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Gravitational lensing detection of an extremely dense environment around a galaxy cluster

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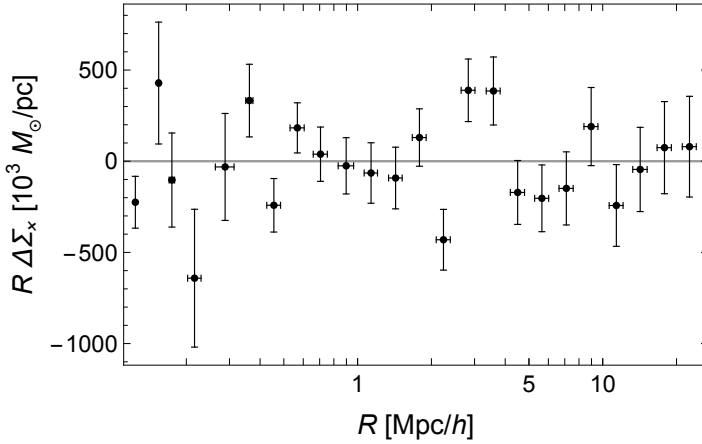
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Supplementary Table 1. Systematic error budget on the differential surface density measurements between $R = 10$ and $25.1 \text{ Mpc } h^{-1}$. Sources of systematics (col. 1) are taken as uncorrelated.

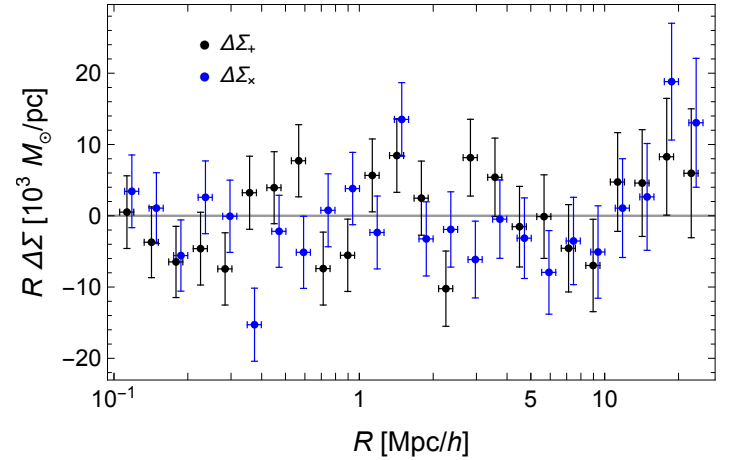
Source	error [%]
Shear measurements	± 3
Photometric redshifts ($z_{cl} = 0.62$)	
bias	± 4.5
scatter	± 3
Line-of-sight projections	± 1
Contamination and membership dilution	± 2
Miscentring	~ 0
Halo modelling	~ 0
Intrinsic alignment	
II	~ 0
GI	-0.6
Total	± 6.5

Supplementary Table 2. WL measurements of PSZ2 G099.86+58.45 and results of the inference analysis under different assumptions. Assumptions are detailed in col. 1. We list the differential surface density $\Delta\Sigma_+$ between $R = 10$ and $25.1 \text{ Mpc } h^{-1}$, in units of $M_\odot h \text{ pc}^{-2}$ in col. 2, $\text{SNR}_{>10\text{Mpc}/h}$ in col. 3 and the estimated environment bias in col. 4.

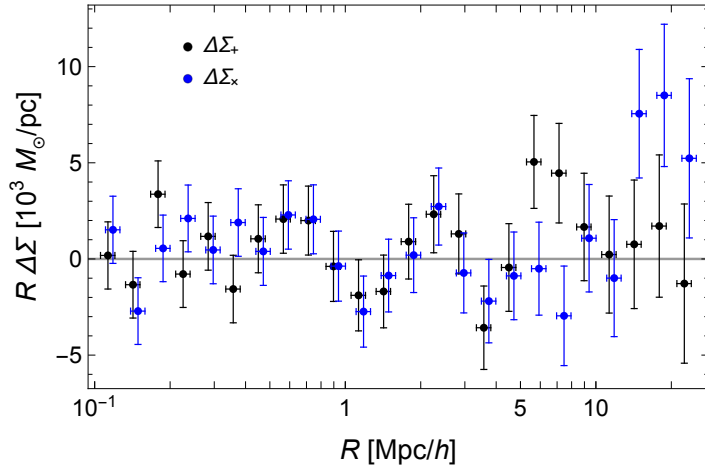
	$\Delta\Sigma_+$	$\text{SNR}_{>10\text{Mpc}/h}$	b_e
reference	$32. \pm 9.$	3.5	$71. \pm 20.$
Shape bias			
WL pass	$24. \pm 10.$	2.4	$54. \pm 22.$
$c_2 = 0$	$32. \pm 9.$	3.5	$72. \pm 20.$
Quadrants			
NW	$55. \pm 12.$	4.5	$107. \pm 28.$
NE	$3. \pm 12.$	0.3	$23. \pm 18.$
SE	$36. \pm 12.$	3.1	$78. \pm 27.$
SW	$33. \pm 12.$	2.7	$84. \pm 28.$
Background selection			
gri	$31. \pm 9.$	3.3	$66. \pm 20.$
z_{phot}	$31. \pm 12.$	2.5	$68. \pm 28.$
photo- z uncertainties			
bias	$32. \pm 11.$	2.9	$75. \pm 25.$
scatter	$38. \pm 11.$	3.4	$73. \pm 24.$
centring and member dilution			
SZ centred	$32. \pm 9.$	3.4	$78. \pm 20.$
$R > 0.5 \text{ Mpc } h^{-1}$	$32. \pm 9.$	3.5	$59. \pm 17.$
Cosmology			
WMAP9	$32. \pm 9.$	3.5	$67. \pm 19.$
NL- P_δ	$32. \pm 9.$	3.5	$57. \pm 16.$



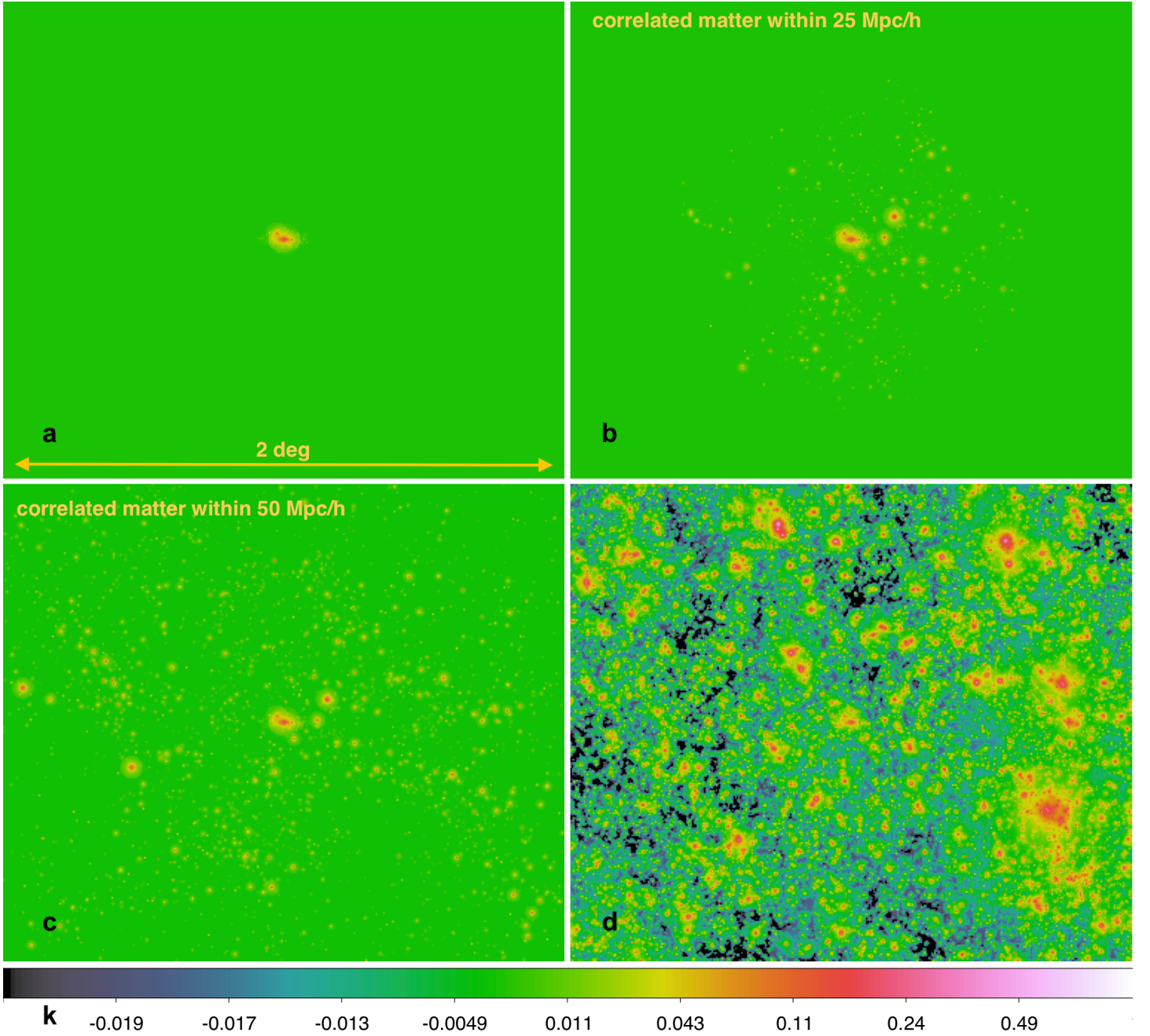
Supplementary Fig. 1. Cross-component of the shear profile of PSZ2 G099.86+58.45. Shown is the renormalised cross-component of the differential surface density $\Delta\Sigma_x$. The horizontal error bars are the weighted standard deviations of the distribution of radial distances in the annulus. The vertical error bars represent the square root of the diagonal elements of the total uncertainty covariance matrix, including statistical and LSS noise. The horizontal line shows a null signal.



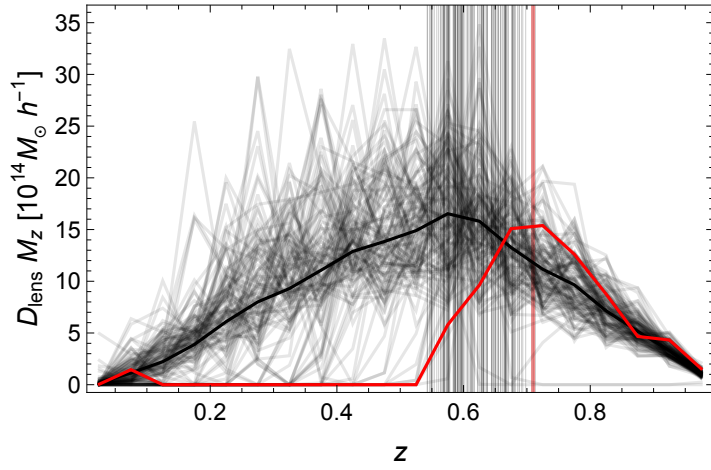
Supplementary Fig. 2. Lensing profile around random points at $z = 0.616$. Shown are the renormalised tangential (black, $\Delta\Sigma_+$) and cross (blue, $\Delta\Sigma_x$) component of the differential surface density of the stacked signal collected around 1,000 random locations in the CFHT-W3 field at $z = 0.616$. Error bars are as in Supplementary Fig. 1. The horizontal line shows a null signal. Blue points are horizontally shifted for visualization purposes.



Supplementary Fig. 3. Stacked lensing profile of PSZ2LenS-like random catalogues. Shown are the renormalised tangential (black, $\Delta\Sigma_{+}$) and cross (blue, $\Delta\Sigma_{\times}$) component of the differential surface density of the stacked signal collected around 100 random PSZ2LenS-like catalogues. Error bars are as in Supplementary Fig. 1. The horizontal line shows a null signal. Blue points are horizontally shifted for visualization purposes.



Supplementary Fig. 4. Simulated convergence map. Panel **a** shows an isolated cluster with a mass of $\sim 7.4 \times 10^{14} M_{\odot} h^{-1}$ at $z \sim 0.67$. Panels **b** and **c**: central halo plus matter within a comoving distance of 25 or 50 Mpc h^{-1} , respectively. Panel **d**: all the correlated and uncorrelated structures present in the field of view of the cluster. The source redshift is set at $z = 1$.



Supplementary Fig. 5. Simulated mass distributions. Shown is the total matter in simulated collapsed halos as a function of redshift. We added the masses of halos more massive than $7 \times 10^{11} M_\odot h^{-1}$ in redshift slices of thickness $\Delta z = 0.05$ and within an aperture of 1 deg. The mass is normalized by the lensing kernel $D_{\text{lens}} = D_{\text{ds}}/D_s$. The vertical lines mark the redshift of the simulated lens. The black, grey, and red lines correspond to the simulation average, the individual systems, and the system with the highest shear signal between 10 and 25.1 $\text{Mpc } h^{-1}$, respectively.