Molecular clouds and Star Clusters put back in their galactic context

Florent Renaud
CEA-Saclay, Paris

Mind the Gaps

- Cosmology
- Galaxy formation
- Galaxy evolution
- Star formation
- Star cluster evolution

- Gas inflows
- Mergers
- Turbulence
- Shear
- Magnetic field
- Stellar evolution
- Outflows, feedback
- Gravitation
Resolving star forming cores, in the galactic context

cores: 0.01 pc
galaxy: 100 kpc

7 orders of magnitude in space AND time

How:
self-consistent simulation of a galaxy, at subparsec resolution
computational domain: $(100 \text{ kpc})^3$
turbulence cascade described (almost ...) down to dissipation scale

Larson (1981)
### INITIAL CONDITIONS, CODE

**pyMGE**  
Emsellem et al. (1993)  
Emsellem & Renaud (in prep)

**Besançon model**  
Robin et al. (2003)

Live DM + stellar components (60M particles)
Gas disk: analytical setup on grid (~ $2.4 \times 10^8$ cells)

**RAMSES**  
Teyssier (2002)

star formation + stellar feedback

HII regions + radiative pressure  
Renaud et al. (submitted)

SNe  
Dubois & Teyssier (2008)  
Teyssier et al. (2013)
Formation of GMCs

- Fragmenting spiral
- Formation of *beads on a string* within 10-15 Myr
see also Elmegreen & Elmegreen (1983) ...
when stars form: \[ \sigma_\star = \sigma_{\text{gas}} \approx 10 \text{ km/s} \]

10 Myr later: \[ \sigma_\star \approx 15 \text{ km/s} \] (relaxation...)

\[ \sigma_{\text{gas}} \approx 9 \text{ km/s} \] (dissipation...)

\[ v_{\text{rotation}}^2 \approx v_{\text{circular}}^2 - \sigma^2 \]
**Galactic context is important**

- Decoupling star-gas
- SN progenitors lag behind the cloud
- Asymmetric, offset feedback
- Inefficient at destroying clouds
**SPURS**

- **Surface density**
  - M 51
  - Chakrabarti et al. (2003)
  - Kim & Ostriker (2006)
  - Shetty & Ostriker (2006)

- **Velocity (horizontal)**
  - 5 Myr older spurs
  - Spurs in formation
  - On the leading side of spirals

- **Kelvin-Helmholz instabilities**
  - Exist in 3D models (without MHD)

- **Image:**
  - Image of galaxy with labeled regions.
SF ON THE LEADING SIDE

contours: CO(1-0)

Schinnerer et al. (2013)
Shear
Cloud-cloud collisions
Tidal features
Probable SF enhancement

Tasker & Tan (2009)
Fukui et al. (2013)
YASA (Yet Another Simulation of the Antennae)

- Gas
- All stars

10 kpc
NGC 474    Duc et al. / CFHT, MegaCam

29 mag/arcsec$^2$
The galactic context matters!

SF is mostly regulated by supersonic turbulence

The galactic context matters!
Bridging the collisional and collisionless scale in the numerical N-body problem

see Mark Gieles' talk tomorrow
http://irfu.cea.fr/Pisp/florent.renaud/mw.php