North & South: Low Mass Star Formation in Serpens

A Infrared & X-ray View of Serpens North and South Clusters

Elaine Winston

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UNIVERSITY OF EXETER

RTN-Constellation (Exeter & Grenoble Nodes):

J. Bouvier, E. Moraux, M. McCaughrean, C. Alves de Oliveira

CHFT/WIRCAM - J, H, Ks, CH4on, CH4off bands

- Serpens North, Serpens South

Harvard-Smithsonian CfA:

S.T. Megeath, S. Wolk, T. Bourke, R. Gutermuth

Spitzer/IRAC - 3.6, 4.5, 5.8, 8.0μm

Chandra/ACIS-I

- Serpens North, Serpens South

E. Winston is funded by the European Commission Sixth Framework Programme (FP6) Marie Curie Research Training Network (EC MC RTN) CONSTELLATION (MRTN-CT-2006-035890)

Outline

- Spitzer & Chandra previous studies
- WIRCam Near-IR: new YSOs and YBDs
- Comparison with Spitzer & Chandra
- North & South: clustered stellar evolution
- Conclusions

W40, 600pc
Serpens South

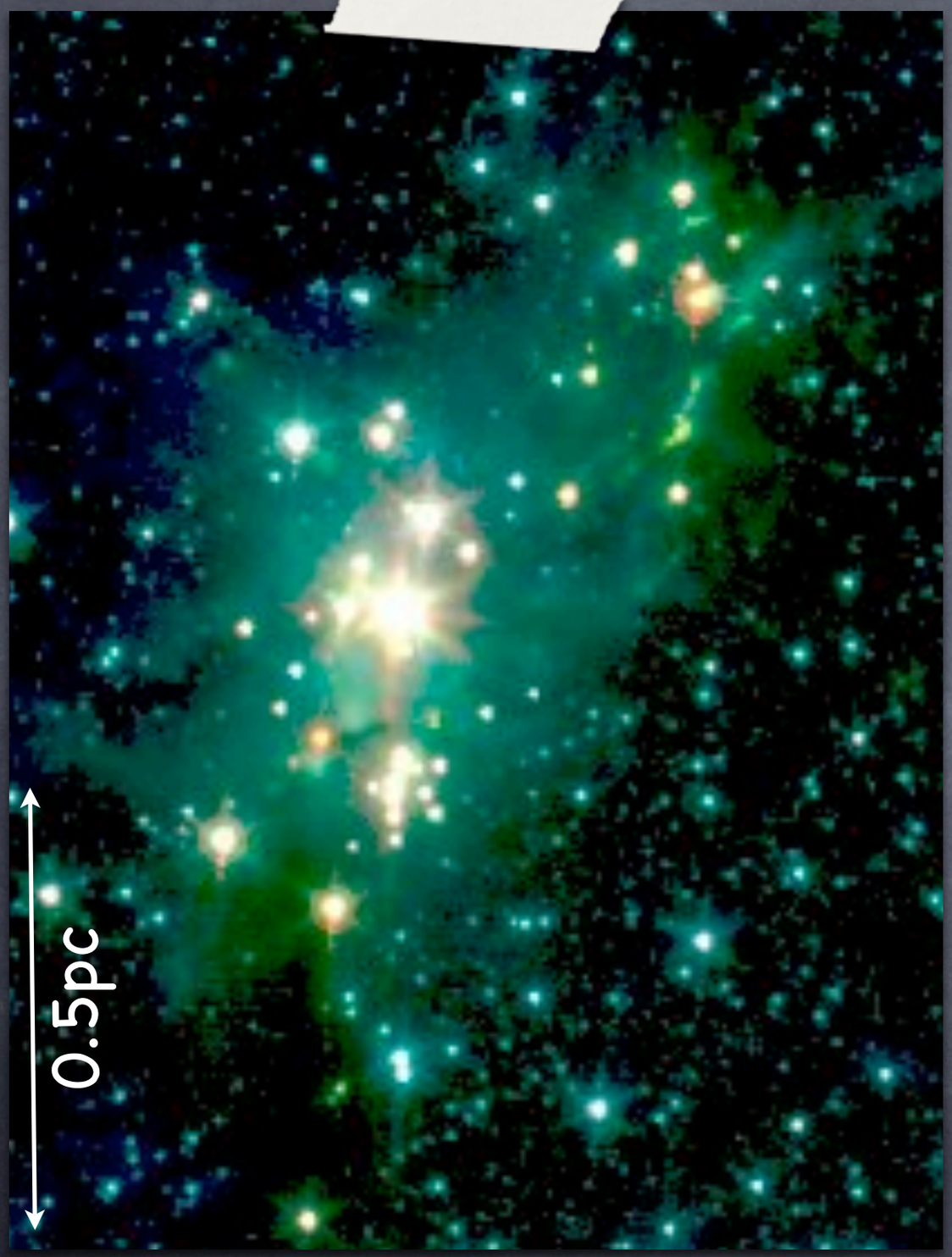
Serpens North

- Nearby (260-410pc), Low Mass
- Embedded, Av ≈ 20
- Numerous Protostars & Outflows
- 137 known members
- 21 Class 0/I (9 X-ray)
- 17 Flat Spectrum (9 X-ray)
- 63 Class II (20 X-ray)
- 4 Transition Disks (2 X-ray)
- 21 Class III

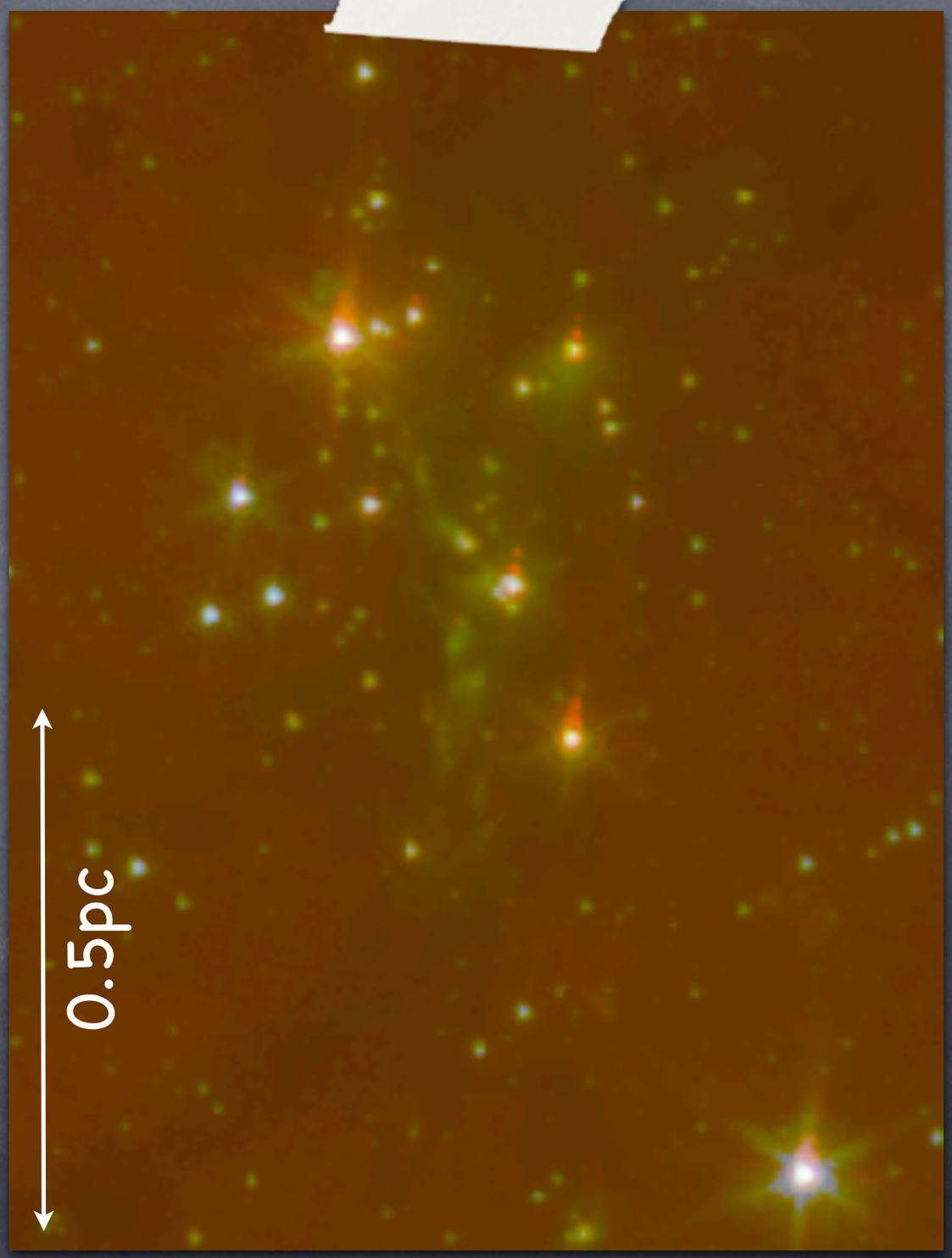
Serpens South

- Nearby? Low Mass
- Deeply Embedded, Av ≈ 50
- Extremely High Protostar fraction & many Outflows
- 92 known members (Gutermuth 2008)
- 46 Class 0/I (10 X-ray)
- Possibly 1-15 of which FS
- 46 Class II (14 X-ray)
- Possibly 1-2 Transition Disks
- 4 Class III

Serpens North

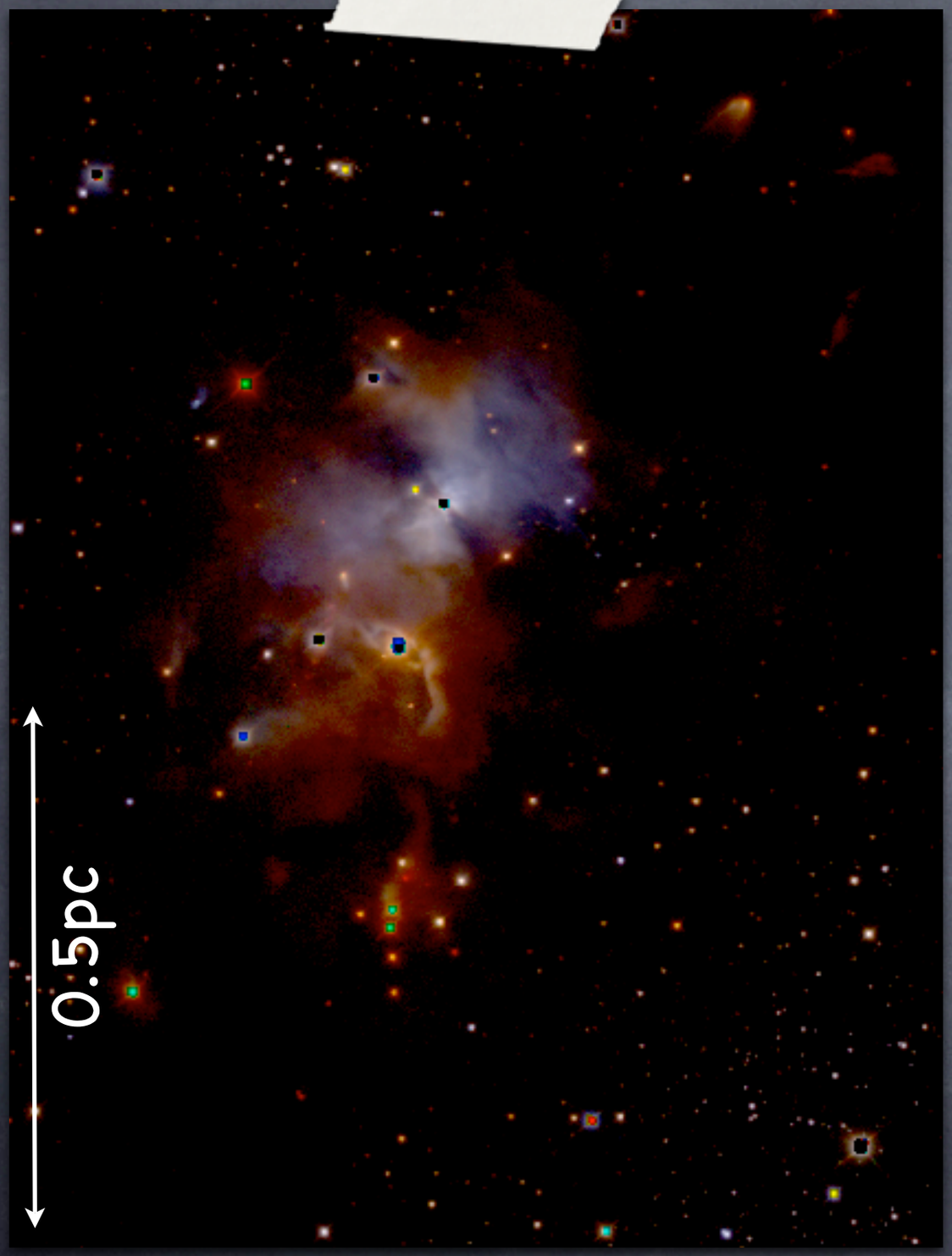


Serpens South

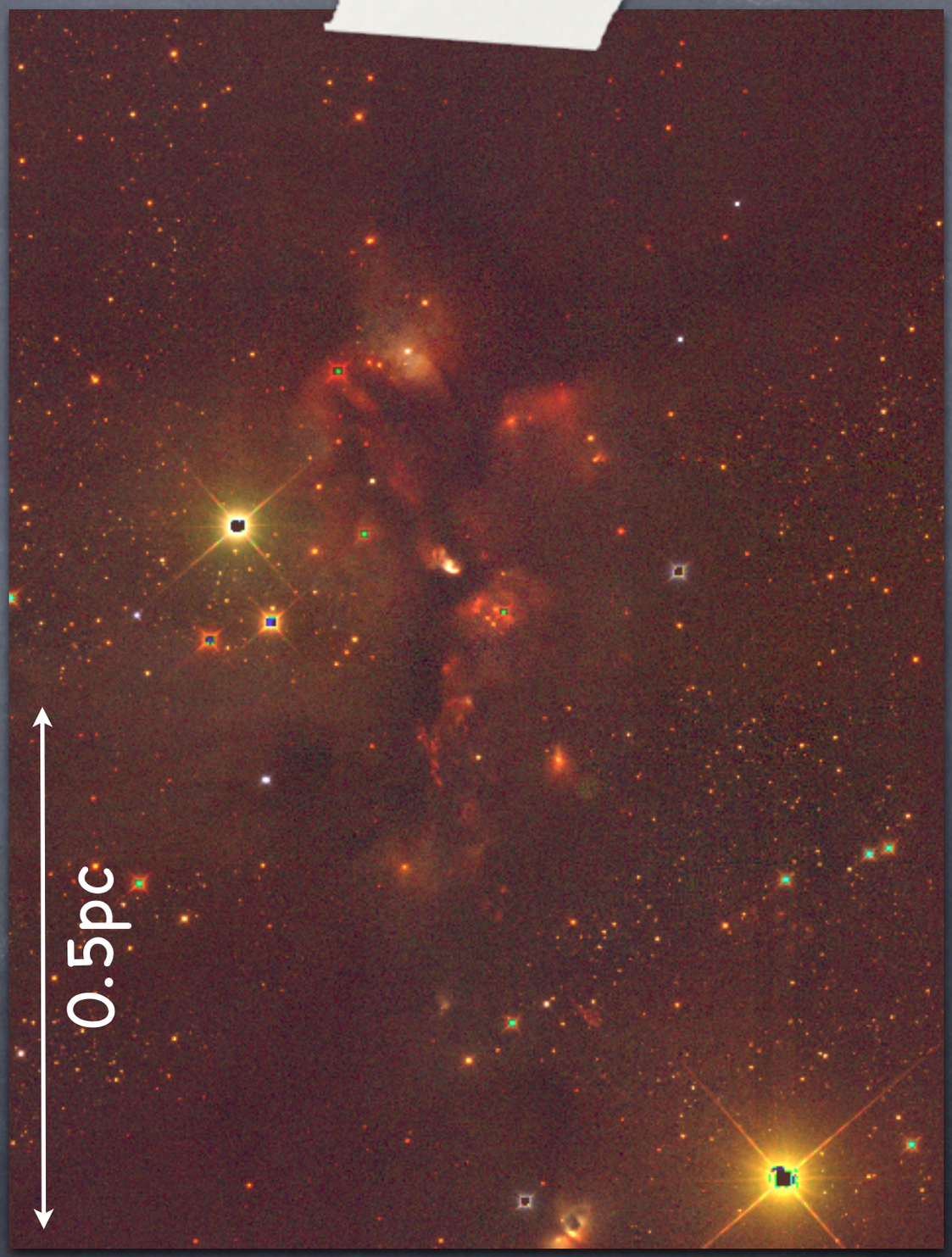


3.6: Blue, 4.5: Green, 5.8: Red

Serpens North

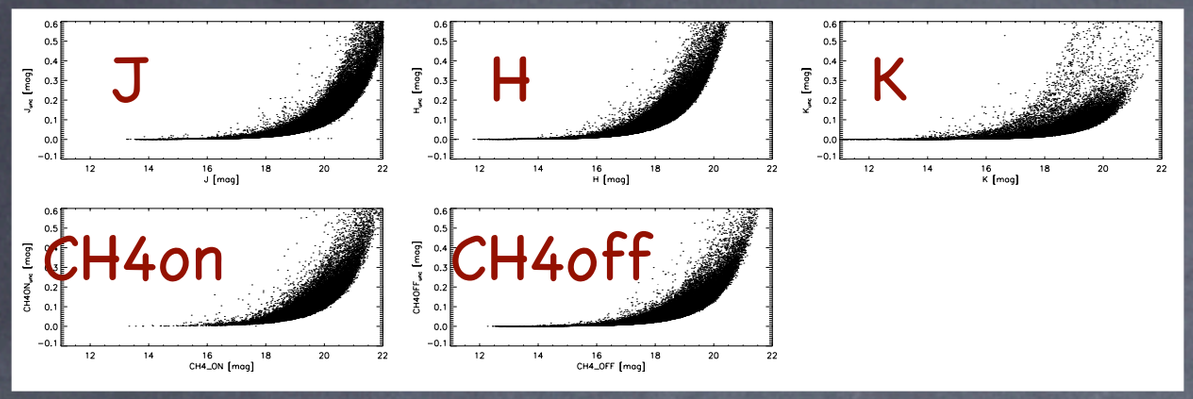


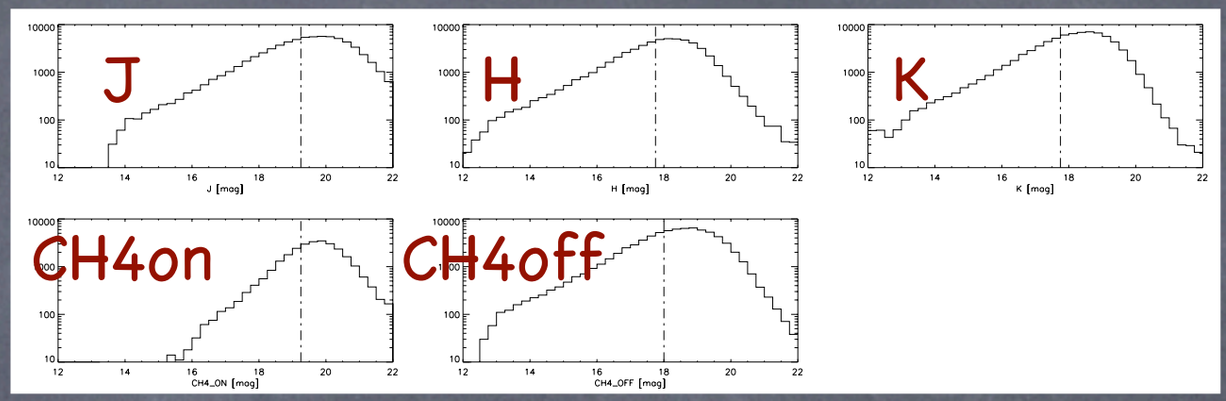
Serpens South

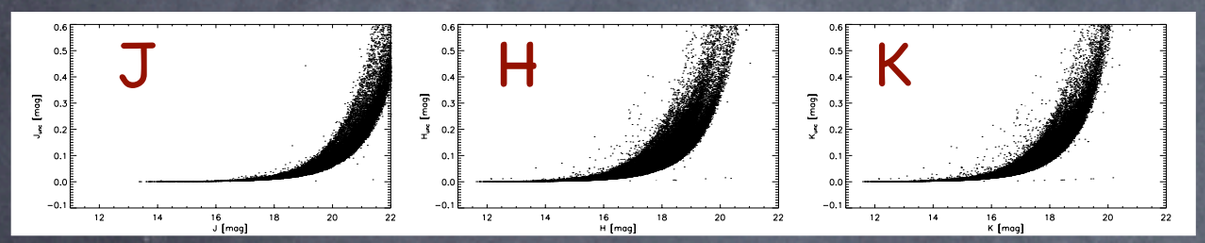


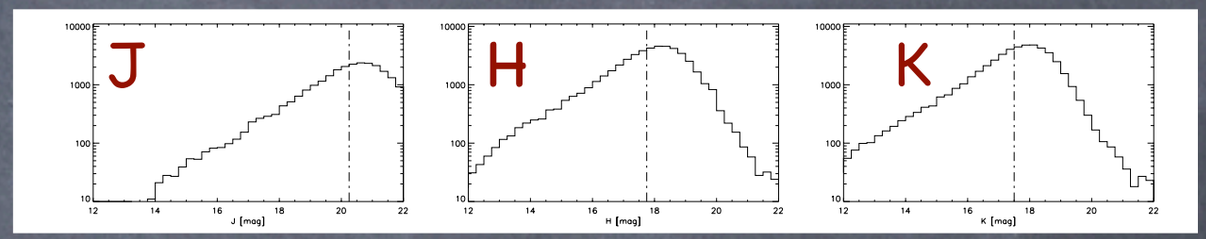
J: Blue, H: Green, K: Red

WIRCam Aperture Photometry







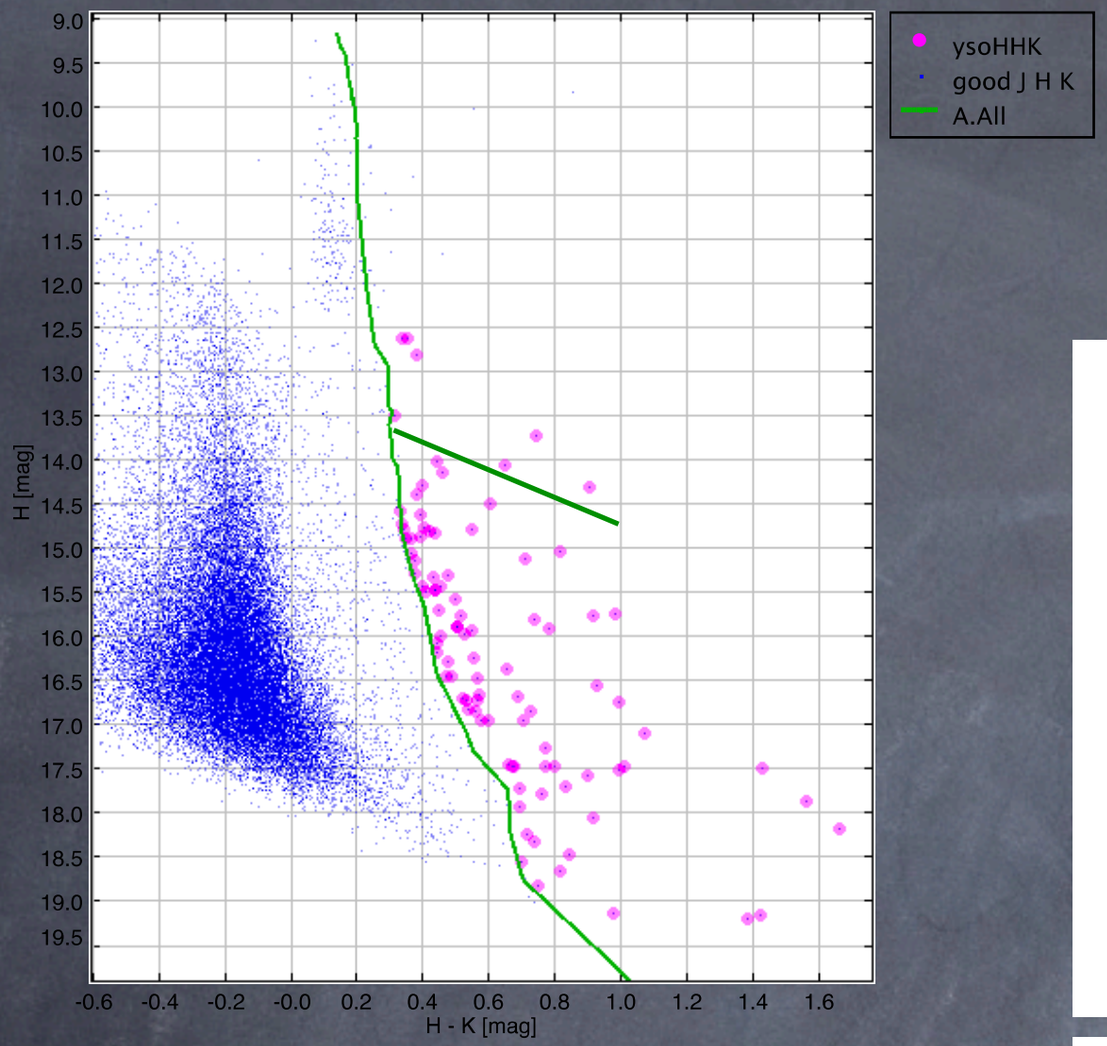


Source Detections using PhotVis: IDL based on DAOPhot routines
Detections per field: ~60,000-90,000 in J, H, K
~20,000 in CH4on, CH4off

Detection threshold: J: 22, H: 21, K: 21 (~5mag fainter than 2MASS)
Completeness Limit: J: 20, H: 18, K: 17.5

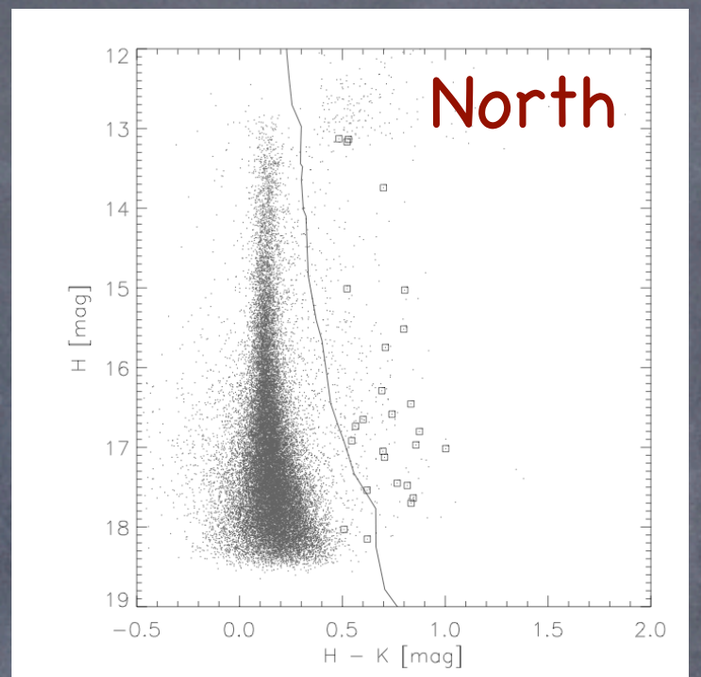
Comparison with 2MASS: ~0.05-0.07 offsets (expected with filters)

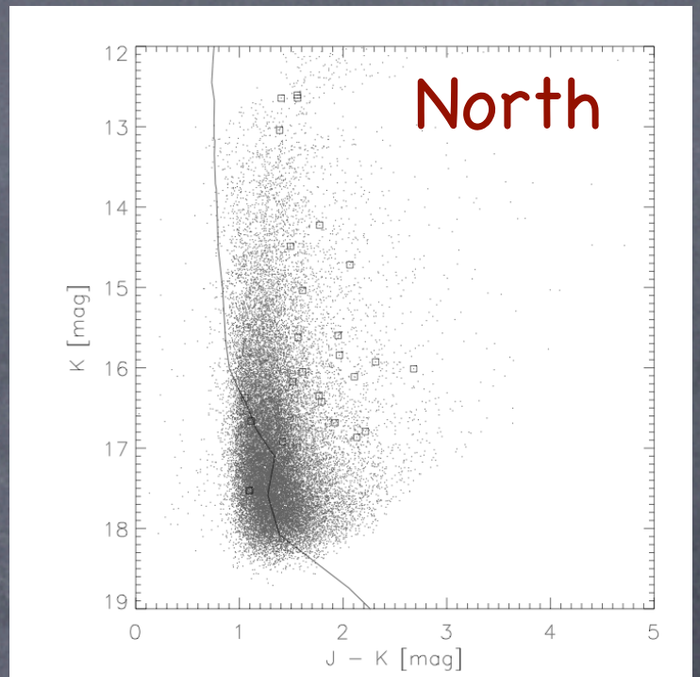
Selection of YSOs/YBDs

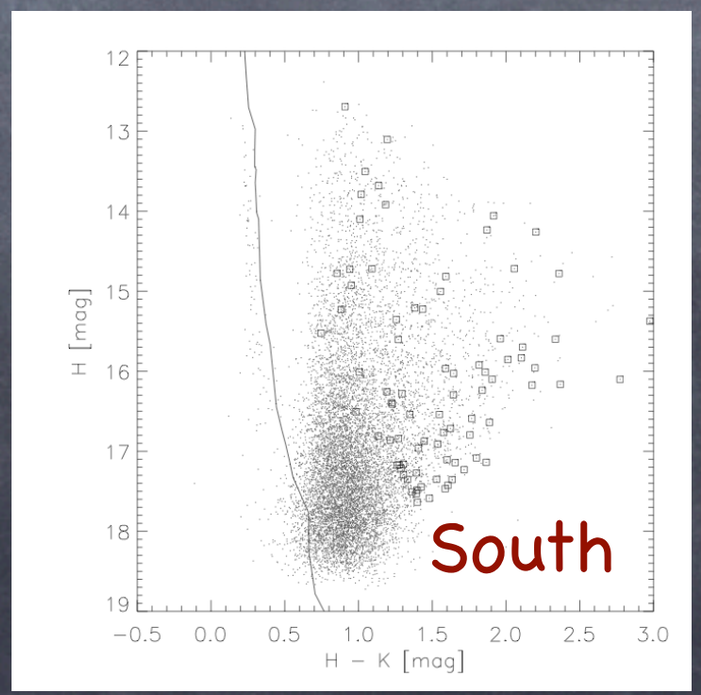


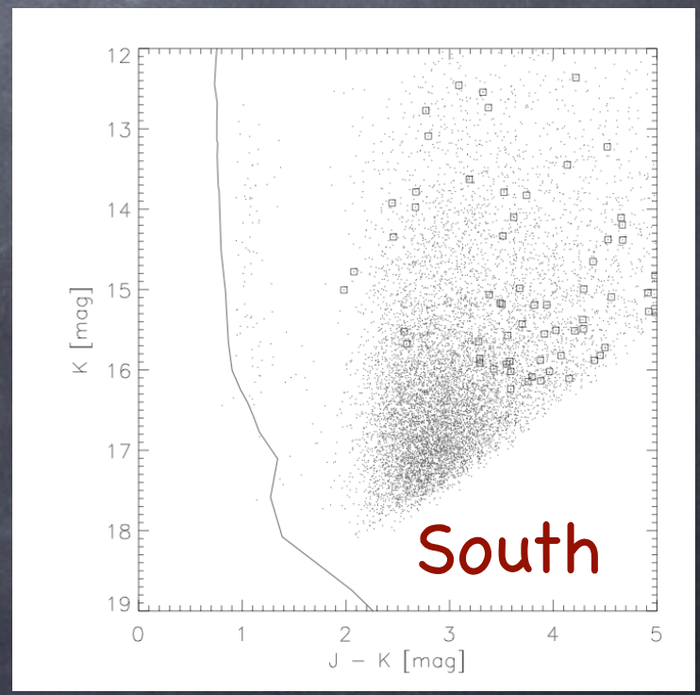
Colour Magnitude Diagrams:
K v J-K & H v H-K

Photometry is dereddened before selection is made.
Plots on right show undereddened photometry









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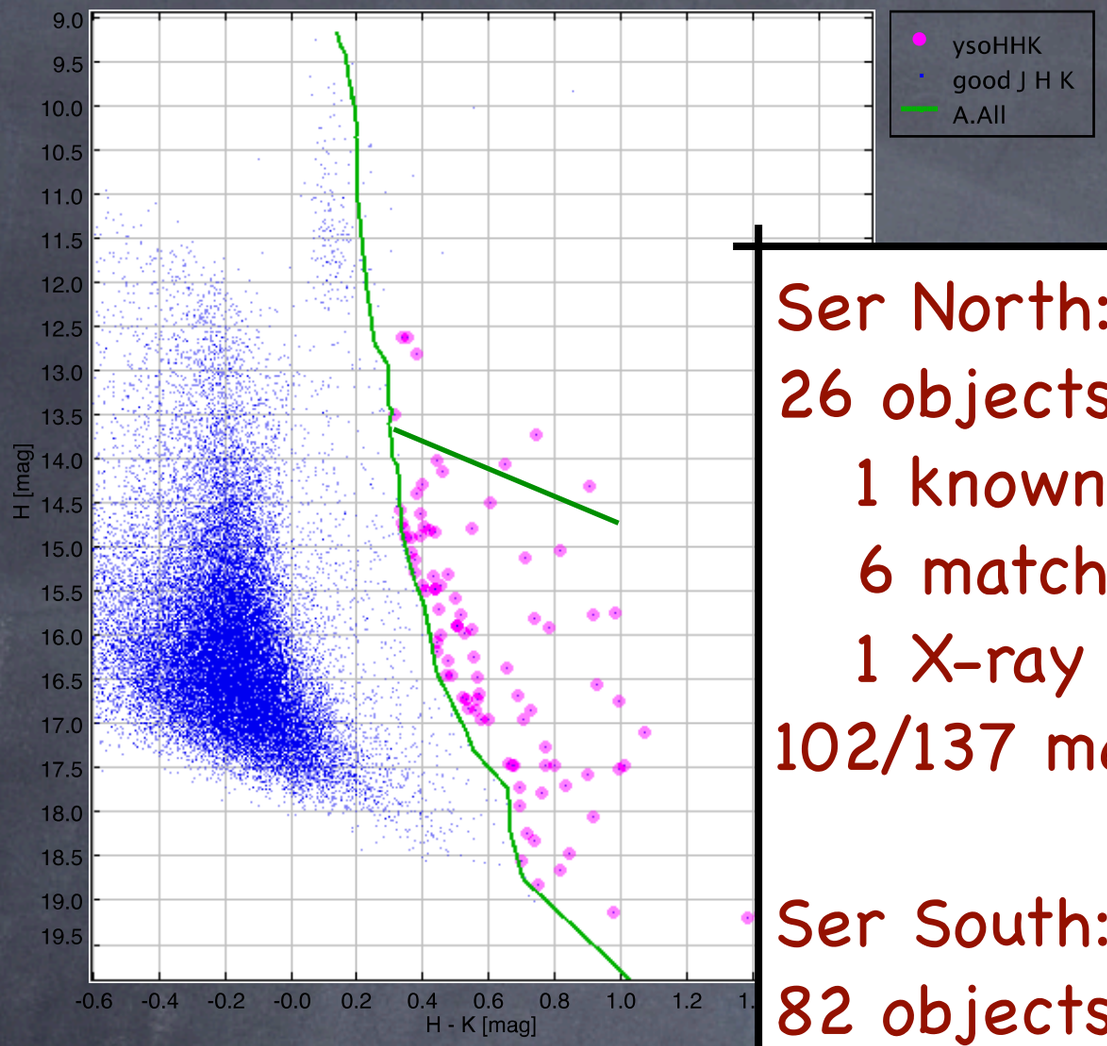

Colour Magnitude Dia
K v J-K & H v H-K

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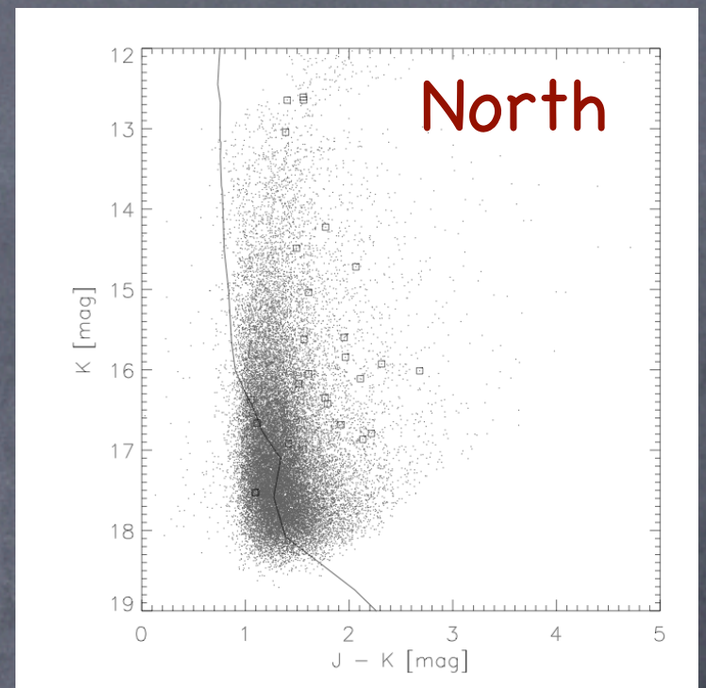
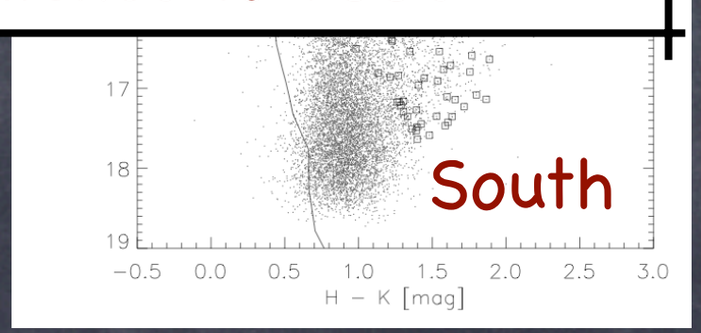
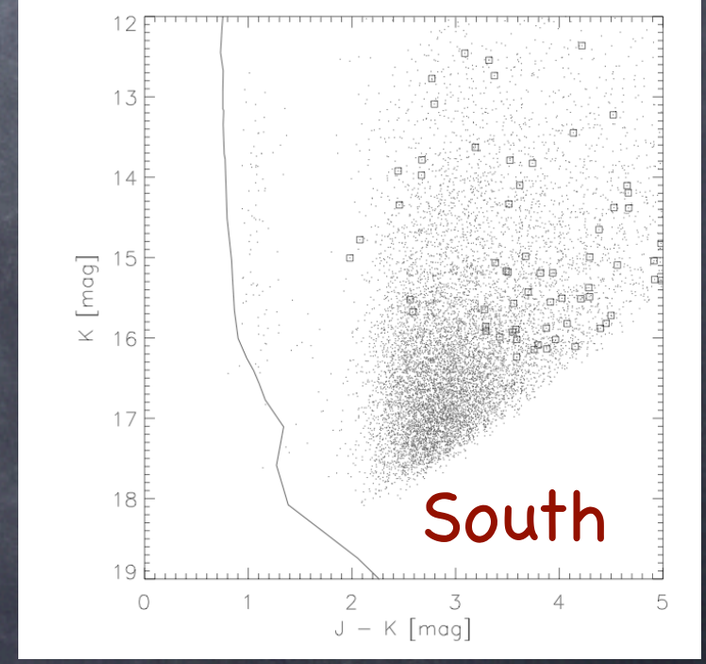
selection is made.
Plots on right show undereddened
photometry

Ser North:
26 objects < 1 Myrs:
1 known YSO
6 match in IR catalogue
1 X-ray detection
102/137 matches to YSOs

Ser South:
82 objects < 1 Myrs:
11 known YSO
59 match in IR catalogue
2 X-ray detection
76/92 matches to YSOs







North & South

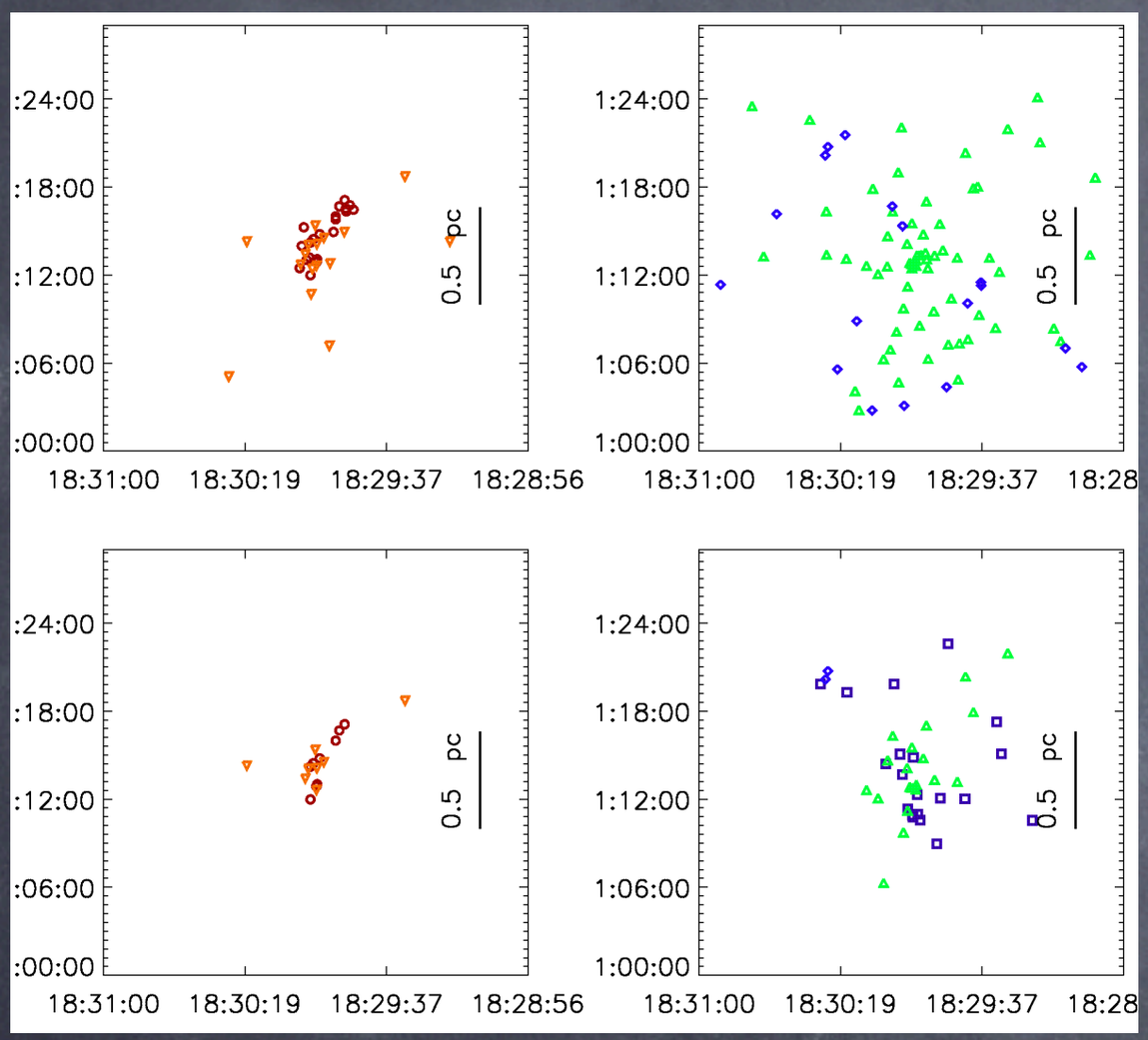
Spatial Distribution:
  Young Stars
  Young Brown Dwarfs

X-ray Luminosity Functions:
    Distance to the clusters

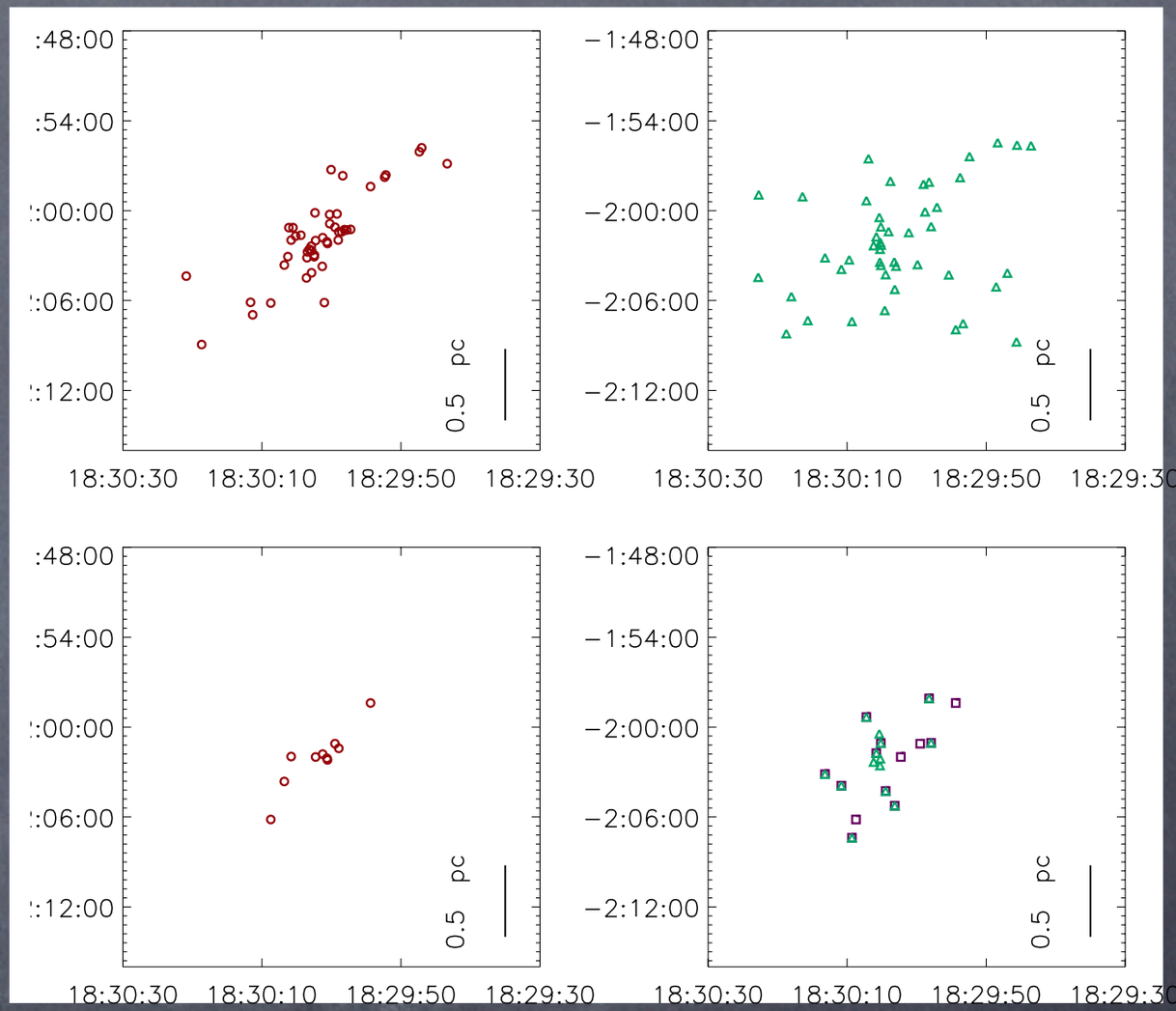
Disk & X-ray Properties of the clusters

Spatial Distribution for North & South

North



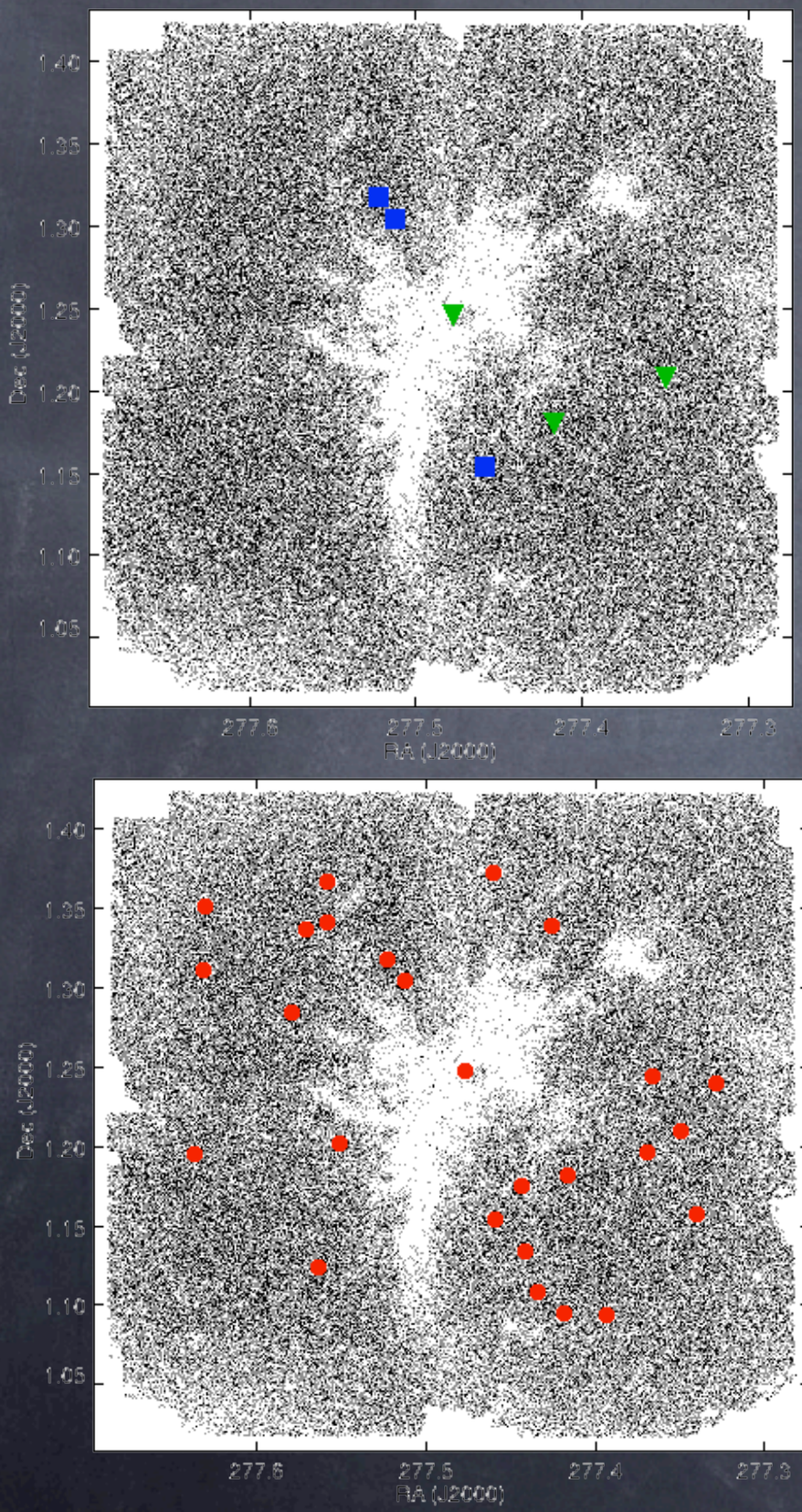
South



Fragmentation processes, Formation of protostellar cores, Dynamical evolution of the stars from protostellar to pre-main sequence.

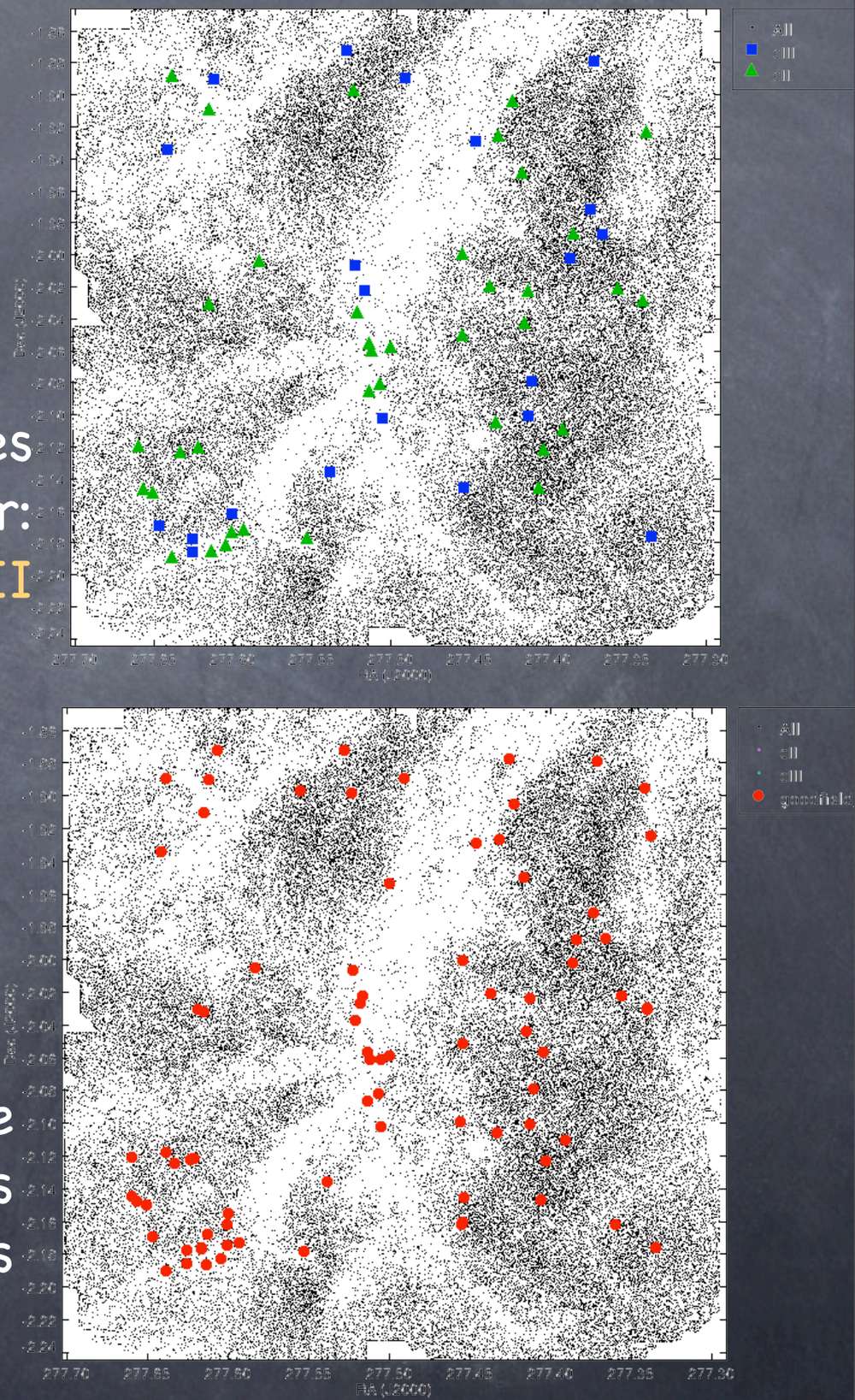
Recent studies have shown that in many clusters the sources trace the underlying molecular gas distribution.

Spatial Distribution of YSOs/YBDs



6 candidates
match to midIR:
3 CII, 3 CIII

59 candidates
match to Spitzer:
38 CII, 21 CIII



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new YSOs/YBDs
< 1 Myrs

82 canditate
new YSOs/YBDs
< 1 Myrs

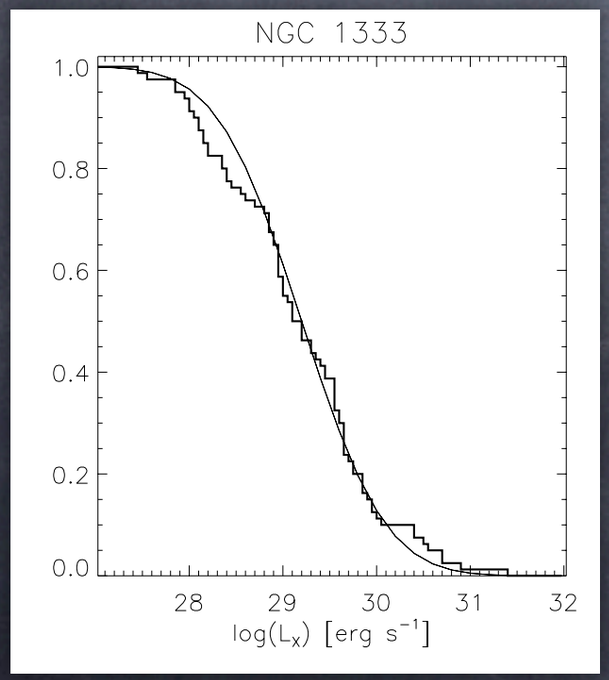
X-ray Luminosity Function: Distance to Serpens

Feigelson & Getman 2005 have found a universal log-normal distribution for the XLFs of Orion IC 348 & NGC 1333:
$\langle \log(Lx) \rangle = 29.3$, $\sigma_{\log(Lx)} = 1$

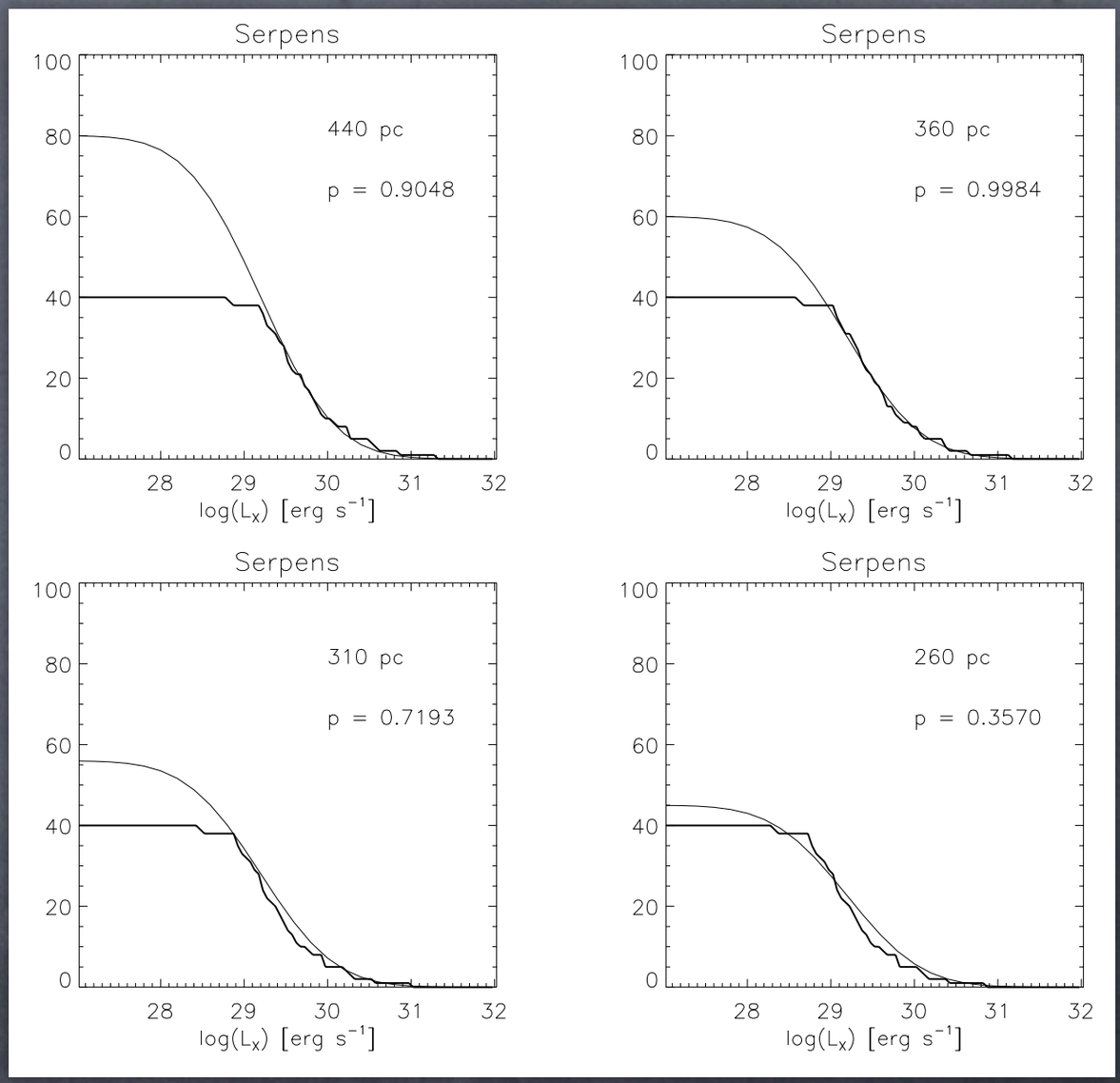
Can fit XLF by varying distance and number of sources in the cluster

Current Accepted Distance to Serpens: 260 pc

NGC 1333 at 240pc



Serpens at 410, 360, 310, 260pc



Best Fit to Serpens at 360pc

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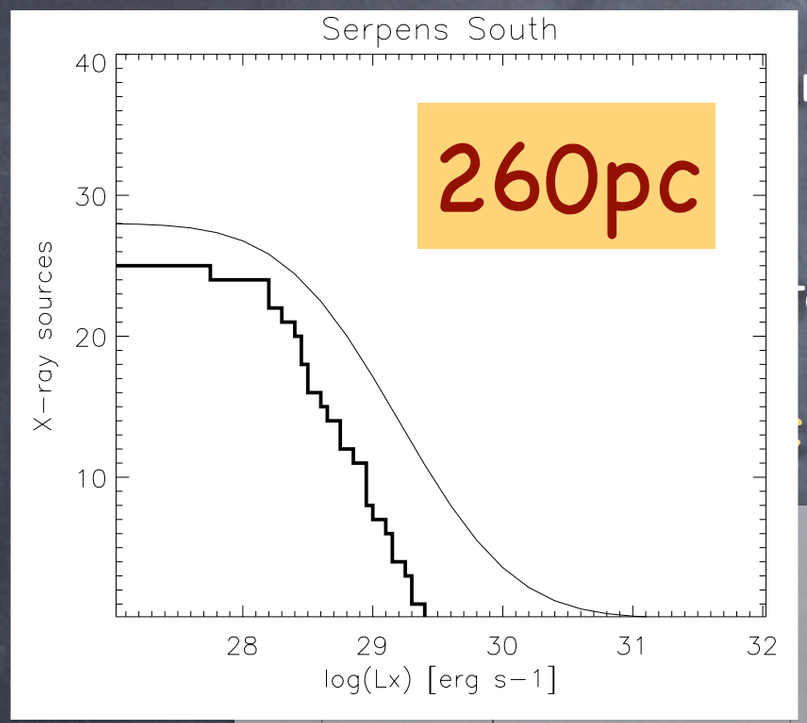
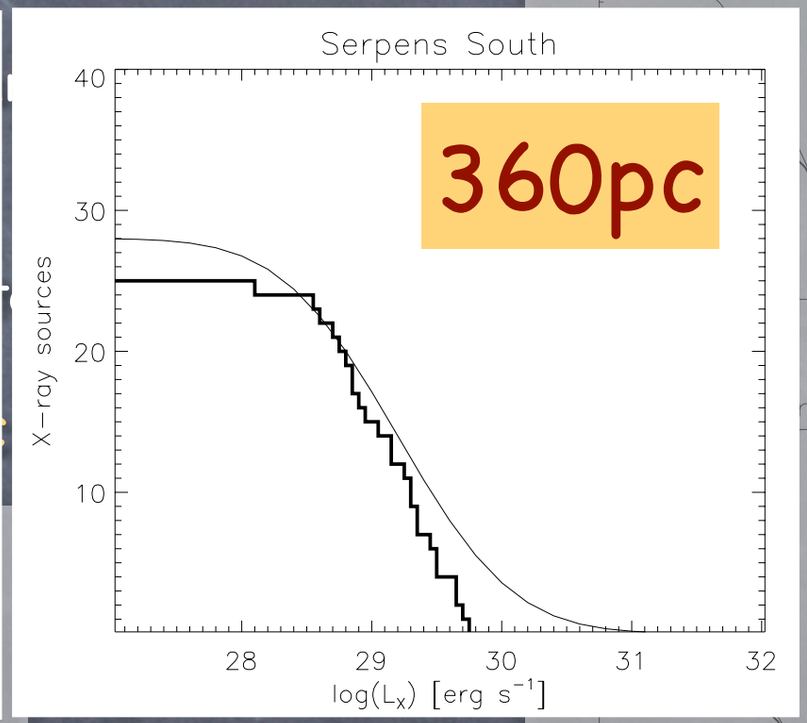
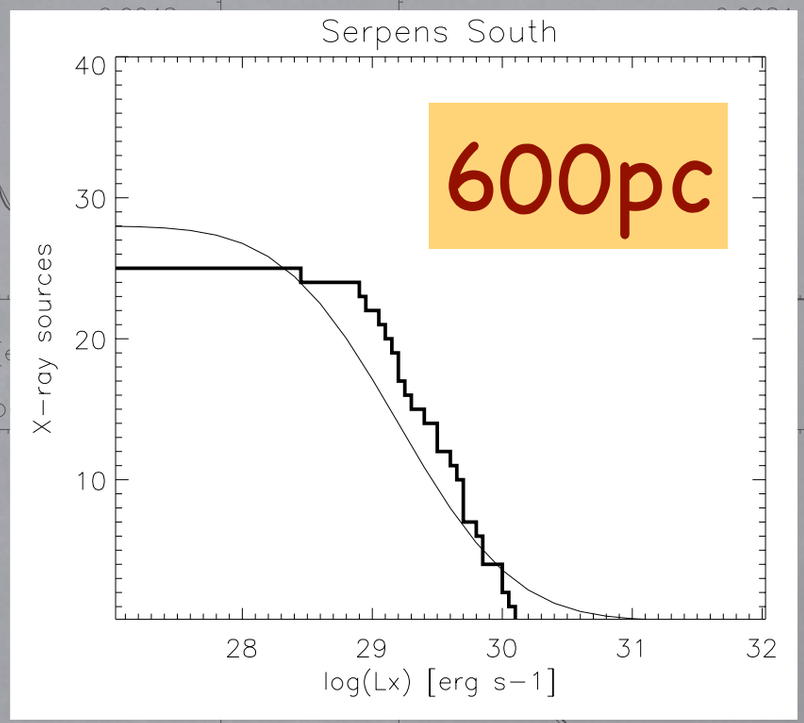
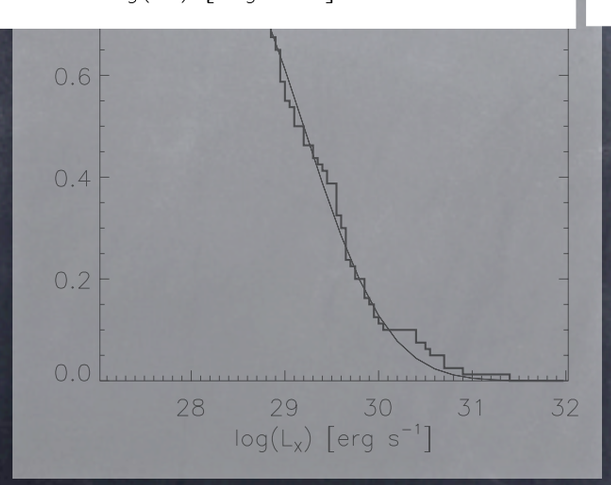
Serpens South?

Serpens at 410, 360, 310, 260pc



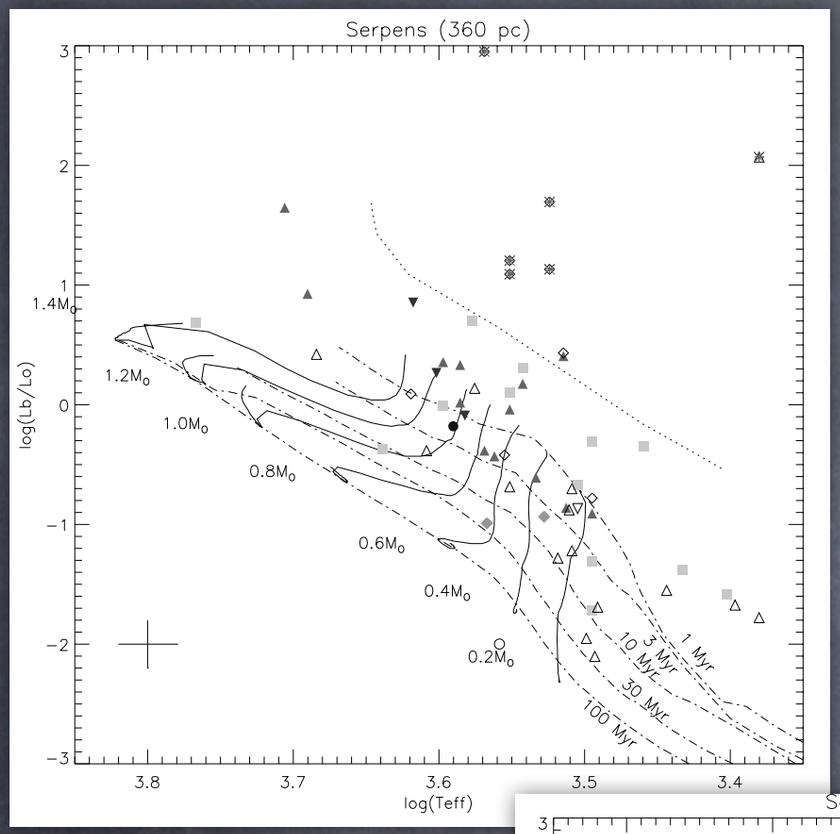




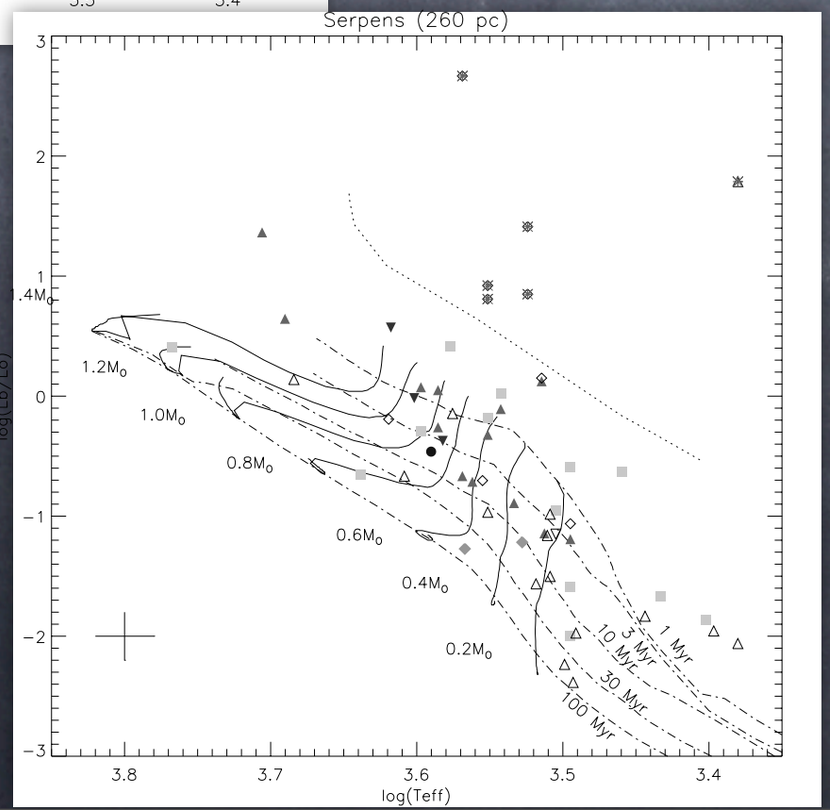


Best Fit to Serpens at 360pc

Hertzprung-Russel Diagram for Serpens North



360pc



260pc

Winston et al 2009,2010

Class 0/I: circles
Flat Spectrum: inverted triangles
Class II: triangles
Transition Disks: diamonds
Class III: squares.

MMT/HectoSpec: far red 4000-9000Å
IRTF/SpeX: near-IR, J,H,K bands

Filled Symbols are X-ray detected YSOs

Assumed Cluster Distance: 260, 360 pc

Average cluster age: 3-5, 1 Myrs

Class II & Class III have statisically similar ages

Isochrones from Baraffe et al 1998

Birthline: objects above are likely AGB

X-ray Detection by Class

In Serpens North: 50% of sources in each evolutionary class detected in X-rays.

In Serpens South: 30% of sources detected in X-rays

More Deeply Embedded Region
Envelope/Disk obscuration/absorption
Younger objects not yet emitting as strongly??
How does this affect the estimate of the Class III fraction?

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Disk Fraction

Serpens North: 49% ± 11%
Serpens South: 78% ± 21%

Appreciably higher in South, indicating young evolutionary stage of cluster

BD candidates: North: 3/(3+3) = 50% ± 28%, South: 38/(38+21) = 64% ± 10%

Assume a similar detection fraction of CII and CIII (may not hold here)
Implies total of 13 CIIIs in cluster for this completeness limit (~0.2 Msun)

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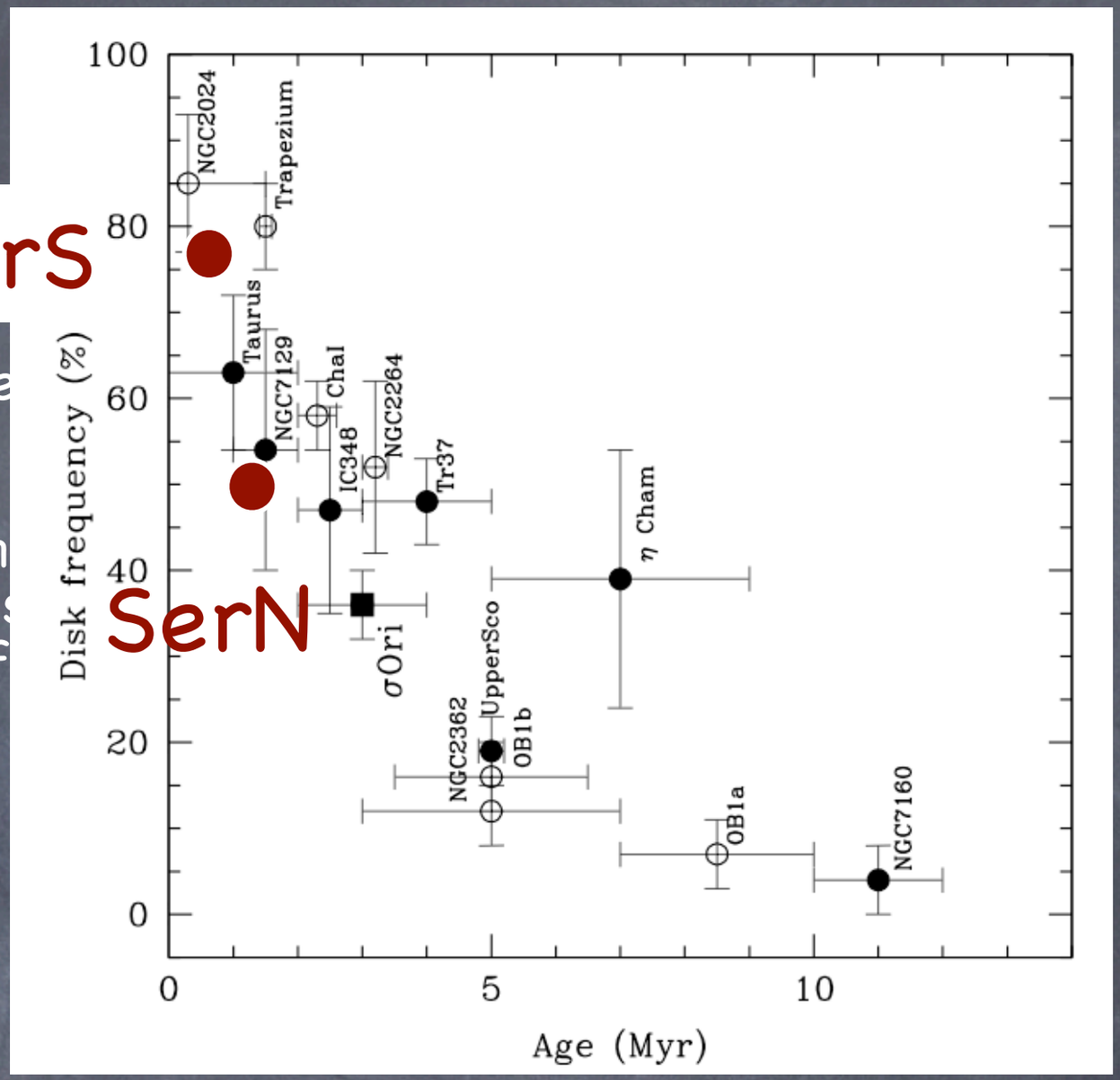

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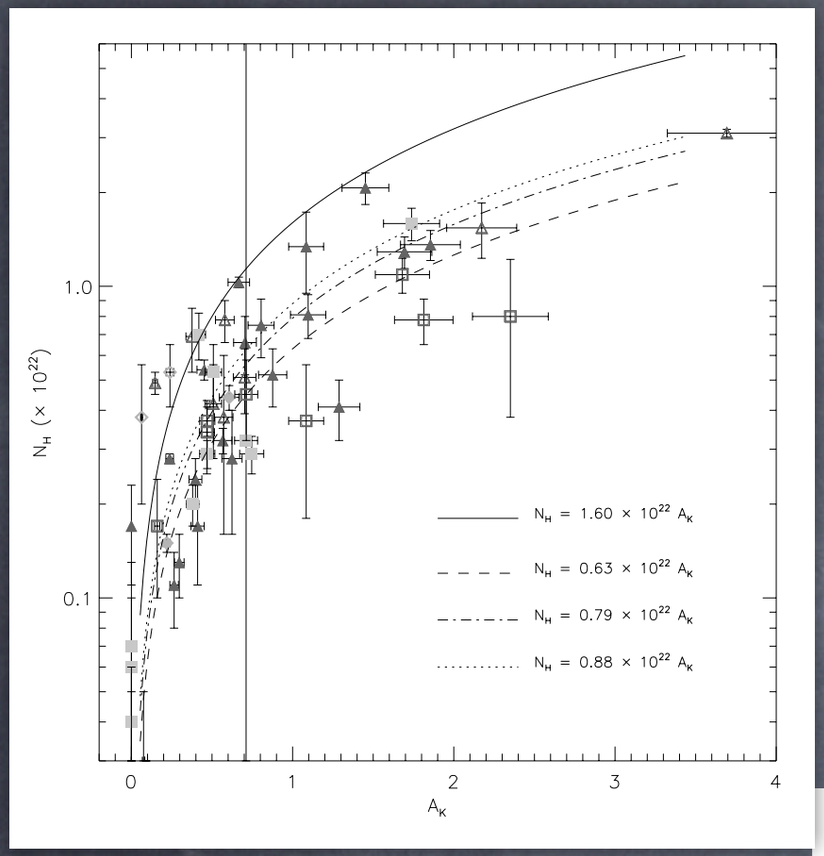
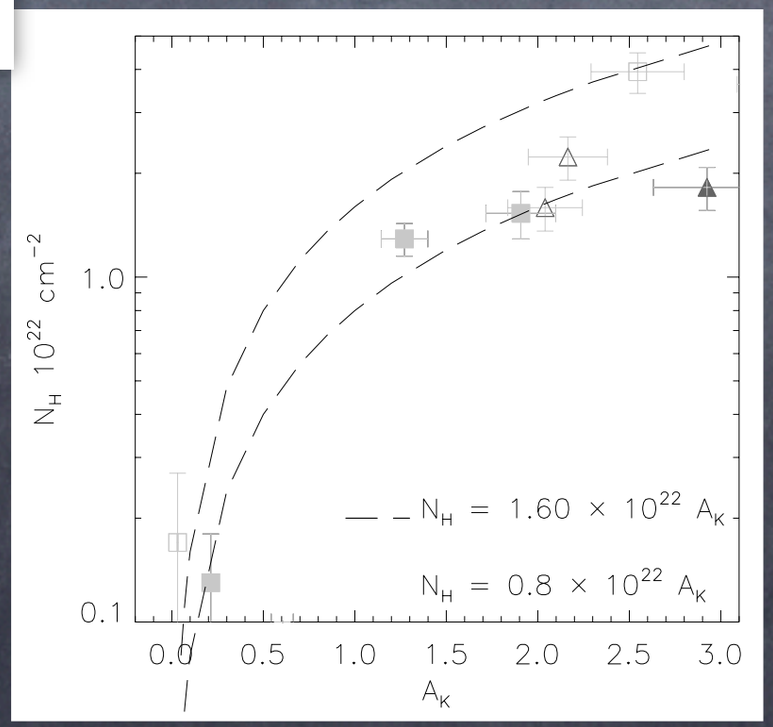
X-ray to IR properties



N_H v A_K:

Hydrogen Column Density (N_H) vs. Extinction at K-Band (A_K)
Standard ISM: $N_H \sim 1.6 \times 10^{21} A_v$ (Voung et al 2003)

Serpens exhibits a lower than Expected Ratio: ~0.6 x $10^{22(21)}$ $A_{k(v)}$



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Class II: triangles
Transition Disks: diamonds
Class III: squares.

Grain Growth

Change in Dust to Gas Ratio

Icy Mantles

Conclusions

- Spitzer & Chandra identify 137 & 92 YSOs in Serpens North and South, respectively.
- WIRCam: 26 (6: 3 CII, 3 CIII) new candidates in Serpens North and 82 (59: 38 CII, 21 CIII) new candidates in Serpens South.
- Spatial Distributions similar; South more condensed.
- Distance to both clusters is likely to be 360pc or higher..
- Disk Fraction in South > North : younger age.
- Evidence of Grain growth occuring in both clusters.

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