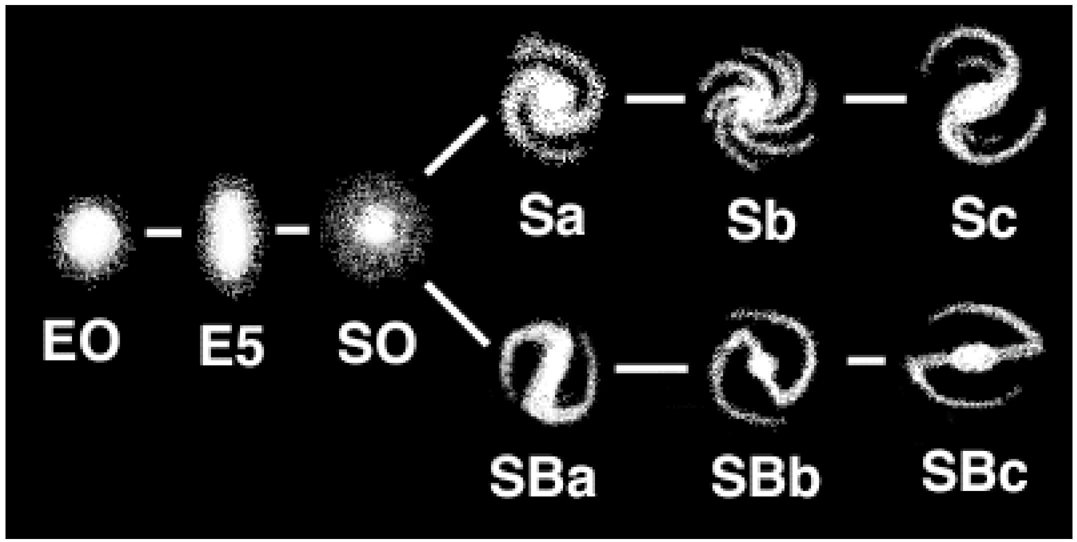
Encounters at the Edge of a Cluster

Environment's Effect on Galaxy Evolution

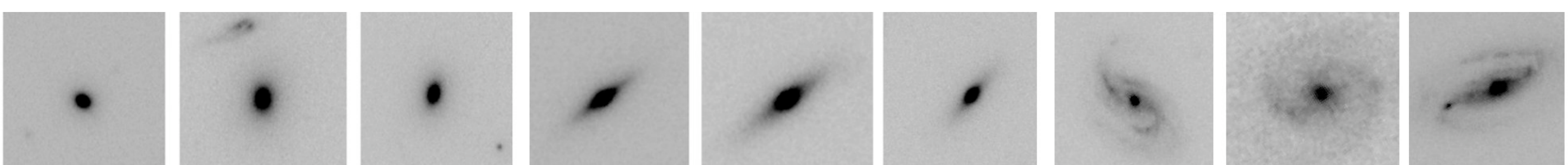
Dennis W. Just
(Steward Observatory)

Morphologies

Early-type Late-type



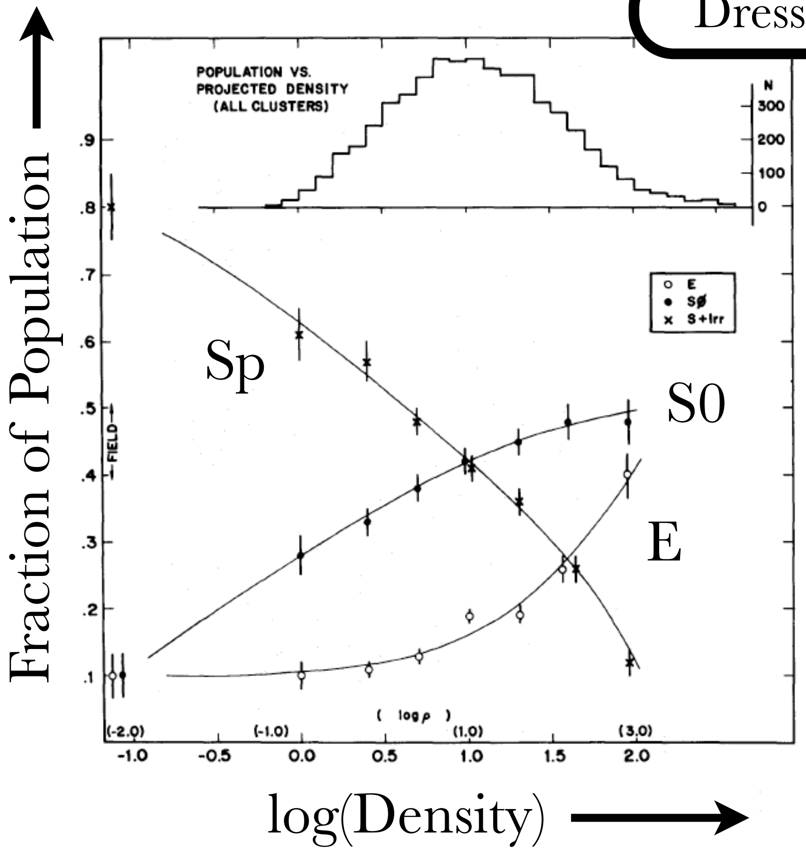
Ellipticals S0s Spirals

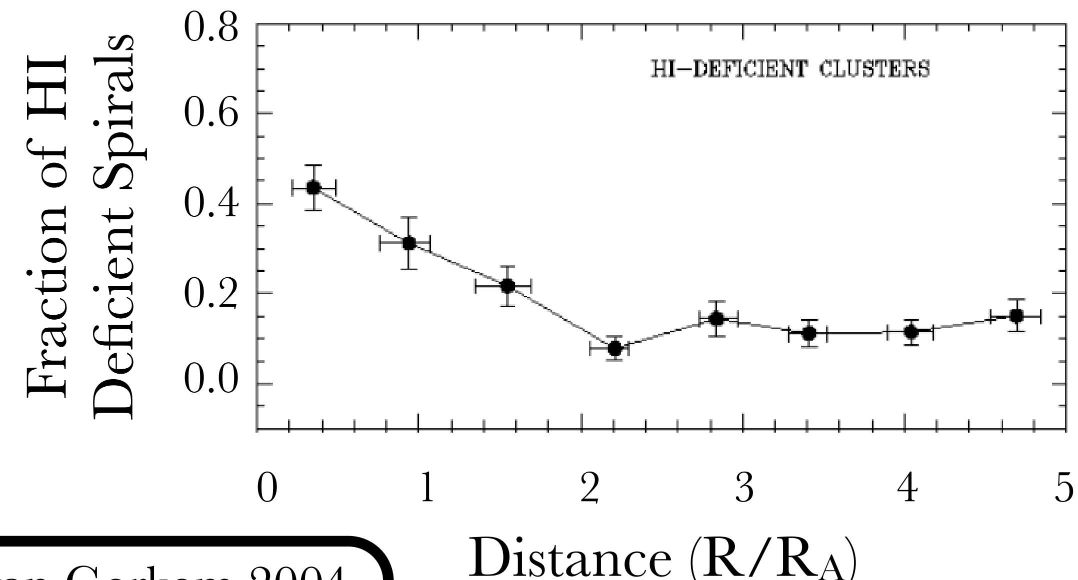


HST/ACS

Galaxies and Environment

Dressler 1980

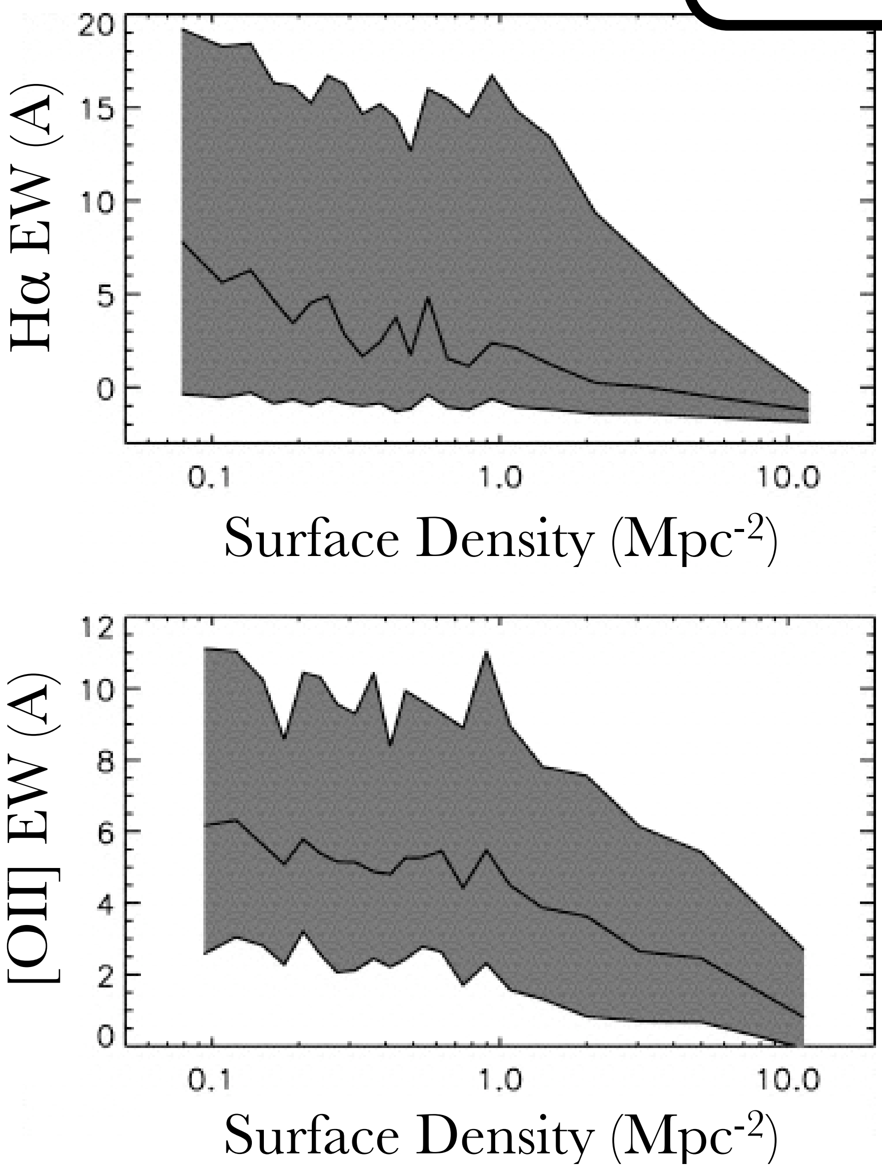


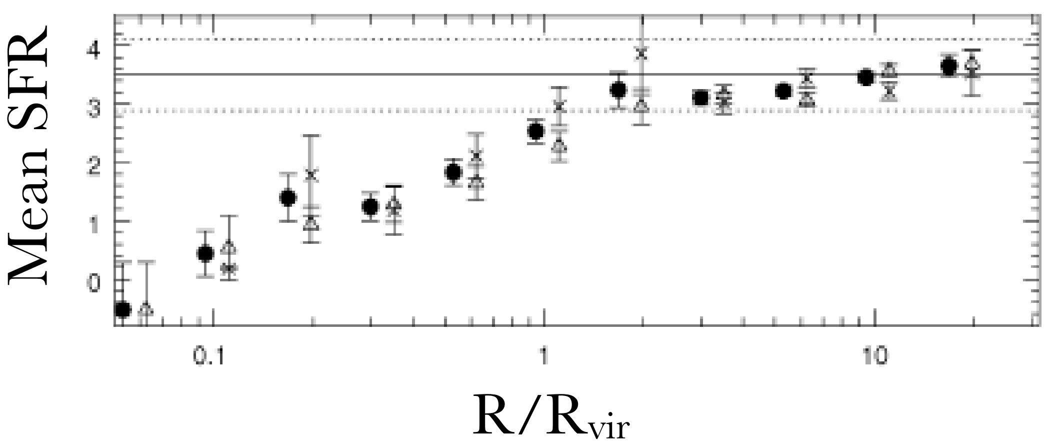


van Gorkom 2004

Galaxies and Environment

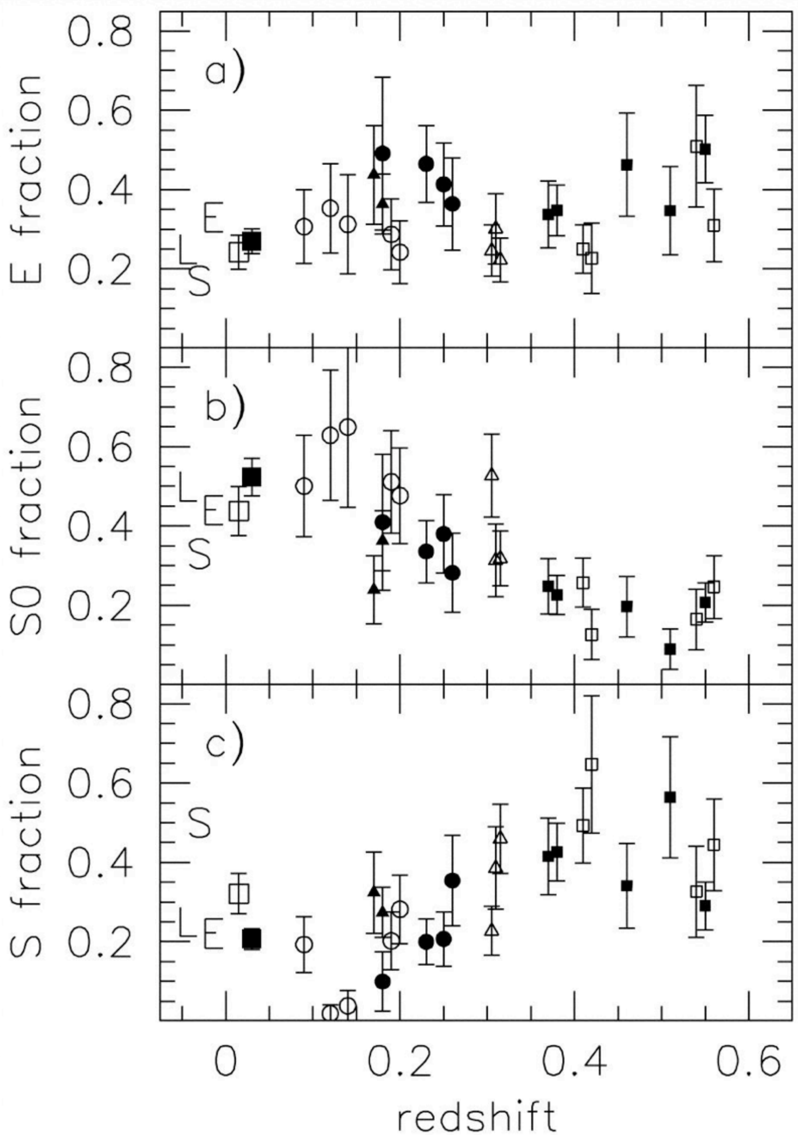
Gomez et al. 2003



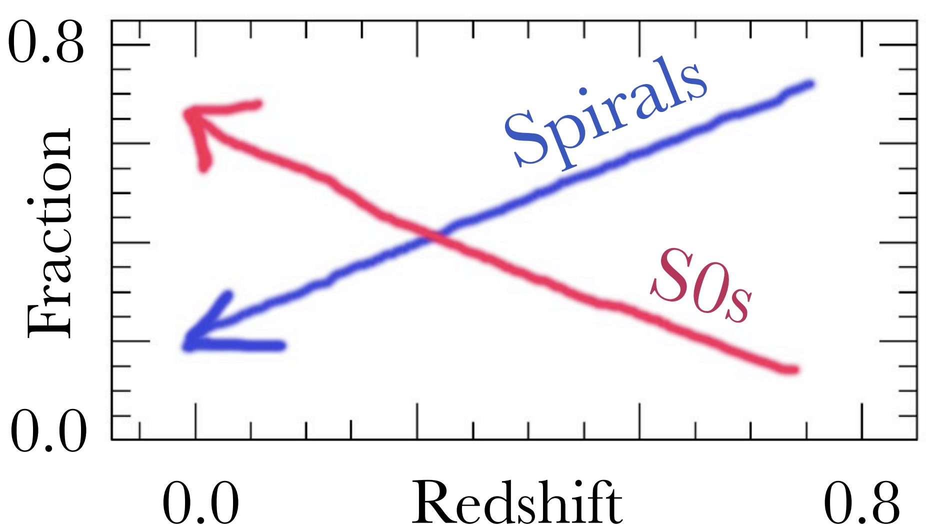


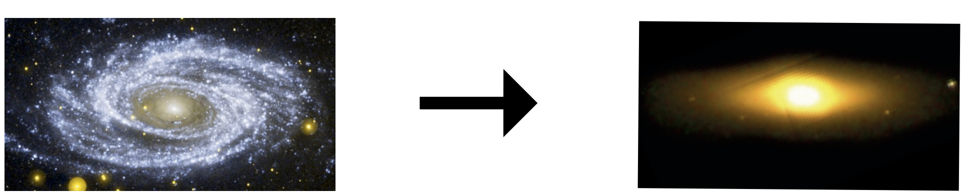
Lewis et al. 2002

S0 Formation: Evidence



Fasano et al. 2000, Dressler et al. 1997





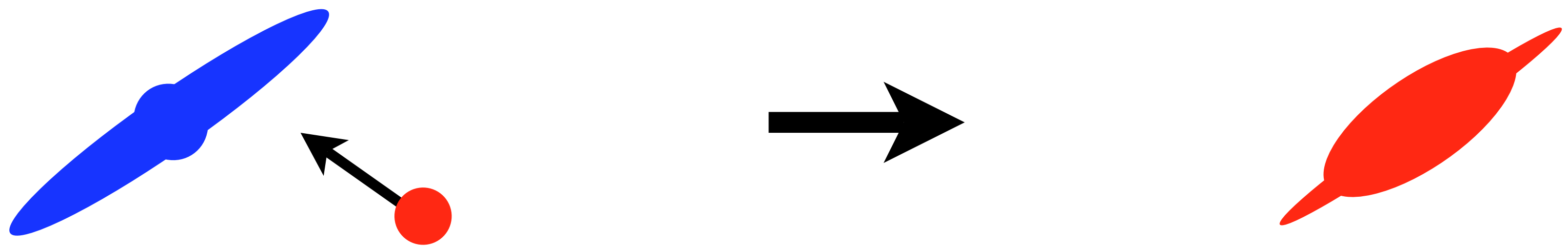
Insight on Galaxy Evolution

→

- Process of going from a spiral to an S0 involves:
    - Halting star formation
    - Removing gas supply
    - Creating a significant spheroidal component

The Litany of Violence

- There are many different ways to form an S0:
  - Minor Mergers — e.g., Toomre & Toomre 1972, Icke 1985
  - Ram pressure stripping
  - Strangulation
  - Tidal Interactions
  - Harassment



The Litany of Violence

- There are many different ways to form an S0:
  - Minor Mergers
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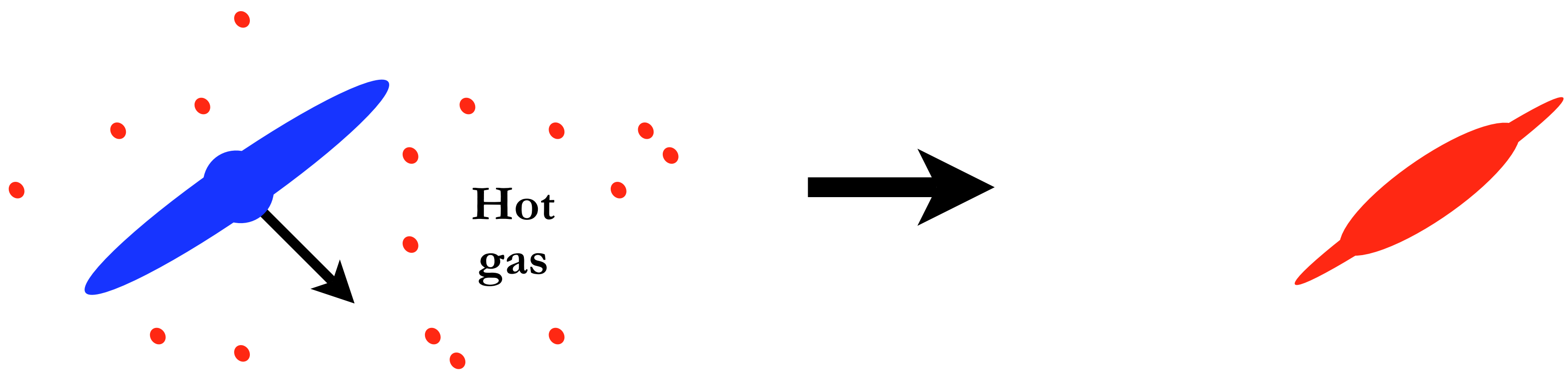
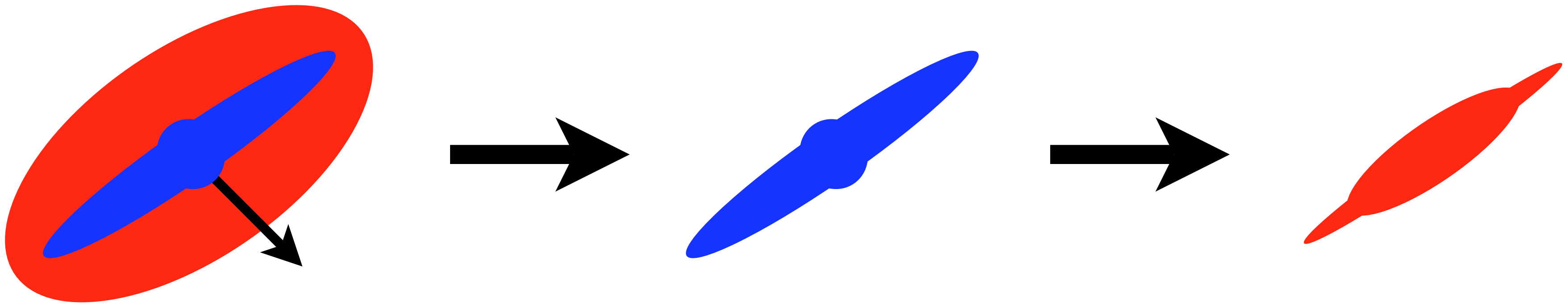


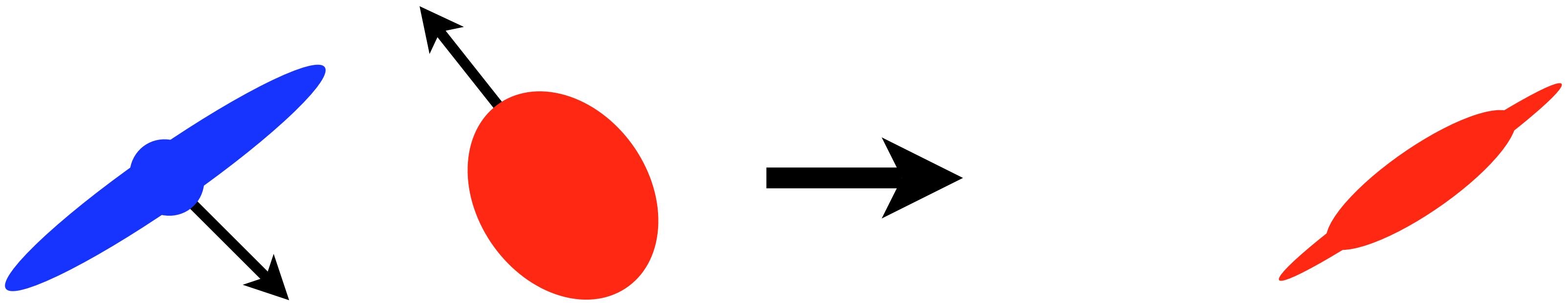
The Litany of Violence

- There are many different ways to form an S0:
  - Minor Mergers
  - Ram pressure stripping
  - Strangulation — e.g., Larson et al. 1980, Bekki et al. 2002
  - Tidal Interactions
  - Harassment



The Litany of Violence

- There are many different ways to form an S0:
    - Minor Mergers
    - Ram pressure stripping
    - Strangulation
    - Tidal Interactions   e.g., Fujita 1998
    - Harassment



The Litany of Violence

- There are many different ways to form an S0:
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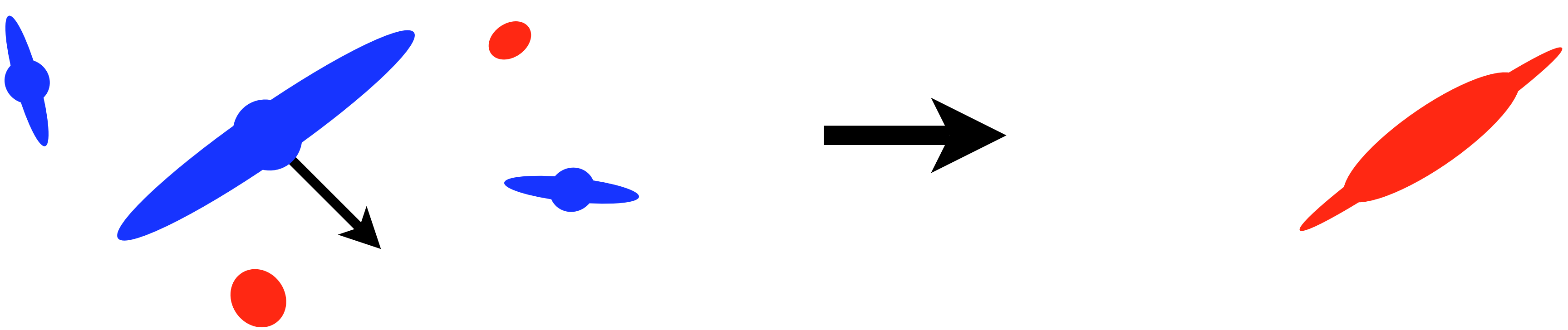
  - Harassment

e.g., Richstone 1976, Moore et al. 1998



The Litany of Violence

- There are many different ways to form an S0:
    - Minor Mergers
    - Ram pressure stripping
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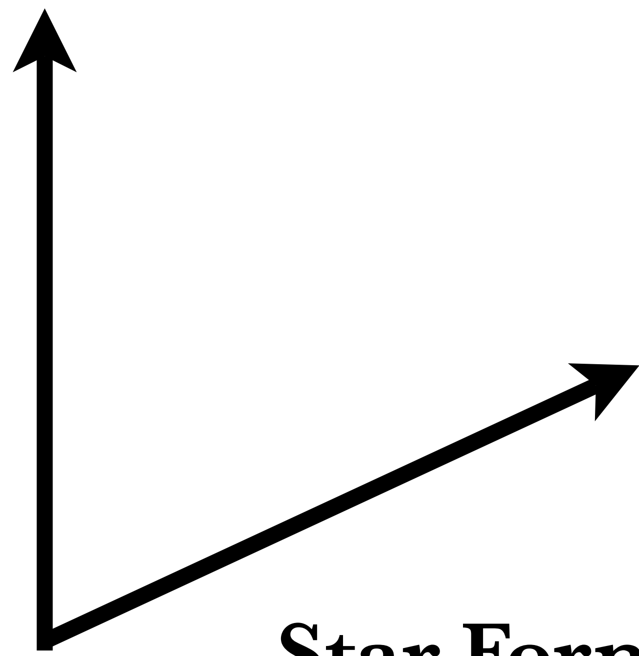
    - Tidal Interactions
    - Harassment

- What can we use to distinguish among them, and identify which process or processes are primarily responsible S0 formation?

S0 Formation Scenarios

Environment

- Cluster?
- Infalling region?
- Isolated groups?



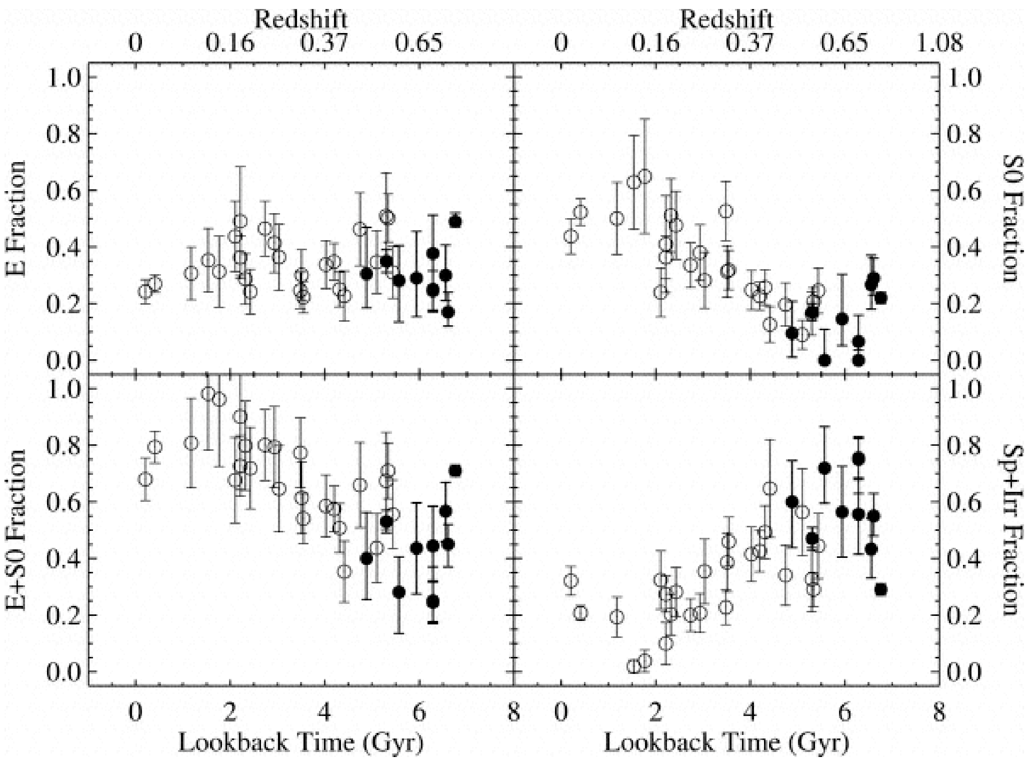
Star Formation History

- Rapid truncation?
- Gradual decline?

Evolution of the S0 Fraction vs. Environment

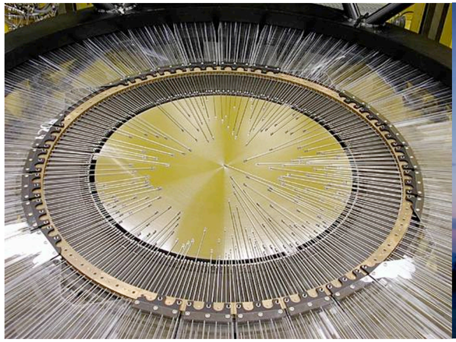
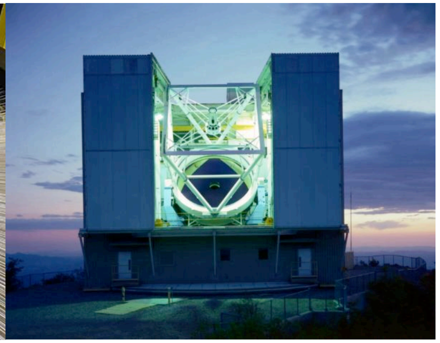
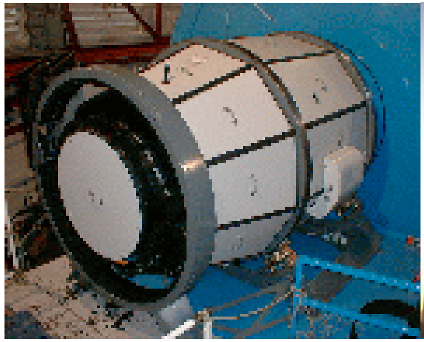
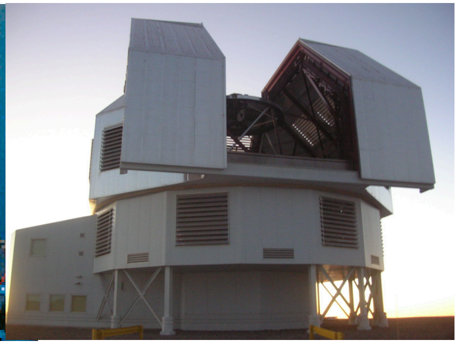
w/ D. Zaritsky, D.J. Sand, V. Desai, and G. Rudnick

Evolution in the S0 Fraction

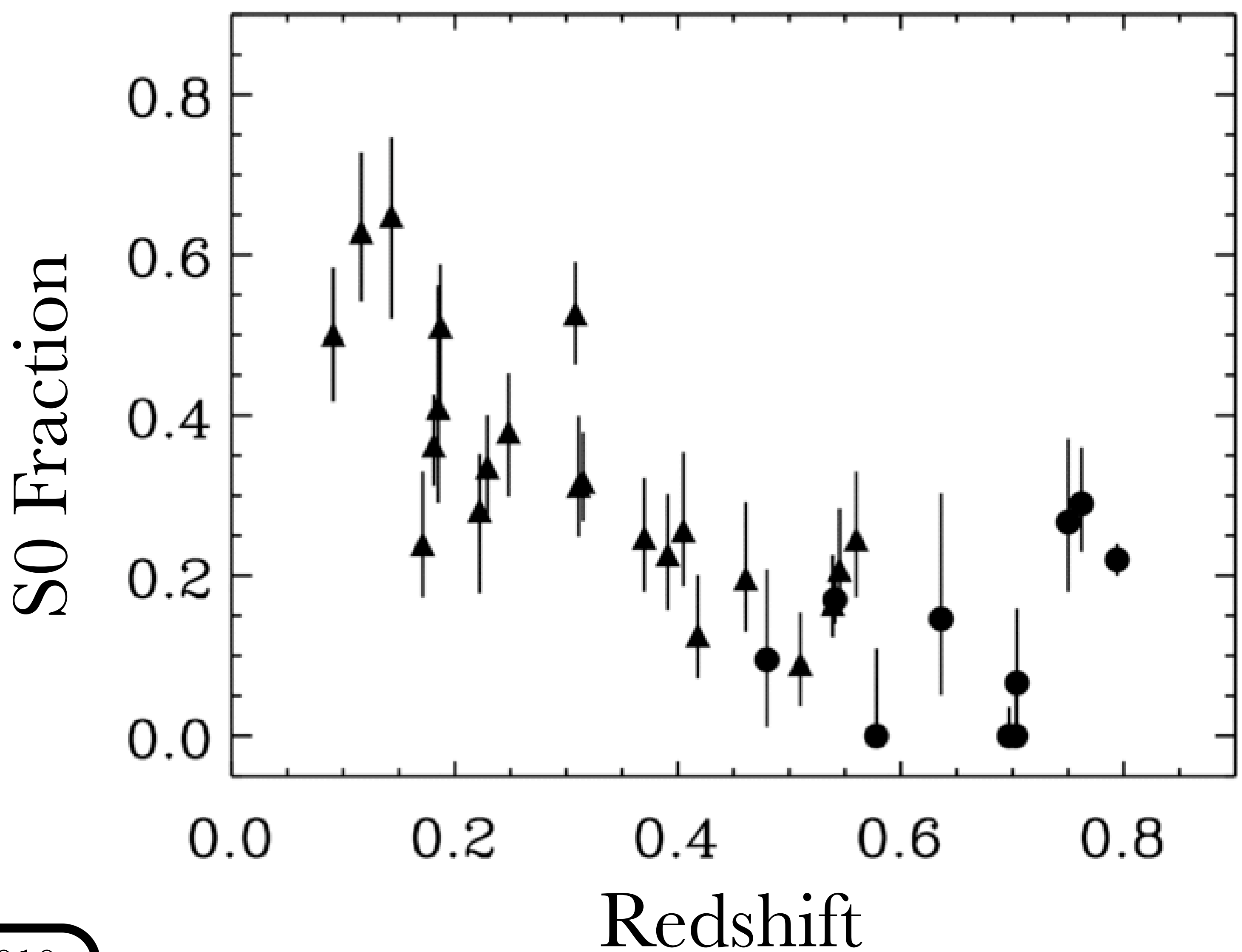


Desai et al. 2007

- Desai et al. (2007) added 10 z~0.5-0.8 clusters (EDisCS)
- Used Hectospec and IMACS to measure velocity dispersions (σ)

Driven by Lower-σ Clusters



Just et al. 2010

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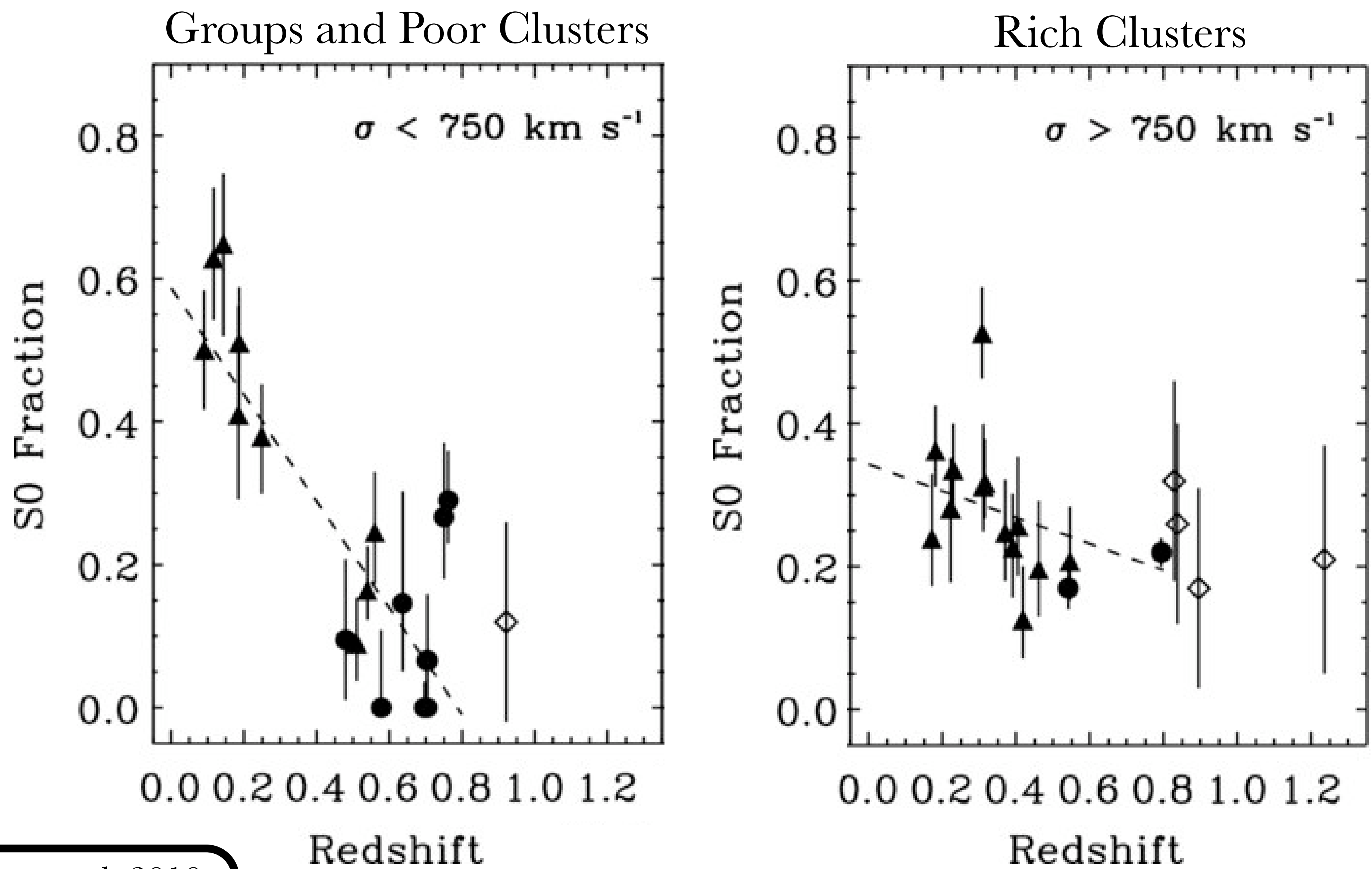


Just et al. 2010

Super Group 1120

w/ D. Zaritsky, K.V. Tran, A. Gonzalez, S. Kautsch, and J. Moustakas

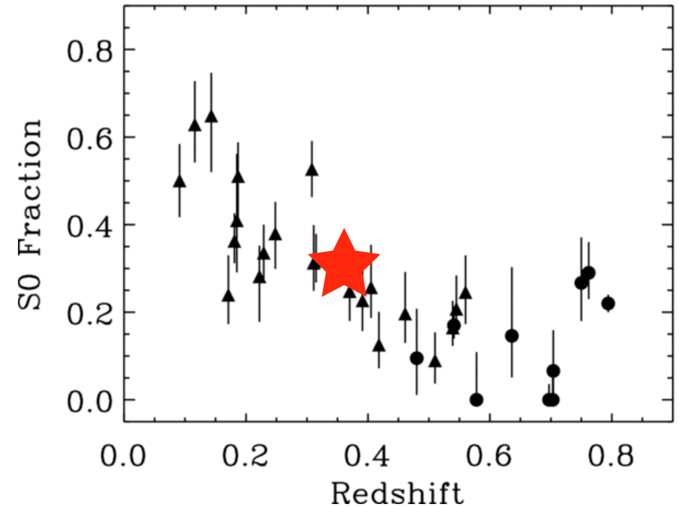
SG1120

- 4 gravitationally-bound groups at z~0.37
- X-ray detected

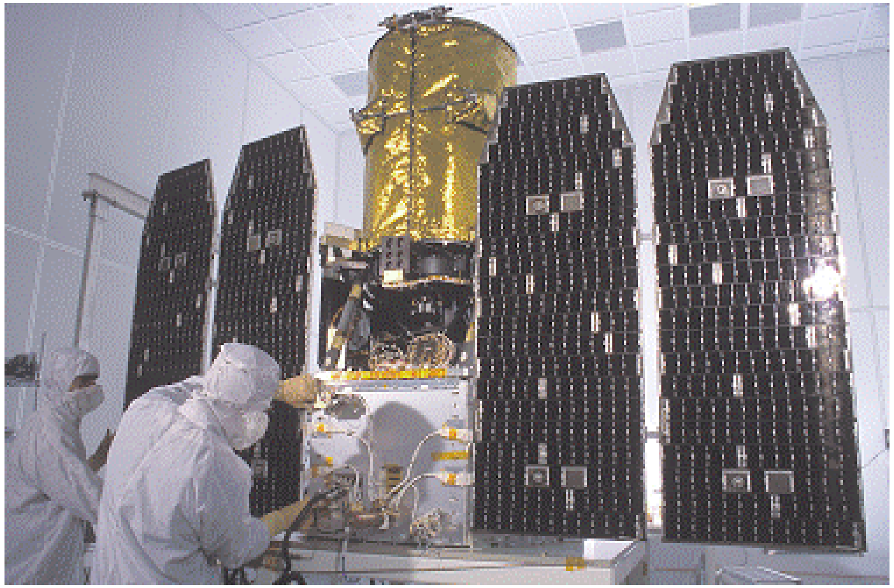
Gonzalez et al. 2005

- Velocity dispersions ~ 300-500 km s^{-1}
- Will form ~ Coma-sized cluster by z=0
- High S0 fraction (~30%)

Kautsch et al. 2008



Search for RSF

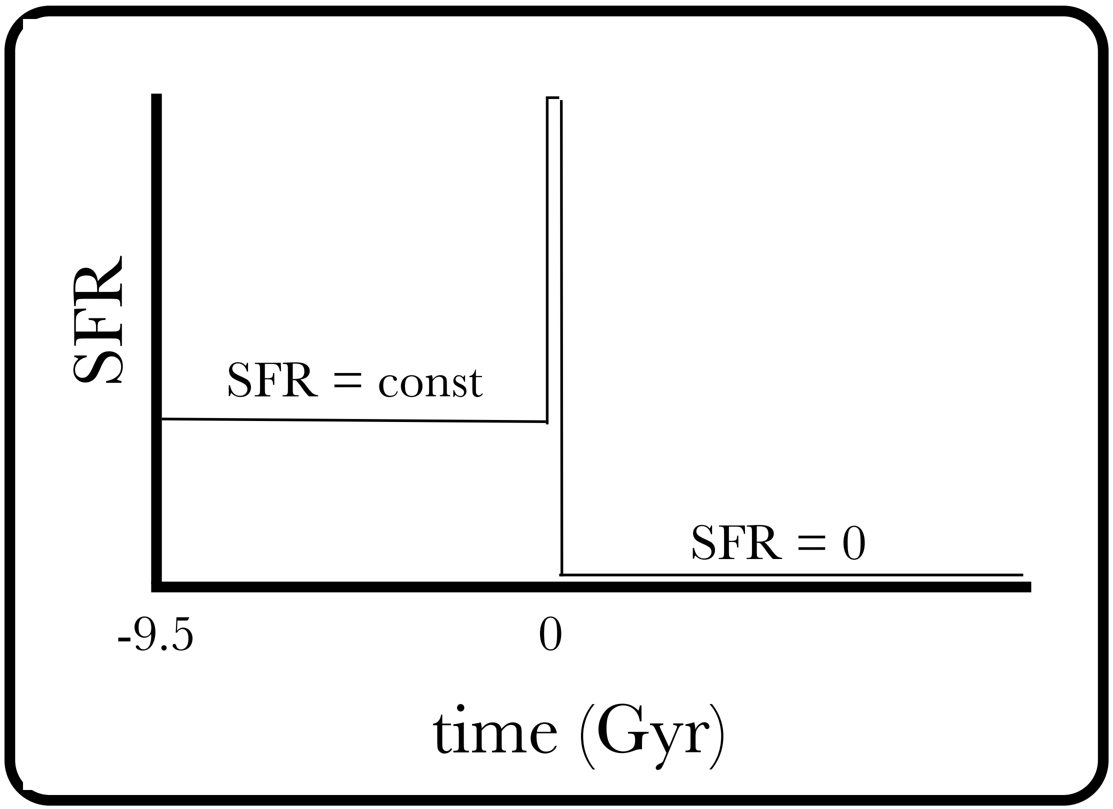


- GALEX: NUV imaging
- S0s not detected
- $<0.01\ M_{sol}\ yr^{-1}$ (Kennicutt 1998)
- MIPS limits weaker, but also not detected

Evidently, not only are the S0s morphologically in place, but their stars are "in place" as well.

Modeling the SFH: Results

- PEGASE Stellar Pop. Code (Fioc & Rocca-Volmerange 1999)



- Burst strengths from 0 to 45% of final stellar mass

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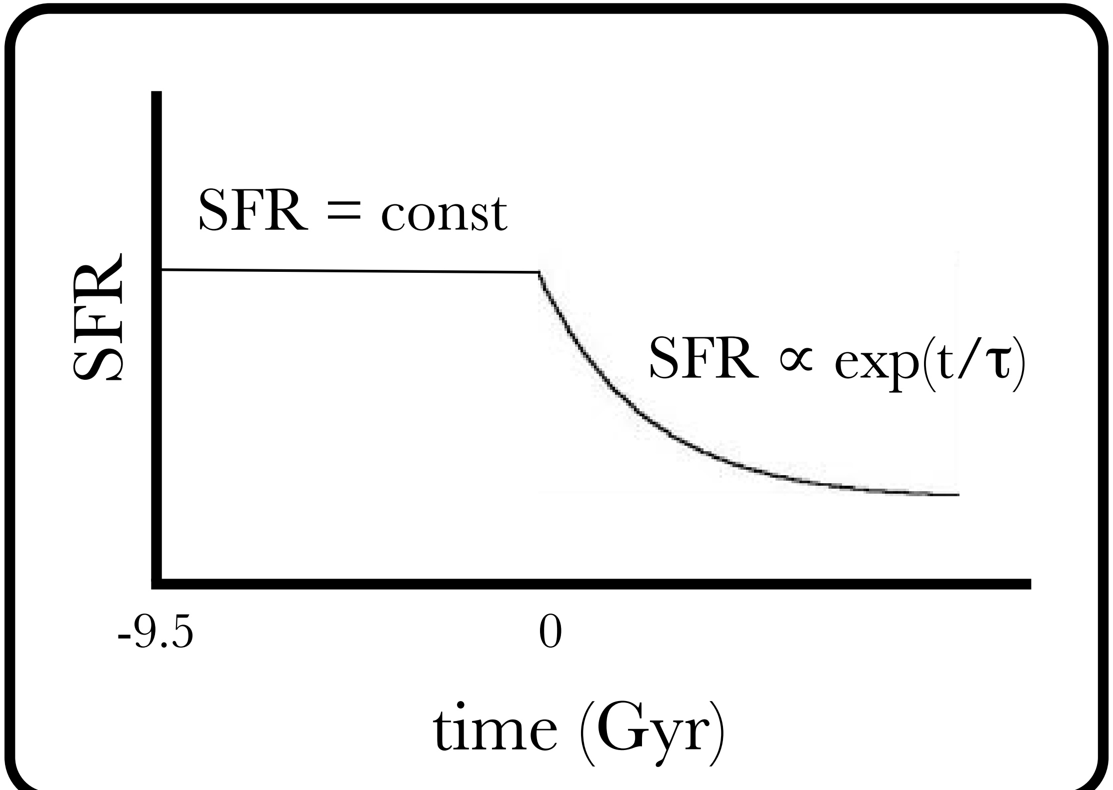
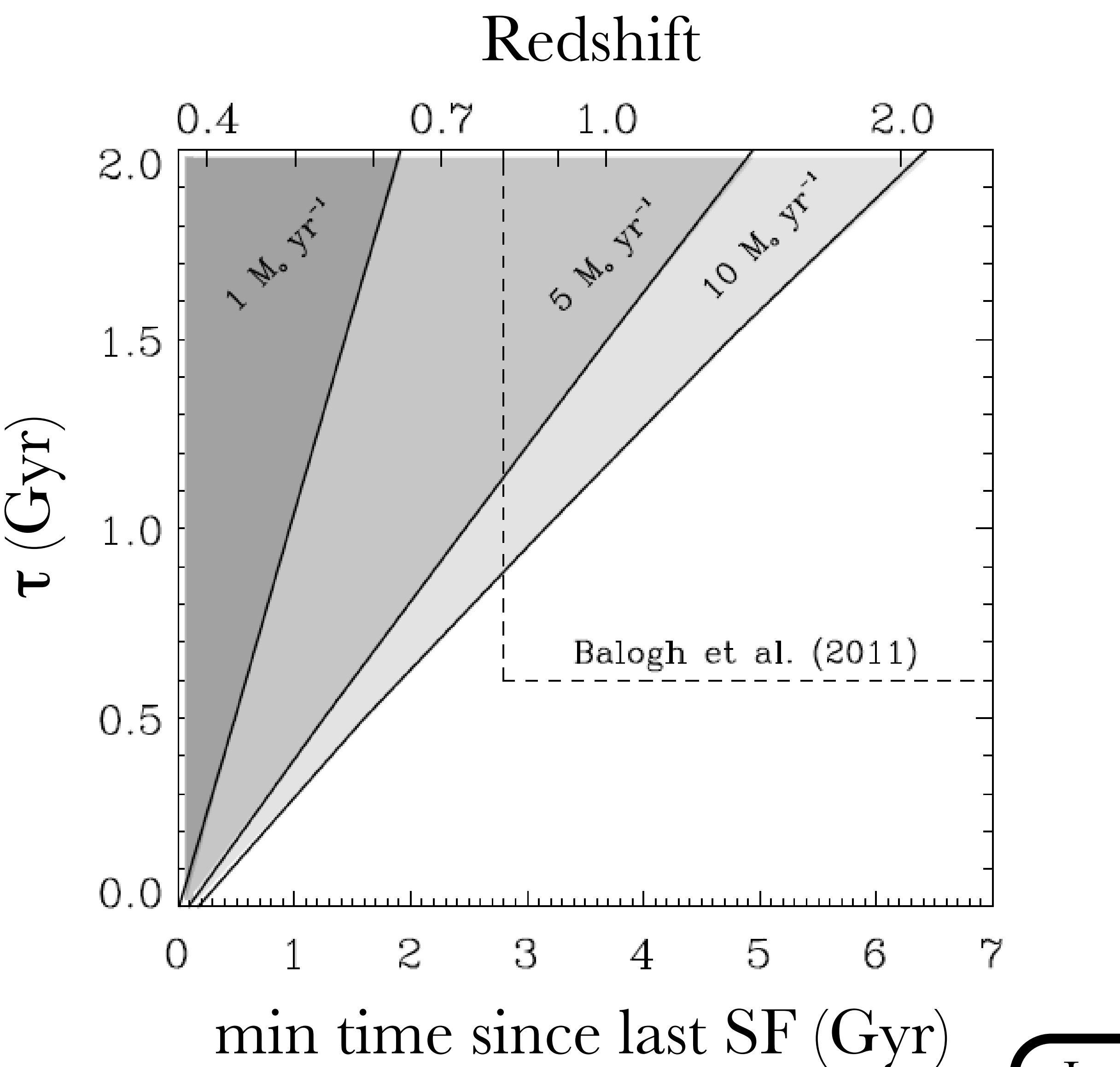


- Burst strengths from 0 to 45% of final stellar mass
- Exponential time scales ranging from $\tau = 0$ to 2 Gyr
- $\log(M_\star) = 10 - 11$

- Measure time for NUV to drop below our limit

Gradually Declining SFH's



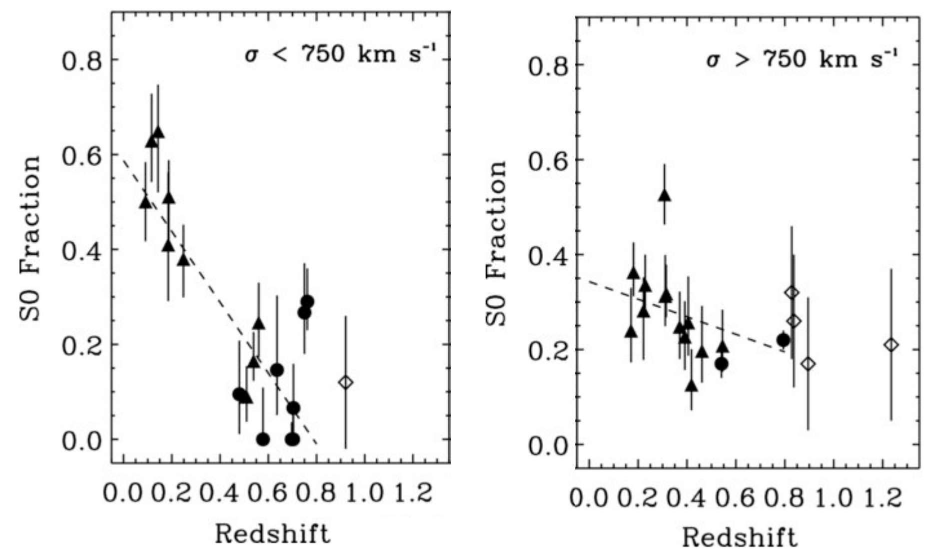
Just et al. 2011a

Where the action is...

- It appears the cores of clusters are not the site of S0 formation:
  - Groups have high S0 fractions (e.g., Postman & Gellar 1984, Kautsch et al. 2008, Wilman et al. 2009)
  - Star formation truncation seen at intermediate densities (Lewis et al. 2002, Gomez et al. 2003)
  - Spirals transforming in infalling groups (Moran et al. 2007)
  - f_{S0}-z trend driven by less-massive systems (Just et al. 2010)
  - SG1120's S0s have stellar pop's in place (Just et al. 2011a)

... and what we have learned.

e.g., Just et al. 2010



<u>Cluster-centric</u>

Ram Pressure Stripping
Harassment

<u>Lower-density</u>

Minor Mergers
Tidal Interactions

Strangulation/Starvation

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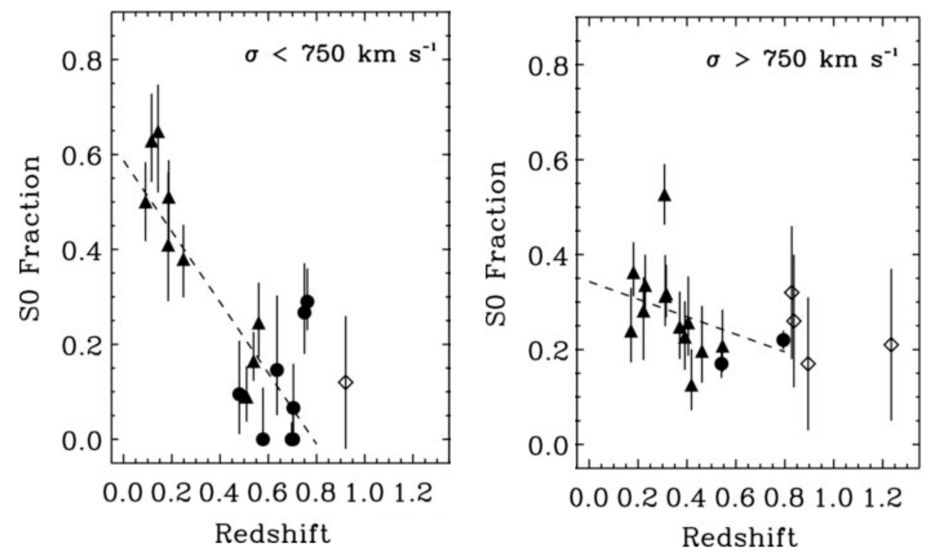
e.g., Just et al. 2010



Cluster-centric

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Strangulation/Starvation

LDP Observations of z~0.4-0.8 EDisCS Clusters

w/ D. Zaritsky, G. Rudnick, J. Moustakas, R. Cool, F. Bian,
and the EDisCS Team

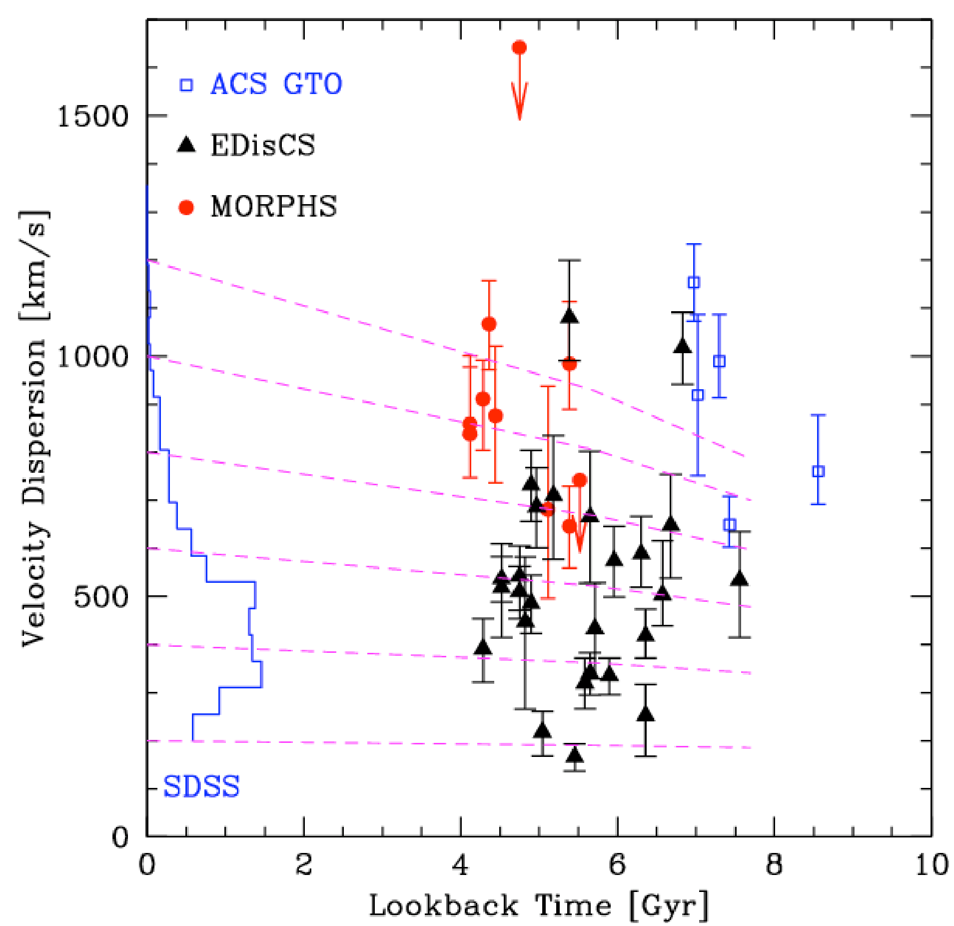
ESO Distant Cluster Survey

PI: Simon White

- 20 cluster fields
- $0.4 < z < 0.8$
- Well-studied cores

imaging:
VLT/FORS2
HST
NTT/SOFI
MIPS

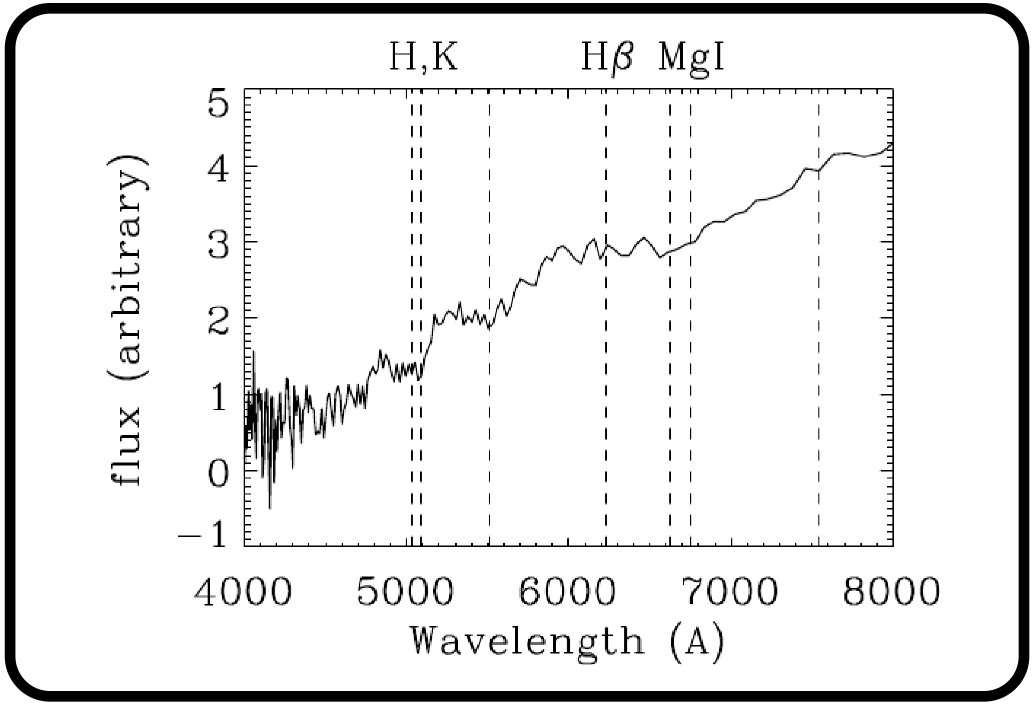
spectra:
VLT/FORS2



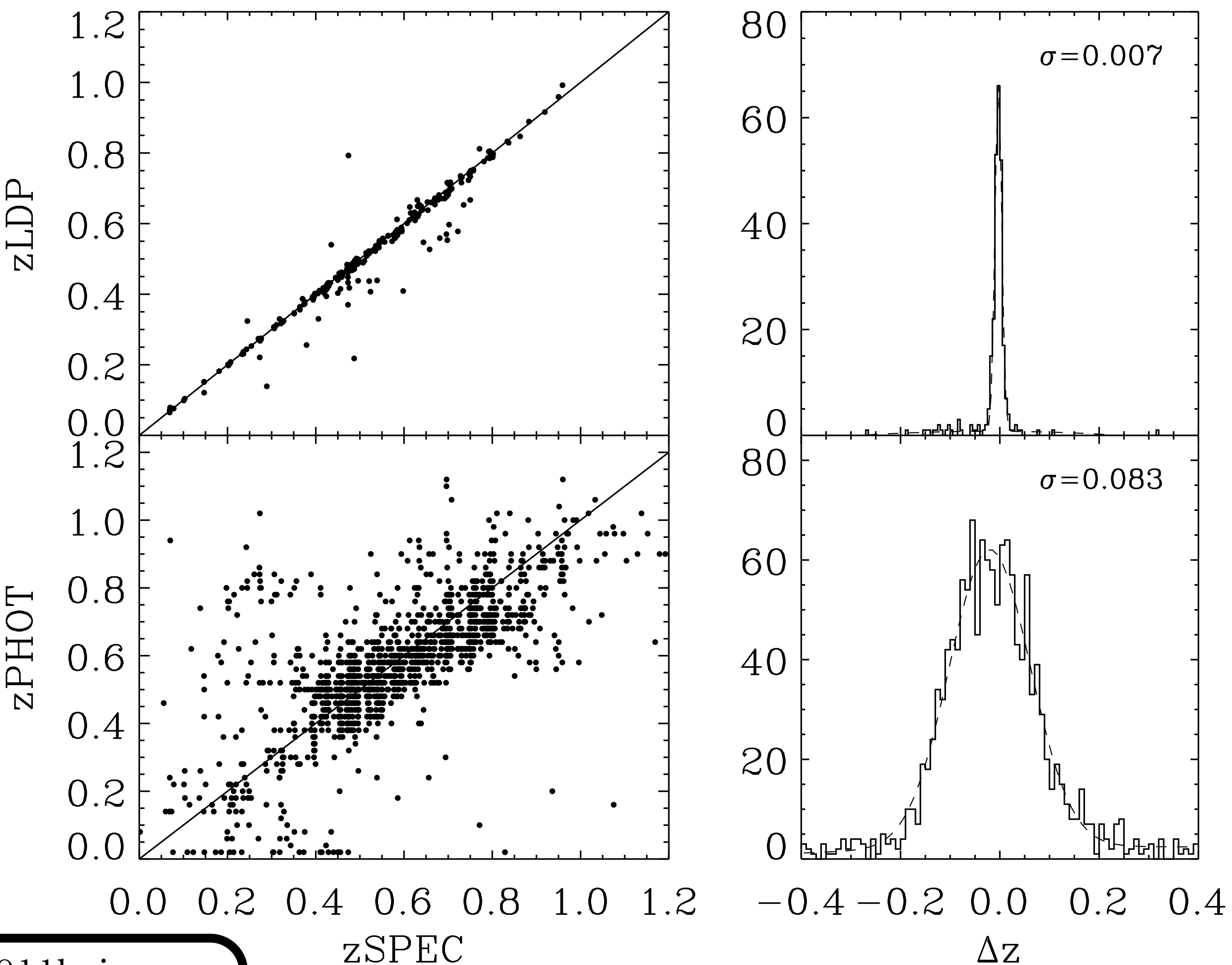
Milvang-Jensen et al. 2008

Low Dispersion Prism (LDP)

- Installed on IMACS (f/2)
- Low resolution (R~40) still better than ~5-band photometric redshifts
- ~2000 slits per mask
- Remove enough interlopers to isolate the infall region

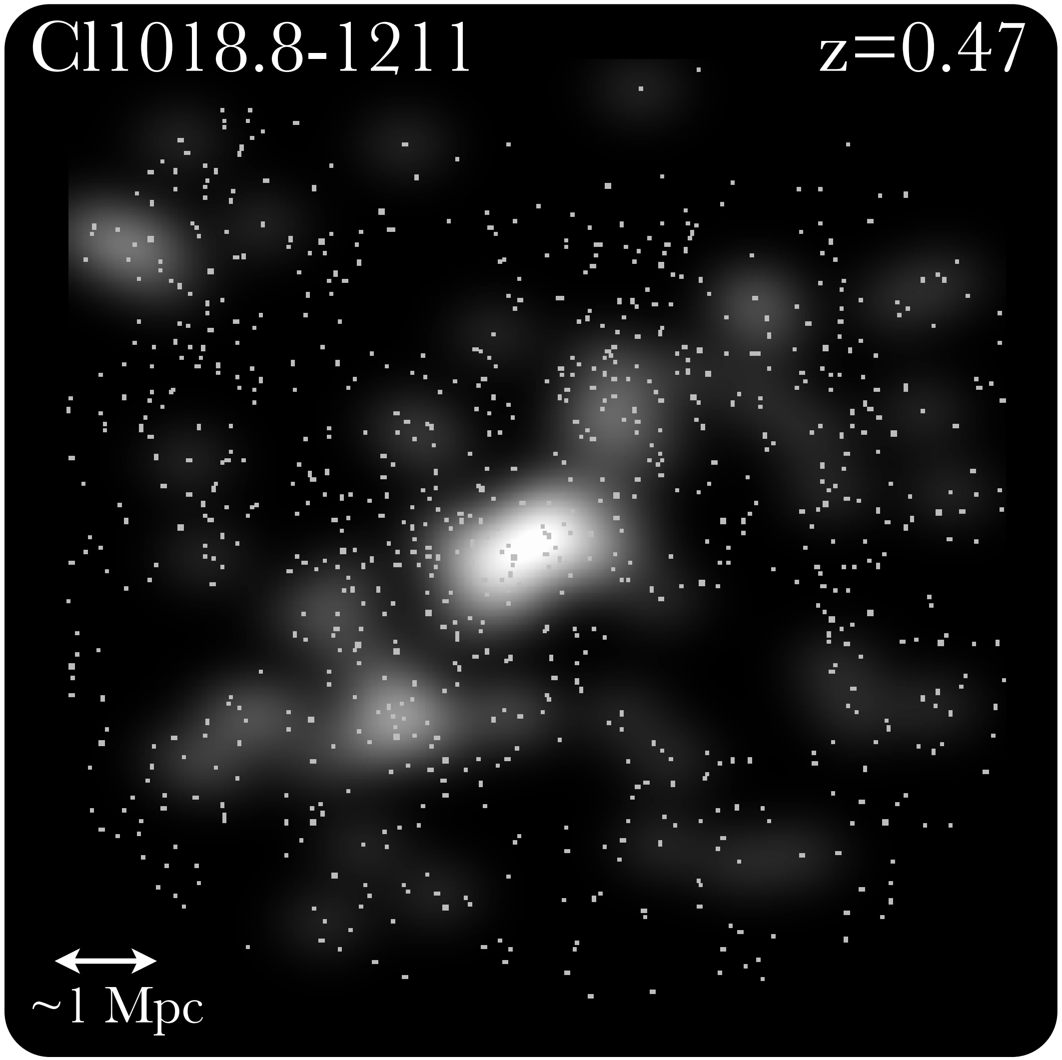


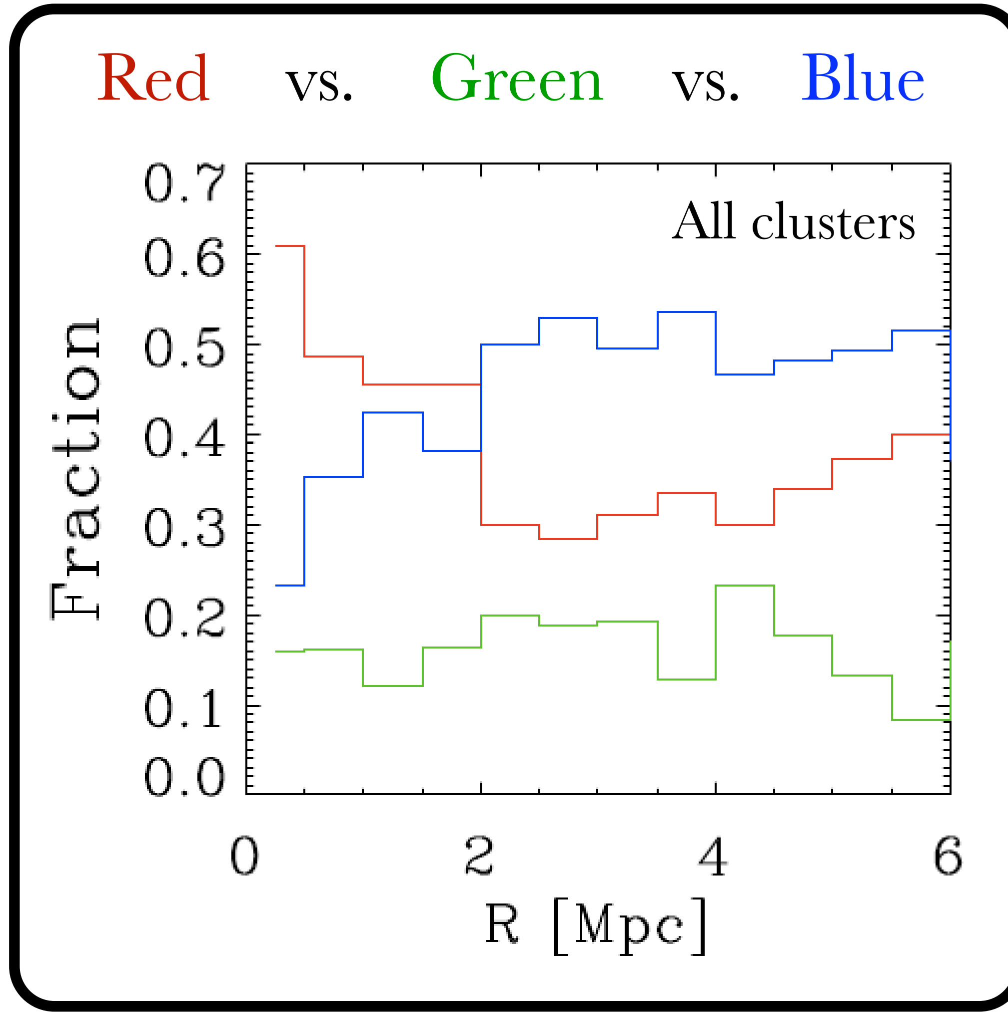
Low Dispersion Prism (LDP)



Just et al. 2011b, in prep

Some Preliminary Results





Future Work

Complementary Data

- SFR's (GALEX, MIPS)
- Morphologies (HST)
- Spatially-resolve colors (HST)
- Kinematics+Emission lines (IMACS, DEIMOS)

Conclusion

- **Environment** influences galaxies, an example being the transformation of spirals into S0s
- **Less-massive systems** drive trend as opposed to **more-massive clusters**
- In SG1120, a "**protocluster**", the S0s do not appear to have had recent star-formation

Direct Interactions Strangulation/Starvation	preferred over	Ram-pressure Stripping Harassment

- With the LDP, we can now investigate the **infall regions** around likely **progenitor clusters** of typical z=0 **clusters**
- Combining the LDP with multi-wavelength data can enhance our understand of spiral/S0 evolution