Toward Better Merger Modeling

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MERGING CLUSTER COLLABORATION

NSF

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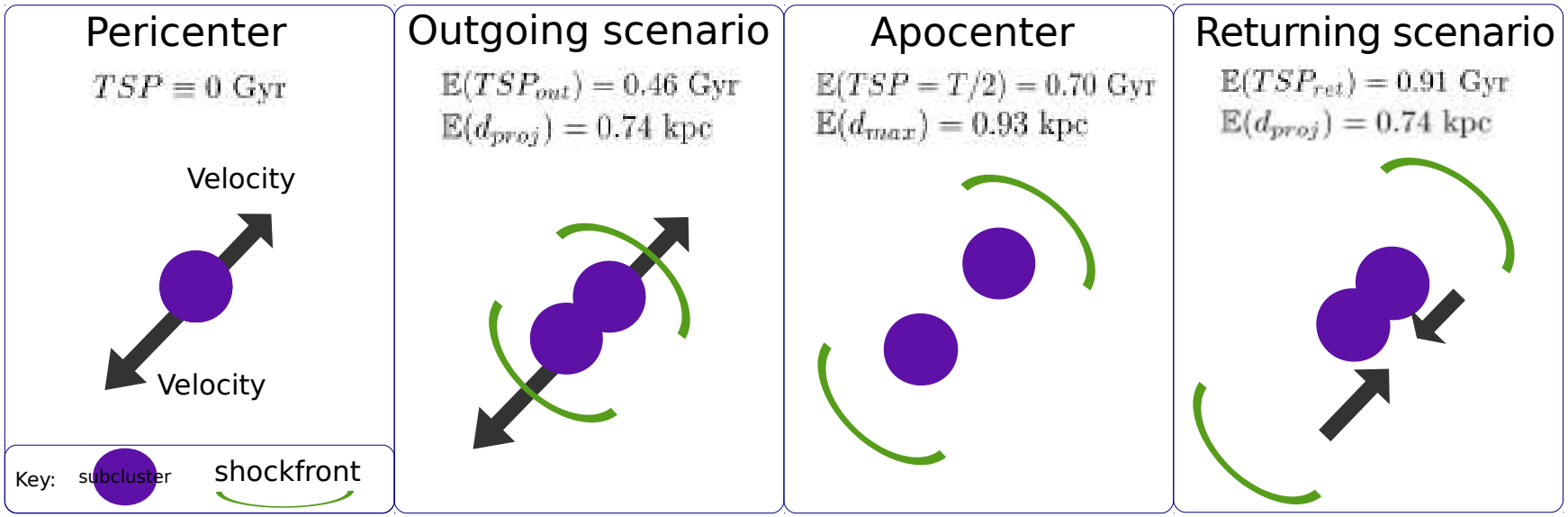
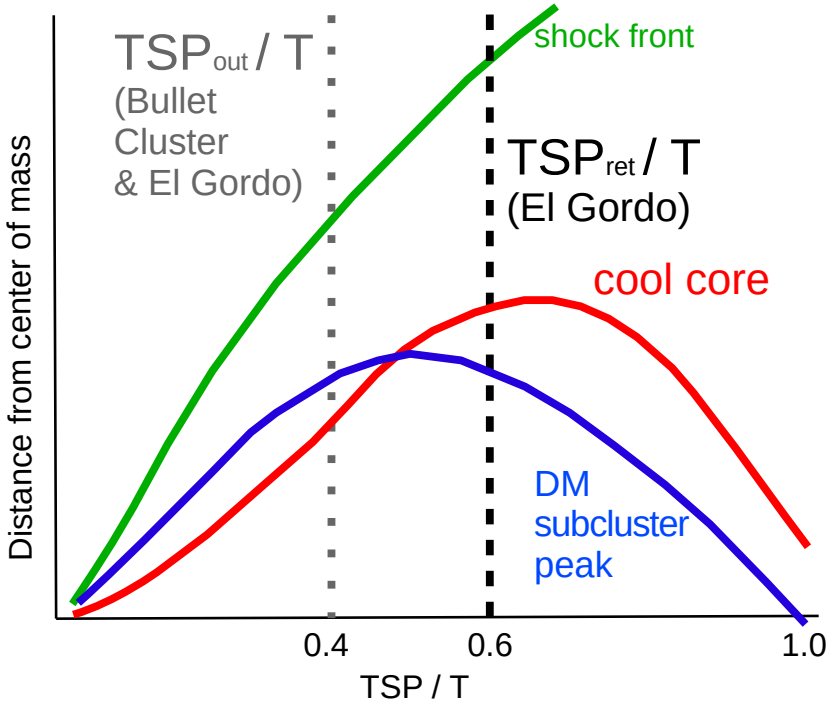
Merger. Phase. Matters.

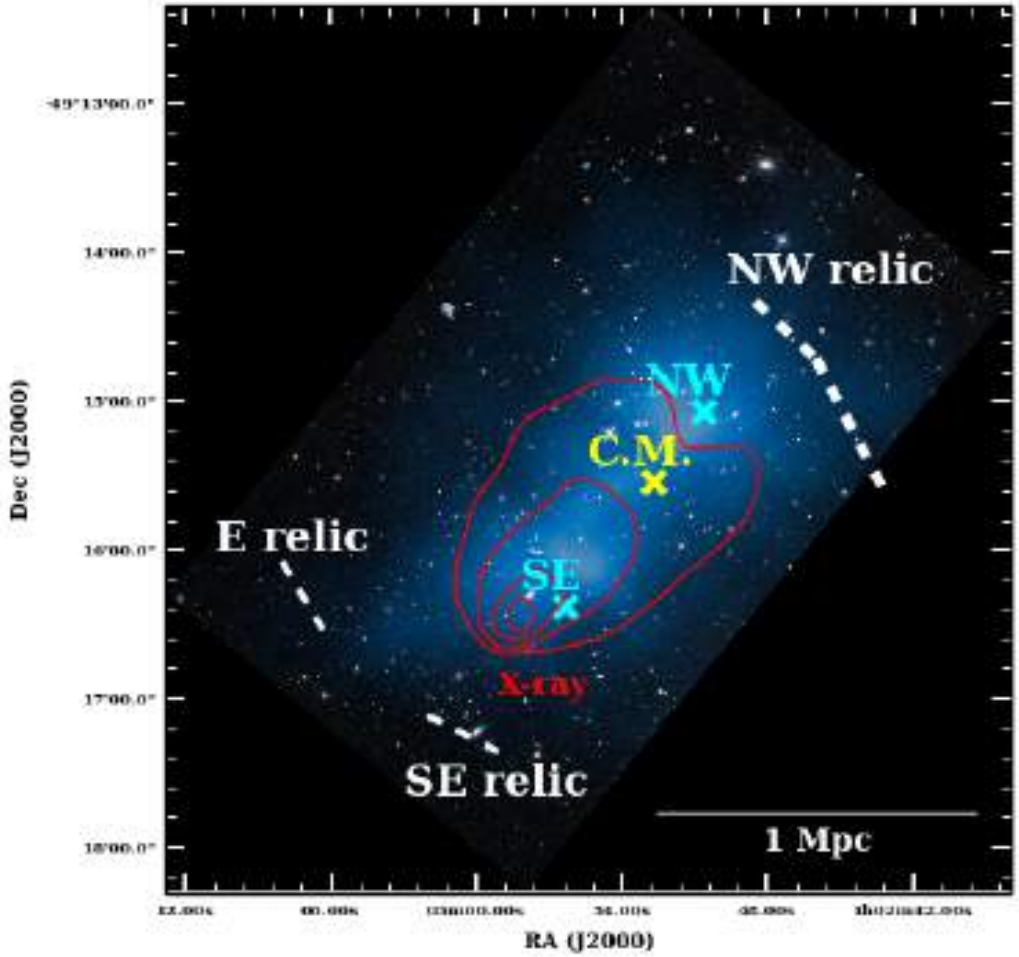


Ng+, 1412.1826

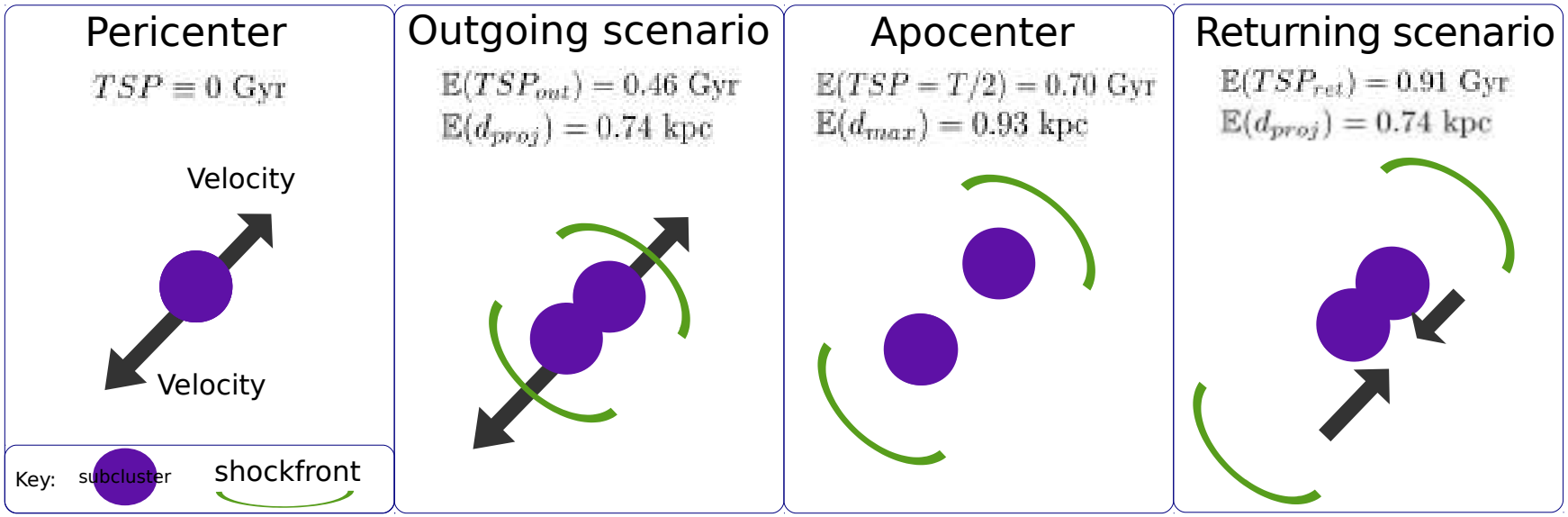
Case in point: El Gordo



Cartoon based on simulations by Mathis+05



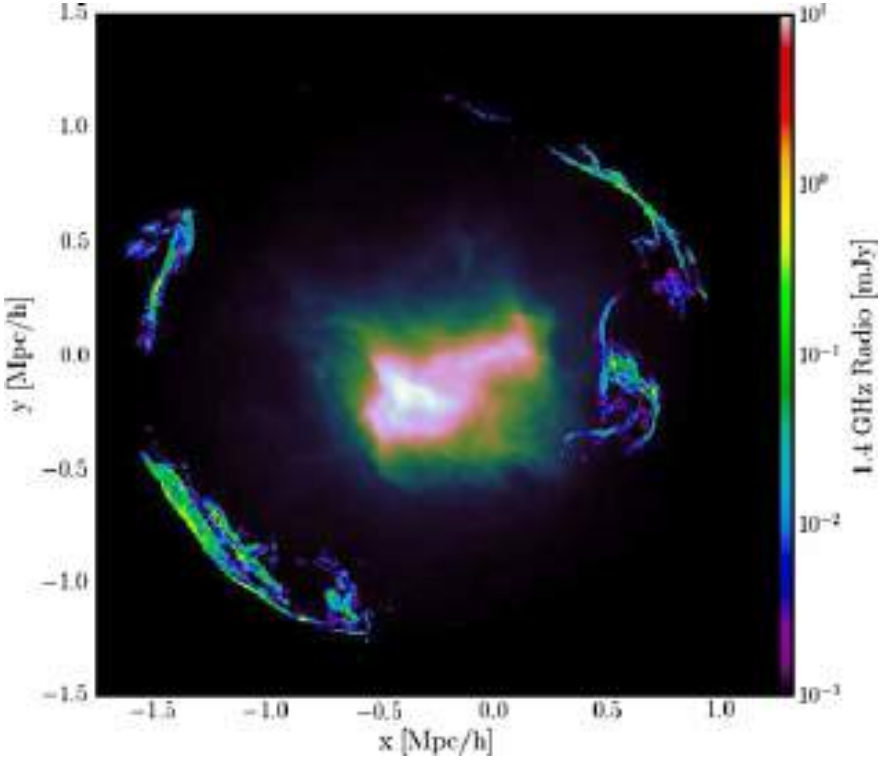
Outbound or returning? Check the shock location.



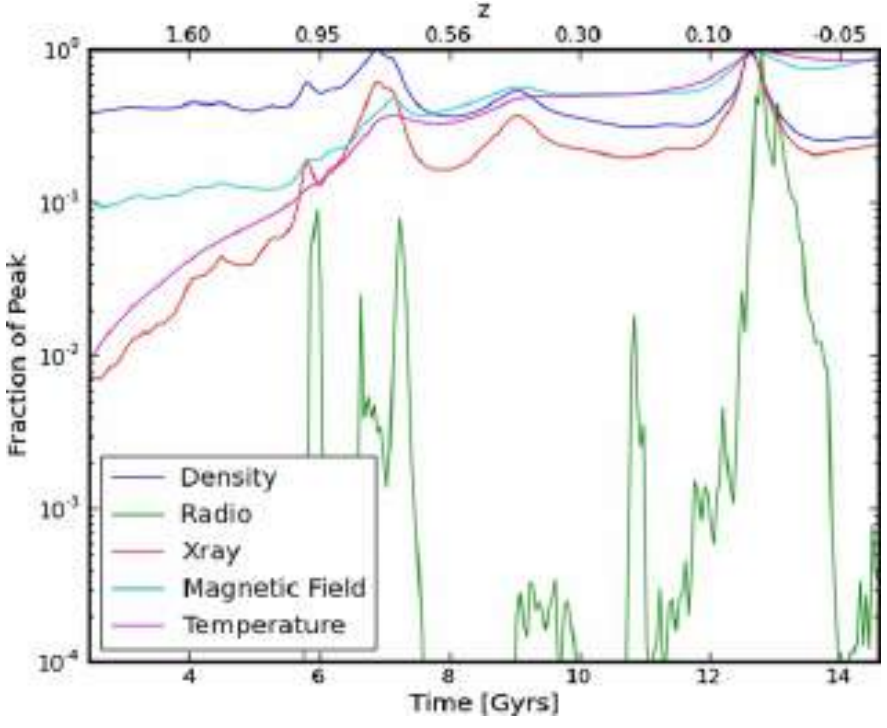
Ng+, 1412.1826

Radio "Relics" Mark the Shock

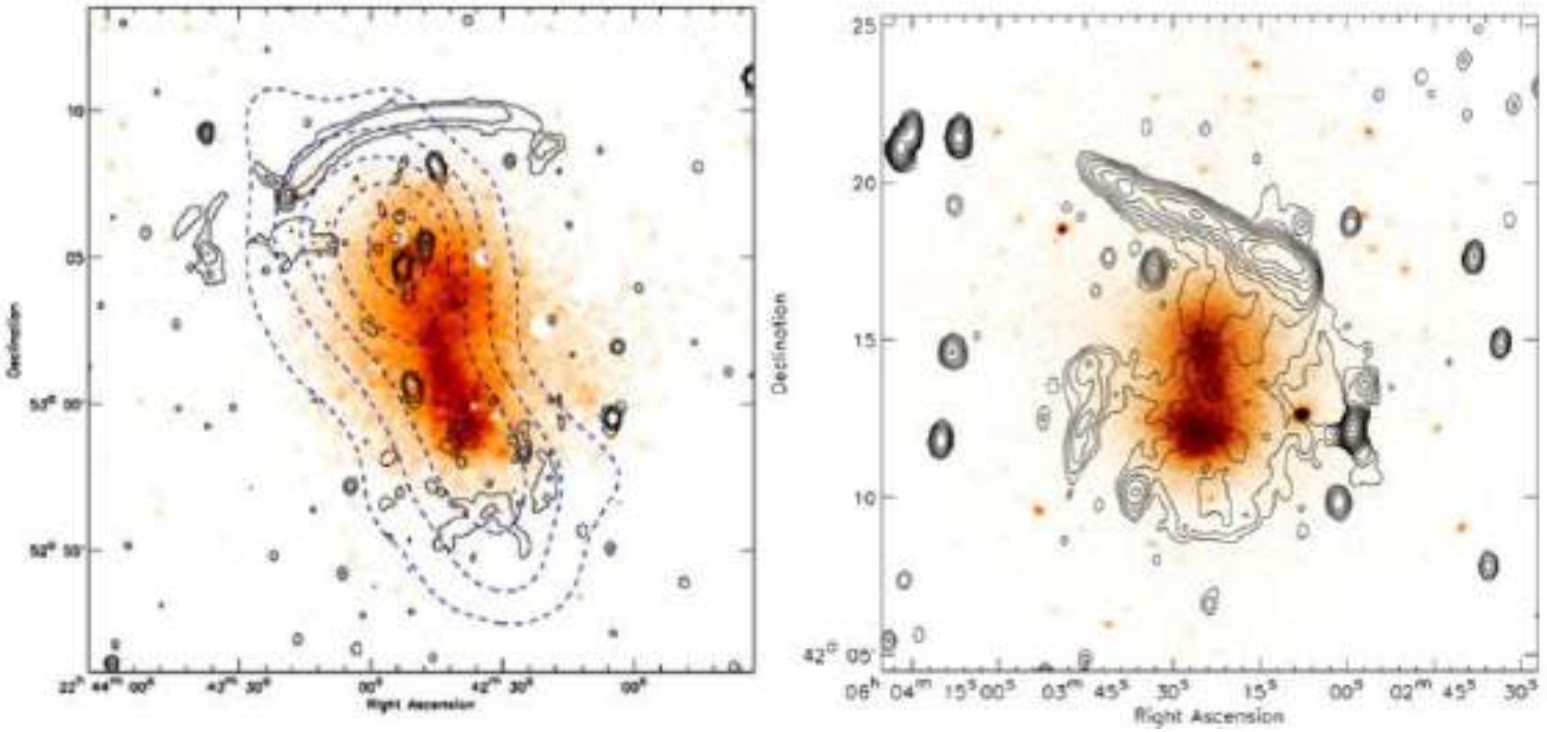
And Constrain the Viewing Geometry



Skillman+2013



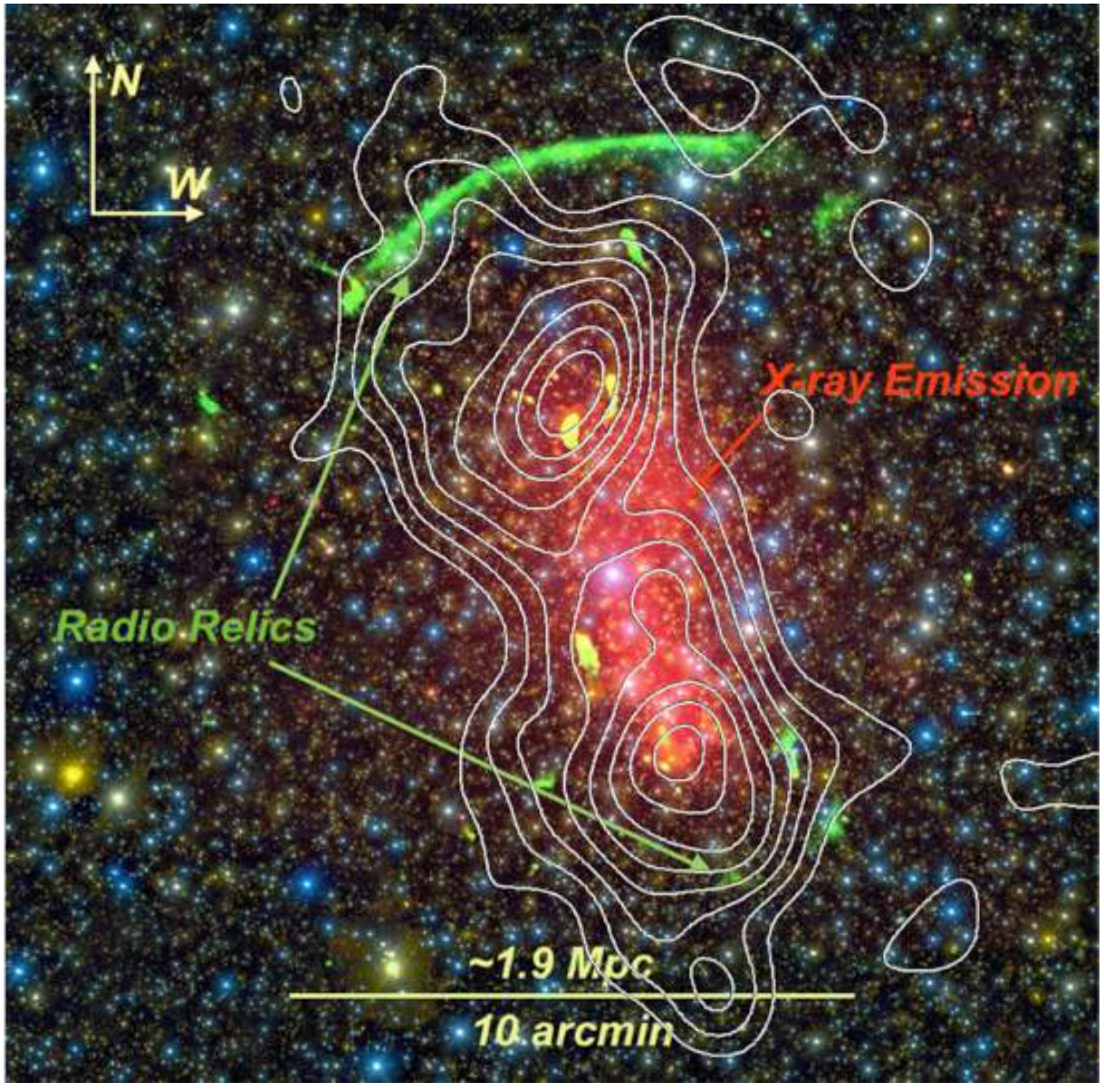
$\sim$ 50 Relic Systems Already Known



van Weeren+11

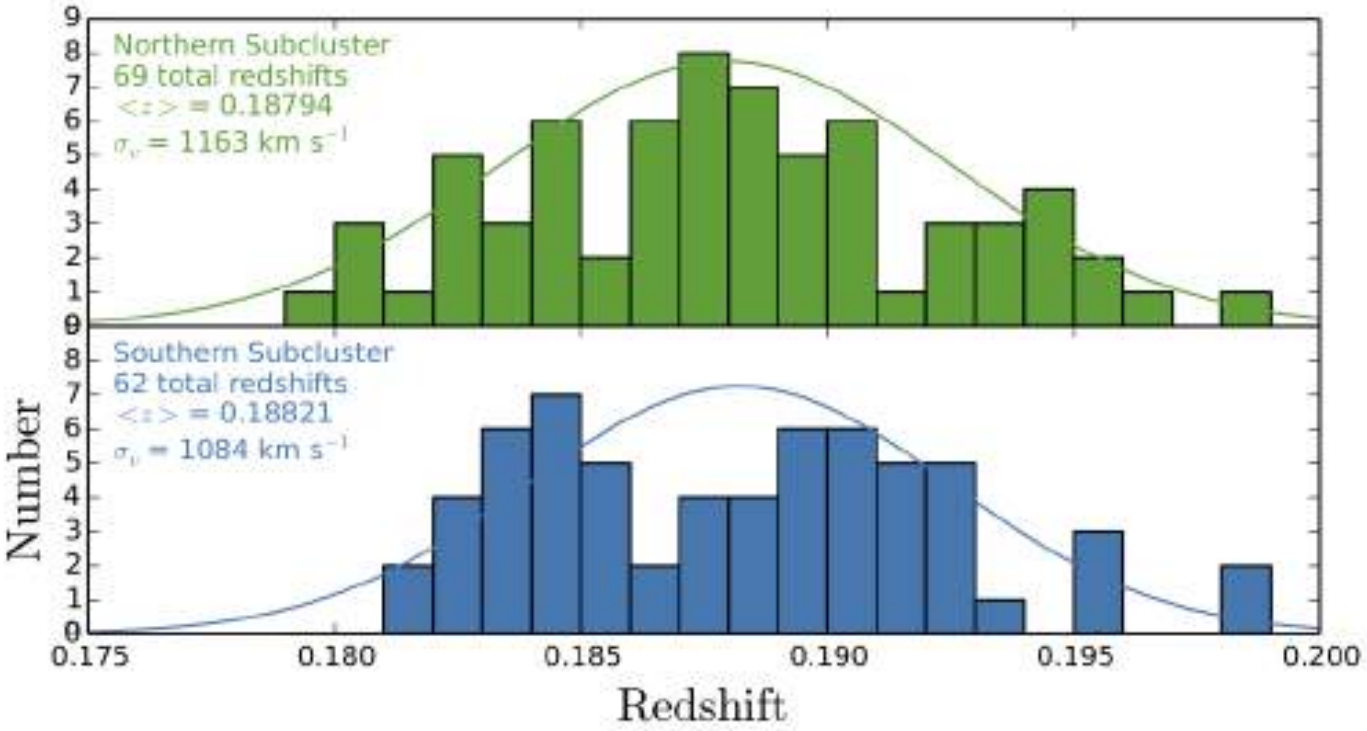
Our task: spectroscopic and weak-lensing surveys to constrain merger dynamics and galaxy-DM offsets; better polarization measurements to constrain viewing angle.

"Sausage" Cluster: **CIZA** J2242.8+5301 ($z = 0.19$)



Jee+, 1410.2898:
Image: Subaru
GMRT 610 Mhz
(van Weeren+ 2010)
Chandra
red sequence galaxies

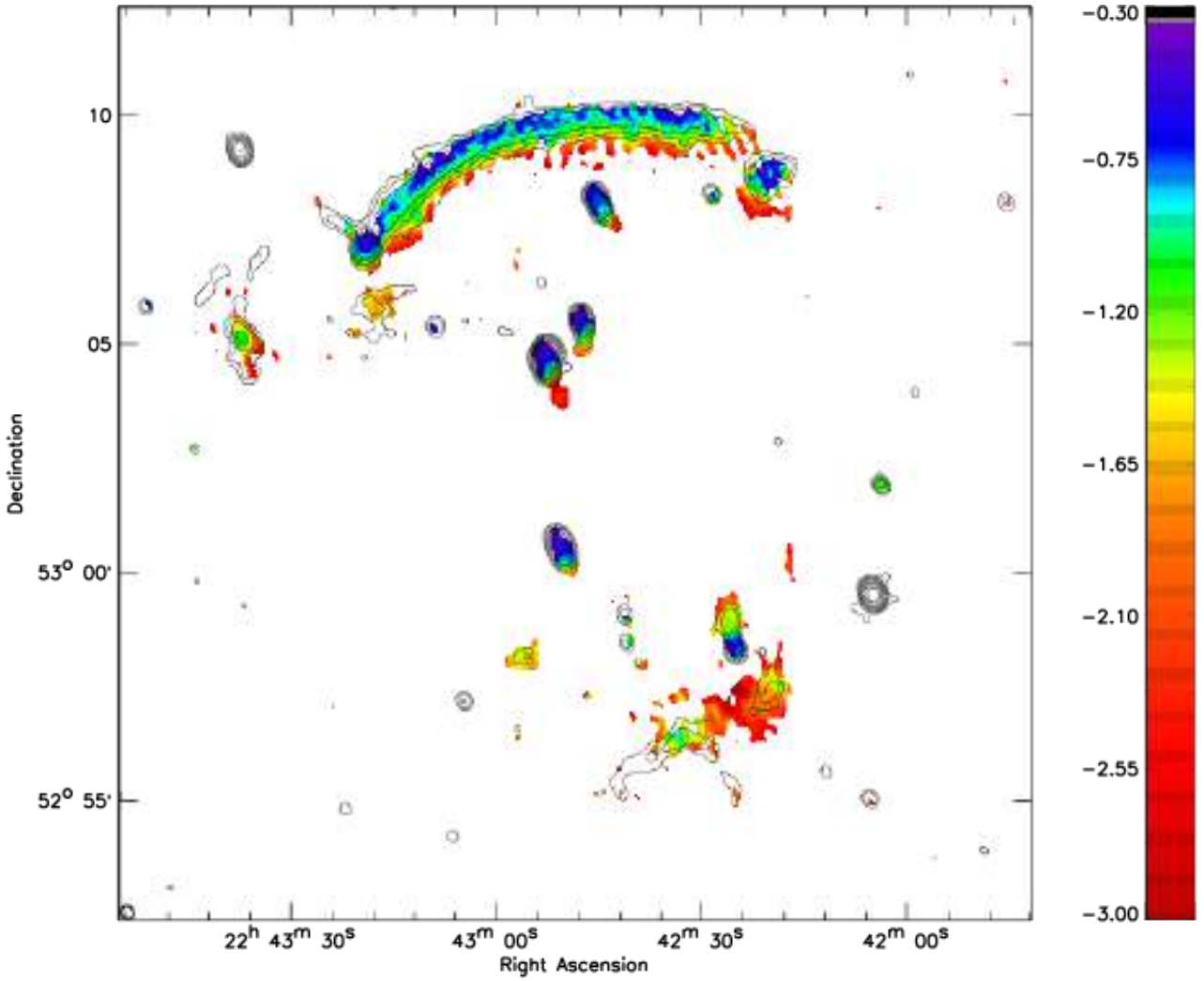
Sausage: Keck/DEIMOS Spectroscopy



Dawson et al, arXiv:1410.2893: $v_{los} = 69 \pm 190$ km/s!

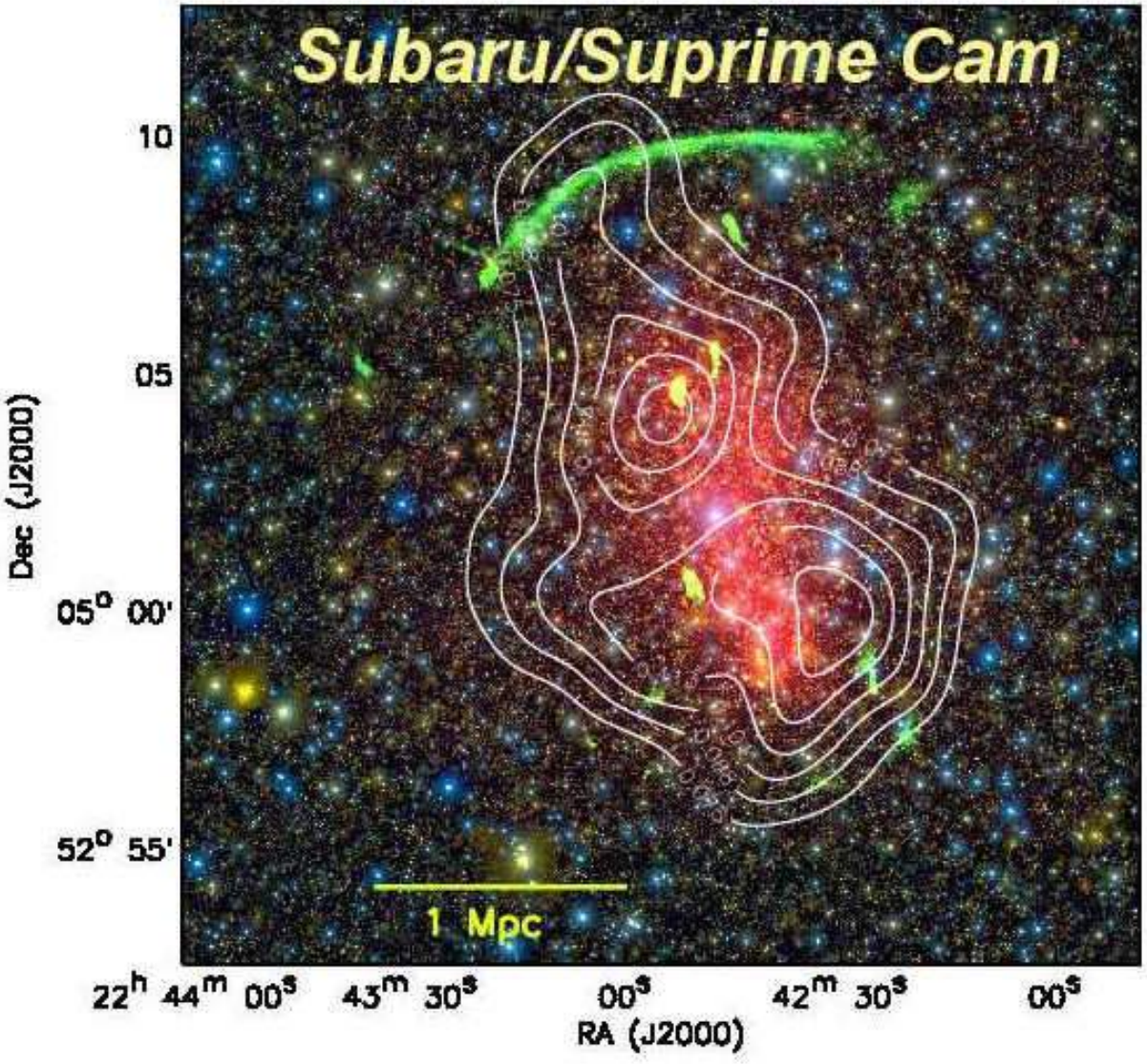
Sausage: galaxies outbound

relative to surrounding gas



Stroe+2013 radio spectral index map

Sausage: Weak Lensing Morphology and Masses

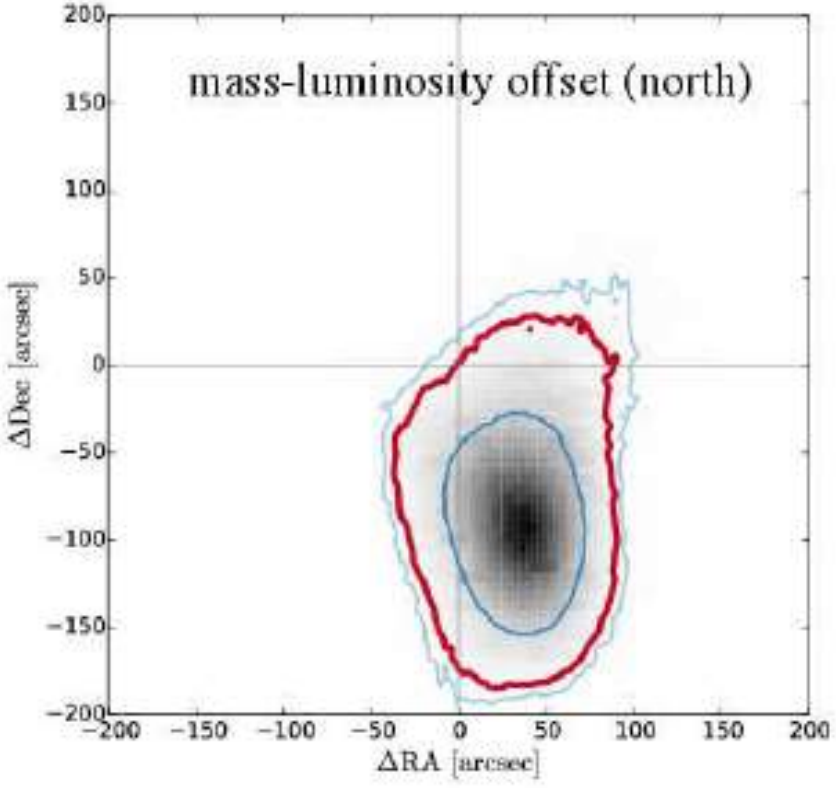


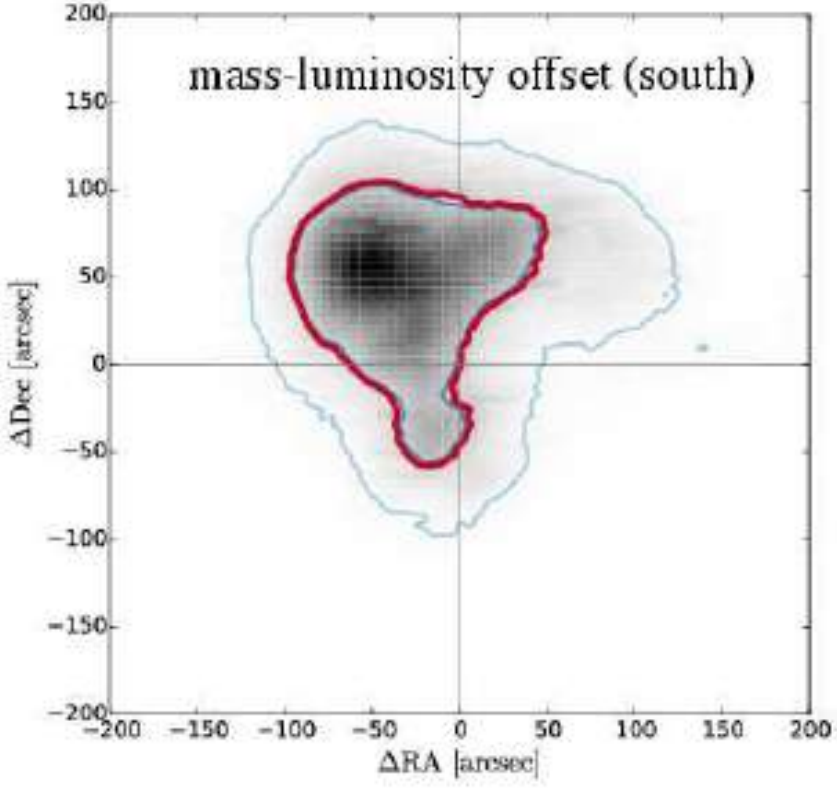
Jee et al, arXiv:1410.2898:

South: $1 \pm 0.2 \times 10^{15} M_{\odot}$

North: $1.1 \pm 0.2 \times 10^{15} M_{\odot}$

Sausage: Lensing vs Galaxy Centers

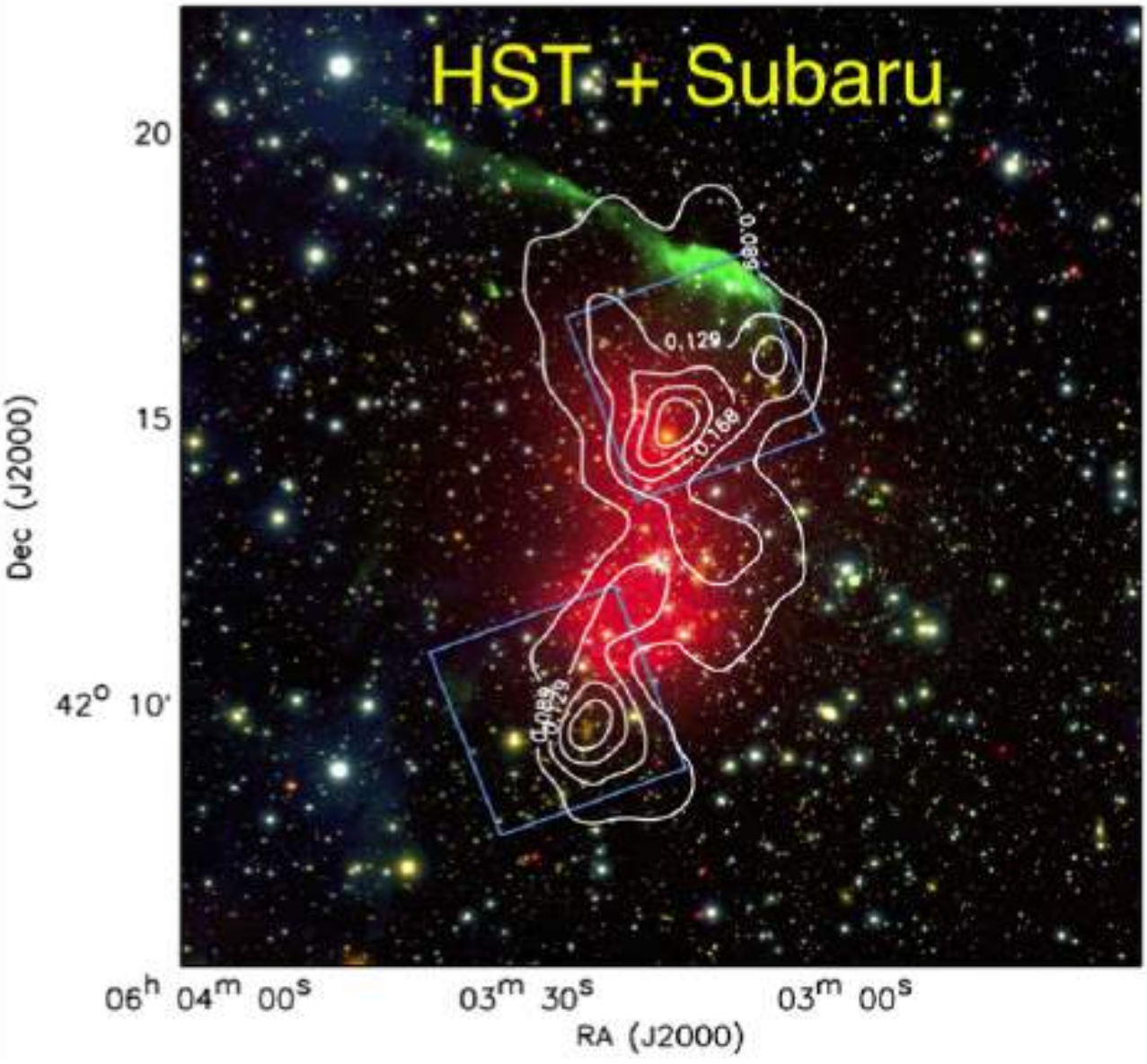




Jee et al, arXiv:1410.2898

HST lensing data in hand to refine the mass location

We Also Find "Train Wrecks"



Jee+,arXiv:1510.03486

Radio (van Weeren)

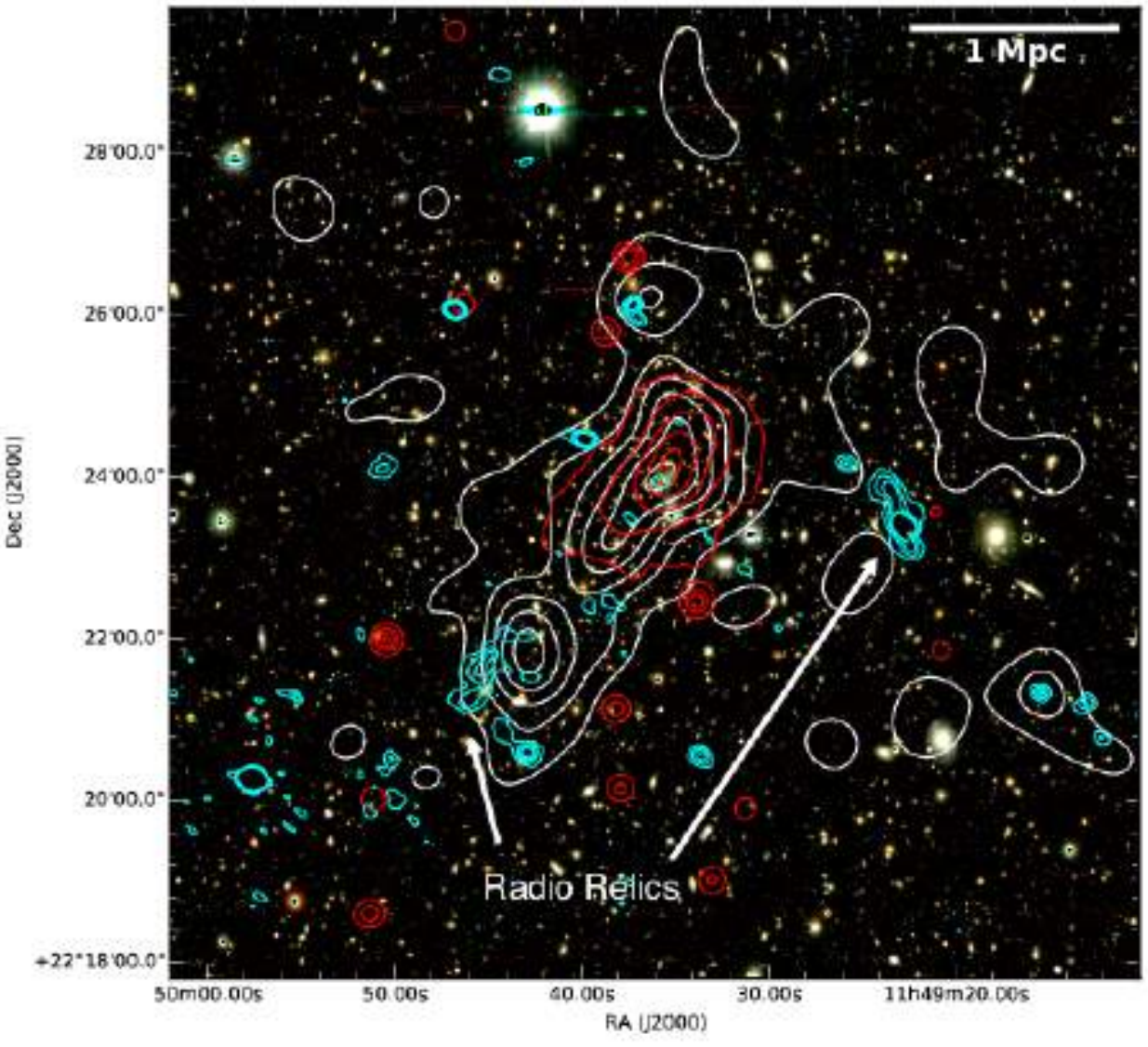
Chandra (van Weeren)

weak lensing

North: $6 \pm 2 \times 10^{14} M_{\odot}$

South: $2 \pm 1 \times 10^{14} M_{\odot}$

And new things about old friends

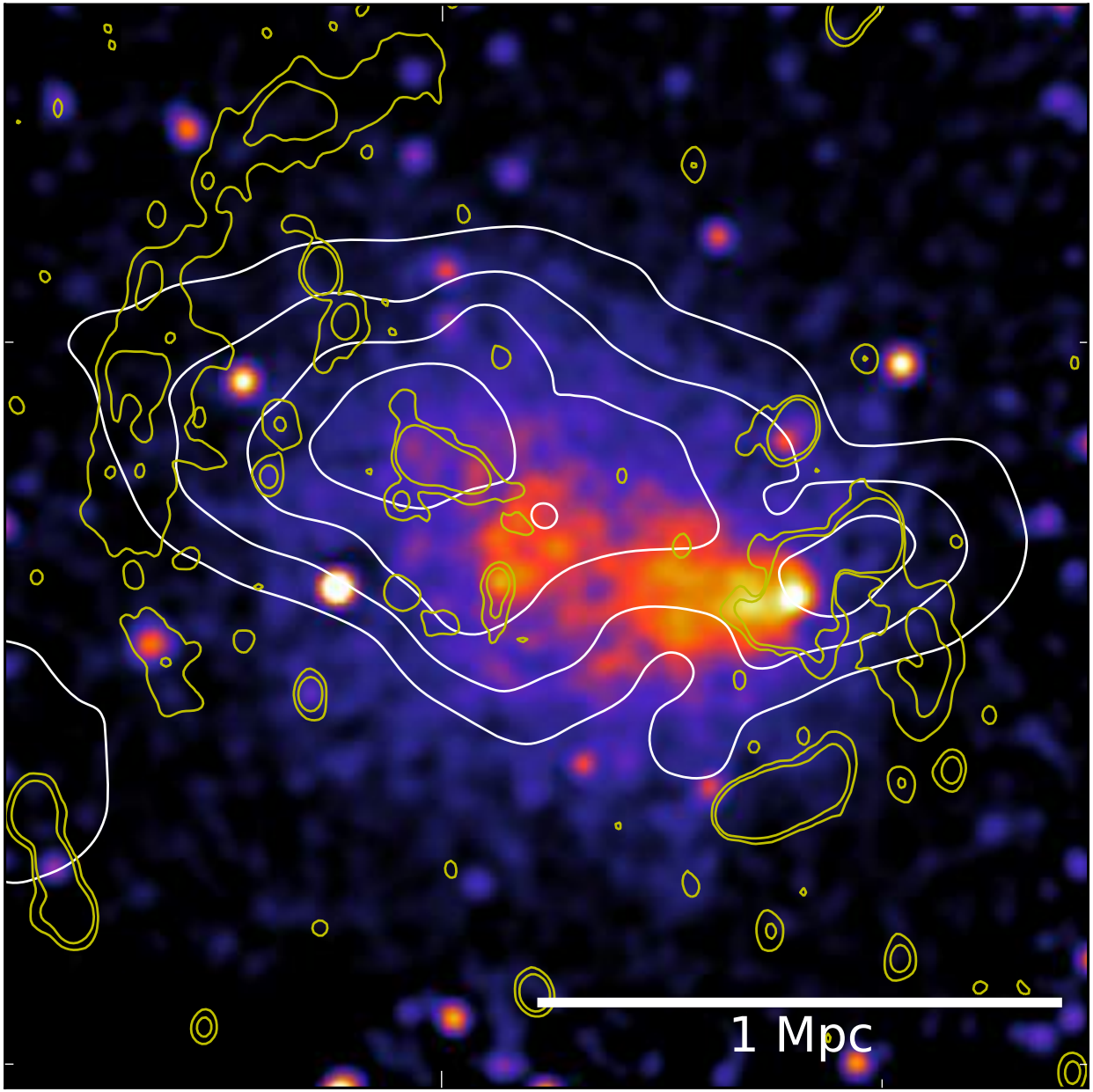


Golovich+,1608.01329:

- MACS1149 is a massive bimodal merger
- previously unknown 10^{15} $M_\odot$ subcluster in south explains relic
- $\Delta v_{los} = 302 \pm 220$ km/s

Chandra (Ogrean+16)
galaxy luminosity

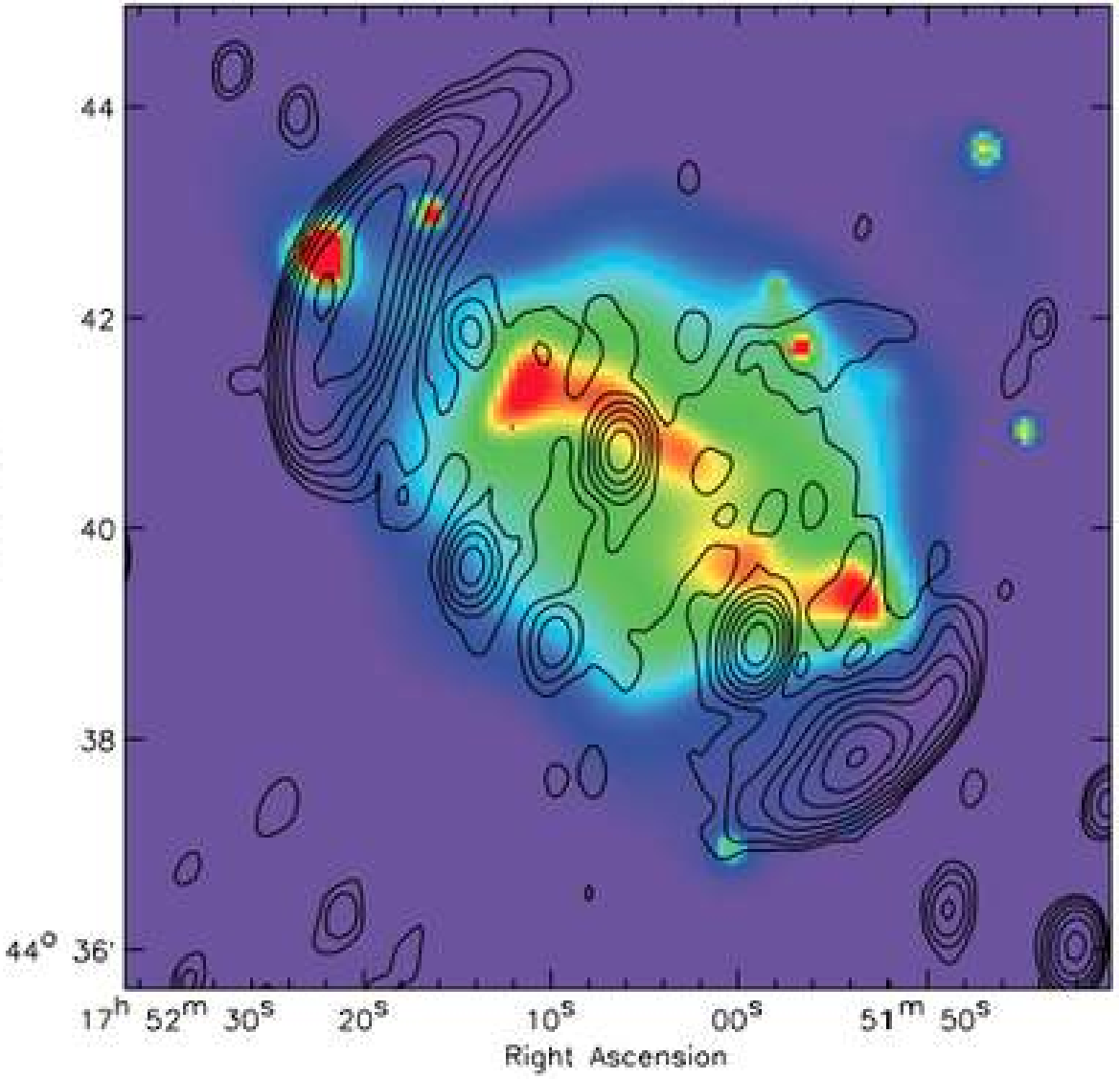
ZwCl 0008+5215: A Lower-Mass Bullet



Golovich+, 1703.04803:

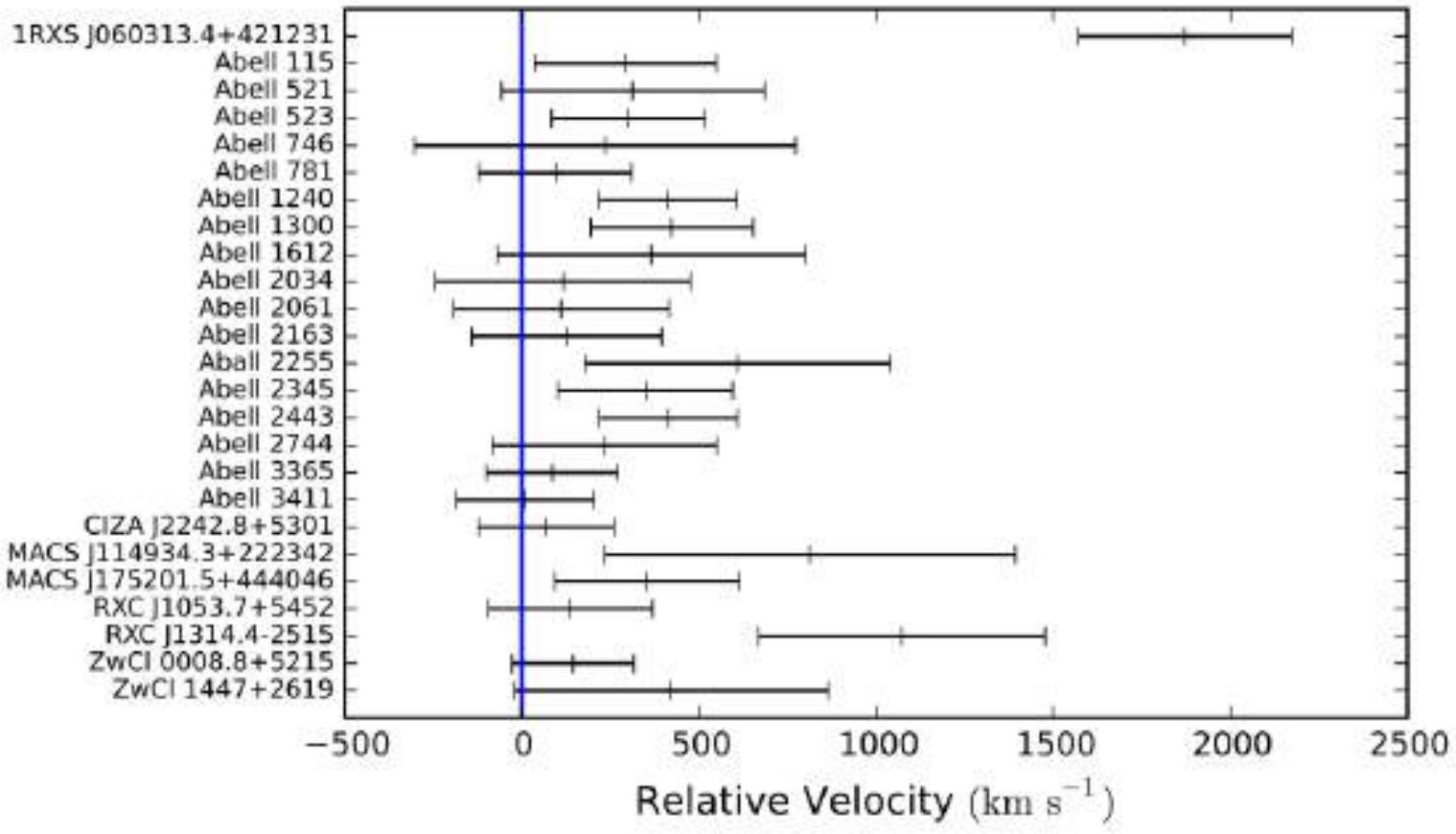
X-ray
WSRT 1.4 GHz
mass (lensing)

MACS J1752+4440: Two Bullets That Missed?



XMM
WSRT 21cm
(Bonafede+12)

Relic Sample Results: Radio Selection Works!

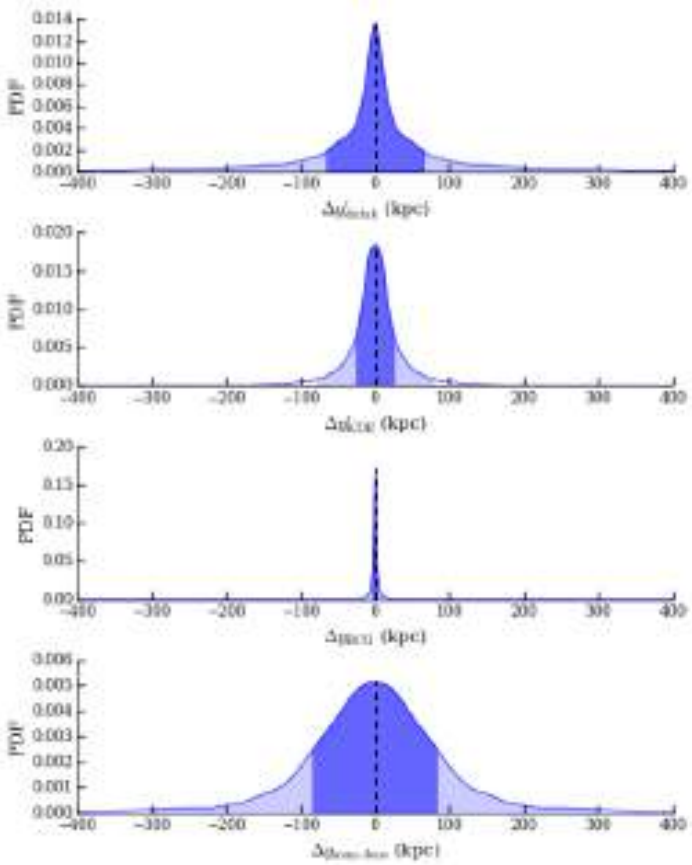


Low v_{los}: merger in plane of sky and/or near turnaround.
Lensing: systems often quite massive ($\sim 10^{15}$ M$_\odot$)

Next Steps

- select “gold sample” from full relic sample
- get better lensing data to refine mass model
- combine with (younger) X-ray selected systems to span full merger timeline

Baseline level of offsets with CDM



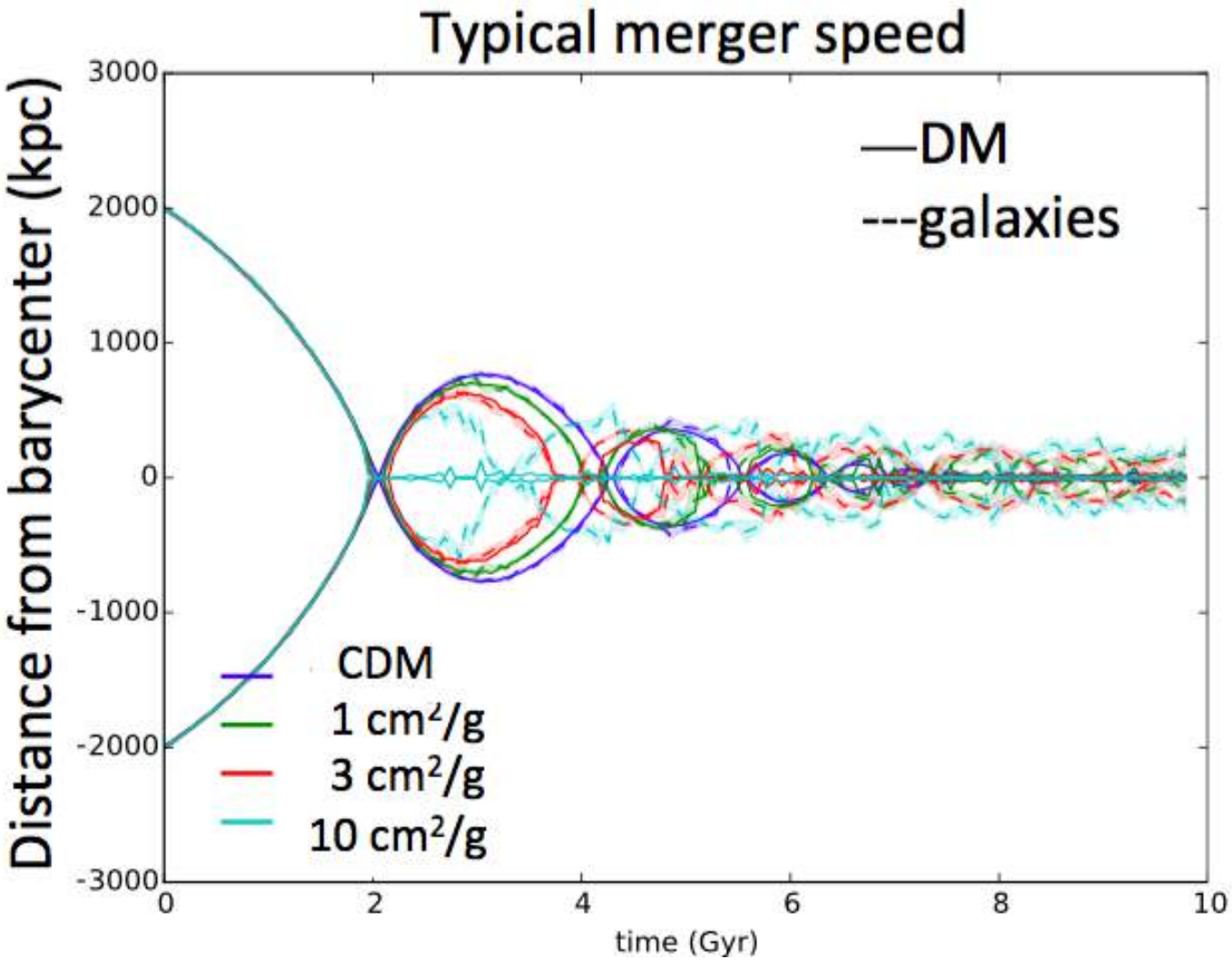
- The BCG has the smallest one-sigma offset level to the dominant DM peak (68-th percentile of $\Delta y_{\rm BCG} \approx 3$ kpc for $1.2 < \nu < 2.2$).

- The identified BCG offsets have a 5% tail at $\Delta y_{\rm BCG} > 160$ kpc for $1.2 < \nu < 2.2$. This heavy tail is due to a combination of effects from substructures and projection and is not seen in the relaxed sample with $\nu < 1.2$.

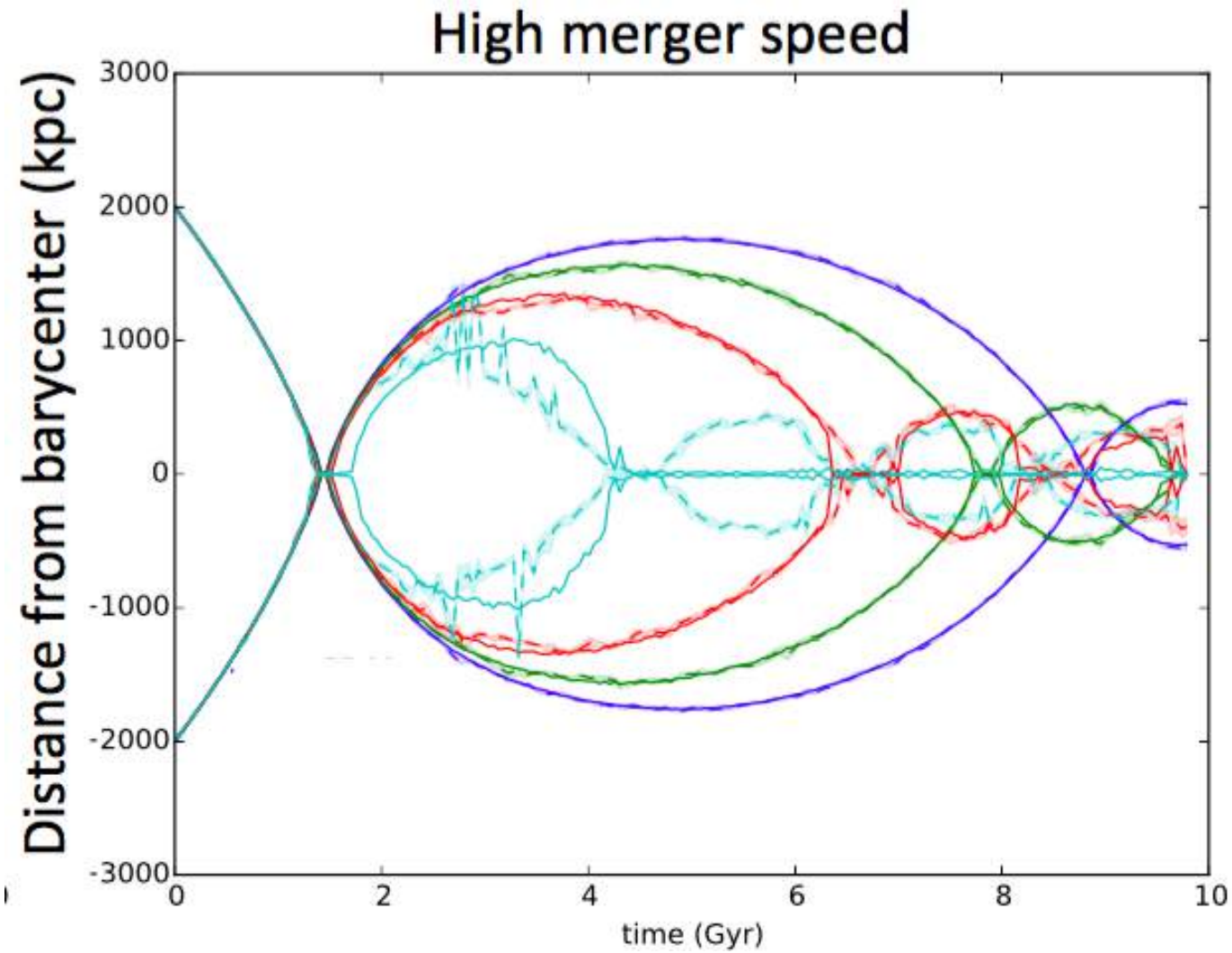
Ng+, 1703.00010

Equal-mass merger sims: Kim+, 1608.08630

Simulations can suggest new observational signatures



Dynamical modeling is important!



Summary

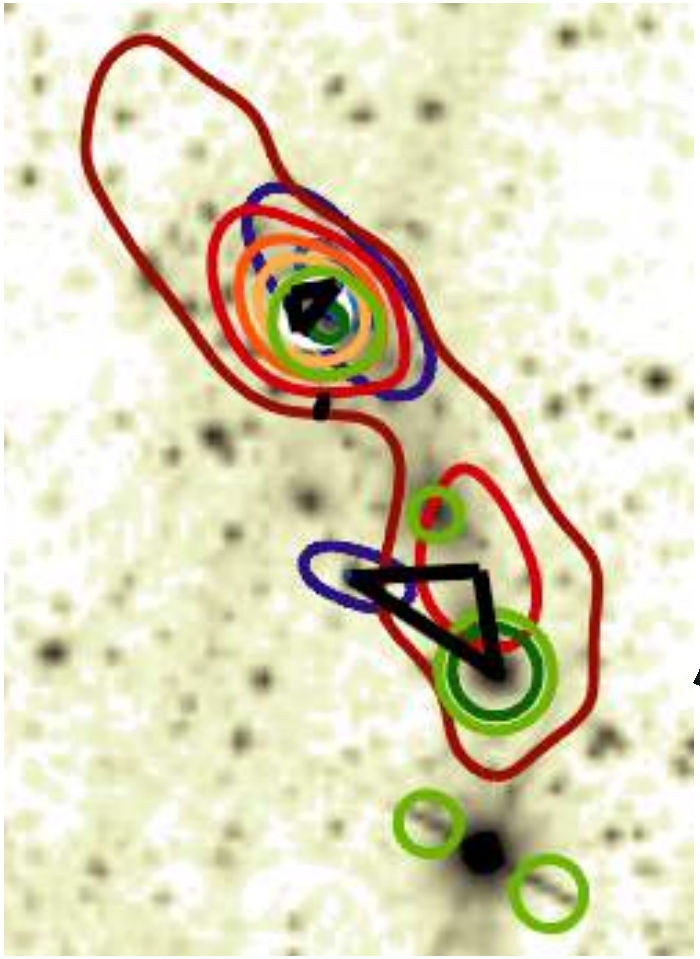
- **merger phase matters**: components change relative position over time
- radio selection has given us many more massive, transverse mergers (but alone is not sufficient)
- this could be a strength in terms of drawing DM inferences from an ensemble—but can be a weakness if not done right
- modeling each system takes time and many types of observations (lensing, spectroscopy, radio polarization...)
- more simulations needed to properly interpret data
- simulations may also reveal new signatures
- **cluster mergers can play a key role—but we're in the early days of a difficult task**

Discussion question(s)

Is it better to study a few golden systems in detail, or make an ensemble as large as possible (implying less data/modeling per cluster)?

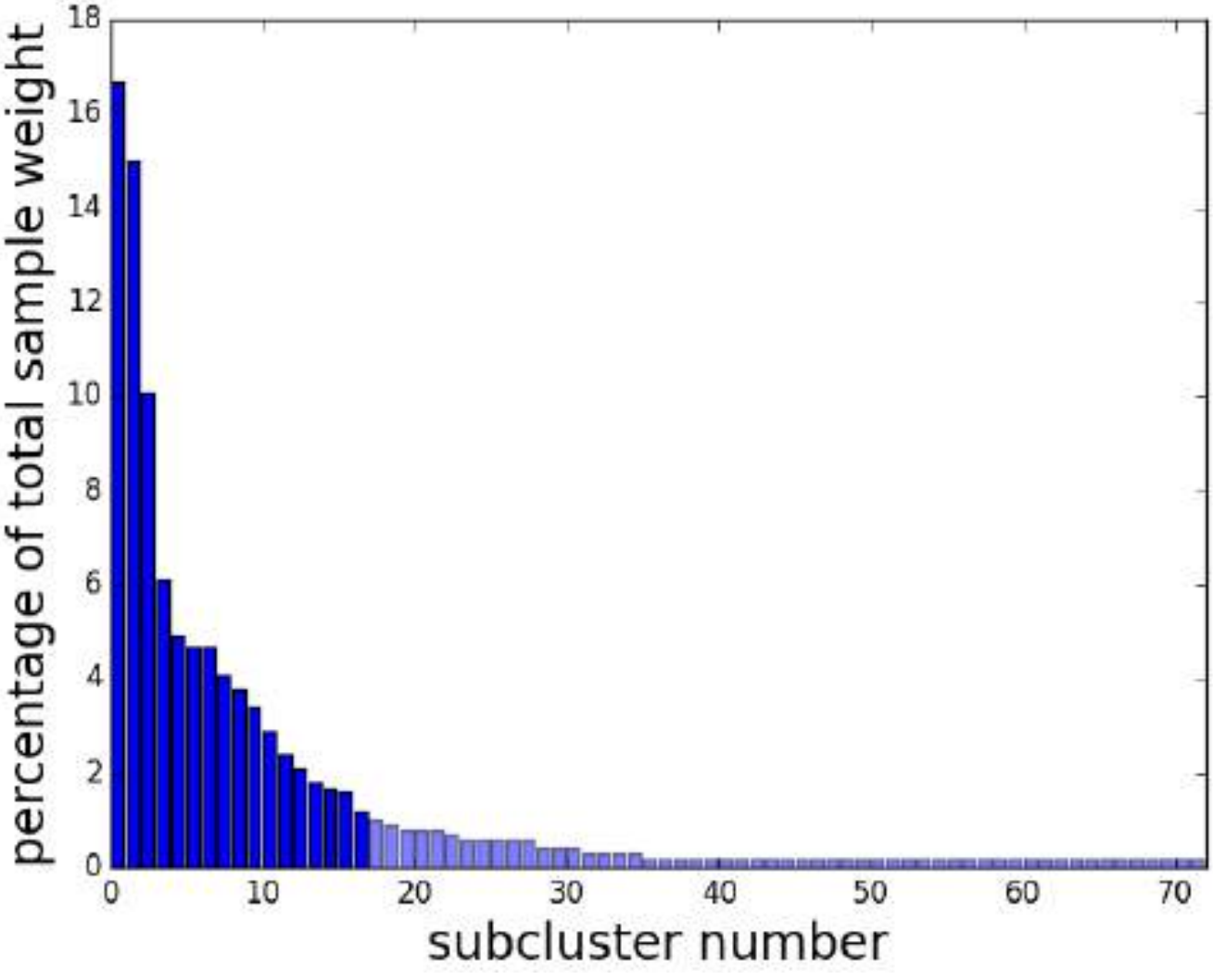
Can the SIDM community come up with a compelling 500-orbit plan to pitch to the committee on Fundamental Physics with HST?

Extra slides: why single-band data are insufficient



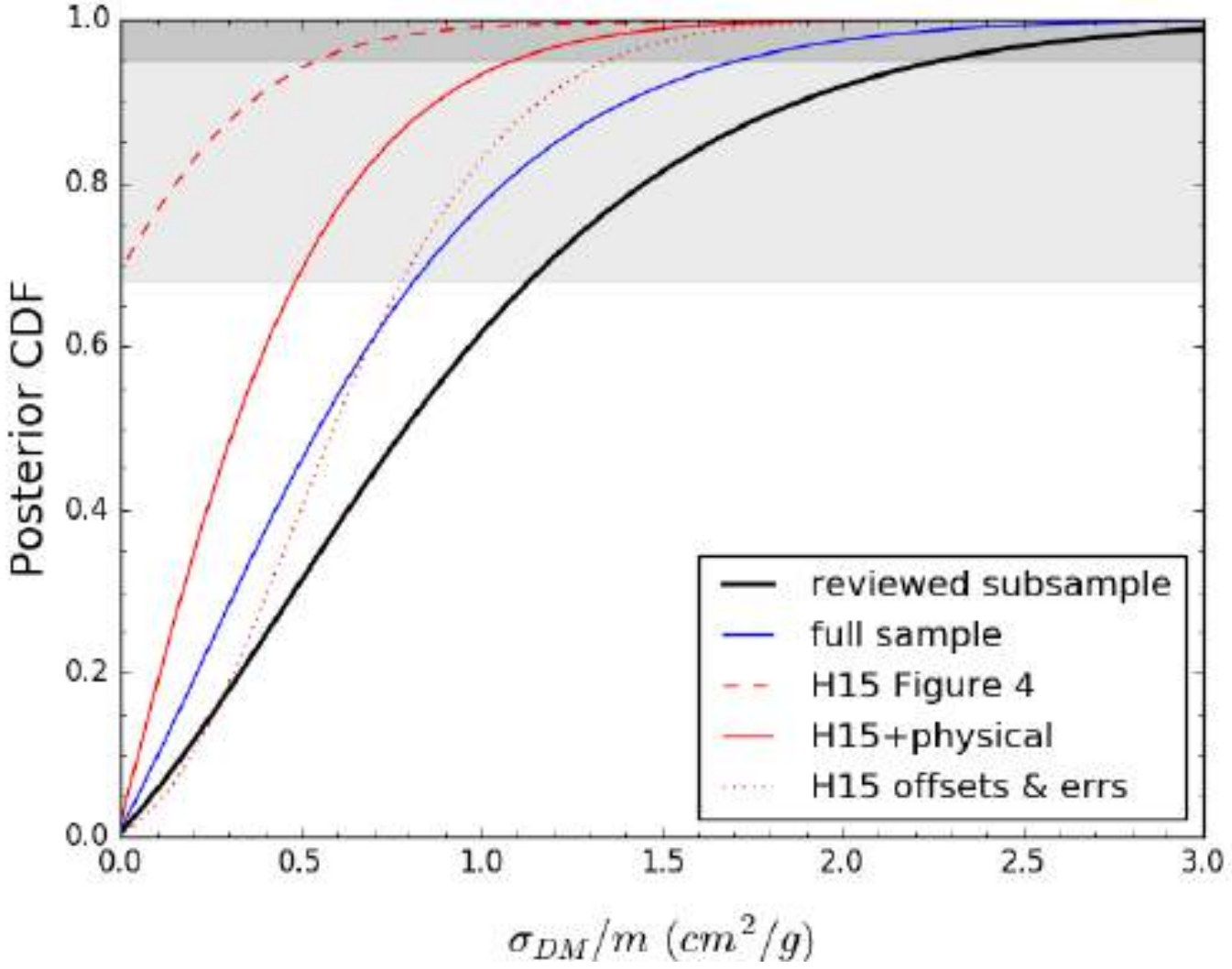
Harvey+15

Reanalysis of Harvey+15 Ensemble



Wittman+, 1701.05877

Reanalysis of Harvey+15 Ensemble



Wittman+, 1701.05877