The Mass and Size of Clouds and Cores

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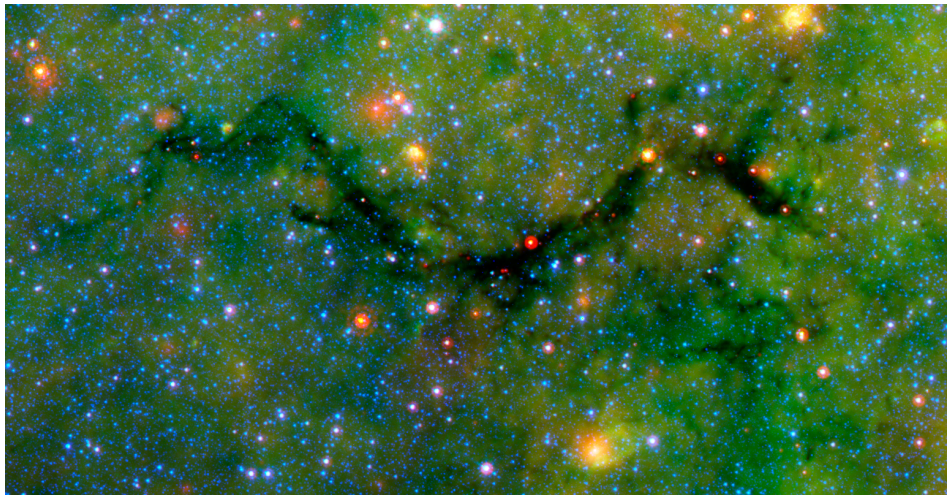
Early Phases of Star Formation
Ringberg, Germany, 2010 June 14

Nested Structure



or

Cloud Structure Studies

massive star formation (MSF)

Paresce et al.

formation of MSF dense cores:

- overall density?
- cloud hierarchy?

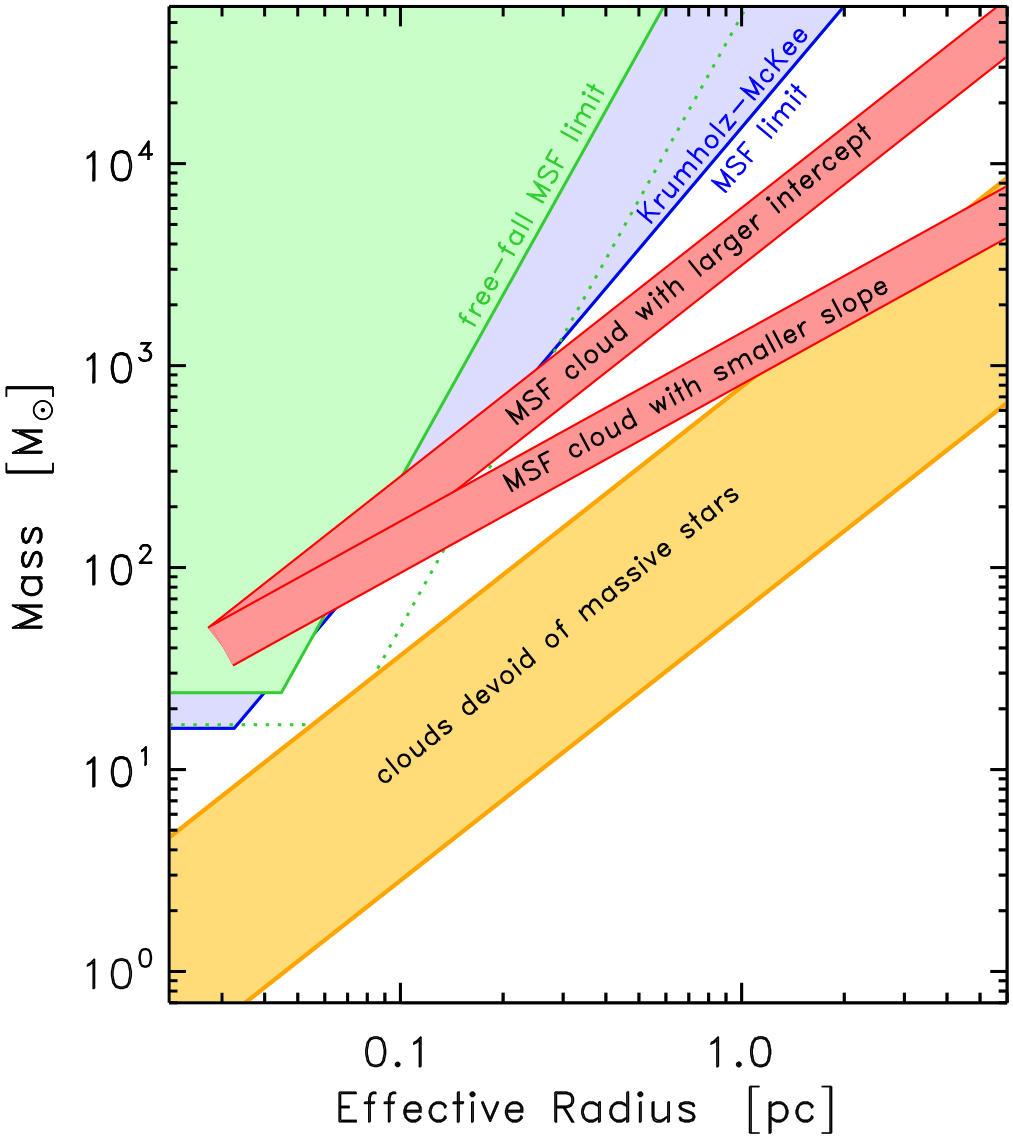
$\Rightarrow$ MSF criteria

low-mass star formation

Martial Figenwald

MSF criteria
$\Rightarrow$ assess SF from large distances
$\Rightarrow$ constrain galactic SF budget

Mass-Size Diagram as a Diagnostic Tool



References

Kauffmann et al. (2010a,b,c)
Papers I–III

Contributors

COMPLETE survey of star-forming regions, lead by Alyssa Goodman

with help from:

- Rahul Shetty
- Phil Myers
- Jaime Pineda
- Jonathan Foster

Erik Rosolowsky:
dendrogram code

Thushara Pillai:
Co-I and data

Outline

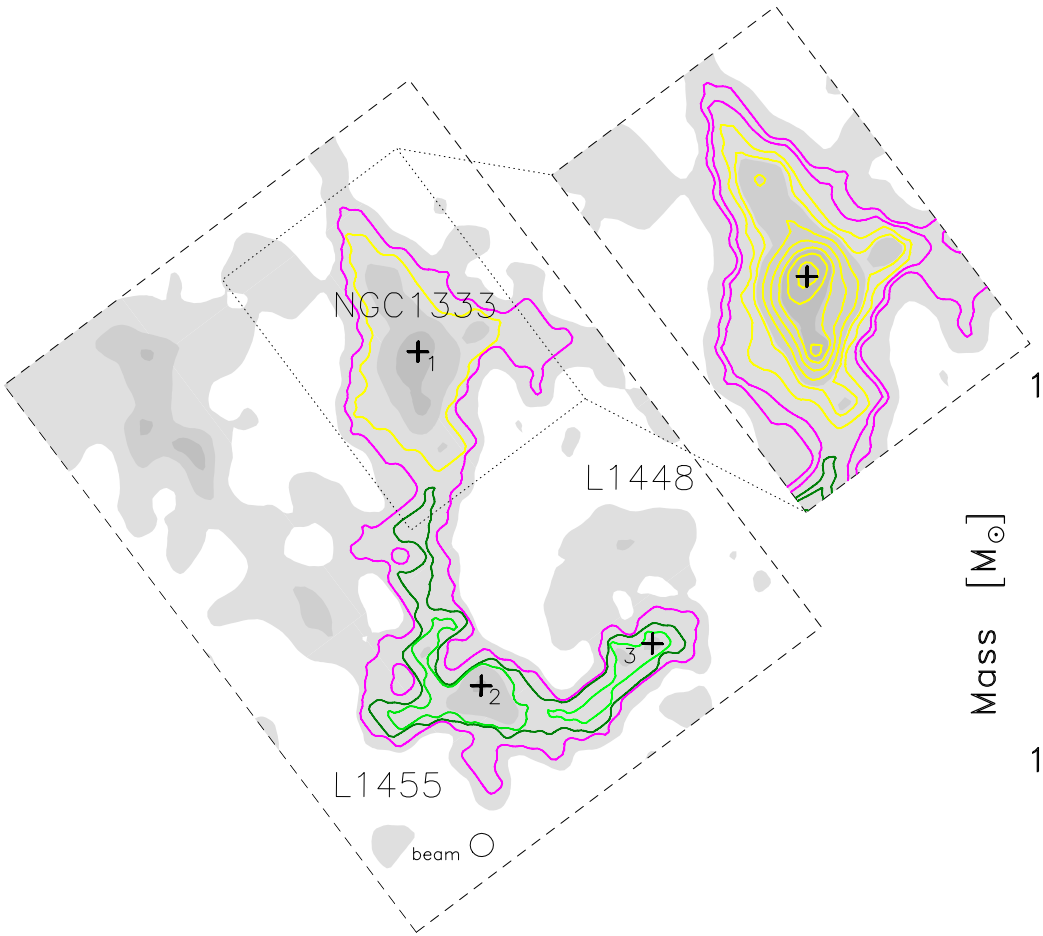
Outline

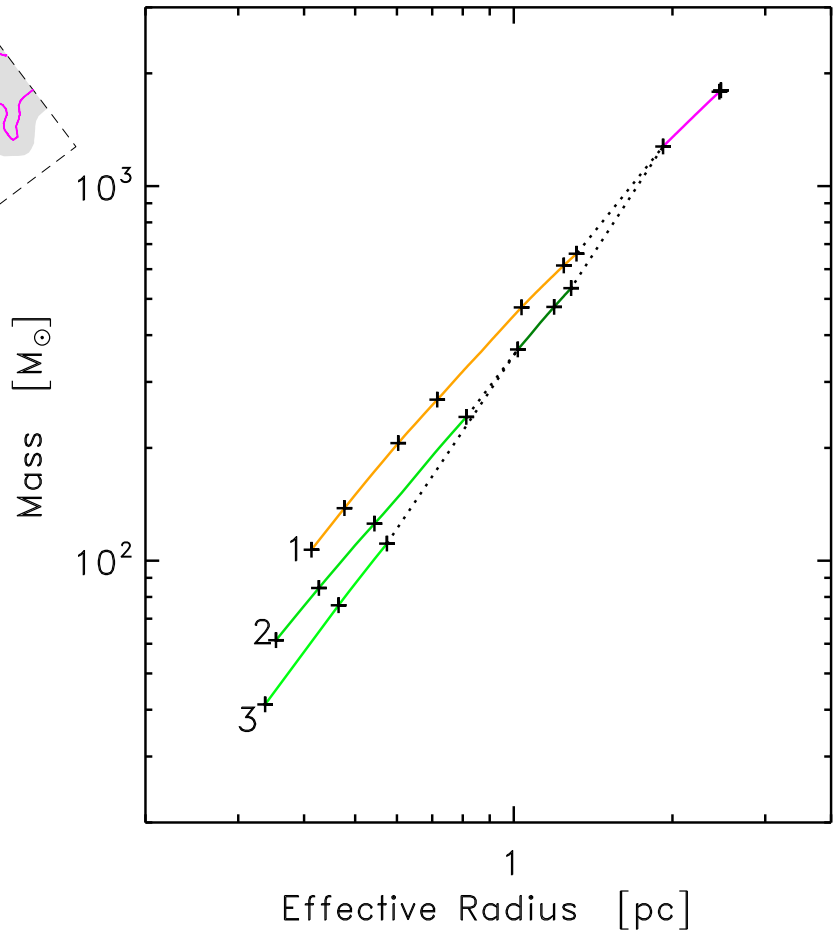
References

Rosolowsky et al. (2008)

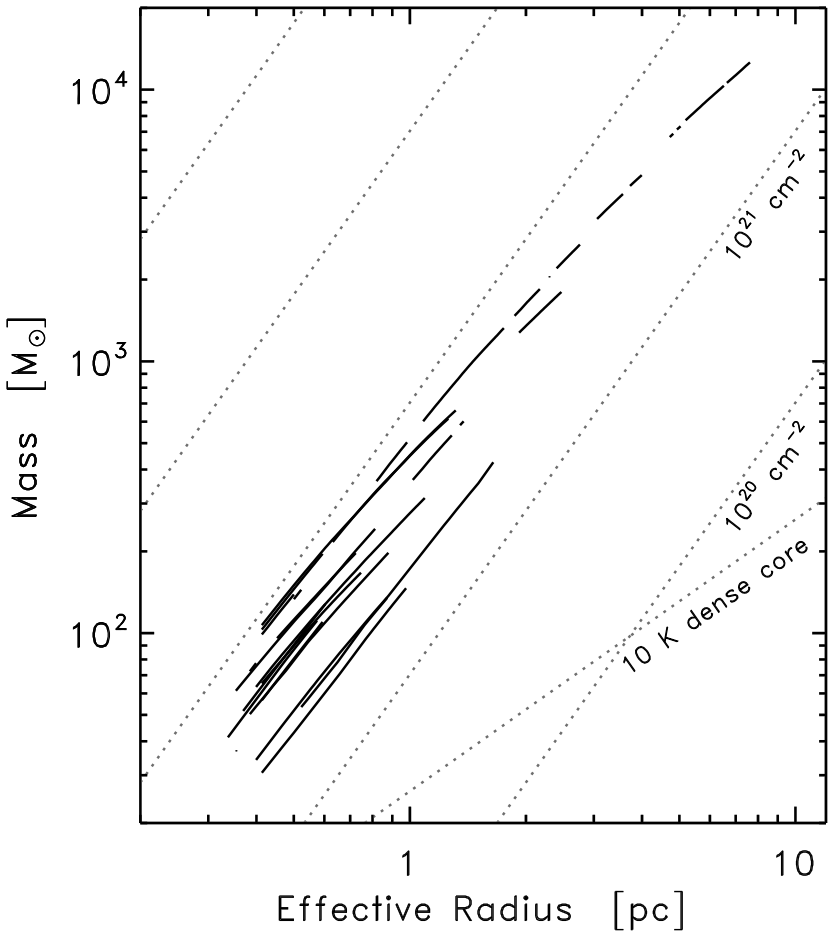
Kauffmann et al. (2010a), paper I

Method


NGC1333
1
L1448
3
2
L1455
beam


10^3
10^2
Mass [$M_\odot$]
1
2
3
1
Effective Radius [pc]

Basic Properties



generally:

$$m(r) = 71\,M_\odot \left(\frac{\langle N_{H_2}\rangle}{10^{21}\ \mathrm{cm}^{-2}}\right)\left(\frac{r}{\mathrm{pc}}\right)^2$$

for spheres:

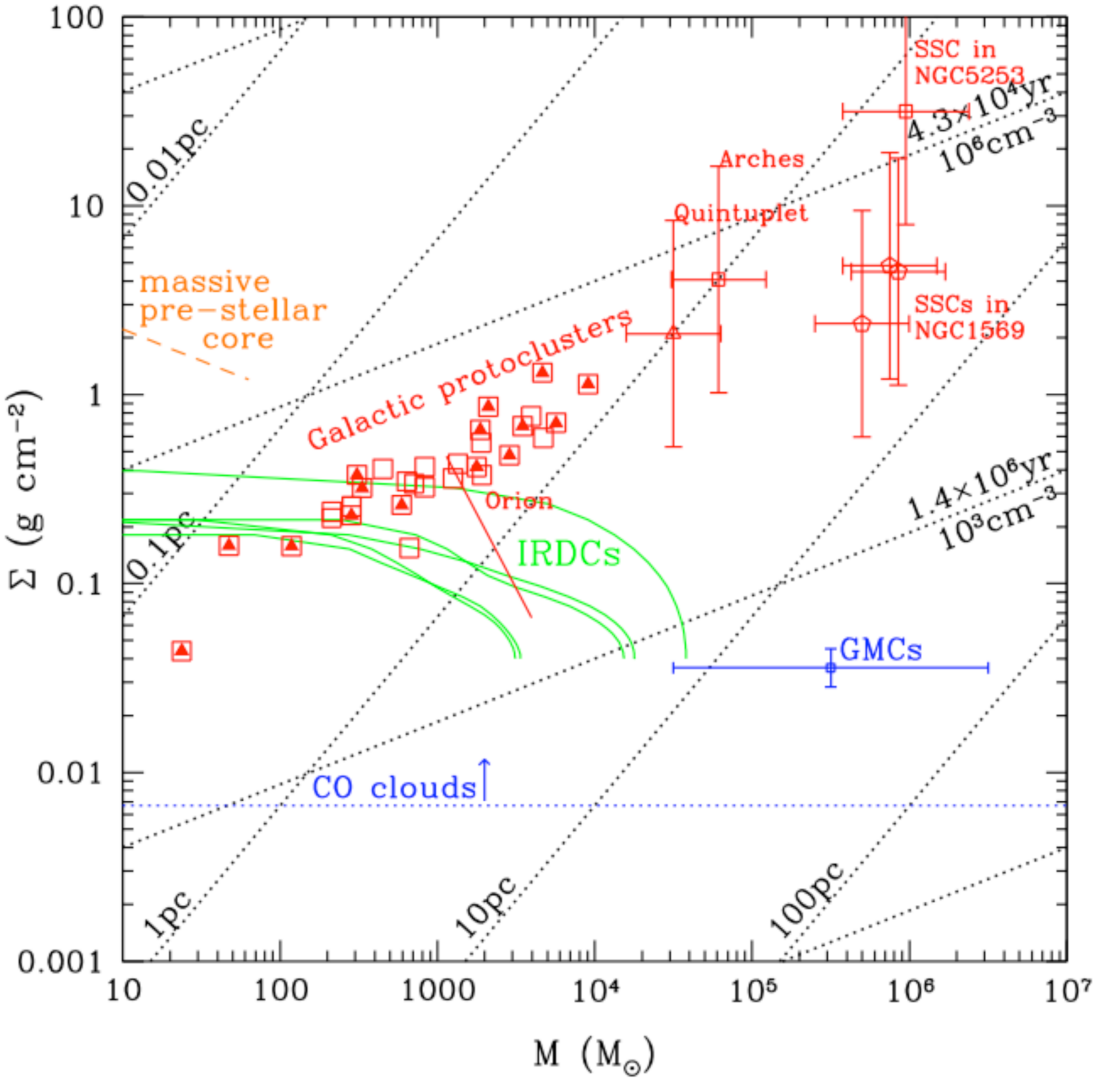
$$m(r) = 28\,M_\odot \left(\frac{\langle n_{H_2}\rangle}{100\ \mathrm{cm}^{-3}}\right)\left(\frac{r}{\mathrm{pc}}\right)^3$$

$$\varrho(s) \propto s^{-k} \Leftrightarrow m(r) \propto r^{3-k}$$

for singular cores:

$$m(r) = 2.6\,M_\odot \left(\frac{T_{\mathrm{gas}}}{\mathrm{K}}\right)\left(\frac{r}{\mathrm{pc}}\right)$$

A similar Diagram



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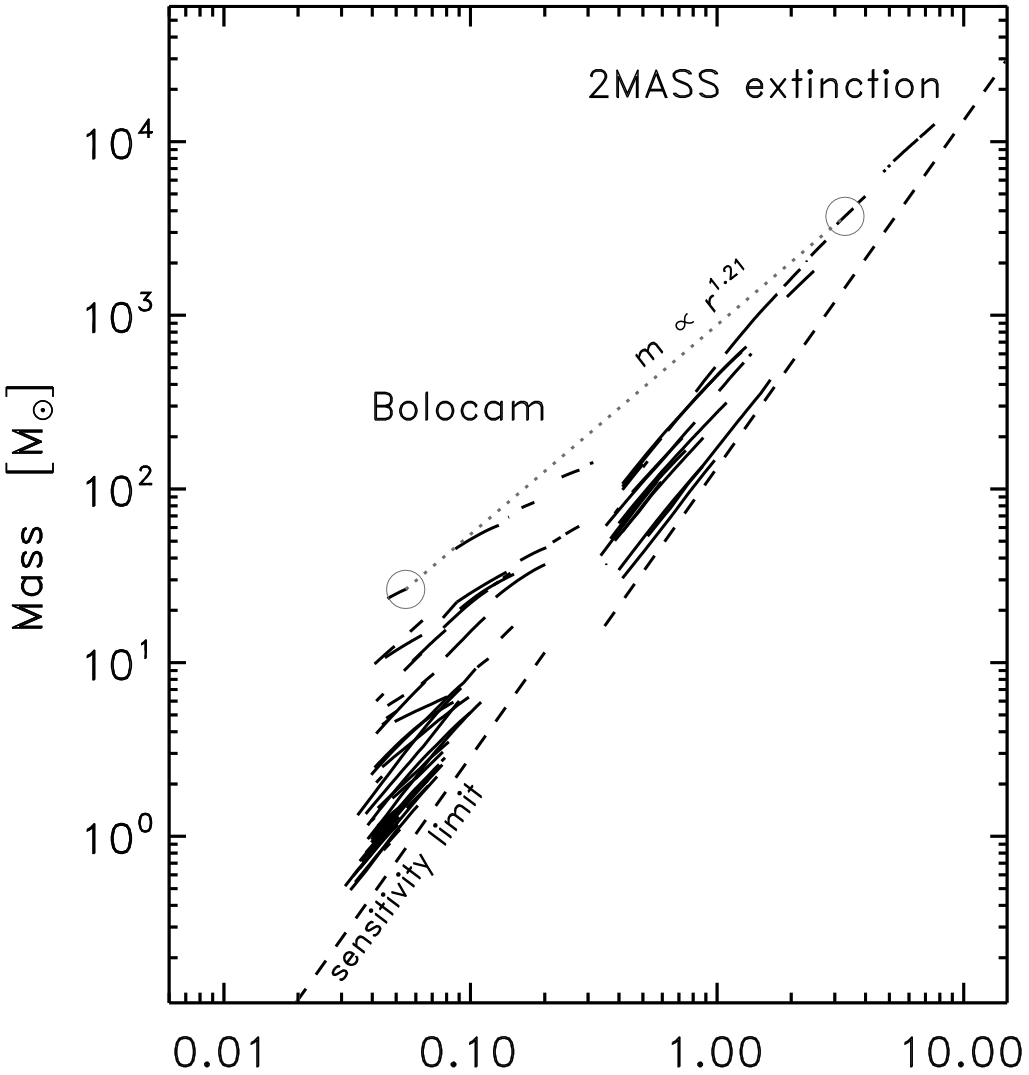
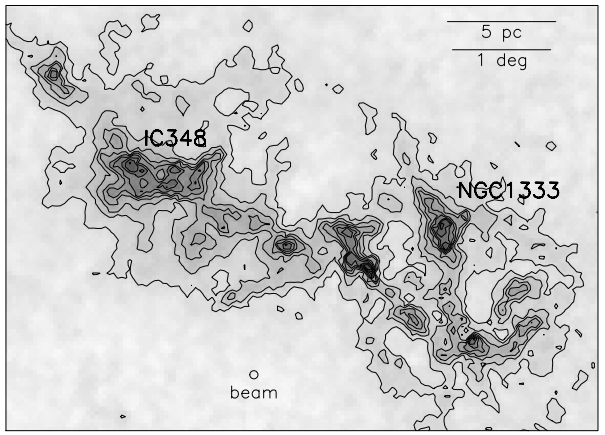
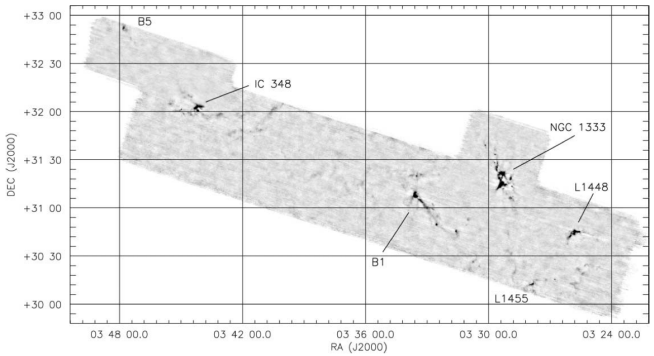
References

Kauffmann et al. (2010b), paper II

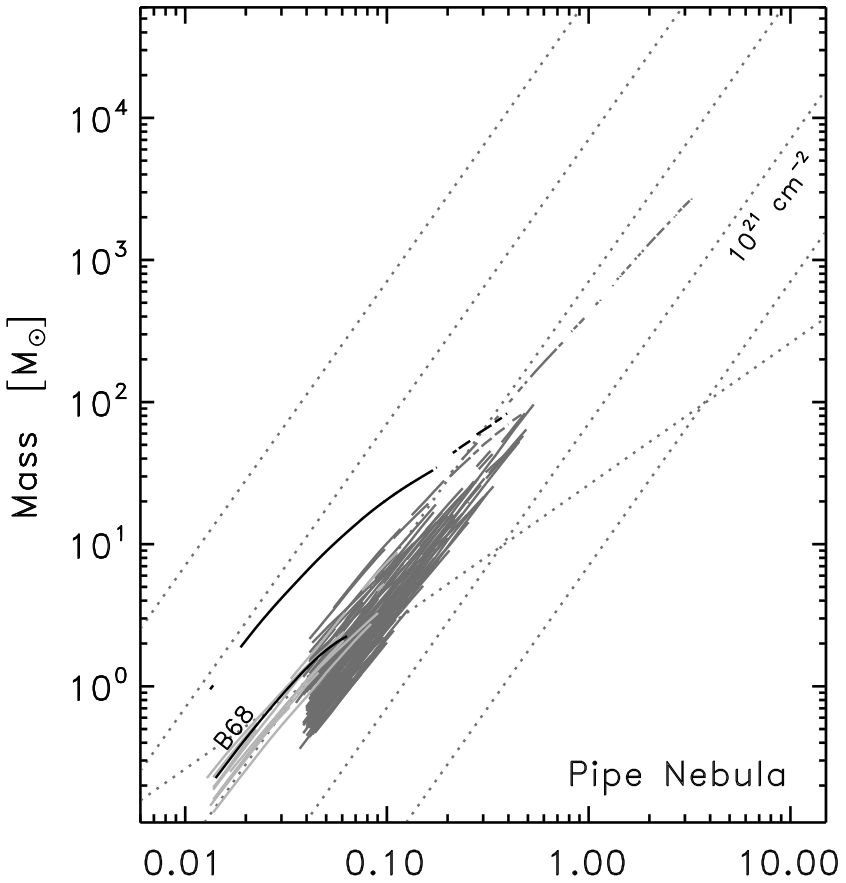
Large and Small Scales

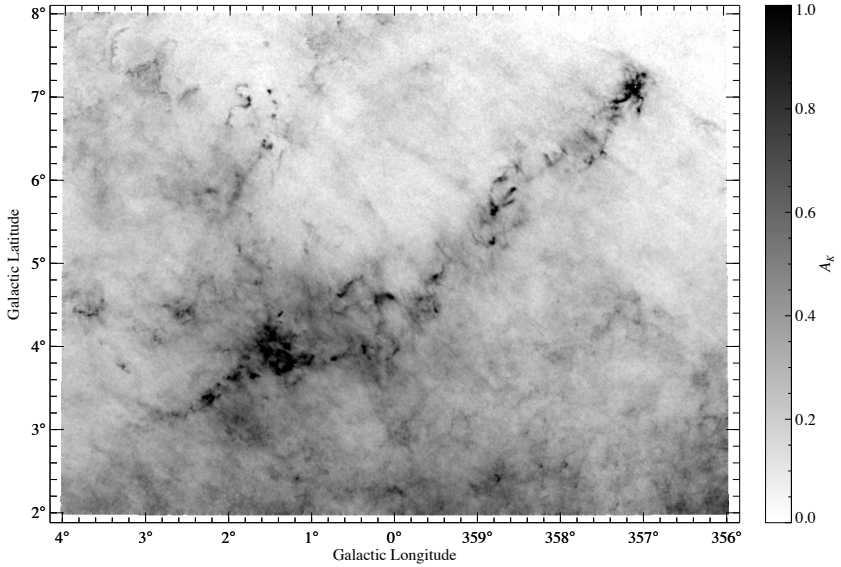






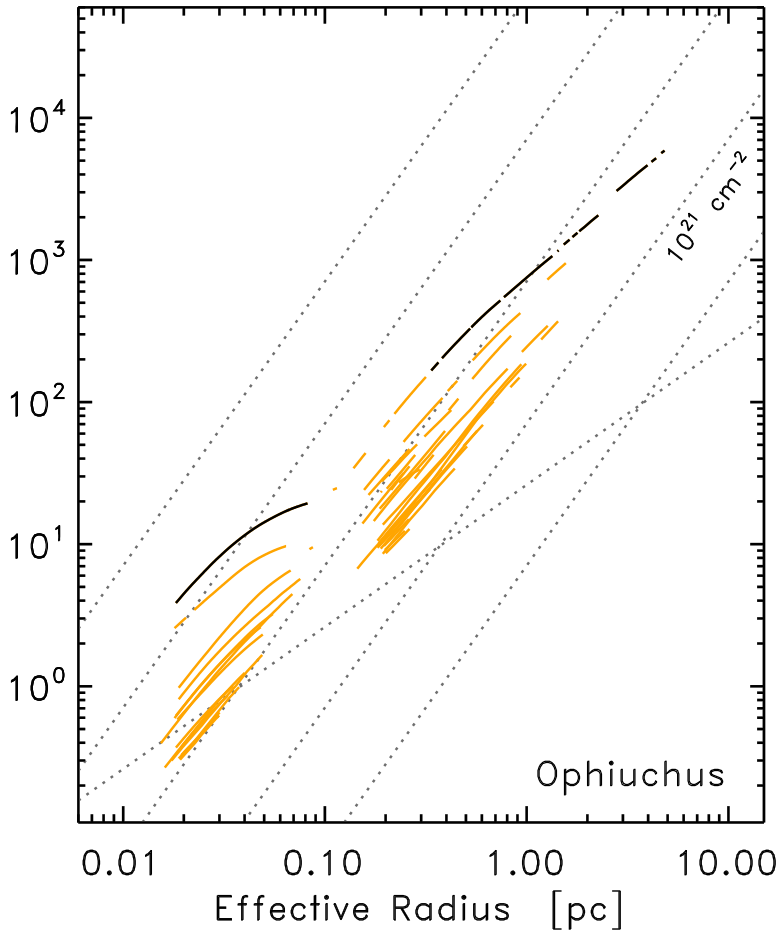
Pipe Nebula

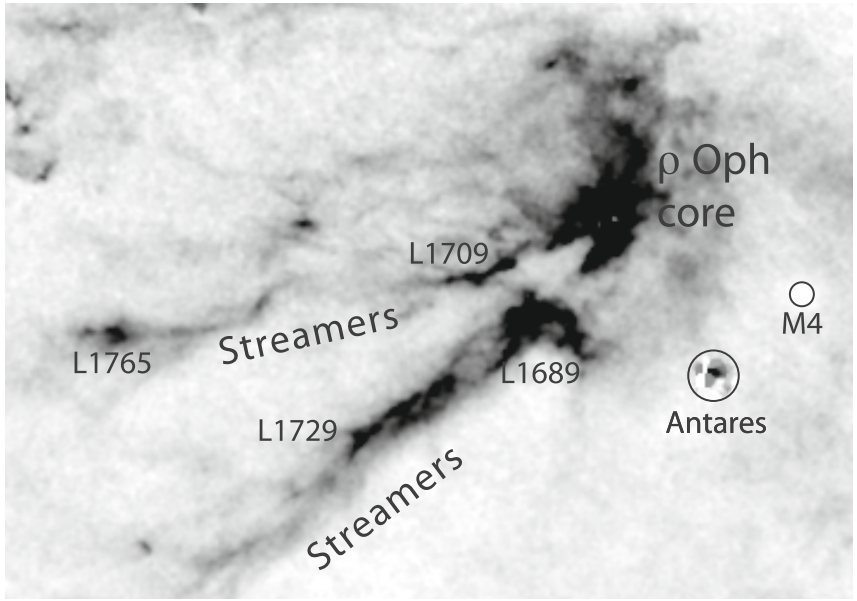




insignificant cluster is offset from cloud main body

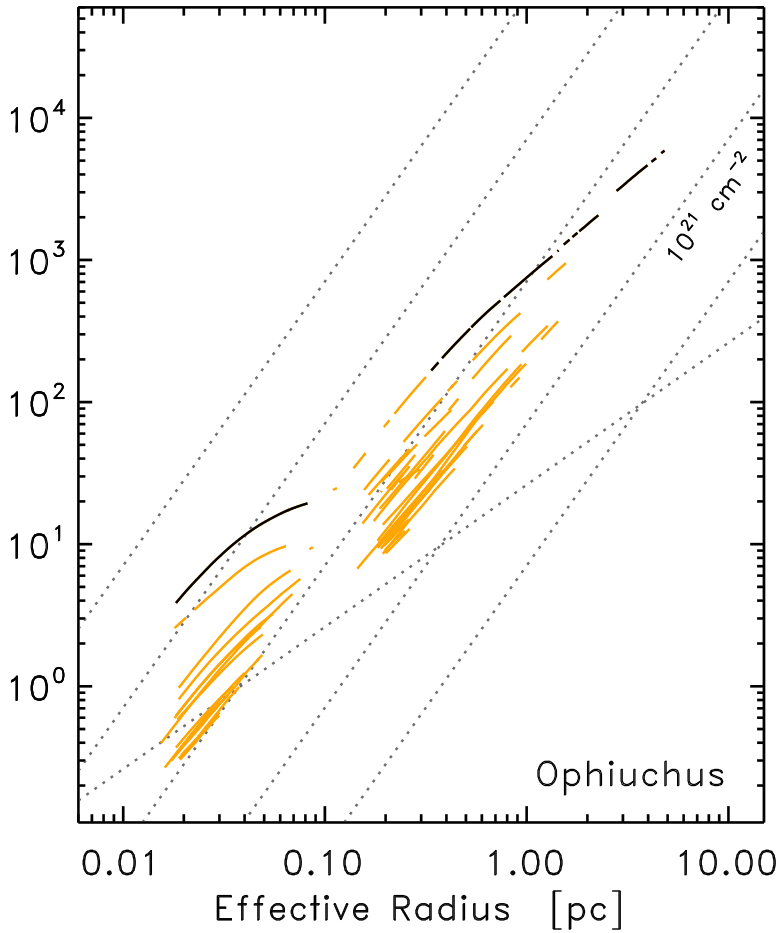
Ophiuchus Molecular Cloud

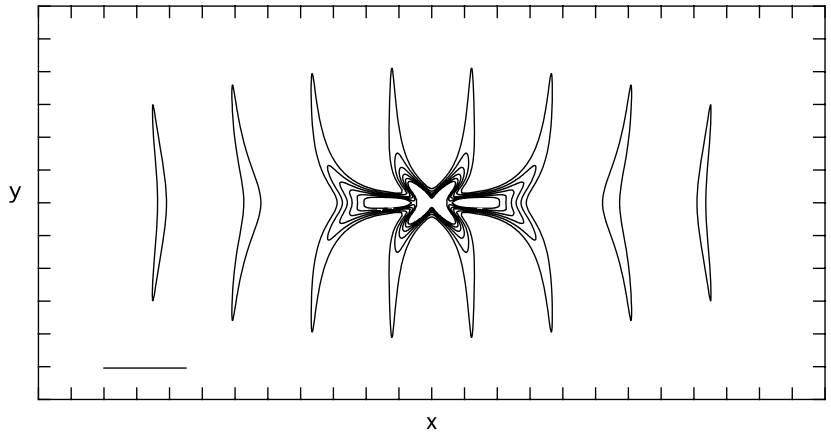




dominating cluster is embedded in cloud main body

Hubs in Star-Forming Regions?

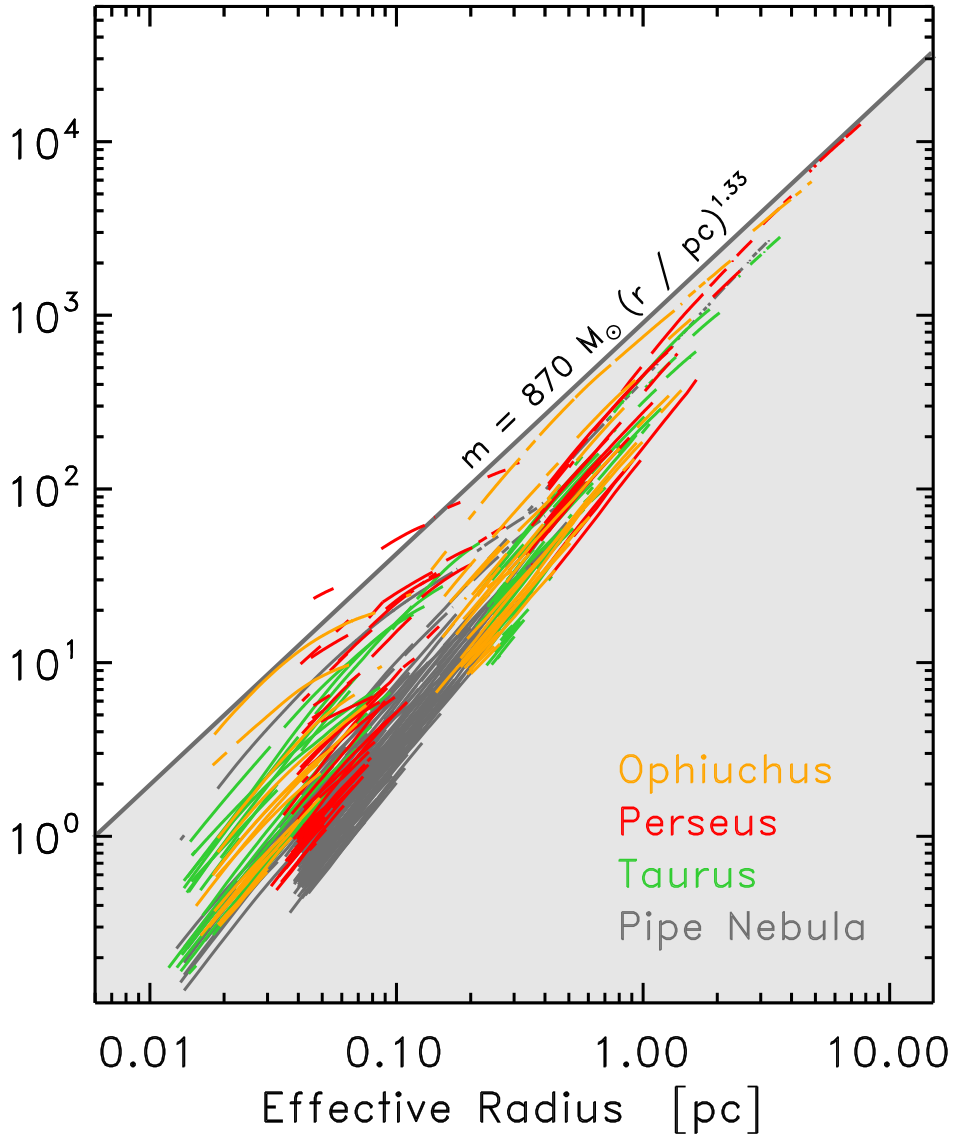




hubs in clouds

quantitative definition via cloud hierarchy?

Without Massive Star Formation



without MSF:

$m(r) \leq 870\, M_\odot\, (r/\mathrm{pc})^{1.33}$

nearby non-MSF clouds

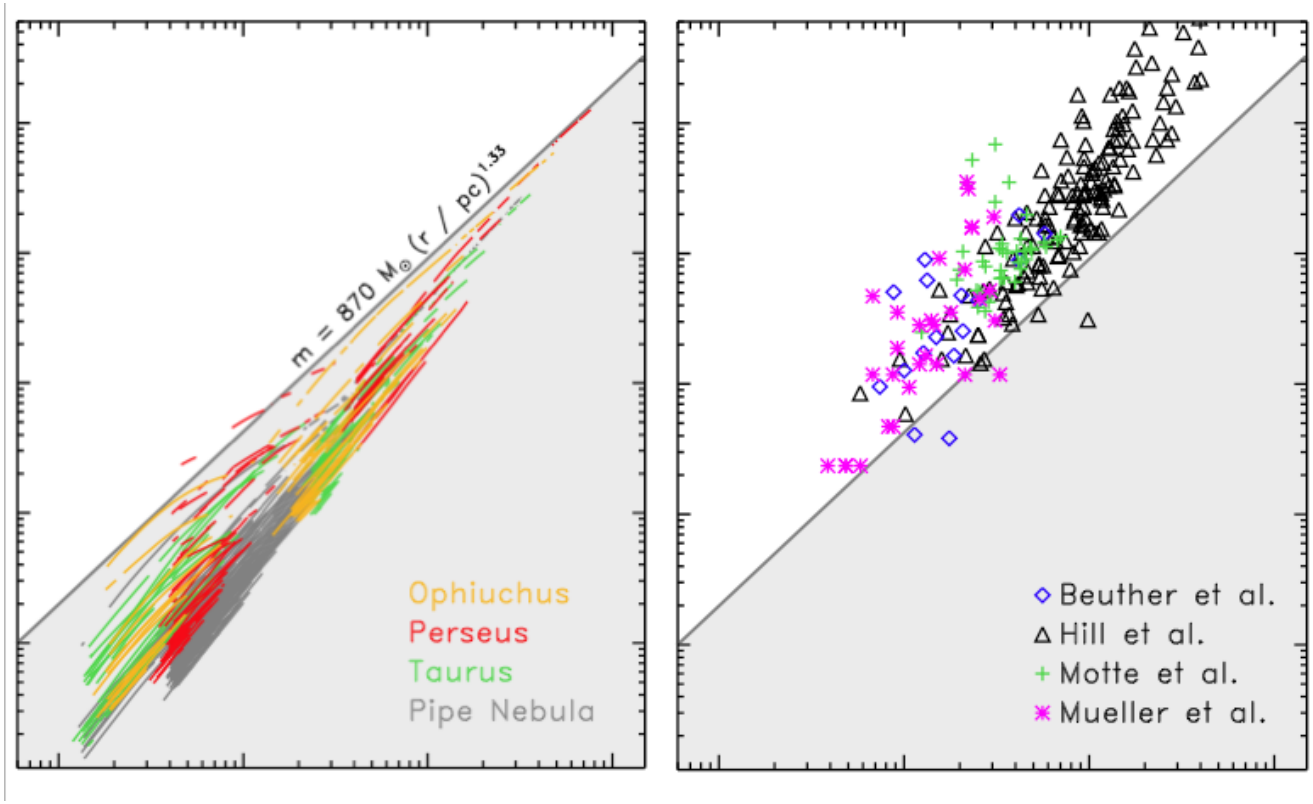
well defined parameter space

Outline

References

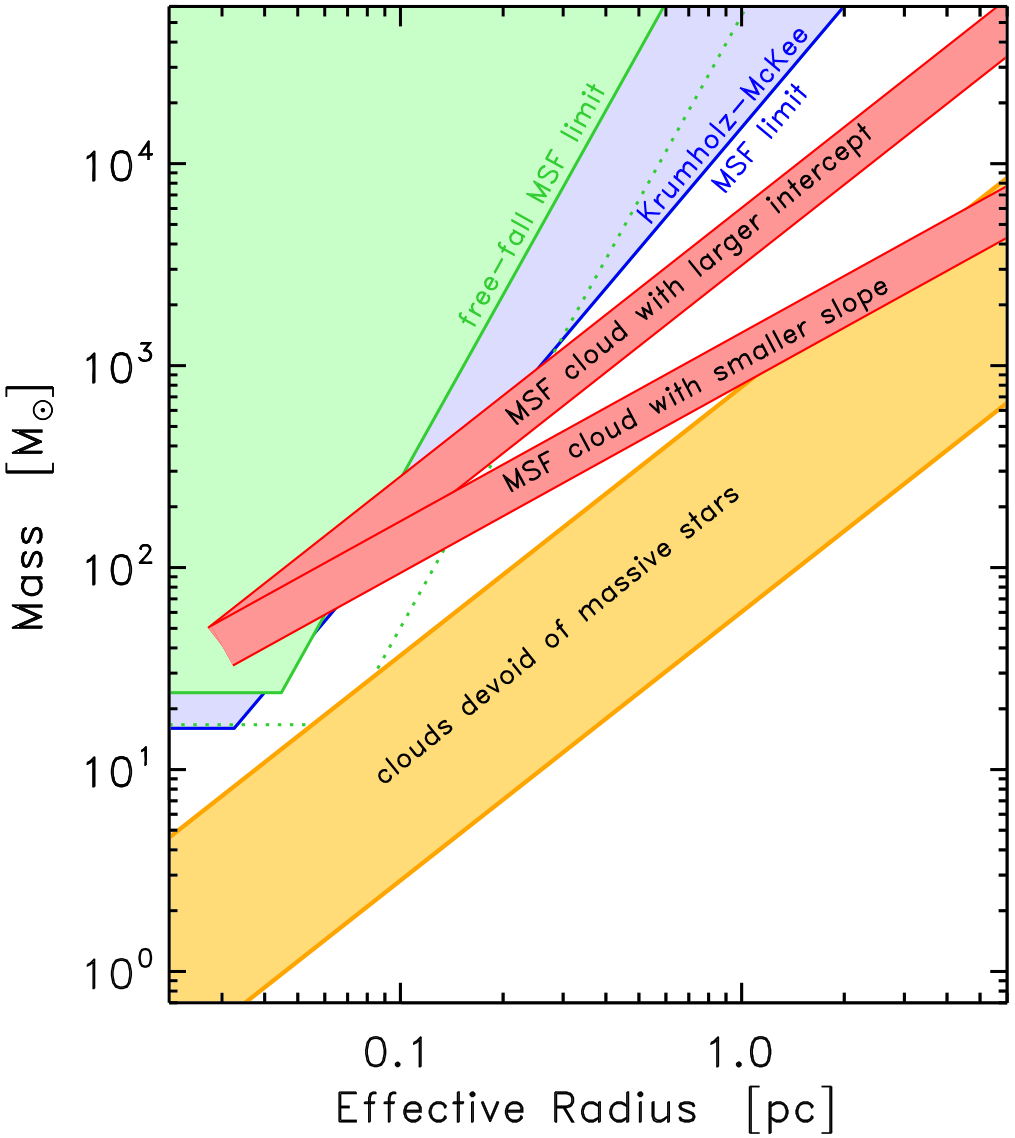
Kauffmann et al. (2010c), paper III

Clouds with and without Massive Star Formation



$m(r) \sim 870\,M_\odot\,(r/\mathrm{pc})^{1.33}$ is a good MSF threshold

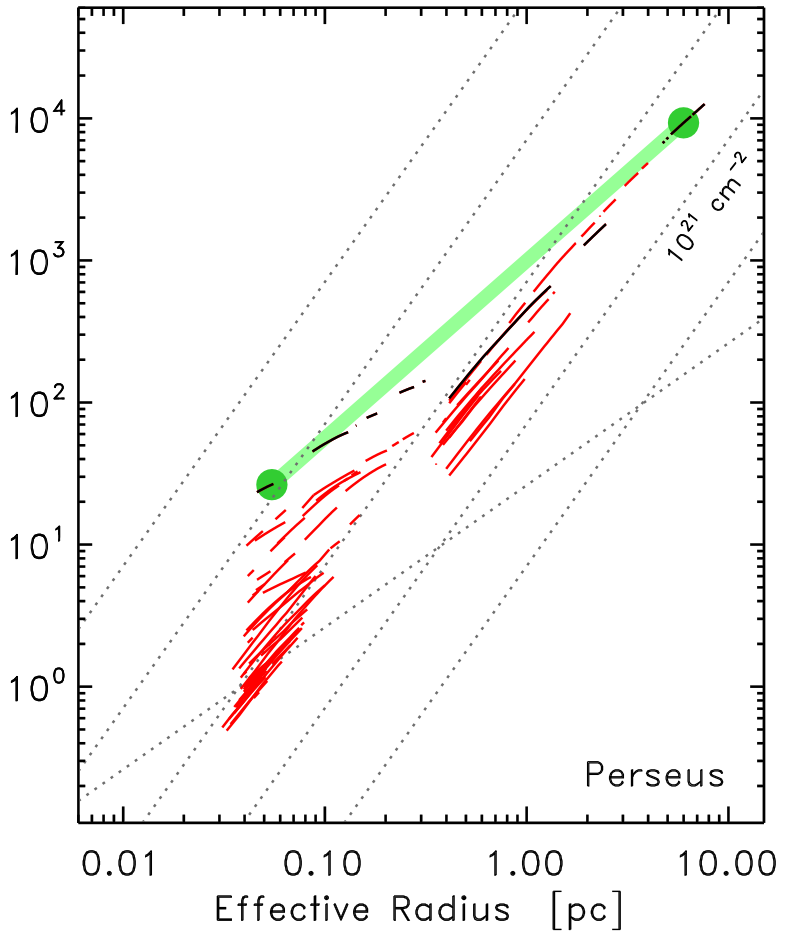
A Diagnostic Diagram

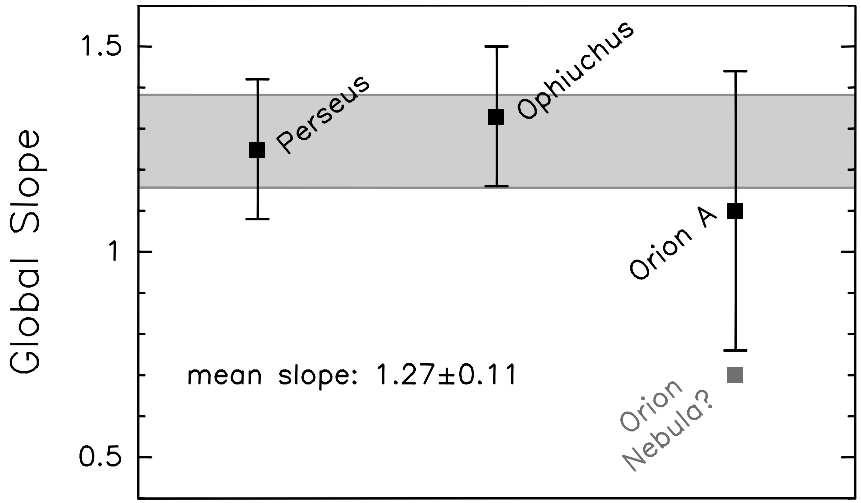


MSF vs. low mass SF:

- absolute differences?
- relative differences?

Larson's Mass-Size Law





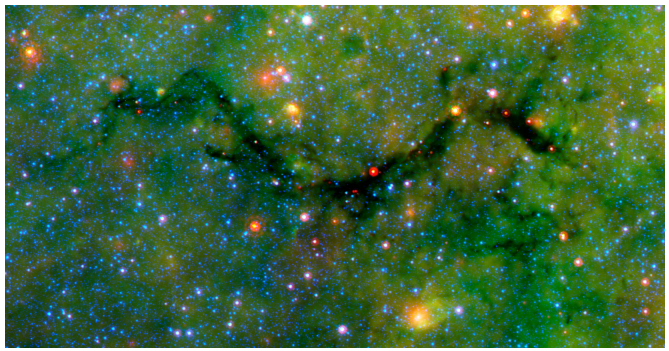
inconsistent with

$m(r) \propto r^2 \Leftrightarrow \langle N_{H_2} \rangle = \text{const.}$

Larson's mass-size law

slope does not hold

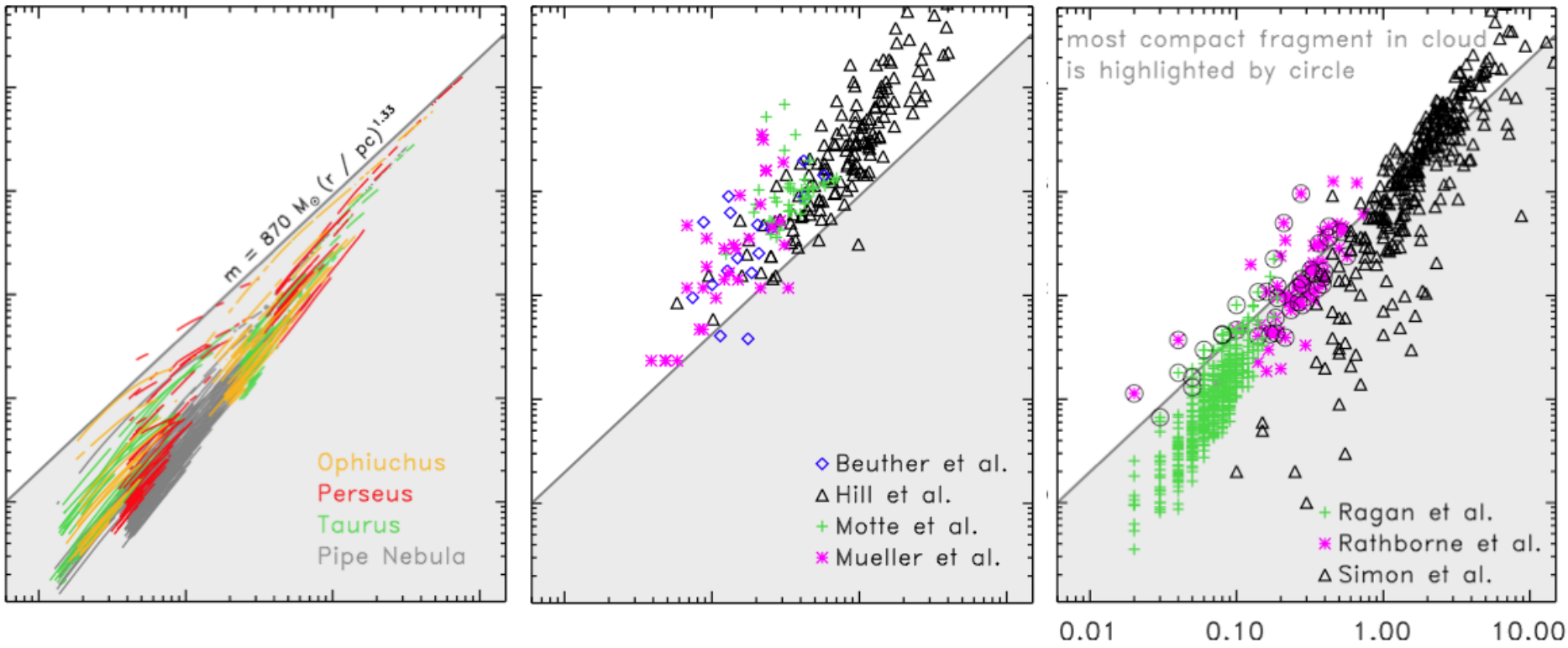
Outline



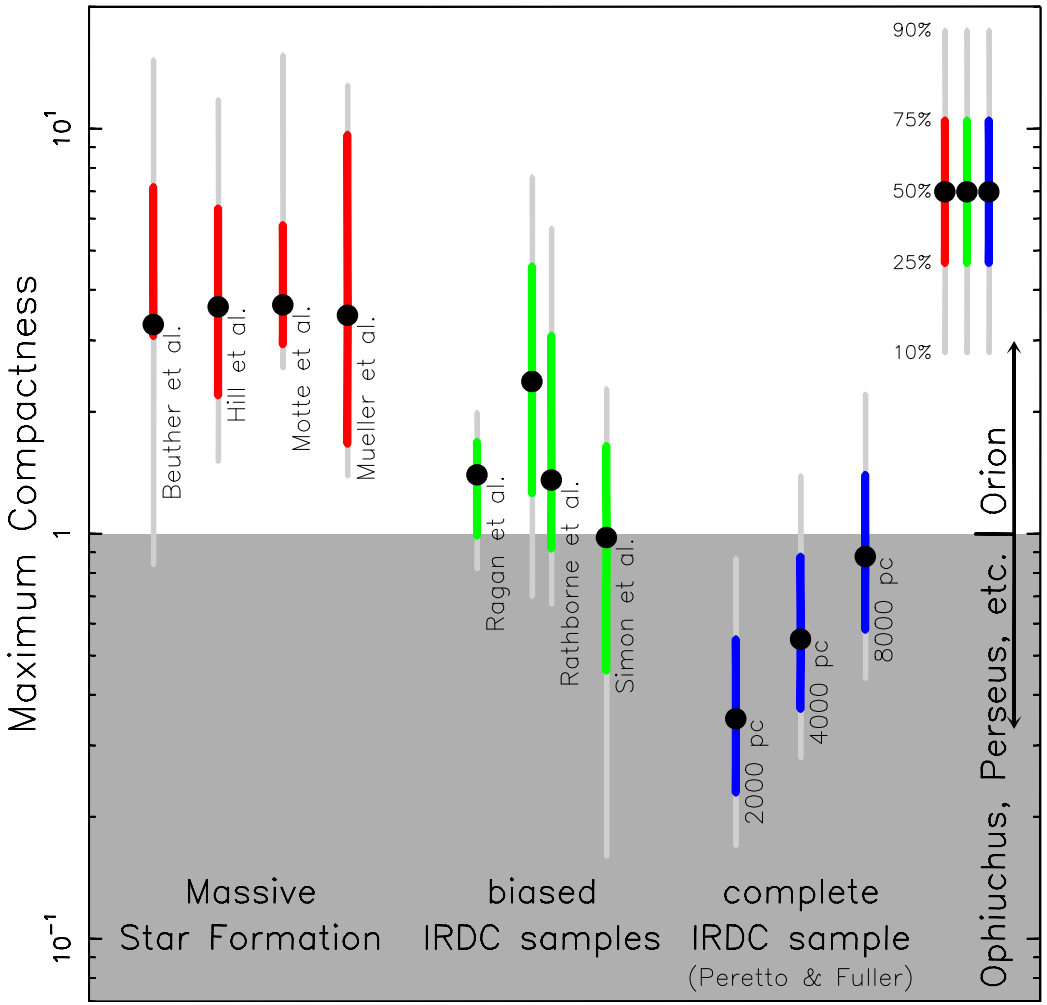
References

Kauffmann et al. (2010c), paper III

IRDCs in Context



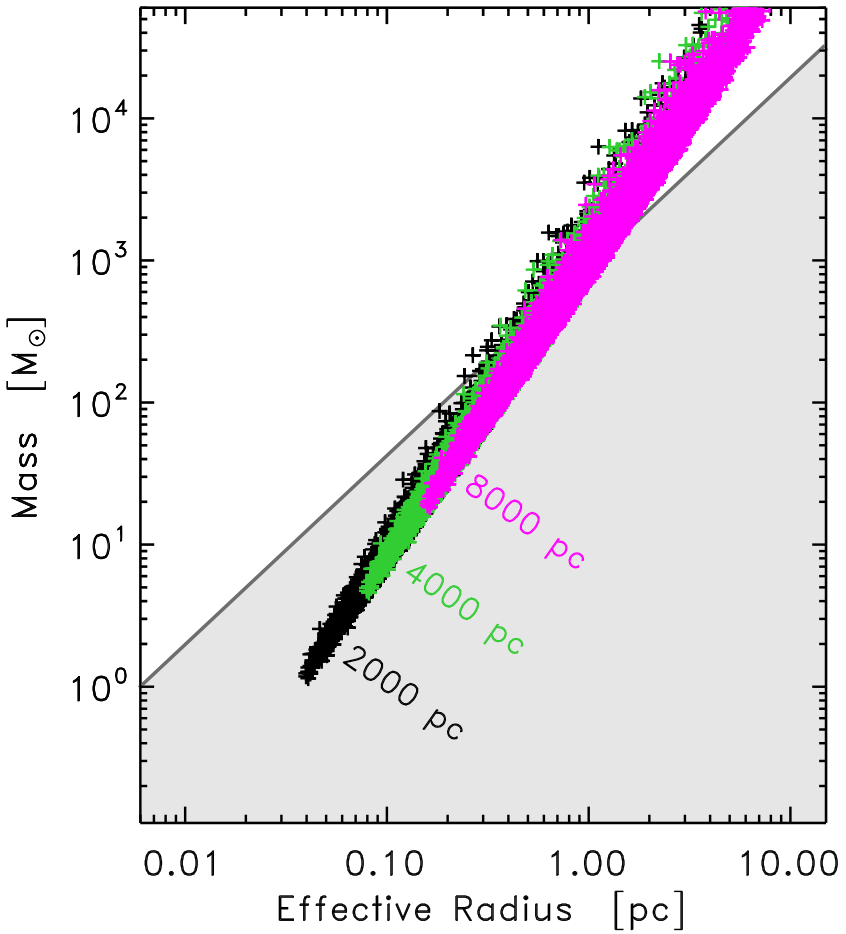
Compactness



$m(r)/m_{\rm lim}(r) \rightsquigarrow$ compactness

$m_{\rm lim}(r) = 870\,M_\odot\,(r/{\rm pc})^{1.33}$

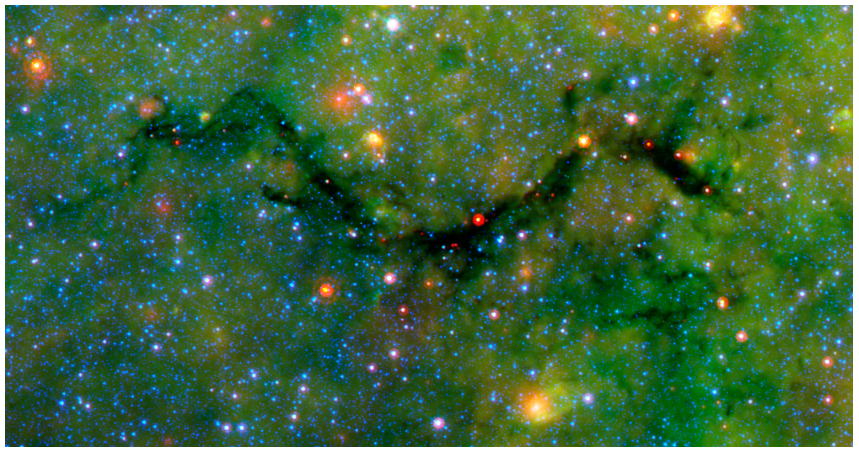
Typical IRDC Conditions



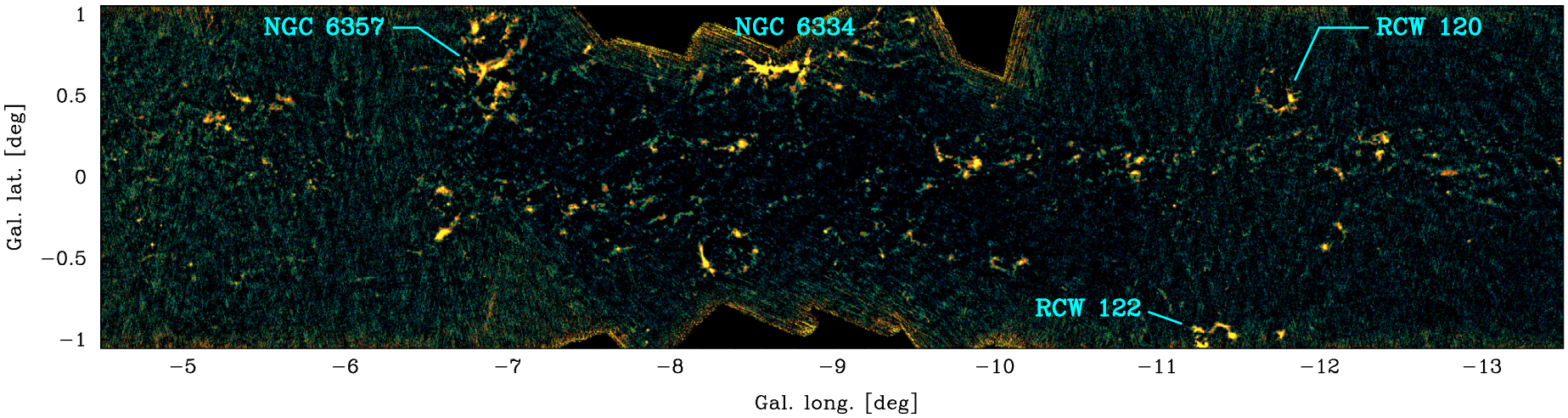
compact IRDCs:

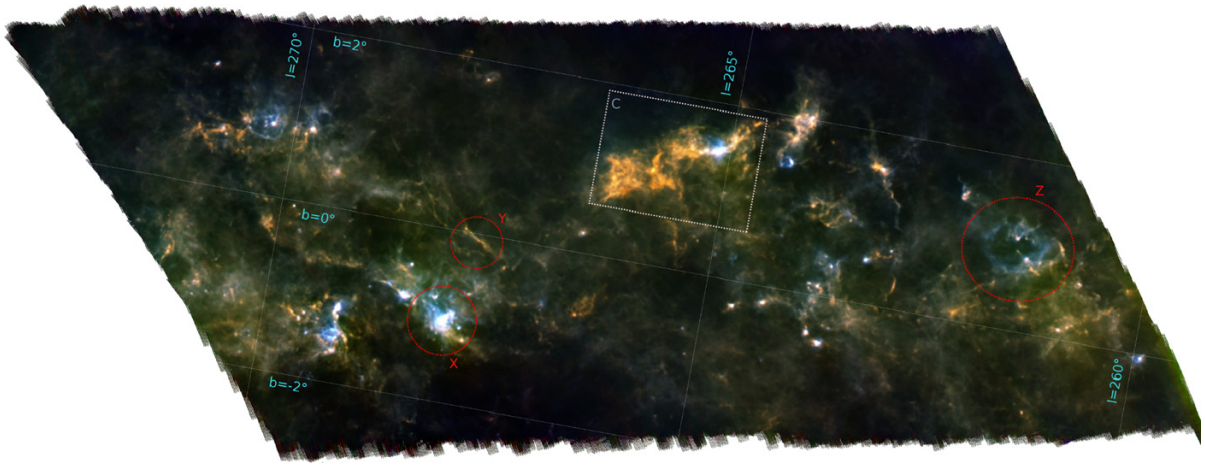
Distance	Number	Fraction	Mass Fraction
kpc	–	%	%
2	831	7	71
4	2218	20	87
6	3639	32	93
8	4778	42	96

250 clouds contain 50% of total $\int N_{H_2}\, d\Omega$



Galactic Star Formation Environments





LaBoCa, Bolocam, Scuba-II, Herschel

$\Rightarrow$ survey galaxy

$\Rightarrow$ galactic SF budget

Outline

Recap

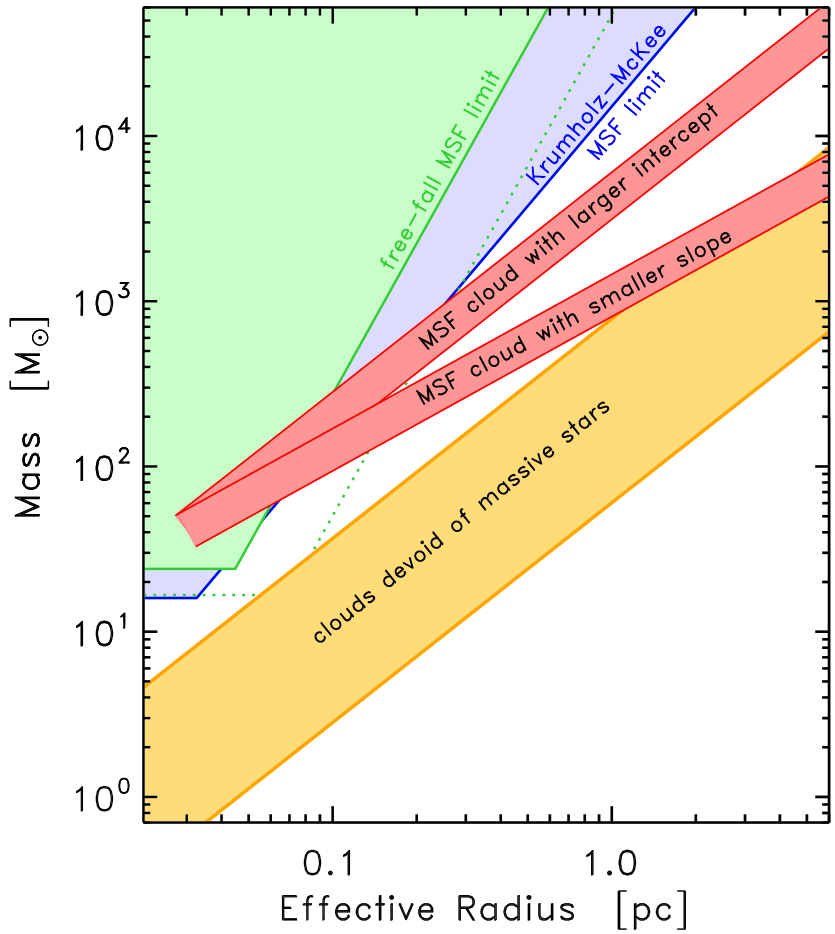
Main Thoughts

origin of MSF dense cores

$\Rightarrow$ density, hierarchy?

can be analyzed in mass-size space, considering slopes and intercepts

yields diagnostic diagram



Recap

Main Thoughts

origin of MSF dense cores

$\Rightarrow$ density, hierarchy?

can be analyzed in mass-size space, considering slopes and intercepts

yields diagnostic diagram

Infrared Dark Clouds

by number: non-MSF regions ($\geq$ 50%)

by mass: MSF regions ($\geq$ 70%)

if present data characteristic...

Larson's Law

typical $m(r)$ slope $\sim$ 1.3

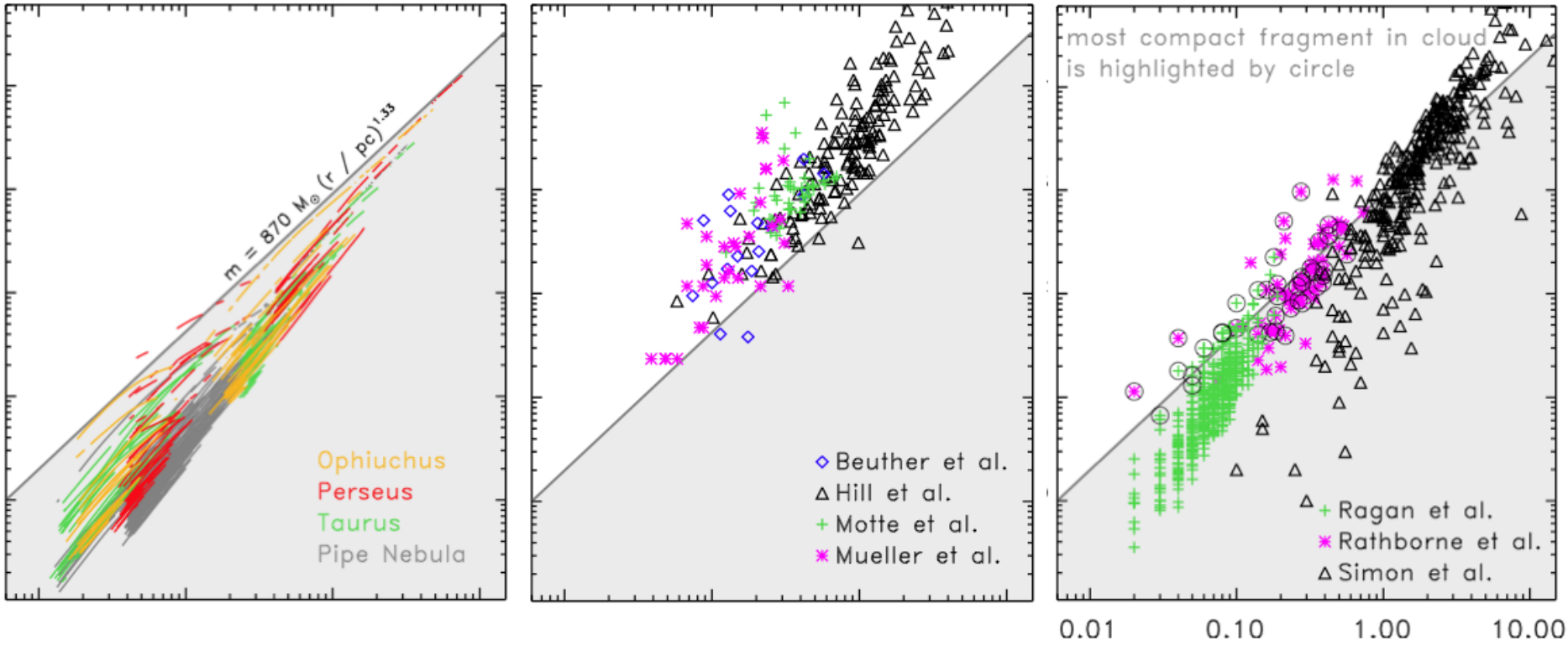
$\Rightarrow$ Larson's $m \propto r^2$ law does not hold

Clusters

manifest in cloud hierarchy

Unfinished Business

homogenize & expand data:



clusters:
draw into mass-size diagrams?

other diagrams:
unification of $m(r)$ with mass functions and N_{H_2} PDFs seems possible

Nested Structure: Future Challenges