

# **Globular Cluster Surveys in Virgo**

## **Progress and Future Works**

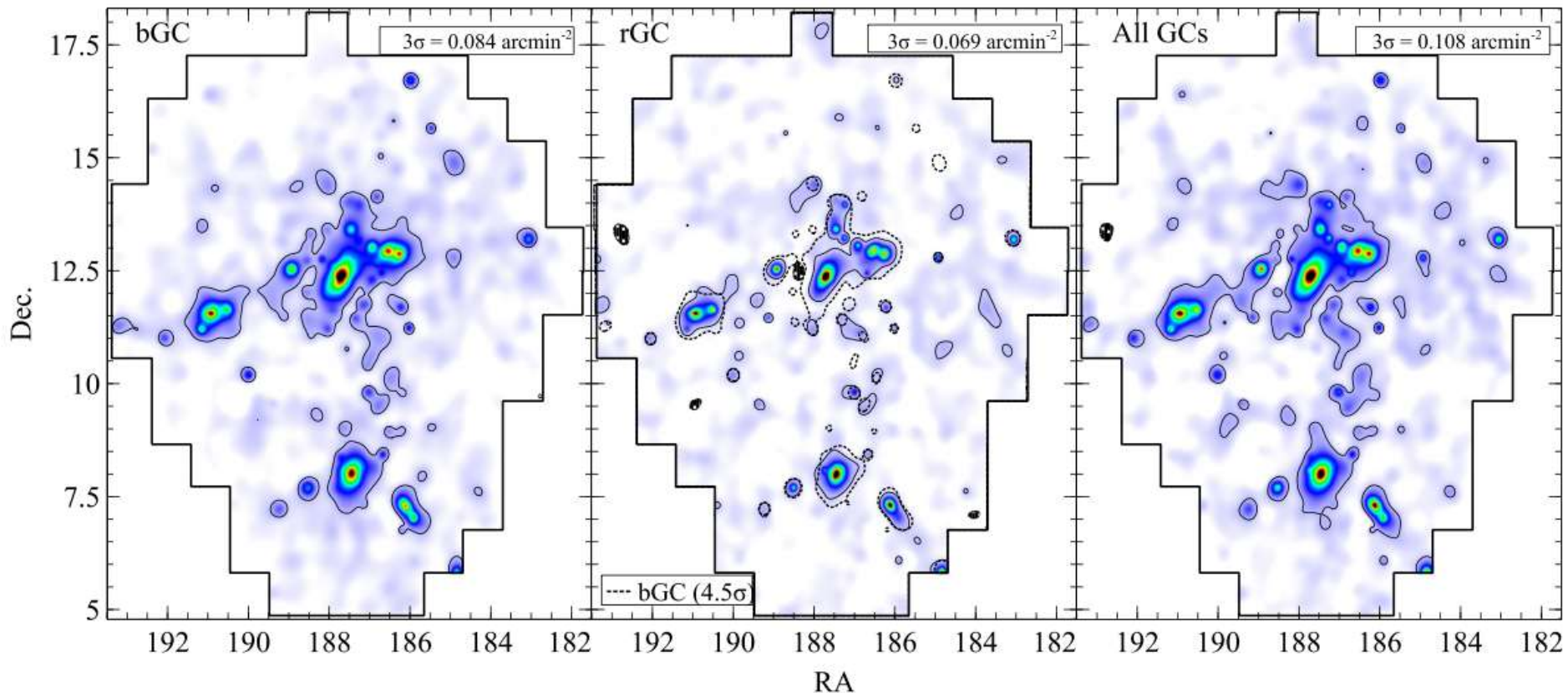
**Youkyung Ko (SNU)**

# *Two Projects with K-GMT Science Program*

- **Intracluster Globular Clusters in the Virgo Cluster**
  - “A Spectroscopic Survey of Intracluster Globular Clusters in the Virgo Cluster” (**MMT/Hectospec, 2014A, 1 night = 10 hrs**)
  - Ko, Y. et al. 2017, “To the Edge of M87 and Beyond: Spectroscopy of Intracluster Globular Clusters and Ultracompact Dwarfs in the Virgo Cluster”, *ApJ*, 835, 212
- **Globular Cluster System of the Merger Remnant Galaxy M85**
  - “Tracing the Merger History of the Intriguing Elliptical Galaxy M85 with Globular Clusters” (**CFHT/MegaCam, 2014A, 2.95 hours**)
  - “A Spectroscopy of Globular Clusters in the Merger Remnant M85 (**Gemini-N/GMOS, 2015A, 4 hours**)
  - “A Wide-field Kinematics of “Green” Globular Clusters in the Merger Remnant Galaxy M85” (**MMT/Hectospec, 2016A, 1 night = 6.5 hrs**)

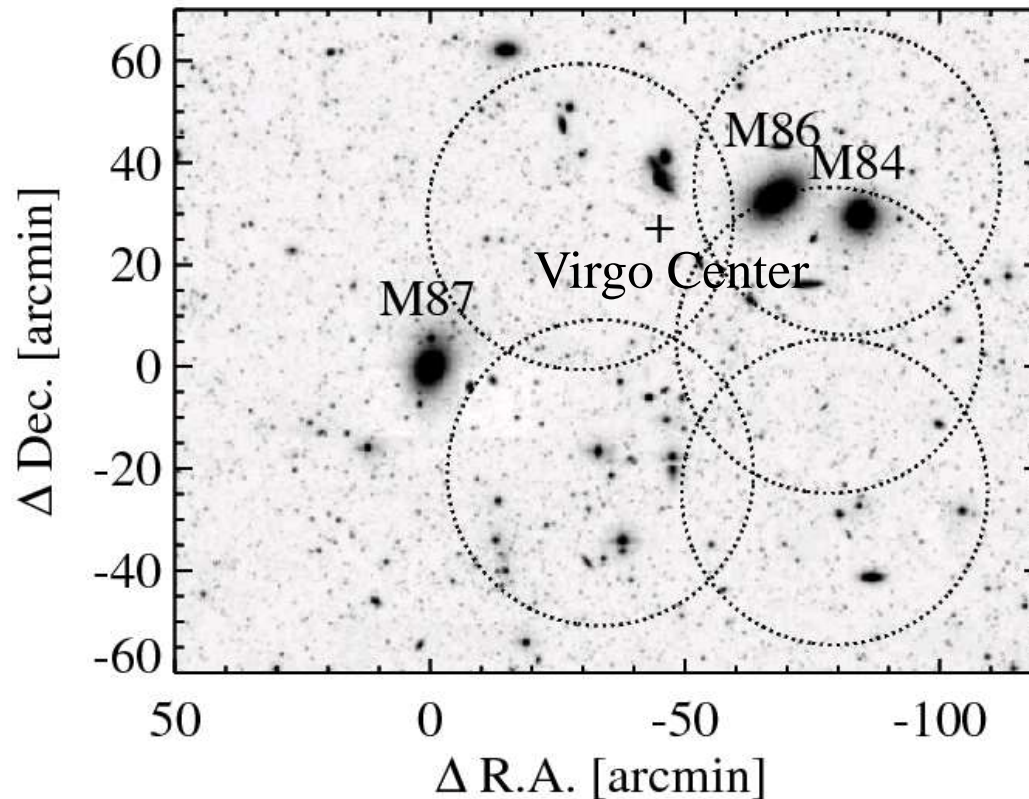
# *Intracluster Globular Clusters*

- Cluster-wide population of globular clusters
- Number density map of GC candidates in the Virgo using SDSS (Lee+10) and NGVS (Durrell+14) photometric data

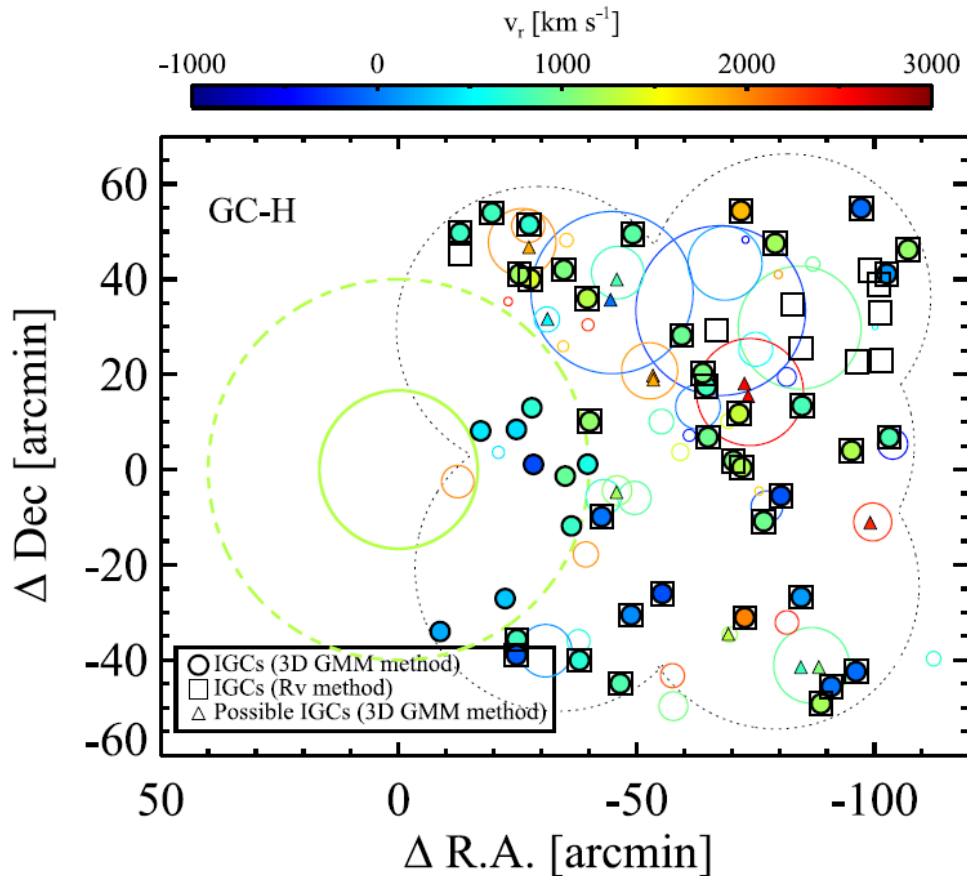


# *Spectroscopy of IGCs*

- Only three IGCs confirmed by Firth+08 so far
- **The first wide-field spectroscopic survey** of IGCs in the central region of the Virgo Cluster



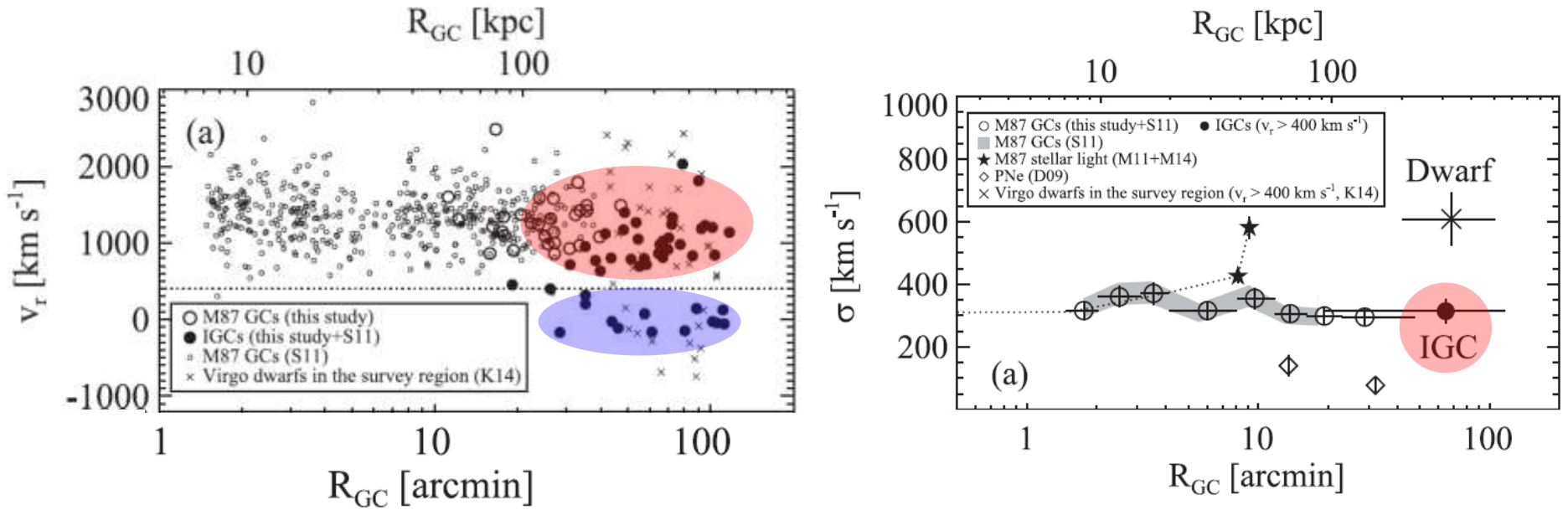
# IGC selection



**46 IGCs are found!**

- 1) 3D GMM classification based on  $\Delta$ R.A.,  $\Delta$ decl.,  $v_r$
- 2) Not in the Virgo galaxy region ( $R < 2D_{25}$ )
- 3) Radial velocities deviate from those of nearby galaxies

# Kinematics of M87 GCs and IGCs



- \* **Two groups** of IGCs with high and low velocities ( $v_r = 400$  km s<sup>-1</sup>)
- \* **Much lower velocity dispersion** of IGC system than that of dwarfs

## 2. Globular Cluster System of the Merger Remnant Galaxy M85

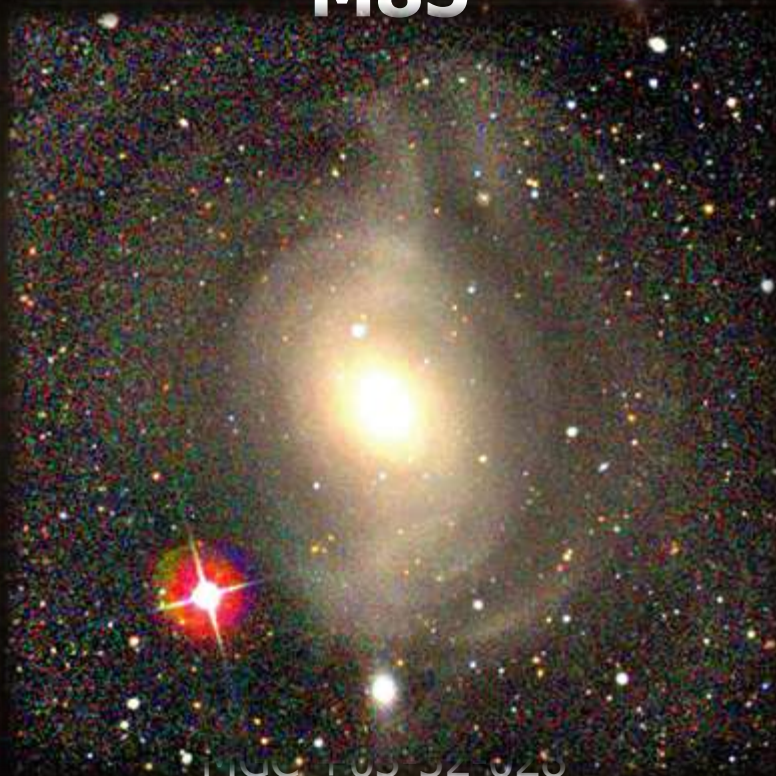
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**M85**

NGC 4394  
(922 km/s)

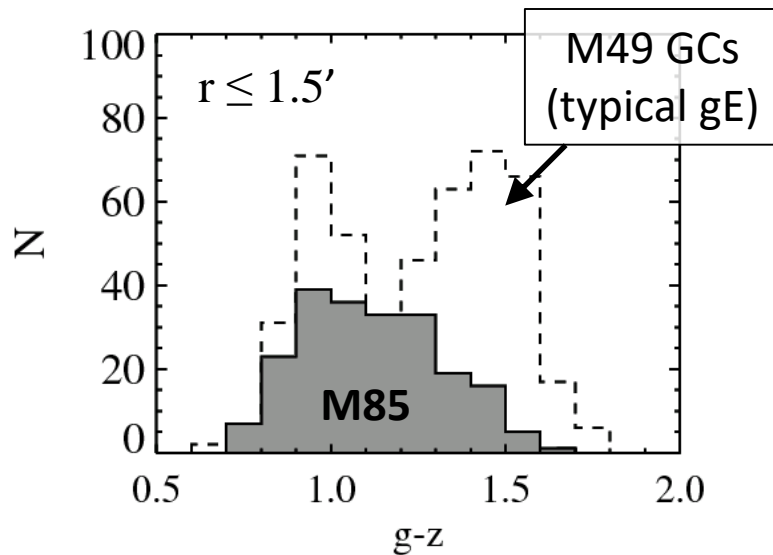
IC 3292  
(697 km/s)

NGC 705-52-025  
(773 km/s)

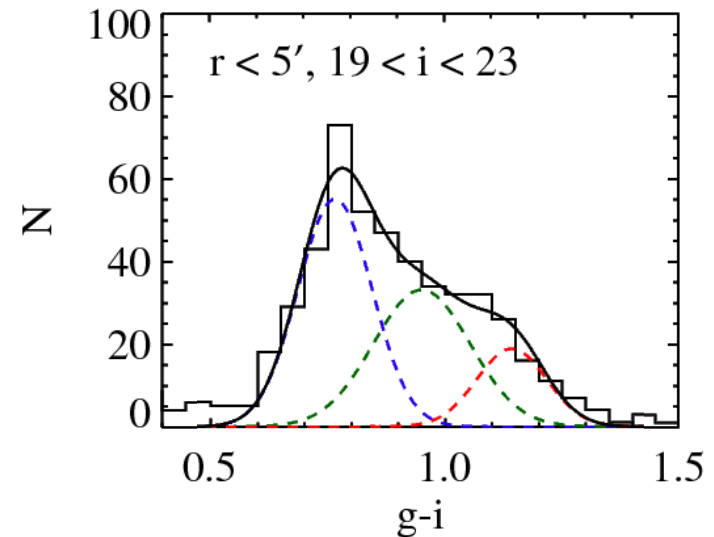


# Color Distribution of M85 GCs

**HST/ACS Virgo Cluster Survey**  
(Cote+04, Jordan+09)



**CFHT/MegaCam**  
(Ko+17 in prep.)



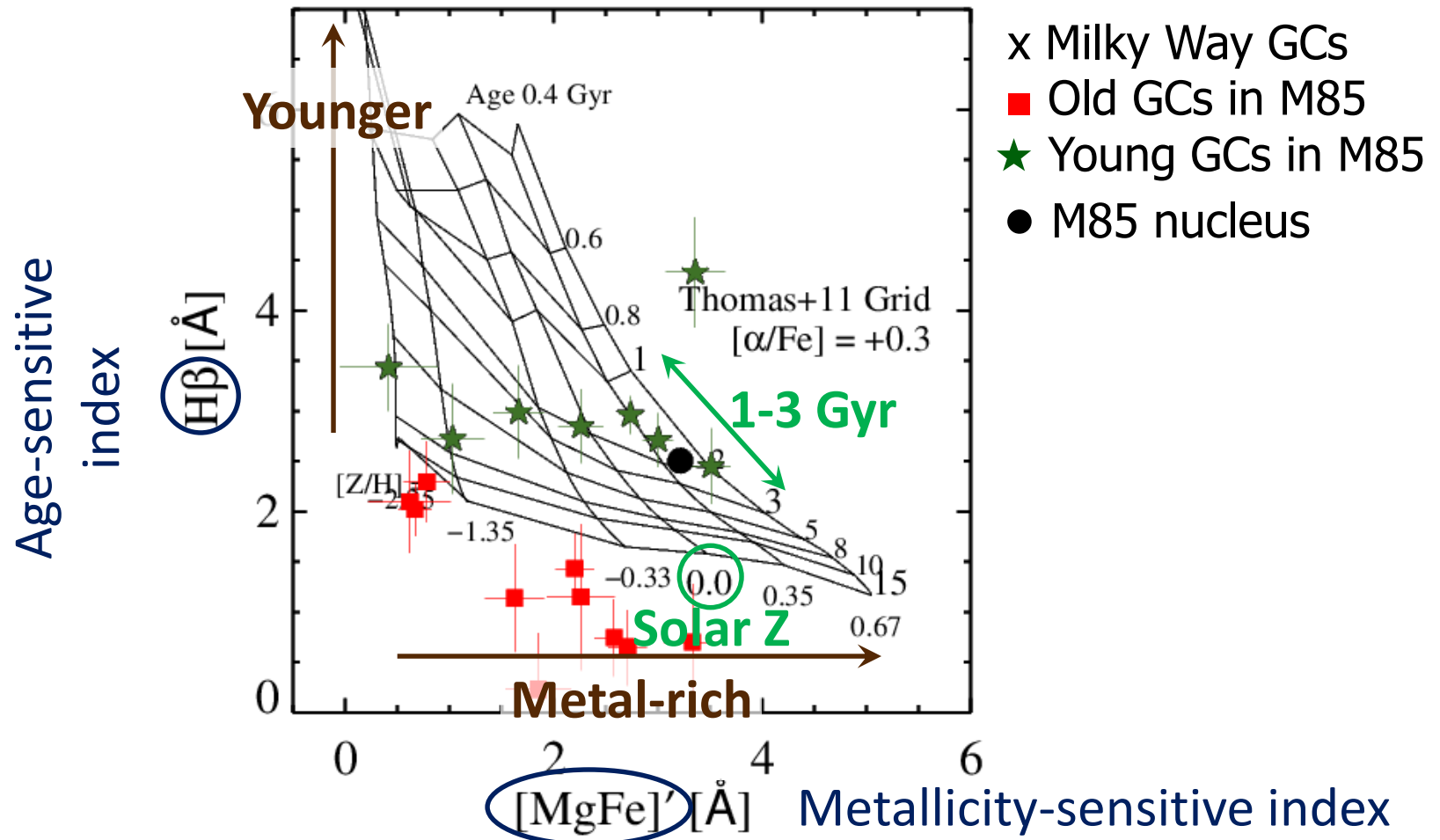
The color distribution of M85 GCs **does not show clear bimodality.**

**Blue, Green, Red GCs?**

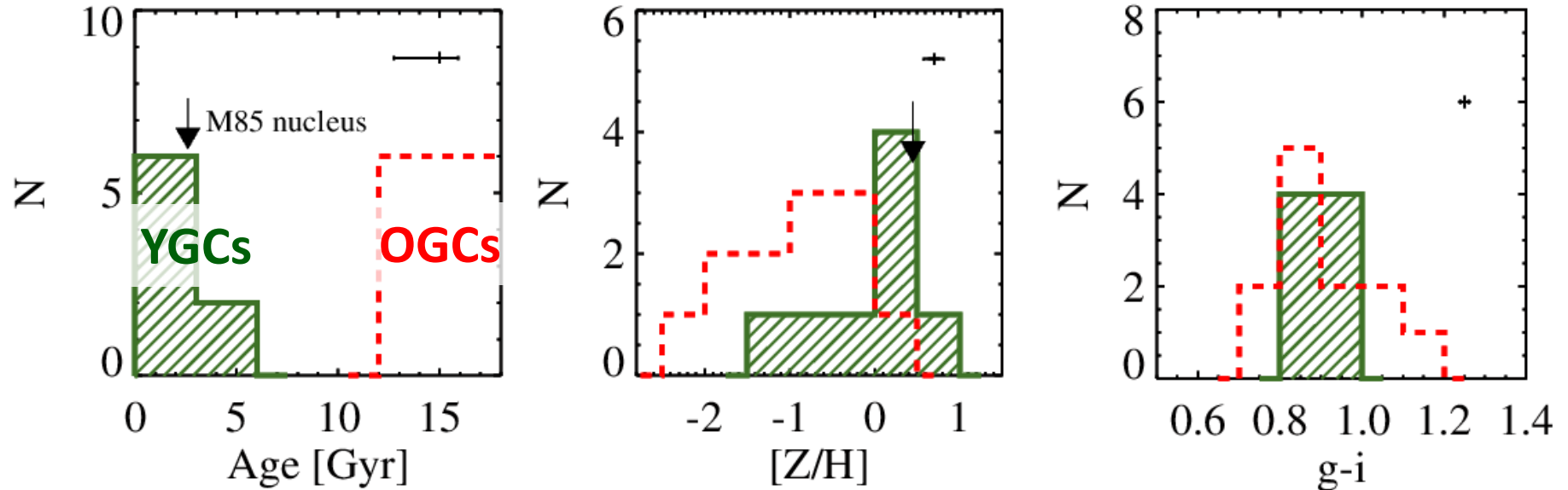


# Lick Index Diagram

- **20 GCs** confirmed with GMOS spectroscopy
- **The first spectroscopic study** of M85 GCs



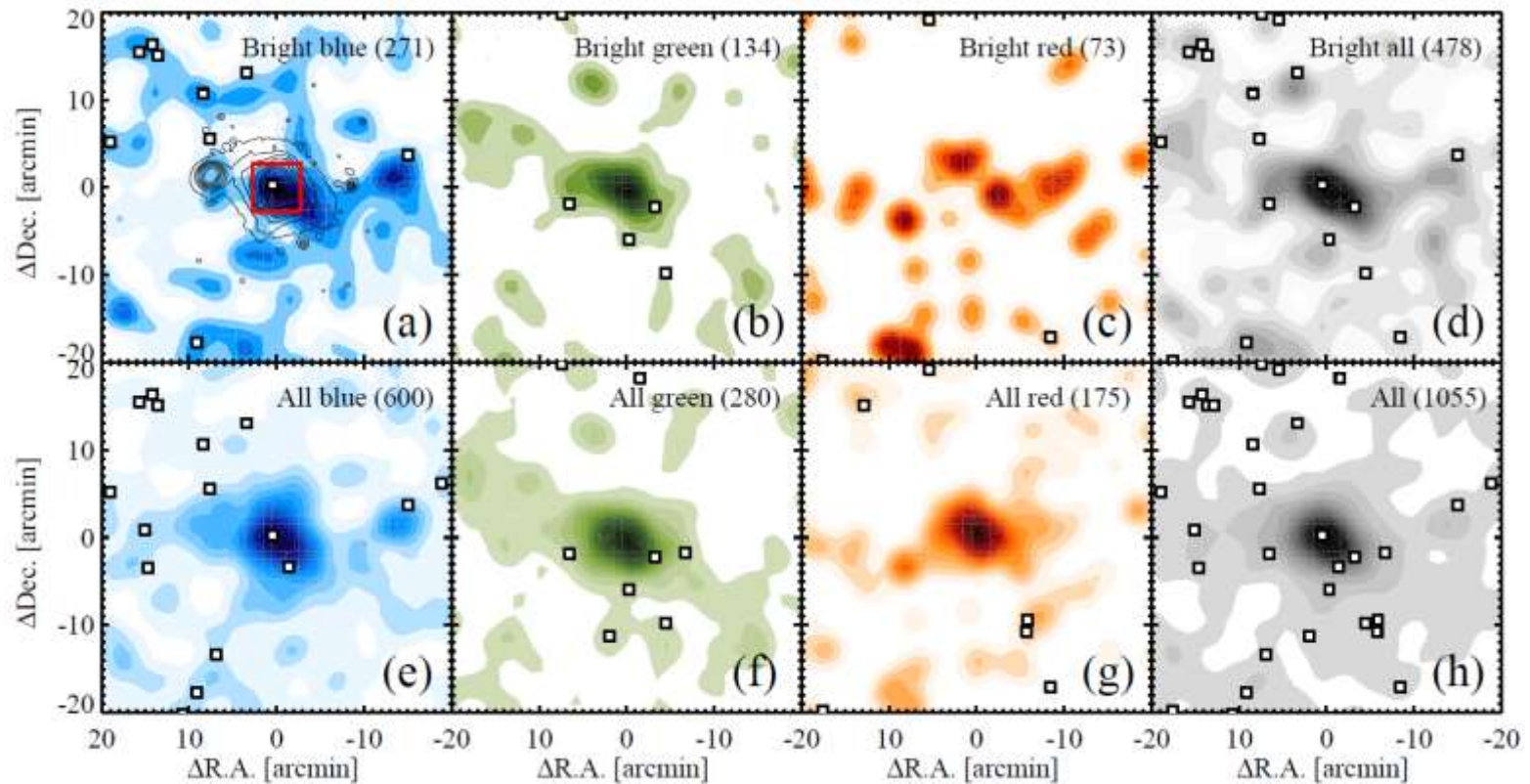
# Age & Metallicity Distribution



1. There are two bursts at  $> 10$  Gyr and 2 Gyr (YGC age =  $2.3 \pm 1.0$  Gyr).
2. YGCs have solar metallicity ( $[Z/H] \sim -0.06$ ),  
while OGCs are more metal-poor ( $[Z/H] \sim -0.87$ ).  
→ **A wet merger happened ~2 Gyr ago.**
3. YGCs have "GREEN" colors?

# *Future Works*

- Enlarge the number of M85 GC sample
- Investigate the wide-field kinematics of M85 GCs based on MMT/Hectospec spectroscopy



NGC 4526





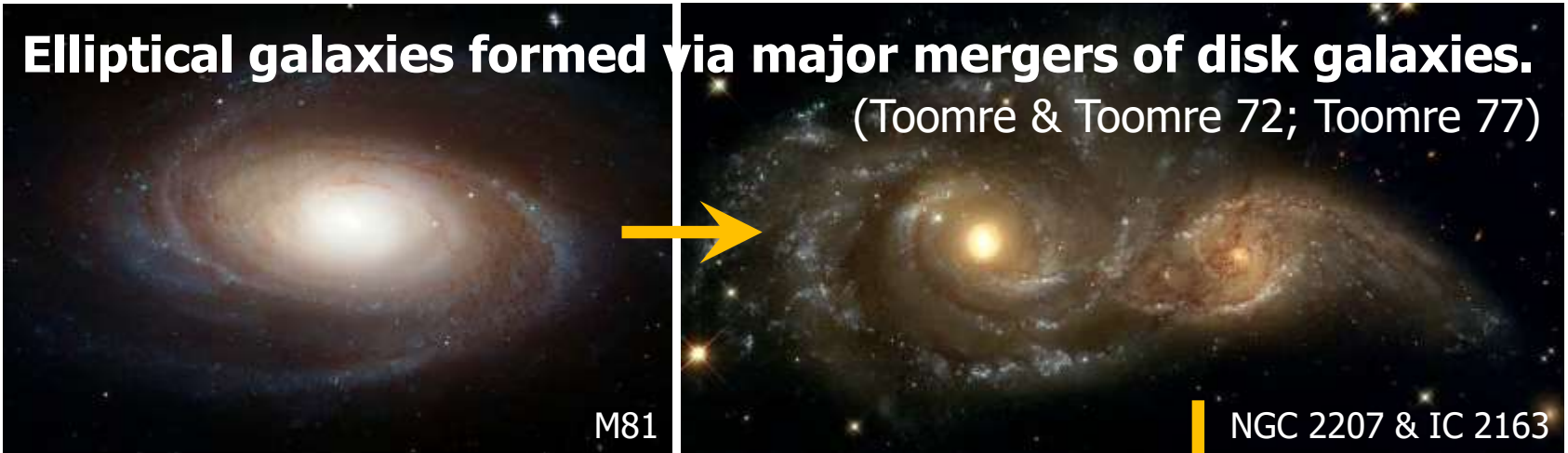
## *Merging history of M85*

- **Detect three different GC populations**
  - **Old metal-poor:** Age > 10 Gyr,  $[Z/H] \sim -1.5$
  - **Old-metal-rich:** Age > 10 Gyr,  $[Z/H] \sim -0.6$
  - **Intermediate-age metal-rich:** Age  $\sim 2$  Gyr,  $[Z/H] \sim +0.1$
- Old metal-poor and metal-rich GCs were formed at similar epochs (>10 Gyr ago). - **Mixture (*bibimbap*) model** (Lee+10)
  - Old metal-poor GCs might be accreted from dwarfs.
  - Old metal-rich GCs are formed via merging at early epoch.
- **At 2 Gyr ago, a wet merger happened.**
  - Formation of intermediate-age GCs with solar metallicity

# Hierarchical Galaxy Formation

Elliptical galaxies formed via major mergers of disk galaxies.

(Toomre & Toomre 72; Toomre 77)



Major or minor merging? Wet or dry merging?

