GES Open Clusters: II

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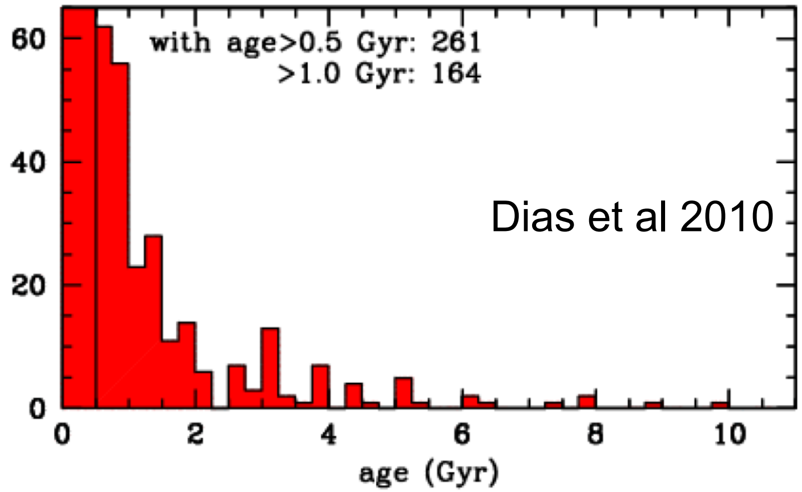
Open clusters as disk tracers

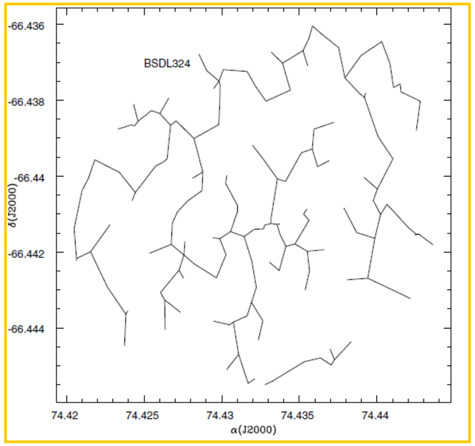


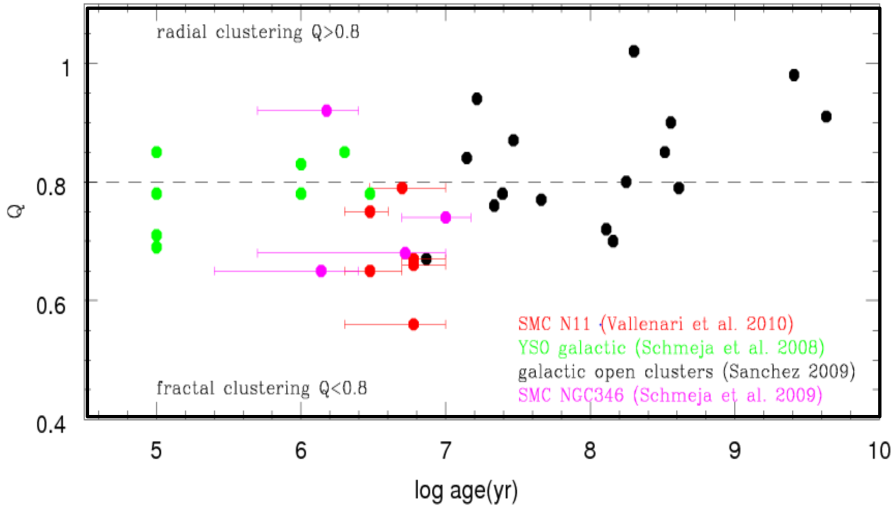
- Only 5% of the Ocs are older than 1 Gyr :90% disruption rate (Bonatto + 2011)

- The internal dynamical evolution of OC
  birth, evaporation, disruption, self-pollution → field stars

  → dependency on the environment: :
  - Tidal field : orbit averaged tidal forcing (not potential shape)
    (Berentzen & Athanassoula 2011, Kupper et al 2010)

Two modes of SF?





- All stars form in clusters → dispersed in the field (e.g. Lada & Lada, 2003)
- In Orion nebula, 20% of stars are distributed→ formed in isolation? (Allen et al 2007)

- Hierarchical formation (Klessen + 2008, Carthwright + 2004)
- High environmental density → bound OCs
- Low density environment → unbound structures/ dispersed SF (Gieles& Portegies Zwart 2011, Bressert et al 2010).

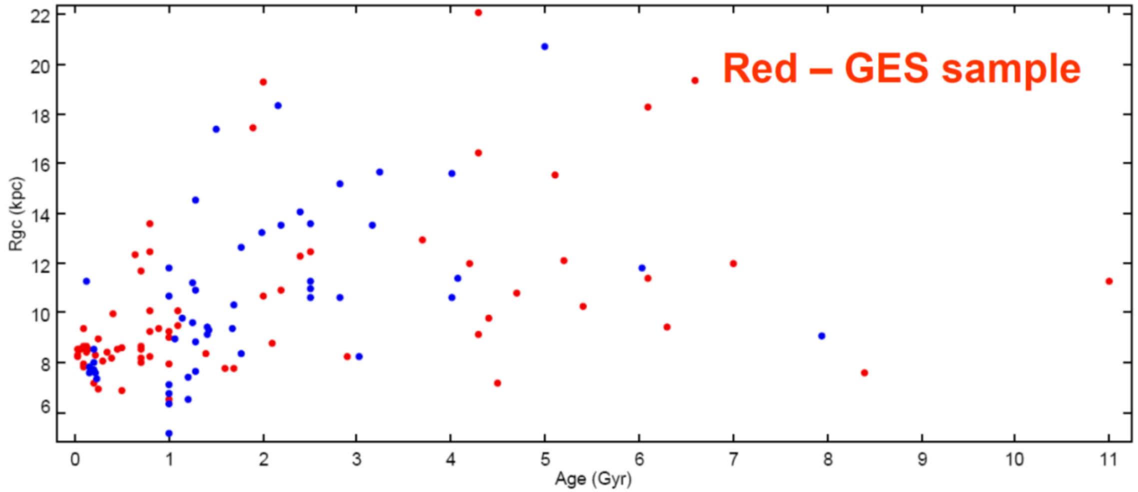
→ **Role of the environment in OC formation**

Cluster disruption

Star clusters can disperse due to different processes:

- gas espulsion due to SN and stellar evolution (Boily & Kroupa 2003…) → 100 Myr (infant mortality)
- Two body relaxation in a tidal field (Gieles et al 2007, Takahashi et al 2000, Baumgardt & Makino 2003) >> 1Gyr
- External perturbation in the disk/giant molecular clouds (Gieles et al 2006, Alfaro et al 2009) → depending on environment
- Is the disruption time varying among galaxies and in different regions in the same galaxy (Gieles et al 2007, 2008, deGrijs et al…, Fritze 2009, Kruijssen et al 2011)

Which data: GES OC Selection



GES Survey
PIs. Gilmore, Randich
+300 CoIs

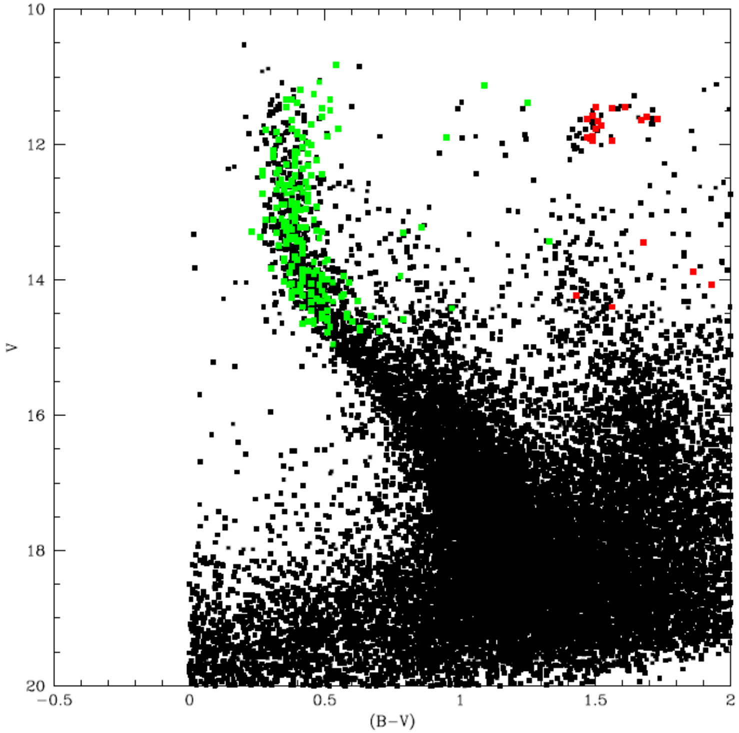
300 n. at Flames/VLT

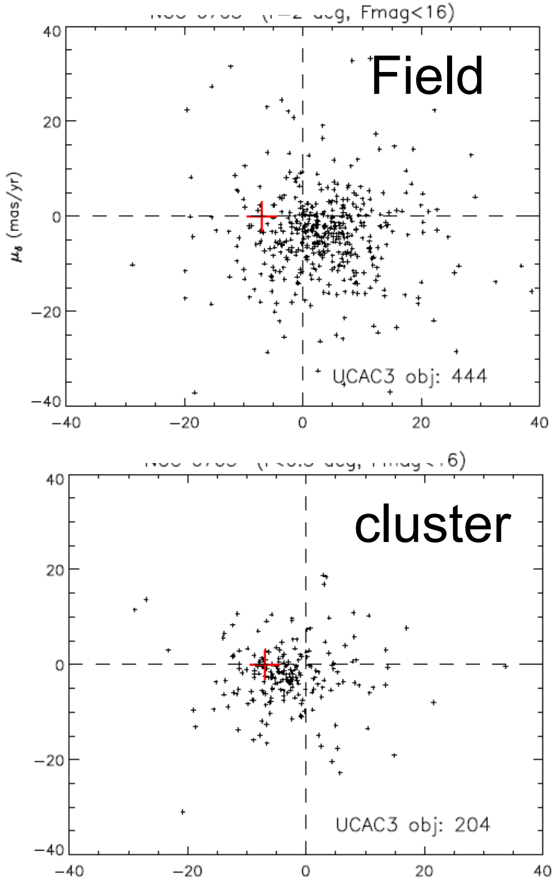
- Young: 1-100 Myr → evolution of OCs from birth to dissolution: IMF, stellar evolution : stars down to M dwarfs

  requirement: vrad< 0.3 m/s for a M star, Gaia 1% precision

  → dc=1.5 kpc: 30 OCs
- Intermediate age : 100-500 Myr req. 1) → dc=700 pc : 15 Ocs
- Old age : > 500 Myr ; large dist → stellar evolution; galactic evolution : red clump stars : 50 Ocs

Which data: membership selection





D=1800 pc,
Age=250 Myr
[Fe/H]=+0.1,

UCAC4 (Smart+2012)

BV (Zaggia + 2012)

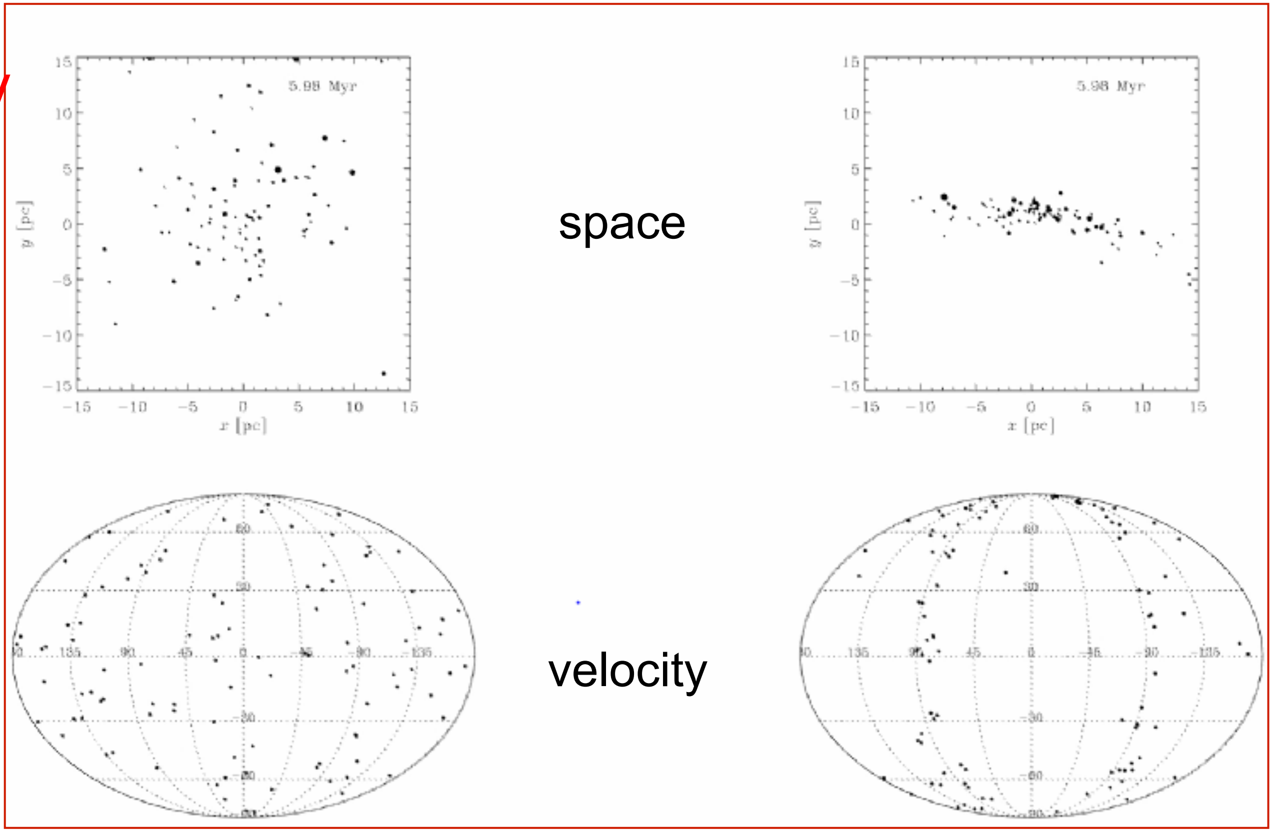
Vecchiato, Abbas, Re Fiorentin+ (2012)

Wide criteria for star selection: trace halo of stars

Gaia+GES OCs

Infant mortality

Cruel Craddle



Kruijssen+ 2011

- Very accurate analysis of the 6D structure of OCs
  - Important issue: Identification of OC halo's members and dynamics.
  - Detection on new stellar clusters based on the analysis of the phase space within a radius of 5 kpc.

Which modelling: N Body

- Large Scale:

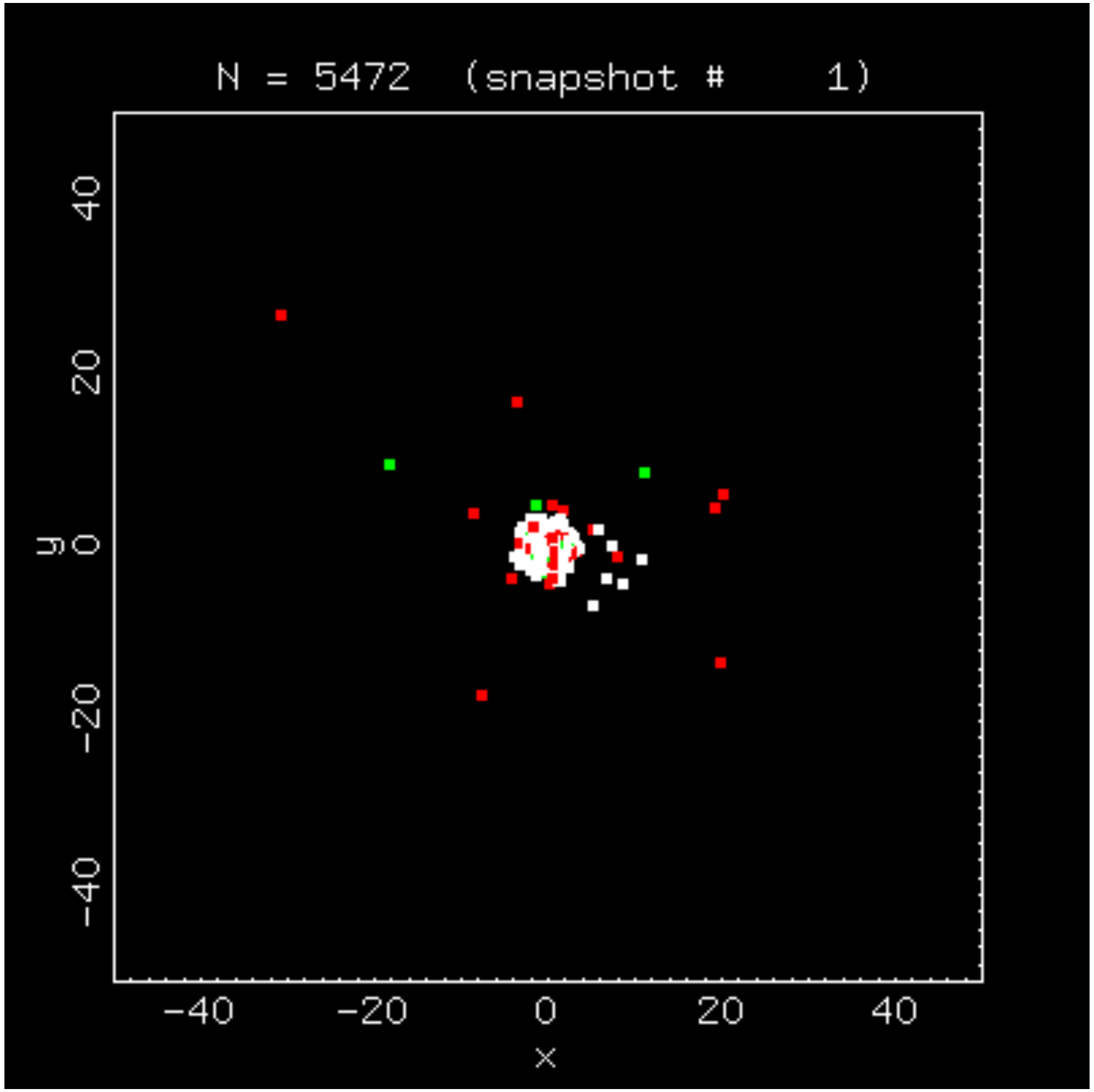
- gas effect
- galactic field

- Small scale:

- up to date stellar evolution (Mapelli+ 2012)

Simulation: STARLAB
Explosive gas removal

unbound
bound
binaries



Cluster modelling: stellar evolution

- **Stellar evolution is fundamental for:**
- Binary stars
- Metallicity dependent mass loss and SN explosions

- **Existing Codes:**
- SeBa -- STARLAB (TREE code Portegies Zwart+2001) :
  Z=Zo
  - Stellar evolution by Eggleton et al (1989)
- BSE using SSE (Hurley + 2000) overshoot +recent opacities

- **Missing: up to date advanced phase treatment**

-Vink's winds (2001) for MS

- WR stars (with metal dependence, Belczynski+2010)

- LBV stars (Humphreys & Davidson 1994, Belczynski+2010)

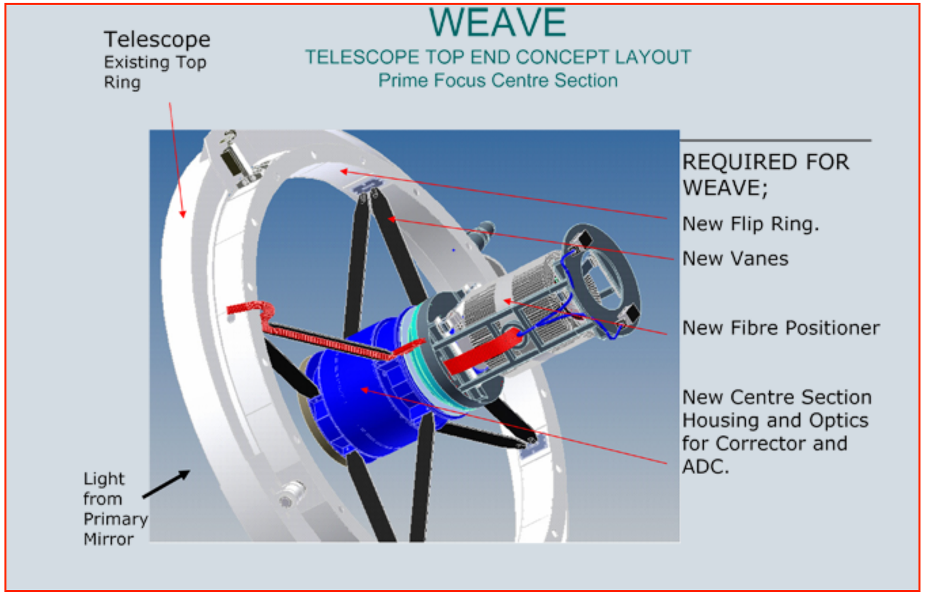
WEAVE Survey

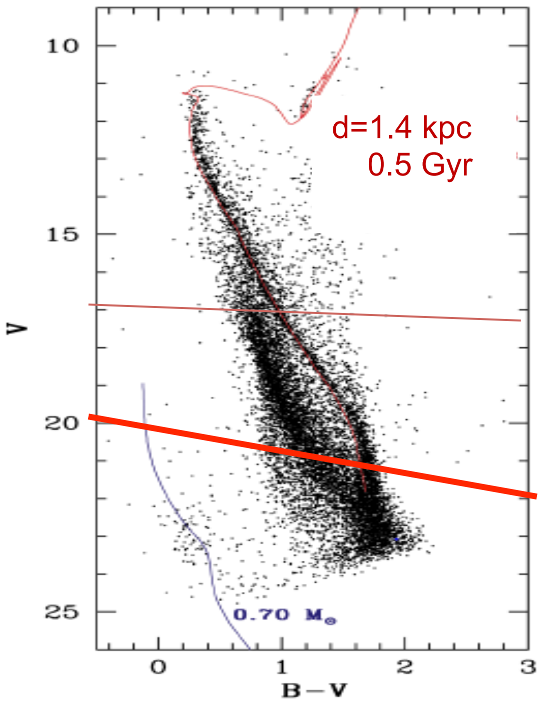
- WEAVE at WHT (Spain, UK, France, Netherlands)
- 2017 + 5 years, D=2deg field, 1000 fibers
- 1) R=20000, Vlim = 17 mag → *chemical labelling*
- 2) R=5000 Vlim = 20 mag → *radial velocity*
- HR spectral range: [450-680]nm
- Goal: complement Gaia
    - field (10^6 stars)and 60 Ocs survey in the North
    - halo formation: streams (v<5 km/s)
    - thin/thick disk formation: kinematics and metallicity
    - external disk
    - Ocs associated with streams
- Expected accuracy for OCs: vrad < 1 km/s
- Chemical labelling : 0.1-0.2 dex

WEAVE- WHT OC Survey

- About 300 Ocs visible from N
- [Fe/H] available only for a few (< 40)
- Gaia distances < 2% for 240 OCs
- Young (age < 500 Myr): 130 OCs

  diameter>20':100 Ocs





Kalirai et al 2001

Red clump stars as tracers: age > 0.5 Gyr

Mv(RC)=0.5 → V=12 at dist=2 Kpc : 60 OCs

→ V=13.5 at dist=4Kpc : 10 OCs

→ V=15.0 at dist=8 Kpc : a few

Conclusions

- Gaia+Ges will produce extremely accurate data on chemistry and kinematics to be compared with accurate models
- New modelling of Ocs should account large scale effects and stellar evolution

What can be done with GAIA?

2 proper motions (μas photometry)+
radial velocity (1-10 km s^{-1} error)

stars undergoing evaporation/ ejection from parent cluster
(comparison with simulations)

accurate binary fraction & BSSs
(comparison with simulations)

kick associated with BSSs
(comparison with simulations)

Cons: dense young clusters in crowded fields (MW centre) → study only open clusters and associations

What do we need

- Very accurate analysis of the 6D structure of a few well known clusters (e.g. Hyades, Praesepe, Pleiades)
  - Important issue: Identification of OC halo's members and dynamics. Interaction with the Galaxy
- Detection on new stellar clusters based on the analysis of the phase space within a radius of 5 kpc.
- Membership analysis based on the complete information obtained from the phase space.

Cluster internal structure and interaction with the Galaxy

- Very accurate analysis of the 6D structure of a few well known clusters (e.g. Hyades, Praesepe, Pleiades)
  - Important issue: Identification of OC halo's members and dynamics. Interaction with the Galaxy
- Detection on new stellar clusters based on the analysis of the phase space within a radius of 5 kpc.
- Membership analysis based on the complete information obtained from the phase space.
- Evolution of the internal structure of stellar clusters with age
- Analysis of the velocity structure of the clusters

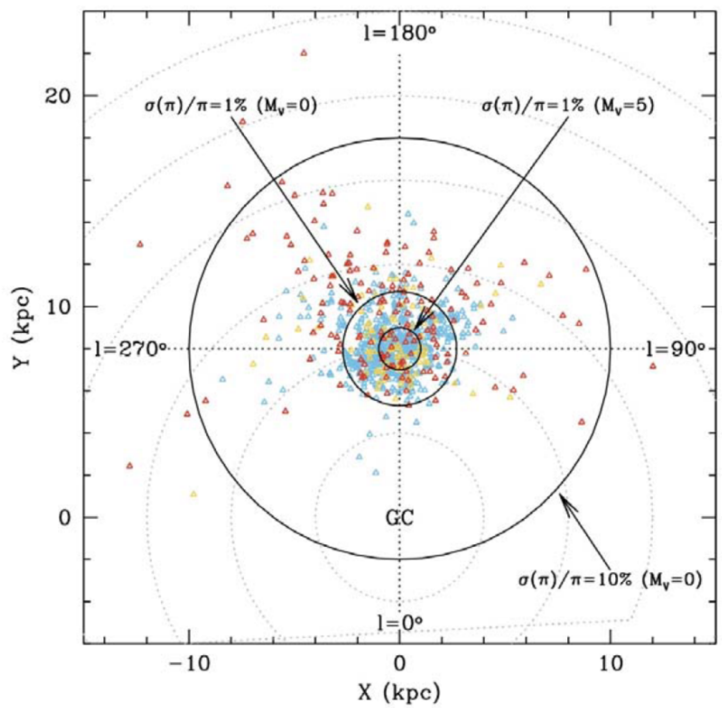
Gaia limitations : the OCs case

- Small velocity dispersion in OCYA (1 - 2 km/sec) requires accuracies < 1 km/sec:
  - studies of the internal dynamics require ~ 0.2 km/sec
  - Gaia: accuracy better than 1% for

    G0 stars brighter than V~13 (d<500pc),

    K1 III (red clump in old clusters) V<14 :d < 5 kpc

- Limited wavelength range of RVS.
  - No r- and s-process elements
  - No Li
  - No Halpha
  - No chromospheric activity index for faint stars



Reconstructing the MW disk

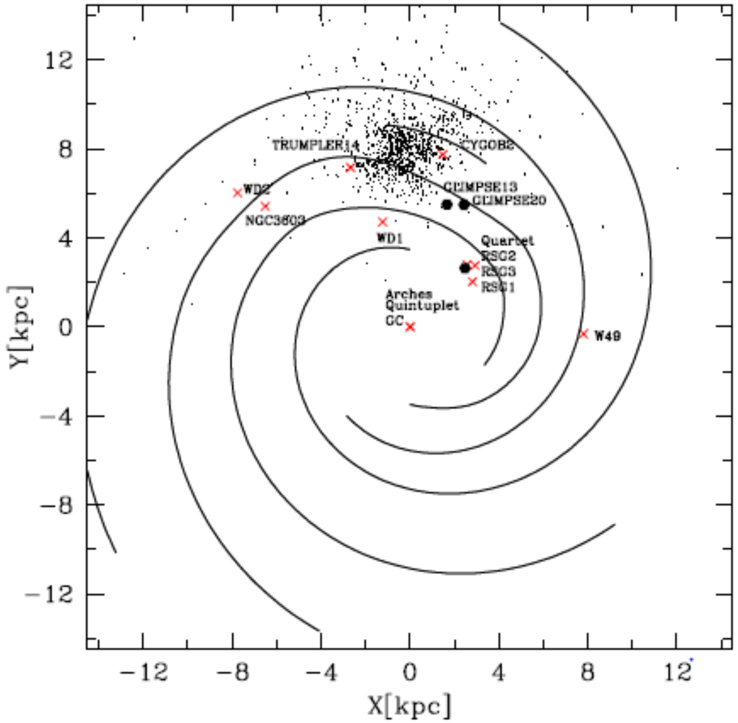


Fig. 15.— Galactic distribution of clusters optically detected (dots) taken from (Dias et al. 2002), known massive clusters (see Table 4) are shown with crosses. The Galactic center is at (0,0) and the Sun is at (0,8). The three clusters presented in this work are marked with hexagons. Spiral arms are from Cordes & Lazio (2002).

- **2095** Ocs
- **1193** with distance
- **177** with a [Fe/H] estimate
  (few from high-res) (Dias et al 2010)

- Spiral structure: 2-4 arms?
- Stellar warps
- Stellar debris in the disk: open clusters associated to stellar streams/debris

Radial gradient and radial mixing (open clusters, field population)

- Distribution of the Galactic OCs
- OCs and metallicity distribution in the disk

Stellar migration?

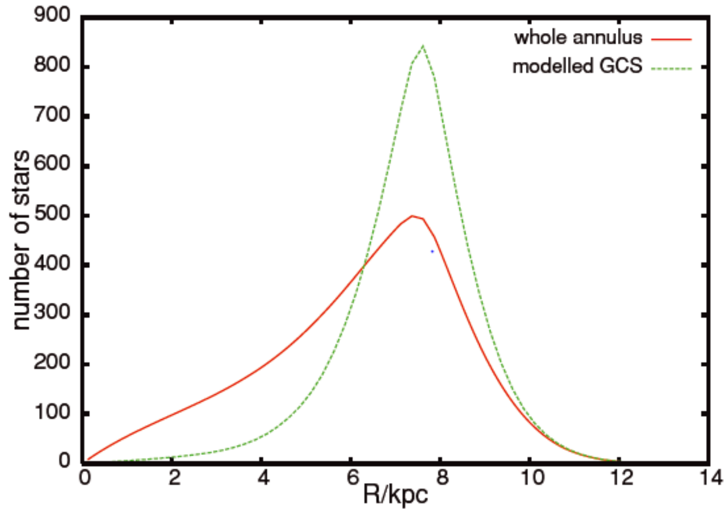
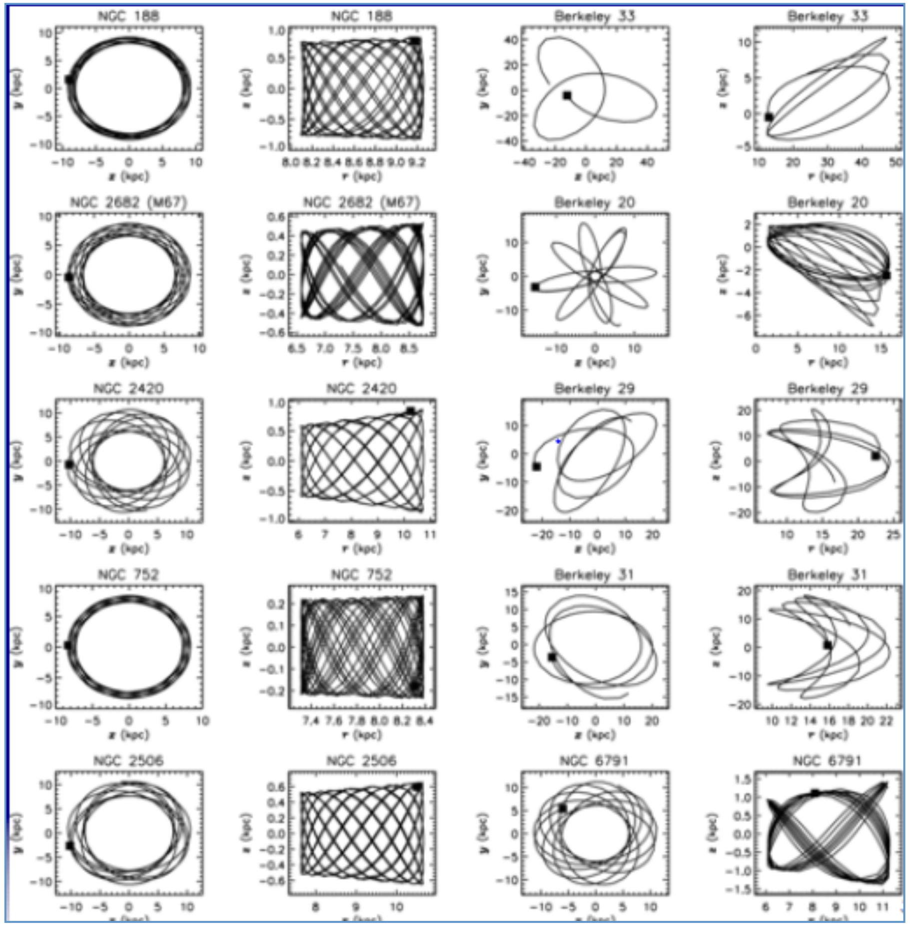


Figure 1. The distribution of birth radii of stars in the model GCS sample (green dashed line) and of all stars in the solar cylinder (solid red line).

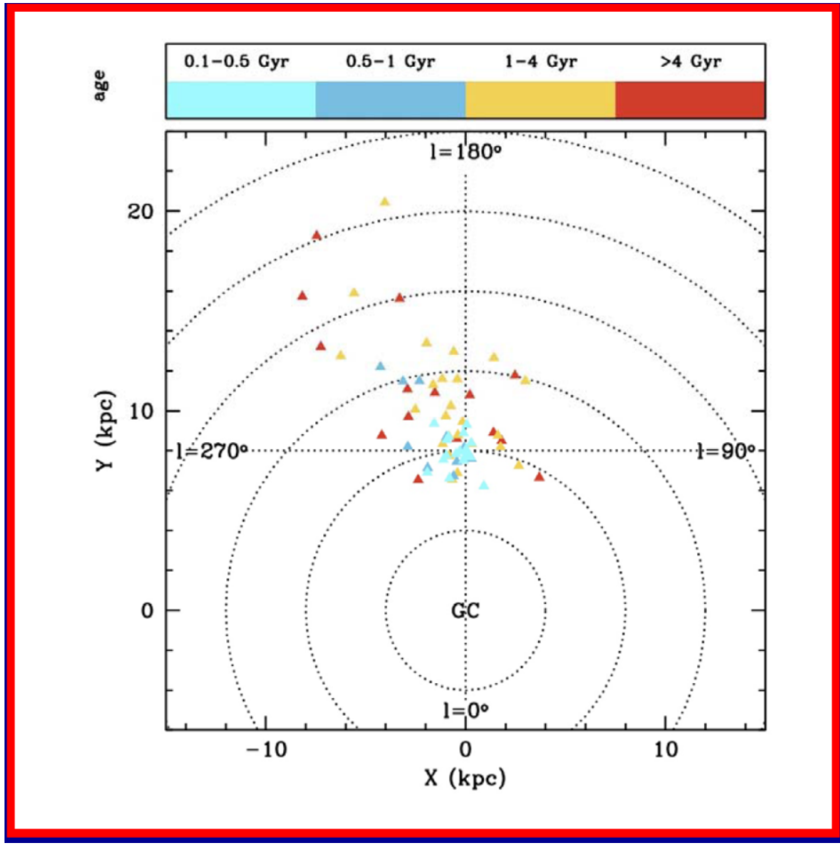
Schoenrich et al 2009, Lee et al 2011

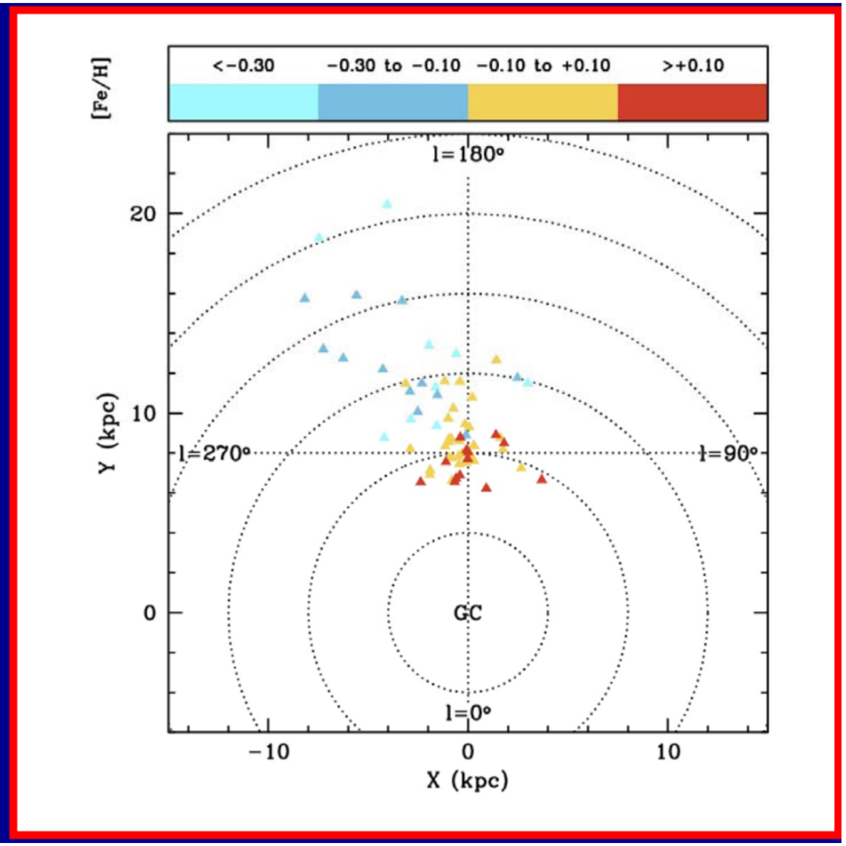


Wu et al 2009 : 400 Ocs

obs. errors dominate
(d~20%, p.m.~25%),

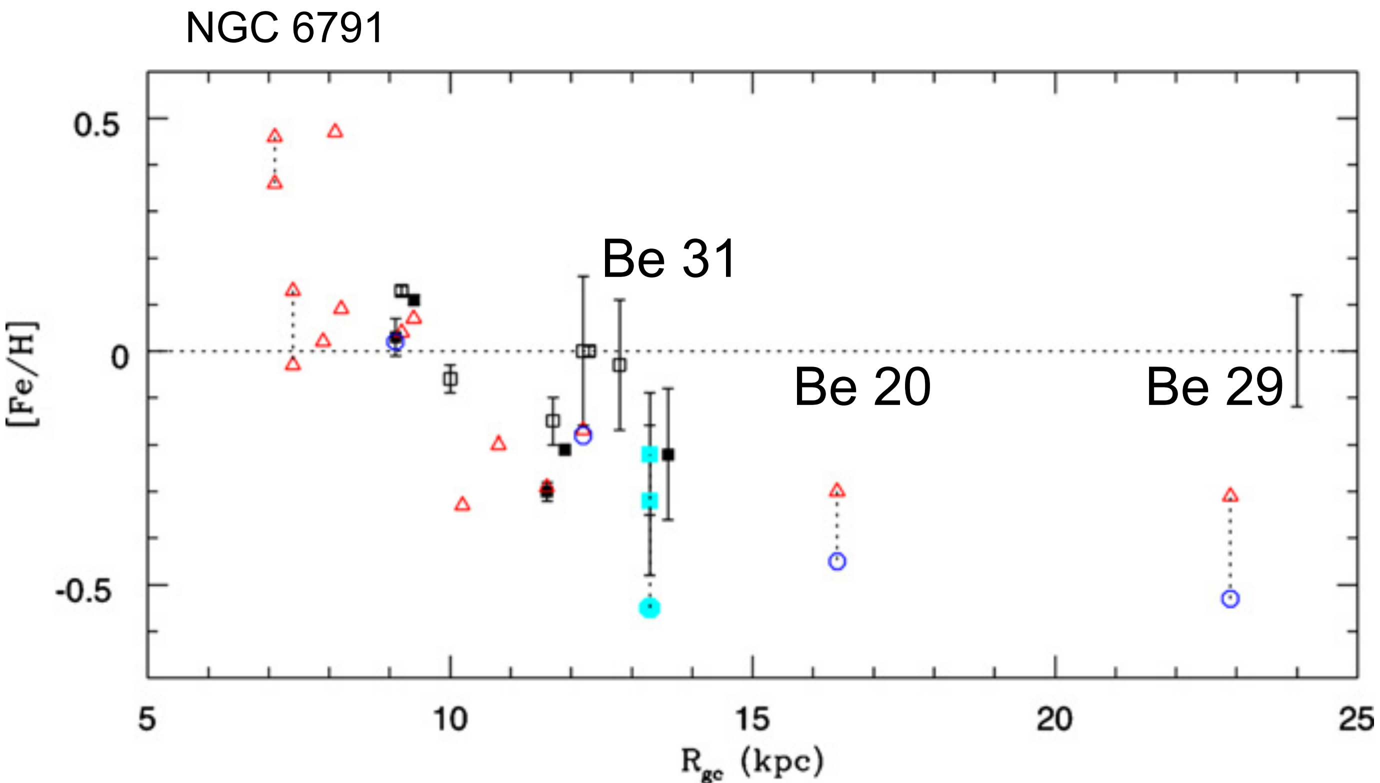
What do we know?





- Dias et al (2002-2010): 1800 Ocs
- Only 69 Ocs with known age, distance, high res [Fe/H]

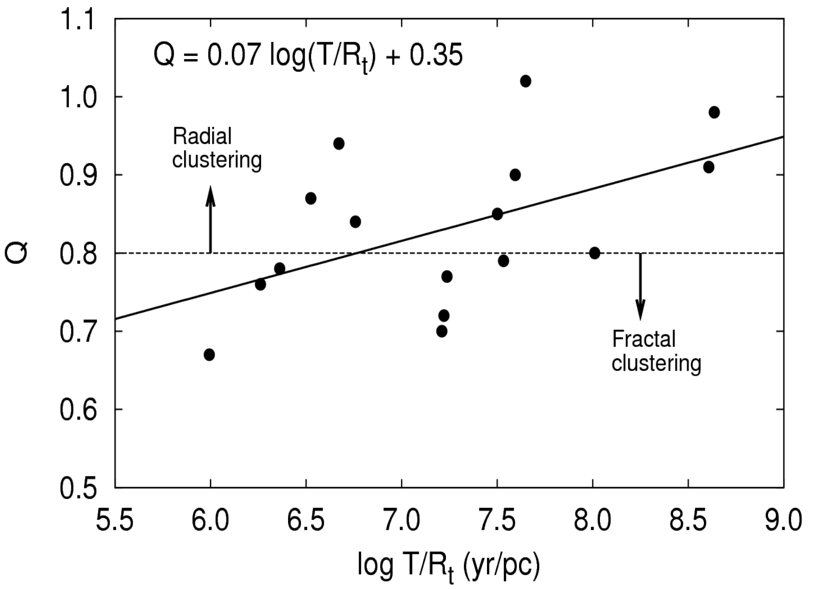
Do we know age and distance?



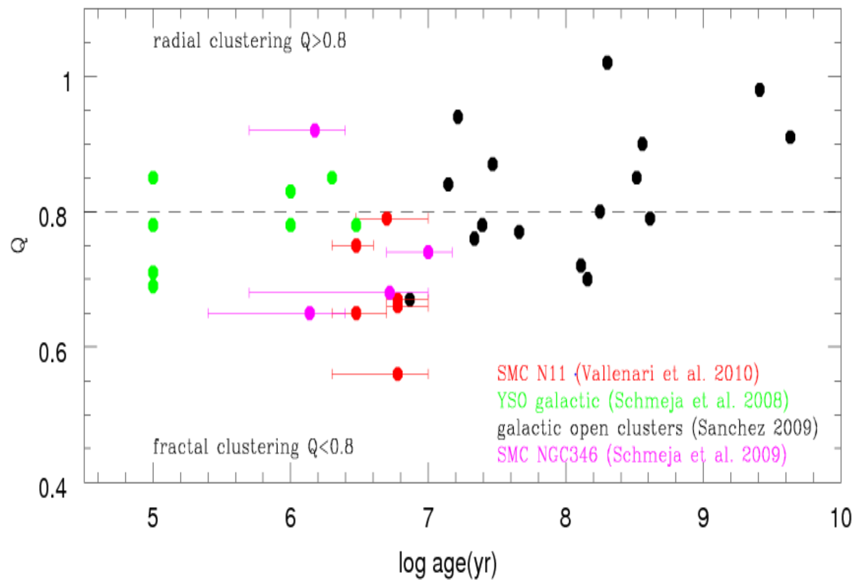
Friel et al 2010

- Distance 4 Kpc age =7Gyr He enhanced (Brogaard et al 2010)
- Distance 4 Kpc age =9 Gyr (King et al 2005)
- Distance 3.6 kpc age =12 (Stetson 2003)

Cluster disruption: observations



Sanchez+09:
- Spatial substructure in old clusters in the MW (eg. NGC1513,NGC1647)
- Q increases with ~ T/Tcross



Vallenari et al 2010