



THE QUEEN'S
ANNIVERSARY PRIZES
FOR HIGHER AND FURTHER EDUCATION

2005

The Hubble Space Telescope Treasury Coma Cluster Survey

*Introduction, initial results, and future
plans*

David Carter (Liverpool John Moores University)

With 35+ collaborators from 25 institutions, in 10 countries



From exoplanets to galaxy clusters: science with Astro-WISE

Science Team

- Dave Carter, Mustapha Mouhcine, Habib Khosroshahi (LJMU)
- Harry Ferguson, Paul Goudfrooij, Eric Peng (STScI),
- Bahram Mobasher (UC Riverside), Thomas Puzia (HIA)
- John Lucey, Russell Smith, Ray Sharples (Durham), Neil Trentham (Cambridge)
- Jon Davies (Cardiff); Steve Phillipps, James Price, Avon Huxor (Bristol)
- Terry Bridges (Queens, Kingston); Mike Hudson (Waterloo)
- David Merritt, Dan Batcheldor (Rochester), Shardha Jogee (Texas)
- Rafael Guzman, Ana Matkovic, Nicolas Gruel, Carlos Hoyos (Florida)
- Brent Tully, Kristen Chiboucas (Hawaii), Ron Marzke (SFSU)
- Sadanori Okamura (Tokyo); Yutaka Komiyama (Subaru)
- Bianca Poggianti (Padova); Alister Graham (Swinburne)
- Marc Balcells, Alfonso Aguerri (IAC); Peter Erwin (MPIE)
- Ann Hornschemeier (GSFC); Neal Miller, Derek Hammer (JHU)
- Bryan Miller (Gemini); Jennifer Lotz (NOAO)
- Reynier Peletier, Edwin Valentijn, Gijs Verdoes Kleijn, Mark den Brok (Groningen)
- + postdocs and students of the above, and some later additions

Talks at this workshop

- Introduction and Cycle 17 ambitions (Dave Carter)
- Photometric analysis and structural parameters (Marc Balcells).
- Galaxy surface photometry and colour gradients (Mark den Brock/Reynier Peletier)

Clusters of galaxies - big questions

- Galaxy formation - cluster dwarfs may be the earliest galaxies
- Effect of environment on galaxy structure and morphology
- Star formation history and current star formation from integrated properties.

Why a survey of the Coma cluster?

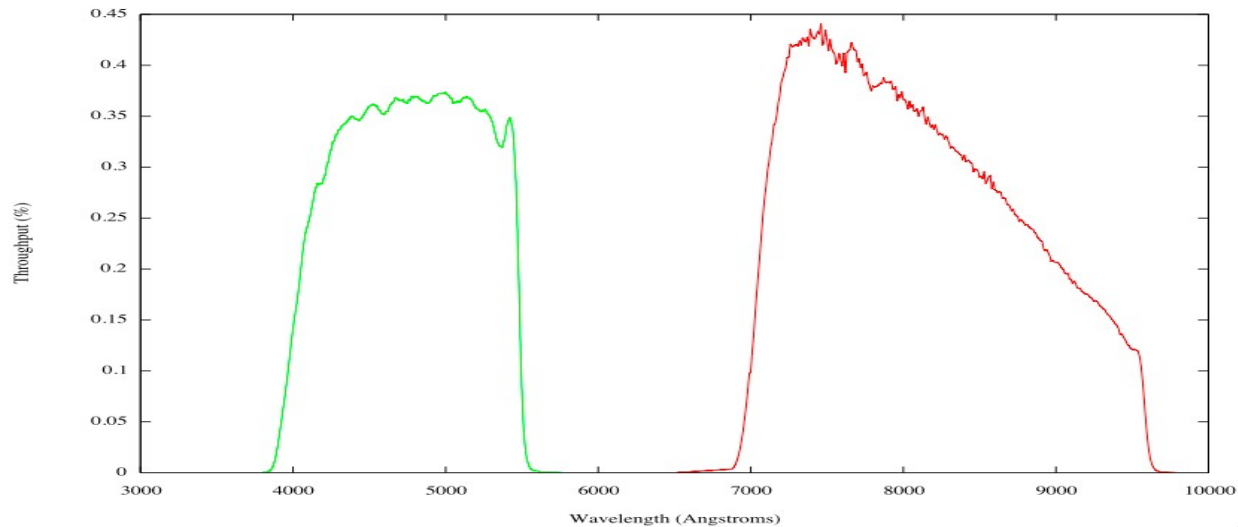
- Nearest dense environment (gas and galaxies).
- High galactic latitude.
- Excellent coverage at many wavebands, particularly X-ray
- Over 1000 cluster members with redshifts
- Optical photometry over wide areas
- Local benchmark for studies of high redshift clusters.



SDSS image
of Coma core

The HST Coma Cluster Survey

- A survey of 740 sq arcmin in the Coma cluster in F475W and F814W filters
- 164 orbits allocated with ACS/WFC. 46 orbits before ACS failure.
- 82 pointings 2 orbits per pointing
 - Contiguous 18 x 21 arcmin area in the core
 - Outer fields target low-luminosity cluster members





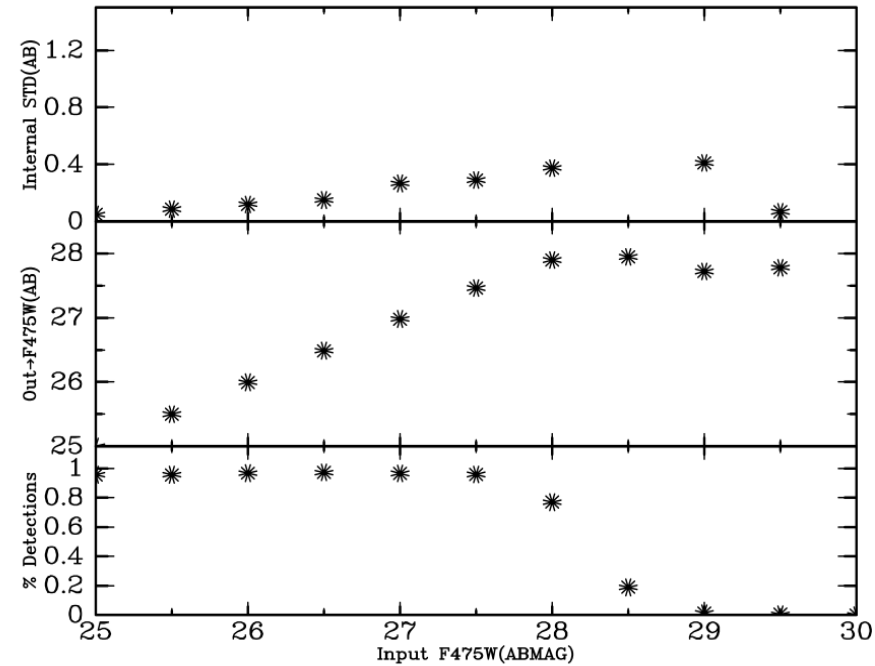
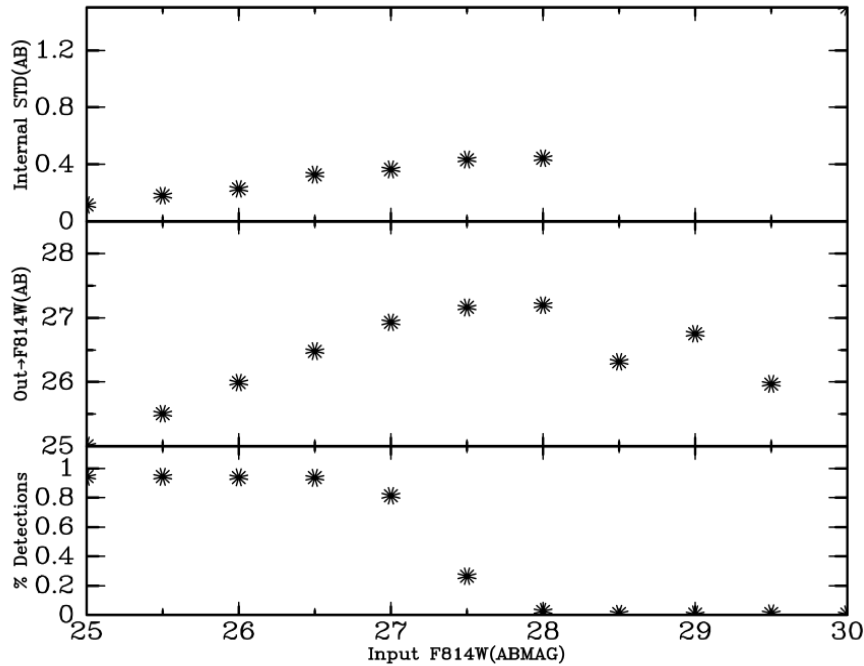
Survey objectives

- Luminosity Function to $M_V \sim -9$.
- Morphologies for a wide range of luminosity and environment.
- Colours and colour gradients.
- Bright and faint ends of the global scaling laws.
- C-M diagrams for globular clusters.
- Detection of UCDs
- Morphology of “E+A” galaxies
- Selection of samples for spectroscopy.
- Surface Brightness Fluctuations as indicator of distance and stellar populations (Cycle 17 IR only)

Overarching Treasury Objective

- To provide a reference database on a dense environment for comparison with studies of less dense clusters, of field samples, and of high redshift samples for galaxy evolution and cosmology studies.

Point source limiting magnitudes

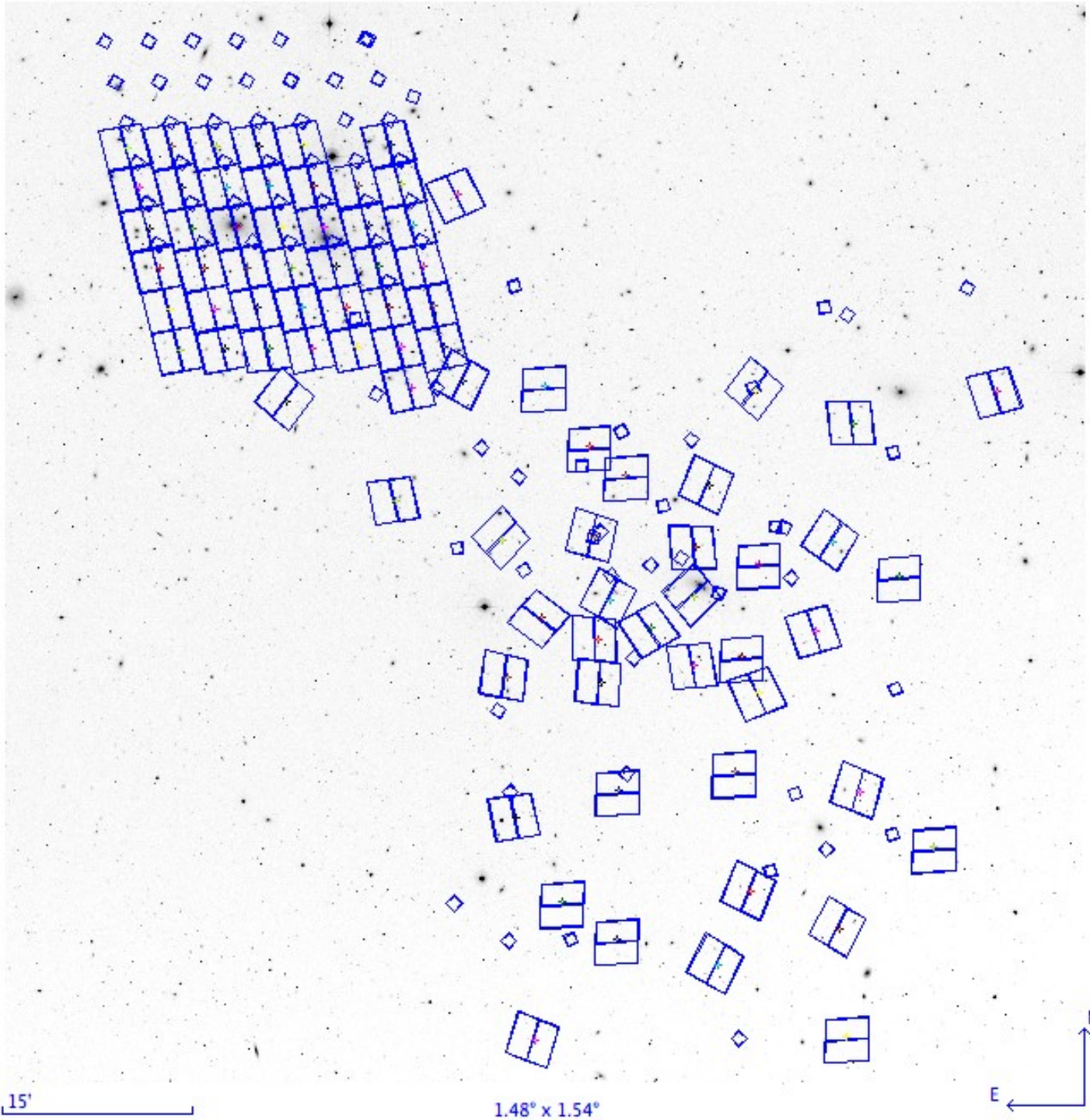


Plot shows fraction of artificial point sources injected into real data frames, recovered by SExtractor. 90% recovery limits are $g' = 27.55$; $I_c = 26.65$ (AB).

Limiting magnitudes for science goals

- Limiting magnitude for galaxies surface brightness dependent $V \sim 26$ ($M_V \sim -9$)
- Basic structural parameters for sample selection (mean surface brightness, effective radius) to $V \sim 23$ ($M_V \sim -12$).
- Detailed structural parameters (Sersic index) to $V \sim 21$ ($M_V \sim -14$).
- Colour gradients to $V \sim 19.5$ ($M_V \sim -15.5$).

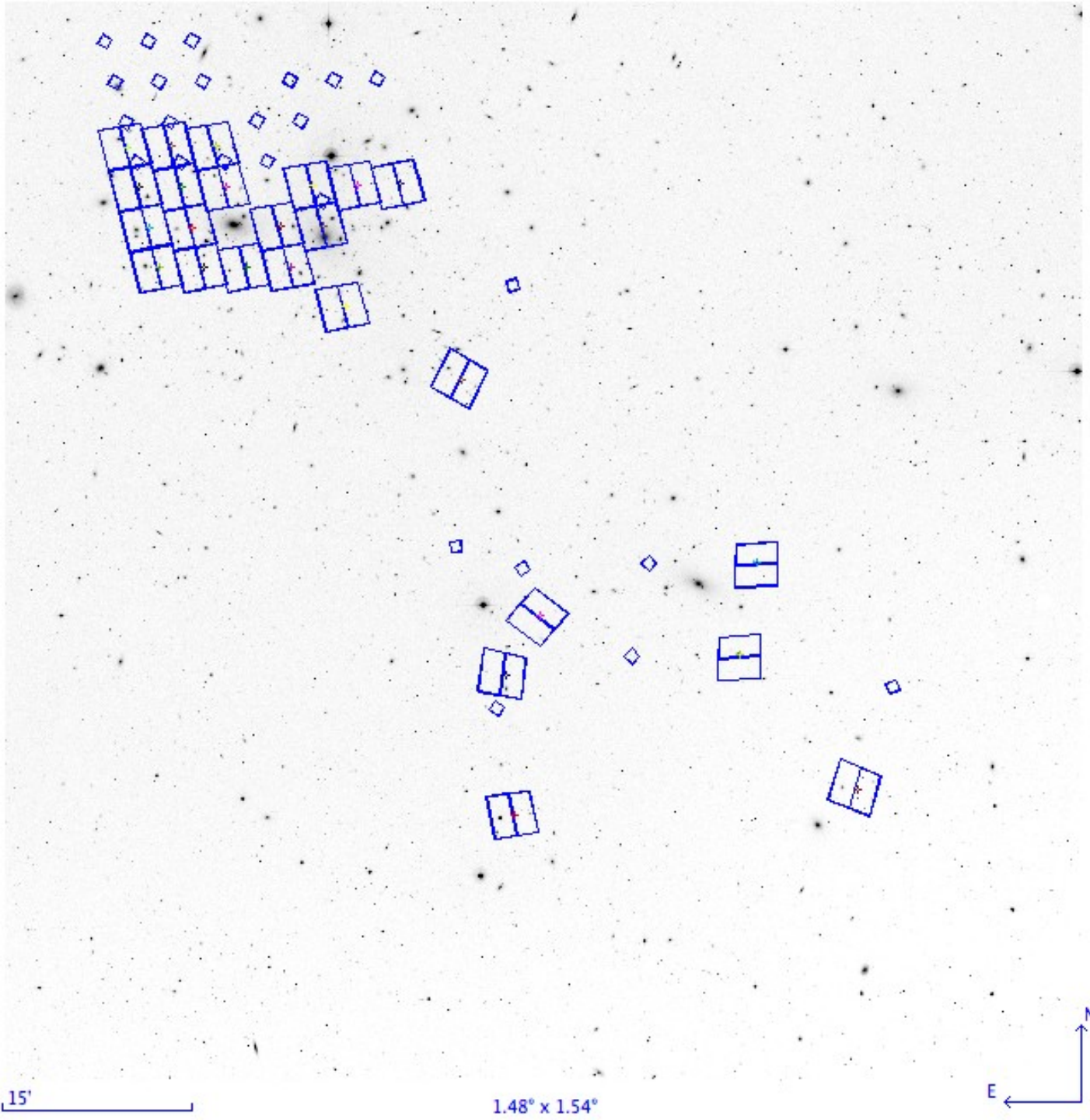
Survey area



What has been observed

- 21 positions fully observed.
- 4 further positions we have two or three of the four dither positions.
- 46 orbits of 164 done (28% complete).

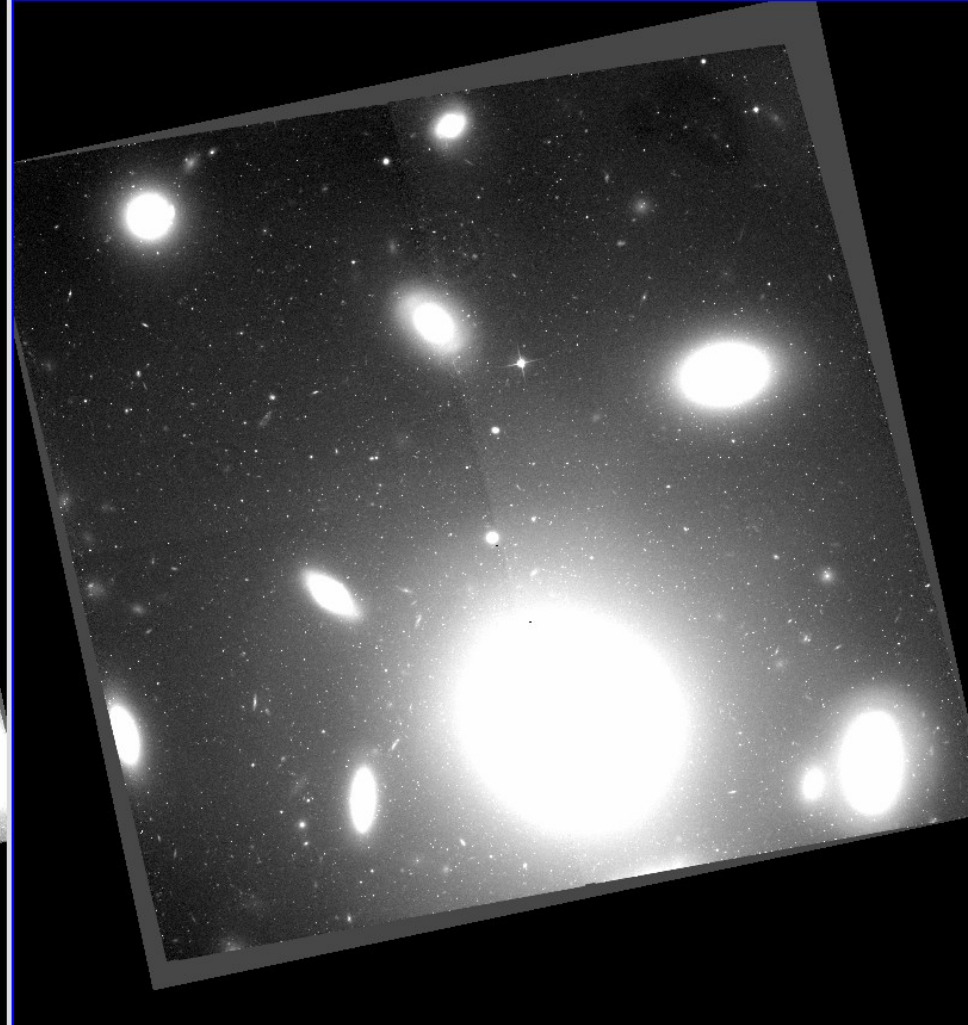
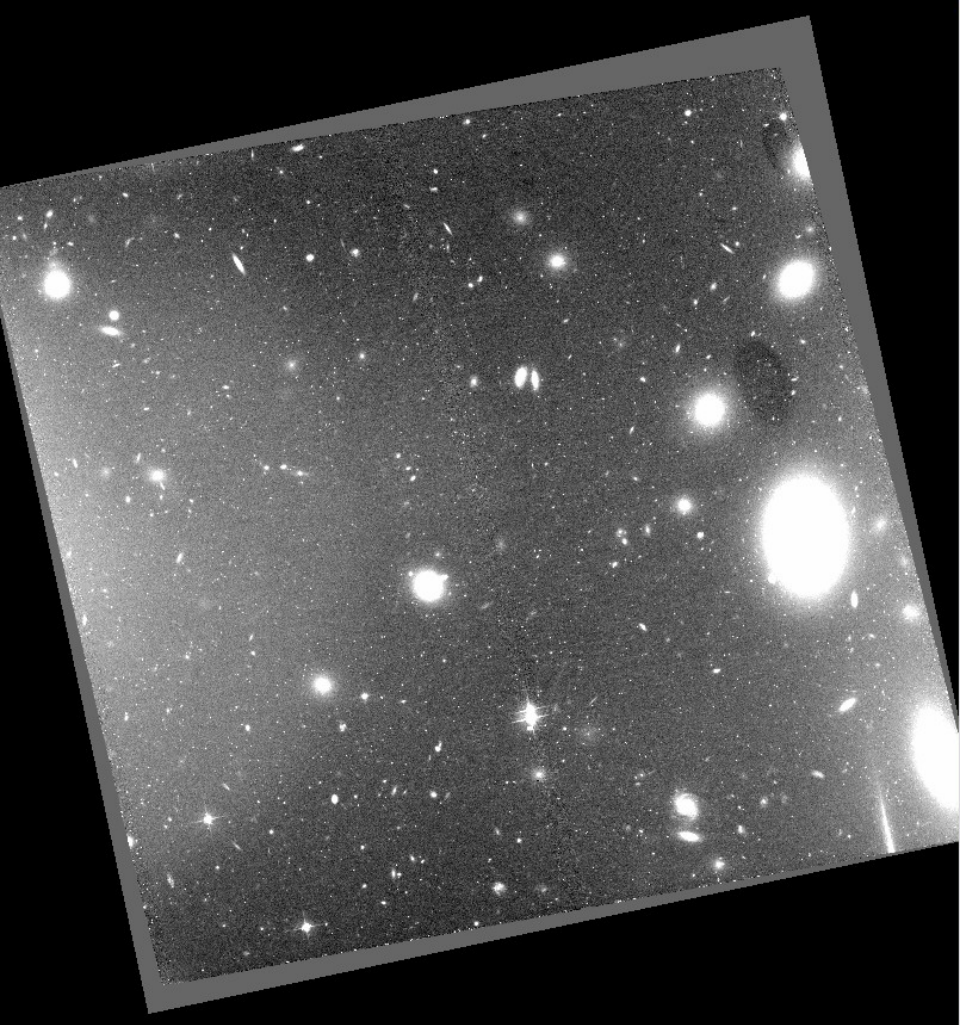
Fields with full
or partial data



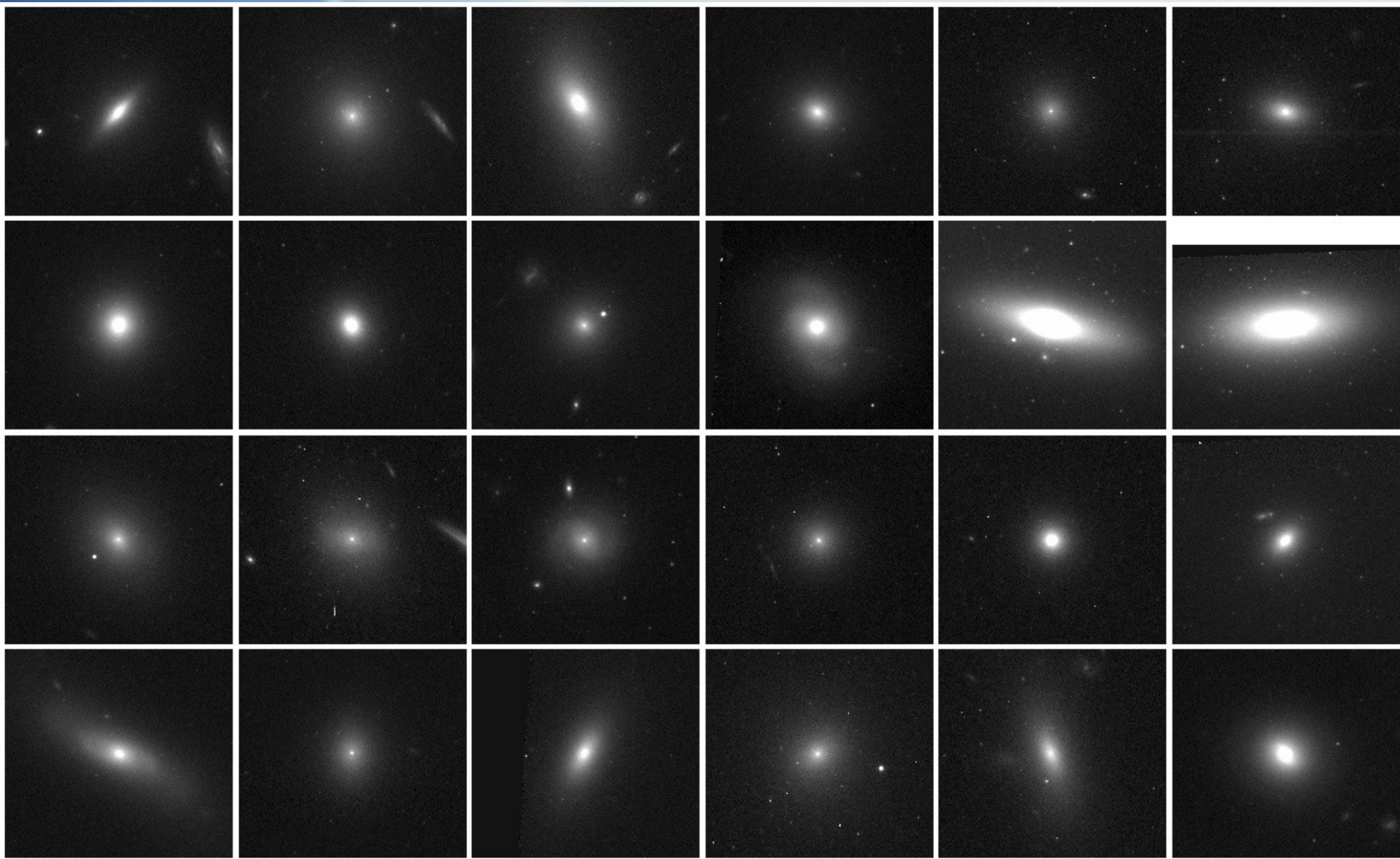
15'

1.48° x 1.54°

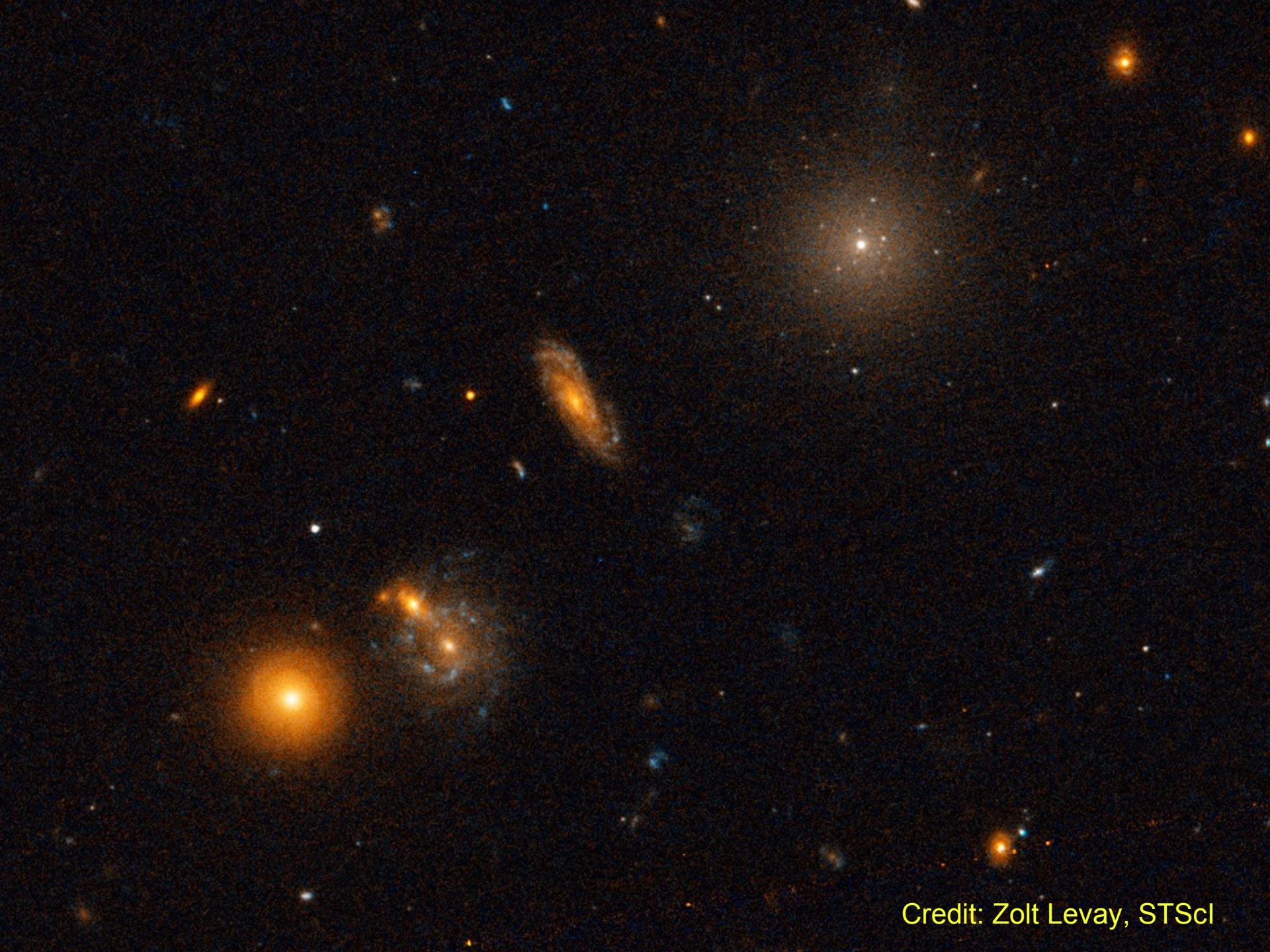




Two adjacent visits (18 and 19) in the cluster core, showing the density of point sources, the size of the overlap region, bias differences between quadrant amplifiers, and some low level crosstalk ghosting



Montage of ACS images of galaxies from the line index sample



Credit: Zolt Levay, STScI



Credit: Zolt Levay, STScI

Key workpackages for public data release

- Data processing and source lists: Paul Goudfrooij (STScI), Derek Hammer (JHU)
- Galaxy recovery simulations, error analysis; Marc Balcells (IAC), Carlos Hoyos (Madrid)
- Large galaxy modelling and subtraction: Gijs Verdoes Kleijn (Groningen)
- Structural analysis Galfit/Gim2D: Balcells, Hoyos, Verdoes Kleijn, Rafael Guzman (Madrid/Florida), Reynier Peletier (Groningen).
- Public data interfaces: AstroWISE and MAST teams

Data products

- Reprocessed images with optimum reference files. Release on AstroWISE within 1 month.
- First pass SExtractor position/magnitude catalogue. 2-3 months.
- Galaxy parameters (Galfit/Gim2D output) - ~6 months

Data portals

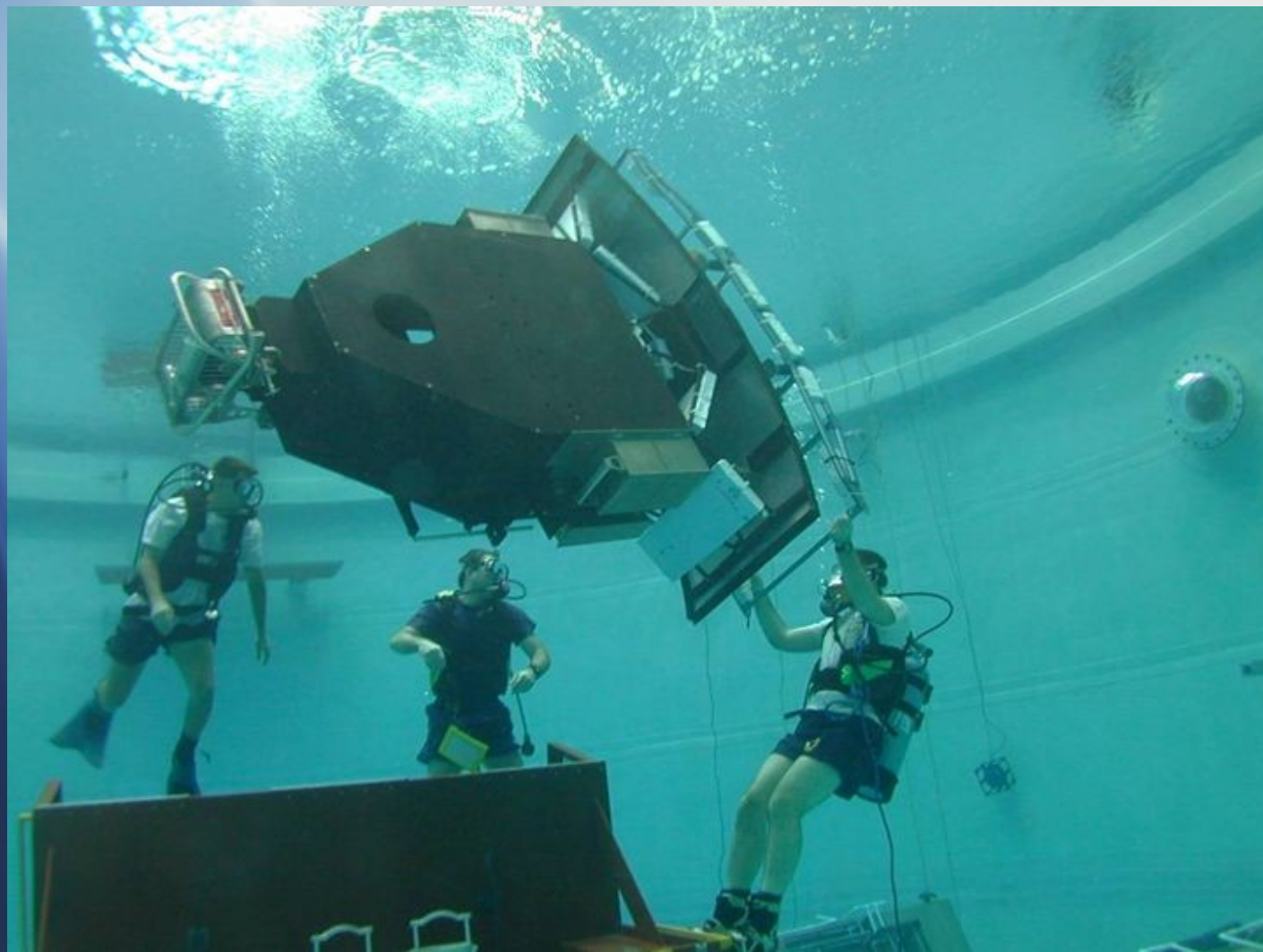
- Astrowise - <http://www.astro-wise.org/projects/COMALS/>
- MAST Treasury archive - <http://archive.stsci.edu/hst/tall.html>
- Project web site at Rochester - <http://coma.rit.edu/>

Initial ACS science programs

- Luminosity function (STScI, Cambridge, Hawaii, LJMU)
- Morphology (Texas, IAC, Groningen, MPIE)
- Nucleii (Swinburne, RIT)
- Globular Clusters (HIA, STScI, IAC)
- Dwarf galaxy properties (STScI, Bristol, Cardiff)
- Scaling laws (Florida, Madrid, IAC, Groningen)
- Colour gradients (Groningen)

Plans for post-SM4 cycles

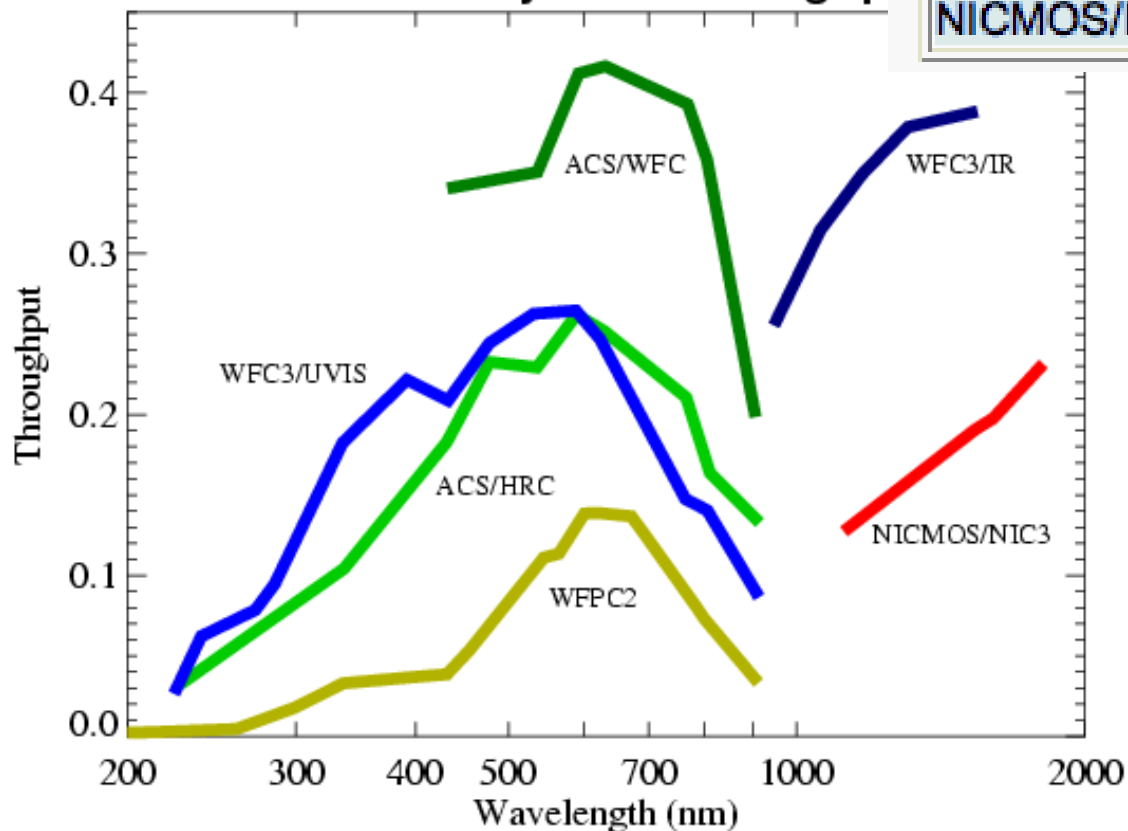
- Complete survey with ACS.
- Smaller area near-IR survey with WFC3/IR. Largely achievable in parallel with ACS survey completion.
- WFC3/UVIS as fallback in case ACS does not come back. Smaller format and less sensitive than ACS, so completion would take more orbits.



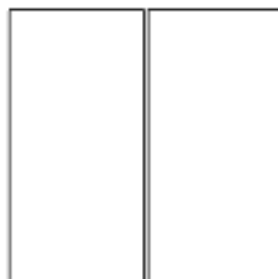
System performance

Detector	Read-out noise, e ⁻ rms	Dark current, e ⁻ /pix/s
WFC3/UVIS	3.1	<0.00014
ACS/WFC	5.0	0.0038
ACS/HRC	4.7	0.0044
STIS/CCD	5.4	0.004
WFC3/IR	16	<0.4
NICMOS/NIC2	26	0.3
NICMOS/NIC3	29	0.3

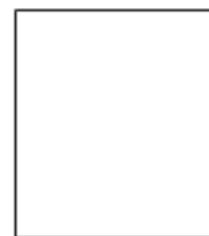
HST Total System Throughput



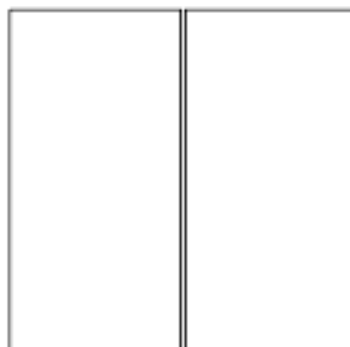
Detector areas



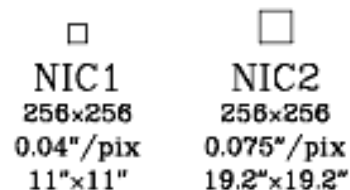
WFC3/UVIS
2x2051x4096
0.04"/pix
163"x164"



WFC3/IR
1014x1014
0.13"/pix
123"x137"



ACS/WFC
2x2048x4096
0.05"/pix
202"x202"



NIC1
256x256
0.04"/pix
11"x11"

NIC2
256x256
0.075"/pix
19.2"x19.2"



NIC3
256x256
0.2"/pix
51.2"x51.2"



ACS/SBC
1024x1024
0.032"/pix
34"x31"



ACS/HRC
1024x1024
0.026"/pix
29"x28"



MAMA
1024x1024
0.025"/pix
25"x25"



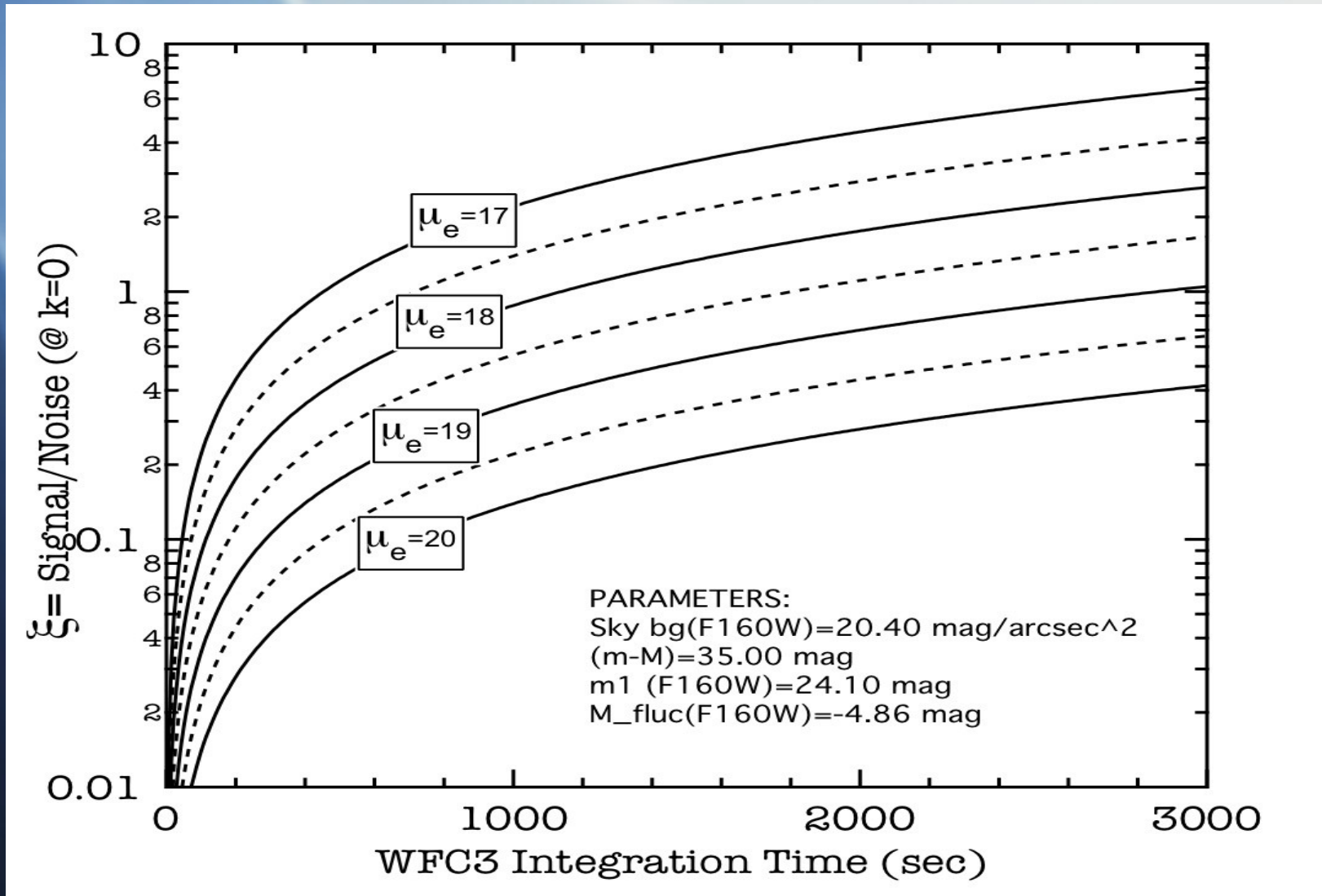
CCD
1024x1024
0.05"/pix
52"x52"

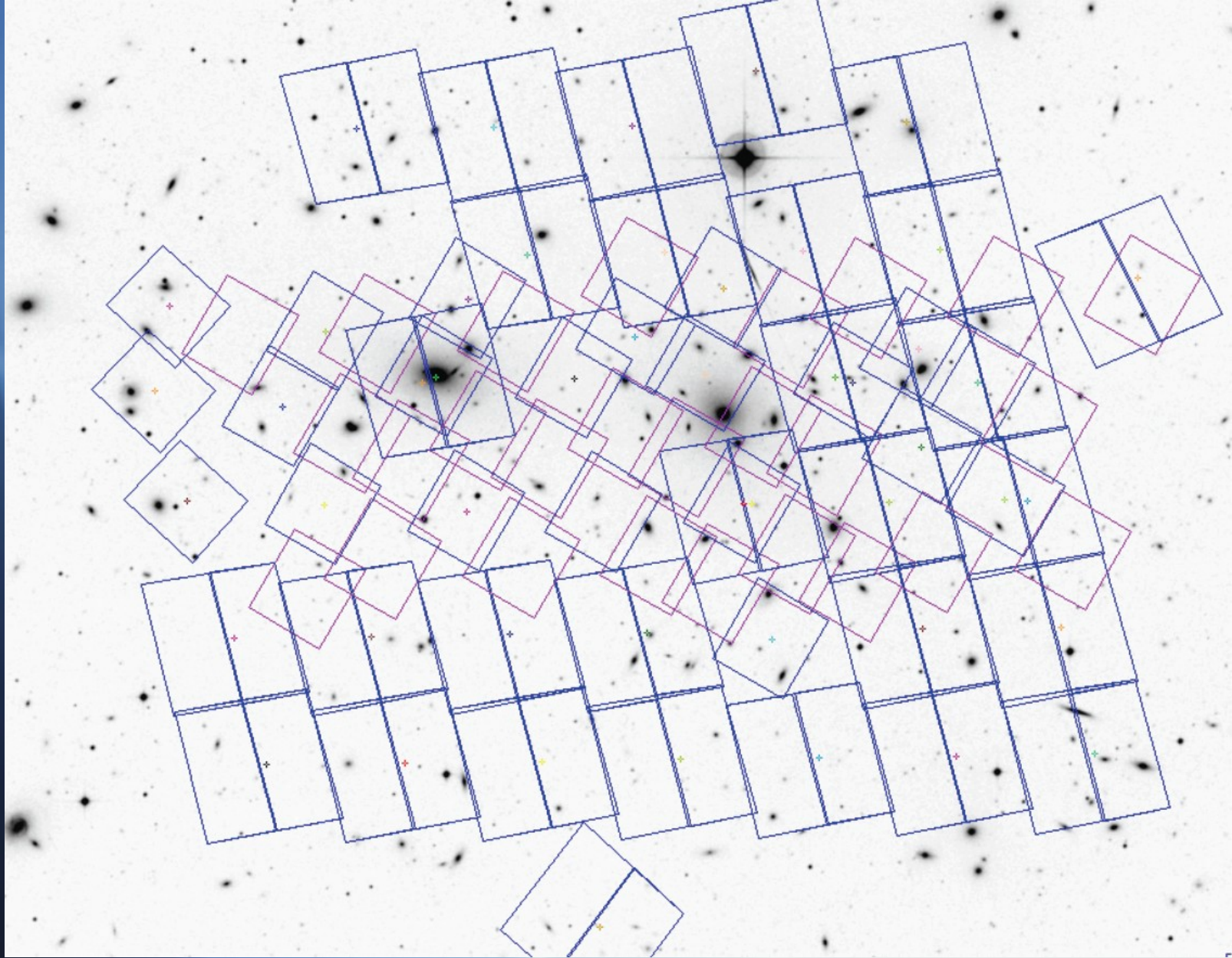
STIS

Cycle 17 Proposal

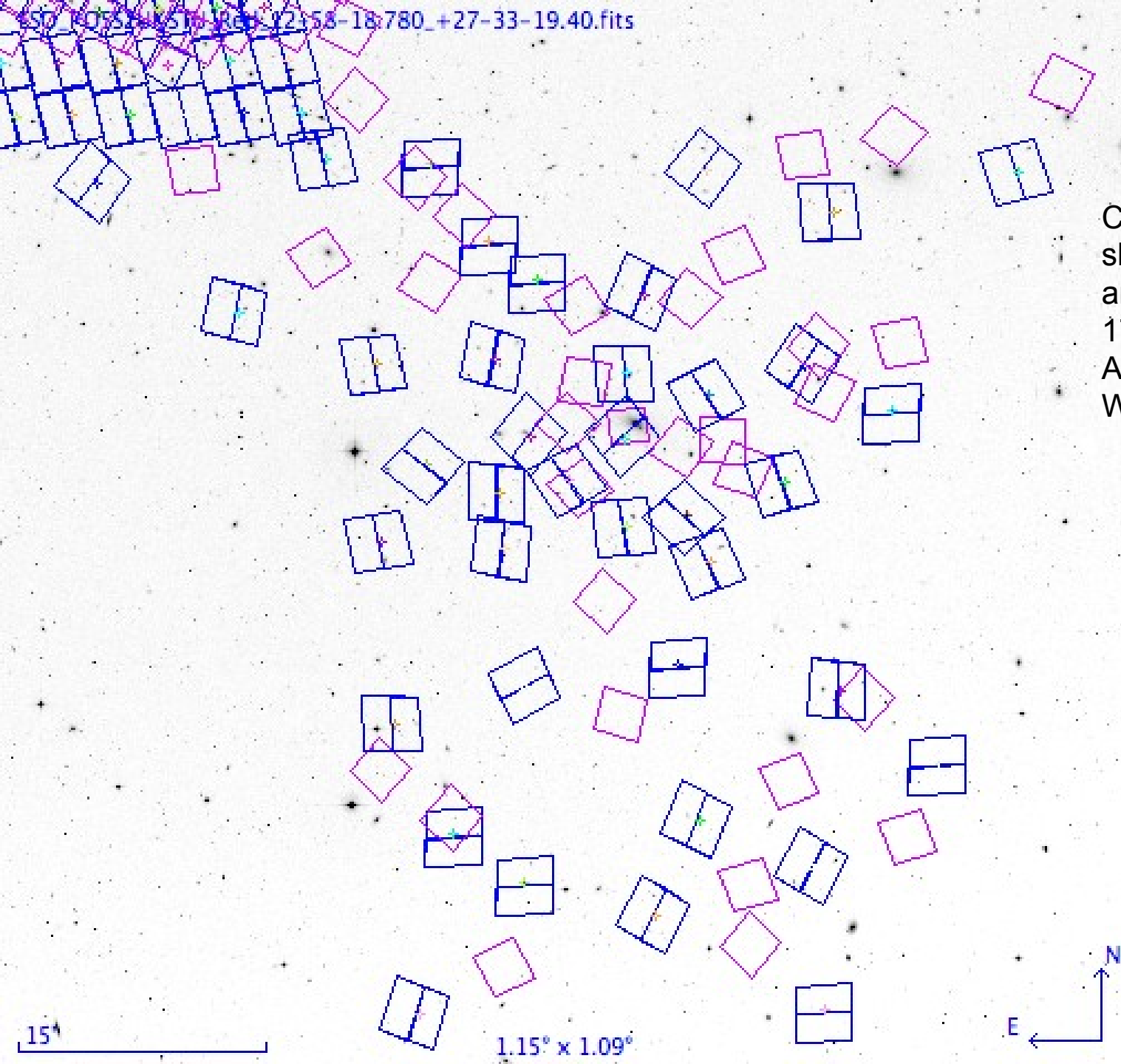
- Total proposal 139 orbits
 - Completion of original survey to 740 sq arcmin in F475W and F814W
 - Addition of survey of 180 sq arcmin in F160W (H band) in cluster core with WFC3/IR
 - Use IR to resolve age-metallicity degeneracy in globular clusters and dwarf galaxies.
 - SBF as distance and population determinant in IR.
 - Fallback to complete optical survey with WFC3/UVIS if ACS is not repaired.

SBF feasibility with WFC3/IR





Coma core showing proposed cycle 17 ACS and WFC3/IR observations



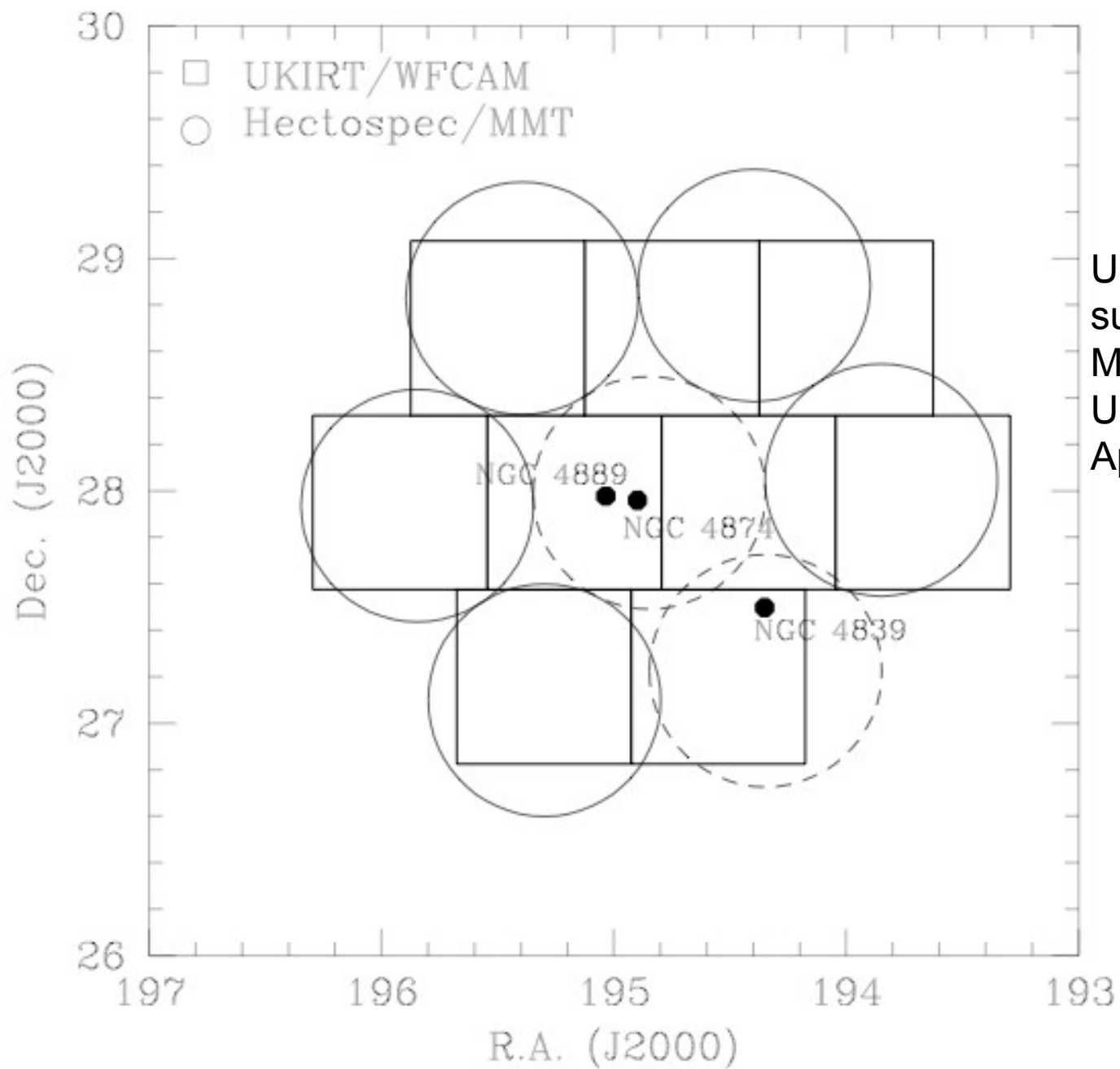
Coma outer fields showing Cycle 15 and proposed cycle 17 footprints. Primary ACS in blue, parallel WFC3 in magenta.

Associated observations

- Many other space and ground observatories contribute to this project
- All data will be made available in a unified way through the project portals.

Ground-based followup

- UKIRT K-band 10 square degree imaging survey (M. Mouhcine)
- CFHT/Megacam u^* , g' , i' to complement UKIRT (M. Hudson)
- CFHT high resolution IR (M. Hudson)
- Subaru broad band and $H\alpha$ (Y. Komiyama/M. Yagi)
- KPNO intermediate (BATC) band imaging (R. Marzke)

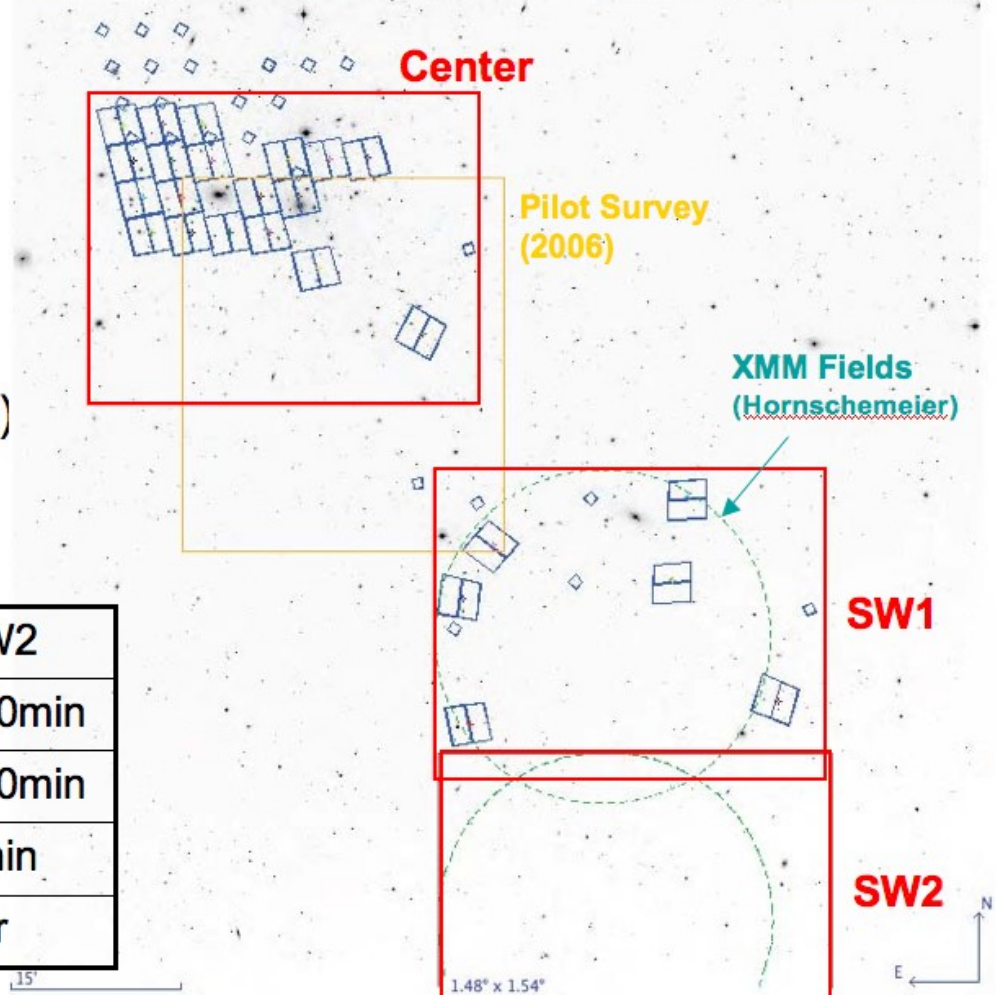


UKIRT and Hectospec survey fields, CFHT Megacam matched UKIRT. UKIRT run April 1-8.

Observed Fields and Data Quality

- Seeing FWHM
 - Median: $\sim 0''.7$
- Limiting Magnitude
 - B: ~ 26.8 (mag AB)
 - R: ~ 26.3 (mag AB)
 - NB: ~ 26.0 (mag AB)
 - i': (not reduced)
- Integration Times

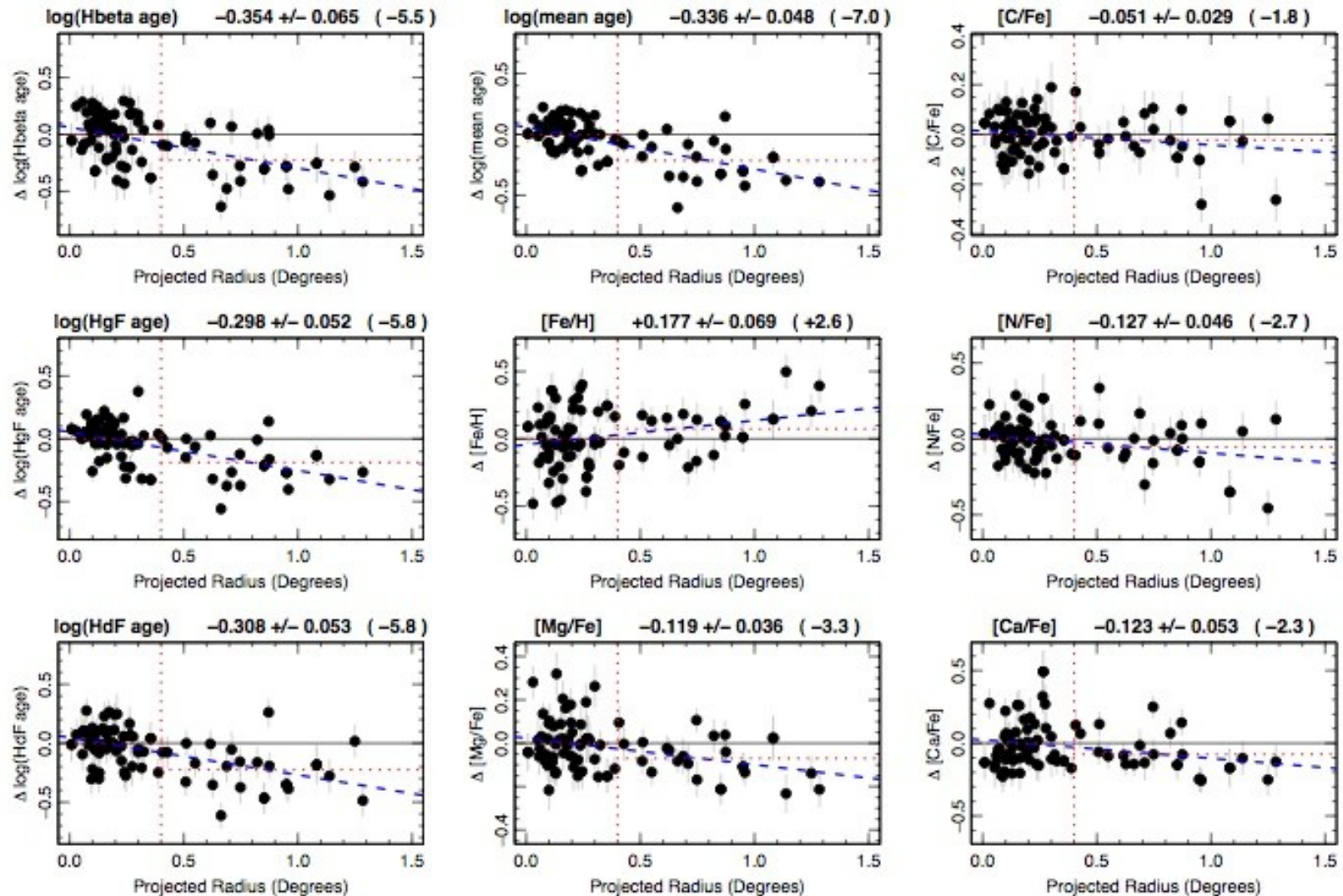
	Center	SW1	SW2
B	<20min	<20min	<20min
R	~ 40 min	~ 30 min	~ 50 min
i'	<15min	<10min	0min
NB	4hr	1hr	4hr



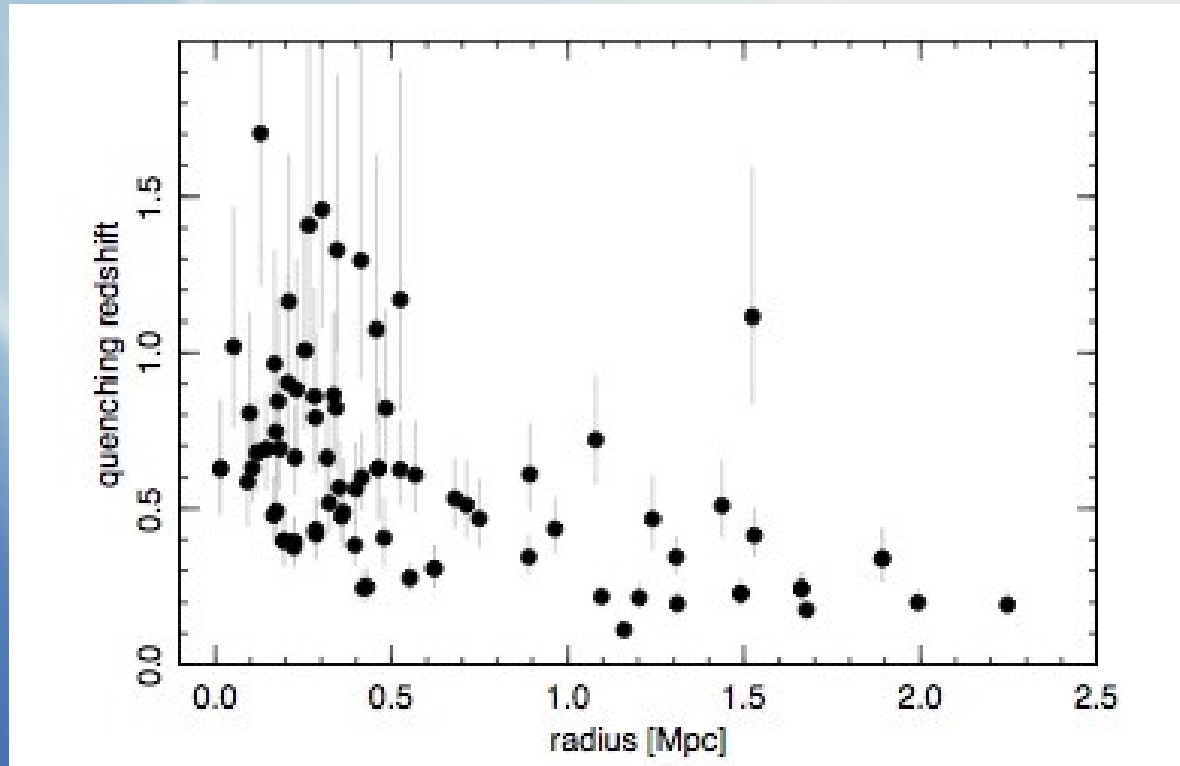
Ground-based followup

- Deep spectroscopy of samples selected from the ACS images
 - Keck/DEIMOS/LRIS (R.B. Tully). Faint membership survey and velocity dispersions
 - MMT/Hectospec (A. Hornschemeier/R.Marzke/T. Bridges). Membership and line indices. Line index work led by Russell Smith (Durham) and Mike Hudson (Waterloo)

Hectospec line index residuals from index luminosity plot



Age gradient in Coma cluster galaxies?



Summary

- Science team working on science output from 28% of survey data.
- 10-12 papers identified. One on press, two more about to be submitted.
- Data products being prepared for public access at STScI and Groningen. Data release via AstroWISE and MAST imminent.
- Season 2 ground-based observing plans being prepared (Subaru, UKIRT, Keck, MMT, CFHT).
- Proposal for 139 orbits submitted for Cycle 17 call. Results expected early June.