The Globular Cluster - UCD - Dwarf Galaxy Connection

What is a Galaxy ?
Voting Results

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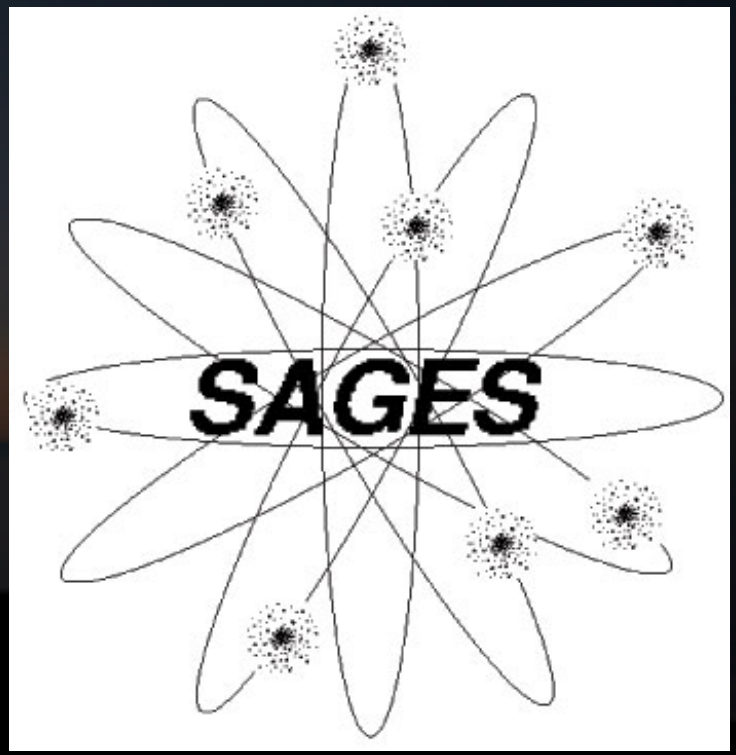

- Caroline Foster (Swinburne)
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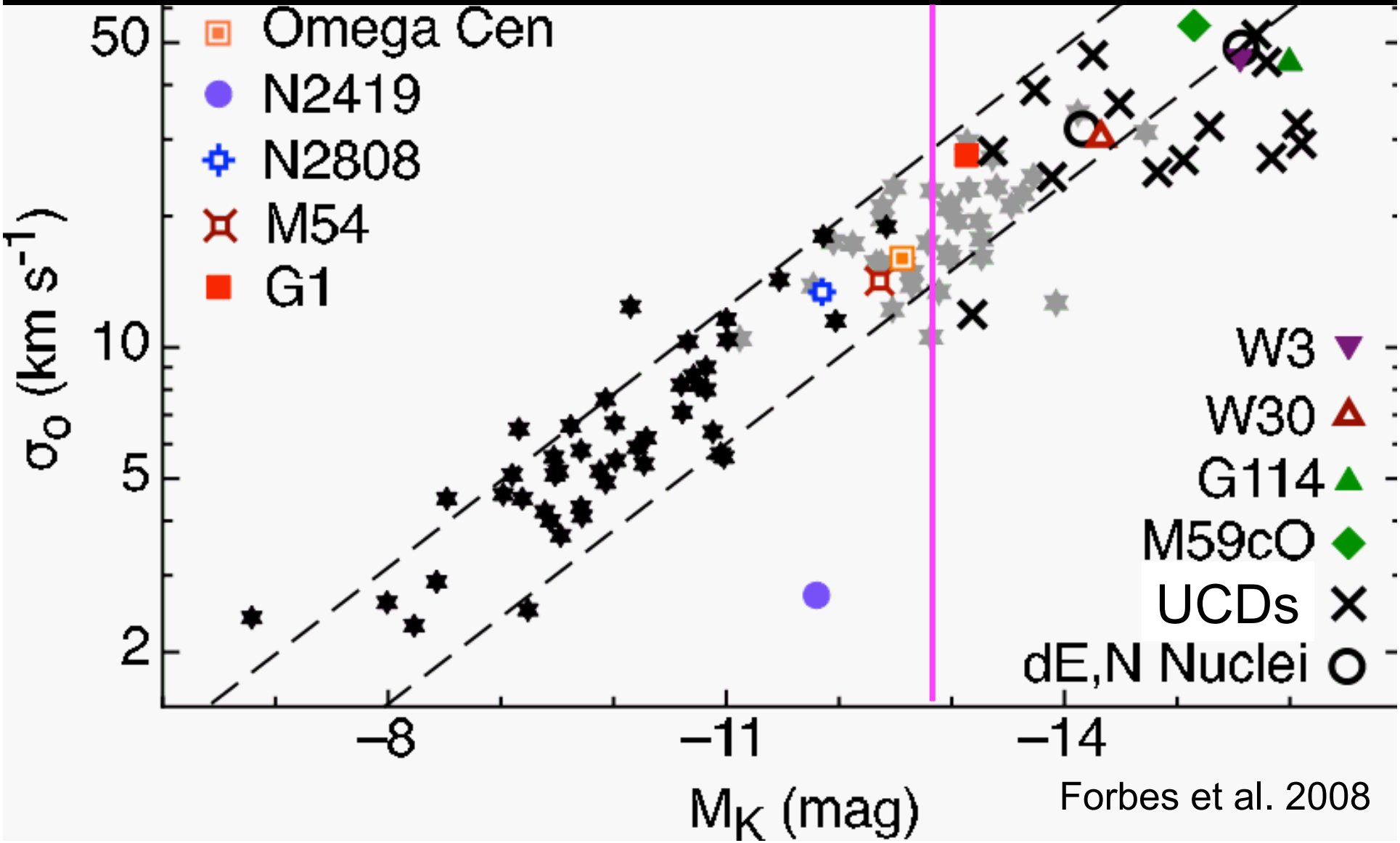
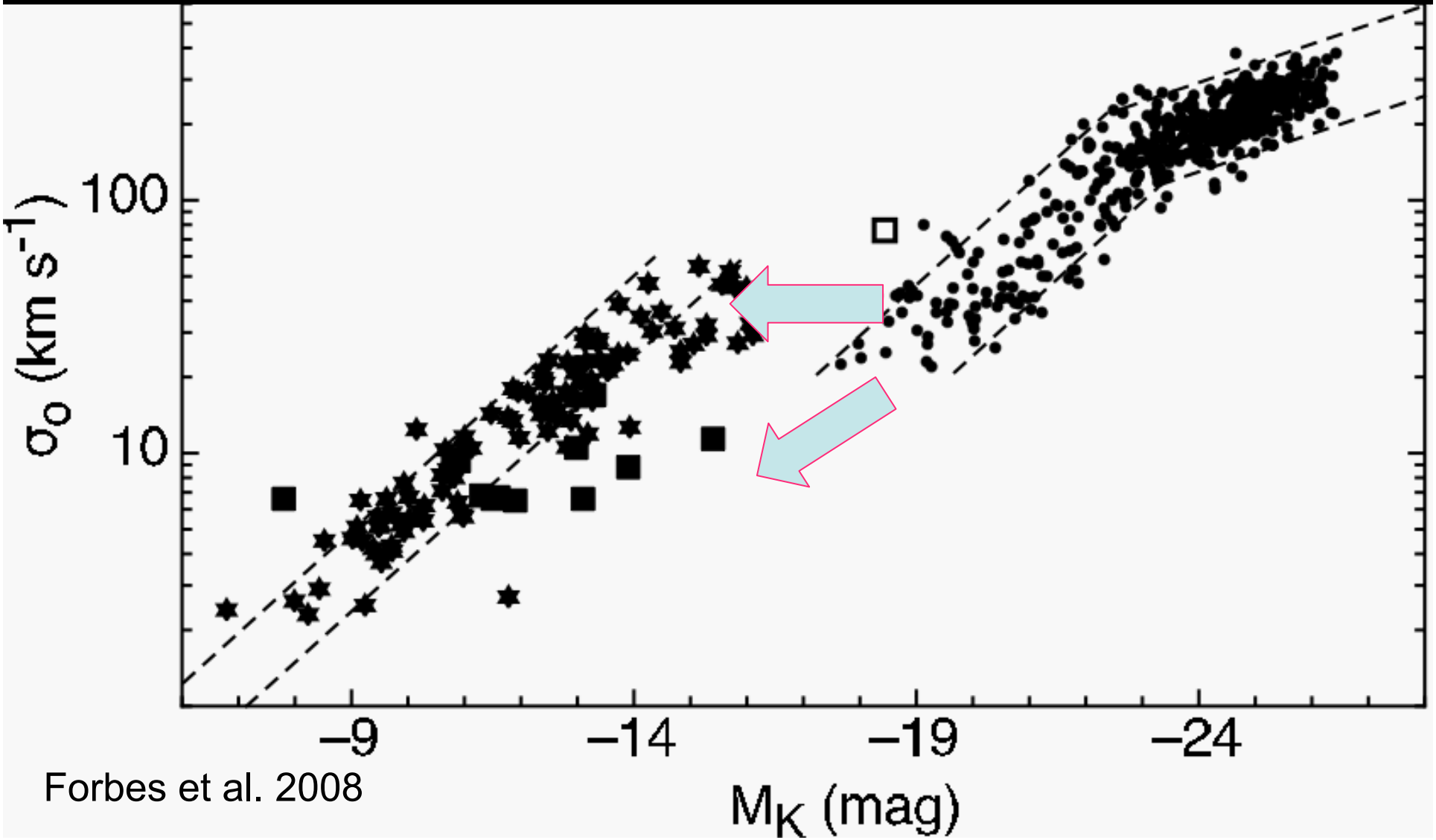
- Alister Graham (Swinburne)
- Andrew Benson (Caltech), George Hau (ESO)

Velocity dispersion vs M_K



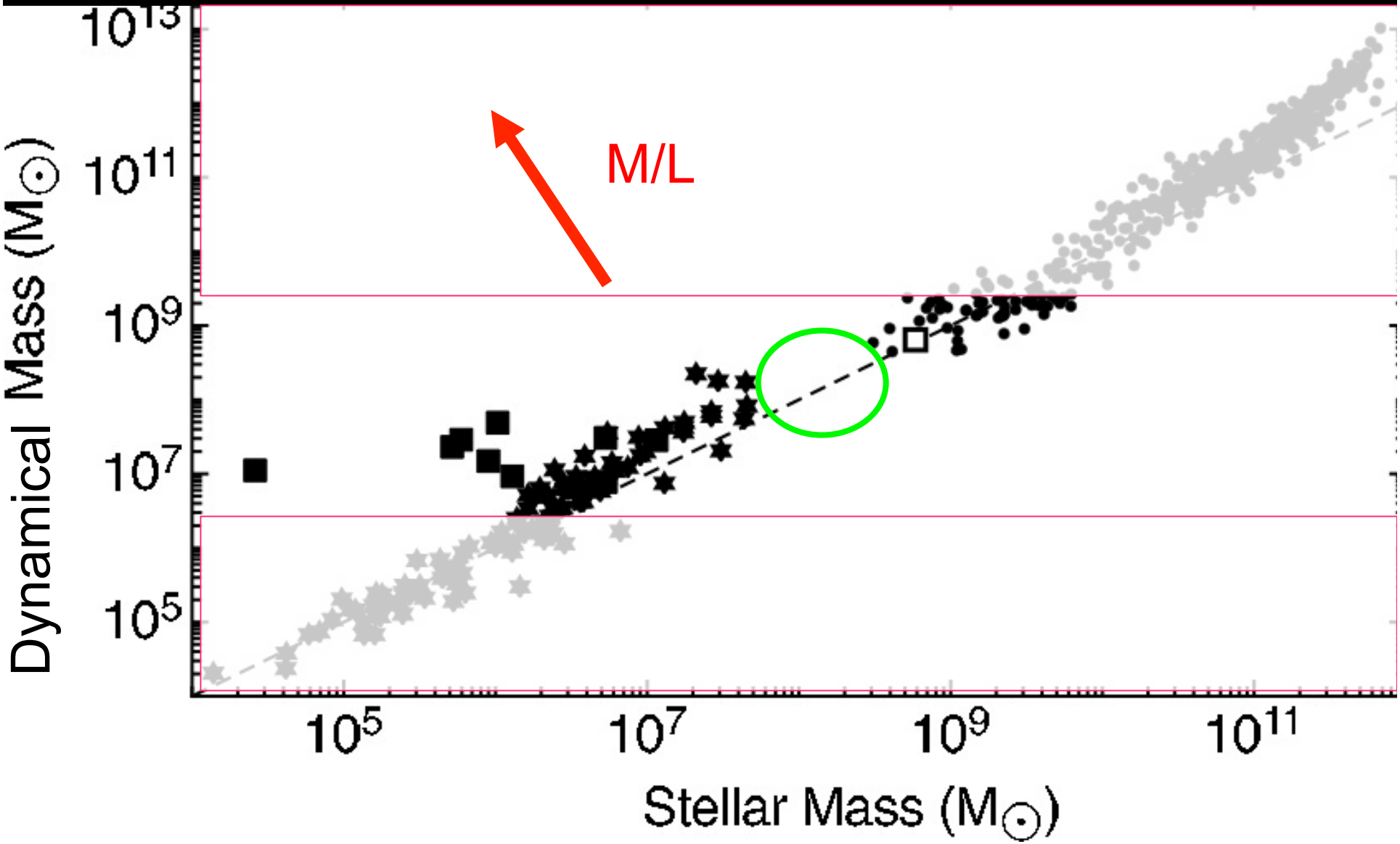
Forbes et al. 2008

Velocity dispersion vs M_K



Forbes et al. 2008

Dynamical mass vs stellar mass



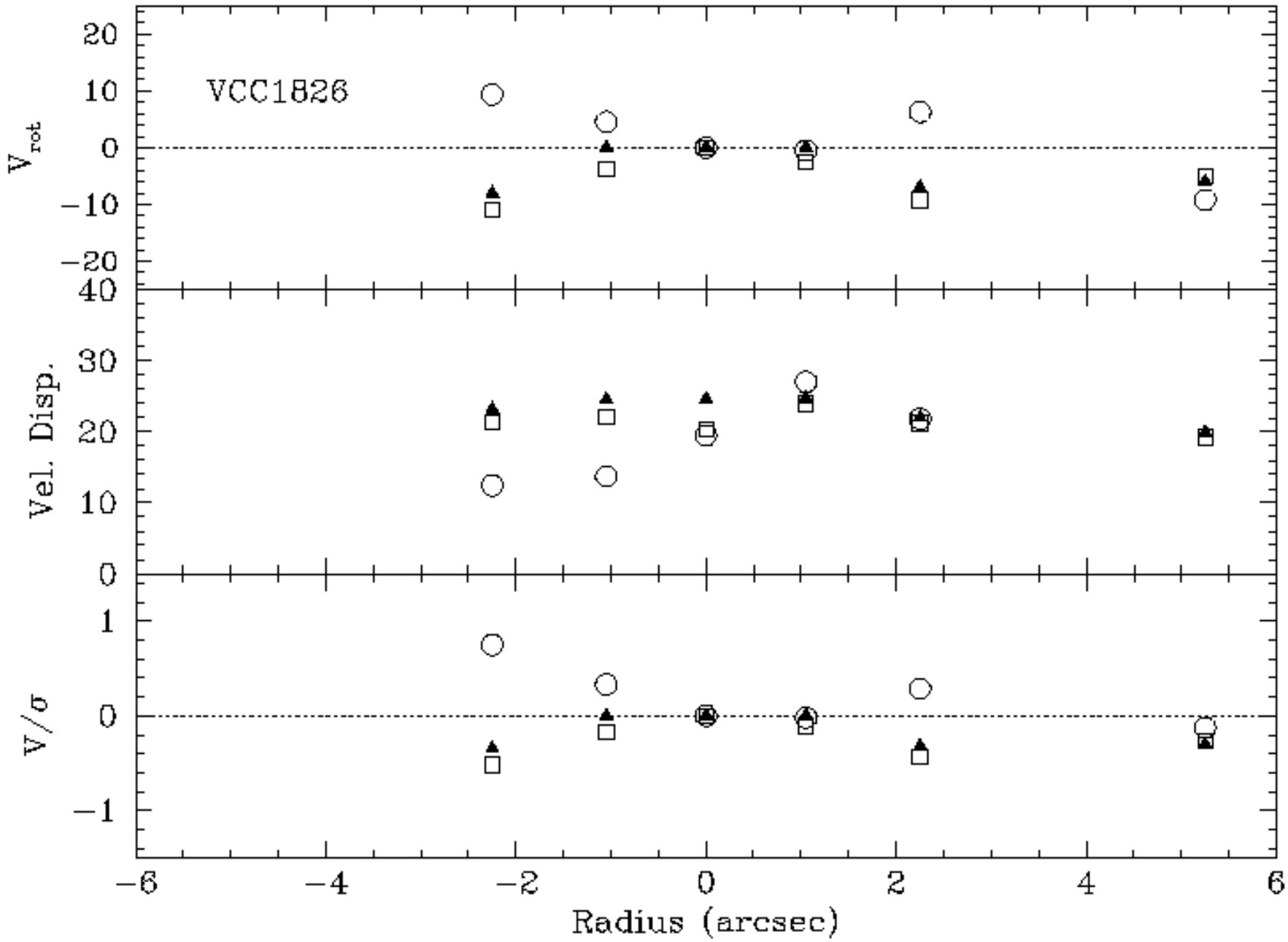
Dwarf elliptical velocity dispersions

"…it is still challenging (or even impossible) to obtain accurate velocity dispersions for such low surface brightness [dwarf elliptical] galaxies."

" This will be a promising science case for the …ELT or the JWST."

Misgeld & Hilker 2011 MNRAS in press

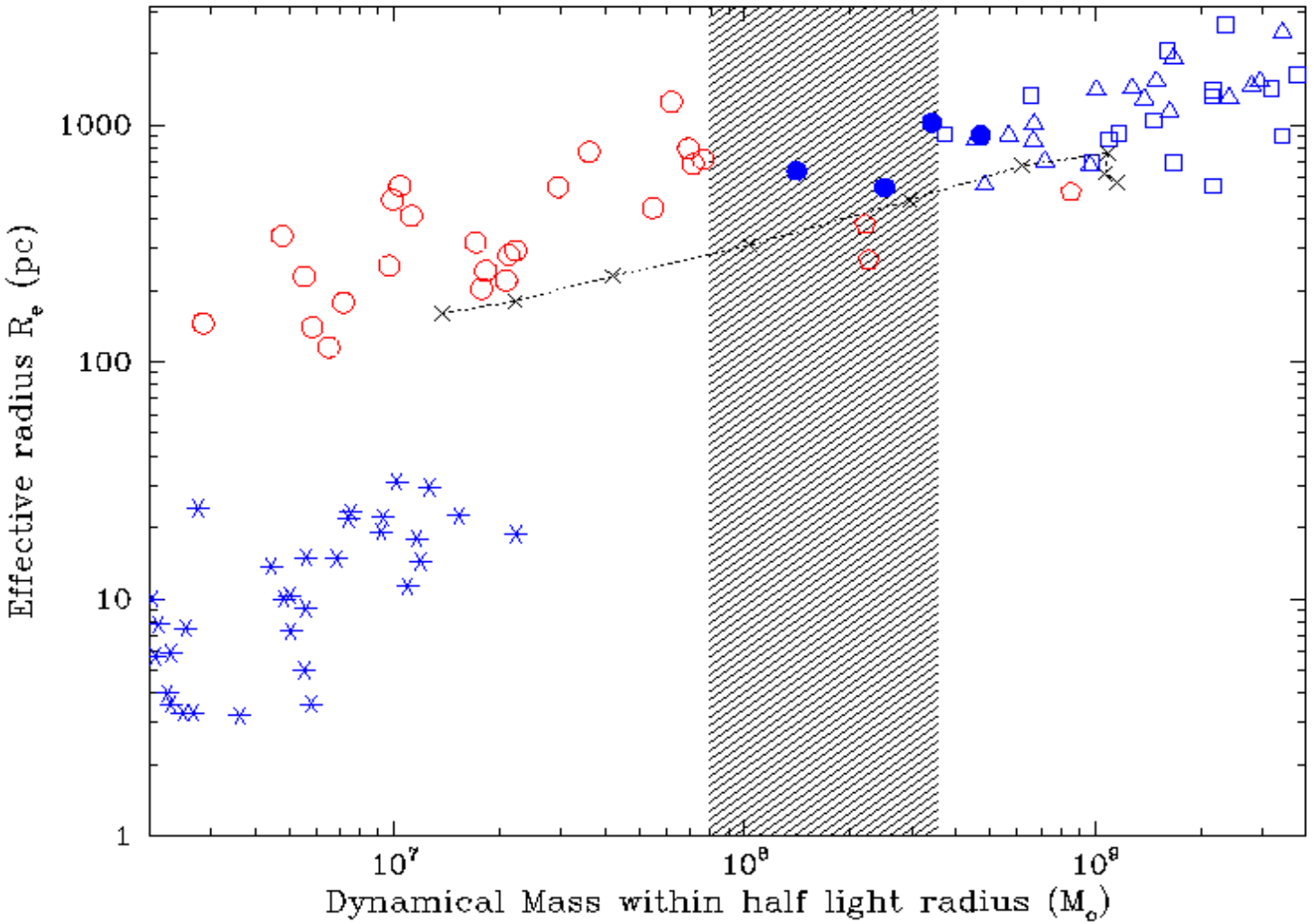

Keck/ESI observations
Echelle spectra (res ~ 15 km/s)
5 dE (no nucleus), M_V ~ -16
In Leo, Eridanus and Virgo
~2hrs per galaxy, S/N ~ 20


VCC1826
V_{rot}
Vel. Disp.
V/σ
Radius (arcsec)
20
10
0
−10
−20
40
30
20
10
0
1
0
−1
−6
−4
−2
0
2
4
6

dE galaxy measurements

- Central galaxy velocity dispersions from Ca Triplet and Mg lines using ESI (galaxies have little or no nucleus)
- Effective radii (R_e) from Sersic fits
- Dynamical mass within deprojected R_e from Wolf et al. (2010) formula, ie $4\ \sigma^2\ R_e/G$ which is insensitive to orbital anisotropy
- Plus data from literature for Virgo/Fornax UCDs, Virgo dE, LG dSph, LG dEp (NGC 147, 185, 205)

Size vs Dyn. Mass within deprojected half light radius



dSph

dEp

UCD

dE

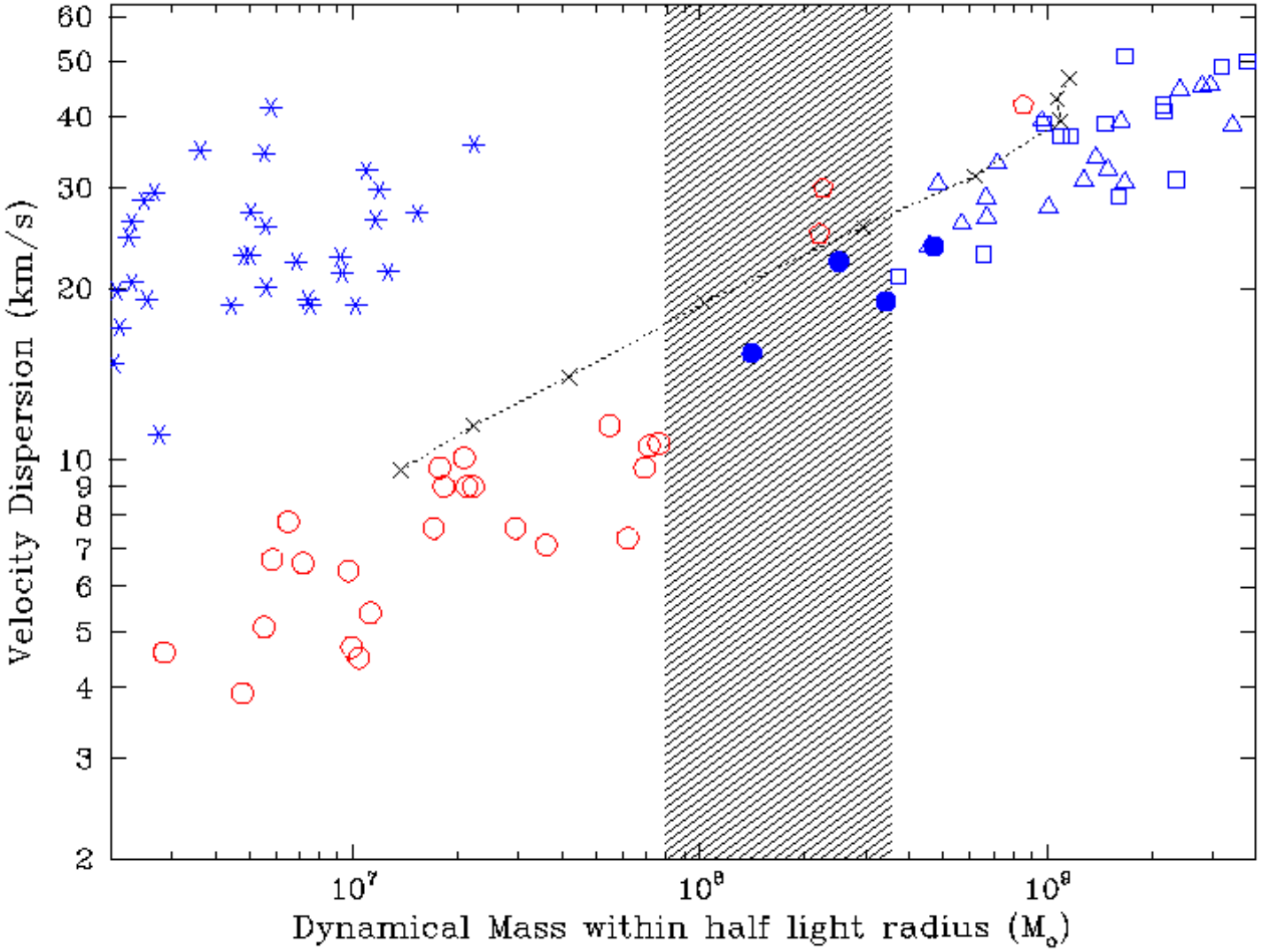
dE

new

LG

Virgo

Sigma vs Dyn. Mass within deprojected half light radius



dSph

dEp

UCD

dE

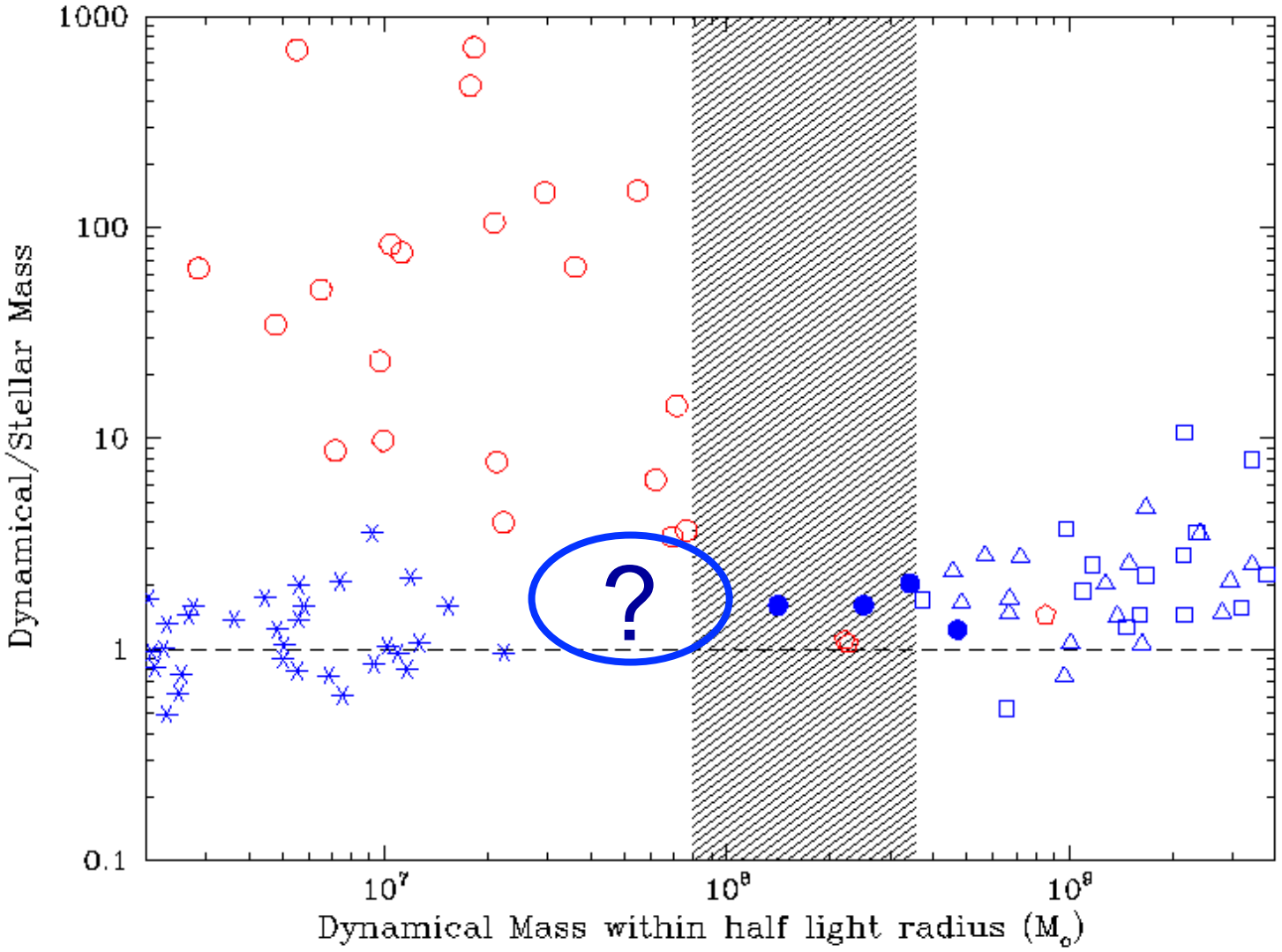
dE

new

LG

Virgo

Dyn/stellar mass



dSph

dEp

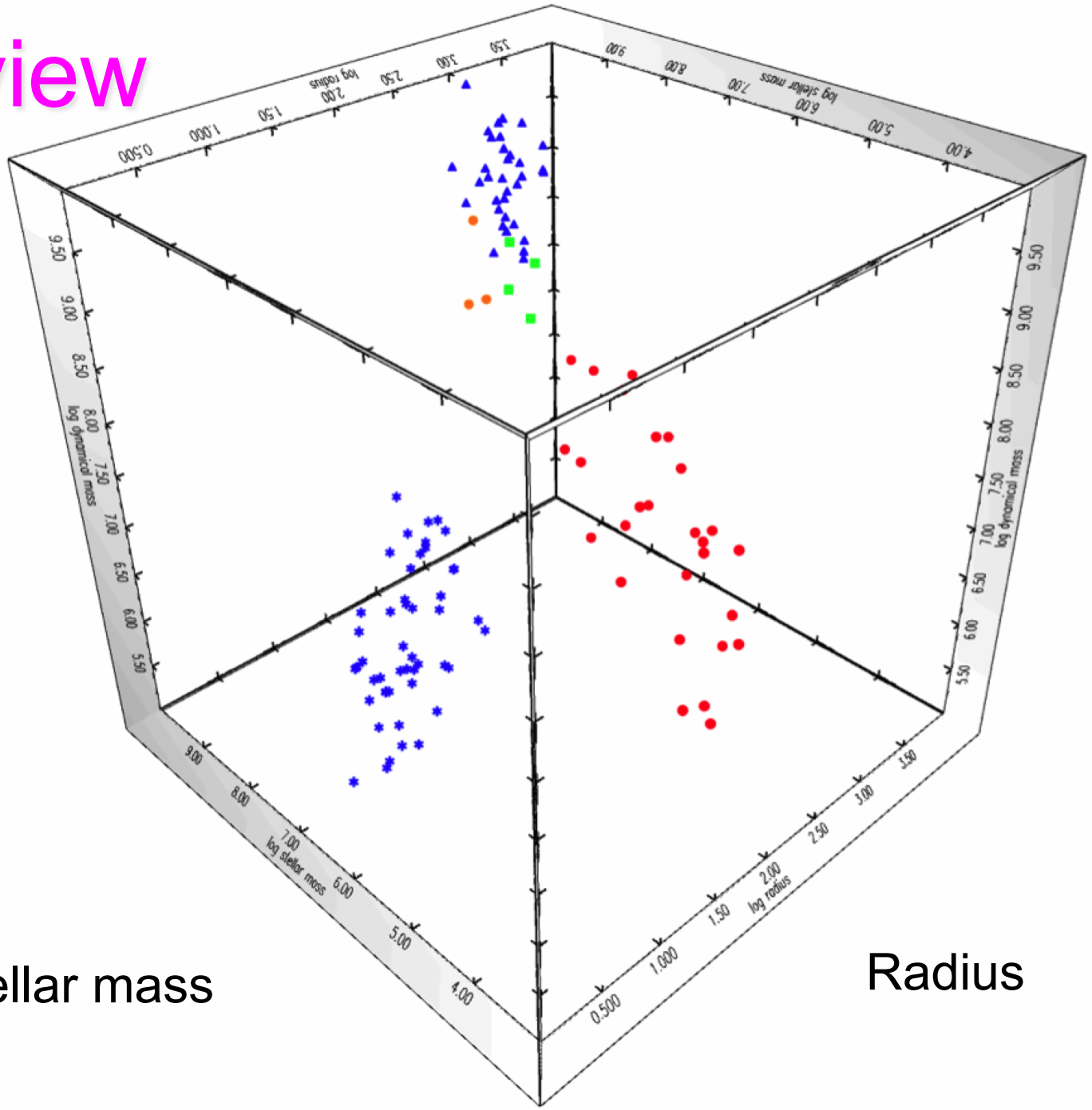
UCD

dE

dE

new

3D view



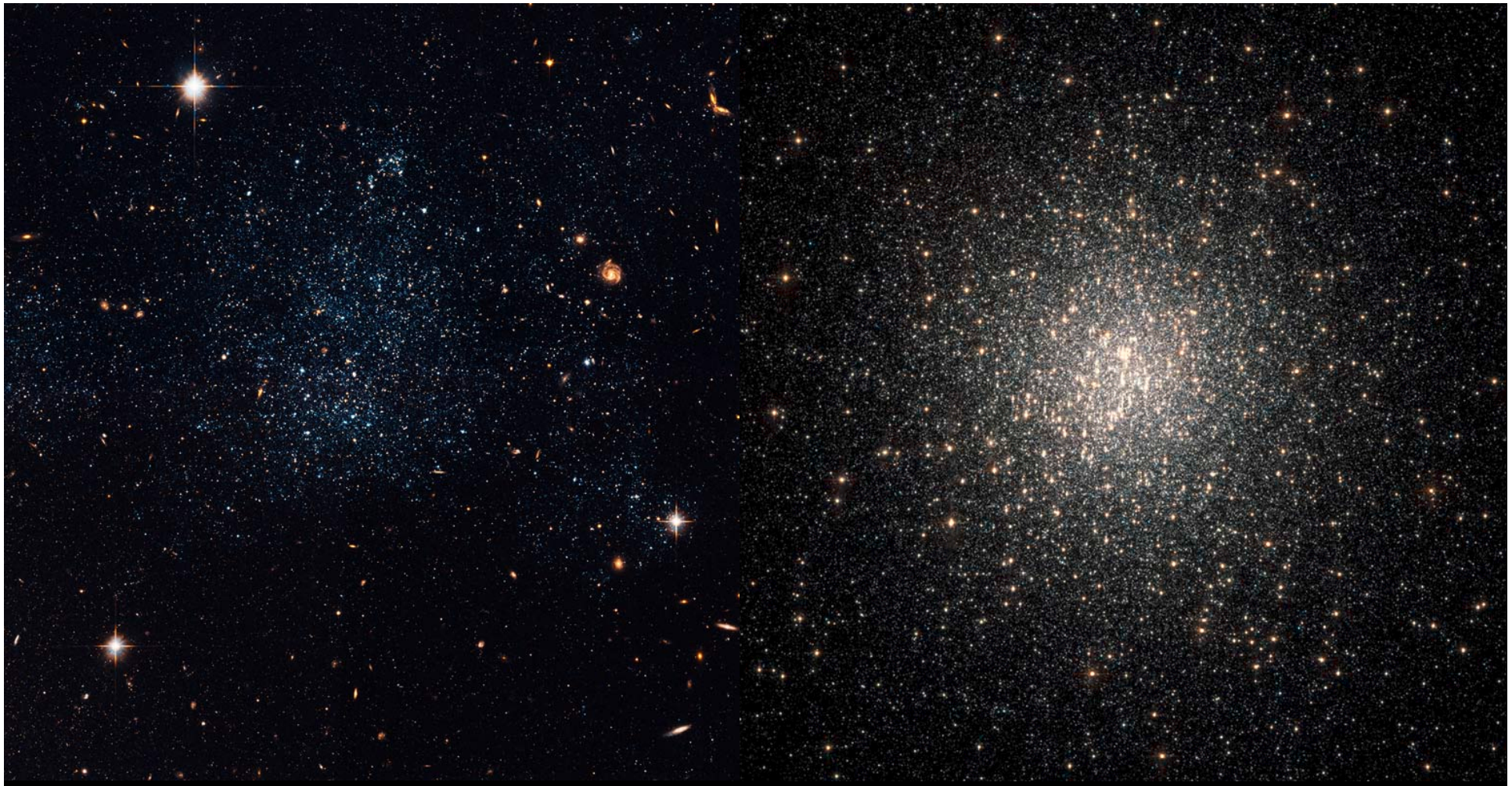
Stellar mass

Radius

Dynmass

Interpretation

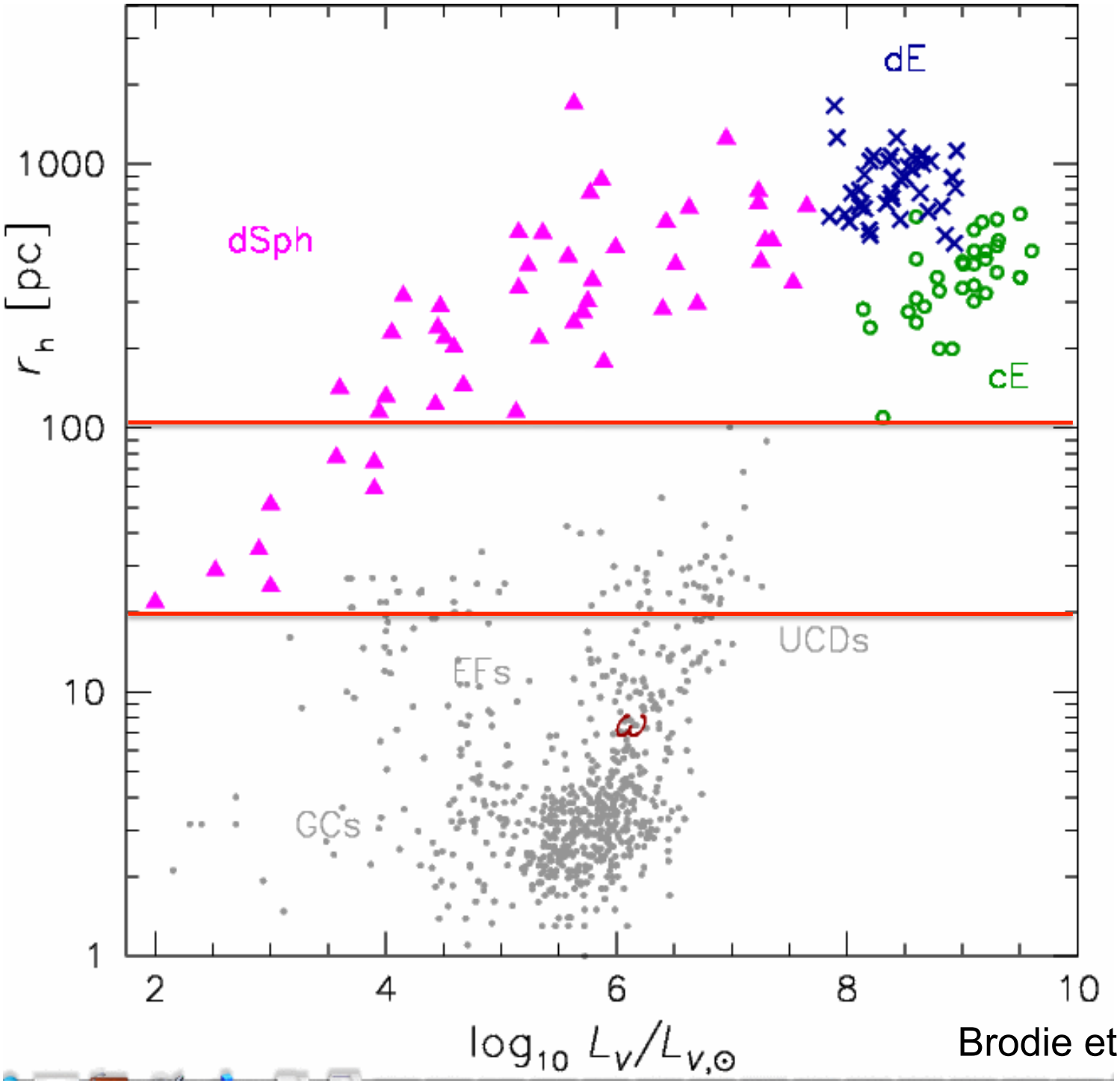
- Ultra Compact Dwarfs appear to be dark matter free star clusters, like globular clusters.
- Low luminosity dE galaxies are relatively dark matter free within Re. SN feedback -> lower DM fractions in dEs
- dSph galaxies appear to be dark matter dominated. Tidal and ram pressure stripping -> higher DM fractions in dSph
- Dabringhausen, Zaritsky,Tollerund, Misgeld



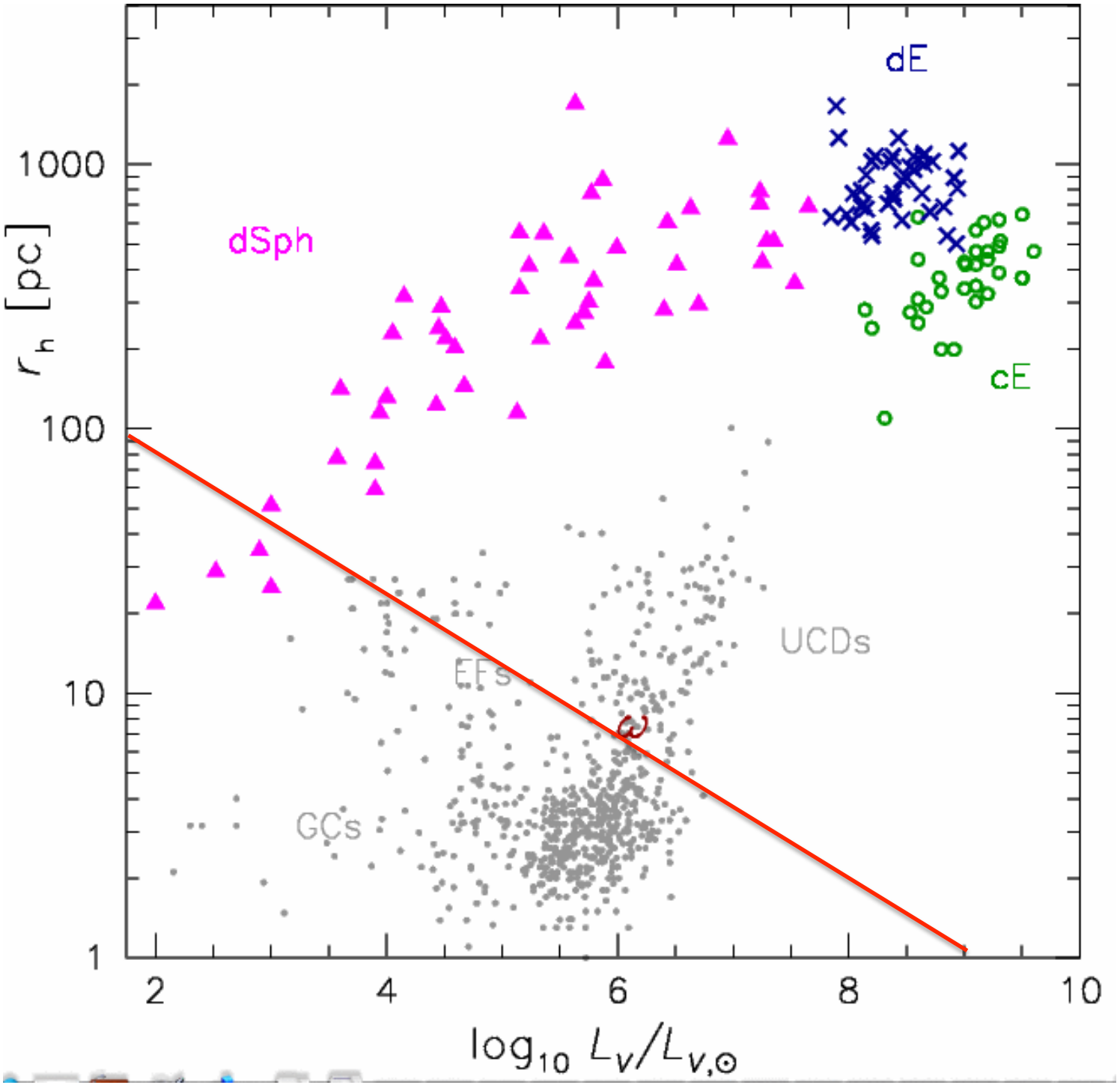
What is a galaxy ?

What is a Galaxy ?

- Gilmore et al. 2007: Galaxies have dark matter and effective radii > 100 pc. GCs and UCDs are dark matter free star clusters.
- Kroupa 2007: Galaxies have Relaxation times > Hubble time. UCDs are galaxies, GCs are star clusters. Both GCs and UCDs are dark matter free.



Brodie et al. 2011


dE
dSph
cE
UCDs
EFs
ω
GCs
1000
100
10
1
2
4
6
8
10
r_h [pc]
$\log_{10} L_V/L_{V,\odot}$

Galaxy Definition

- Gravitationally bound

Excludes: tidal material

- Contains stars

Excludes: dark galaxies

Includes globular clusters…so perhaps we need additional criteria - Forbes & Kroupa 2011

Galaxy Definition

- Half light radius > 100 pc

Excludes: GCs and UCDs

- Relaxation time > age of Universe

Includes: UCDs and tidal dwarf galaxies

- Hosts satellites

Excludes: most dwarf galaxies and UCDs

Galaxy Definition

- Presence of dark matter

Difficult to measure for individual objects

Excludes: GCs, tidal dwarf galaxies, probably UCDs, perhaps some dEs

- Presence of complex stellar pops

Includes: some massive GCs

What is a Galaxy? – Crowd Wisdom

- Write paper on "What is a Galaxy?"
- Submit it to PASA, get it accepted
- Setup surveymonkey voting site

1)Have you read the paper?

2)Pick the best definition(s) for a galaxy

3)Comments

- Issue Media Release
- Watch the votes and comments come in

What is a Galaxy? – voting results

- 1638 votes in 2 months
- 56% or 920 people have read the paper
- Multiple choices allowed
- 68% voted for Complex Stellar Populations
- 28% voted for Long Two-body Relaxation
- 31% voted for Sizes > 100 pc
- 31% voted for Presence of Dark Matter
- 29% voted for Presence of Satellites