Modelling of molecular clouds with formation of prestellar cores

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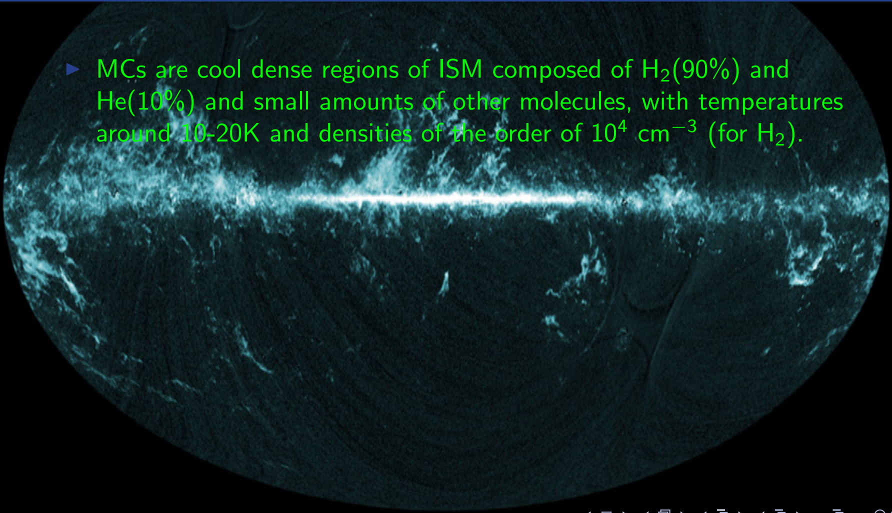
- Global properties of MCs – morphology and substructures
- Goal in this work and Core Mass Function (CMF)
- Basic assumptions
- Principles to derive the CMF
- Results for time-weighted cumulative CMF
- Summary

Global properties of MCs



- MCs are cool dense regions of ISM composed of H_2(90%) and He(10%) and small amounts of other molecules, with temperatures around 10-20K and densities of the order of 10^4 cm^{-3} (for H_2).

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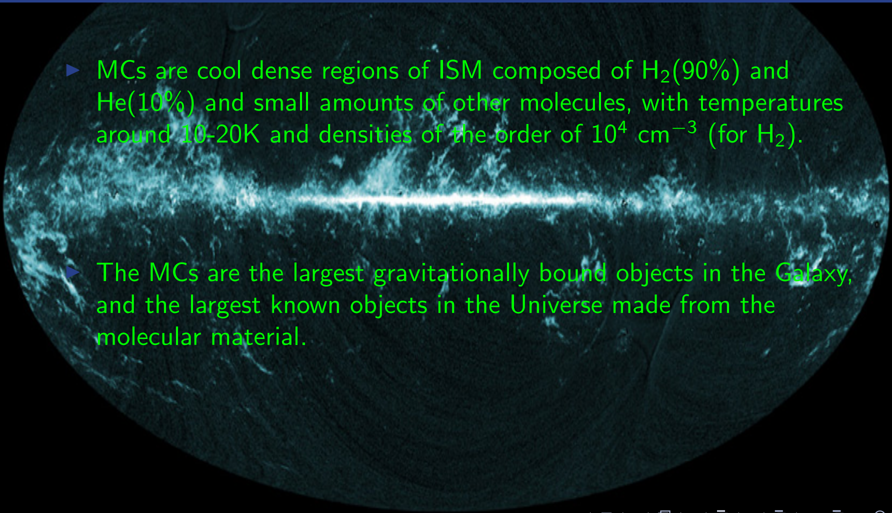

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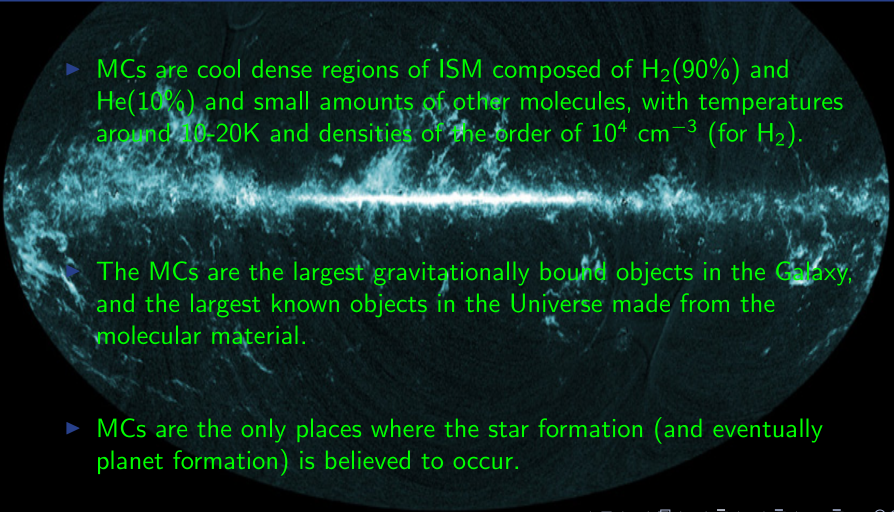

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- MCs are the only places where the star formation (and eventually planet formation) is believed to occur.

Global properties of MCs

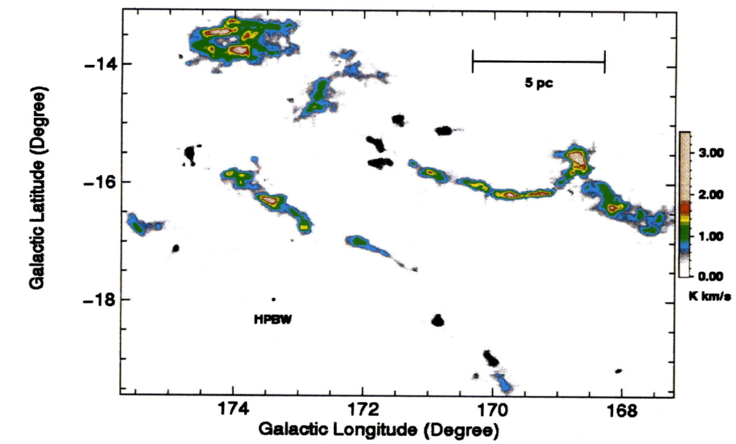
Cloud Type	A_V (mag)	n_{tot} (cm^{-3})	L (pc)	T (K)	M ($M_\odot$)	Example
Diffuse	1	500	3	50	50	ζ Ophiuchi
Giant Molecular	2	100	50	15	10^5	Orion
Dark						
Complex	5	500	10	10-25	10^4	Taurus-Auriga
Individual	10	10^3	2	10	30	B1
Dense	10	10^4	10^{-1}	10	10	TMC-1/B335

Table 1.1: Physical Attributes of Galactic Molecular Clouds

Table data courtesy of Stahler & Palla (2004)

Taurus MC (Onishi et al. 1996); tracer $C^{18}O(J = 1 - 0)$

$n \sim 10^2 - 10^4$ cm^{-3}; $\ell \sim 0.1 - 1.0$ pc



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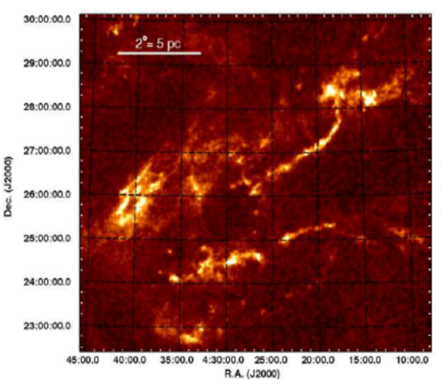

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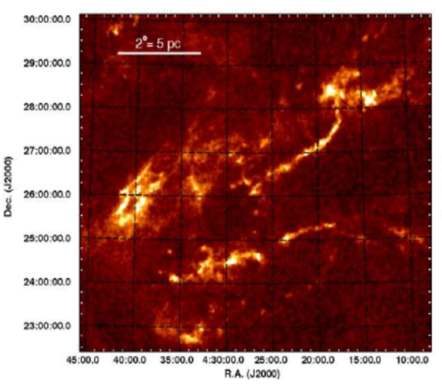

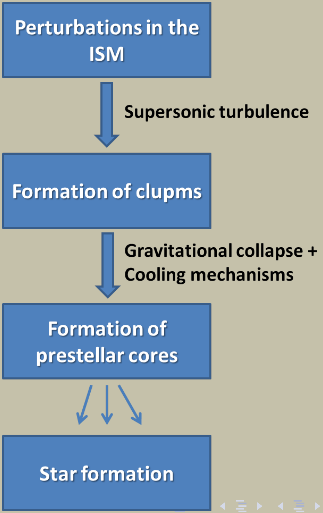

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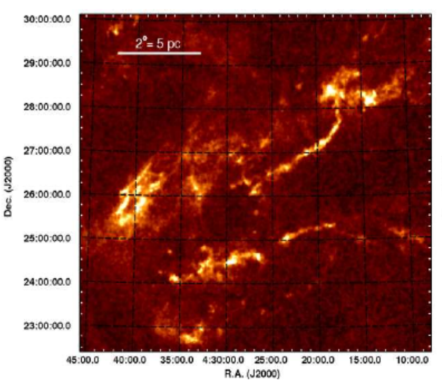
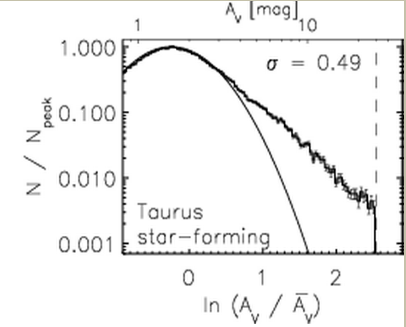
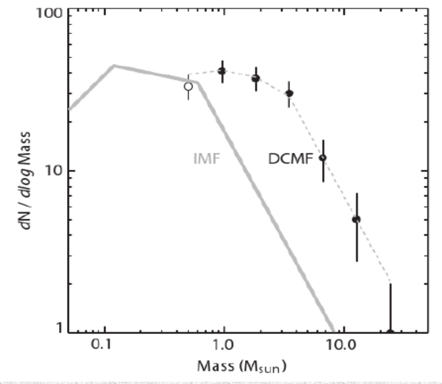




Column-Density PDF (N-PDF)

Core Mass Function (CMF) and our goal



Dense (Core) mass function; Pipe MC (Alves , Lombardi, Lada, 2007)

$$\frac{dN}{d\log m} \propto m^{\Gamma}$$

$$\Gamma \sim -1.35$$

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  Statistical approach to describe the powr-low (PL) tail of the N-PDF and ρ-PDF.

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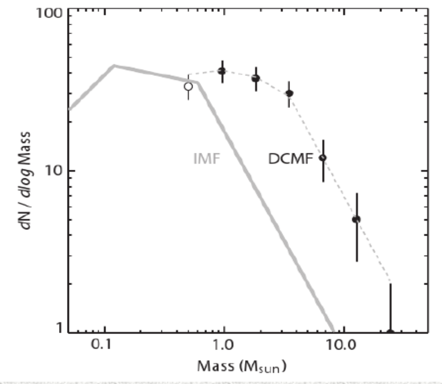

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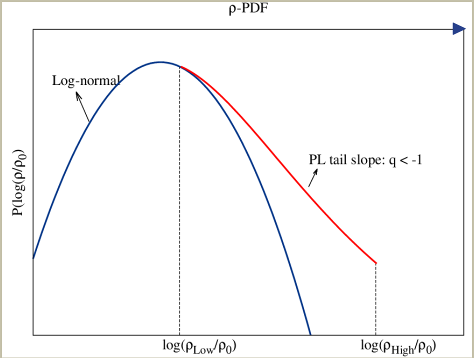
  Statistical approach to describe the powr-low (PL) tail of the N-PDF and ρ-PDF.
- Derivation of the CMF (with and without time-weighting)

Basic assumptions



Scheme of the ρ-PDF

Statistics of the PL tail

$$dP_s = A_s 10^{qs} ds = A_s \left(\frac{\rho}{\rho_0}\right)^q d\log\left(\frac{\rho}{\rho_0}\right)$$

$$s \equiv \log\left(\frac{\rho}{\rho_0}\right)$$

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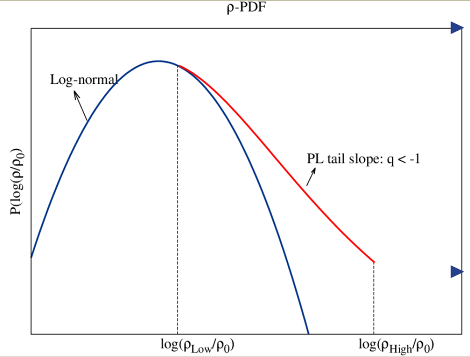

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- Core mass-density relation

$$\ln\left(\frac{\rho}{\rho_0}\right) = x\ln\left(\frac{m}{m_0}\right); \quad x < 0$$

Arithmetic / Logarithmic average

- Arithmetic average

$$\overline{\left(\frac{\rho}{\rho_0}\right)}_{ar} = A_s \int_{s_1}^{s_2} \left(\frac{\rho}{\rho_0}\right) \left(\frac{\rho}{\rho_0}\right)^q d\log\left(\frac{\rho}{\rho_0}\right)$$

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- Logarithmic average

$$\overline{\log\left(\frac{\rho}{\rho_0}\right)} = A_s \int_{s_1}^{s_2} \log\left(\frac{\rho}{\rho_0}\right) \left(\frac{\rho}{\rho_0}\right)^q d\log\left(\frac{\rho}{\rho_0}\right)$$

$$\overline{\left(\frac{\rho}{\rho_0}\right)}_{log} \equiv 10^{[\log(\rho/\rho_0)]}$$

Principles to derive the CMF

- The total number of cores over a fixed density threshold and at single scale $\rho' \leq \rho \leq \rho_2$; $\ell_0 \equiv \kappa L$

$$N_{tot}(\rho') = \frac{r(\rho')}{\kappa^3} \left[\overline{\left(\frac{\rho}{\rho_0}\right)}(\rho') Q(q, x, \rho') \right]^{-1}$$

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- Total number of scales over a fixed density threshold

$$N_{scales}(\rho') = \frac{r}{r(\rho')}$$

Principles to derive the CMF

- Cumulative CMF (without time-weighting)
  $\rho' \leq \rho \leq \rho_2 \;\; \leftrightarrow \;\; m' \geq m \geq m_2; \quad \rho' = \rho_0 (m'/m_0)^x$

$$N_\tau \propto \frac{r}{\kappa^3} \left(\frac{\rho'}{\rho_0} \right)^{-\frac{1}{x}} = \frac{r}{\kappa^3} \left(\frac{m'}{m_0} \right)^{-1}$$

$$(\rho' << \rho_2)$$

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Results for time-weighted cumulative CMF

Table 1: Slopes of CMFs derived from various authors in comparison with our model predictions.

Galactic MC	Ref.	Note	Slope of the CMF	x
Pipe	1		-1.35	-0.7
Orion	2		-1.35	-0.7
Orion A	3		-1.3 ± 0.3	-0.6 ± -0.6
Perseus	4	(a) lognormal	$-1. \pm 0.1$	~ 0
		(b) time-weighted	-2.15 ± 0.08	~ -2.3
Ophiuchus	5	time-weighted	-1.35	-0.7
Perseus, Serpens, Ophiuchus	6		-1.3 ± 0.4	-0.6 ± 0.8
–	7	Simulations (PP, PPV)	$-1.15 \leq \Gamma \leq -1.35$	$-0.3 \geq x \geq -0.7$

[1] Alves, Lombardi & Lada (2007), [2] Nutter & Ward-Thompson (2007), [3] Ikeda & Kitamura (2009), [4] Curtis & Richer (2010), [5] André et al. (2007), [6] Enoch et al. (2008), [7] Smith, Clark & Bonnell (2008)

Summary

- The PDF in star-forming MCs is a combination of lognormal and PL shape. The PL tail can be used to describe the density distribution of dense (prestellar) cores.

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- The PDF in star-forming MCs is a combination of lognormal and PL shape. The PL tail can be used to describe the density distribution of dense (prestellar) cores.
- Starting from the basic assumption of core mass-density relationship $\rho \propto m^x$, we derive a power-law core mass function with "fractal" slope -1.
- Time-weighted CMF has a slope close to that of Salpeter IMF (-1.35) when the mass-density power index x takes values $\sim$-0.7, in consistency with our estimates for dense regions of MCs.