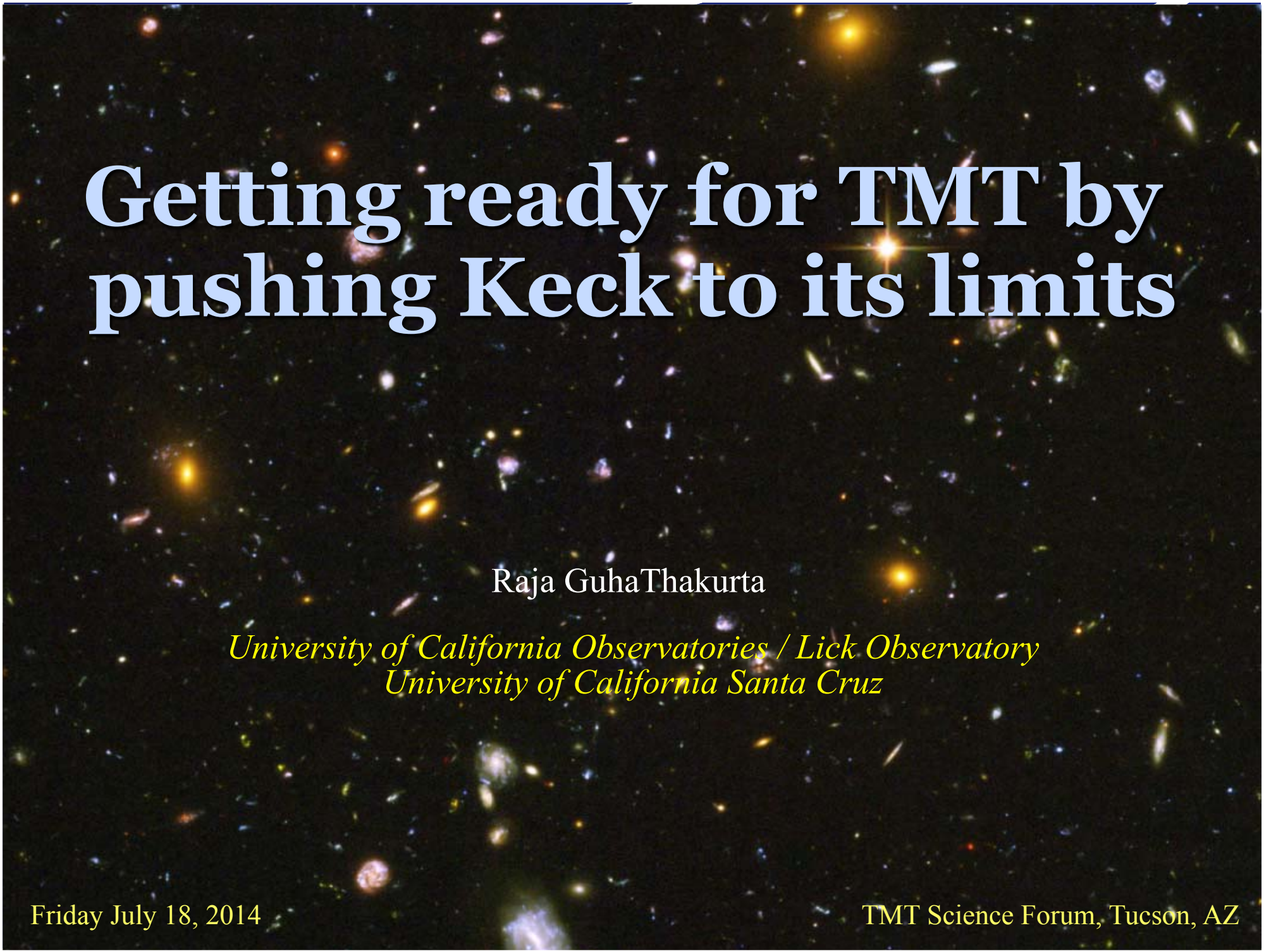


Getting ready for TMT by pushing Keck to its limits

Raja GuhaThakurta

University of California Observatories / Lick Observatory
University of California Santa Cruz

Friday July 18, 2014

TMT Science Forum, Tucson, AZ

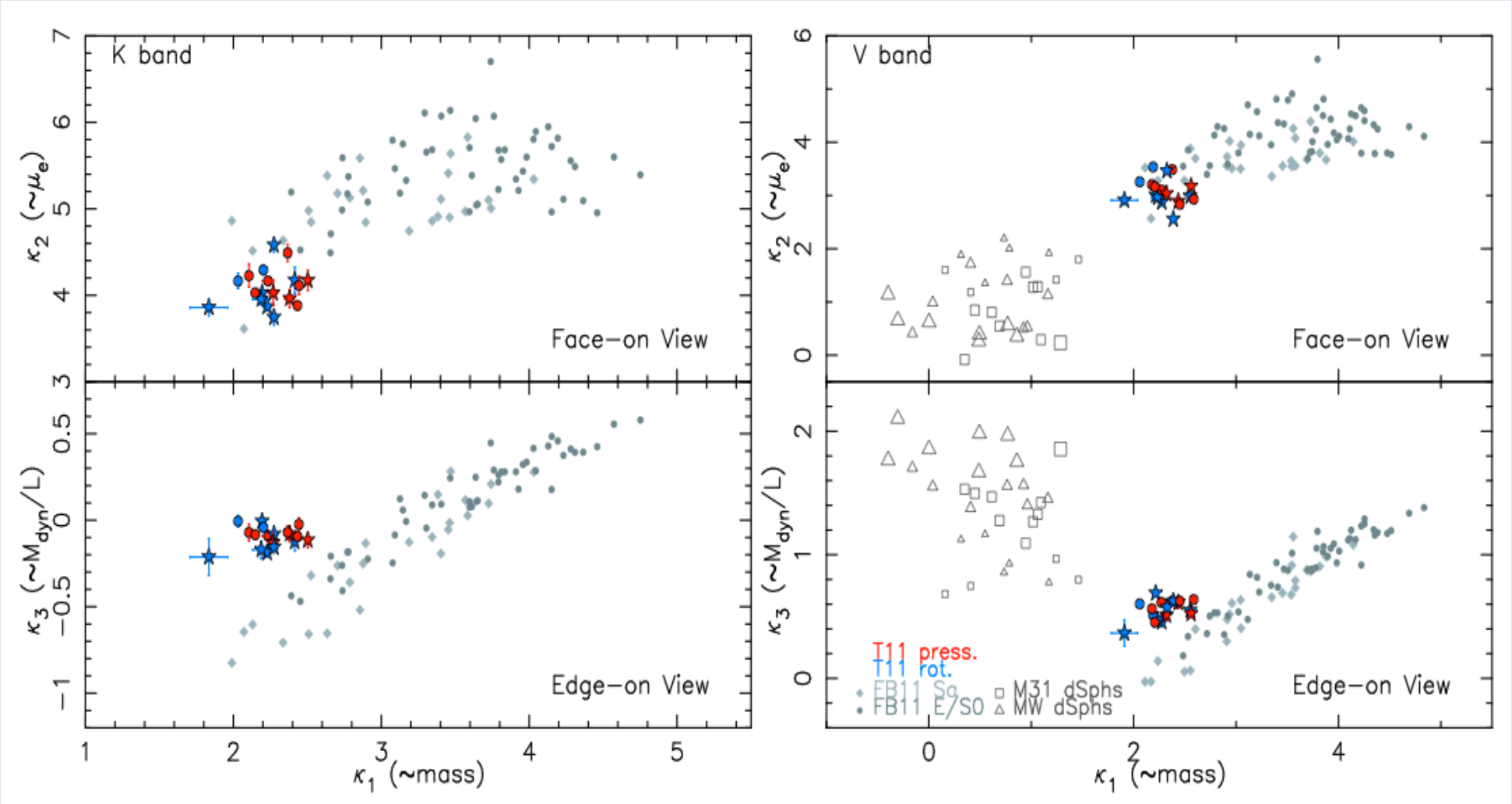
Technical advantages that TMT is expected to offer for studies of nearby galaxies

- Going beyond the tip of the iceberg: statistical studies with large sample sizes
- Expanding the survey volume: sampling a range of galaxy environments
- Making measurements of individual objects without having to co-add samples
- Spectroscopy at low surface brightness levels: outskirts of galaxies, faint tidal streams, etc
- Synergy with JWST, LSST, HSC, WFIRST, Euclid, etc.

A few examples of what TMT can do for Local Group / Local Volume science

- Dwarf elliptical galaxies: dark matter content; nature of their nuclei; origin of their kinematic anomalies
- Finding and measuring the masses of ultra-faint dwarf spheroidal galaxies in the Local Group – the smallest dark matter sub-halos
- Characterizing the smallest of the dark matter sub-halos – constraints on baryonic physics
- Dust mapping of Andromeda's disk based on "thermometry" of M giant stars
- The gastronomical habits and mass of the Milky Way

Mass-to-light ratios of early-type galaxies of different masses



Virgo Cluster dEs: Integrated light kinematics measured out to ~ 1 r_{eff}
Local Group dEs: Resolved stellar kinematics measured out to ~ 7–8 r_{eff}

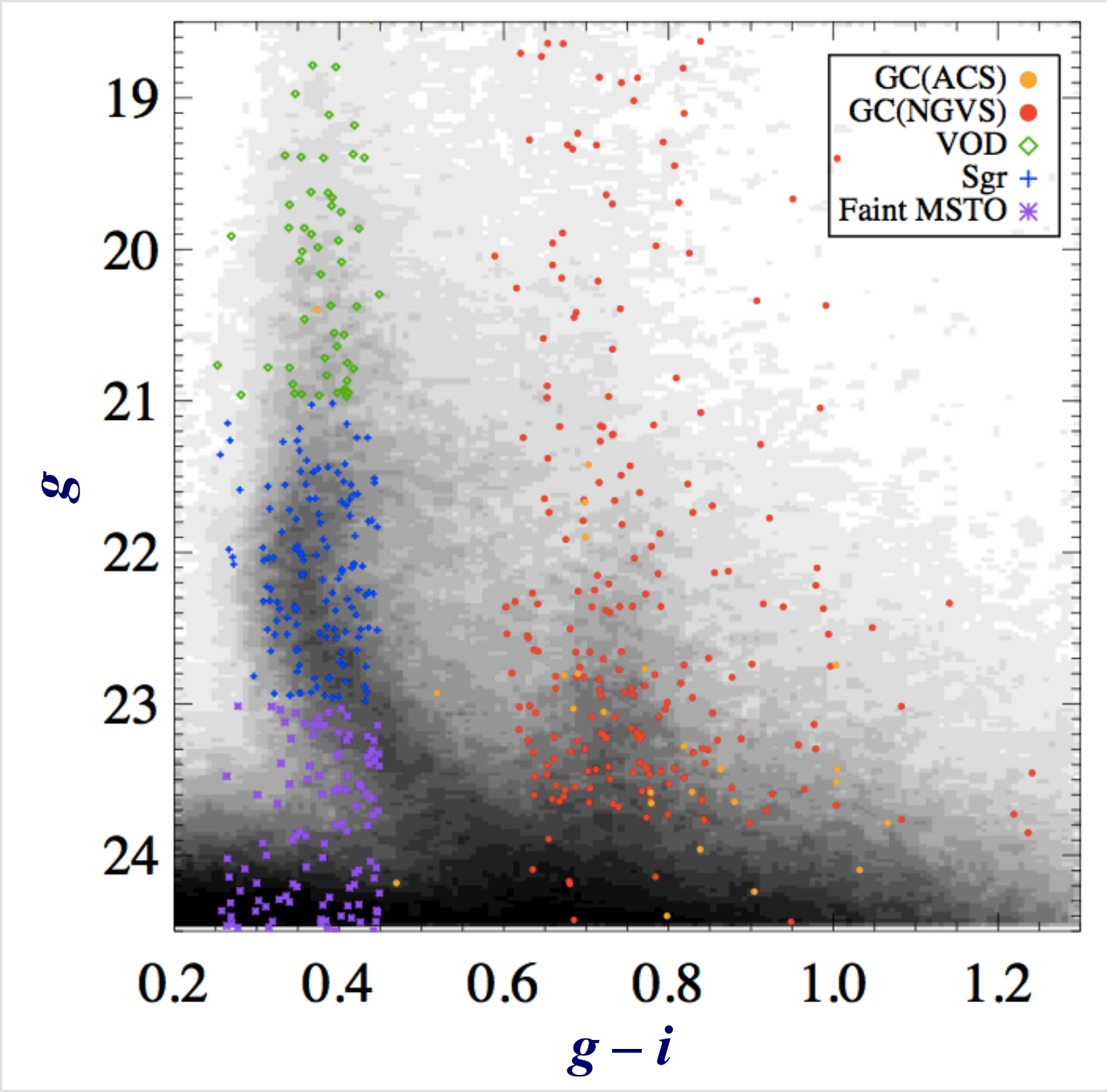
Toloba et al (2012)

An experiment: Stacking globular cluster satellites of Virgo Cluster dwarf ellipticals

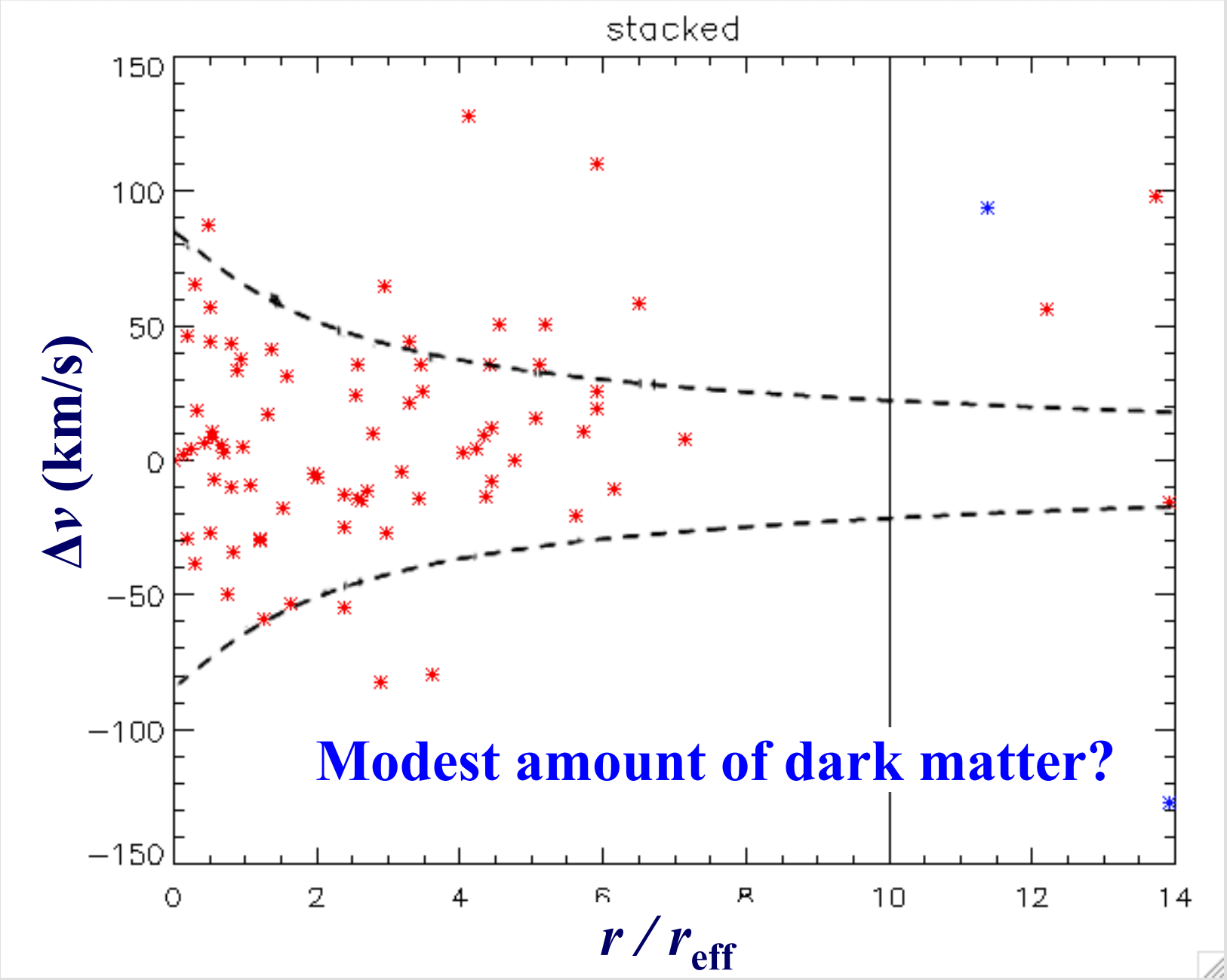
– We are targeting dEs that are low enough luminosity such that they each contain only a handful of GC satellites

– Photometric selection of GC satellites candidates using the Next Generation Virgo Survey (NGVS)

– Keck/DEIMOS spectroscopy of GC satellite candidates; TMT will go fainter than the peak of the GC luminosity function

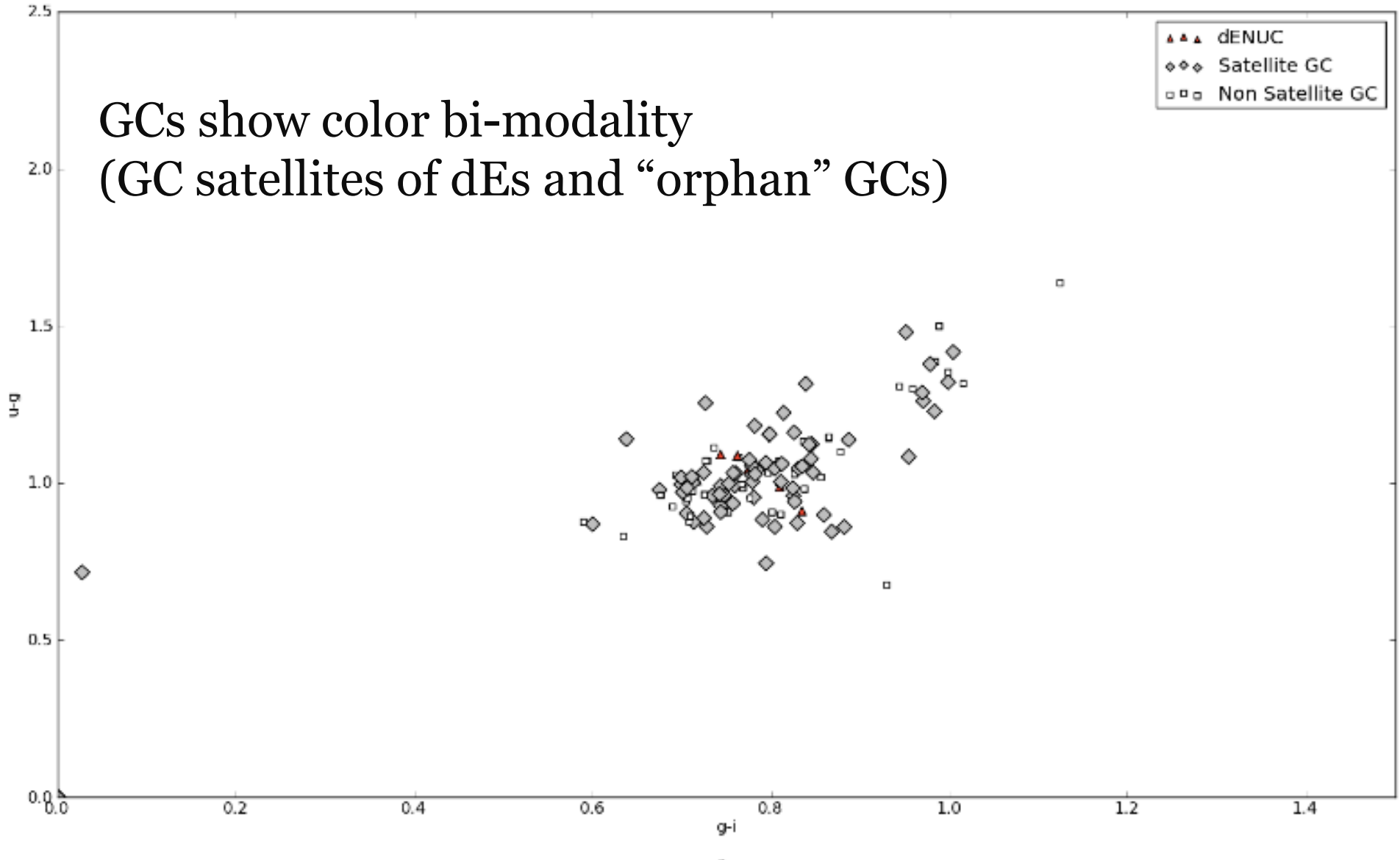

GC(ACS)
GC(NGVS)
VOD
Sgr
Faint MSTO
19
20
21
22
23
24
g
0.2
0.4
0.6
0.8
1.0
1.2
g – i

Stack of GC satellites for 21 Virgo Cluster dwarf ellipticals

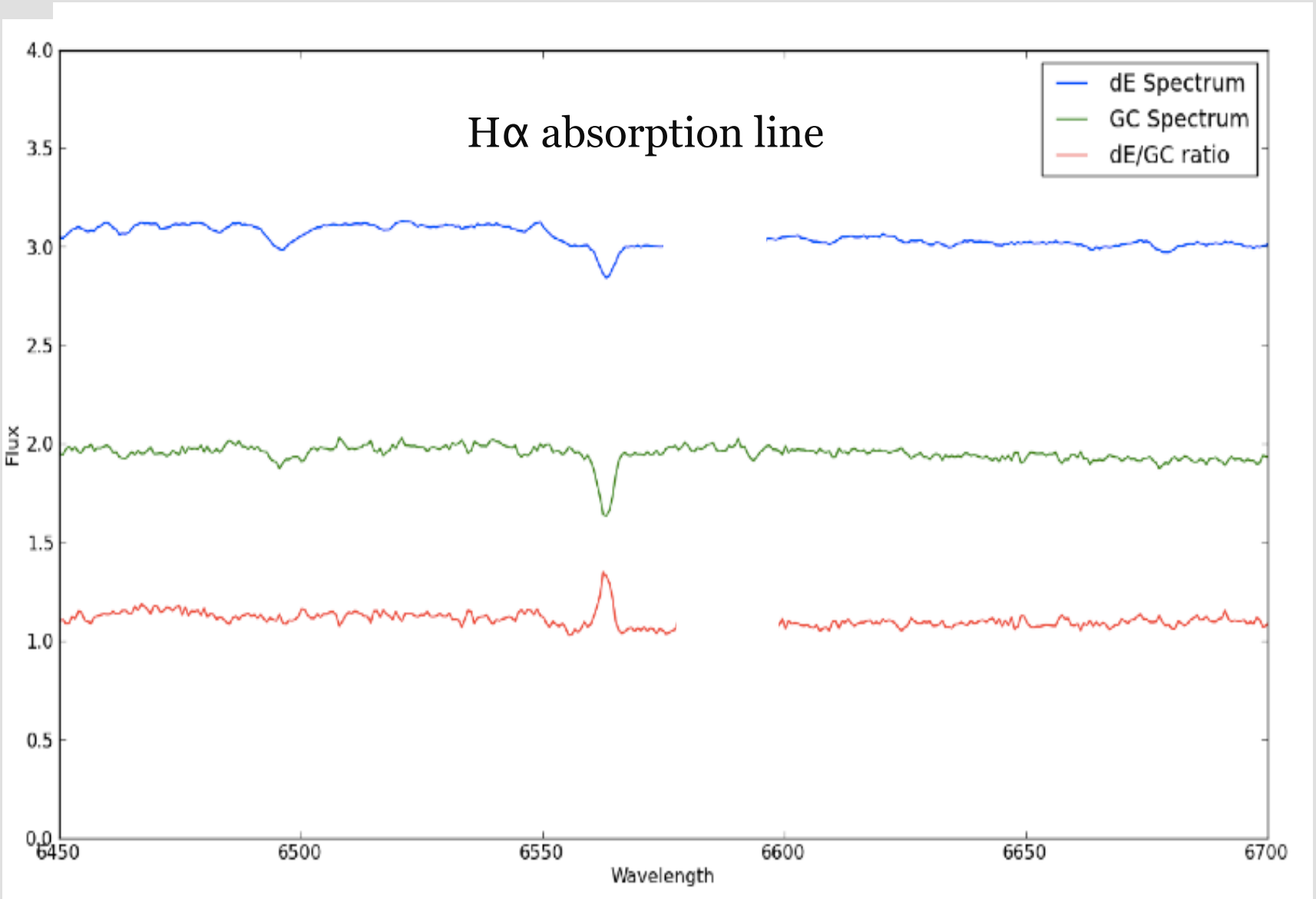


Elisa Toloba, Eric Peng, Biao Li
Stephanie Chen, Jason Chu, Lea Sparkman, Samyu Yagati,
Pat Côté, Laura Ferrarese

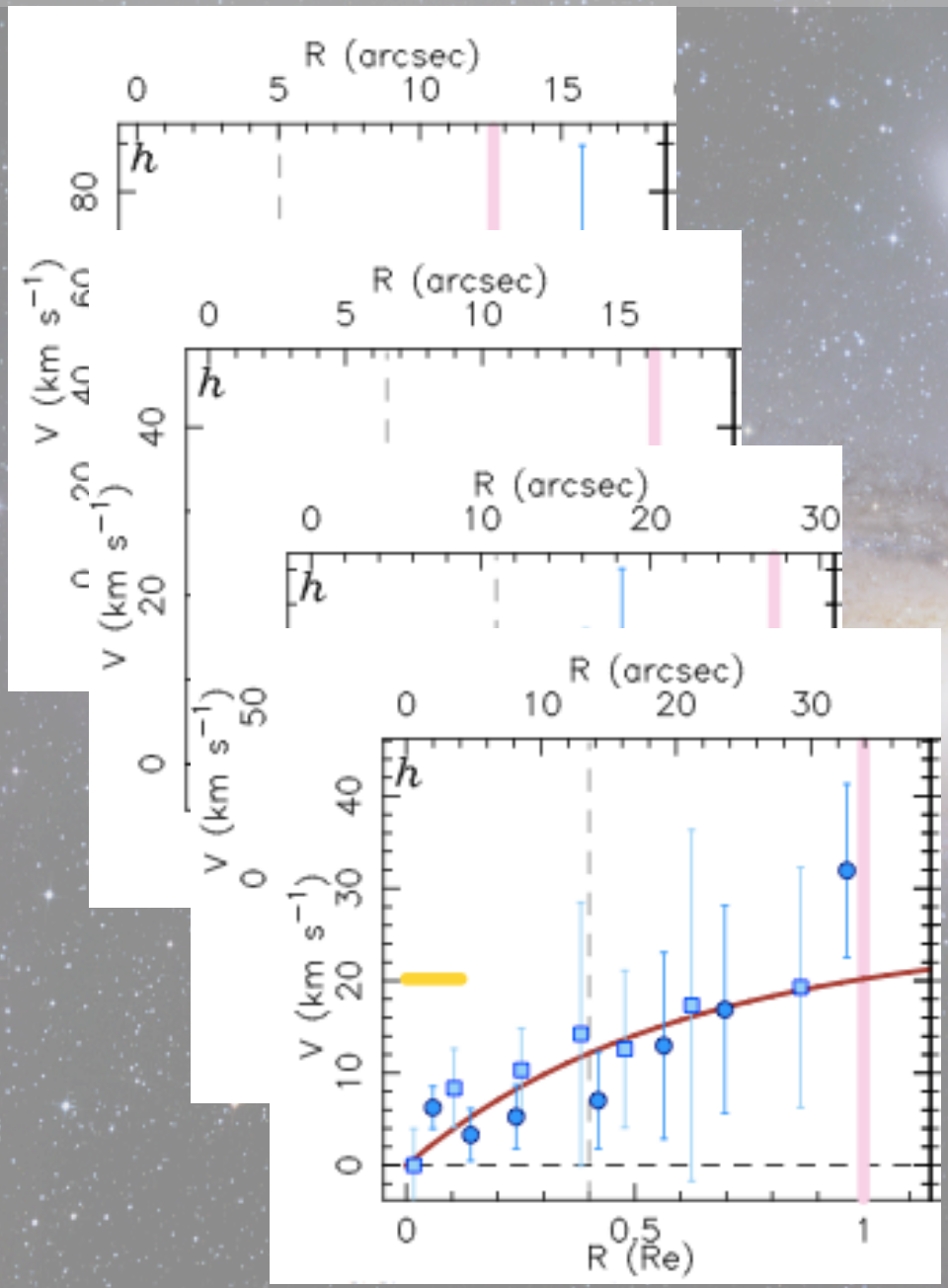
Color-color diagram

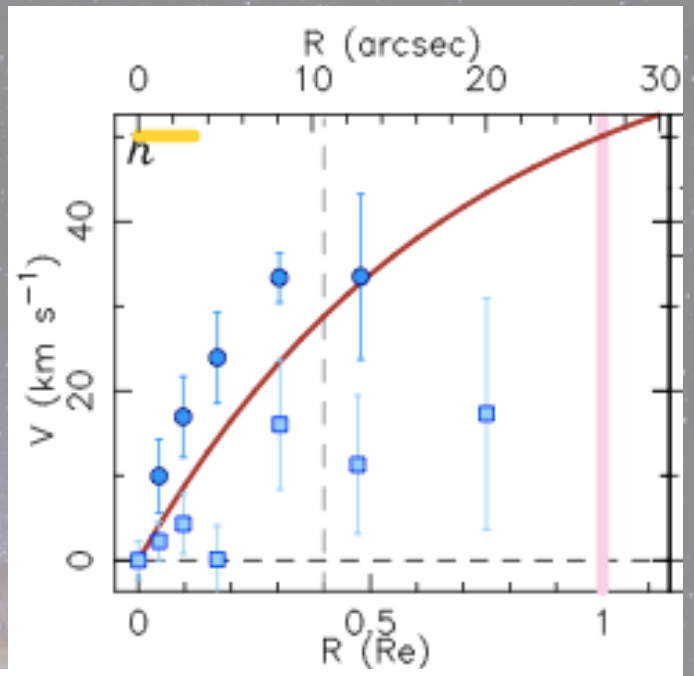


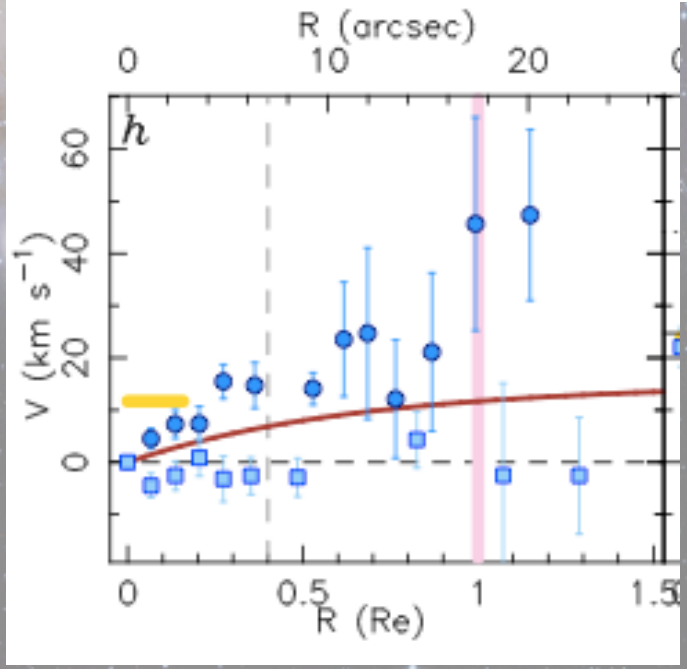
Co-added spectra



Dwarf early-types often show asymmetric “rotation curves”







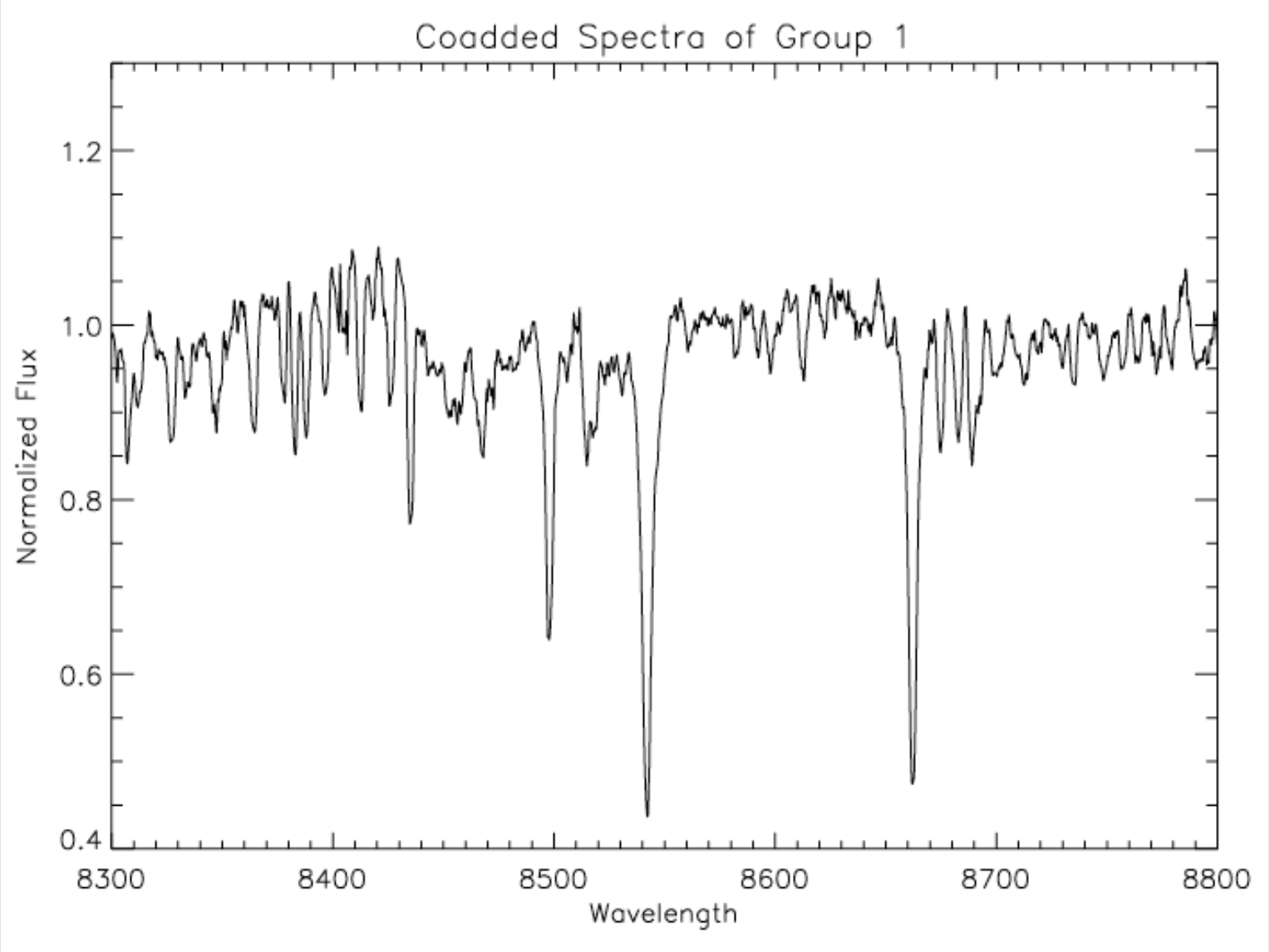
Toloba, PG, et al. ApJ, submitted

Characterizing dwarf satellites in the Local Group

– Chemical abundance measurements of old stars are very challenging with Keck

– Metallicity distribution functions of dwarf satellites from spectra of *individual* stars versus mean metallicities of dwarf satellites from *co-added* spectra

Series of *co-added* spectra of red giant stars in the luminous Andromeda satellite, NGC 147

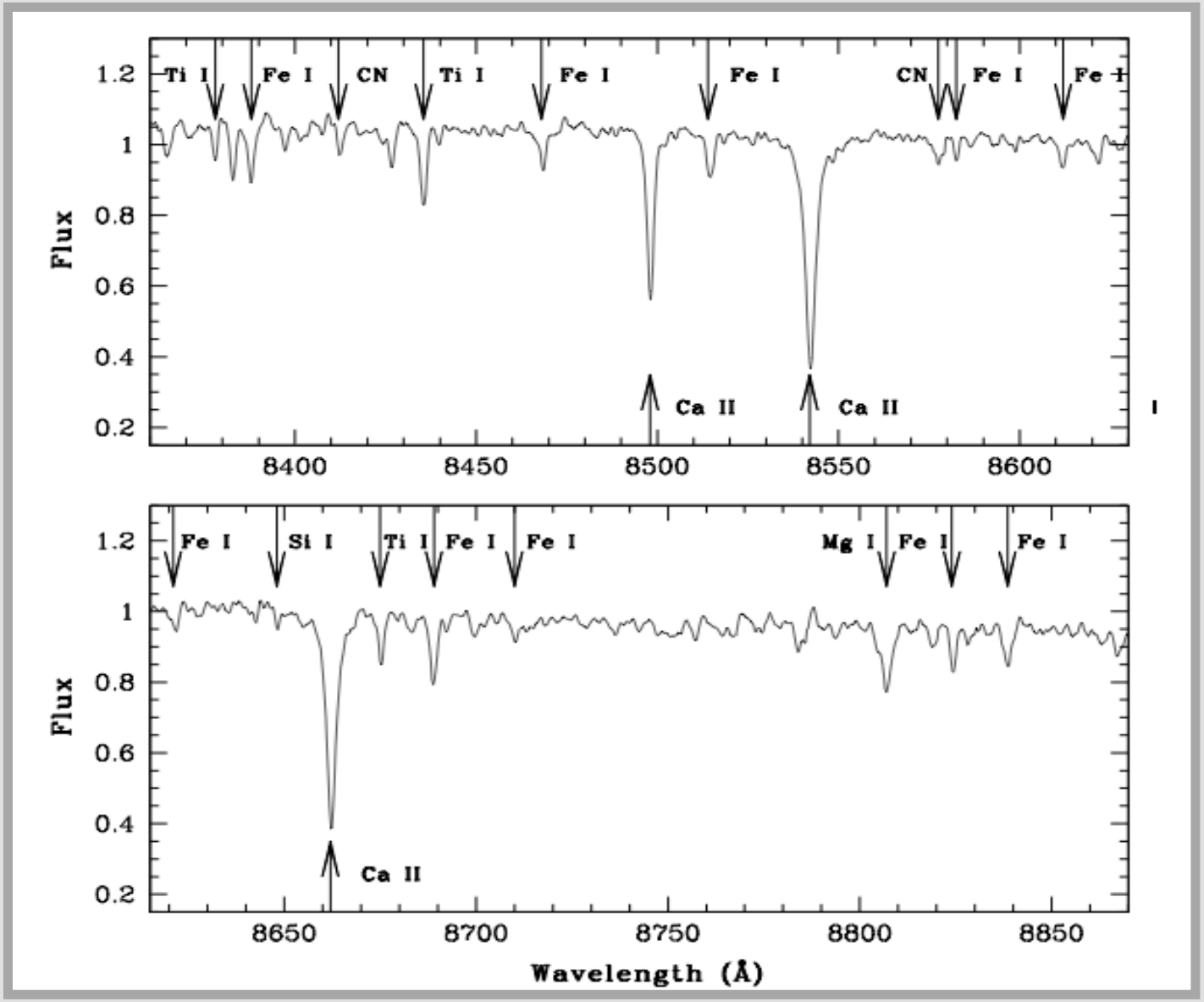


Lucy Cheng
Harker High School
(summer intern at UCSC)

Lei Yang
KIAA/Peking Univ
(visiting student at UCSC + Caltech)

Detailed chemical abundances from co-added spectra of RGB stars in M31 dSph/dE galaxies (Kirby et al. 2013)

Weak “metal” absorption lines are clearly detectable in co-added spectra



Evan Kirby, PhD thesis, UCSC

Detailed chemical abundances from Keck/DEIMOS spectra of individual red giant stars in MW GCs and dSph satellite galaxies:

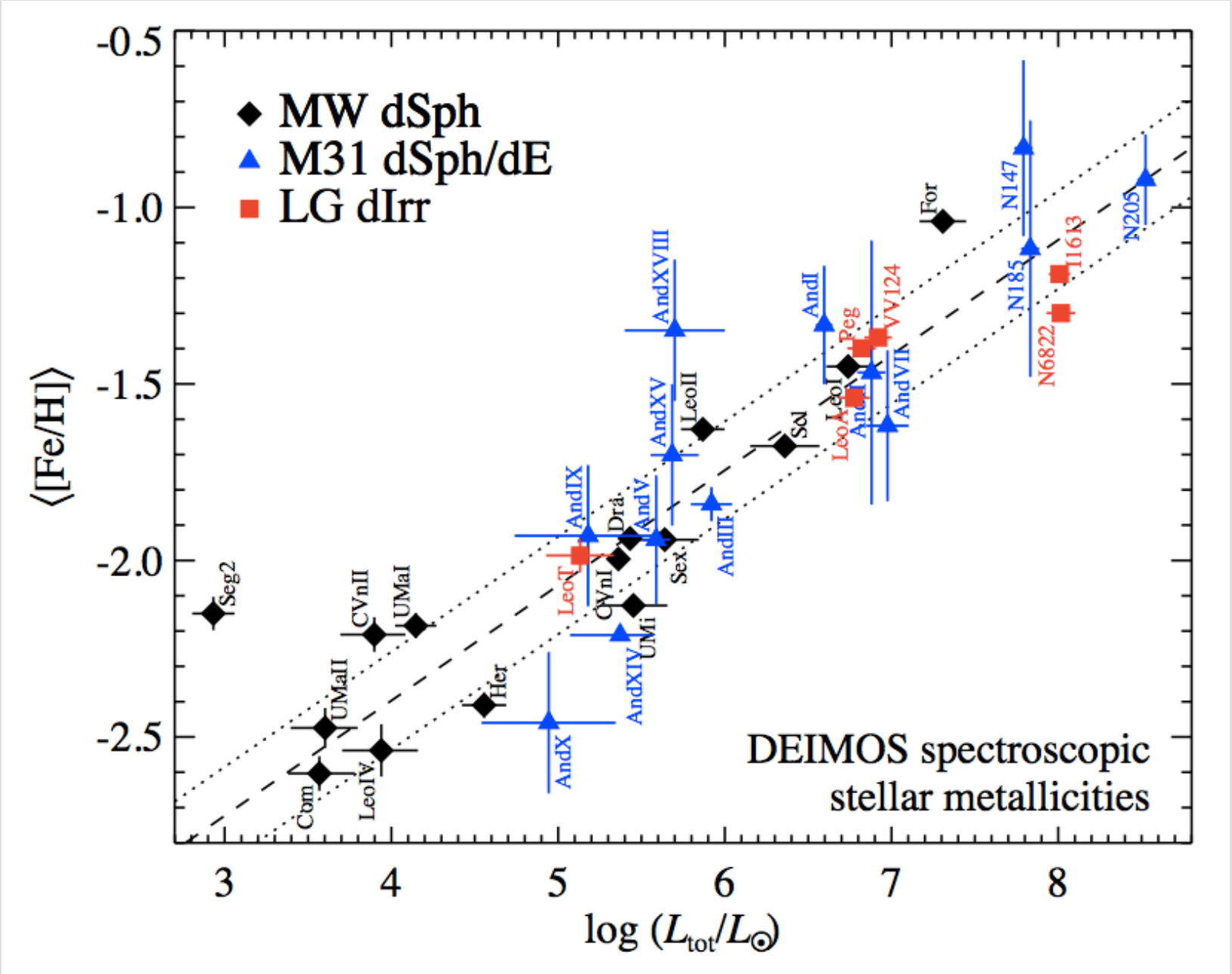
– Kirby, PG & Sneden (2008, ApJ)

– Kirby et al. (2009–2011)

Lei Yang, MS thesis, KIAA/PKU (+ UCSC + Caltech)

Detailed chemical abundances from coadded spectra of RGB stars in M31 dSph/dE galaxies (Kirby et al. 2013)

Andromeda satellites resemble their Milky Way counterparts



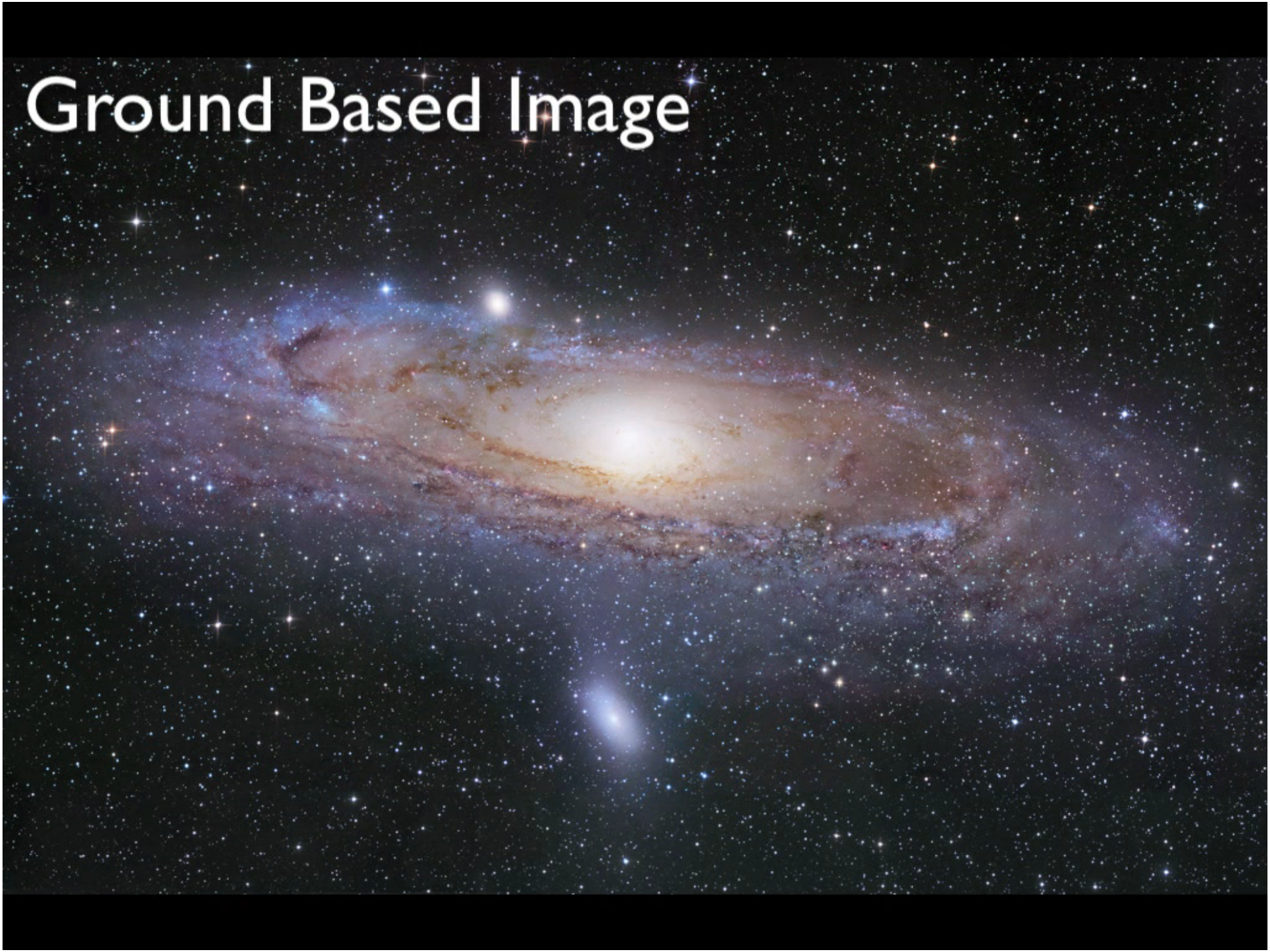
Kirby et al. (2013)

Lucy Cheng (SIP 2011/2012; Harker School / Harvard Univ)

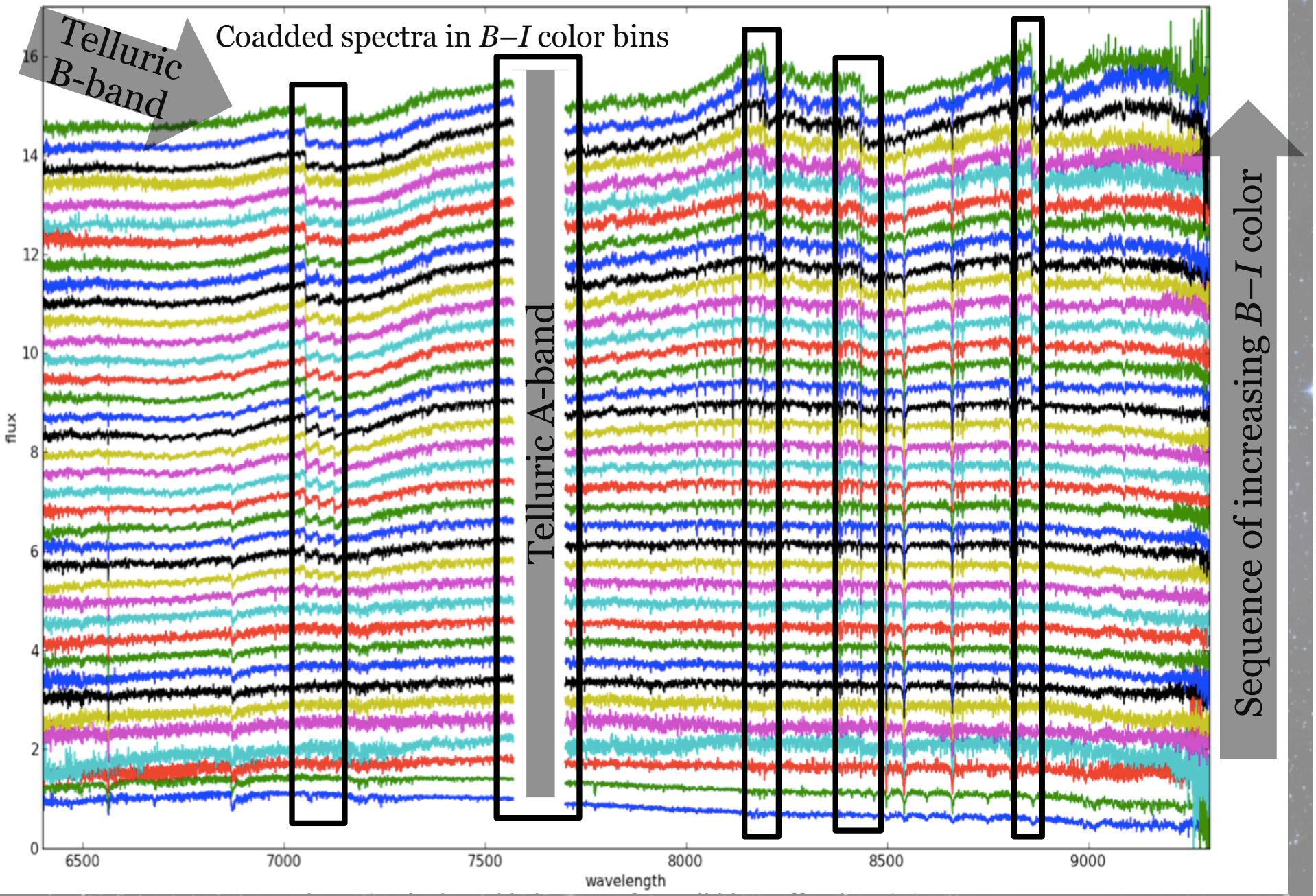
Dust mapping in the disk of the Andromeda galaxy

– M31: A laboratory for interstellar medium studies

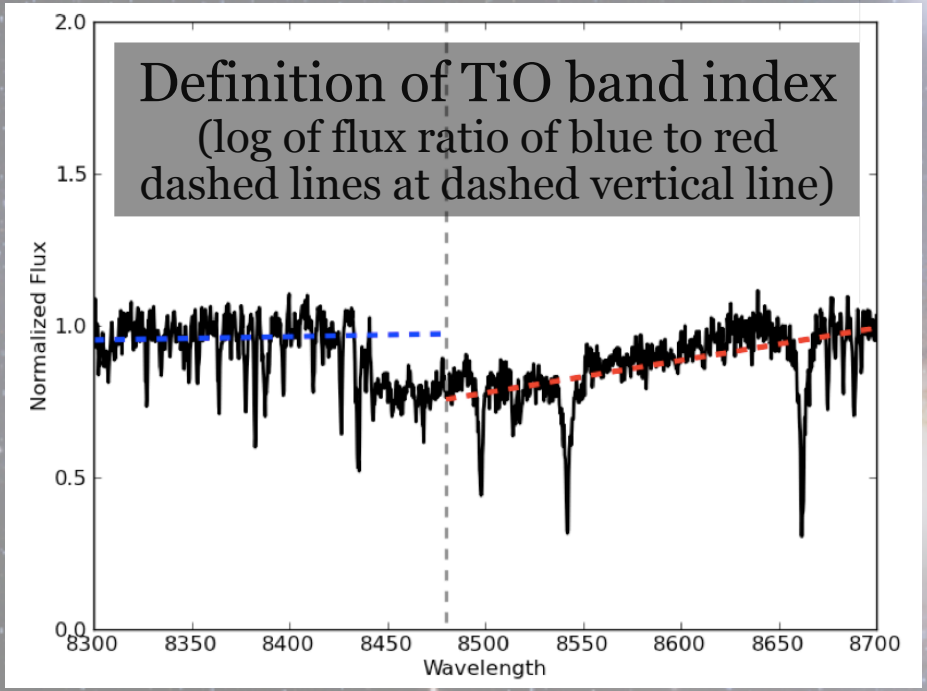
– Combining the power of HST and Keck: Need to work with *co-added* spectra now but can target *individual* stars with TMT

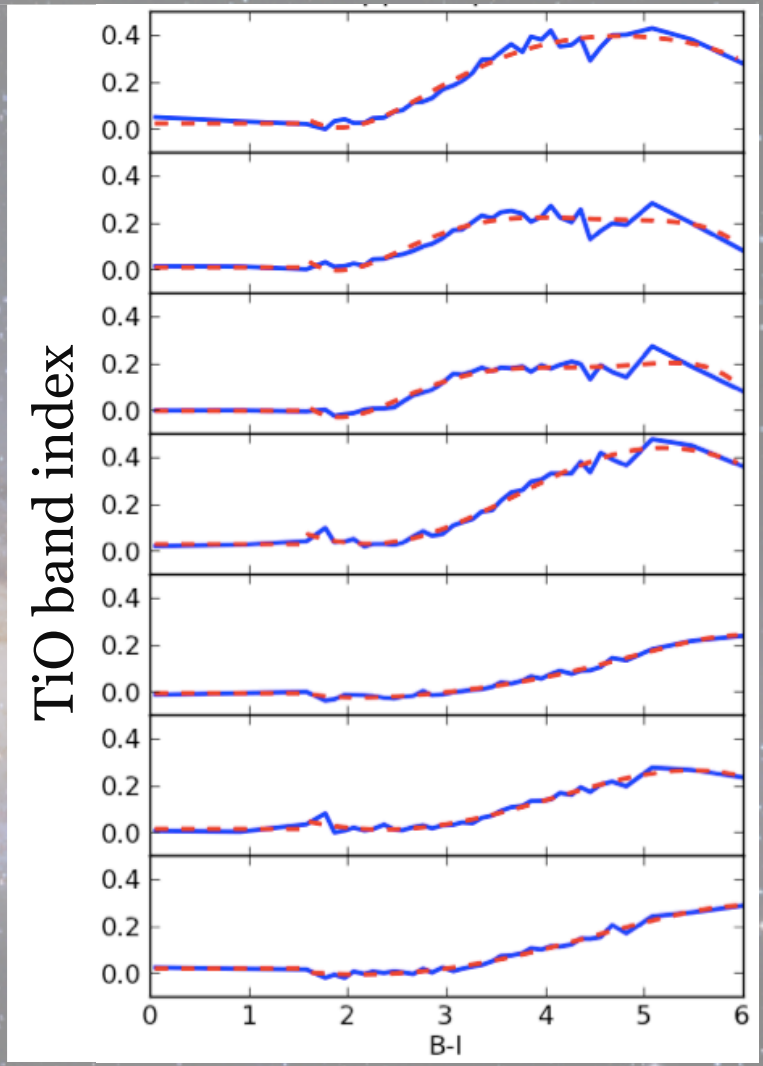

Ground Based Image

"Thermometry" of M giant stars



"Thermometry" of M giant stars

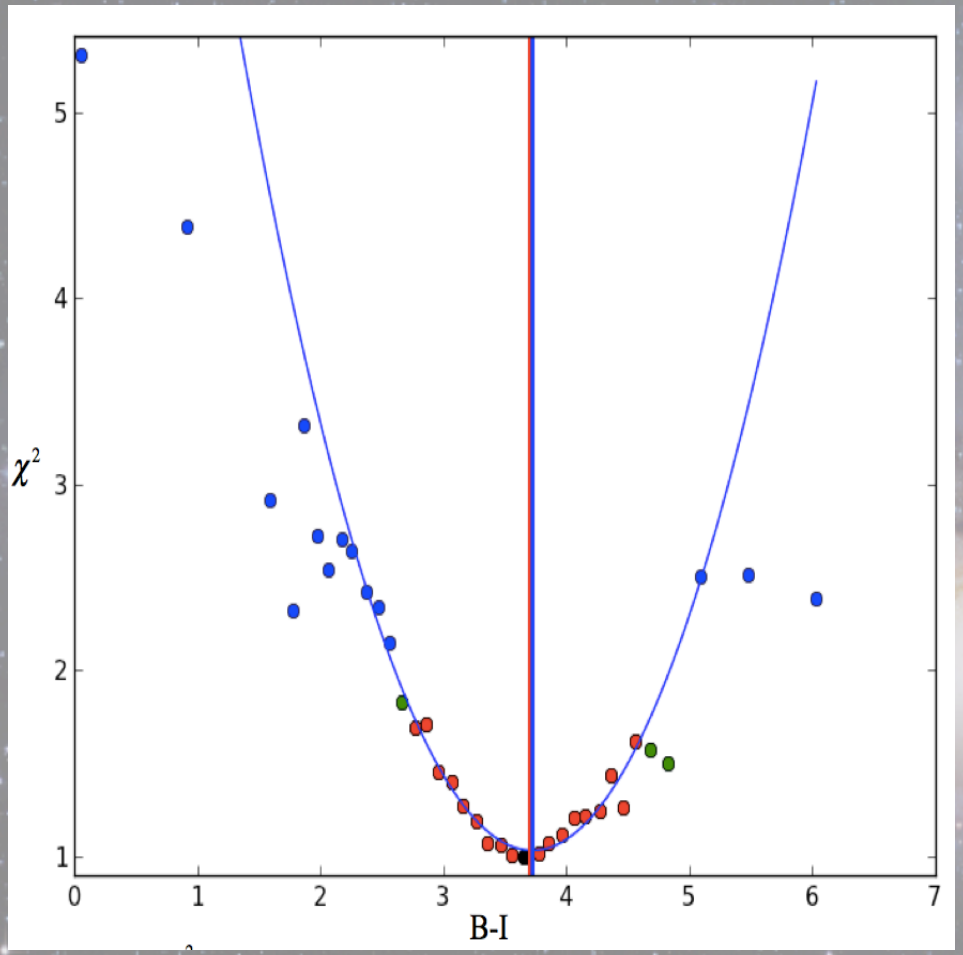




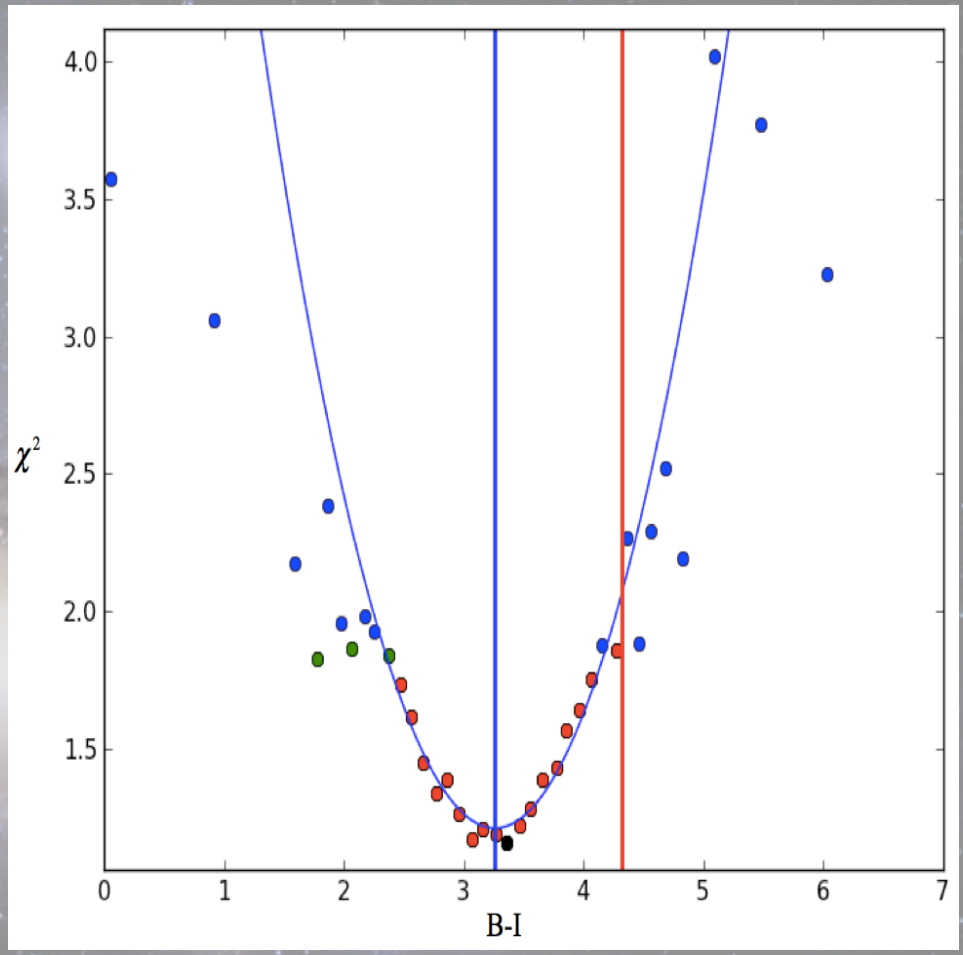
Teresa Krause *(Castilleja School)*

Katie Hamren, Claire Dorman, Elisa Toloba *(UCSC)*
Sumedh Guha *(Archbishop Mitty High School)*

Application of M giant thermometer: Dust reddening



Unreddened star



Reddened star

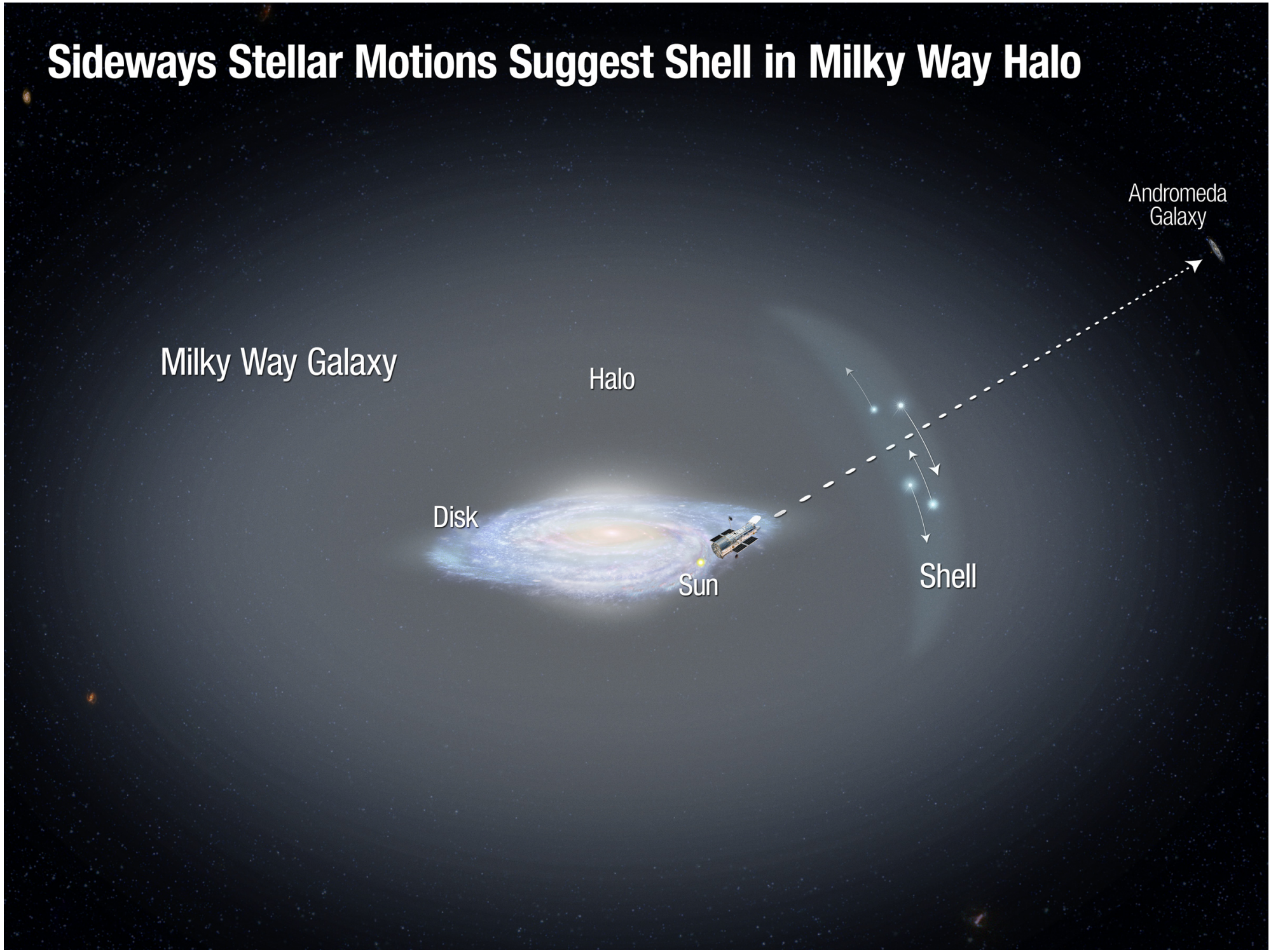
Teresa Krause *(Castilleja School)*

Katie Hamren, Patrick Draper *(UCSC)*

Substructure in and mass of the Milky Way

– Leveraging the remarkable *astrometric* potential of deep, multi-epoch HST images

– Need TMT to measure radial velocties of faint blue main sequence turnoff stars in the MW outer halo


Sideways Stellar Motions Suggest Shell in Milky Way Halo
Andromeda Galaxy
Milky Way Galaxy
Halo
Disk
Sun
Shell

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

- Proper motions from multi-epoch HST imaging and, in the future, Gaia
- Need TMT/WFOS to measure radial velocities (and especially chemical abundances) of faint MSTO stars
- Very long integrations required with Keck/DEIMOS (8 to 32 hours per mask!)

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

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