

CHANDRA, SPITZER & VLA OBSERVATIONS OF YOUNG CLUSTERS

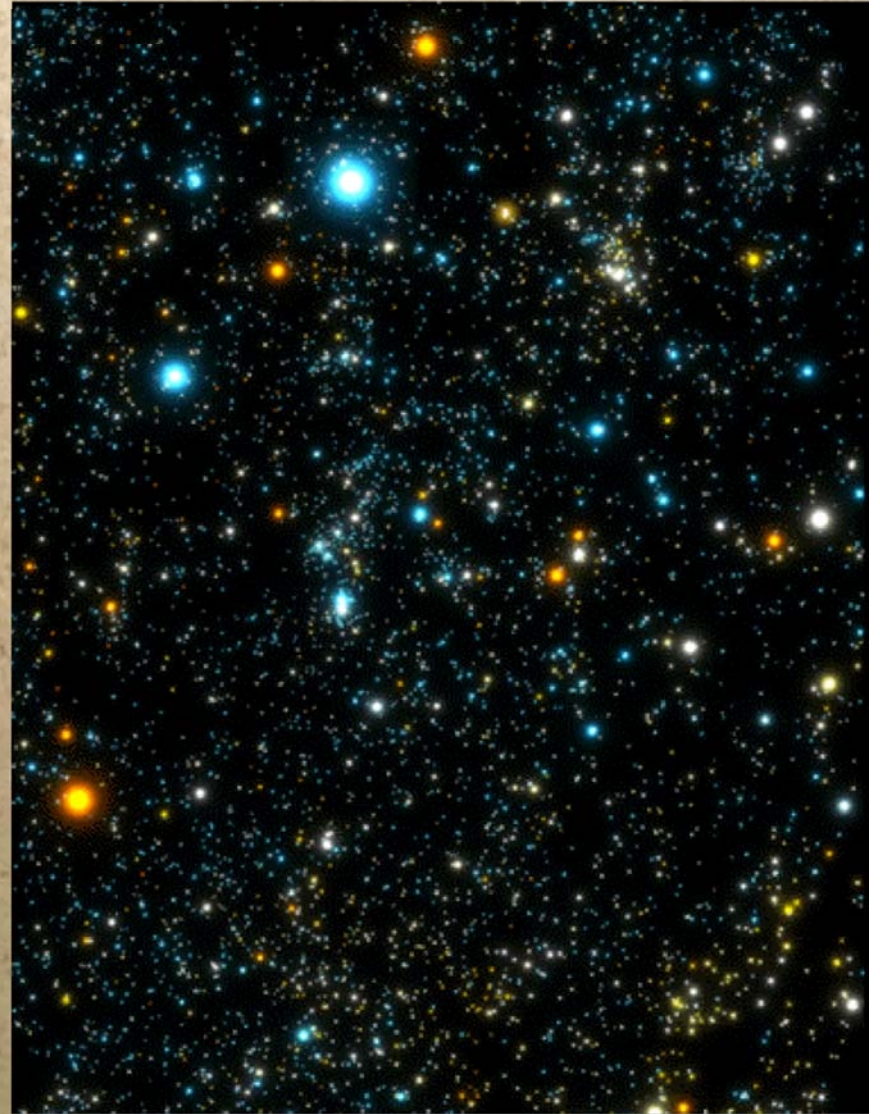
SCOTT WOLK - CXC/CFA

WITH HELP FROM...

R. OSTEN (UMD), T. BOURKE, R. GUTERMUTH,
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 - 1 1 PAPER A&A SPECIAL EDITION ON TAURUS SFR.
- SO AREN'T WE DONE?

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3

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SUPPLEMENT SERIES

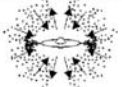
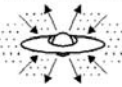
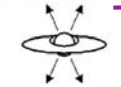
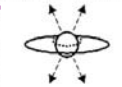

2005 OCTOBER

THE *CHANDRA* ORION ULTRADEEP PROJECT

	Page
<i>CHANDRA</i> ORION ULTRADEEP PROJECT: OBSERVATIONS AND SOURCE LISTS [⊙] <i>K. V. Getman, E. Flaccomio, P. S. Broos, N. Grosso, M. Tsujimoto, L. Townsley, G. P. Garmire, J. Kastner, J. Li, F. R. Harnden Jr., S. Wolk, S. S. Murray, C. J. Lada, A. A. Muench, M. J. McCaughrean, G. Meeus, F. Damiani, G. Micela, S. Sciortino, J. Bally, L. A. Hillenbrand, W. Herbst, T. Preibisch, & E. D. Feigelson</i>	319
MEMBERSHIP OF THE ORION NEBULA POPULATION FROM THE <i>CHANDRA</i> ORION ULTRADEEP PROJECT [⊙] <i>Konstantin V. Getman, Eric D. Feigelson, Nicolas Grosso, Mark J. McCaughrean, Giusti Micela, Patrick Broos, Gordon Garmire, & Leisa Townsley</i>	353
GLOBAL X-RAY PROPERTIES OF THE ORION NEBULA REGION <i>Eric D. Feigelson, Konstantin Getman, Leisa Townsley, Gordon Garmire, Thomas Preibisch, Nicolas Grosso, Thierry Montmerle, Augustus Muench, & Mark McCaughrean</i>	379
THE EVOLUTION OF X-RAY EMISSION IN YOUNG STARS <i>Thomas Preibisch & Eric D. Feigelson</i>	390
THE ORIGIN OF T TAURI X-RAY EMISSION: NEW INSIGHTS FROM THE <i>CHANDRA</i> ORION ULTRADEEP PROJECT <i>Thomas Preibisch, Yong-Cheol Kim, Fabio Favata, Eric D. Feigelson, Ettore Flaccomio, Konstantin Getman, Giusti Micela, Salvatore Sciortino, Ketsan Stassun, Beate Stelzer, & Hans Zinnecker</i>	401
STELLAR ACTIVITY ON THE YOUNG SUNS OF ORION: COUP OBSERVATIONS OF K5-7 PRE-MAIN-SEQUENCE STARS <i>S. J. Wolk, F. R. Harnden Jr., E. Flaccomio, G. Micela, F. Favata, H. Shang, & E. D. Feigelson</i>	423
ROTATIONAL MODULATION OF X-RAY EMISSION IN ORION NEBULA YOUNG STARS [⊙] <i>E. Flaccomio, G. Micela, S. Sciortino, E. D. Feigelson, W. Herbst, F. Favata, F. R. Harnden Jr., & S. D. Vrilek</i>	450
BRIGHT X-RAY FLARES IN ORION YOUNG STARS FROM COUP: EVIDENCE FOR STAR-DISK MAGNETIC FIELDS? [⊙] <i>F. Favata, E. Flaccomio, F. Reale, G. Micela, S. Sciortino, H. Shang, K. G. Stassun, & E. D. Feigelson</i>	469
IRON FLUORESCENT LINE EMISSION FROM YOUNG STELLAR OBJECTS IN THE ORION NEBULA <i>M. Tsujimoto, E. D. Feigelson, N. Grosso, G. Micela, Y. Tsuboi, F. Favata, H. Shang, & J. H. Kastner</i>	503
X-RAY EMISSION FROM ORION NEBULA CLUSTER STARS WITH CIRCUMSTELLAR DISKS AND JETS [⊙] <i>Joel H. Kastner, Geoffrey Franz, Nicolas Grosso, John Bally, Mark J. McCaughrean, Konstantin Getman, Eric D. Feigelson, & Norbert S. Schulz</i>	511

(Continued on inside page)

THE PROGRAM: MULTIWAVELENGTH STUDIES OF NEARBY REGIONS OF STAR FORMATION

PROPERTIES	<i>Infalling Protostar</i>	<i>Evolved Protostar</i>	<i>Classical T Tauri Star</i>	<i>Weak-lined T Tauri Star</i>	<i>Main Sequence Star</i>
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

■ GOALS

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

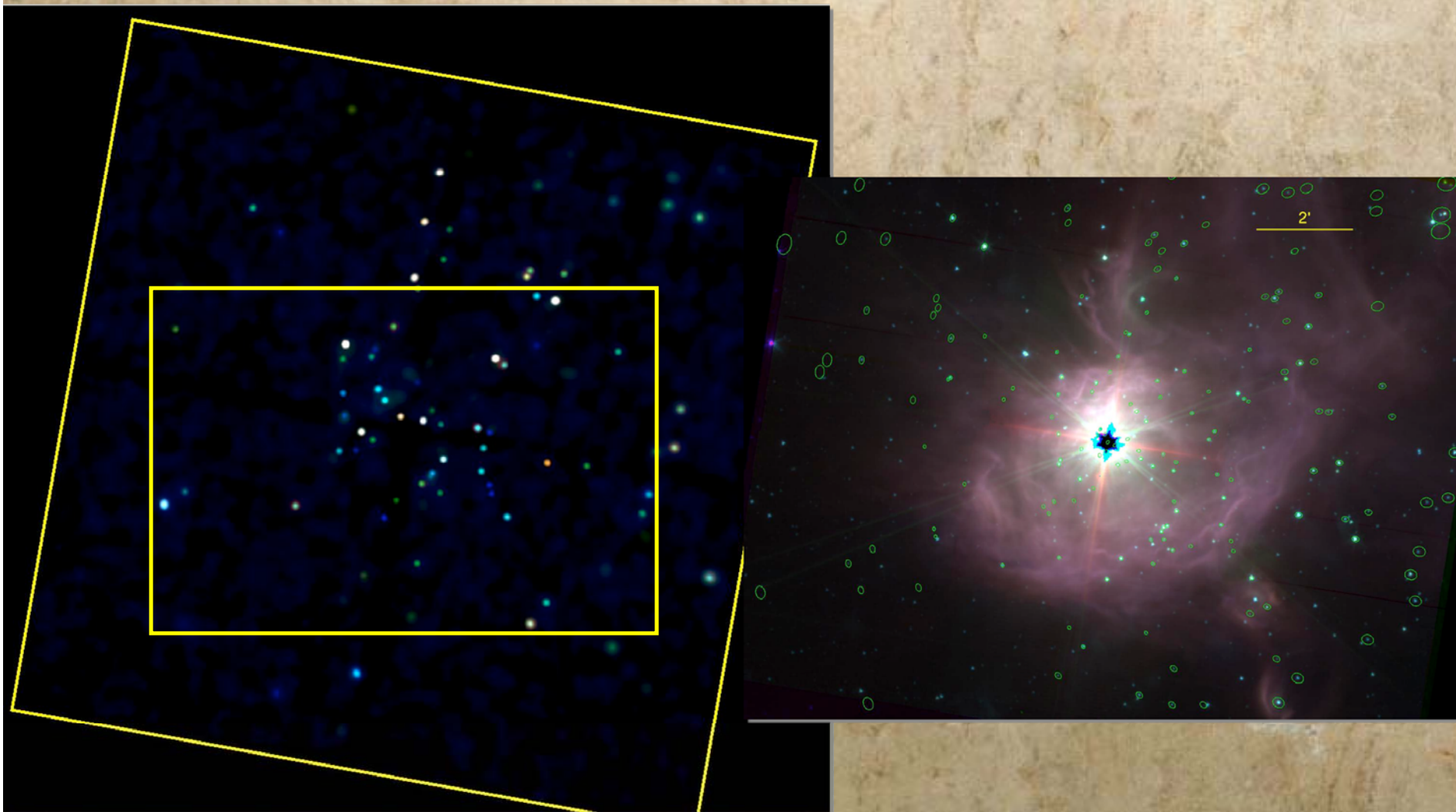
FEIGELSON & MONTMERLE 1999

LK H α 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)

LkH α 101 CLUSTER

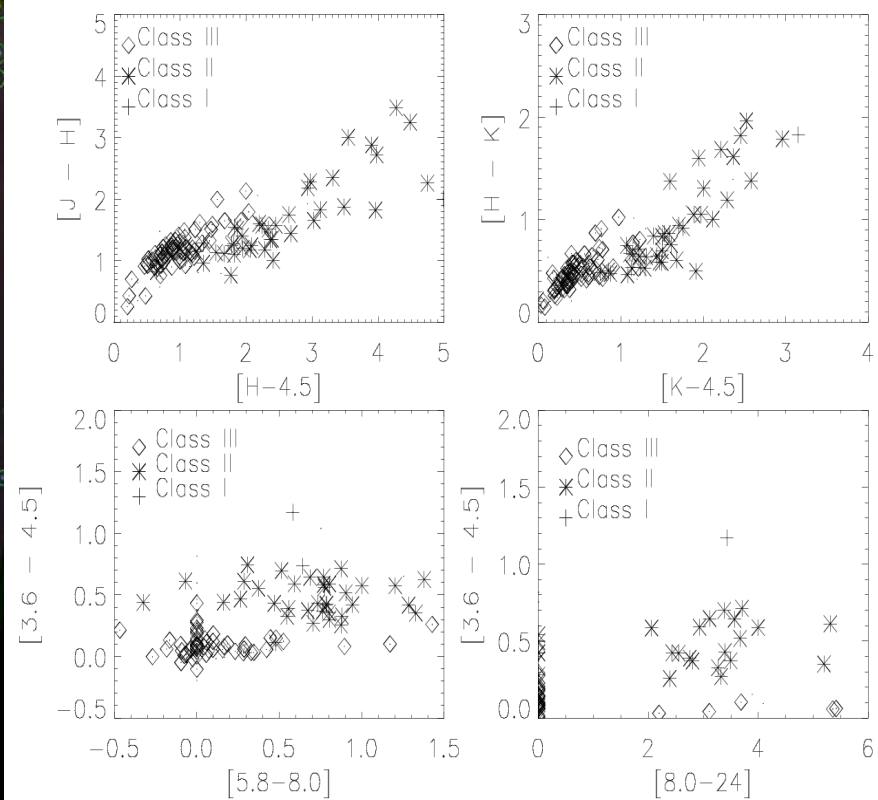


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6

SPITZER DATA

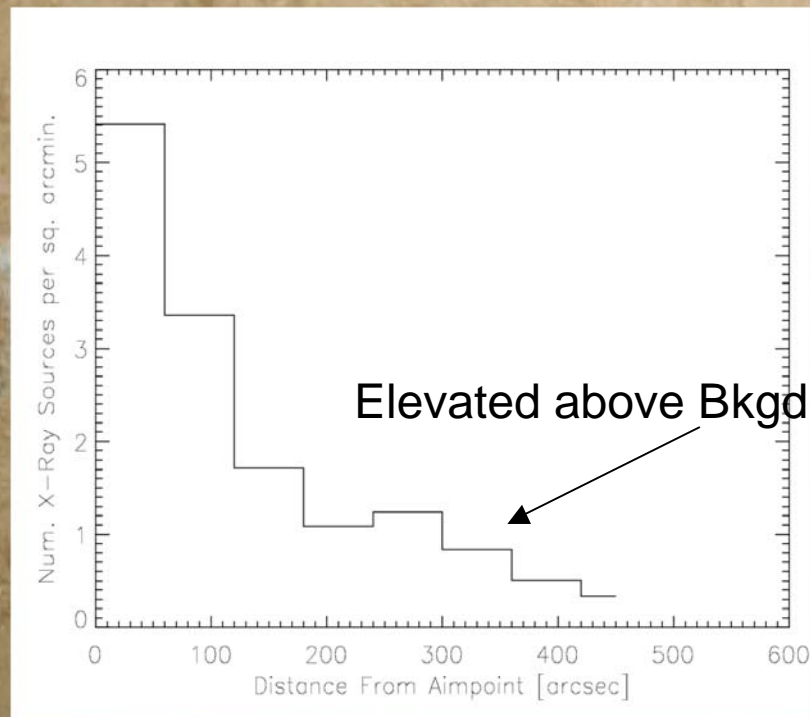


IR COLORS OF
X-RAY SOURCES

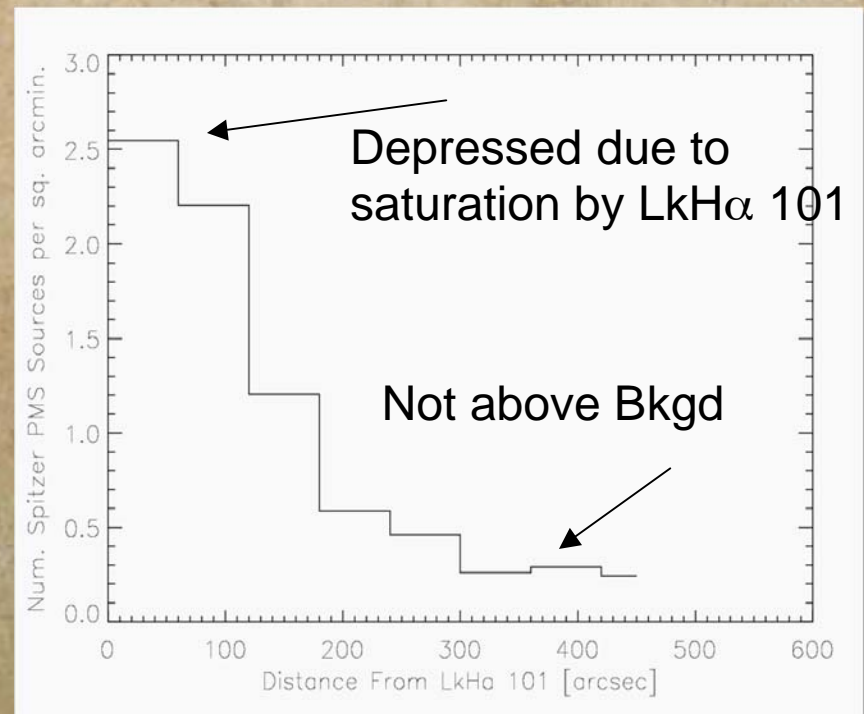
SPATIAL DISTRIBUTION

CLASS IIIs MORE DISTRIBUTED THAN CLASS I/IIs

X-Ray



Spitzer/IRAC

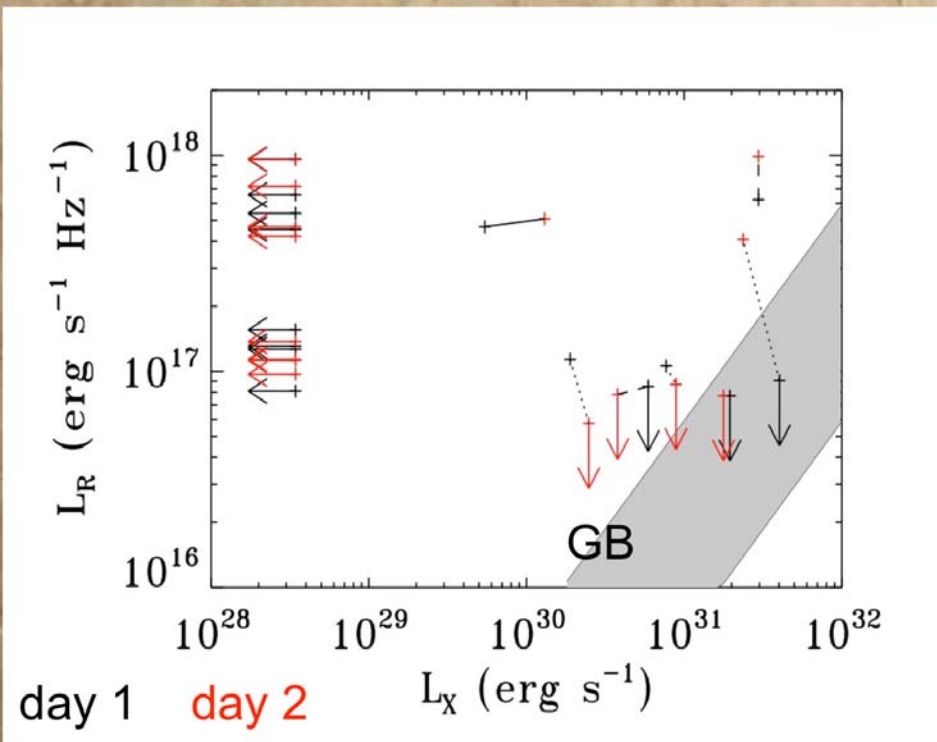


STELLAR CONTENT OF LKH α 101

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

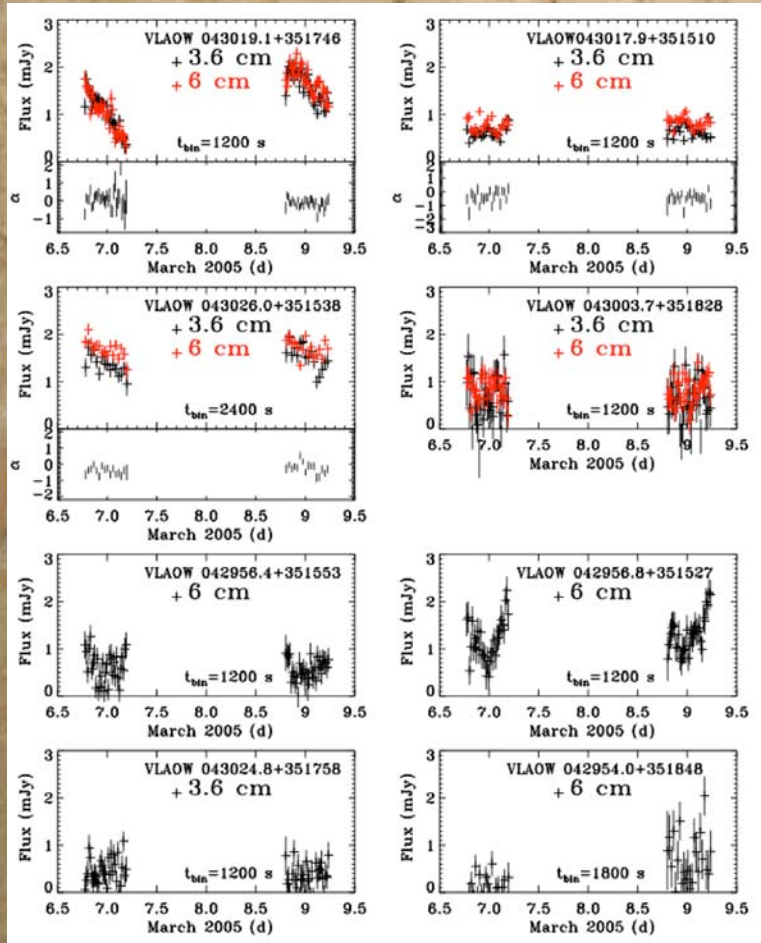
X-RAY RADIO RELATION?



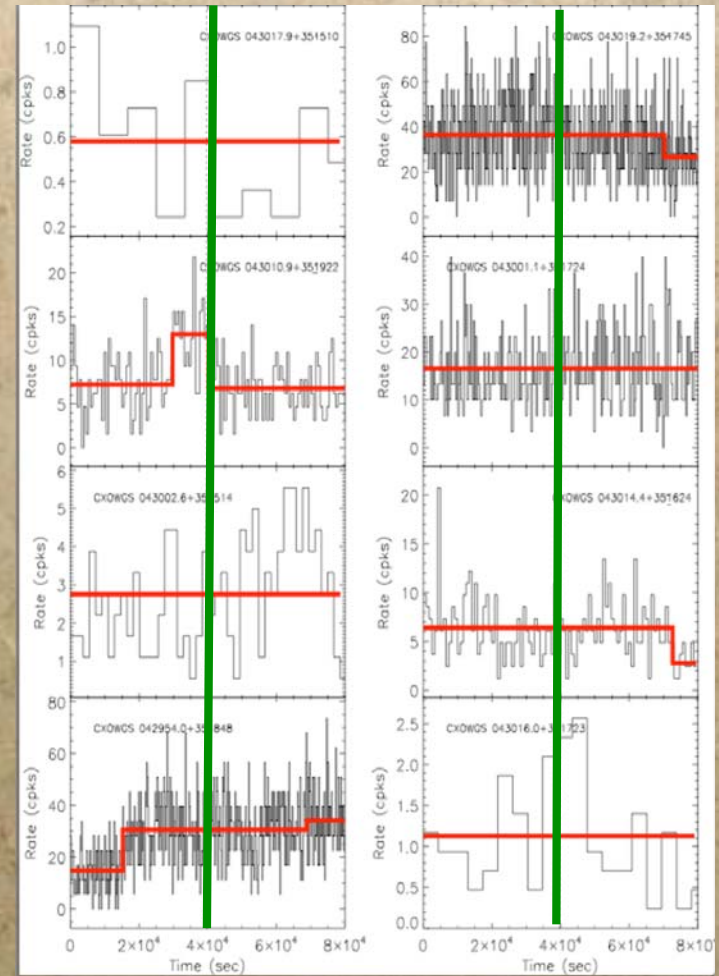
- 8 COINCIDENT OBJECTS BETWEEN CHANDRA/SPITZER AND VLA
- MOST OBJECTS LIE OUTSIDE THE GÜDEL-BENZ RELATION.
- NO NOTICEABLE X-RAY RADIO CORRELATION
- SIMILAR RESULTS FOUND IN ρ OPH (GANGÉ ET AL. 2004) AND THE CORONET (FORBRICH ET AL. 2007)

RADIO/X-RAY VARIABILITY

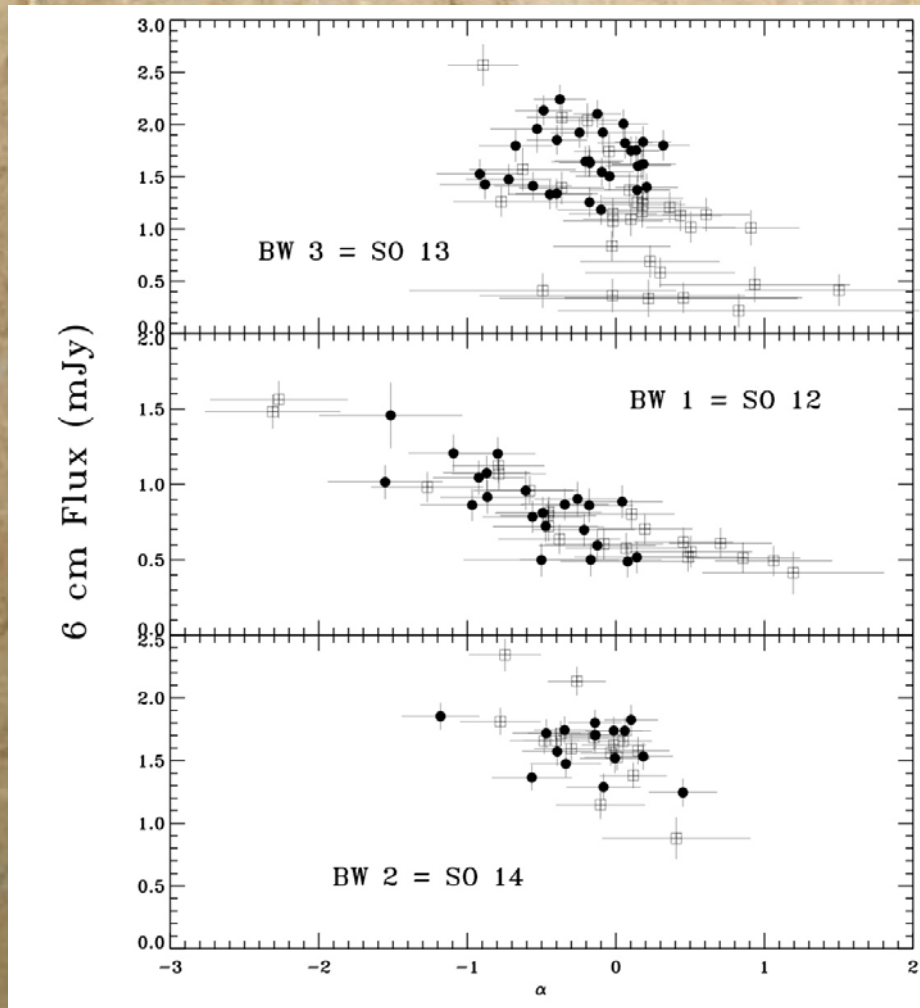
RADIO



X-RAY

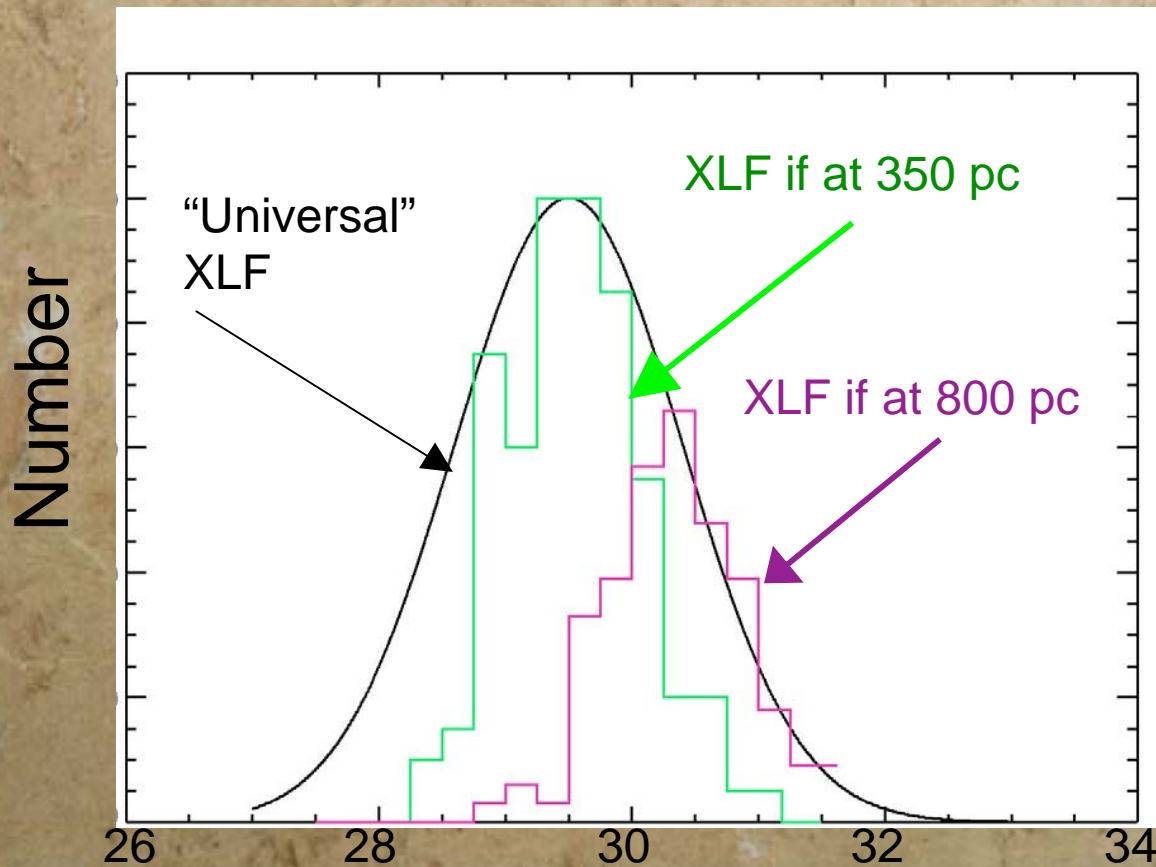


RADIO VARIABILITY



- AS RADIO FLUX DECREASES, THE SPECTRAL INDEX α INCREASES.
- 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 LKH α 101



CONCEPT FROM
FEIGELSON
AND GETMAN (2005)

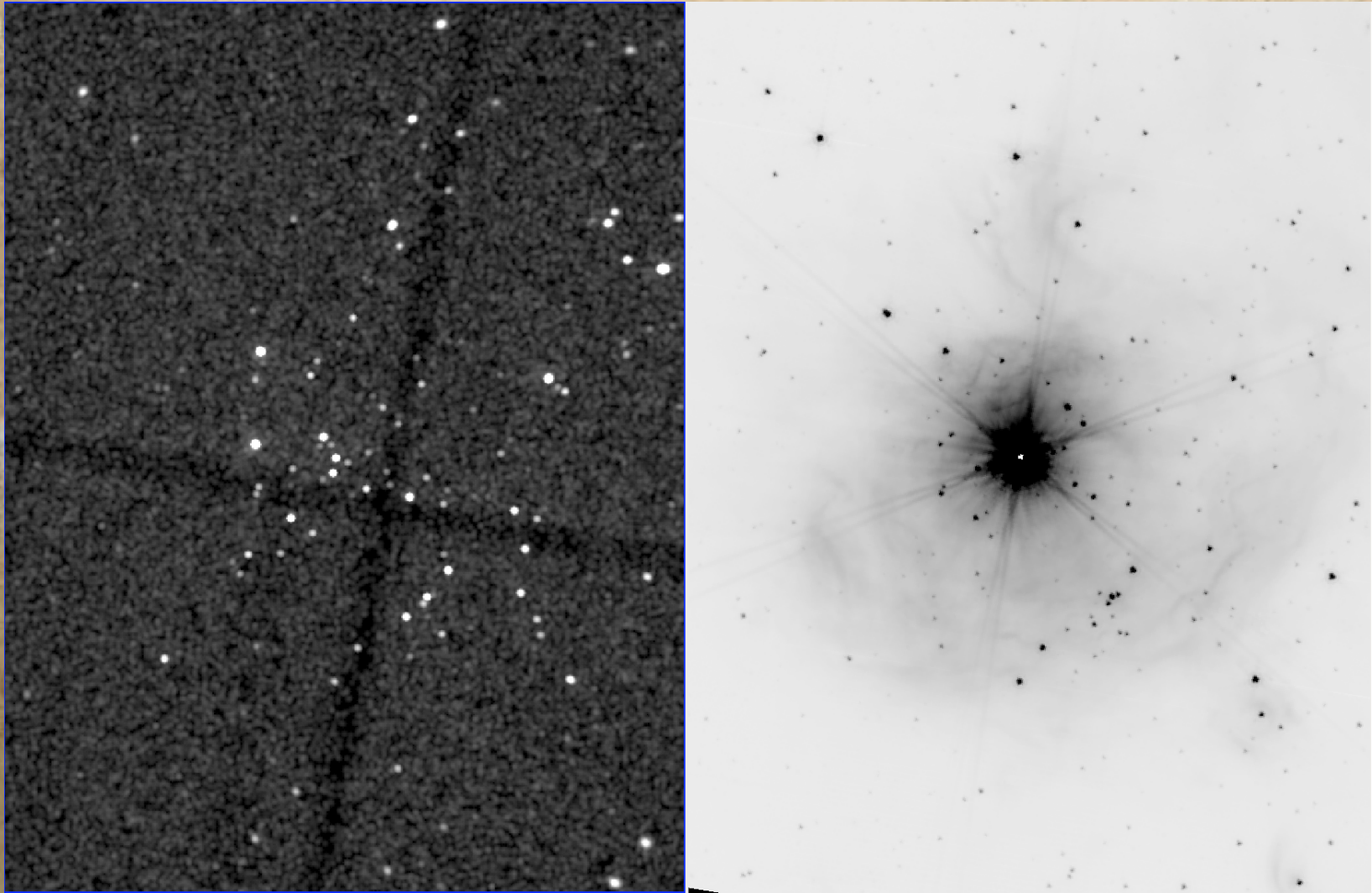
FIT IMPLIES CLUSTER
SIZE:
300 PC ~ 200 STARS

800PC ~ 350 STARS

BEST FIT 550-700 PC
➤ 275-310 STARS

➤ CONSISTENT WITH
CHANDRA+SPITZER
ESTIMATE.

A BIT OF FUN

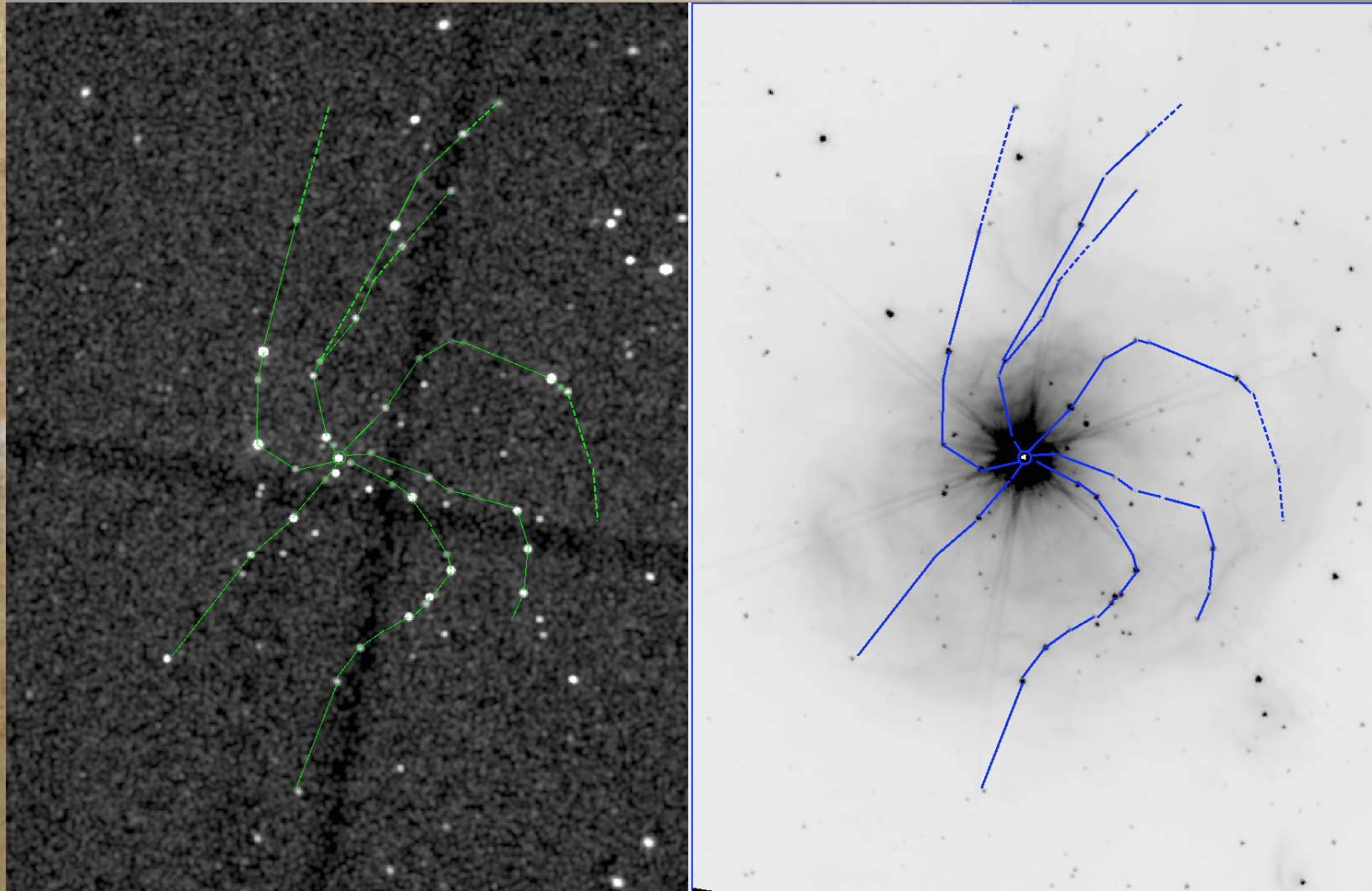


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14

A BIT OF FUN



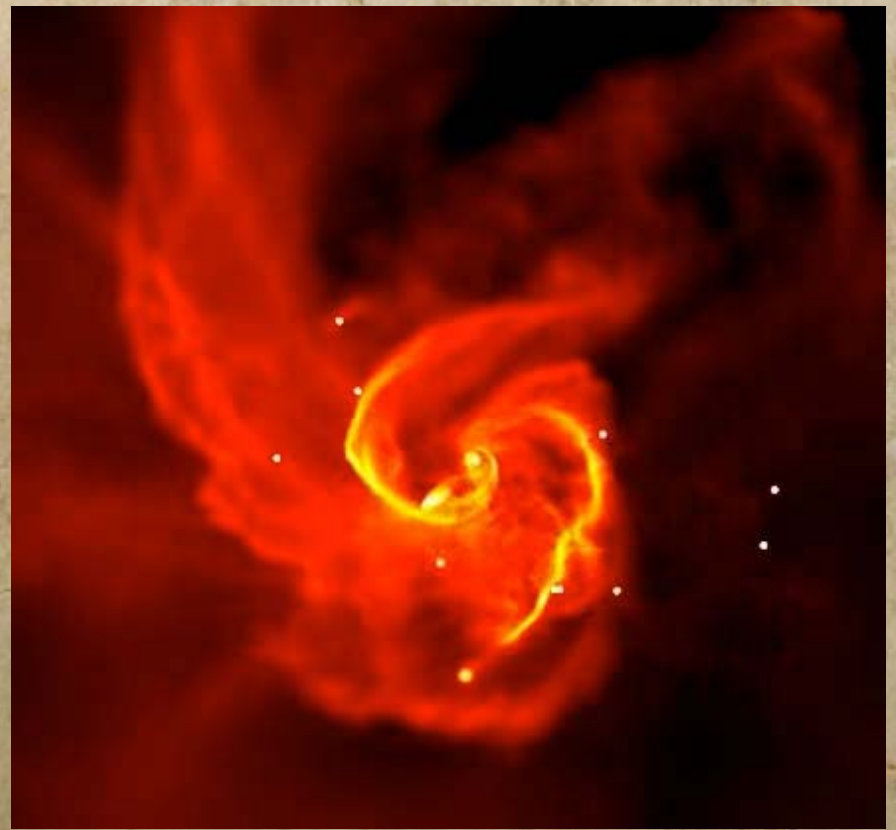
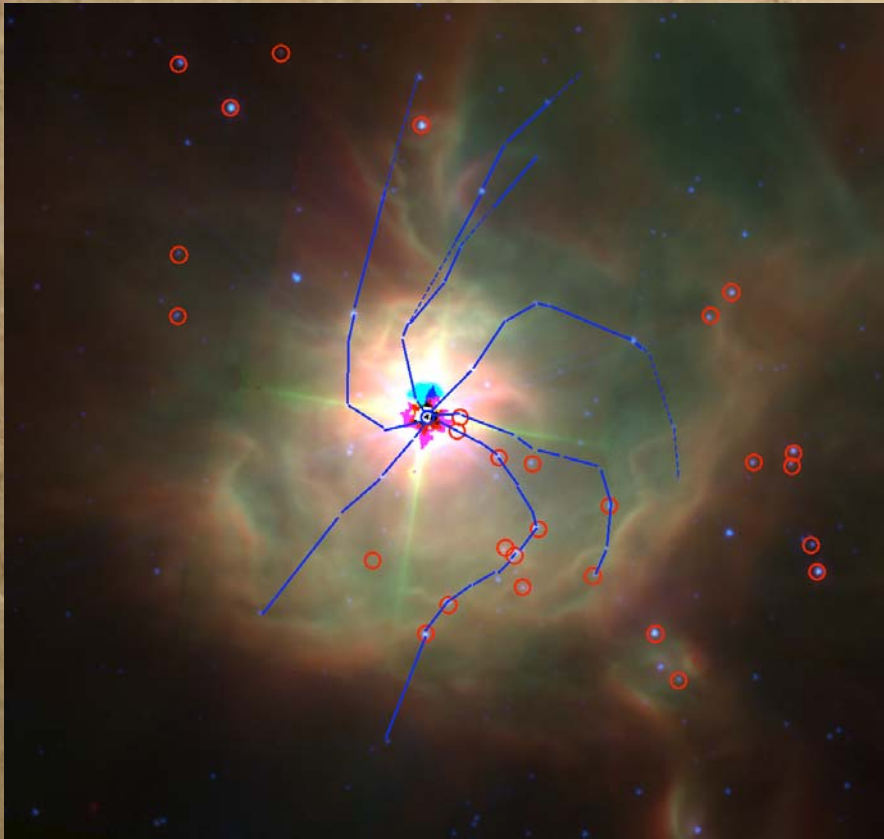
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15

A BIT OF FUN

- BATE ET AL. (2002, 2005)



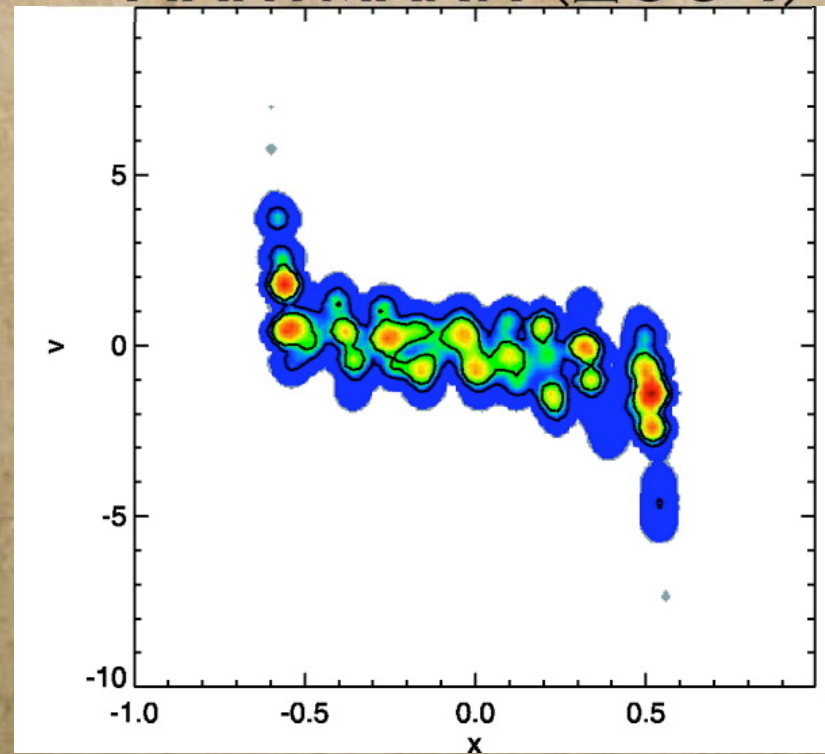
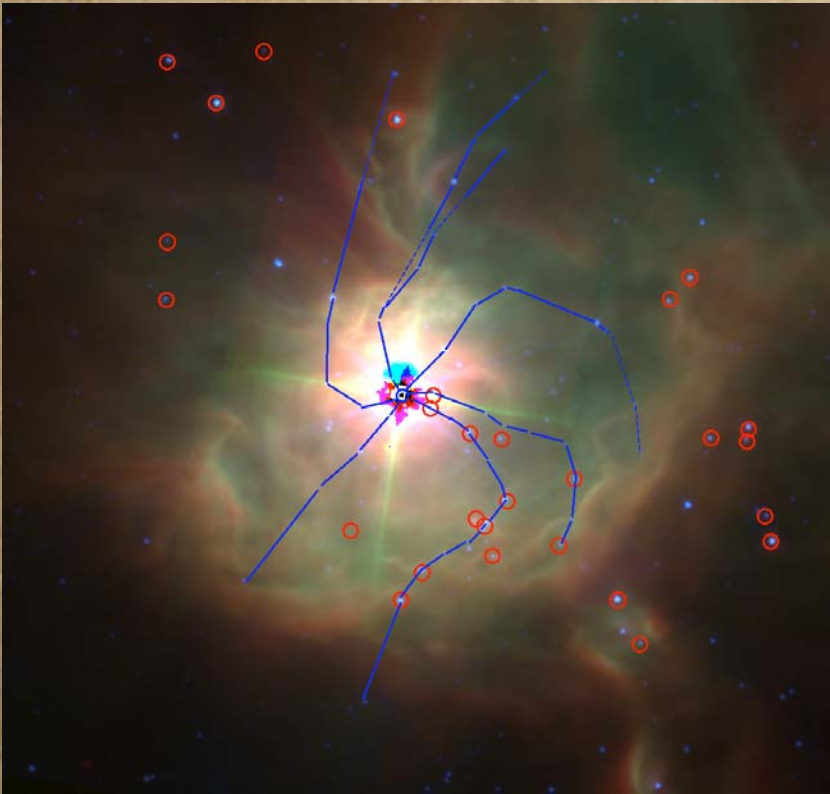
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16

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 ~ 600 PC.
 - 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.

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19