The Surface Brightness and Velocity Function of Virgo Cluster Galaxies

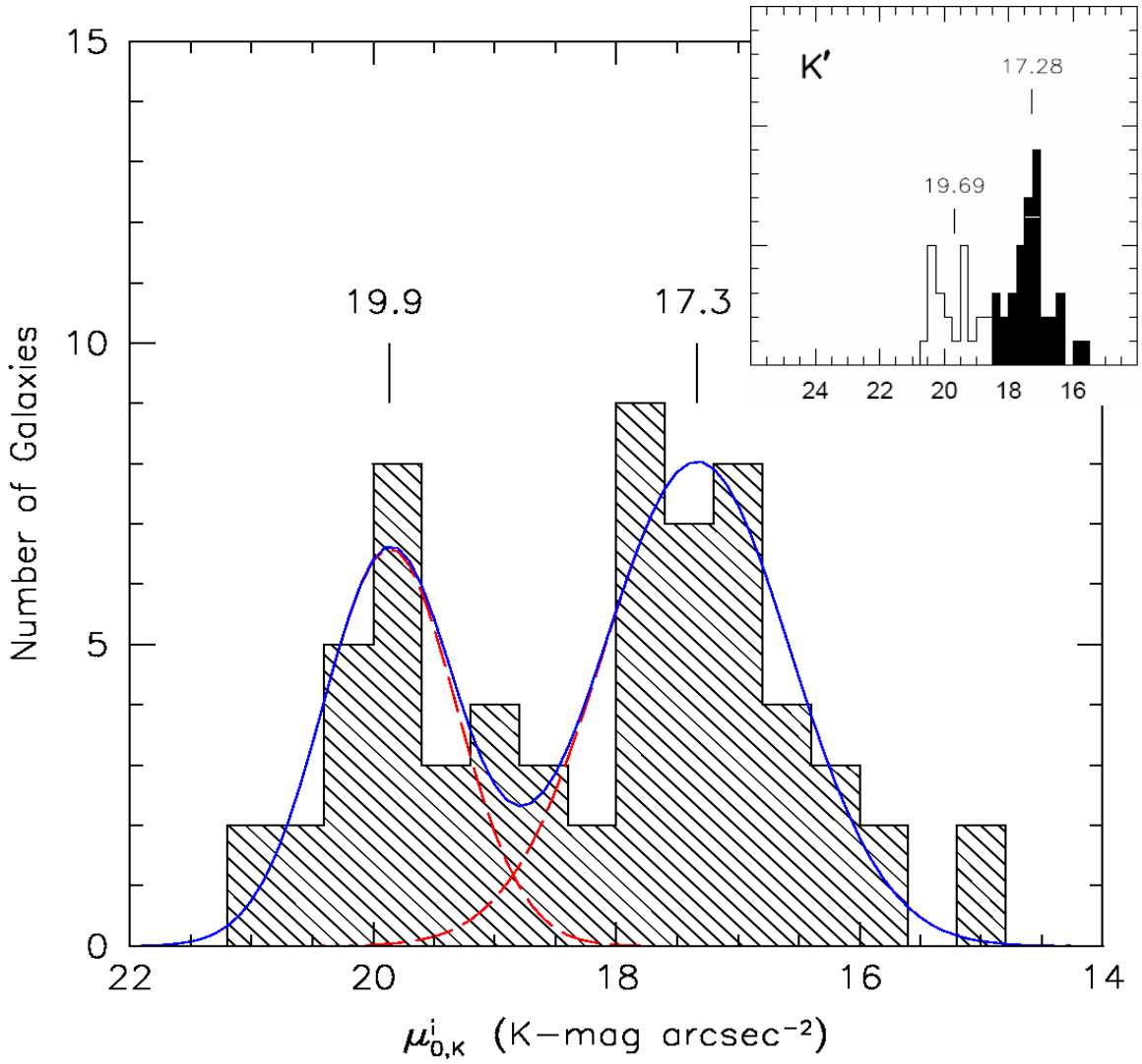
Stéphane Courteau
Queen's University

Col's

Julianne Dalcanton (UWash)
Jon Holtzman (NMSU)
Lauren MacArthur (HIA/UVic)
Michael McDonald (MIT)
Nathalie Ouellette (Queen's)
Joel Roediger (Queen's)
Brent Tully (Hawaii)
Yucong Zhu (Harvard/CfA)

Intro – UMa revisited

- B/D decompositions on K'-band profiles for the 63 UMa galaxies confirmed Tully & Vereijhen (1997)'s result to within 0.2 K-mag arcsec^{-2}.
- Observed bimodality is not due to systematic bias by TV97.
- Bimodality not seen at optical wavelengths



McDonald, Courteau & Tully 2009a

SHIVir Virgo Sample

- Start with Virgo Cluster Catalog (VCC) (Bingelli et al. 1985)
    - 2096 galaxies covering ~140 deg^2
    - Complete to B_T ~18 mag
- Limiting magnitude B_T=16 mag
    - 1.3 mag deeper than TV97's UMa study
- Make spatial cut to exclude 40% of cluster suffering from contamination from the W, W' and M background groups, + radial cut at roughly R_{vir}, and redshift cut to avoid background gals
  – A total of 314 galaxies remain in the sample

Virgo H-band Sample

- Need IR H-band photometry (needed for transparency and stellar population analysis)
  - Near-IR imaging obtained for 286 of our 314 sample galaxies:
    - 99 from the GOLDMine/2MASS Database
    - 122 from UH88/ULBCAM (30 nights from 2005-2008)
    - 65 from UKIRT/WFCAM and CFHT/WIRCAM (12 nights in 2008)
- *g,r,i,z* optical imaging from SDSS

Improved VCC/NIR Photometry: going deeper than 2MASS/Goldmine

- Initial motivation: test Tully's claim of NIR surface brightness bimodality in UMa cluster galaxies (Tully & Verheijen 1997)
- *Bulge-disc decompositions and structural bimodality of UMa cluster spiral galaxies*

  McDonald, Courteau & Tully 2009a, MNRAS, 393, 628
- *The near-IR luminosity function and bimodal surface brightness distributions of Virgo cluster galaxies*

  McDonald, Courteau & Tully 2009b, MNRAS, 394, 2022

SHIVir Imaging Data Paper

- *A Survey of 286 Virgo Cluster Galaxies at Optical griz and NIR H-band: SB Profiles and Bulge-Disk Decompositions*

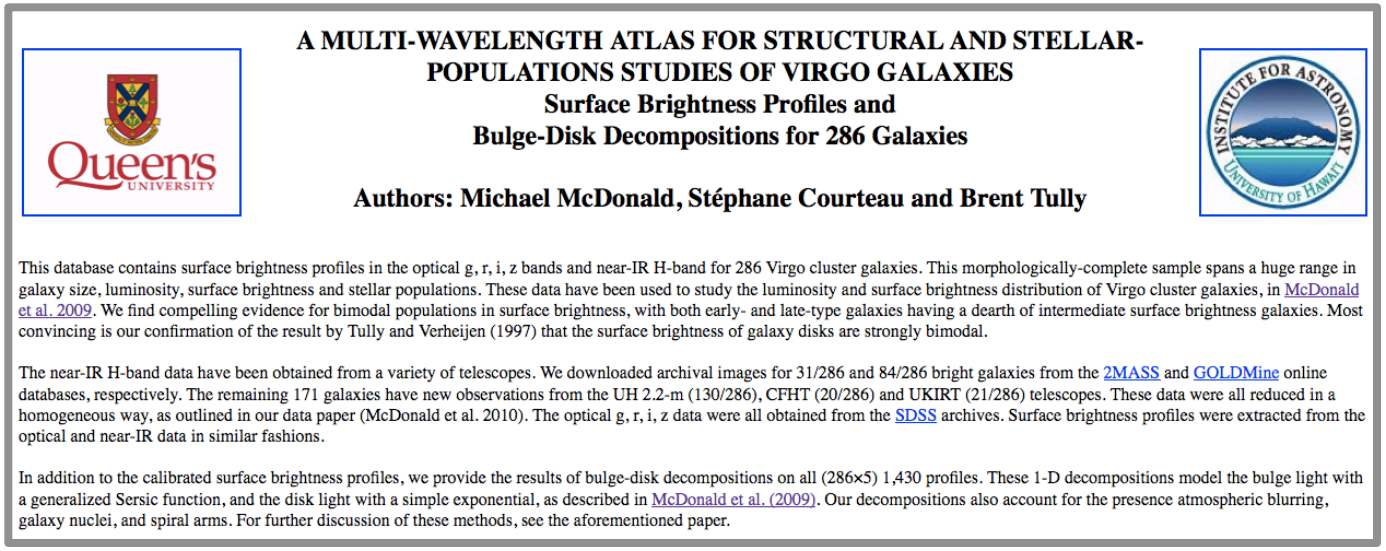
  McDonald, Courteau, Tully and Roediger 2011, MNRAS, in press

- This paper contains:
  - Detailed description of the selection, reduction and analysis of optical+ NIR surface photometry for 286 Virgo cluster galaxies
  - Comparison of pipeline data products with:
    - 2MASS, SDSS, and GOLDMine products with our own
    - Background levels, total aperture luminosities, concentration/radii
  - Azimuthally-averaged radial SB profiles at grizH for each galaxy and mean SB profiles at grizH for each morphological class **(~careful! E.g., M31 Courteau etal 2011)**
  - Tables of structural parameters (SB models and non-parametric) for each galaxy in each filter (griz+H)

Virgo Website: http://www.astro.queensu.ca/virgo/

SB profiles
And tables of structural parameters for 286 VCC galaxies

Combination of optical and NIR data *essential* for stellar population studies



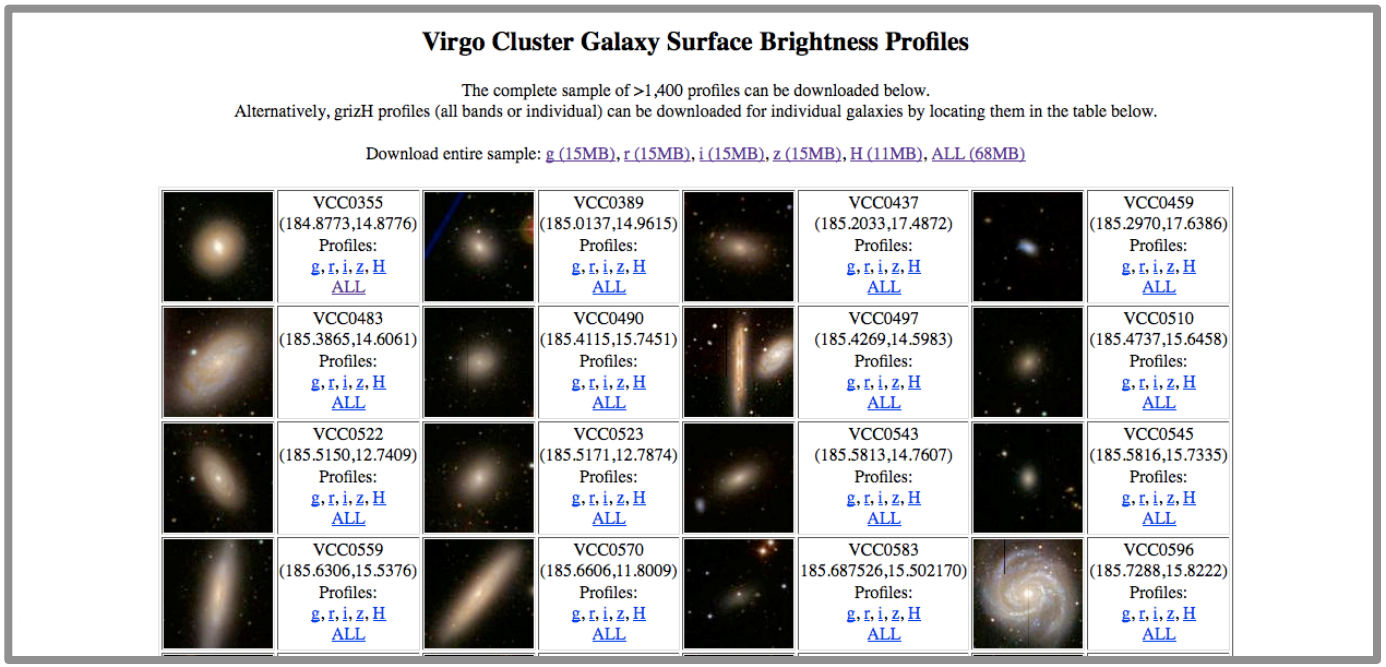
A MULTI-WAVELENGTH ATLAS FOR STRUCTURAL AND STELLAR-POPULATIONS STUDIES OF VIRGO GALAXIES
Surface Brightness Profiles and Bulge-Disk Decompositions for 286 Galaxies

Authors: Michael McDonald, Stéphane Courteau and Brent Tully

This database contains surface brightness profiles in the optical g, r, i, z bands and near-IR H-band for 286 Virgo cluster galaxies. This morphologically-complete sample spans a huge range in galaxy size, luminosity, surface brightness and stellar populations. These data have been used to study the luminosity and surface brightness distribution of Virgo cluster galaxies, in McDonald et al. 2009. We find compelling evidence for bimodal populations in surface brightness, with both early- and late-type galaxies having a dearth of intermediate surface brightness galaxies. Most convincing is our confirmation of the result by Tully and Verheijen (1997) that the surface brightness of galaxy disks are strongly bimodal.

The near-IR H-band data have been obtained from a variety of telescopes. We downloaded archival images for 31/286 and 84/286 bright galaxies from the 2MASS and GOLDMine online databases, respectively. The remaining 171 galaxies have new observations from the UH 2.2-m (130/286), CFHT (20/286) and UKIRT (21/286) telescopes. These data were all reduced in a homogeneous way, as outlined in our data paper (McDonald et al. 2010). The optical g, r, i, z data were all obtained from the SDSS archives. Surface brightness profiles were extracted from the optical and near-IR data in similar fashions.

In addition to the calibrated surface brightness profiles, we provide the results of bulge-disk decompositions on all (286×5) 1,430 profiles. These 1-D decompositions model the bulge light with a generalized Sersic function, and the disk light with a simple exponential, as described in McDonald et al. (2009). Our decompositions also account for the presence atmospheric blurring, galaxy nuclei, and spiral arms. For further discussion of these methods, see the aforementioned paper.



Virgo Cluster Galaxy Surface Brightness Profiles

The complete sample of >1,400 profiles can be downloaded below.
Alternatively, grizH profiles (all bands or individual) can be downloaded for individual galaxies by locating them in the table below.

Download entire sample: g (15MB), r (15MB), i (15MB), z (15MB), H (11MB), ALL (68MB)

	VCC0355 (184.8773,14.8776) Profiles: g, r, i, z, H ALL		VCC0389 (185.0137,14.9615) Profiles: g, r, i, z, H ALL		VCC0437 (185.2033,17.4872) Profiles: g, r, i, z, H ALL		VCC0459 (185.2970,17.6386) Profiles: g, r, i, z, H ALL
	VCC0483 (185.3865,14.6061) Profiles: g, r, i, z, H ALL		VCC0490 (185.4115,15.7451) Profiles: g, r, i, z, H ALL		VCC0497 (185.4269,14.5983) Profiles: g, r, i, z, H ALL		VCC0510 (185.4737,15.6458) Profiles: g, r, i, z, H ALL
	VCC0522 (185.5150,12.7409) Profiles: g, r, i, z, H ALL		VCC0523 (185.5171,12.7874) Profiles: g, r, i, z, H ALL		VCC0543 (185.5813,14.7607) Profiles: g, r, i, z, H ALL		VCC0545 (185.5816,15.7335) Profiles: g, r, i, z, H ALL
	VCC0559 (185.6306,15.5376) Profiles: g, r, i, z, H ALL		VCC0570 (185.6606,11.8009) Profiles: g, r, i, z, H ALL		VCC0583 185.687526,15.502170) Profiles: g, r, i, z, H ALL		VCC0596 (185.7288,15.8222) Profiles: g, r, i, z, H ALL

Stellar Population Studies of Virgo Galaxies

uses MacArthur+04 method:

Roediger/Prochaska PhD theses

- *Stellar population trends in S0 galaxies (Age Upturns)*

  Prochaska Chamberlain, Courteau, McDonald and Rose 2011, MNRAS, 412, 423

- *The Formation and Evolution of Virgo Cluster Galaxies - I. Broadband Optical & Infrared Colours*

  Roediger, Courteau, McDonald, MacArthur 2011

  MNRAS, in print

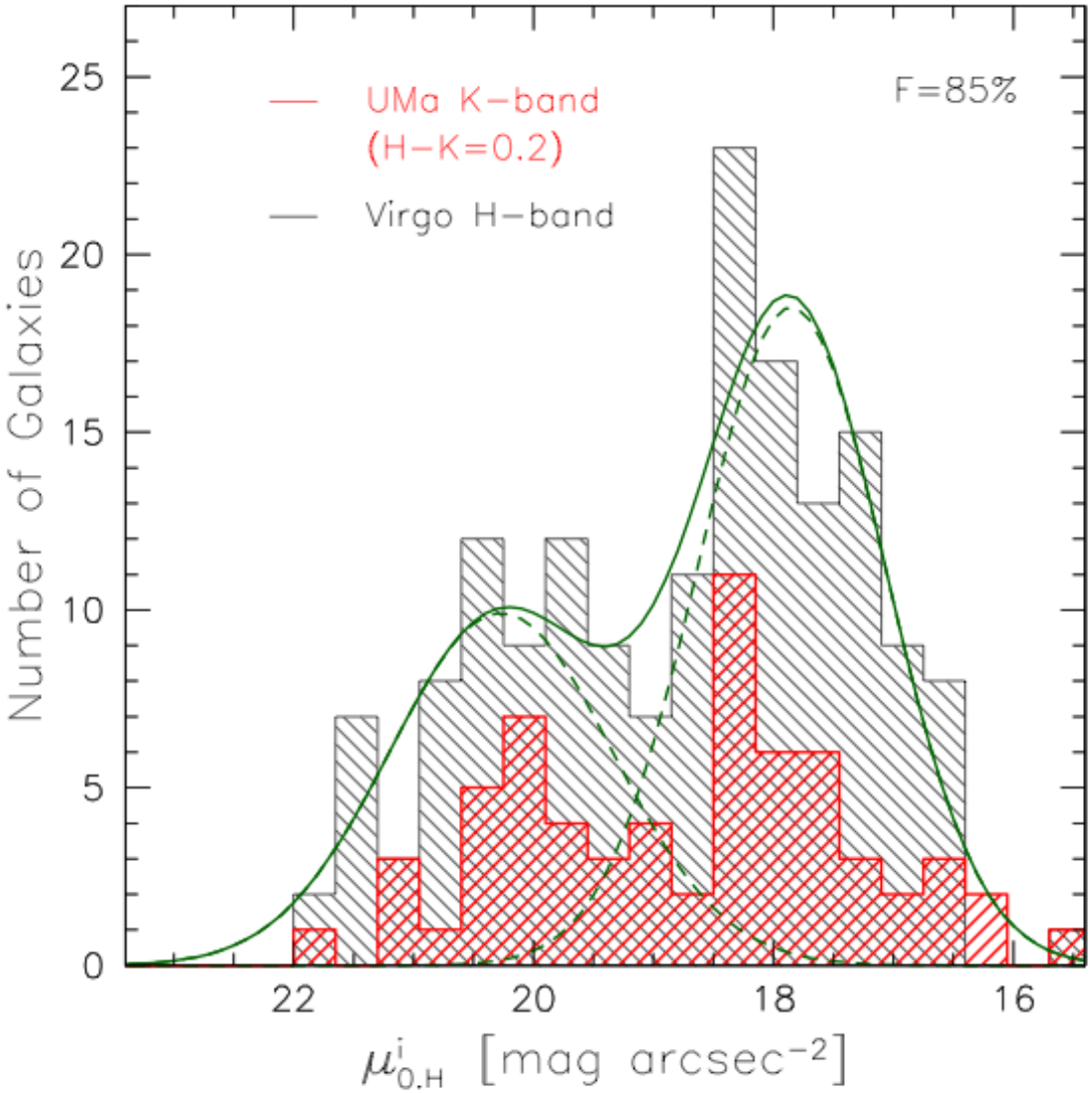
- *The Formation and Evolution of Virgo Cluster Galaxies - II. Stellar Populations*

  Roediger, Courteau, MacArthur, McDonald 2011

  MNRAS, in print

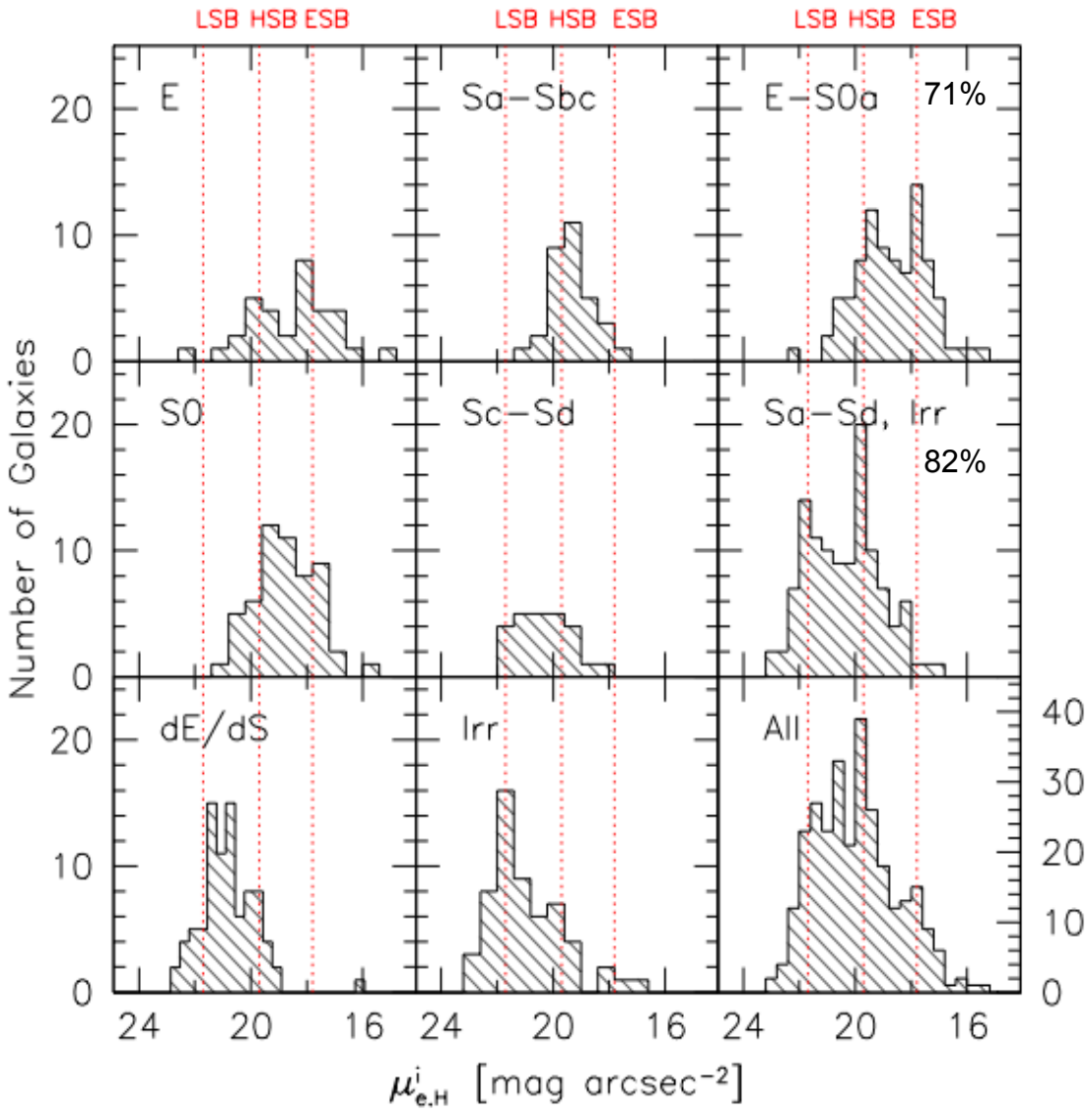
Results – now Virgo

- B/D decompositions for 161 VCC disk galaxies
  - Distribution of μ_0 identical to that found by TV97 and ourselves for UMa galaxies



McDonald, Courteau & Tully 2009b

Results – SB Distribution

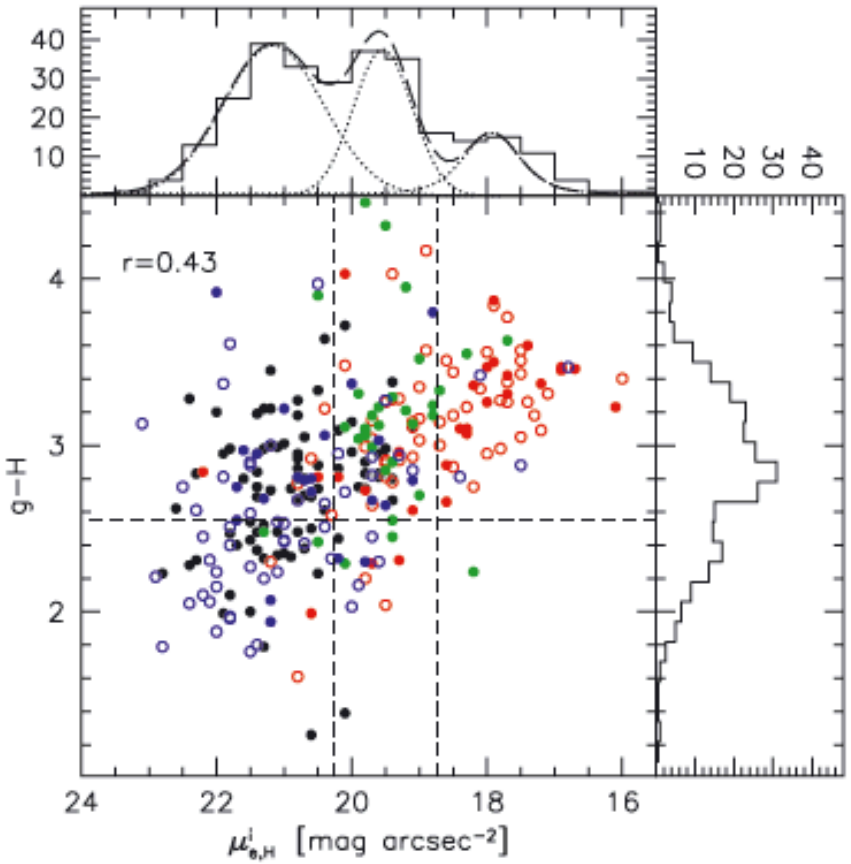


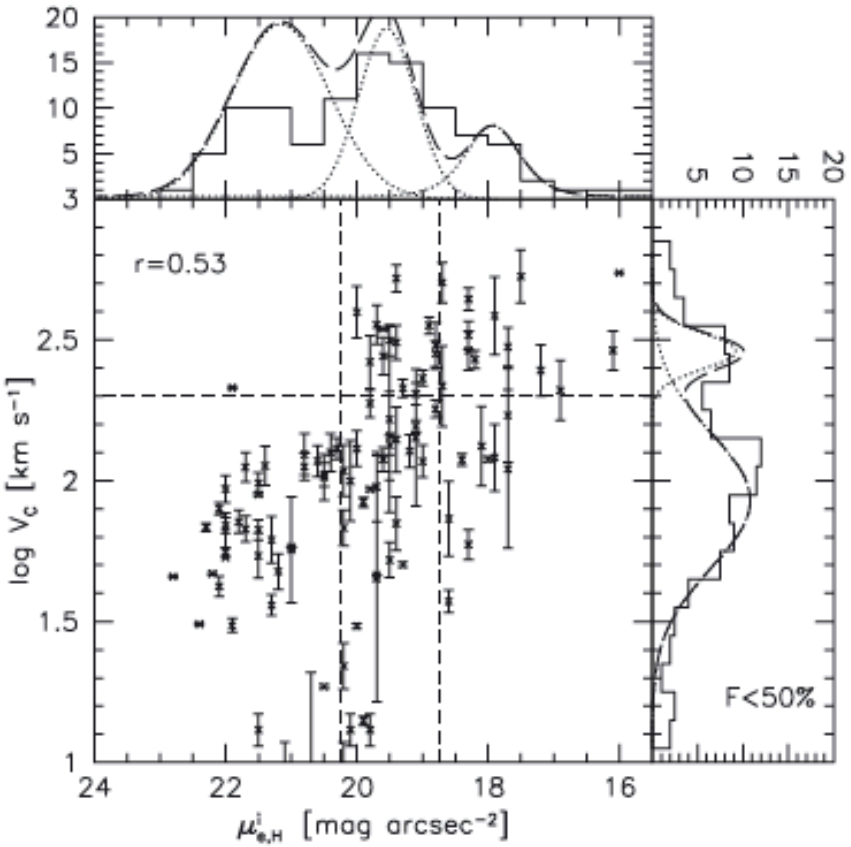
Model independent μ_e for 286 VCC galaxies

- HSB-ESB=1.61
- LSB-HSB=1.61

McDonald, Courteau & Tully 2009b, MNRAS, 394, 2022

Results – Bivariate Distributions



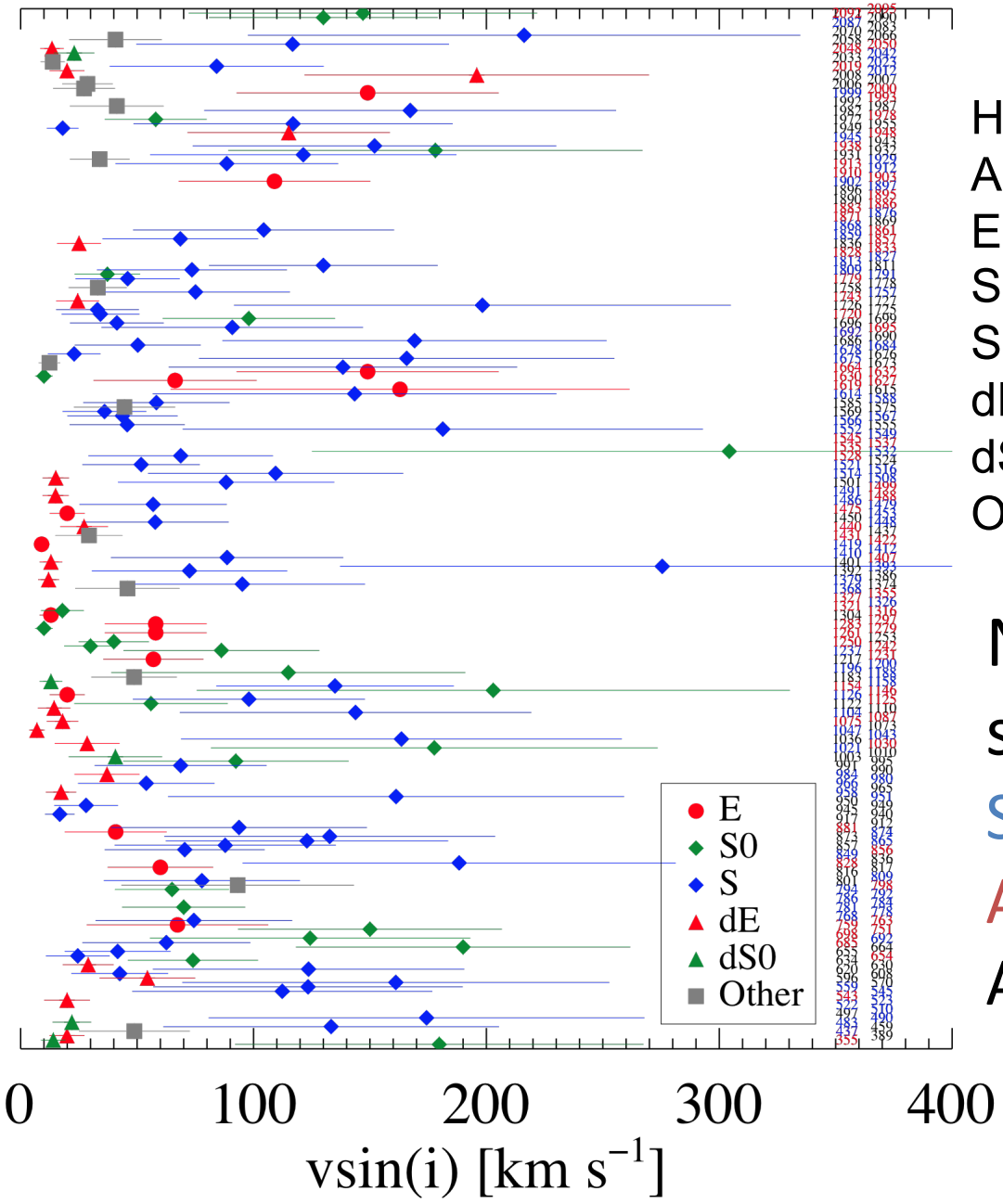


Possible dynamical correlation

Spectroscopy of *SHIVir* Galaxies

- 20 nights in 07-09 at APO, Palomar, KPNO
  - with Holtzman, Dalcanton, MacArthur, McDonald, Hall, Ouellette, Roediger ...
  - Spectroscopic sample is a reduced version of the IR sample (includes some ACSVCS galaxies)
  - reductions in progress
- Challenges: literature data extremely heterogeneous; must sample the low and bright ends of the VF

VCC Literature Data



Hubble type	Mean error (km/s)
All	25.3 ± 32.5
E	17.7 ± 24.5
S0	35.0 ± 42.3
S	44.9 ± 33.2
dE	5.0 ± 11.8
dS0	2.6 ± 5.3
Other	14.7 ± 12.2

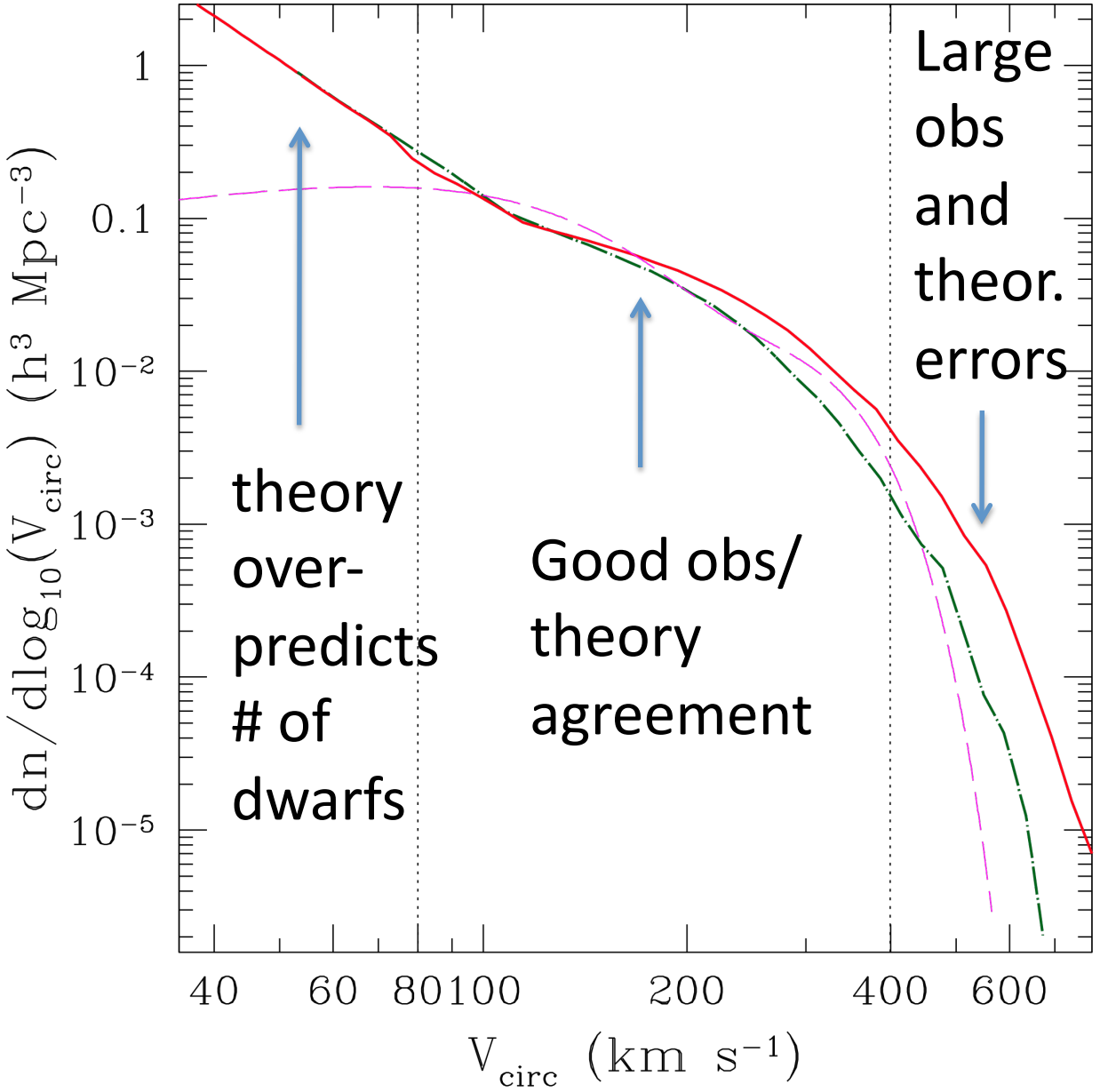
Need homogeneous surveys

SHIVir: 80/234

ACSVCS: 72/234

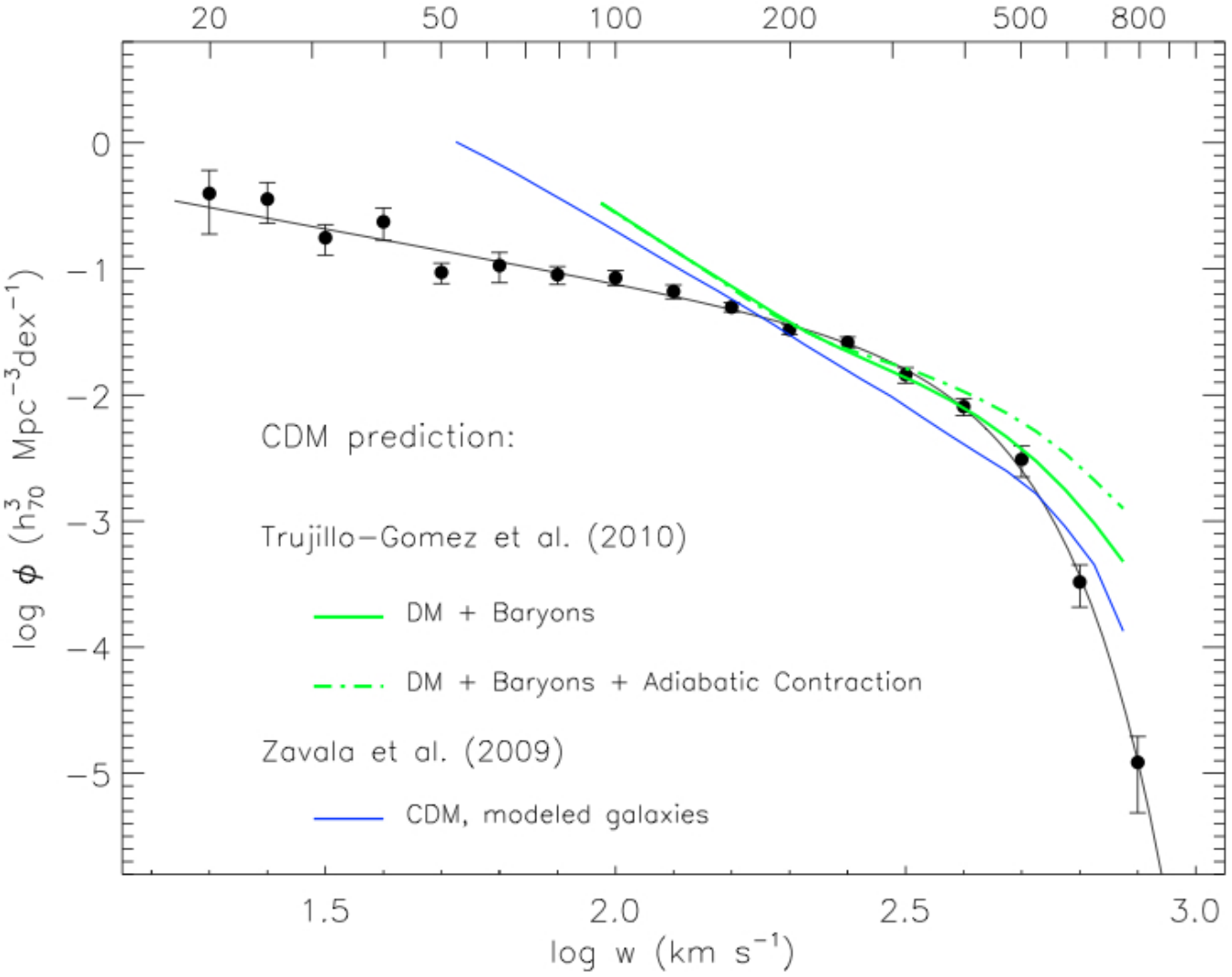
ALFALFA (>10,000)

Galaxy Velocity Function



Trujillo-Gomez+ 2011

ALFALFA Virgo Velocity Width Function



Note w=2ΔV

Papastergis+2011

Ongoing/Future Work

- Need VF at all velocities for all morphological types: Takes time - combine efforts
  - e.g., ALFALFA, ACSVCS, SMAKCED, SHIVir
- **SHIVir / NGVS-IR (H-K)**

  http://www.astro.queensu.ca/virgo/
  http://www.astro.puc.cl/~tpuzia/PUC/NGVS-IR.html
- Explanation for ESB-HSB and HSB-LSB dichotomy?
  - ESB-HSB: NGVS at i-band
  - HSB-LSB: Compute SB distribution for Coma at K-band (Mouhcine UKIRT H-band)
- **Stellar Pops! Joel Roediger's poster**