The old clusters of the Milky Way disk

Angela Bragaglia

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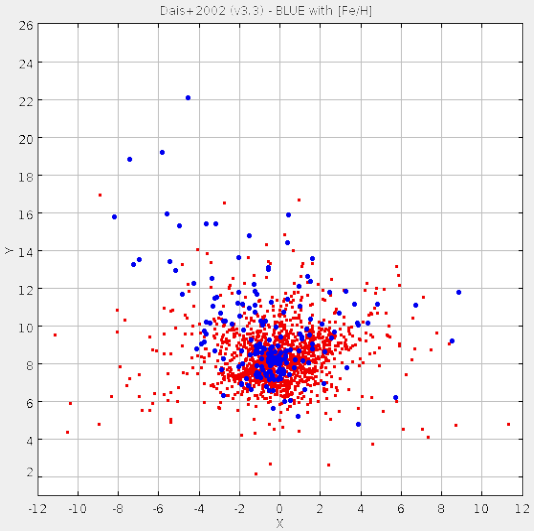
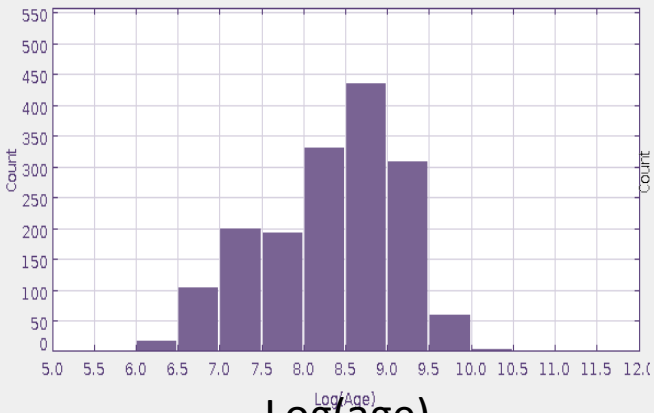
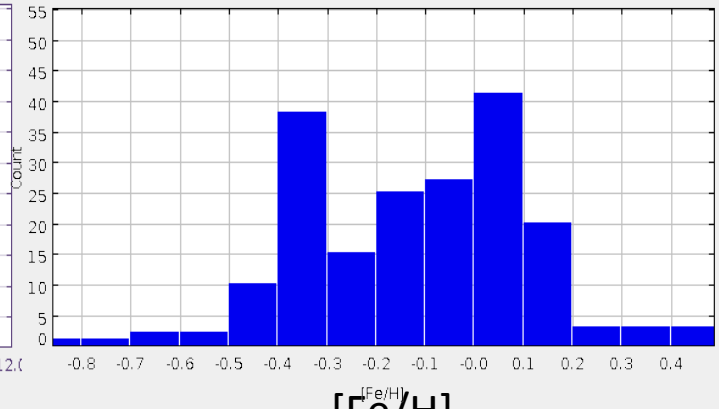
Dias, Alessi, Moitinho, Lepine 2002



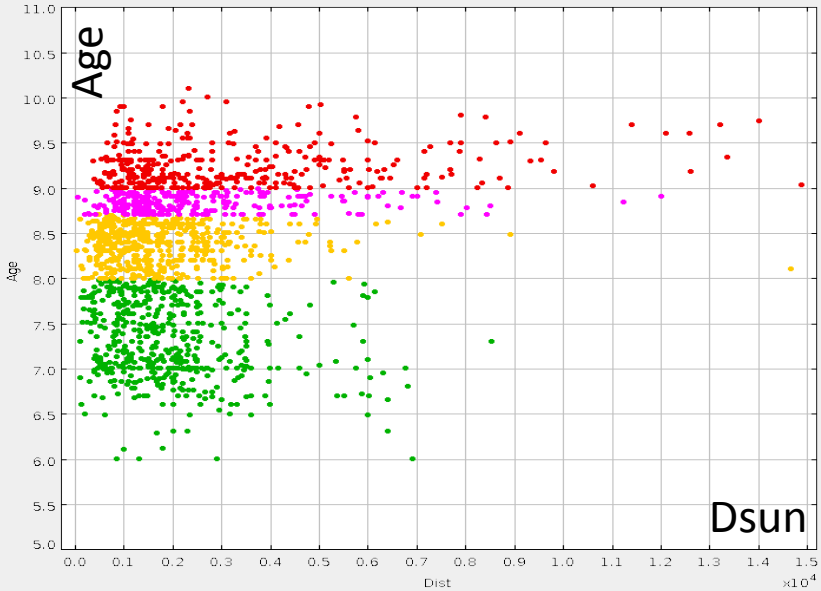


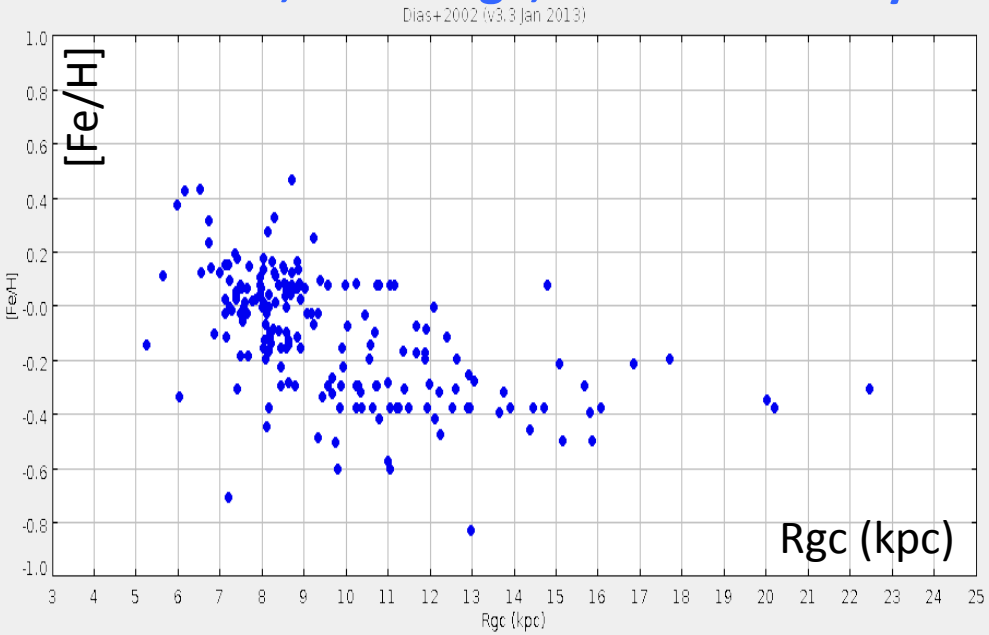
Log(age)



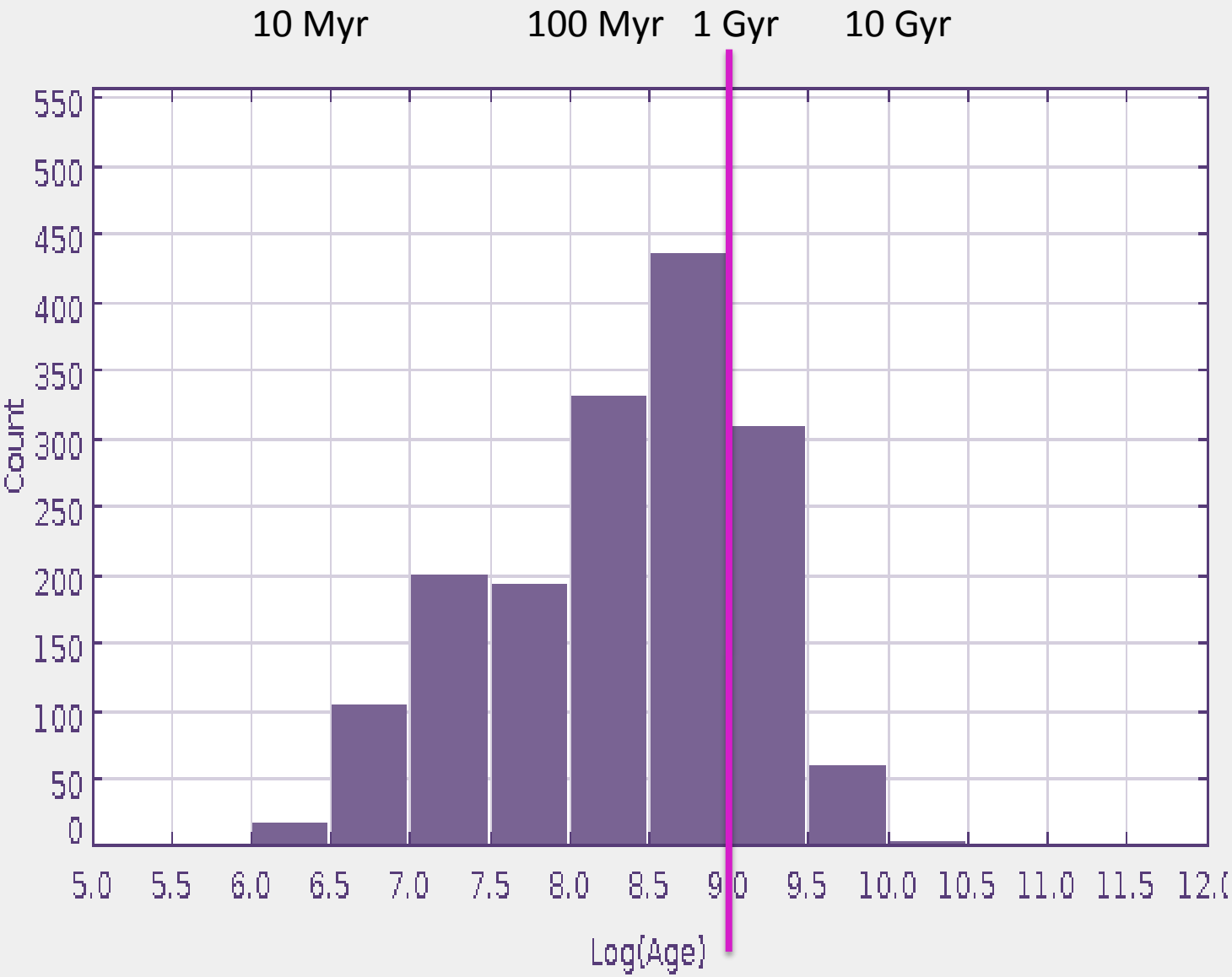
[Fe/H]

2174 OCs, ≈1650 distance, ≈1600 age, ≈190 metallicity





Dias, Alessi, Moitinho, Lepine 2002



age ≥ 1 Gyr
364/2174 17%
age ≥ 2 Gyr
132/2174 6%
age ≥ 4 Gyr
36/2174 2%

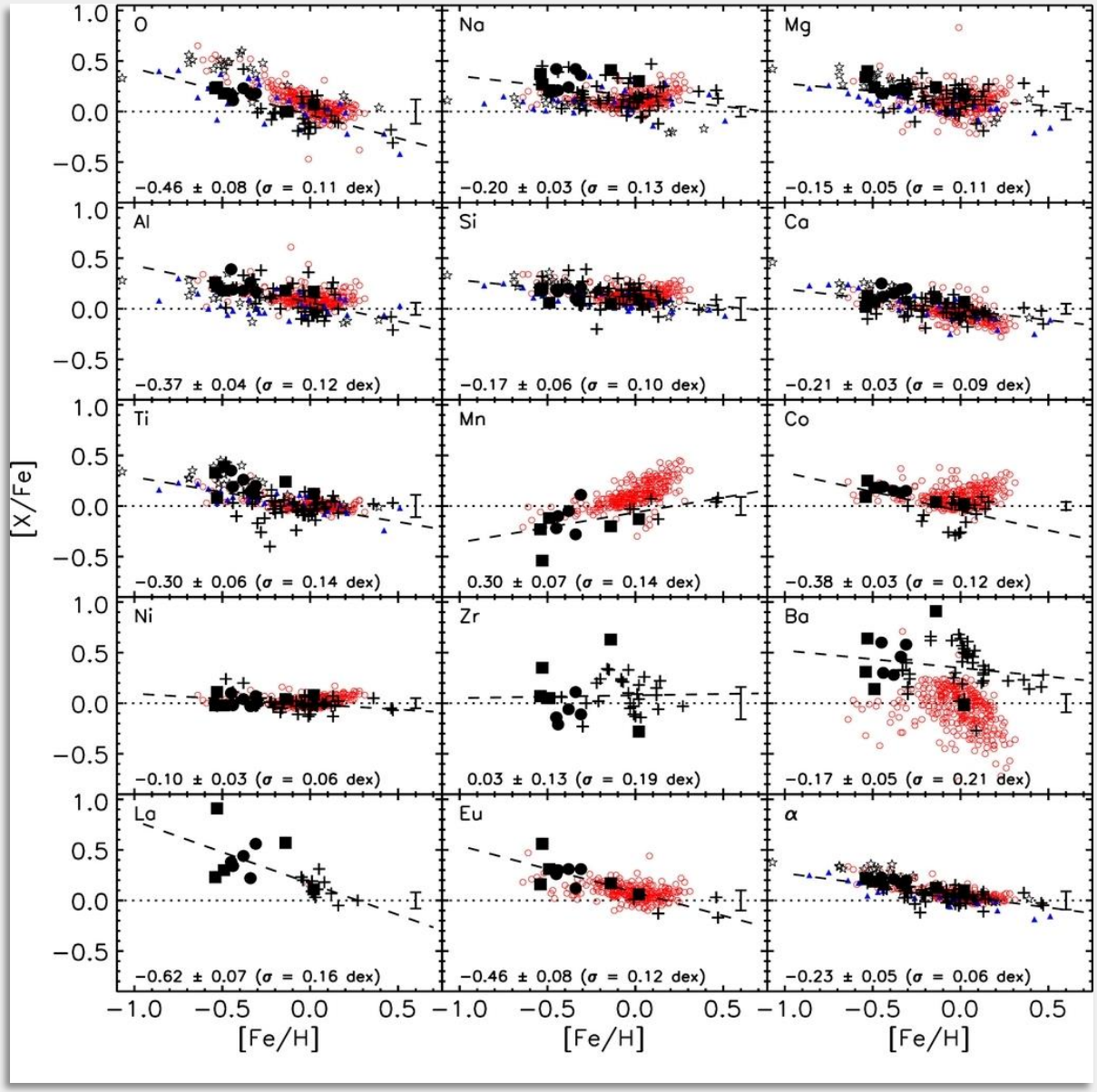
All we need is …

Open clusters useful to study MW disk (formation & evolution)

- **large, significant samples**
- **deep, precise photometry**
- **membership**
- **distances**
- **orbits**
- **ages (evol. models)**
- **metallicity & detailed abundances**
- ***homogeneity***

> ground-based photo & spectro data (surveys)
> theoretical models (formation, dissolution, evolution)
> Gaia

OC & disk : same language?



Yong, Carney & Friel 2012

Radial gradients (no radial mixing)

cf DAML02

age ≥ 1 Gyr
364/2174 17%
age ≥ 2 Gyr
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age ≥ 4 Gyr
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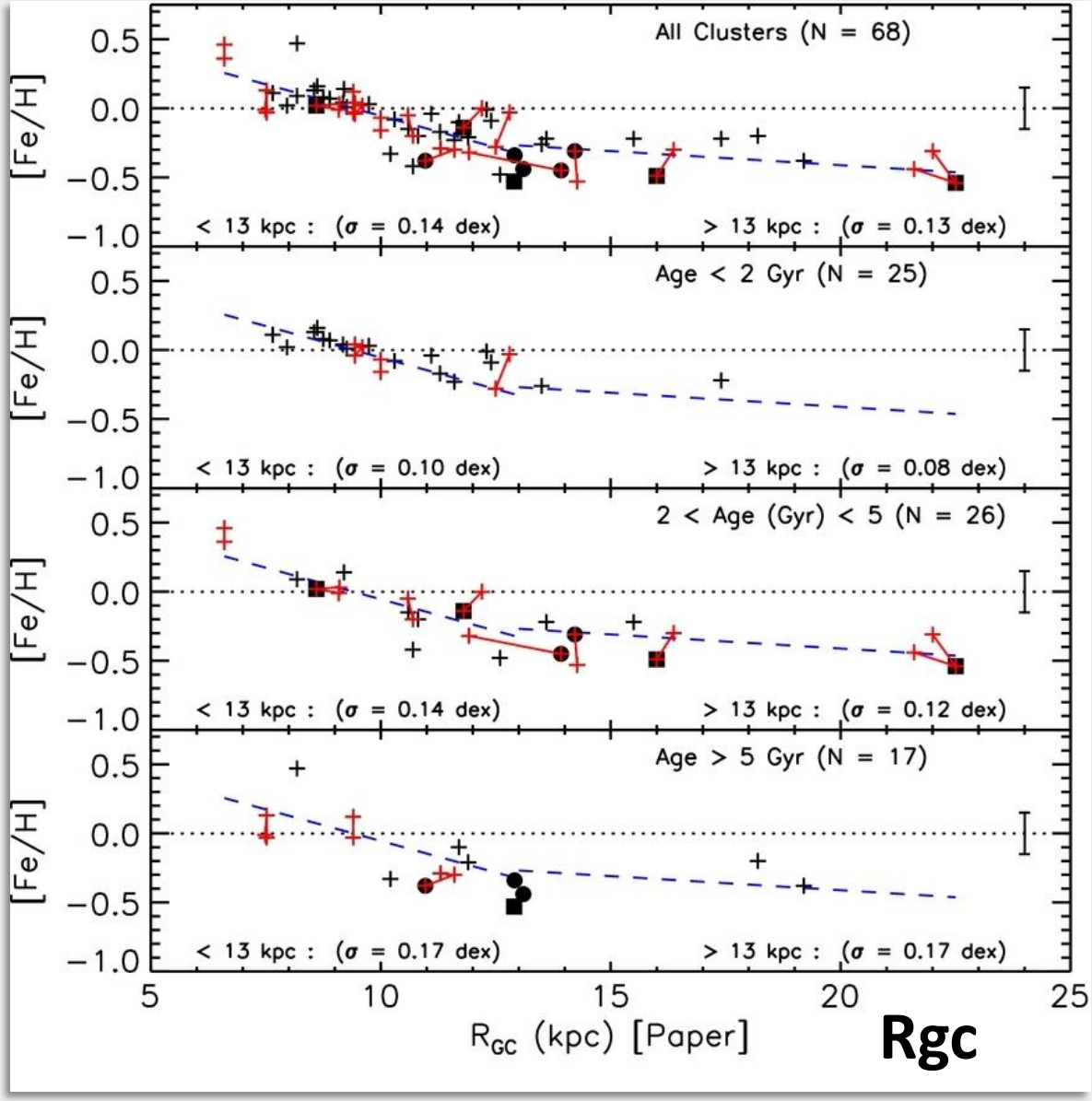
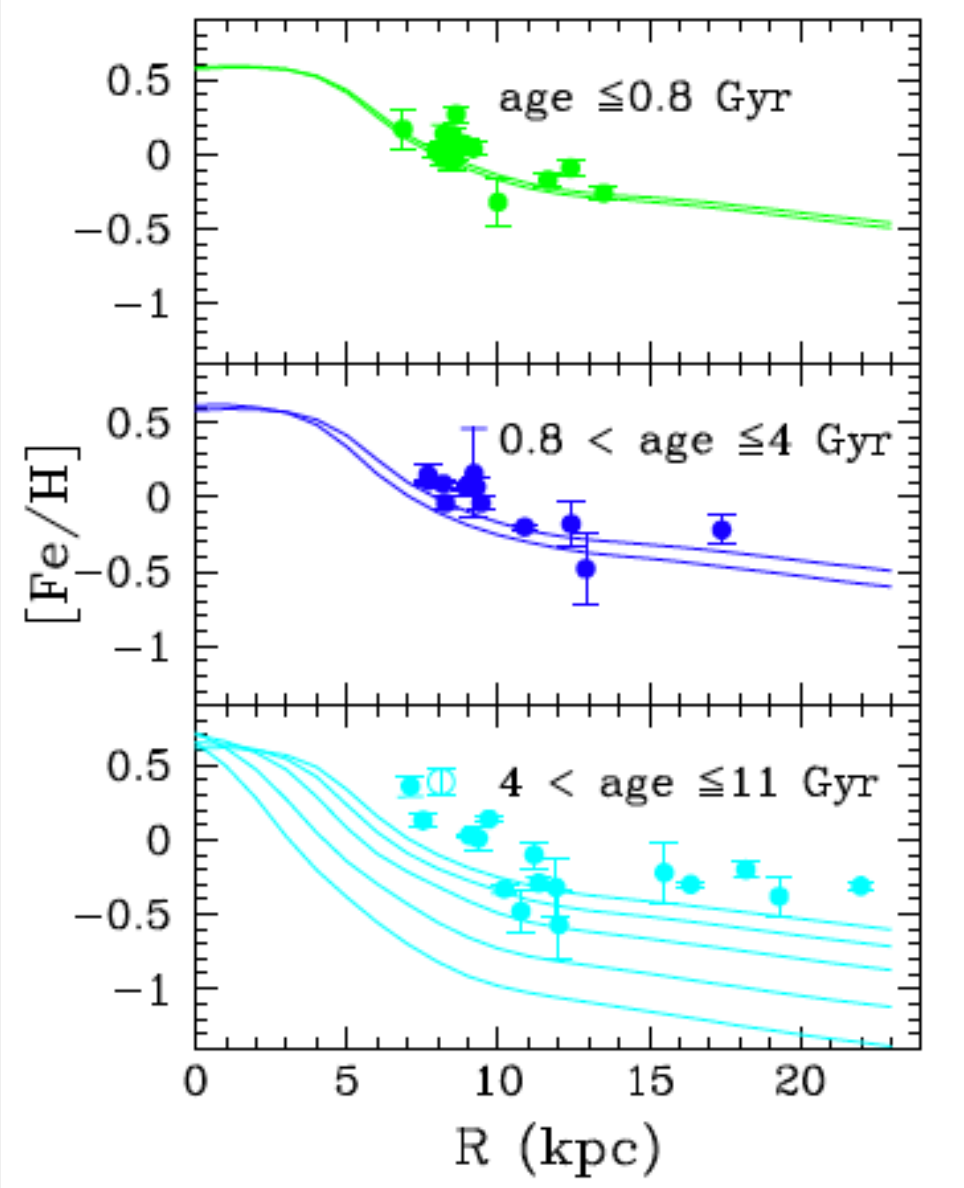
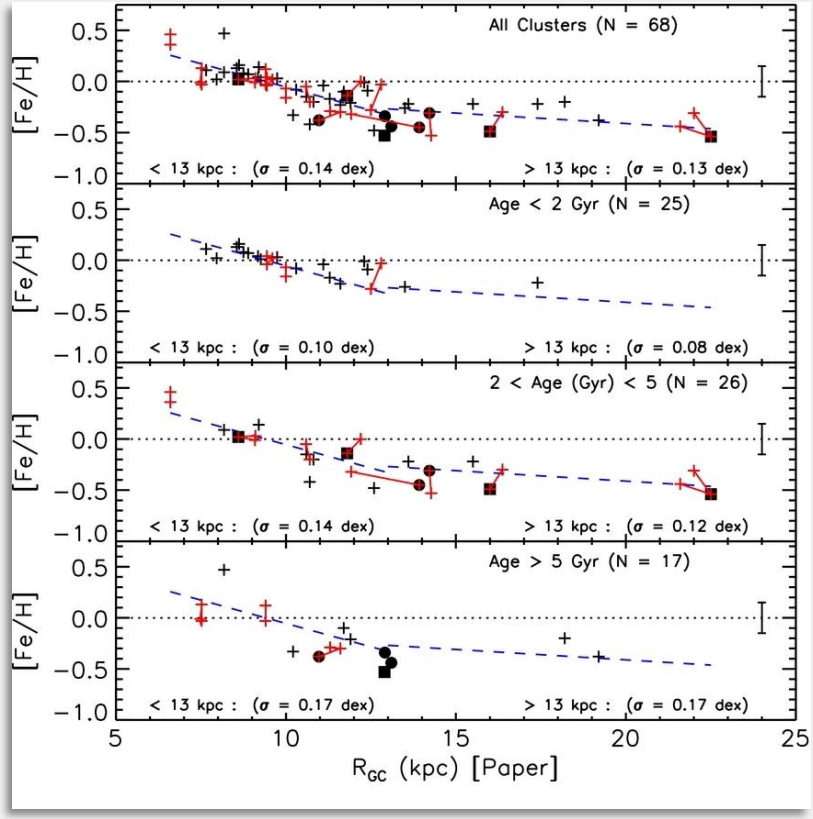


Yong, Carney & Friel 2012

Radial gradients (no radial mixing)





Magrini et al. 2009

Radial gradients (no radial mixing)

O

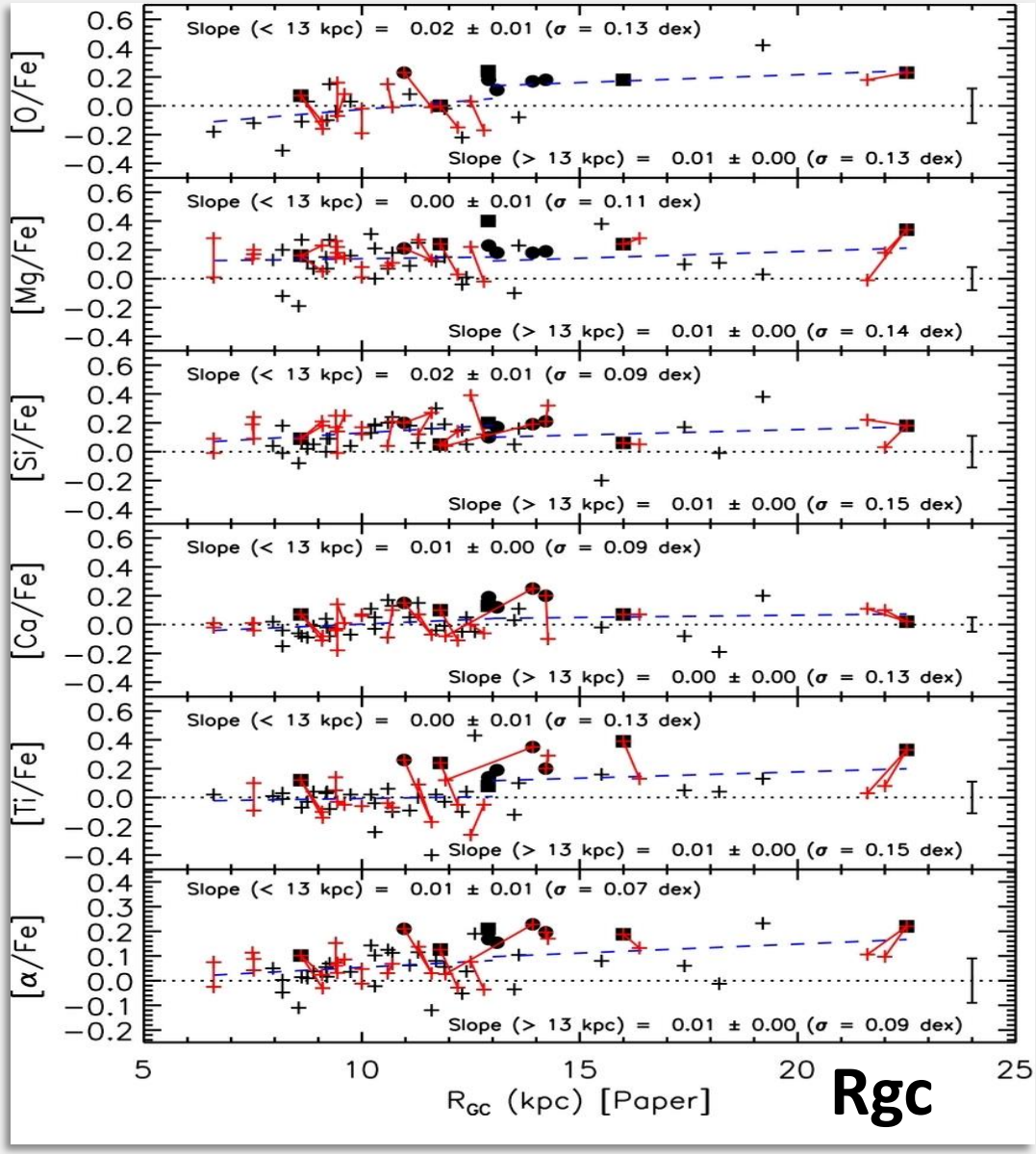
Mg

Si

Ca

Ti

α



Yong, Carney & Friel 2012

Age does not matter

Fe

O

Mg

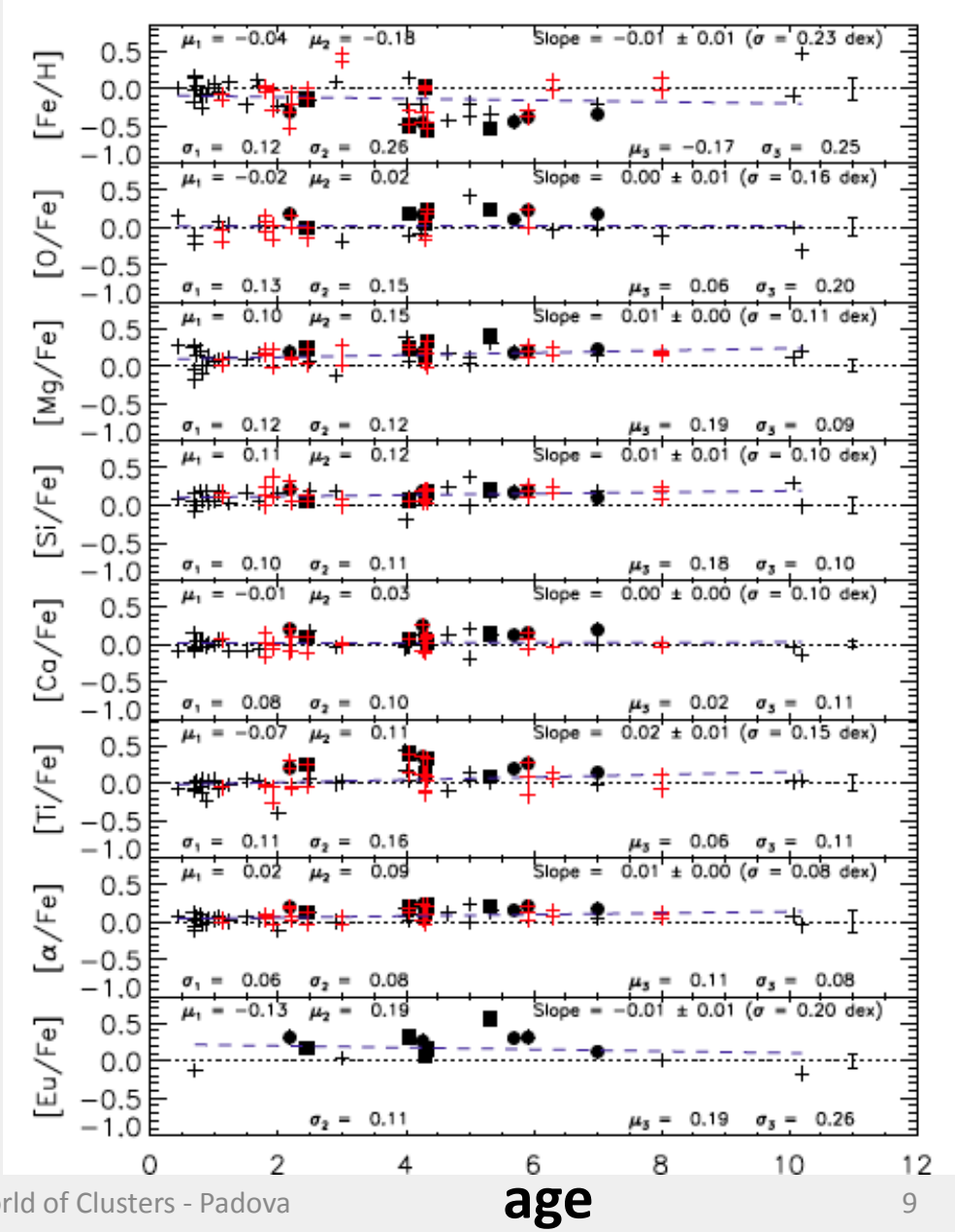
Si

Ca

Ti

α

Eu



Yong, Carney & Friel 2012

How well do we know…

> distance
> age
> metallicity

How well do we know…

NGC 6791 : quite well, but well enough ?

AGE (only a selection) :

- **8 Gyr E(B-V)=0.14 (m-M)v=13.51 [Fe/H]=+0.30 (Brogaard+2011, 2012)**
- **7 Gyr E(B-V)=0.15 (m-M)v=13.6 [Fe/H]=+0.45 (Anthony-Twarog et al. 2007)**
- **12 Gyr E(B-V)=0.09 (m-M)v=13.07 [Fe/H]=+0.3 (Stetson et al. 2003)**

- two populations Δage ≈ 1 Gyr inner/outer (Twarog et al. 2011)
- WD cooling age 4, 6, 8 Gyr ? (Bedin et al. 2008, Garcia-Berro et al. 2010)

METALLICITY :

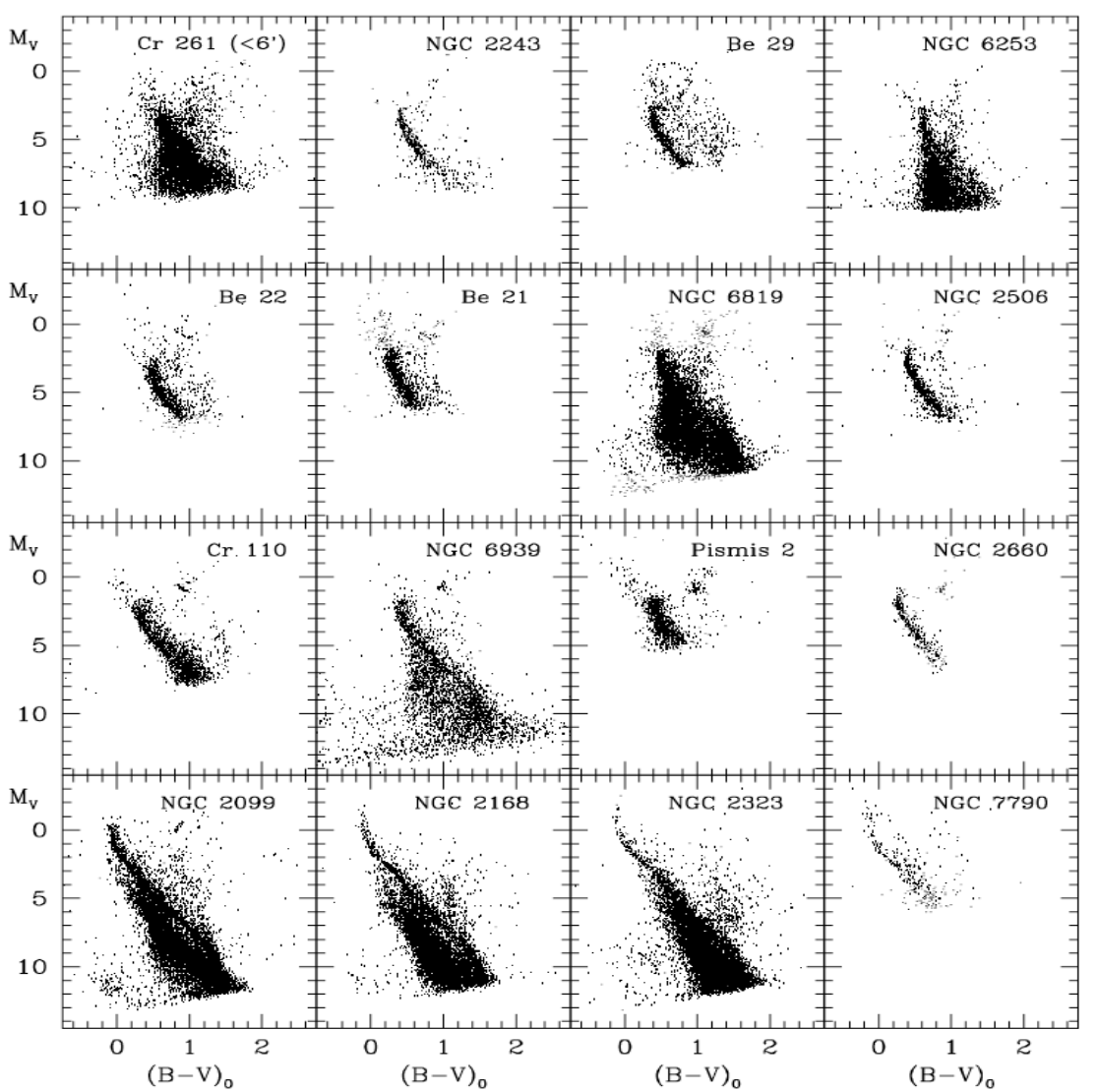
+0.38 APOGEE (Frinchaboy+2013)
+0.30 MSTO (Boesgaard et al. 2009)
+0.46 RC (Gratton et al. 2006)
+0.35 IR (Origlia et al. 2006)
+0.39 giants (Carraro et al. 2006)
i.e. 2 or 3 x $Z_\odot$

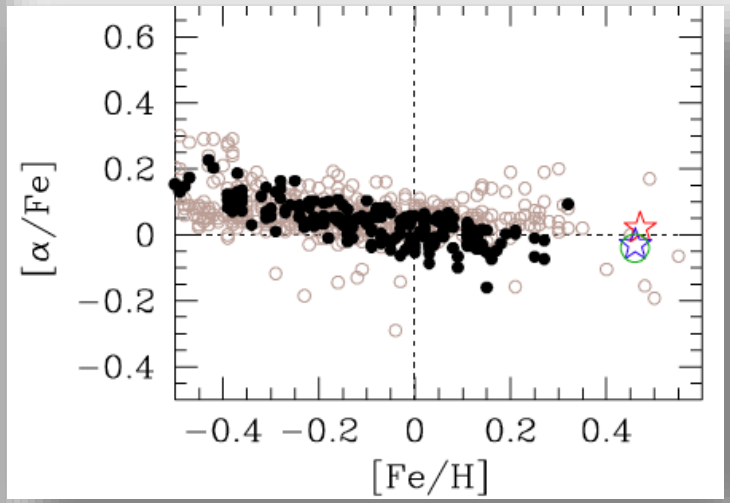
“Private projects”

…too many to name, even limiting to old clusters …

BOCCE: Bologna Open Clusters Chemical Evolution

> see Paolo Donati's talk (Wednesday)





Carretta et al. 2007

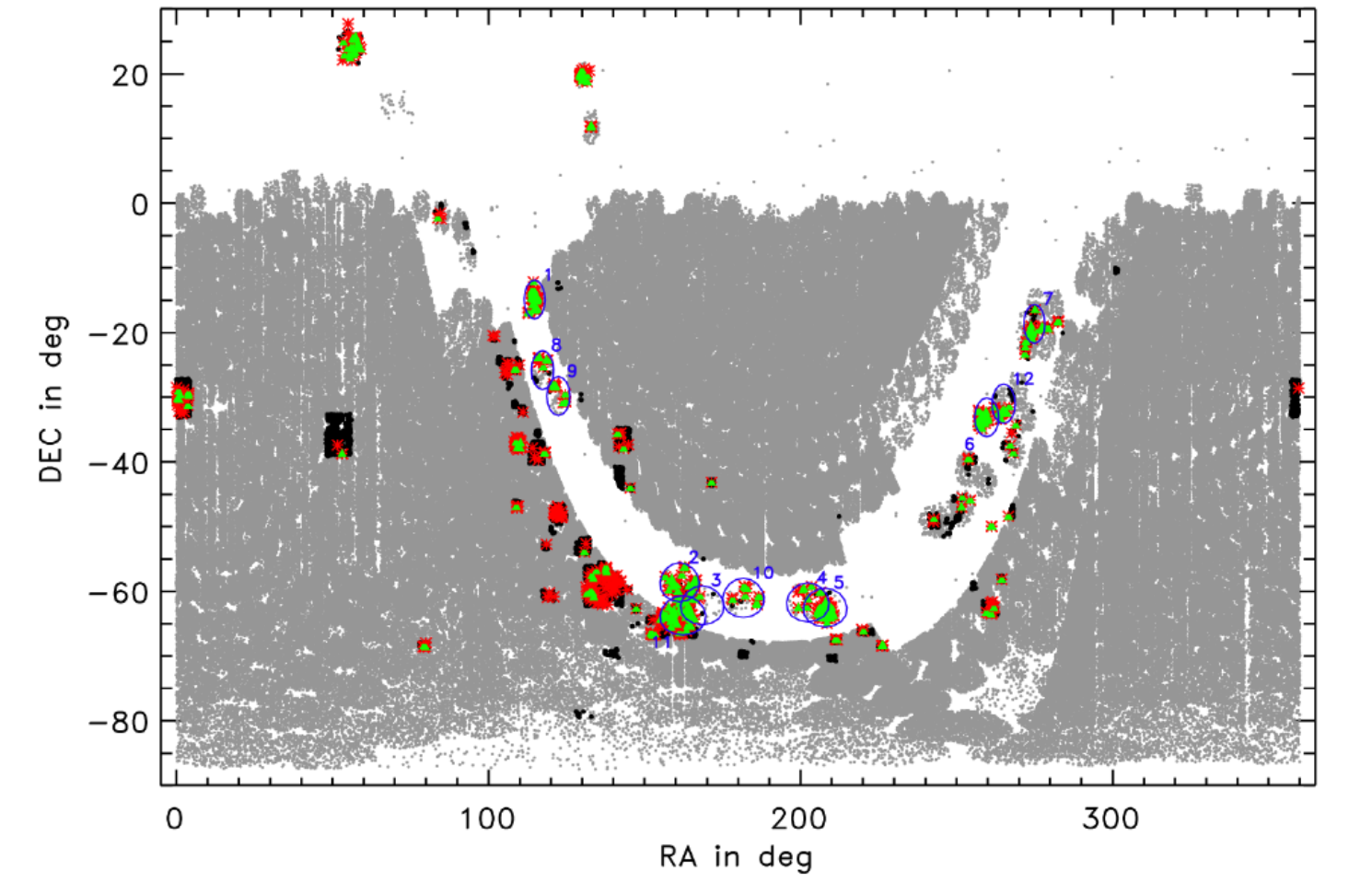
Bragaglia & Tosi 2006

Large datasets: RAVE

RAVE open clusters : **(6dF AAT, CaT, R=7500)**

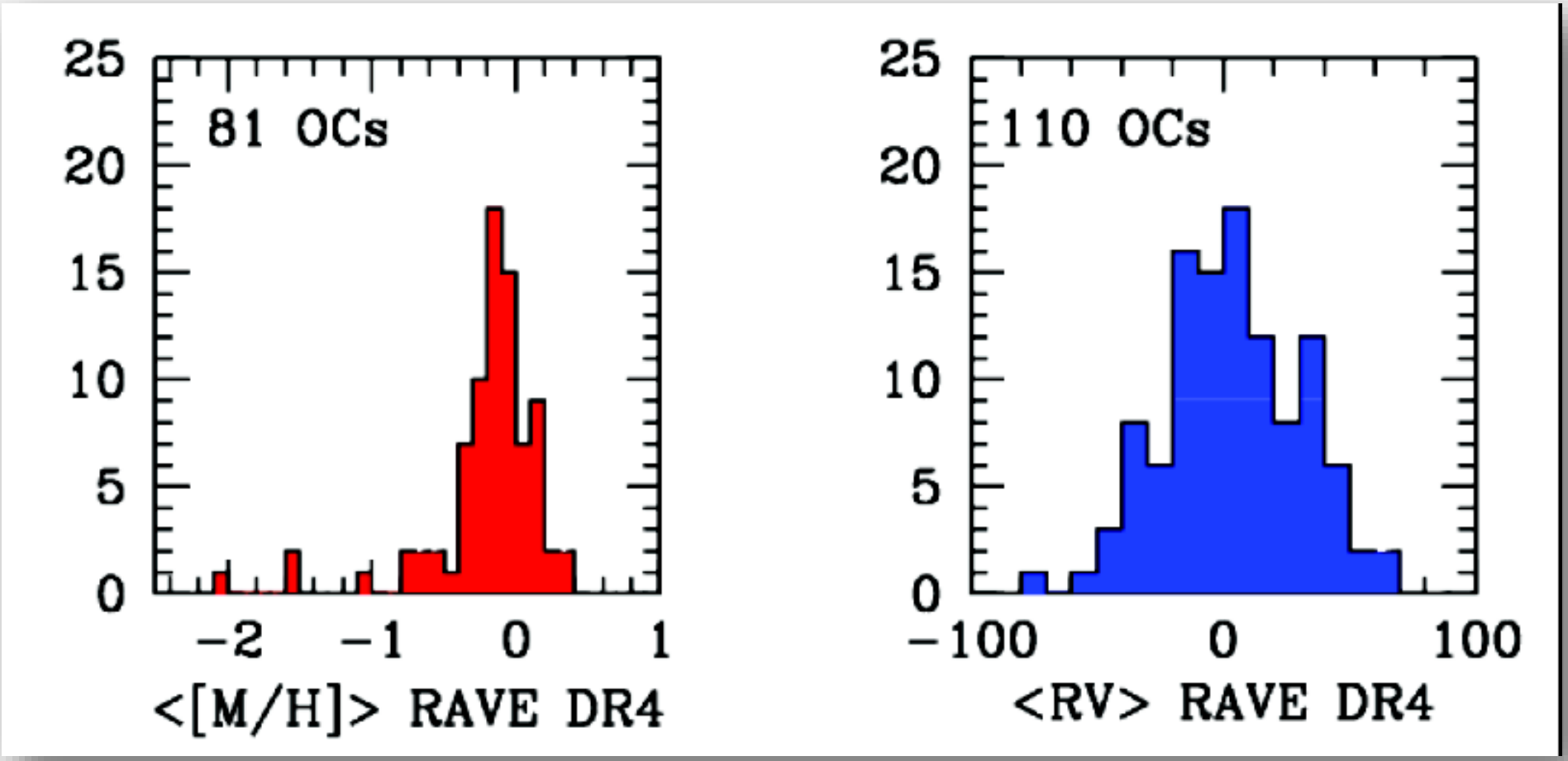
110 <RV> (new for 37) – generally <5 stars

81 <[M/H]> (69 new) – in 68 cases 1-5 stars



Conrad et al. arXiv:1309.4325

Large datasets: RAVE



Conrad et al. arXiv:1309.4325

Large datasets: APOGEE

APOGEE (SDSS DR10) open clusters

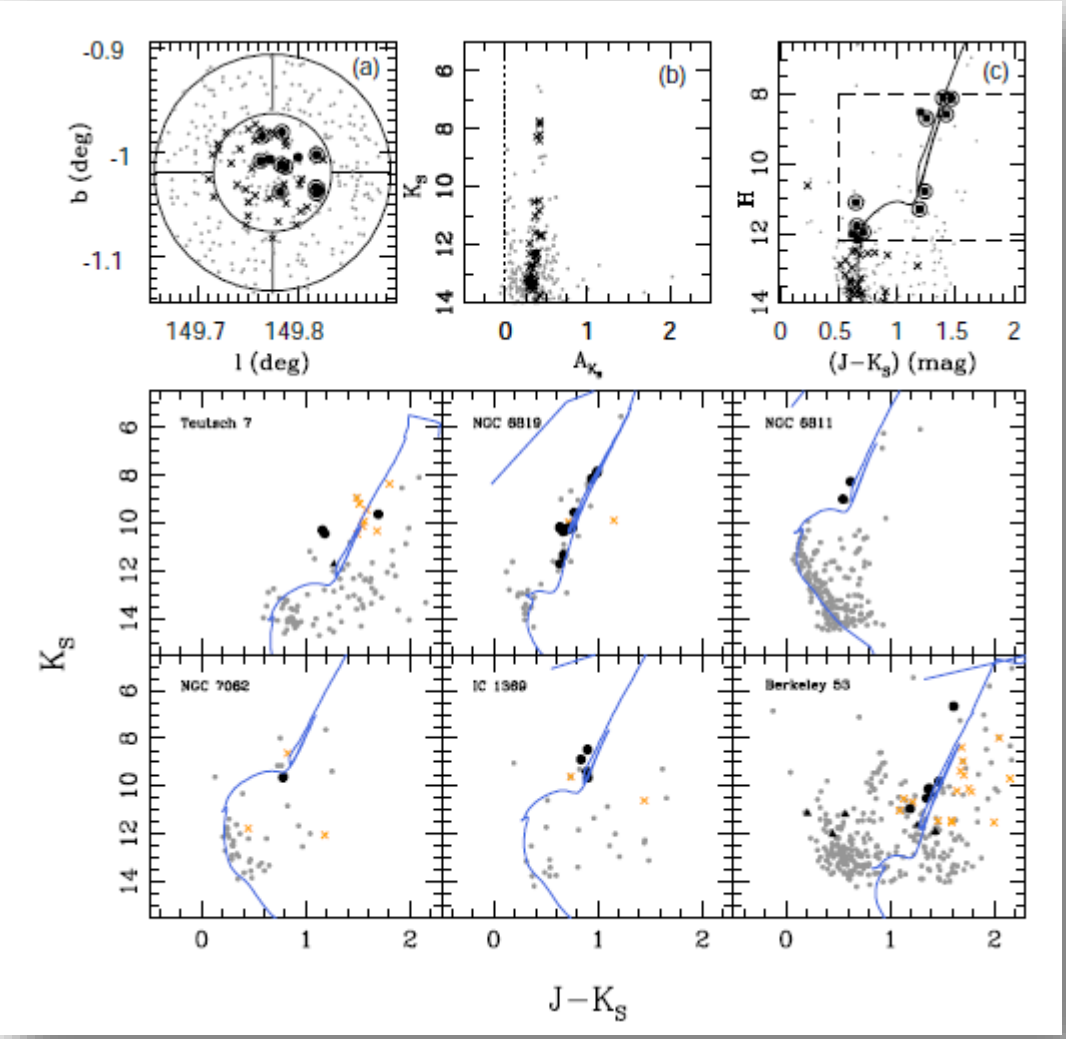
(OCCAM : Open Clusters Chemical Analysis and Mapping)

APOGEE=Apache Point Observatory Galactic Evolution Experiment

H-band, R=22500

141 stars in 28 OCs
(22 new)

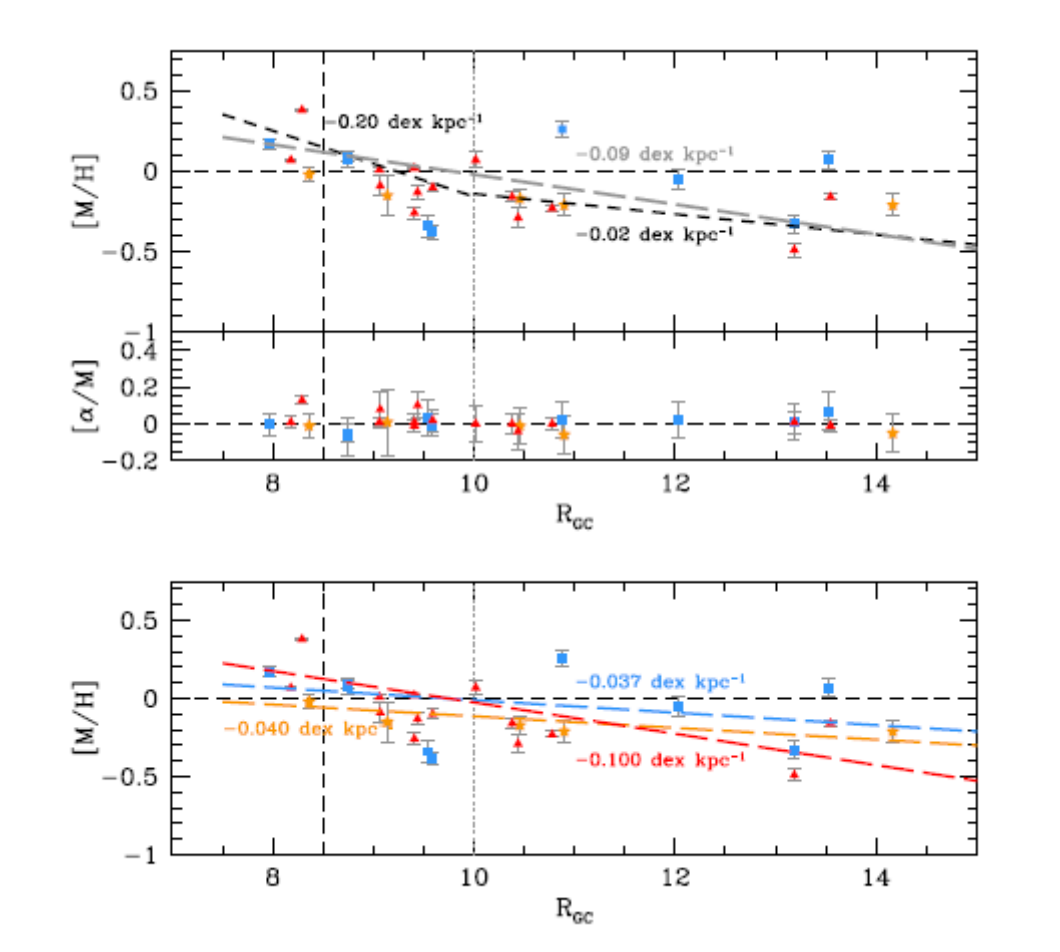
15 OCs : 1 star
6 : 2-5 stars
1 : 5-10 stars
6 : >10 stars



Frinchaboy et al. arXiv:1308.4195

Large datasets: APOGEE

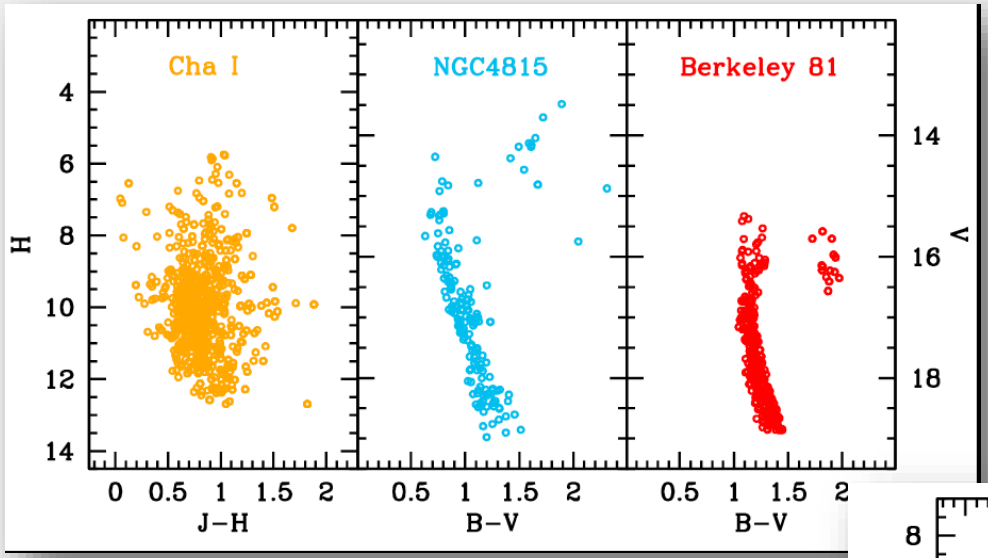
> see Peter Frinchaboy's talk



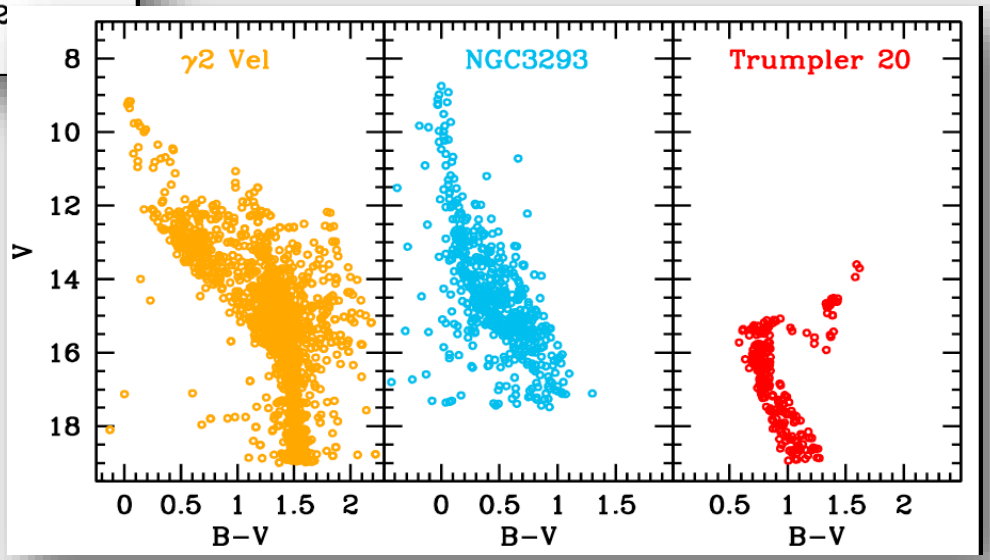
Frinchaboy et al. arXiv:1308.4195

Large datasets: Gaia-ESO survey

> see Sofia Randich's talk (& many more)



FLAMES-VLT
UVES R=45000 (to V=16.5)
GIRAFFE R=15-25000 (to V=19)

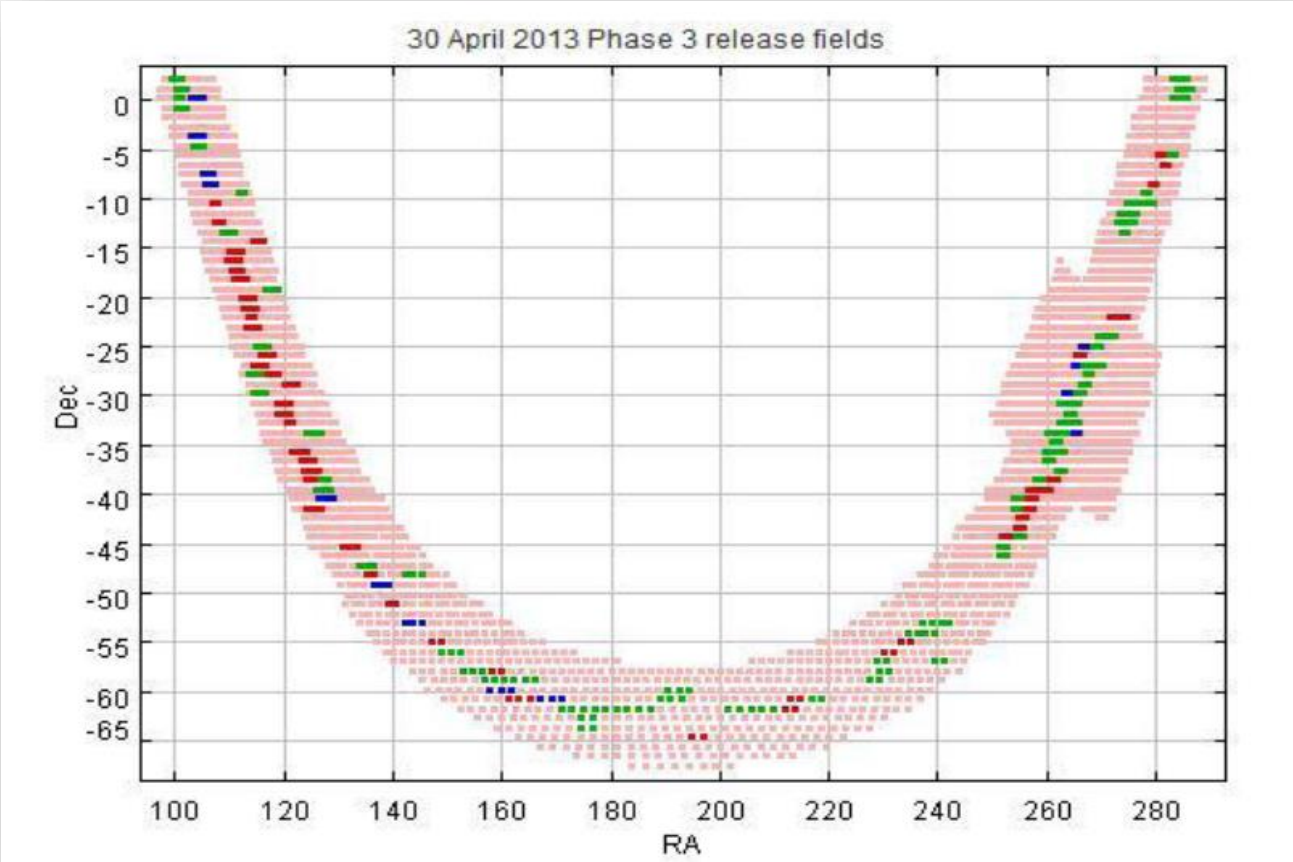


100 young/old OCs
(met/dist/mass/age)

Don’t forget photometry: VPHAS+

VPHAS+ : public ESO photometric survey*, VST, ugriHα (Drew et al.)
(cf IPHAS, nord)

> see Janet Drew’s talk



*** see also VHS, the VISTA Hemisphere Survey : all southern sky, JK bands**

New photometry, new clusters

VVV :
Vista
Variables
in the
Via Lactea

…data of all lands unite…

are we reaching our goals?

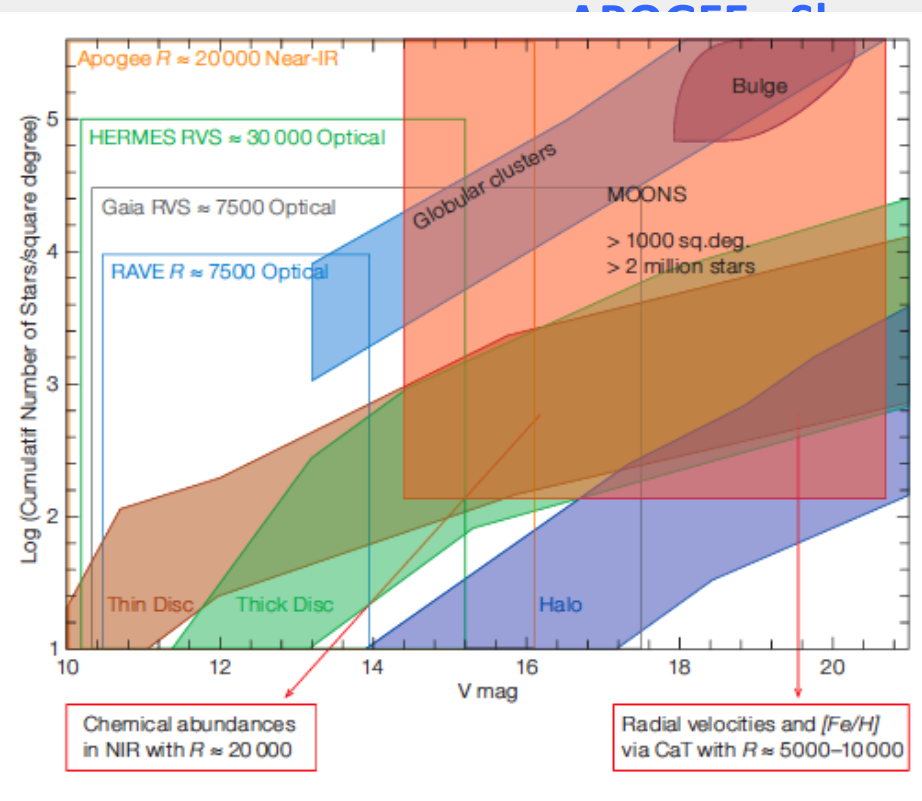
…the future is now…

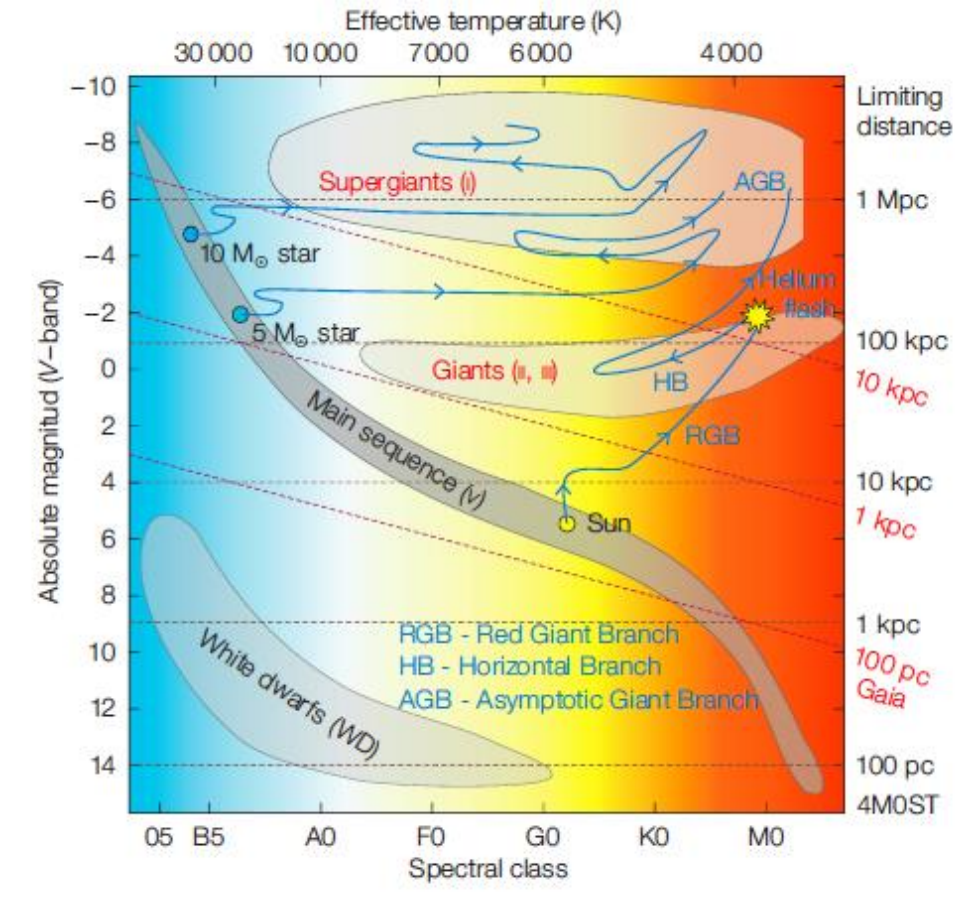
APOGEE -- Sloan
GES – ESO/VLT
LAMOST – China
GALAH/HERMES - Aus
4MOST – ESO/VISTA
MOONS – ESO/VLT
WEAVE -- WHT
…

SKYMAPPER – Aus
PAN-STARRS – Hawaii
LSST – South.Em.
…

Gaia

…the future is now…

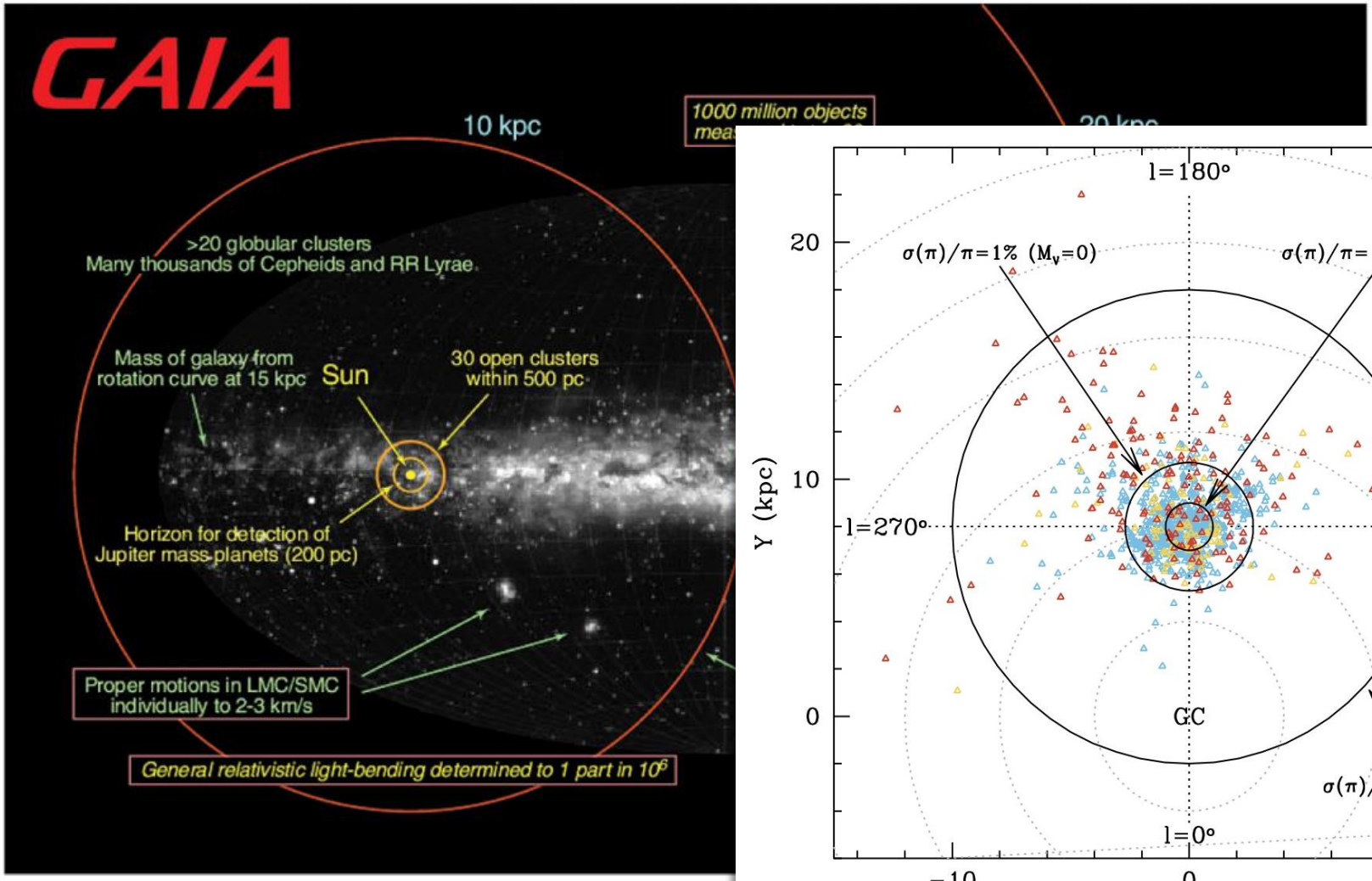




MOONS

4MOST (for RV)

Gaia: so close



Gaia: so close

μas **precision in proper motions & parallax (vs *mas* Hipparcos)**
distances, internal structure (near*), members (core & halo)

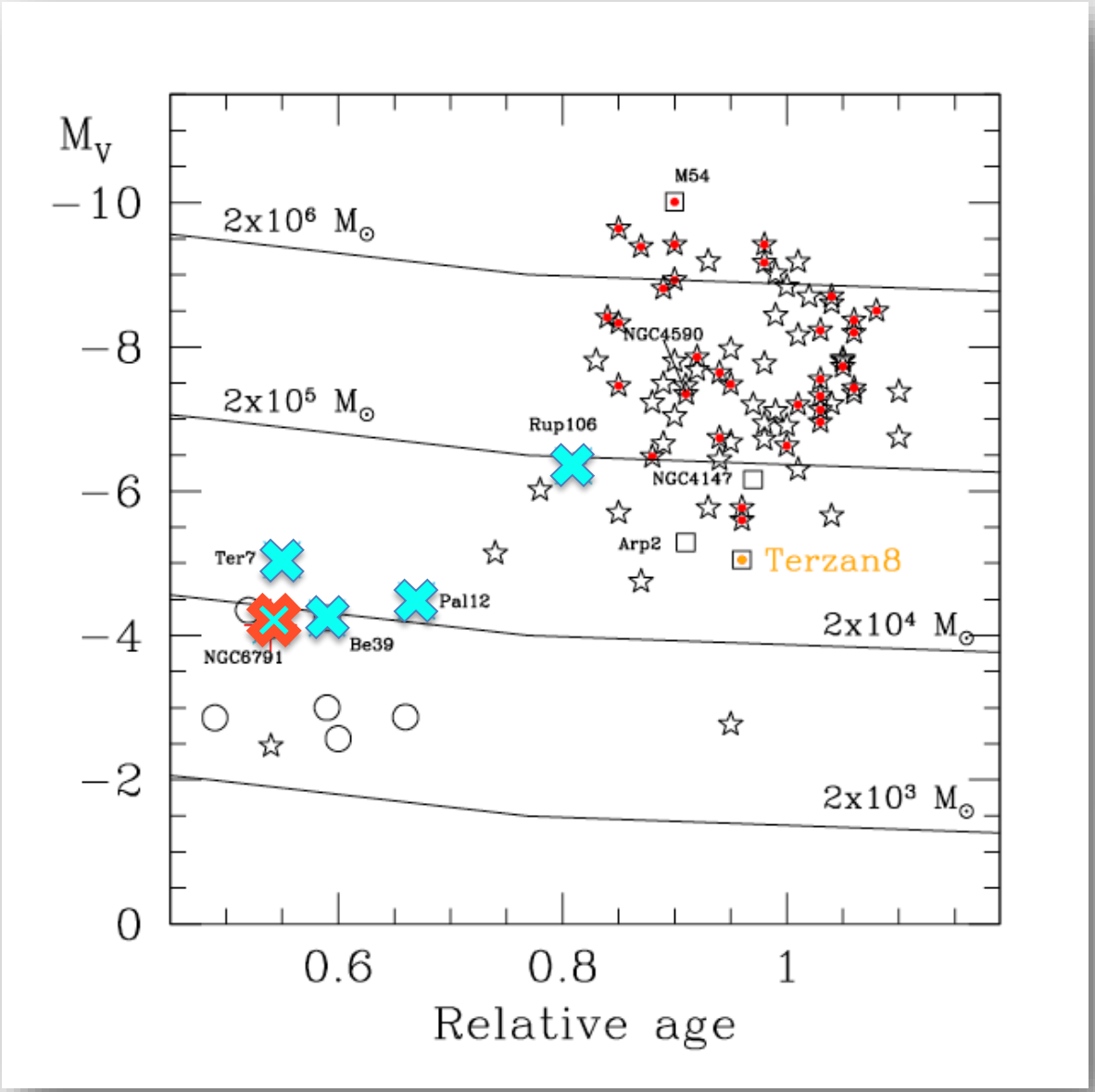
cluster confirmation & new ones

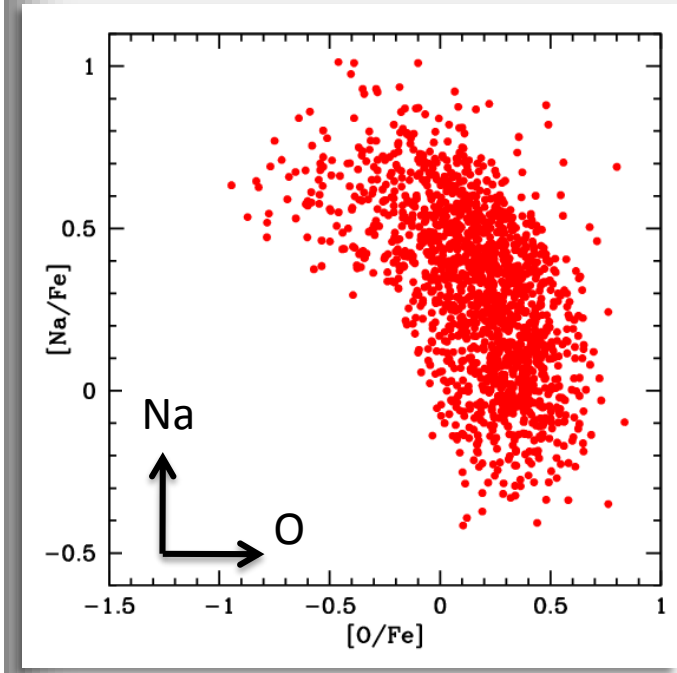
6-d space information
link between clusters ; lost members

clusters of all ages (very young to globular clusters) :
observational isochrones

*** dist<1 kpc : ≈ 400 OCs (at V≈19, Mv≥12 : all HRD)**

Single or multiple, that is the question

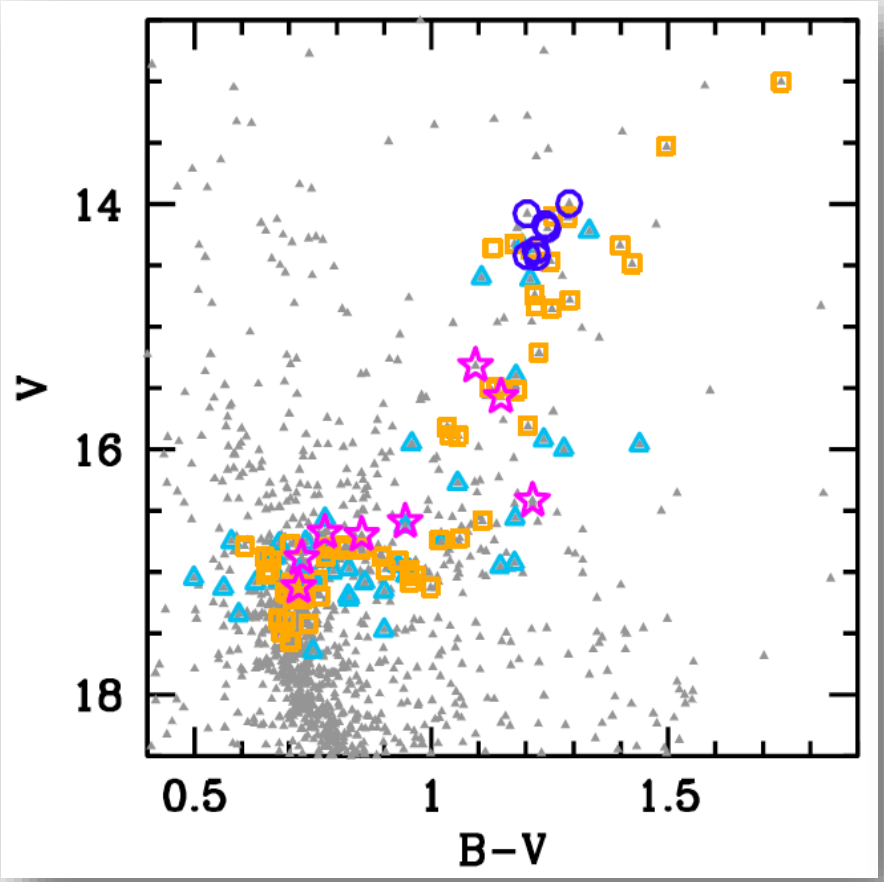


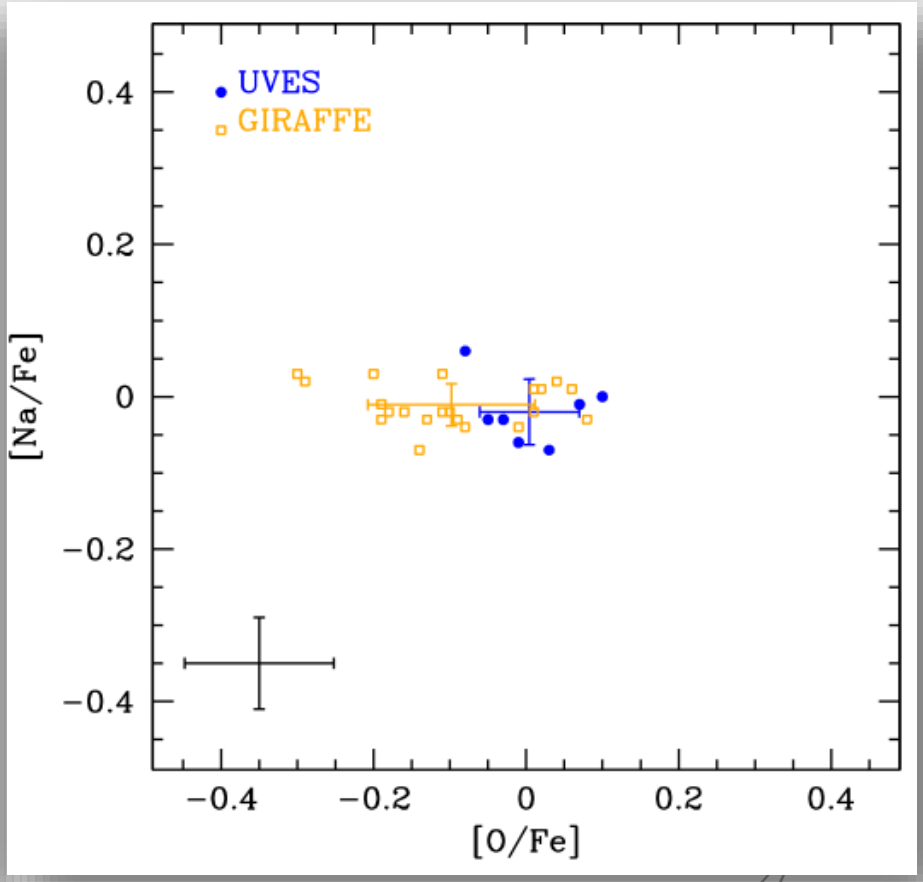


Carretta et al. 2010 +updates

Berkeley 39: all quiet on the OC front

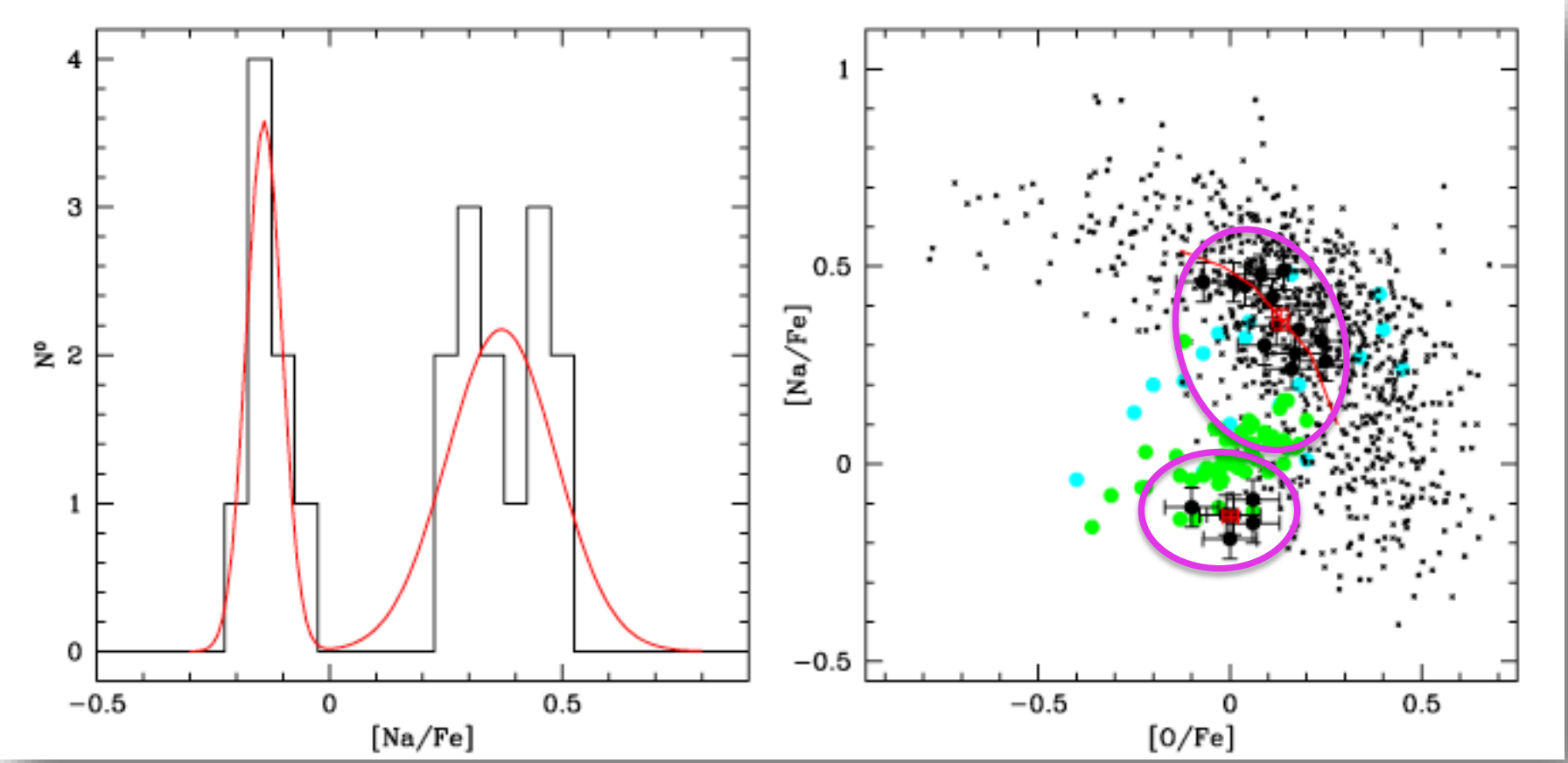
Bragaglia et al. 2012



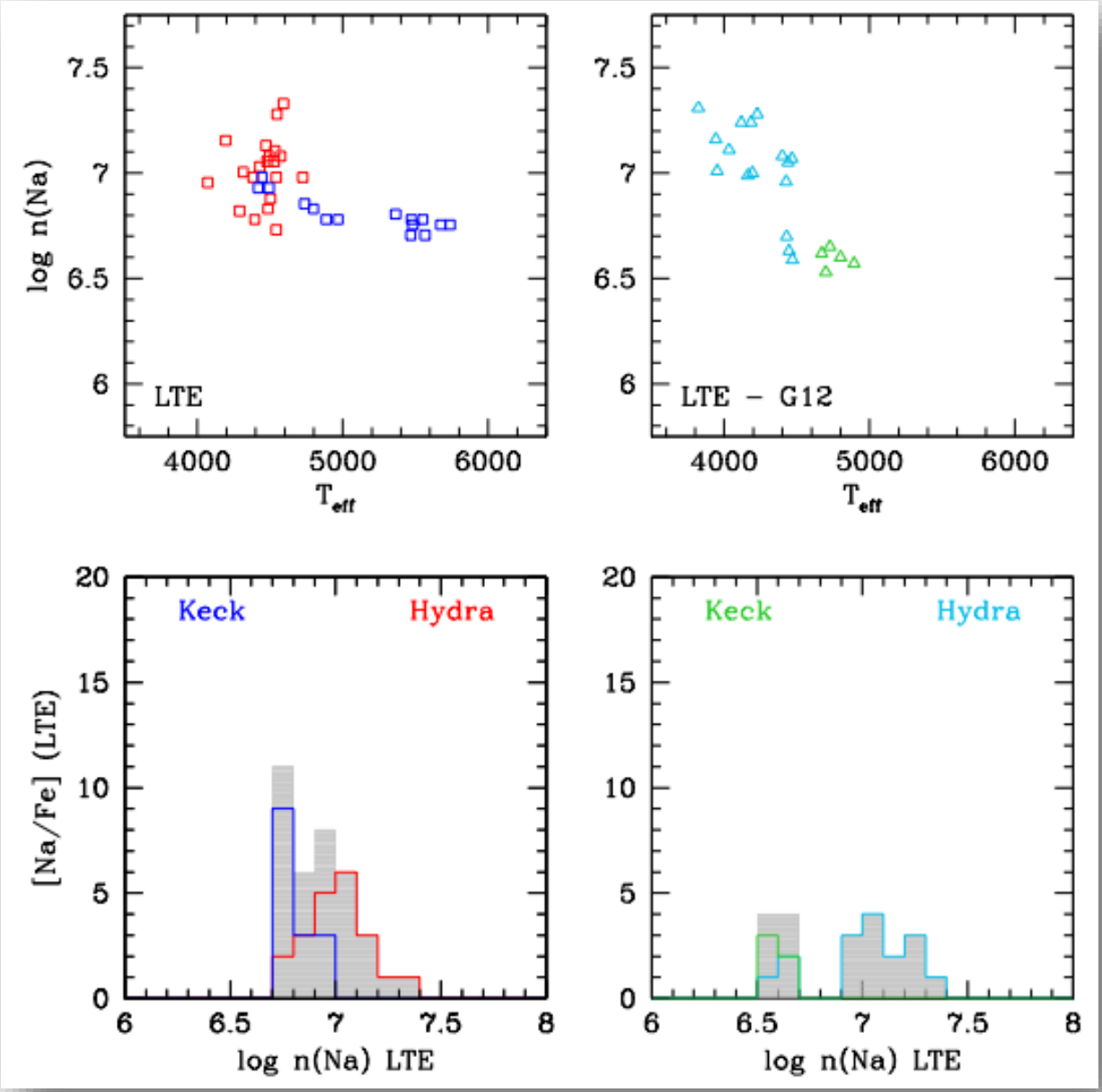


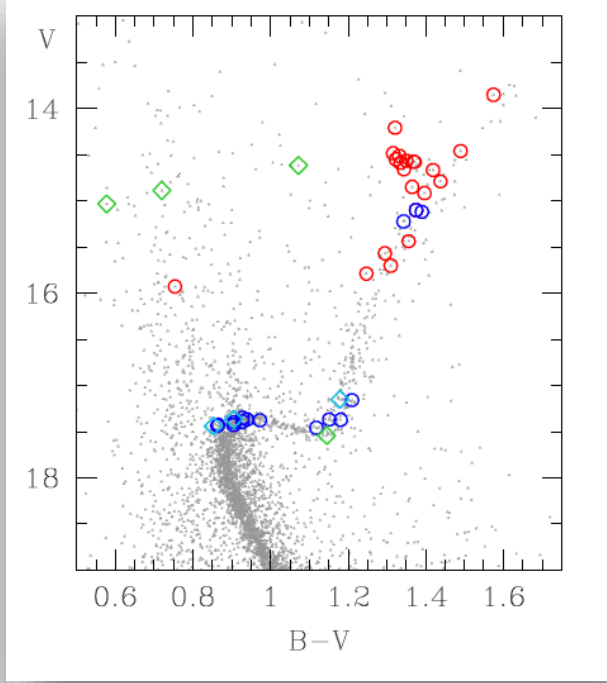
NGC 6791 : the exception ?

Geisler et al. 2012



NGC 6791 : no exception ?





(in progress)

NGC 6791 : a small, odd-looking GC?

-BHB ? no, it's BSS, not HB

-EHB ? yes

-"short RGB" above RC ? mass loss ? He-core WDs ?

-WDs : double WD peak, age, binaries?

-Δage? differential reddening

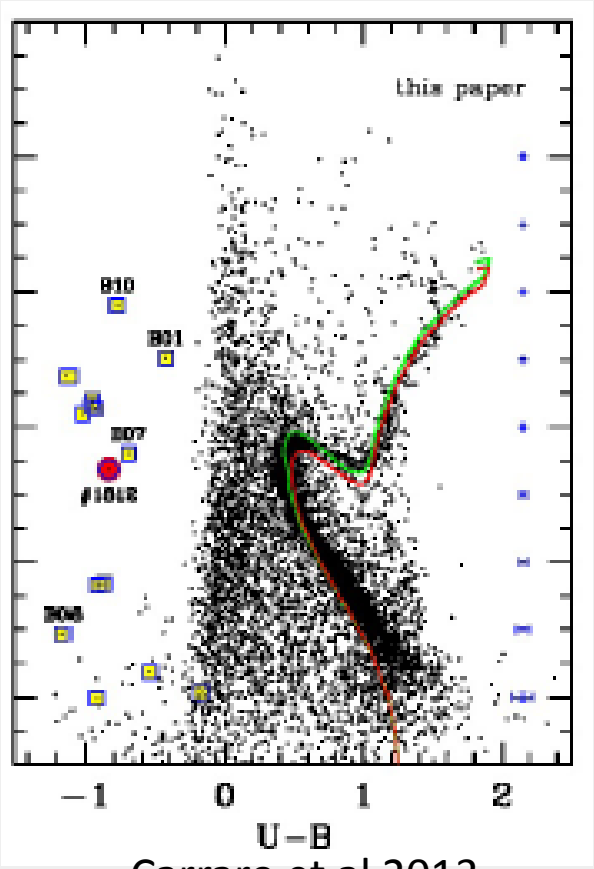
(also explains "large" RGB)

-CN maybe bimodal, CH no

-high Na? but not high N (spectro)

-no large spread in RGB v-y, no large spread in N

-no He spread found (photo / seismo)



Carraro et al 2013

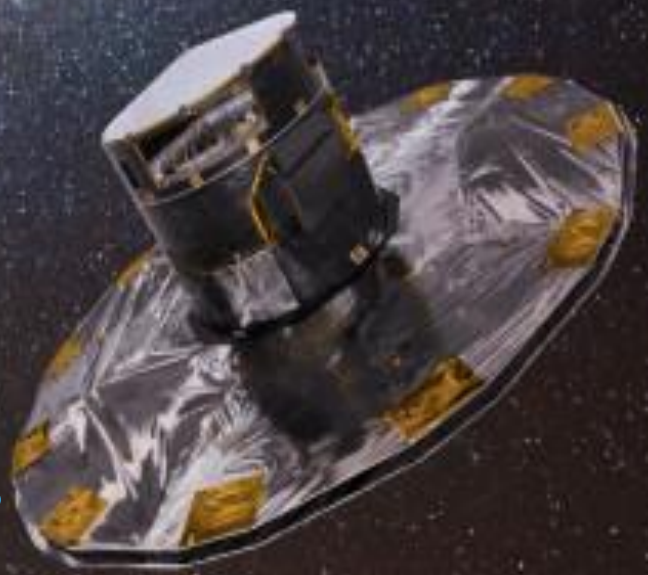
odd, difficult to explain but NO stringent indication of being GC

The future is now

- APOGEE (Sloan)
- Gaia-ESO Survey (FLAMES)
-Galah (HERMES)
-photometric all-sky surveys

+ 4MOST, MOONS, WEAVE, etc

…and **Gaia**…



> open clusters
> globular clusters
> field stars

Thank you