Nearby Galaxy Clusters with DECam from SV to 2022B (and beyond)

A look back and forward

Ian Dell'Antonio

DECam at 10 years

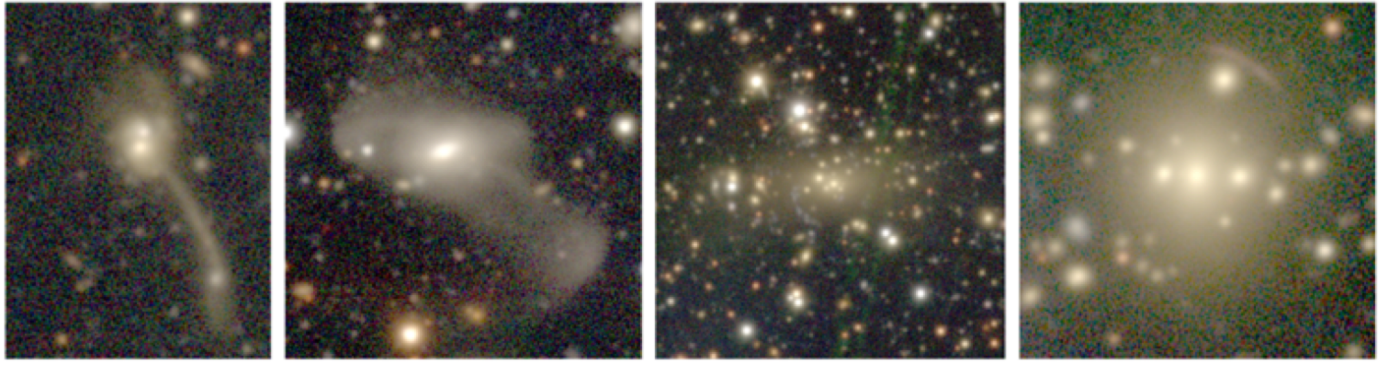
9/14/22

Galaxy Clusters, Why?

Important for Cosmology

Important for Galaxy evolution

Important as laboratories to study dark matter



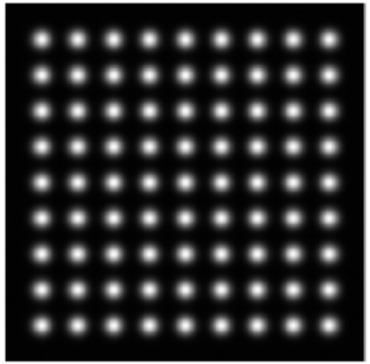
Weak lensing by Clusters

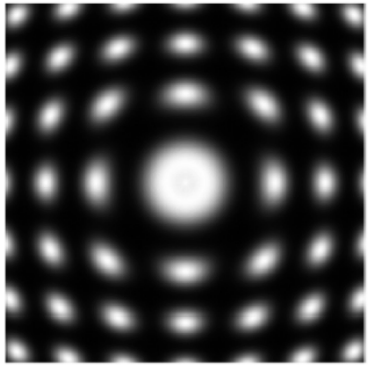
A good way to map out the mass content of the cluster.

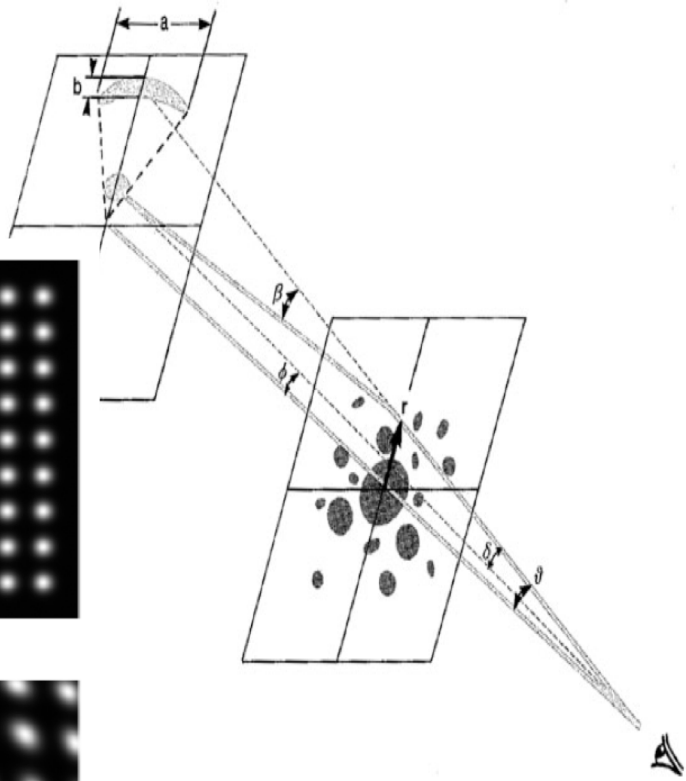
Use the shear pattern or the magnification pattern (but only shear in this talk)

Tangential shear pattern maps out the dark matter.

S/N per galaxy is <<1 –need to measure shapes of many galaxies.







A long history at CTIO…

Blanco 4m imaging goes deep enough…

A1689 from the Blanco using the 512k 1024k camera –Frank Valdes was involved….

Image by Oscar Saa (late 1990s?)

But getting the field of view has been a challenge…

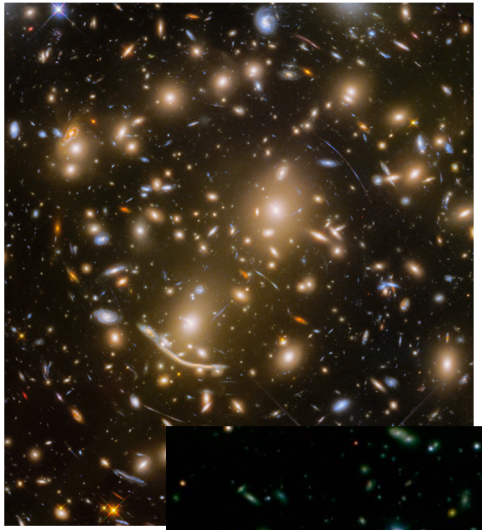
Why Low-z Clusters

Pre-DECam, weak lensing measurements focused on higher-z clusters.

- The field of view needed is smaller
- The shear signal is larger within a fixed aperture
- Einstein radius outside of central galaxies.

But these clusters are harder to study in other ways:

- Fewer spectroscopic redshifts
- Less detailed X-ray information
- Galaxy population fainter

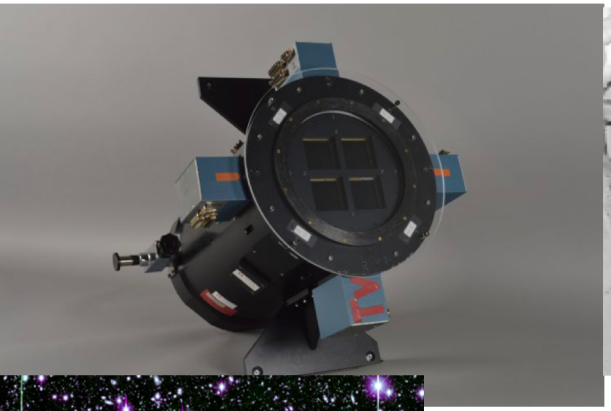


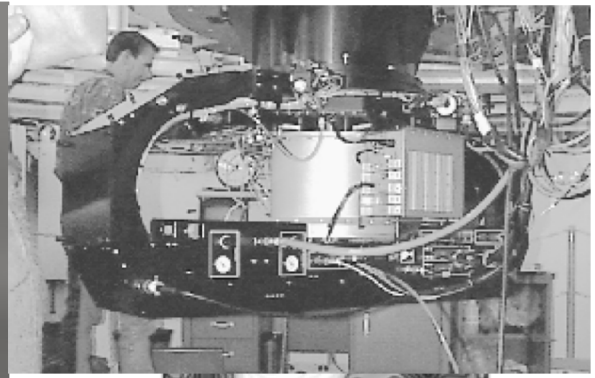
Abell 370

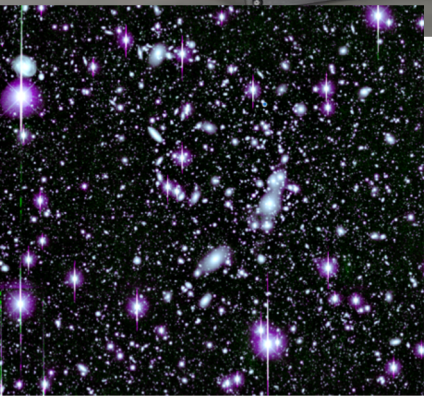
Abell 3827

BTC to Mosaic to DECam

Each time, the number of pixels grew by 5-10x. Efficiency and ease of use also increased!







Abell 3364 IDA et al 1999

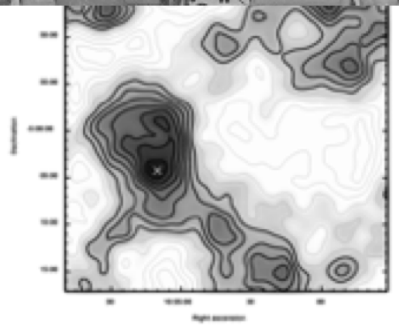
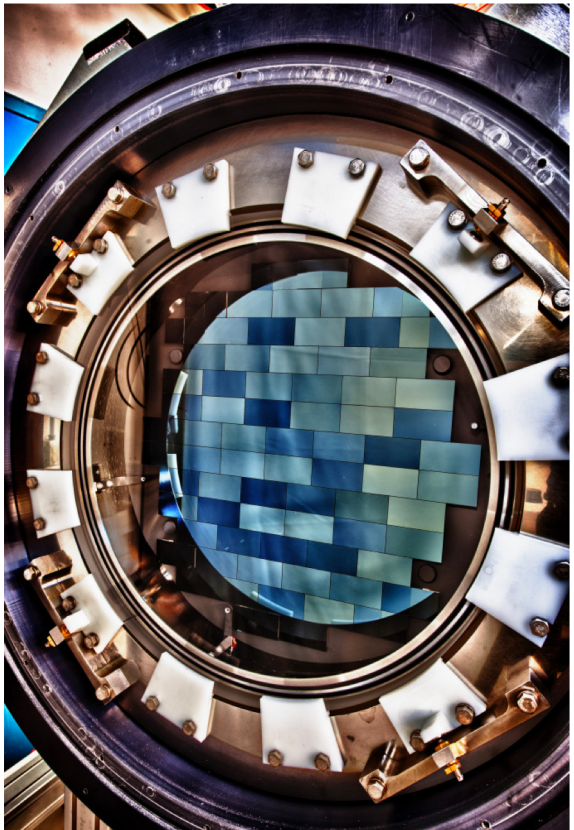


FIG. 2.—Projected mass map of the 35′ field, smoothed with a 30″ rms Gaussian. *Black*: Most dense regions (the units are arbitrary). *Contours*: Equally spaced from the lowest to the highest value. Negative and zero contours are drawn more thinly than positive contours. Note that only departures from the mean density are measured so that negative contours

Wittman et al. 2003



Why DECam?

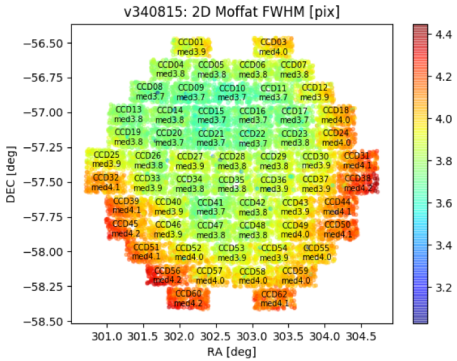
Design is optimized for weak lensing–we take advantage of the hard work of DES!

Hexapod for active optics correction

Wide field (greater than r_{vir} for z>0.03)

Uniform depth, fairly uniform seeing

Very sensitive CCDs (in the red especially, but also going to u).



NGC 4234 u,g,r from LoVoCCS

Science Verification–Observations of Abell 3128

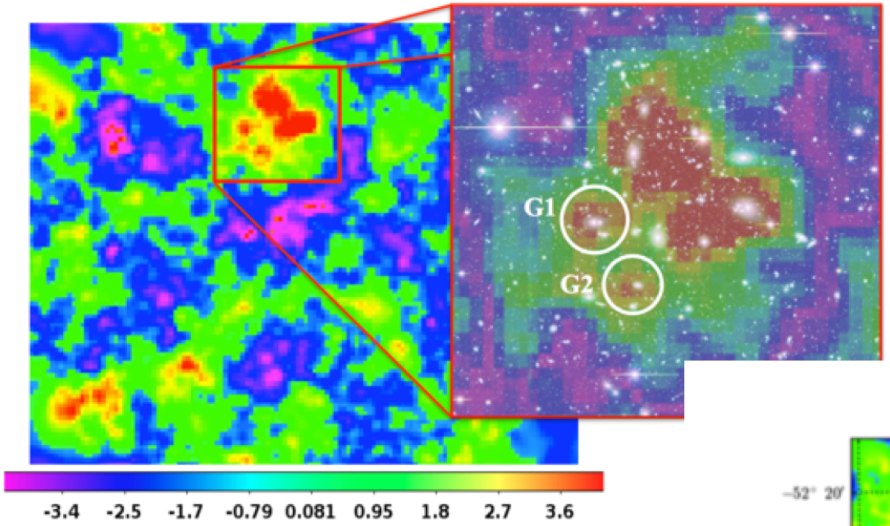
Data taken 11/09/2012 by Dara Norman in u,g,r,i,z,Y (1-3 hours/filter).

Test case because it's a massive cluster with another (equally massive) background cluster–test of shear and photo-z separation at the same time.

McCleary et al. 2015

I don't have an image from SV–this was a few years earlier…

What we learned from Abell 3128



We could detect the resolved weak lensing signal and complex substructure

Images from McCleary et al. 2015

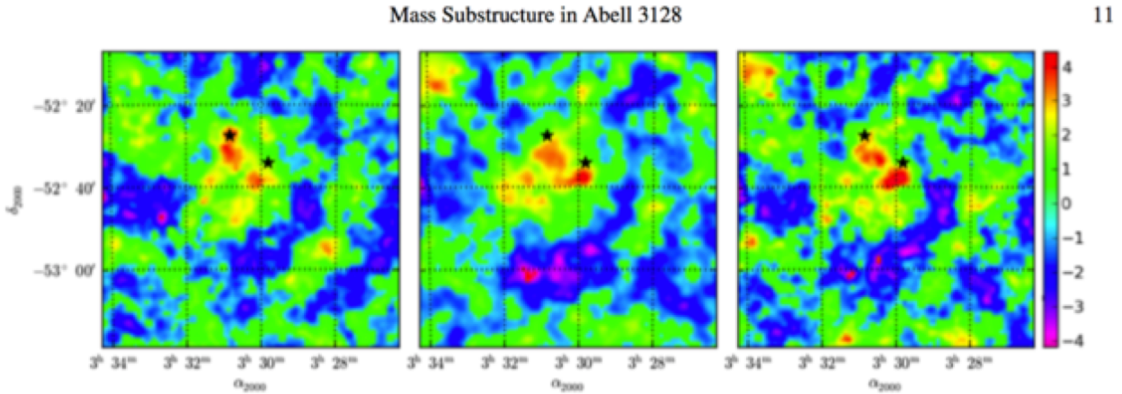
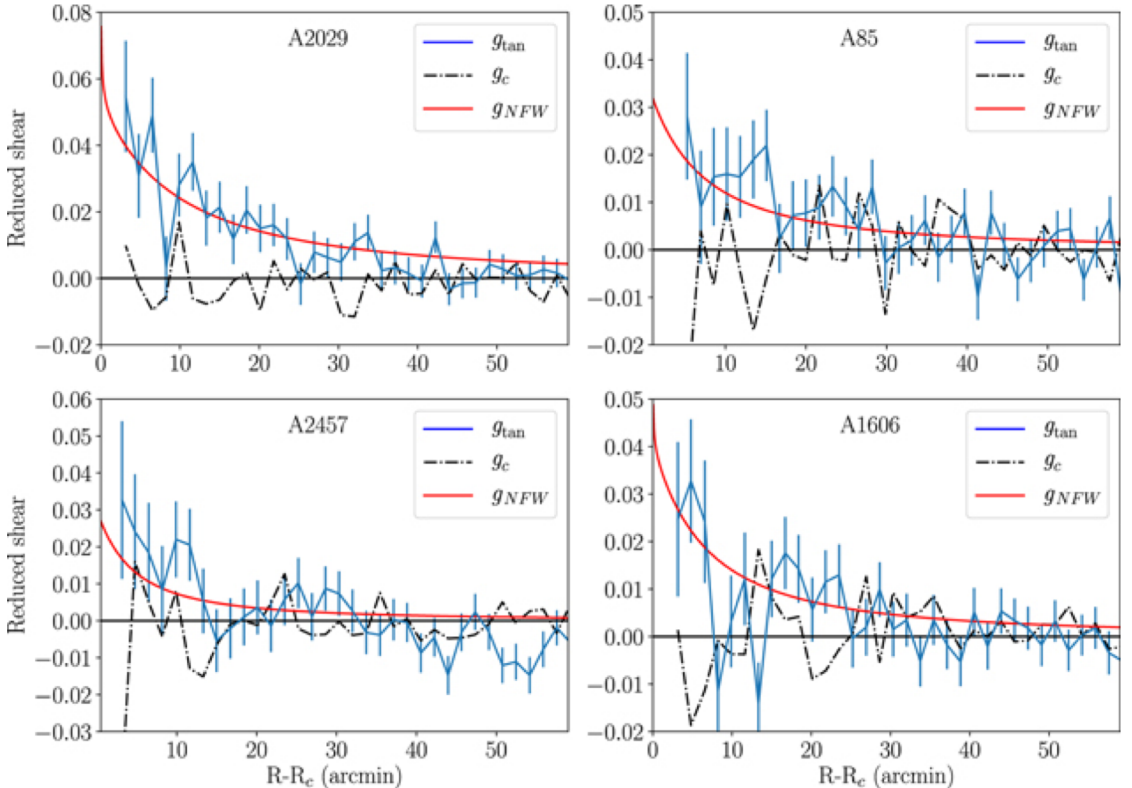


Figure 9. Significance maps marked with the published positions of the Abell 3128 X-ray "southwest peak" (bottom right star) and the $z = 0.44$ cluster ACT-CL J0330-5227 (top left star). Pixels in all maps span 52″ on the observation. The two extended high-σ regions apparent in all three panels are the principal substructures of A3128; they are discussed as A1 and A2 in §5.3. *Left:* Close-up of map made with background galaxy redshift restricted to $z \geq 0.44$ and a Schirmer aperture of 4000 pixels. The high-redshift cluster is plainly visible. *Center:* Map made with galaxies at redshifts between $0.16 \leq z \leq 0.4$ and a 6000 pixel aperture. While A3128 is still identifiable, albeit at slightly reduced significance, the high-redshift cluster has dropped out of view. *Right:* Map made with the full background galaxy sample and a 4000 pixel aperture.

We could separate out the contribution of the background cluster via tomography.

More clusters…

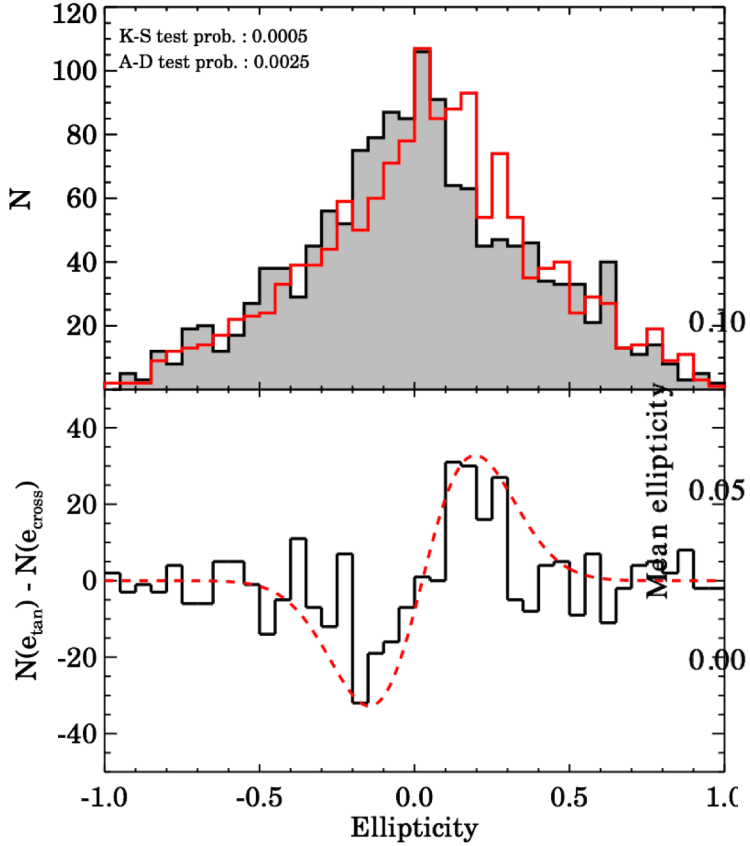
2013-2017: We (and others, see Lucie Beaumont's talk next) observed several individual clusters (here's A2029; McCleary et al. 2020

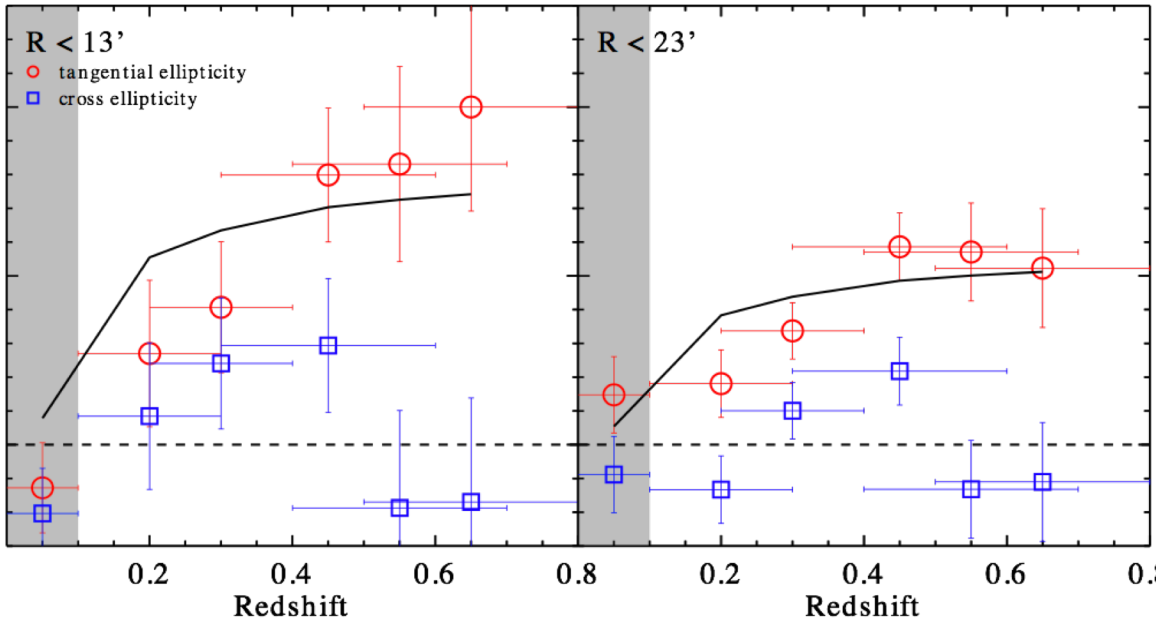


Lensing and redshifts–tomography

Measuring mean distortion versus redshift separates out the growth of structure from the geometry. Images from DECam, spectra from MMT (M. Geller and J. Sohn)

IDA et al. 2020





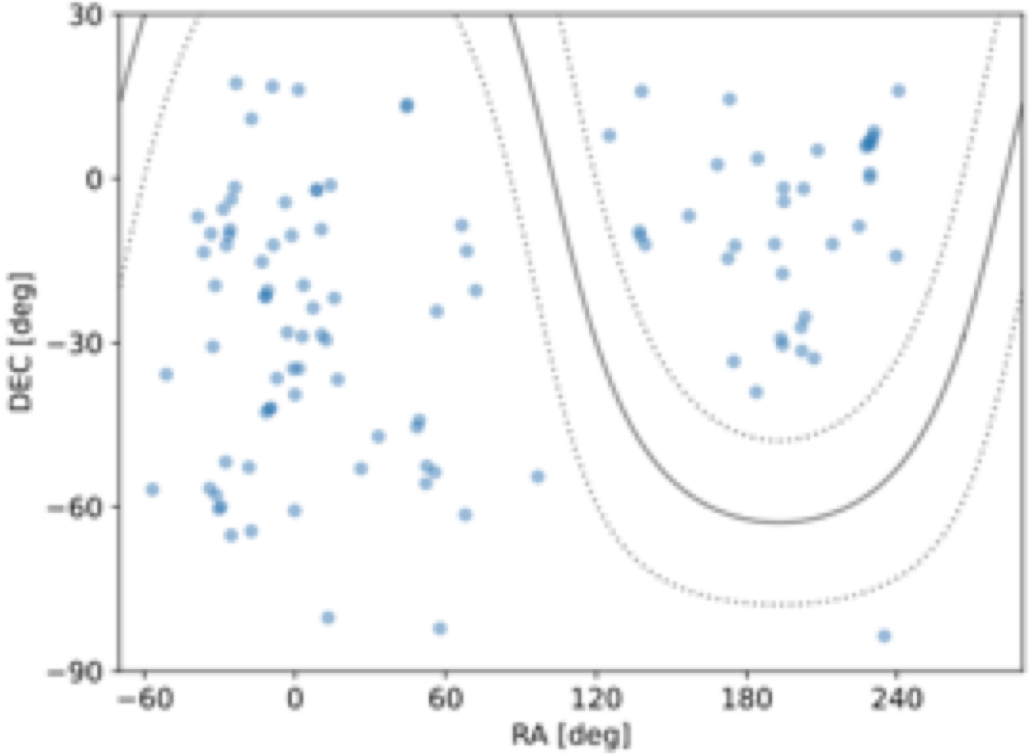
A Systematic study–the Local Volume Complete Cluster Survey – LoVoCCS

2019A-0308–although observations started in 2019B

Observe the 107 highest Lx clusters with dec<20, low-ish extinction (<0.4 in r), and 0.03<z<0.12

Image in u,g,r,i,z –Y1 to Y2 LSST stacked depth in each filter (a little less in u)--~5 hours livetime per cluster.

Uniform seeing in r, photo-zs from other bands.



What LoVoCCS is (more details in Shenming Fu's talk later)

A test of the population of clusters and how their lensing signal depends on their detailed properties

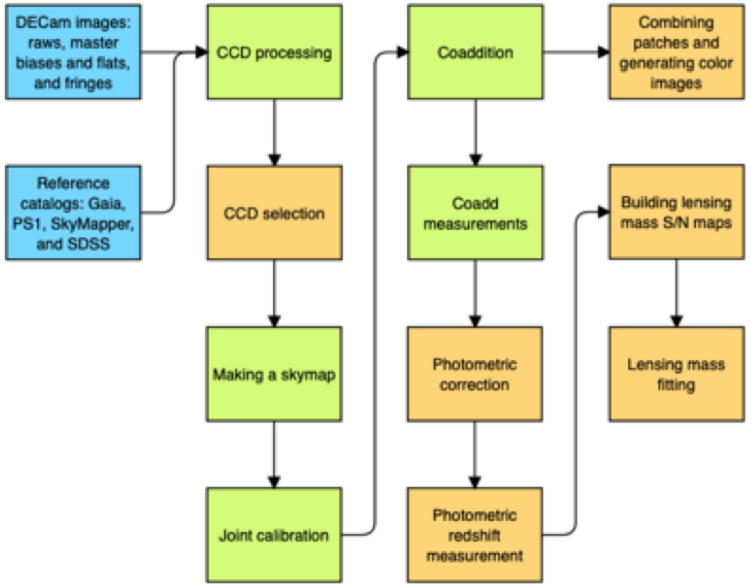
A precursor to cluster analysis with Rubin/LSST;

Data processed with LSST/DM pipelines (gen 2

For now, transitioning to gen 3)

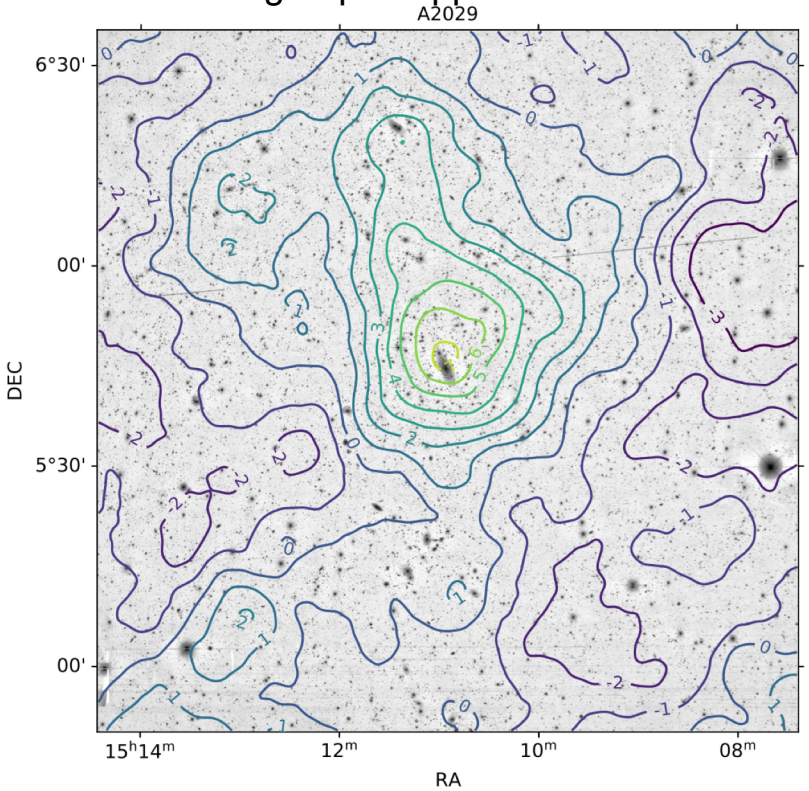
Status: ~70 clusters complete; ~25 partially

Imaged. Paper I published (Fu et al. 2022)

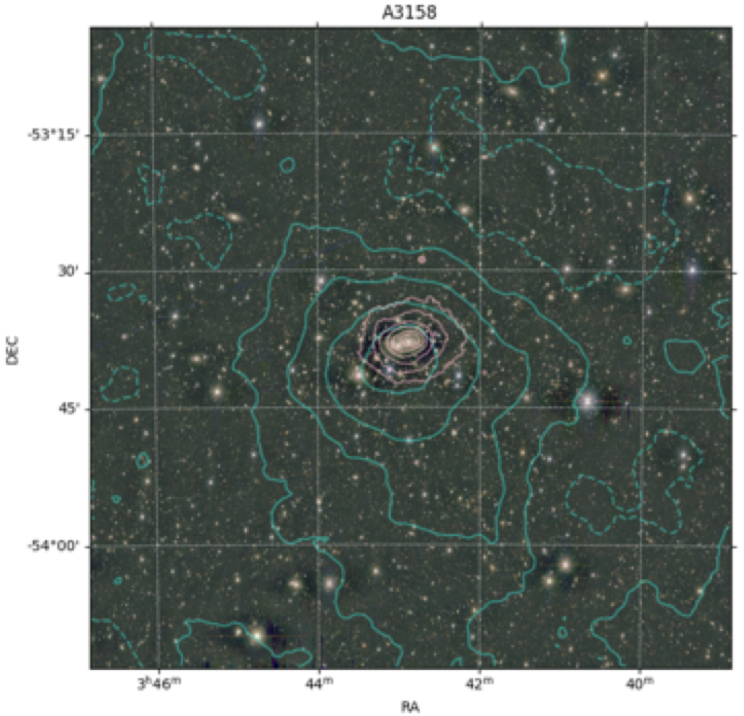


Results–Resolved mass distributions

A2029, note connection with A2033 and detection of group at upper left.



Note contrast between X-ray and mass density isophotes



Results–photo-Zs and masses

Masses and uncertainties obtained by resampling

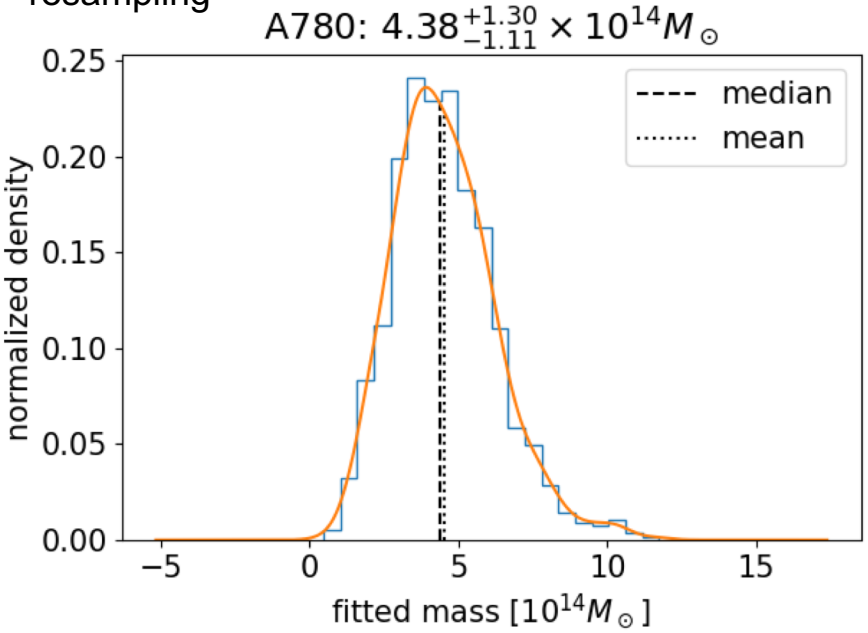
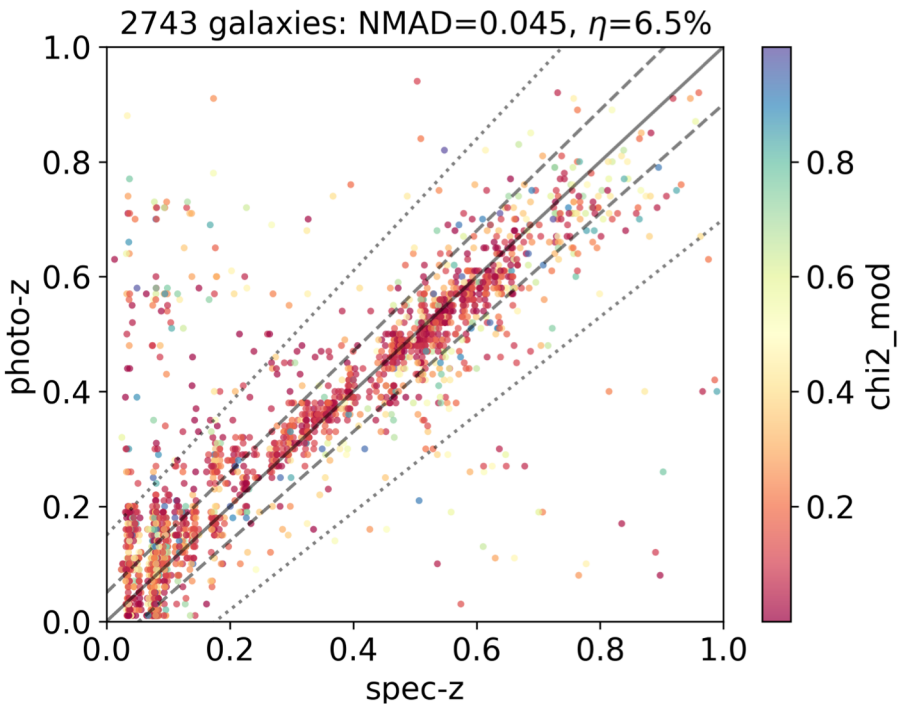
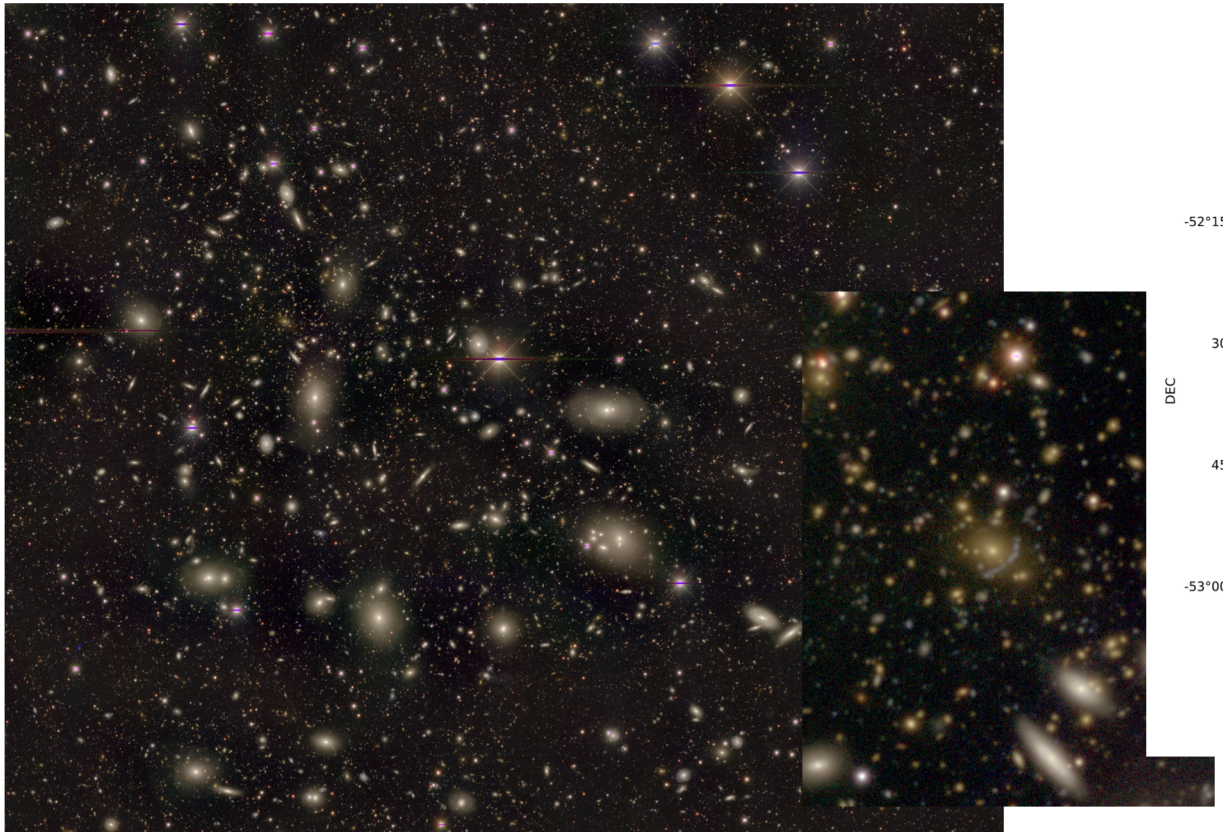


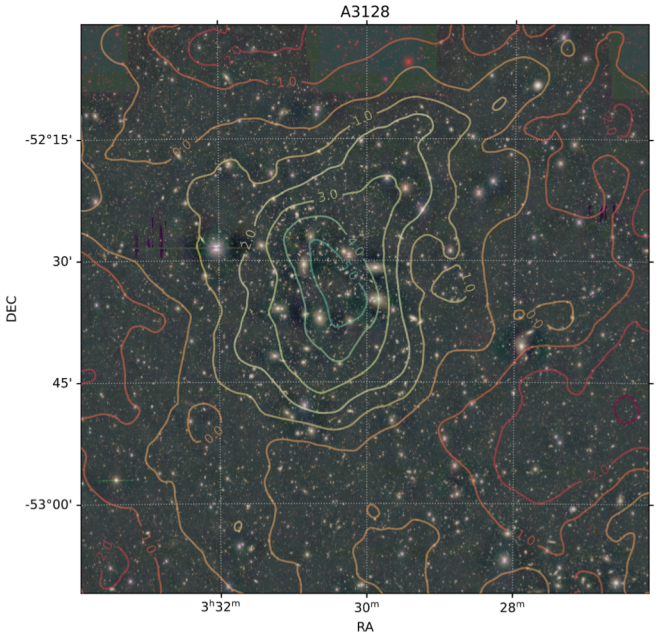
Photo-zs “o.k.”-- Note this is the A2029 field, not A780



Back to Abell 3128!

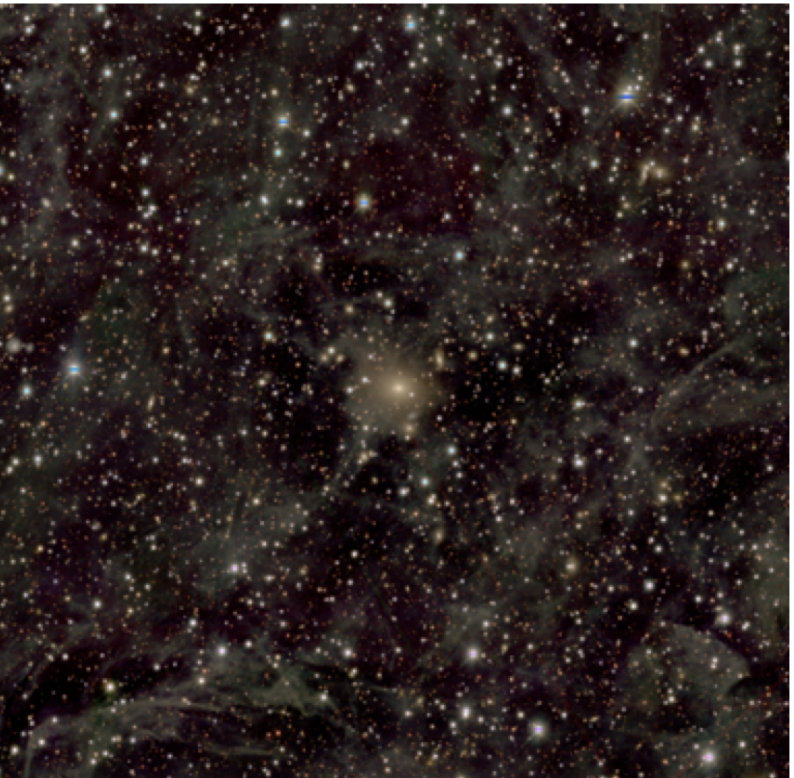
LoVoCCS observations finished in 2022A (but analysis finished last week…)



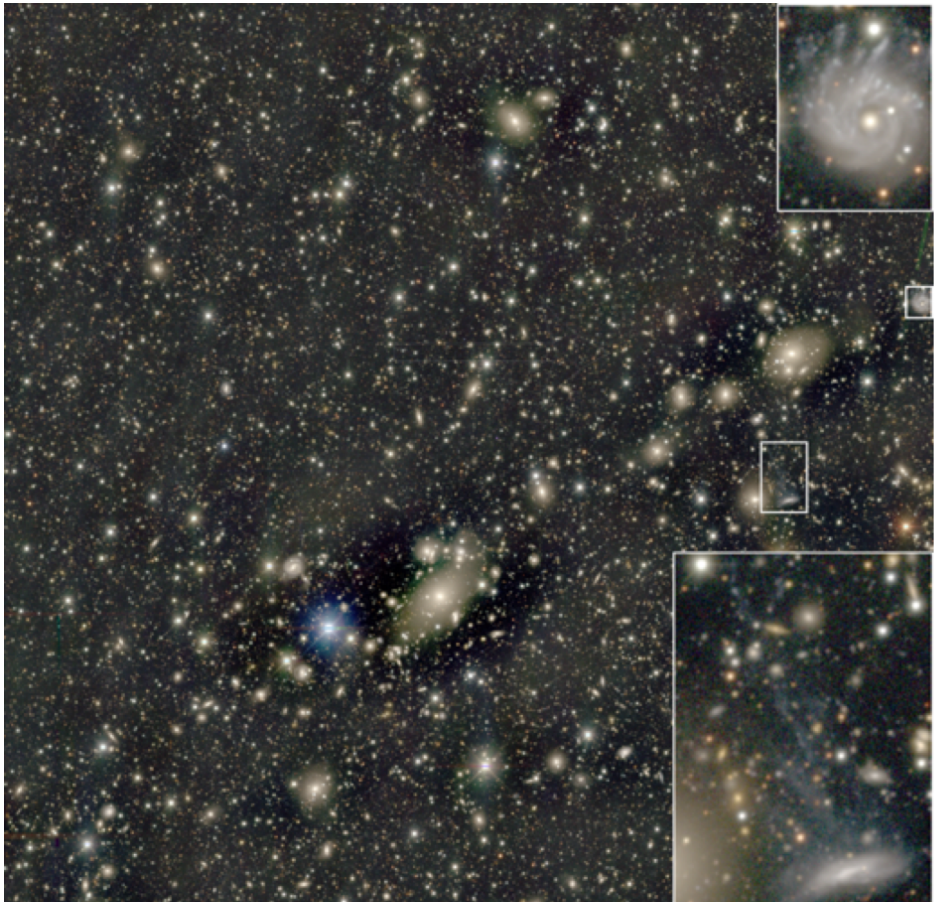


Unsolved problems…

RXCJ1539.5-8335–Cirrus! (unavoidable)



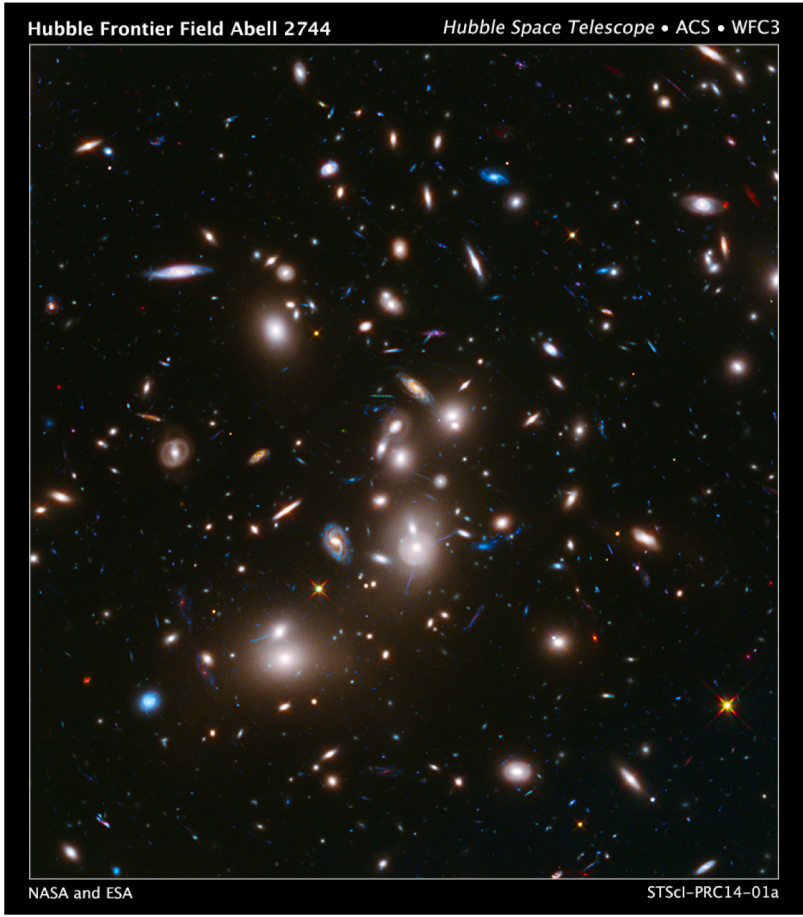
Sky subtraction in LSST DM–working on it!



What's next–Roman Space Telescope

Rubin/LSST will be a natural place to study the clusters–with the 5-10x increase in depth, and the full sky coverage, and the improvement in seeing and filter coverage: increase local sample from 100 to ~350.

But there's another avenue: imagine a telescope that would image the virial region of a z=0.5 cluster with 7-8x the spatial resolution, a higher lensing resolution, and similar rest frame wavelength coverage…



(Part of) What's next for Galaxy Clusters with DECam?

Narrow band filters! Spectroscopy of faint cluster members will be hard until the ELTs come along. Narrowband filters can do two things:

1) Improve photo-zs for galaxies behind the clusters (better lensing)
2) Determine where star formation occurs in and near clusters! This works best for doubly (or multiply) "magic" filter combinations, for which multiple emission lines end up in the narrow filter bands

This is already possible–the Merian survey filters at z~0.1,

but also N501/N673 (OII and Hb at z~0.35),

N501/N662 (MgII and OII at z~0.78), and

N540/N708/N964 (MgII/OII/OIII at z~0.925)

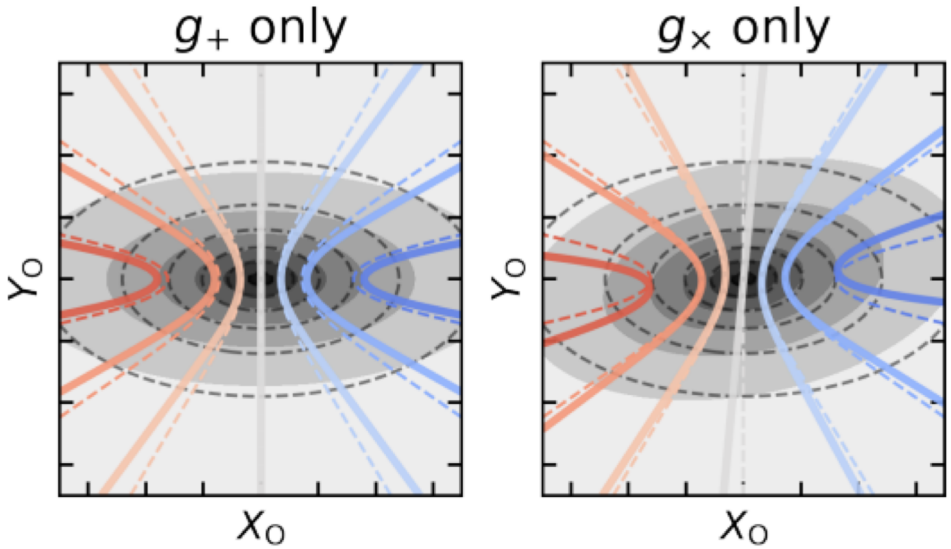
But it's "easy" tune these!

What's next for the Blanco?

An obvious case is for spectroscopic capability (although a NIR imager might be interesting if on a scale larger than NEWFIRM). But I would advocate a system focused on IFUs

Spatially resolved spectroscopy.

Specific Lensing case:



Xu et al. 2022