A Weak-Lensing Signature of the LSS Filament in the Abell 222/223 Super-Cluster

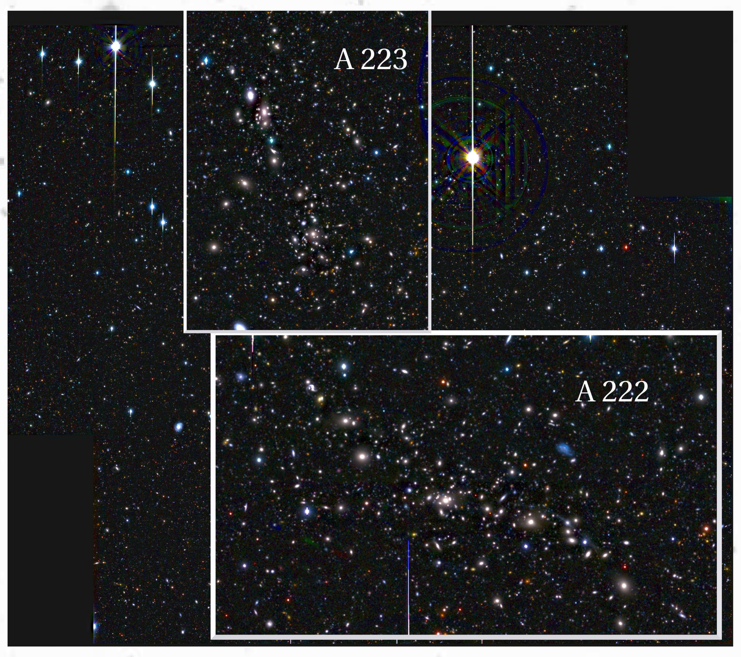
Jörg P. Dietrich[1], Norbert Werner[2], Lance Miller[3], Alexis Finoguenov[4], Aurora Simionescu[2]

[1]University of Michigan, Ann Arbor, MI, USA, [2]KIPAC, Stanford, USA, [3] University of Oxford, Oxford, UK, [4]MPE, Garching, Germany

Abstract

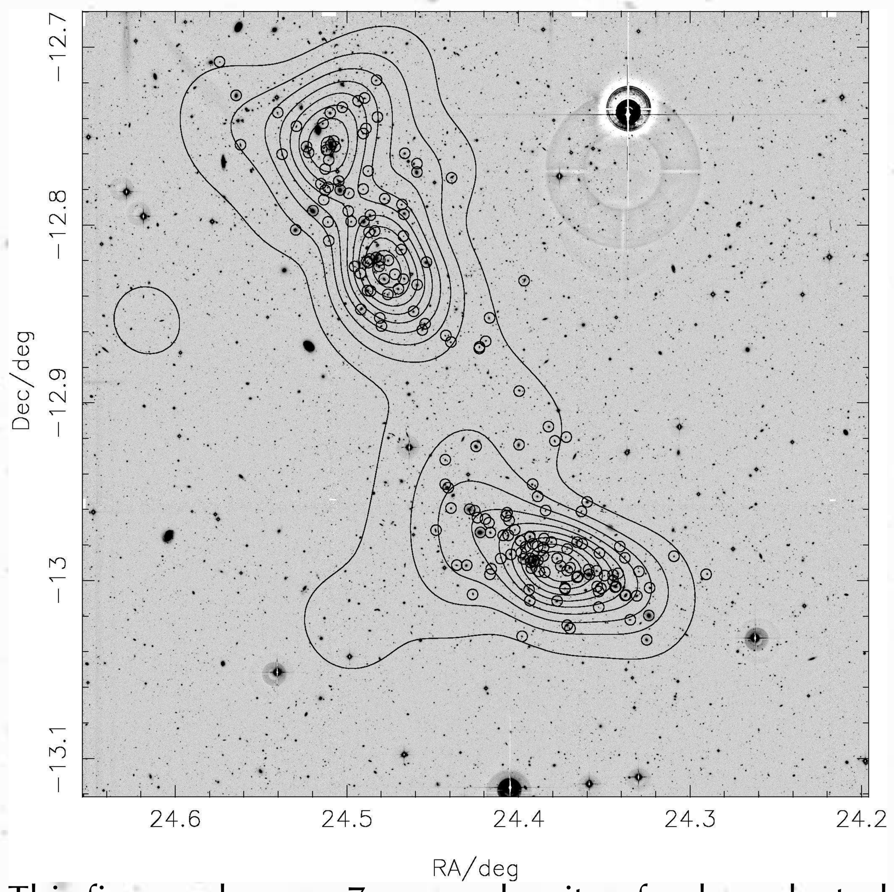
It is a firm prediction of the cold dark-matter model that galaxy clusters live at the intersection of large-scale structure filaments. Baryonic tracers of these filaments have been observed for a long time. Although several candidates for the detection of their gravitational potential via weak lensing were reported in the literature (Kaiser et al. 1998; Gray et al. 2002; Dietrich et al. 2005), a convincing signal remained elusive (Gavazzi et al. 2004; Heymans et al. 2008). We revisit the possible weak-lensing detection of the LSS filament between the clusters A 222 and A 223 based on much improved Suprime-Cam data. These data show tantalizing evidence for a matter bridge connecting the main components of the super-cluster system. We discuss the significance of this signal. Together with the deep XMM-Newton data, which led to a detection of WHIM emission from the filament (Werner et al. 2008), we try to constrain the physical properties of the baryonic and non-baryonic components of the super-cluster's inter-cluster medium.

The Abell 222/223 System



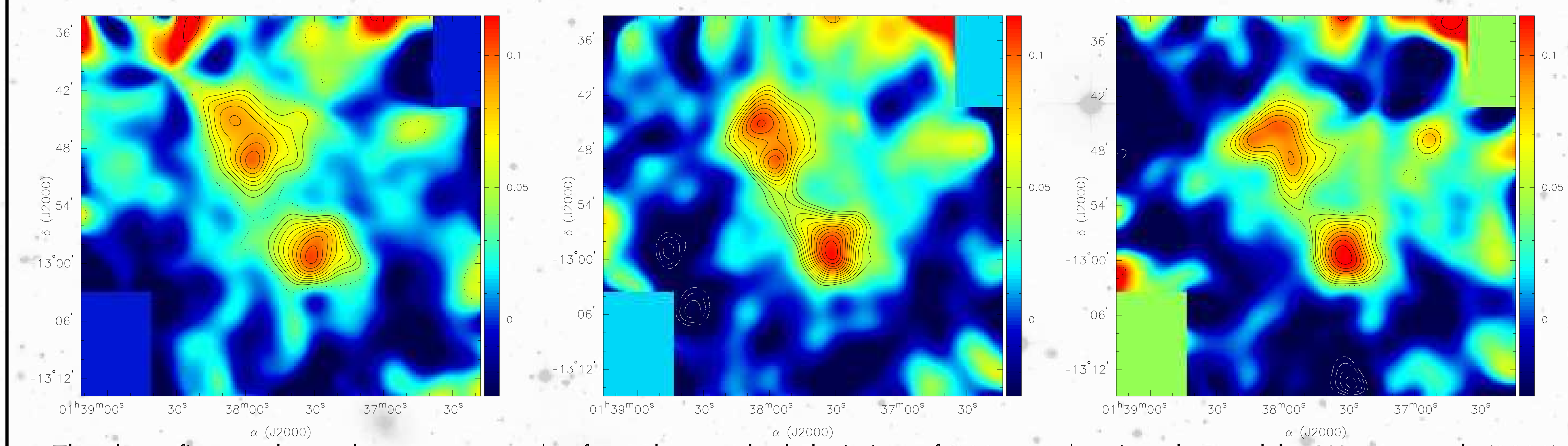
Abell 222/223 is a super-cluster system at $z \approx 0.21$ separated by $\sim 14'$ on the sky, or $\sim 2800\,h_{70}^{-1}$ kpc. Their redshift difference of $\Delta z = 0.005 \pm 0.001$ translates to a physical separation along the line of sight of $(15 \pm 3)h_{70}^{-1}$ Mpc, if no peculiar velocities are assumed. A previous weak-lensing study (Dietrich et al. 2005) provided mass estimates of $M_{200}(\mathrm{A\,222}) = 3.0^{+0.7}_{-0.8} \times 10^{14}\,h_{70}^{-1}\,M_\odot$ and $M_{200}(\mathrm{A\,223}) = 5.3^{+1.6}_{-1.4} \times 10^{14}\,h_{70}^{-1}\,M_\odot$.
Here we present a lensing analysis of deep Suprime-Cam data in three passbands with seeing $0\farcs57$–$0\farcs70$. The shear was estimated using the *lens*fit algorithm (Miller et al. 2007; Kitching et al. 2008).

Galaxy Filament



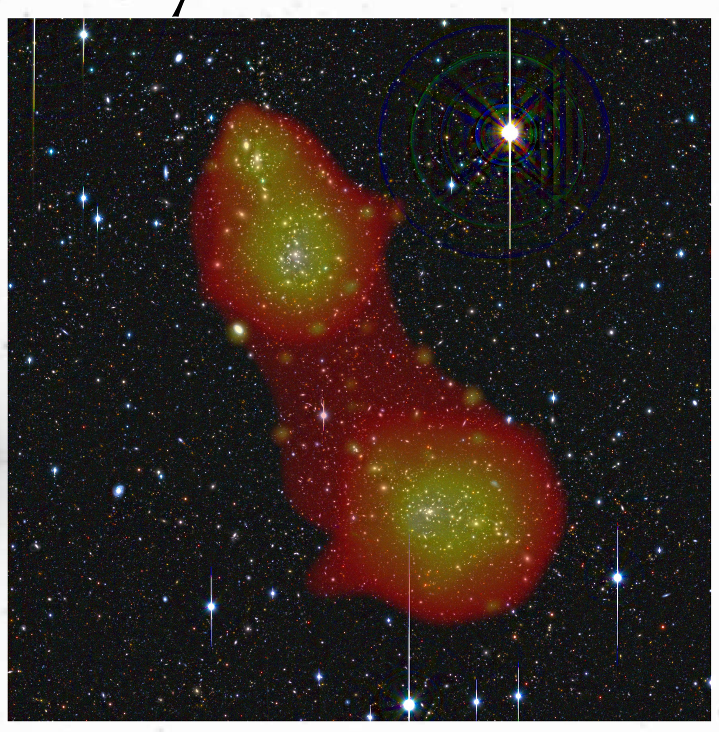
This figures shows a 7σ over-density of color-selected early-type galaxies connecting A 222 and A 223 found by Dietrich et al. (2002, 2005).

Mass Reconstructions



The three figures above show mass reconstructions of the A 222/3 super-cluster field made from the V-, R_C-, and i′-band data (from left to right). The color image in the background is surface mass density. The shear field was smoothed using a 2′ Gaussian.
The contour lines are signal-to-noise ratio, with the solid lines starting at 3σ, increasing in steps of 0.5σ. Dashed contour lines correspond to the same negative SNR. The noise levels were estimated from the standard deviation of 800 realizations of convergence maps created by randomizing the orientation of faint background galaxies while keeping their positions fixed.
The middle panel (R_C-band) shows a mass bridge connecting the two main components of the super-cluster system at the 4σ level. This dark matter structure is aligned with the galaxy overdensity reported in Dietrich et al. (2002) and the X-ray emission detected by Werner et al. (2008). The shallower V- and i′-band data also show this connection at the 2σ and 2.5σ levels, respectively, as illustrated by the dotted contour line in the left and right panels.
No color cuts were made when selecting the background galaxies. Thus, the lensing signal is probably somewhat diluted by the inclusion of foreground and cluster galaxies.

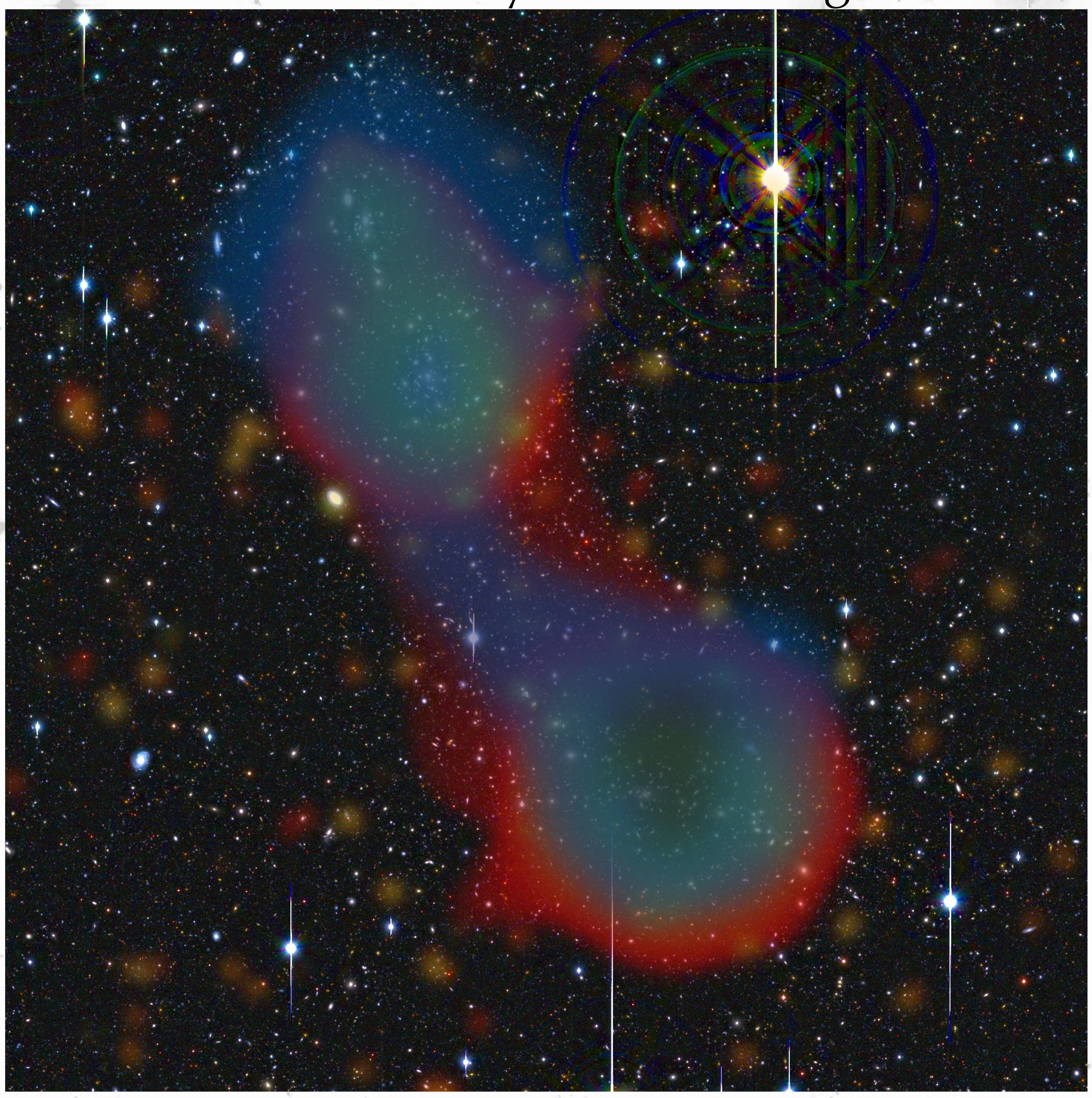
X-ray Filament



X-ray emission (with point sources removed) over a three-color composite Suprime-Cam image.

Werner et al. (2008) reported the discovery of soft, extended X-ray emission from the region between A 222 and A 223 with a temperature of $kT = 0.91 \pm 0.24 \pm 0.07$ keV. This is consistent with the hottest phase of the Warm-Hot Intergalactic Medium expected to live in LSS filaments. This emission is aligned with the galaxy over-density.
Werner et al. (2008) placed a circular aperture with radius $1\farcm6$ (corresponding to $330\,h_{70}^{-1}$ kpc) on the filament region and determined the gas mass to be $\approx 1.8 \times 10^{13}(l/15\,\mathrm{Mpc})^{1/2}$, where l is the length of the filament along the line-of-sight.

Dark Matter and X-ray Filament Aligned



Discussion

We have presented strong evidence for the presence of a dark matter filament connecting A 222 and A 223 based on high-quality weak-lensing observations. This filament is aligned with an optical over-density of galaxies and soft, extended X-ray emission, further supporting the theory that the observed signal is caused by a large-scale structure filament. We obtained an estimate of the filament mass from the R-band reconstruction by measuring the surface mass density inside the same aperture used for the X-ray measurement. Assuming $z = 1$ for the background galaxies, the filament mass is $(1.5 \pm 0.3) \times 10^{14}\,M_\odot$. This implies a baryon fraction of 0.12, slightly lower than the universal value but with a large error bar.

References

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