

SF2A; ATELIER GÉNÉRAL PNPS

**The gaseous protocluster as a product of gravoturbulent interaction:
modified local environment for stellar cluster formation?**

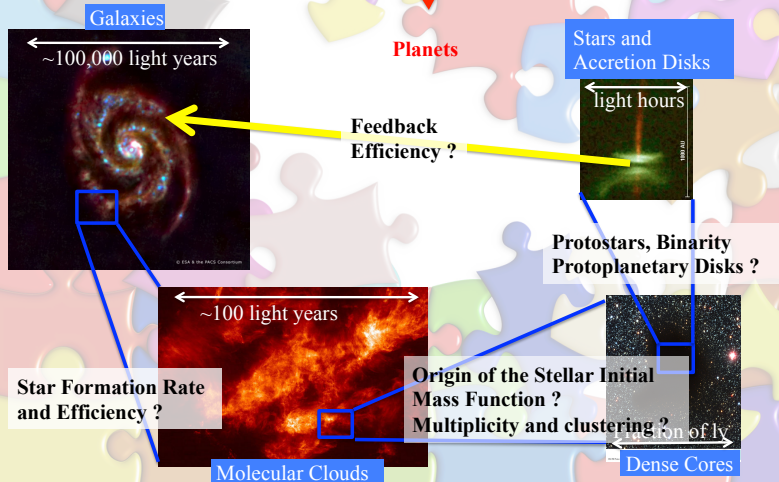
LEE Yueh-Ning, HENNEBELLE Patrick

SAP, CEA Saclay

SF2A, Lyon — June 14th, 2016

Context

Interstellar Cycle and Star Formation



Context

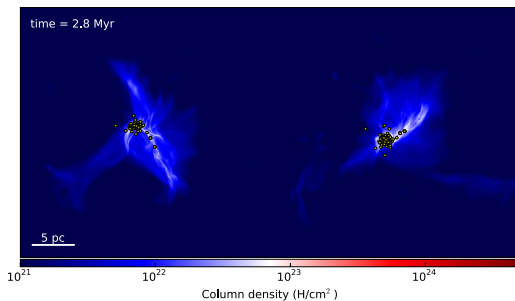
Main difficulties in the interstellar medium

- Large range of temporal and spatial scales
- Energy equipartition among radiative, thermal, kinetic, magnetic energies and cosmos rays
- Strong coupling between several physical processes
- Difficult to simplify and isolate the problems

Outline

- 1 Star formation environment
- 2 The gaseous protocluster
- 3 Analytical 2D virial model
- 4 Toward a universal IMF

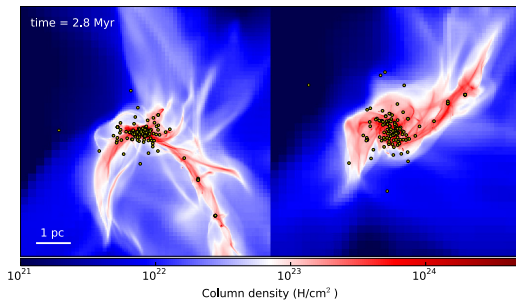
Star formation environment



Stars in molecular clouds form

- in isolation
- in filaments
- in clusters Lada & Lada (2003)

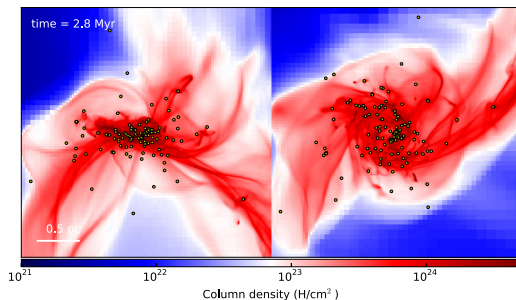
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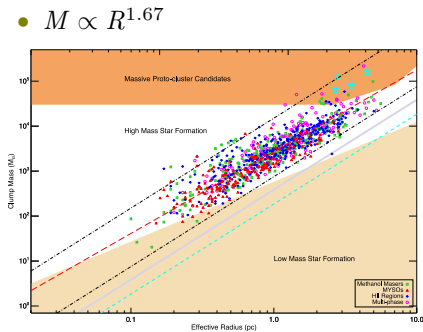
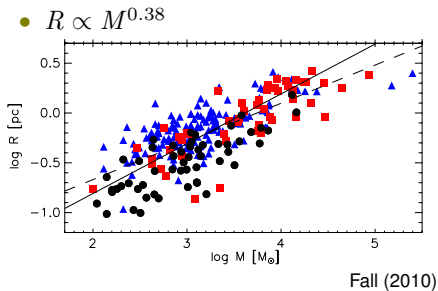


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The gaseous protocluster

Star forming clumps from molecular and continuum observations

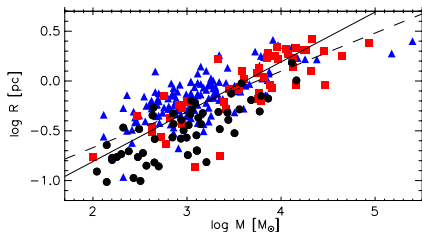


Urquhart+ (2014)

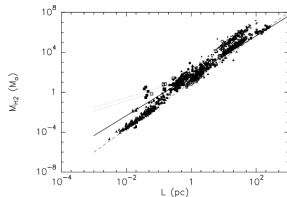
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Star forming clumps from molecular and continuum observations

● $R \propto M^{0.38}$

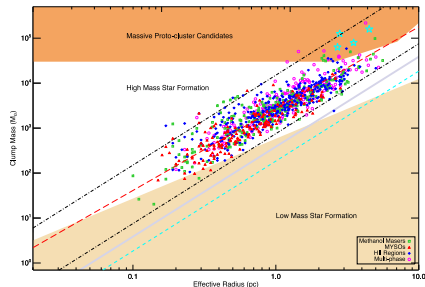


Fall (2010)



Larson's relation Hennebelle & Falgarone (2012)

● $M \propto R^{1.67}$



Urquhart+ (2014)

Analytical 2D virial model

The virial theorem

- momentum equation: $\rho d_t \mathbf{u} = -\rho \nabla \phi$

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- virial equilibrium: $0 \approx 2E_{\text{kin}} + E_{\text{grav}}$

Analytical 2D virial model

However, **rotation** is important!

Spherical symmetry no longer valid.

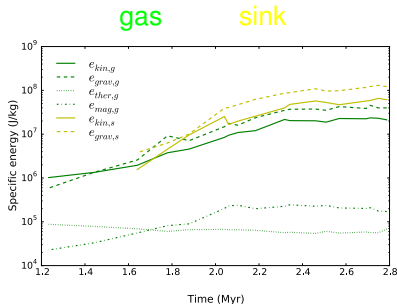
We choose an oblate cluster of semi-axes R and H and separate the integration in two dimensions of the cylindrical coordinate.

$$Mu_{2d}^2 = M\left(\frac{j}{R}\right)^2 + M\sigma_r^2 = \frac{GM^2}{R}u_r(\eta)$$

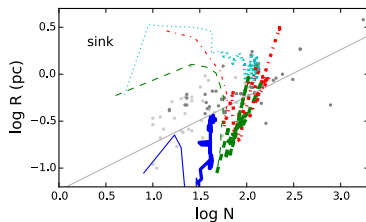
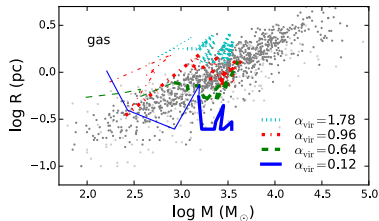
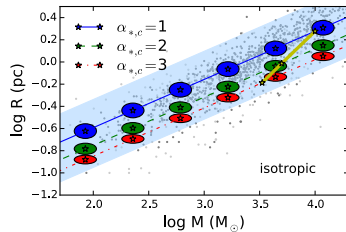
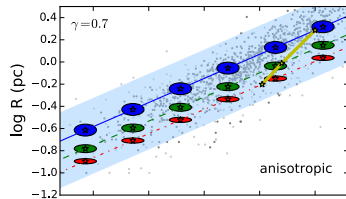
$$Mu_{1d}^2 = M\sigma_z^2 = \frac{GM^2}{R}u_z(\eta)$$

$$\dot{E}_{\text{diss}} = \epsilon \dot{E}_{\text{grav}} = \epsilon \frac{2GM\dot{M}}{R}u_g(\eta)$$

Given M, j, \dot{M} , solve for R, η, σ .

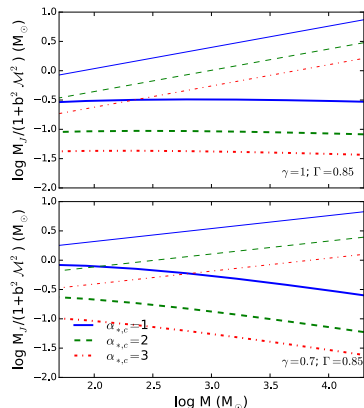


Analytical 2D virial model



Conclusions and outlook

- Stars do not form uniformly in molecular clouds

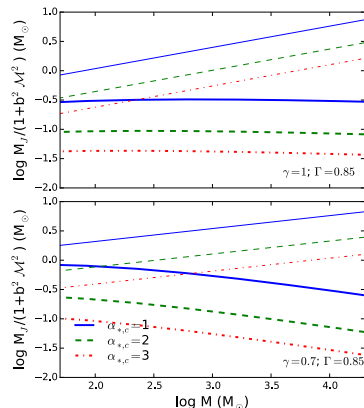


L & H 2016, A&A, 591, A30

L & H 2016, A&A, 591, A31

Conclusions and outlook

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- Observed protocluster mass-size relation successfully reproduced by simulation and model, conditions different from molecular clouds

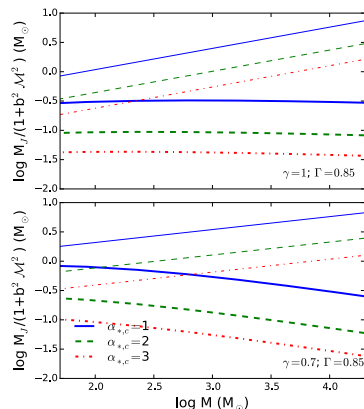


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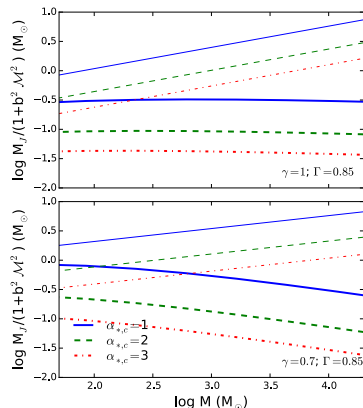


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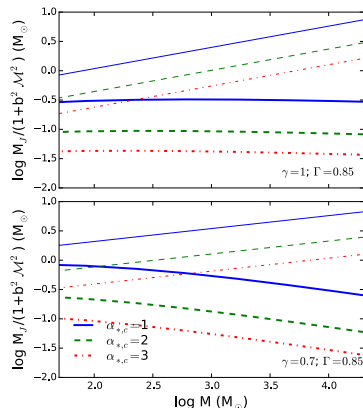


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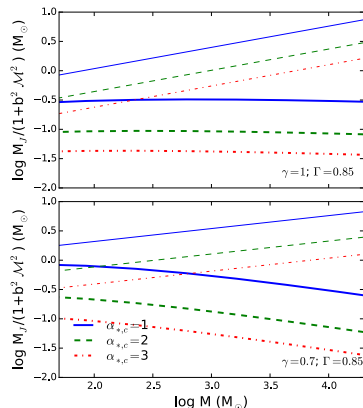


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- Towards a more realistic cluster with stellar feedback: jet, ionizing radiation, supernovae



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Thank you for your attention