

XILO (XMM-Newton Investigations of the λ Orionis star forming region)

Beate Stelzer

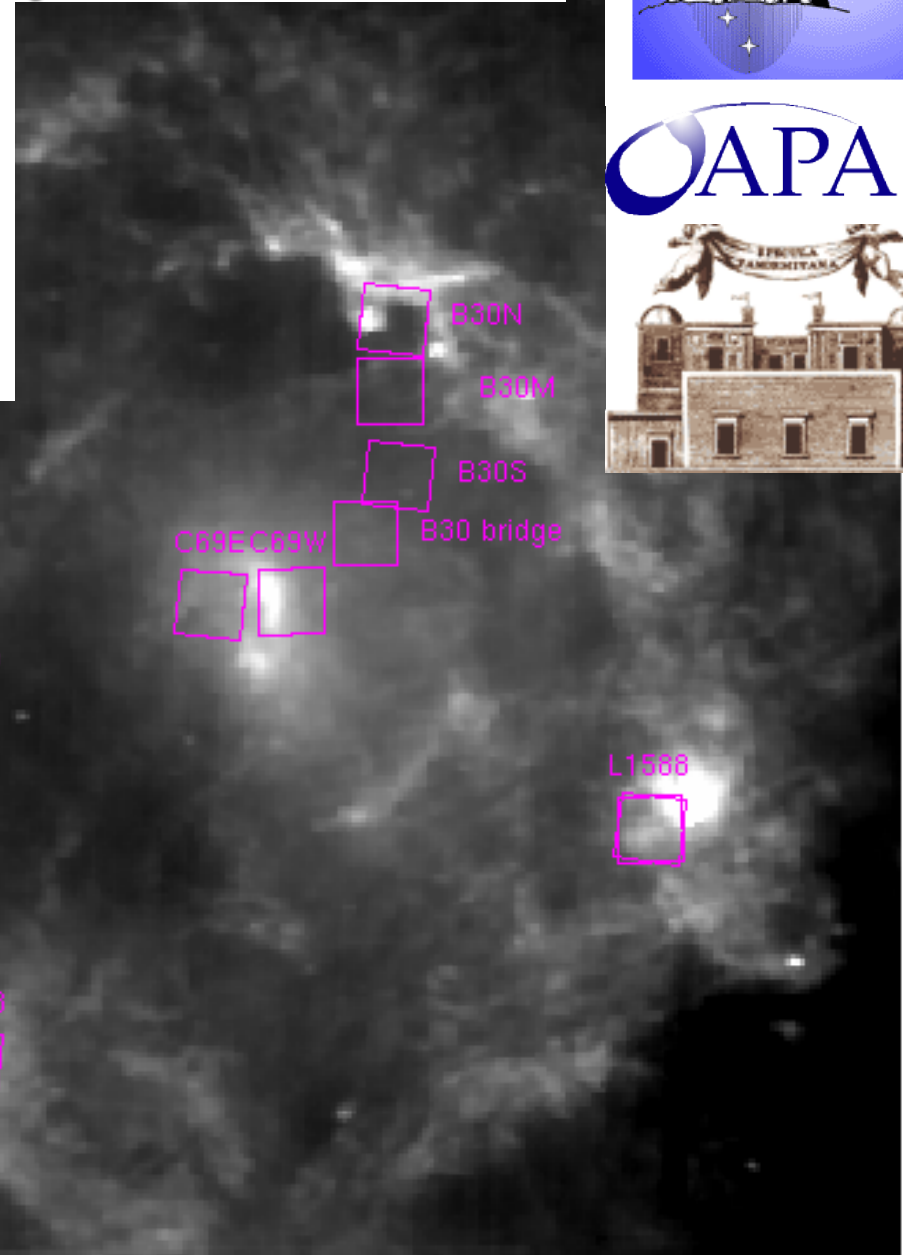
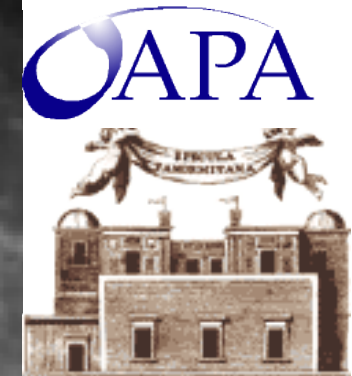
INAF – Osservatorio Astronomico di Palermo

D. Barrado y Navascués, N. Huelamo,

M. Morales-Calderon, A. Bayo

LAEFF-INTA, VILSPA (ESOC), Madrid

J. Stauffer IPAC/Caltech **S.Hodgkin** Cambridge

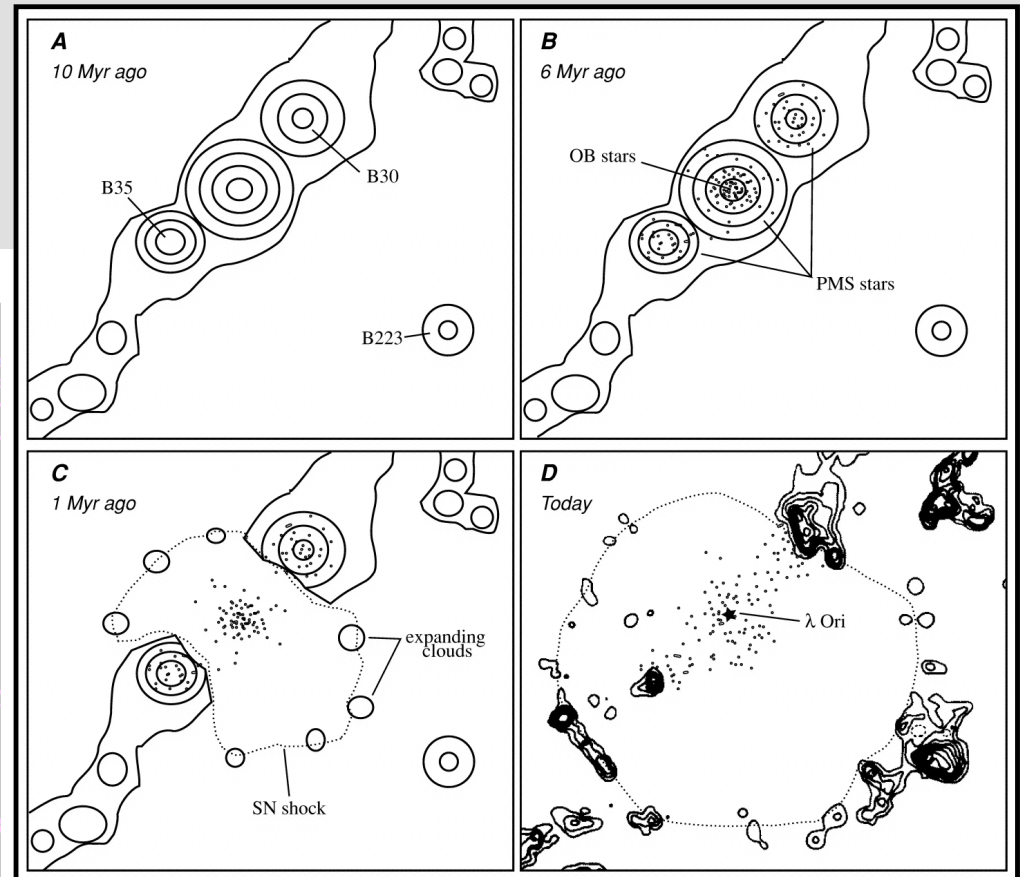
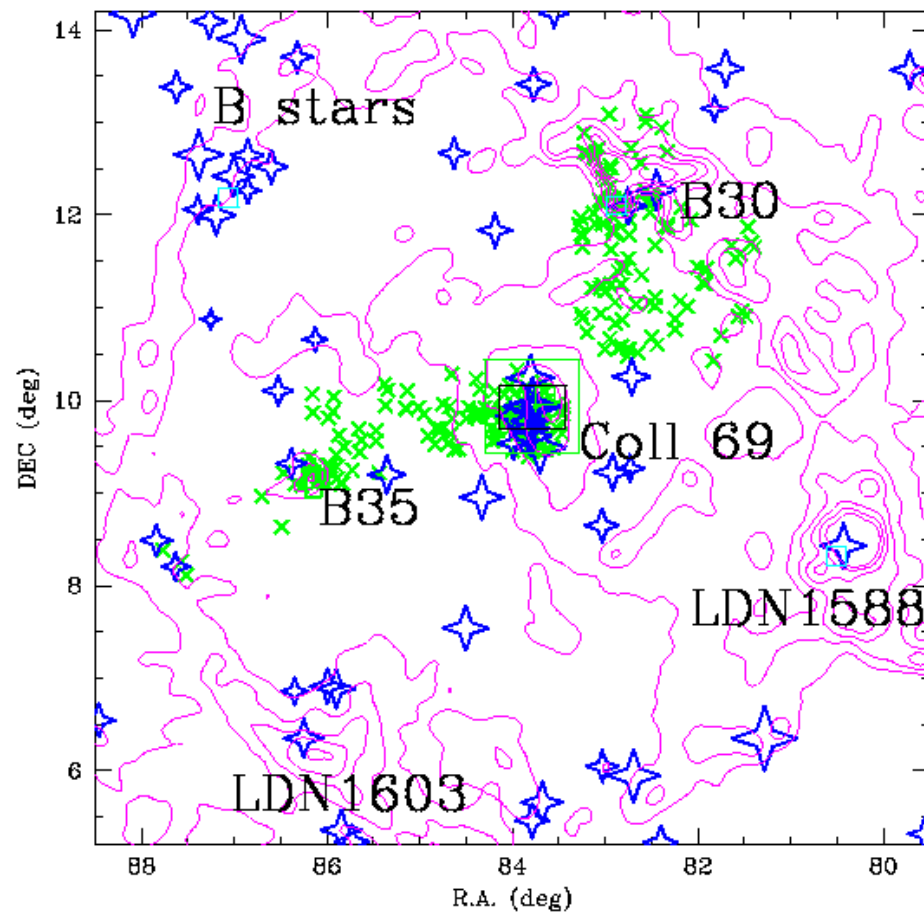


λ Ori: intermediate-scale triggered star formation?

Dolan & Mathieu 2001

B stars

IRAS



Dolan & Mathieu (2002)

String of low-mass pre-MS stars within cavity.

Possible explanation:

SN blows away original elongated cloud,
ceases star formation and
creates the molecular ring

XMM-Newton pointings

B-stars



B30N



B30M



B30S



B30 bridge



C69E C69W



B35W



B35E



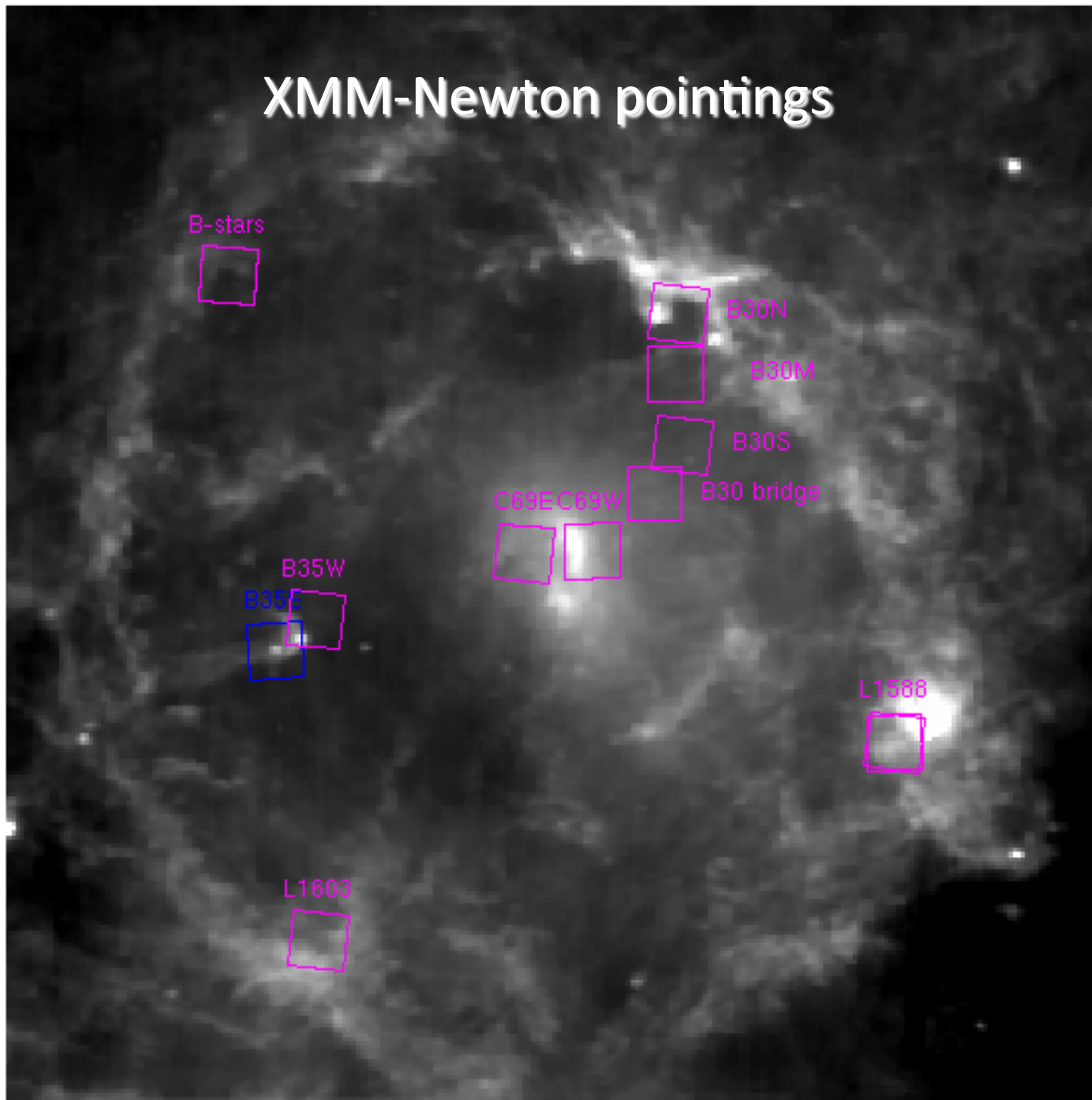
L1588



L1603



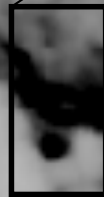
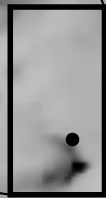
XMM-Newton pointings



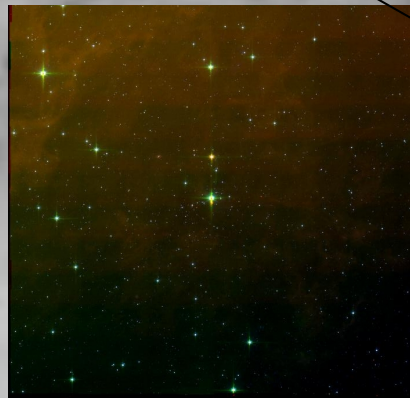
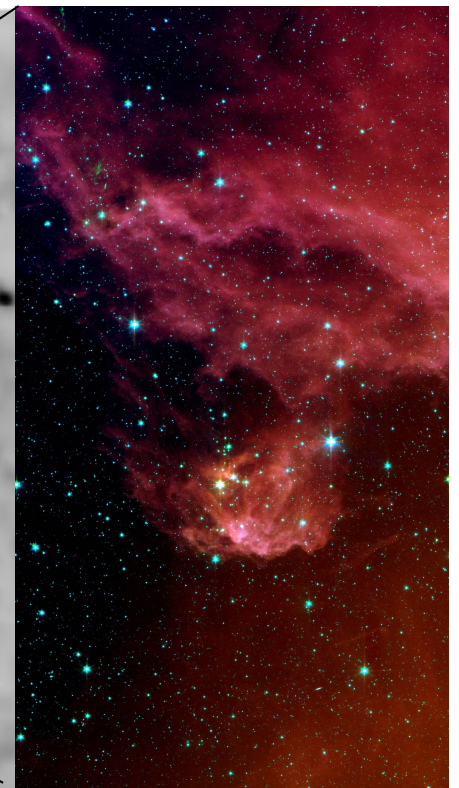
Spitzer data



B35



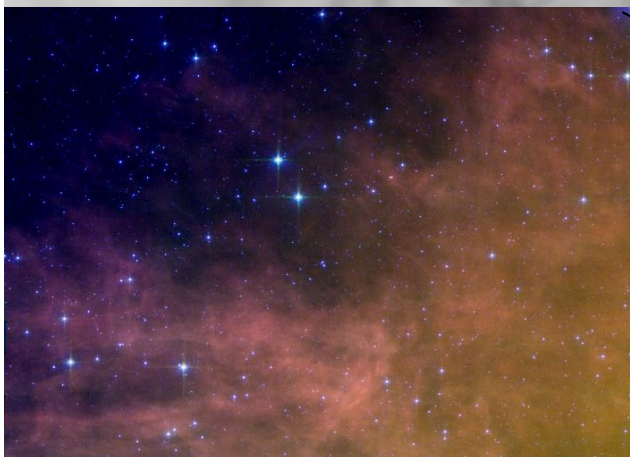
B30



LDN1603



LDN1588



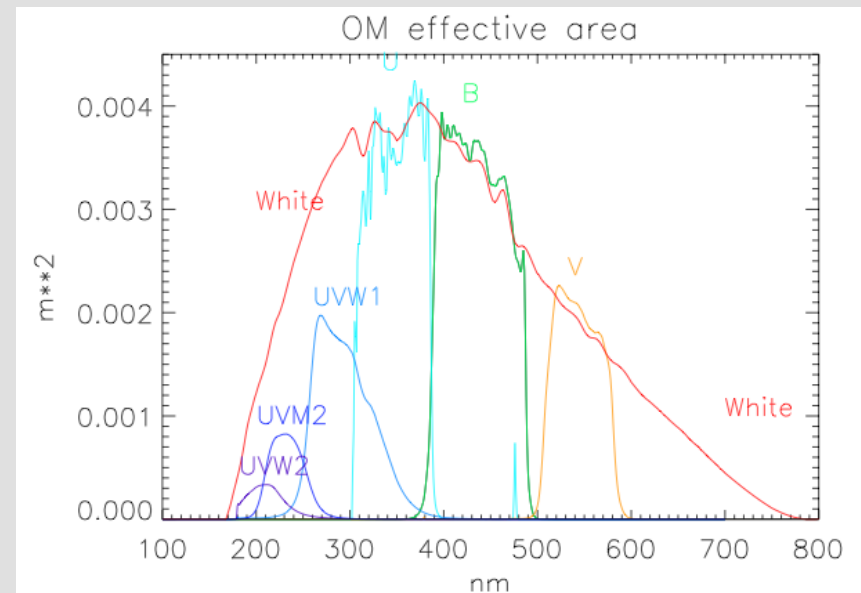
XILO overview

Field	Obs.Cycle	Exposure [ksec]		Opt.Monitor			Status
		Perform.	Effect.	Filter			
Col 69E	AO 4	37	37		B	V	Barrado et al., A&A in press
Col 69W	AO 5	26	19			V	Barrado et al., A&A in press
B 35 W	AO 5	25	11		B	V	Stelzer et al., in prep.
B 35 E (FU Ori)	AO 4	37	30				Stelzer et al., in prep.
B 30 N	AO 5	30	25	UVW 2	U		observed
B 30 S	AO 5	35	19		B	V	observed
LDN 1603	AO 5	30	9		U	V	observed
LDN 1588	AO 5	52	9		B	V	observed
B cluster on ring	AO 8	40	19	UVW 2			observed
B 30 M	AO 9	40		UVW 1	U	B V	observed
B 30 Bridge	AO 9	40		UVW 1	U	B V	observed

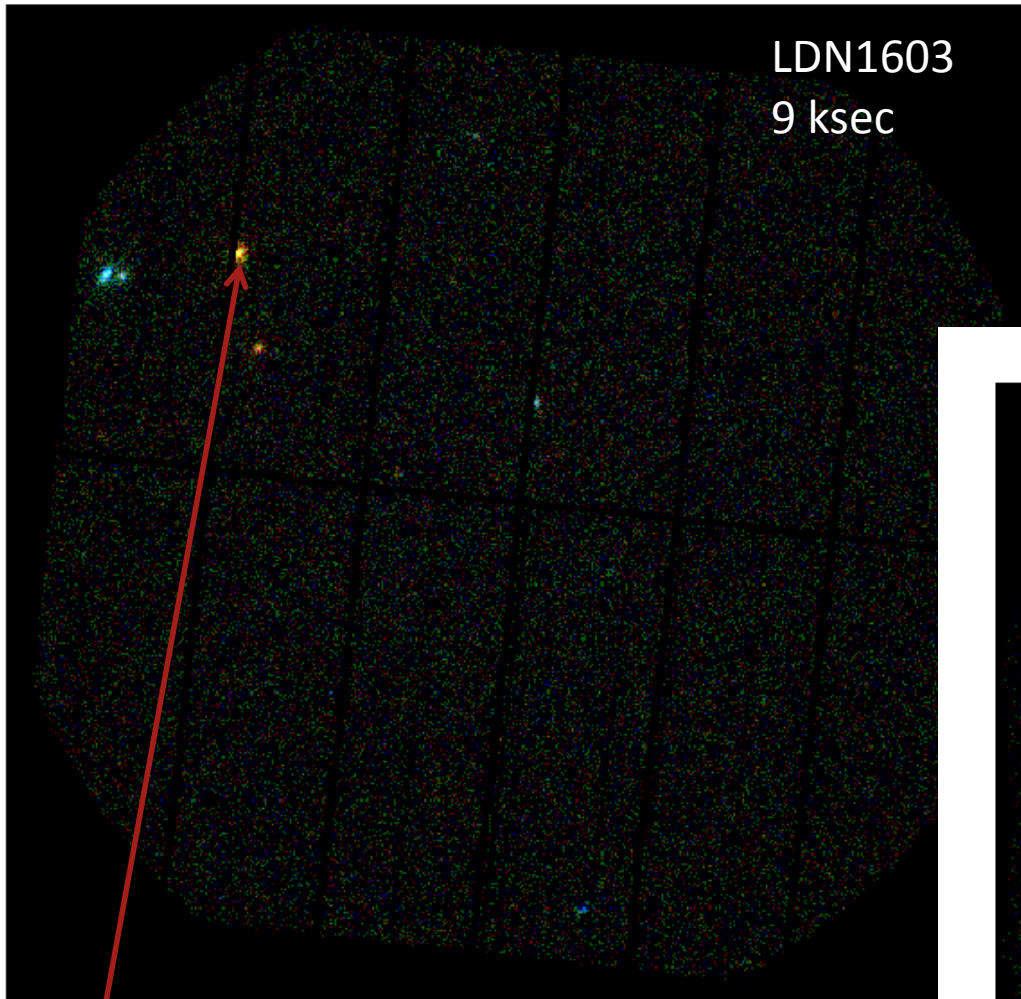
Technical issues:

- several observations spoiled by high background
- problems with the Optical Monitor (less exposures + filters than requested)

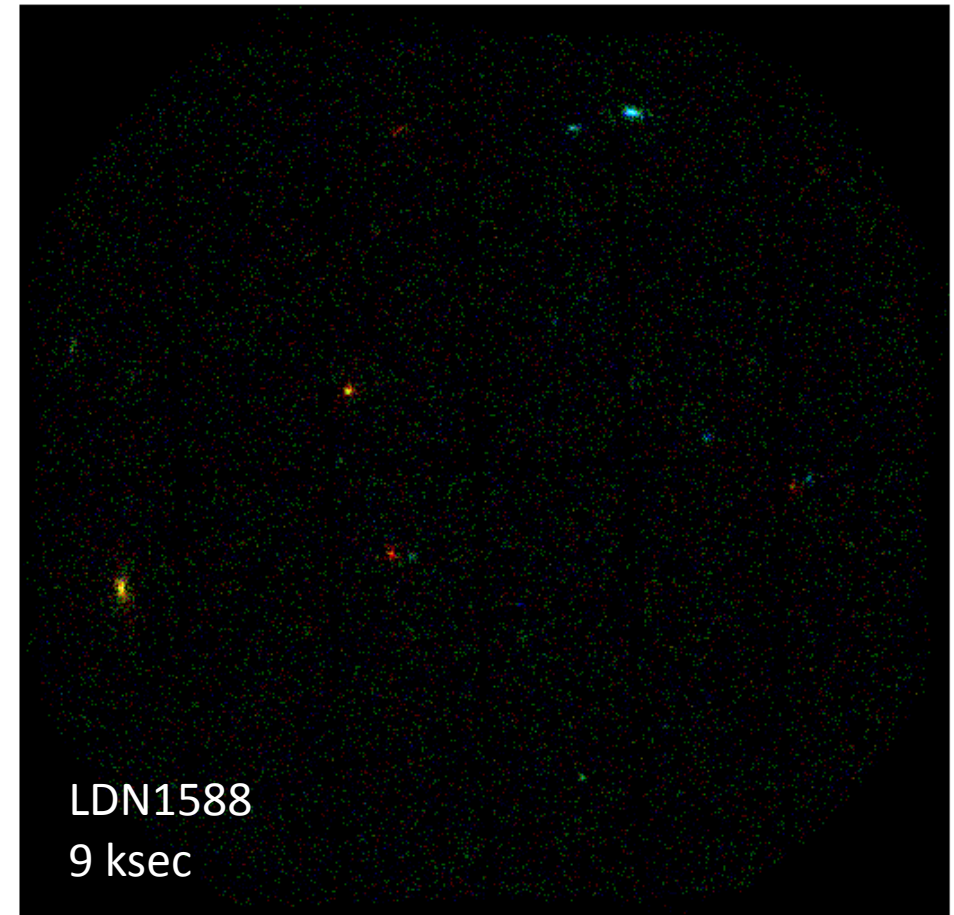
↑
Only pn;
Merging with MOS1+2
increases sensitivity
by ~ 60%



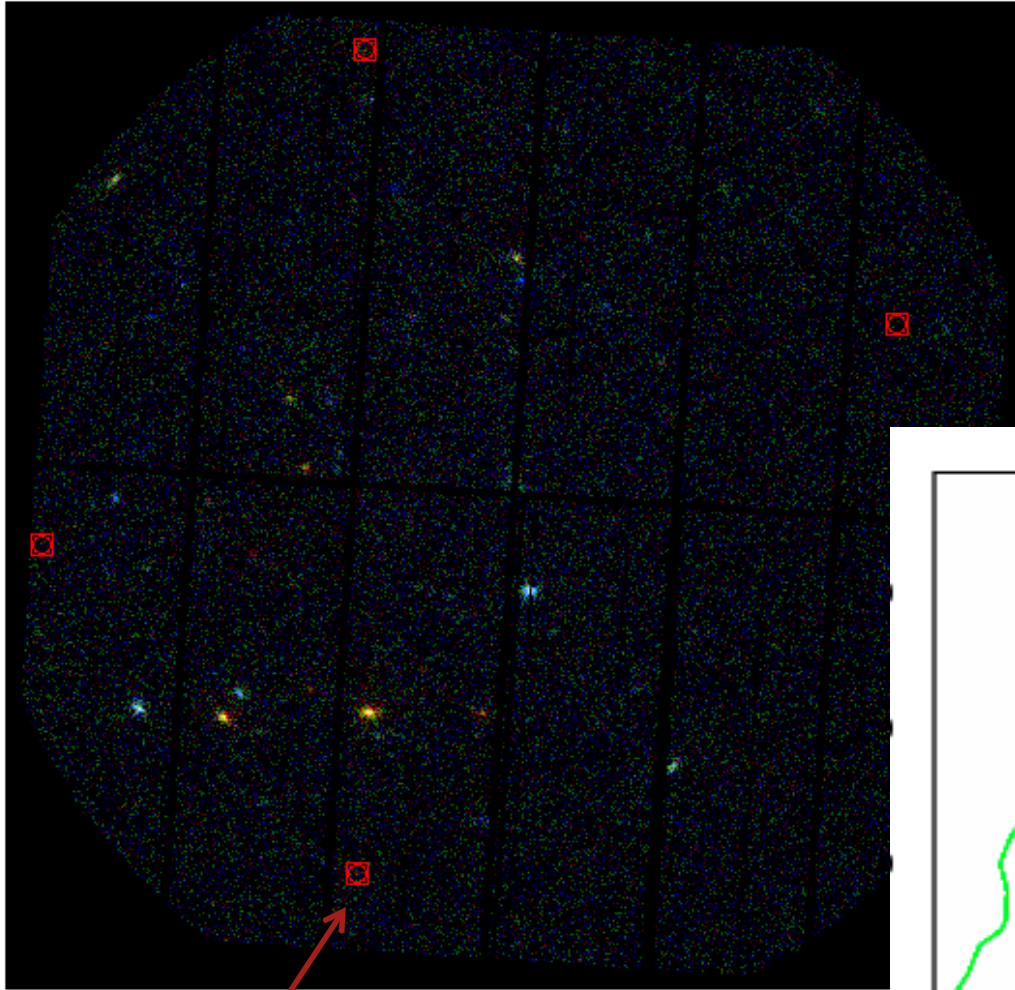
XMM-Newton view
of dark clouds
on the molecular ring



DM2002: VRI colors of late-G star;
XMM serendip. source cat: $\log L_x \sim 30.9$

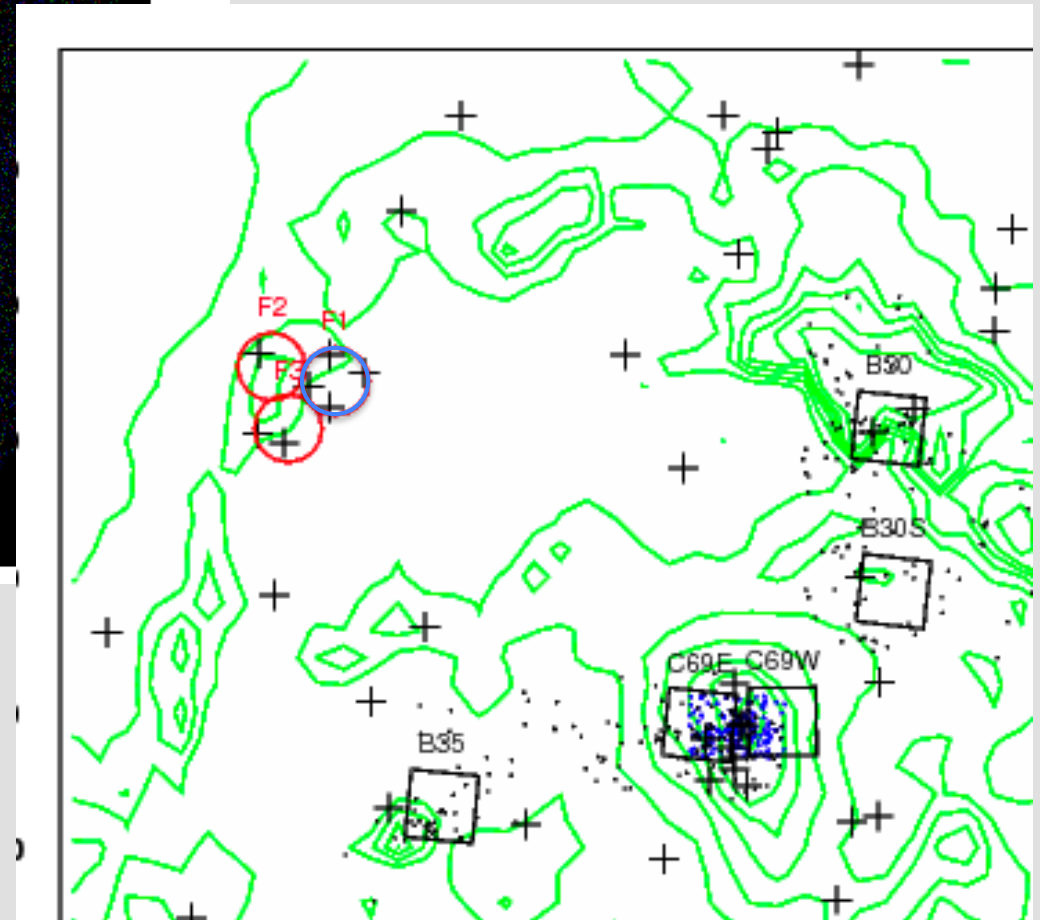


XMM-Newton view
of the mol.ring:
a low-mass cluster
associated with B-stars?



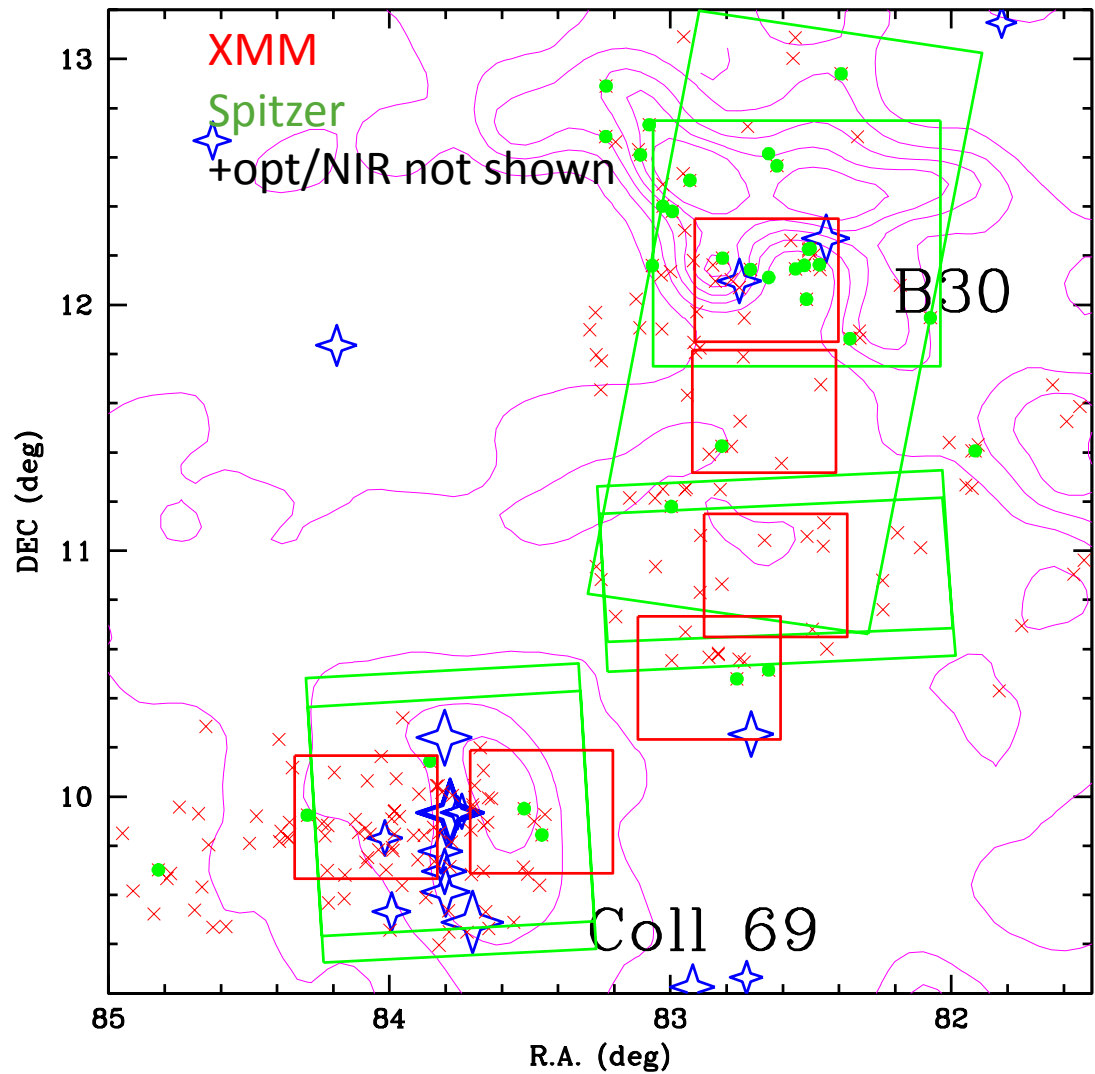
4 B-type stars
from PPM catalog (Roeser & Bastian 1988)

Expected sensitivity: $\log L_x \sim 29$ erg/s





XMM-Newton view of B30

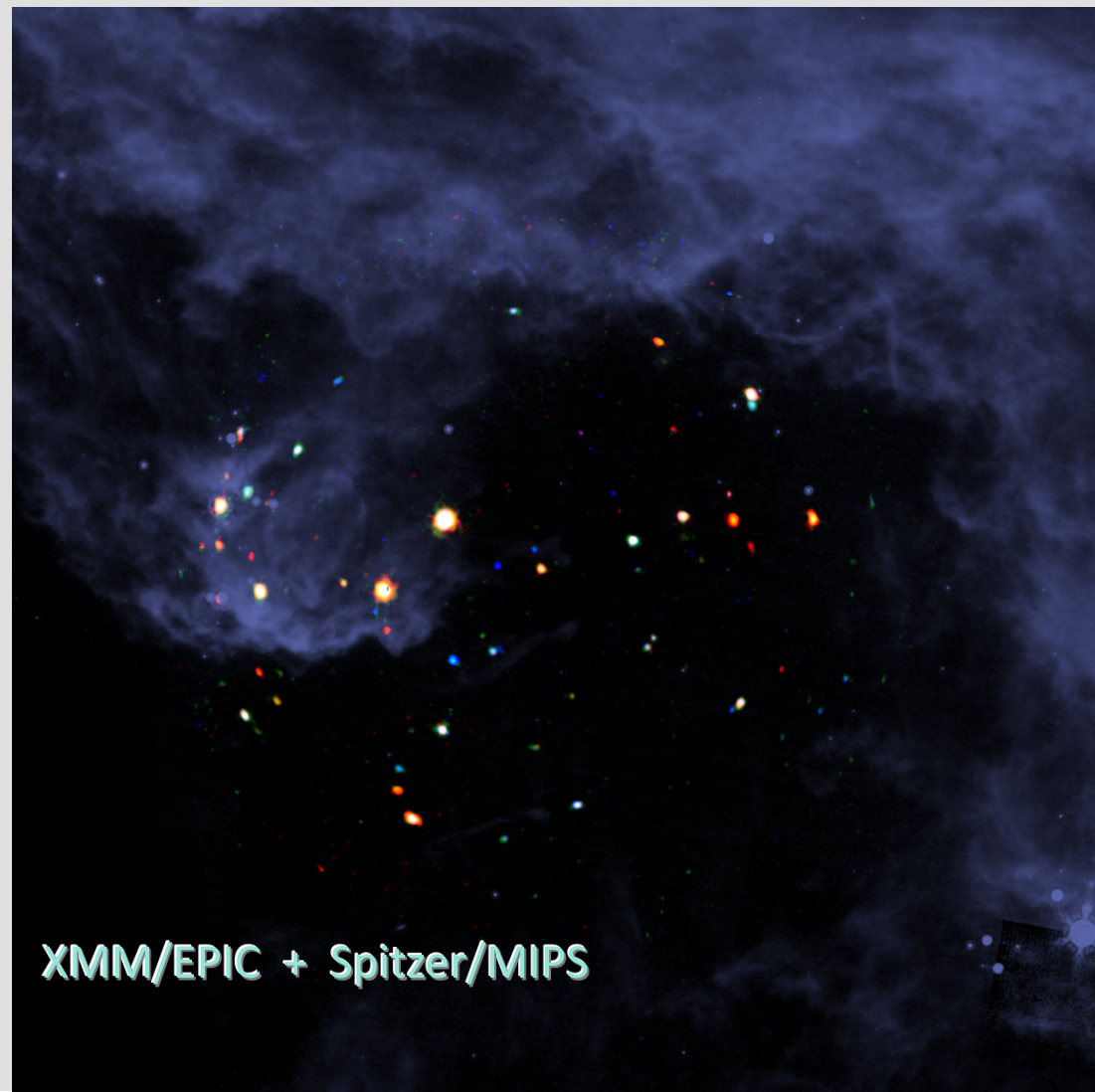


B30:

XMM-Newton / Spitzer

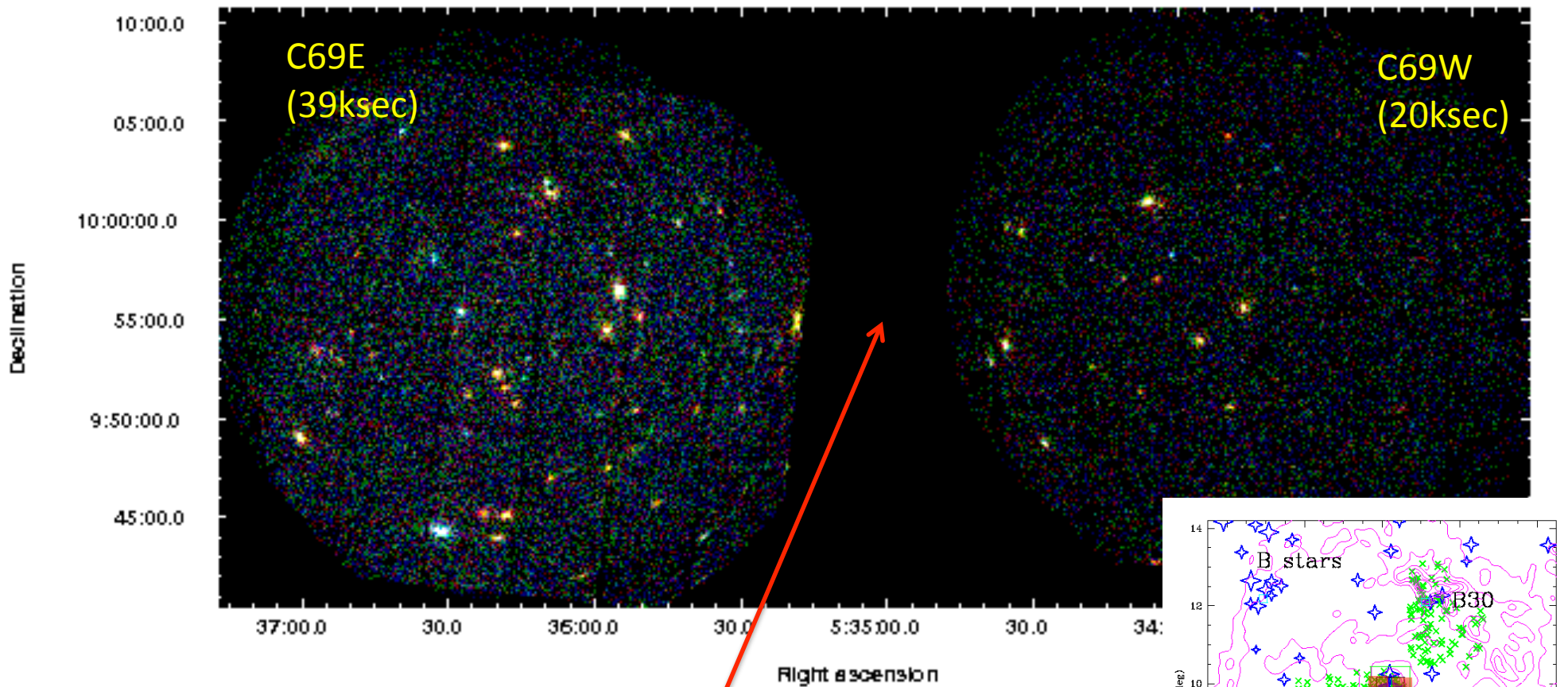


Spitzer/IRAC



XMM/EPIC + Spitzer/MIPS

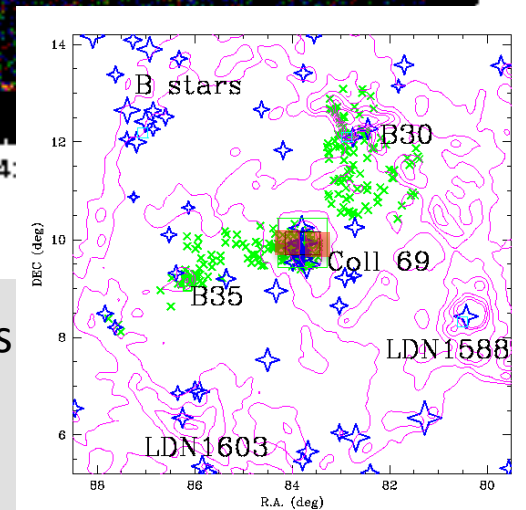
XMM-Newton view of Collinder 69



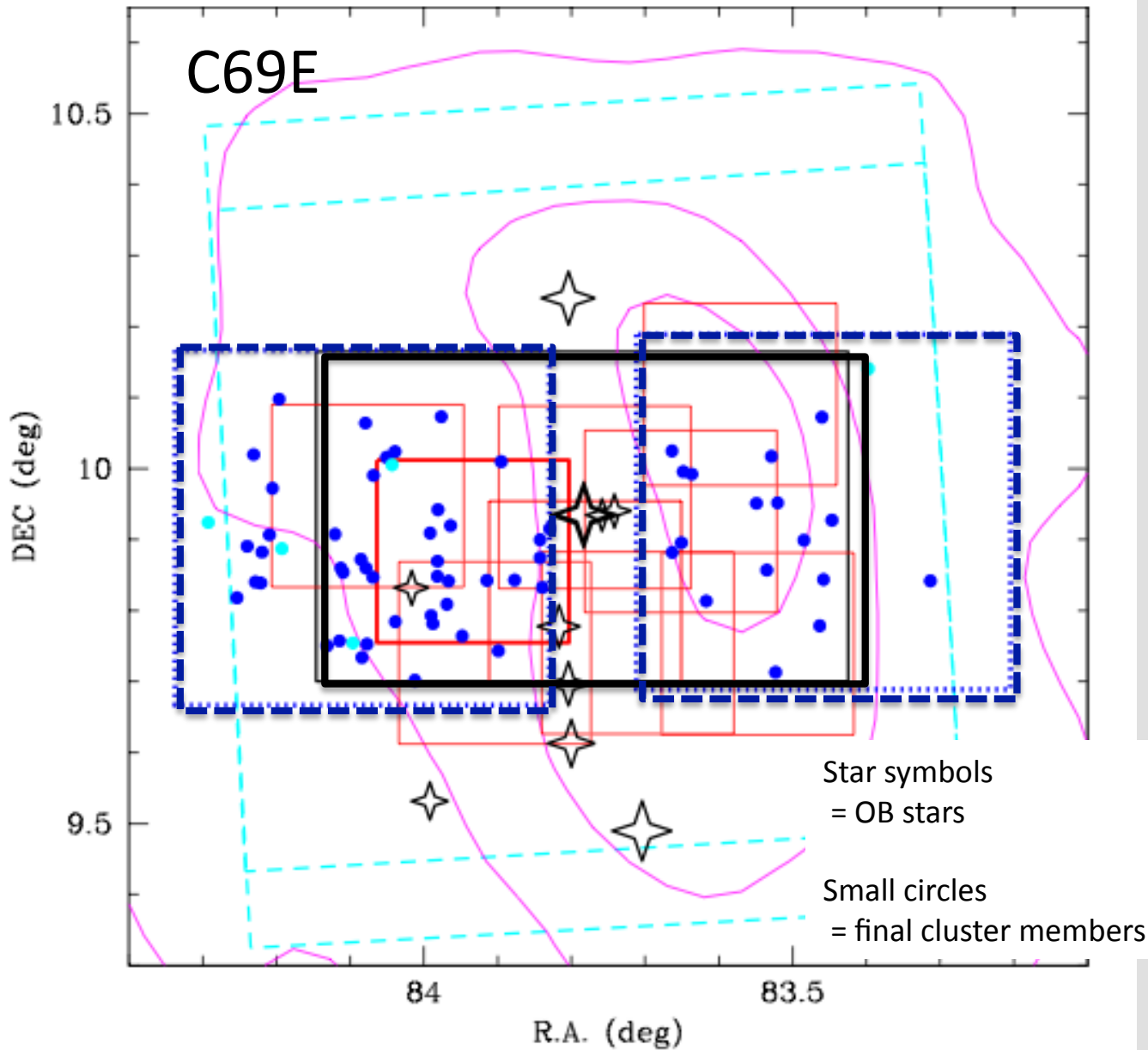
C69E: 112 X-ray sources
(48 members)

λ Ori

C69W: 52 X-ray sources
(18 members)



Multi- λ data base for Collinder 69



CFHT (R_{I_c})

$I_c < 20.2 \rightarrow$ ByN04

2MASS: $K_s < 15.6$ ($I_c < 19$)

 OMEGA 2000 (JHK)
 $K_s < 18$ ($I_c < 20.5$)
 Spitzer/IRAC
 $[4.5] < 16.5$ ($I_c < 21.0$)

\rightarrow ByN07

XMM-Newton

C69E – Aug 2006

C69W – Oct 2005

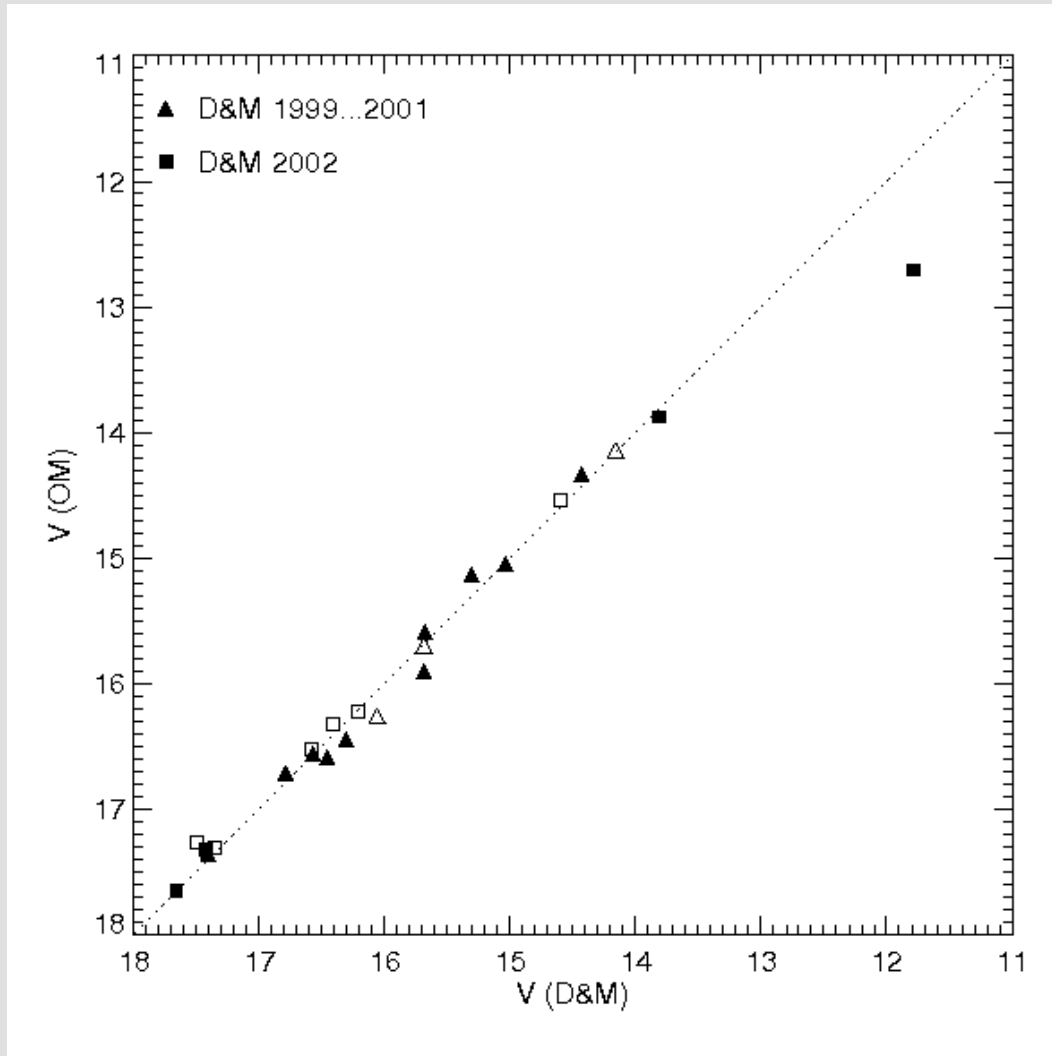
($I_c < 15.6$; $0.3M_{\text{sun}}$)

5Myr; Baraffe et al. (1998):

substellar limit: $I_c = 17.5$

planetary limit: $I_c = 21.5$

Photometry from XMM-Newton's Optical Monitor



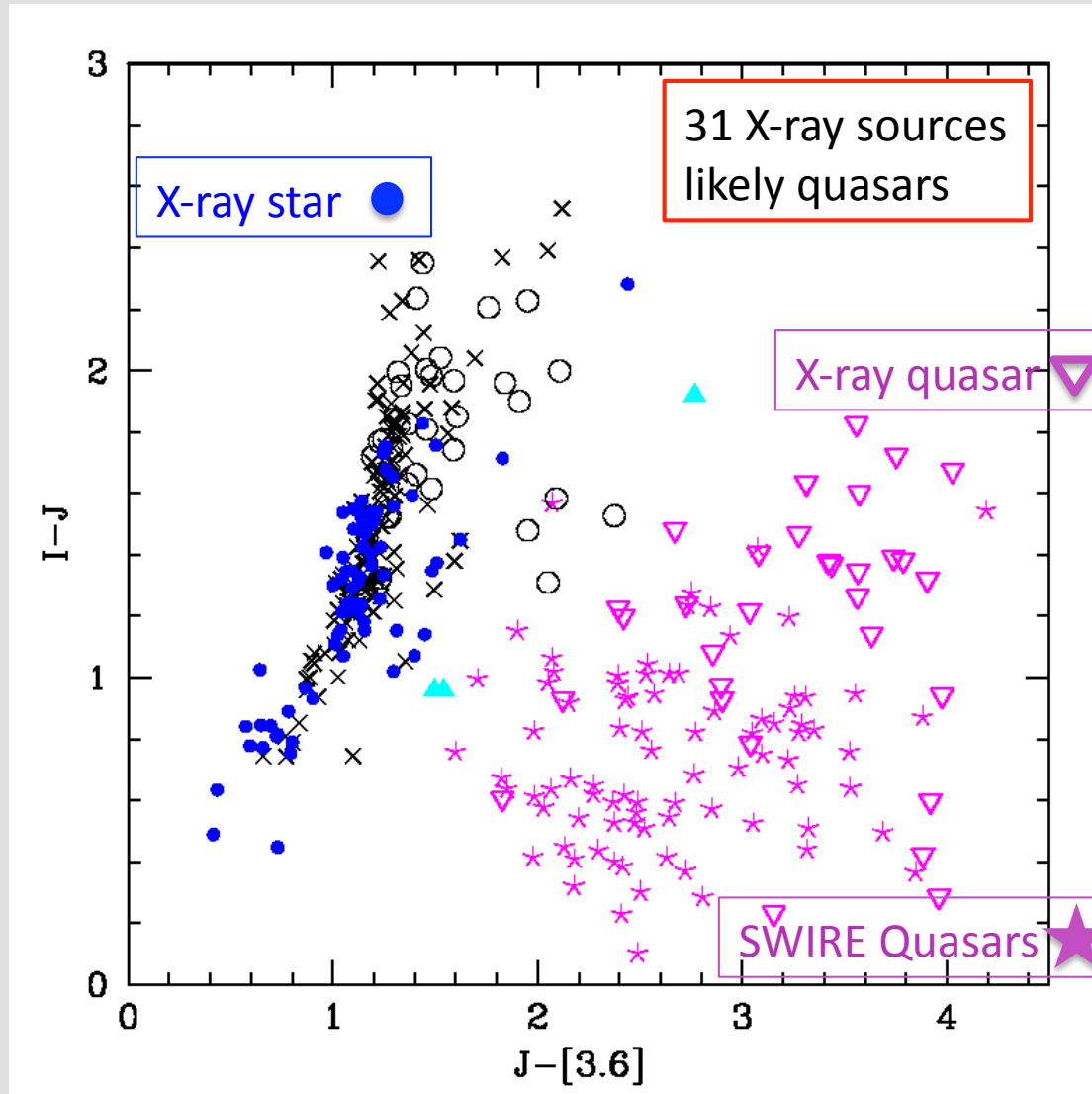
OM: V=7.3 19.4 mag (nominal)
V > 12 (in practice)

Good match of photometry
from OM with published data;

add.photometry for X-ray sources:
27 in B-band
20 in V-band

Definition of the pre-MS sample

(The case of Col 69)



1.) The Quasar-Killer

young stars well separated from quasars
(Bouy et al. 2009)

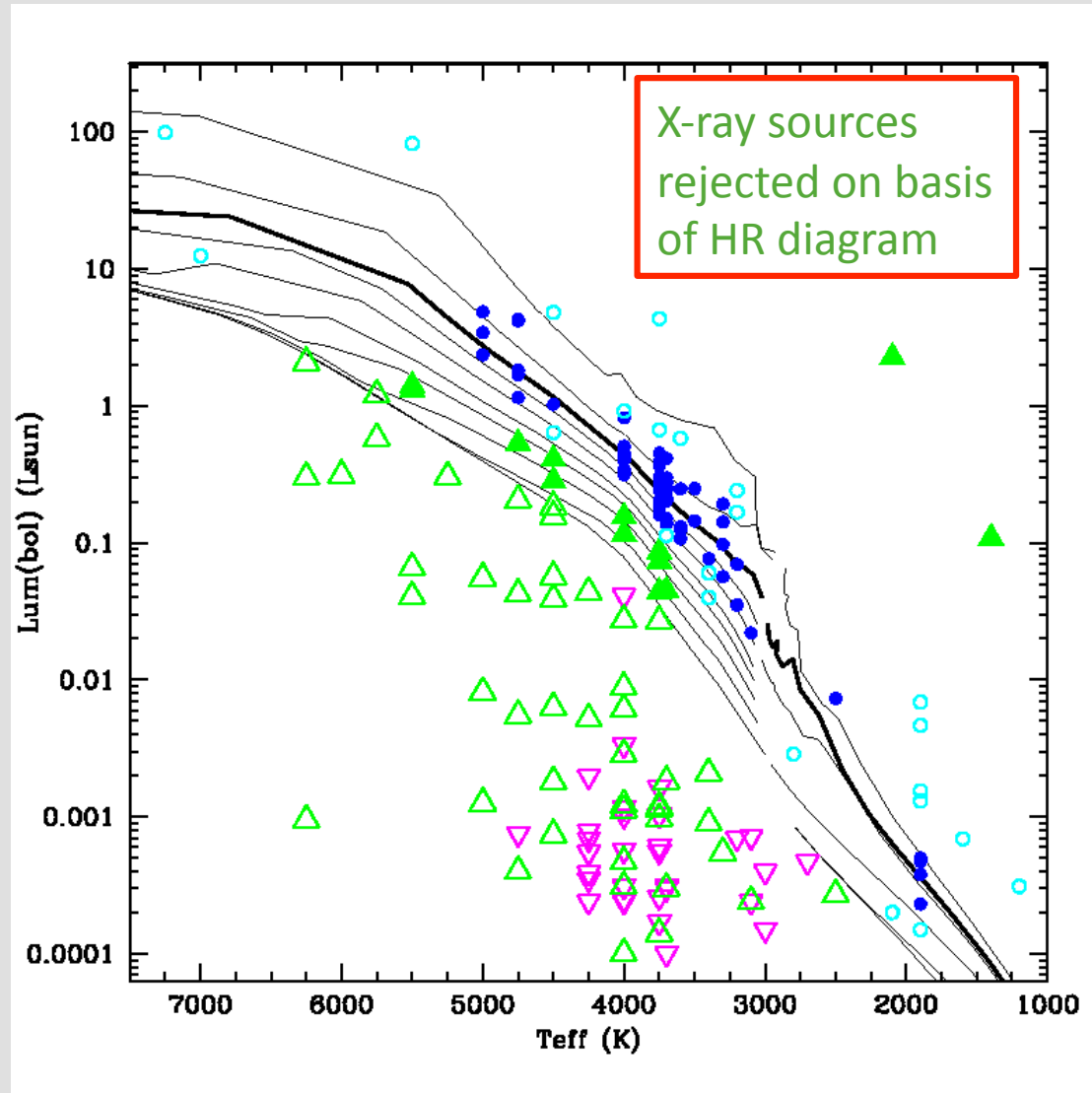
2.) HR diagram

3.) color-magn. diagrams

4.) X-ray hardness ratios

Definition of the pre-MS sample

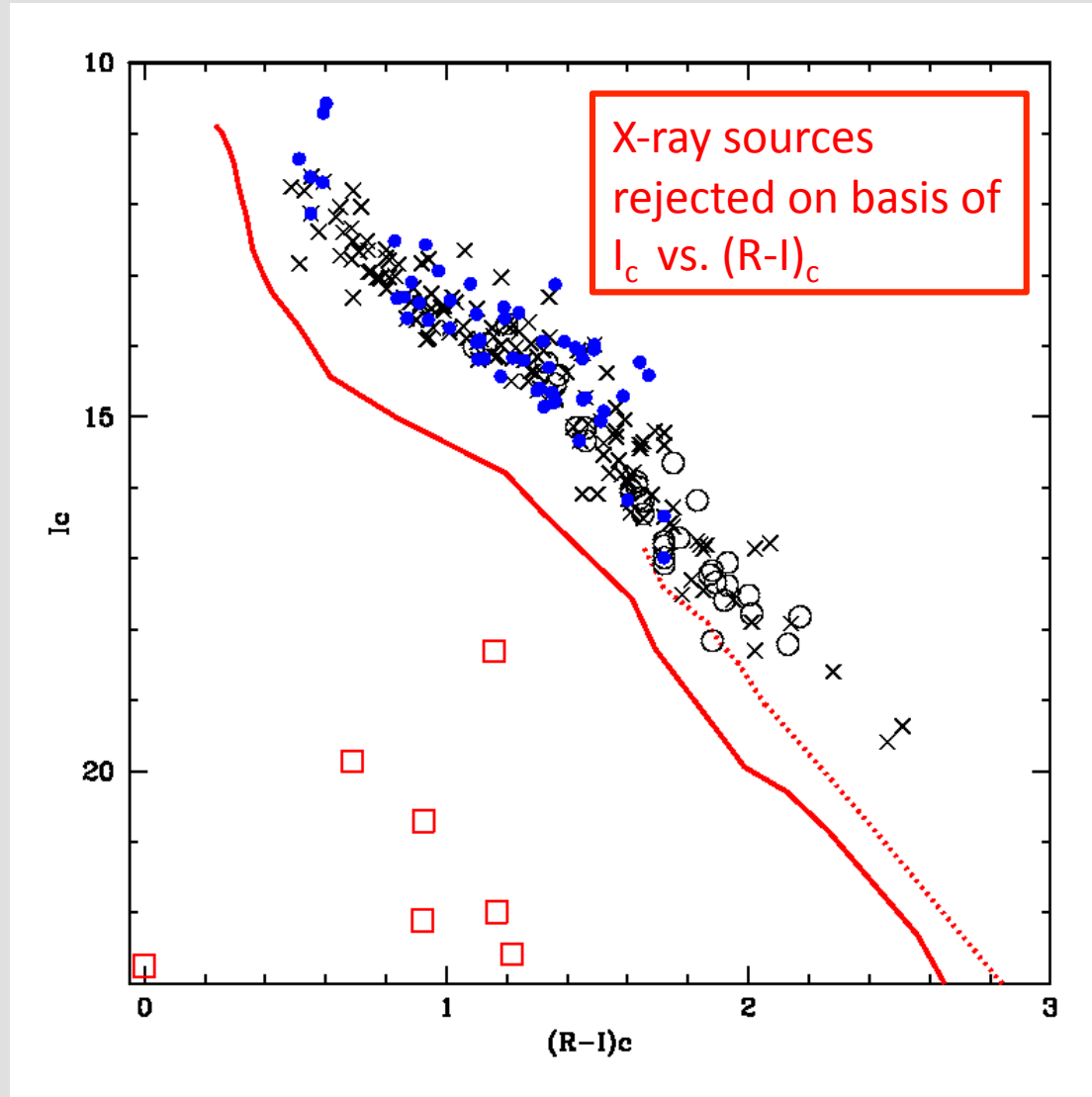
(The case of Col 69)



- 1.) **The Quasar-Killer**
young stars well separated from quasars
(Bouy et al. 2009)
- 2.) **HR diagram**
reject objects below 20Myr
and well above 1 Myr
- 3.) **color-magn. diagrams**
- 4.) **X-ray hardness ratios**

Definition of the pre-MS sample

(The case of Col 69)



1.) The Quasar-Killer

young stars well separated from quasars

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2.) HR diagram

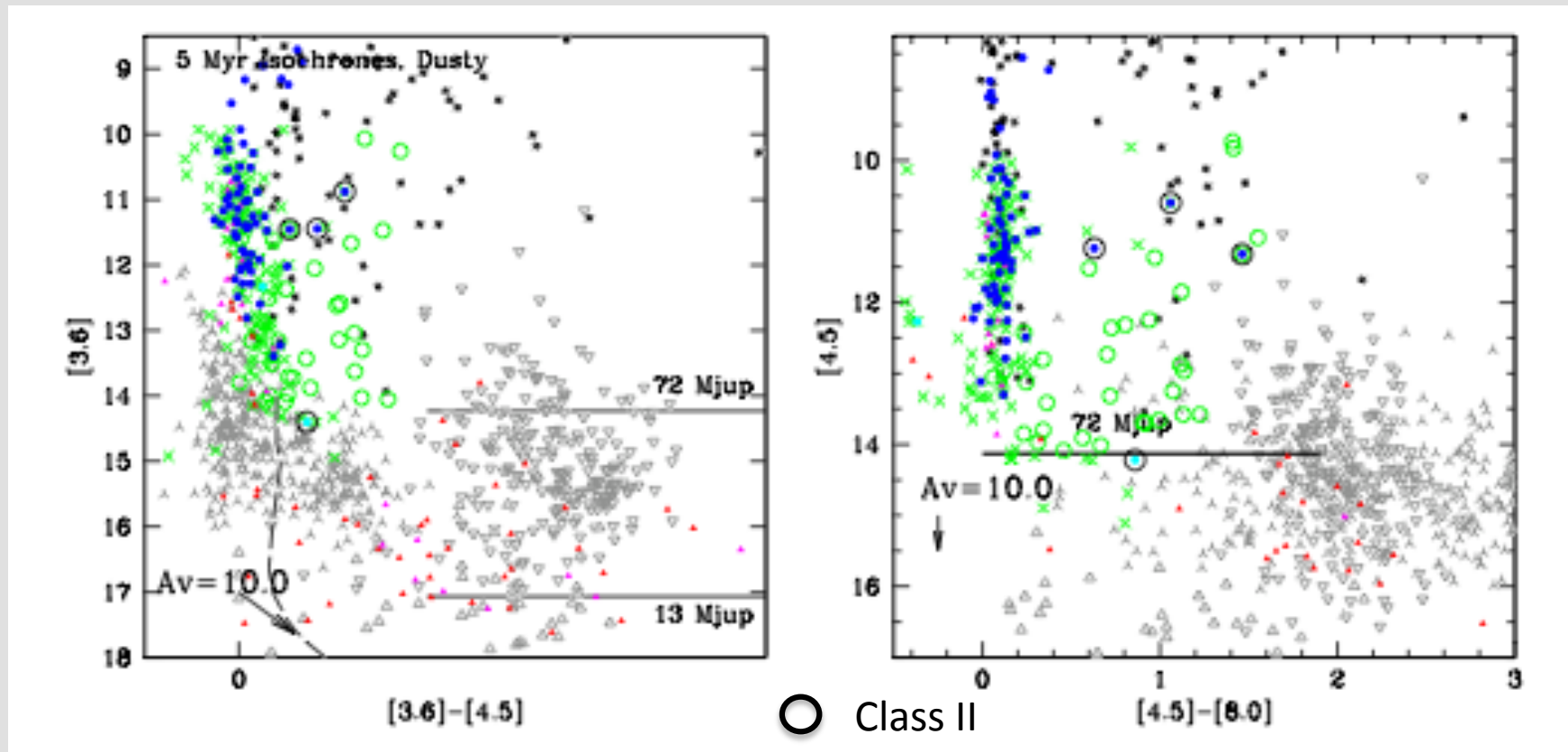
reject objects below 20Myr
and well above 1 Myr

3.) color-magn. diagrams

reject objects below empirical
main-sequence (ByN04)

4.) X-ray hardness ratios

Definition of the pre-MS sample (The case of Col 69)



Multi- λ selected C69 member

Previous C69 member

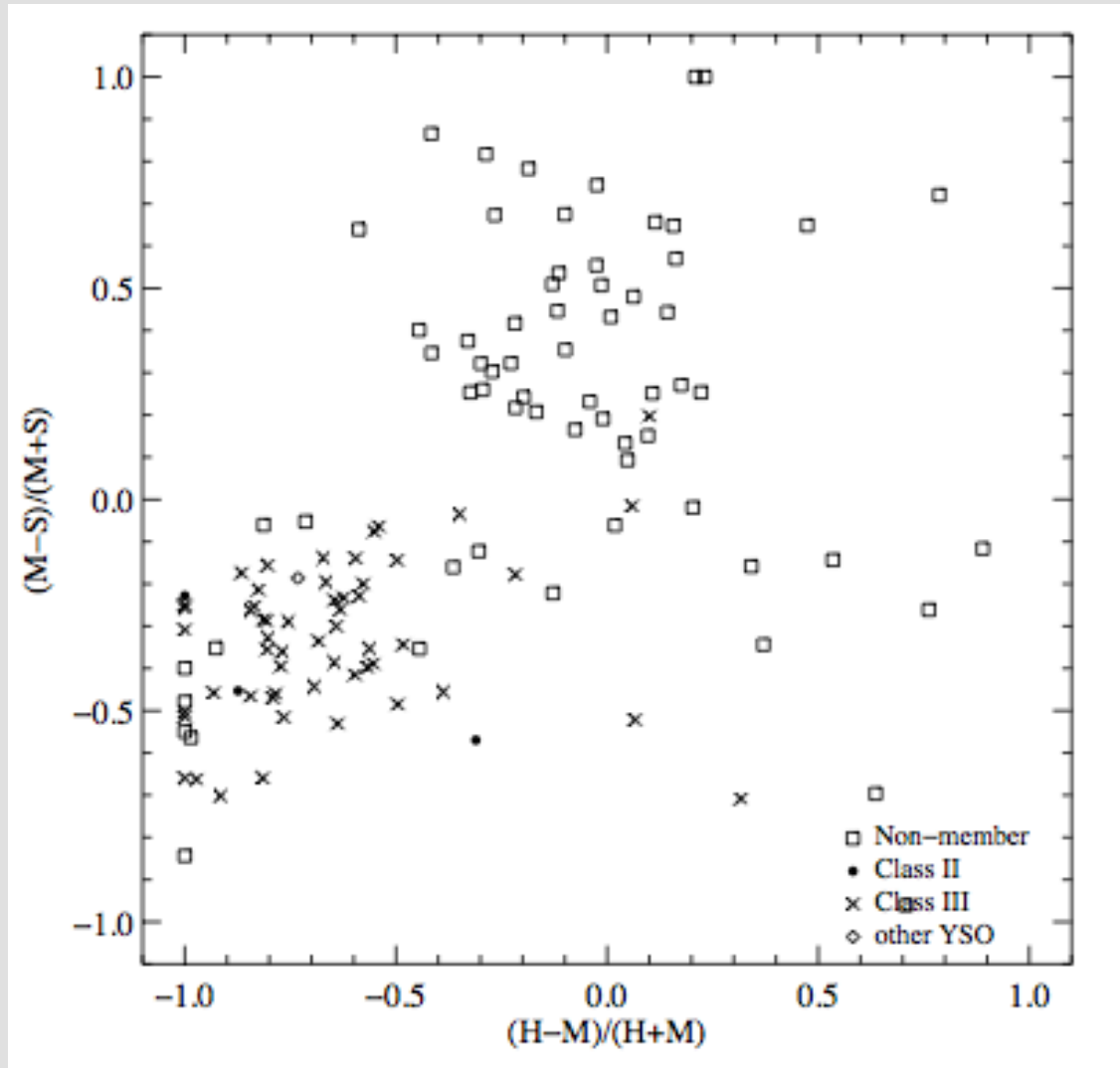
Probable non-members

Taurus members (Luhman et al 2006)

Extragal. samples

Result of selection process:
66 X-ray sources are C69 members
of which **19 new**

Definition of the pre-MS sample (The case of Col 69)



1.) The Quasar-Killer

young stars well separated from quasars
(Bouy et al. 2009)

2.) HR diagram

reject objects below 20 Myr
and well above 1 Myr

3.) color-magn. diagrams

reject objects below empirical
main-sequence (ByN04)

4.) X-ray hardness ratios

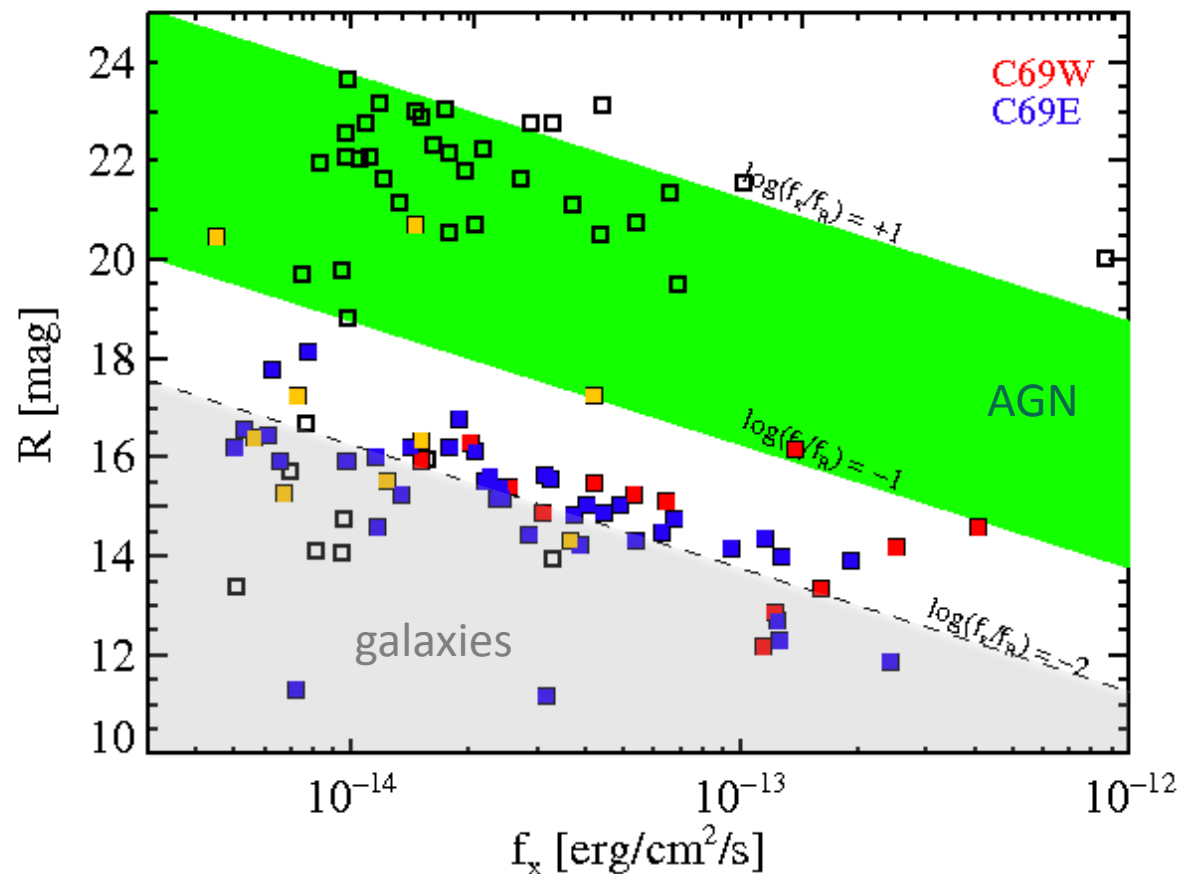
selected cluster members
have soft X-rays

Extragalactic contamination

(The case of Col 69)

From logN – logS distributions: expected ~ 40 extragal. sources / XMM-Newton field
@ $5 \cdot 10^{-15}$ erg/cm²/s

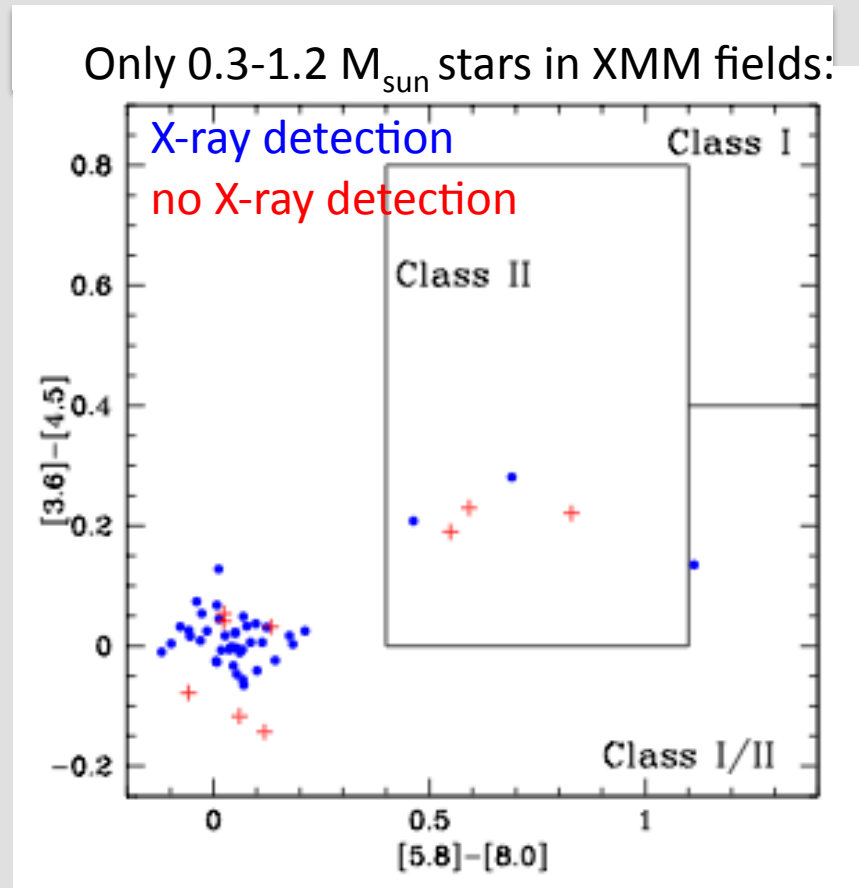
Data: C69E 48 cluster members / 112 X-ray sources
C69W 18 cluster members / 52 X-ray sources



Spitzer photometry of pre-MS stars in Col 69

No Class I
in agreement with
several Myr age
of the cluster

Few Class II,
i.e. small disk fraction



X-ray properties of Col69 members

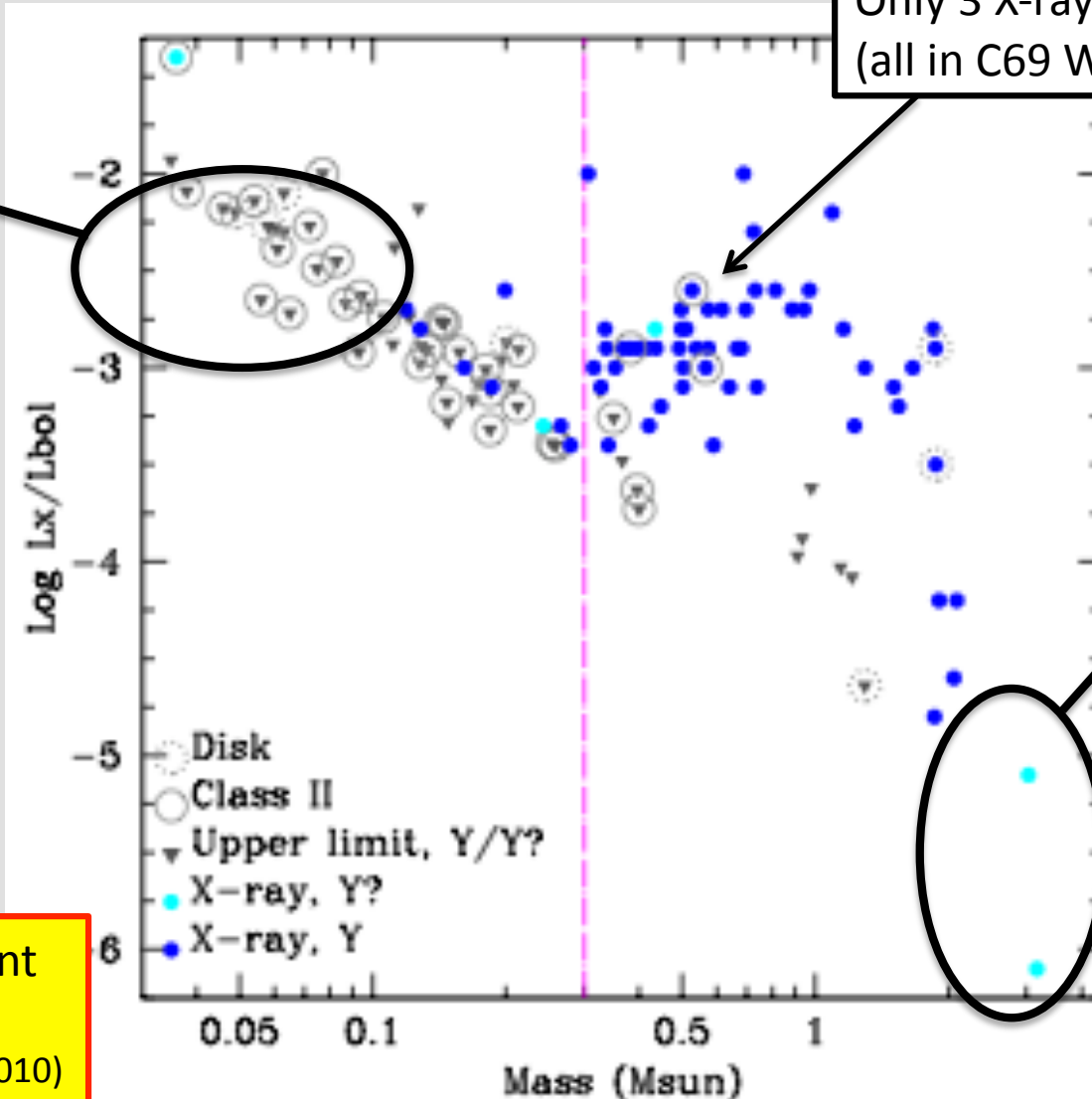
X-ray emission and mass

VLM stars dominated by Class II upper limits

- A) Unusual IMF
- B) High disk fraction for VLM stars

(no star $> 1 M_{\text{sun}}$ has disk)

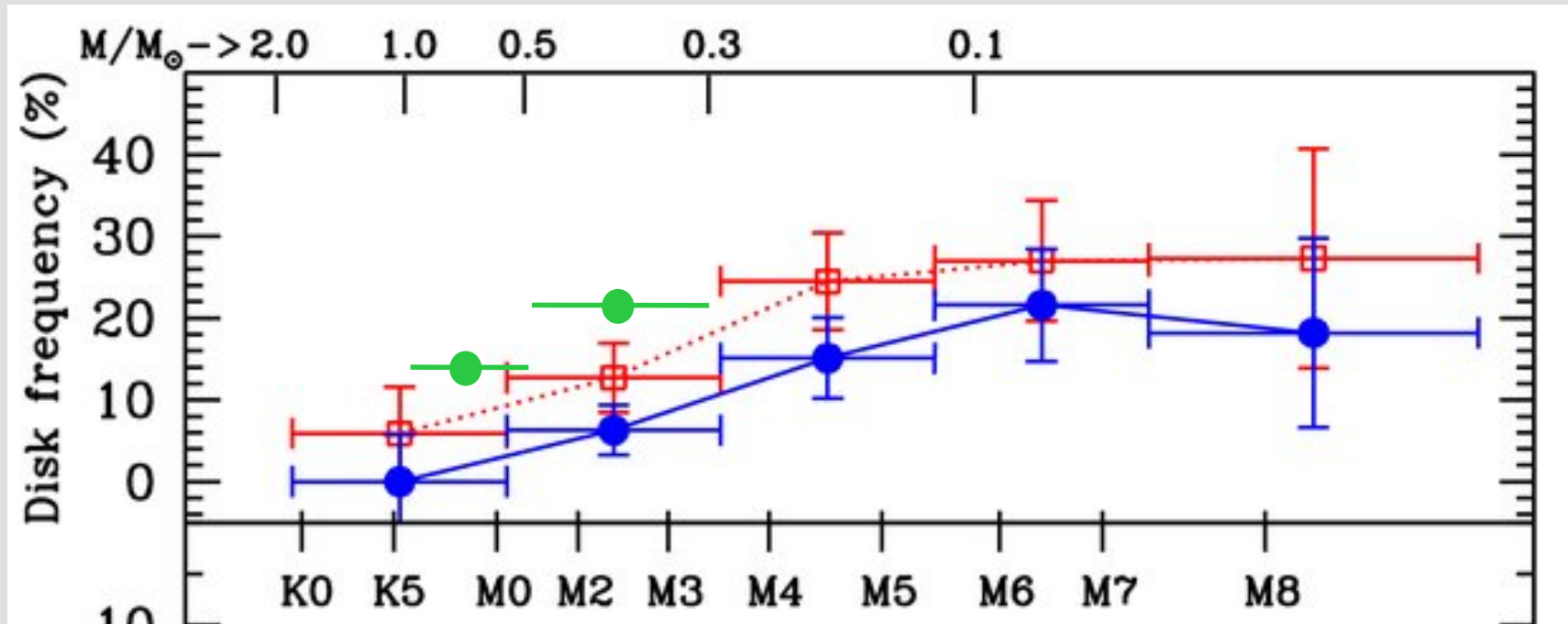
Highly mass-dependent disk fraction !
(see also Hernandez et al. 2010)



Only 3 X-ray detected Class II
(all in C69 West)

Most massive stars have no YSO class
(too bright)
+ very faint X-ray emission
(shallow conv. zone)

Disk fraction in Col 69



All disks
Opt.thick

Hernandez et al. (2010)

Different samples,
different YSO definition
(measures of excesses)

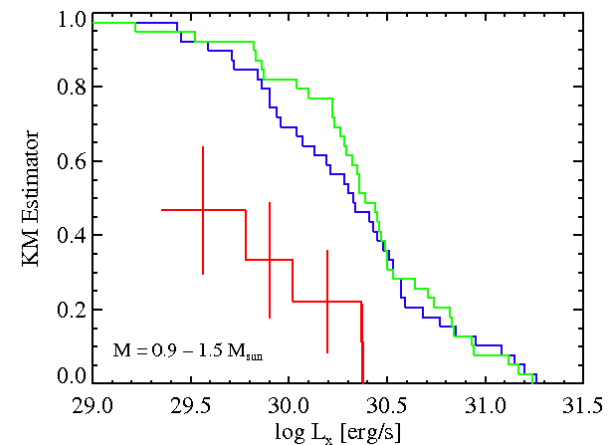
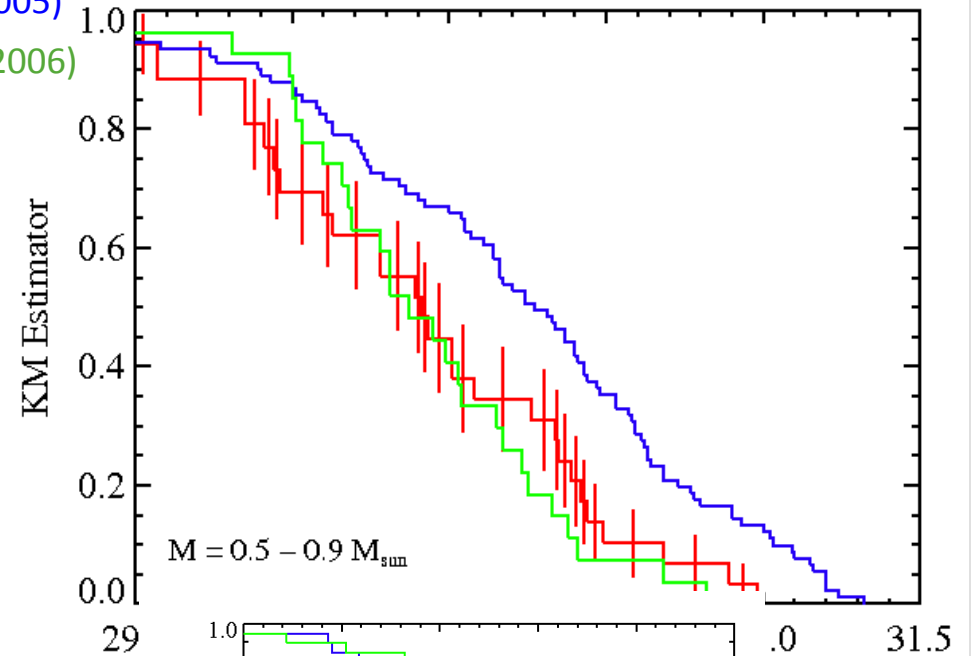
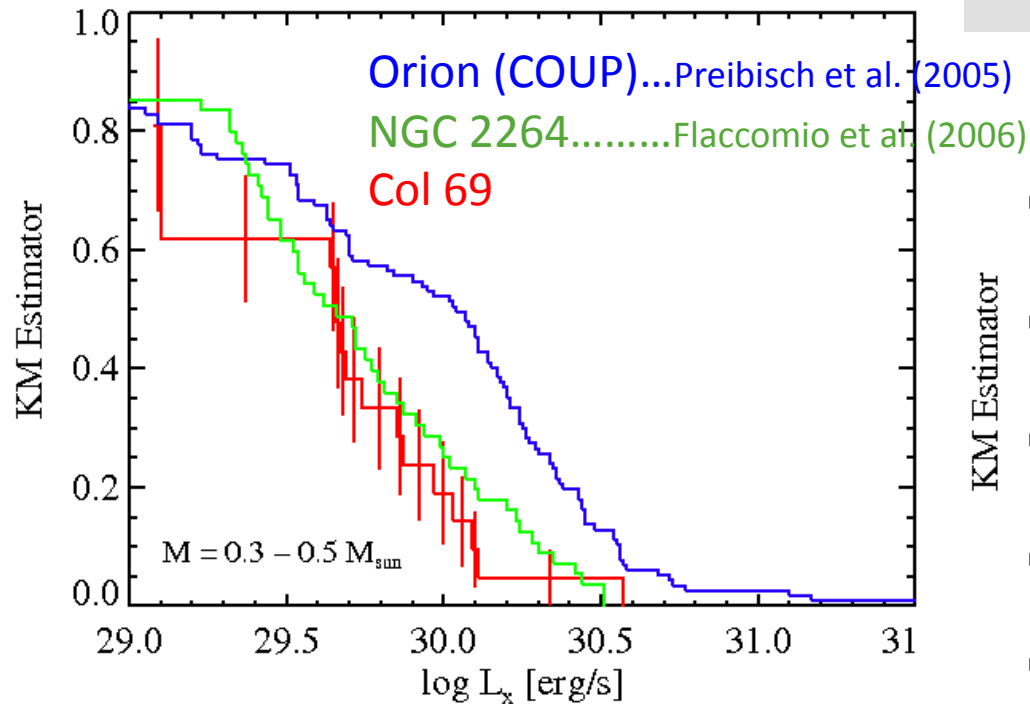
XILO disk fractions:

0.3-0.5 M_{sun} : 11.1 % (21.7 % incl. upper limits)

0.5-0.9 M_{sun} : 14.3 % (all stars detected)

X-ray properties of Col69 members

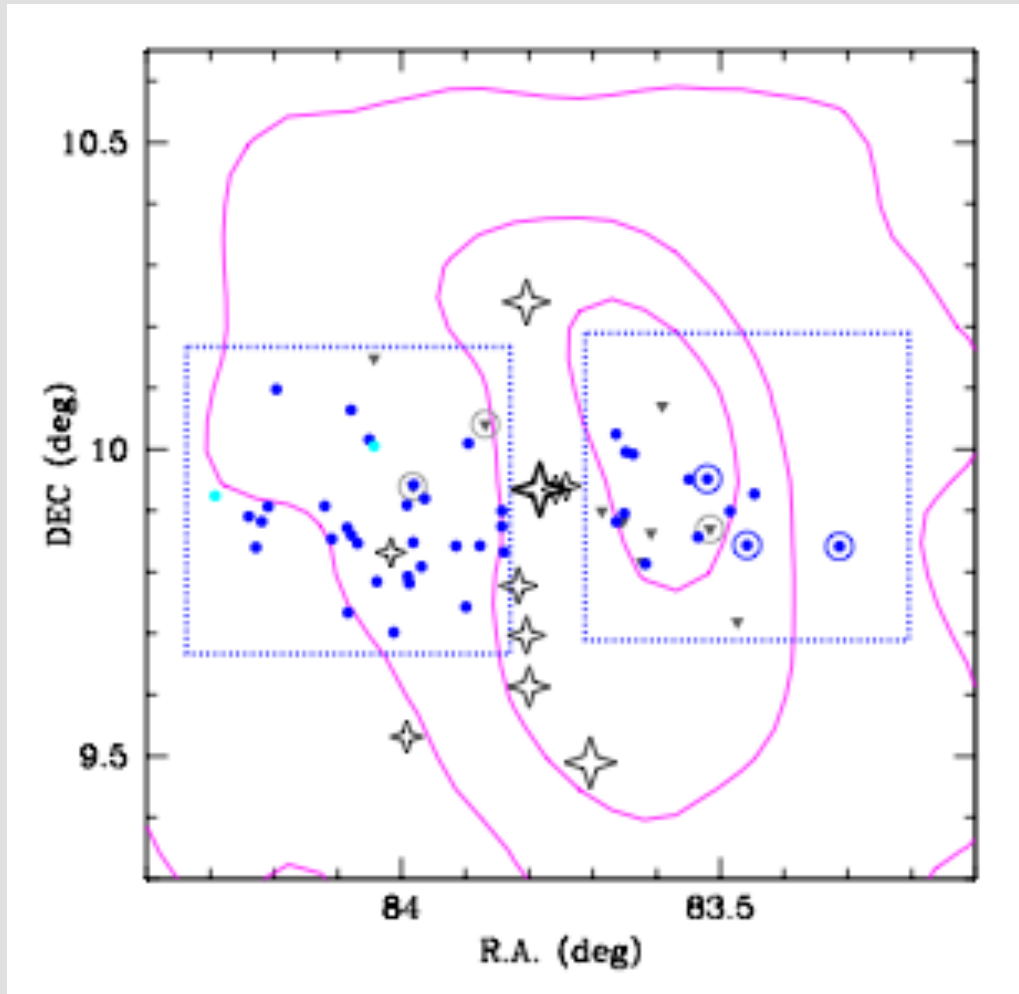
X-ray luminosity functions



- XLF of Col69 confirms age of $\geq 3\text{Myr}$
- XLF of Col69 incomplete for $M > 0.9 M_{\text{sun}}$

X-ray properties of Col69 members

Spatial distribution



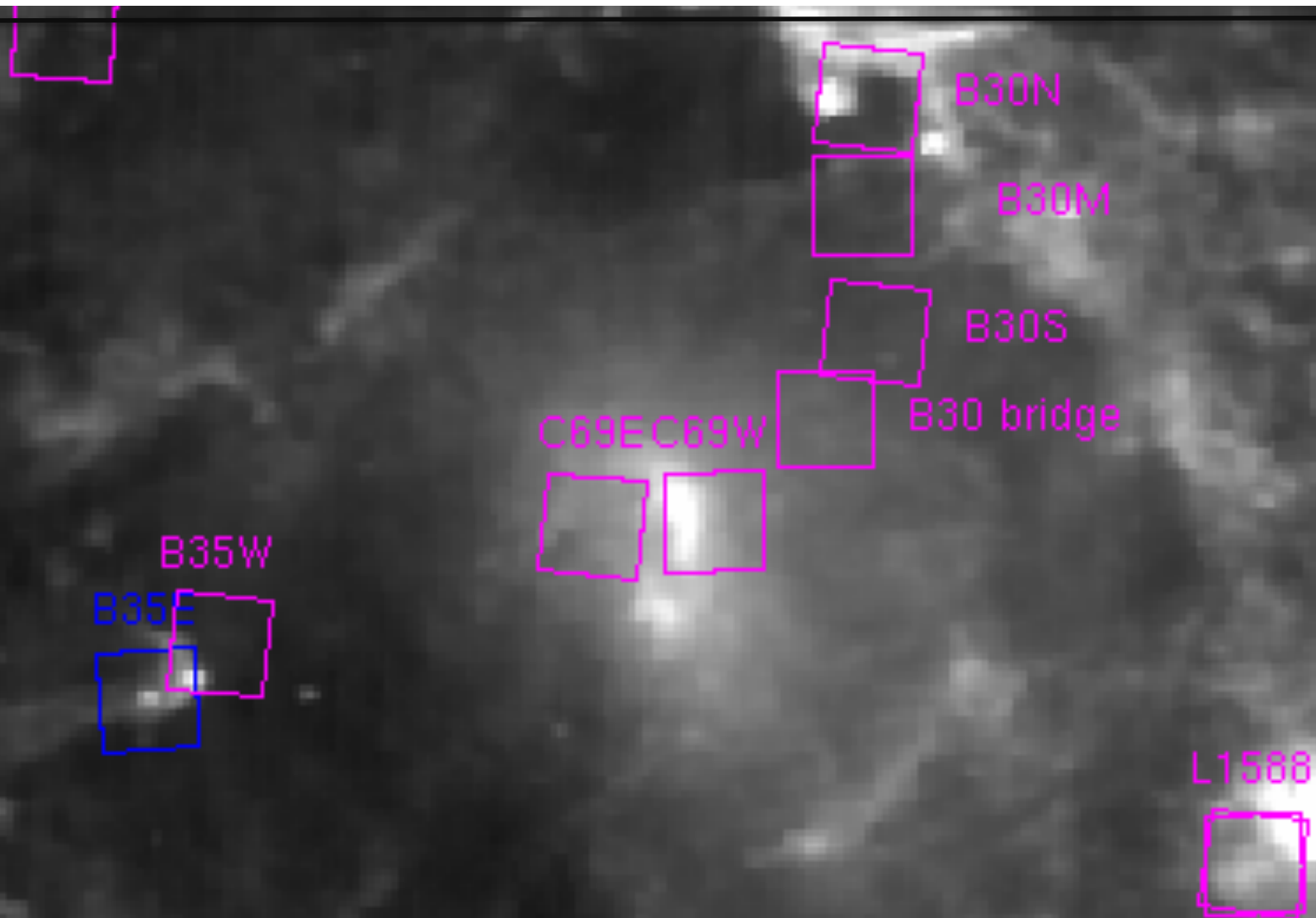
Asymmetric distribution
of cluster around center:
-- larger extension to East
-- more Class II in West (?)

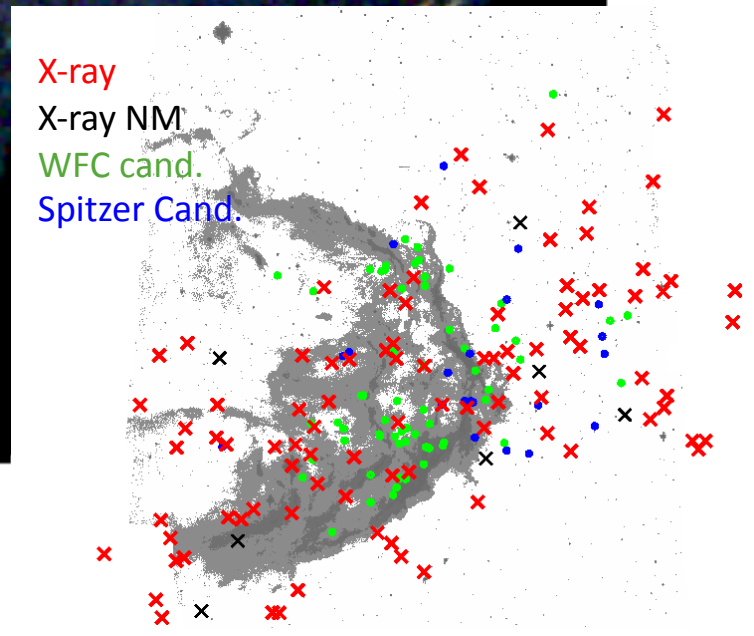
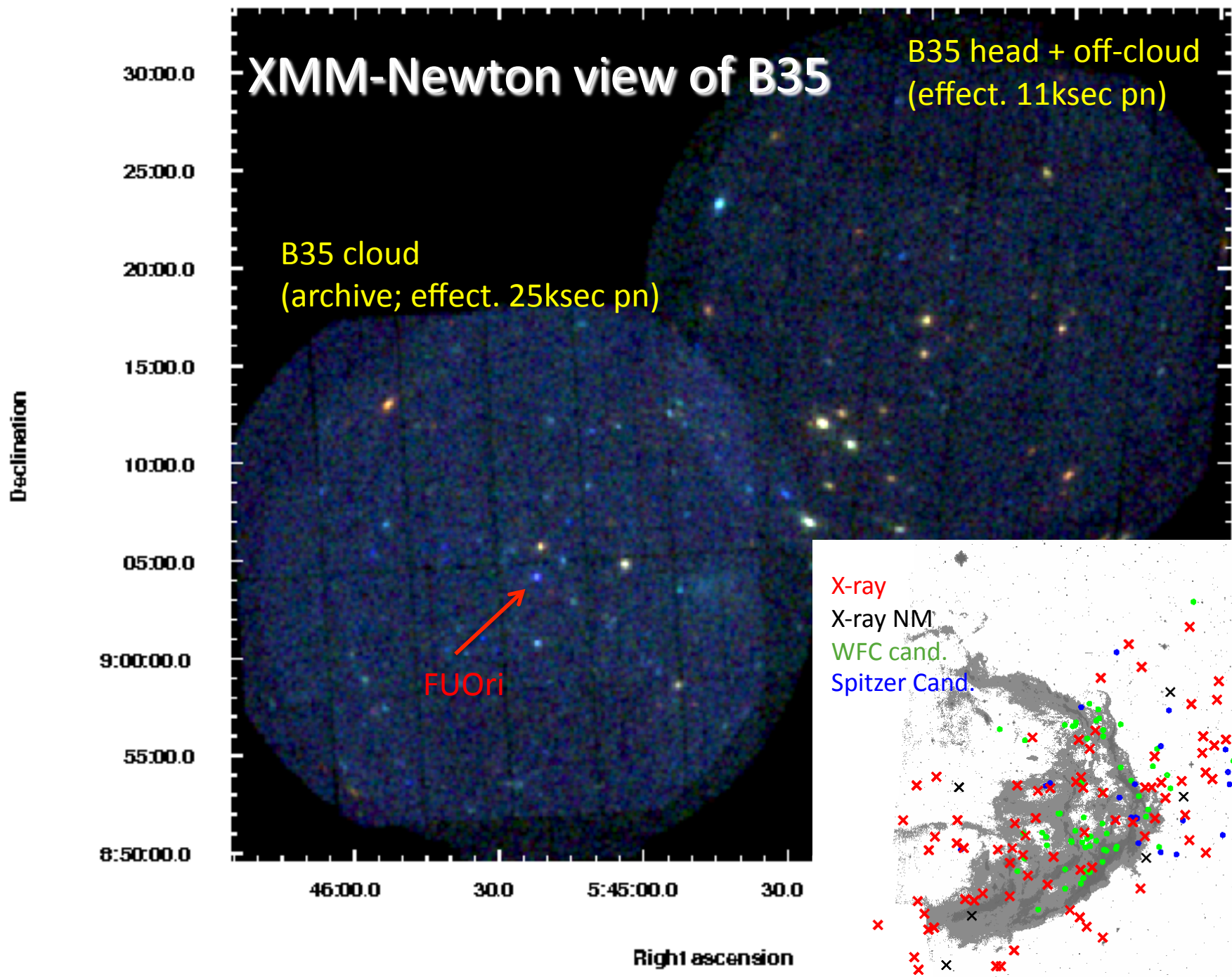
...tracing original
cloud structure

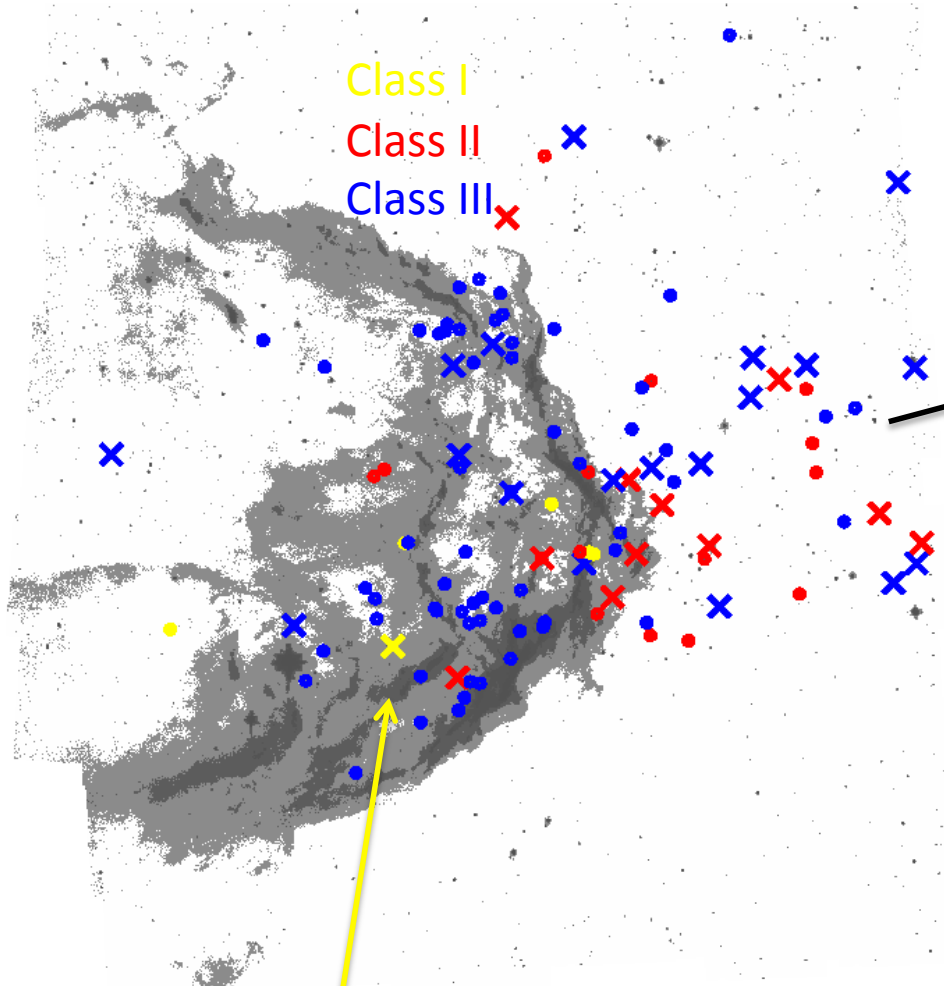
XMM-Newton investigations of the Lambda Orionis star forming region (XILO)

I. The young cluster Collinder 69

D. Barrado¹, B. Stelzer², M. Morales-Calderón³, A. Bayo⁴, N. Huélamo¹, J.R. Stauffer³, S. Hodgkin⁶, F. Galindo¹, and E. Verdugo⁵,







Class I
Class II
Class III

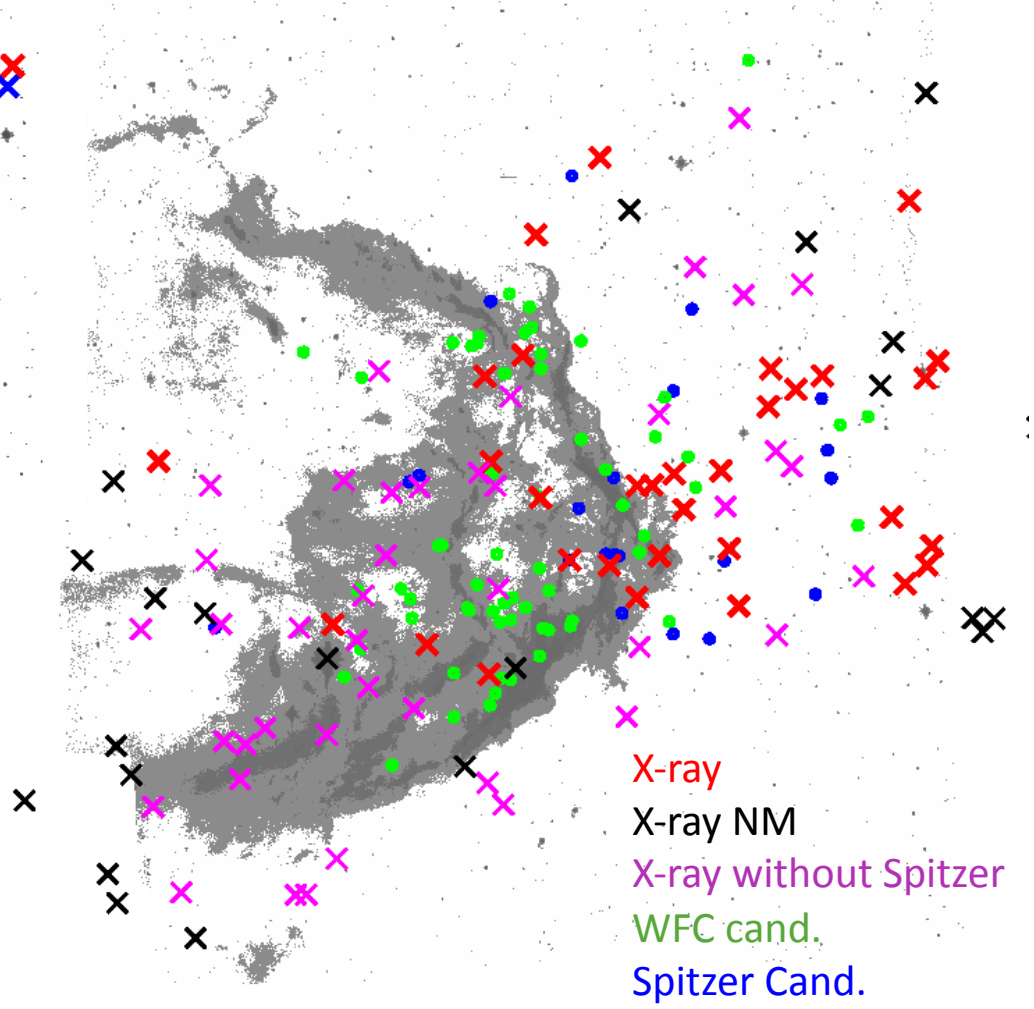
towards λ Ori

B35:
Spatial distribution

X-ray emitting Class I ?

6 protostars in cloud
→ Presently active star formation?

6 Class I in 30ks Chandra of the BRC IC1395N
(Getman et al. 2007)

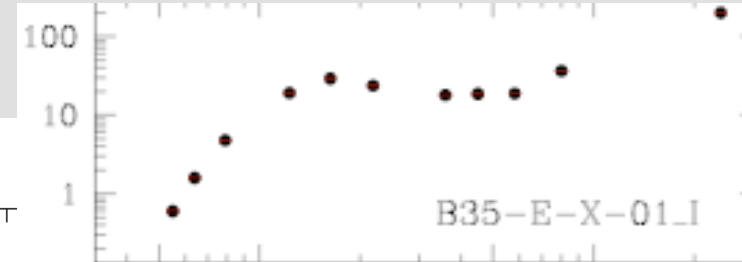
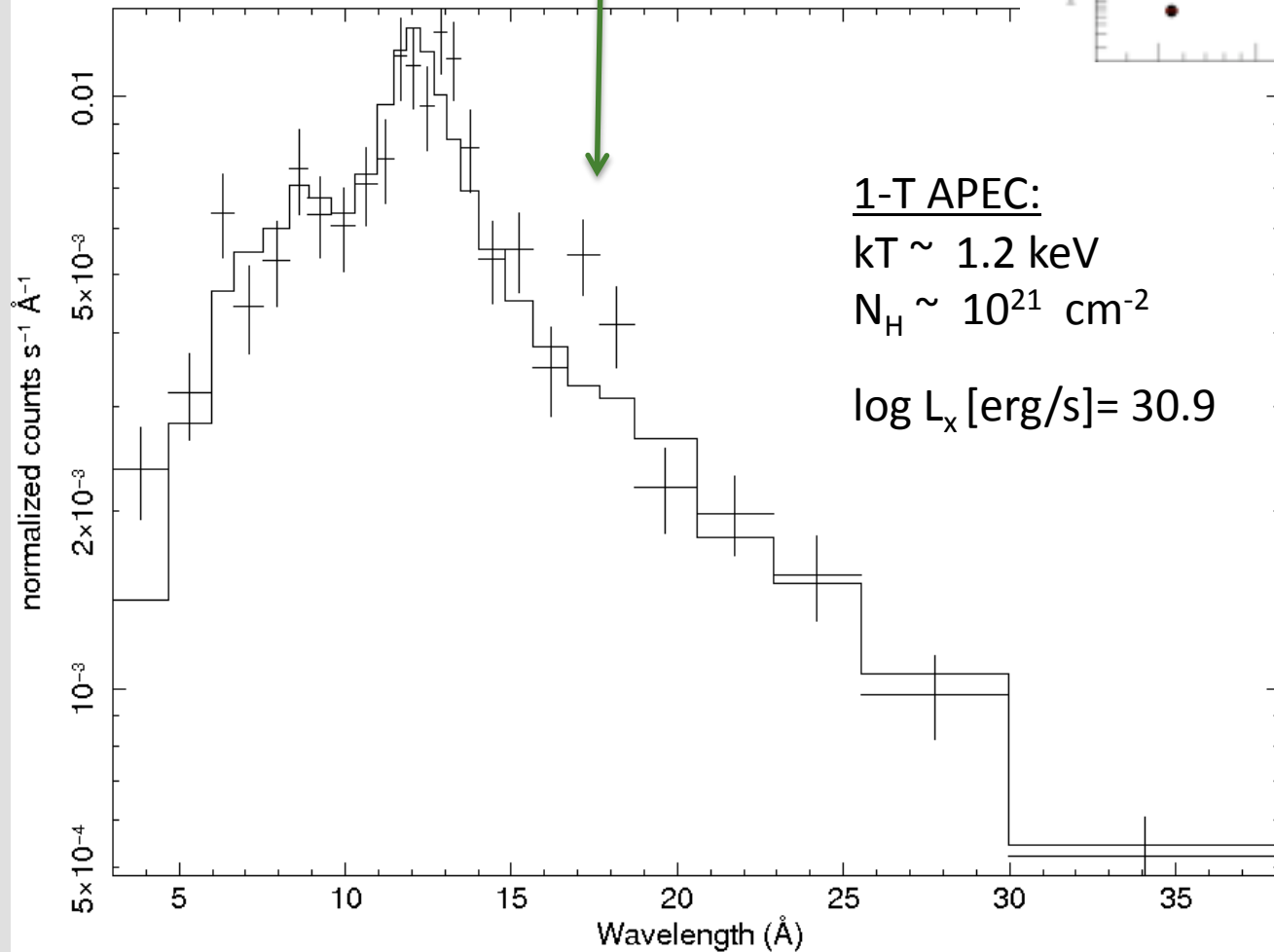


X-ray
X-ray NM
X-ray without Spitzer
WFC cand.
Spitzer Cand.

B35: An X-ray bright Class I ?

Fe XVII ?
Calibration?

data and folded model



SED: Class I

D&M 259:

Optical spectrum:

$W_{li} = 0.66 \text{ \AA}$

$W_{ha} = 4.8 \text{ \AA}$

SpT = M6.5

$A_V = 1.6 \text{ mag}$

X-ray source is a VLM star ?
(not a Class I)

1. Results from XILO:

Central cluster Col69 shows

inhomogeneous distribution of pre-MS stars
with string of stars connecting Col69+B35,
age $\geq 3\text{Myr}$ (from XLF+no ClassI+disk fraction),

Col69 disk fraction mass-dependent $\sim 15\text{-}20\%$
(maybe no need for disk removal ahead of time?)

B35 cloud has
higher disk fraction (mostly in front of cloud),
active star formation (ClassI)

Possible low-mass cluster(s) on mol. ring

X-rays essential ($\sim 25\%$ increase of member list)

L1603

B-100

B30M

B30S

C69EC69W

B30 bridge

B35W

B35E

L1588