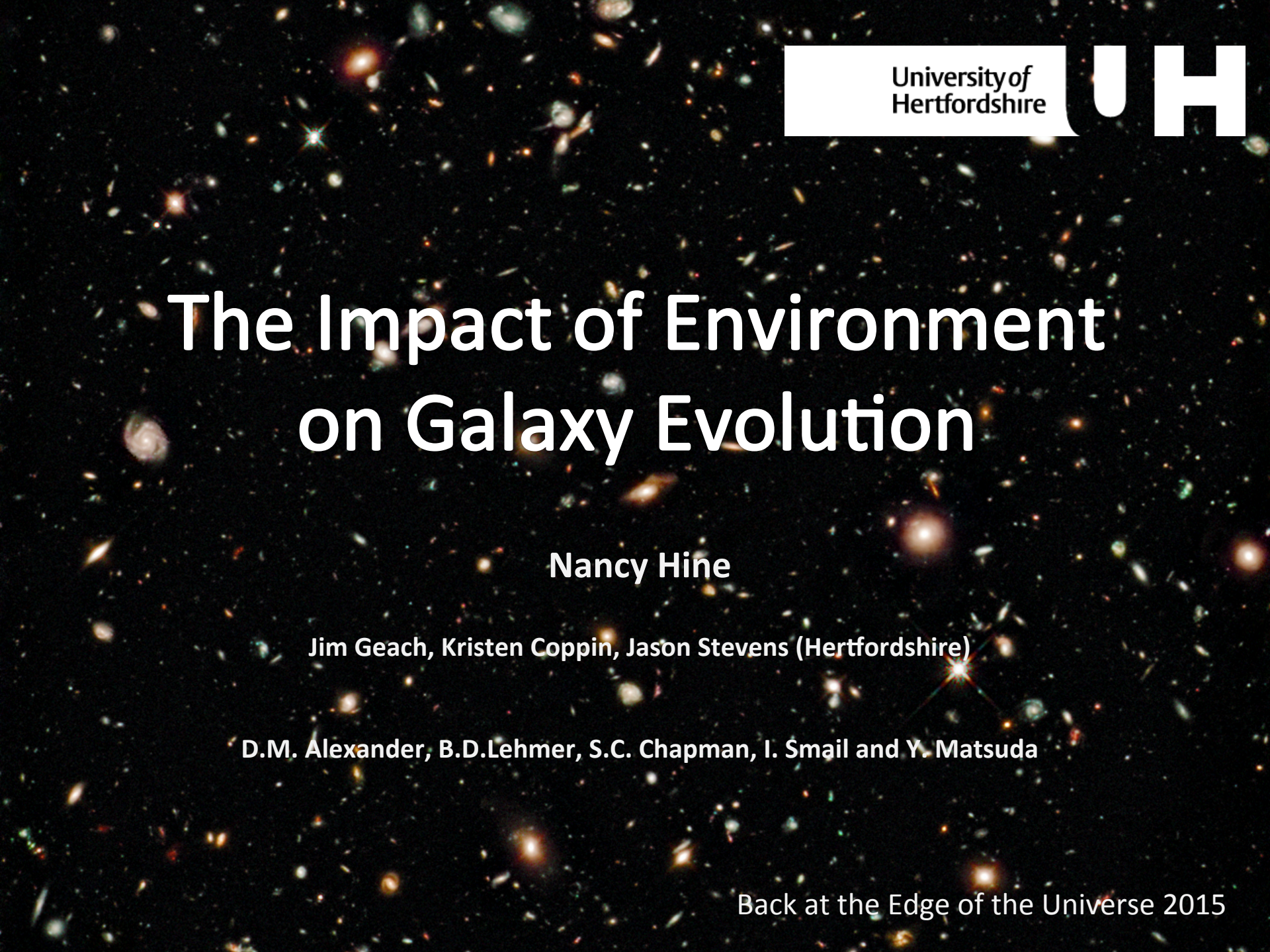

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The Impact of Environment on Galaxy Evolution

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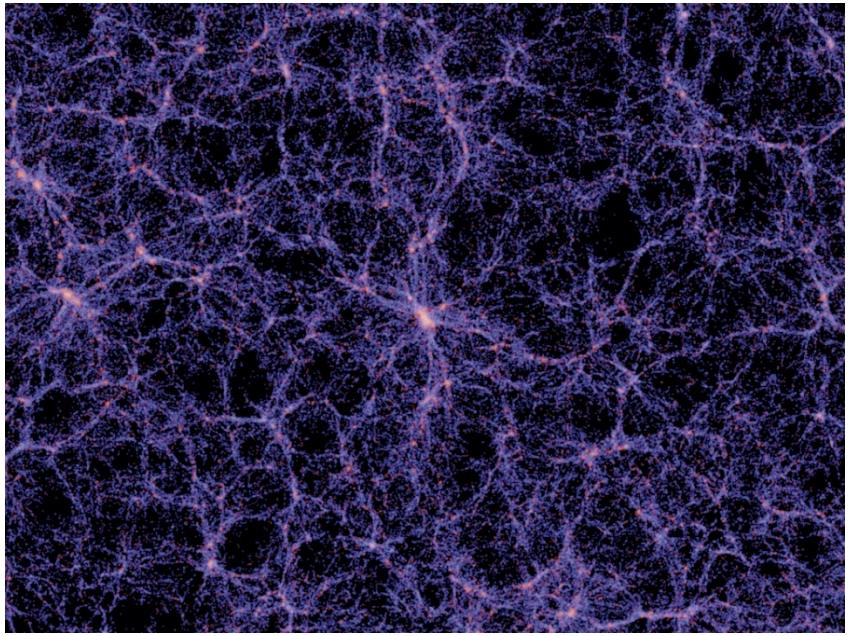
Back at the Edge of the Universe 2015

Do galaxies evolve in the same way and over the same timescales in all environments?

Galaxies form preferentially along dark matter filaments and in particular in the most dense regions where filaments meet.

Protoclusters – high density regions (not yet virialised) thought to evolve into massive clusters in the local Universe.



Millennium Simulation – galaxy distribution

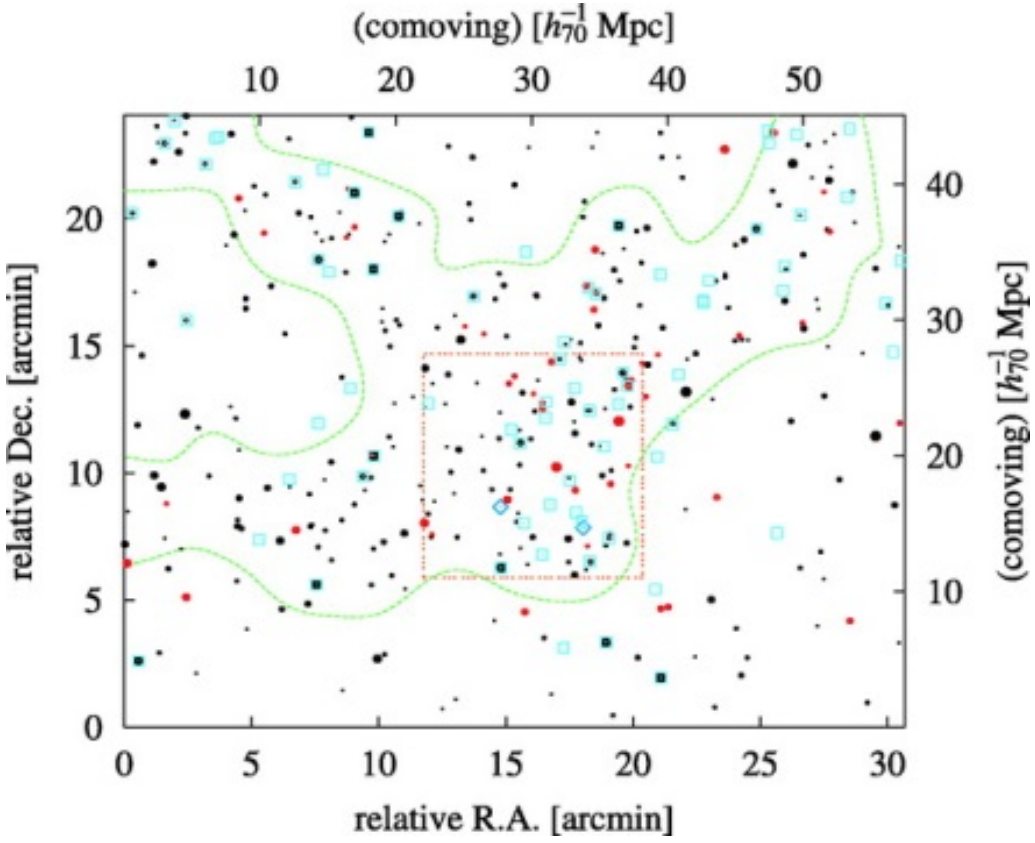
It has been suggested that both SMBH and galaxies grow more rapidly in protocluster environments (Lehmer+09).

SSA22 Protocluster

High density of Lyman Break Galaxies at z~3.1 (Steidel+ 98).

Hawaii deep survey field -1st pointing RA 22:17:34 Dec 00:15:01 2nd pointing 525 arcsecs south.

Further studies identified high density of Lyman alpha emitters , Lyman alpha absorbers, Lyman alpha blobs, AGN, Passive galaxies, extending beyond the initial area. (Steidel+ 2000, Hayashino+ 2000, Lehmer+ 2009, Kubo+ 2013).



Hayashino+ 2000

Merger Fractions

Question: Does environment have an impact on the merger fraction of galaxies?

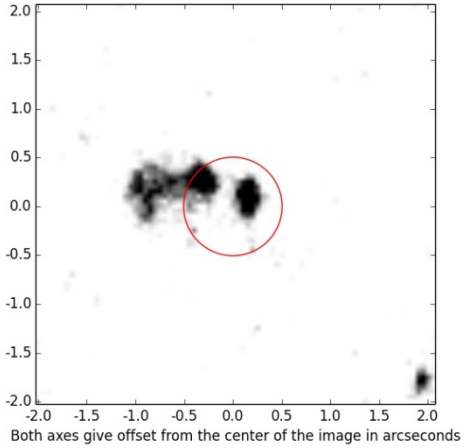
Aim: Compare merger fraction in the SSA22 protocluster with the merger fraction in a region of average density, HDF-N.

$$\text{Merger fraction} = \frac{\text{Number of mergers}}{\text{Total number of galaxies}}$$

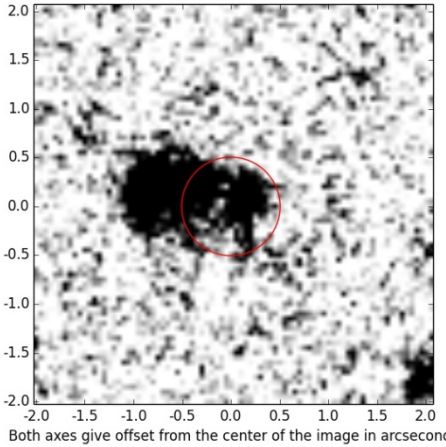
Sample

- LBG catalogues from Steidel+ 2003.
- Restricted redshift range
  - Protocluster $3.06<z<3.12$
  - Fields $2.5<z<3.5$
- Obtained HST (ACS F814W) cut out images of samples where available (HDF-N: 53, SSA22 field: 33 out of 55, SSA22 protocluster: 23 out of 27). These trace the rest-frame uv.

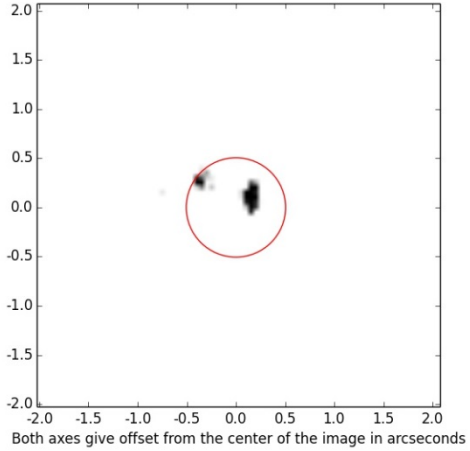
Preparing images



Medium scaling: flux at 15-50% of maximum flux value.



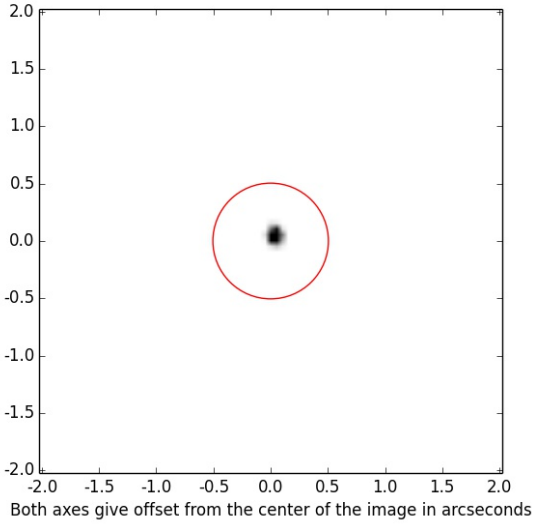
Faint scaling: flux at 1-15% of maximum flux value.

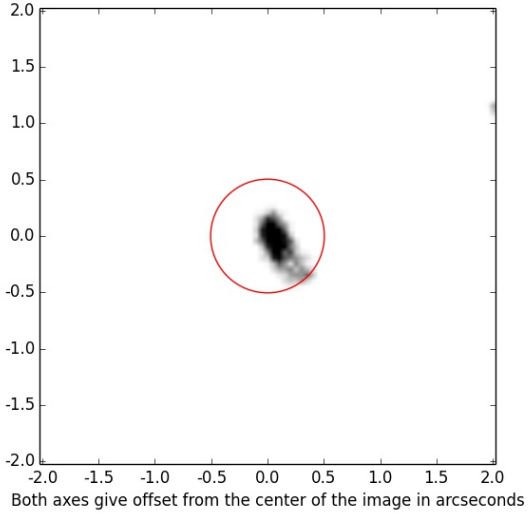


Bright scaling: flux at 55-80% of maximum flux value.

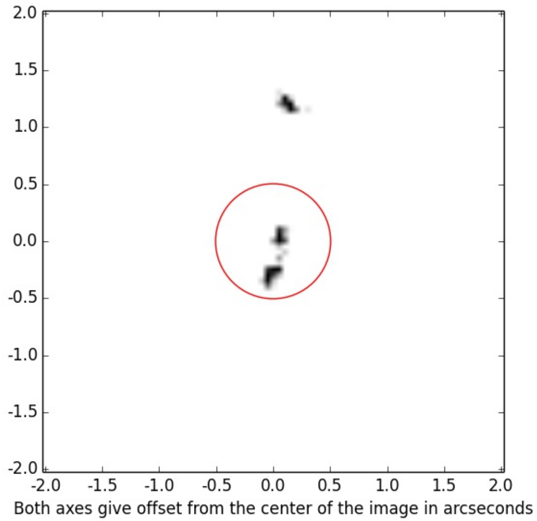
Red circle 0.5 arscec radius (~4kpc at z~3)

Compact galaxies





Mergers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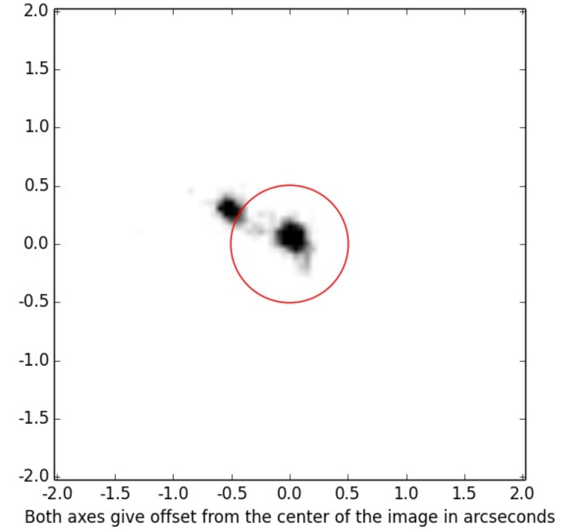
Both axes give offset from the center of the image in arcseconds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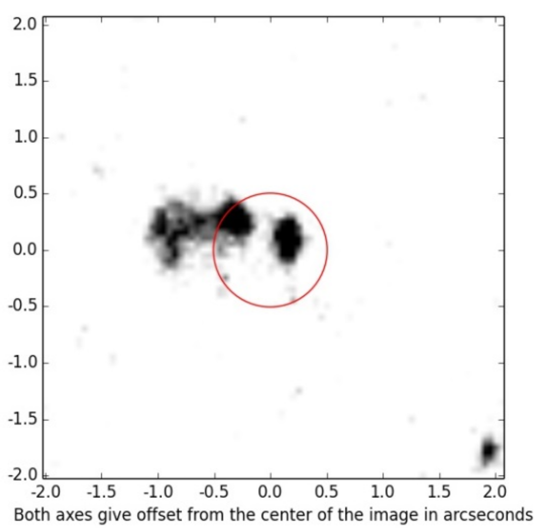
Both axes give offset from the center of the image in arcseconds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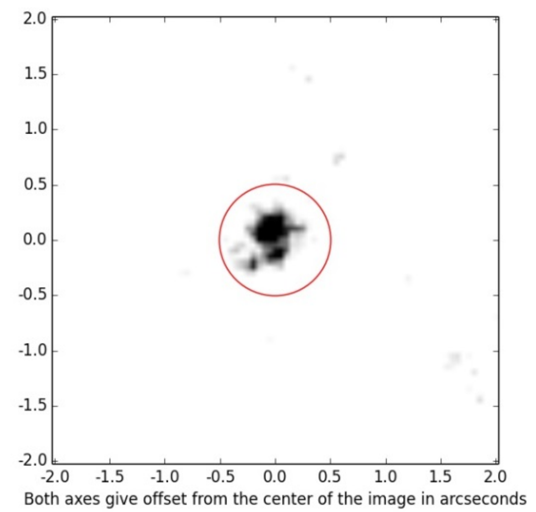
Both axes give offset from the center of the image in arcseconds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Both axes give offset from the center of the image in arcseconds

Classification Process

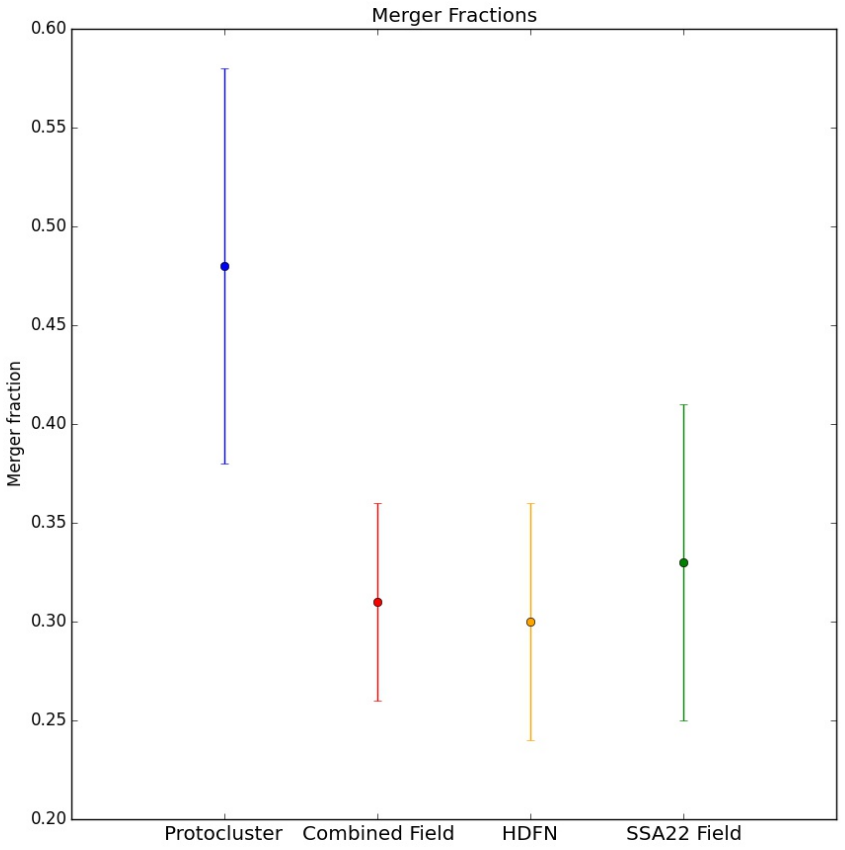
- We used the scaled images to classify the LBGs twice.
- We also carried out a blind classification.
- Additional visual inspections if the classification was unclear.
- Checked for biases due to varying exposure rates.
- Likelihood of chance alignment less than 2%.

Results

48 +/-10% SSA22 protocluster (11 out of 23)

33 +/- 8% SSA22 field

30 +/- 6% HDF-N field (16 out of 53)



~6% probability of finding 11 or more mergers in the protocluster sample if the actual merger fraction were 30%.

Conclusions and Comments

- The protocluster is marginally enhanced by a factor of 1.6 compared to the field at z~3.
- This could be due to a higher merger rate or longer duty cycle.
- Fakhouri & Ma (2009) examined the merger histories of dark matter halos in the Millennium Simulation – found subhalos in the densest regions had merger rates 2-2.5 times those in voids to z=2.
- Given the enhanced merger fraction and enhanced AGN activity (Lehmer + 2009) are the mergers triggering black hole growth?

Future Work

- **Merger fractions**
  - Submit paper
  - Analyse rest-frame optical morphology using HST longer wavelength data as it becomes available
  - Apply to other fields and protoclusters if data becomes available
- **SSA22 Lyman alpha blobs**: Stacking of SCUBA2 data
  - Paper in preperation
- **Star formation histories** of LBGs along the merger sequence:
  - Using optical spectroscopy to characterise SFH (SED Stacking)
  - Linking to different merger stages
- **Summary:** A coherent picture of stellar mass assembly and black hole growth in the densest environment at z~3.