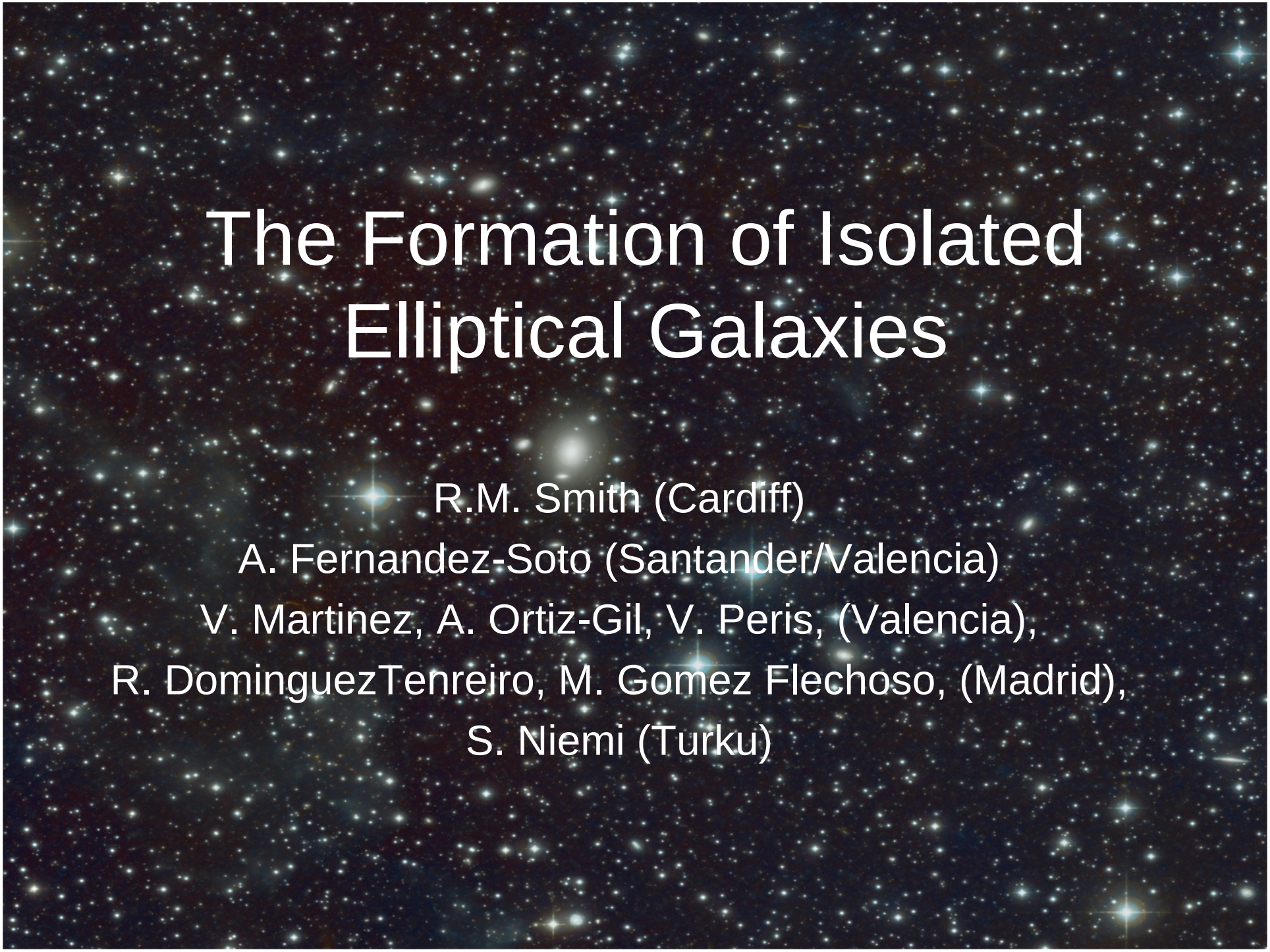

The Formation of Isolated Elliptical Galaxies

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Introduction

Three major formation mechanisms for elliptical galaxies:-

1) Single object evolution, with no merging or cannabalism – monolithic collapse?

2) Major merging of large objects

3) Minor merging/cannabalism of several smaller units

Do all three operate? And if so, in what proportion? When, where and how?

What observational properties can be used to distinguish between these processes?

Try and remove the environmental influences by observing isolated galaxies.

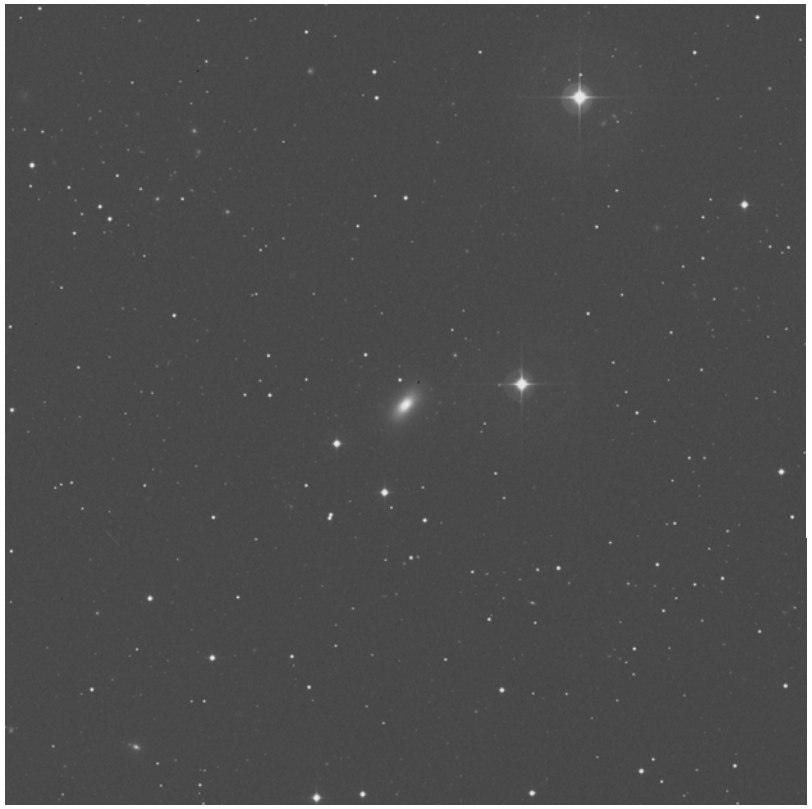
Morphology-density relation may suggest that merging is the major formation mechanism for ellipticals. Isolated elliptical galaxies should be rare, if they exist at all. But we know they do:

Also indicates that early merging is primary cause for current properties (elliptical morphology, little star formation, red colours, little dust and ISM – ‘red and dead’)

Isolated ellipticals should not suffer the major dynamical effects seen in clusters.

Classic formation scenario => isolated ellipticals may well have very different properties to those in clusters as merging will occur over a much longer timescale – with evidence of recent star formation and disturbed morphologies.

First of all we need a sample of isolated ellipticals.



NGC7785 – DSS image

Classification Schemes

Many different classification schemes (e.g. Karachentseva (1973), Reda et al (2004), Smith et al. (2004))

Crucial to analysis that galaxies are truly isolated and are elliptical to remove environmental effects.

Major problem in that all galaxy catalogues are incomplete – especially redshift

What limits to use?

Background features such as groups and clusters can seriously affect any analysis of the properties of the isolated galaxy and it's environment.

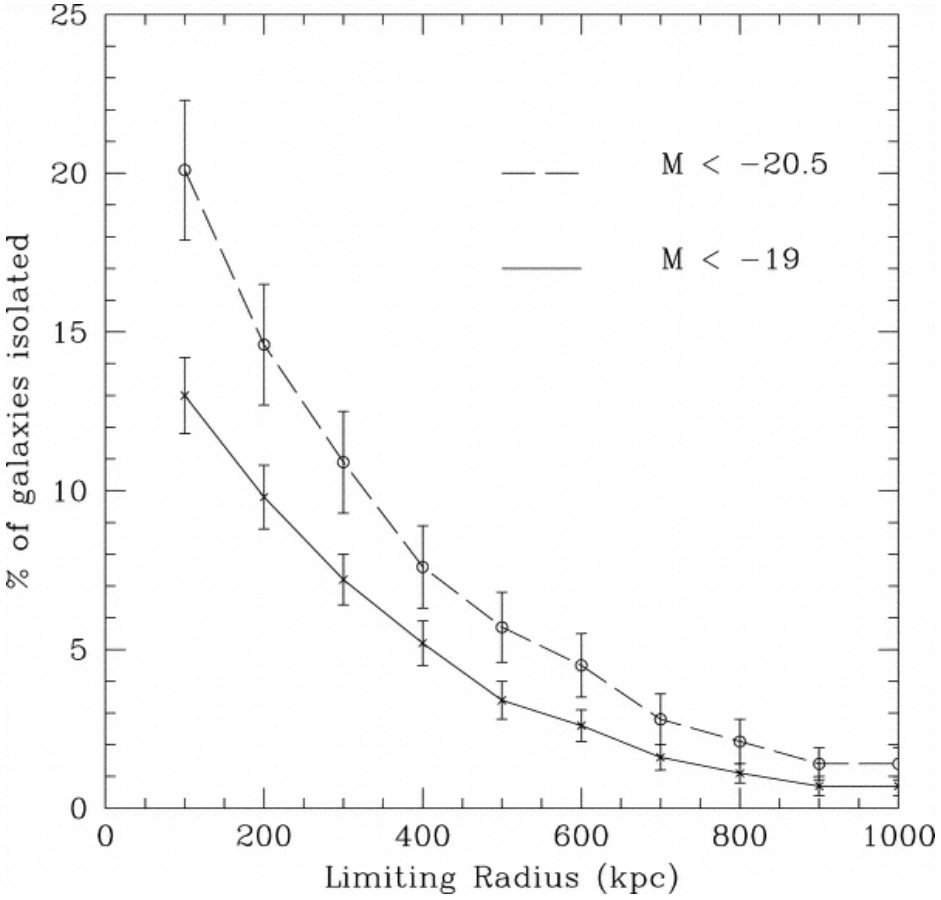
By using the criteria that any neighbour cannot have a major dynamical effect on the 'parent' then should produce a sample of non-group/cluster galaxies.

Smith et al (2004) sample criteria similar to that of Karachentseva –

No redshift information for neighbours as such catalogues are incomplete
No projected groups/clusters complicate any analysis of neighbourhood.

A galaxy is isolated if it has no neighbour within 0.7 mag closer than 1Mpc and no neighbour within 500kpc less than 2.2mag fainter (i.e. 8 times less luminous and hence approx 8 times less massive – dynamical effects small?)

Less than 3% of elliptical galaxies are isolated using the Smith et al. criteria, although not by any means a complete sample.



Results so far

All the studies show that isolated elliptical galaxies, with no bright neighbours, exist but are relatively rare.

The catalogues share some objects but none of them are identical due to their varying methods of construction.

Several studies show that the properties of the isolated galaxies vary significantly, with some showing tidal tails, dust and other tell-tale signs of recent merging.

Some (~40%) show kinematically distinct cores (Hau and Forbes 2006) – possible evidence of merging activity.

Several show spectral signatures of recent star-formation

Thus field ellipticals show evidence of being younger than cluster/group ellipticals but a wide range of properties, mimicking somewhat their counterparts in high density regions.

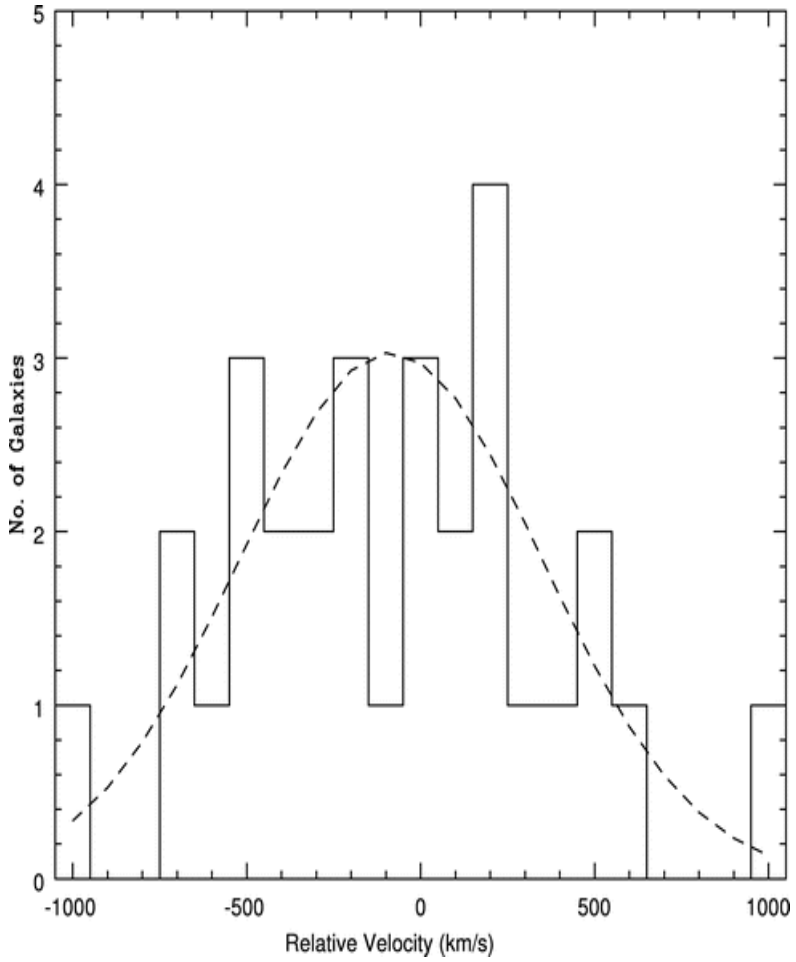
Mass and Environment of Isolated Ellipticals

Mass is one of the fundamental properties of galaxies yet is poorly known for elliptical galaxies.

Does the mass give any indication of the formation mechanism?

Again need a sample of isolated galaxies, away from a cluster potential.

NGC 1600 – already known group but satisfies the Smith et al isolation criteria as neighbours are much fainter
Has enough neighbours to derive a velocity dispersion for this galaxy



Velocity dispersion of 429±57 km/s (from 30 satellites).

Gives a mass of the order of $10^{14} M_{\odot}$

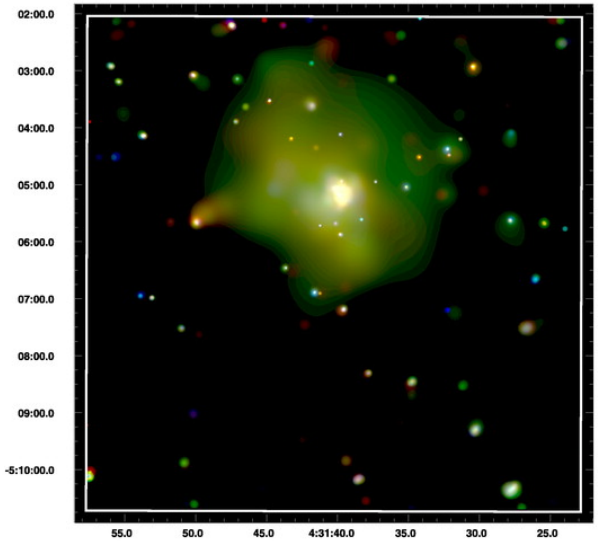
This is more typical of that of groups than expected from an individual galaxy.

Uncertain whether this large mass is typical of all ellipticals or just a result of the formation history of NGC 1600.

But NGC 1600 maybe not your typical ‘isolated’ or ‘field’ galaxy-

There is X-ray emission from NGC 1600 (Sivakoff et al. 2004) - emission from the ISM in NGC 1600 and also intragroup emission

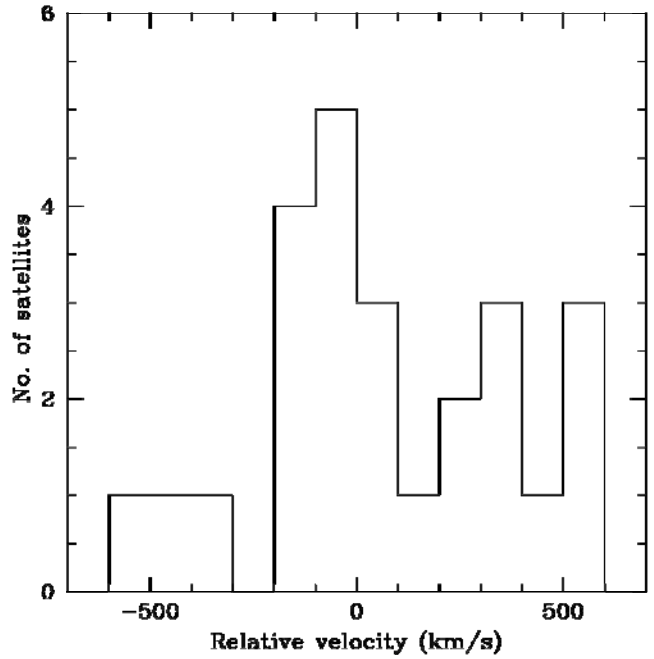
The centre of the X-rays and also the central velocity of the satellite population are not centred at the velocity of NGC 1600, also suggestive that NGC 1600 does not sit at the centre of the potential.



Presence of boxy isophotes, dust and line emission also suggests a merger history for this galaxy, although with typical broadband colours of an elliptical galaxy, the last major merger was between 4.6 and 8.8Gyr ago.
Smith et al. (2008) tentatively suggested that NGC 1600 was similar to fossil groups, with the central galaxy having merged with other dominant group members leaving only the smaller members behind. Like NGC 1132?

Due to lack of companions difficult to use neighbours as test particles to map the potential of many of our sample galaxy.

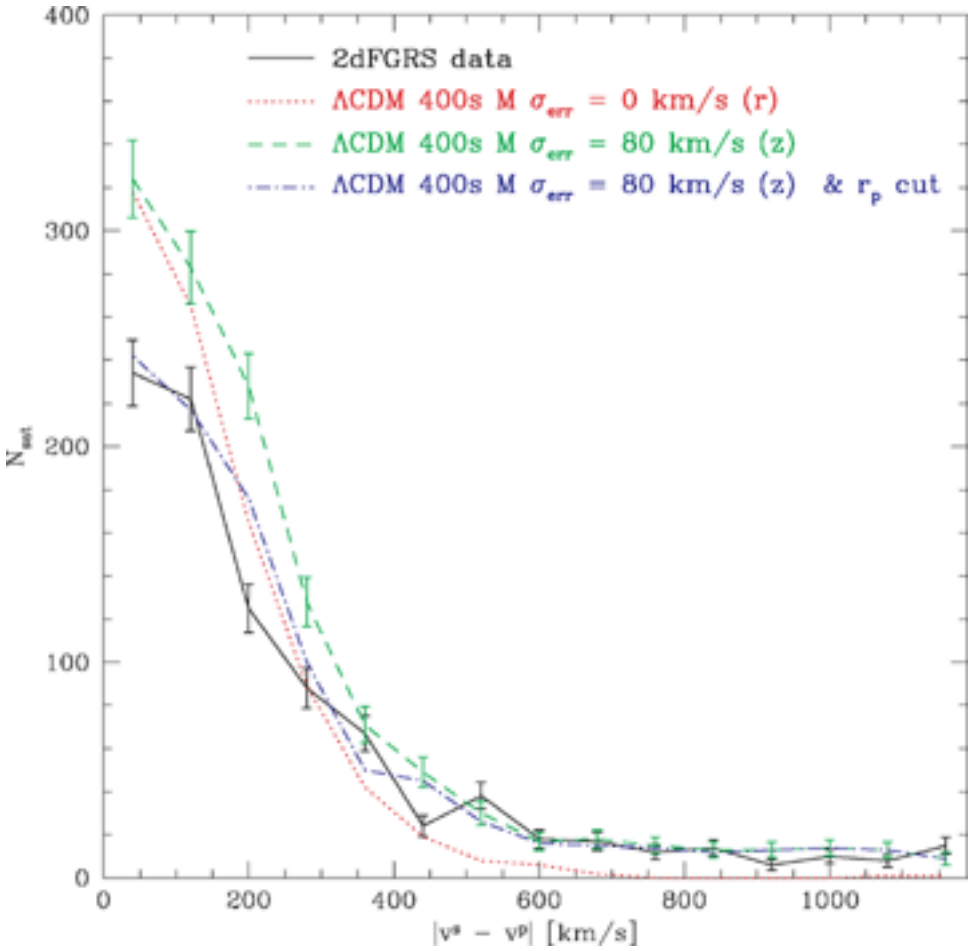
Use technique similar to that of Zaritsky et al. (1993, 1997) – stack kinematic results of several galaxies to provide a ‘mean’ potential.
We have also observed other galaxies in the Smith et al. sample, but results so far inconclusive (not enough neighbours)

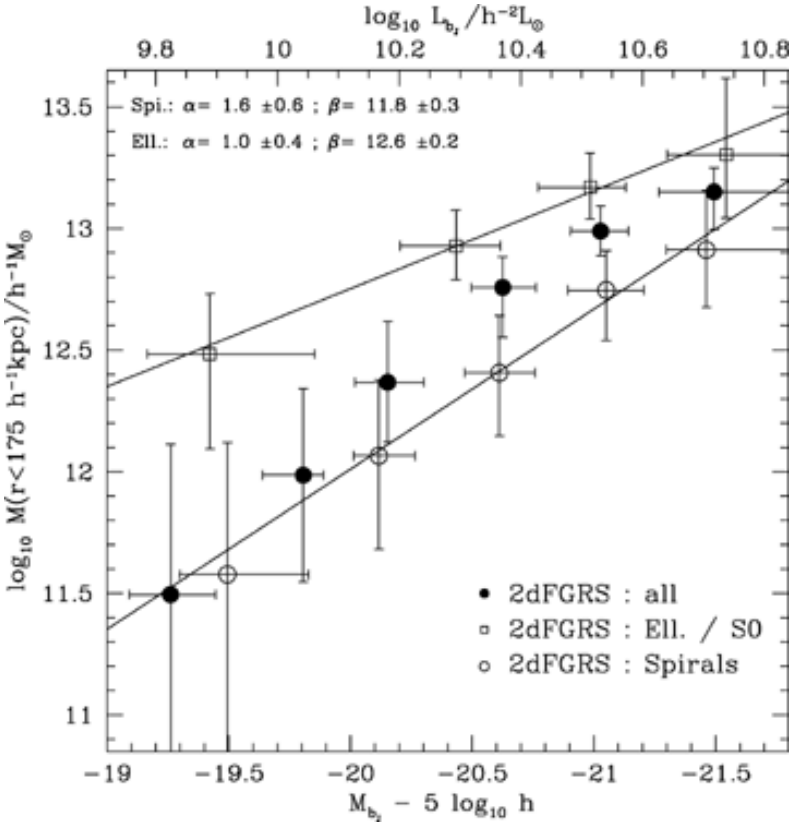


Norberg et al. (2008) used the 2dfGRS sample and similar selection criteria to that of Smith et al. to measure the redshift distribution of satellites around isolated elliptical galaxies.

They derive a sample size of 135 isolated elliptical galaxies (down to b_j~17).

Mass derived from comparison with mock catalogues.





With NGC 1600 having M_b=-21.4 the result from our study is in approximate agreement with this result.

Masses of bright isolated ellipticals comparable to poor groups.

A large mass and the possibility that isolated ellipticals are the result of group mergers in the past suggest that they may have extended X-ray haloes.

The X-ray properties of isolated ellipticals appear to be very varied as shown by Trinchieri earlier this conference (Memola et al. 2009)

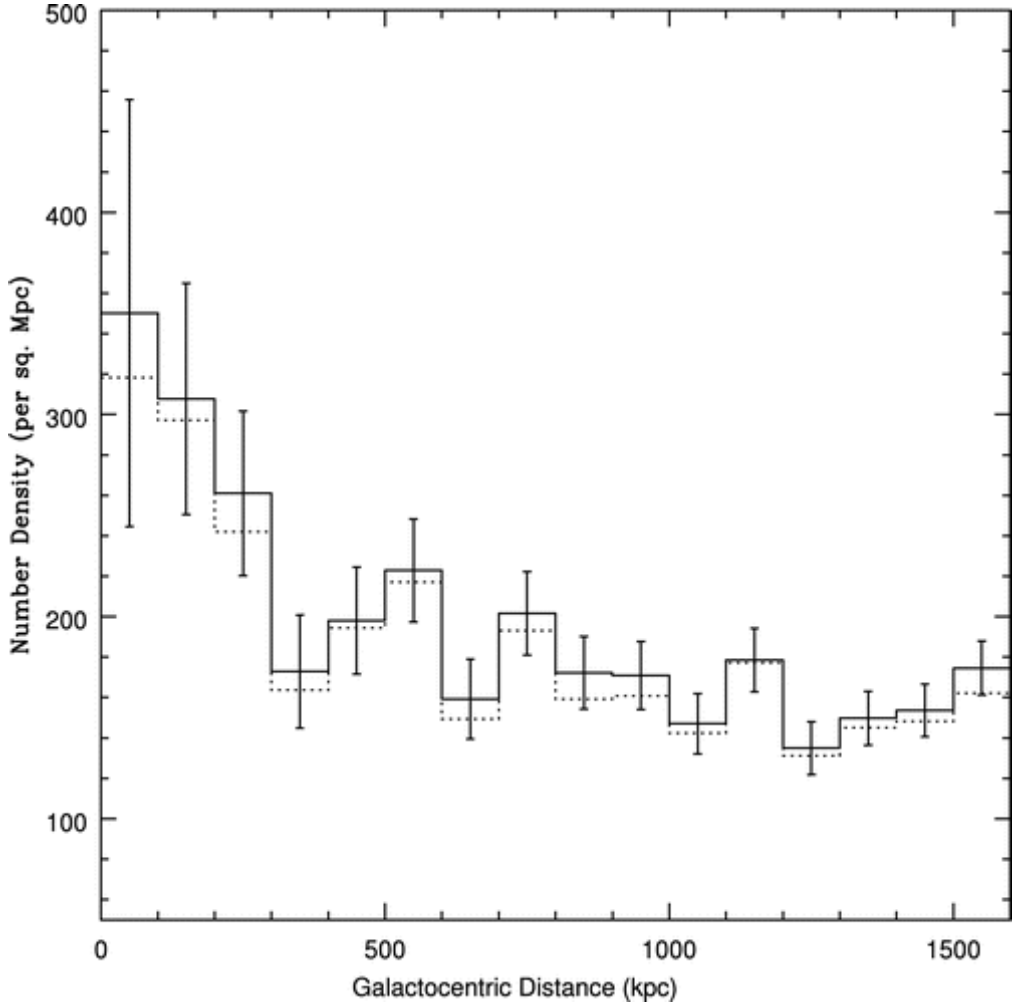
Two of their sample galaxies (NGC 2954 and NGC 7785) are in the Smith et al. survey and show very diverse properties.

NGC 2954 is a weak, (~10^{39}ergs/s) unresolved source whilst NGC 7785 is a powerful (~10^{41}ergs/s) and extended source.

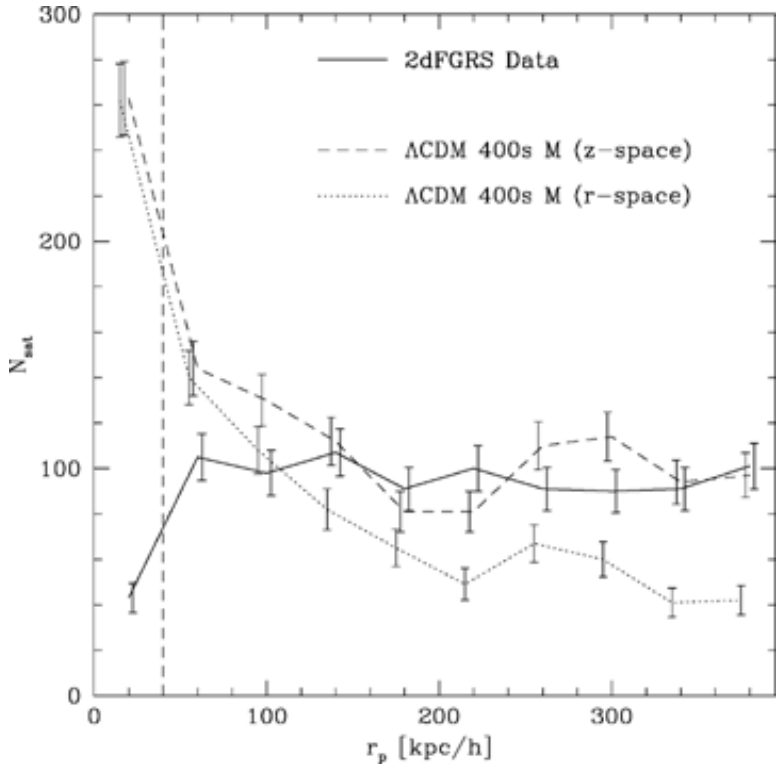
Are the ellipticals surrounded by a large population of much fainter galaxies that are the less-massive members of a remnant group from which the central galaxy formed?

The original study by Smith et al. did find evidence of a population but there were large variations.

NGC 1600 does have a large population of fainter galaxies out to about 1Mpc. Suggestive that this is a ‘fossil group’?



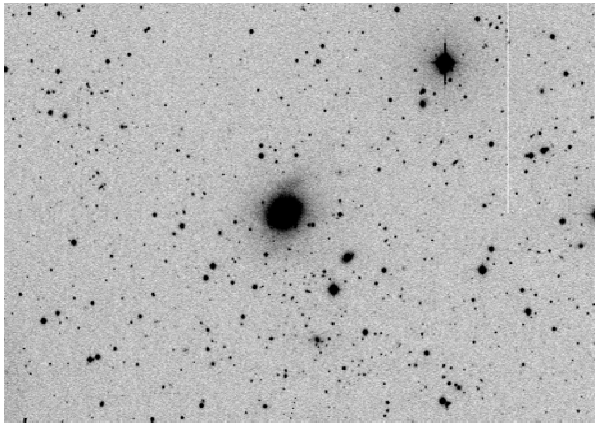
The 2dfGRS analysis showed little evidence of a population of faint galaxies around isolated ellipticals – but only to b~19.4

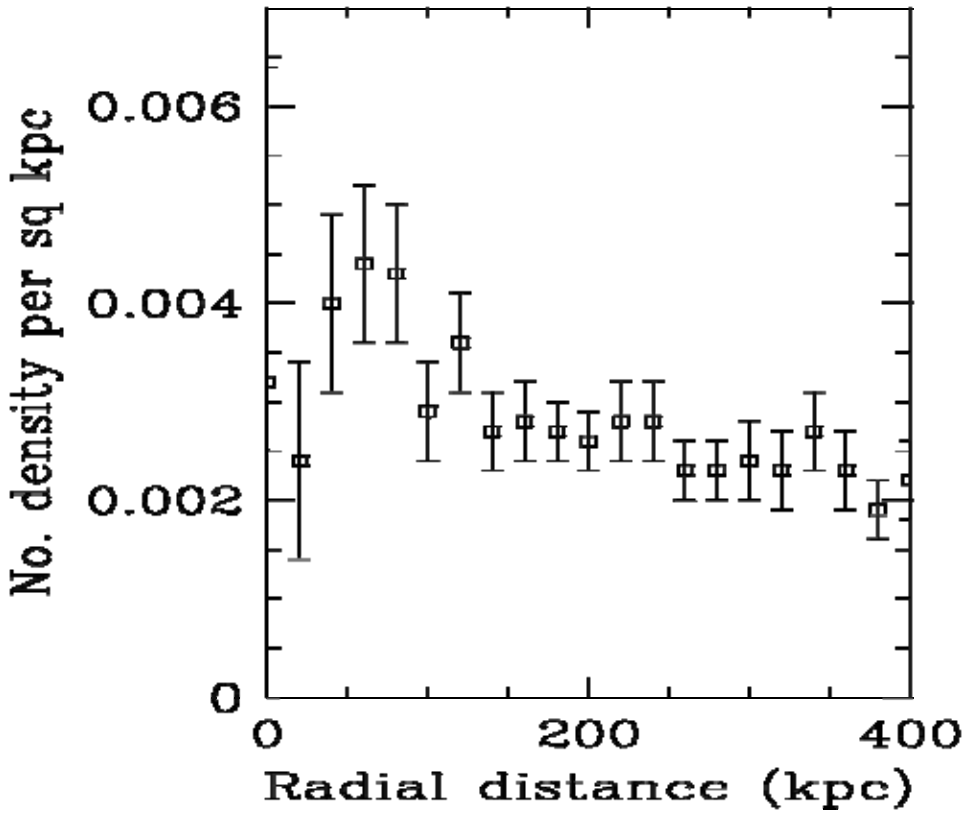


Now started a deep imaging survey of the fields around a sample of field ellipticals to search for this population.

Using the WFC on the INT to create a mosaic around the central galaxy.

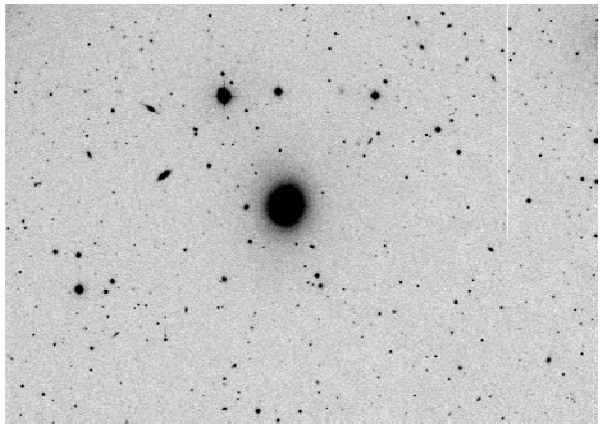
Present here only the first preliminary results to show some tantalizing possibilities:



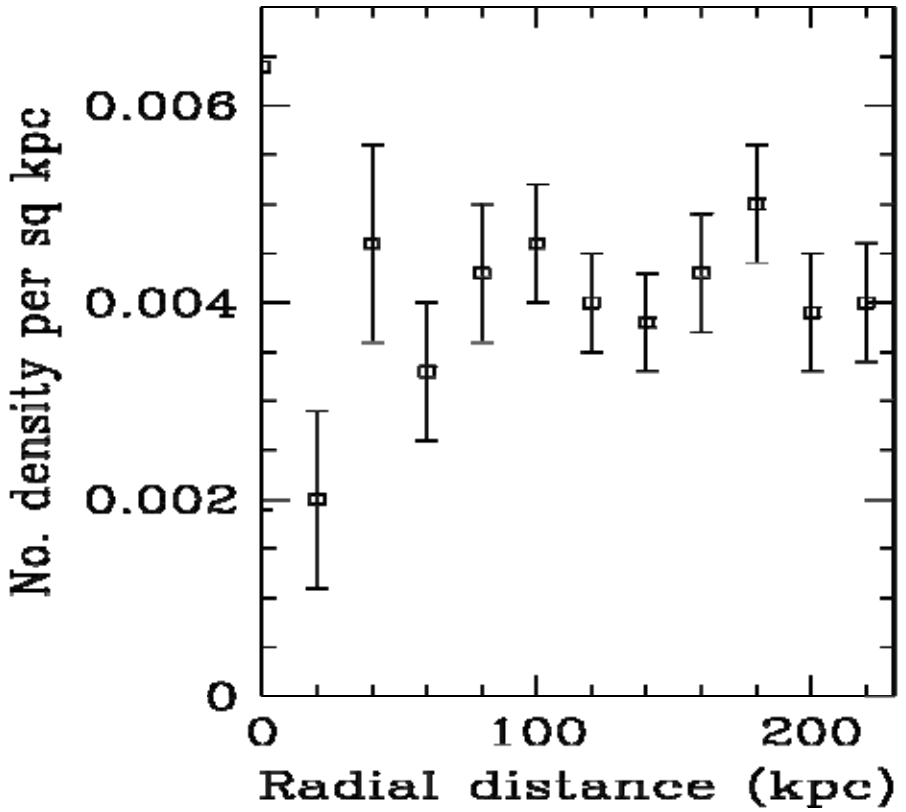


NGC 6363
R=13.2
m-M=35.5
(1arcsec=0.604kpc)
V=8912km/s
M_B=-21.2
Not in AMIGA

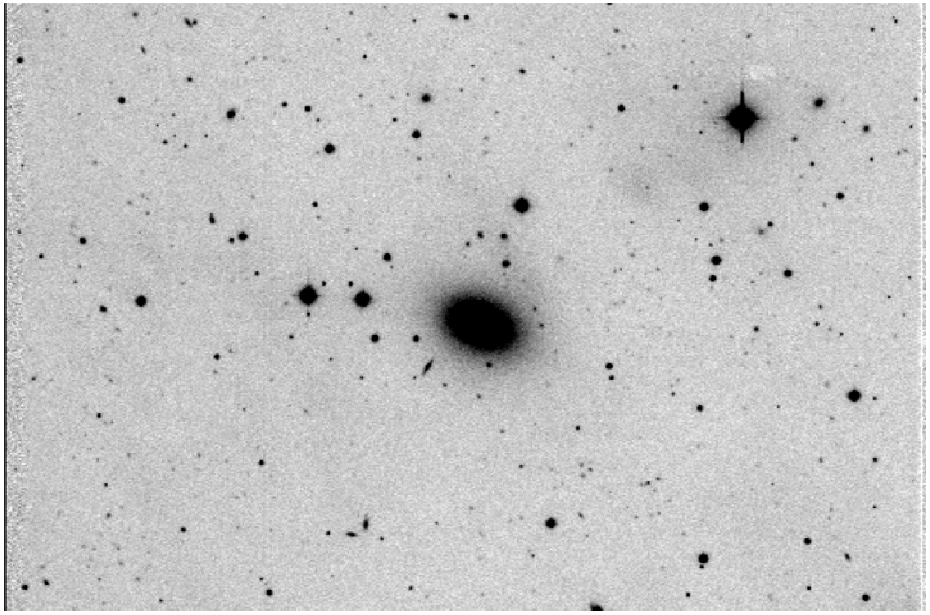
NGC 6363 multicolour INT WFC image



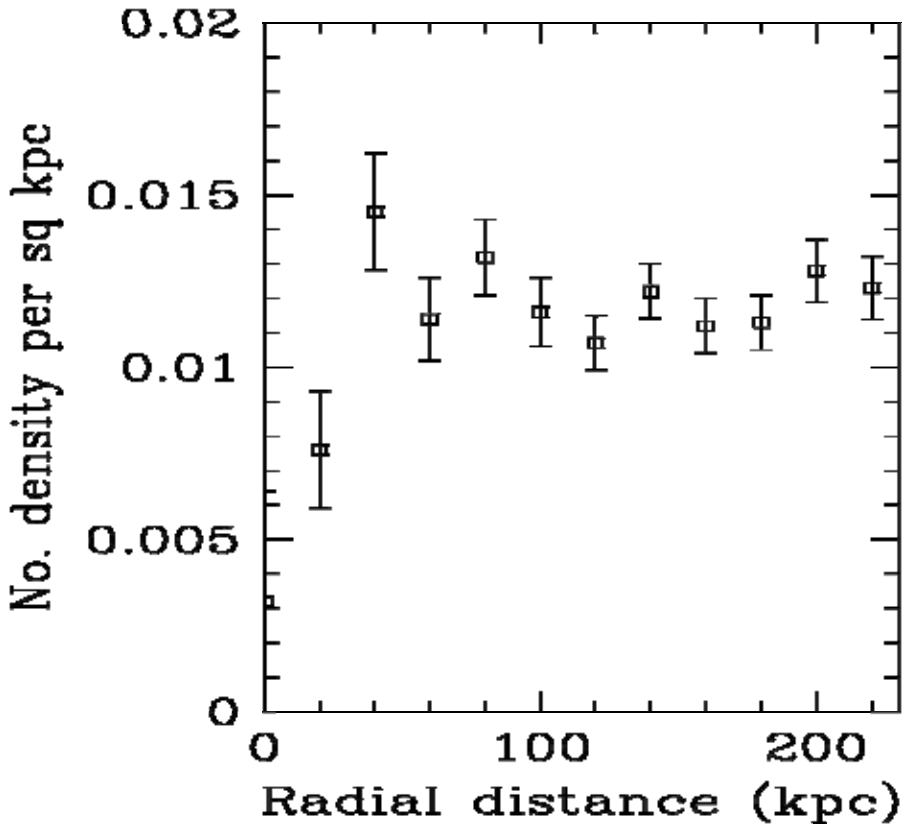
NGC 3017
R=12.82
m-M=34.6
(1arcsec=0.403kpc)
V=6229km/s
M_B=-20.6
Not in AMIGA



NGC 3017 multicolour INT WFC image



NGC 2954
R=12.21
m-M=33.5
(1”=0.204kpc)
V=3821km/s
Unresolved X-ray source
In AMIGA sample
M_B=-20.2



Summary and Conclusions

- Elliptical galaxies in low density regions are rare but do exist
- Their intrinsic properties are somewhat similar to those in groups and clusters, with evidence of more recent star formation
- Their masses are larger than spiral galaxies and, for the brighter galaxies, are similar to that of groups
- The environment of isolated elliptical galaxies varies, with evidence that the presence of faint neighbours can lead to tidal features.
- Isolated elliptical galaxies exist with no large excess of faint neighbours – these may be the fainter ellipticals (and therefore the less massive?)
- Need a large deep imaging survey of a wide range of isolated ellipticals, together with a theoretical interpretation.