Weighing the Giants : X-ray and Weak Lensing Studies of the most Massive Clusters

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KIPAC / Stanford

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Motivation

or: why is lensing so important for X-rays?

- X-ray hydrostatic mass measurements may be biased:
  - non-thermal pressure support
  - $\sim 20\%$ for typical clusters
  - $\sim 5\%$ for relaxed clusters

Nagai et al. 2007

$\longrightarrow$ source of systematic uncertainty in cluster cosmology projects

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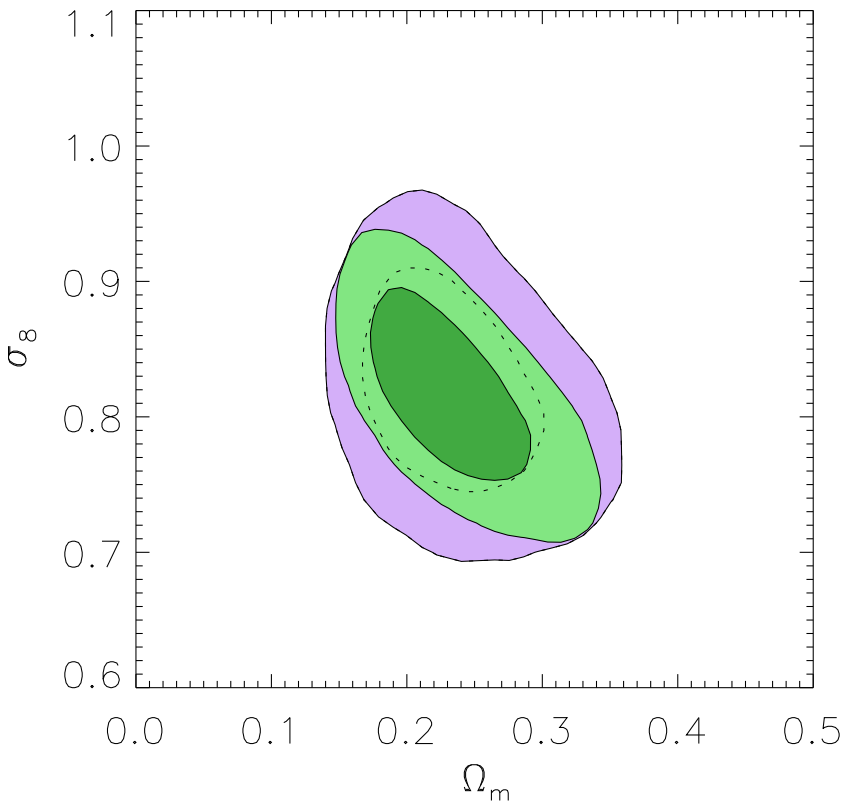
- mass estimates from gravitational lensing:
  - $+$ on average unbiased
  - $-$ but individual masses noisy

$\longrightarrow$ *measure lensing masses of a* **large** *sample of clusters*

$\longrightarrow$ significantly reduce uncertainties on σ_8

Several other efforts underway:

Mahdavi et al. (2008)
LoCuSS
400d
...



- also: multi-wavelength studies of (merging) clusters

The Team

Optical:

Anja von der Linden (KIPAC)

Doug Applegate (KIPAC)

Pat Kelly (KIPAC)

Mark Allen (KIPAC)

Maruša Bradač (UC Davis)

X-rays:

Steve Allen (KIPAC)

Harald Ebeling (Hawaii)

Glenn Morris (KIPAC)

Evan Million (KIPAC)

Cosmology:

Adam Mantz (KIPAC; Goddard)

David Rapetti (KIPAC)

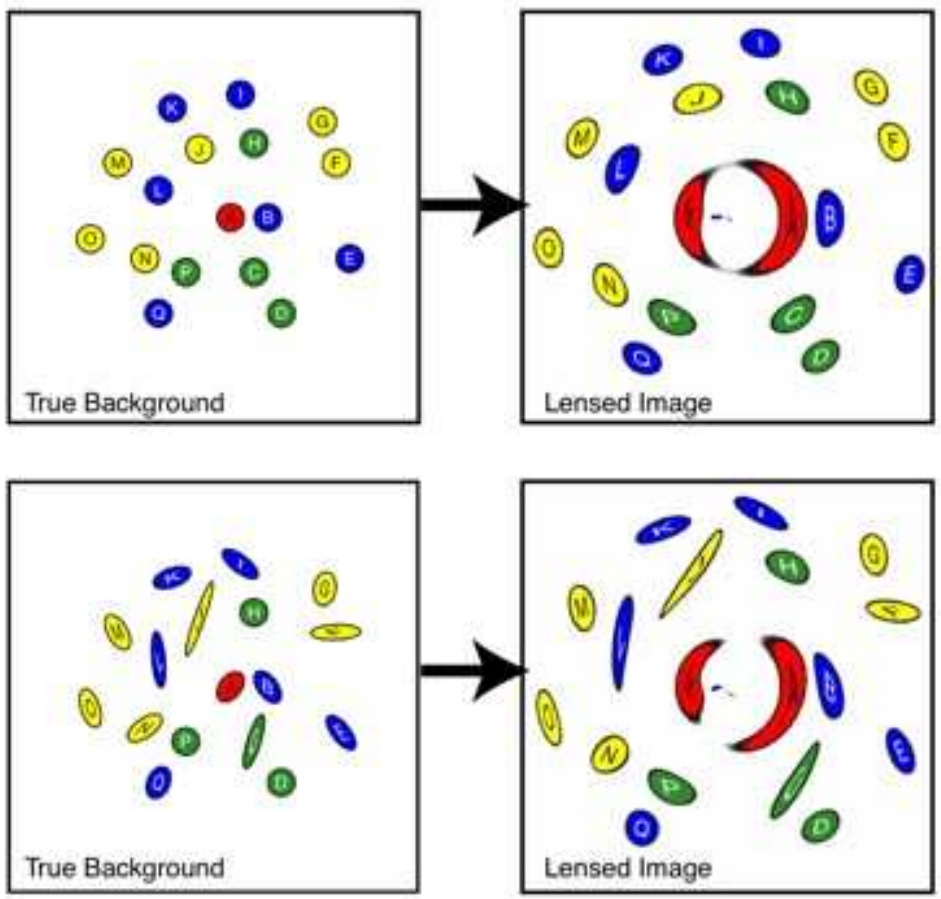
The Sample

- massive, high-redshift, X-ray selected clusters: the MACS sample at $z > 0.3$ (Ebeling et al. 2001,2007)
- $+$ lower redshift clusters

  data:
  - Chandra X-ray imaging ($\sim$ 70 clusters)
  - optical multi-band imaging ($\sim$ 40 clusters)
    - SuprimeCam @ Subaru ($BVRIz$)
    - MegaPrime @ CFHT (u)
  - HST, XMM data for some clusters

The Challenge

- weak lensing - tangential distortion of background galaxies, measured statistically
- need to understand and control systematics to $\lesssim 5\%$



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- shape measurements
  - shear $\propto$ gradient of gravitational potential
  - under-/overestimating shear biases mass
  - learn from cosmic shear: Shear TEsting Program (STEP)

Heymans et al. 2006, Massey et al. 2008

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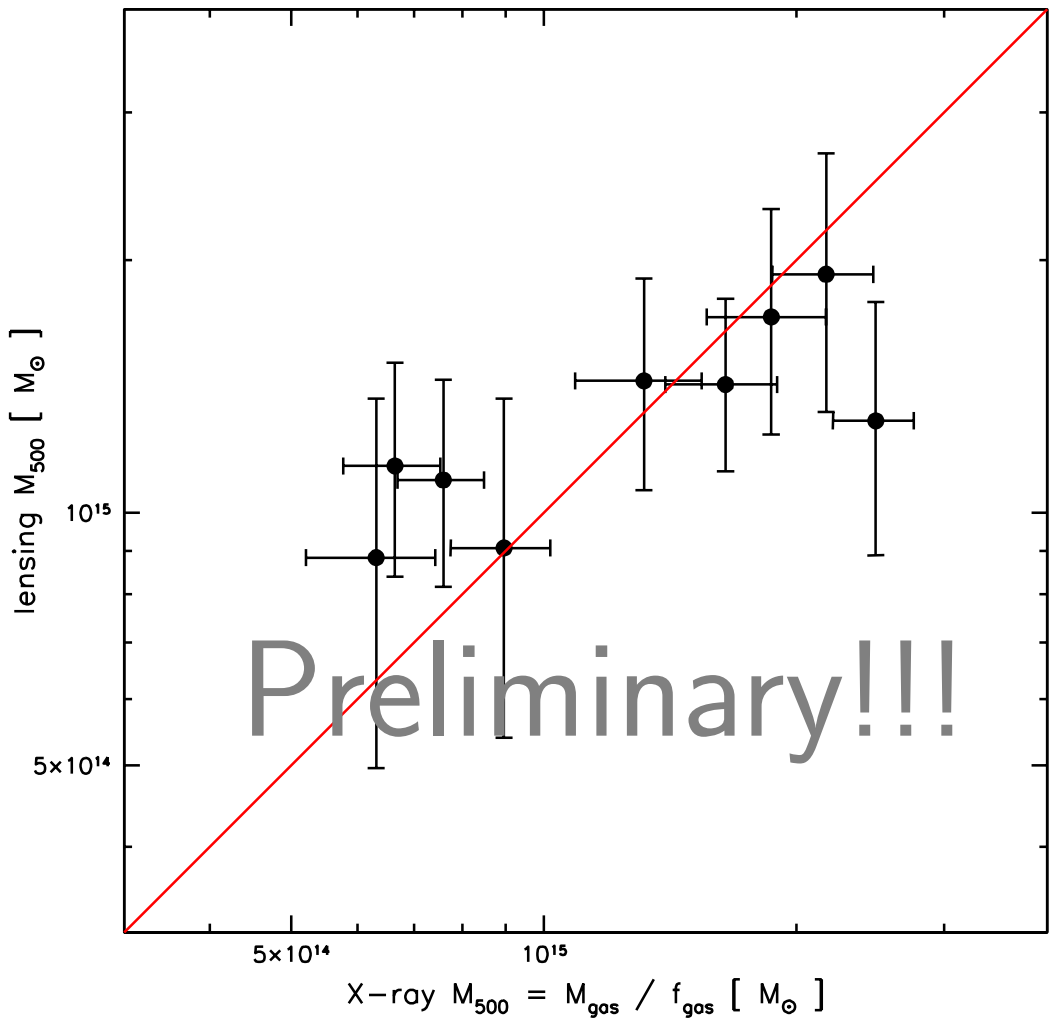
    Heymans et al. 2006, Massey et al. 2008
- photometric redshifts
  - shear signal depends on distance cluster – sources
  - the higher the cluster redshift, the more sensitive to background z
  - accurate photometry in multiple bands critical

$\Rightarrow$ require excellent image processing

Status / First Results

- data reduction complete
- shear measurements complete
- finalizing of photo-metric redshifts



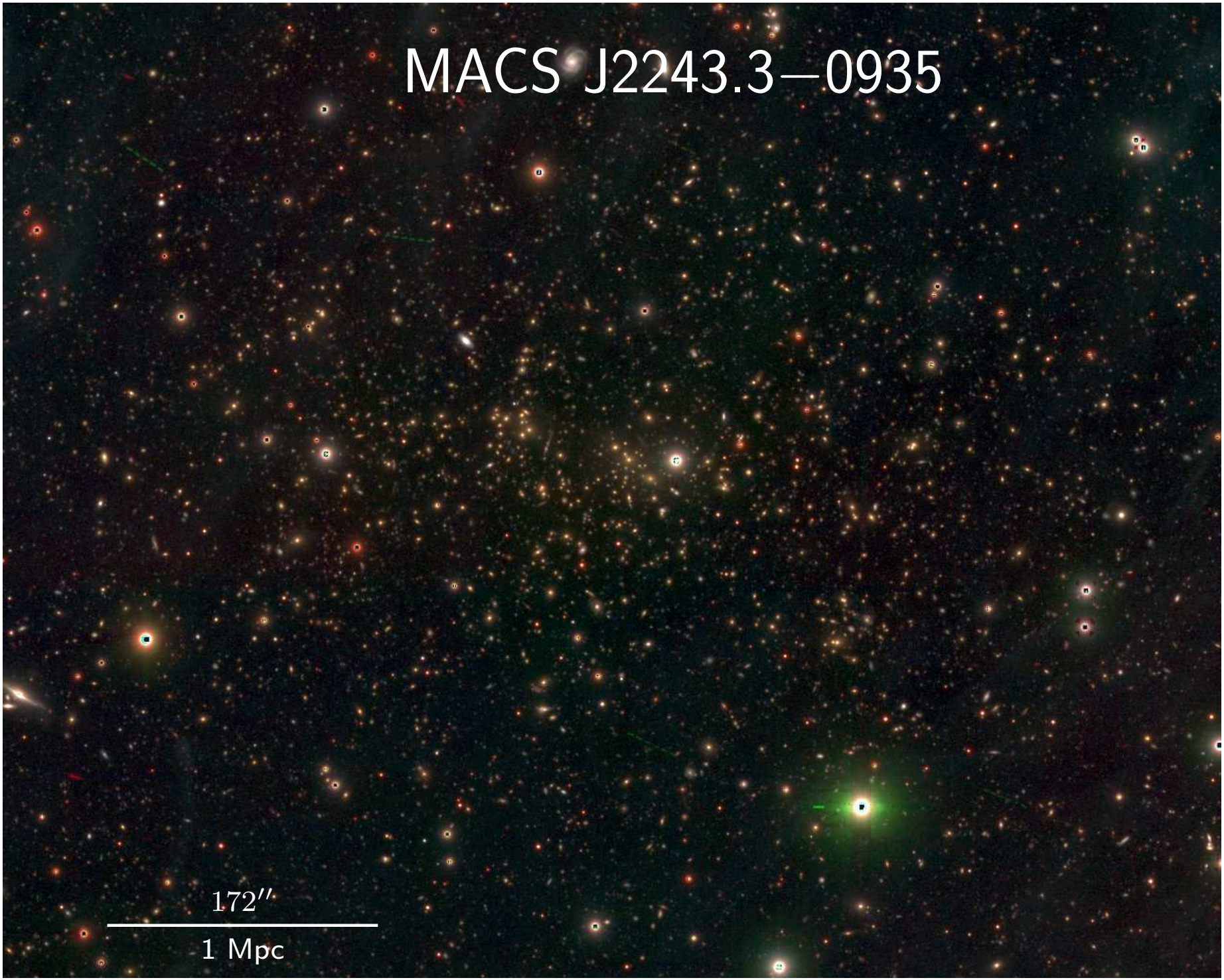
- but also interesting: individual clusters...

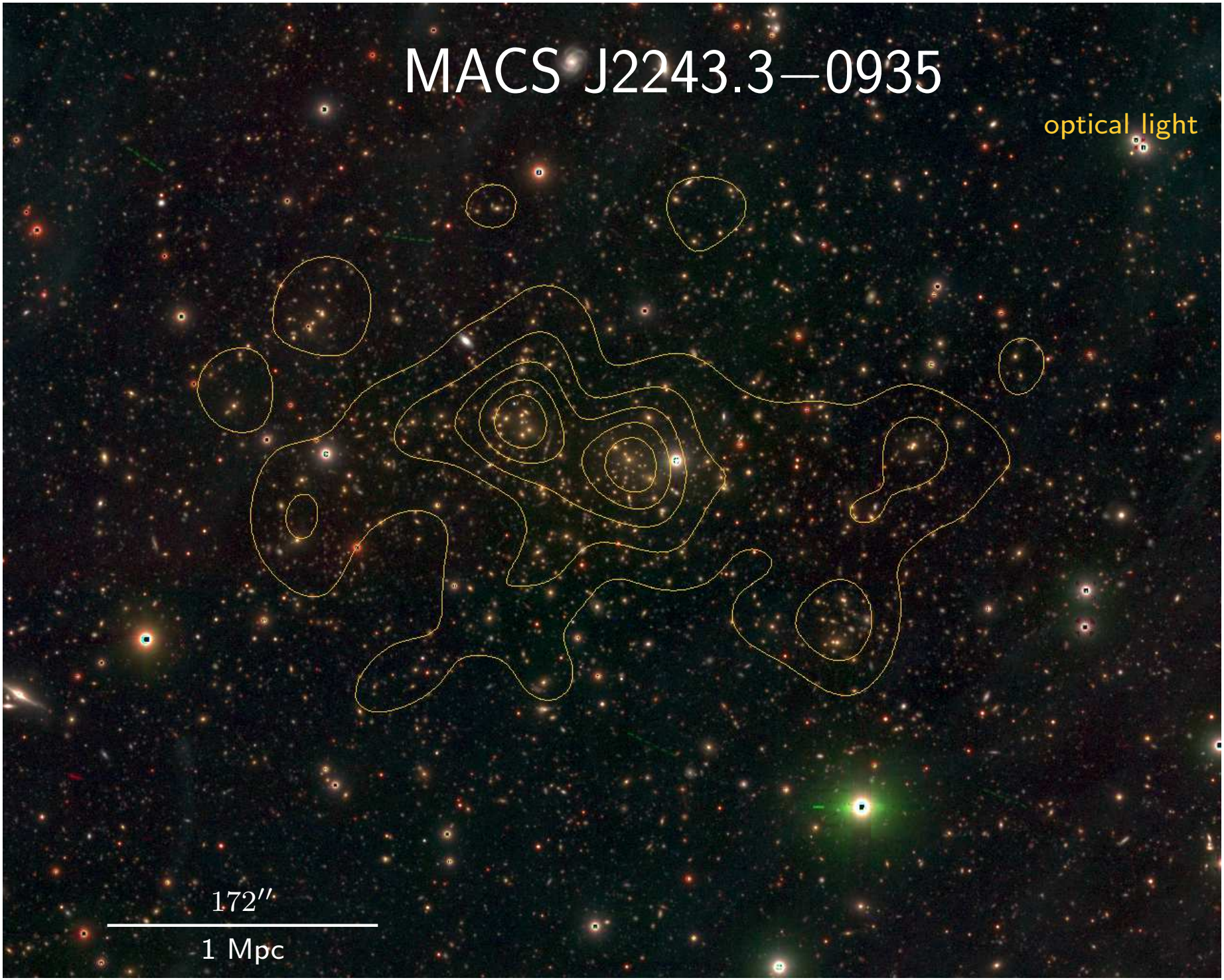
MACS J0025.4−1222

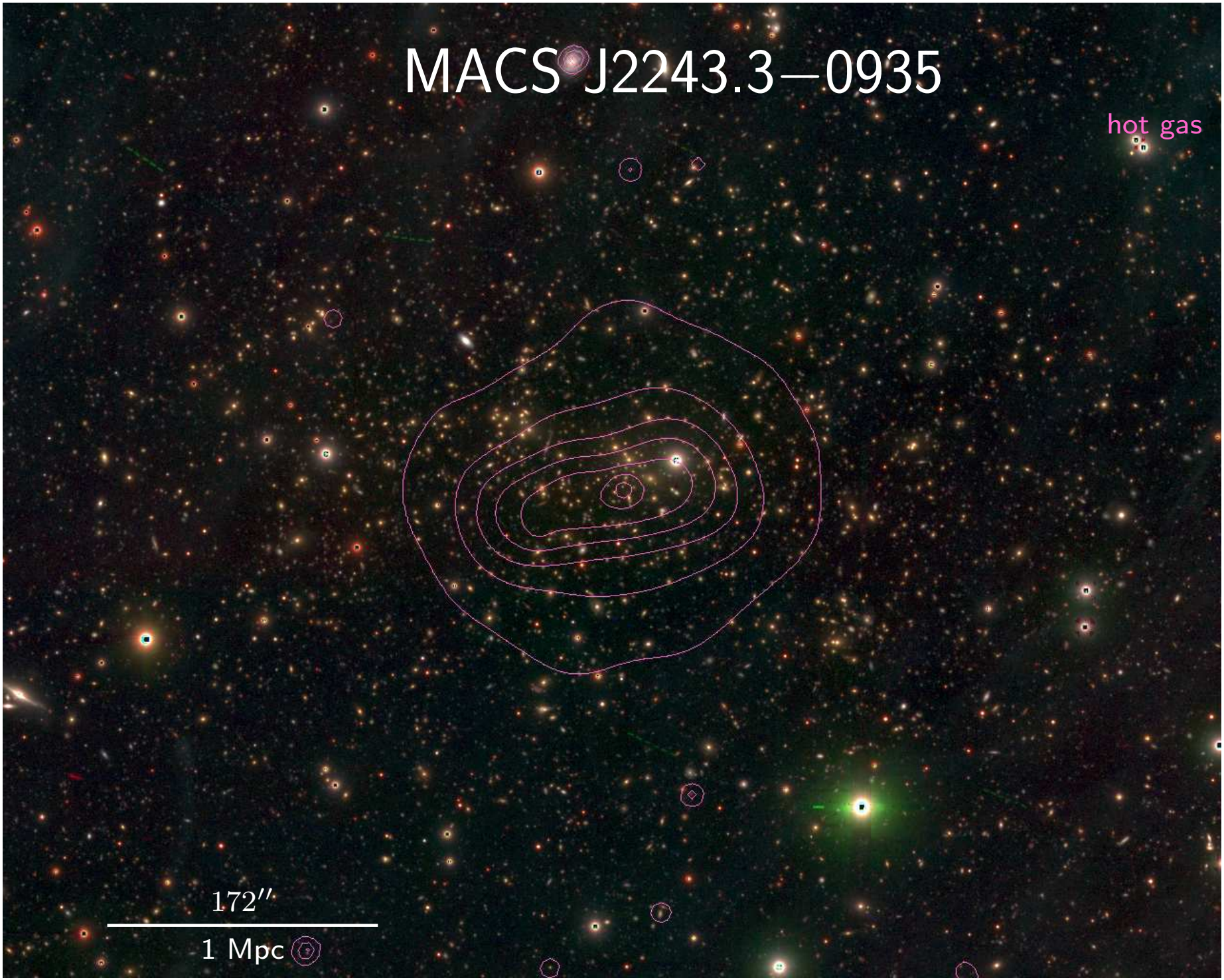
Bradač et al. 2008

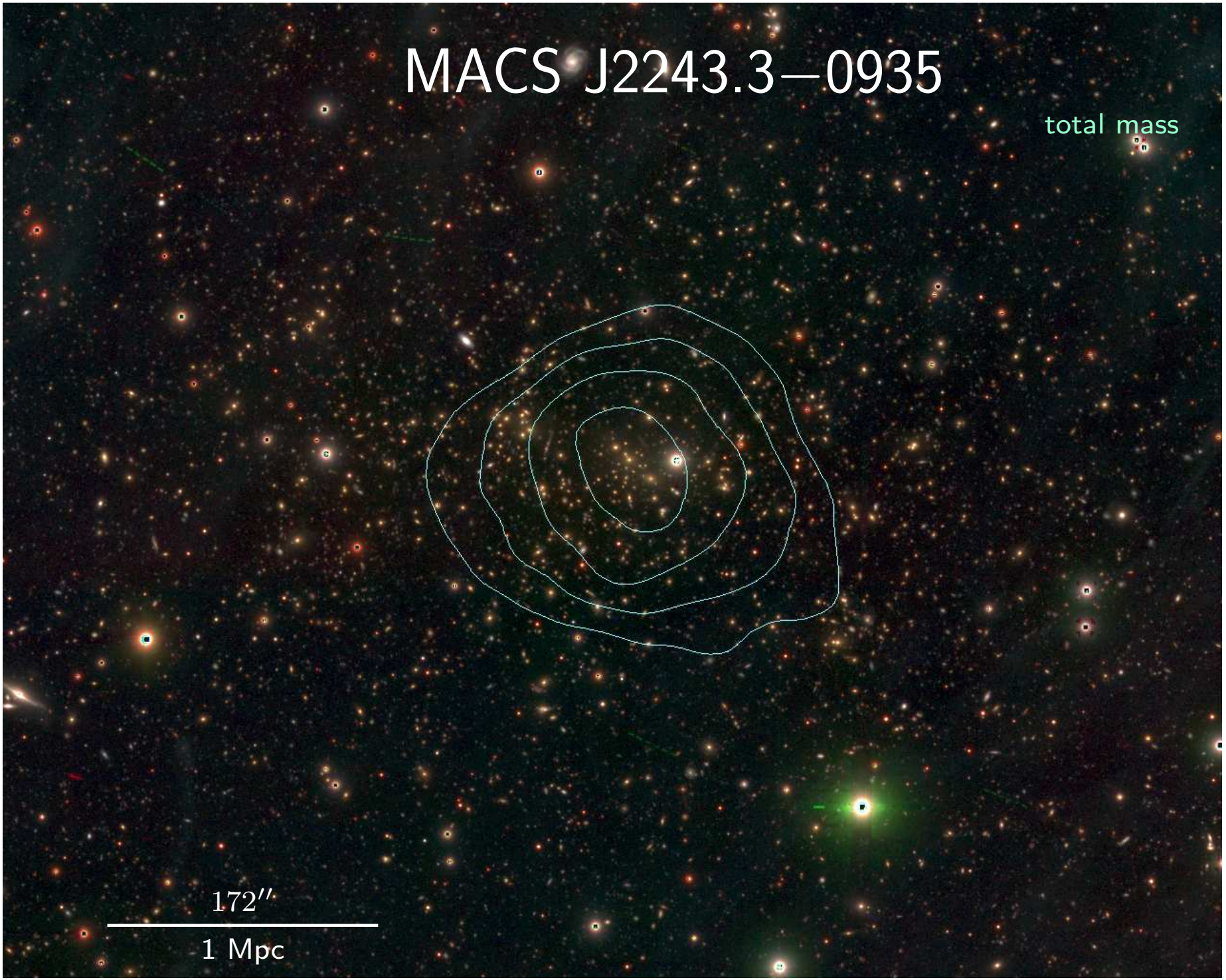
- clear separation of dark matter and hot gas - like the Bullet Cluster
- head-on collision of two equal-mass clusters
- galaxies follow dark matter
- dark matter cold and collisionless

- cluster mergers allow to study the collisional nature of dark matter

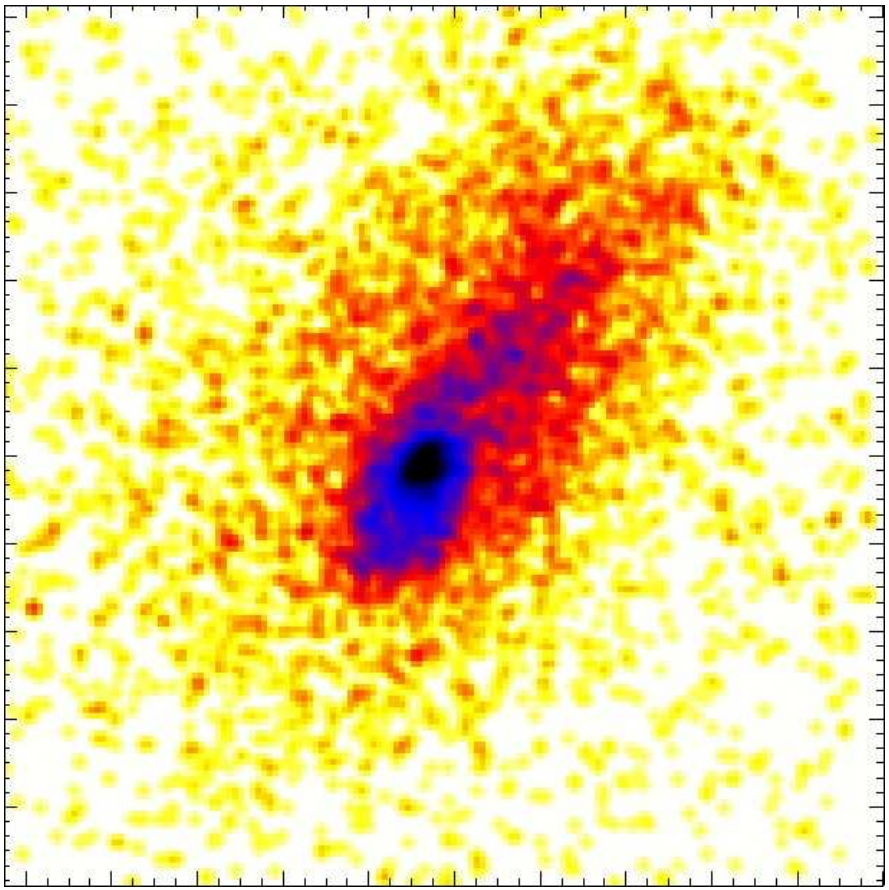

MACS J2243.3−0935
172″
1 Mpc

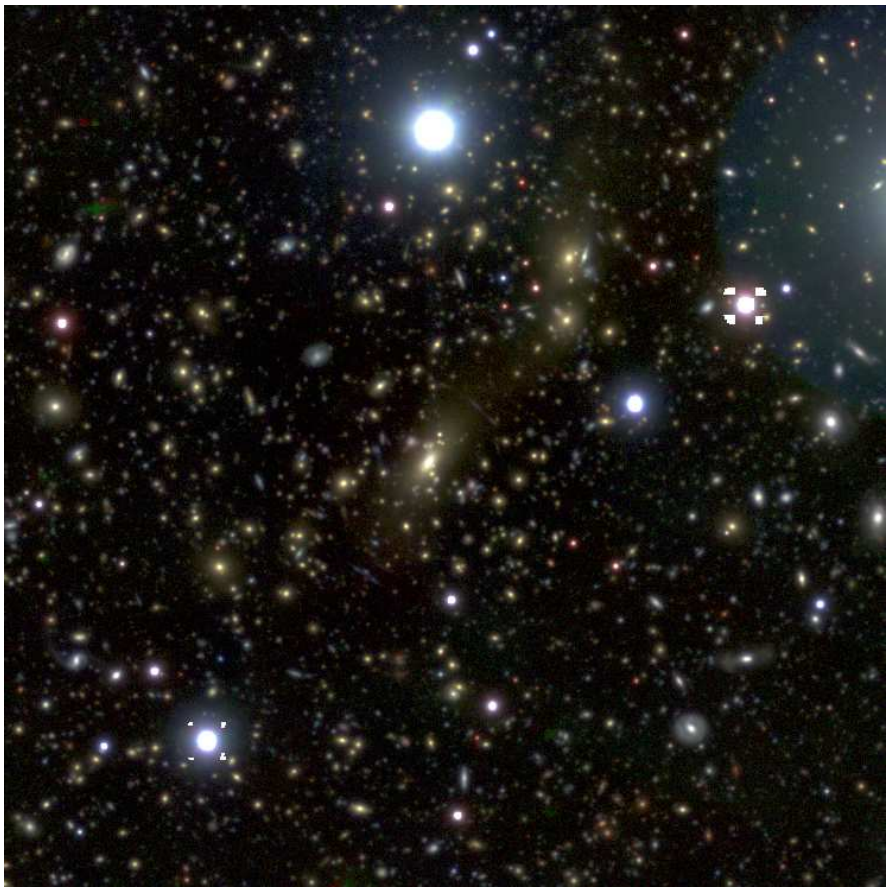

MACS J2243.3−0935
optical light
172″
1 Mpc


MACS J2243.3−0935
hot gas
172″
1 Mpc


MACS J2243.3−0935
total mass
172″
1 Mpc

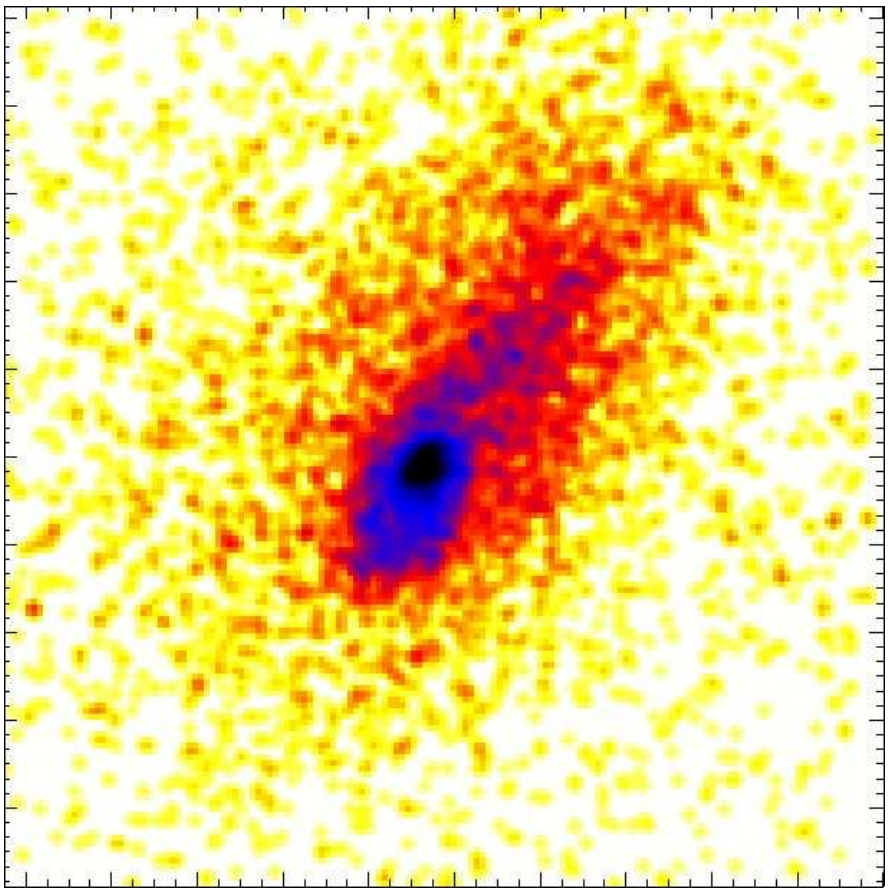
MACS J0417.5−1154

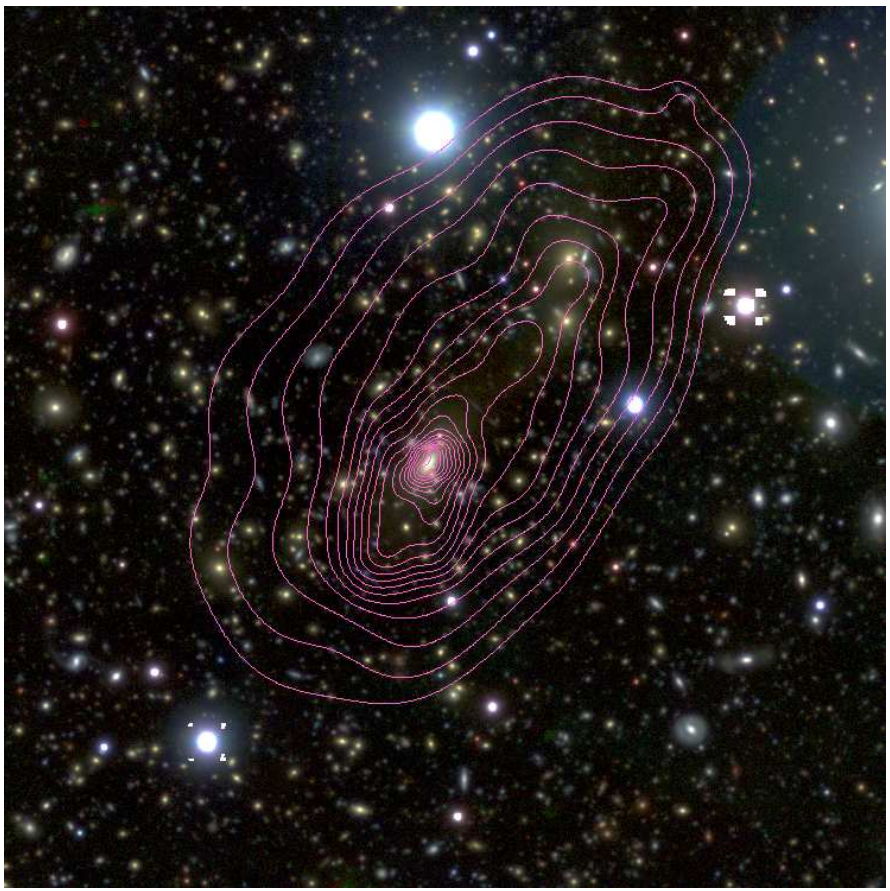




- very massive merger
- gas distribution “comet-like”
- intracluster light follows gas
- 80 ksec Chandra + 4 orbits HST underway

MACS J0417.5−1154





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Stay tuned for:

- results on X-ray mass measurement bias
- multi-wavelength studies of awesome clusters

Happy Birthday, Chandra!