The SpARCS $1 < z < 2$ Cluster Survey

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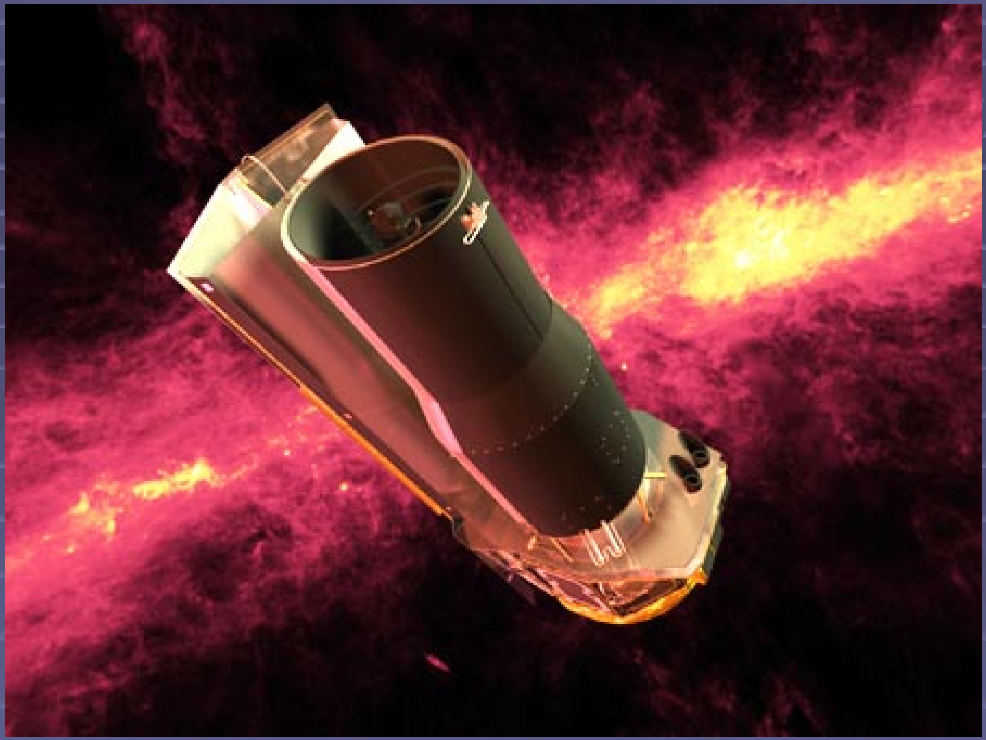
The Spitzer Space Telescope



IRAC, MIPS, IRS infrared imaging and spectroscopy

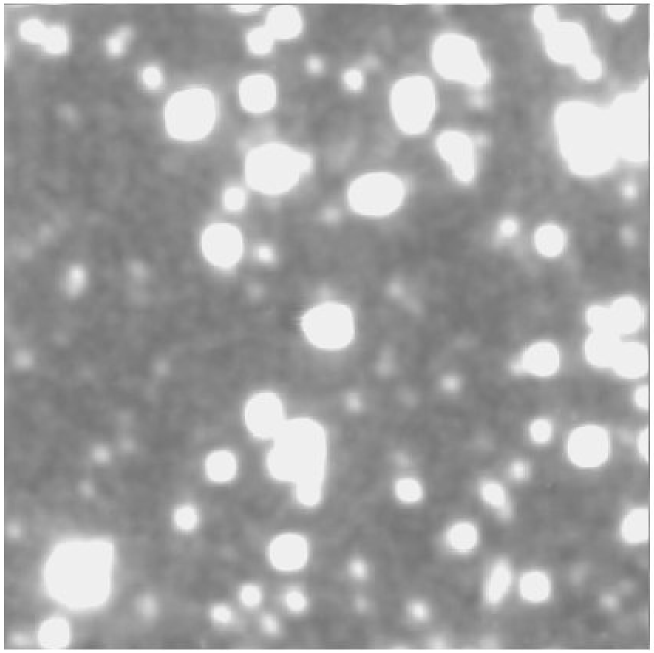
3.6, 4.5, 5.8, 8.0, 24, 70 & 160 microns

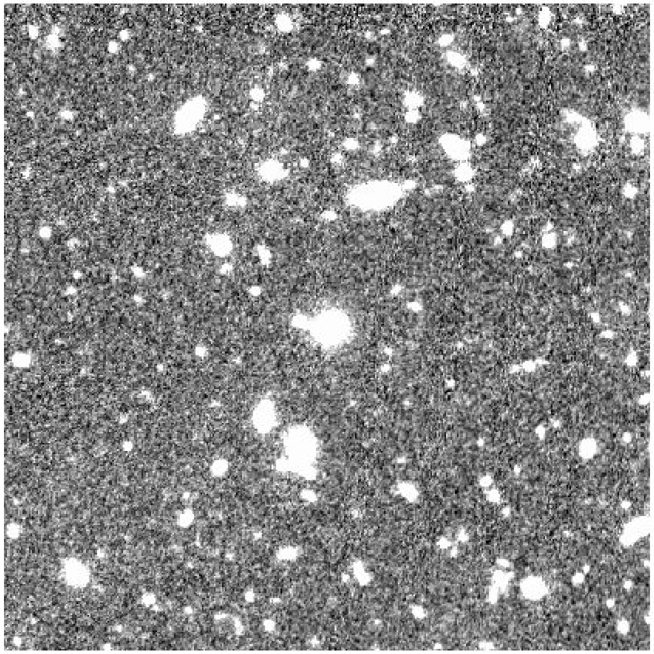
5 x 5 arcmin FOV (full moon is 30 x 30 arcmin)

No lensing with Spitzer !

Spitzer Point Response Function (PRF)

85 cm Telescope => 1.8” PRF @ 3.6 micron





IRAC ch1
3.6 micron

Ground 8-m R
0.62 micron

REPORT OF THE

DARK ENERGY TASK FORCE

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Robert Cahn, Lawrence Berkeley National Laboratory
Wendy L. Freedman, Carnegie Observatories
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Dark energy appears to be the dominant component of the physical Universe, yet there is no persuasive theoretical explanation for its existence or magnitude. The acceleration of the Universe is, along with dark matter, the observed phenomenon that most directly demonstrates that our theories of fundamental particles and gravity are either incorrect or incomplete. Most experts believe that nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration. For these reasons, the nature of dark energy ranks among the very most compelling of all outstanding problems in physical science. These circumstances demand an ambitious observational program to determine the dark energy properties as well as possible.

The Dark Energy Task Force (DETF) was established by the Astronomy and Astrophysics Advisory Committee (AAAC) and the High Energy Physics Advisory Panel (HEPAP) as a joint sub-committee to advise the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation on future dark energy research.

Baryon Acoustic Oscillations

Standard Candle / Ruler Probes => Test Universe's Homogeneity

Supernovae

V. Recommendations of the Dark Energy Task Force

Among the outstanding problems in physical science, the nature of dark energy ranks among the very most compelling

I. We strongly recommend that there be an aggressive program to explore dark energy as fully as possible, since it challenges our understanding of fundamental physical laws and the nature of the cosmos.

We model advances in dark energy science in Stages. Stage I represents what is now known. Stage II represents the anticipated state of knowledge upon completion of ongoing dark energy projects. Stage III comprises near-term, medium-cost, currently proposed projects. Stage IV comprises a Large Survey Telescope (LST), and/or the Square Kilometer Array (SKA), and/or a Joint Dark Energy (Space) Mission (JDEM).

There are four primary observational techniques for studying dark energy: Baryon Acoustic Oscillations, Clusters, Supernovae, and Weak Lensing. We find that no single observational technique alone is sufficiently powerful and well established that we can be certain it will adequately address the question of dark energy. We also find that combinations of techniques are much more powerful than individual techniques. In addition, we find that techniques sensitive to growth of cosmological structure have the potential of testing the possibility that the acceleration is caused by a modification of general relativity. Finally, multiple techniques are valuable not just for their improvement of the figure of merit but for the protection they provide against modeling errors, either in the dark energy or the observables.

II. We recommend that the dark energy program have multiple techniques at every stage, at least one of which is a probe sensitive to the growth of cosmological structure in the form of galaxies and clusters of galaxies.

Clusters of Galaxies

Growth of Structure Probes => Test Universe's Inhomogeneity

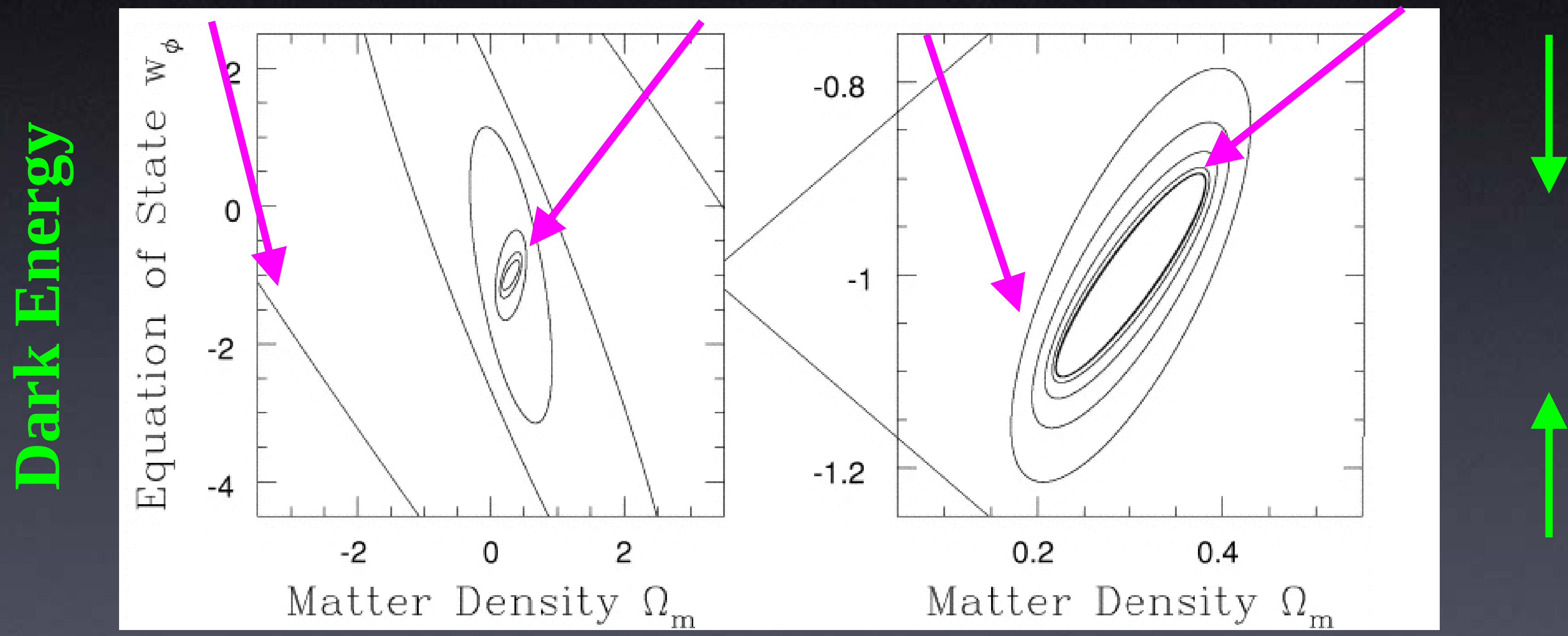
Weak Gravitational Lensing

Advantages of A Distant Cluster Survey

Finding Clusters at 1 < z < 2 is Highly Desirable because of their Potential to Strongly Constrain Dark Energy!

Volume Effect Dominates DE — Growth of Structure Dominates DE

Z = 0.1, 0.2, 0.3, 0.5, 0.7 & 0.9 — 0.9, 1.1, 1.3, 1.5. 1.7 & 1.9



Dark Matter

1000 sq. deg survey - Levine, Schulz & White, 2002, Astrophysical Journal, 577, 569

SpARCS: Spitzer Adaptation of the Red-sequence Cluster Survey

A survey for clusters at 1 < z < 2 using the red-sequence technique

Current sample of spectroscopically confirmed galaxy clusters:

Low-z	Mid-z	High-z	Cluster “Desert”	Lyman-break Proto-clusters
z < 0.5	0.5 < z < 1.1	1.1 < z < 1.45	1.45 < z < 2.2	2.2 < z < 6.5
~ 1000’s	~ 100’s	~15	0	~10’s

SpARCS

Quiescent
Well-defined red-sequence

Vigorously Star Forming
Some Old Massive
Red Galaxies Formed

Detecting Clusters using the Red-Sequence

Wilson et al. (astro-ph/0503638 ; astro-ph/0604289)

Muzzin et al (astro-ph/0503640)

Utilize the observational fact that all early-type galaxies in clusters have a very similar color regardless of magnitude.

Only 2 filters required!

The two filters should bracket the 4000 Angstrom Break

CRS extremely insensitive to projection effects

The color of the red sequence => the cluster z

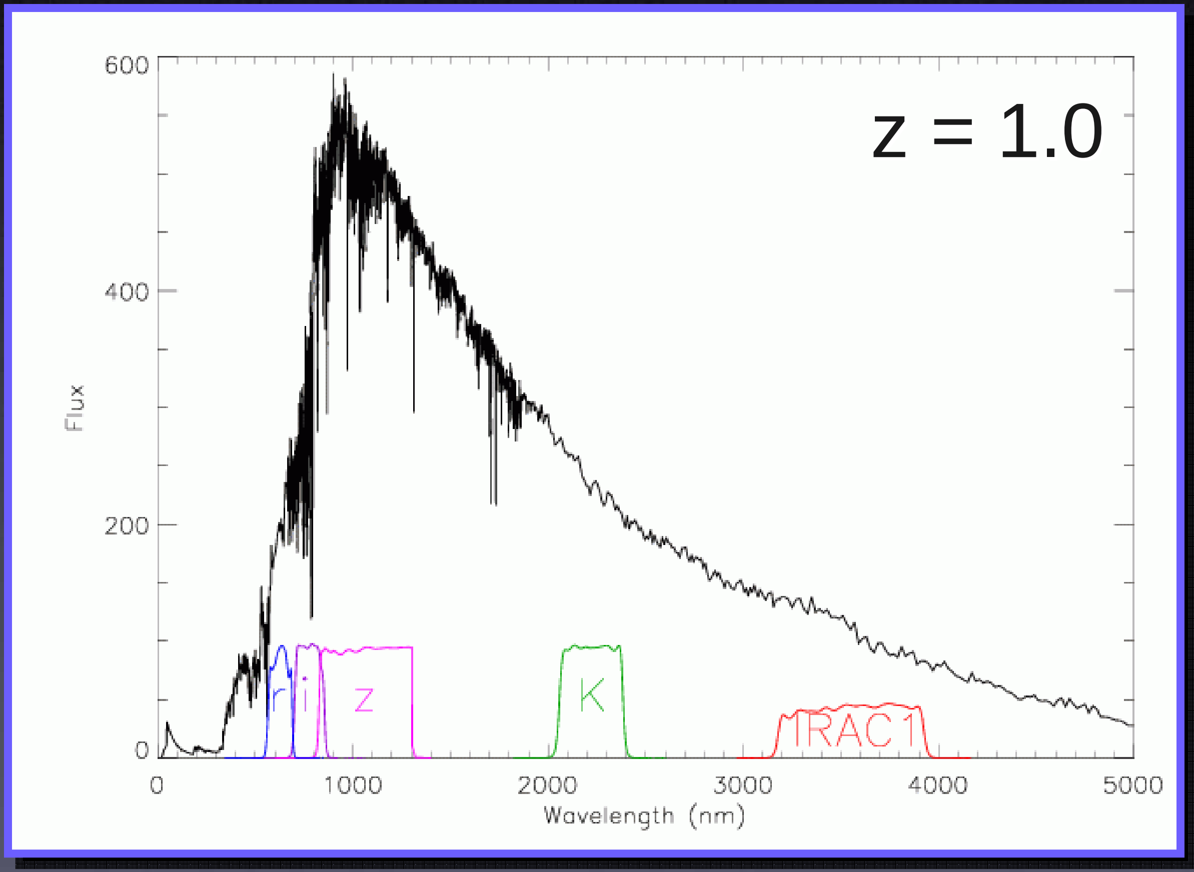
Spitzer IRAC's 3.6 micron filter allows $z > 1$ cluster detection

IF cluster galaxies form sufficiently early to have a hi-z RS

Early-type galaxies in clusters DO exhibit a red-sequence by at LEAST $z = 2$!!

RCS1+2 can find clusters to z ~ 1.1 using R and z'

Cannot just observe deeper with the RCS -
We need to change filters

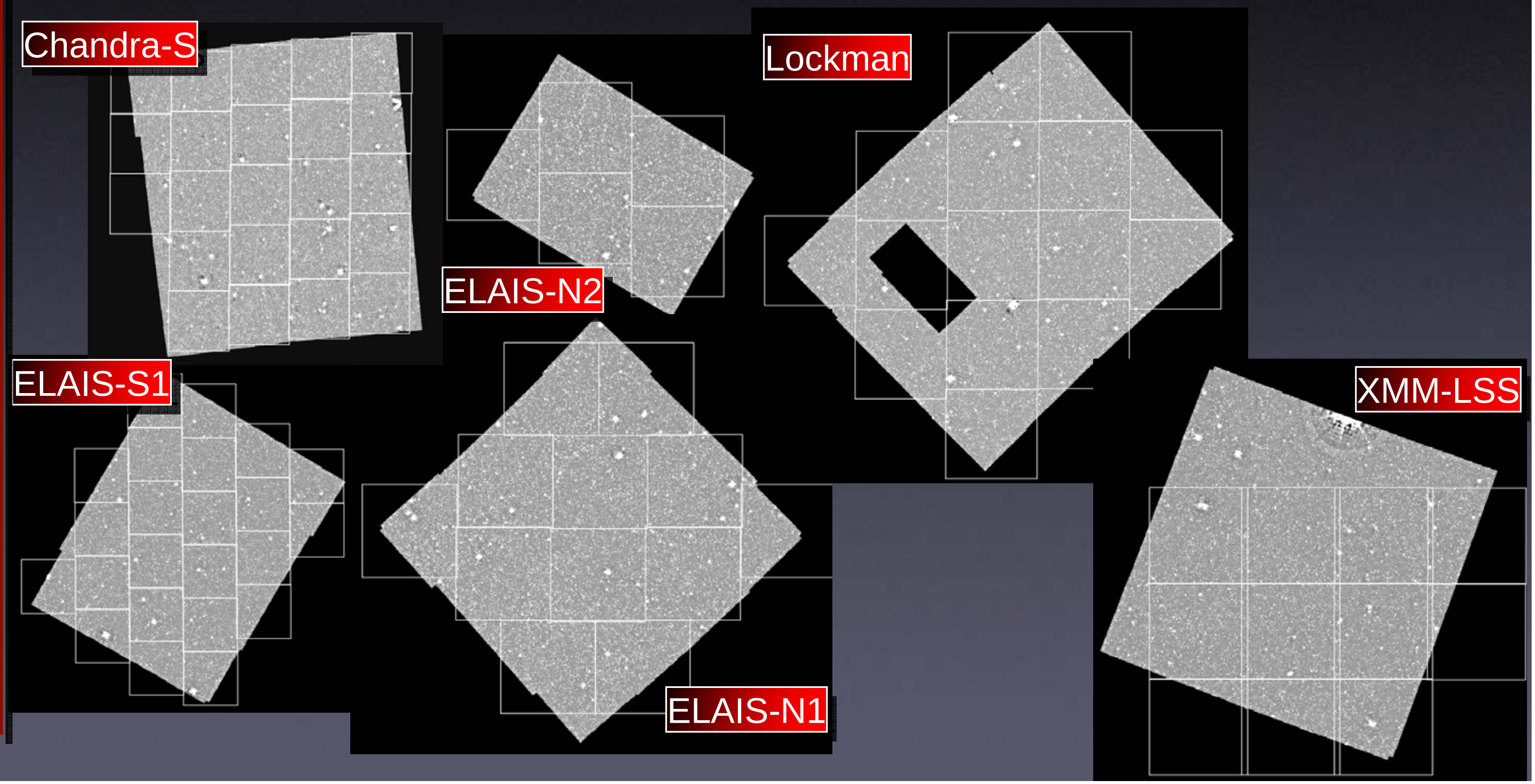


SpARCS: Spitzer Adaptation of the Red-sequence Cluster Survey

50 deg^2 z'-imaging survey in the SWIRE fields

Use z'-[3.6] color to find 200 clusters at 1 < z < 2

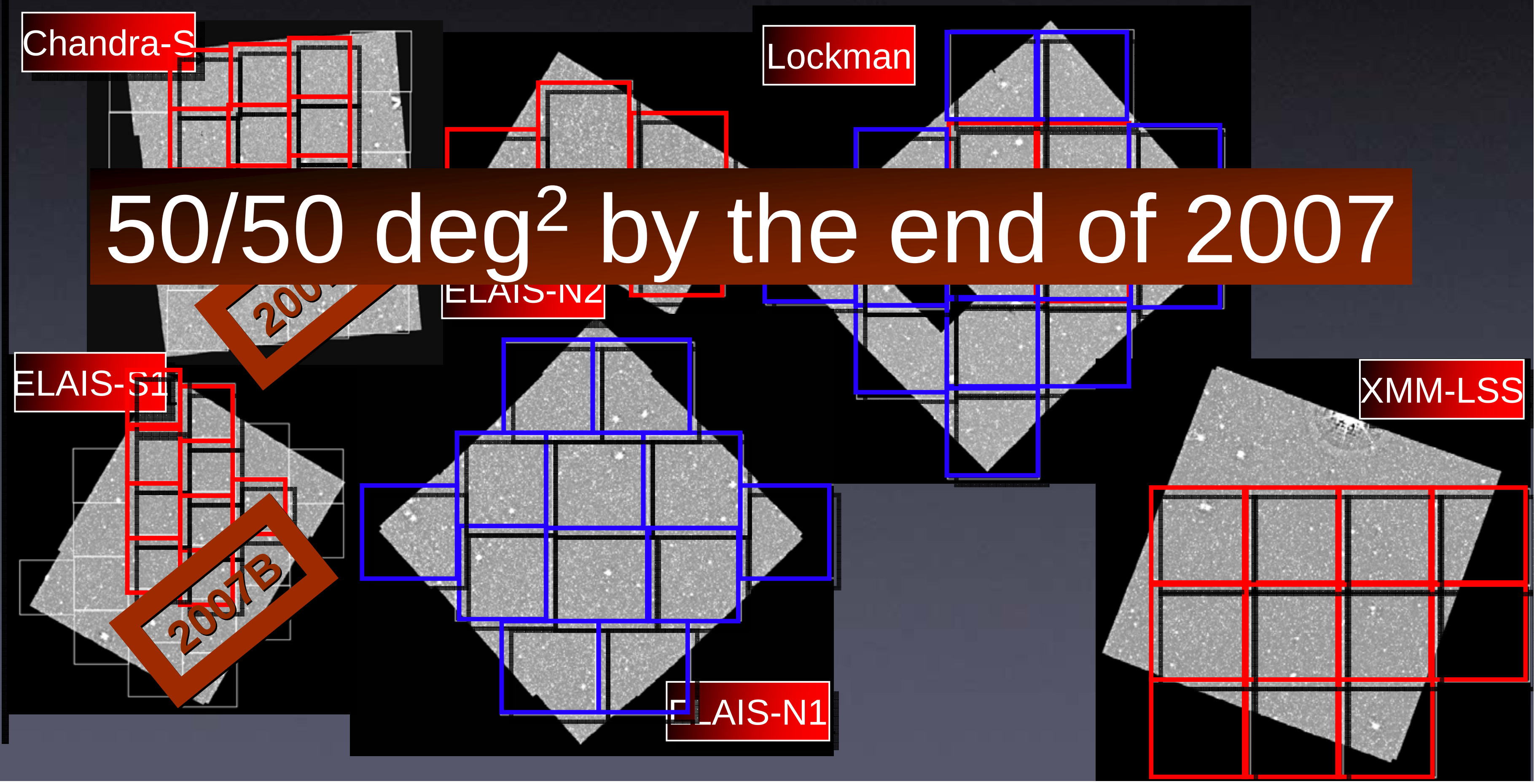
(the optical-IR color also gives you the redshift)



SpARCS Status (Aug 07)

Current area: Reduced, 22/50 deg^2

In hand, 42/50 deg^2



50/50 deg^2 by the end of 2007

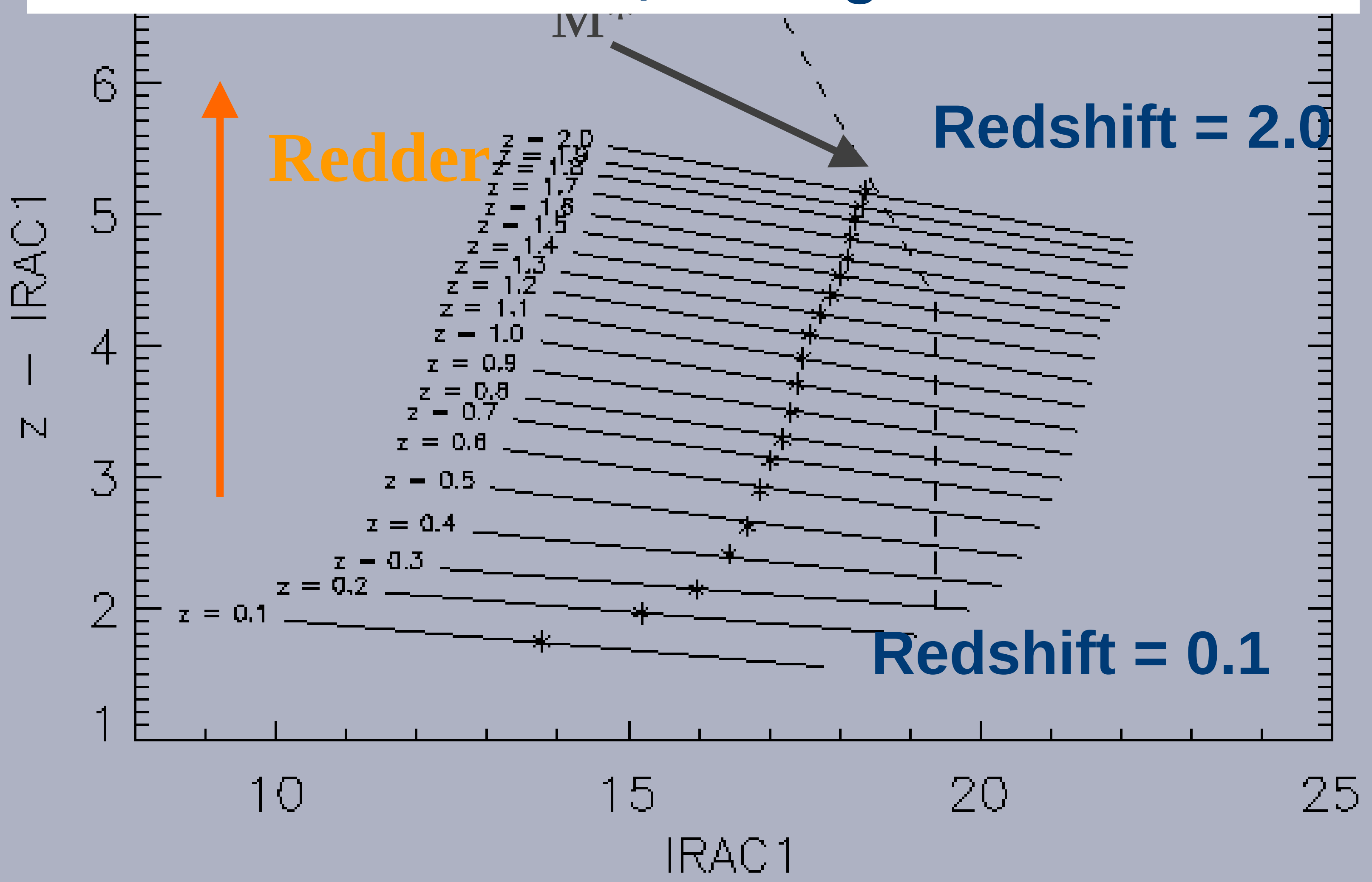
Infrared Imaging from Space is MUCH more Efficient than from the Ground

IR : IRAC exposure time = 120s !

Optical : z’ exposure time (4m) = 2 hrs

The “redness” of the color of the cluster galaxies gives you the redshift “for free”

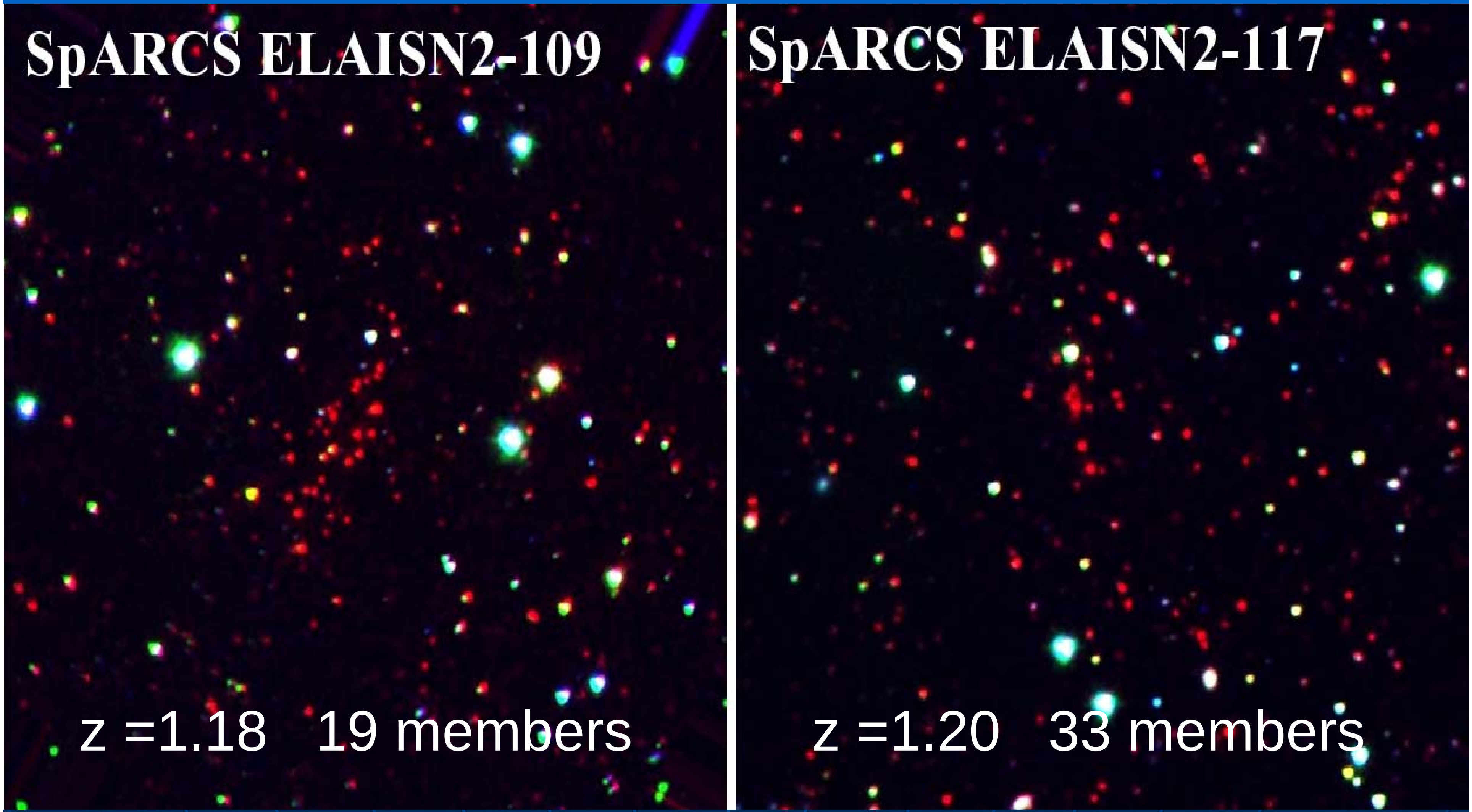
The redder the CRS, the higher the redshift



Confirming cluster redshifts spectroscopically is very slow!

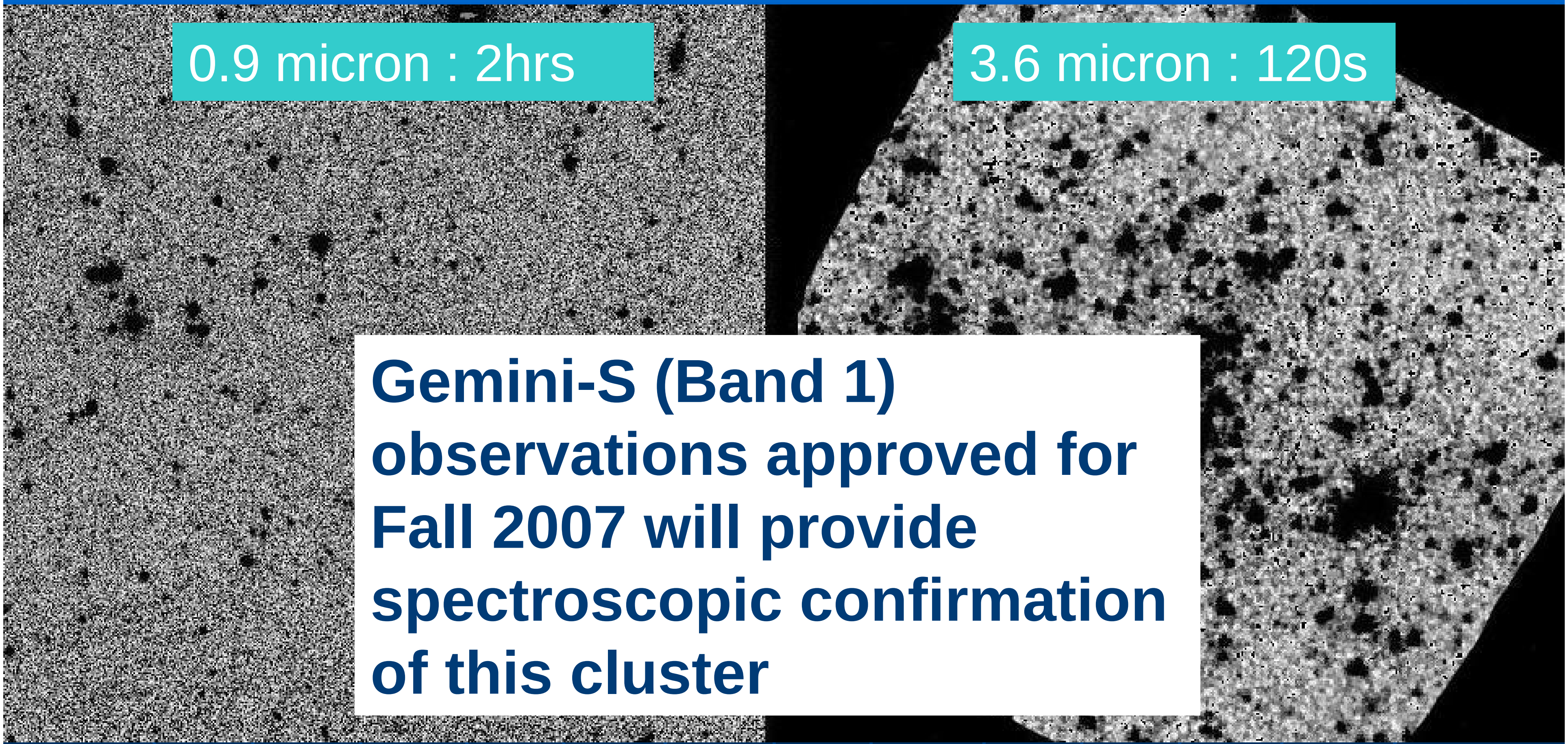
We have ~15 confirmed clusters at $z < 1.05$

Two SpARCS spectroscopically-confirmed clusters at z~1.2



FOV = 1.5 Mpc

SpARCS ELAIS-S175

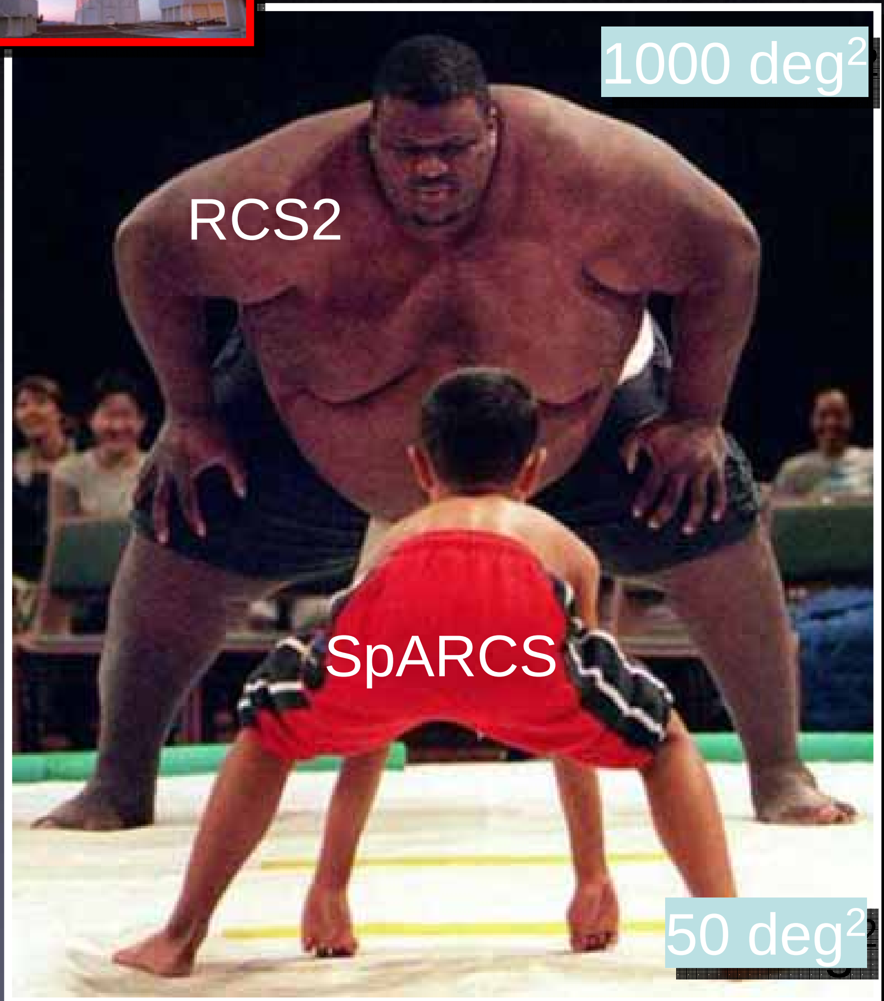


Gemini-S (Band 1) observations approved for Fall 2007 will provide spectroscopic confirmation of this cluster

$$z_{\text{phot}} = 1.70$$

Future Prospects

50 deg^2 is not a REAL cluster survey



The Future:

Spitzer Extended “Warm” Mission: ~ 500 deg^2

Require good optical data

e.g. CFHTLS/KIDS/ SDSS/DES/Pan-STARRS

- Enormous potential for cosmology - dark energy
- Find rare M > 10^{15} solar z > 1 clusters

Spitzer’s cryogen expected to run out in early-mid 2009
IRAC [3.6] and [4.5] will operate equally well without cryogen

Pasadena Workshop June 4 & 5th 2007
“Science Opportunities for the Warm Spitzer Mission ”
1000 - 6000 hour proposals likely solicited

Different tiers of proposals likely
(SWIRE was a 400 hour 50 sq. deg. IRAC program)

http://ssc.spitzer.caltech.edu/meetings/warm/wp.html

“White Papers”

Gardner, Fan, Wilson & Stiavelli “A Spitzer Warm Mission as a Target Finder for JWST”

=> ~ 500 square degree SWIRE-depth (120s) survey


SpARCS
Spitzer Adaptation of the Red-sequence Cluster Survey
http://spider.ipac.caltech.edu/staff/gillian/SpARCS