Joint ICL/shear mapping of nearby galaxy clusters with DECam from LoVoCCS

(more like a list of difficulties we've encountered)

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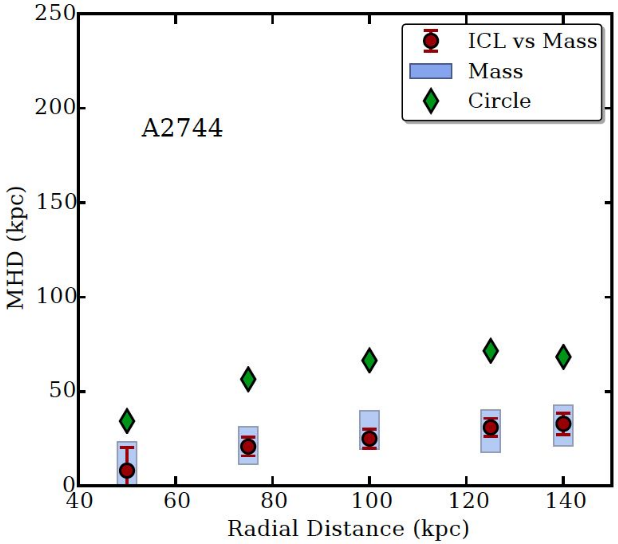
Why study Weak Lensing and the ICL together?

- Both trace the underlying gravitational potential of the cluster (cross checks).
- Both are less collisional than the X-ray emitting gas, giving information about the dynamical state of the cluster
- If the dark matter has a measurable self-interaction cross-section, then intercomparisons can reveal information about dark matter.
- The systematic errors encountered are extremely different in character (joint analysis is more powerful than individual ones.)

From Montes and Trujillo 2018



Why LoVoCCS, and what is it?

- An NSF's NOIRLab survey (2019A-0308). Observing started in 2019B just before the pandemic. Observations will continue into 2023. Paper I is published (https://doi.org/10.3847/1538-4357/ac68e8); paper II in prep,

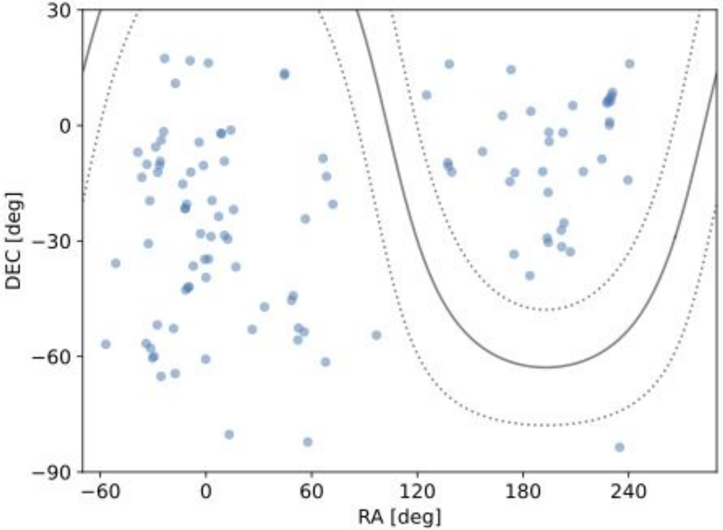
- Using DECam to study all of the $L_x > 10^{44}$ erg/s clusters at $0.03<z<0.12$ that are far enough south and not obscured by the Milky Way—107 clusters!

- Five-band imaging u,g,r,i,z bands

(1-2 hours/band; LSST Y1-2 depth) for photo-z; use archival

data where available

- Optimized for weak lensing (r-band deeper and <1" seeing)

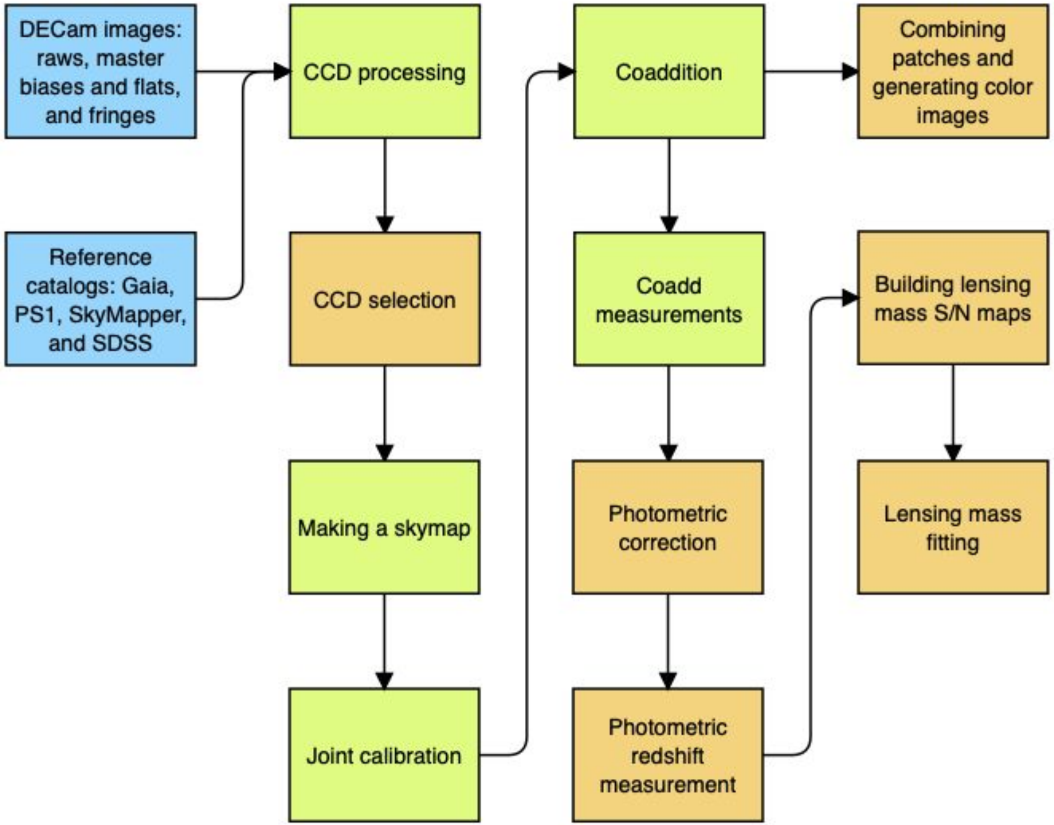


- ~60 clusters complete, another 25 with partial imaging so far

- But not designed for ICL studies (more on this later)

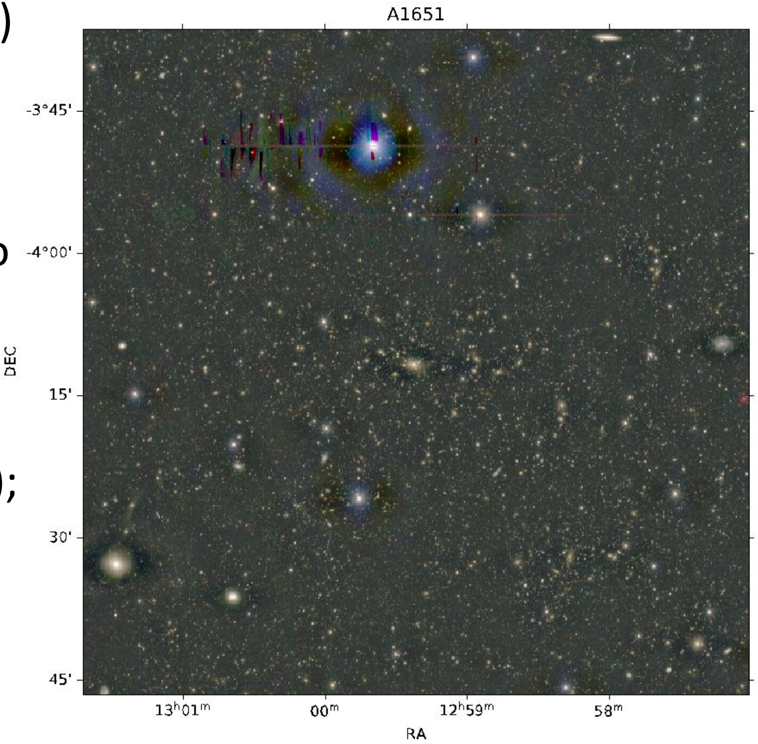
Built to use Rubin LSST Pipelines (and obs_decam)

- Use PS1/SkyMapper (for griz) and SDSS/SkyMapper (for u) for photometric reference—correct via precalculated color terms and stellar locus; (Gaia for astrometry)
- Use the key reduction steps from the pipeline (processCcd,jointcal,Coadd) and the Rubin LSST measurement algorithms (including forced photometry for photo-z determination). Currently using Gen2 tools, transition to Gen3 just beginning.
- Currently using the NOIRLab master calibrations; with the move to Gen3 will have to make new calibrations.
- Will provide images/catalogs that should be directly comparable with Y1 LSST data.



What LoVoCCS (currently) can do

- Produce convergence and aperture mass maps across the full field of view (>2 R_{vir} for every cluster)
- Estimate mass substructure via multi-resolution reconstructions; detect structures to 2-3x10^{13} M_{sun} (group scale)— ~5-10% of cluster mass.
- Measure masses of individual components down to ~5x10^{13} Msun.
- Detect background structures (via red-sequence or other clustering algorithms).
- Ancillary data! Spectroscopy (e.g. Sohn et al. 2019); X-rays (Donahue et al. NASA ADAP-2022); SZ (Pierpaoli). Compare multiple observables over a complete sample.
- Detect lensing signal from filaments connecting nearby clusters.



What LoVoCCS currently can't do….

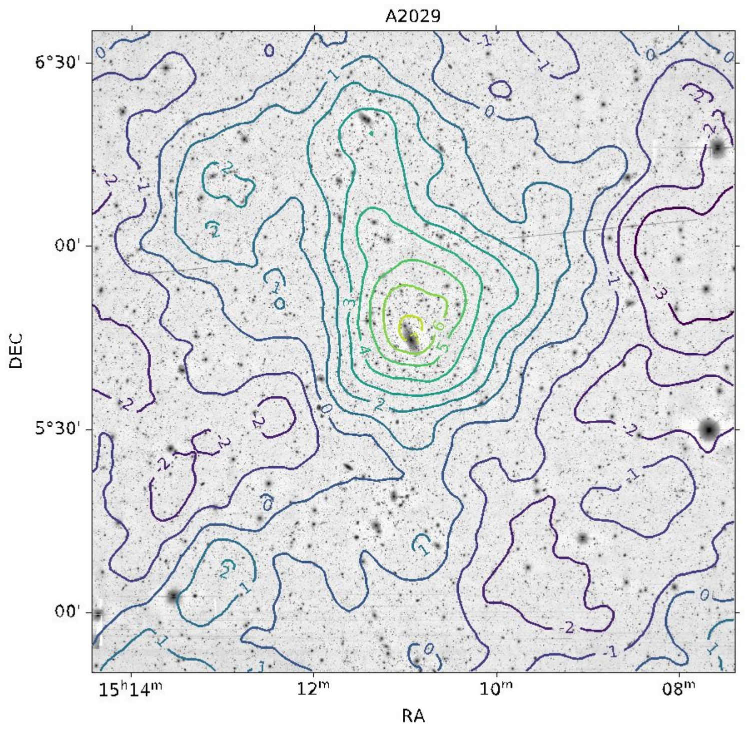
Measure the ICL correctly.

The obs-decam default pipeline greatly oversubtracts both the ICL, the outer envelopes of elliptical galaxies, and the PSF/scattered light around bright stars.

Due to the local subtraction algorithm in both processCcd and assembleCoadd (chip and patch-based).

Requires designing new sky subtraction (global or at least on scales >>10') and/or sky models built from other exposures without the cluster.

Need to preserve small object shapes; current plan is to make two separate stacks.



Why nearby Clusters are particularly hard:

- The BCG can be larger than a single DECam chip—need chip to chip sky model to be continuous
- The ICL is on a larger scale than a single patch– this means that sky modeling can't be done on the scale of single patches (i.e. measureCoadd).
- There are thousands of background objects that need to be either modeled or masked out.

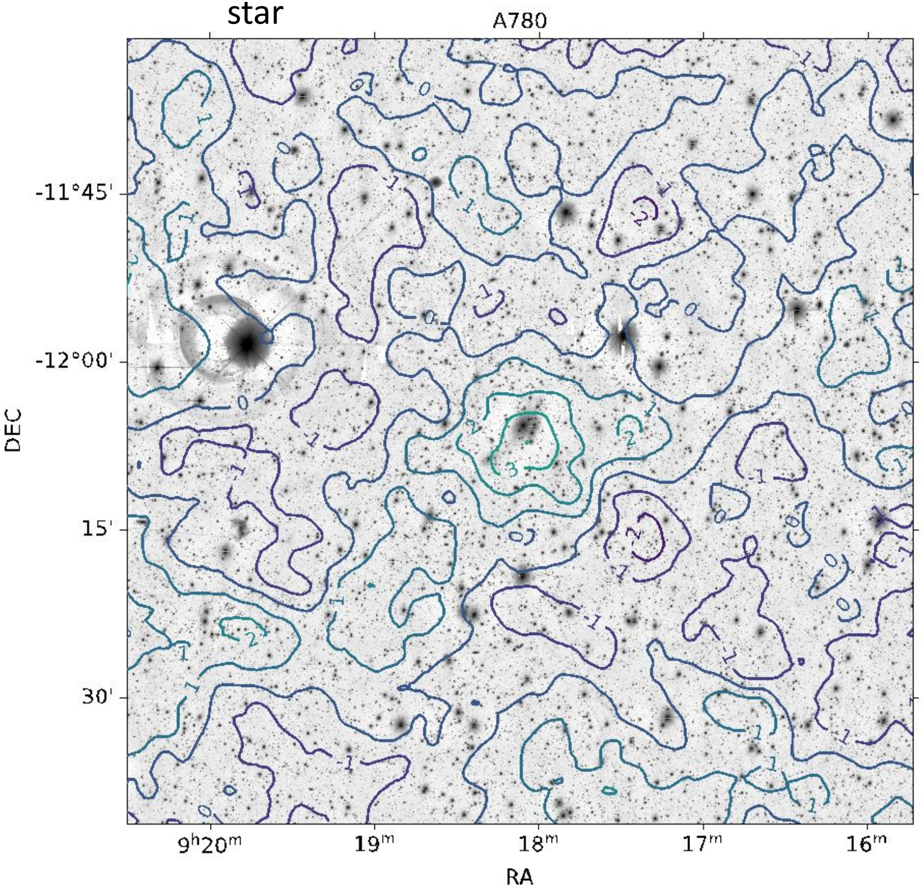
IC1101 detail…

Why LoVoCCS is particularly hard:

- LoVoCCS fields have a cluster at the center; median of our images is not a good sky estimator.
- Data on individual clusters taken over several years (sometimes 10 individual years); hard to build sky models for all observations
- Observations taken under a variety of Moon angles (except for u and g which are in dark time); as as low as 30 degrees Need to fit significant sky gradients.

Fortunately, these are effects that will be much less important for Rubin LSST!

1.25x1.25 degree image of A780, showing the effect of a 6th magnitude star



Lessons for Rubin LSST

- Big galaxies exist—will need to have a way of modeling the sky on large scales to recover the ICL (and also LSB unresolved galaxies, see upper right)
- LoVoCCS is a good test bed—the data will be deep enough to test ICL/diffuse emission recovery algorithms
- There’s much work to do!

Abell 458 center, plus unrelated LSB galaxy in foreground

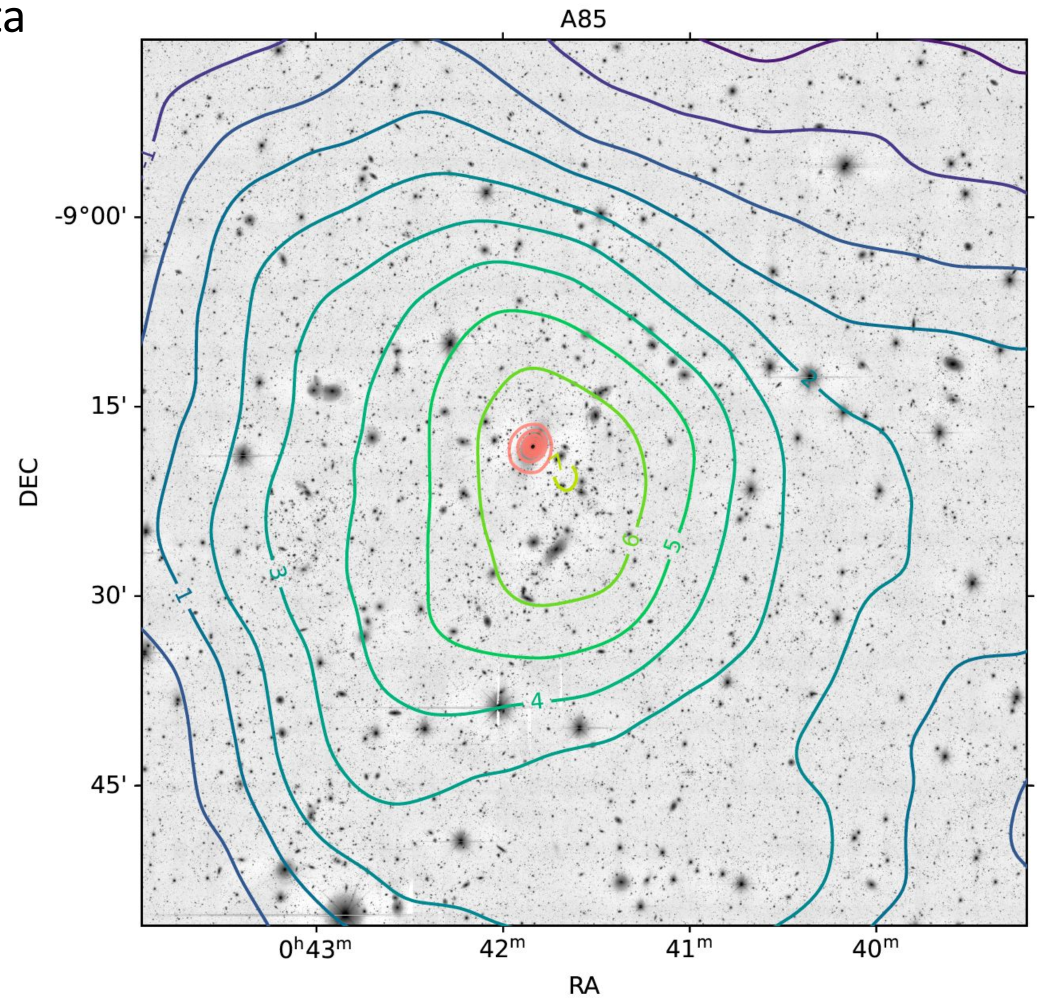
BACKUP SLIDES

Problems with LoVoCCS ancillary data

1: lensing covers a much large area than X-ray data–particularly Chandra. Will be partly helped by XMM but really need e-Rosita observations

For example, A85 Chandra doesn't cover all giant ellipticals…

2. Spectroscopy is very uneven. Some clusters (A85,A2029 have >1000 member redshifts, others have ~10).



Cirrus is also a problem, even 30 degrees from the plane.

In principle the Cirrus is different in color from the ICL (see figure of RXCJ1539-8335 on right) Can separate it if we fit for the ICL in multiple bands…

Lensing signal not always centered right on BCG–can we model the ICL as not completely centered on the BCG as well?