Astronomy & Physics Resources for Middle & High School Teachers

Gillian Wilson

http://www.faculty.ucr.edu/~gillianw/K12

Observational Cosmology

- Galaxy Clusters and Mapping Dark Matter
- Observational Cosmology
- Dark Matter & Dark Energy
- $1 < z < 3$ Clusters of Galaxies
- “SpARCS” and “GCLASS” Cluster Surveys
- Galaxy Evolution
- Structure Formation
- Spitzer Space Telescope Infrared Studies

http://www.faculty.ucr.edu/~gillianw

Outline

- Overview of NASA, NSF & Other Educational Links
- Overview of cosmology and short summary of my research, with reference to Next Generation Science Standards (NGSS)

EVERYTHING I will show / say today is linked to my webpage

http://www.faculty.ucr.edu/~gillianw/K12

In Next Generation Science Standards (NGSS), Astronomy falls mostly under Earth Sciences

Are there any Earth Sciences Teachers present?

Are there any General Science Teachers present?

Are there any Middle School Teachers present?

Next Generation State Science Standards G9-12

HS Space Systems

ESS1.A : The Universe and Its Stars

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years (HS-ESS1-1)
- The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe. (HS-ESS1-2)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode. (HS-ESS1-2),(HS-ESS1-3)

Next Generation State Science Standards G9-12

HS Space Systems

PS4.B : Electromagnetic Radiation

- Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. *(secondary to HS-ESS1-2)*

Next Generation State Science Standards Grade 8

MS Space Systems

ESS1.A : The Universe and Its Stars

- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2)

UNIVERSITY OF CALIFORNIA, RIVERSIDE

UC RIVERSIDE
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Physics & Astronomy

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Gillian Wilson

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Personal Home Page

Research Interests:

- **Galaxy Clusters and Mapping Dark Matter**
- Observational Cosmology
- Dark Matter and Dark Energy
- 1 < z < 3 Clusters of Galaxies
- "SpARCS" & "GCLASS" cluster surveys
- Galaxy Evolution
- Structure Formation
- Infrared Galaxy Studies

Education:

Ph.D. 1996, University of Durham, UK

Selected Publications:

1. "The Phase Space and Stellar Populations of Cluster Galaxies at z~1: Simultaneous Constraints on the Location and Timescale of Satellite Quenching," Muzzin, A., van der Burg, R. F. J., McGee, S. L., Balogh, M., Franx, M., Hoekstra, H., Hudson, M. J., Noble, A. Taranu, D., Webb, T. Wilson, G., & Yee H. K. C., 2014, ApJ, submitted (arXiv:1402.7077)
2. "A Census of Stellar Mass in 10 Massive Haloes at z~1 from the GCLASS Survey," van der Burg, R. F. J, Muzzin, A., Hoekstra, H., Lidman, C., Wilson, G., Yee, H. K. C. & Kuijken, K., 2014, A&A, 561, 79

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Public talk for Girl Scouts, Boy Scouts and local K-12 students

Postdocs & Students

Publications

Teaching

Links for K-12 Educators

I enjoy Public Outreach. Other recent activites

I lead

The SpARCS Survey,

which has detected hundreds of clusters at $z > 1$ in the 50 square degree Spitzer SWIRE Legacy Survey Fields. Because clusters are rare, a wide-area survey is important to detect a representative sample. SpARCS' innovation is that it utilizes Spitzer Space Telescope IR observations, in combination with ground-based optical imaging, allowing clusters to be detected to higher redshift than traditional techniques. The SpARCS collaboration will be studying these new clusters for many years to come.

I also lead

The Gemini Cluster Astrophysics Spectroscopic Survey (GCLASS),

a large (25 night) multi-year (2007-2012) follow-up program of SpARCS clusters using the Gemini Telescopes.

SpARCS and GCLASS in the News

http://www.faculty.ucr.edu/~gillianw/K12

Resources for Middle and High School Teachers

"Cool Cosmos"
The Infrared Universe

NASA's "The Teachers's Corner" website
Includes Lesson Plans, Posters and Information/Activity Booklets, DVD-ROMS, Data Suitable for Students to Analyze, Links to Education Resources

NASA's Science Mission Directorate Space Science Education Resource Directory
NASA searchable database of space science products for use in classrooms, science museums, planetariums, and other settings.

NSF Astronomy and Space Classroom Resources
A variety of Astronomy resources including Hands-on Labs.

NSF Physics Classroom Resources
A variety of Physics resources including Hands-on Labs.

"The Physics Classroom"
Online High School Physics Tutorials

American Astronomical Society (AAS) K-12 Resources
Links to "especially effective astronomy activities designed for K-12 classes and science projects"

National Science Teachers Association
A comprehensive list of resources for science teachers

http://www.faculty.ucr.edu/~gillianw/K12

The Biggest Baddest Babies in the Nursery

What we are learning about

Distant Clusters of Galaxies

from

The SpARCS Survey

Gillian Wilson
UC Riverside

What is a Cluster of Galaxies?

Exactly what it sounds like!

Galaxies sometimes collect together, they “cluster”

The Universe is expanding and most galaxies are moving away from each other but there are some rare regions where hundreds or even thousands of galaxies are gravitationally bound together.

The galaxies in these regions will stay close together for all time….

Clusters were first discovered by accident

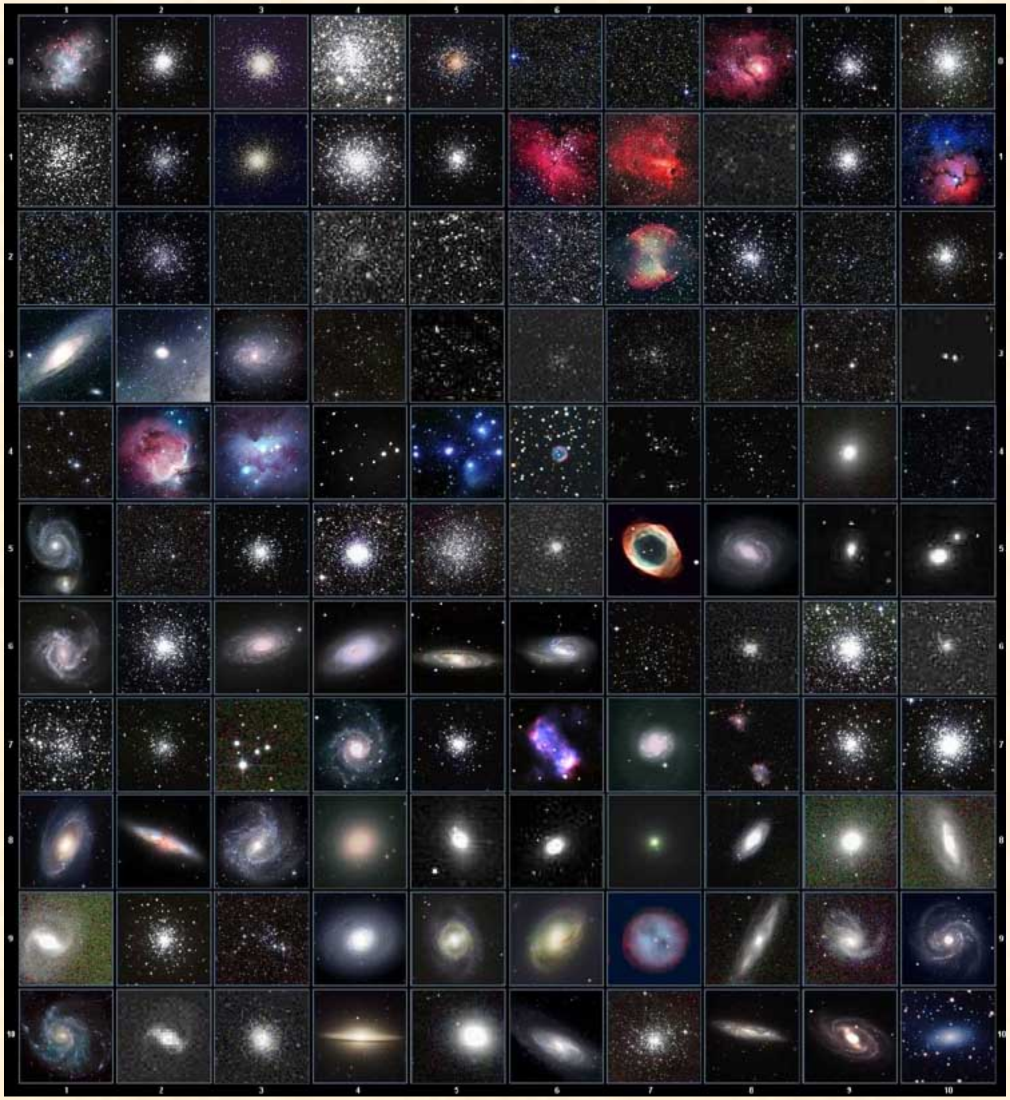
Astronomers e.g., Halley were really looking for comets.

Comets are diffuse i.e., not points of light like stars. But there were some other pesky diffuse objects which the Astronomers kept confusing as possibly being new comets.

Comet McNaught (C. Milovic 2007)

Frustrated by these “nuisance” fuzzy objects, Charles Messier (1730-1817) decided to make a catalog of their positions (which didn’t change with time).

Messier Catalog 1781 (~100 objects)



Later, after much debate including the famous Curtis-Shapley "Great Debate" of 1920, and Hubble's work with the Mt. Wilson 100-inch, Astronomers recognized some of these Messier objects were galaxies or "island universes", separate from our own Milky Way

(also open clusters, globular clusters, planetary nebulae)

William Herschel (1738-1822)

- William Herschel later extended Messier's catalog to 2500 nebulae (Latin for cloud)
- In 1785 he identified the Coma cluster of galaxies.
- Herschel also discovered Uranus …
- … and the infrared.

The Coma Cluster

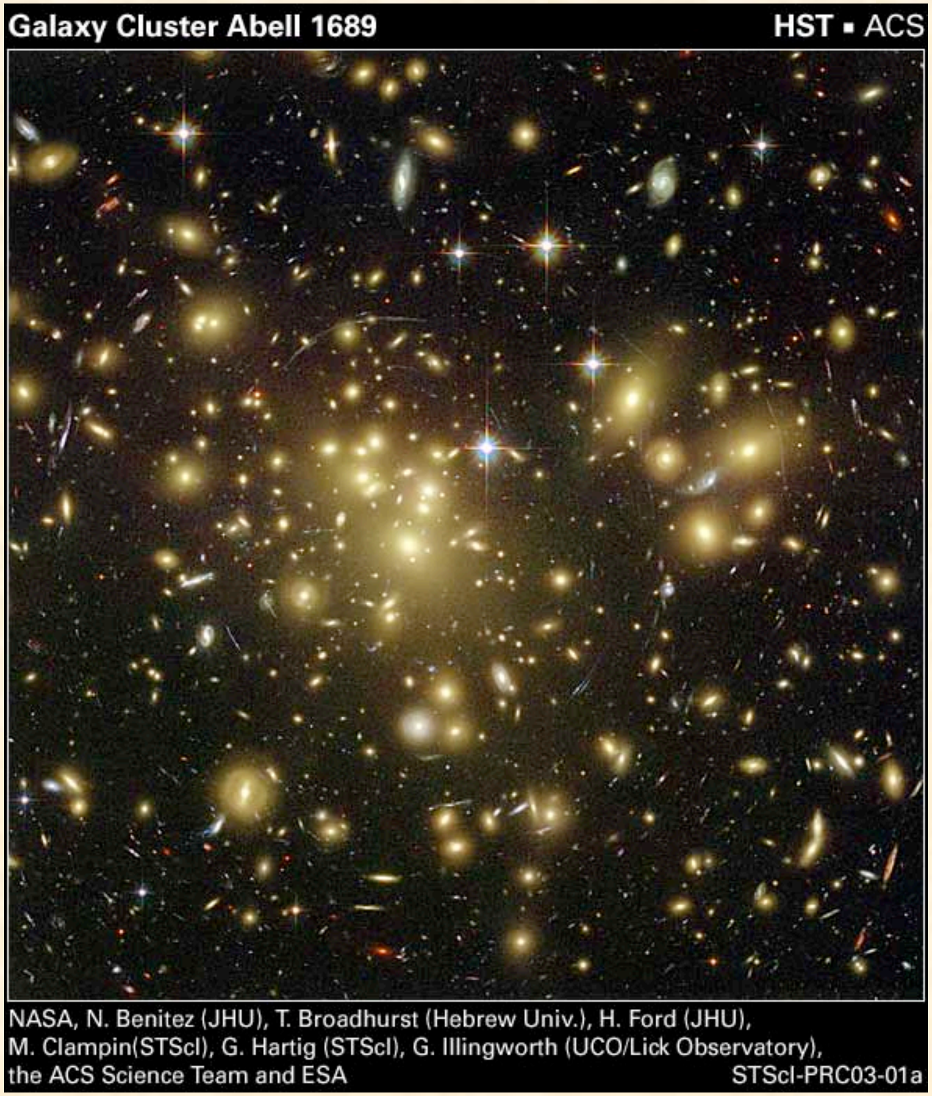
Clusters are the most massive gravitationally bound structures in the Universe! (big and bad :)

- Named after the constellation in which it is found, Coma Berenices.
- Coma means “hair” in Latin (legend of hair-sacrificing Queen Berenice II of Egypt)
- Nearest example of a rich (many galaxies) cluster
- At a distance of 333 million light years (z = 0.02)
- 10,000 galaxies = more galaxies than stars visible to the naked eye!
- Total mass of 10^15 solar masses.

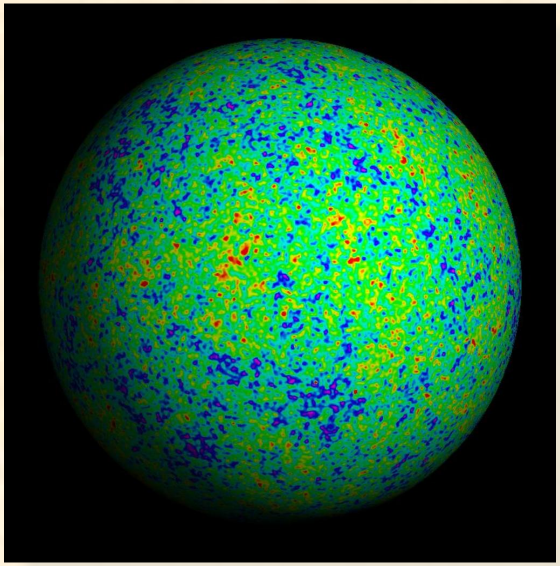
Cluster Catalogs

- Gradually Astronomers realized that clusters were very interesting objects in their own right and began to make cluster catalogs
- The most famous of these is the Abell catalog, compiled in the 1950's by George Abell (a graduate student) from Palomar Observatory Sky Survey Photographs
- It contained ~2700 clusters at $z < 0.2$
- Coma was #1656 in the catalog - A1656

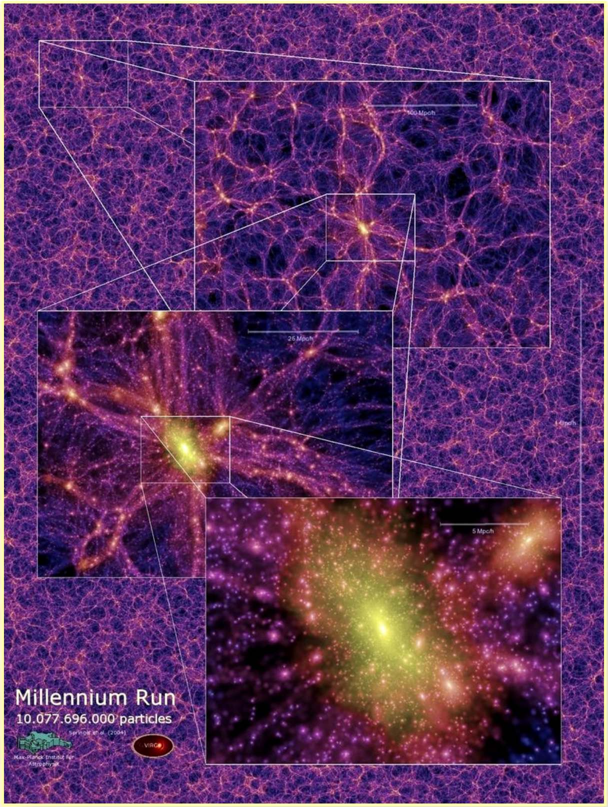
Galaxy Cluster Abell 1689

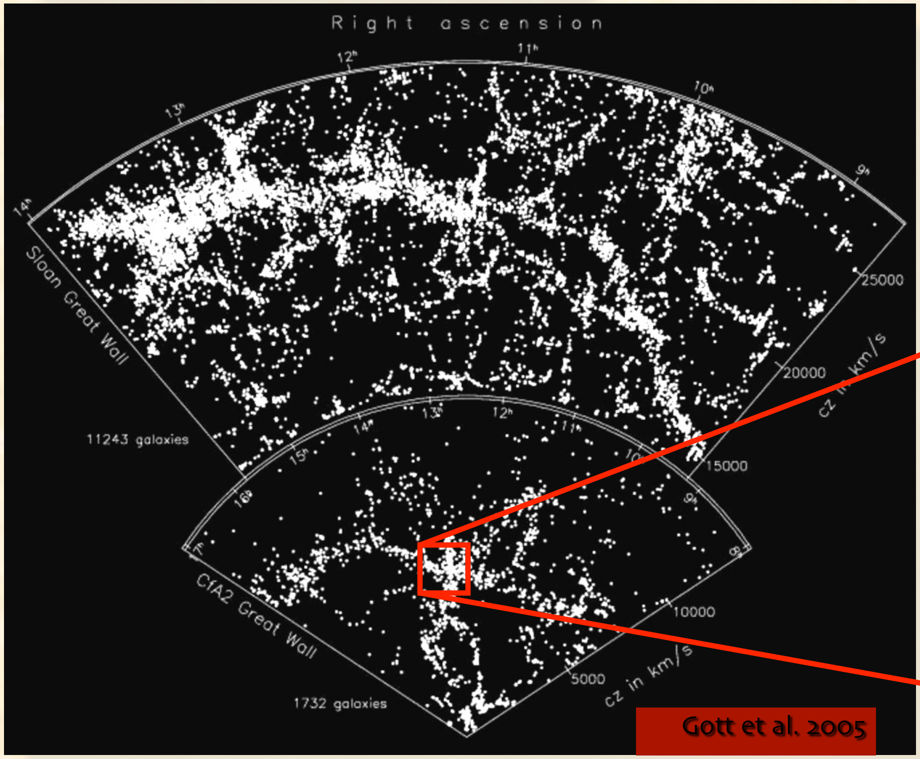


Hubble Space Telescope Image



Clusters form from regions of the Universe which were very slightly overdense when the Universe is young.





Why are Clusters Interesting?

Galaxy Evolution Studies

A 370 : Refurbished ACS

Cosmological Constraints

From SDSS (Nearby Clusters)

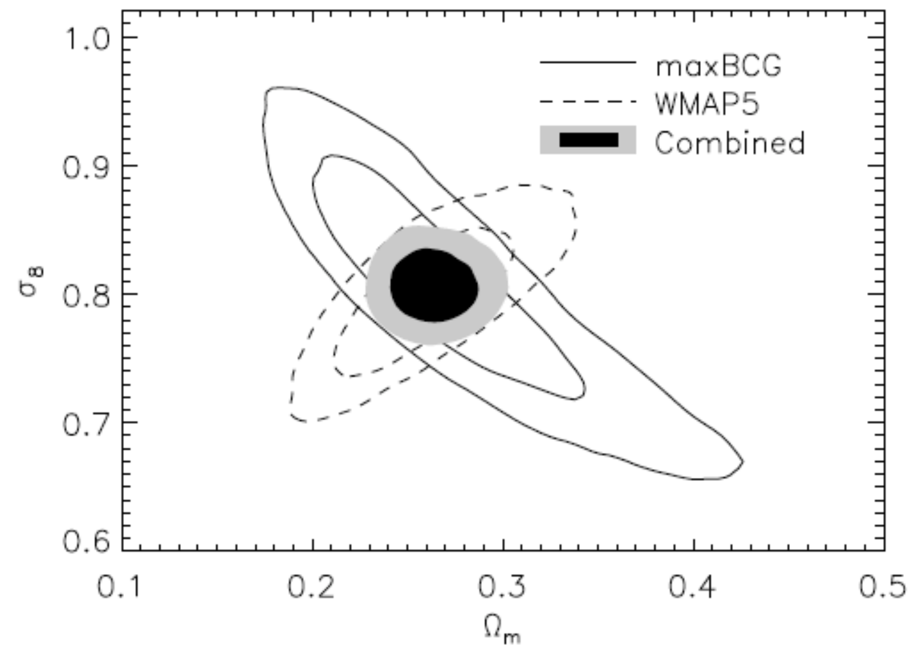
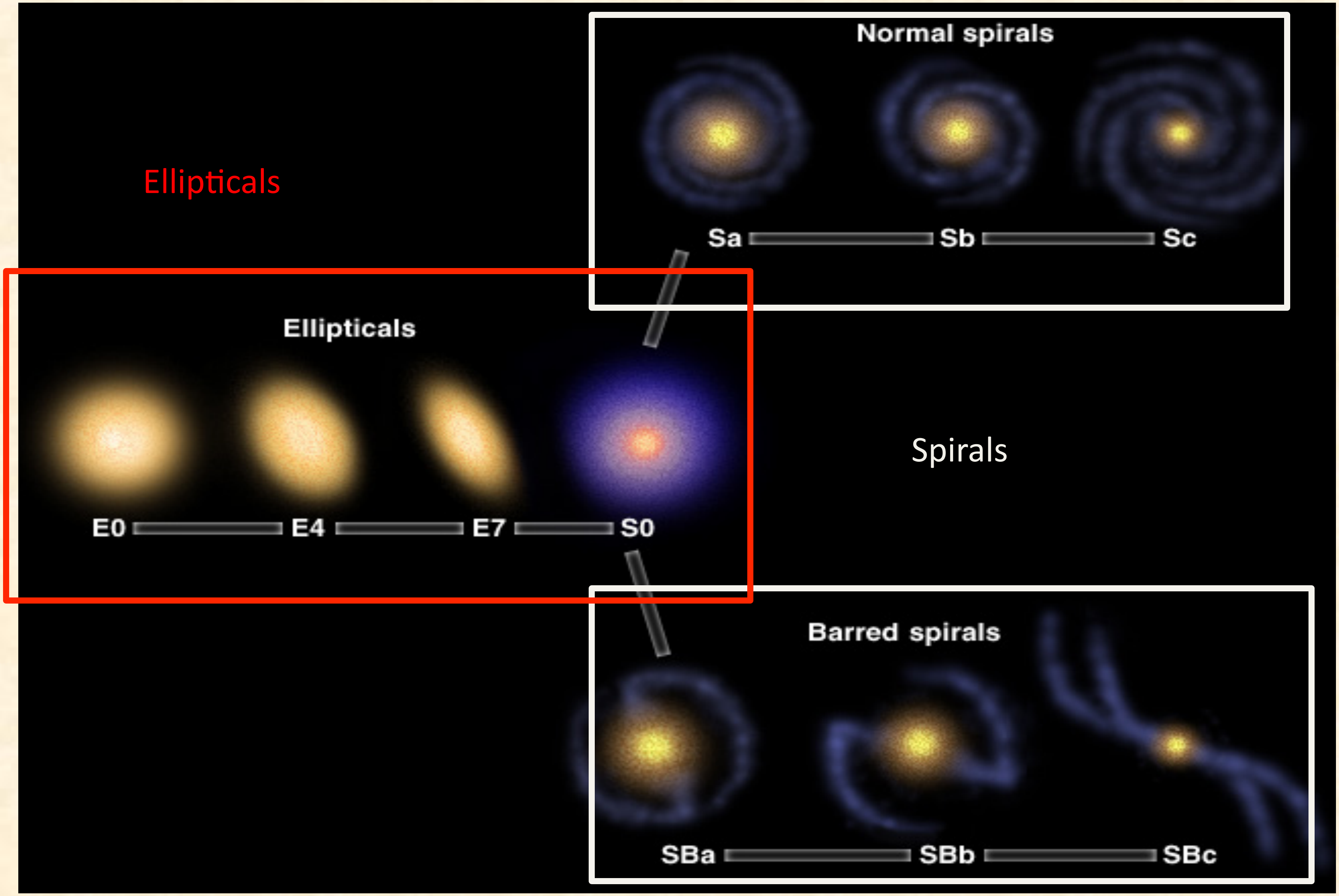


FIG. 5.— Constraints on the $\sigma_8 - \Omega_m$ plane from maxBCG and WMAP5 for a flat ΛCDM cosmology. Contours show the 68% and 95% confidence regions for maxBCG (solid), WMAP5 (dashed), and the combined results (filled ellipses). The thin axis of the maxBCG-only ellipse corresponds to $\sigma_8(\Omega_m/0.25)^{0.41} = 0.832 \pm 0.033$. The joint constraints are $\sigma_8 = 0.807 \pm 0.020$ and $\Omega_m = 0.265 \pm 0.016$ (one-sigma errors).

Hubble Tuning Fork Diagram (1926)

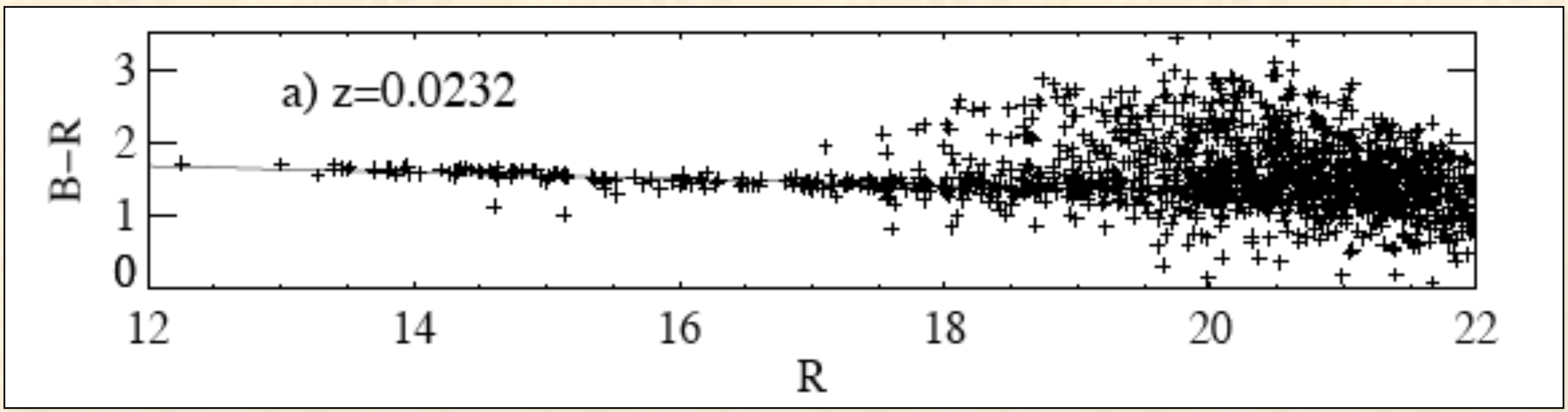


The Cluster Red Sequence

10s-1000s of red bulgy "elliptical" galaxies (surprisingly few blue galaxies with "spiral" arms)

+

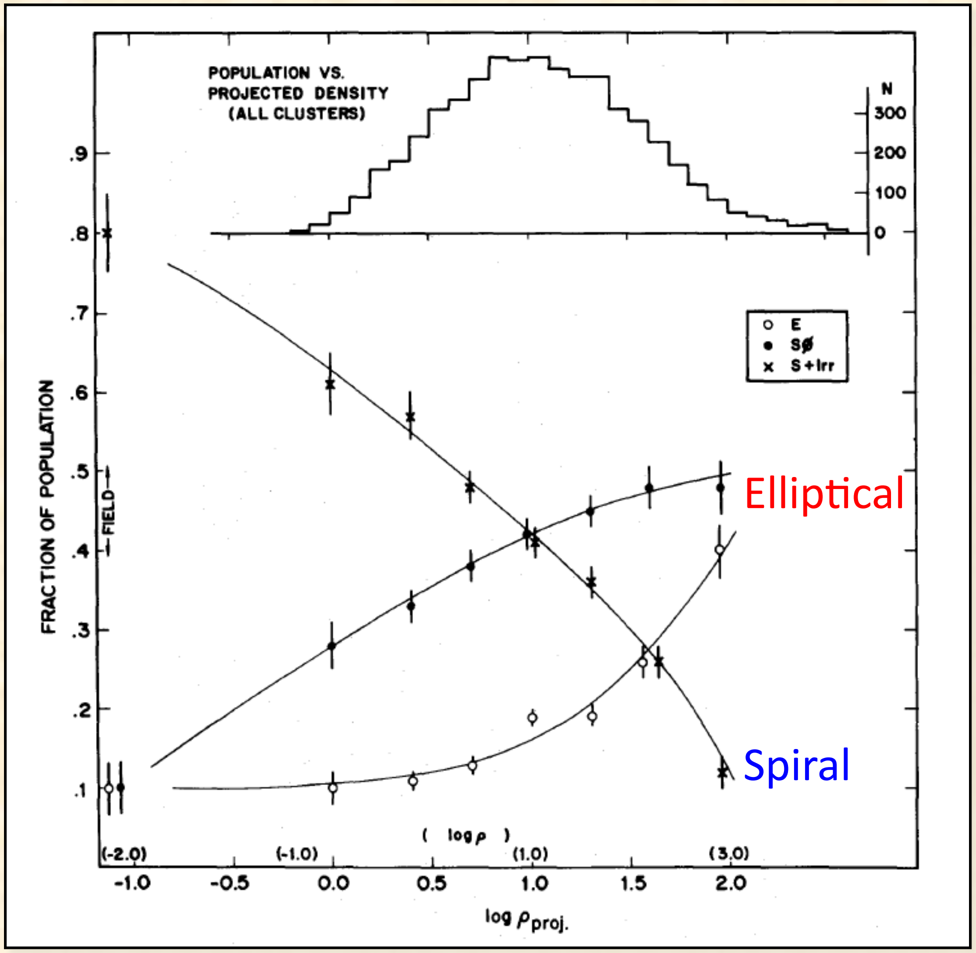
Dark Matter & Hot Gas

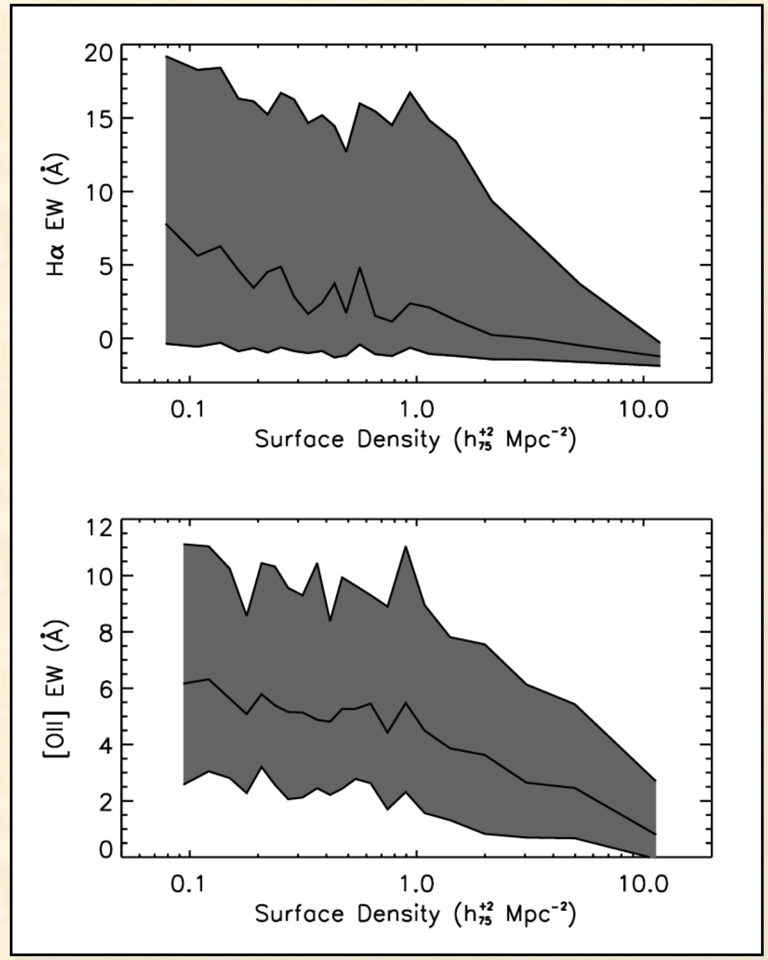


Color-Magnitude

Gladders et al. (1998)

Environment Drives Galaxy Evolution





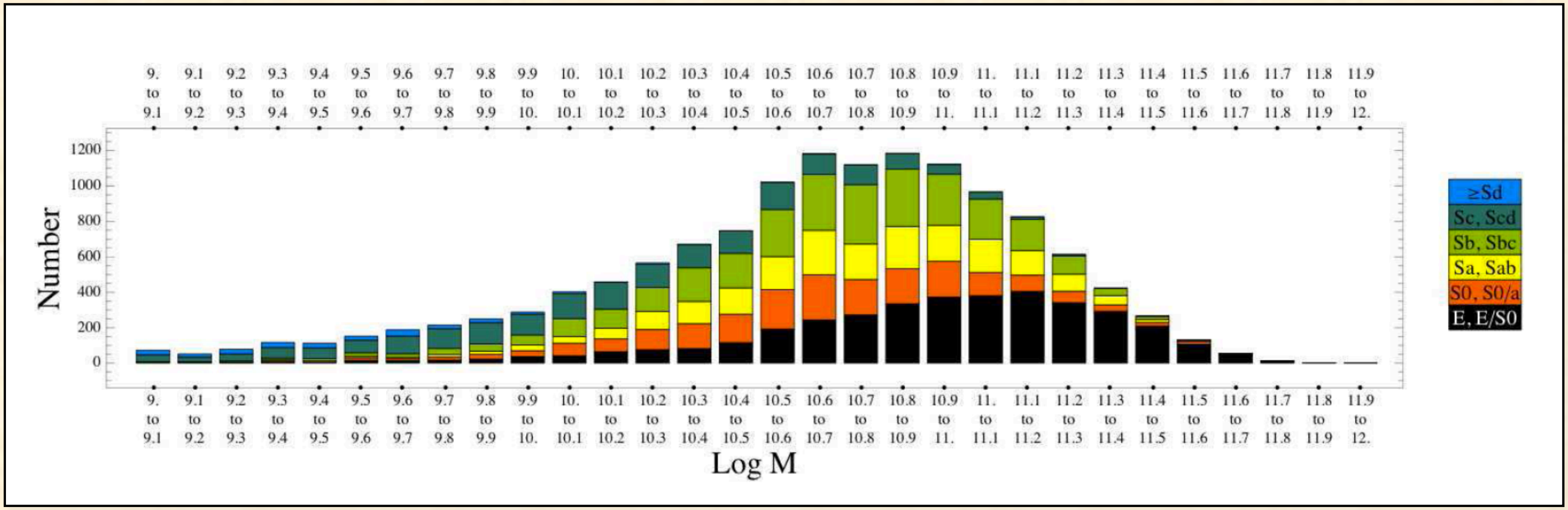
Morphology-Density

Dressler (1980)

Star Formation-Density

Gomez et al. (2003)

Mass Drives Galaxy Evolution



Morphology-Mass

Nair et al. (2010)

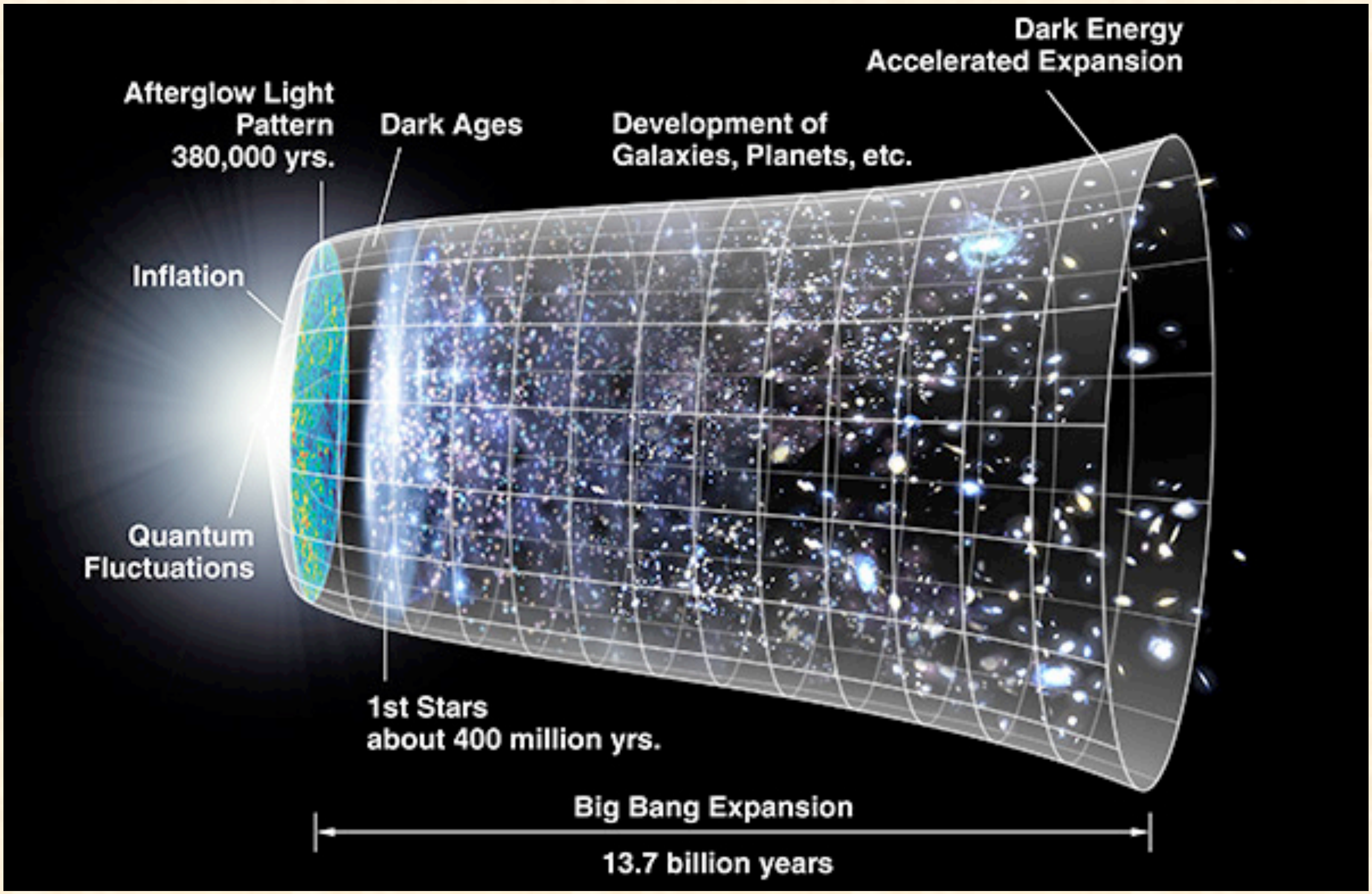
Galaxy Evolution

Mass versus Environment
(“nature” versus “nurture” debate)

Clusters are Excellent Laboratories for Studying Factors Important to Galaxy Evolution

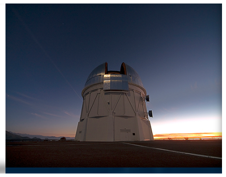
- Clusters are unique, high-density regions in the Universe, containing many of the oldest, most massive galaxies.
- Clusters are the perfect laboratories to try to tease apart effects of mass versus effects of environment.
- Next Step : Find younger clusters "babies in the nursery" => more obvious which processes are important for shaping galaxy formation.
- How shall we find young clusters?

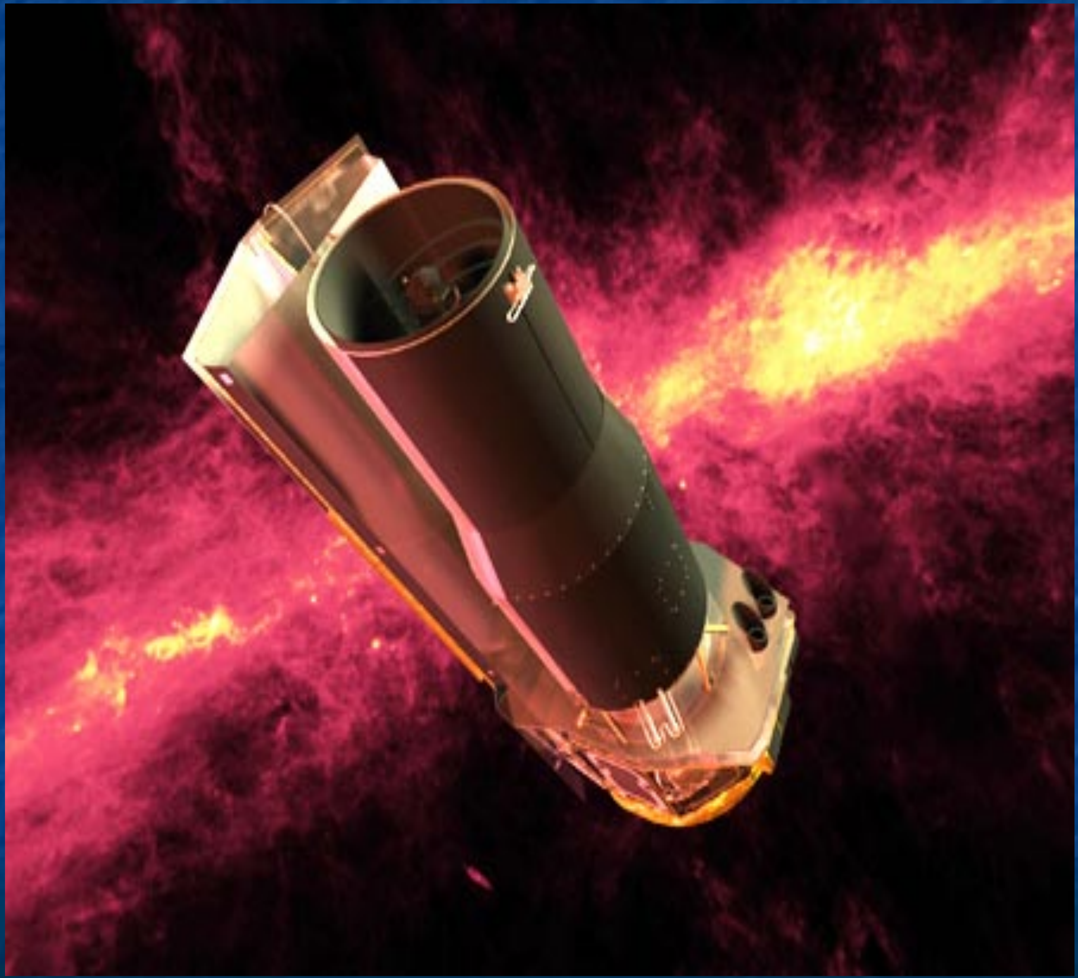
Observing More and More Distant Objects = Looking Further and Further Back in Time



The Spitzer Space Telescope

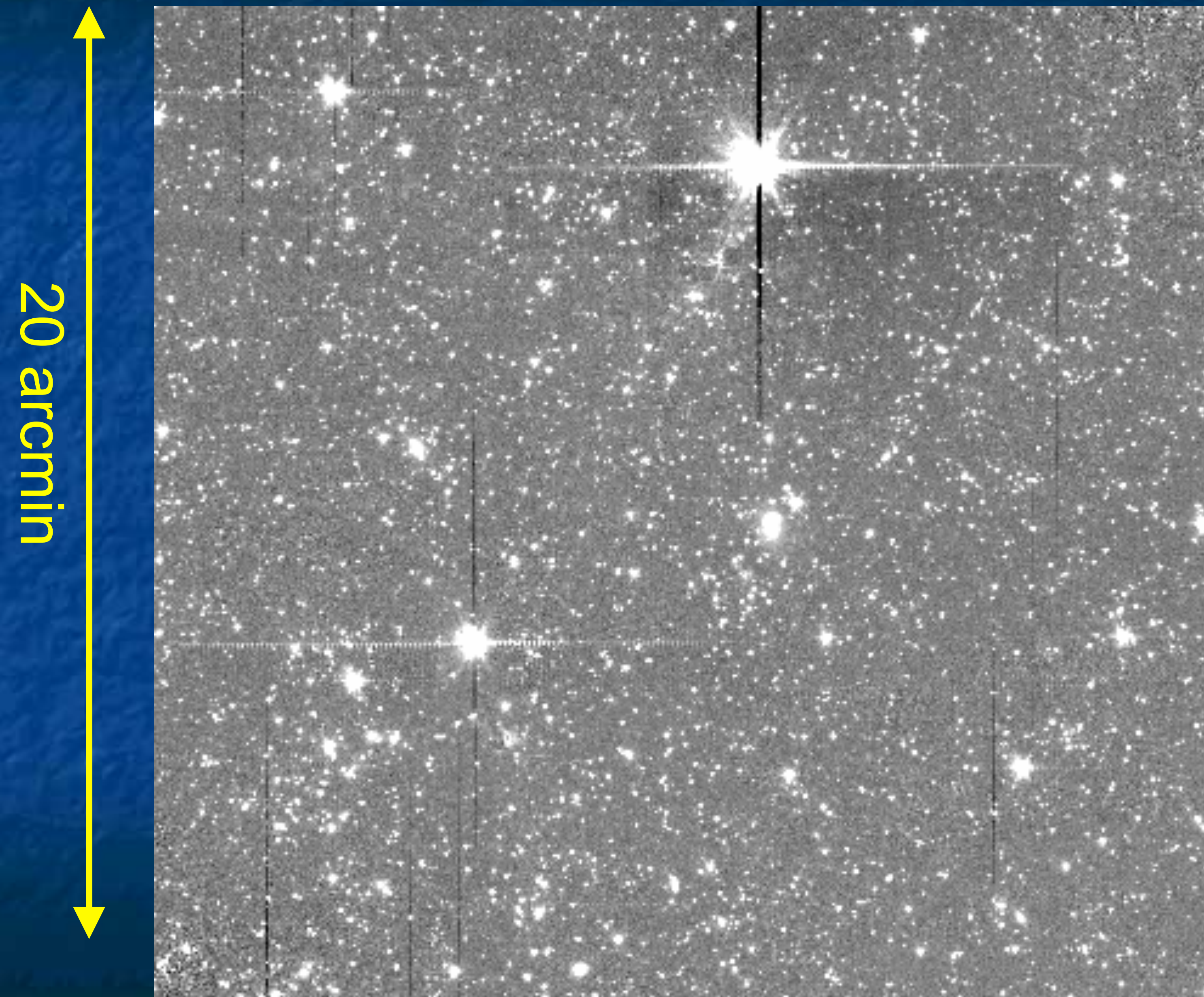
Infrared (3.6 - 160) microns



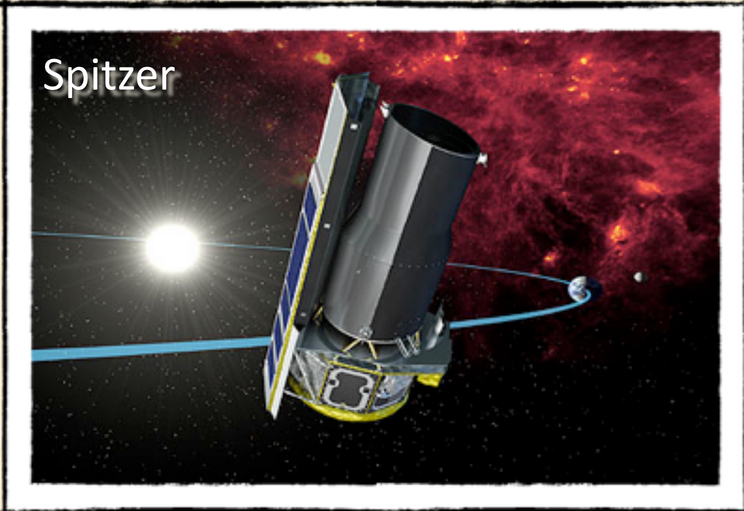


Mirror = 85cm Diameter

Spitzer IRAC 3.6 micron 120s



The SpARCS Survey (PI Wilson)



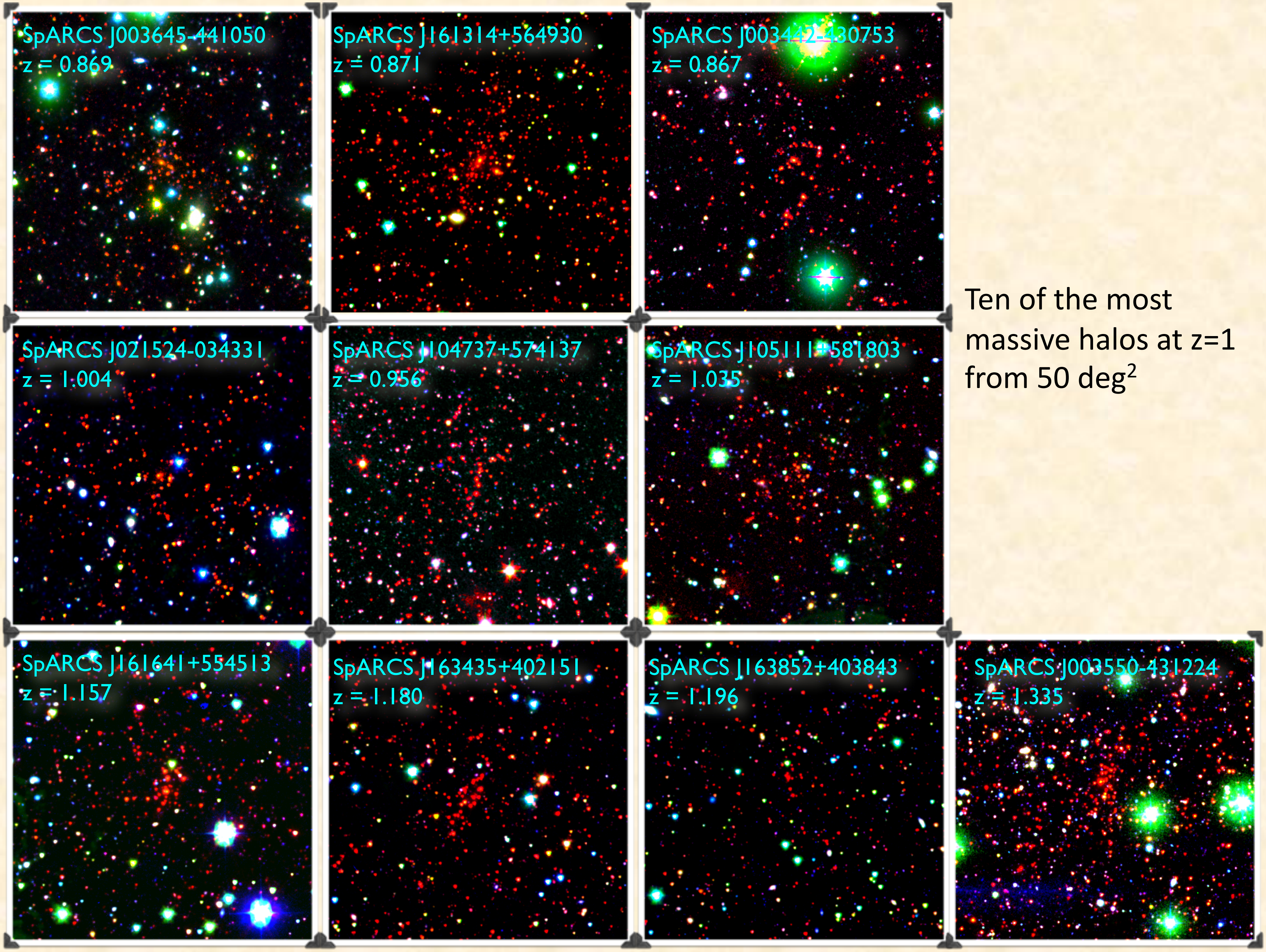
- Spitzer Adaptation of the Red-sequence Cluster Survey
- Deep-wide z'-band survey combined with Spitzer SWIRE 50 deg^2 survey
- Clusters are selected based on z'-[3.6] color (gives photo-z)*
- 200 new cluster candidates z > 1 with estimated M > 1 x 10^14 M_{Sun}

SAMPLES OF CLUSTERS !!

Wilson et al. (2009), Muzzin et al. (2009), Demarco et al. (2010)

Clusters at $z \sim 1$

Seen as they appeared when
Universe was 6 billion years old



Ten of the most massive halos at z=1 from 50 deg^2

“Going Observing”

a.k.a. “getting data”

I grew up in Scotland

where it rains a lot

You can’t see stars through clouds!

So I didn’t own a telescope growing up.

But I have used the largest telescopes in the world

<= Subaru 8.2m
(operational 1999)

Canada-France-Hawaii 3.8m =>
(operational 1979)

Big Island,
Hawaii

“Going Observing”

The culture of getting data is changing….

…in a way which is bad for young people

Big Telescopes are moving to “queue” or “remote” observing

Which means astronomers don’t go to the telescope, and often don’t even take their own data

The GCLASS Survey (PIs Wilson/Yee)

- Spectroscopic survey of 10 rich clusters at $z \sim 1$ ($0.87 < z < 1.34$) with Gemini/GMOS

- The Gemini Cluster Astrophysics Survey "GCLASS"

- Low-res: R=450 =17Å = 400km/s
- 4 to 6 masks per cluster (45 total)
- 3.6um selected sample of galaxies

- Nod + Shuffle mode with microslits

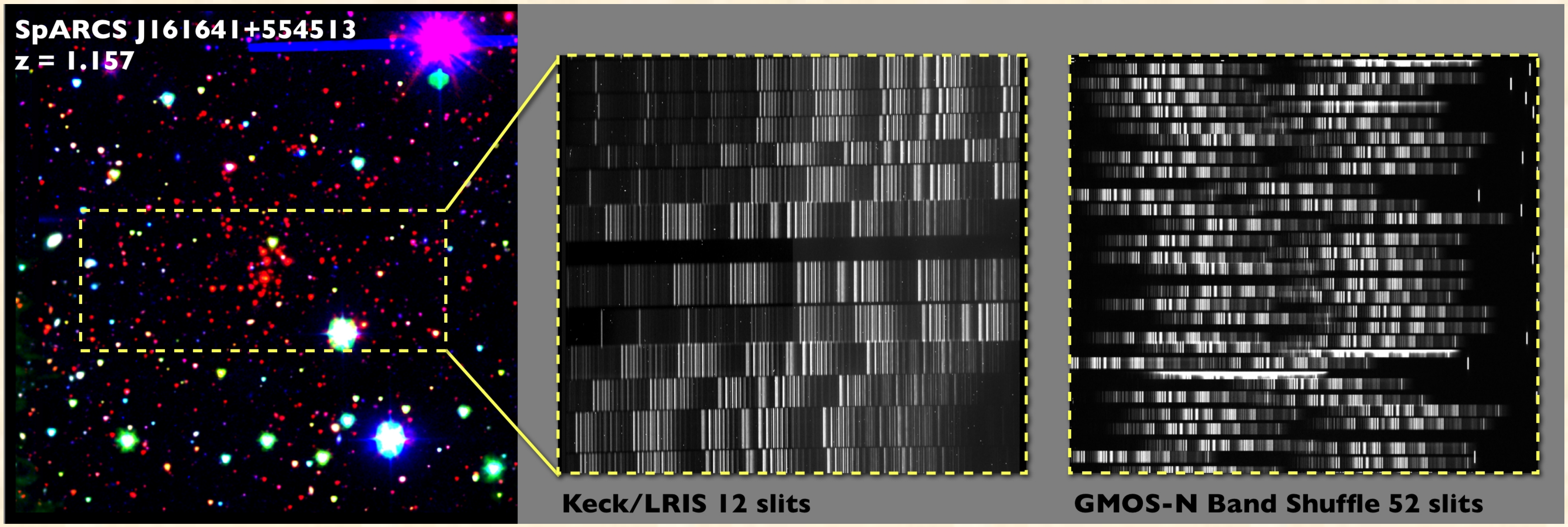
- Observational goal: Spectroscopy of **50 members** in each cluster(!)

- 222 hr (25 night) multi-semester project with Gemini/GMOS (completed 2012)

GCLASS took advantage of GMOS's unique capability for Microslit Nod & Shuffle Spectroscopy

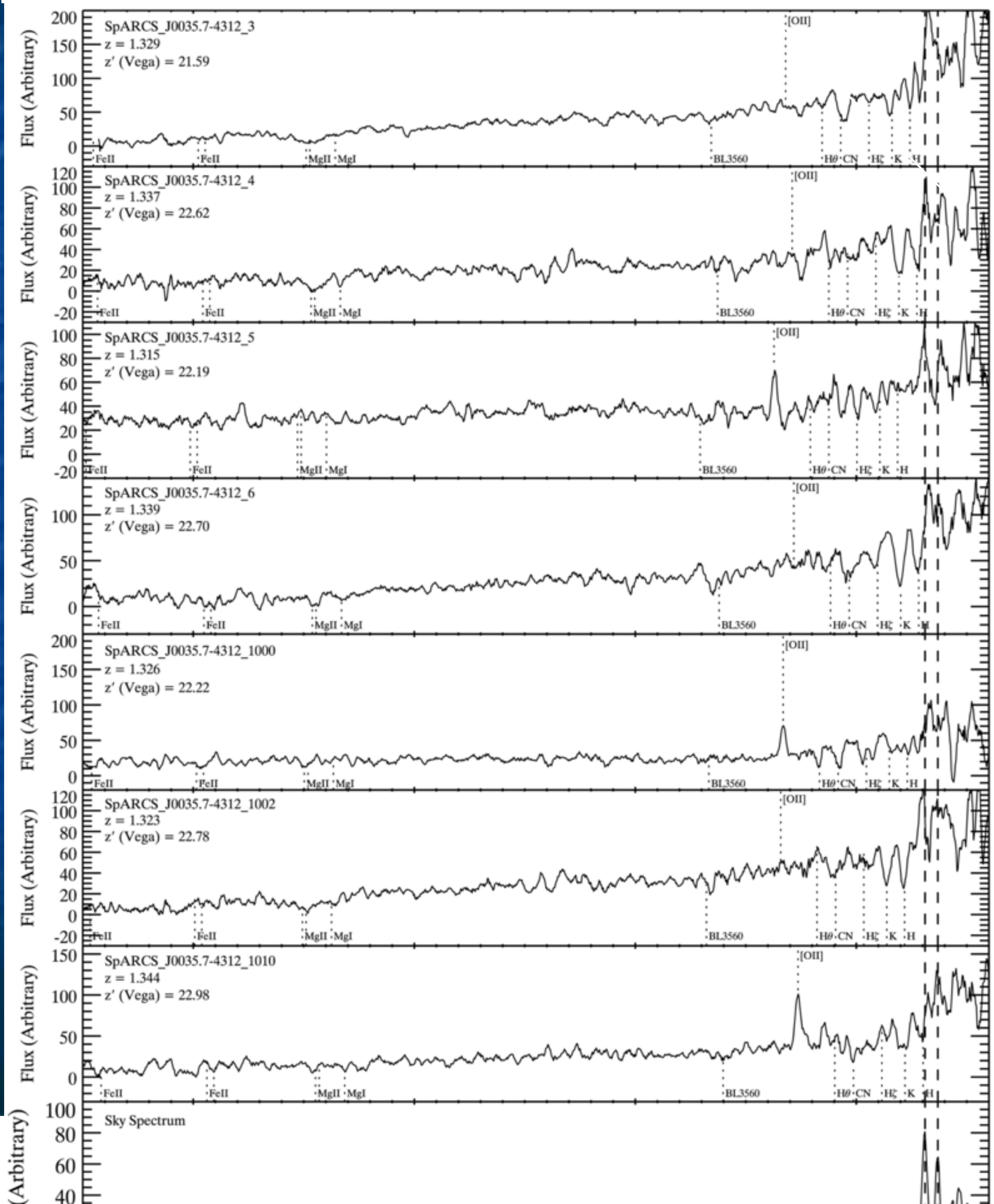
No other spectrograph on an 8-10m class telescope can target such a high number density of galaxies making this project best suited to Gemini/GMOS

Gemini/GMOS Nod & Shuffle: An Efficient Redshift Machine



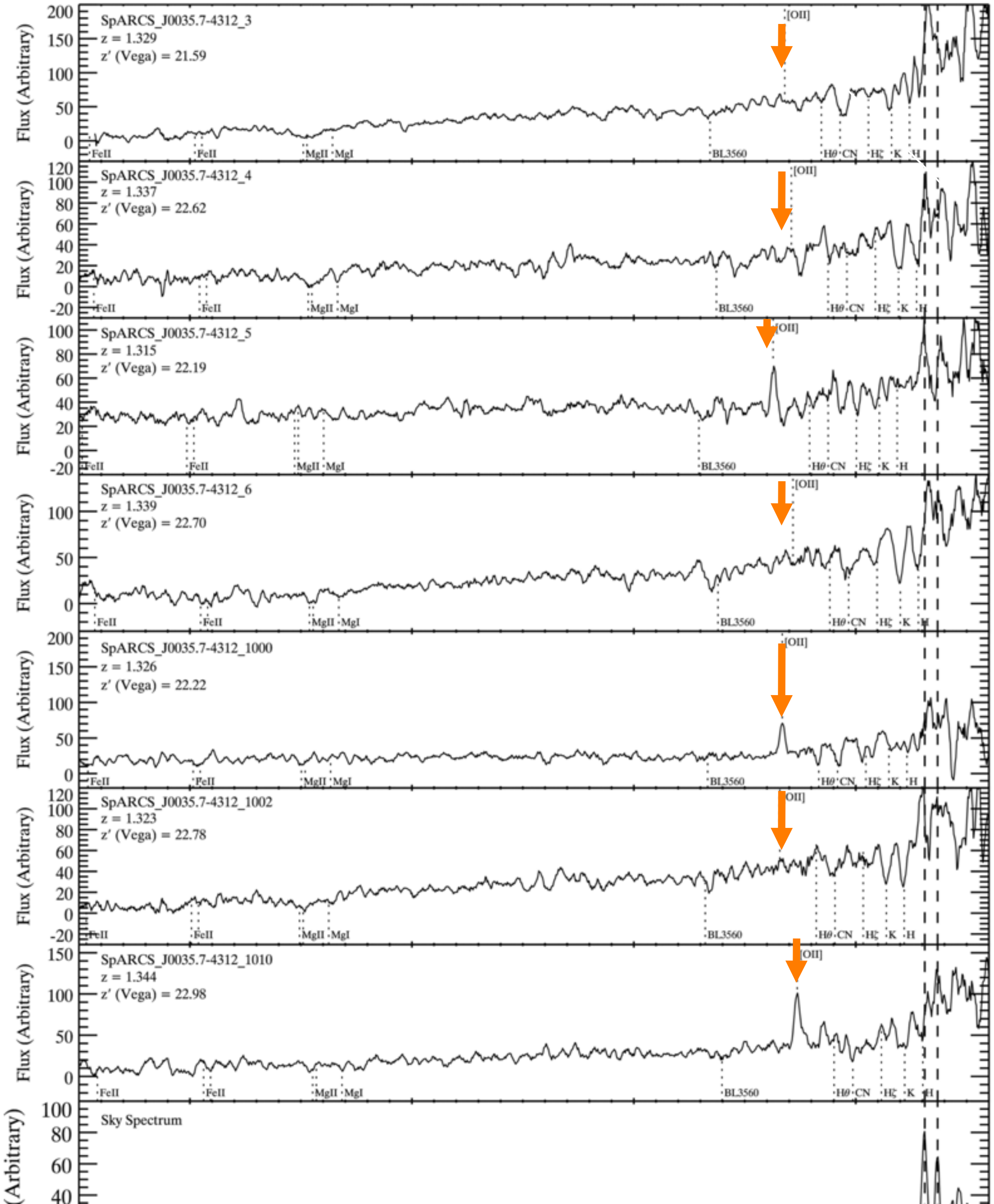
More than 4x as many galaxies can be targeted at one time more slits using GMOS vs. LRIS, a significant improvement in efficiency.

Example Spectra of 7 Cluster Members



from Wilson et al., 2009 Astrophysical Journal, 698, 1943

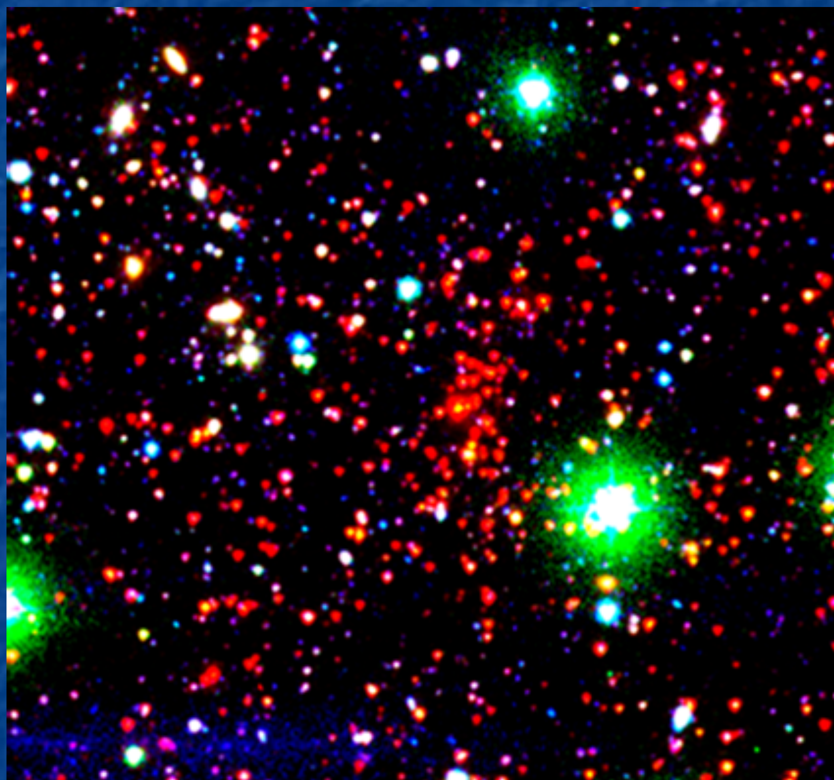
Example Spectra of 7 Cluster Members

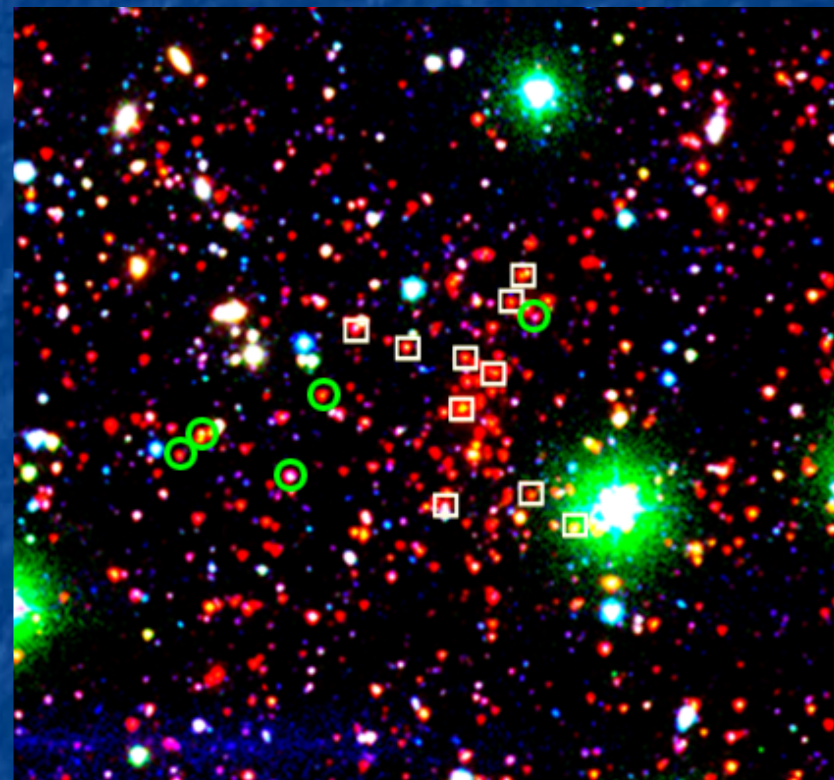


from Wilson et al., 2009 Astrophysical Journal, 698, 1943

SpARCS J003550-431224

Seen as it appeared when Universe was 4.7 billion years old





$$\sigma = 1050 \pm 230 \text{km s}^{-1}$$

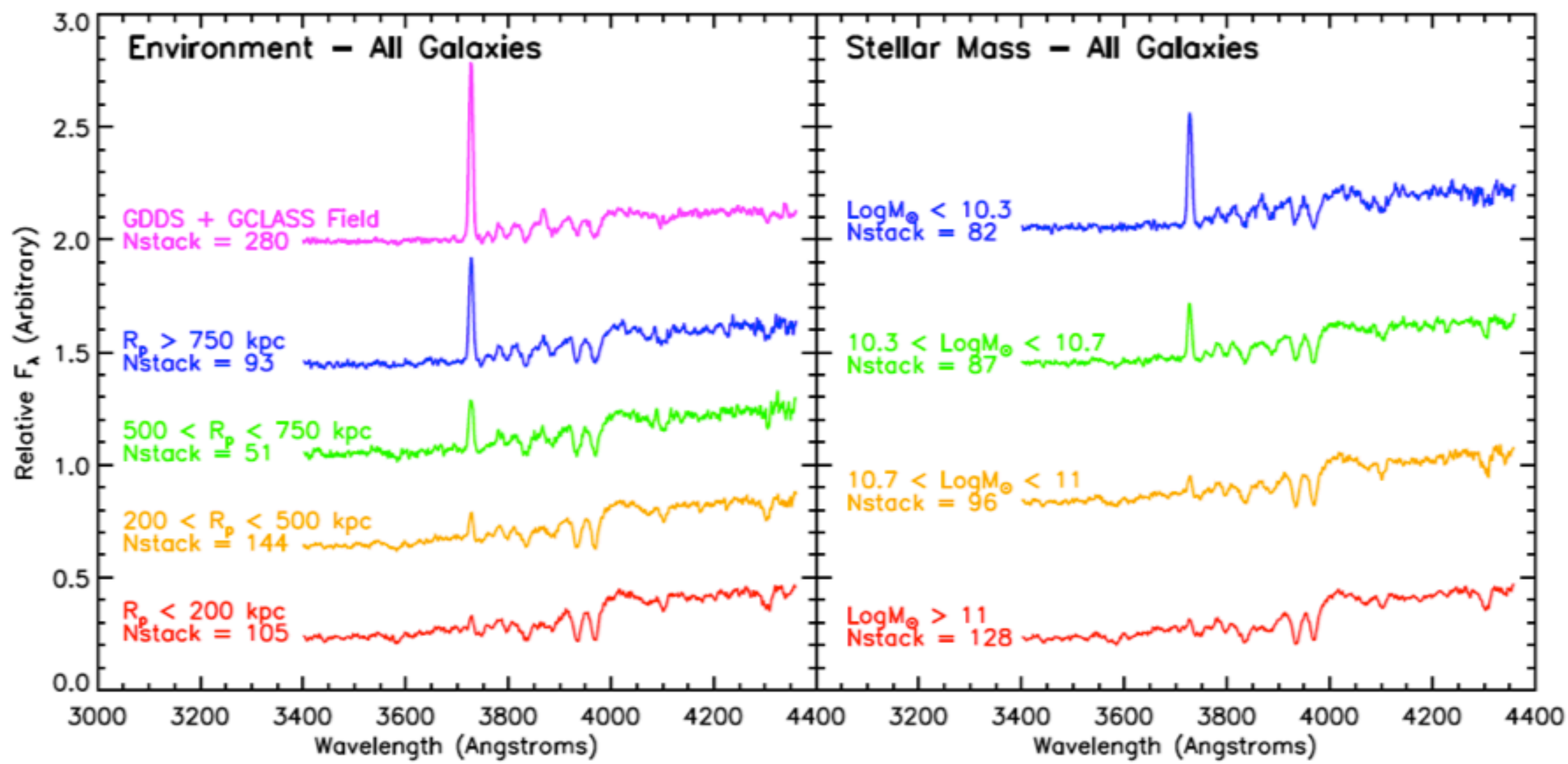
$$M_{200} = (9.4 \pm 6.2) \times 10^{14} M_{\text{Sun}}$$

□ 10 members

○ non-member

http://www.faculty.ucr.edu/~gillianw/SpARCS

How Galaxies Evolve is shaped by both Nature & Nurture



Stacked spectra (~500 members), as a fn of clustercentric distance (left) and SM (right).

Muzzin et al., 2012, ApJ, 746, 188

Star formation decreases with increasing density (left) and increasing mass (right)

At z~1, galaxies are strongly influenced both by environment AND stellar mass.

Both being in a cluster or being massive will stop a Galaxy from Forming Stars

Both Environment "Nurture" and Mass "Nature" Quench Star Formation but Environmental Quenching is a Faster Process

What is the Primary Physical Process(es) Causing Environmental Quenching?

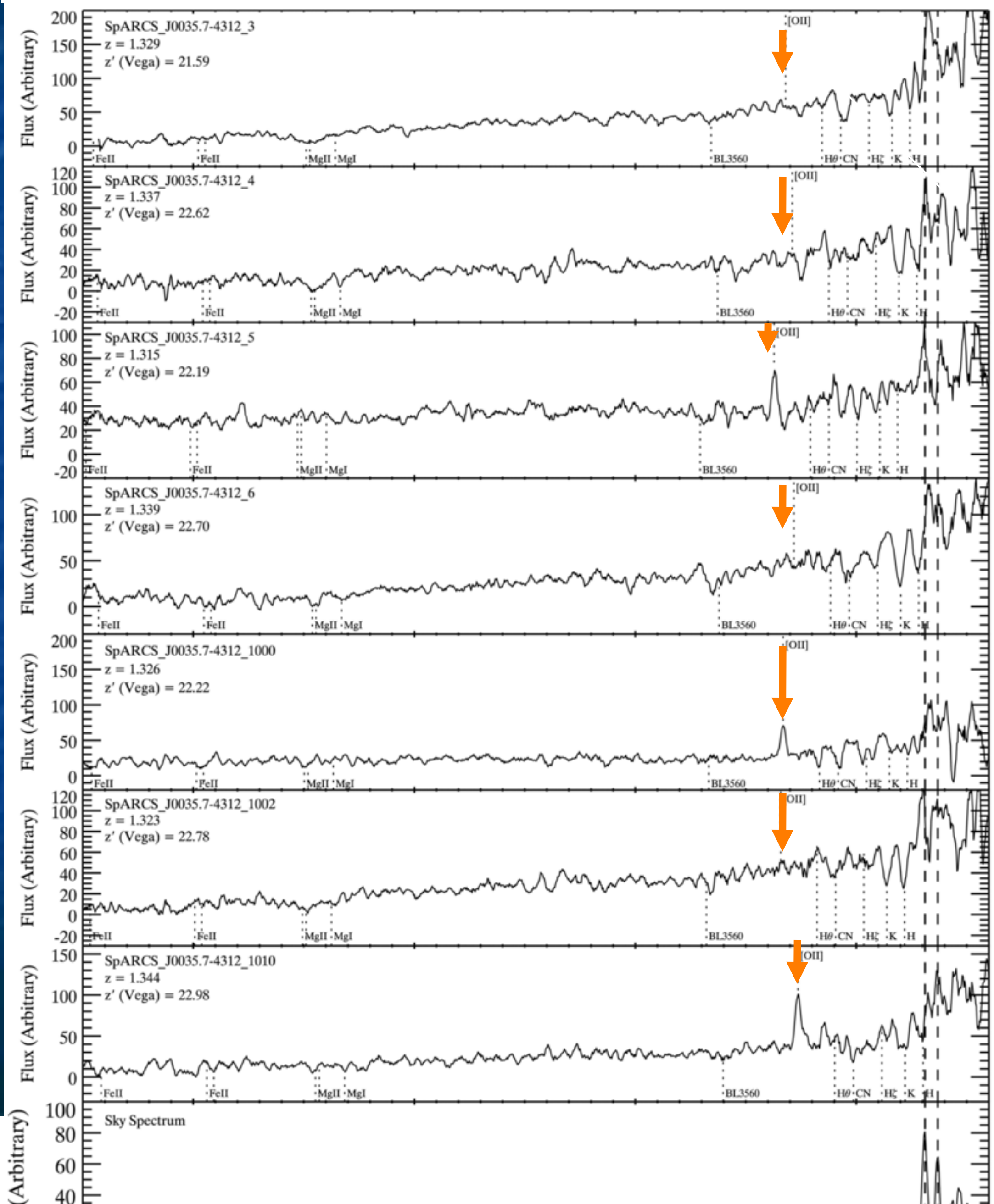
We don't know yet

Need to study clusters at higher redshift to get a larger redshift baseline and a better handle on the physical processes behind environmental quenching.

Clusters at $z > 1.0$

Seen as they appeared when Universe was less than 6 billion years old

Why Not use Gemini/GMOS?



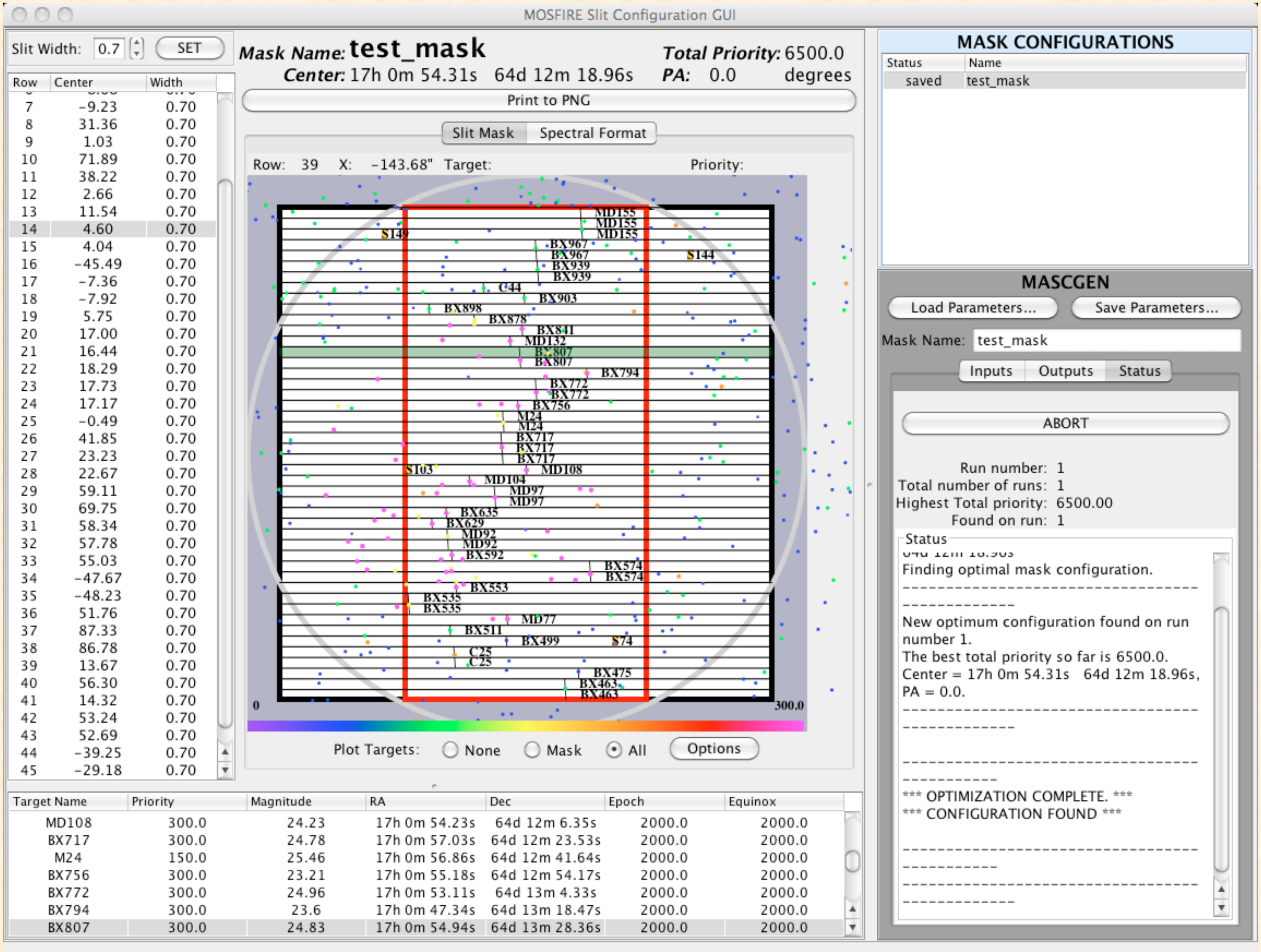
from Wilson et al., 2009
Astrophysical Journal,
698, 1943

Keck/MOSFIRE

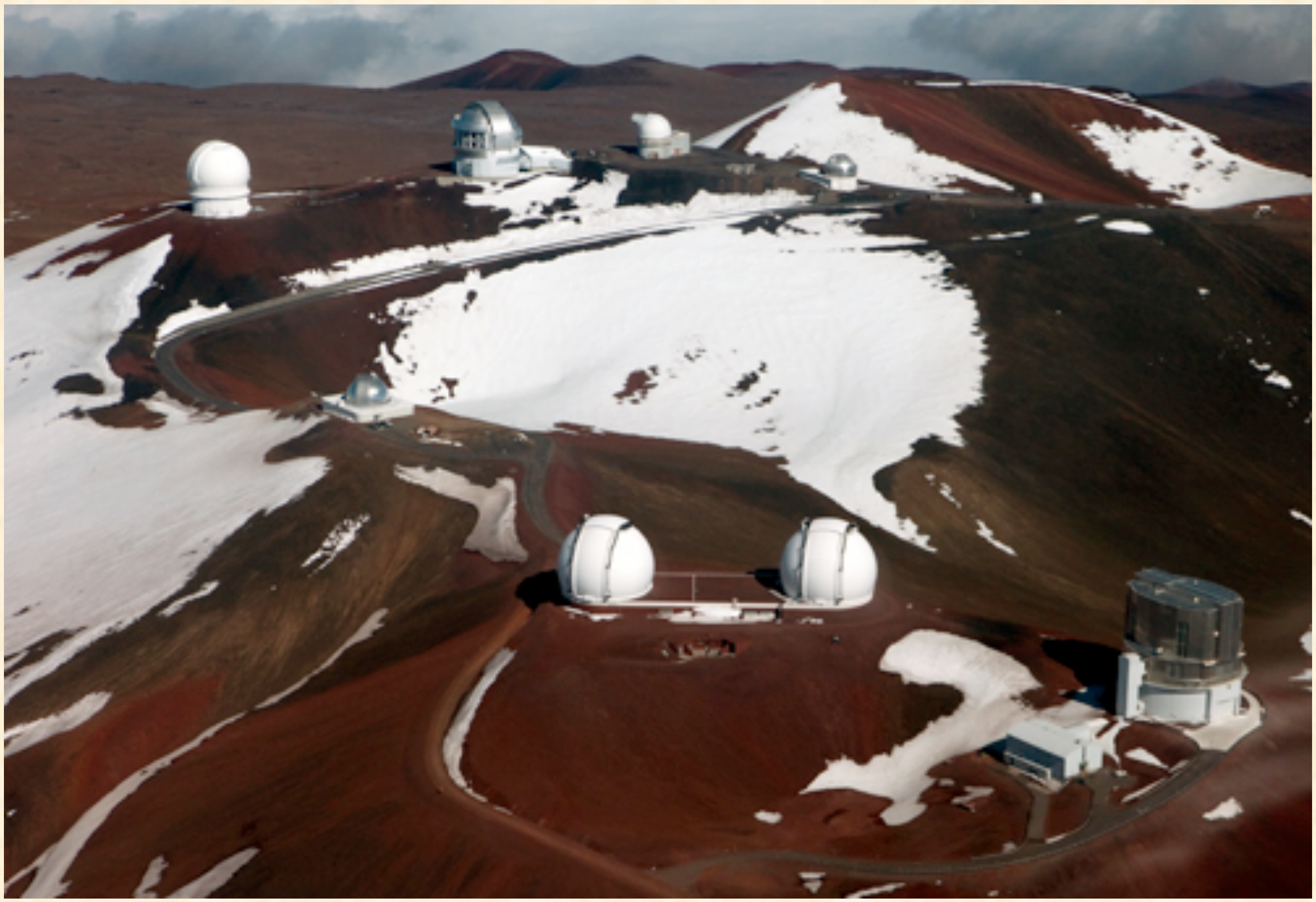
near-IR multi-object spectrograph

46 real-time configurable slits

Designing Slitmasks



The twin 10m Keck telecopes, summit of Mauna Kea, HI



Keck Headquarters, Waimea, HI

Keck Headquarters, Waimea, HI

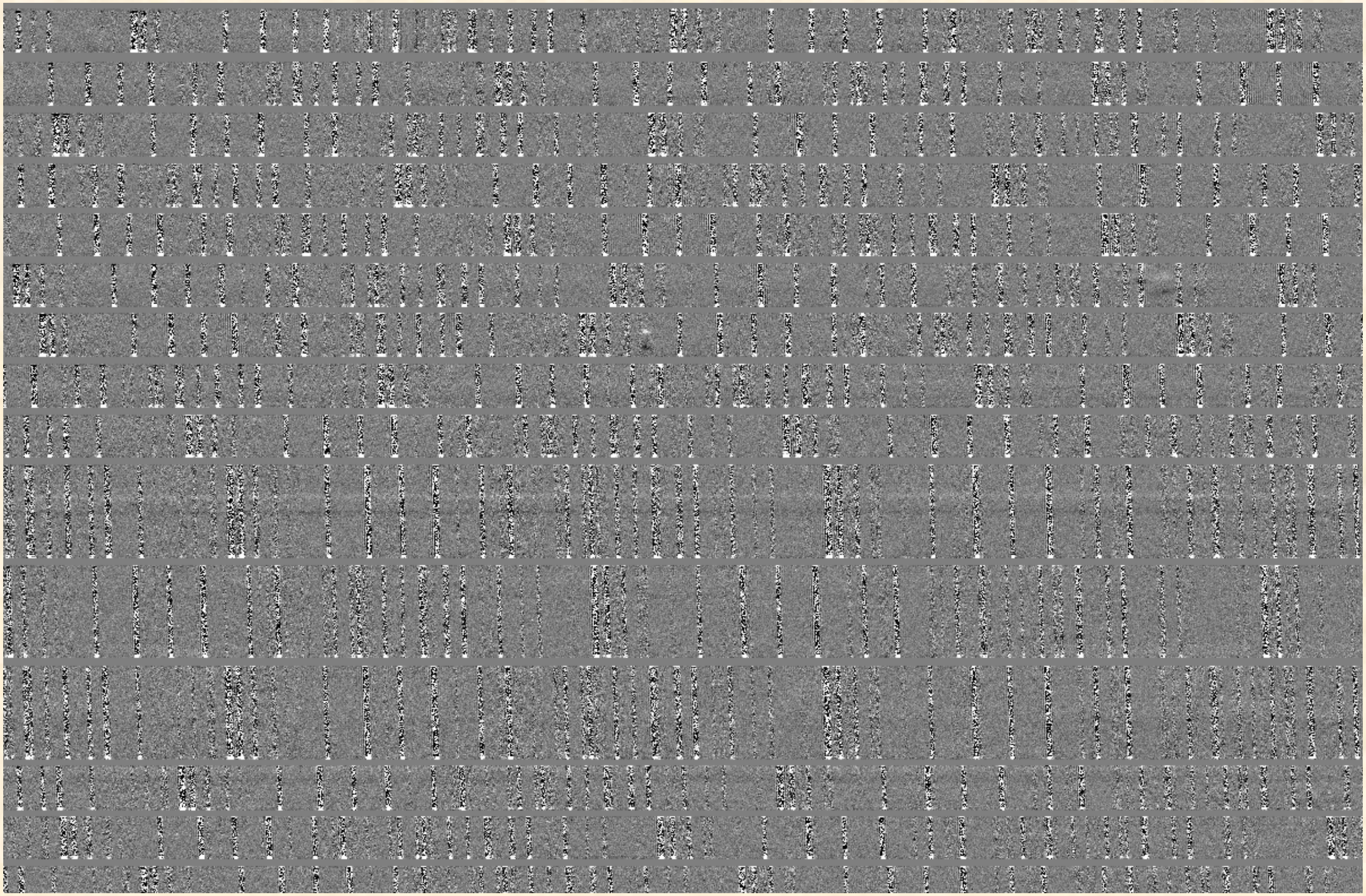
You can see the Telescopes

Control Room

Control Room

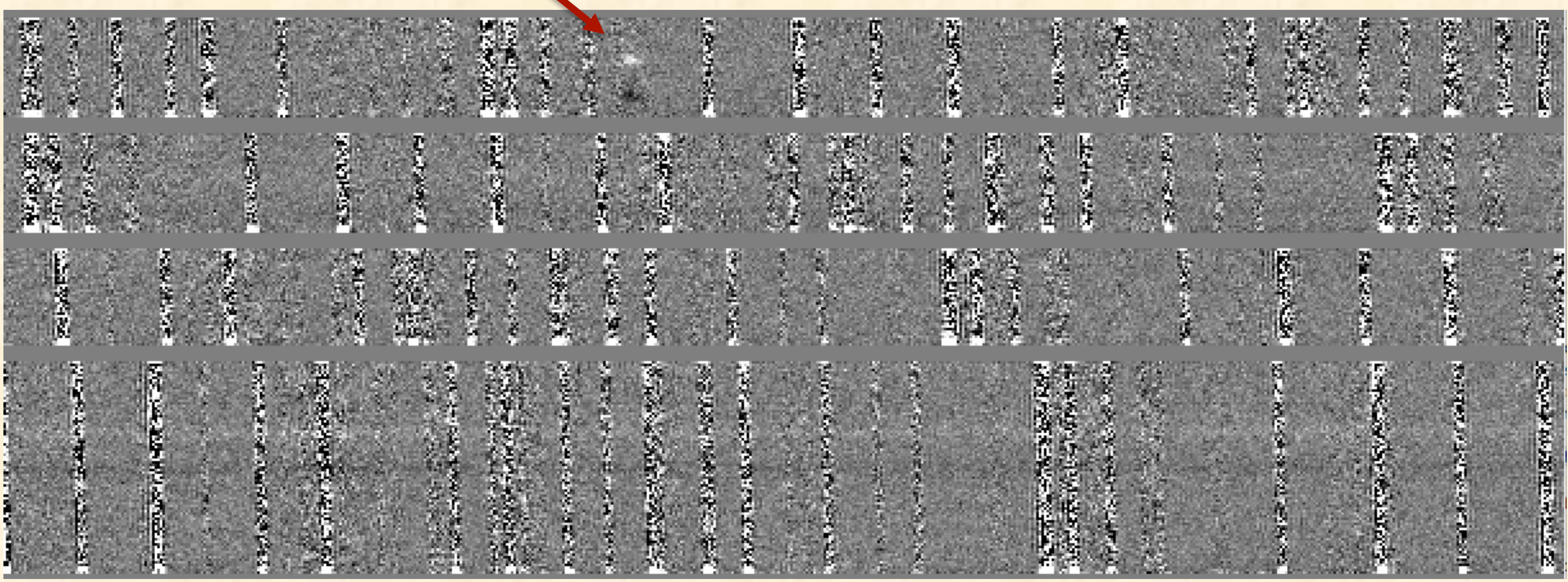
Control Room

Data from MOSFIRE



Data from MOSFIRE

H-alpha emission line
(rest-frame 6563 Angstroms redshifted into infrared -> ~17000 Angstroms)



Solar telescopes often employ H-alpha filters

Data from MOSFIRE

H-alpha emission line
(rest-frame 6563 Angstroms redshifted into infrared -> ~17000 Angstroms)

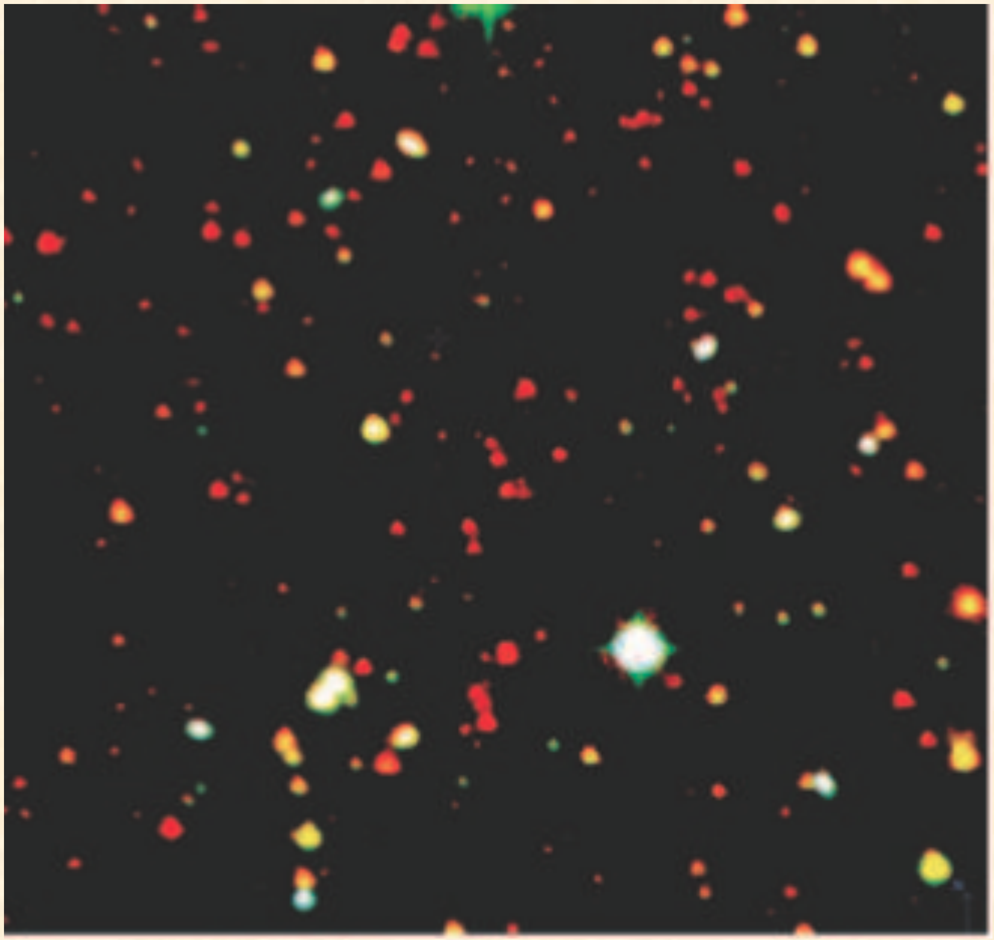
Weak [NII] emission line

[OII] is produced by both star formation & AGN (quasars etc)

H-alpha (and ratio H-alpha/N[II]) gives much more accurate measurement of star formation

Andrew DeGroot, one of my graduate students, is leading the MOSFIRE data reduction

New cluster seen as it appeared when the Universe was only 4 billion years old

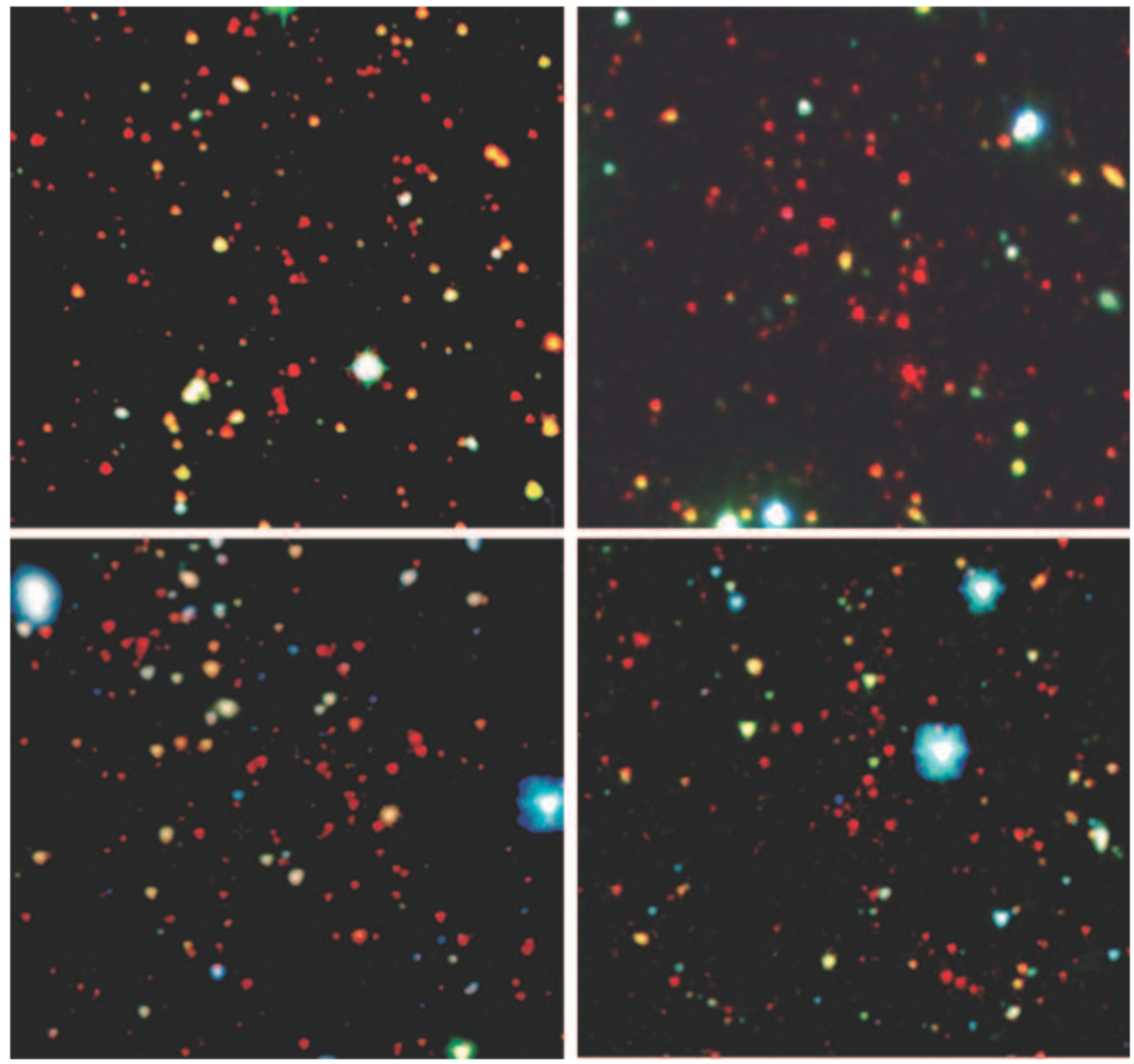


De Groot et al., 2014, in prep

g’z’[3.6] color image. FOV is 3 x 3 arcmin (1.5 x 1.5 Mpc)

Hubble Space Telescope (HST) is currently taking observations of ***Four SpARCS Clusters***

Spitzer Space Telescope images of four of the most distant clusters ever discovered, seen as they appeared 9.6 billion years ago when the Universe was only 4.1 billion years old



Questions?

"Astronomer by Candlelight"

"Astronomer by Daylight"