Starless Clumps through Protoclusters: Physical properties of clumps from the Bolocam Galactic Plane Survey

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Image Credit: Adam Ginsburg

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Clumps

BGPS 1.1 mm Survey Data

`Bolocat` Source Extraction

Common Survey Overlap $10 < l < 65$

SF Indicators

Starless Clump Candidates

Protostellar Clumps

HG70 Uniq. : Hi-GAL 70 um Unique

Mid. IR : 2–20 um YSO

H_2O : Water Maser

CH_3OH : Methanol Maser

UCHII : Ultra-Compact HII Reg.

Monte Carlo

Contamination Resampling

Monte Carlo Random Sample

d Heliocentric Distance PDF

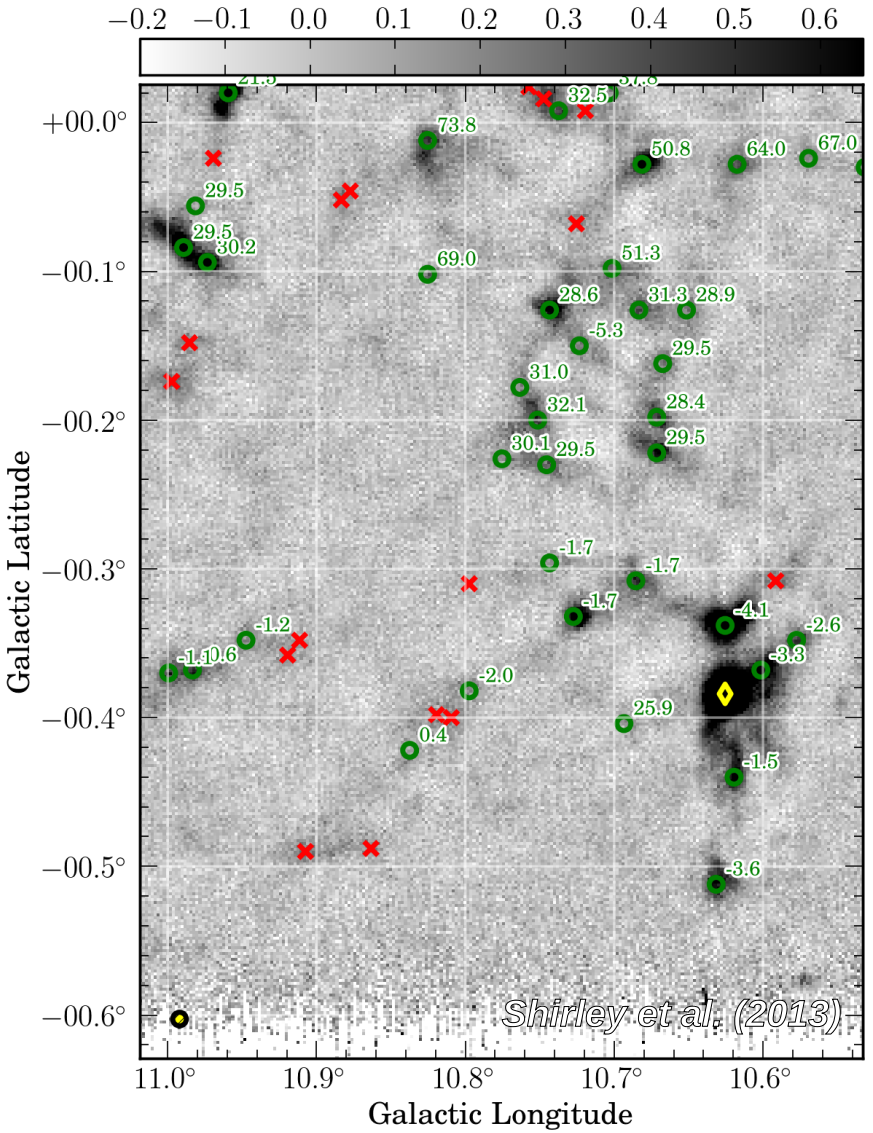
T_K Observed OR Category PDF

$S_{1.1}$, Δv, θ_{eq}, ... Observed

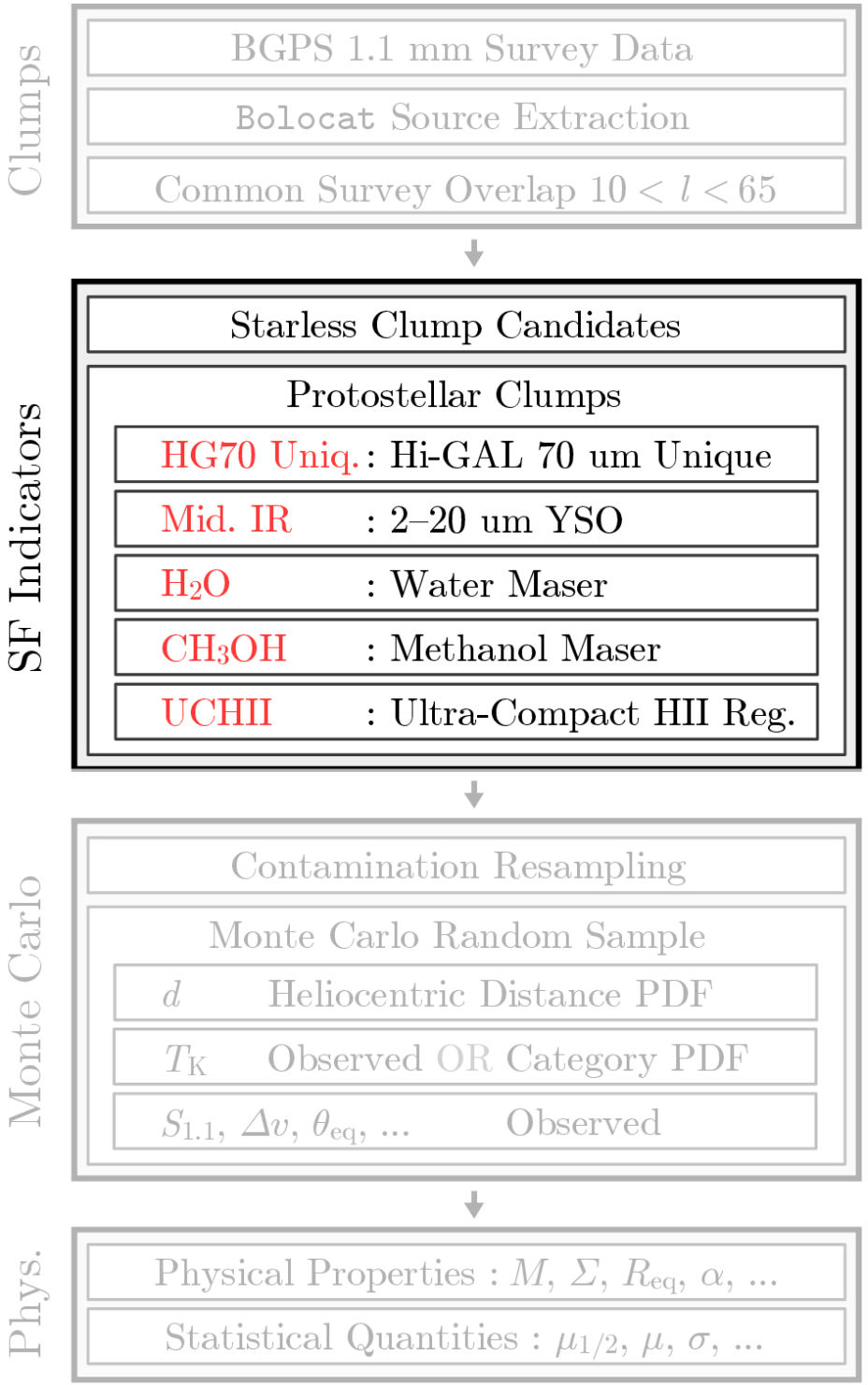
Phys.

Physical Properties : M, Σ, R_{eq}, α, ...

Statistical Quantities : $\mu_{1/2}$, μ, σ, ...



4683 clumps in survey overlap
2925 unique velocities
1462 GBT NH_3 gas kinetic temps.
1650 well-constrained distances



2237 (48%) **Starless Candidate**
2446 (52%) **Protostellar**
1043 (22%) **Hi-GAL Unique**
70 um visual inspection
1022 (22%) **Mid. IR**
Red MSX, EGO, Robitaille+08
461 (10%) **Water Maser**
GBT, Arcetri, HOPS
237 (5%) **Methanol Maser**
MMB, Arecibo, Pestalozzi+05
170 (4%) **UCHII**
CORNISH

Not an Evolutionary Sequence:
Sorted by more extreme indicator of star-formation activity.

Indicators are not Unique:
There exists significant overlap Between all individual indicators.

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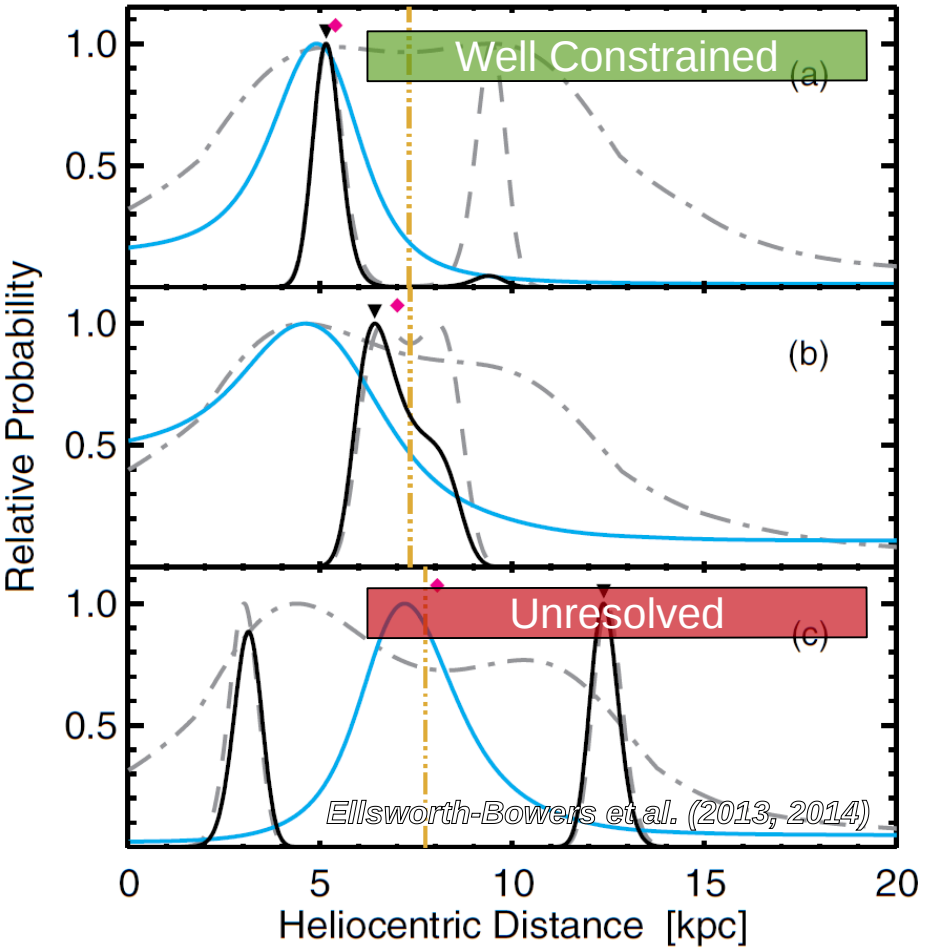
Resample: 280 (6%) R08 unique

AGB 50% **YSO**

Clump **Distance PDF**
Monte Carlo simulations to calculate physical properties

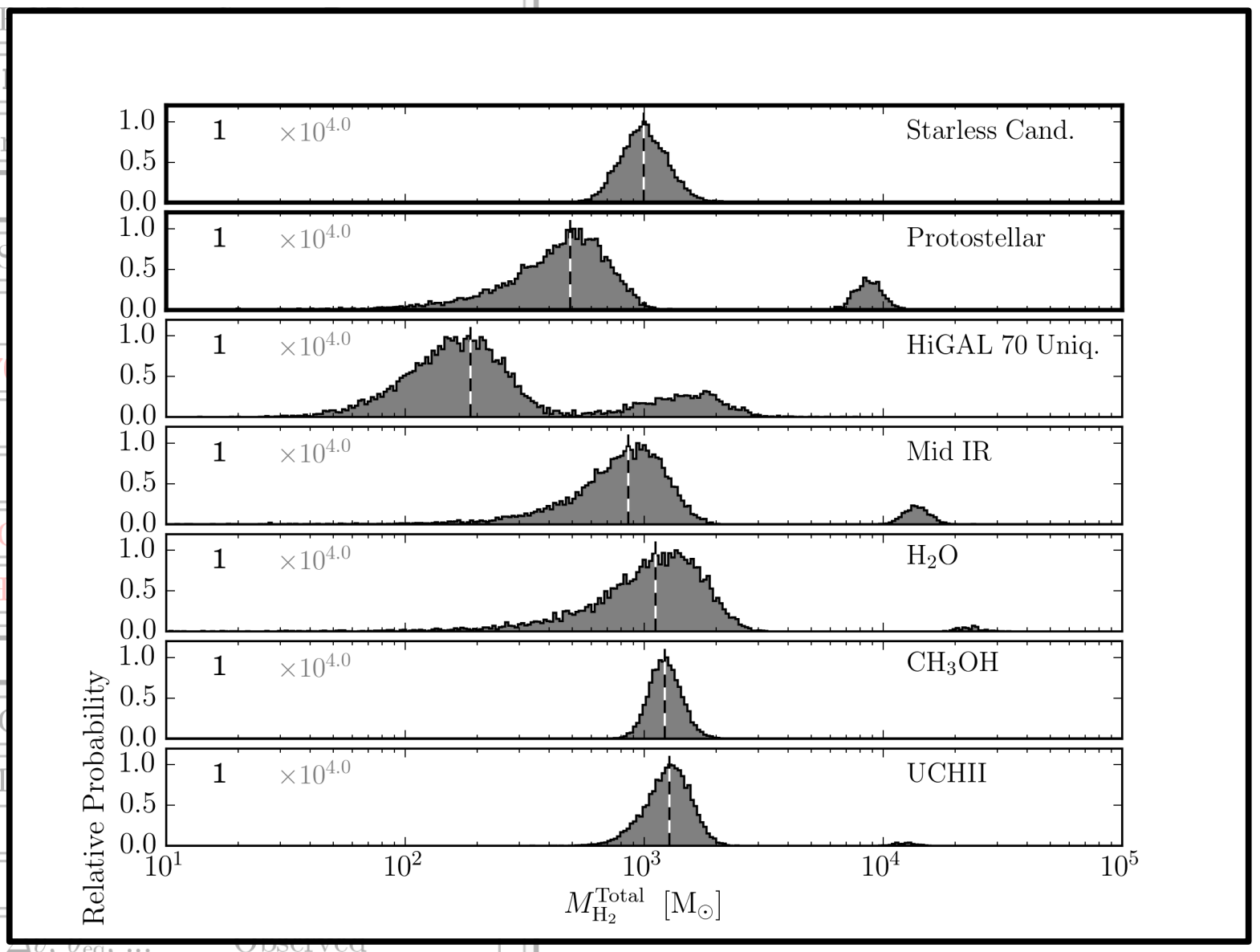


Clumps

SF Indicators

Monte Carlo

Phys.

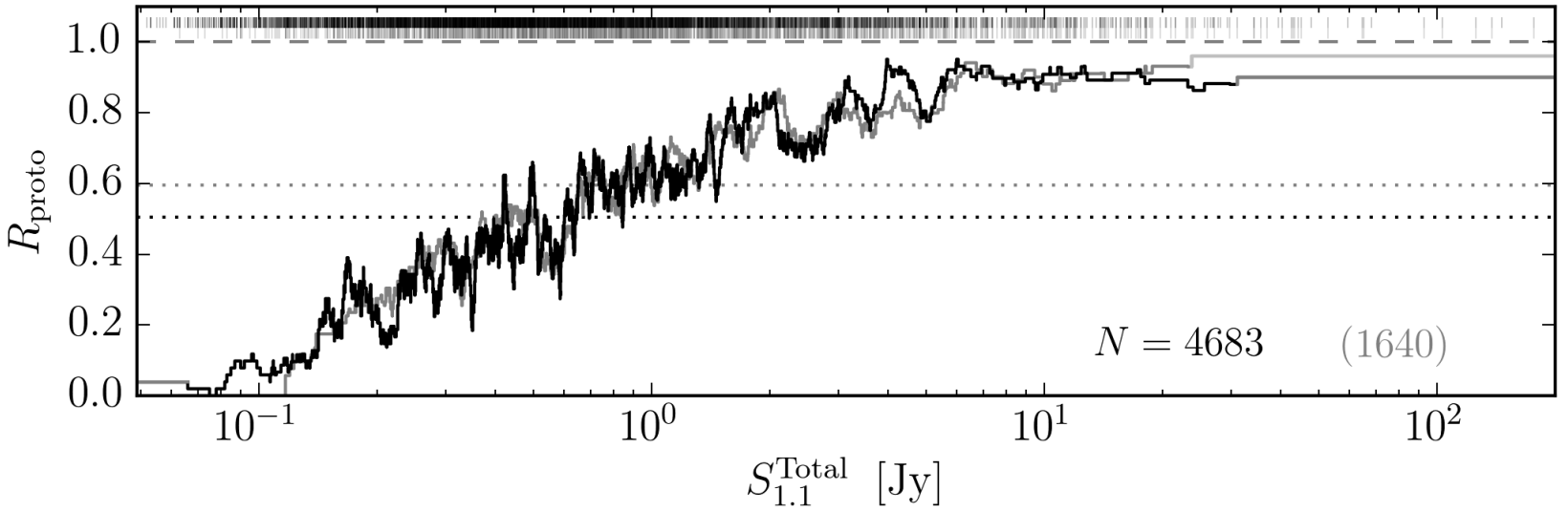


Physical Properties : M, Σ, R_{eq}, α, ...

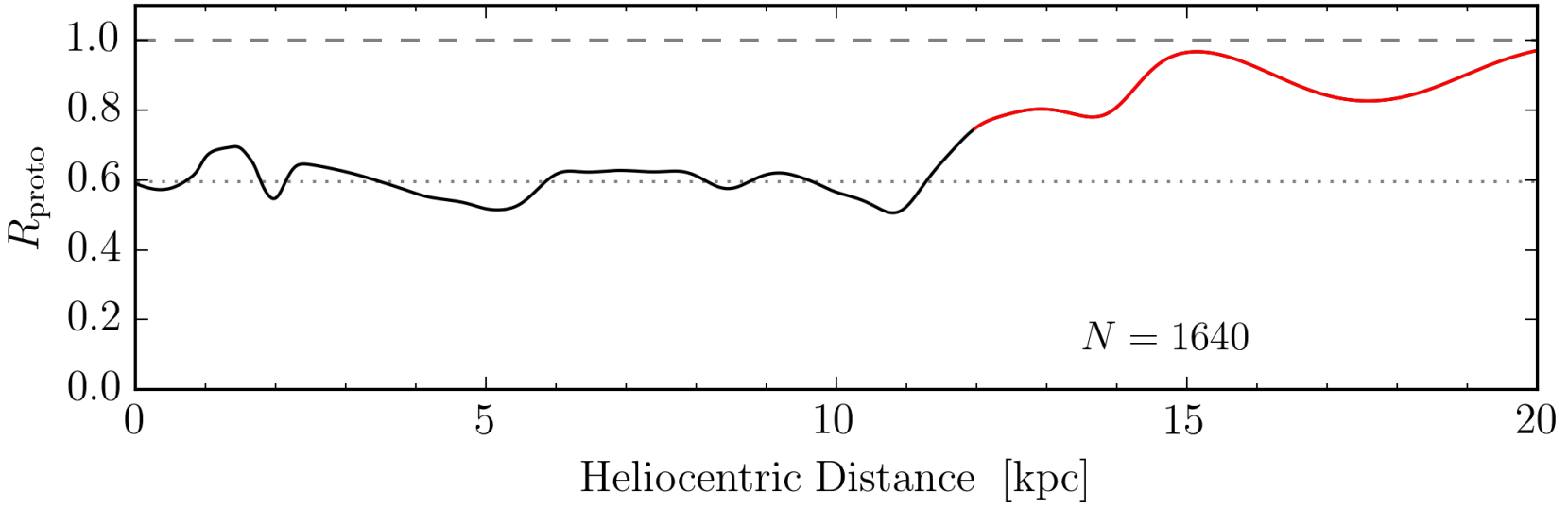
Statistical Quantities : $\mu_{1/2}$, μ, σ, ...

Single clump: MC simulations for a single clump, high relative uncertainties but large samples.

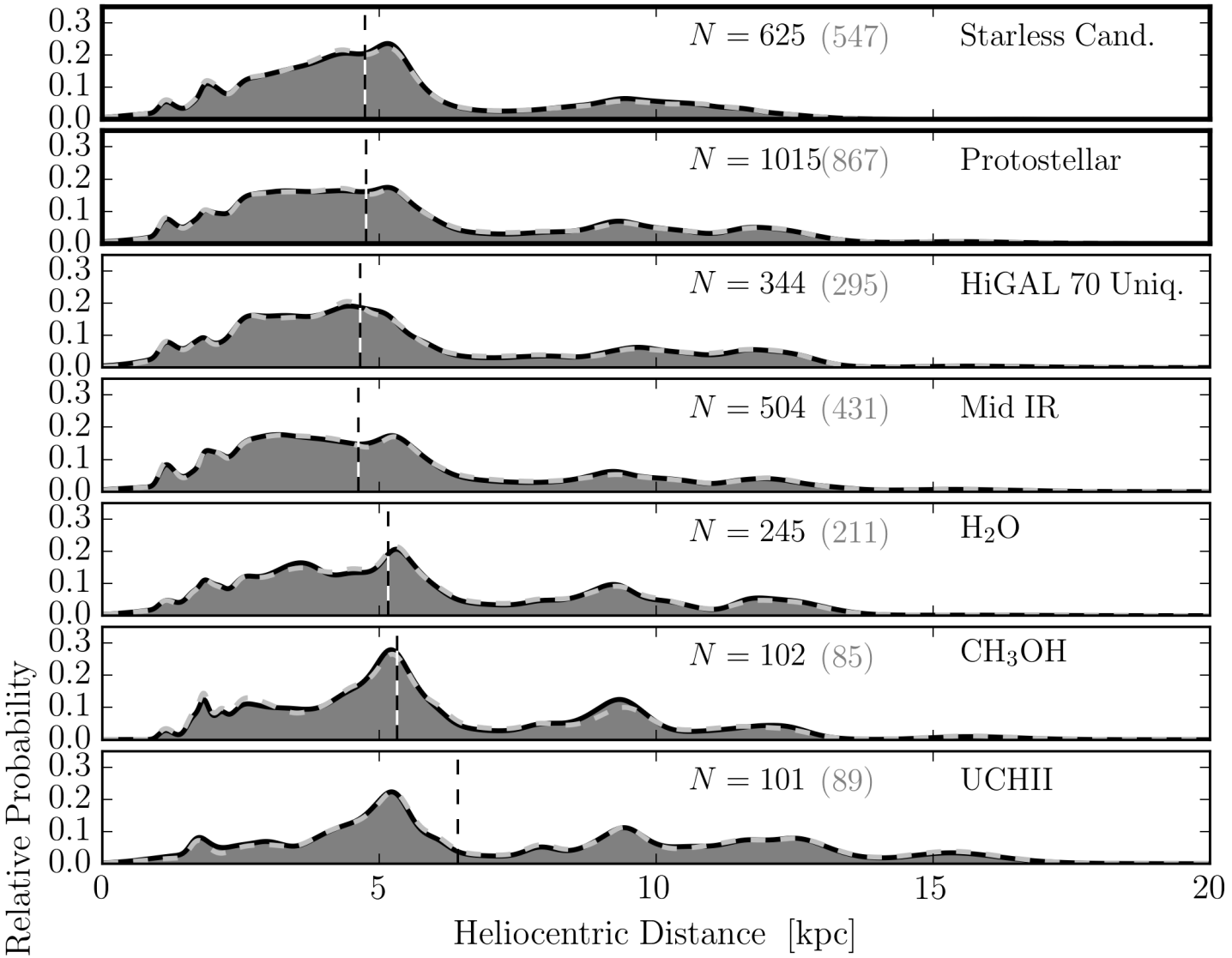
Flux Density: Lower flux clumps more frequently starless, but Full and Distance samples similar.



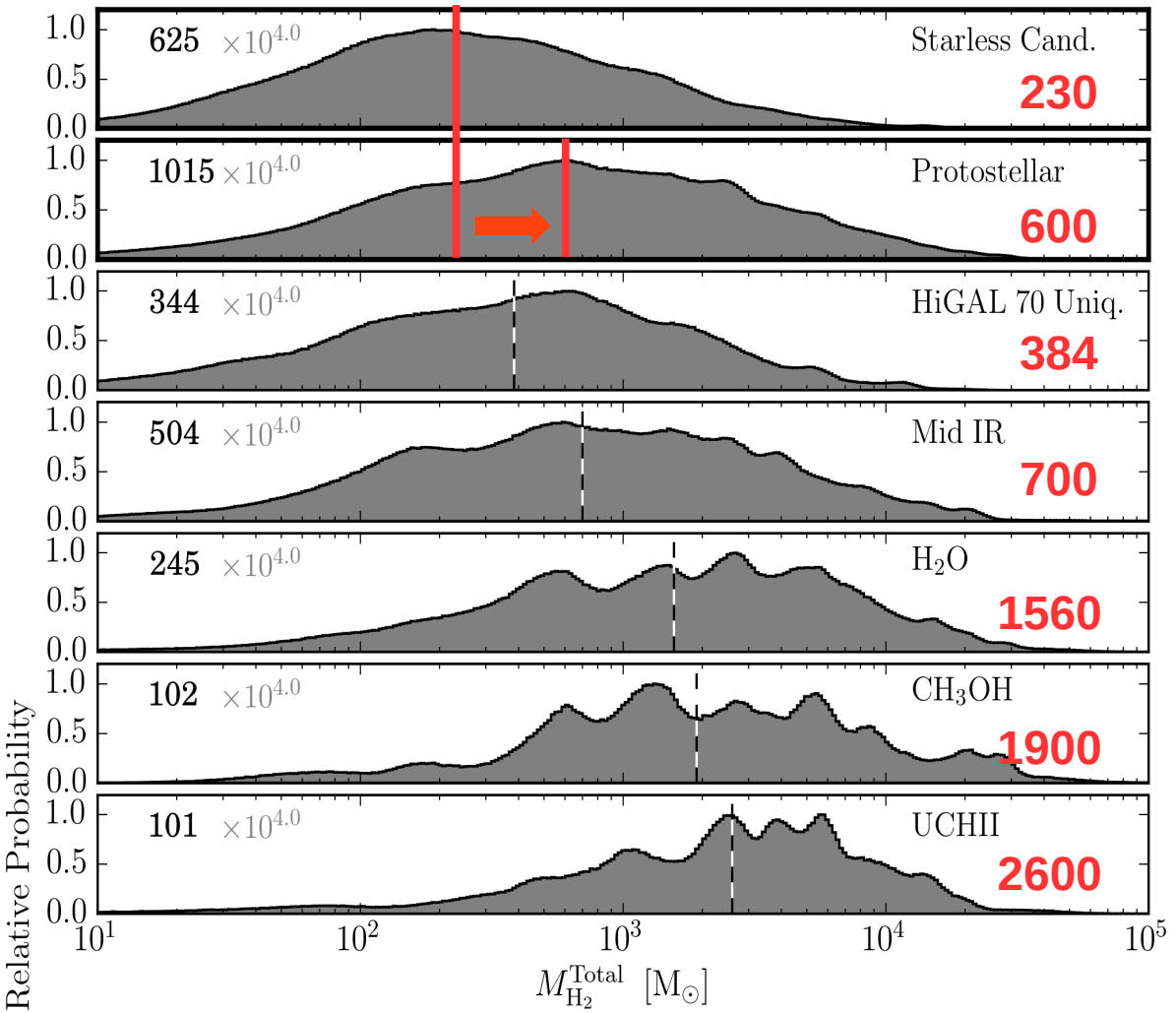
Distance PDFs: Fraction is constant. Does not suggest significant incompleteness in indicators.



Distance PDFs: Group distances are similar. Does not suggest strong distance bias.



Mass Segregation: Increase in median mass from 230 to 600 from Starless to Protostellar. Evidence for growth?



Cannot be due to:

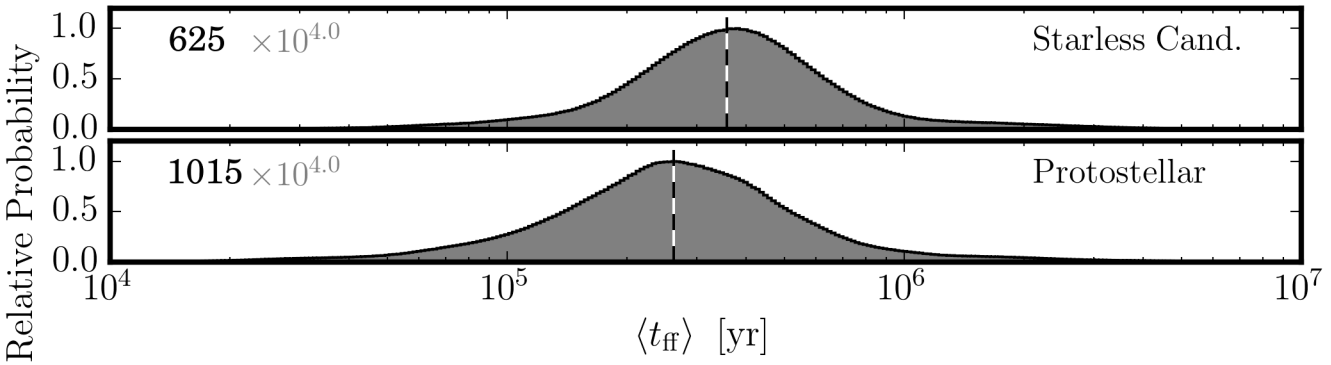
- Mass incompleteness for starless candidates
- NH_3 underestimate of TK
- Isothermal assumption
- Bias in distance or incomplete SF indicators

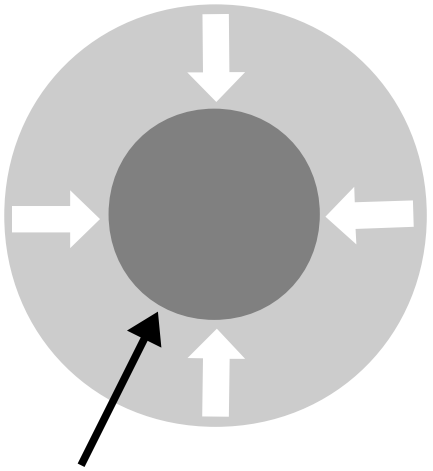
Explanations:

- Trend in dust opacity
- Decreasing lifetime of starless phase with mass
- Accretion onto clump from surrounding cloud: *"mass conveyor belt"*

BGPS clump total mass (isothermal) from MC simulations that sample fluxes, temperatures, and distances.

Mass Growth: Accretion rate and total mass growth consistent with reasonable assumptions of GMC properties.



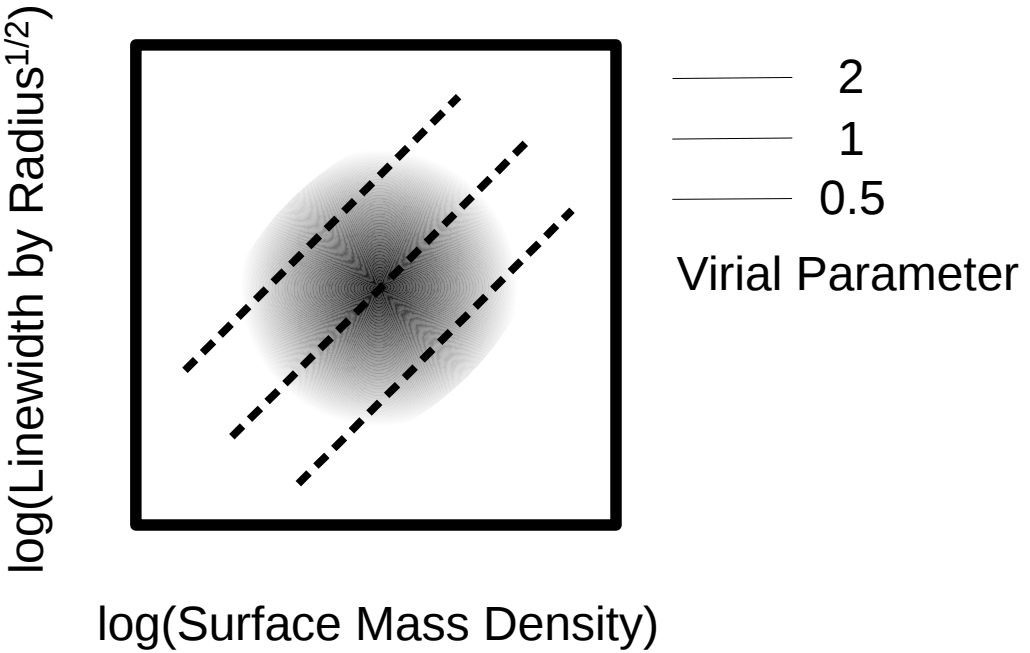


Clump : R ~ 1 pc

Feeding Zone : R ~ 1.5 pc

- Calculated free fall time is **~0.3 Myr**. Median mass difference of **~350 M_{sun}** implies **~10^{-3} M_{sun} yr^{-1}** , similar to that of a high-mass protostar.
- GMC gas velocities of **1.5 km s^{-1}** suggest feeding zone of **0.5 pc** over 0.3 Myr, with **~500 cm^{-3}** densities yields a mass reservoir of **~350 Msun**

Virialized motions: No correlation in size-linewidth observed, but related by parametrization in Heyer+09. Median follows α of unity.



Monte Carlo simulations
create two dimensional distribution

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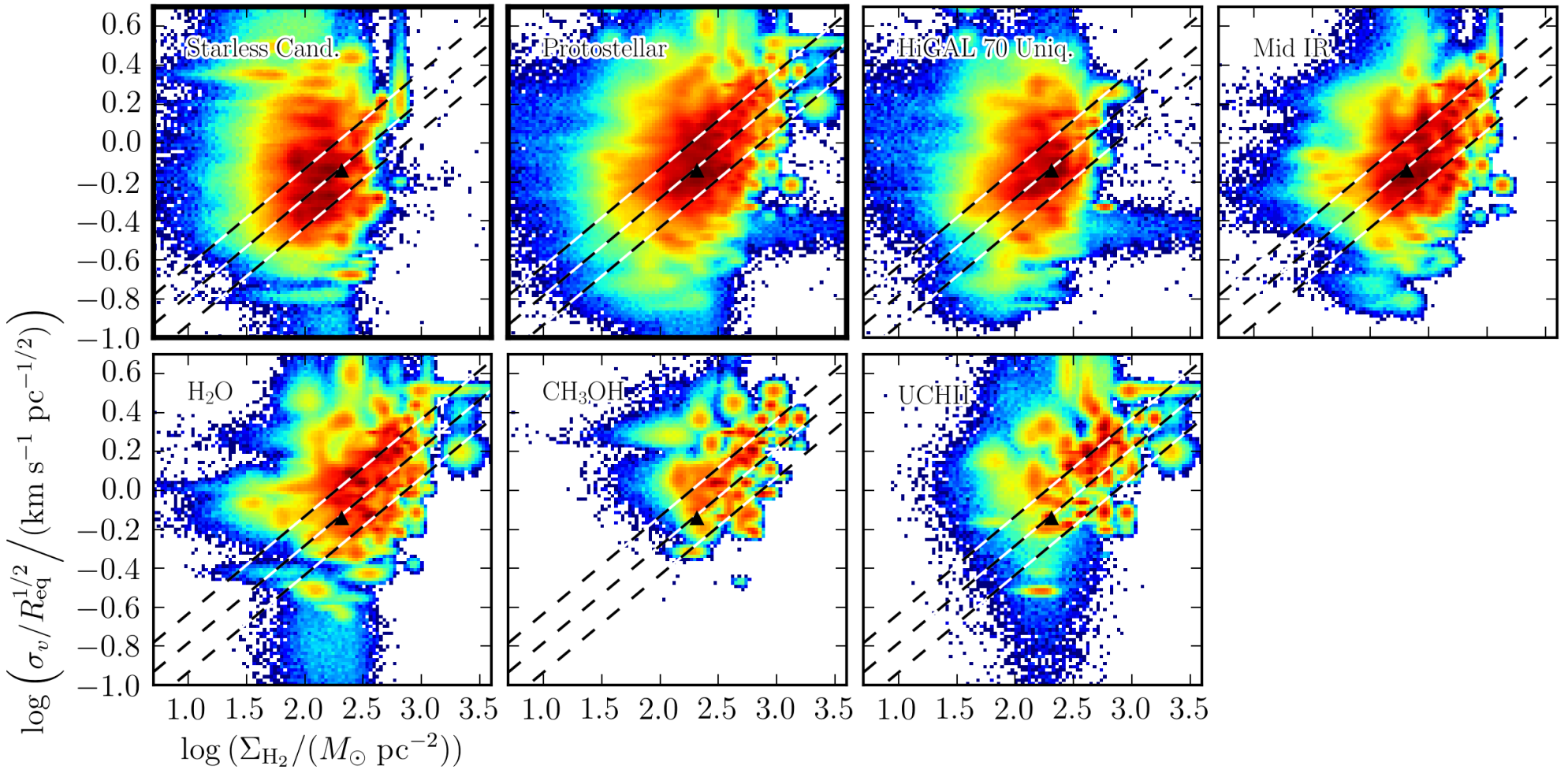

Parametrization from Heyer+09, virial parameters of 2, 1, 0.5 overplotted with triangle for median from Solomen+82

In comparison, no correlation observed in size-linewidth

Summary and Conclusions

- We sort BGPS clumps by star-formation indicators, and with unique-velocities, temperatures, and distances PDFs, we compute MC simulations of clump physical properties
- Sample of **~2200** starless clump candidates, the largest and most robust sample to date
- Consistent trends by indicator suggest that starless candidates are colder, lower column density, narrower linewidth, less concentrated, smaller, less dense, and less massive than active clumps
- Increase in median mass is suggestive of multiple explanations: cloud accretion, lifetime effects, and systematic biases in assumptions (beta, etc.)
- The majority (75%) of clumps are gravitationally bound by having virial parameters less than two.