Kinematic Properties and Dark Matter Halos of Dwarf Early-Type Galaxies in the Virgo Cluster

Elisa Toloba (Fulbright Fellow at UCO/Lick & Carnegie Observatories)

Collaborators:
Alessandro Boselli (LAM-Marseille)
Reynier Peletier (Kapteyn Institute-Groningen)
Thorsten Lisker (Heidelberg University)
Jesus Falcon-Barroso (IAC-Spain)
Glenn van de Ven (MPIA-Heidelberg)
& SMAKCED collaboration

Raja Guhathakurta (UCSC)
Josh Simon (Carnegie Observatories)
Andrew Benson (Carnegie Observatories)
Dwarf early-types

dEs are the dominant galaxy class in the Universe

- **LF**: number of objects per unit volume for a given luminosity (or abs magnitude)
- **In the field**: dEs are rare
- **In clusters (Virgo)**: dEs are the major contributors to the LF

The environment must be responsible for this morphology segregation

Binggeli 1988
dEs are not simple systems

Are dEs faded dIrrs?

Lisker et al. 2006a,b, 2007, 2008 from SDSS data

Importance of the kinematics

- dIrr are rotating galaxies $\rightarrow$ dEs should rotate if they are faded dIrrs
- But, not all dEs show rotation

Origin of dEs?

Geha et al. 2003
Observed sample of 39 Virgo dEs

- 21 more (Toloba+2013, in prep.)

**Long-slit spectroscopy**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>WHT(4.2m)</th>
<th>INT(2.5m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISIS</td>
<td></td>
<td>IDS</td>
</tr>
<tr>
<td>Wavelength</td>
<td>4200-6800 Å</td>
<td>4600-6000 Å</td>
</tr>
<tr>
<td>Spectral Res.</td>
<td>1.6 Å (FWHM) 40 km/s</td>
<td>1.8 Å (FWHM) 45 km/s</td>
</tr>
<tr>
<td>Objects</td>
<td>8 dEs (1h exposure) 21 dEs (3h)</td>
<td>10 dEs (1h exposure)</td>
</tr>
</tbody>
</table>

Objects:
- VCC0009
- VCC0021
- VCC0033
- VCC0170
- VCC0308
- VCC0389
- VCC0397
- VCC0437
- VCC0523
- VCC0634
- VCC0750
- VCC0751
- VCC0781
- VCC0904
- VCC0990
- VCC1010
- VCC1087
- VCC1122
- VCC1183
- VCC1261
- VCC1304
- VCC1355
- VCC1388
- VCC1407
- VCC1431
- VCC1481
Kinematic profiles

Toloba et al. 2011, A&A 526 114
Toloba et al. 2013, in prep.
Fitting Rotation Curves

Polyex model (Giovanelli & Haynes 2002)

\[ V_{PE}(r) = V_0 \left( 1 - e^{-r/r_{PE}} \right) \left( 1 + \frac{\alpha r}{r_{PE}} \right), \]

- \( V_0 \) amplitude
- \( r_{PE} \) exponential scale of the inner region
- \( \alpha \) slope of the outer part of the rotation curve: fixed value
Rotation Curves: lopsided/irregularities?

10% are lopsided at 3σ significance

low-luminosity spiral (Swaters+1999,2009)
Kinematically decoupled cores: cannibalism?

5% have kinematically decoupled cores

- Cannibalism in dwarf galaxies: very rare
  (e.g. NGC4449: Martínez-Delgado+2012, NGC770: Geha+2005)
- Not possible in clusters -> possible evidence of groups coming into Virgo
Dynamical support

Colour classification: Lisker et al. (2006a)

Previously found in

Solid line: model for isotropic oblate ellipsoid supported by rotation (Binney 1978)
Dash line: Slow/Fast rotators distinction (Emsellem+2011, ATLAS3D)
Rotational support: distance and age dependence

Rotationally supported systems in the outskirts of the cluster

dEs in the center of the cluster do not rotate


On average, disky dEs are \(\sim 3\) Gyr younger than no disky dEs
More proofs for a late-type origin

Toloba et al. 2011, A&A 526 114

Templates by Catinella et al. (2006)

Similarity between dEs and normal disk galaxies

Toloba et al. (2012, A&A 548 78)

Blue dots: median of rotating dEs

- Black solid line: Falcon-Barroso+2011 (SAURON)
- Blue solid line: Shen+2003 (Spirals in SDSS)
- Dashed-dotted line: Brasseur+2011 (dSphs)
Fundamental Plane & Faber-Jackson

Rotationally and Pressure supported dEs: different galaxy pops?

FP: dEs ABOVE Es
F-J: dEs BELOW Es

WHY??

Toloba et al. (2012, A&A 548 78)
Fundamental Plane in $\kappa$-space

K band: dEs follow the same mass-surface brightness relation as Es, but their total mass-to-light is larger than that of Es.

V band: same as in K band but extended to dSphs

Toloba et al. (2012, A&A 548 78)
FP as a measurement of the dark matter content of dEs

\[
\log R_{\text{eff}} = \alpha \log \sigma + \beta \log \langle \mu_{\text{eff}} \rangle + \gamma + \delta \log (M^*/L) + \delta \log (M_{\text{dyn}}/M^*)
\]

Fundamental Plane - Dark Matter Content

Toloba et al. (2012, A&A 548 78)
Dark Matter Content

Are dEs dark matter dominated systems?

- Toloba et al. 2011, A&A 526 114
  - I band: $M_{\text{dyn}}/M^* = 1.6 \pm 1.2$
  - V band: $M_{\text{dyn}}/M^* \geq 1.7 \pm 0.6$
  - K band: $M_{\text{dyn}}/M^* \geq 1.7 \pm 0.5$

Their dark matter fraction within $1Re$ is $M_{DM}/M^* \geq 42\%$

- Work in progress: DM halo of dEs up to $>15Re$

People: Toloba, Guhathakurta, Peng, Ferrarese, Cote, Jordan

Observations completed: Keck/DEIMOS

GCs used as tracers of the potential well

300 GC candidates observed (124 ACSVCS catalog, 176 NGVS) on 21 Virgo dEs

Raja’s talk on Thursday
Properties and origin of dEs

Field

Very few dEs

Virgo-Outer parts

- disky structures
- younger pops.
- rotational support
- smooth + 10%
- lopsided/irregular curves
- less dense

Virgo-Center

- no underlying structures
- old ages
- pressure supported
- smooth rot. curves
- more dense

Evolution

dEs in the outskirts: ram pressure stripping (Boselli et al. 2008)
dEs in the centre: ram pressure + harassment (Mastropietro et al. 2005)? / in-situ formation?
Possible formation mechanisms

Semi-analytic models by A. Benson (Preliminary)

Harassment

Ram pressure stripping

- Median of 39 random dEs in the simulation
- Median of all dEs in the simulation
- Some random dEs in the simulation
dEs are transformed low-luminosity late-type galaxies that are observed at different stages of their transformation as a function of the clustercentric distance.
Possible formation mechanisms

Semi-analytic models by A. Benson (Preliminary)

Harassment

Harassment
More properties that depend on the distance to M87