WFIRST Imaging and Ground-based Spectroscopy

A Powerful Combination for Near-field Cosmology

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Wednesday, June 19, 2019   Science in our Own Backyard with WFIRST, Caltech, Pasadena, CA

Next Generation Virgo Cluster Survey

— CFHT/MegaCam imaging (104 deg^2)
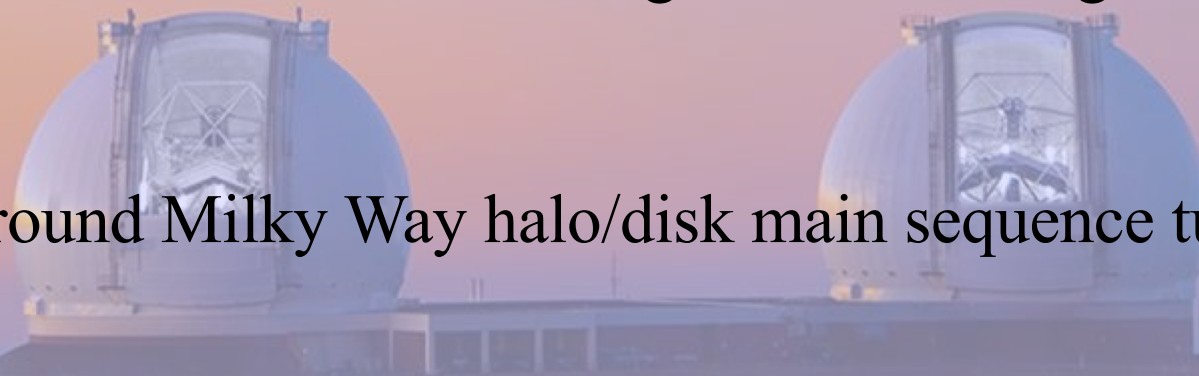*— Keck/DEIMOS spectroscopy*

Collaborators:

Pat Côté, Yuting Feng, Laura Ferrarese, Biao Li, Sungsoon Lim, Chris Mihos, Alessia Longobardi, <u>Eric Peng</u>, Elisa Toloba, Yunhao Zhang

Stephanie Chen, Jason Chu, Rachel Guo, Teddy Liang, Tiffany Louie, Adhara Martellini, Celia Ramirez, Arushi Sahai, Andrew Shao, Lea Sparkman, Kovid Tallam, Jin Tuan

NGVS Keck/DEIMOS Spectroscopy

❖ Keck/DEIMOS multislit spectroscopy: 600 lines/mm grating, medium resolution (R ~ 2000), 4800–9500Å wavelength coverage

❖ Targets
— Candidate GC satellites of Virgo dwarf elliptical galaxies (dEs)
— Candidate GC satellites of Virgo ultra diffuse galaxies (UDGs)

❖ Fillers
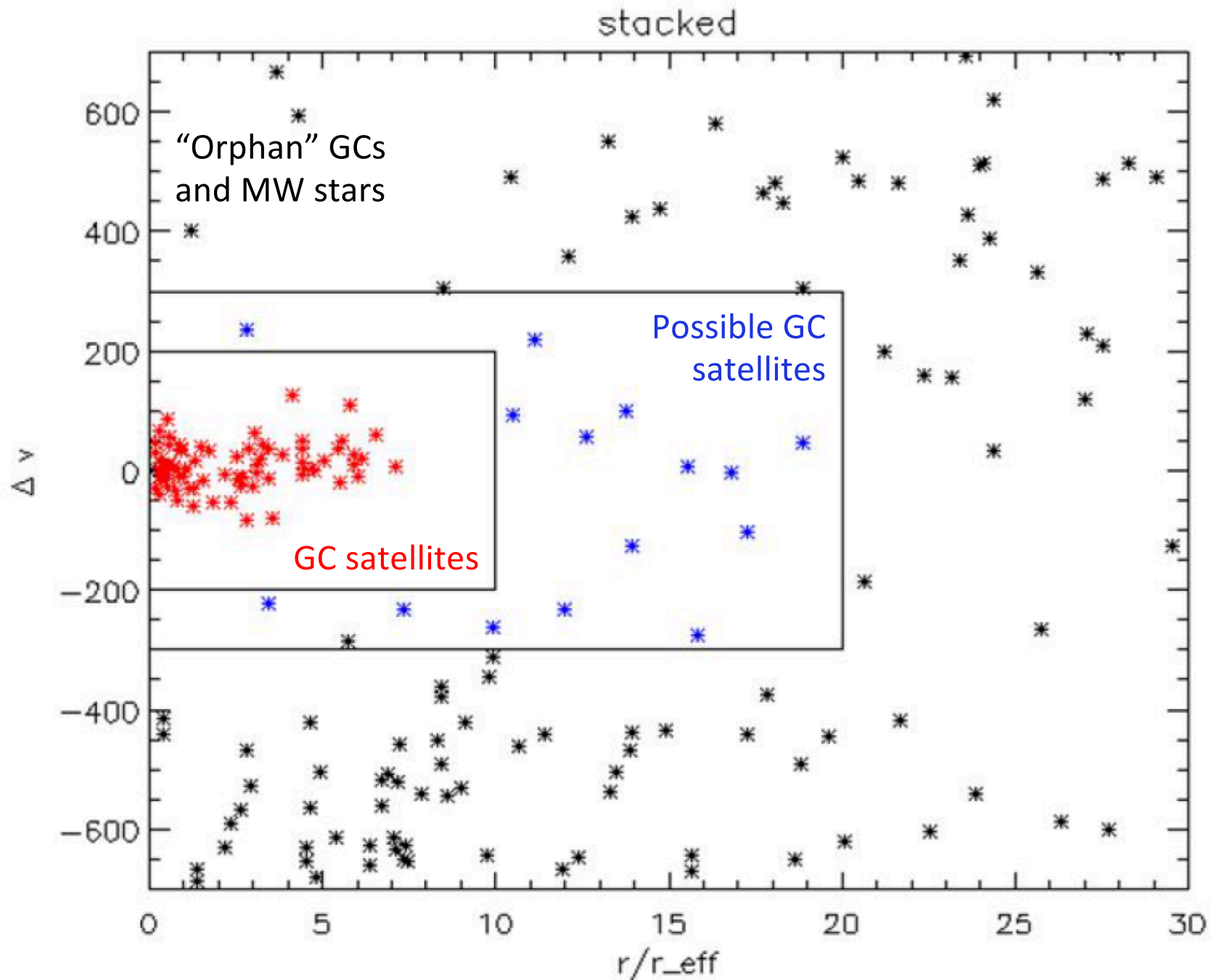— Foreground Milky Way halo/disk main sequence turnoff stars

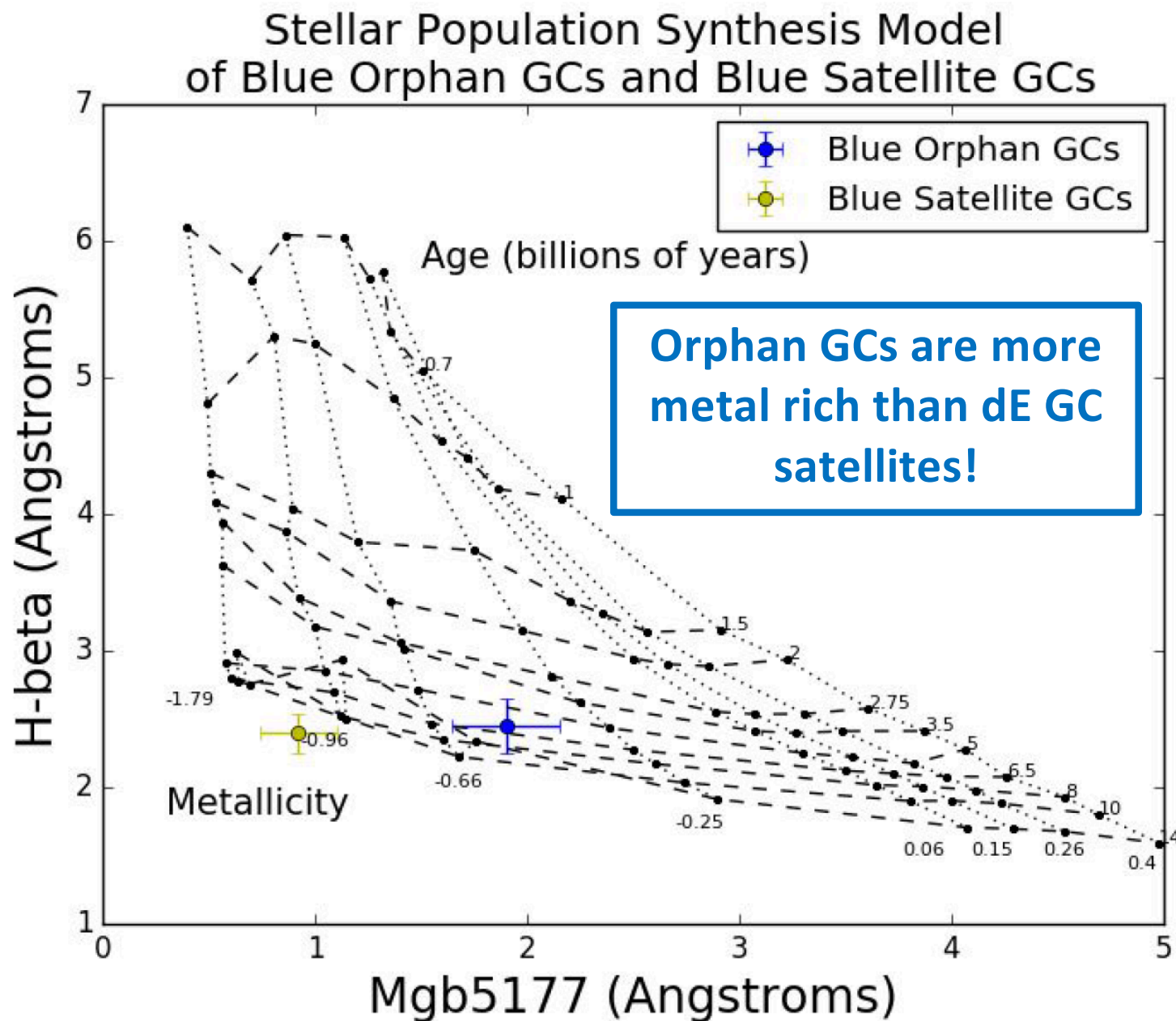# Keck/DEIMOS Spectroscopic Sample

## Keck/DEIMOS spectroscopy of GC satellites of Virgo cluster dEs
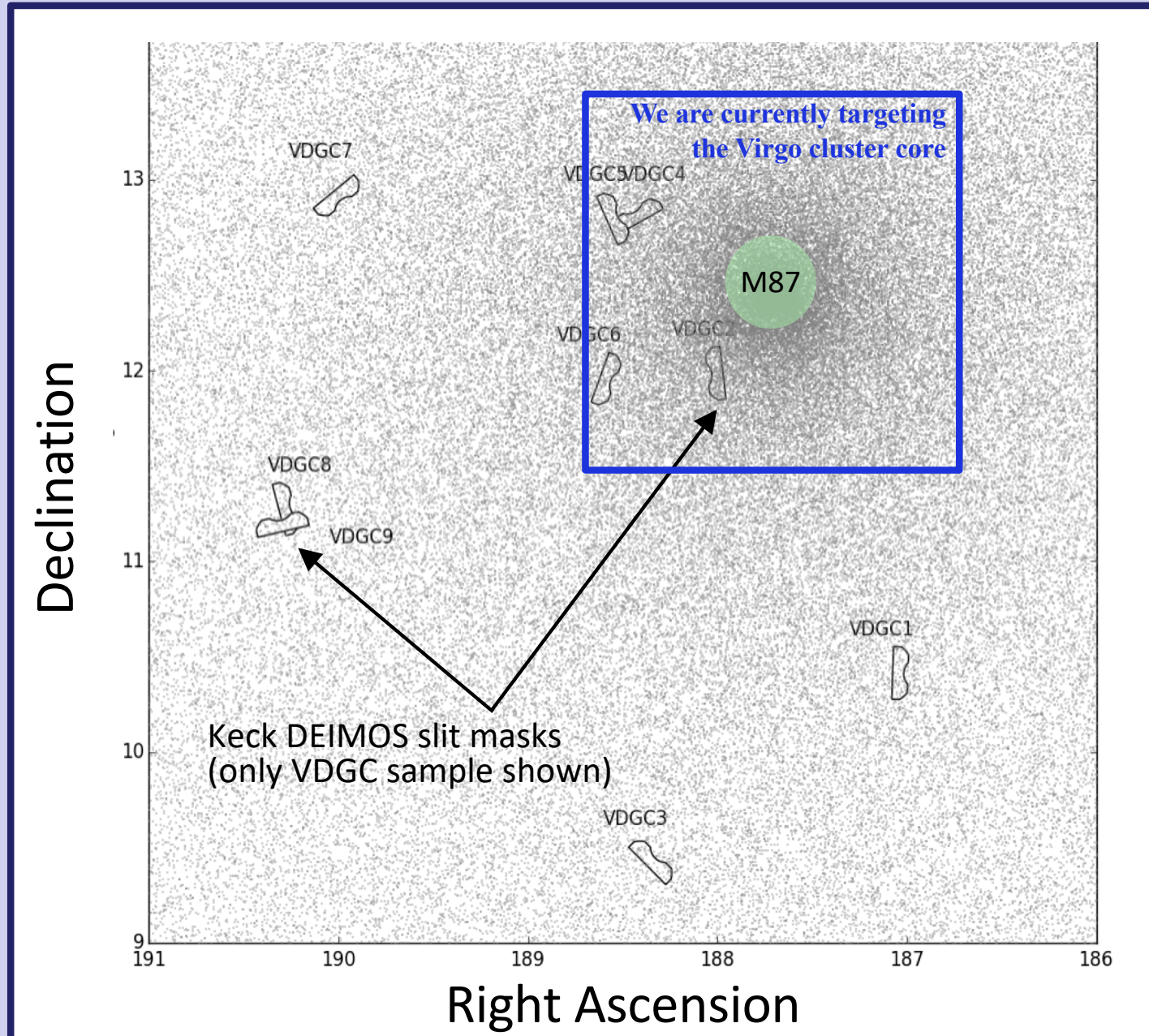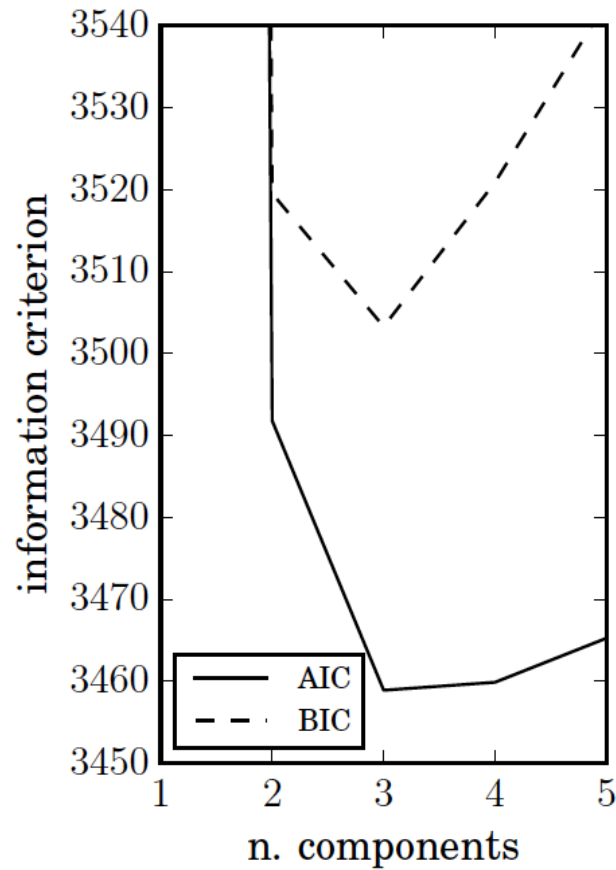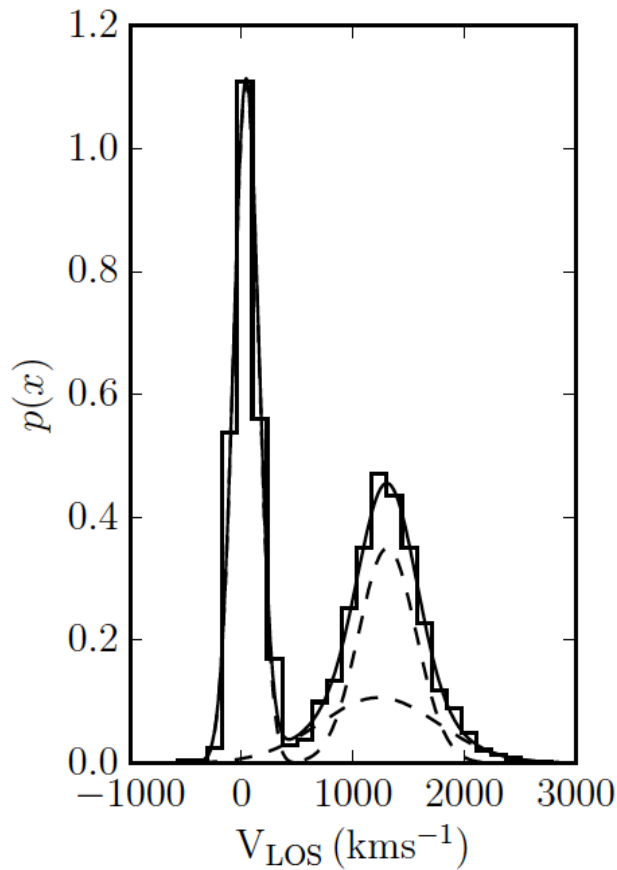
Definition of GC satellites versus "orphan" GCs

stacked

"Orphan" GCs and MW stars

Possible GC satellites

GC satellites

Comparing ages and metallicities of "orphan" GCs and dE GC satellites

Stellar Population Synthesis Model
of Blue Orphan GCs and Blue Satellite GCs

Two flavors of "orphan" GCs: M87 halo GCs and intracluster GCs
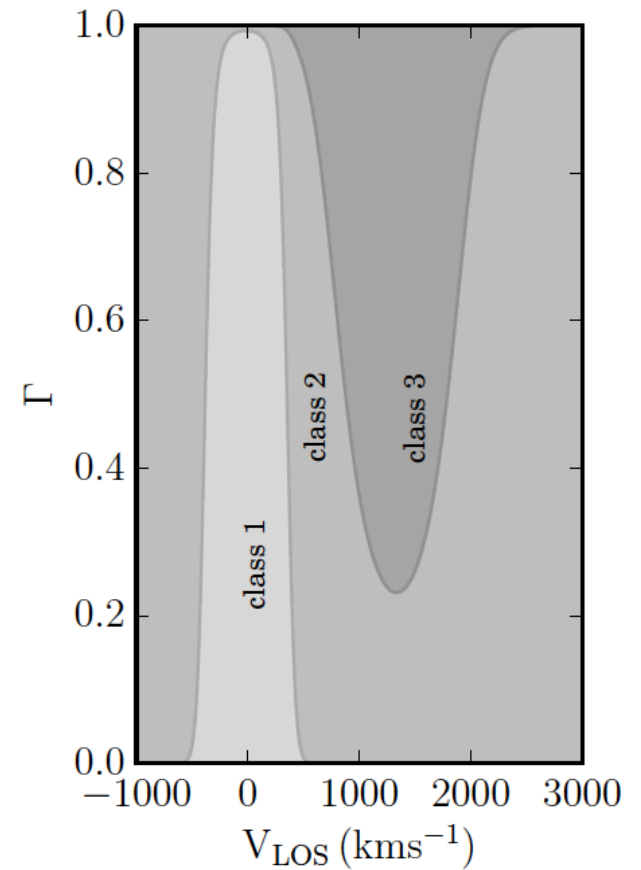
- M87 halo GCs: <v> = 1300 km/s; σ_v ~ 400 km/s
- Intracluster GCs: <v> = 1100 km/s; σ_v ~ 700 km/s

Longobardi et al. (2018)

Virgo Core Photometric GC Sample

- Photometric sample of GCs selected using Eric Peng's "extreme deconvolution" (XD) method based on broadband colors ($ugizK_s$) and image morphology

- This has resulted in the most complete map to date of GCs in Virgo cluster core ($r < 200$ kpc)

GC selection based on "extreme deconvolution"

Peng et al. (in prep.)
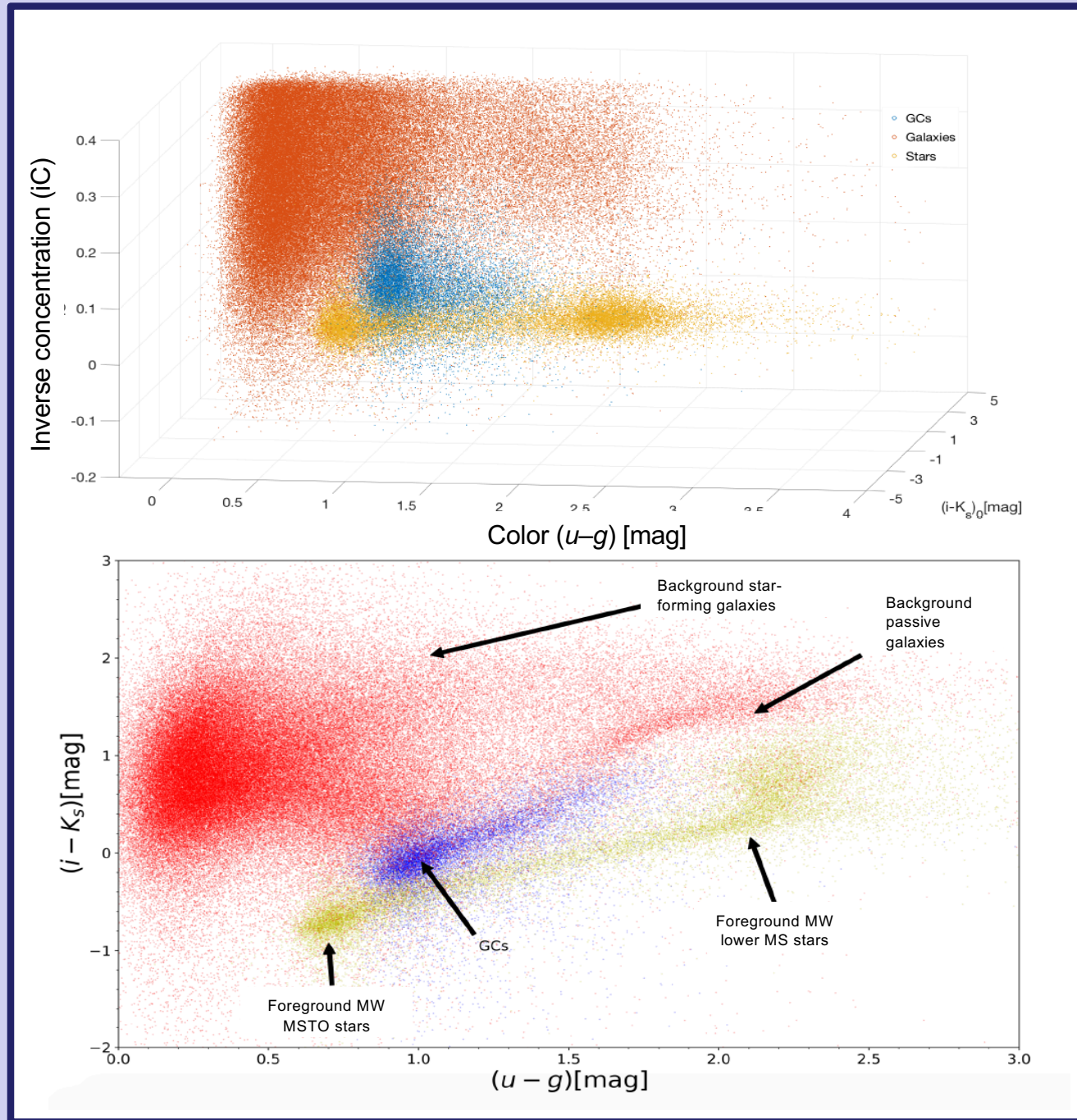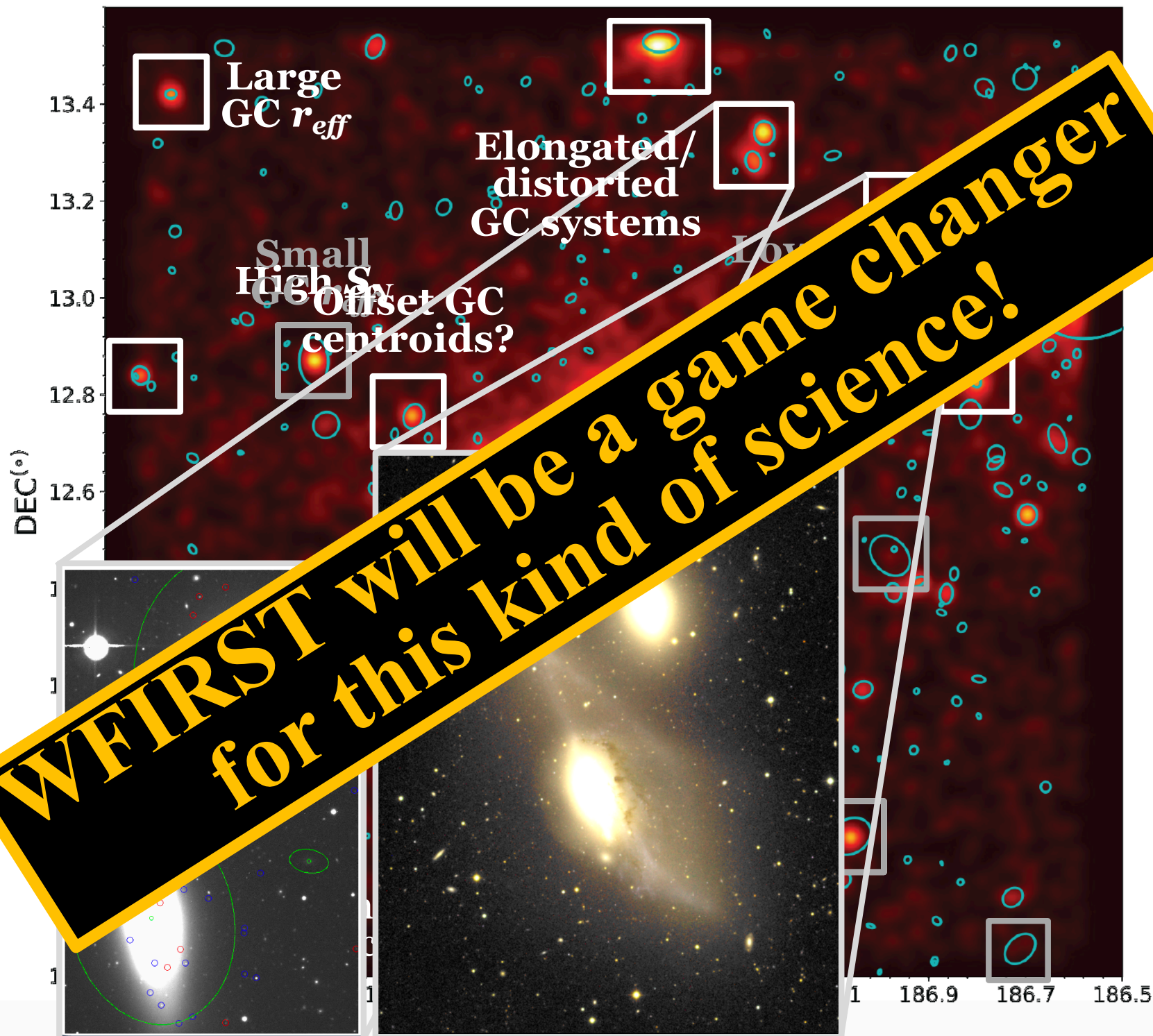
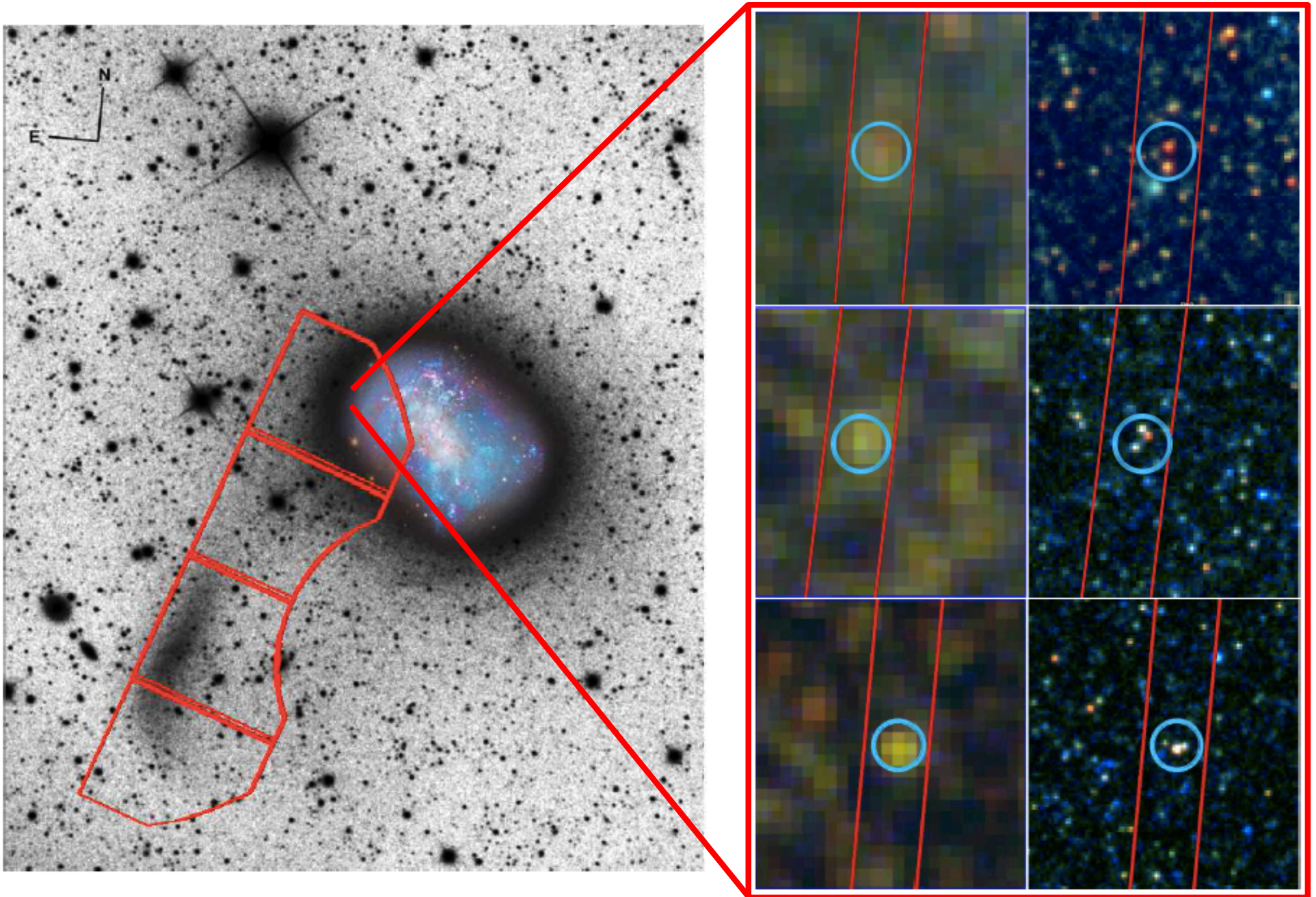WFIRST will be a game changer for this kind of science!

Panoramic Imaging Survey of Centaurus and Sculptor (PISCeS)

— Magellan/MegaCam imaging
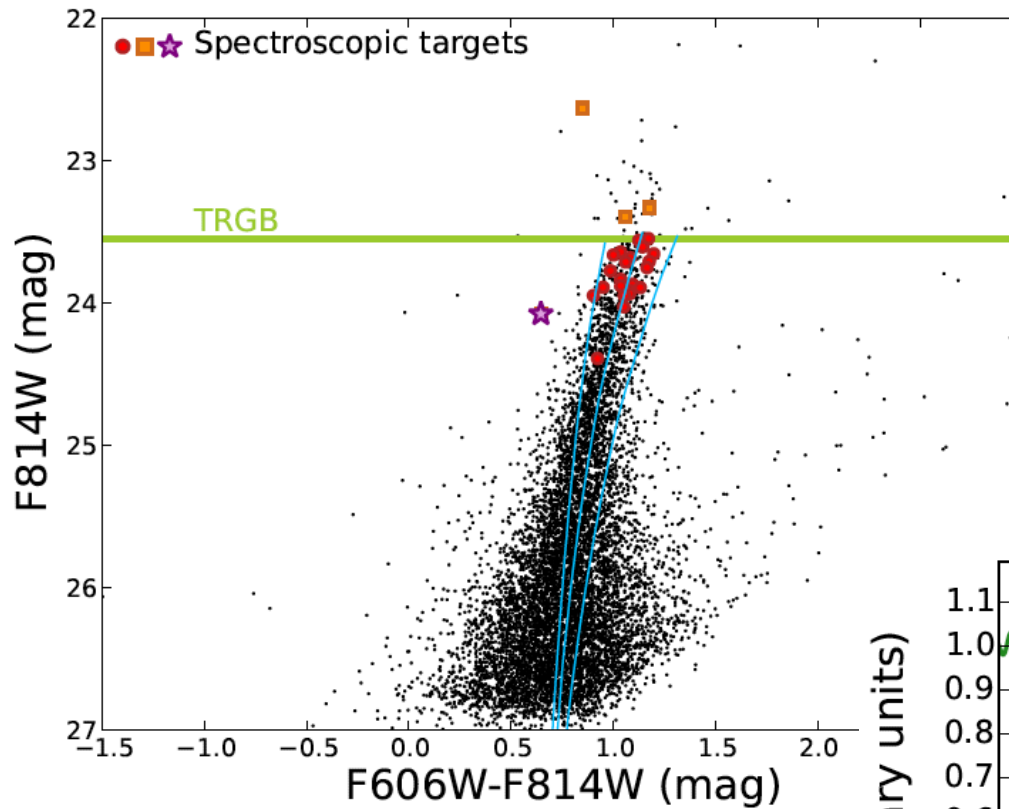*— Keck/DEIMOS spectroscopy*

Collaborators:

Denija Crnojević, Dave Sand, Josh Simon, Elisa Toloba

Coadded spectroscopy of positive SBFs in a LSB stellar stream

Toloba, PG, et al. (2016a)

Coadded spectroscopy of stars & blends in an M81 dwarf satellite

Spectroscopic targets

TRGB

F814W (mag)

F606W-F814W (mag)

Obvious H-alpha and Ca triplet absorption in the coadded spectrum

CMD of individual stars and blends in M81 dwarf satellite

Toloba et al (2016c)

Raw counts (arbitrary units)

Hα

Ca$_1$ Ca$_2$ Ca$_3$

$v_{hel}=-38.3\pm9.8km/s$
$S/N=9.3\text{Å}^{-1}$

[Fe/H]$_{mod}=-1.26$
[Fe/H]$=-1.32\pm0.34$
$S/N=6.7\text{Å}^{-1}$

λ (Å)
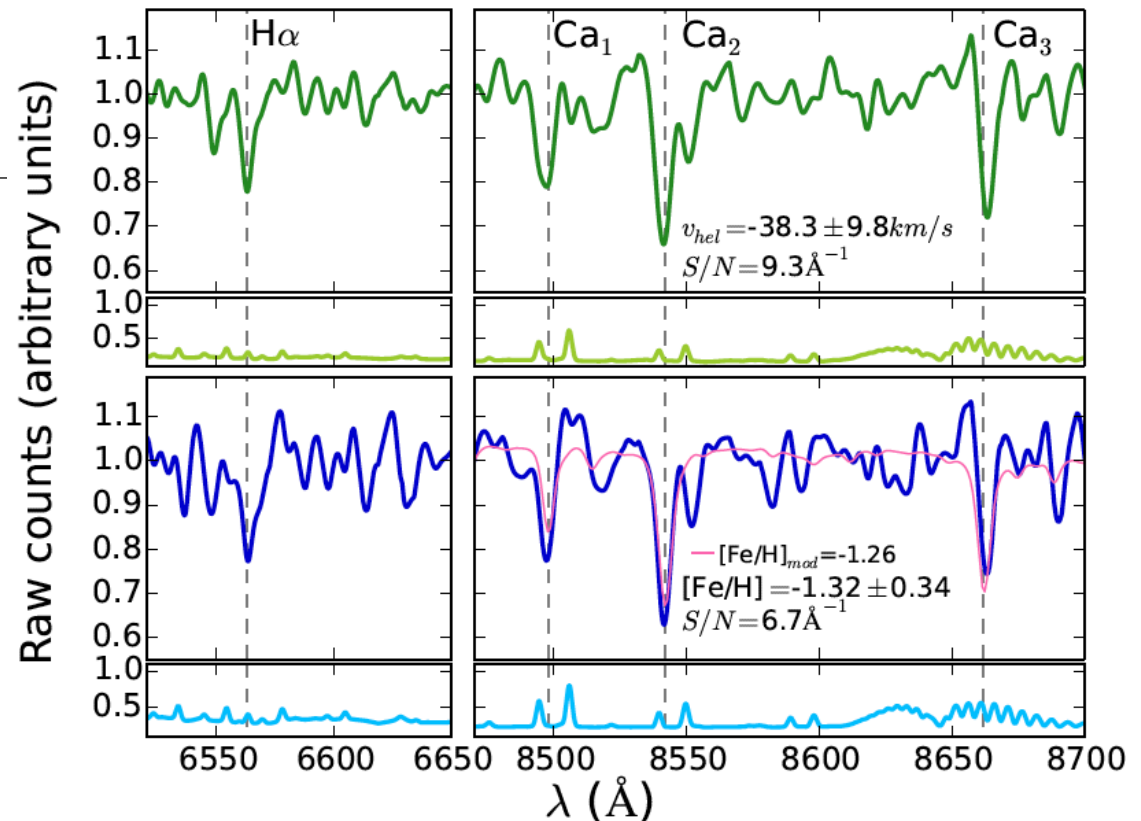
PISCeS survey: Tidal stream in NGC 253's halo (Sculptor group galaxy) with Keck/DEIMOS mask overlay

Spectra from ~150 slitlets coadded in 3 spatial bins

Velocity gradient of ~3 km/s/kpc

Toloba et al (2016b)
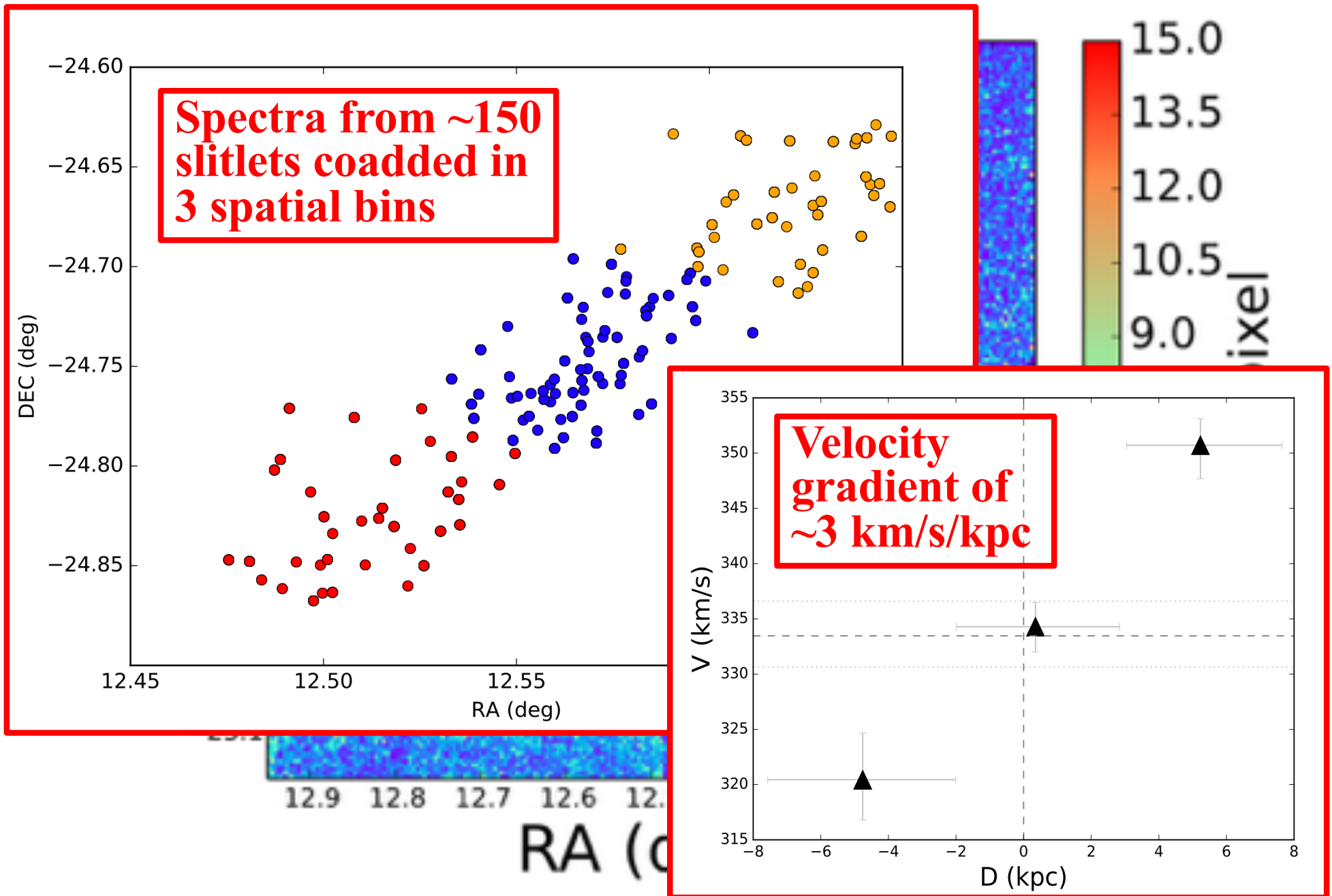
PISCeS survey: Tidal streams in the halo of Centaurus A

Elisa Toloba

Denija Crnojević

Sand+14, Crnojevic+14,
Crnojevic+16, Toloba+16

Accretion history and mass of the Milky Way

HALO7D survey
Looking at (and through) the remote Milky Way stellar halo

Emily Cunningham

Alis Deason

!

— Anderson, <u>Cunningham</u>, <u>Deason</u>, PG, Kirby, Rockosi, Sohn, van der Marel, Wetzel
— <u>Barro</u>, Conroy, Faber, <u>Guo</u>, Koo, <u>Yesuf</u>

"7D" mapping of the Milky Way halo: Accretion history and mass estimate

- ❖ Proper motions from multi-epoch imaging with HST, Gaia, and, in the future, WFIRST and JWST

- ❖ Keck/DEIMOS spectroscopy (8 to 32 hours per mask!) and ultimately spectroscopy with ELTs to measure radial velocities and especially chemical abundances of faint MSTO stars

HALO7D Collaboration
HSTPROMO: The HST Proper Motion Collaboration
Alis Deason, Emily Cunningham, Connie Rockosi, PG (*UCSC*), Evan Kirby (Caltech)
Roeland van der Marel, Jay Anderson, Tony Sohn (*STScI*)

Cunningham et al. (2016, 2018, 2019)

Summary: Local Volume Science with WFIRST and Ground-based Spectroscopy

1. _Globular clusters as probes of the dark matter halo, star formation history, and chemical abundance of ultra-diffuse galaxies and dwarf ellipticals in the dense Virgo cluster environment_

2. _Coadded SBF spectroscopy of partially resolved stellar populations as a probe of the dark matter halos of galaxies out to distances of ~10 Mpc_

3. _6D phase space measurements of remote Milky Way halo stars and 3D kinematics of M31 and M33 resolved stellar populations_

Rogelio Bernal Andreo
DeepSkyColors.com