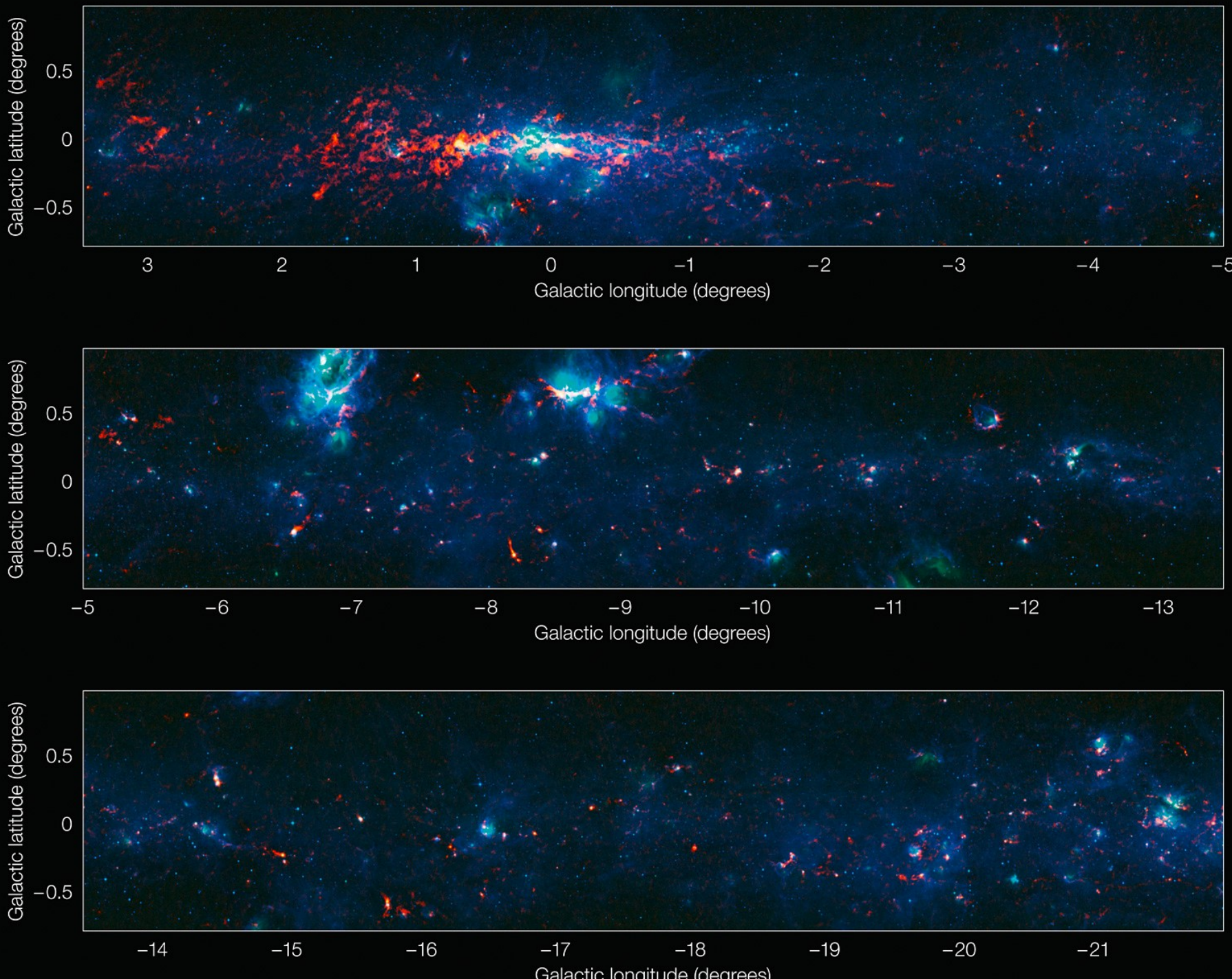
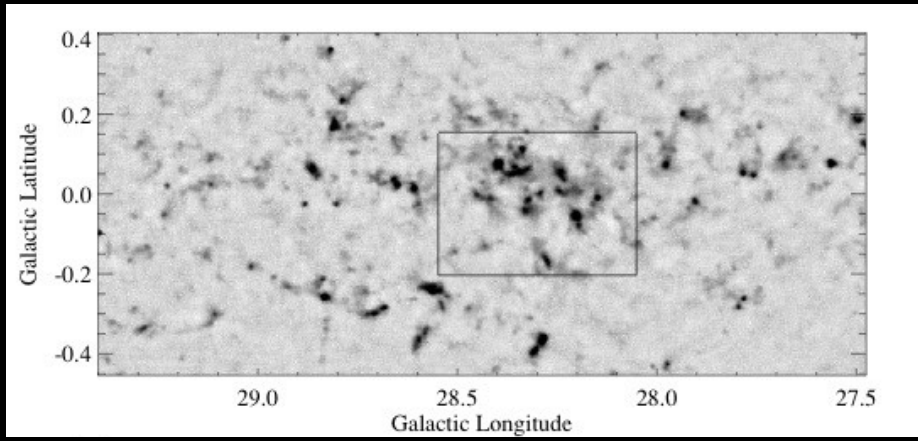
Spectroscopic Observations of Bolocam Galactic Plane Survey Clumps

Yancy Shirley


Galactic latitude (degrees)
0.5
0
−0.5
3
2
1
0
−1
−2
−3
−4
−5
Galactic longitude (degrees)
Galactic latitude (degrees)
0.5
0
−0.5
−5
−6
−7
−8
−9
−10
−11
−12
−13
Galactic longitude (degrees)
Galactic latitude (degrees)
0.5
0
−0.5
−14
−15
−16
−17
−18
−19
−20
−21
Galactic longitude (degrees)

The Bolocam Galactic Plane Survey (BGPS)

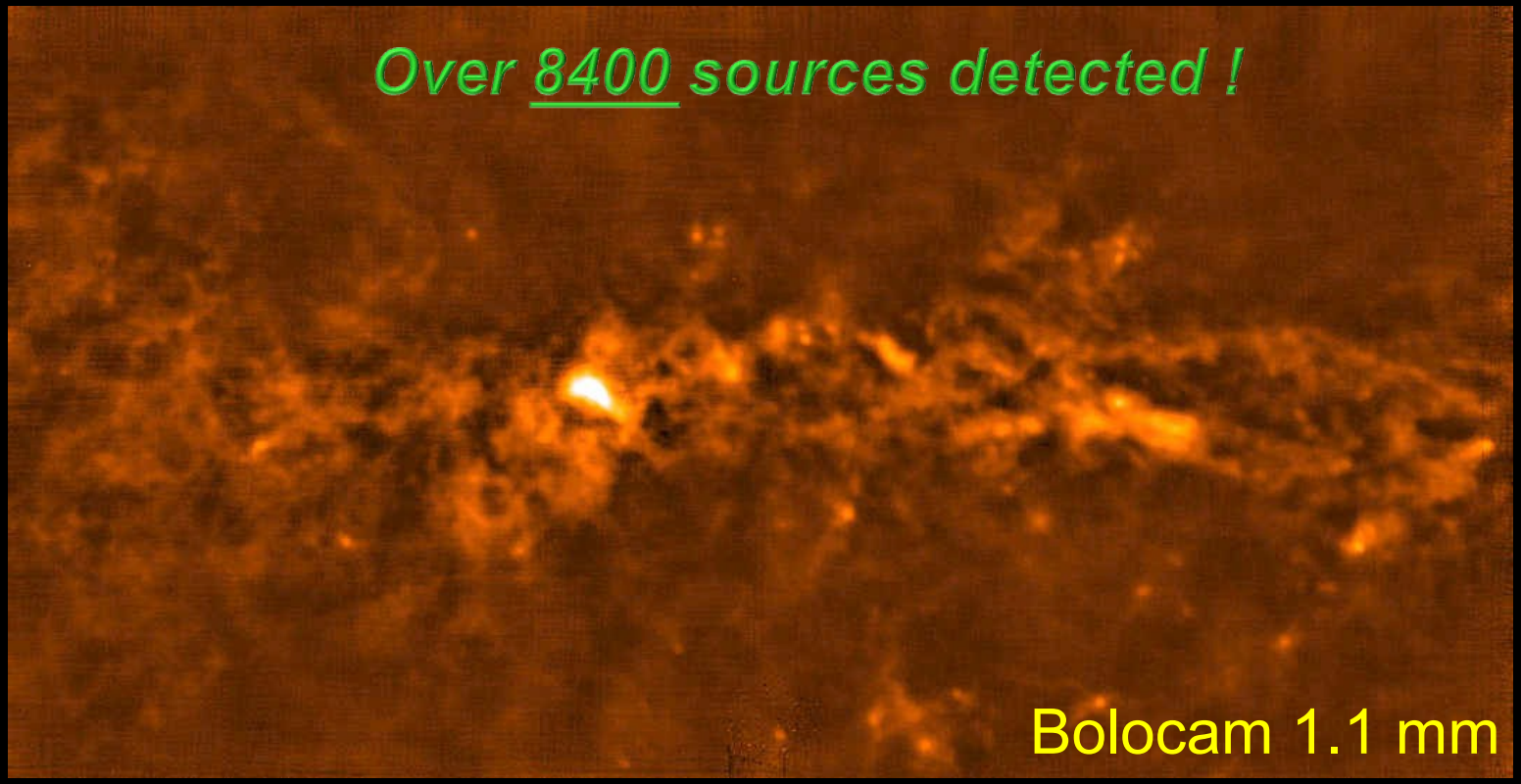


Aguirre et al. 2011

- 170 sq. deg.
- 1.1mm continuum
- 1 deg high strip
- 10.4m CSO 33” resolution
- Complete 1st quadrant
- Selected regions of 2nd quadrant
- ***ALL DATA & CATALOGS RELEASED !***

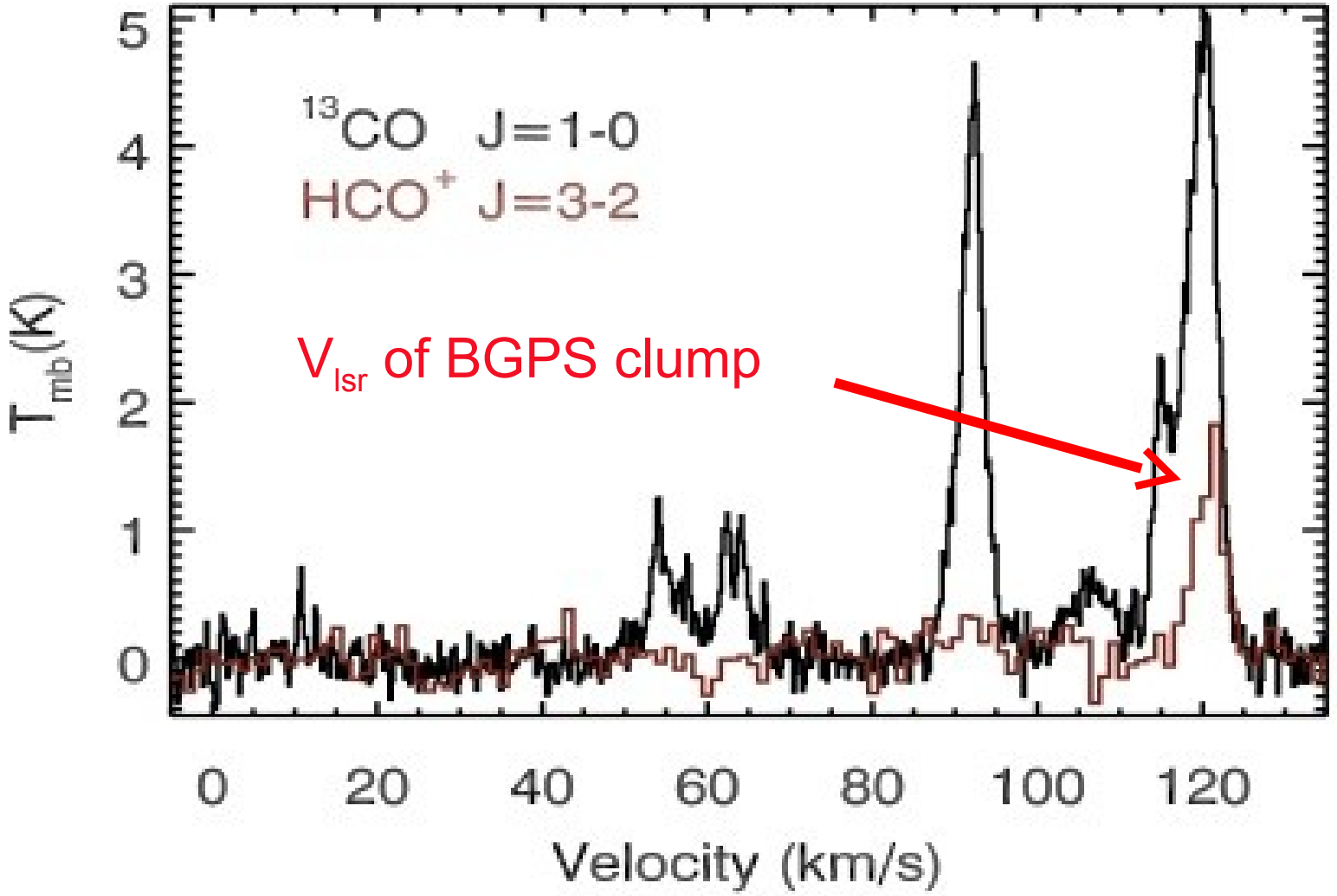
Rosolowsky et al. 2010

What are the properties of these newly discovered sources?

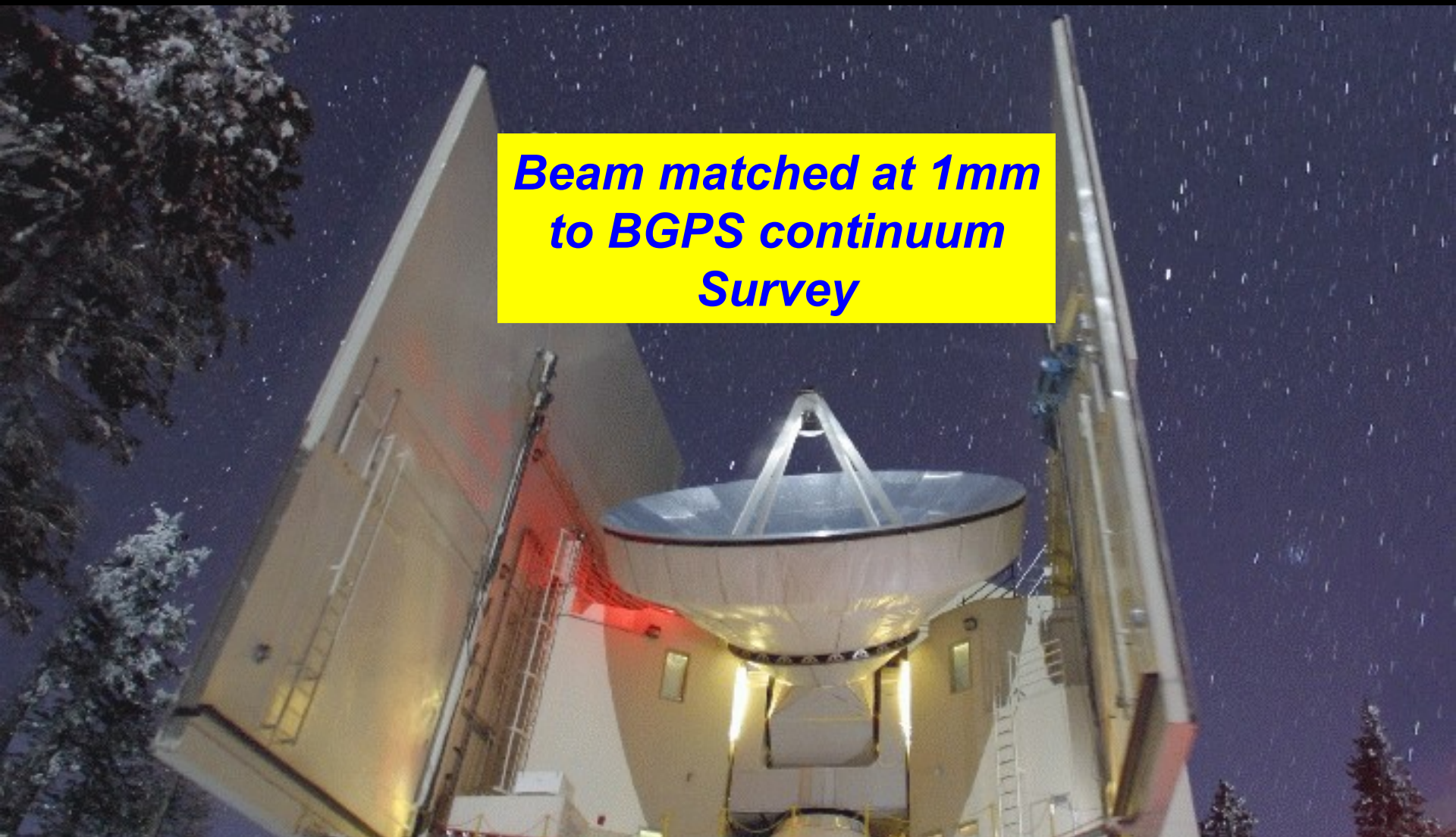


- SIZE, MASS, LUMINOSITY
- ALL DEPENDS ON KNOWING DISTANCE!

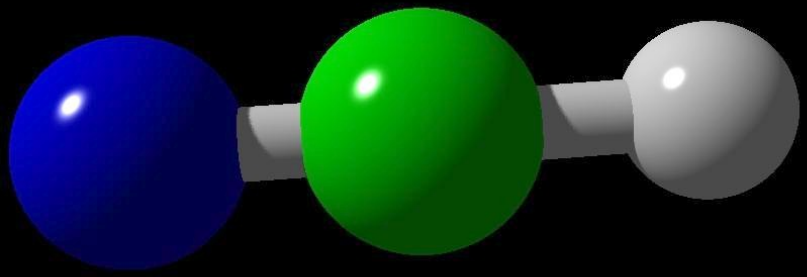
Why Dense Molecular Gas?



HHT Spectroscopic Survey of Dense Molecular Gas in the BGPS

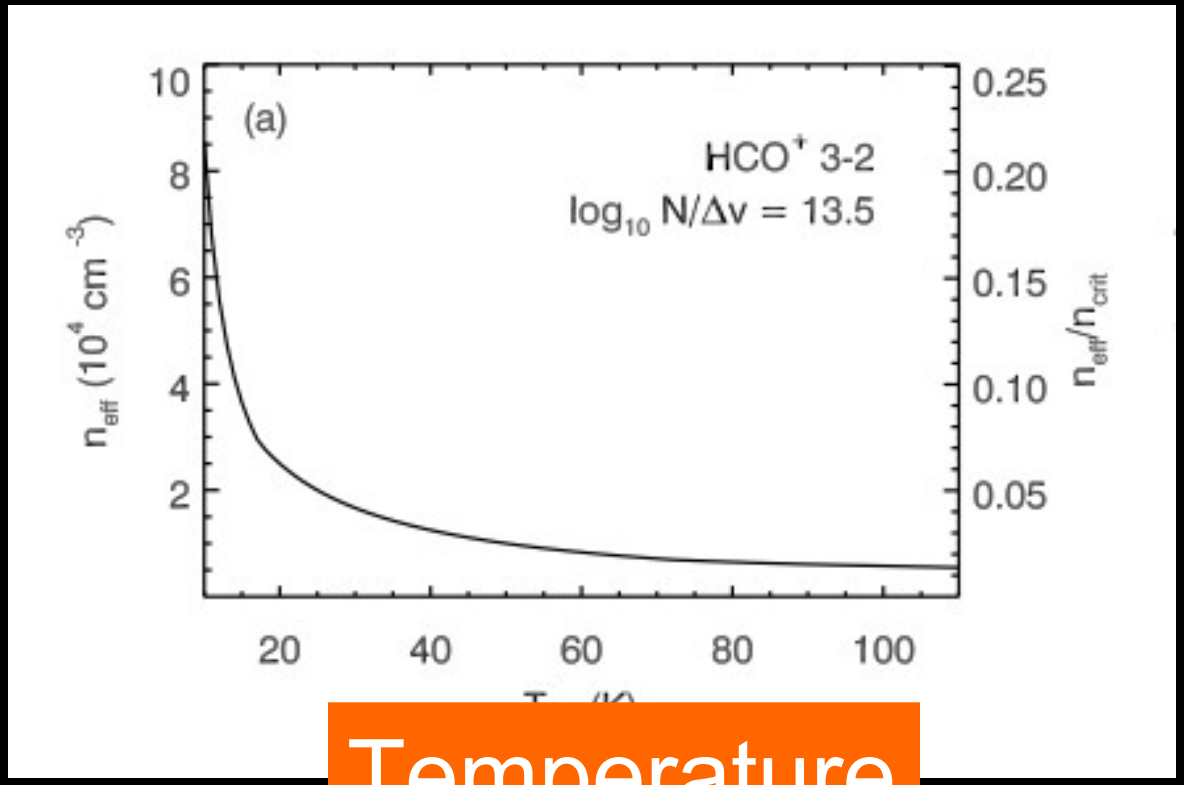


Observing Dense Molecular Gas



HCO^+

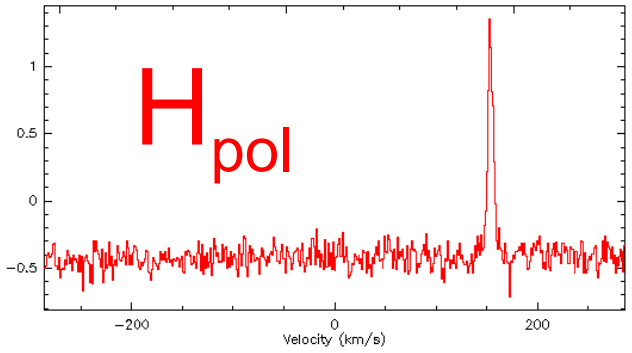
Density x 10^4

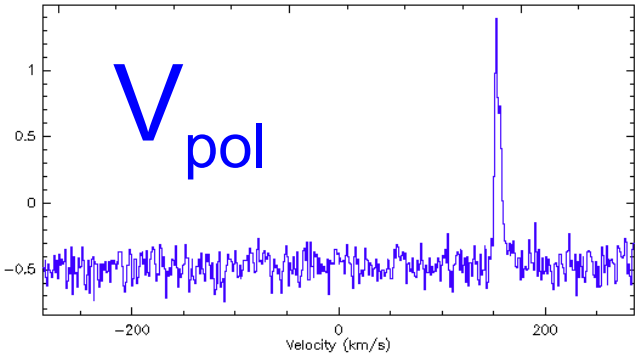


Temperature

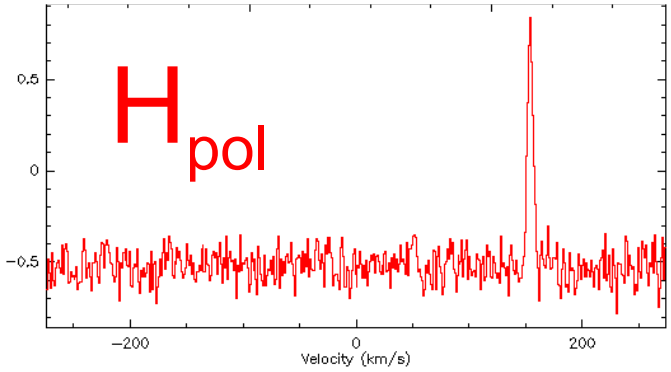
ALMA Band 6 (1mm) Prototype Receiver

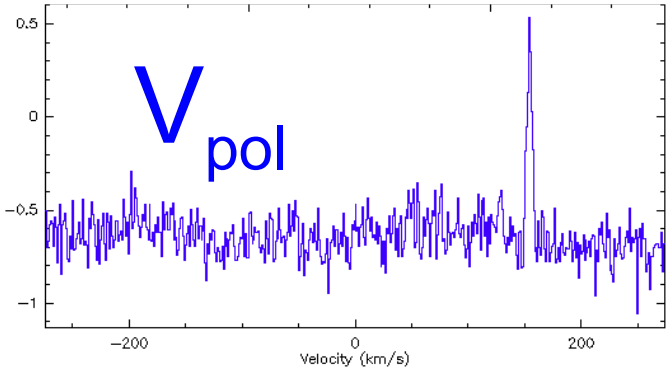
HCO^+ 3-2 LSB





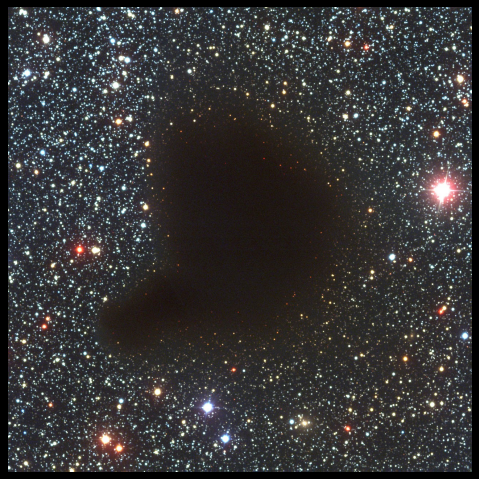
N_2H^+ 3-2 USB

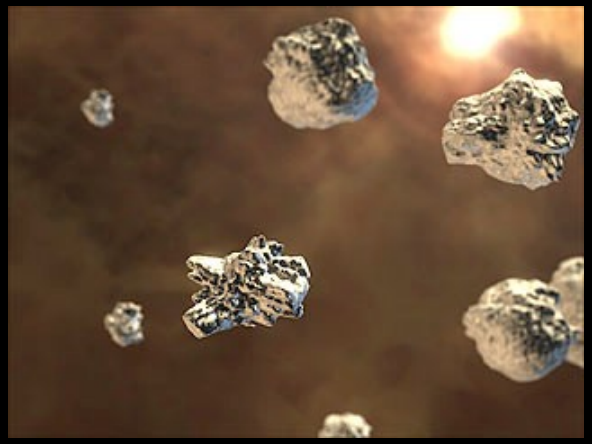




HCO^+ vs. N_2H^+ Chemistry

- HCO^+ formed in gas phase from CO
  - $H_3^+ + CO \rightarrow HCO^+ + H_2$
- CO Freezes out of gas phase at low T

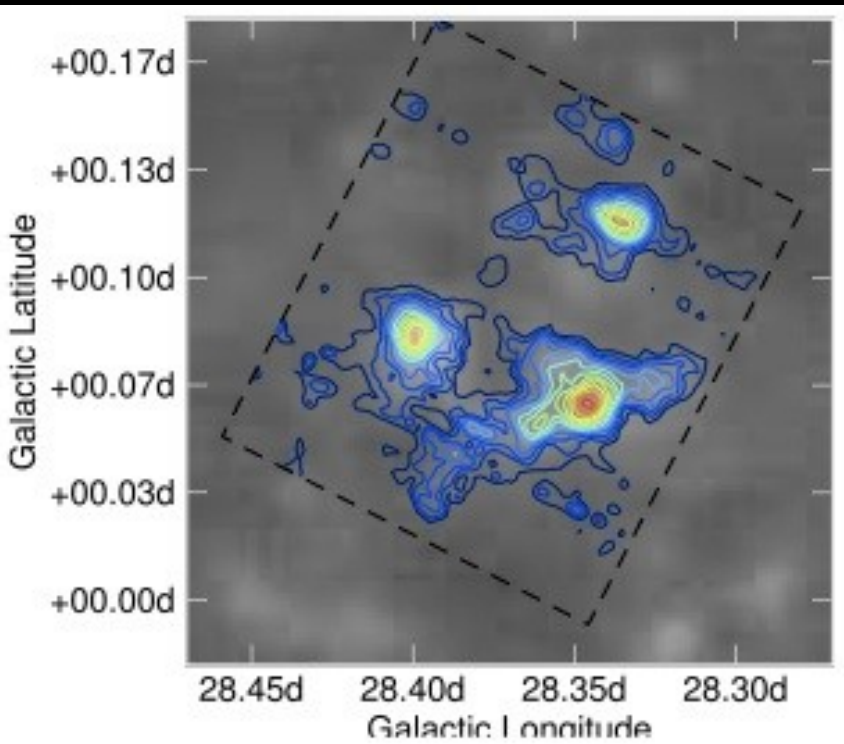




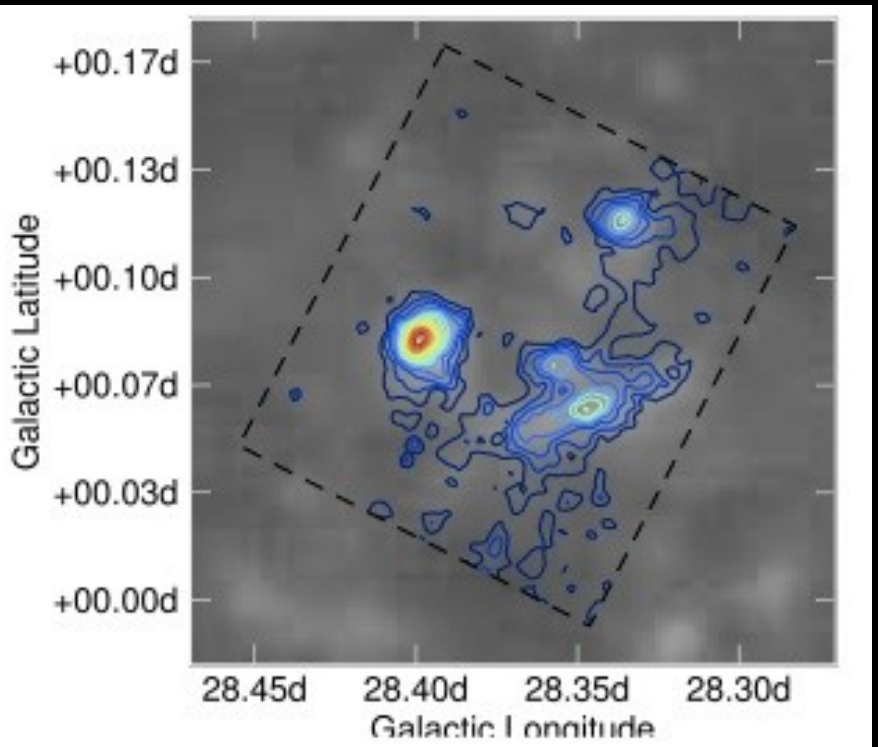
- N_2H^+ destroyed in gas phase by CO – abundant in cold dense regions
  - $N_2H^+ + CO \rightarrow HCO^+ + N_2$

Molecular Emission Maps

HCO^+ 3-2

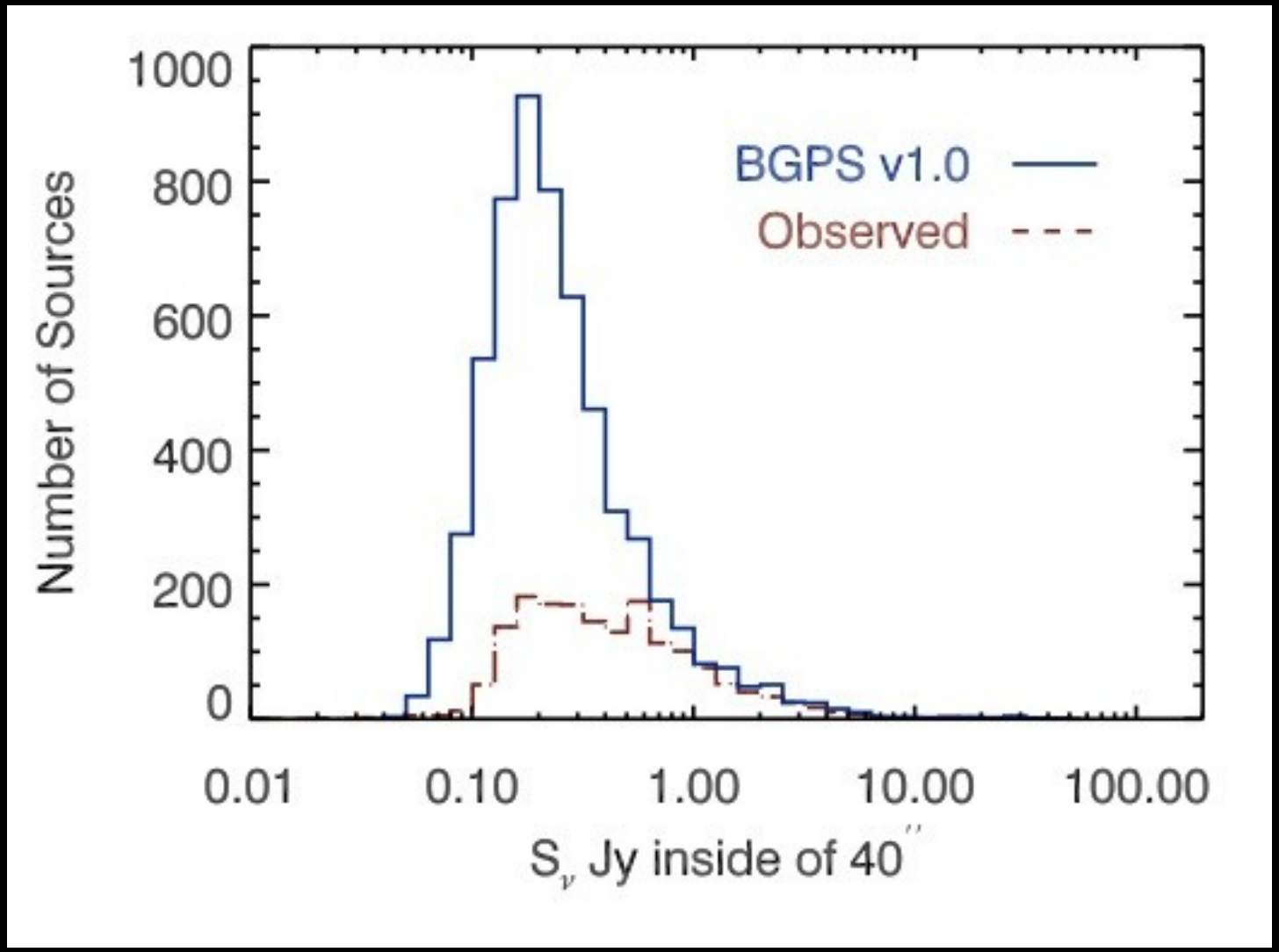


N_2H^+ 3-2



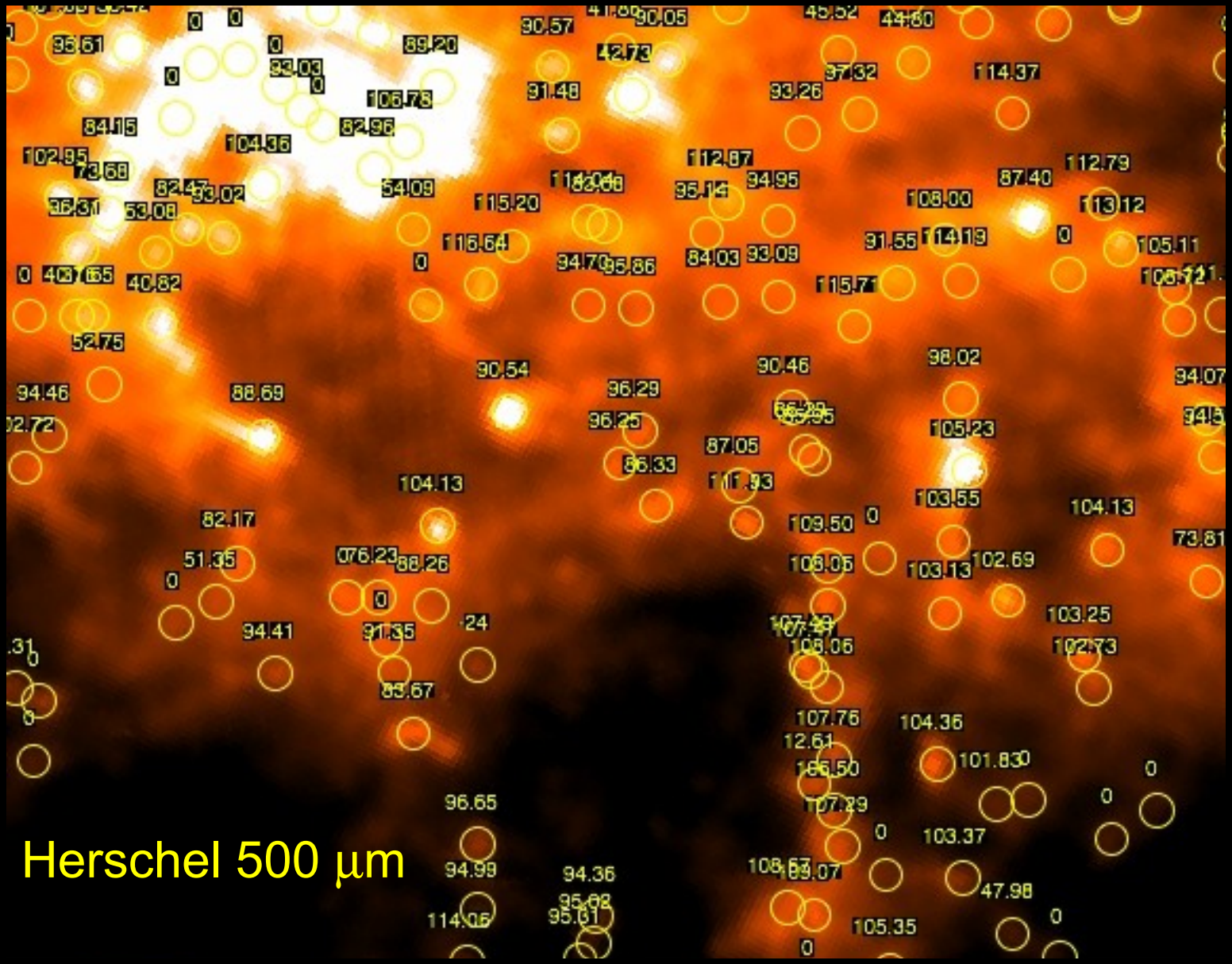
Battersby et al. 2010

Initially Observed 1882 Sources



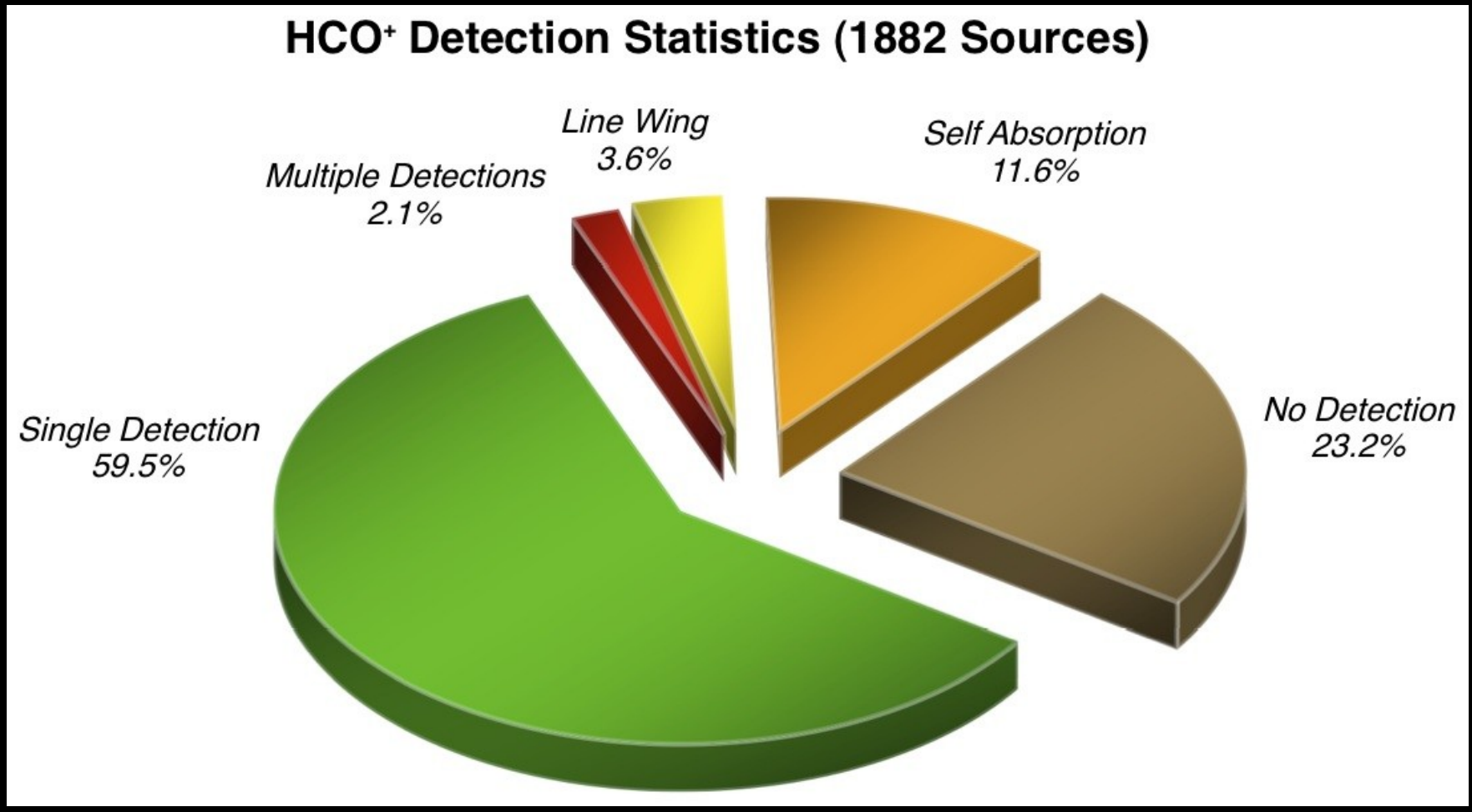
Schlingman et al. 2011

Arizona Spectroscopic Followup



Shirley et al. 2011c, Bally et al. 2010

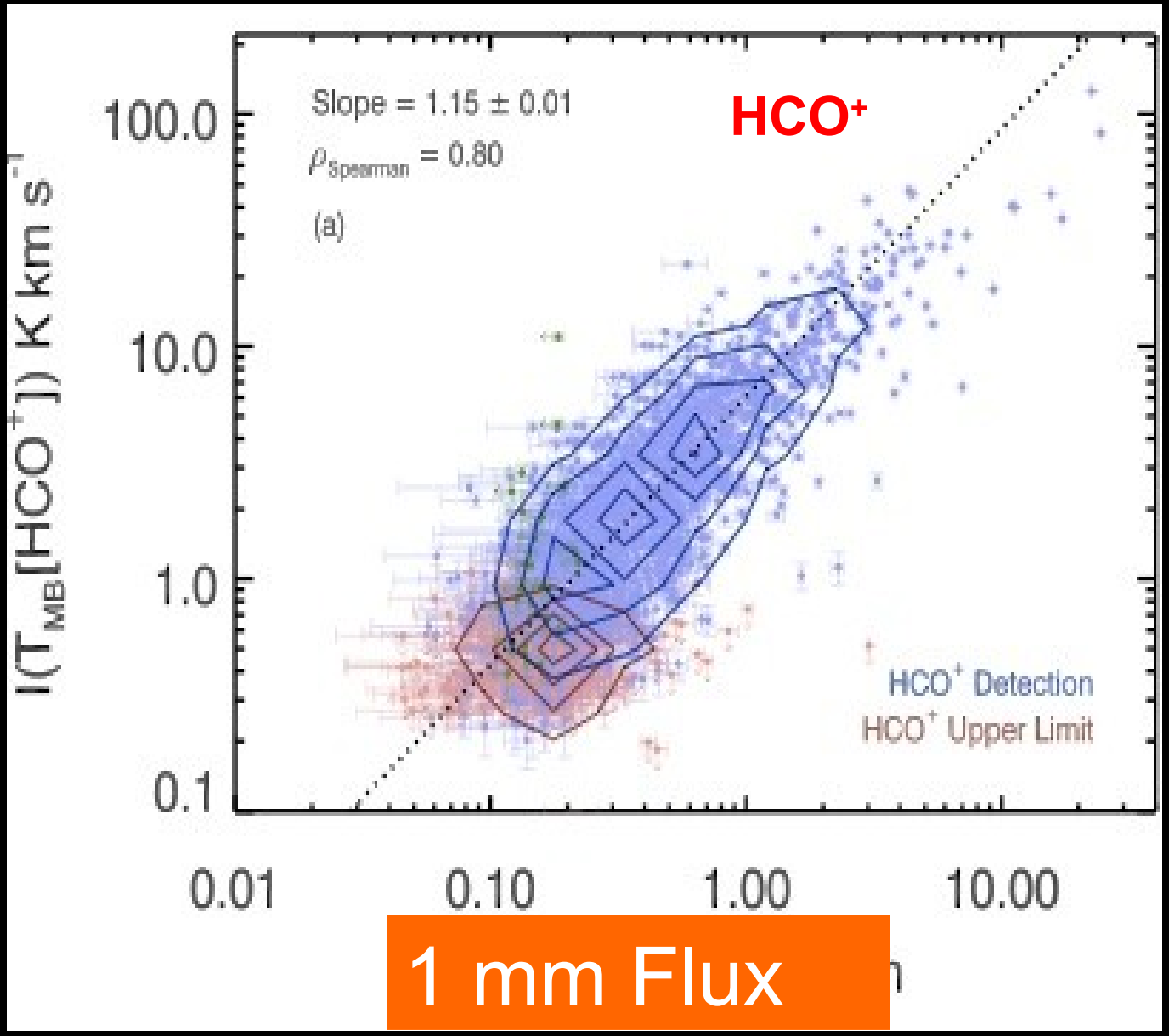
Detection Statistics



Schlingman et al. 2011

Molecular Correlations

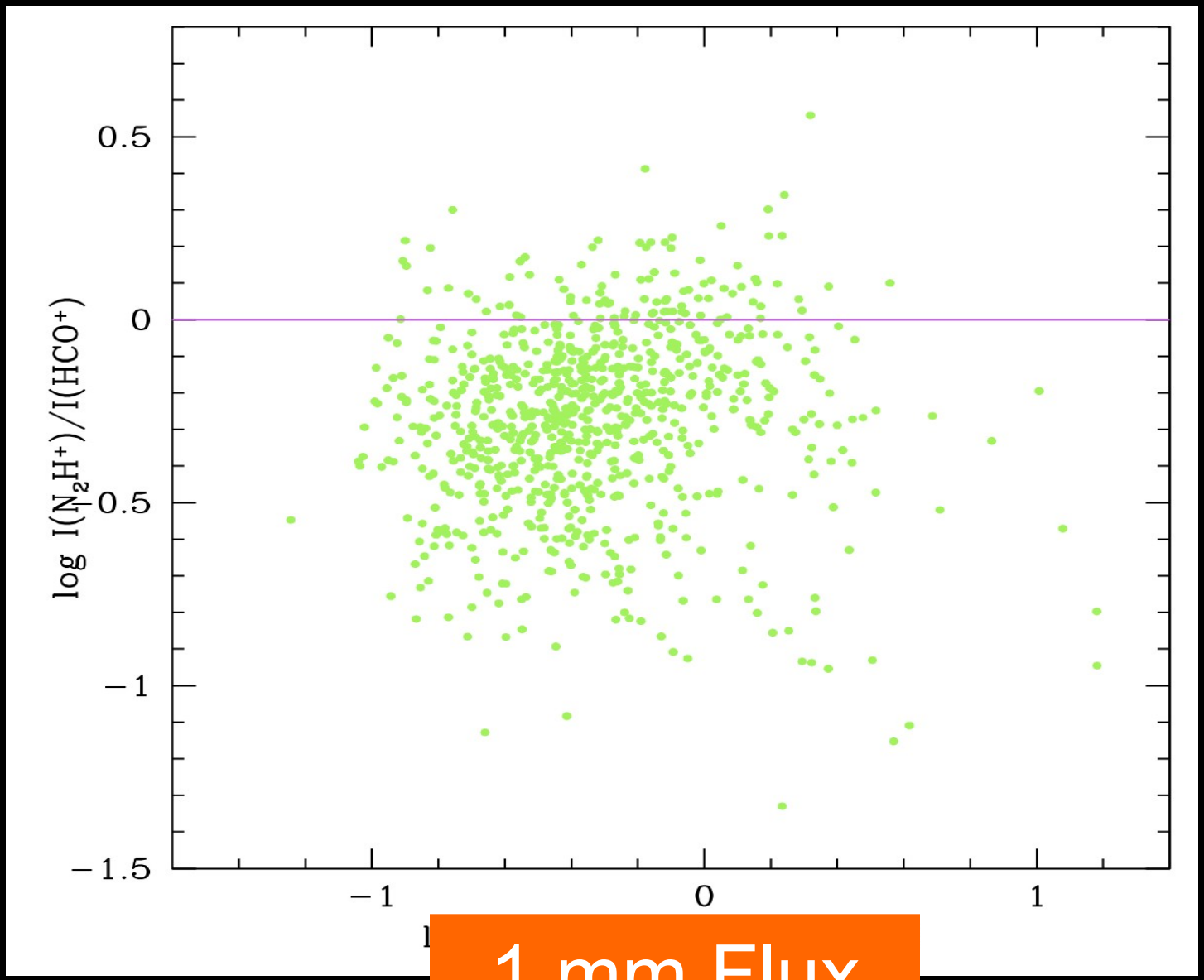
Molecular Intensity



1 mm Flux

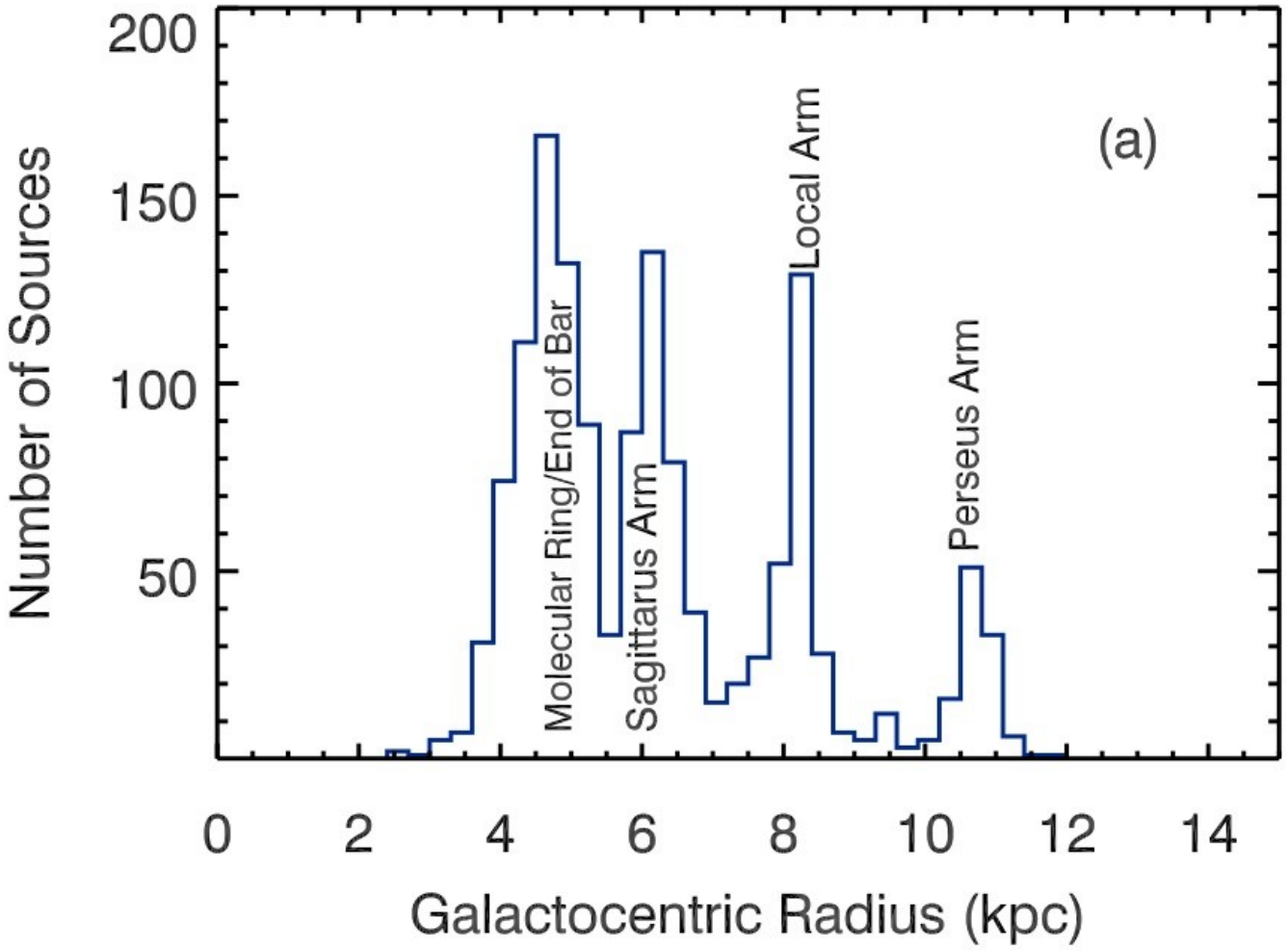
Schlingman et al. 2011

N_2H^+ / HCO^+ - No Correlation



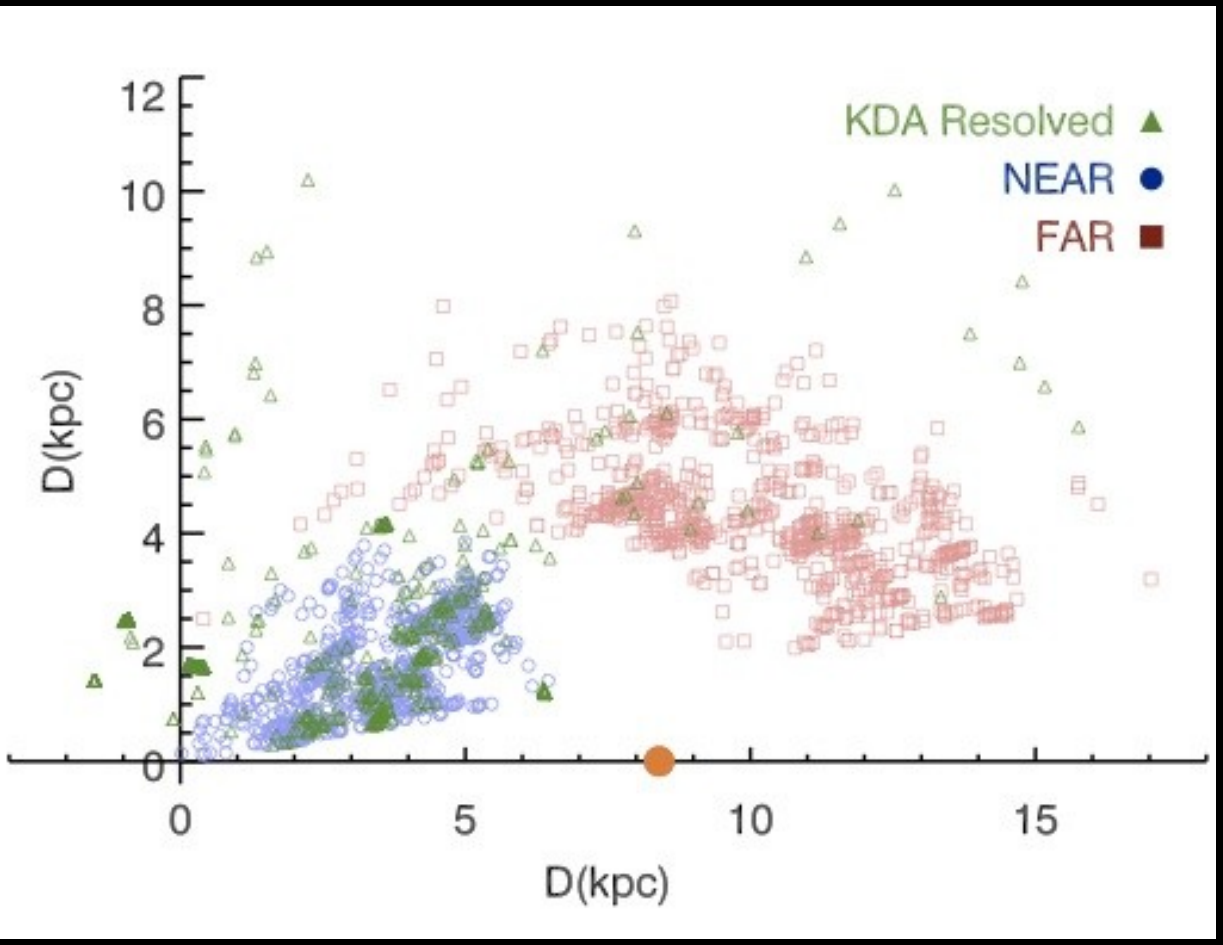
Shirley et al. in prep.

Tracing Spiral Arms in Dense Gas



Schlingman et al. 2011

Initially Resolving Distance Ambiguity



Association w/

(1)VLBA parallax

(2) Known region

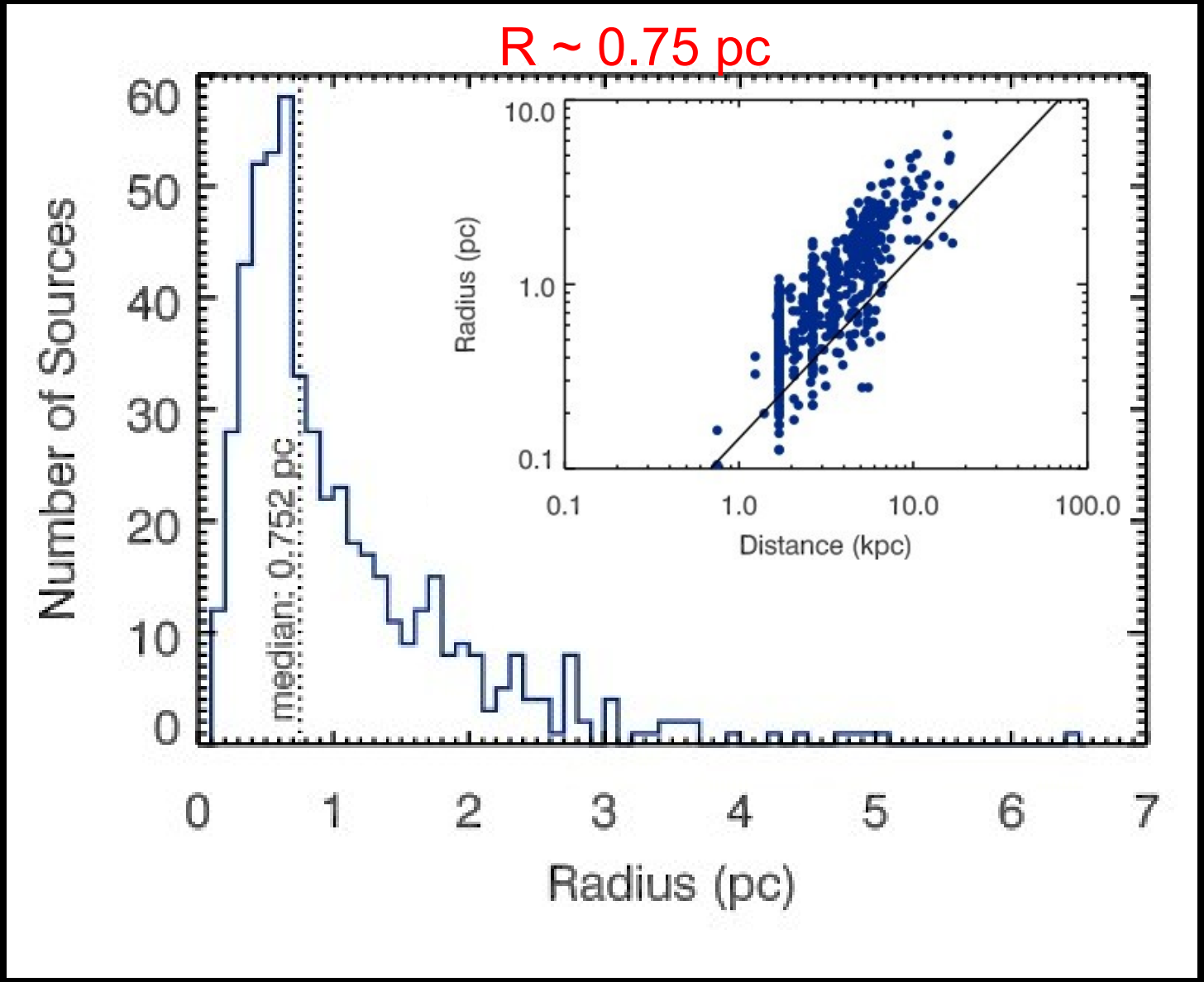
(3) Tangent point

(4) IRDC assoc.

Total N~ 630

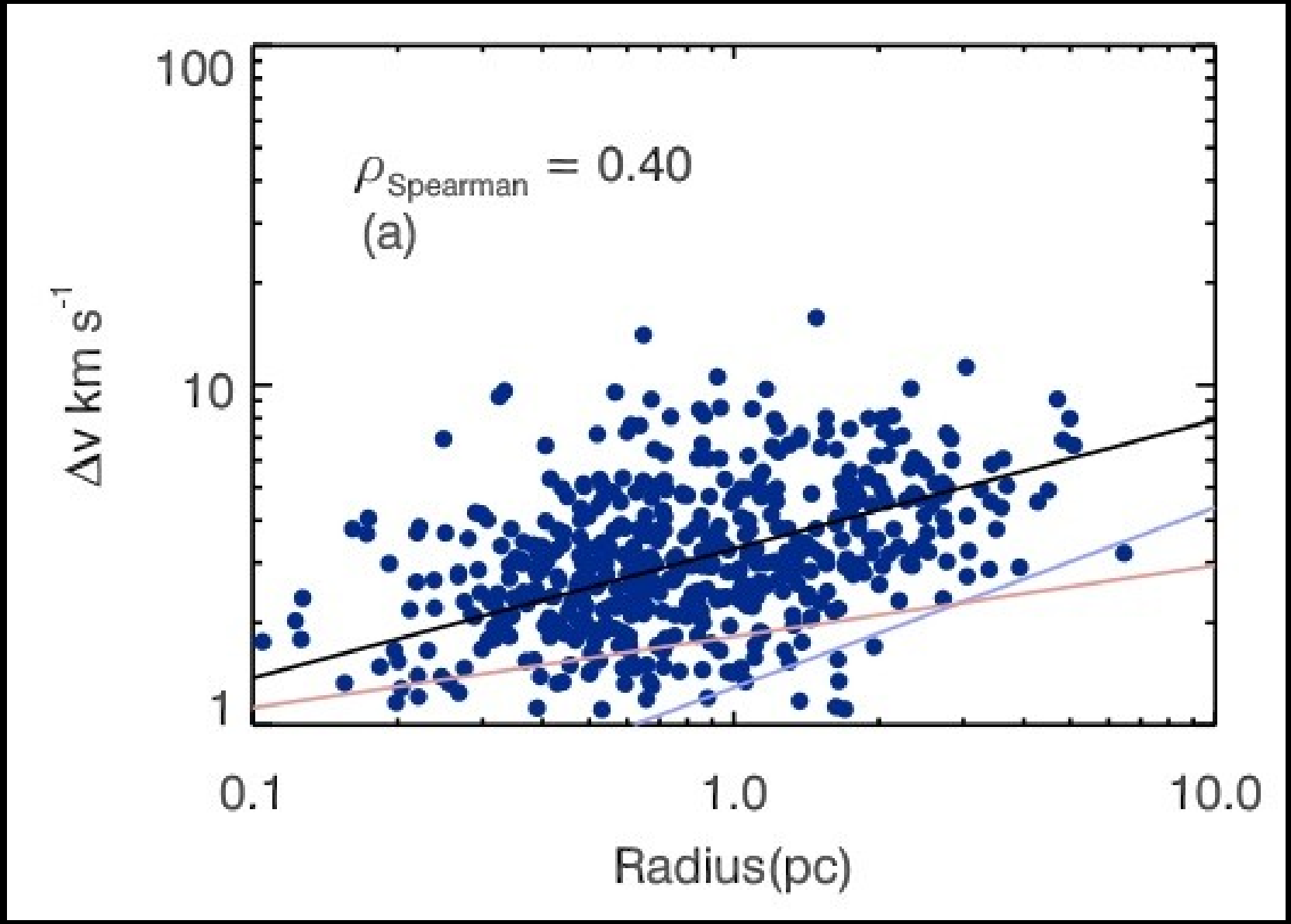
Schlingman et al. 2011

Typical Size = “Clumps”



Schlingman et al. 2011

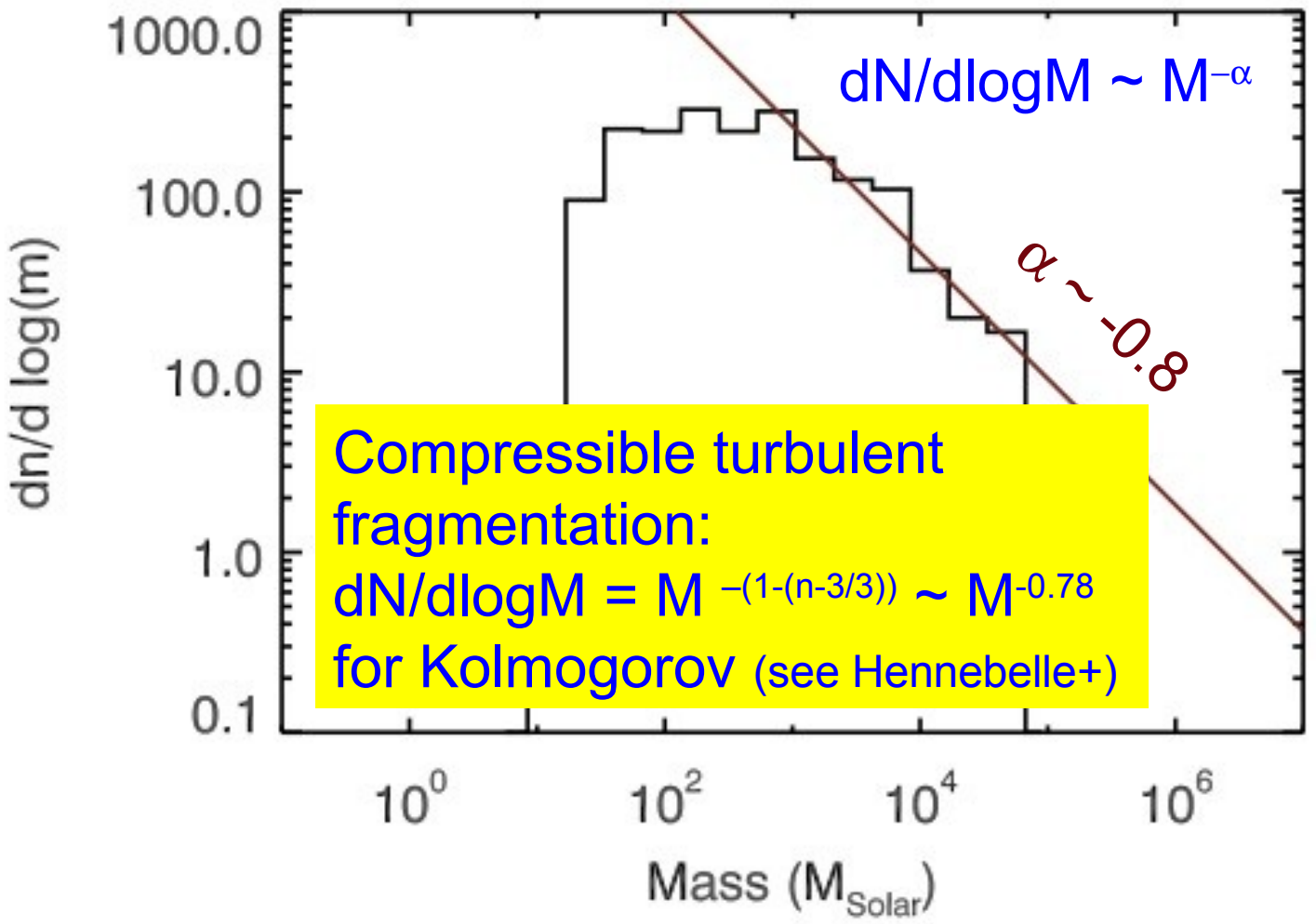
Breakdown of Linewidth-Size Relation



Schlingman et al. 2011

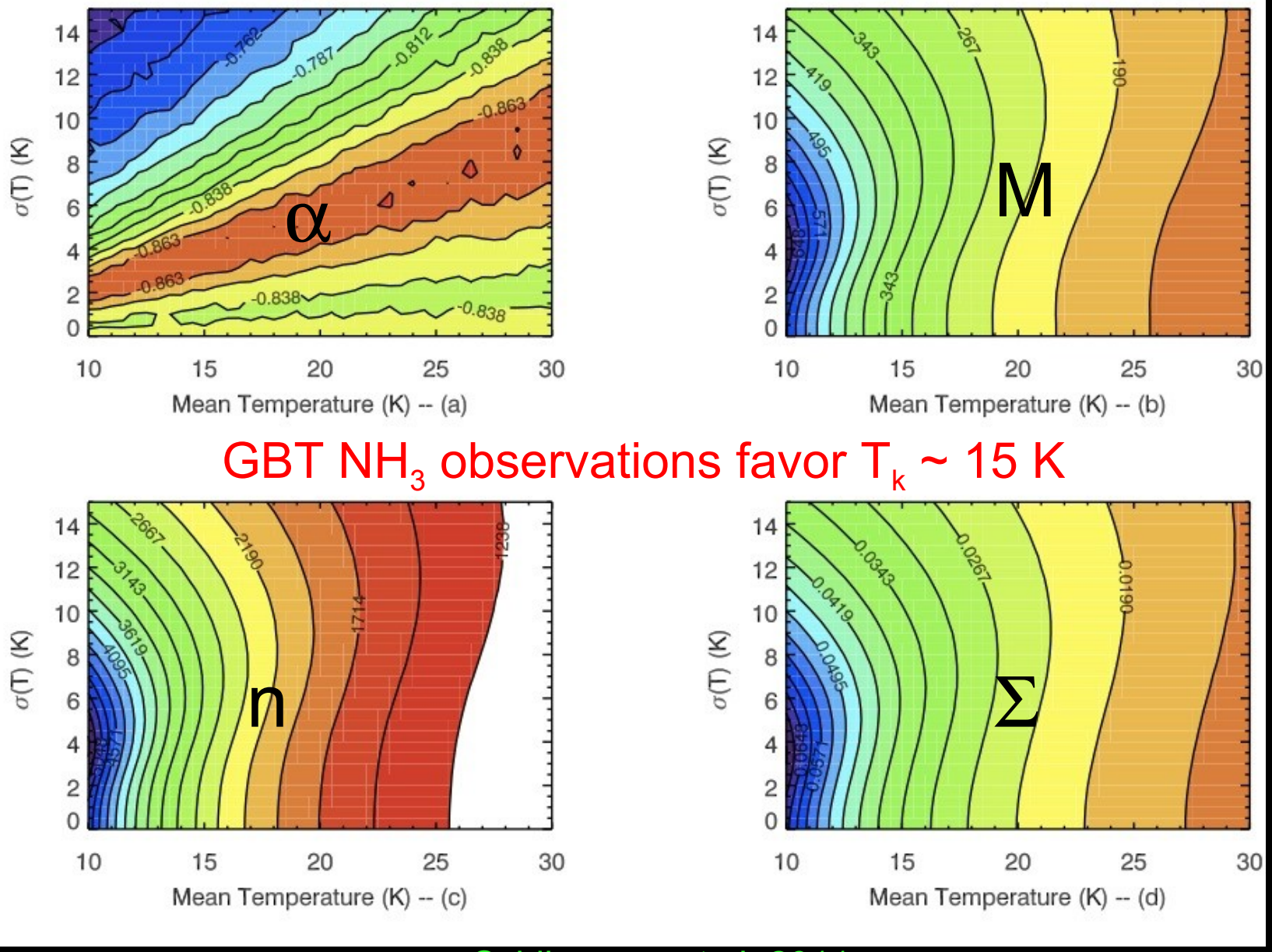
Differential Mass Histogram

Differential Mass



Schlingman et al. 2011

Monte Carlo Simulations of T_d variation

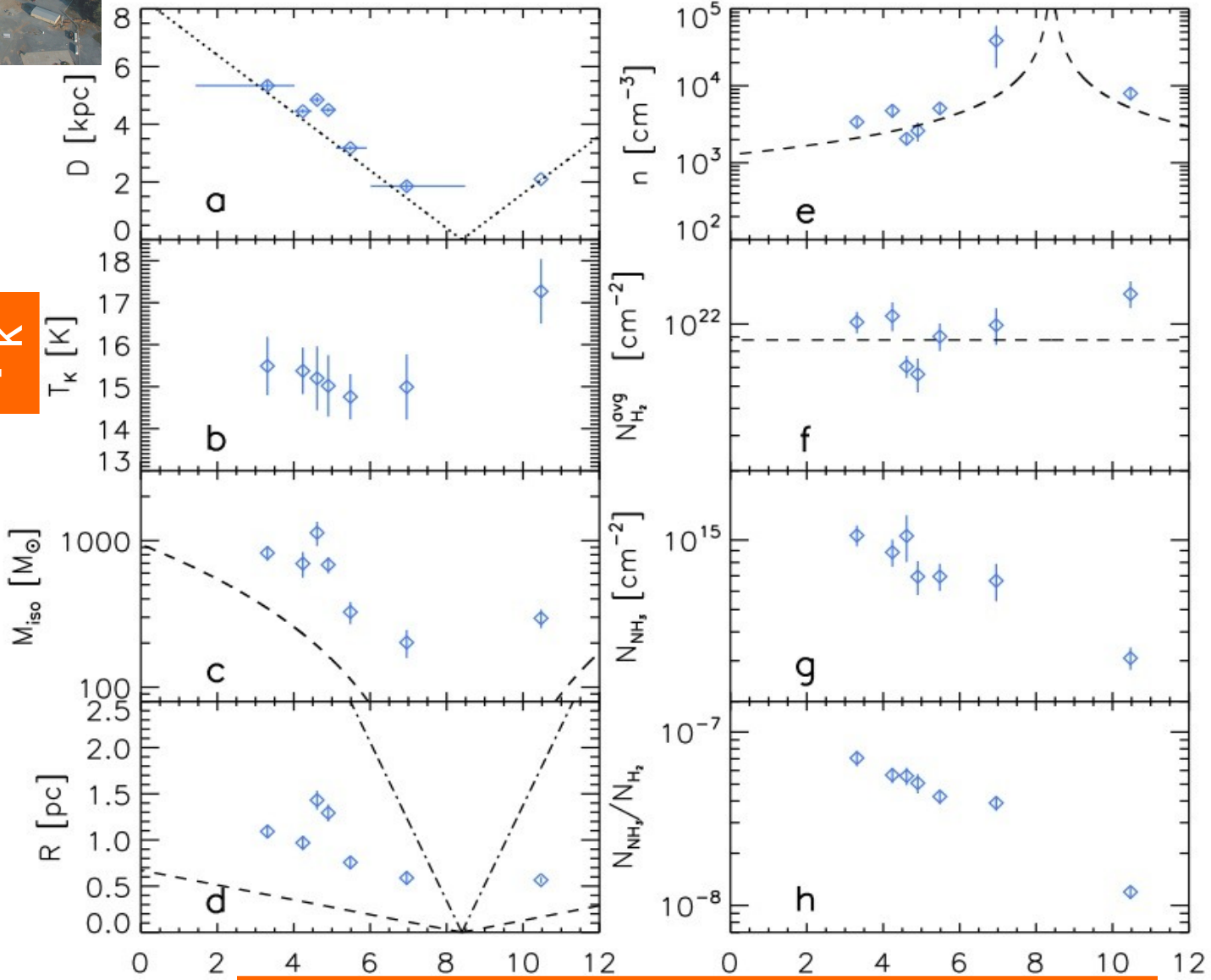


GBT NH_3 observations favor T_k ~ 15 K

Schlingman et al. 2011

GBT Ammonia Survey

T_k



Abundance

Galactocentric Radius

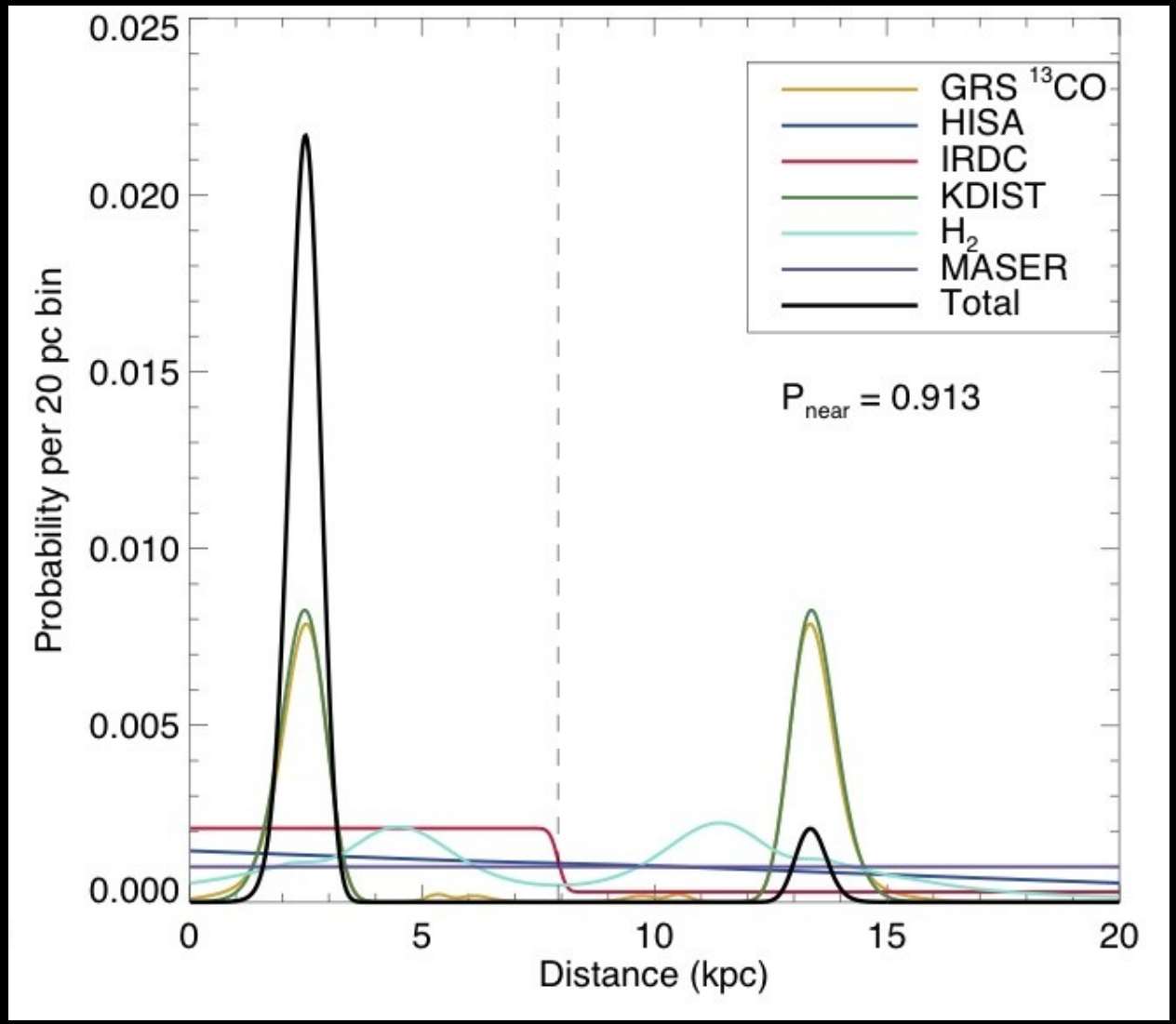
Dunham et al. 2011b

Conclusions – Initial Analysis

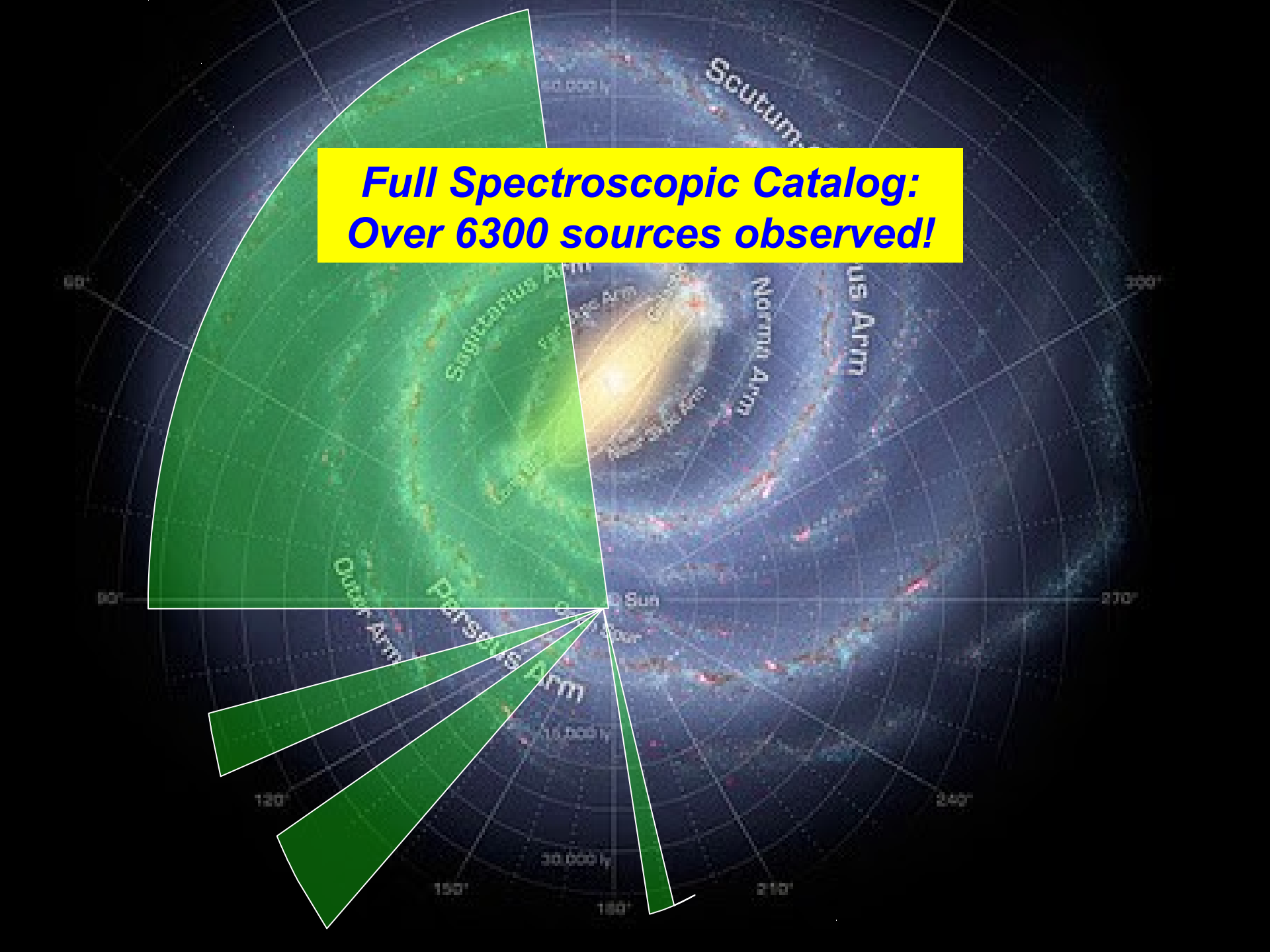
- ¼ of BGPS sources observed – HCO^+ excellent unique dense gas tracer
  - Large variation in N_2H^+/HCO^+ ratio, but no significant trend with 1.1 mm flux
- Typical clump size (median) ~ 0.75 pc, mass ~ 300 M_{sun}, n ~ 2000 cm^{-3}, and Σ ~ 0.02 g cm^{-2}
- Size-linewidth relationship breaks down
  - Linewidth dominated by supersonic turbulence
- $dN/d(\log M) \sim M^{-0.8}$
- Median Free-fall time ~ 750,000 yrs

Schlingman et al. 2011

A probabilistic approach to resolving the distance ambiguity



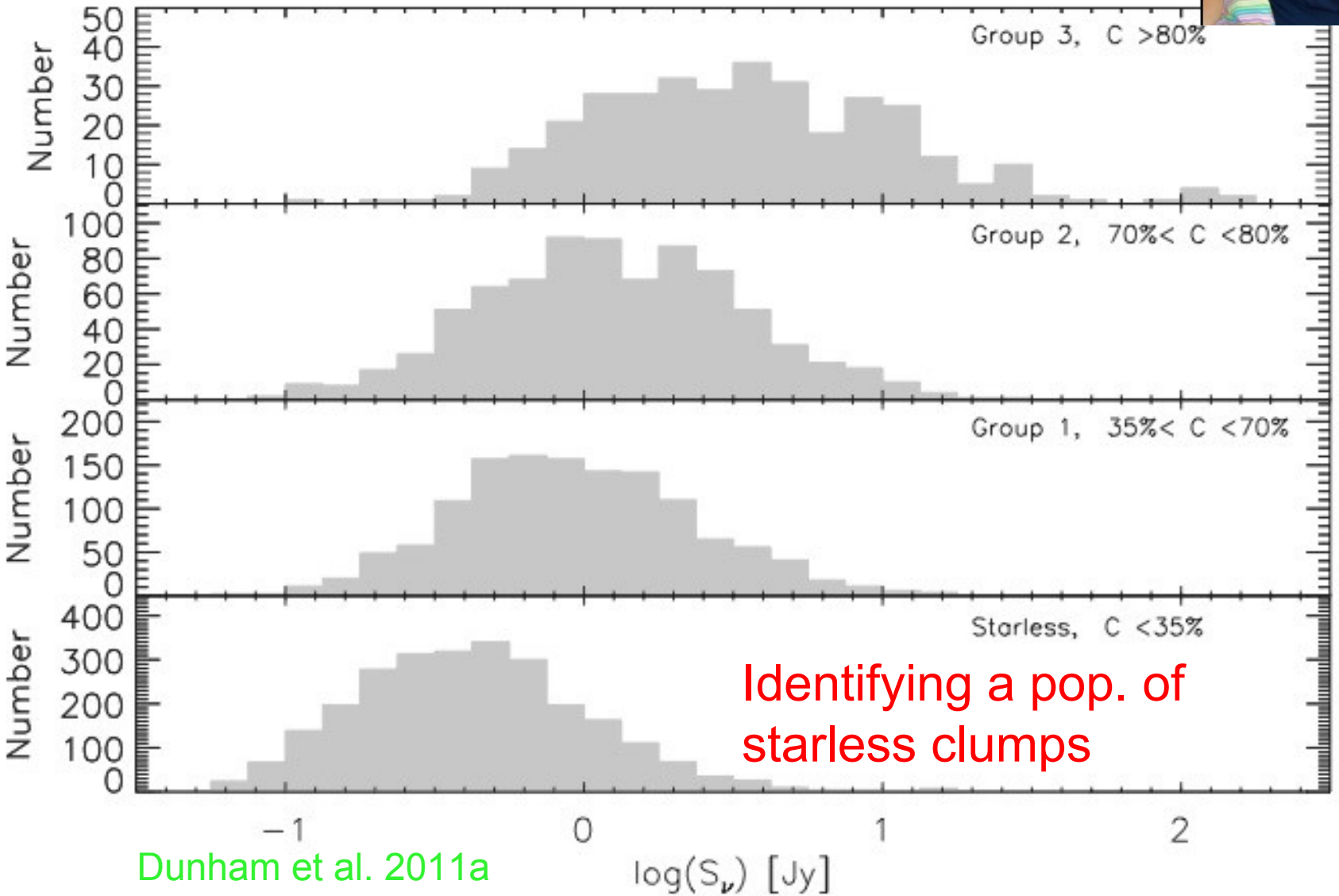
Bowers et al. 2012 in prep.


Full Spectroscopic Catalog:
Over 6300 sources observed!
Scutum-Centaurus Arm
Norma Arm
Outer Arm
Perseus Arm
Sun
60°
300°
90°
270°
120°
240°
150°
210°
180°

Future Plans – Analyzing BGPS

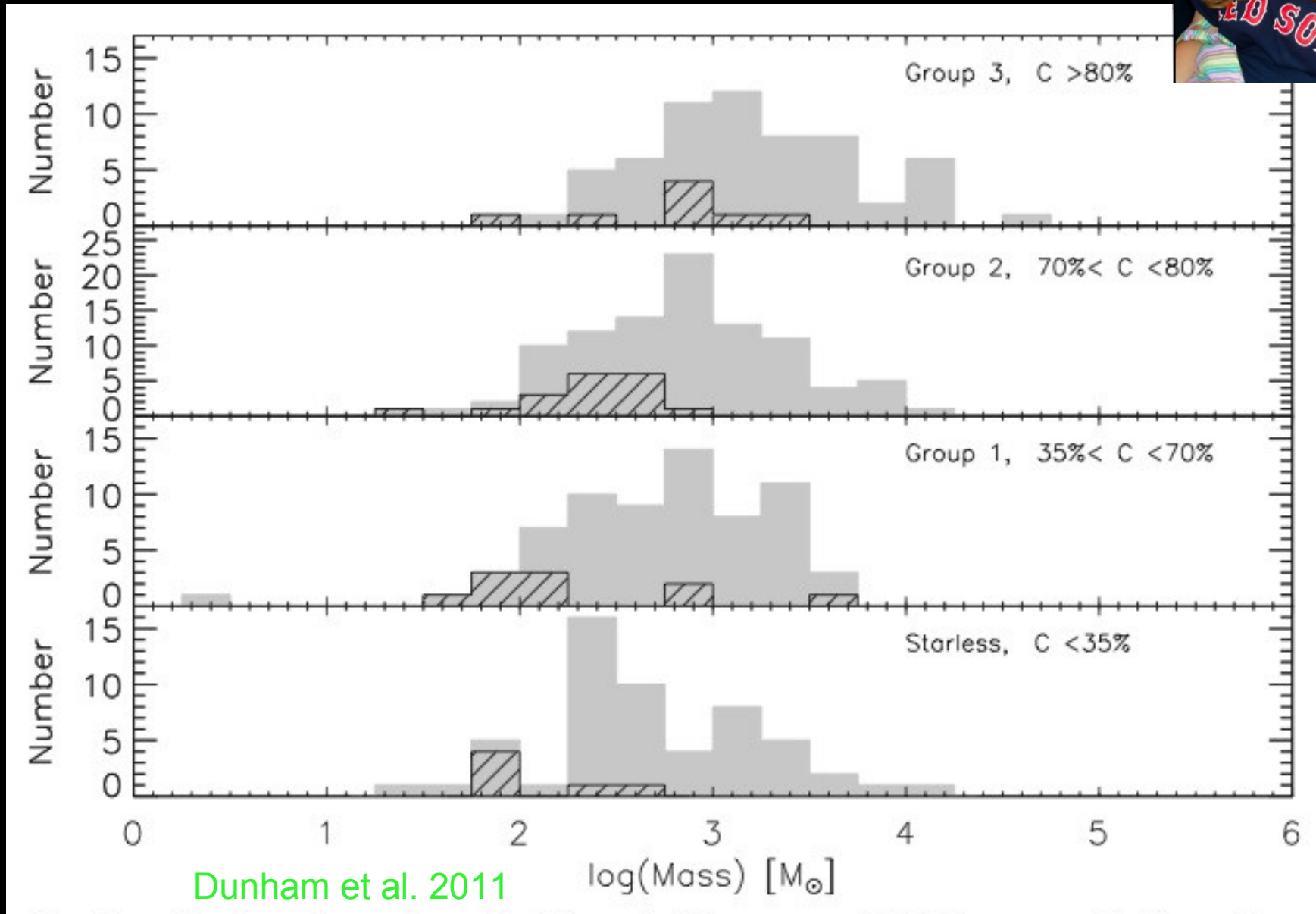
- ***Completed HHT observations of over 6300 BGPS sources l > 7.5 deg (Shirley et al.)***
  - ***Catalog publically released Fall 2012 – ask Yancy if need in advance***
- ***Release of v2.0 BGPS images and catalog by Ginsburg et al. Fall 2012***
- Bowers et al. developing probabilistic method for distance ambiguity resolution to be applied to all BGPS source.
- Ultimately compare BGPS source properties with Galactic environment and evolutionary indicators

Embedded IR Sources



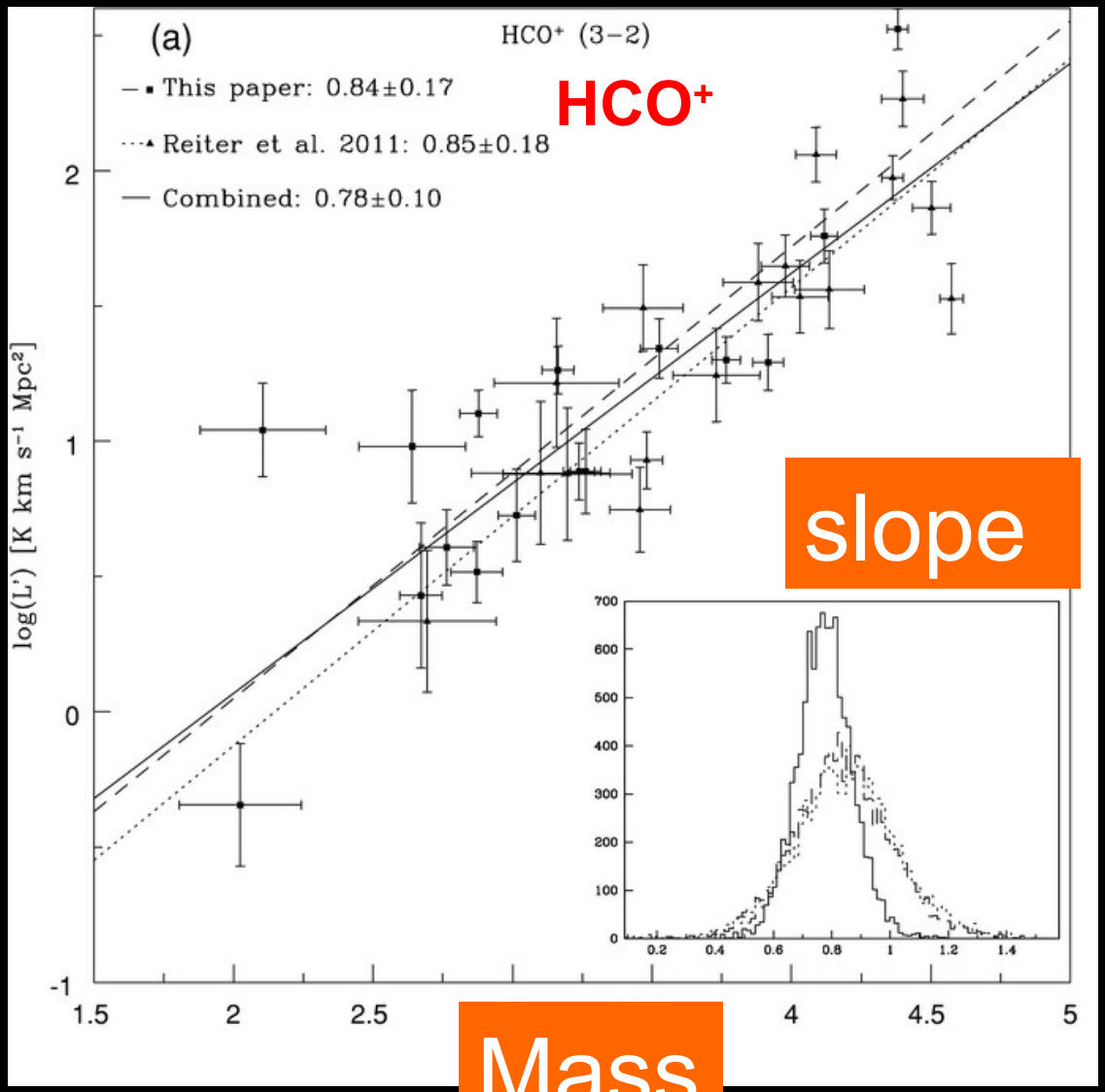
Dunham et al. 2011a

Clump Mass with/without IR Sources



Dunham et al. 2011

L’ correlates well with Mass



HCO+

L’ molecule

slope

Mass

Schenck et al. 2011