Probing star-formation mechanisms in massive star-forming regions:
bridging observations and simulations through

THE ROSETTA STONE PROJECT

Alice Nucara (INAF-IAPS, Università di Roma Tor Vergata), A. Traficante (INAF-IAPS), U. Lebreuilly (Paris-Saclay), S. Molinari (INAF-IAPS), P. Hennebelle (Paris-Saclay), L. Testi (Alma Mater Studiorum - University of Bologna), N.-D. Tung (Paris-Saclay) , C. Mininni (INAF-IAPS) & the ECOGAL team

It is challenging to define a scenario of massive star formation which can be universally valid

Objectives

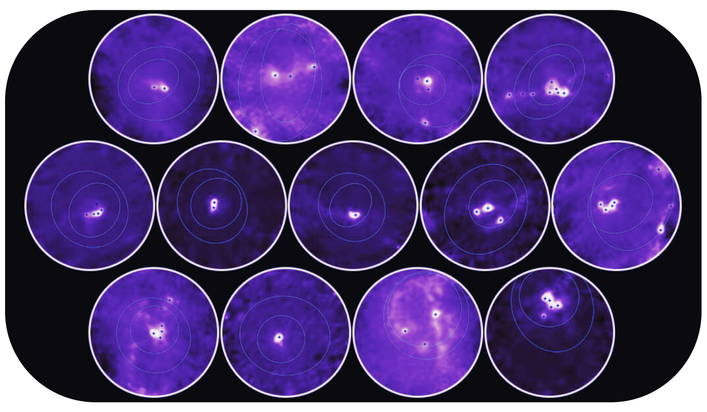
- Identify the **mechanisms responsible of the fragmentation** of dense structures at parsec scales (clumps) into **high-mass star seeds** at scales of thousands of AU (fragments) [1-3]
- **Complement existing massive star-formation scenarios** (e.g., core-fed [4, 5] / clump-fed [6, 7])

Strategy

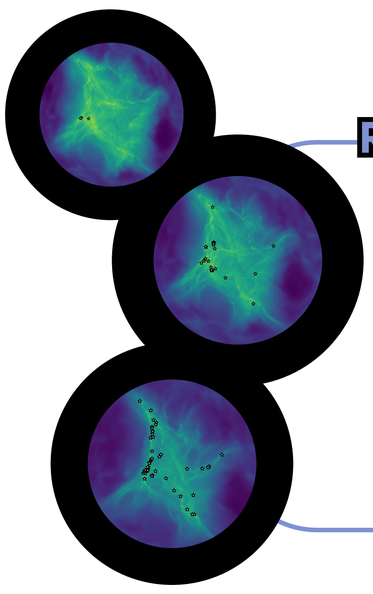
- Enhance our understanding of the star-formation phenomenon by **bridging observations with numerical simulations**
- A systematic approach to produce **synthetic observations** is of key importance
  - *synthetic observations must incorporate **radiative transfer** and mimic **interferometric features***

First science case

ALMA 1.3 mm observations of massive clumps fragmentation from **the SQUALO project** [8]: 13 massive clumps at different evolutionary stages exhibiting different fragmentation modes



Suite of **32 MHD RAMSES simulations** [9, 10] of massive clumps fragmentation and cluster formation with different initial conditions for clumps and environment



RS1.0

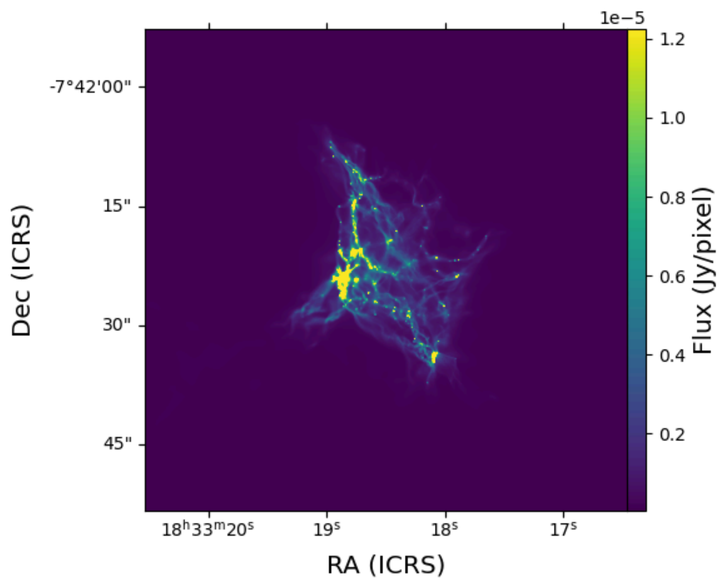
Seed: 1, 2

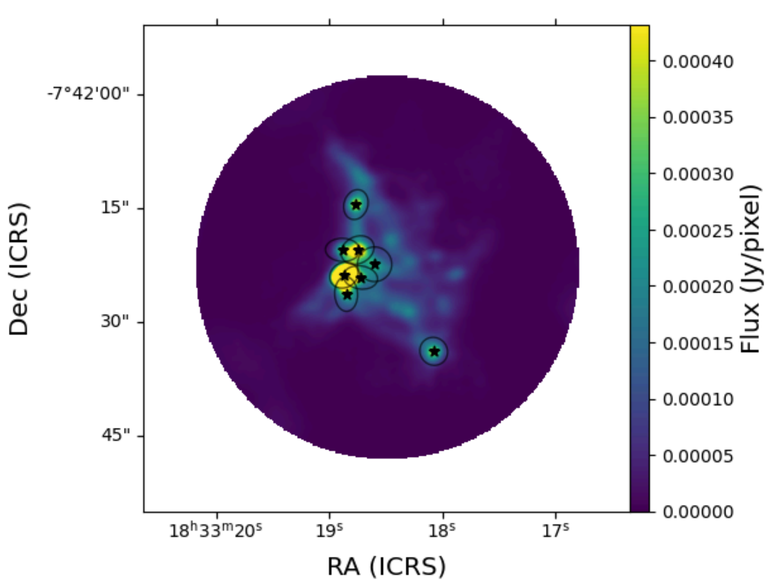
M: (500,1000) $M_\odot$ R: (0.4,0.8)

$\mathscr{M}$: 7,10 μ: 10,100

3 projections, 8+ time steps

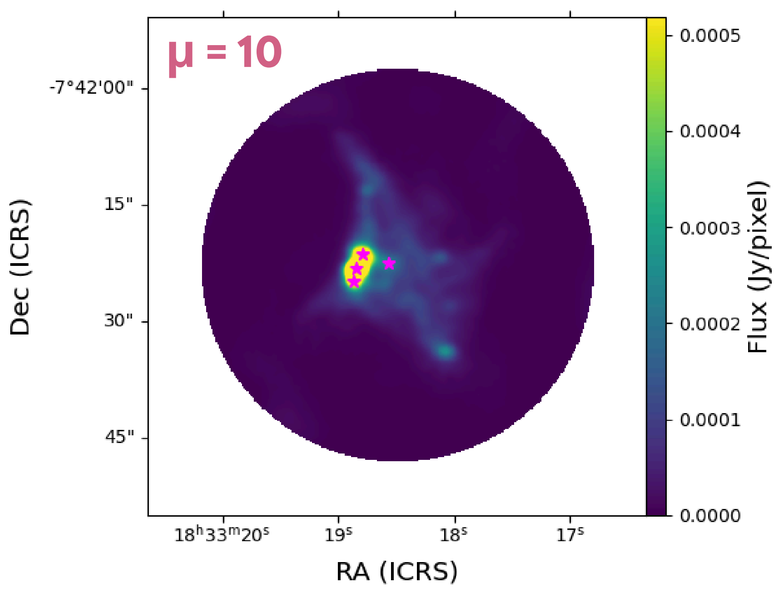
W/ RADMC_3D [11] **and CASA** [12] **software we perform the post-processing to mimic ALMA interferometric observations of the SQUALO data at 1.3 mm ---> The source extraction w/ *Hyper*** [13] **and the analysis of the fragmentation properties** [14] **are carried out as in the SQUALO project.**

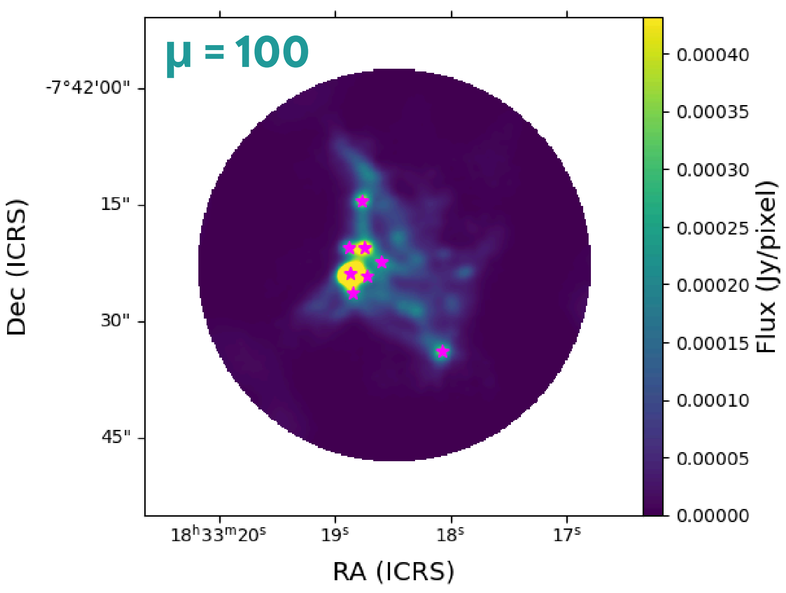


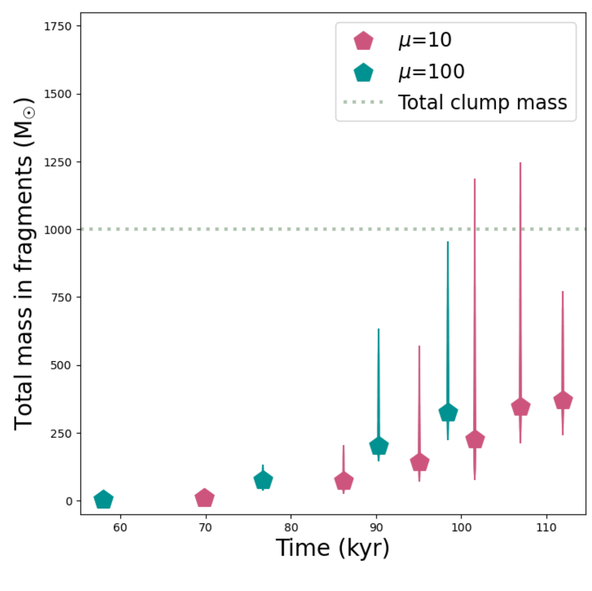


The same approach can be applied to our suite of simulations to mimic any arbitrary set of observations

Fragmentation properties: preliminary results from synthetic observations







Exploration of the **impact of the mass-to-magnetic-flux ratio**, μ = 10 vs. 100, on the fragmentation properties of a 1000 $M_\odot$ clump under identical initial conditions of Seed = 1, R = 0.4 pc, and $\mathscr{M}$ = 10 at SFE ∼5%.

- ***Strong magnetic field --> low fragmentation level***. Magenta stars mark the 4 and 8 fragments identified with *Hyper* at 5σ. [14]
- ***Similar amount of mass accreted onto fragments regardless of magnetic field strength***

Next science case

ALMAGAL [15]: ALMA 1.4 mm observations of massive clumps fragmentation at ∼ 1000 AU.

Questions?
Ask
alice.nucara@inaf.it

Bibliography: ***[1]*** *Sanhueza et al. 2019, ApJ, 886, 102;* ***[2]*** *Svoboda et al. 2019, ApJ, 886, 36;* ***[3]*** *Vázquez-Semadeni et al. 2019, MNRAS, 490, 3061;* ***[4]*** *McKee, C. F. & Tan, J. C. 2003, ApJ, 585, 850;* ***[5]*** *Tan et al. 2014, in PPVI, 149–172;* ***[6]*** *Bonnell, I. A. & Bate, M. R. 2006, MNRAS, 370, 488;* ***[7]*** *Peretto et al. 2020, MNRAS, 496, 3482;* ***[8]*** *Traficante et al. 2023, MNRAS, 520, 2306 ;* ***[9]*** *Teyssier, R. 2002, A&A, 385, 337;* ***[10]*** *Lebreuilly+ (in prep.);* ***[11]*** *Dullemond et al. 2012, ASCL (1202.015);* ***[12]*** *McMullin et al., 2007, in ASPC Series, Vol. 376, ADASSXVI, 127;* ***[13]*** *Traficante at al. 2015, A&A, 574, A119;* ***[14]*** *Nucara+ (in prep.);* ***[15]*** *ALMAGAL - PIs: S. Molinari, P. Schilke, P. Ho, C. Battersby.*