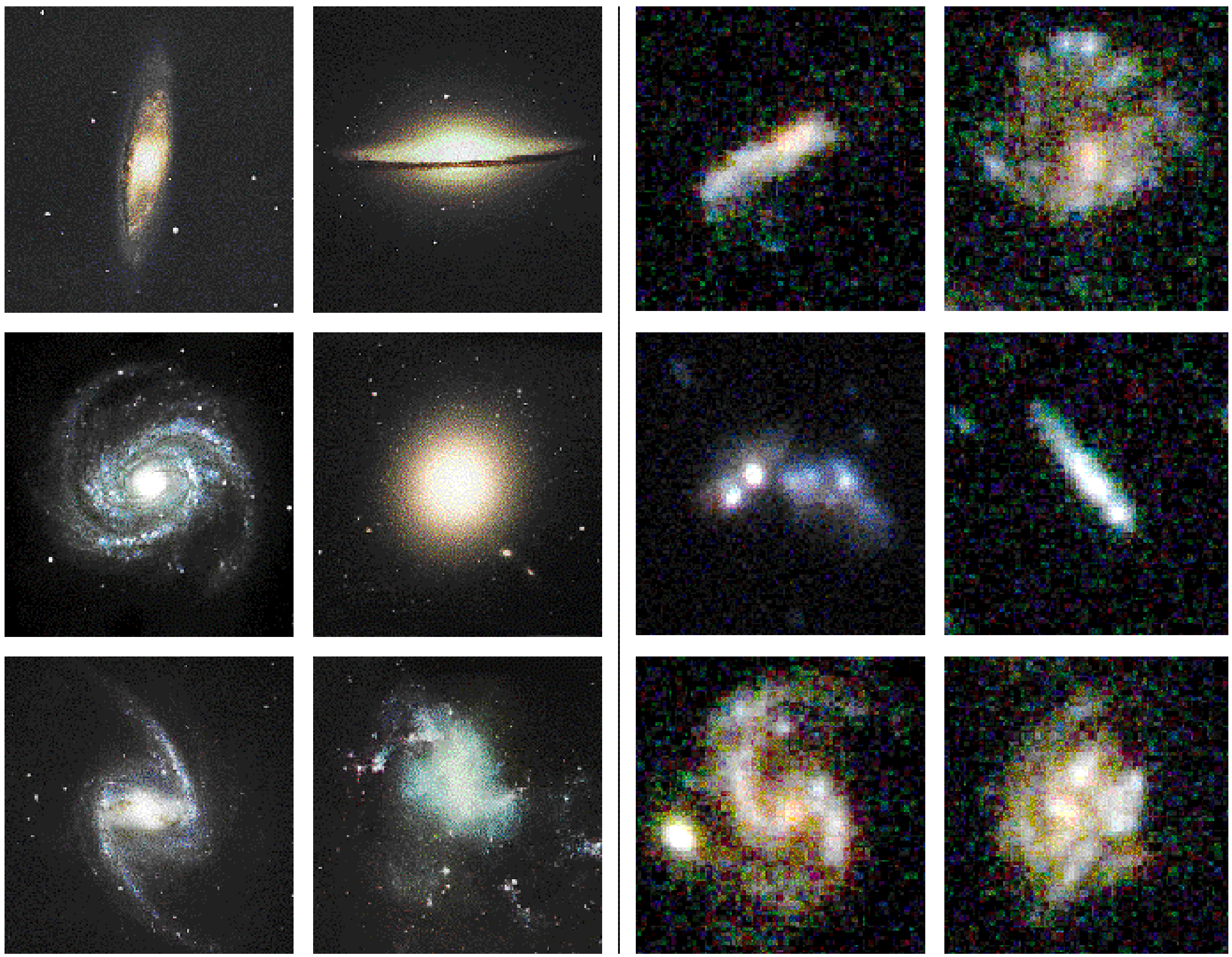
Evolution of Normal Galaxies with ACS

Richard Ellis, Caltech



Main Points

- **Science goals:** *beyond basic exploration towards a physical understanding of how galaxies form & evolve*
- **Lessons learnt from HDF:** *deep versus wide, role of colors*
- **Future ground-based instrumentation:** *how to prepare*
- **Pointers for splinter group discussion meeting**

- Concerned with *optical* survey imaging of moderate & high redshift objects
- Disregarding studies of specific objects: clusters, nearby galactic systems
- Assume others will emphasize role of non-optical/IR facilities

Science Goals for ACS: Deep, Wide or Something New?

• What is the case for deeper-than-HDF *optical* exploration?

No. count slope flattens beyond B=24, I=24, K=19

Most of deep HDF data is still unexploited

• Going beyond simple exploration & "census studies" towards physical understanding of galaxy formation

How to better "connect" samples at various redshifts to get a meaningful "big picture"

Require more detailed & representative datasets at HDF depth targeting physically-relevant parameters

→ Let's **THINK** not just **POINT & SHOOT** deep

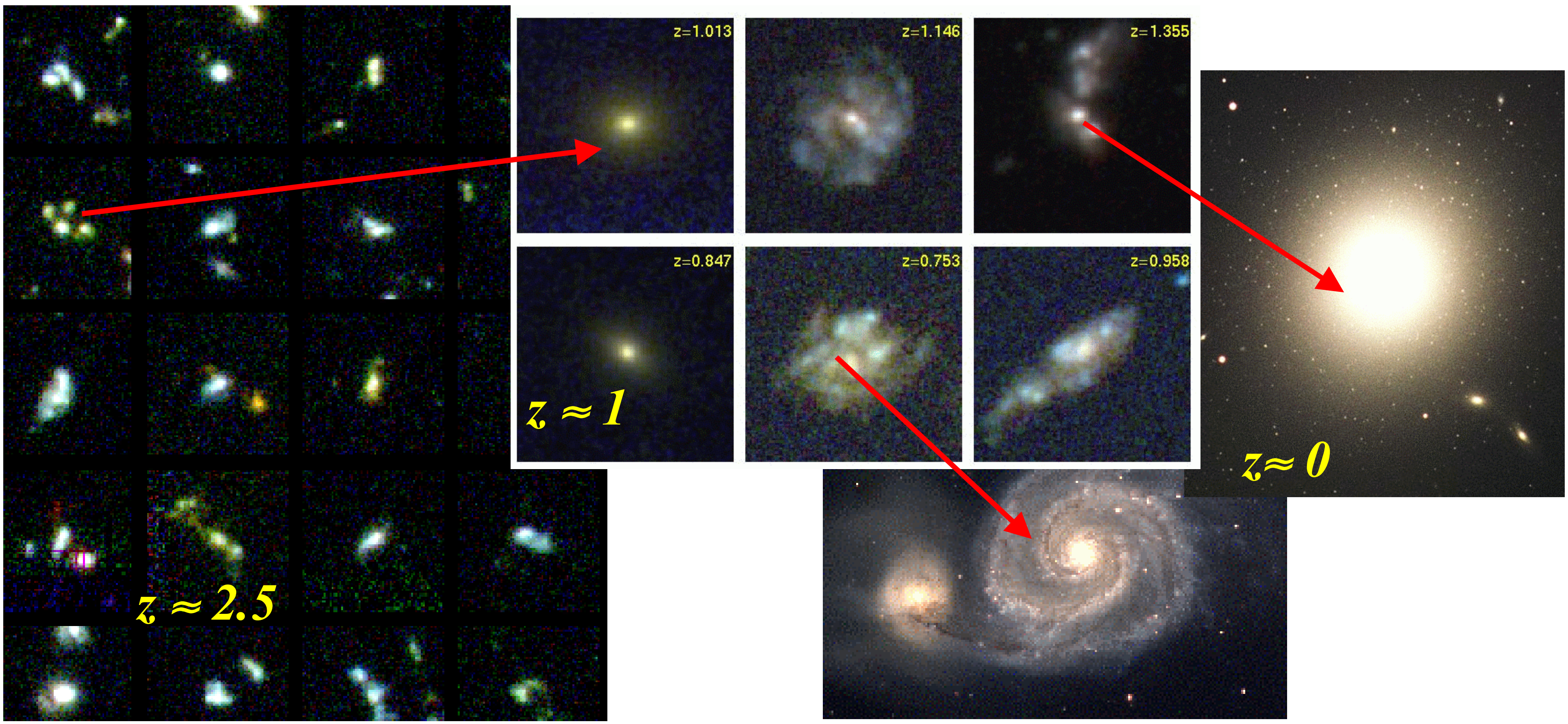
How do we connect samples observed at various z?

We have the capability of isolating well-defined samples at various epochs:

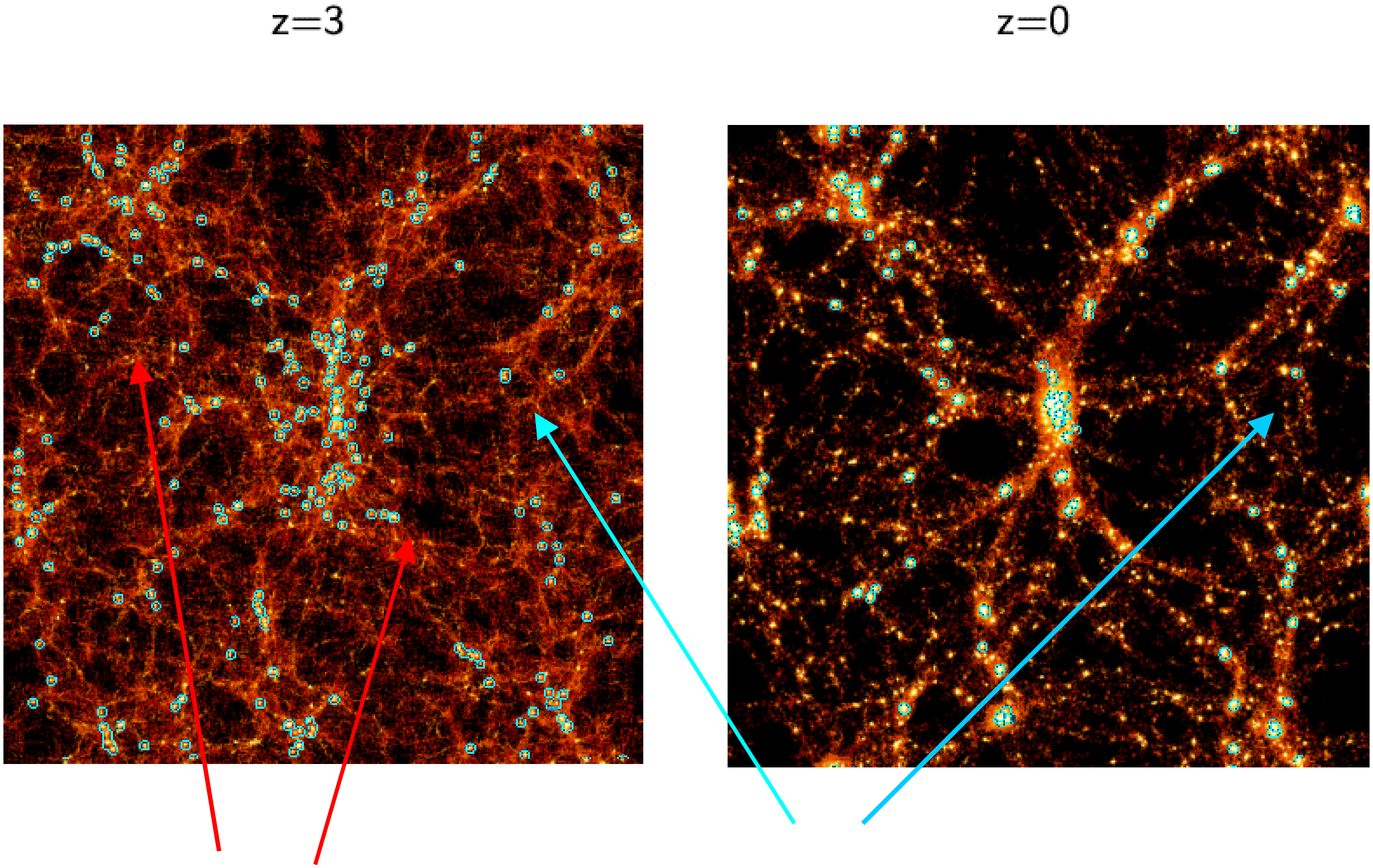
• Lyman/Balmer break samples: star-forming galaxies z≈1-3

• Red, possibly passively-evolving, field ellipticals z>1

→ on what physical basis can we intercompare these samples?



Merging Dark Matter Halos & Structure Formation



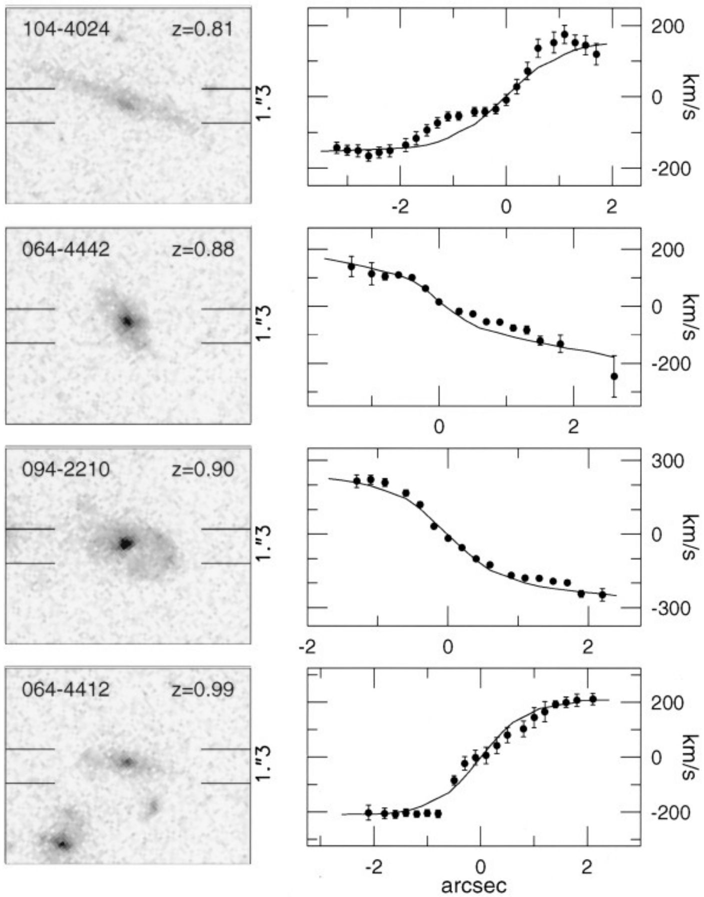
Dark matter "halos" act as seeds for galaxies to form

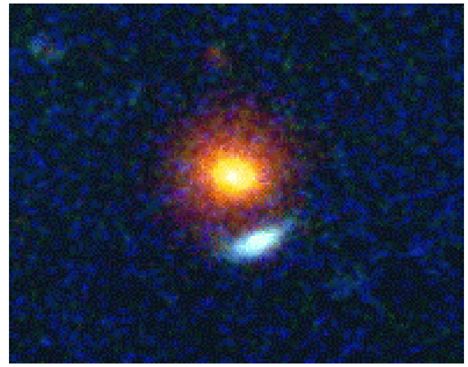
Physical clustering at different epochs provides one basis for intercomparisons:

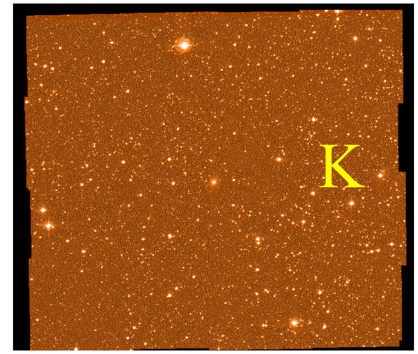
HST can enrich such datasets but only if offered over much wider fields

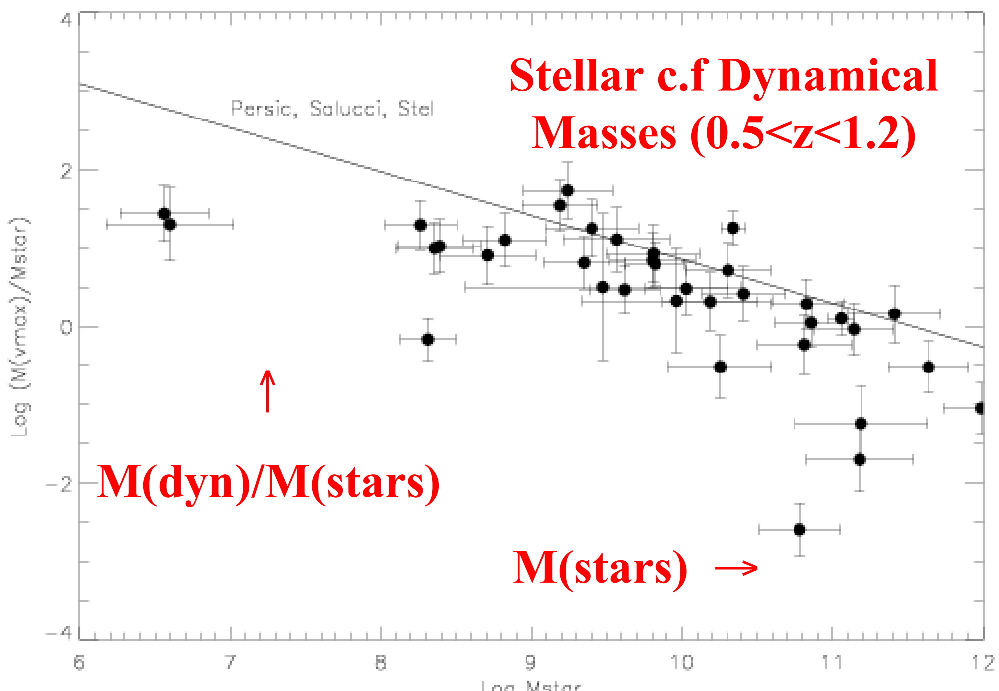
Galaxy Masses: More Useful than Star Formation Rates

Dynamics: rotation & line widths **Grav. lensing** **IR-based stellar masses**







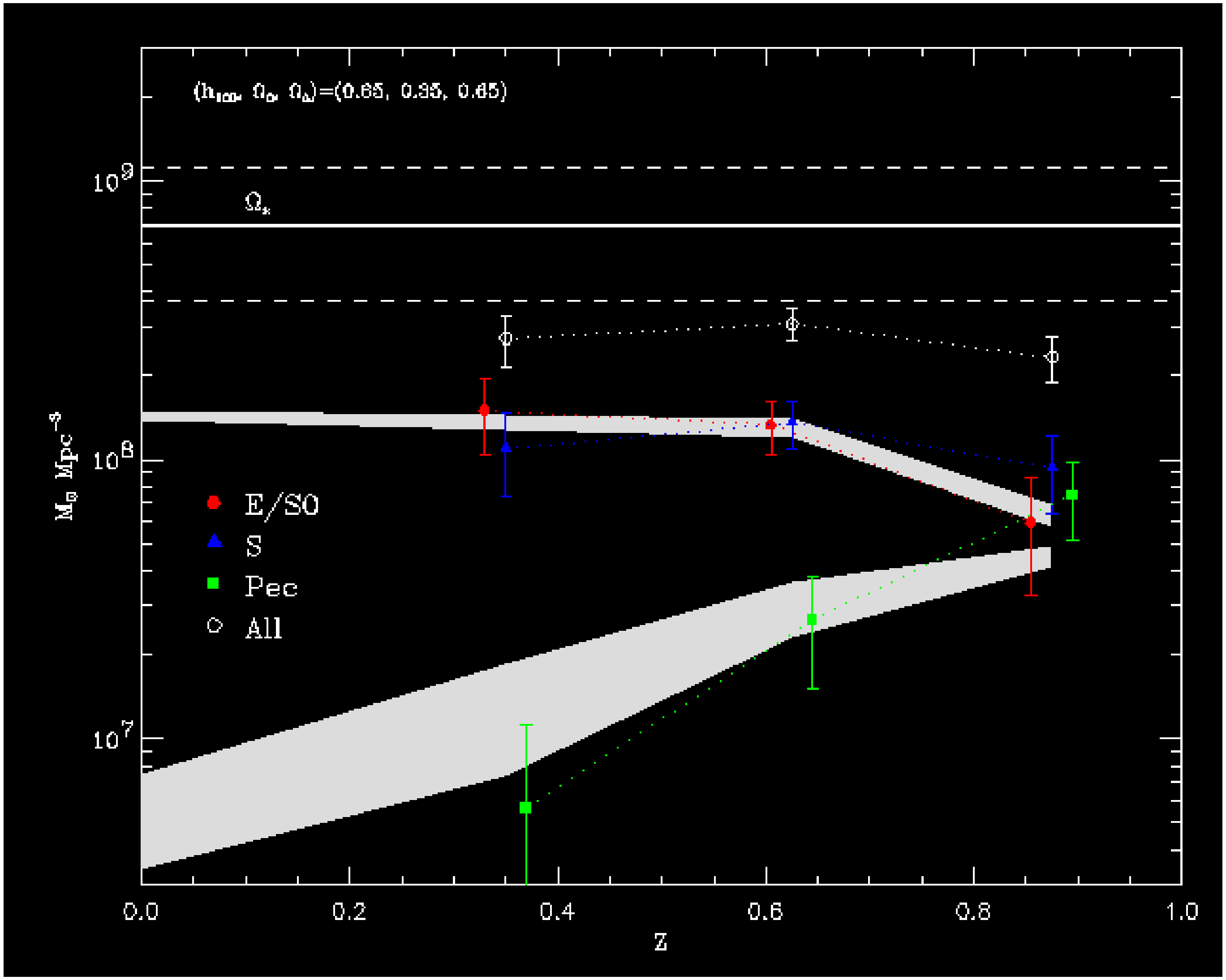


HST data must match complementary ground-based spectra & IR imaging

Stellar Mass Distribution by Morphology

↑

Stellar mass density from K-band data



Decline in mass density in late-types occurs at the expense of a modest growth in regular spirals & ellipticals (Brinchmann & Ellis 2000)

(N ≈ 500g from 30 WFPC fields with redshifts)

Limited overlap of HST & ground-based redshifts

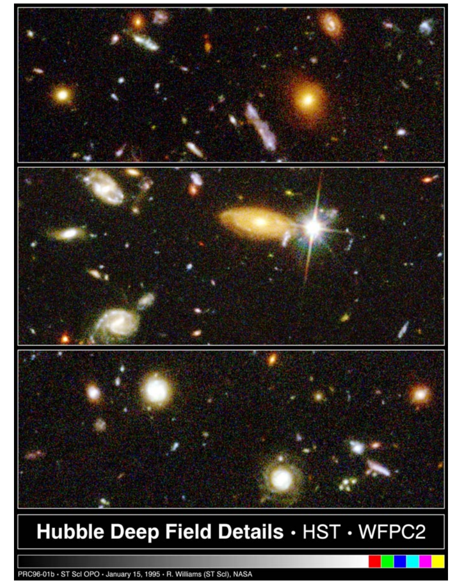
Contiguous WFPC-2 fields (probably incomplete)

Hawaii SSA fields (Cowie):	8 WFPC-2 fields in 4 areas
CFRS (Lilly)	12 WFPC-2 fields in 4 areas
LDSS (Broadhurst)	6 WFPC-2 fields in 2 areas
Groth strip	28 WFPC-2 fields in 1 area
HDF-N/S	16 WFPC-2 fields in 2 areas

Total: 70 WFPC-2 fields (350 $arcmin^2$); <1500 redshifts

Modest considering the unique opportunities!

HDF has shown us new possibilities!



What lessons have we learnt?

Advantages:

• Depth (but not dramatically so)

• Four bands with *unrivalled photometric precision* (photo-z's)

• Resolved color images for galaxies at all z

Limitations:

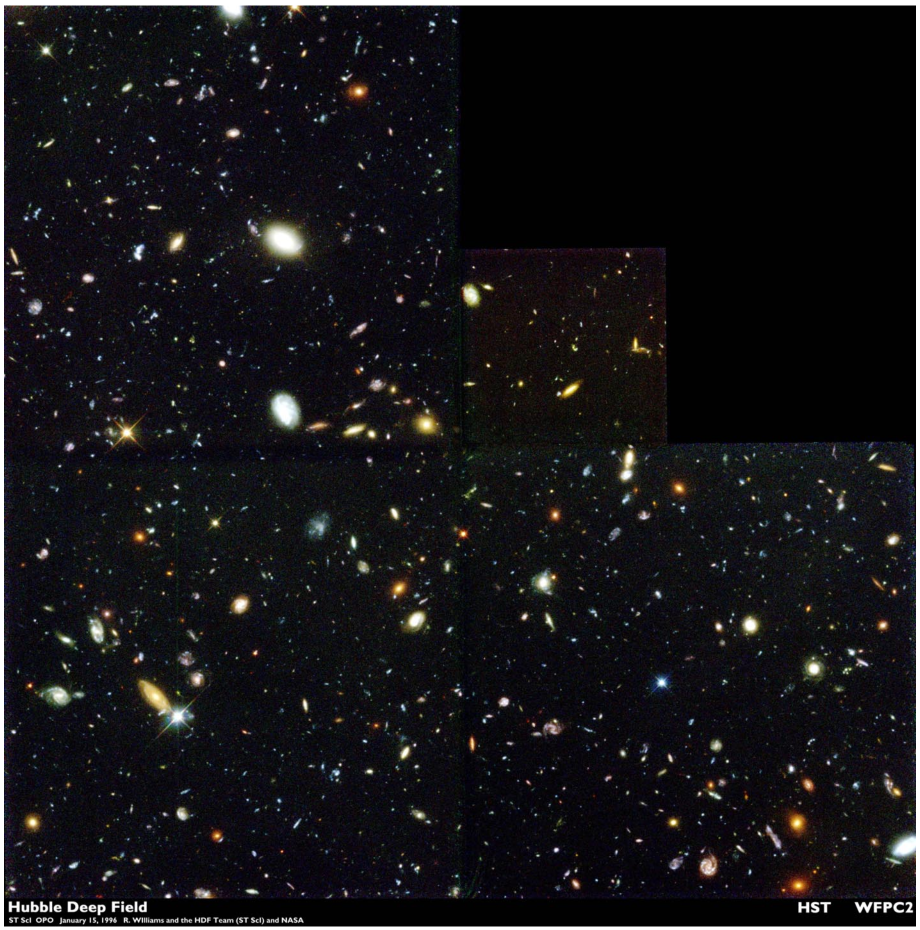
• Restricted field may be unrepresentative, e.g for z<2 samples

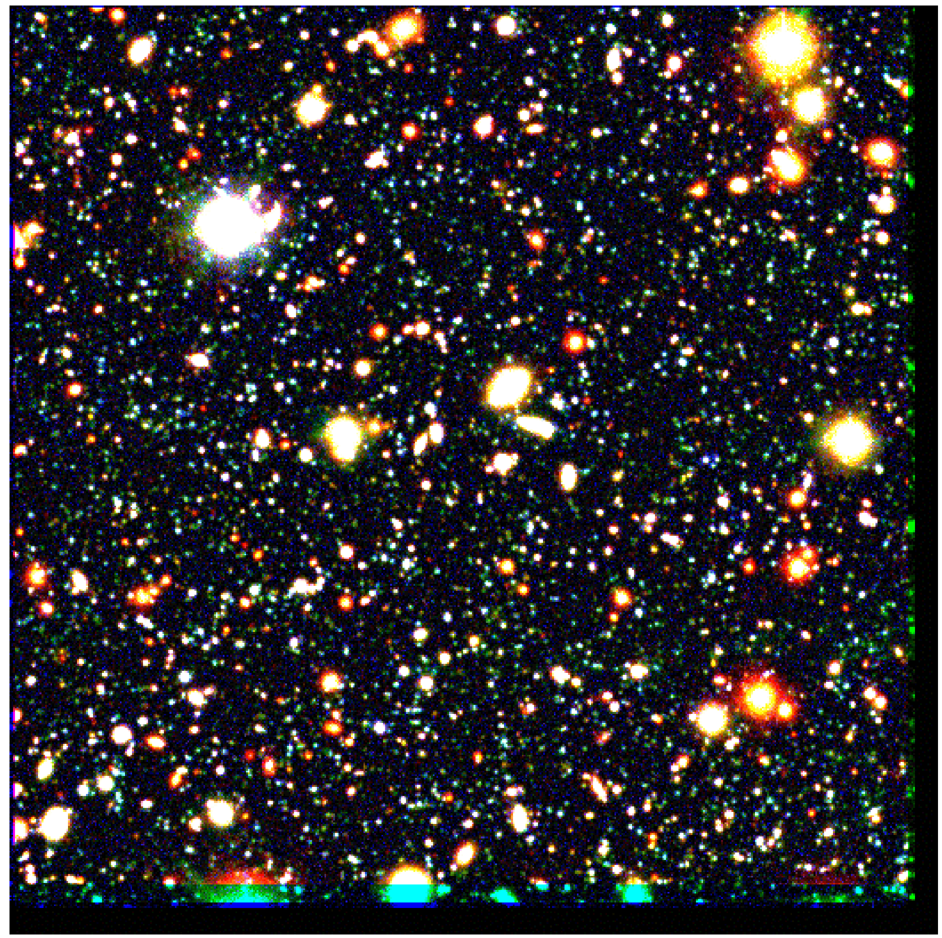
• Field mismatch c.f. essential/complementary facilities

• Large fraction of data yet to be effectively exploited

• Was the U band data worth the extraordinary effort?

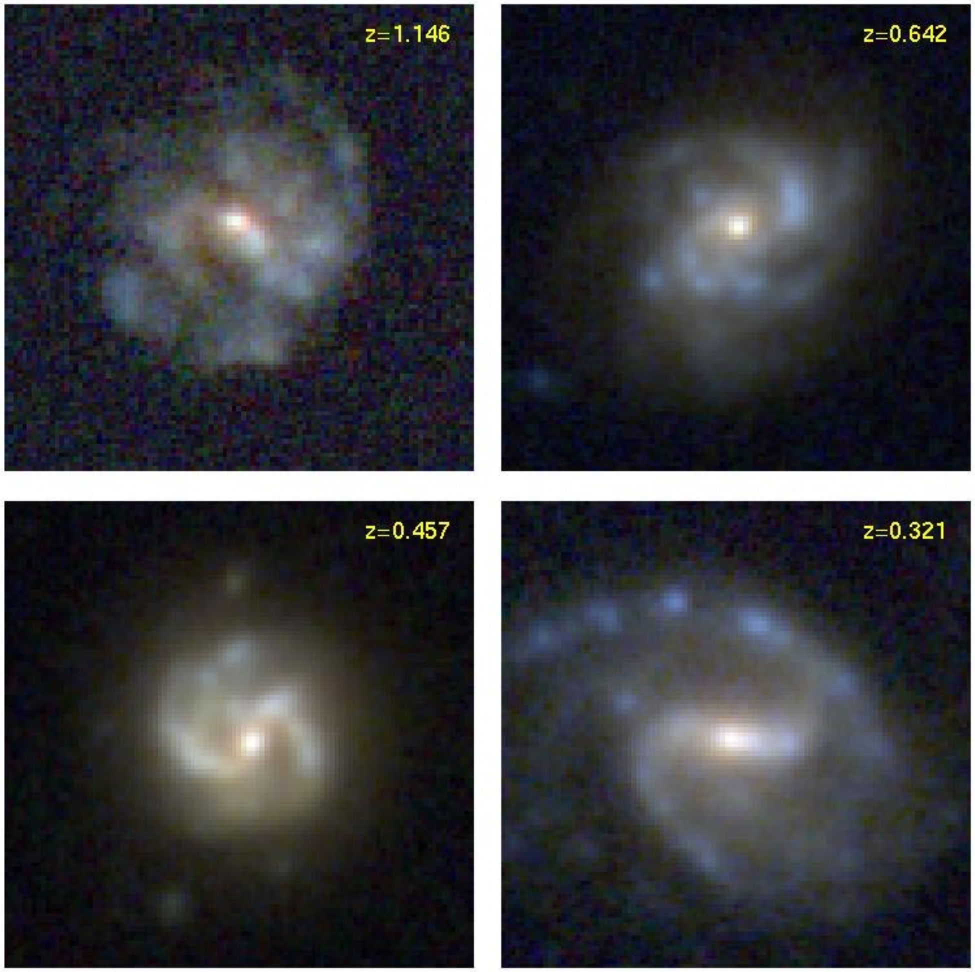
Two HDFs (Hubble vs Herschel)

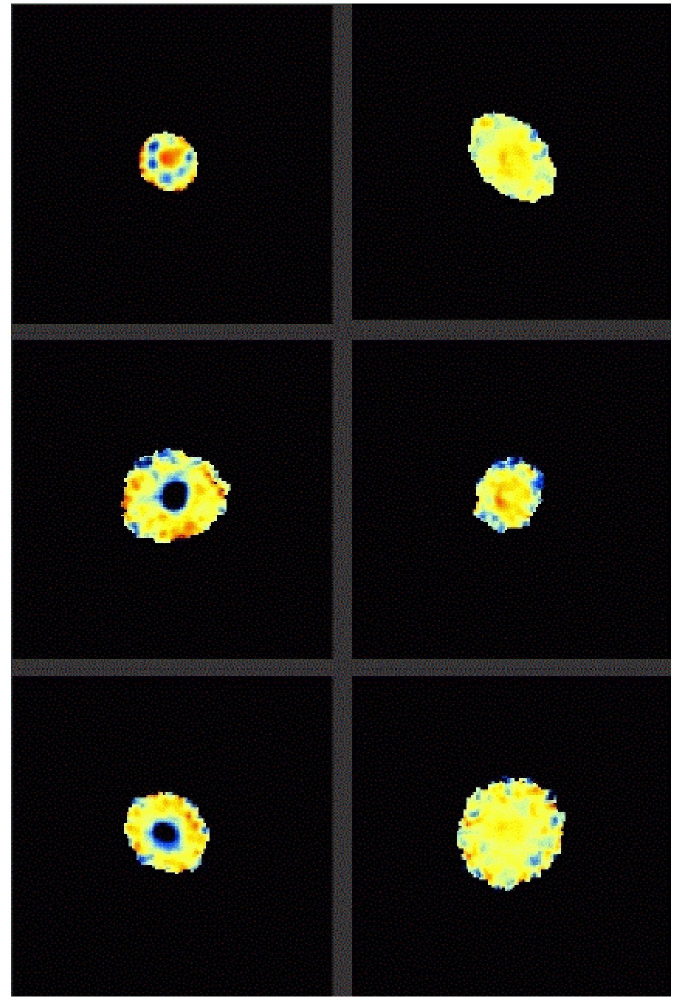




Can expect reasonably deep multi-band imaging from 8-10m telescopes in 0.2-0.5 arcsec resolution → photo-z's etc

Advantages of Resolved Color Data: I

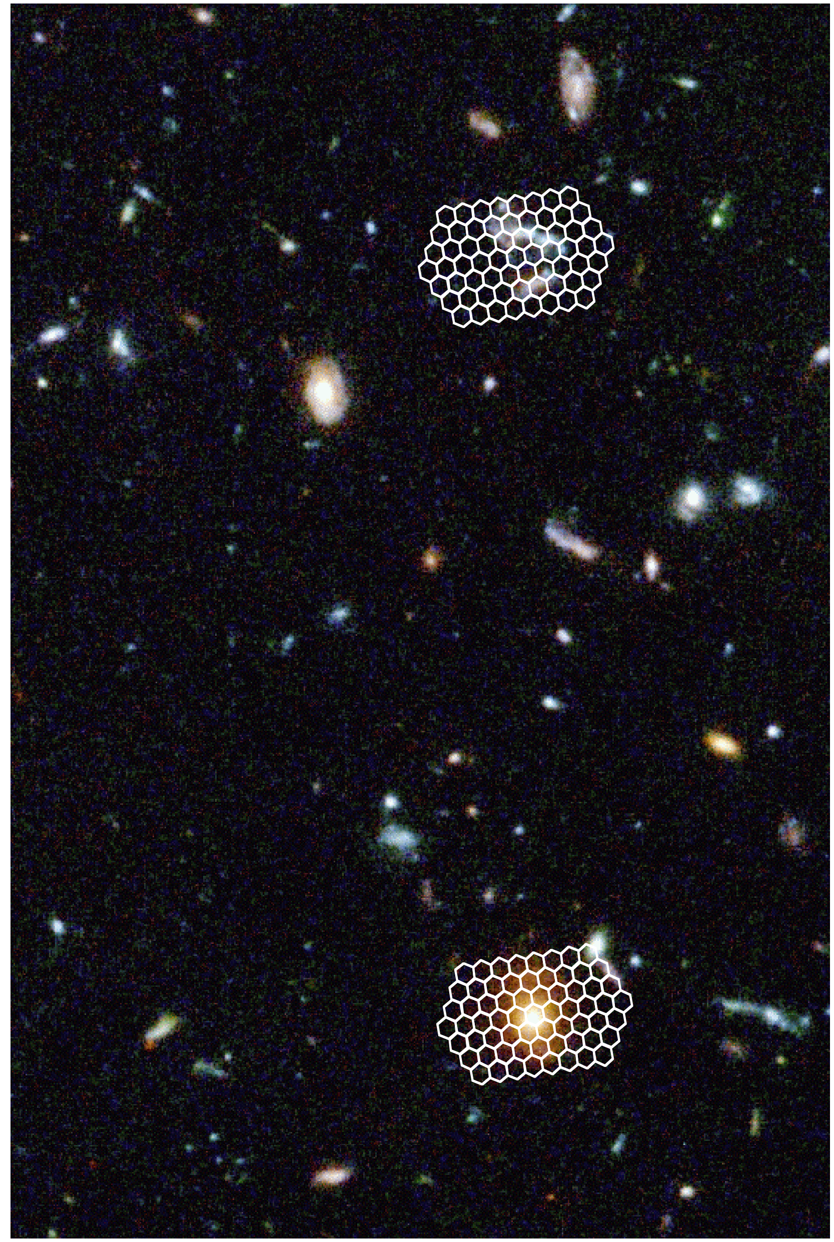




Identification and photometric study of key diagnostic sub-components: (e.g. bars, bulges etc)

Discovering evidence for continued growth in field ellipticals

Advantages of Resolved Color Data: II



Exploiting 2-D information:

• Sophisticated photo-z techniques:
improved precision, role of dust etc

• SF characteristics for objects of known z

Targets for AO instruments:

• IFU spectrographs capable of dynamical and excitation studies of SF galaxies

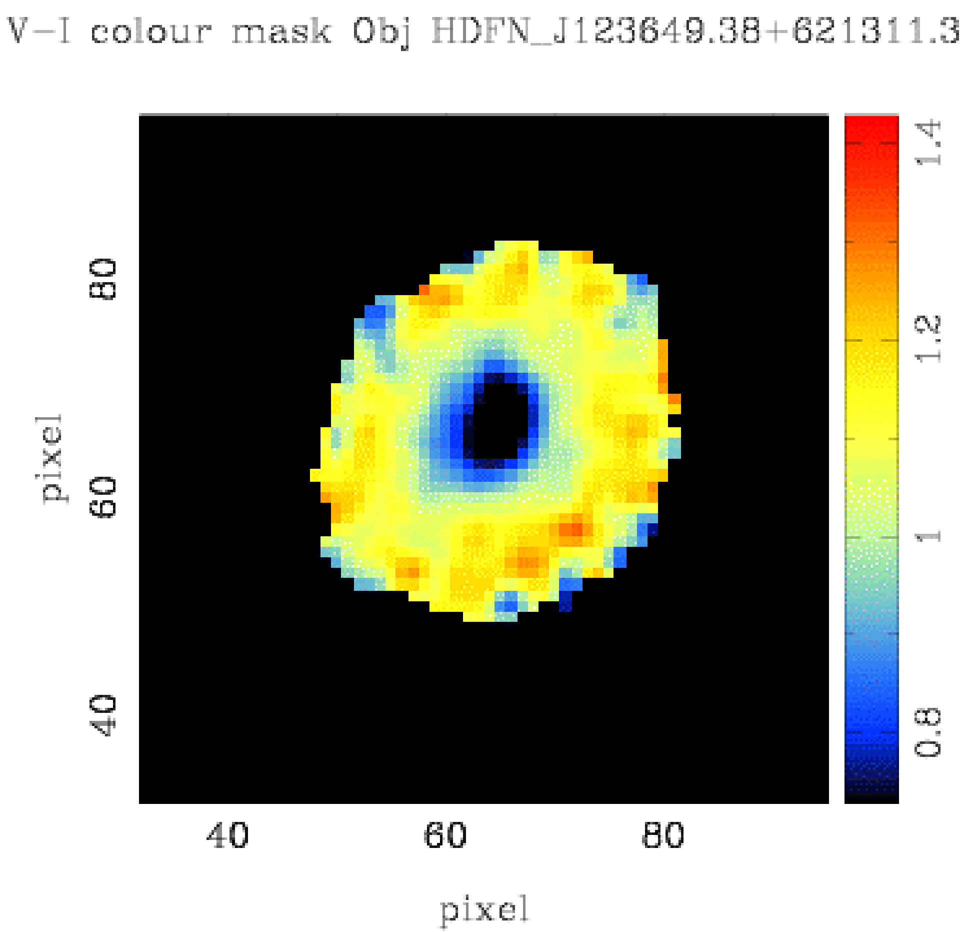
HDF-N Statistics

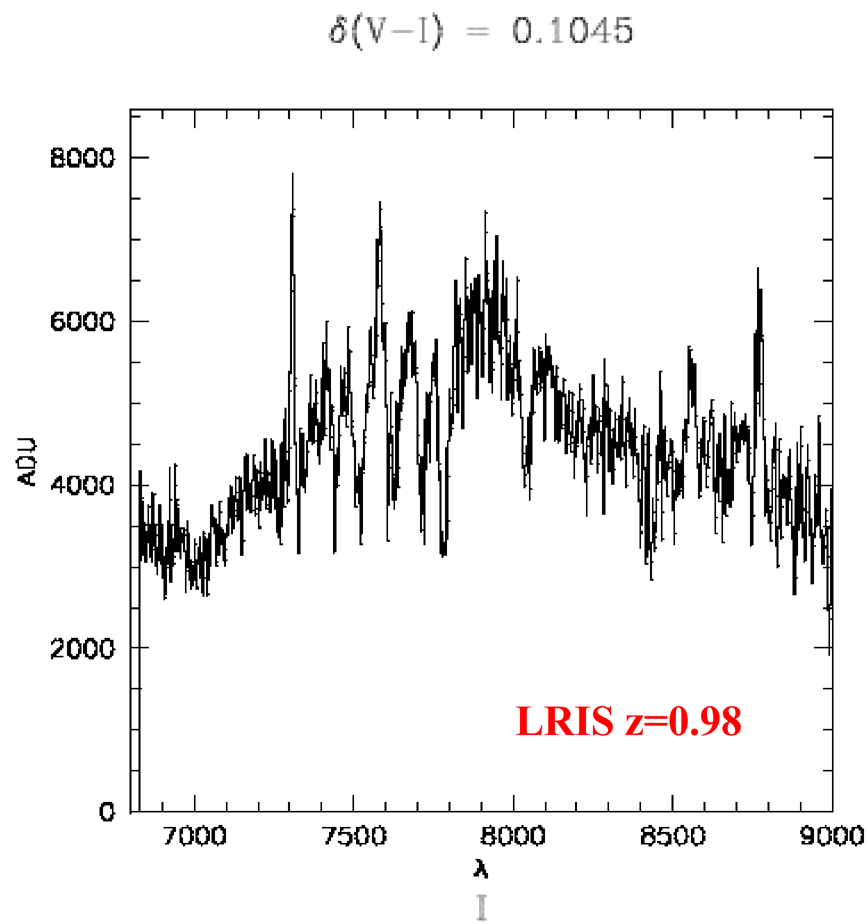
(*after Ferguson et al ARAA 38, 667)*

Galaxies with UBVI	3000
Galaxies with K	300
Spectroscopic redshifts R<24	150
z >0.5 ellipticals ≈ 25	
face-on barred spirals ≈ 10	
chain galaxies 1<z<2 ≈ 10	
Radio galaxies	16
Lenses	<few

Volume to z=2 equivalent to one containing 30-80 L* galaxies

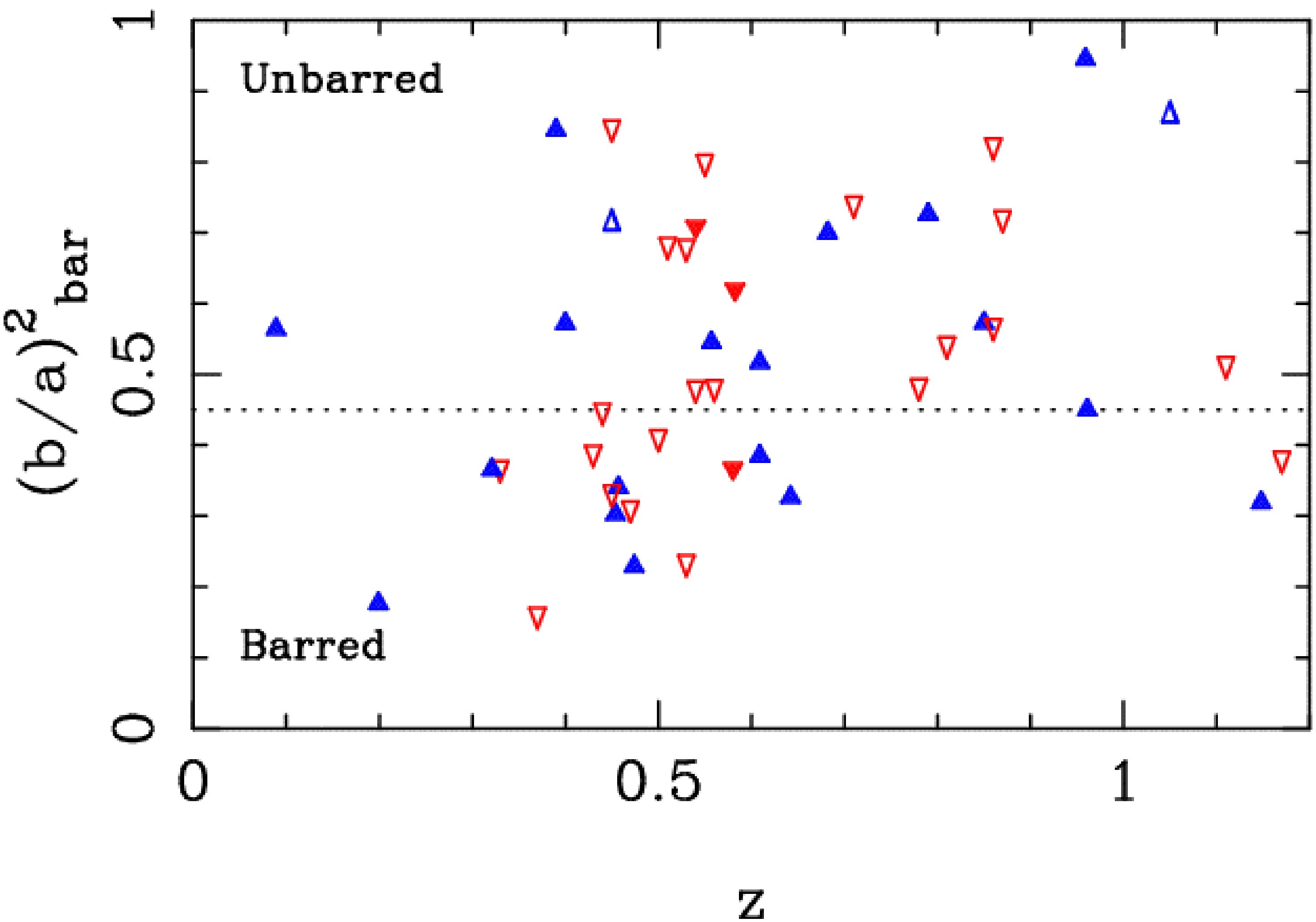
Spectra: <25 HDF-N high z ellipticals within reach of Keck





Ellis, van Dokkum & Abraham: Keck LRIS 600/7500 gr 7.5 hours I<23

Decline in Fraction of Barred Spirals z > 0.5?



Abraham, Merrifield, Ellis et al (2000): HDF-N & HDF-S

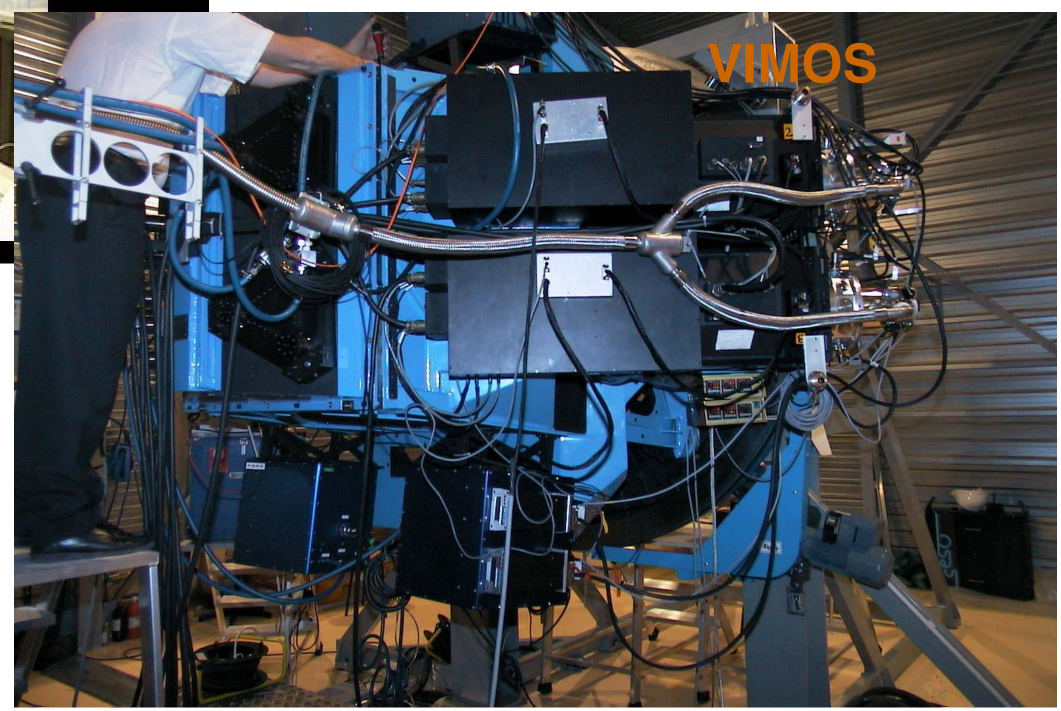
Exploiting Investment in Ground-based Spectroscopy

Deep-1HS: 480 x (4 x 16 arcmin)

Deep-3HS: 60 x (3.5 x 16 arcmin)

Multiplex gain: < 130; R=5000

50,000g I<23.5; 5000g I<24



VIMOS: <145 x (56 x 4 arcmin)

Multiplex gain: 750; R<2500

130,000g I<22.5; 50,000g I<24

1000g I<26

Pointers for Discussion

- What is the physical motivation for *deeper-than-HDF imaging in 1-2 small fields* given high fraction of HDF data remains unexploited?

- Significant limitation lies in connecting data at different epochs: suggested ways forward require *wide field* data, e.g. clustering in representative fields and extensive associated g-based data.

- Community has been slow to exploit *resolved color data* (perhaps as it is restricted largely to HDF); however significant benefits likely even if expensive in HST time.

- How should panoramic ground-based surveys influence what HST does? *Multi-color* HST exploitation of such surveys represents a significant requirement