TMT Capabilities and Instrumentation for Cluster Cosmology

TMT Science Forum 2016

May 26, 2016

Based on Cluster Cosmology Key Program Proposal

(with contributions from Marusa Bradac, Marie Lemoine-Busserole, Michael Pierce, Tommaso Treu, Gillian Wilson)

What cluster cosmology?

- Dark energy!
  - N(m,z)
  - Strong lensing tomography
  - Arcs
  - Weak lensing?
- Dark Matter
  - Subclustering
  - galaxy halos
  - interaction cross sections
- Galaxy evolution
  - galaxy mass assembly
  - Downsizing
  - high z star formation (talks by M. Pierce and M. Lemoine-Busserole in high-z section)

What can TMT contribute

- Not a cluster discovery machine!

LSST, EUCLID, WFIRST, eROSITA, SPT, CMB-S4 will find them.

- "Unique" capabilities:

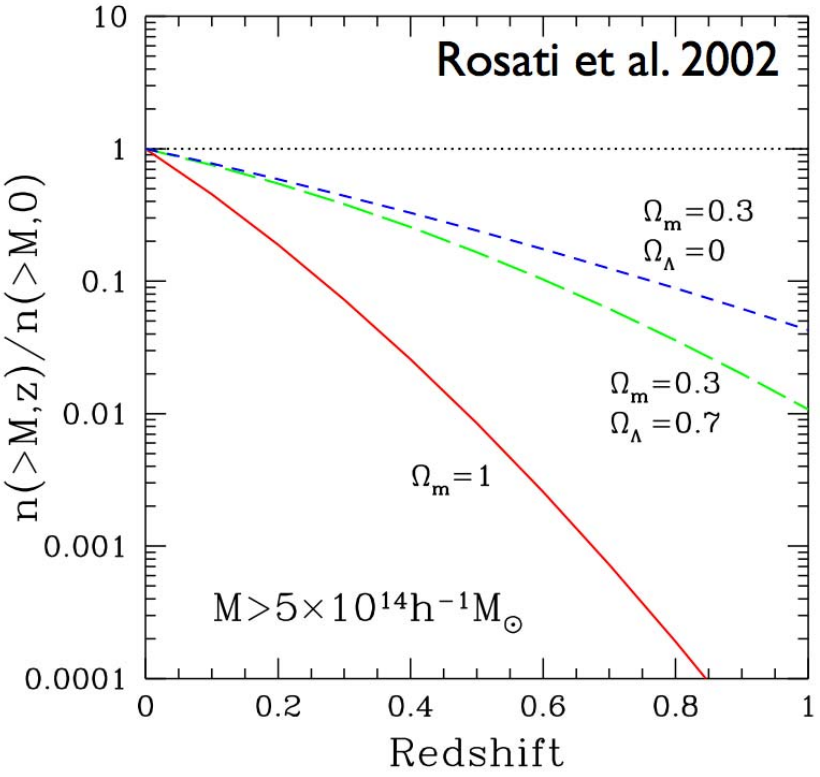
1) Angular resolution– ~5x HST: more arcs and more detail in arcs.
2) (multi)IFU – resolved kinematics of galaxies in and behind clusters
3) AO-assisted spectroscopy: NIR redshifts of fainter objects
4) Wide field spectroscopy—more redshifts for cluster kinematics

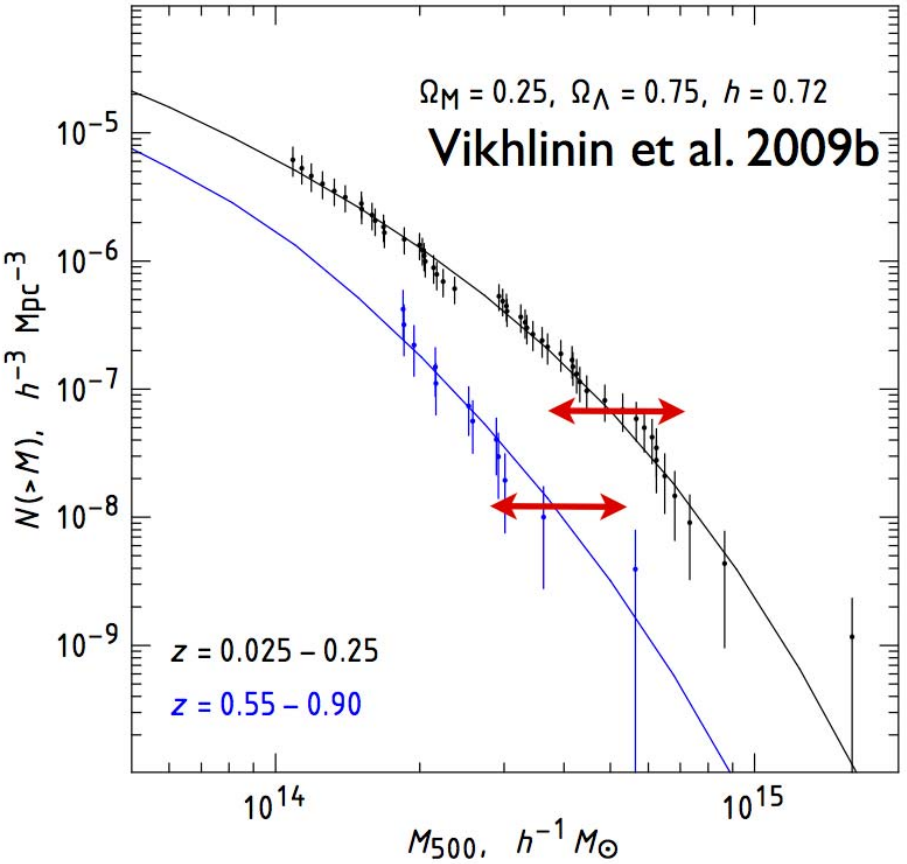
Why clusters?

Strong lensing region for a massive cluster is <200 kpc across 23” at z=1.5, 24.5” at z=1, 32.4” at z=0.5, 60” at z=0.2. Very well-matched to FOV of IRIS/IRMS.

Weak lensing detections to ~2Mpc. WFOS covers entire region of WL interest in one pointing down to z<0.2.

Cluster Mass function evolution





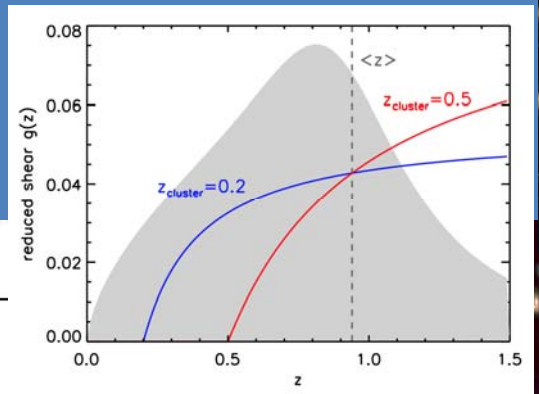
Optical,NIR,X-ray,SZ will detect 10,000-50,000 clusters for evolution measurements. But for DE measure, mass scale must be known to ~1% over 0.1<z<1.5.

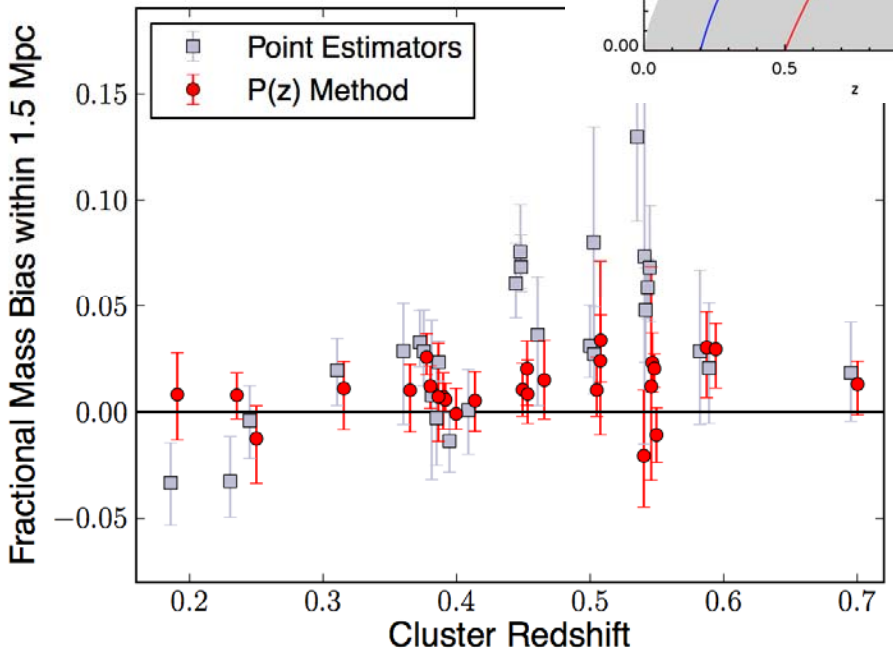
TMT contribution pivotal

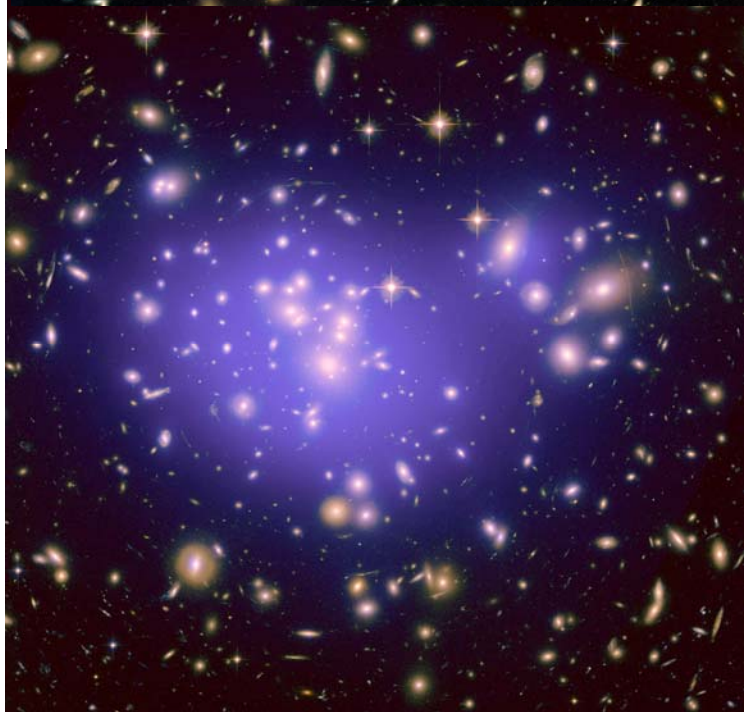
Requires– IRIS imaging (to calibrate mass via strong lensing; and IRMS spectra to verify P(z) for background galaxies.

Can be done with first light instruments.

WtG; von der Linden et al. 2014, Applegate et al. 2014



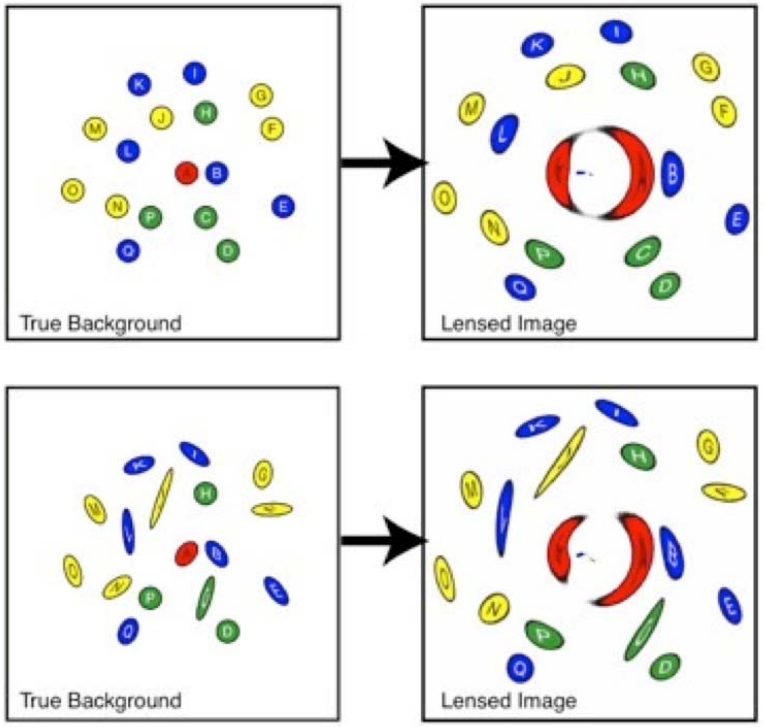


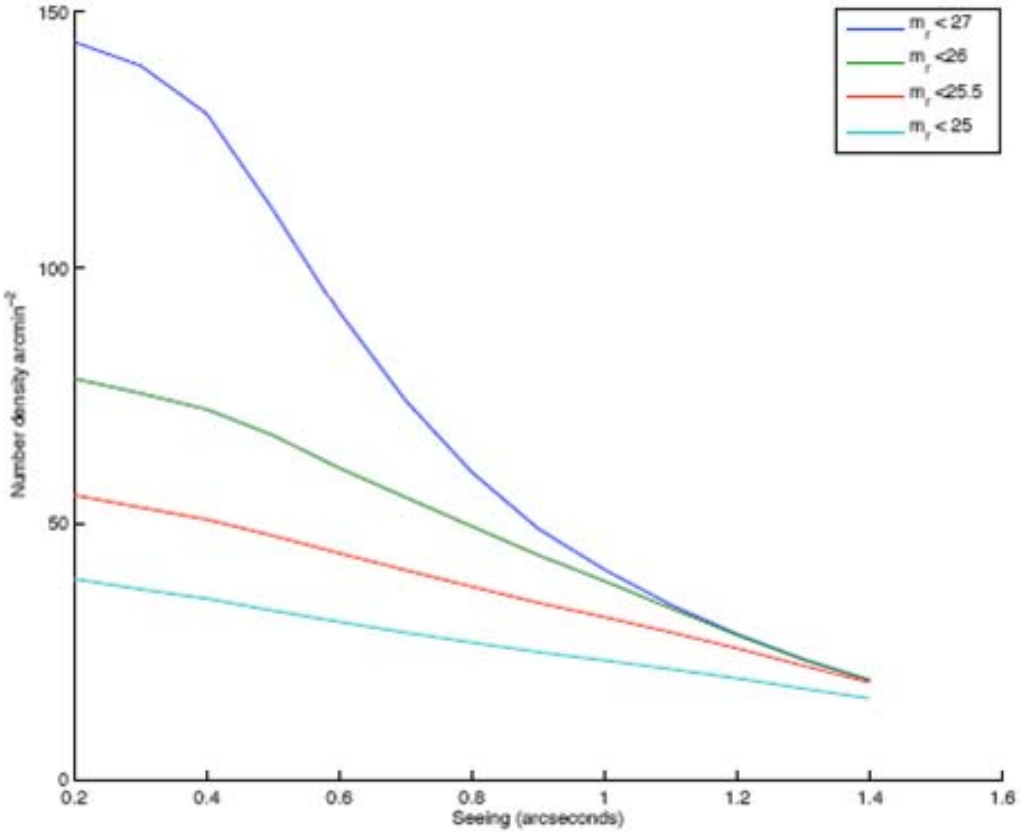


Weak Lensing?

Going faint with good resolution can be a gigantic gain

Outside SL region, galaxy intrinsic ellipticity dominates. S/N scales as $N^{1/2}$





Cook et al. 2014

Competitive WL measures (at z>0.5) require a FOV of > 10 square arcminutes.

Within reach of Next generation WIRC?

Galaxy infall regions with WFOS

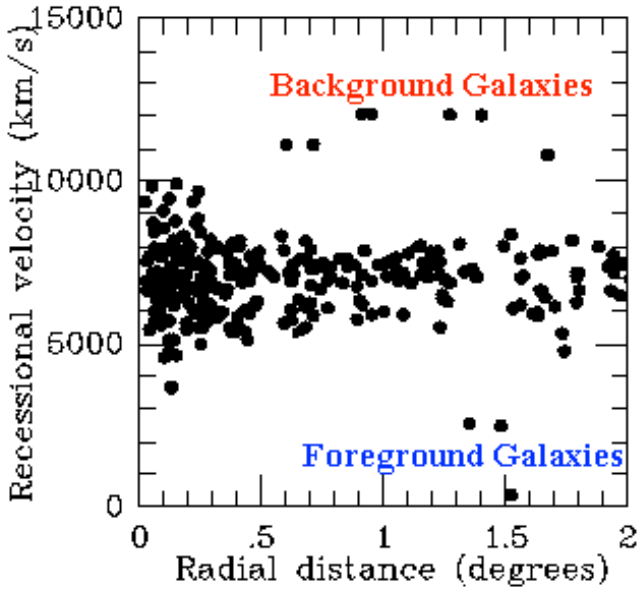
Capability exists already.

Now applicable to z~0.3

Limited by number of galaxies.

WFOS to z~0.8

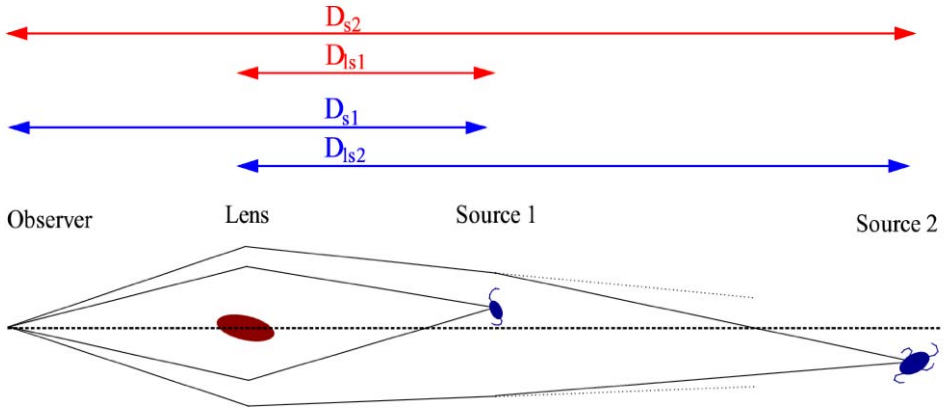
IRMS to z>1.5



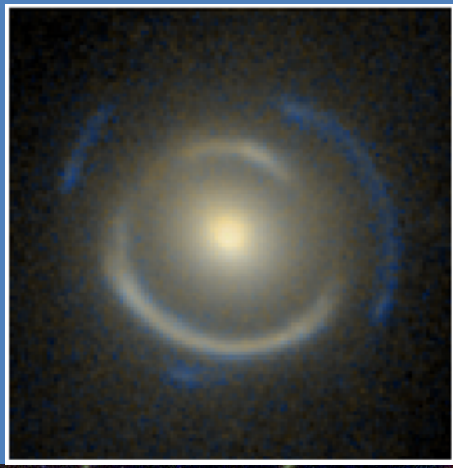
Rines et al. 2012

Strong (and weak) lensing tomography

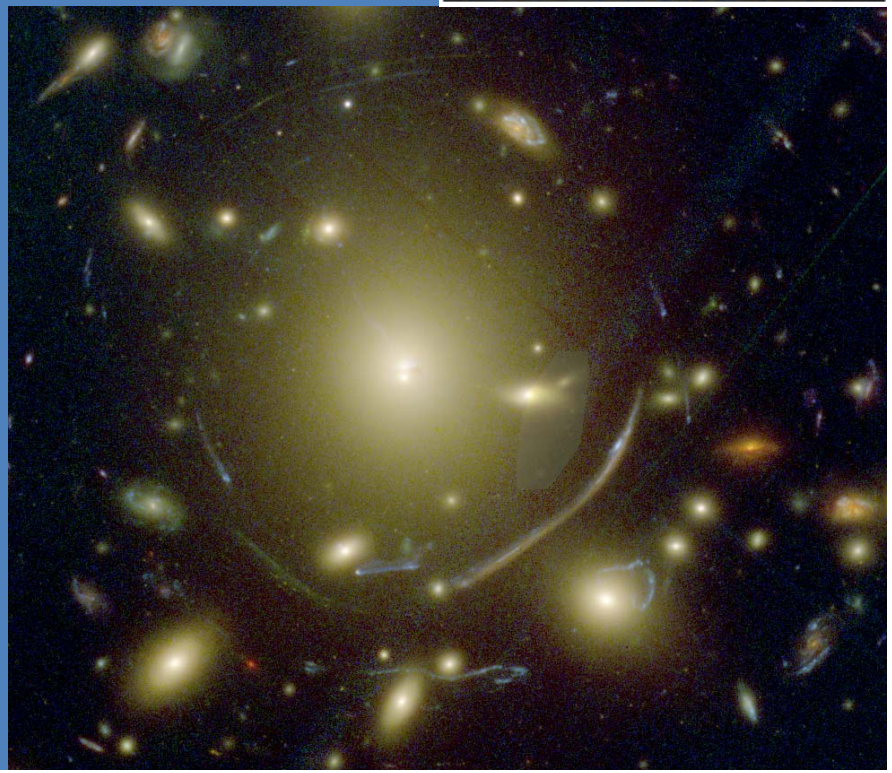
$$\beta = \frac{D_{ls1} D_{s2}}{D_{s1} D_{ls2}}$$



Independent Probe of Expansion History



Abell 383, CLASH, Coe et al. 2014



Requires High resolution imaging and redshifts for the sources. IRIS and IRMS to the rescue.

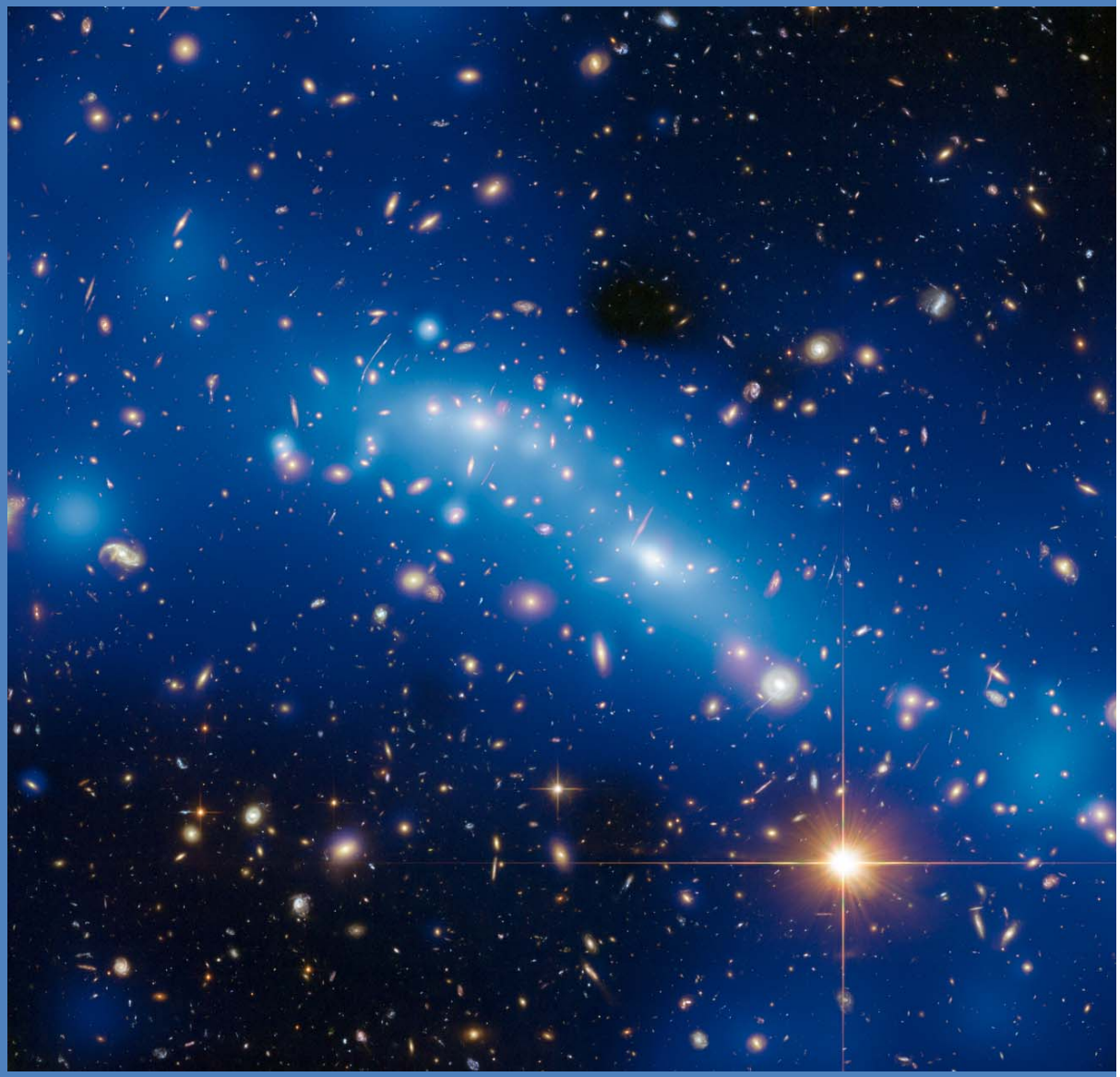
Arc Statistics

Frontier field clusters have >100 multiply imaged galaxies.

Many arcs are still unresolved perpendicular to the arc.

Each multiply-lensed region within an image is its own constraint!

TMT can increase lens mapping spatial resolution by 5-10x over the frontier fields



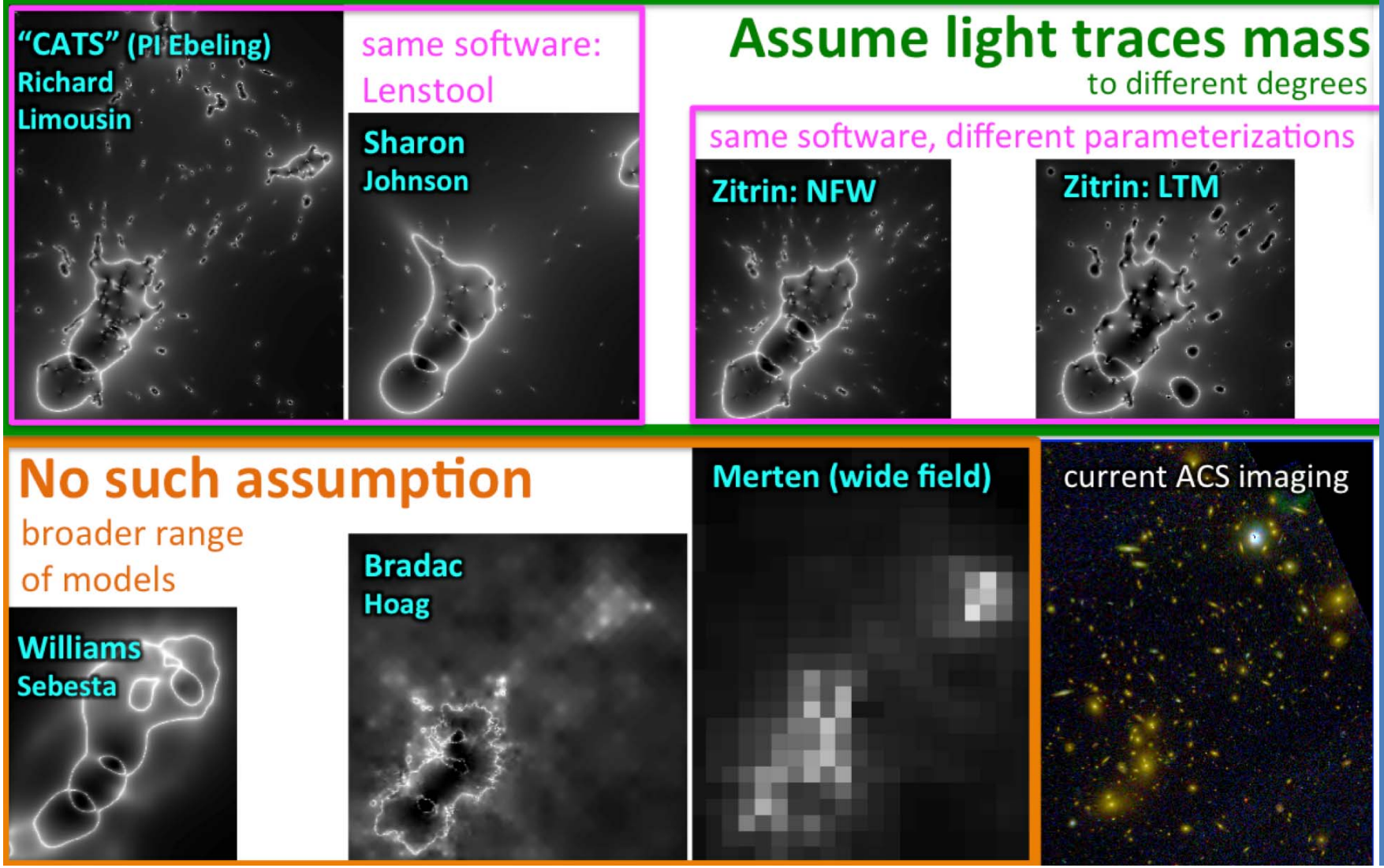
Frontier Fields

Cluster Mass Modeling

Mass mapping resolution scales as N_{arcs} (not uniform). Even frontier field models disagree

Frontier Fields submitted lens models

Abell 2744 magnification maps for a lensed source at z = 9

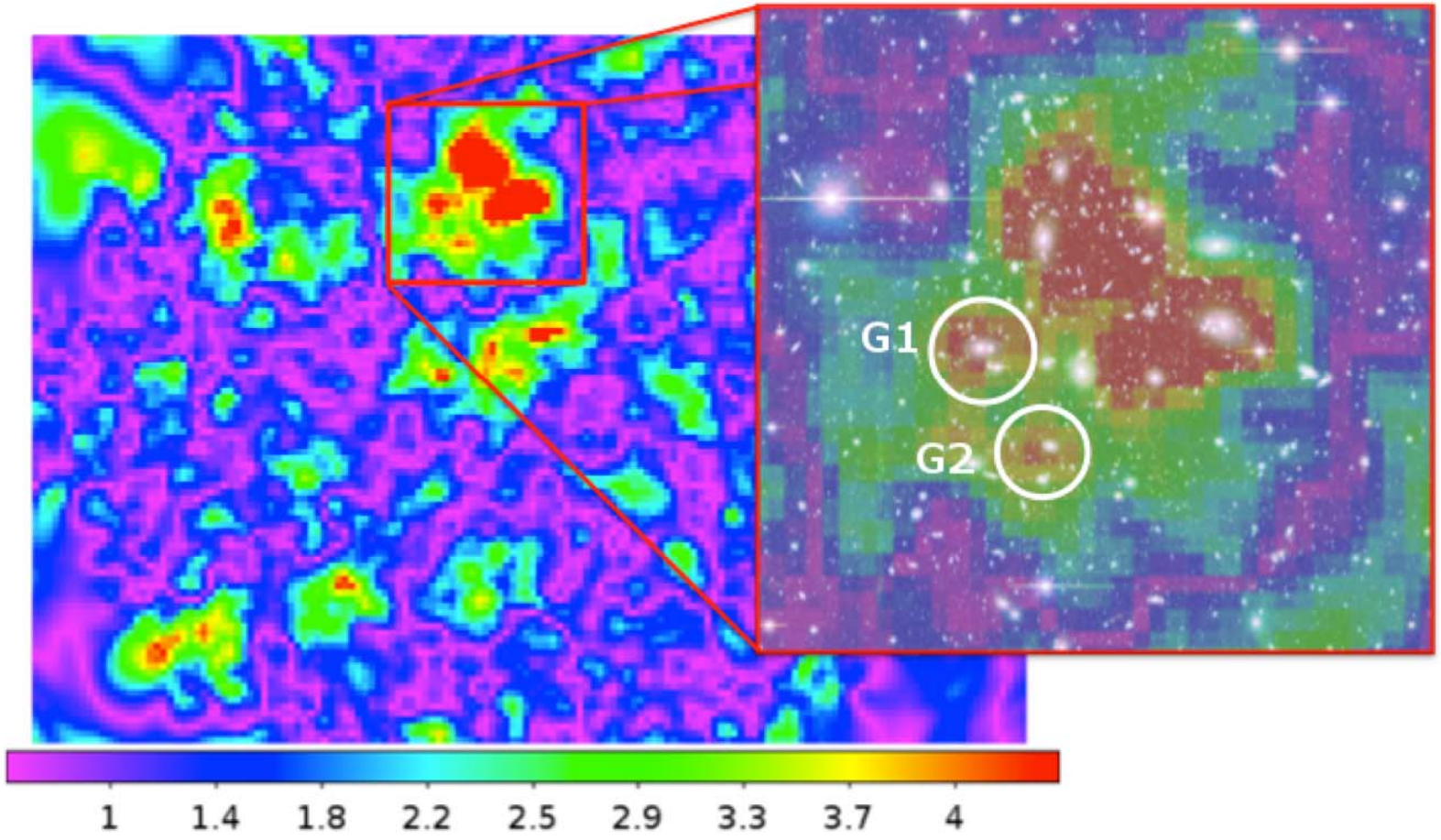



Imagine this at 5x resolution!

Mass substructure

DM substructure probes clustering evolution– increasing source density increases resolution as $N^{1/2}$. Can (and Mass sensitivity as N). IRIS will beat ACS by a factor of 2-3 in mass sensitivity with WL, and a similar factor for SL.

McCleary et al 2015



Exotics…

Lensed Supernovae, QSOs (GRBs?)

LSST (and Euclid, WFIRST) will find them.

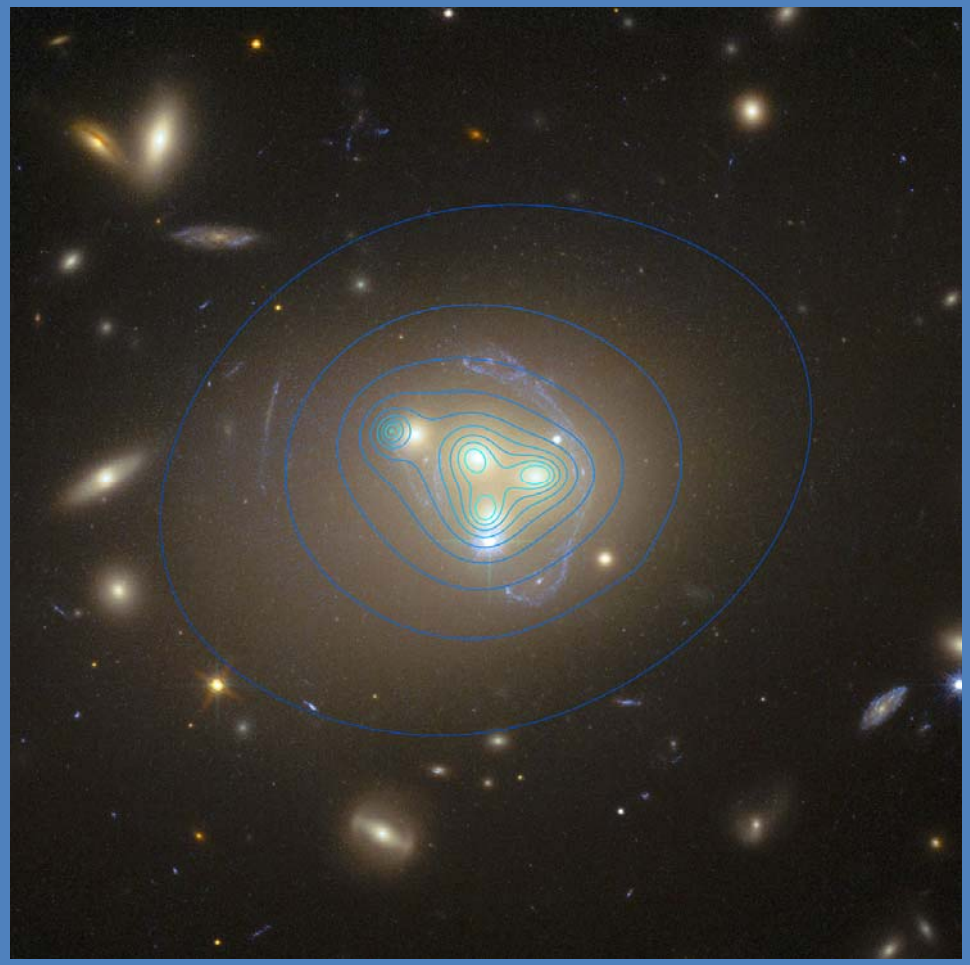
TMT will extract cosmology from them…

DM interaction cross section?

Sensitivity depends on DM positional accuracy.

This again depends on Narcs and Ngalaxies.

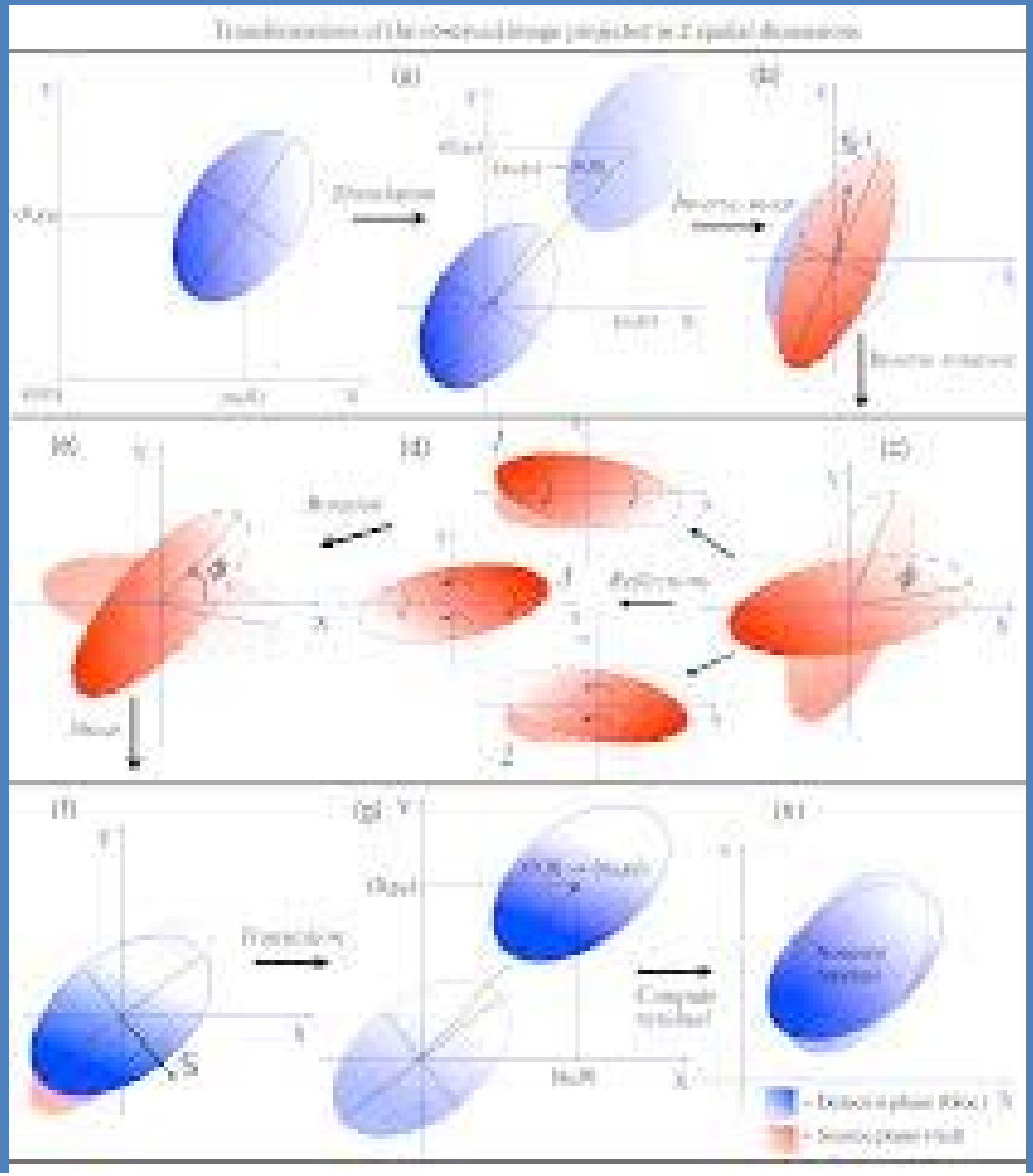
Contribution to DM physics?



Massey et al. 2016

Rotation vs. Shear—WL revisited!

De Burgh-Day et al. 2016
Blain 2002, Morales 2006



Shape Noise 0.01-0.02 vs. 0.35 -- Need 1000x fewer sources for the same S/N

Will require IRMOS