Open clusters as disk tracers: Gaia & GES

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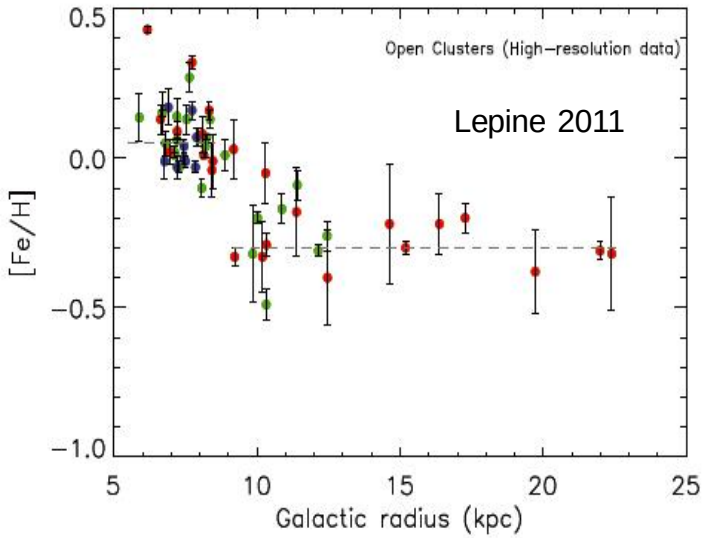
Open clusters as disk tracers

- Clusters age , metallicity, position trace the disk chemical gradient disk
  → disk formation process

(Andriewski+ 2004, Magrini+2009, Chiappini+2001 Yong+ 2005)



Less affected by radial migration ?
(Wu+2007, vandePutte+ 2011)

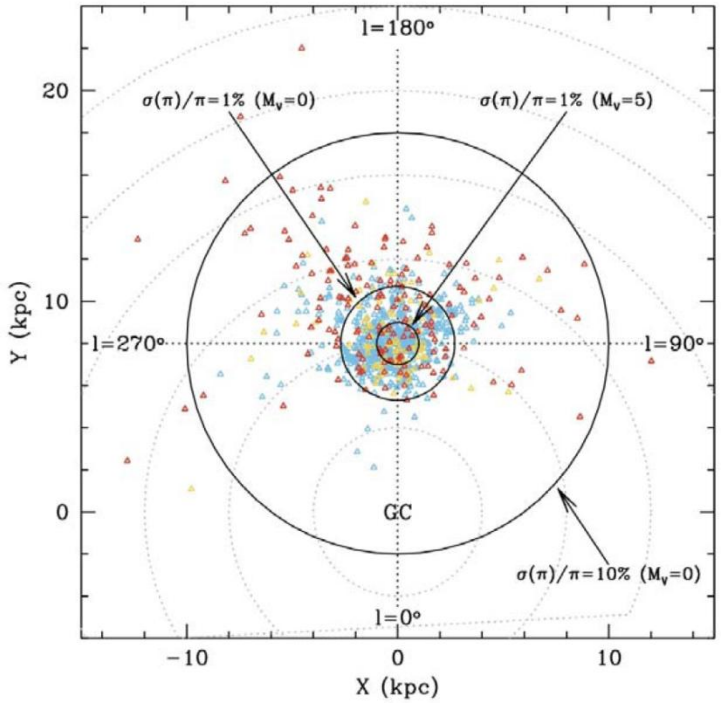
- Their internal kinematics/ dynamical evolution
  birth, evaporation, disruption, self-pollution
  trace the Galactic environment

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

→ - interaction with giant molecular clouds & spiral arms
(Gieles et al 2006, Kujissen+2011)

\+ stellar evolution effects (infant mortality)

Which data: Gaia view of OCs



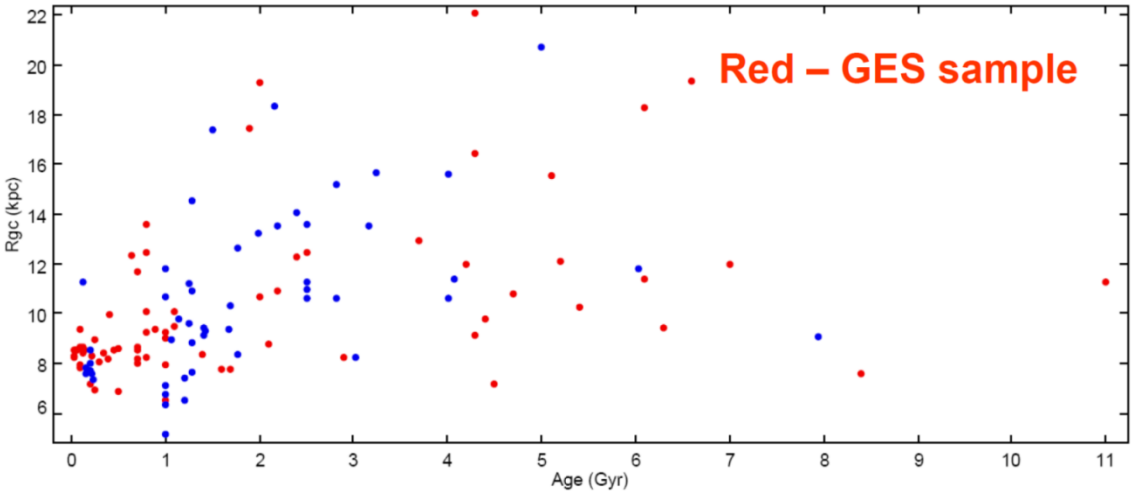
Present situation: 2095 known Ocs
1193 with distance
100 with a [Fe/H] estimate(Dias+2010)

Gaia: Derive distances + pm of individual stars in Ocs
- at 1% for Mv=5 d < 1.5kpc
- at 1% for M=0 d < 4kpc
-at 10% for almost all known cluster
→ accurate membership-- orbits

Small velocity dispersion in OCYA (1 - 2 km/sec) → studies of the internal dynamics require ~ 0.2 km/sec

– Gaia: accuracy better than 1% for transverse velocity
G0 stars brighter than V~13 (d<500pc),

Which data: GES OC Selection



GES Survey
PIs. Gilmore, Randich
+300 CoIs

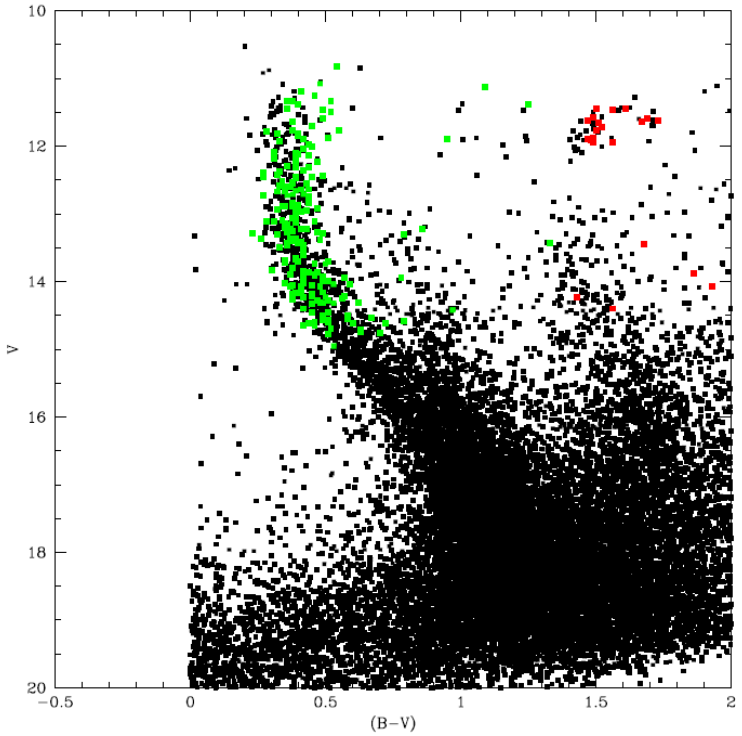
300 n. at Flames/VLT

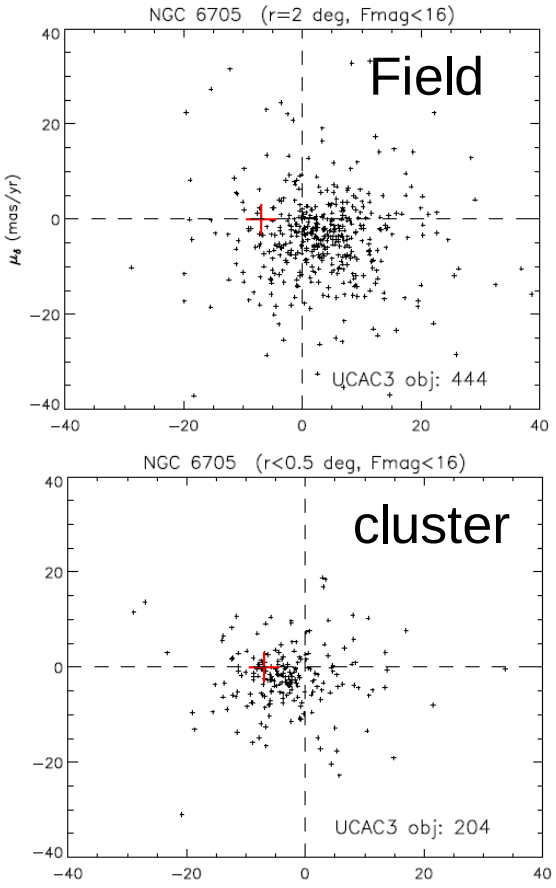
- Young: 1-100 Myr → evolution of OCs from birth to dissolution: IMF, stellar evolution : stars down to M dwarfs

  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)

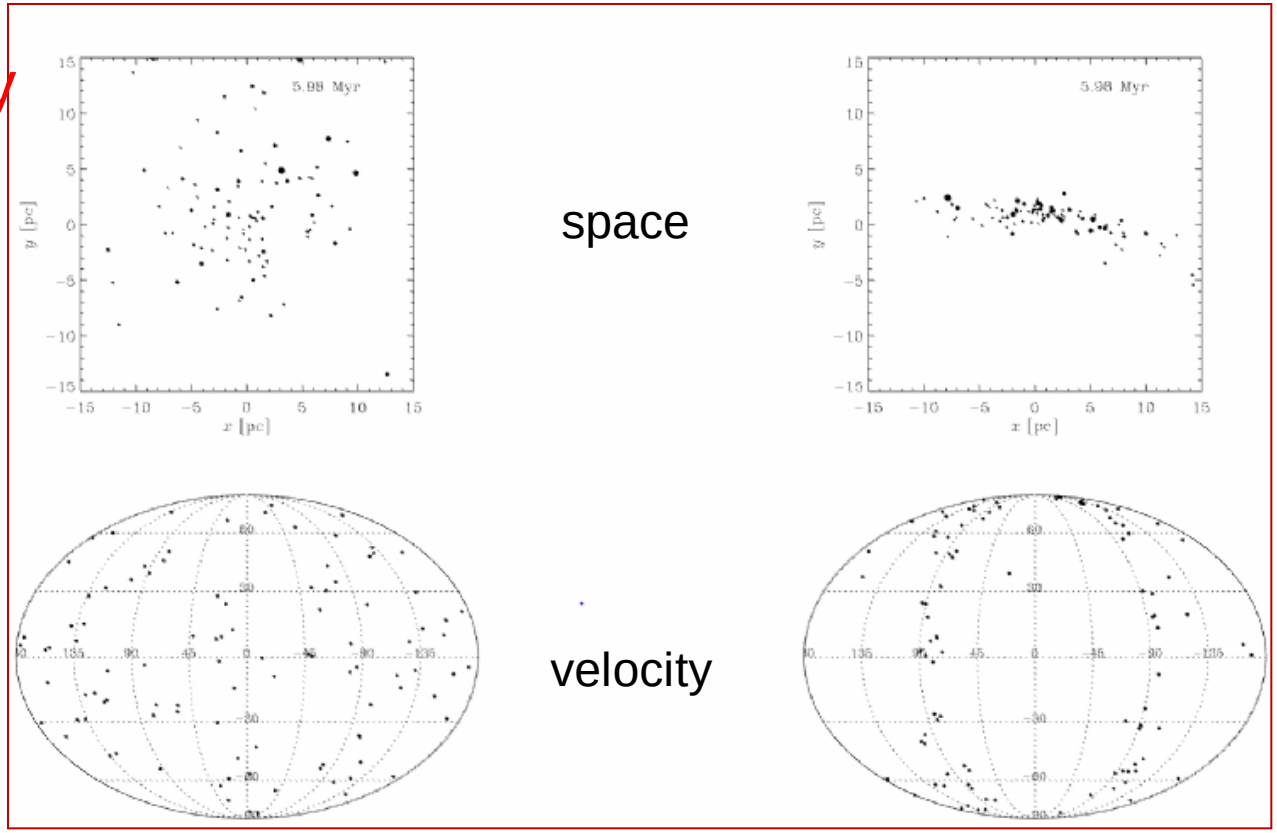
BV (Zaggia + 2012)

Wide criteria for star selection: trace halo of stars

Gaia+GES OCs

Infant mortality

Cruel Craddle



Kruijssen+ 2011

- Very accurate analysis of the 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: Nbody

- Large Scale:

- gas effect

- galactic field

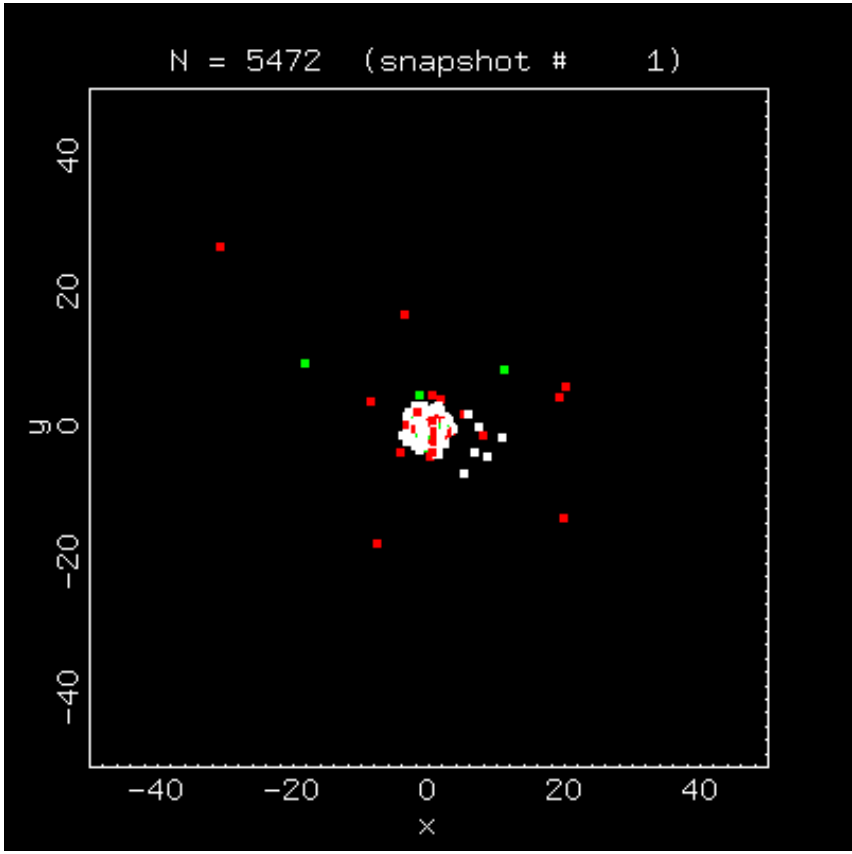
(Berentzen & Athanassoula 2011, Kupper et al 2010, Just+2011)

- Small scale:

- up to date stellar evolution

•SeBa -- STARLAB (TREE code)
(Portegies Zwart+2001) :
-Z=Zo
- Stellar evolution by Eggleton et al (1989)

•BSE using SSE (Hurley + 2000) overshoot



Simulation: STARLAB

Explosive gas removal

unbound

bound

binaries

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

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
- 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)

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

gaia

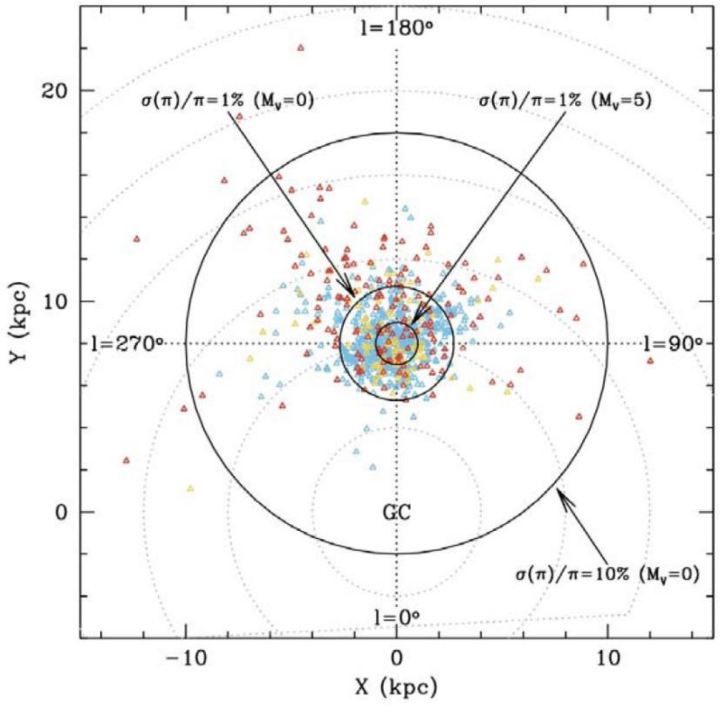
Cluster internal structure and interaction with the Galaxy

- 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

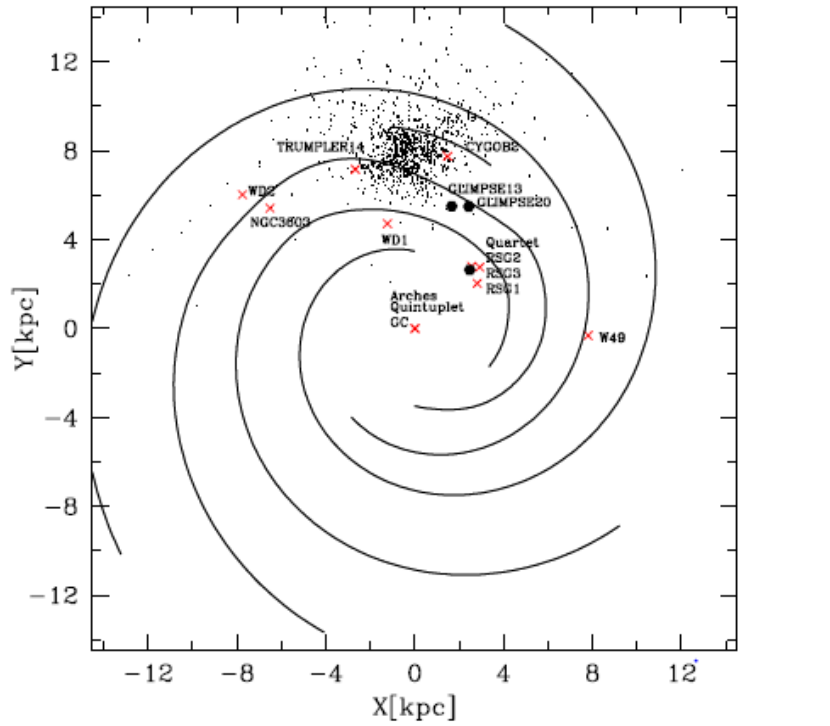


Fig. 15.— Galactic distribution of clusters optically detected (dots) taken from (Diss et al. 2002), known massive clusters (see Table 1) are shown with crosses. The Galactic center is at (0,0) and the Sun is at (0,8). The three clusters presented in this work are marked with hexagons. Spiral arms are 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?

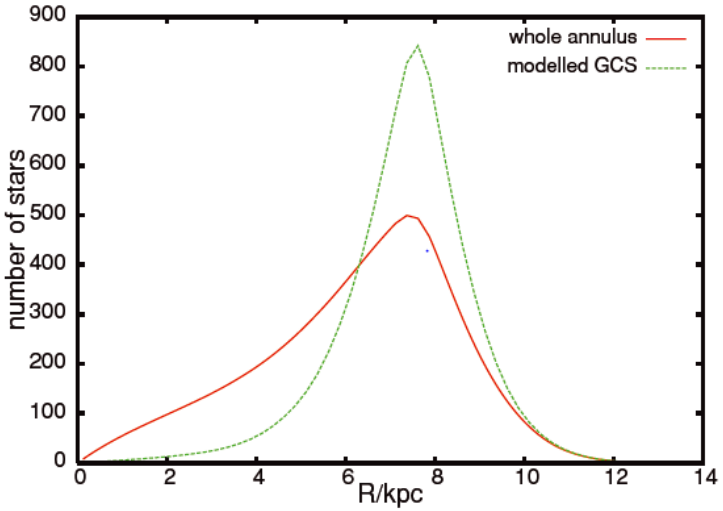
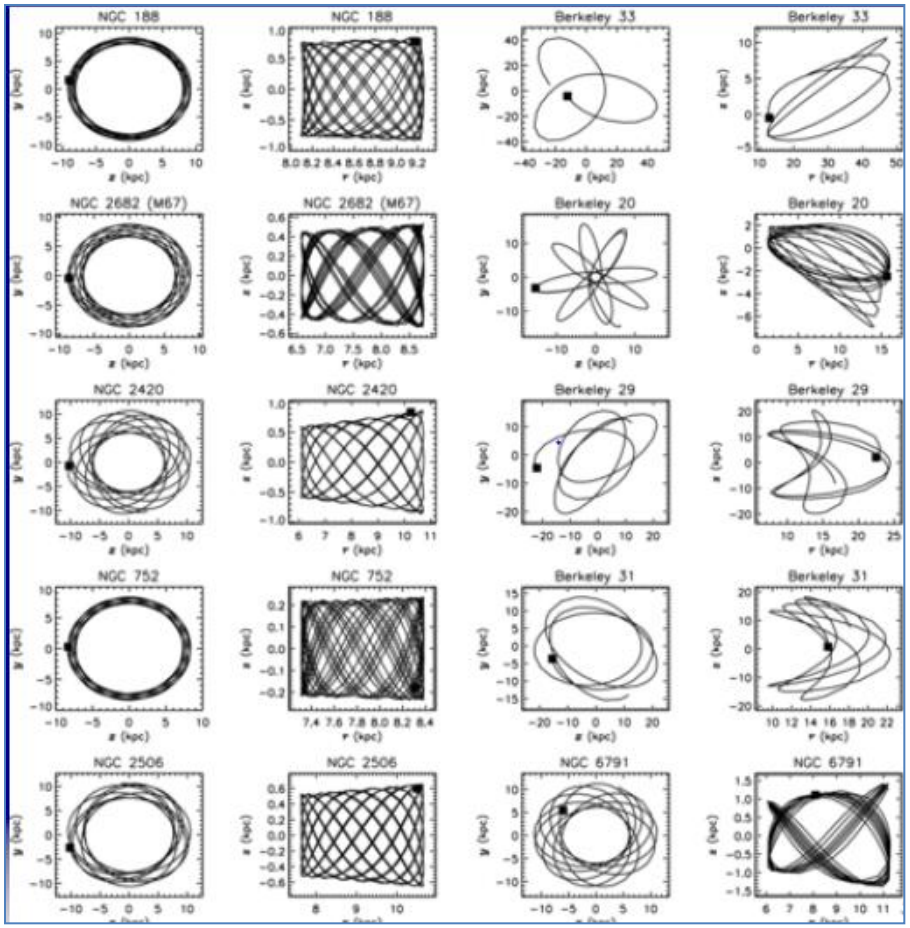


Figure 1. The distribution of birth radii of stars in the model GCS sample (green dashed line) and of all stars in the solar cylinder (solid red line).

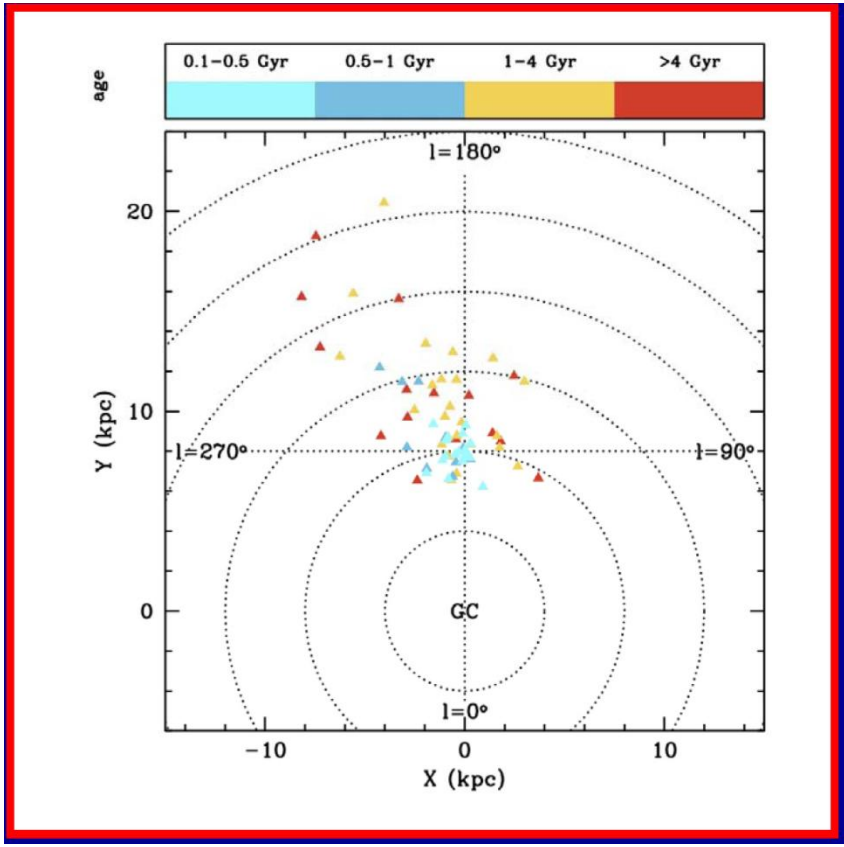
Schoenrich et al 2009, Lee et al 2011

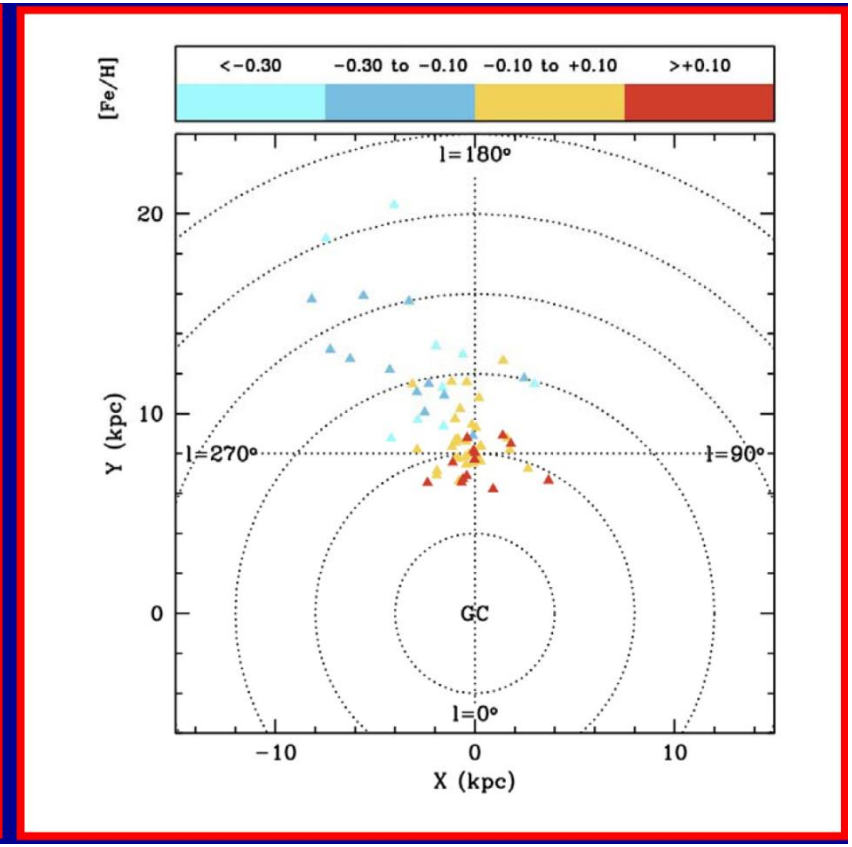


Wu et al 2009 : 400 Ocs

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

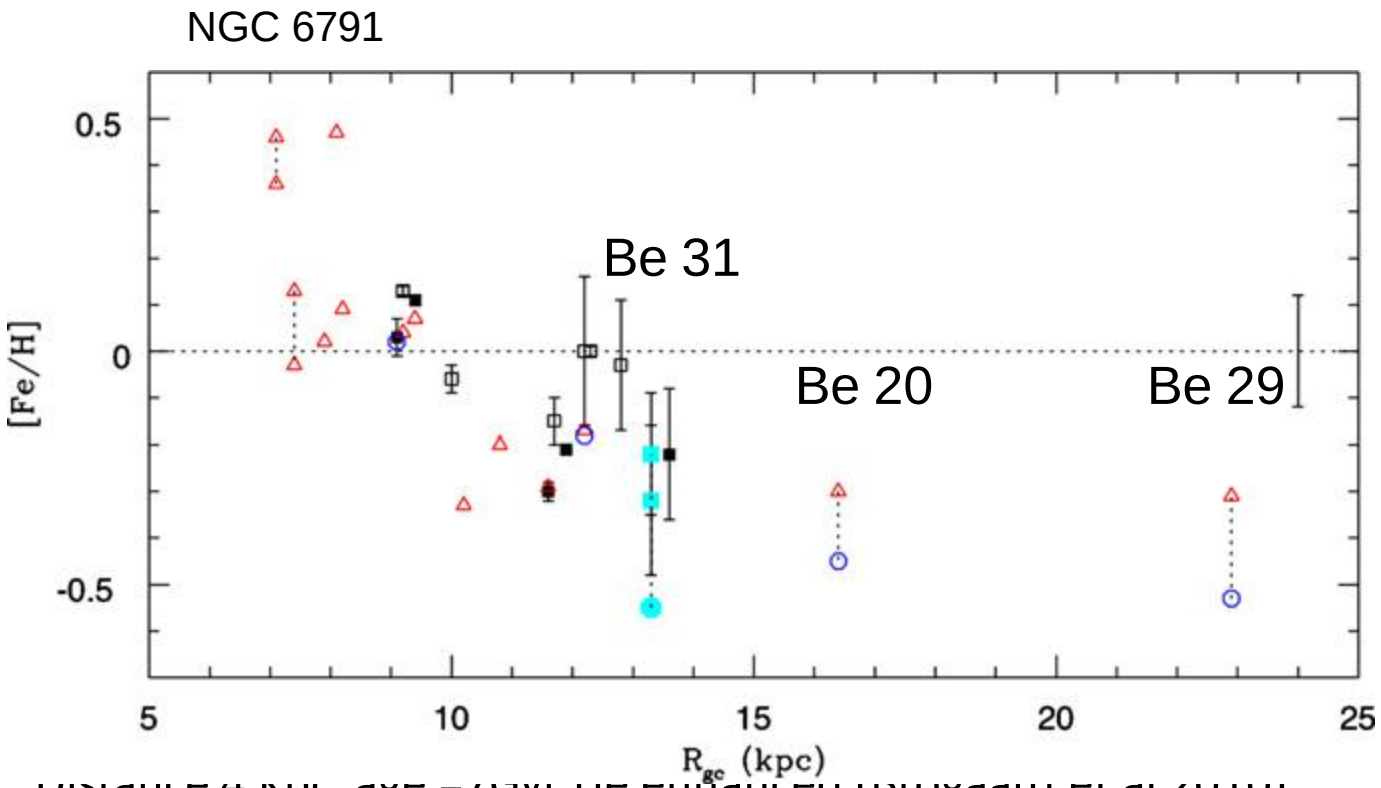
What do we know?





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

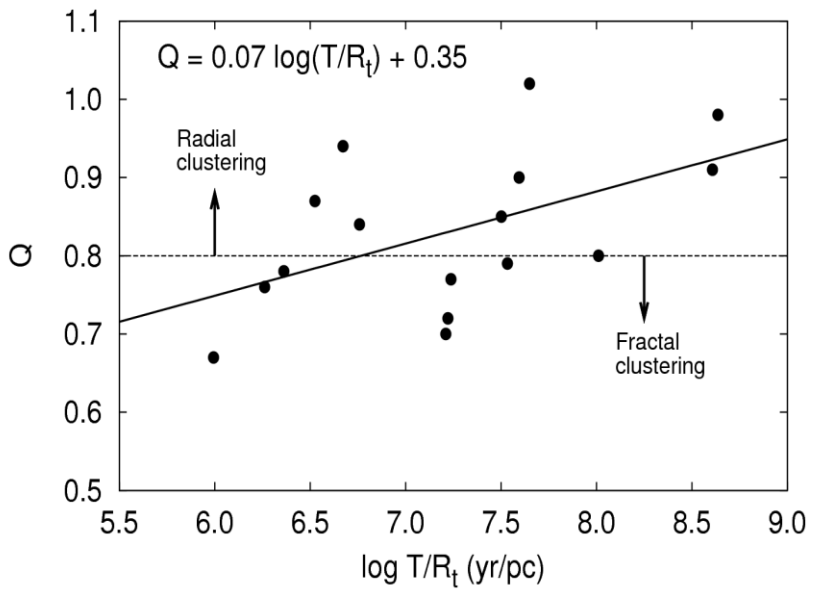
Do we know age and distance?

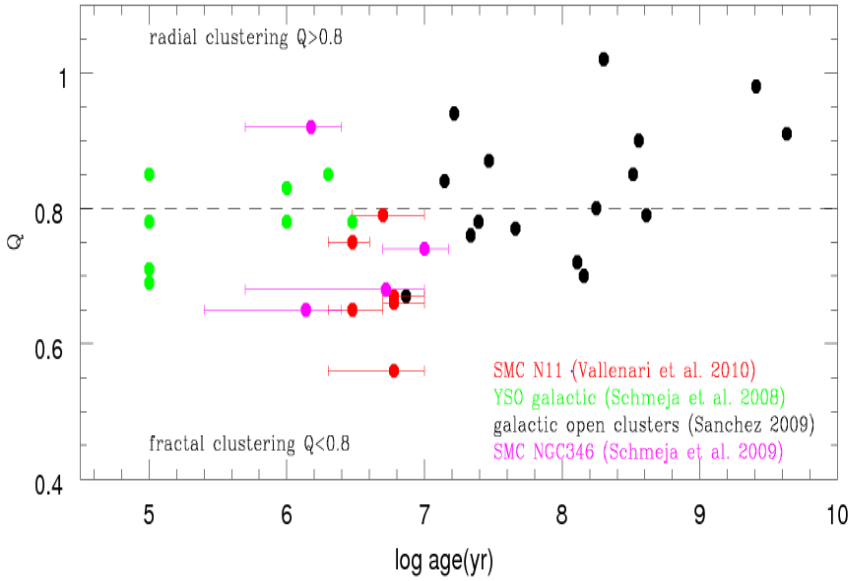


Friel et al 2010

- Distance 4 Kpc age =7 Gyr 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





Vallenari et al 2010

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

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
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