The ESO Distant Cluster Survey
EDisCS

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WMAP Map of the Cosmic Microwave Background

Bennett et al 2003
- $>10^5$ near-independent $5\sigma$ temperature measurements
- Gaussian map: PS fit by a CDM model with parameters consistent with other data
- Extrapolation fits the Ly-\(\alpha\) forest power spectrum
  Confirms standard model to scales well below those of clusters and bright galaxies
Evolution of the galaxy population in a Coma-like cluster

- Formation of the galaxies tracked within evolving (sub)halos
- Luminosity and stellar mass are uncertain
- Position and velocity are followed well

Springel et al 2001
Formation histories of cluster ellipticals

- Cluster mass is $7 \times 10^{14} M_\odot/h$
- 104 member ellipticals with $M_B < -18$
- Stars form early
- Most ellipticals assembled early
- Many ellipticals accreted late

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Springel et al 2003
Science Goals for EDisCS

- Obtain a uniform photometric and spectroscopic database for a large and representative sample of galaxy clusters covering the last half of the Hubble time.

- Characterise the sizes, luminosities, morphologies, internal kinematics, star formation and stellar populations of cluster galaxies.

- Compare cluster samples at $z=0.8$, $0.5$ and $0.1$ (SDSS) to establish trends as a function of redshift and cluster properties.

- Compare with high-resolution simulations of galaxy and galaxy cluster formation in a $\Lambda$CDM universe to determine the role of various physical processes (e.g. harassment, stripping, strangulation, cannibalism, merging, induced star-formation, SN/AGN feedback) in establishing the properties of galaxies.
EDisCS Participants

Co-I Team on Proposal 166.A-0162

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C. Halliday (Padova, I)                                      L. Simard (DAO, Canada)
B. Milvang-Jensen (MPE, D)
The EDisCS Strategy

- Select 15 bright candidates with $z_{\text{est}} \sim 0.5$ and 15 with $z_{\text{est}} \sim 0.8$ from the Las Campanas Distant Cluster Survey (130 deg$^2$)
- Image each field in 2 bands for 20min with FORS2 (3 FORS nights)
- Select 10+10 best cluster fields for deep imaging:
  - VRIJK at $z \sim 0.8$,  BVIK at $z \sim 0.5$ (11 FORS + 20 SOFI nights)
- 30min exposure of one FORS2 mask of each field to confirm reality of cluster (1.5 FORS nights)
- 3 or 4 FORS2 masks of each confirmed field at longer exposure to get spectra of representative systems to $I=23$ (20.5 FORS nights)
- Get HST/ACS imaging of 10 most distant fields (80 orbits)
- Get WFI 3-colour imaging of all 20 fields to study large-scale environment of clusters (84 hours of WFI imaging)

LP Allocation: 36 nights on FORS2 + 20 nights on NTT/SOFI
EDisCS Status

● Deep optical imaging is complete for all 20 cluster fields
  -- data are fully reduced, calibrated and combined
  -- photometry and image quality excellent (seeing 0.5 to 0.8 arcsec)
  -- preliminary weak lensing and morphology analysis complete

● Deep NIR imaging almost complete (one final night required)
  -- data through summer 2002 fully reduced, calibrated and combined with the optical (about 60% of total)

● Nineteen nights of FORS2 spectroscopy successfully completed
  -- data through summer 2002 fully reduced (about 38% of total)
  -- data quality good -- fully consistent with expected performance
  -- three nights still required to complete programme (14% of total)

● HST/ACS data currently being taken, first frames now reduced

● About 60% of WFI data taken and already reduced

● Large suite of high resolution simulations completed
High redshift but no detected lensing

\[ \sigma_{\text{clus}} = 453 \pm 41 \text{ km/s} \]

from measured redshifts
High redshift with strong lensing

\[ \sigma_{\text{clus}} = 1034 \pm 46 \]

from measured redshifts
Interm. redshift with strong lensing

\[ \sigma_{\text{clus}} = 1160 \pm 139 \]

from measured redshifts
Interm. redshift with weak lensing

Insufficient spectra for a robust $\sigma_{\text{clus}}$
Using Photo-z’s to reject foreground

- We use two independent photo-z codes, Hyper-z and Rudnick's thesis code.
- Each code is optimised using our 2002 spectra.
- For each code and each galaxy, we calculate the probability its redshift is in \( z_{clus} \pm 0.1 \).
- If either code gives \( P < 0.25 \) then we reject.
- This rejects half of the confirmed field while it keeps 90% of members.

Pello, Rudnick, De Lucia
Field-corrected cluster luminosity functions are well fit by the shape of the 2dF cluster LF both at \( z = 0.5 \) and \( z = 0.75 \).

Their characteristic \( L_\star \) are brighter at rest B by more than a magnitude.

This brightening is larger than expected from the aging of stars as inferred from fundamental plane studies ( \(-0.57 \) at \( z = 0.5 \) and \(-0.86 \) at \( z = 0.75 \)).
Field corrected C-M diagrams for typical clusters

'Morphologies' are B/T values derived from the 2D image fitting code GIM2D

Clusters show a wide range of richness

Strength of red sequence and of blue 'B-O' population is variable

Many disky galaxies on the red sequence
HST/ACS F814W image of cl1037-1243 at z=0.58, Dalcanton, Desai
Cluster images: observation vs simulation

- Photo-z rejection used on real data
- Only galaxies with $I < 25$ used either in real or in simulated clusters
- Galaxy formation assumptions in simulations are as in Springel et al (2001)
Cluster Density Profiles

$0.7 < z < 0.8, \quad I < 24$

- Galaxies rejected by the photo-z's are not concentrated to cluster centre
- Photo-z rejection gives enhances contrast by a factor of about 5
- Mean cluster profile is detected out to 1.5 Mpc
- Blue galaxies are much less concentrated to the cluster centre than red ones
EDisCS Spectra

Halliday, Poggianti

- FORS2 spectra are of very high quality
- Redshifts can be measured to $I \sim 23$
- Line indices can be measured to $I \sim 22.5$
- Velocity dispersions can be measured accurately to $I \sim 21.5$
Fraction of emission line galaxies in FORS2 field correlates strongly with cluster velocity dispersion.
Velocity dispersion measurements

Saglia

Velocity dispersions with 15% uncertainty at $I \sim 21.5$
Milvang-Jensen
Characteristic sizes and rotation speeds for disk systems from combined HST/VLT data
Possible to I $\sim$ 22

Emission line kinematics

FOR2

$V_{\text{rot}} \sin i = 270.8^{+8.0}_{-12.7}$ km s$^{-1}$
$r_d = 0.84^{+0.08}_{-0.06}$
If our final 3 spectroscopic nights are as successful as the previous 19, we expect our final EDisCS spectroscopic sample to contain:

<table>
<thead>
<tr>
<th></th>
<th>Intermediate z fields</th>
<th>High z fields</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectra</td>
<td>1000</td>
<td>1300</td>
<td>2300</td>
</tr>
<tr>
<td>Redshifts</td>
<td>900</td>
<td>1200</td>
<td>2100</td>
</tr>
<tr>
<td>Cluster members</td>
<td>400</td>
<td>420</td>
<td>820</td>
</tr>
<tr>
<td>Accurate line indices</td>
<td>100 (+ 150 field)</td>
<td>150 (+ 250 field)</td>
<td>650</td>
</tr>
<tr>
<td>velocity dispersions</td>
<td>75 (+ 70 field)</td>
<td>110 (+ 70 field)</td>
<td>325</td>
</tr>
<tr>
<td>rotation curves</td>
<td>60 (+ 100 field)</td>
<td>80 (+ 130 field)</td>
<td>370</td>
</tr>
</tbody>
</table>

Accurate line indices for fainter galaxies will be obtained by stacking spectra for similar systems.
Comments on Large Programmes

- EDisCS is only possible as a Large Programme and at ESO
  -- availability of full instrument suite (FORS2, SOFI, WFI)
  -- commitment to full time needed (incl. weather replacement)
  -- availability of service mode
  -- flexibility of scheduling
  -- high quality and reliability of typical nights at Paranal

- ESOs commitment to complete Large Programmes in a timely fashion helps to get time from other facilities
  -- EDisCS was the only large cluster programme to get time in the first round of HST/ACS allocations

- Large Programmes provide an opportunity to federate and develop European expertise in specific areas. This requires the internal atmosphere to be open and inclusive, rather than competitive