Chandra, Spitzer & VLA Observations of Young Clusters

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With help from...

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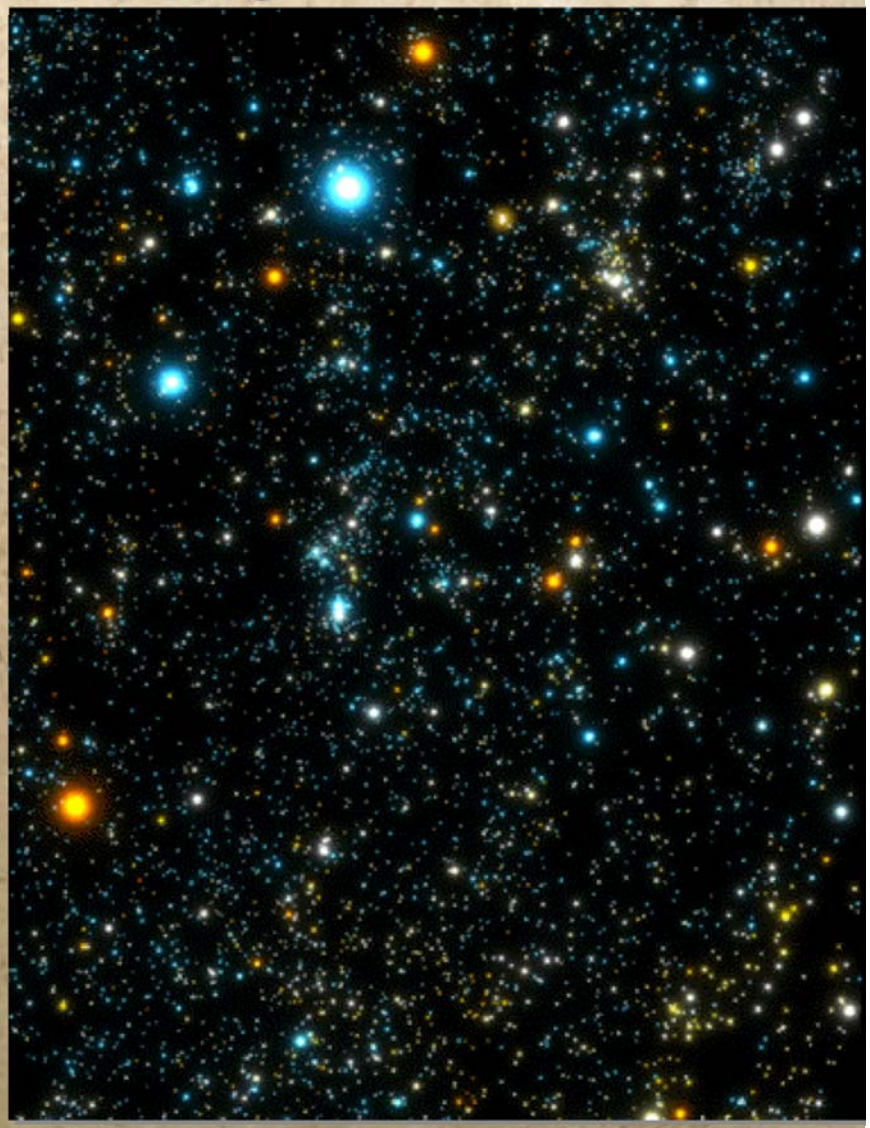
B.Spitzbart (CfA), S.T. Megeath (Toledo),

E. Winston (Dublin) And Many More.

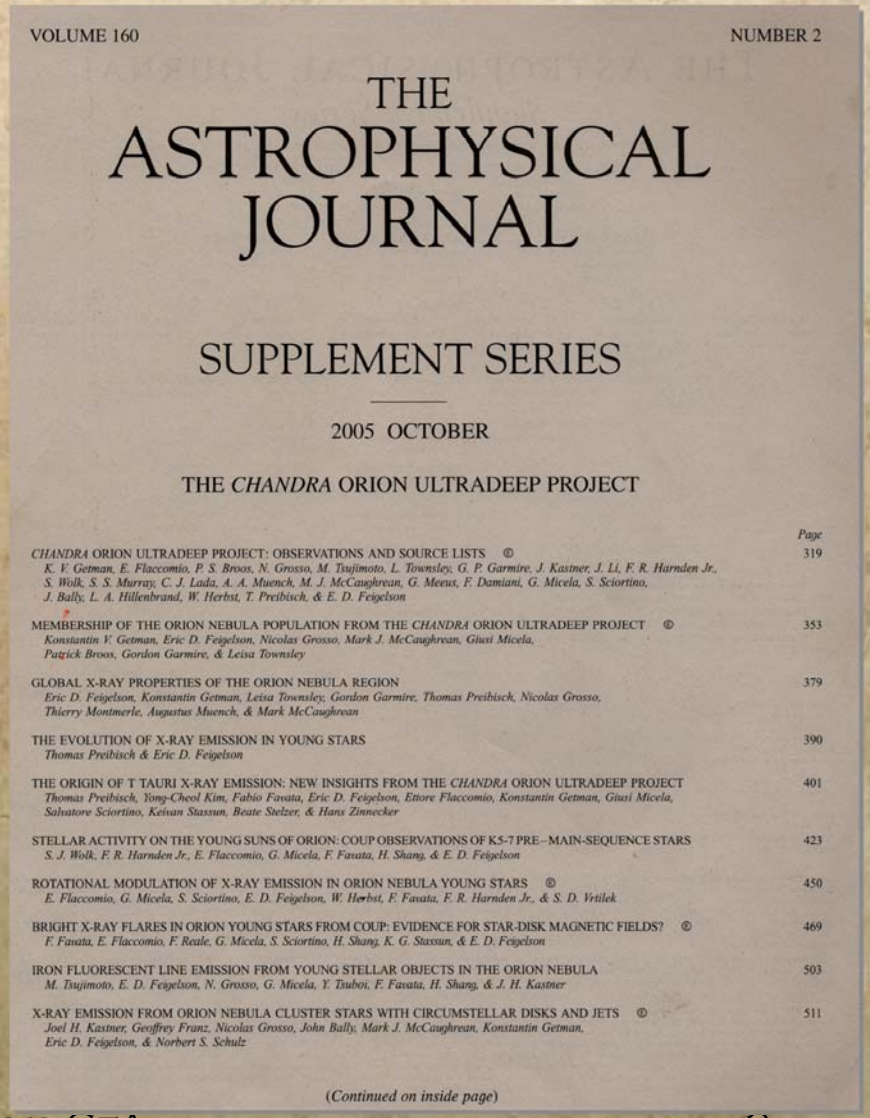
Why Bother Looking at Young Stars in X-rays

- Young stars are X-ray bright
  - HMS- High energy wind shocks?
  - LMS- Despite pedestrian 5000K, temperatures they have hot corona.
    - Insight into the interior workings of LMS.
- To identify young stars.
  - After stars lose their disks X-ray surveys are the only way to find young stellar objects
  - This has allowed us to understand the history of star formation in the galaxy.
- Direct observation of material accreting onto very young stars.
- X-rays are probably responsible for rapid heating of protoplanetary disks.



COUP study of the ONC

- 850 ks
- 13 papers in the APJSupp
- 465 refereed citations
- 6 Refereed Papers since
- XEST - 11 paper A&A special edition on Taurus SFR.
- So aren't we done?



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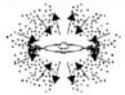
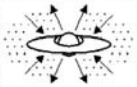
THE *CHANDRA* ORION ULTRADEEP PROJECT

(*Continued on inside page*)

THE PROGRAM: MULTIWAVELENGTH STUDIES OF NEARBY REGIONS OF STAR FORMATION

PROPERTIES	*Infalling Protostar*	*Evolved Protostar*	*Classical T Tauri Star*	*Weak-lined T Tauri Star*	*Main Sequence Star*
SKETCH					
AGE (YEARS)	10^4	10^5	10^6 - 10^7	10^6 - 10^7	> 10^7
mm/INFRARED CLASS	Class 0	Class I	Class II	Class III	(Class III)
DISK	Yes	Thick	Thick	Thin or Non-existent	Possible Planetary System
X-RAY	?	Yes	Strong	Strong	Weak
THERMAL RADIO	Yes	Yes	Yes	No	No
NON-THERMAL RADIO	No	Yes	No ?	Yes	Yes

Transition

FEIGELSON & MONTMERLE 1999

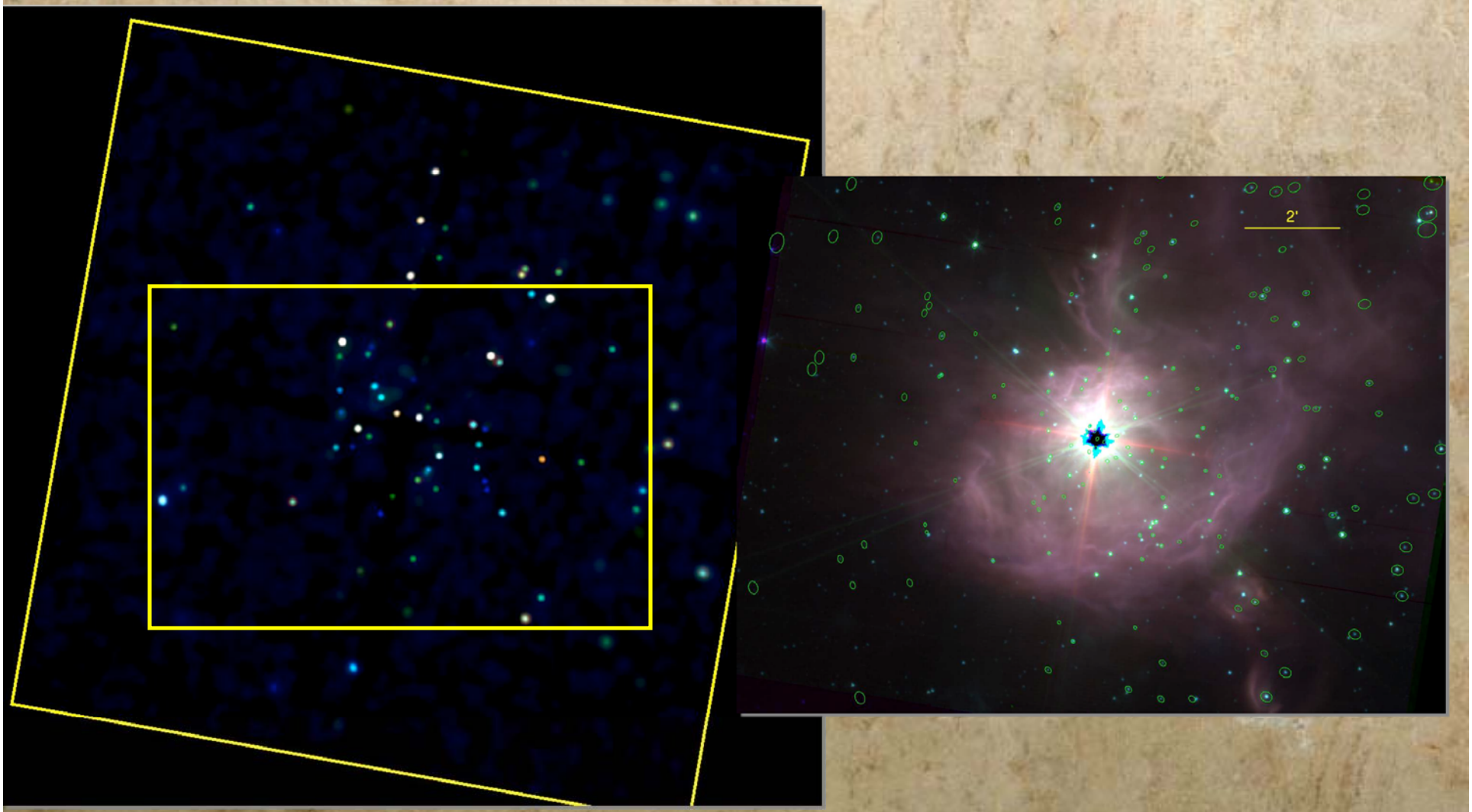
- GOALS
  - CLUSTER CENSUS
  - TRANSITION DISK TIMESCALES
  - EFFECT OF X-RAYS ON PLANET FORMING DISKS
  - ESPECIALLY FLARES

Lk Hα 101

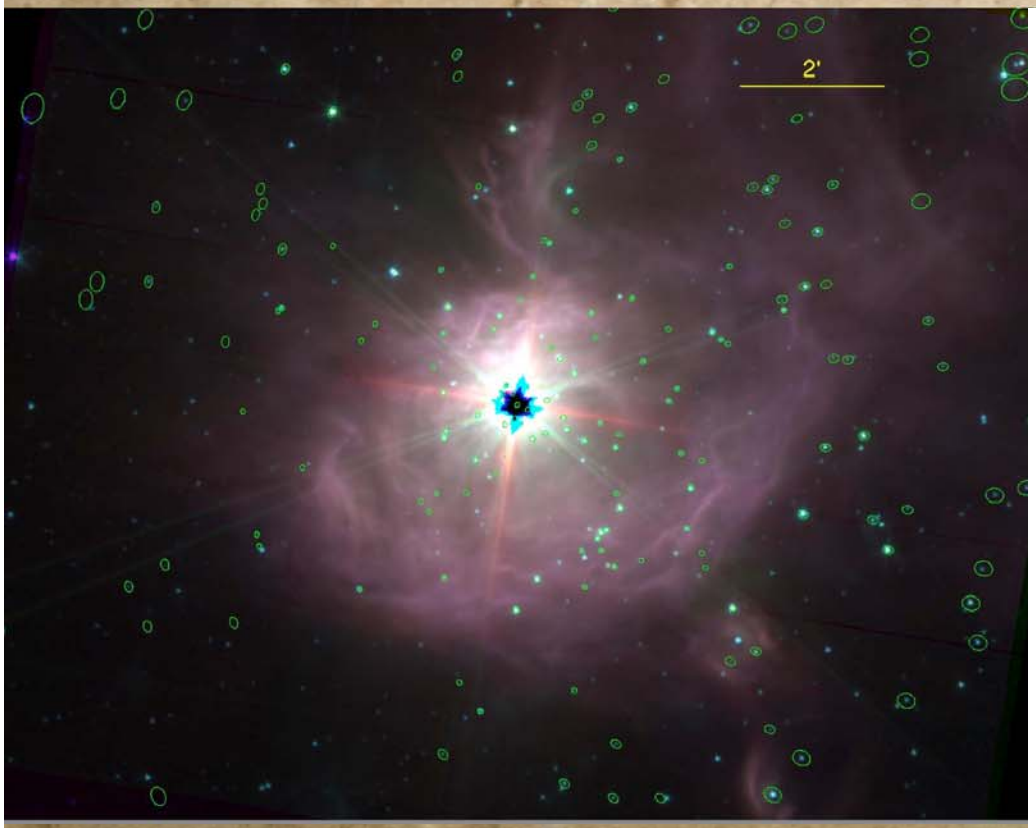
A Be star associated with ~ 65 PMS stars from 2MASS and other IR Surveys.

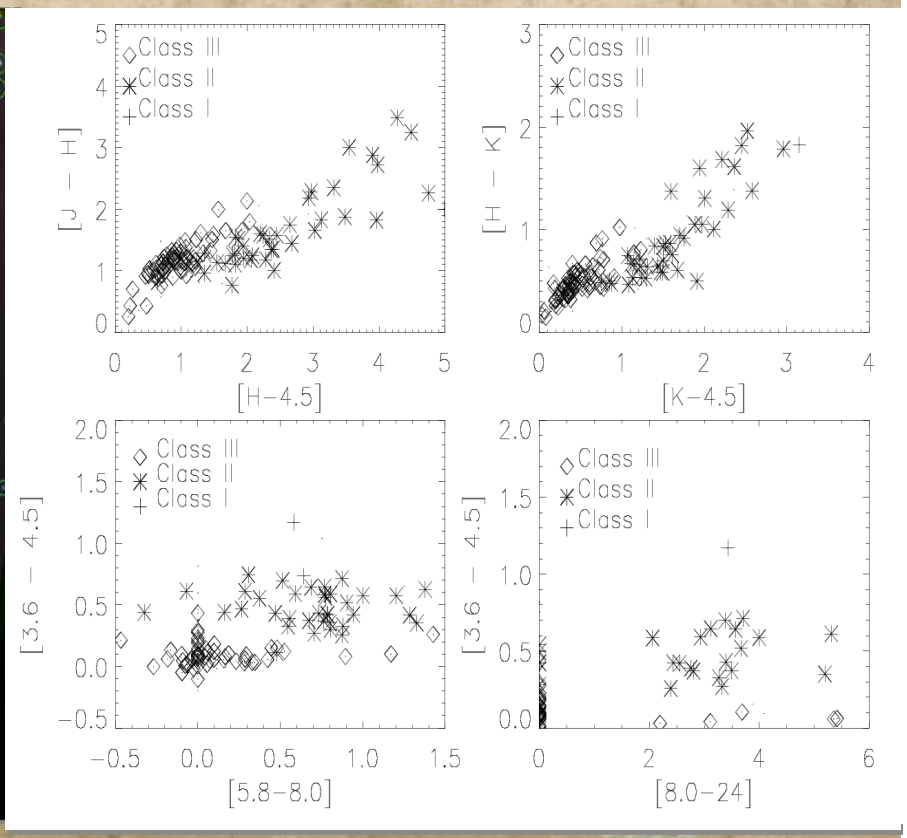
- About 2600 sources detected in at least 1 IRAC band
- About 213 X-ray sources in the combined 2x40ks.
- About 24 VLA sources (at either 3.6 cm or 6 cm)

LkHα101 Cluster



Spitzer Data



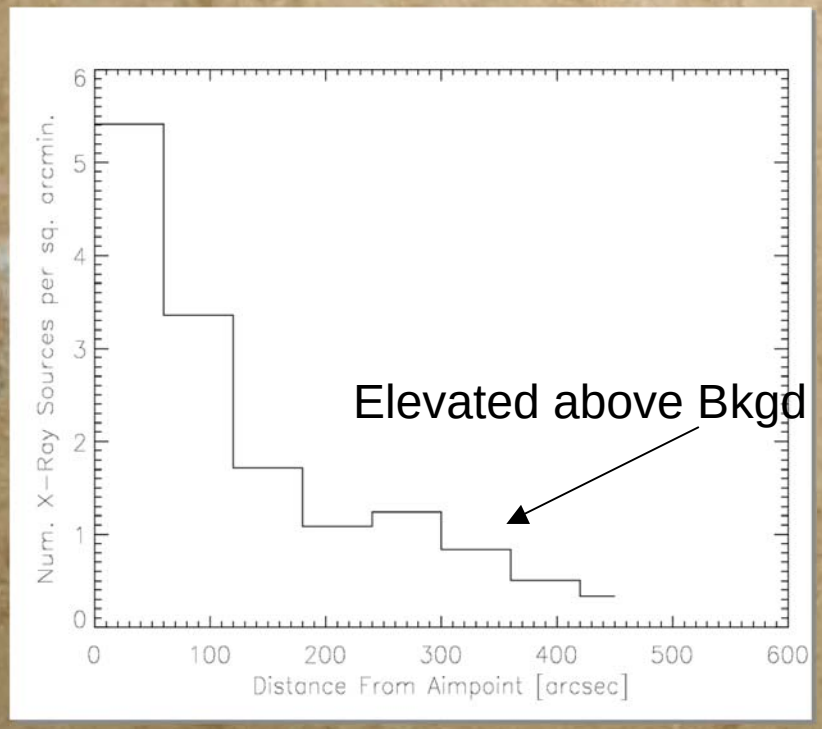


IR colors of X-ray sources

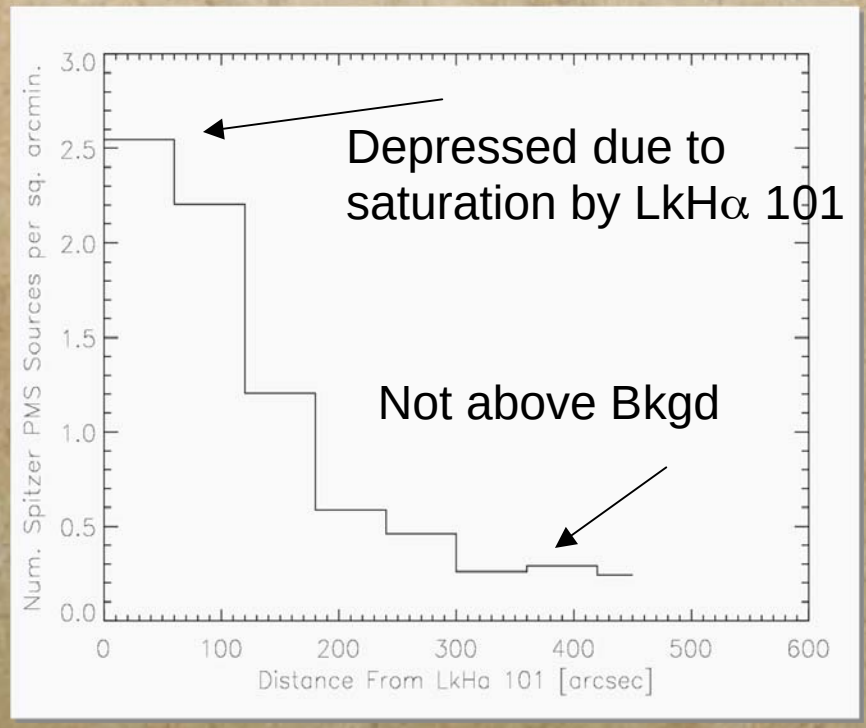
Spatial Distribution

Class IIIs more distributed than Class I/IIs

X-Ray



Spitzer/IRAC

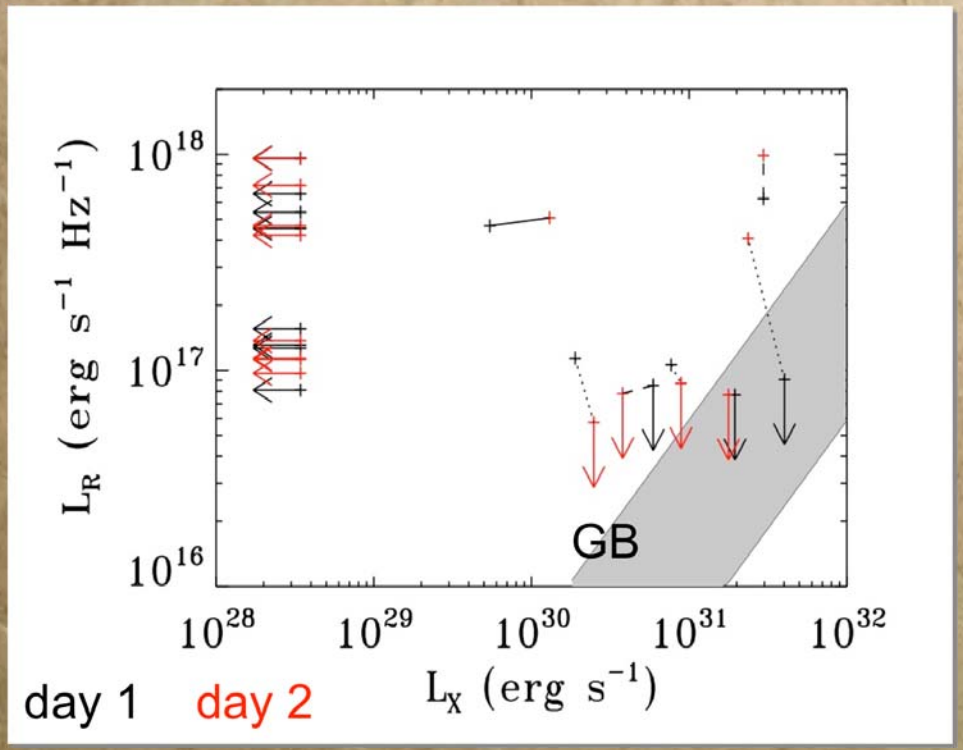


Stellar Content of LkHα 101

Class	0/I	II	Trans.	III	Other PMS?	Bkgd
X-Ray sources	5	41	5	65	26	~65
Spitzer Sources	16	94	9	(147)	(60)	~3000

266-326 stars

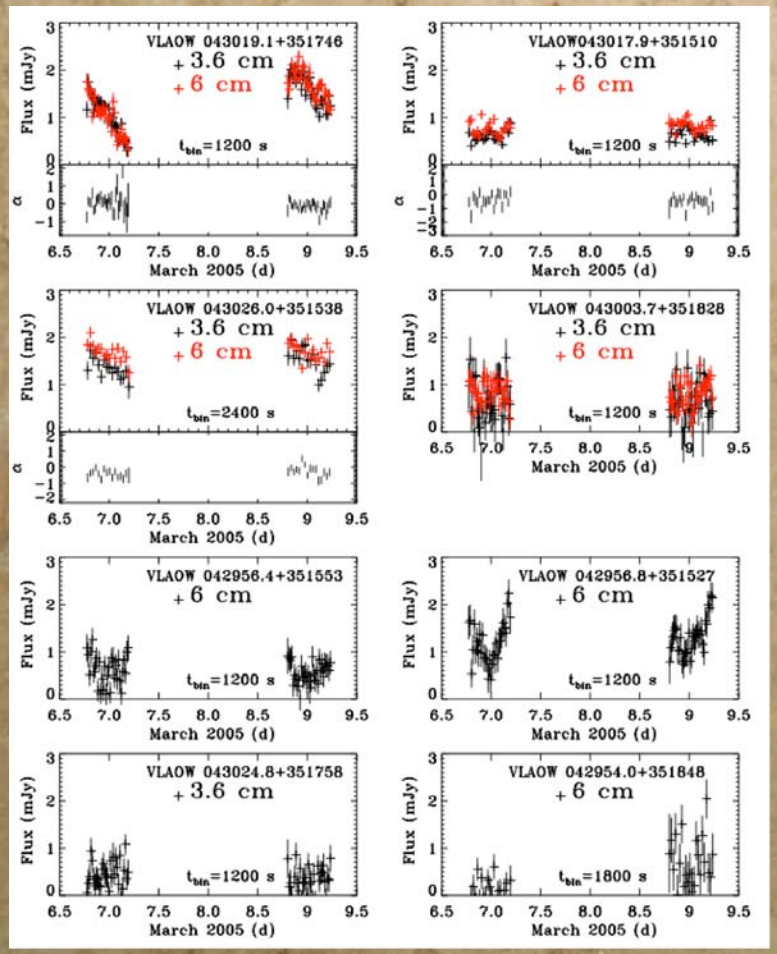
X-ray Radio Relation?



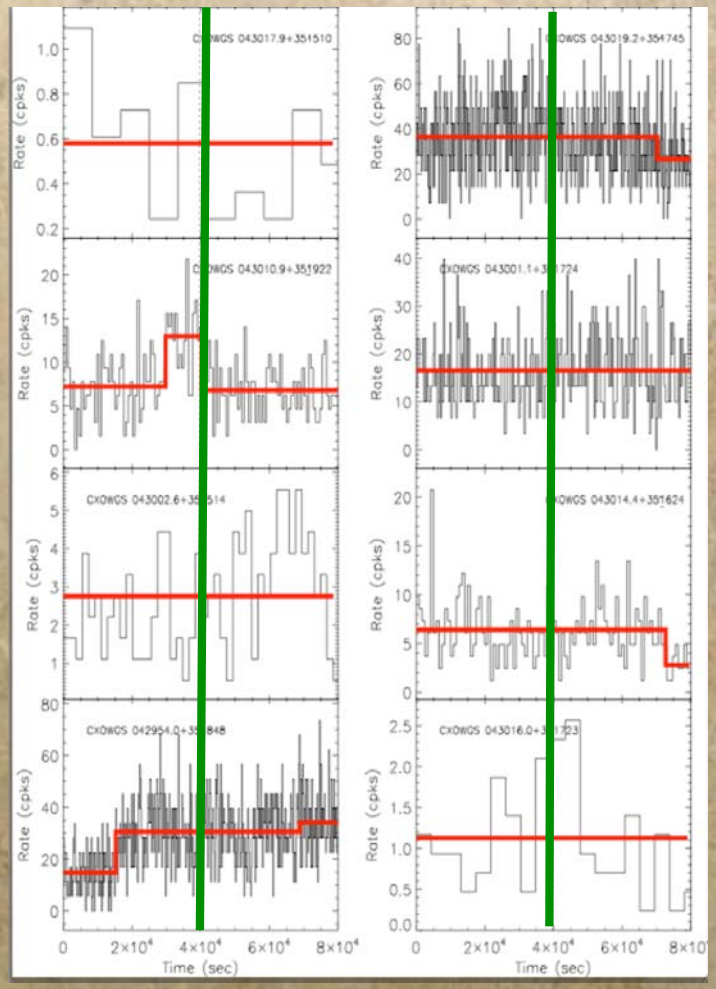
- 8 coincident objects between Chandra/Spitzer and VLA
- Most objects lie outside the Güdel-Benz relation.
- No noticeable X-ray radio correlation
- Similar results found in ρ Oph (Gangé et al. 2004) and the Coronet (Forbrich et al. 2007)

Radio/X-ray Variability

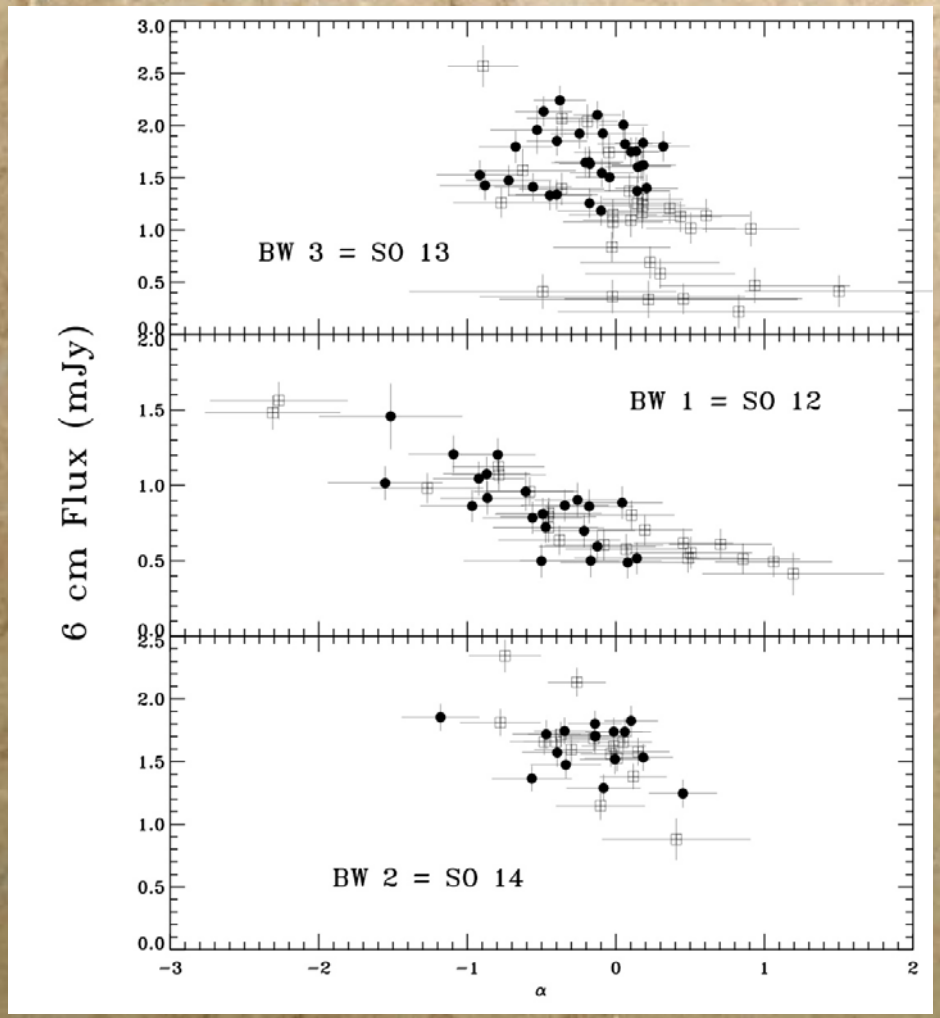
Radio



X-ray

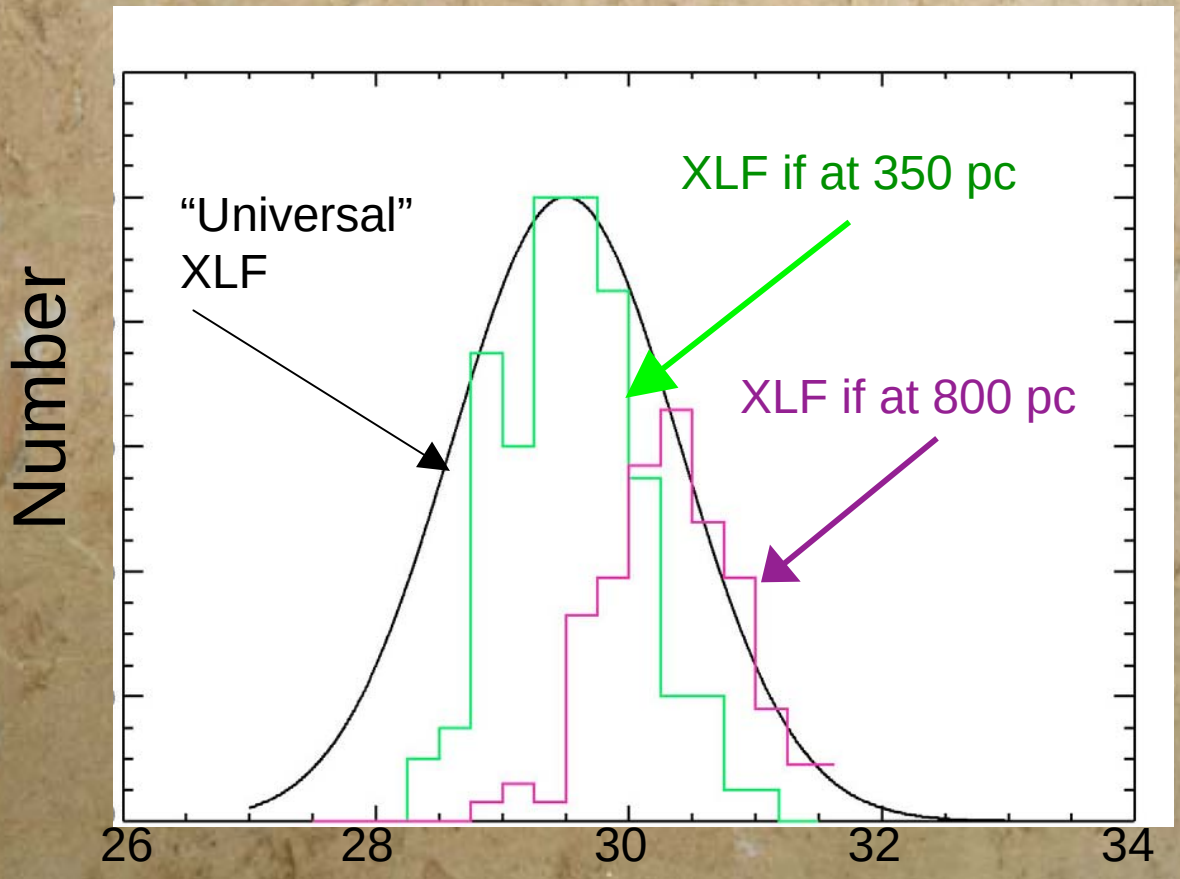


Radio Variability



- As radio flux decreases, the spectral index α increses.
- This is the opposite of what is seen in the Sun.
- Radio and X-ray variability seem decoupled
  - Perhaps this is just small numbers.
  - But has been seen in other regions
- Both radio flares **AND** X-ray radio coupling on young stars seem very **NON-SOLAR** from the high energy perspective.

Distance to LkHα 101



Concept from Feigelson and Getman (2005)

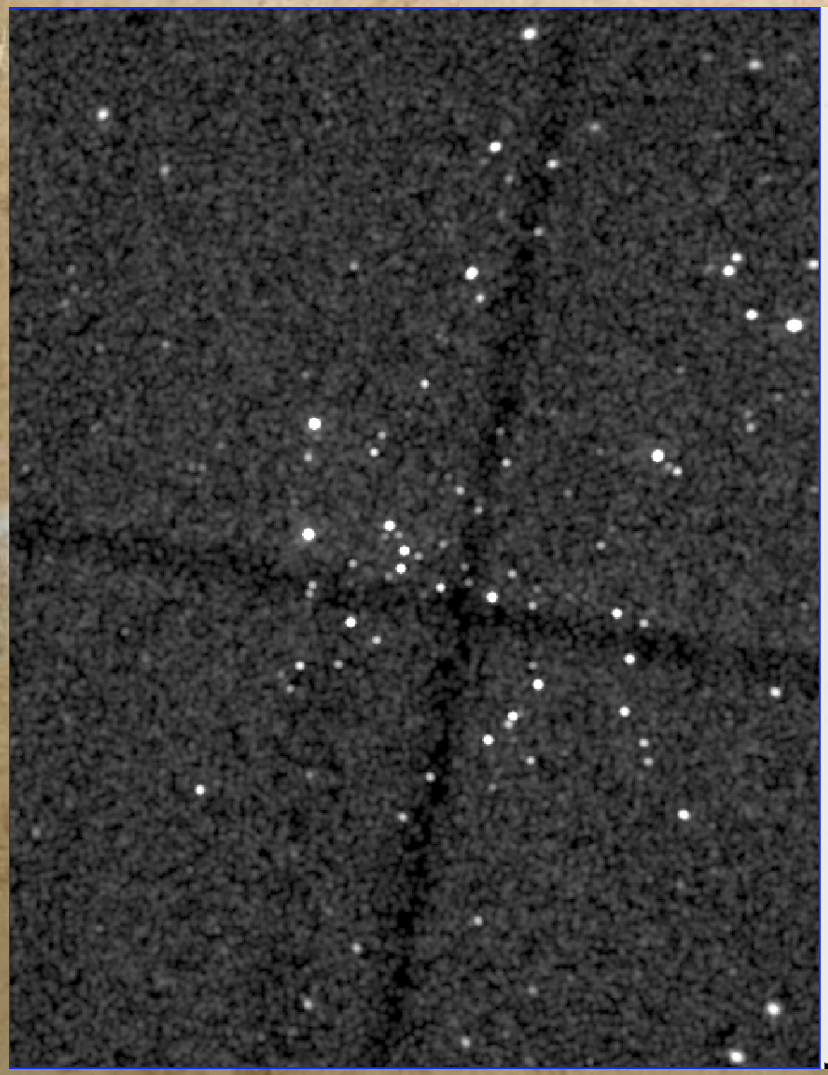
Fit implies cluster size:
300 pc ~ 200 stars

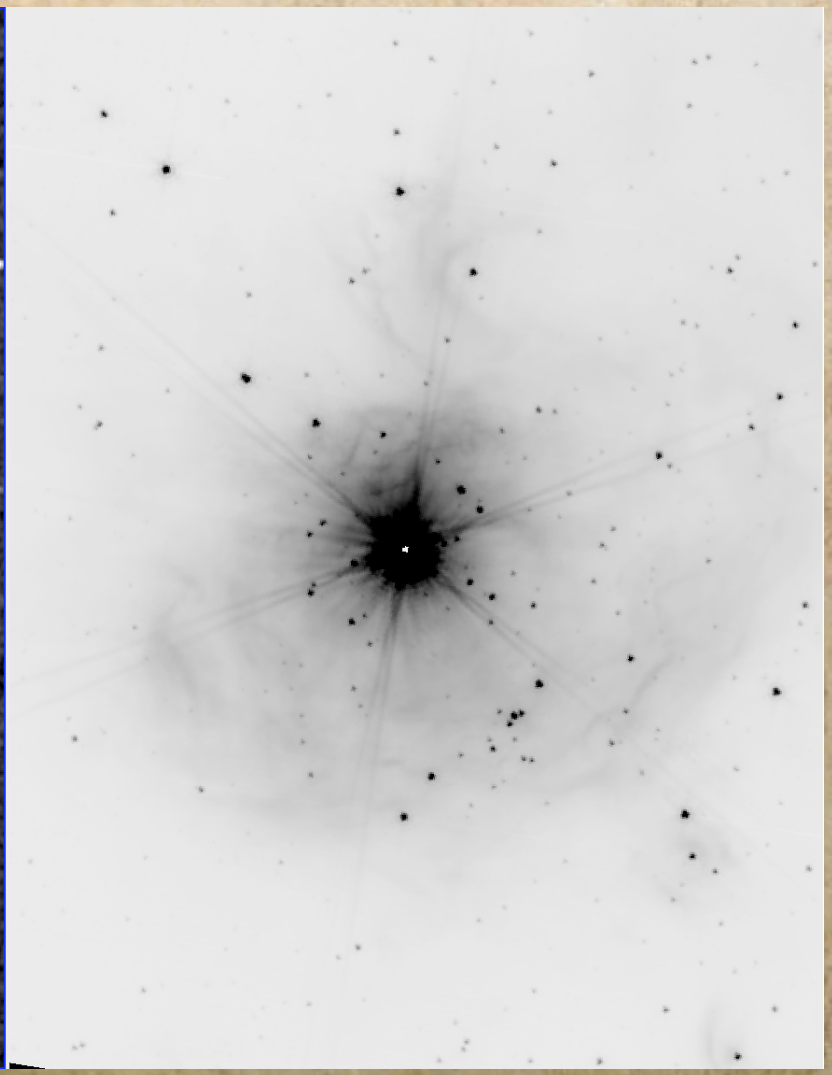
800pc ~ 350 stars

Best fit 550-700 pc
- 275-310 stars

- Consistent with Chandra+Spitzer estimate.

A Bit of Fun





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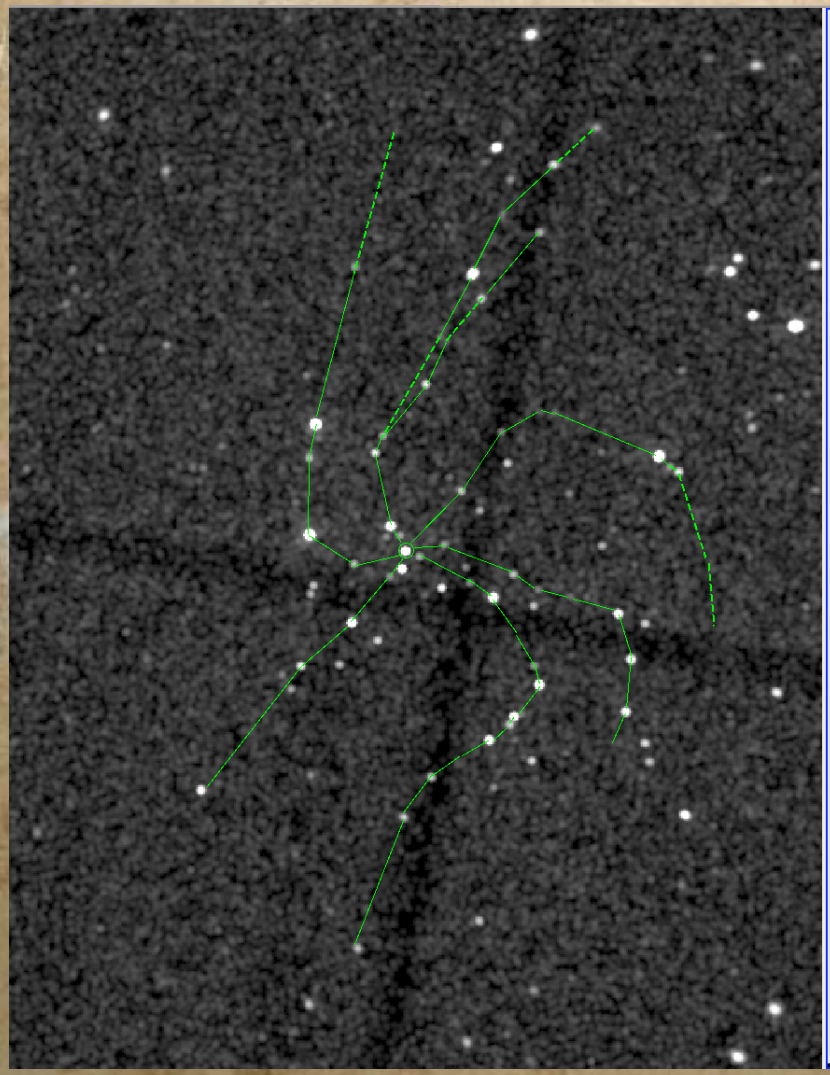
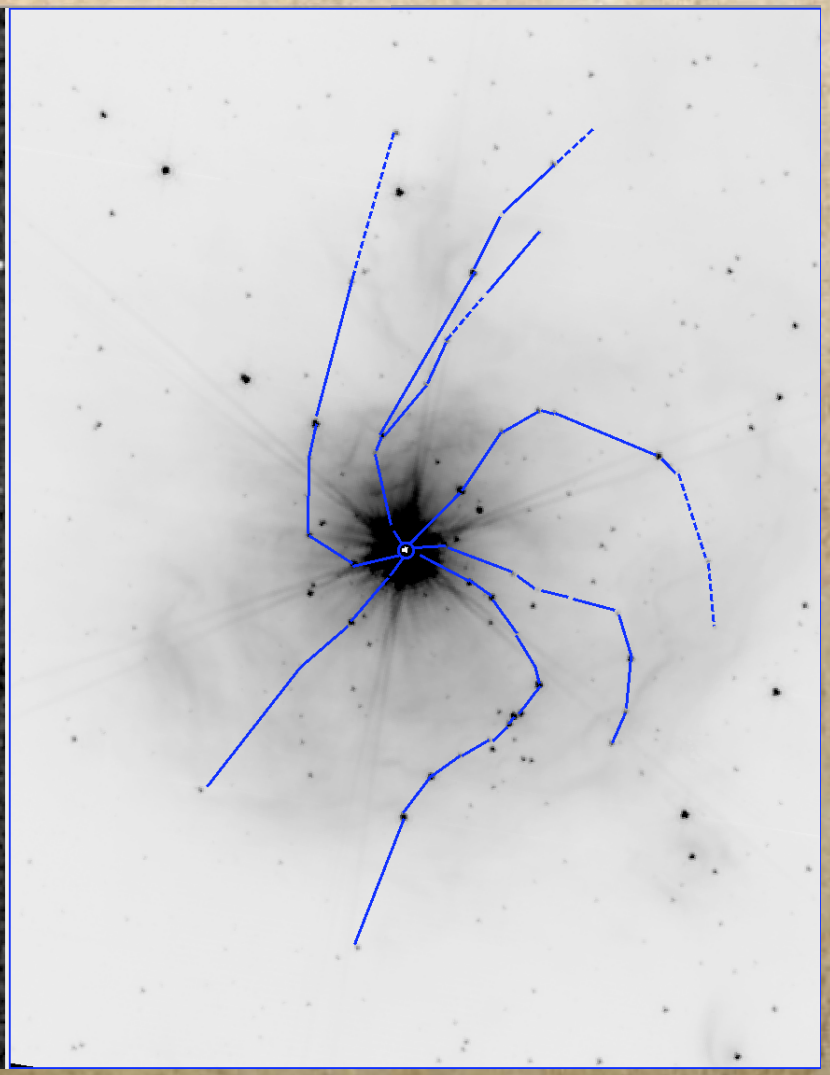
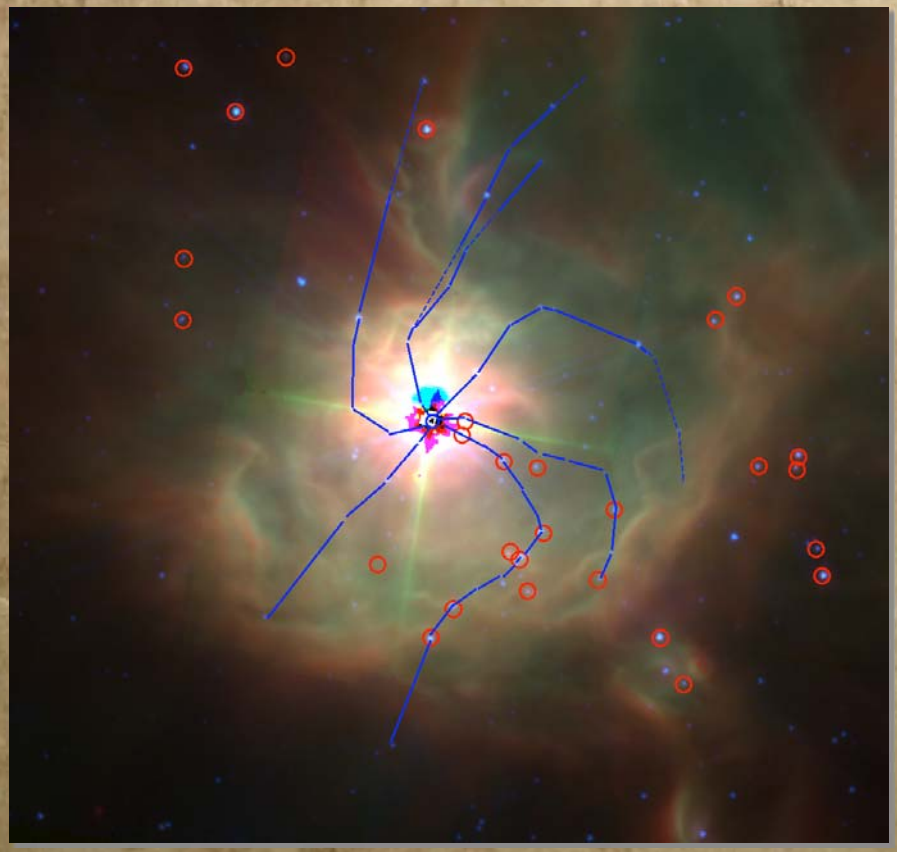
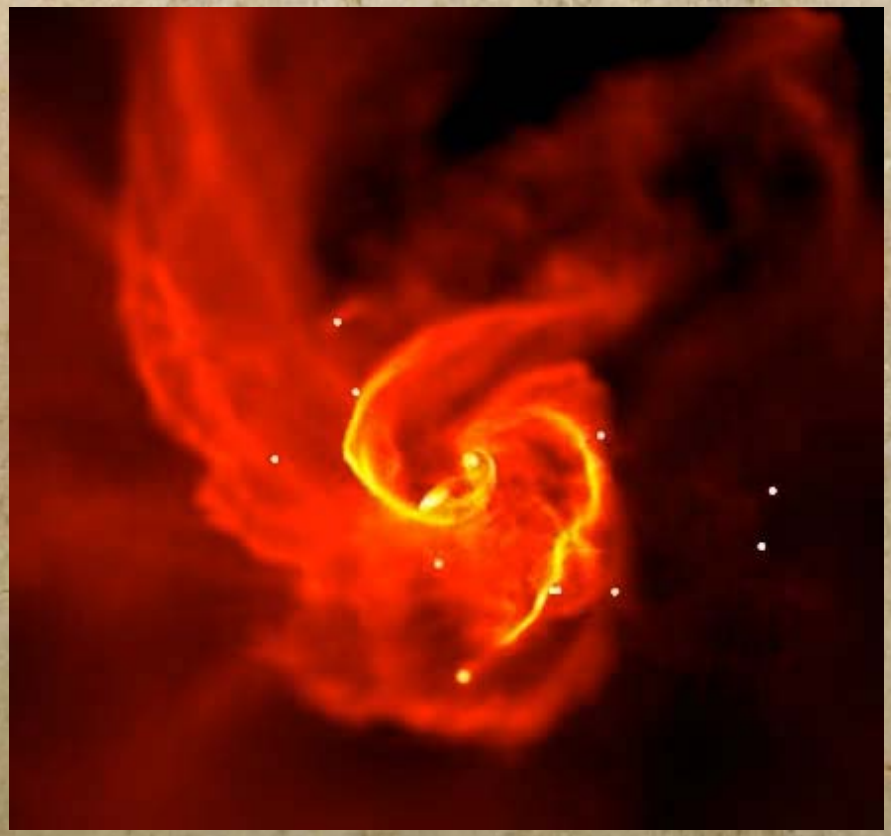




A Bit of Fun

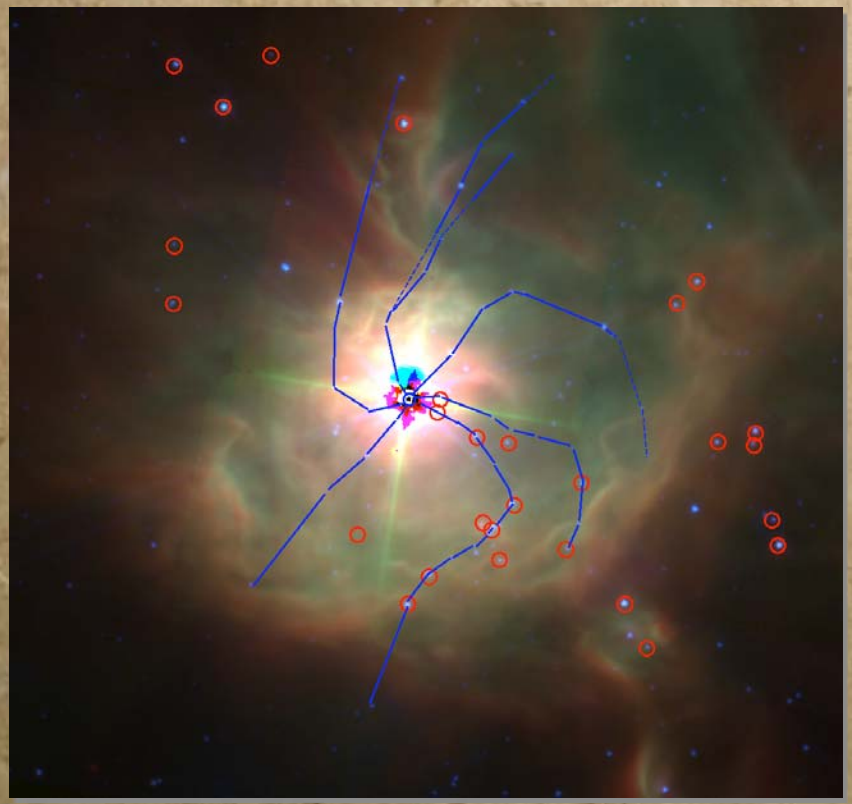
- Bate et al. (2002, 2005)

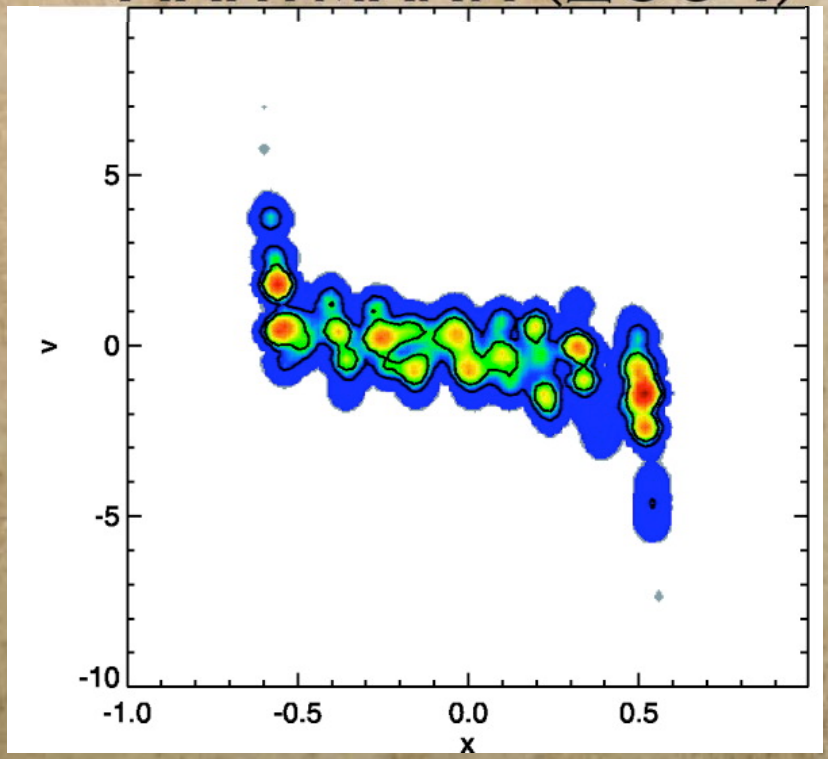




A Bit of Fun

- Burkett and Hartmann (2004)





In two 40 ks Integrations

- We combine the Spitzer and Chandra data to estimate the stellar content.
  - The X-Ray data indicate a distance of ~600pc.
  - Using two independent methods we find a total cluster size of about 300 stars.
  - There appear to be 9 transition disks - 5 seen in X-rays.
- About 10 *Spitzer/Chandra* sources are detected by the VLA. Most are radio variable on both long and short time scales.
- The radio signature of the flares is VERY NON-Solar.
- We may be seeing residual molecular cloud structure. Future HST/JWST observations can distinguish between competing models.