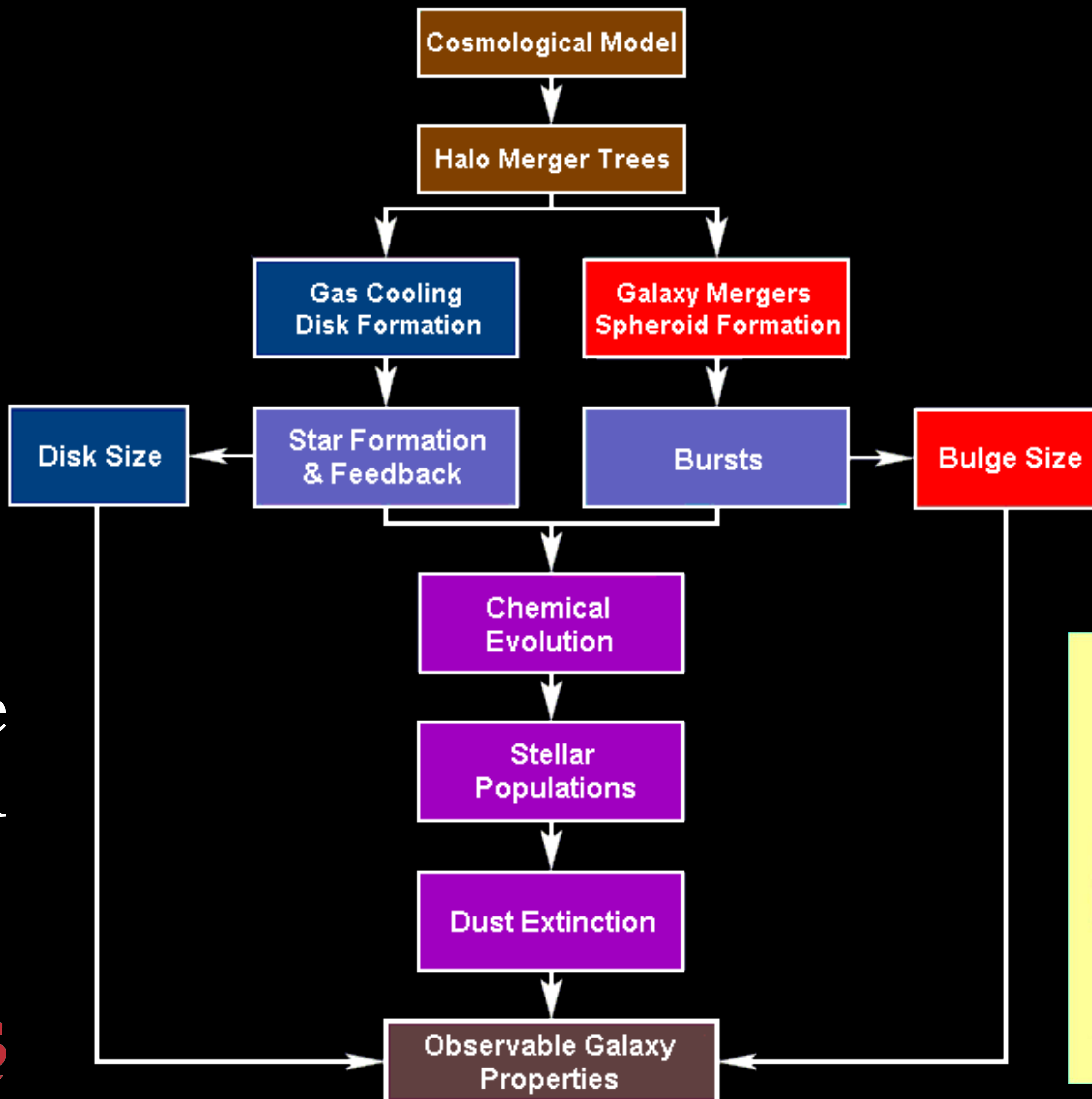
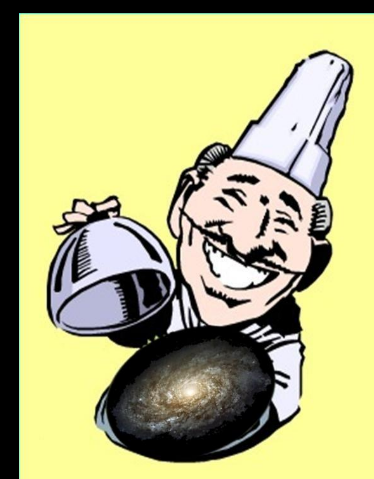
THE FUTURE OF GALAXY SCALING RELATIONS



Stéphane
Courteau

Queen's
UNIVERSITY



“Primitive” Galaxy Structural Parameters and Relations

- Size (R), Velocity (V), Luminosity (L), Colour/ Stellar Mass
- Velocity – Luminosity (VL) relation (aka Tully-Fisher Relation, or TFR)
- Size-Luminosity (RL)
- Size-Velocity (RV)
- Luminosity, Velocity/Mass Functions (predicted by ΛCDM)

Global Galaxy Scaling Relations (based on dynamics)

Tully & Fisher (1977)

$L \sim V^{3.3}$

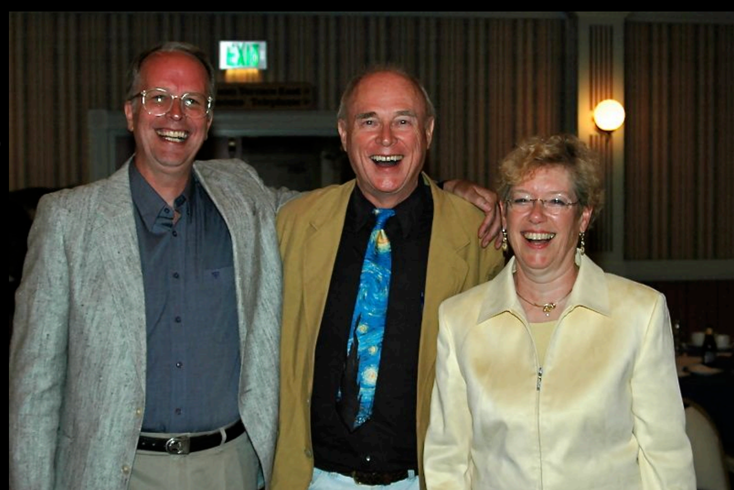
for LTGs

7 Samurai

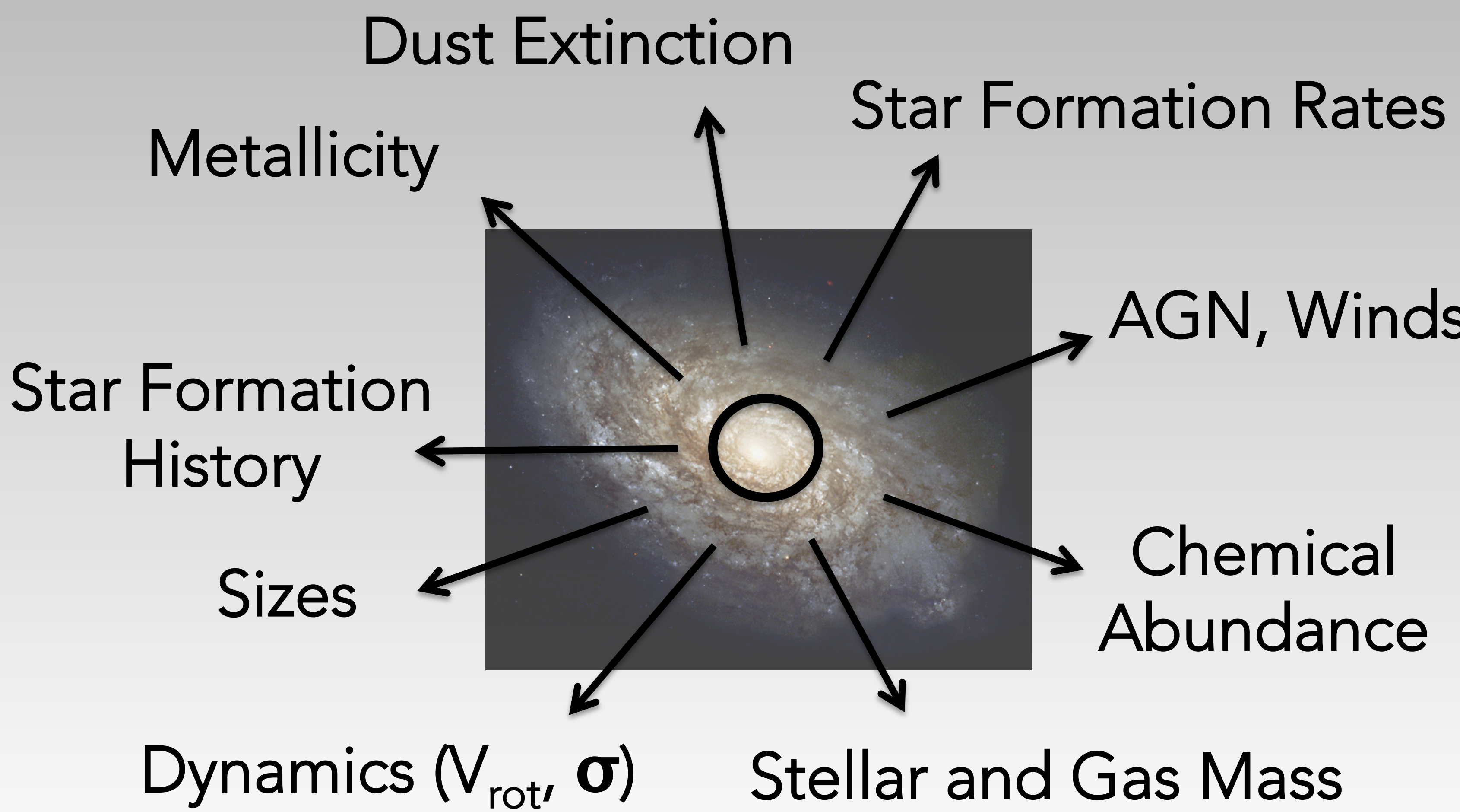
Faber & Jackson (1976)

$L \sim \sigma^4$

for ETGs



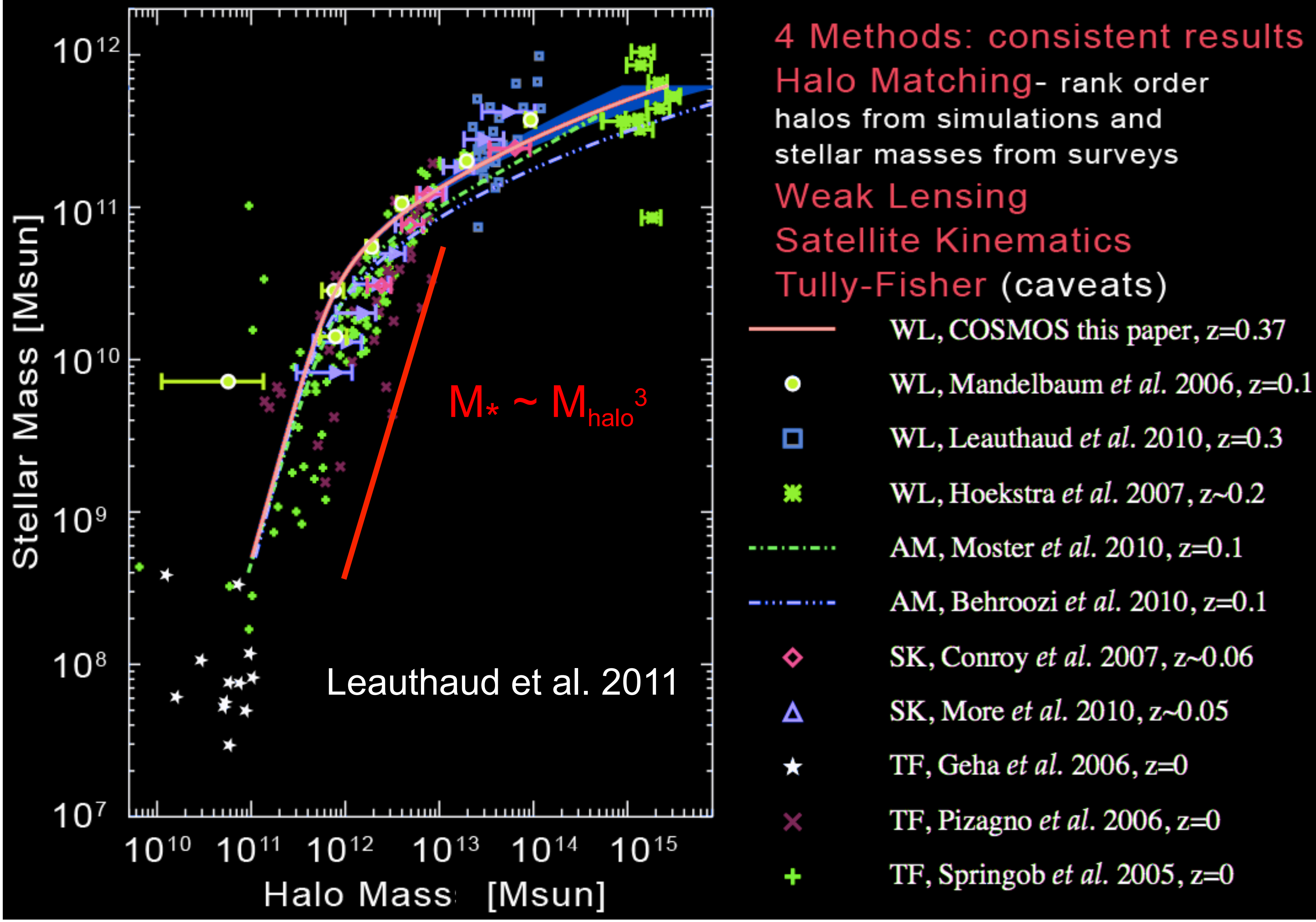
Modern (SDSS) Structural Parameters and Relations



Use of (Disk) Scaling Relations

- Originally, TFRs used to determine galaxy distance for cosmic flow studies [Marseille '13]
  e.g. Tully-Fisher 1977; Courteau+93; Strauss & Willick 1995; Giovanelli+97; Masters+06; Springob+09
- TFRs assembled over broad range of types
  e.g. Courteau+03[bars]; Vogt+04[env.]; Courteau+07; Pizagno+07
  for testing galaxy formation models e.g. Dalcanton+97; MMW99; Navarro & Steinmetz+00; Dutton+07; Gnedin+07
- Connecting ET and LT galaxies with their haloes through dynamics / velocity function
  e.g. Dutton+11; Trujillo-Gomez+11; Papastergis+11; Reyes+12
- Evolution of Scaling Relations with time
  [Oxford July'14] Ziegler+02; Barden04; Kassin+07; Miller+13

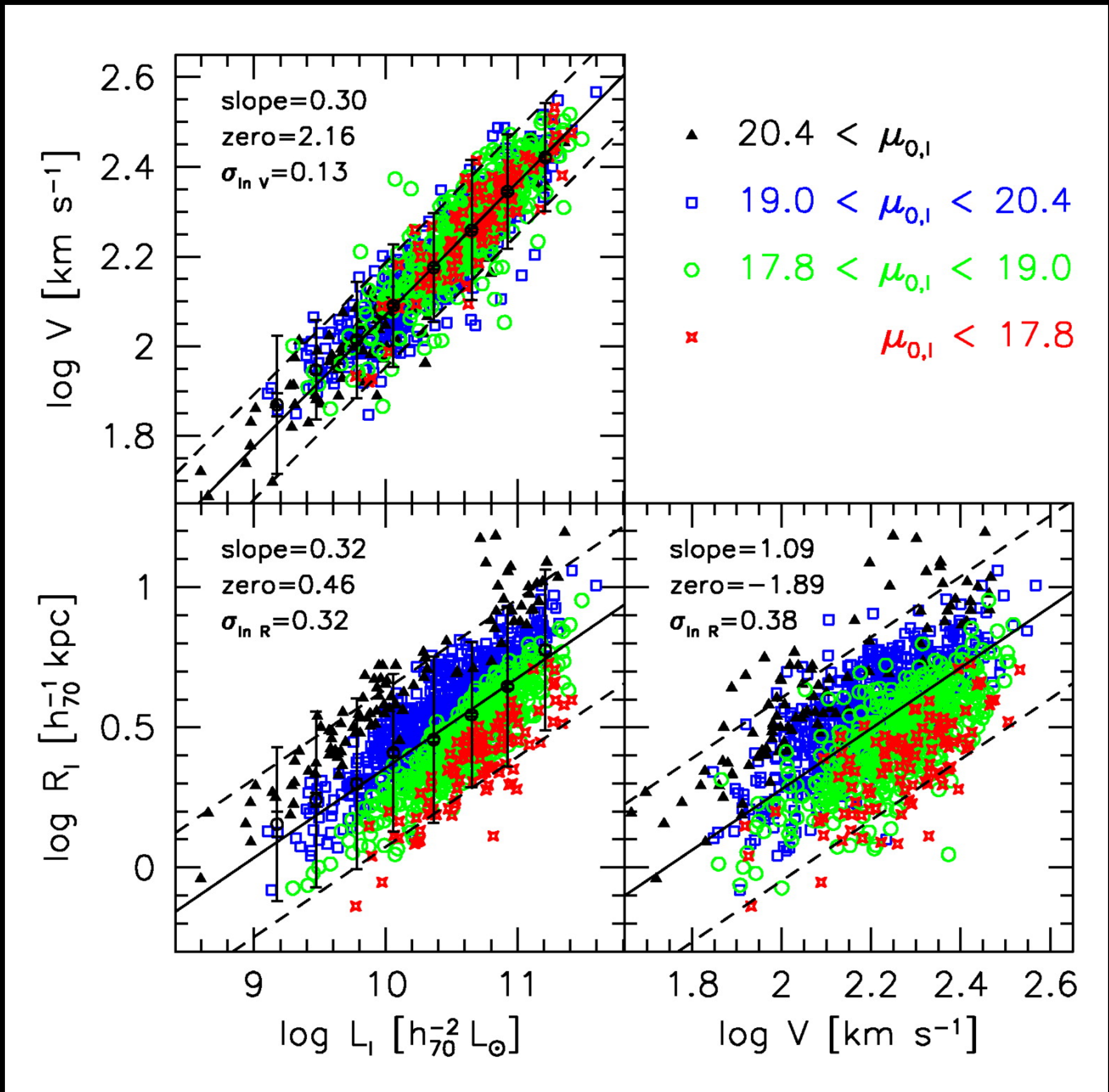
Stellar Mass-Halo Mass



Global Disk Galaxy Scaling Relations

Tully & Fisher (1977)

$L \sim V^3$



Courteau+07;
also Hall+12

Dark halo response and the stellar IMF in early-type and late-type galaxies

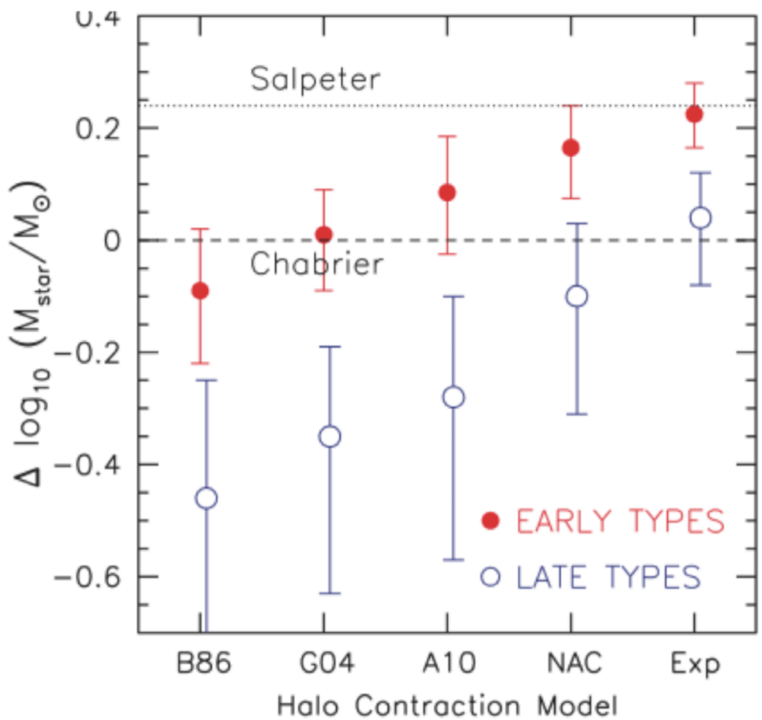


Figure 17. Offset in stellar masses required to match the zero-point of the VM relations as a function of halo response model, calculated at $\log_{10}(V_{opt}/\mathrm{km\,s^{-1}}) = 2.30$, for early-type (red filled symbols) and late-type (blue open symbols) galaxies. The models correspond to the following: B86 – Blumenthal et al. (1986); G04 – Gnedin et al. (2004); A10 – Abadi et al. (2010); NAC – no halo contraction; Exp – halo expansion with $\nu = -0.5$ in equation (17). The error bars show the effects of 2σ systematic errors on the zero-points of the VM and M_{200}–M_{star} relations. For fixed IMF (i.e. horizontal lines) early-type galaxies require stronger contraction than late-type galaxies, while for fixed halo response (vertical direction) early-type galaxies require heavier IMFs than late-type galaxies.

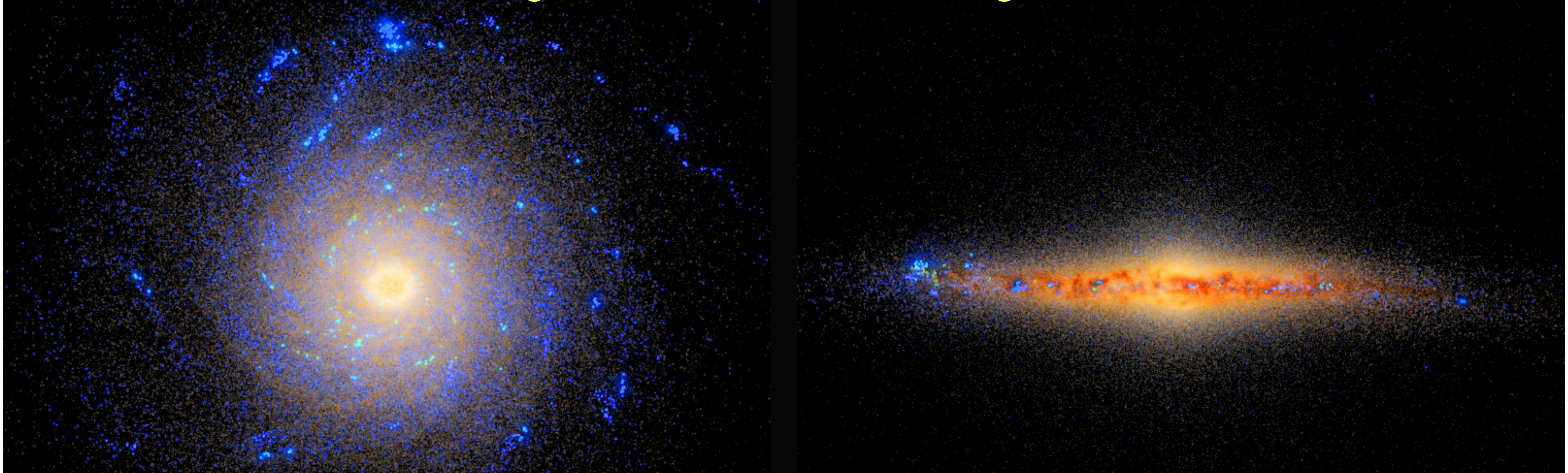
$V=1.54\ \sigma$ for ETGs;
Courteau+07b;
Catinella+12;
Courteau+13

Dutton+11; see also Trujillo-Gomez+11

MaGICC* disks: matching observed galaxy relationships over a wide stellar mass range

(MNRAS, 2012, 424, 1275-1283)

* Making Galaxies in a Cosmological Context

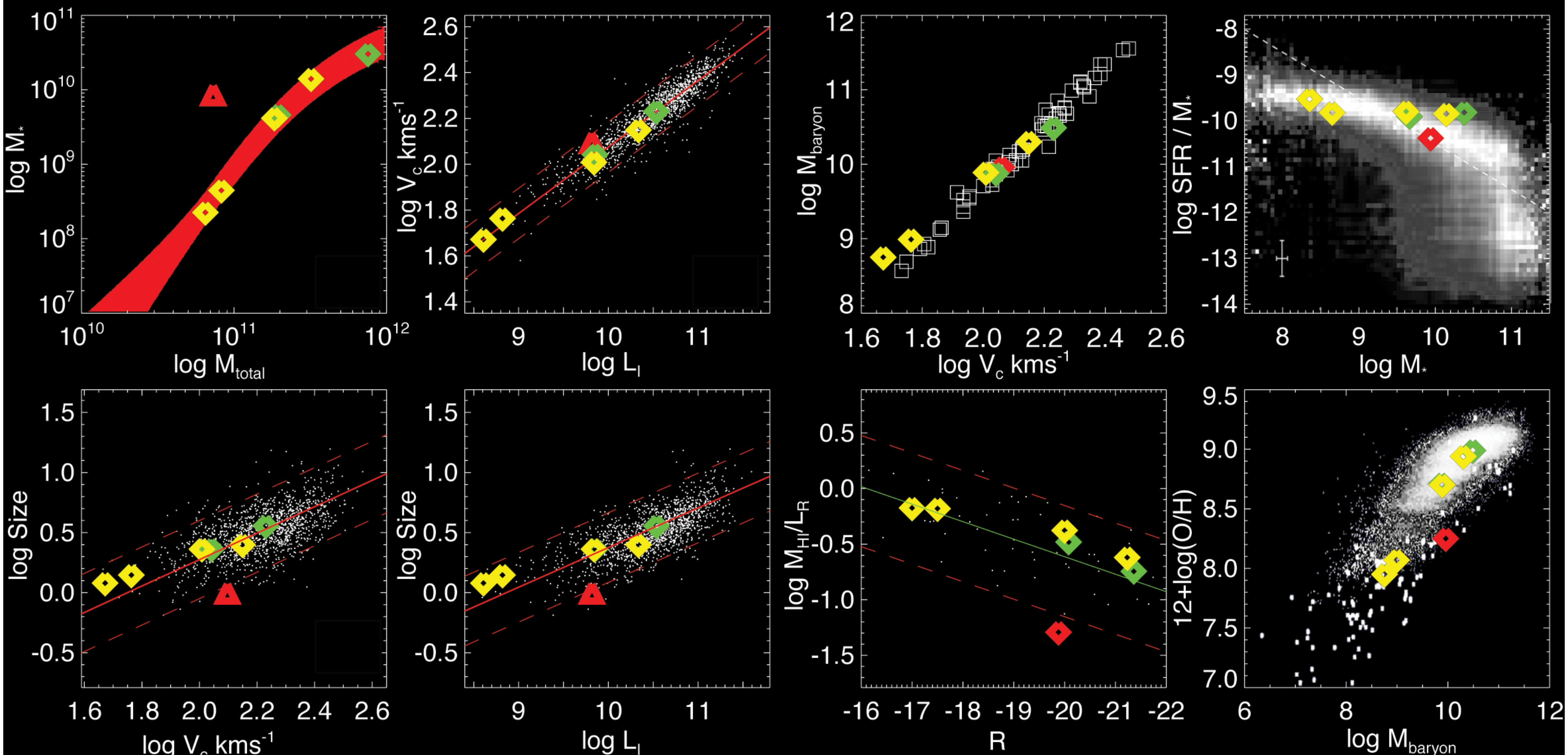


Chris Brook
Universidad Autonoma de Madrid

with Greg Stinson, B.K. Gibson,

James Wadsley, Tom Quinn

Stellar-Mass, Halo-Mass
Size (S), Rotation Velocity (Vc), Luminosity (L), M_{HI},
Specific SFR, Colour, Mbaryons, Metallicity (log O/H)



same resolution
same physics
same feedback

low resolution
same physics
same feedback
C* adjusted

old feedback
Stinson et al 2010
Scannepieco et al. 2012

Data from
Courteau+07
McGaugh+05

Key Science Questions

1. How was angular momentum distributed among baryonic and non-baryonic components as the galaxy formed?
2. How do various mass components assemble and influence one another?
3. How does gas accretion drive the growth of galaxies?
4. What are the relative roles of stellar accretion, minor and major mergers, and instabilities in forming galactic bulges and ellipticals?
5. What quenches star formation? What external forces affect star formation in groups and clusters?

On the choice of scaling parameters

Hall et al (2012, MNRAS, 425, 2741)

"An Investigation of Sloan Digital Sky Survey imaging data and multiband scaling relations of (3041) spiral galaxies"

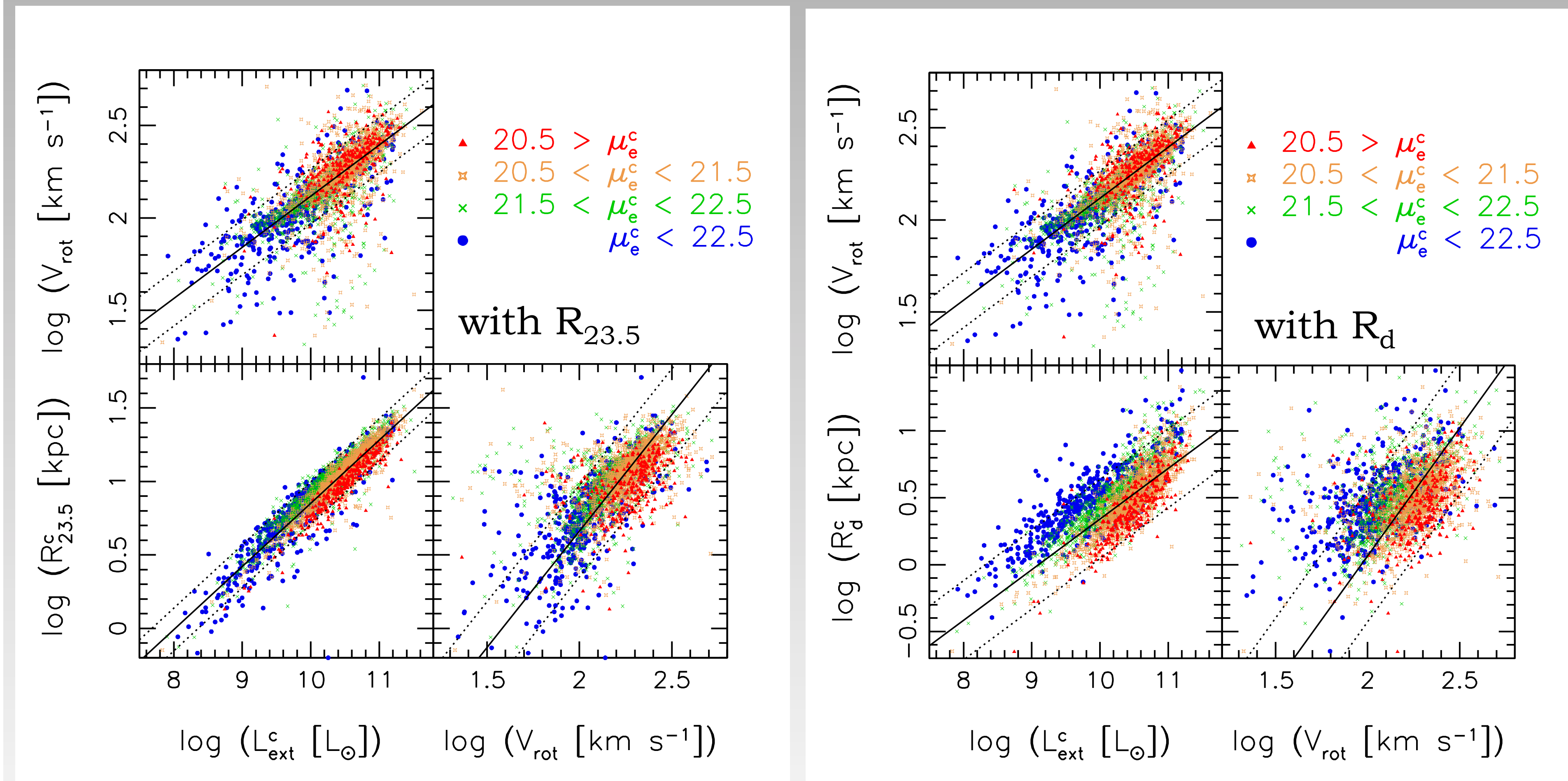
Compare SDSS DR7 Petrosian R and L with similar values from isophotal fits to the SDSS galaxy images.

Scatter degradation VL by ~8% and RV by ~30% with SDSS Petrosian parameters.

Largest (Baryonic) TFR to date: Hall et al (2012)

Ask me for the data.
Web site coming soon!

Careful about catalog (SDSS) data and choice of scaling parameters!



Hall et al (2012); see also Saintonge & Spekkens (2011)

Modern Studies

- Courteau etal (2007), Dutton etal (2007):

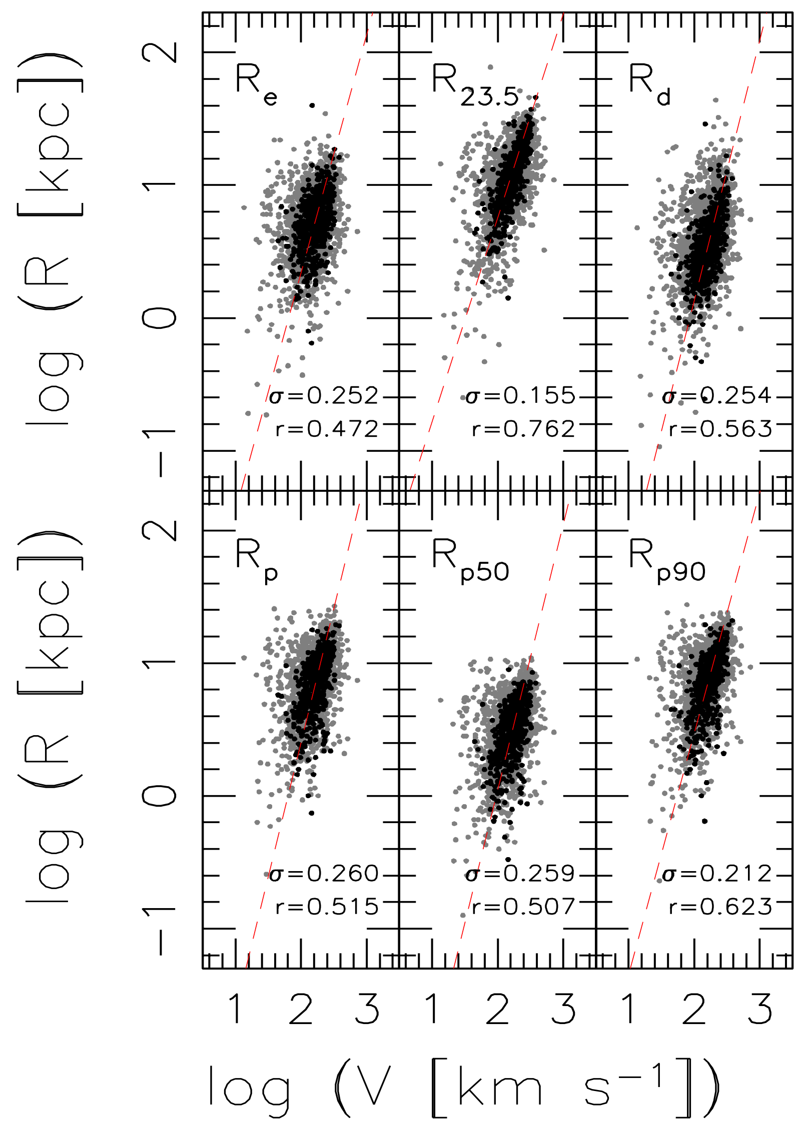
$$V_{obs} \propto L_{ext}^{0.29} \qquad R_d \propto L_{ext}^{0.32} \qquad R_d \propto V_{obs}^{1.1}$$

- Hall etal (2012):

$$V_{obs} \propto L_{23.5}^{0.26} \qquad R_{23.5} \propto L_{23.5}^{0.4} \qquad R_{23.5} \propto V_{obs}^{1.5}$$

Hall+12 based on 3041 spiral galaxies with SDSS imaging and HI line widths. Performed our own *isophotal fitting* and *sky subtraction*

SDSS Study



The best radial measure:

$R_{23.5}$

-- not all radii created equal.

For luminosity: $L_{23.5}$

Hall+12; uses V from Springob+05/07

On the choice of scaling parameters

Hall et al (2012, MNRAS, 425, 2741)

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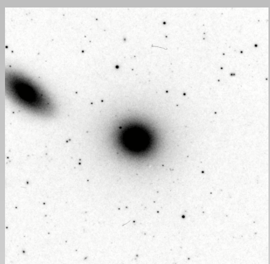
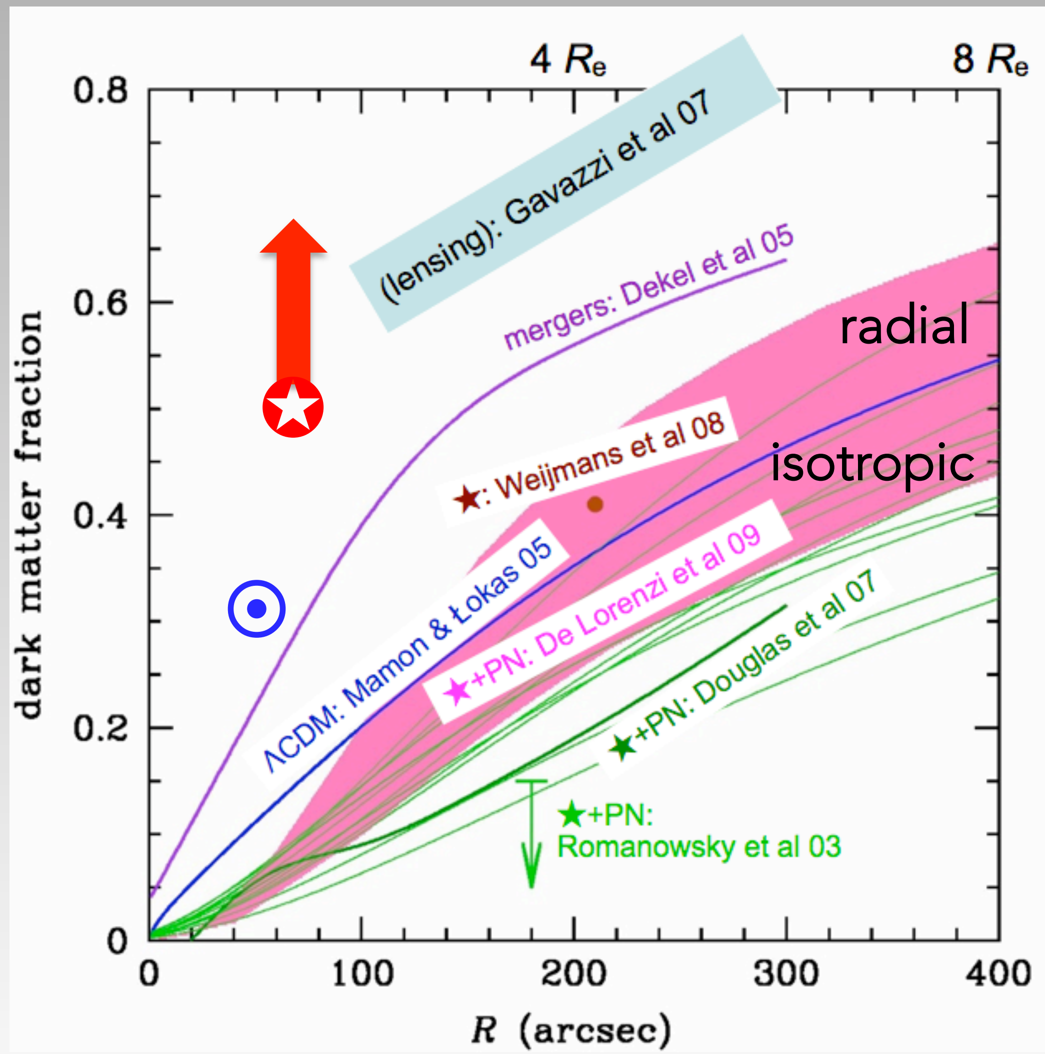
Ask me for the data.
Web site coming soon!

Dark Matter Fractions: Deep, homogeneous sampling needed

M105; E1





Cappellari

Spirals

Courteau et al+13 Reviews of Modern Physics

Dark matter content @ 1,2,3,4… R_e still uncertain!

Joel Roediger

The SHIVir Survey

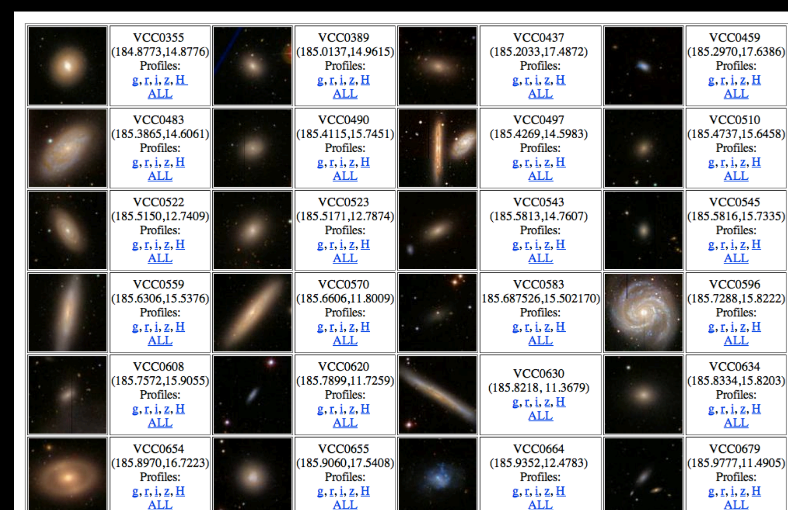
Nathalie Ouellette

*S*pectroscopy and *H*-band *I*maging of the *Vir*go cluster survey

(w/ McDonald, Roediger, Ouellette, Holtzman, Dalcanton)

- g,r,i,z (SDSS DR7) and NIR H-band imaging (CFHT) of 300+ Virgo cluster galaxies: SB profiles, isophotal masses and radii, stellar masses, scale lengths, etc.

- Optical spectroscopy from Palomar, KPNO, and APO for ~200 SHIVir galaxies



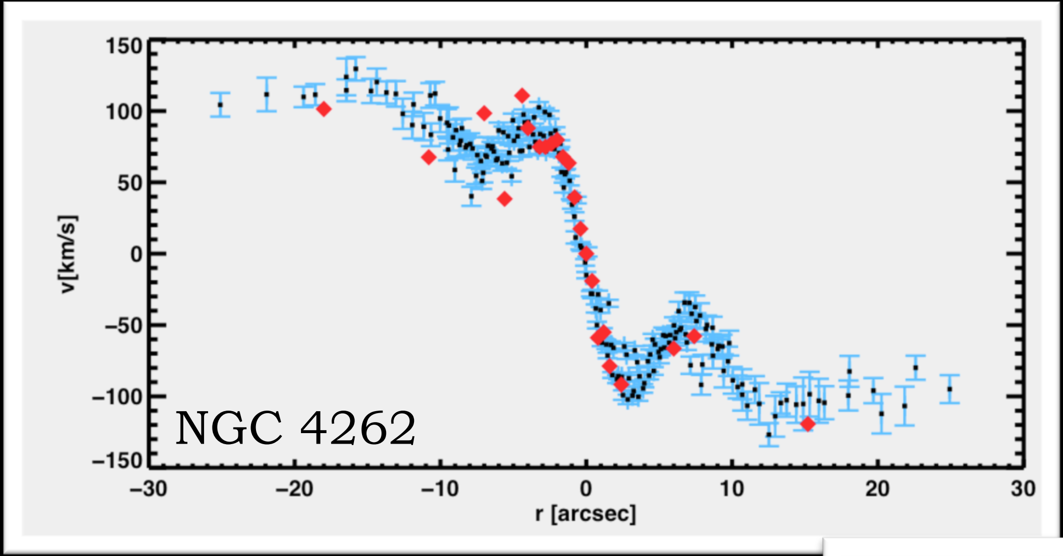
- *Carried out by:*

Mike McDonald (MIT)
Joel Roediger (Queen's/UCSC)
Nathalie Ouellette (Queen's)

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

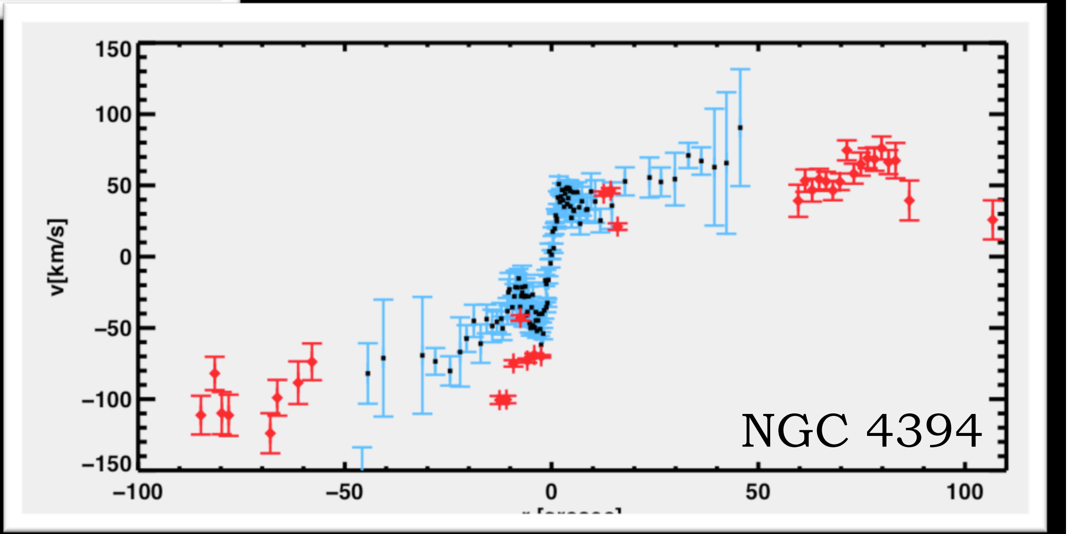
The SHIVIr Survey: Comparisons

SAURON/CALIFA (thanks to J. Falcon-Barroso/M.Seidel)



CALIFA versus SHIVIr

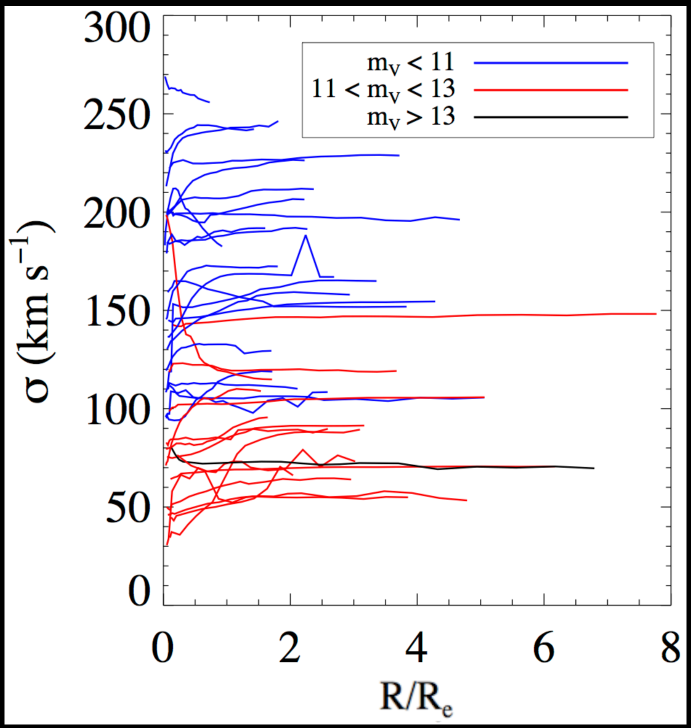
Excellent inner sampling with SAURON; SHIVir reaches deeper

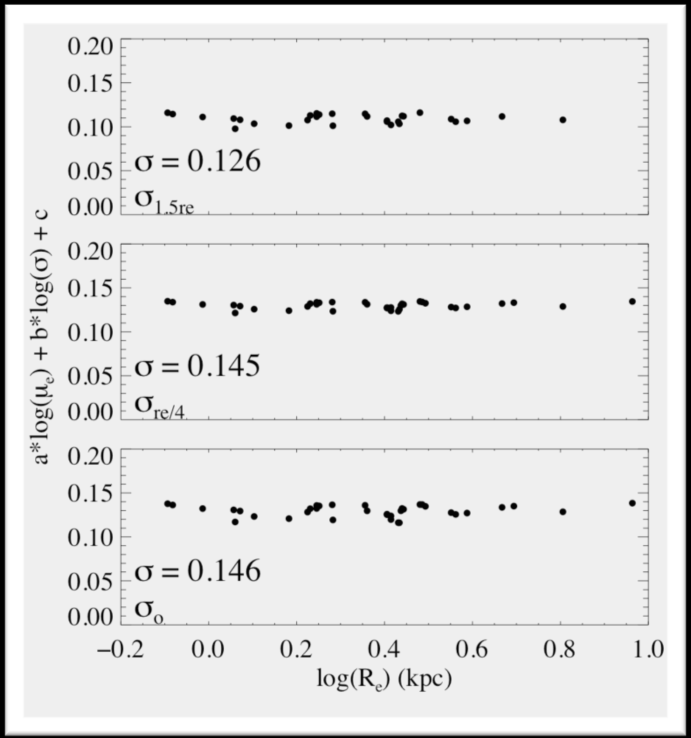


Excellent match for sigmas between SHIVir and ACSVCS and SAURON; i.e. 1D and 2D sigmas comparable

The SHIVIr Survey: Prelim. results

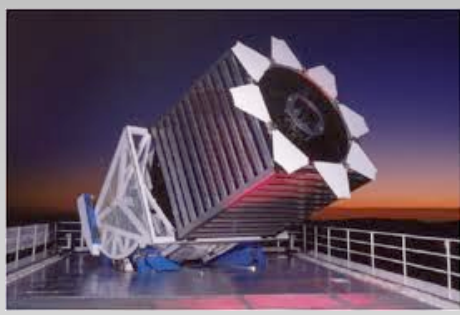
- ***Deep*** optical RCs for 34 LTGs and 31 ETGs
- V-dispersion profiles for 33 ETGs
- Get TFR, FJ, and FP scaling relations



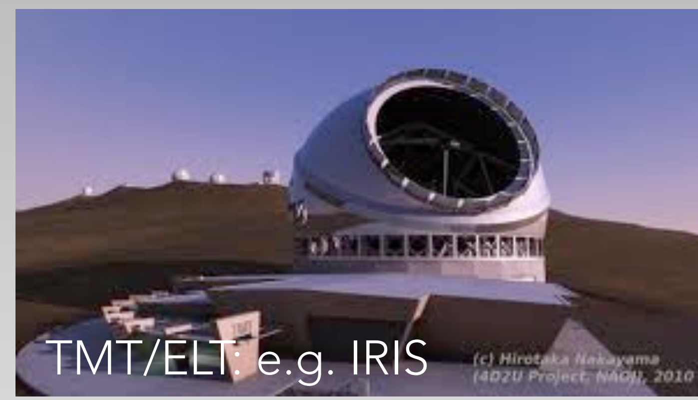


- ***Future: (4-5m exhausted) Gemini/GMOS program***

high-z landscape: era of high-z IFUs



We need a z=0 baseline for spectroscopy



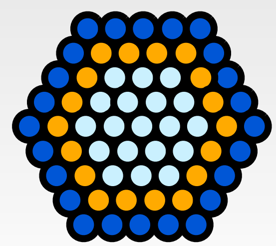
Current & Planned IFU Surveys

- DiskMass (PMAS/PPaK/Calar Alto / 2.7″ fiber /FOV=74″x64″):140 face-on LTGs
- SAURON/Atlas3D (FOV=33″x41″): ~330 mostly ETGs
- CALIFA (Calar Alto: uses PPak): ~600 galaxies (highest resolution / FOV)
- SAMI at AAO (13 IFUs over 1 deg FOV / 14.9″ per IFU): ~3400 galaxies

MaNGA will provide such a baseline for 10,000 galaxies

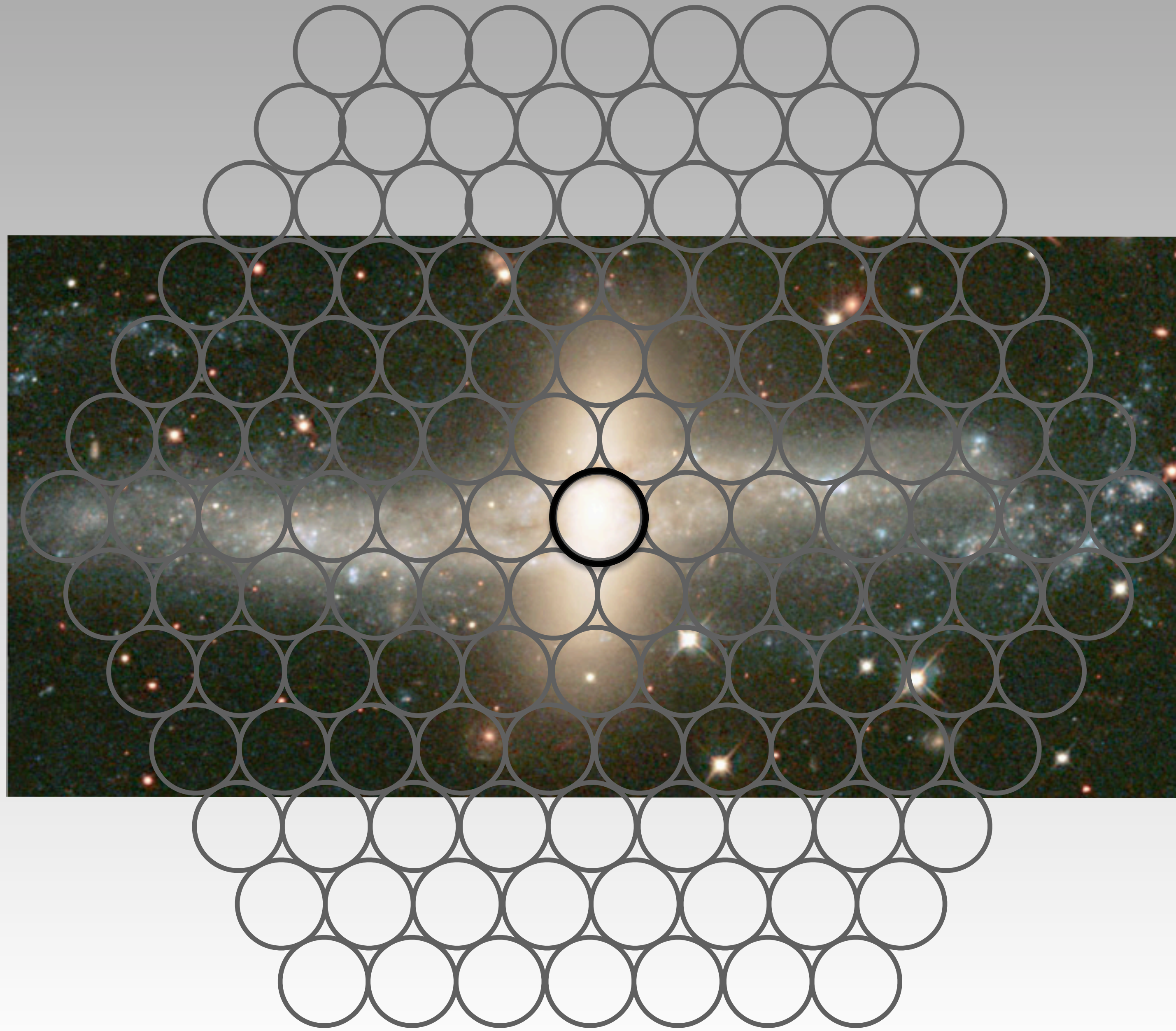
MaNGA Basic Facts

- 10,000 galaxies at z>0.03 with 2D spectra (SFRs, SFHs, V, σ, dust, metallicity, stellar masses, ...)
- Dynamics and stellar pop with S/N=5-10 at $1.5R_e$
- ~3 hour integrations with BOSS
- Spectral coverage: 360-1000 nm
- Spectral resolution (sigma): 50-70 km/s
- 80% of the targets will be resolved by at least 19 spatial elements out to $1.5R_e$
- ~6 year project (2014-2020)
- Science verification: Fall 2014
- First press release: Jan 2015
- DR13: July 16



Actual MaNGA targets

MaNGA Basic Facts



Wish list (Obs.)

- **General:** must determine biases and applicability of structural parameters (V_{rot}, σ, $R_{23.5}$, accurate D, …) Measure V(r) and σ(r) as deeply and homogeneously as possible.

- BTF/FP analysis for *tens of thousands* of LTGs and ETGs: need *deep* dynamics (V, σ), PNe, GCs, lensing, X-ray maps, multi-wavelength imaging, gas fractions E.g. SAURON, Atlas3D, ALFALFA, CALIFA, MaNGA, SLACS, ***SHIVir***, … (bias on dynamics)

- VL/RL/LF analysis for LTGs/ETGs: must constrain stellar population models, IMF and AC. *Slope, zero-point and scatter of scaling relations must be matched.*

Dutton+11; Trujillo-Gomez+11; Papastergis+11; Reyes+12