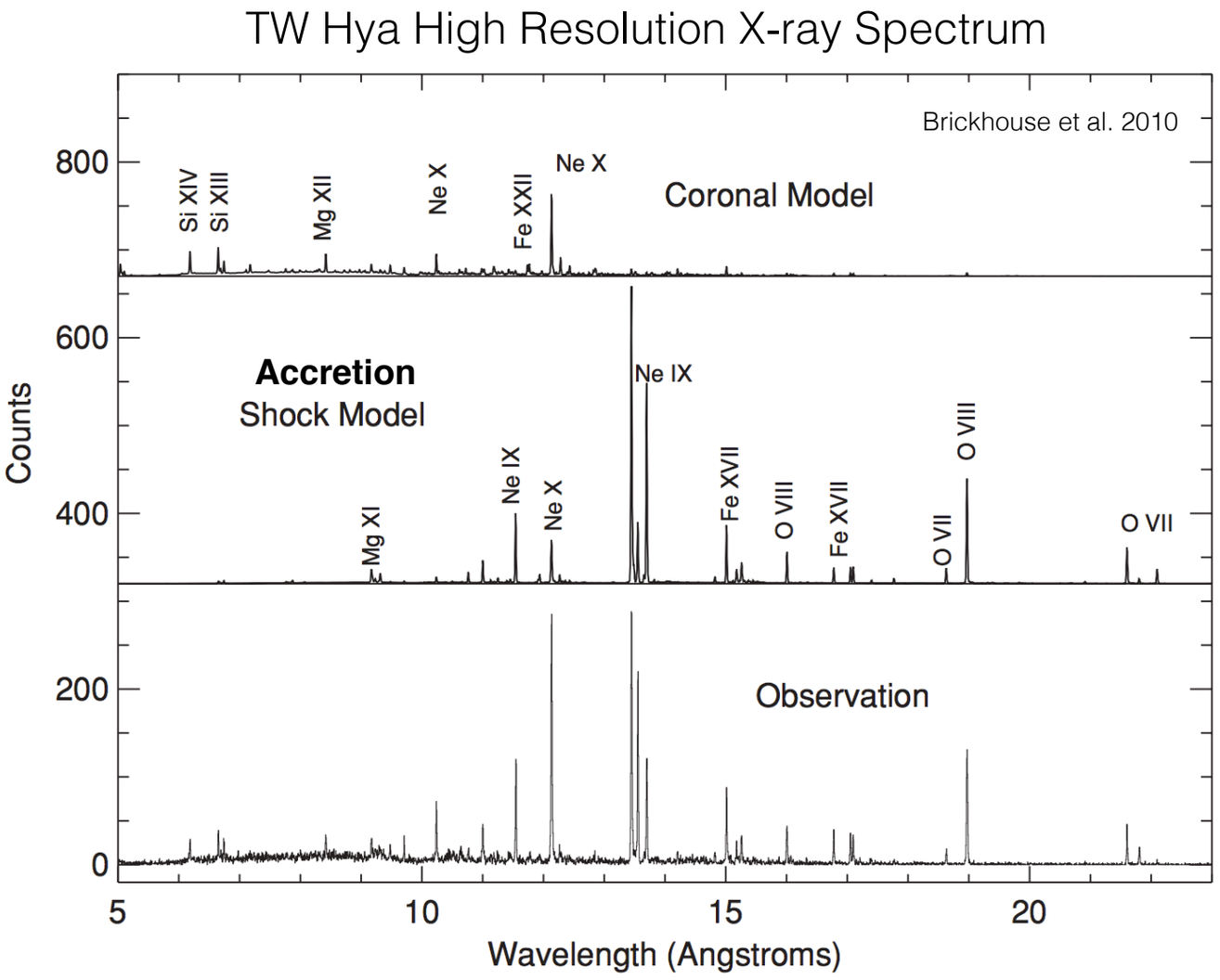
NASA

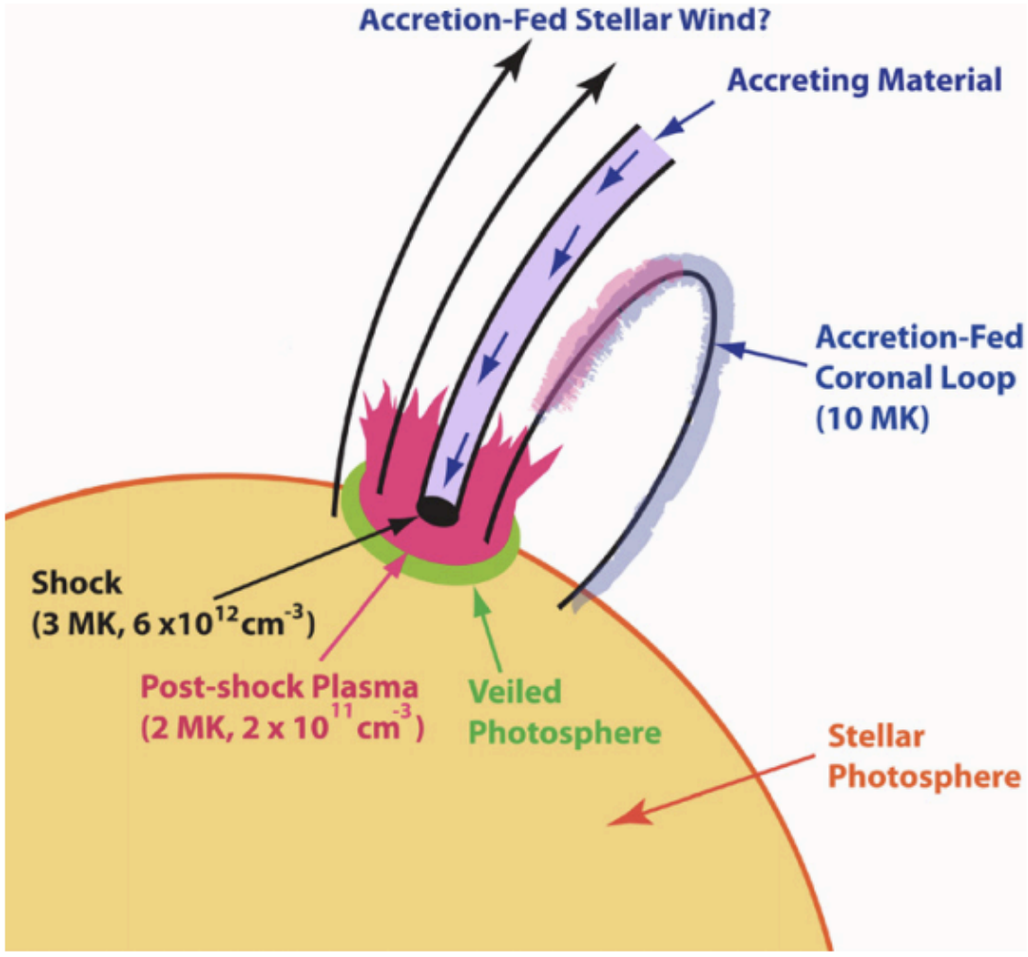
Stellar Coronae: A Window to Understanding Pre-Main Sequence Evolution



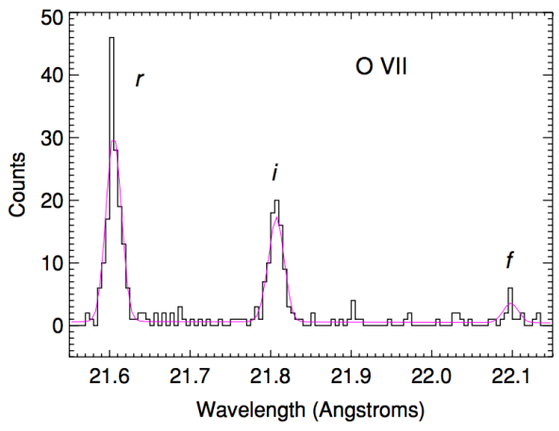
SDO NASA

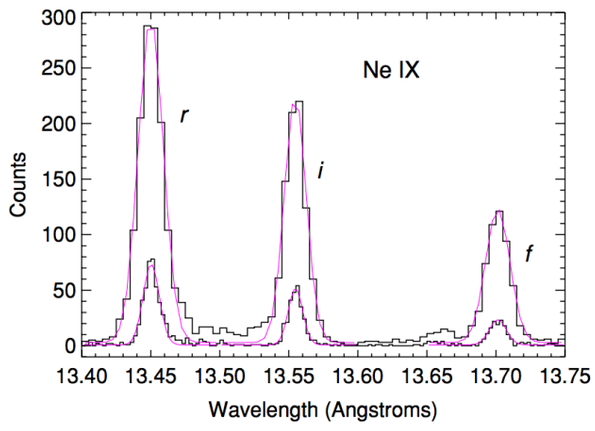
Distinguishing between Coronal X-rays and Accretion Shock-heated X-rays with Gratings





Note: TW Hya's face on inclination readily reveals accretion signatures





Specific line ratios can provide electron number density and temperature diagnostics capable of discerning shock environments from coronal emission.

Brickhouse et al. 2010

TG Cat: The Chandra Transmission Grating Catalog

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+/-	Links	object	simbad_ID	ra (h:m:s)	decl			num_extractions
☐	s d b i	TYC 8979-1997-1	TYC 8979-1997-1	12:27:16.625	-62:3		Y*O	1
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☐	s d b i	2MASS J07185037-2457557	2MASS J07185037-2457557	07:18:50.472	-24:5		Y*O	2
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☐	s d b i	RY Tau	V* RY Tau	04:21:57.439	+28:2		*, TT*, V*, X	2
☐	s d b i	T Cha	V* T Cha	11:57:13.481	-79:21:31.032	Or*	T*, V*, X	3
☐	s d b i	TW Hydrae	V* TW Hya	11:01:51.874	-34:42:17.208	TT*	V*, X	7
☐	s d b i	TWA 14	1RXS J111325.1-452344	11:13:26.189	-45:23:42.900	TT*	*, IR, TT*, X	2
☐	s d b i	UX Ari	V* UX Ari	03:26:35.393	+28:42:54.396	RS*	*, **, IR, Rad, RS*, SB*, TT*, UV, V*, X	2
☐	s d b i	V2129 Oph	V* V2129 Oph	16:27:40.284	-24:22:04.404	Or*	*, Em*, IR, Or*, TT*, TT?, V*, X	2
☐	s d b i	V4046 Sgr	V* V4046 Sgr	18:14:10.466	-3		T*, V*	2
☐	s d b i	V987 Tau (HD 283572)	V* V987 Tau	04:21:58.846	+2		V*, X	1
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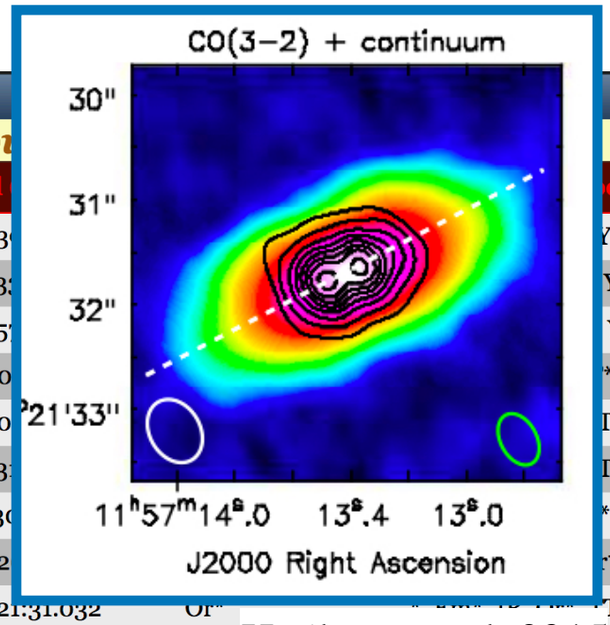
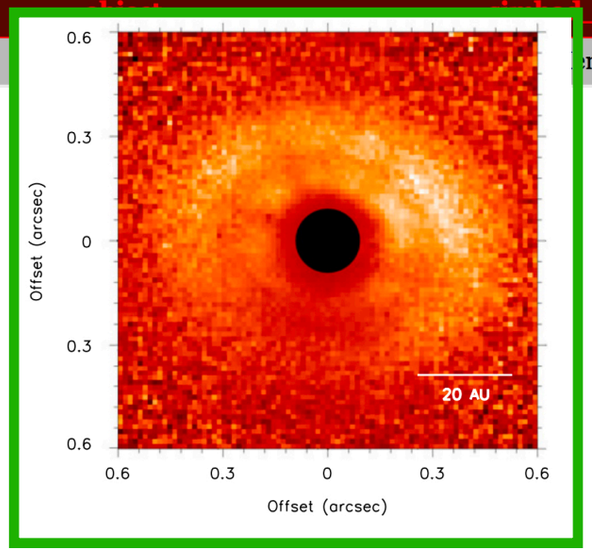
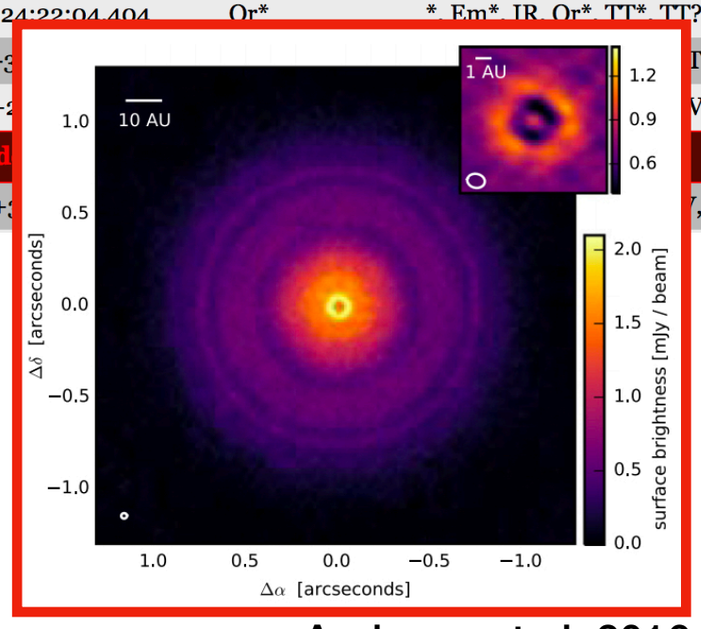


Huélamo et al. 2015



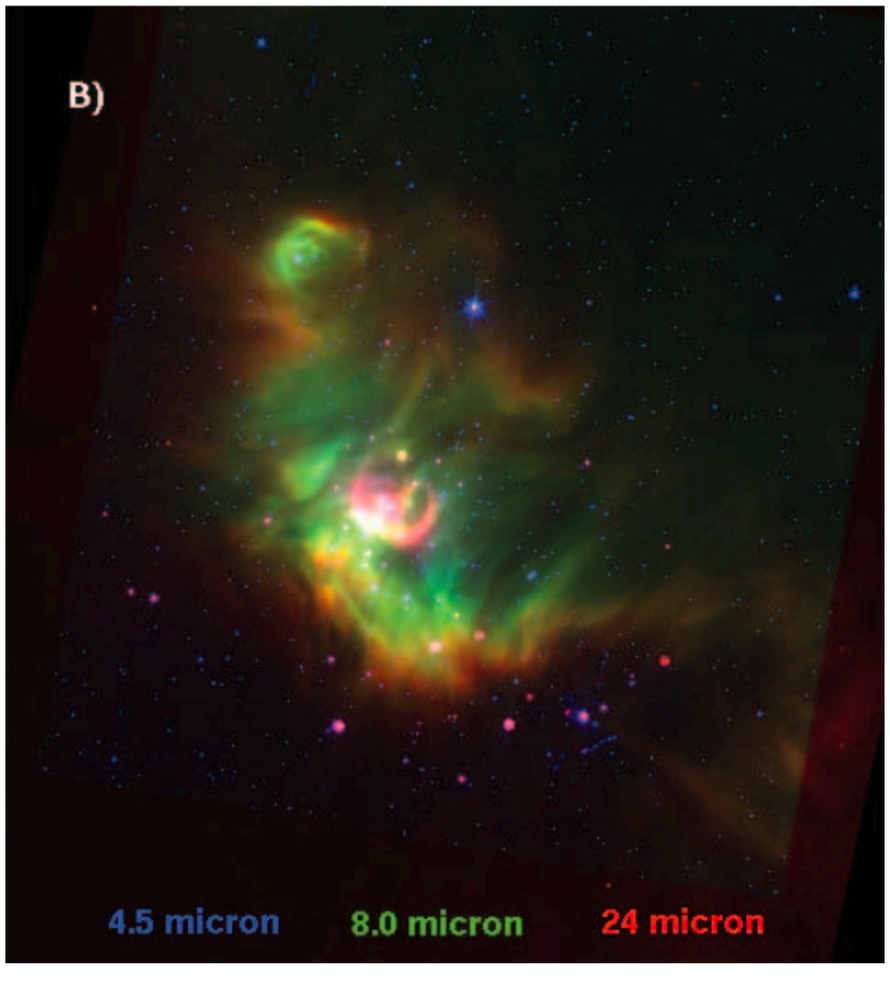
Rapson et al. 2015

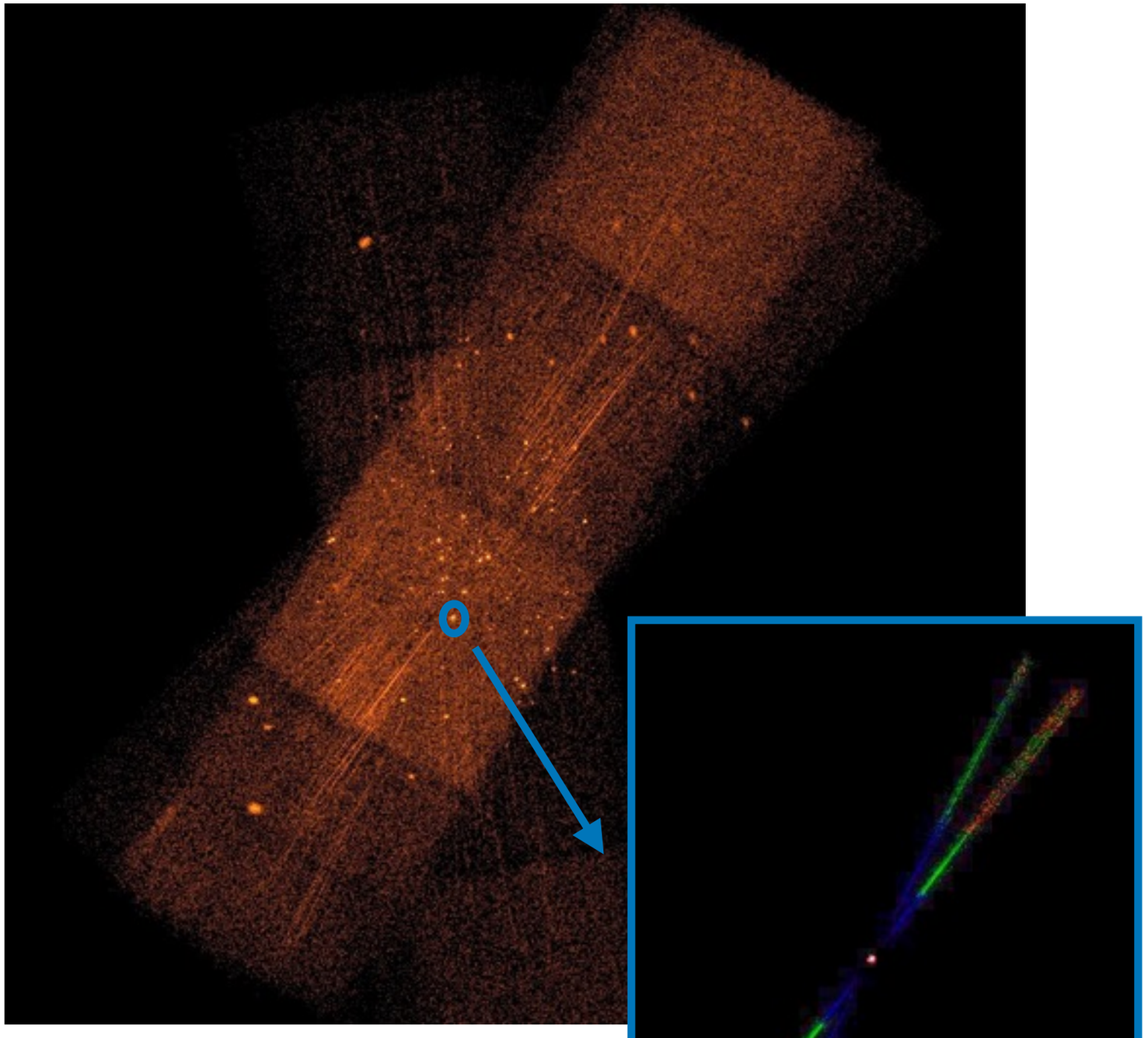


Andrews et al. 2016

IC 348: A Cluster of Pre-MS Stars at the Cusp of Planet Formation

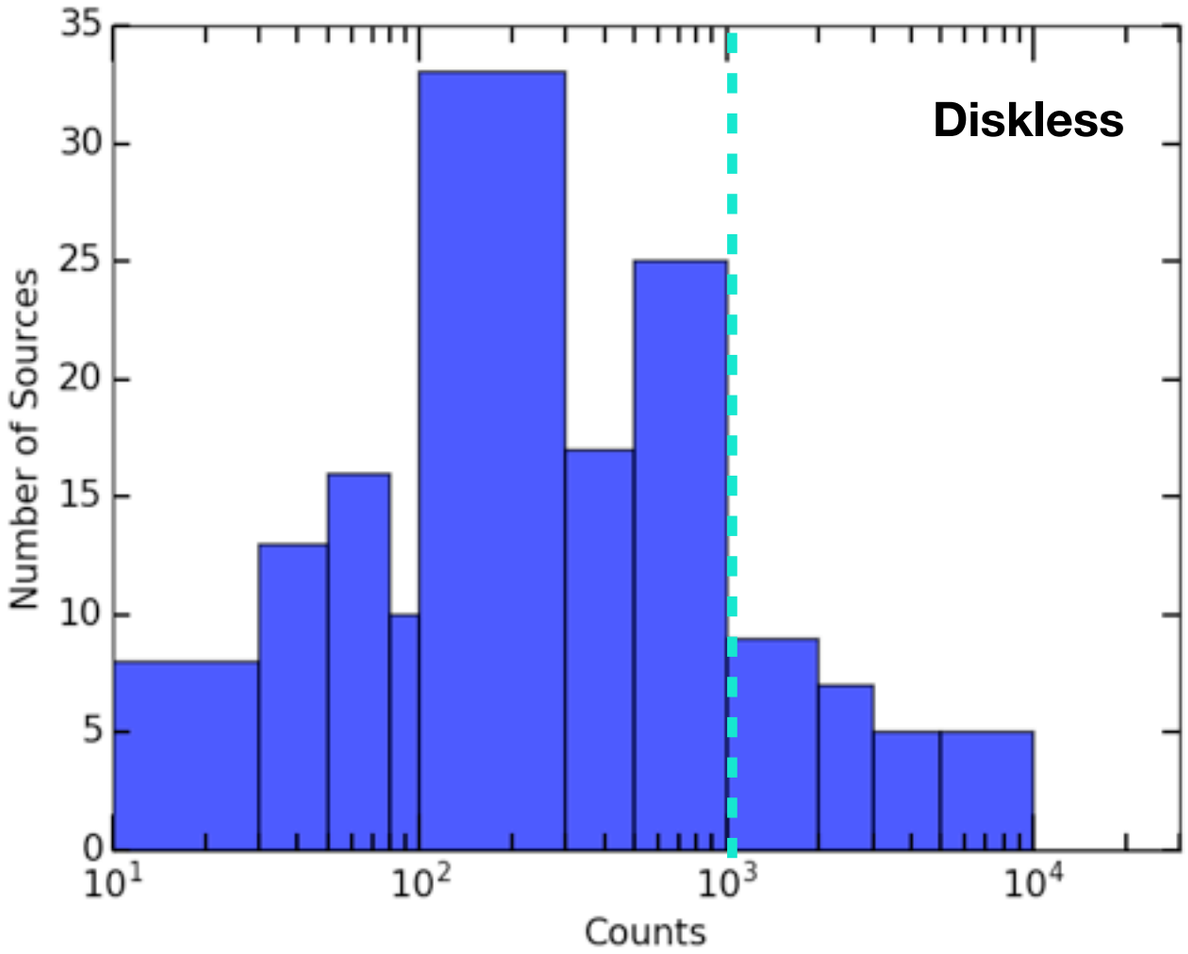
- Age ~2-3 Myr
- Absence of high-mass stars.
- ~400 clusters members at distance of ~300 pc.

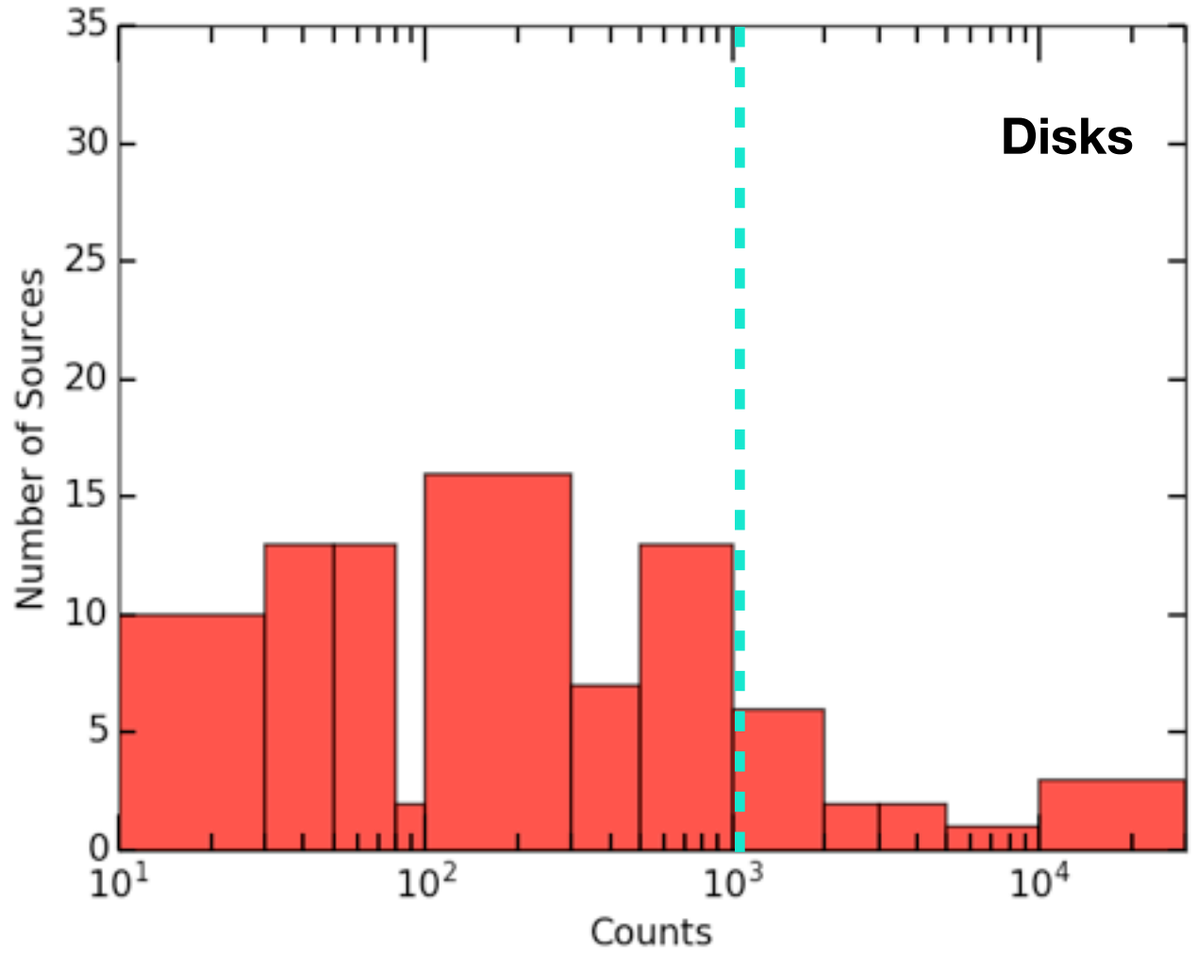




Muench et al. 2007

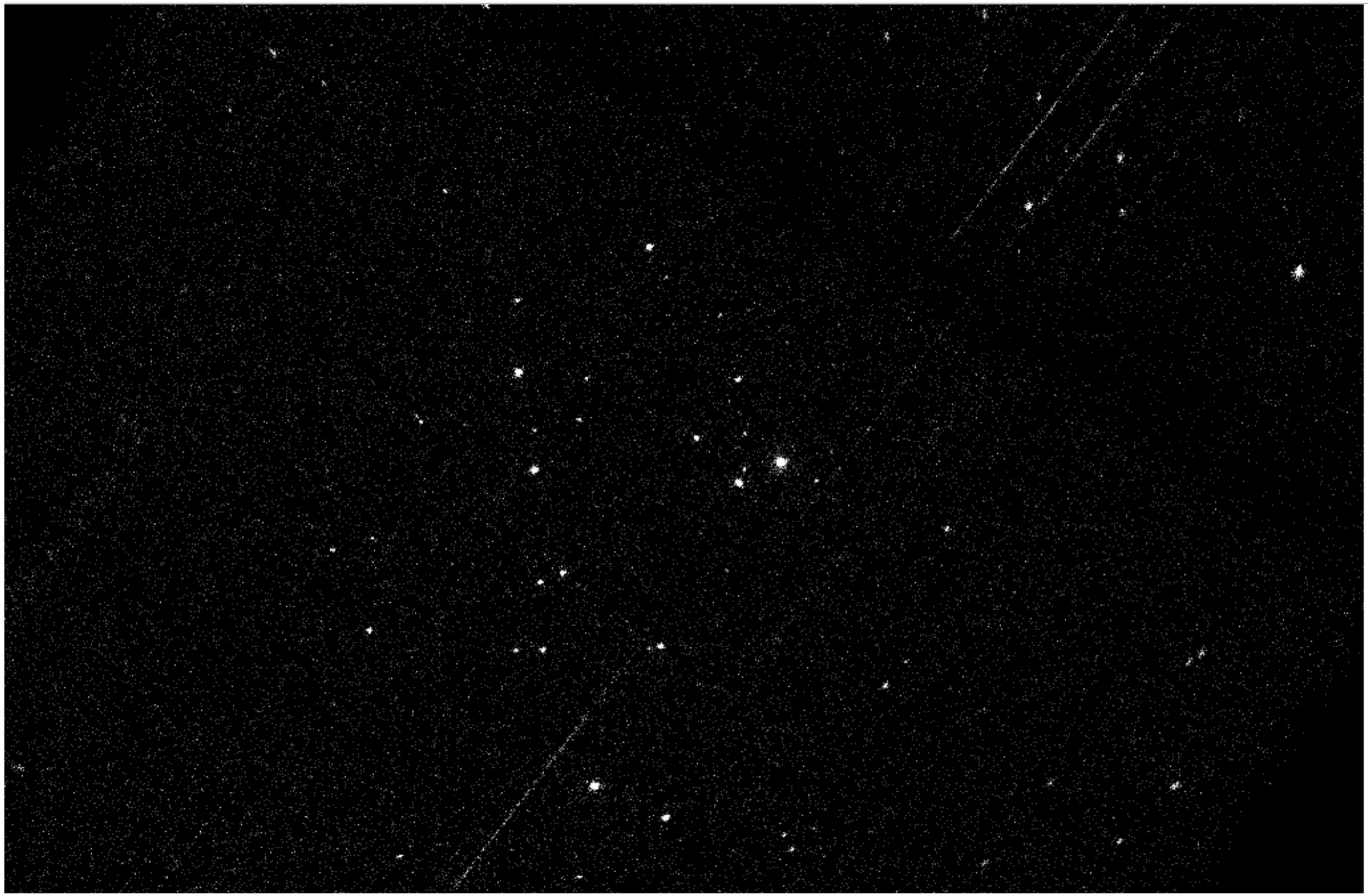
IC 348 Sample in 500 ks with Chandra-HETG



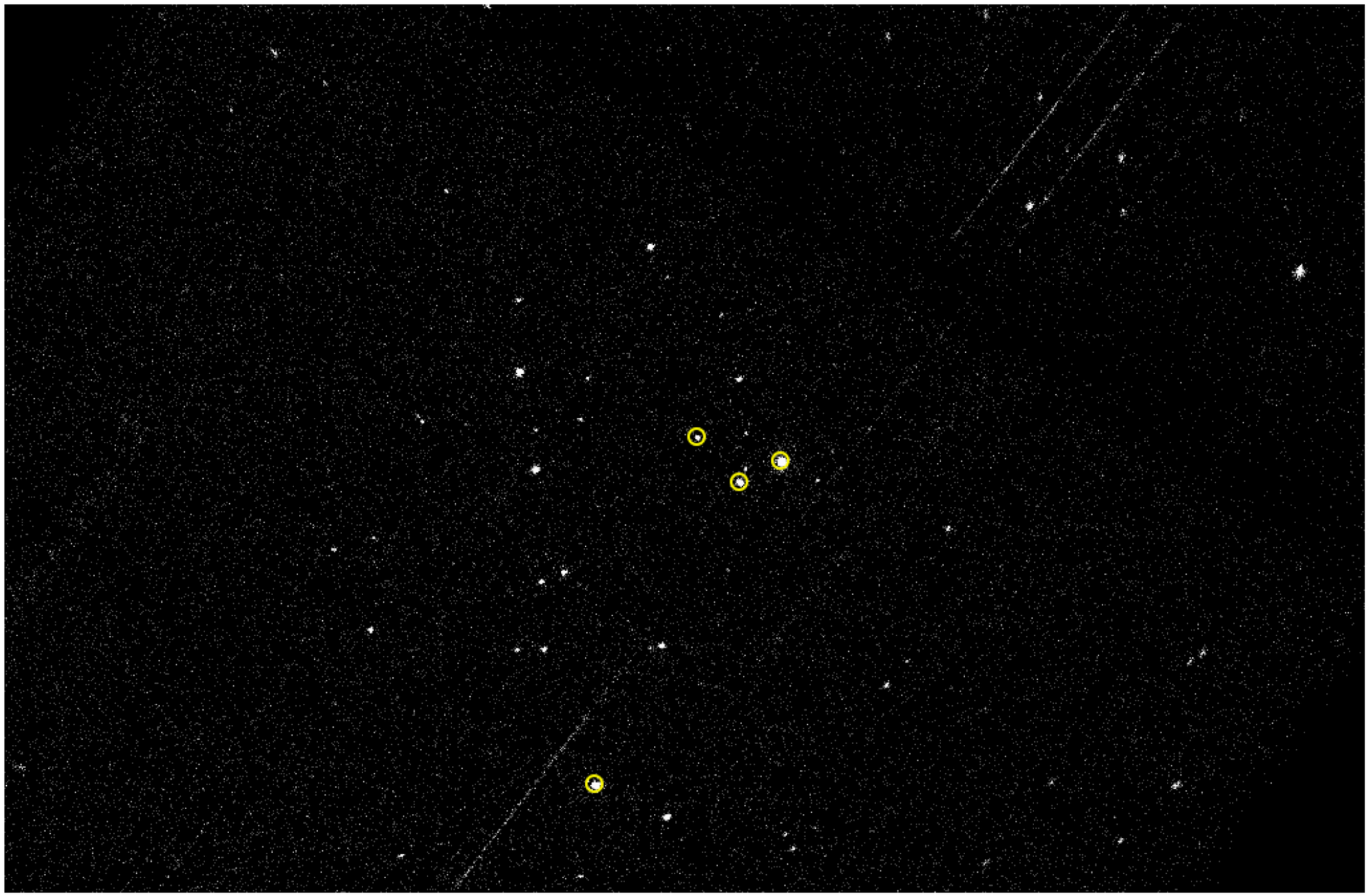


~250 pre-MS stars detected in X-rays

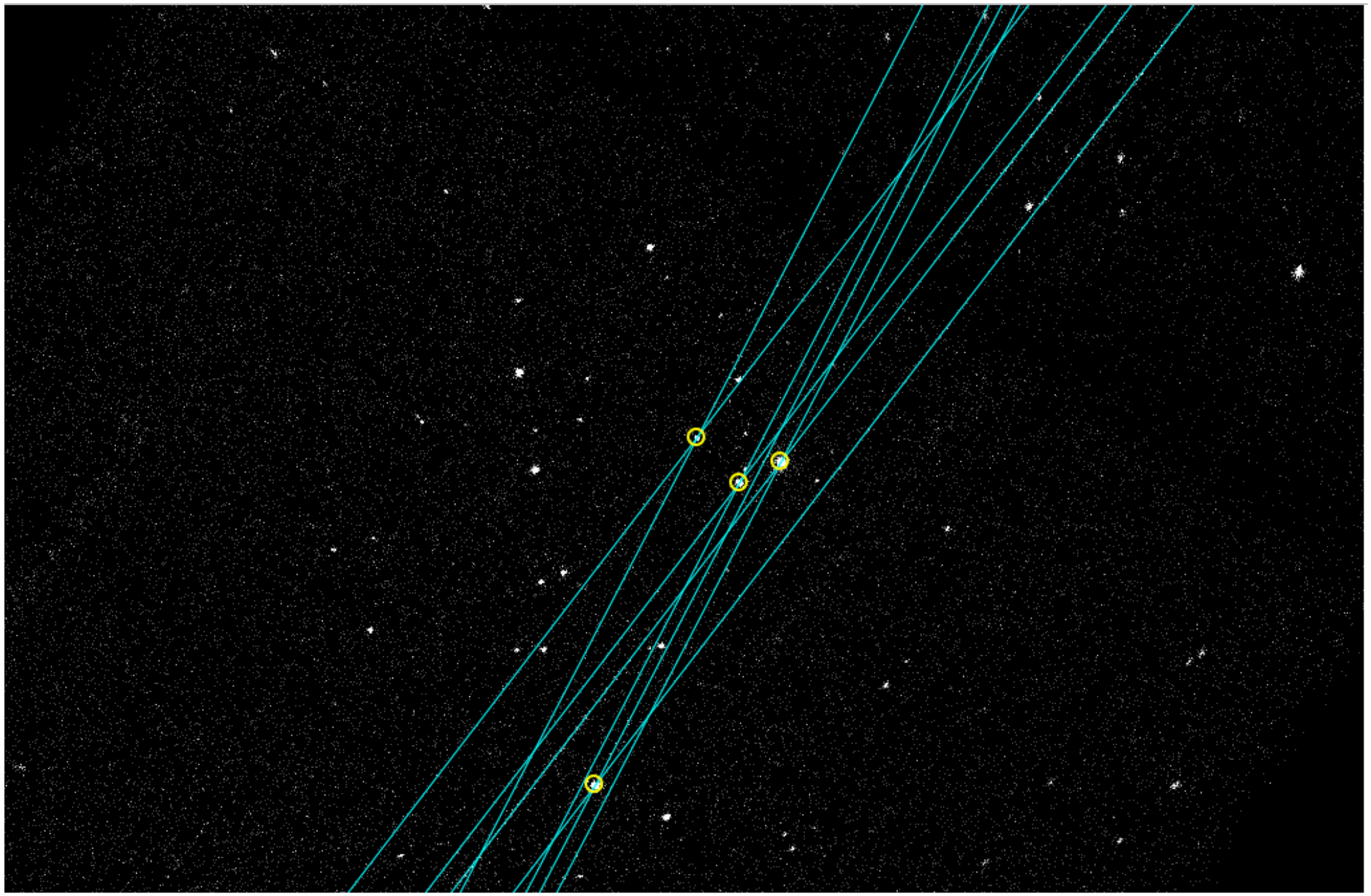
Handling Contamination in Crowded Regions with Multi-Epoch Data



Handling Contamination in Crowded Regions with Multi-Epoch Data



Handling Contamination in Crowded Regions with Multi-Epoch Data



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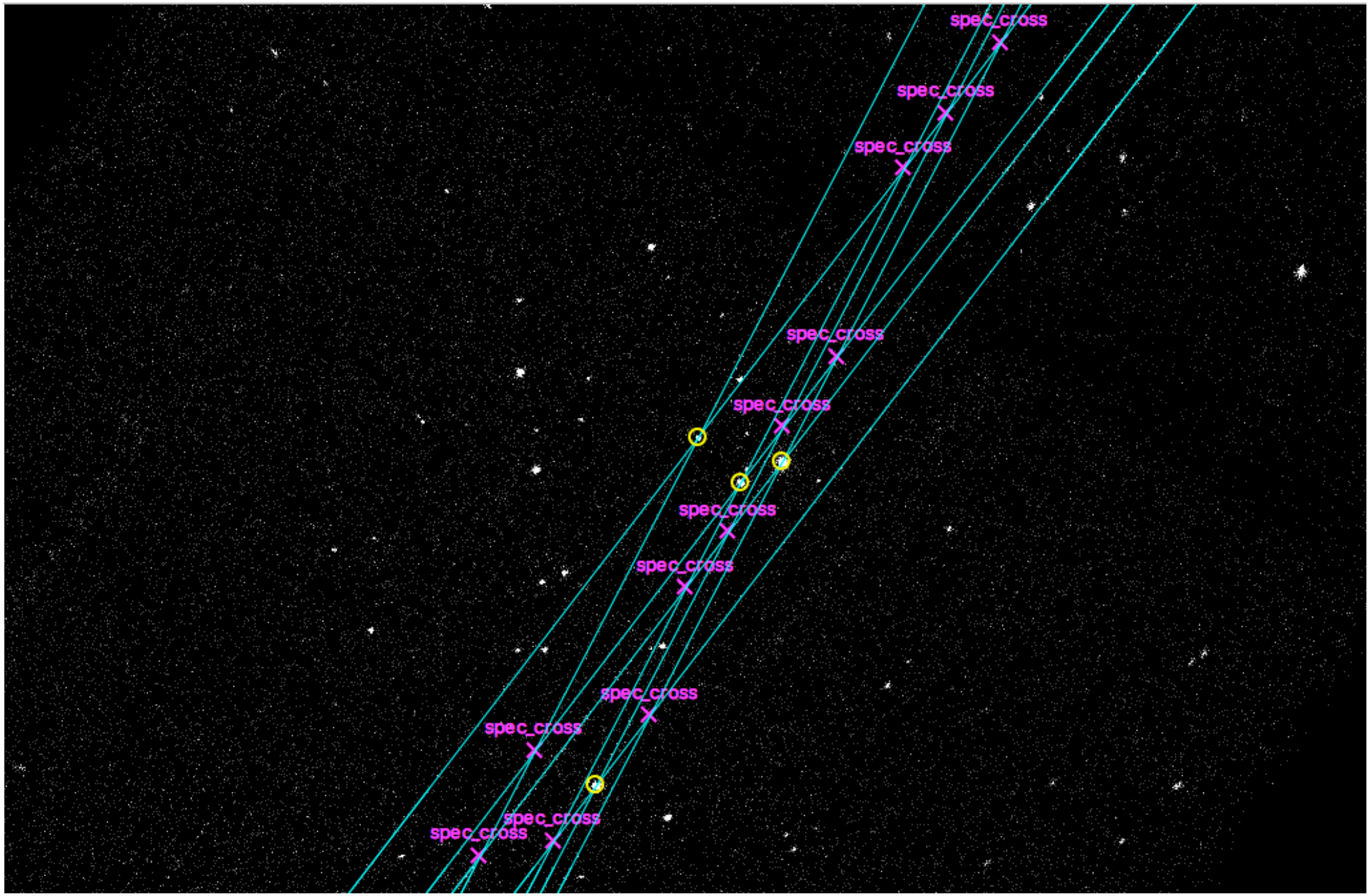
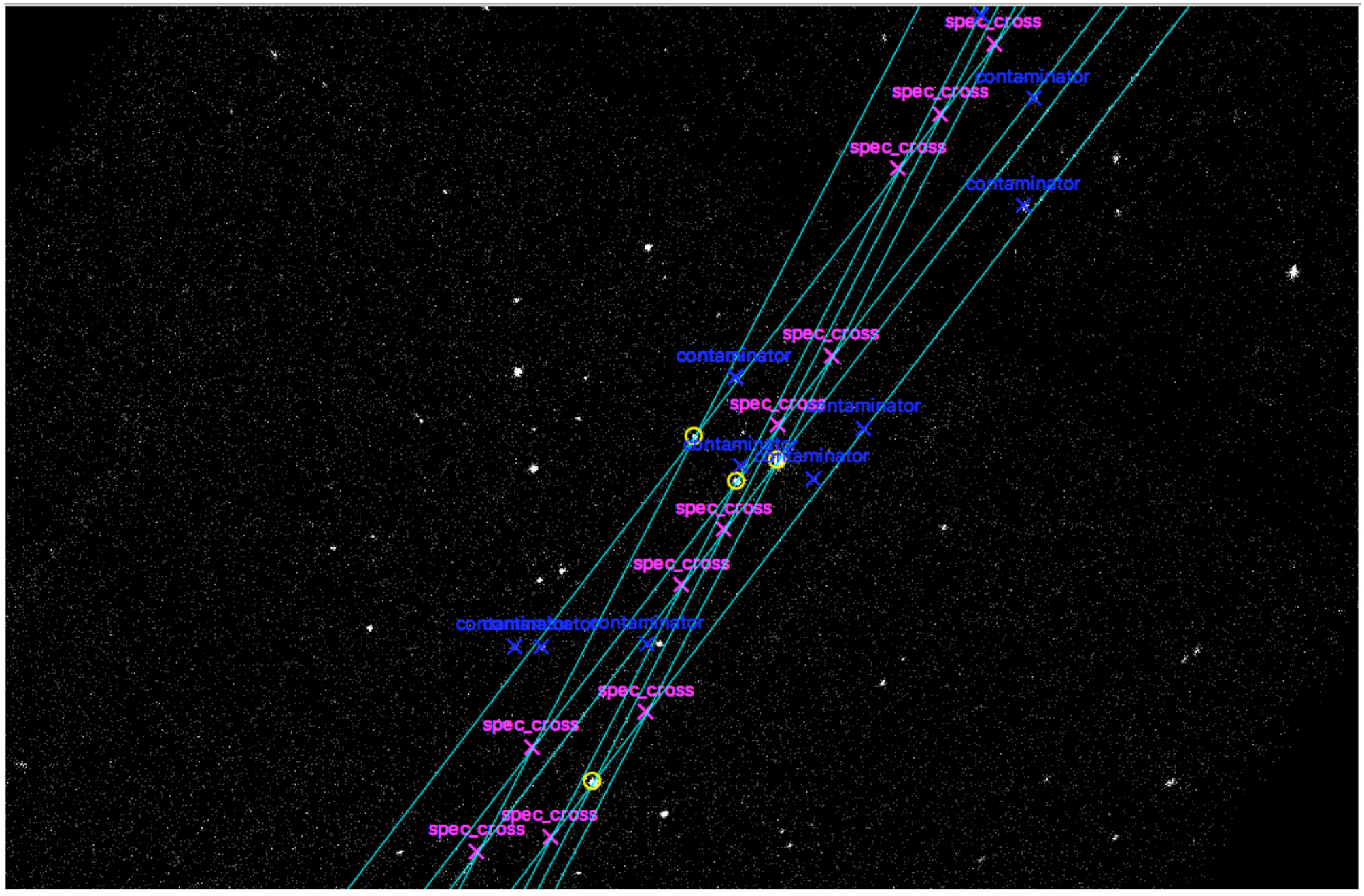
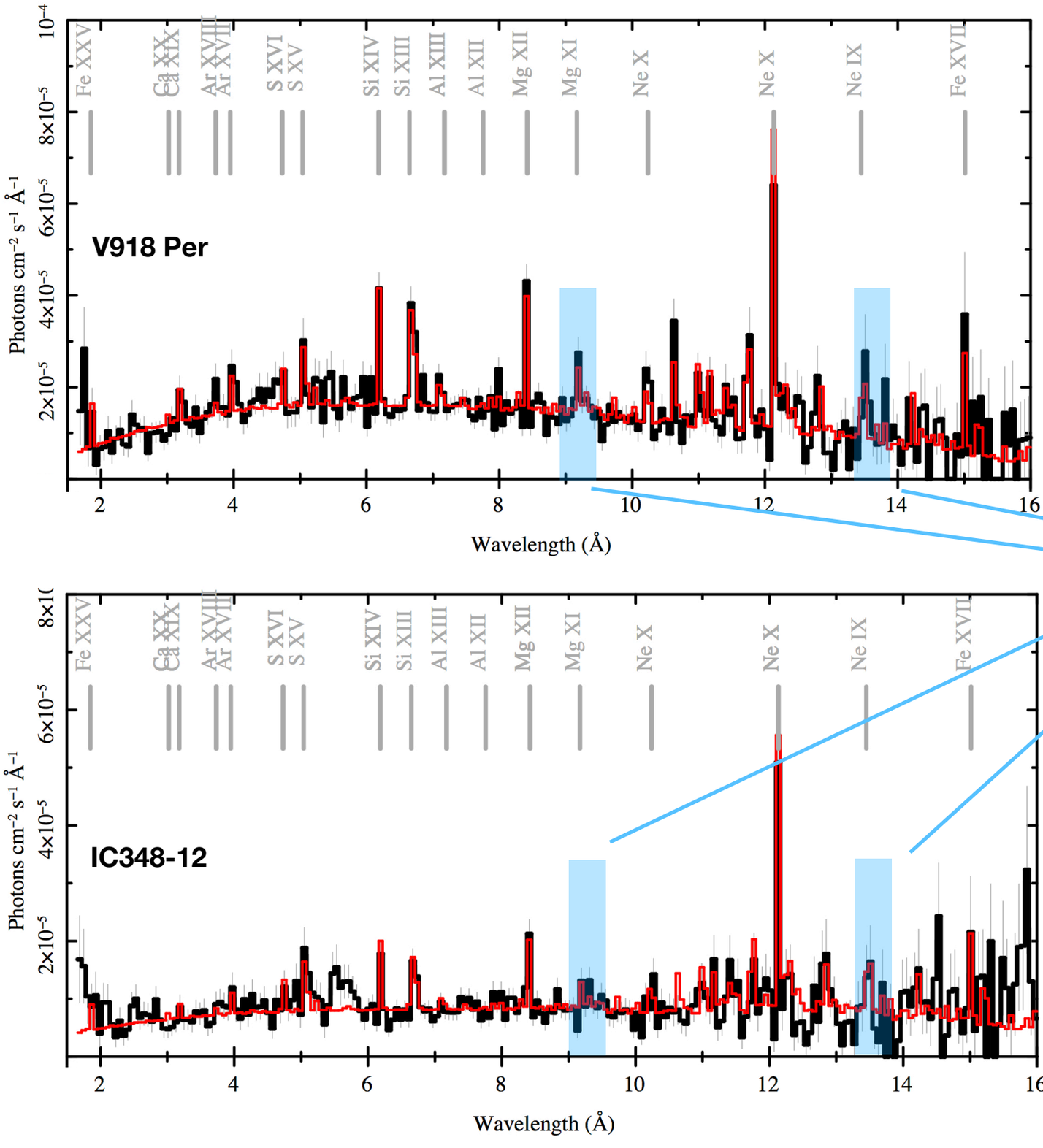


Handling Contamination in Crowded Regions with Multi-Epoch Data



Searching for Accretion in Accreting Stars



Coronal Abundance Comparison

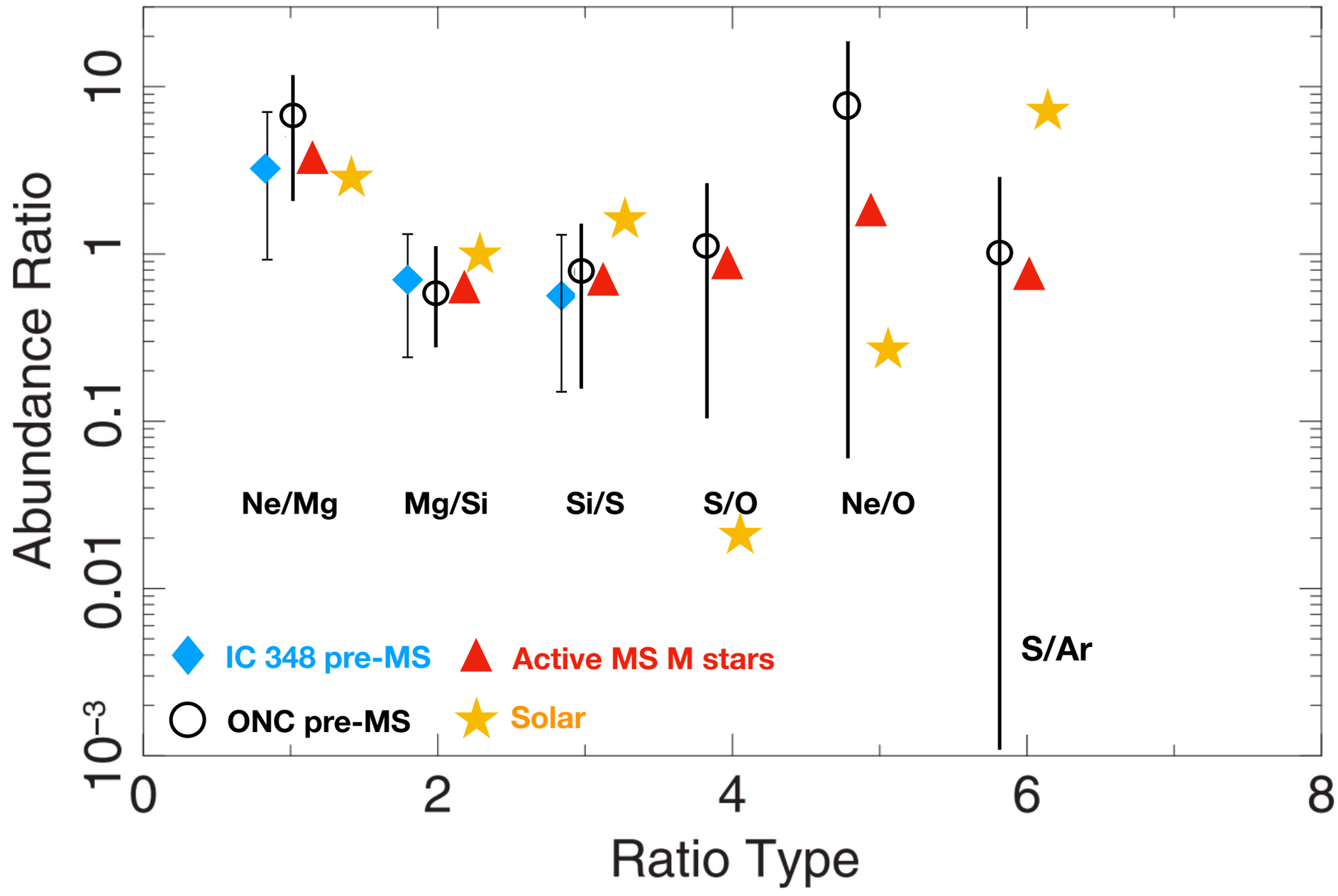


Figure reproduced from Schulz et al. 2015

Flaring Events

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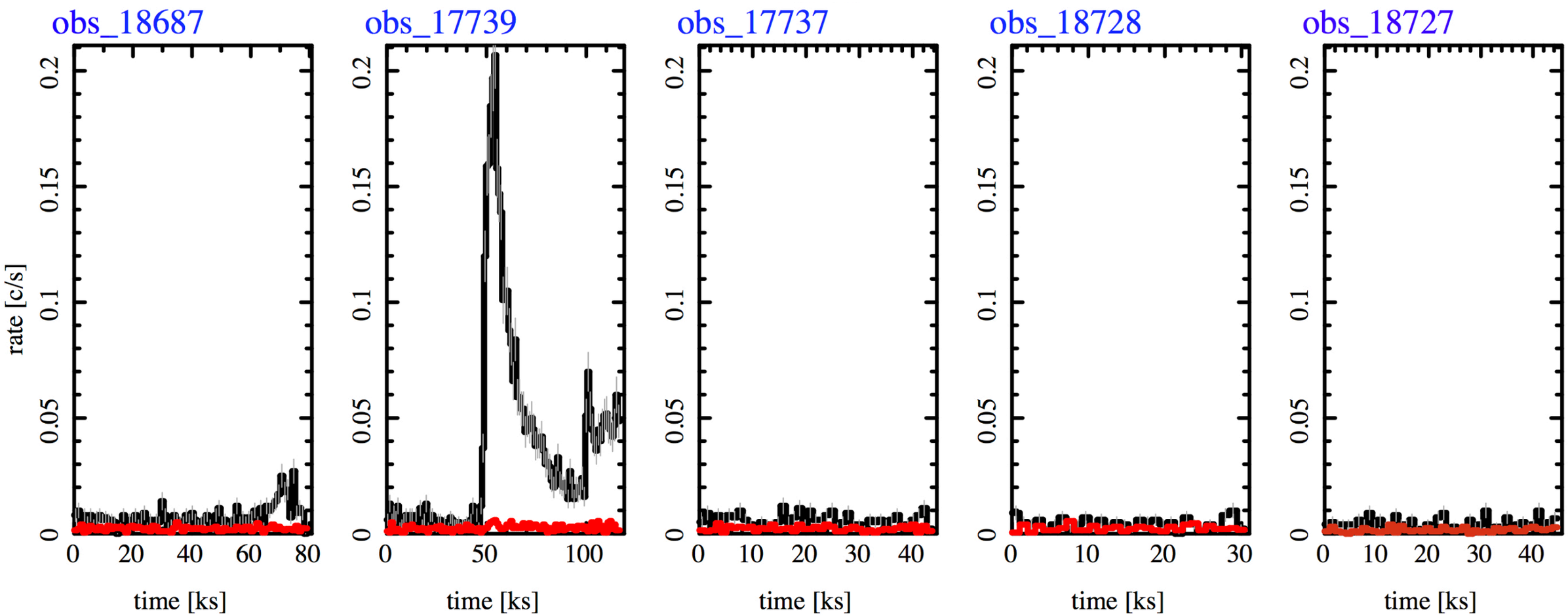
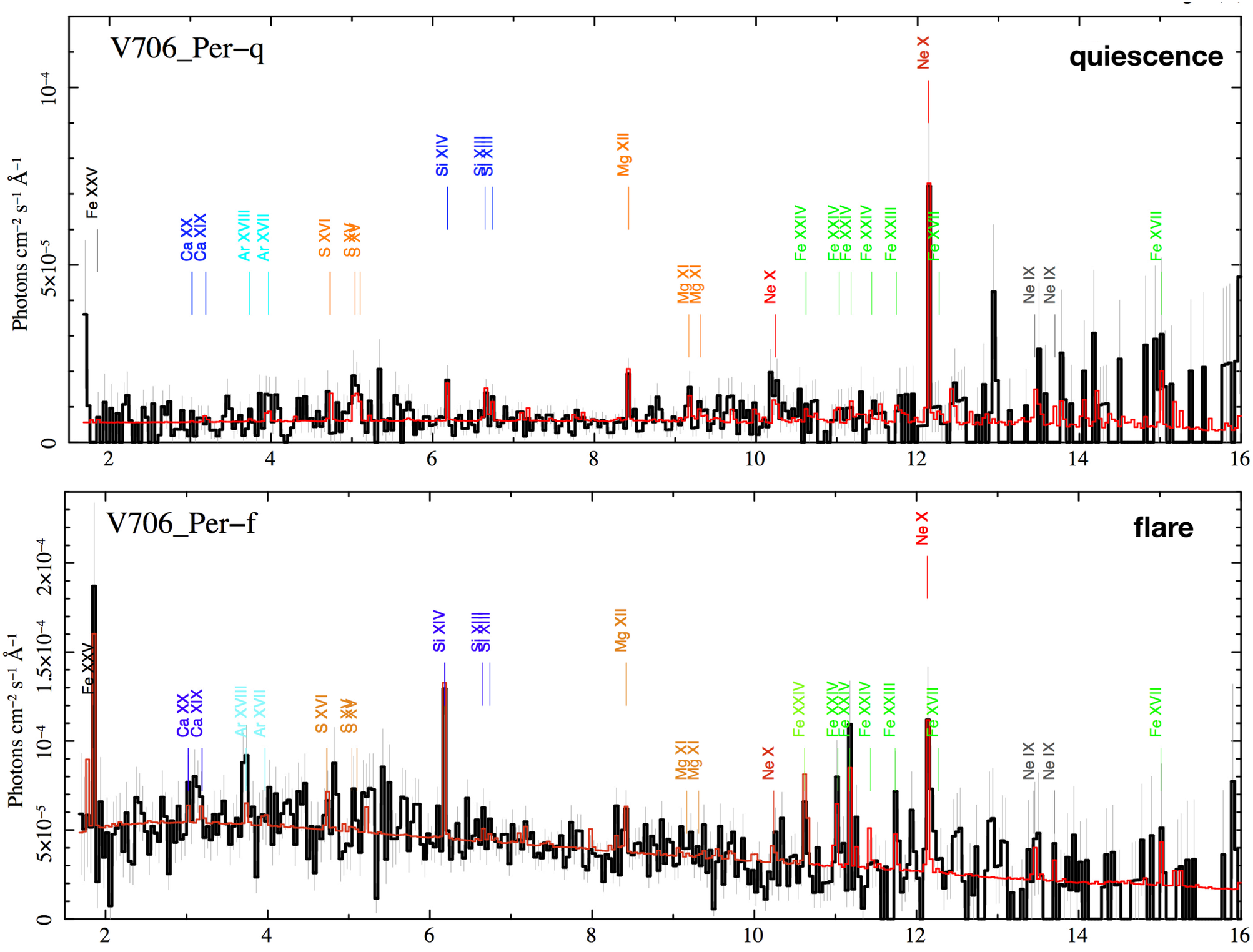
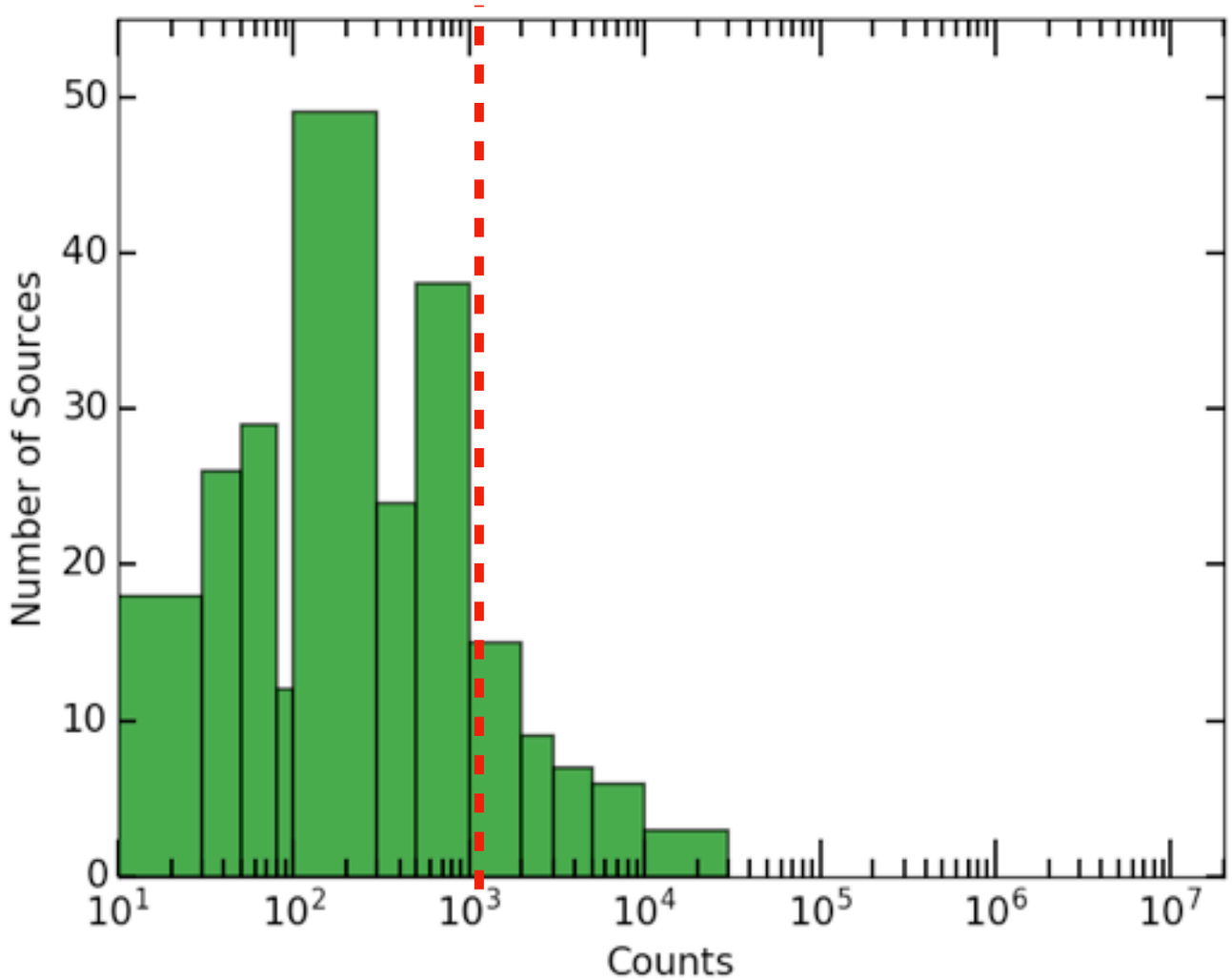


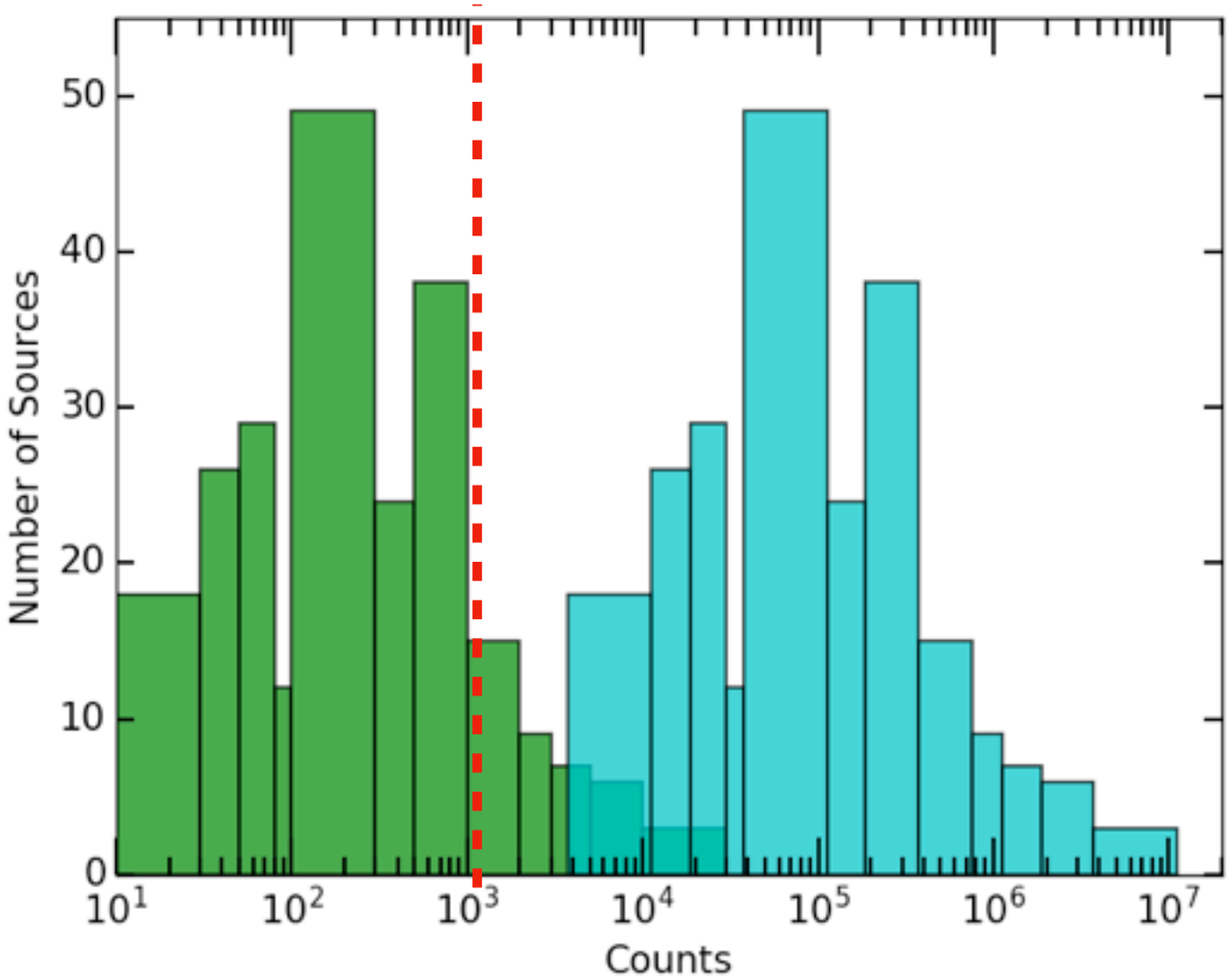
Flaring Events



From Chandra to Lynx



From Chandra to Lynx



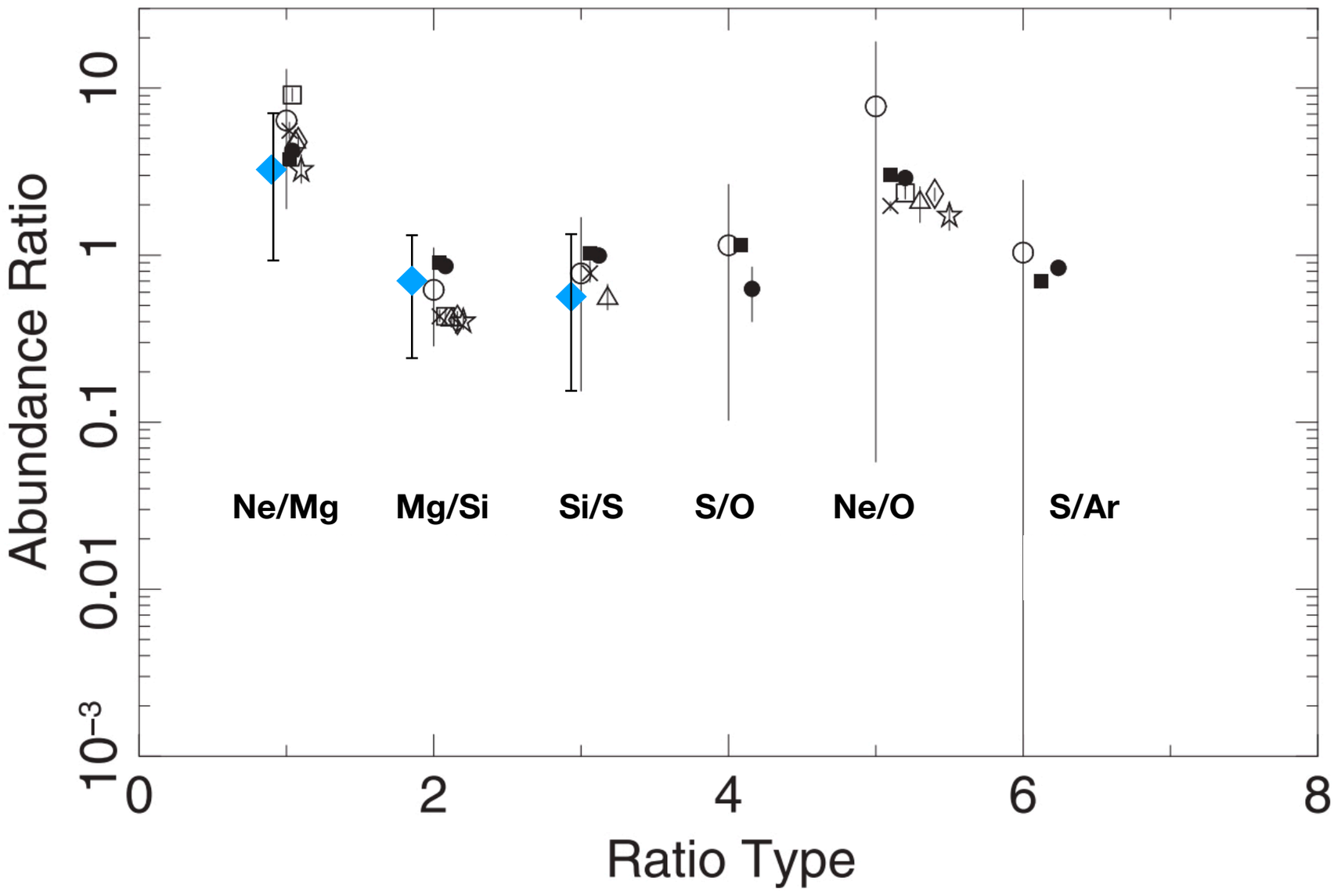
Summary

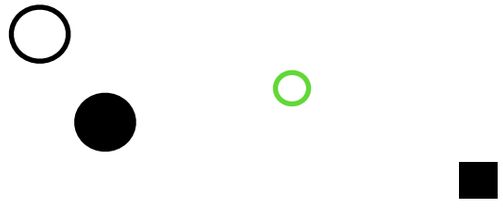
High spatial and spectral observations in the ‘soft’ 0.15 - 2.0 keV bandpass are necessary to study clusters during pre-MS stellar evolution.

Observations of entire stellar clusters are essential to understand pre-MS magnetic and chemical evolution, accretion and irradiation during the stages of evolution critical to the formation of planets.

Lynx with gratings will provide the first opportunity to get quality high spectral resolution spectra of ENTIRE clusters within reasonable exposure times and will provide rich datasets to supplement the surge of exoplanet detections/ characterizations certain in the coming decades.

Coronal Abundances





Schulz et al. 2015