Lens models for the Frontier Fields clusters
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Traci Johnson & Keren Sharon

tljohn@umich.edu, kerens@umich.edu

University of Michigan, Department of Astronomy, 500 Church Street, Ann Arbor, MI 48109, USA

Overview

Strong lens models of the Frontier Fields clusters and files necessary for the creation of magnification maps and errors were produced by Traci Johnson and Keren Sharon (PI). The lens model components, list of constraints, assumptions, priors, best-fit parameters and their uncertainties are fully described in Johnson et al. (2014).

The deliverables in this directory include high-resolution magnification maps for $z = 1, 2, 4, 9$, two-dimensional deflection angles, convergence, and shear maps, along with lower-resolution convergence and shear maps from a simulation of 100 models selected periodically from the MCMC chain which can be used to derive magnification maps and errors for any source plane redshift. All the model products cover $300'' \times 300''$, fully encompassing the HST ACS FOV regardless of orientation angle of observation.

Modifications from version 1 (Sep 2013 release) of the lens models include full image plane minimization in all the clusters, new spectroscopic redshifts for the lensed galaxies in Abell 2744 and Abell S1063, revised priors, a better representation of the uncertainty distribution, and increased field of view to cover the ACS FOV in any orientation.

We assume a flat ΛCDM cosmology, with $\Omega_\Lambda = 0.7$, $\Omega_M = 0.3$, and $\mathrm{H}_0 = 70$ km s^{-1}.

Lens Model

We use the parametric, publicly-available software `LENSTOOL` (Jullo et al. 2007), with a Markov Chain Monte Carlo minimization weighted by Bayesian evidence. The final minimization is conducted in the image plane. We provide a brief description here, and refer the user to Johnson et al. (2014) for a full description of each lens model components, list of constraints, assumptions, priors, best-fit parameters and their uncertainties.

Mass components are represented by pseudo-isothermal elliptical mass distributions (PIEMD; Limousin et al. 2005), with parameters: two-dimensional location in the lens plane (x, y), a lens plane redshift (z), ellipticity (e), position angle (θ), fiducial velocity dispersion (σ), core radius (r_{core}) and cut radius (r_{cut}). Cluster galaxies are selected by their color relative to the red sequence in a color-magnitude diagram. Their geometrical parameters are fixed at the observed values, and (σ), (r_{core}), and (r_{cut}) are scaled to their observed luminosity according to the relationships in Limousin et al. (2005). Some galaxy-scale halos are allowed to be solved for by the lens model if they are in close proximity to lensed images.

Deliverables

We have computed magnification maps for source redshift planes of $z = 1, 2, 4,$ and 9. We also include the x and y deflection maps, representing the deflection angle from image plane to source plane in units of arcseconds, and the convergence κ and shear γ maps, all computed at a redshift of $z = 9$. These additional maps can be used to calculate the magnifications at any source plane redshift. We also include a lower resolution convergence and shear maps for 100 models selected at equal intervals throughout the MCMC chain, which can be used to derive the magnification errors at any source redshift. A summary of the model files is given in Table 14.

Each high-resolution map is a square $300'' \times 300''$ grid oriented north up and east to the left. The lower-resolution maps are 1251×1251 with a pixel scale of $0.24''$. The FITS WCS astrometry has been matched to the preliminary HST science products created by Anton Koekemoer.[1]

Modeling strengths and caveats

Our models best describe the magnifications in the strong lensing regime, or the region more or less enclosed by the strongly-lensed arcs. Therefore, the objects within a few

[1]Pre-Cycle 21 data for each cluster are available at:
http://archive.stsci.edu/pub/hlsp/frontier/abell2744/images/hst/v0.2/
http://archive.stsci.edu/pub/hlsp/frontier/abell370/images/hst/v0.2/
http://archive.stsci.edu/pub/hlsp/frontier/abells1063/images/hst/clash/
http://archive.stsci.edu/pub/hlsp/frontier/macs0416/images/hst/clash/
http://archive.stsci.edu/pub/hlsp/frontier/macs0717/images/hst/clash/
http://archive.stsci.edu/pub/hlsp/frontier/macs1149/images/hst/clash/

arcseconds of any images used as constraints in our model will have the most precise magnifications, especially if those images had fixed spectroscopic redshifts. The regions of the map that are most vulnerable to both systematic and modeling error are near the critical curve and far from any image constraints. See Johnson et al. (2014) for further detail on model uncertainties.

We do not recommend the use of our model for computing the magnifications in the "blank" parallel field, as this would be a crude, unconstrained extrapolation of the magnification. For the parallel field, we suggest that one uses maps generated by other mapping techniques (e.g., Merten et al.), which include weak lensing as constraints.

Future model revisions

The magnification maps we have created in this model version of the FF are at this moment very well constrained and provide precise values for the magnification in the strong lensing regime. However, no model is exact and can alway be improved upon. New arc identifications, from the full-depth Cycle 21-23 HFF data, can add constraint to new regions of the map and spectroscopic redshifts of arcs can greatly reduce magnification errors in areas near those images. We will use our current models to identify new image systems and include them in new model version and will update known image systems with new spectroscopic redshifts as they become available.

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Zitrin, A., Meneghetti, M., Umetsu, K., et al. 2013, ApJ, 762, L30

Table 1. Frontier Fields lens model summaries

cluster	# constraints	# free parameters	image plane rms (″)	total # systems (# spec z systems)
Abell 2744	64	38	0.40	15 (3)
MACS J0416.1-2403	50	21	0.51	15 (10)
MACS J0717.5+3745	56	38	0.38	14 (5)
MACS J1149.5+2223	46	25	0.52	12 (3)
Abell S1063	58	26	0.64	16 (6)
Abell 370	44	19	0.82	9 (5)

Table 2. Abell 2744 image constraints

Image system	R.A.	Dec.	Spec z	Photo z[3]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	00:14:23.41	-30:24:14.10	···	0.5-2.2	$1.74^{+0.09}_{-0.08}$	0.5-2.6	0.04	0.34
1.2	00:14:23.03	-30:24:24.56					0.18	
1.3	00:14:20.69	-30:24:35.95					0.05	
2.1	00:14:19.98	-30:24:12.06	···	0.5-2.9	$1.91^{+0.14}_{-0.05}$	0.4-3.0	0.61	0.61
2.2	00:14:23.35	-30:23:48.21					0.15	
2.3	00:14:20.50	-30:23:59.63					0.19	
2.4	00:14:20.74	-30:24:07.66					0.33	
3.1	00:14:21.45	-30:23:37.95	3.98[1]	···	···	···	0.27	0.49
3.2	00:14:21.31	-30:23:37.69					0.07	
3.3	00:14:18.60	-30:23:58.44					0.32	
4.1	00:14:22.11	-30:24:09.48	3.58[2]	···	···	···	0.42	0.76
4.2	00:14:22.95	-30:24:05.84					0.65	
4.3	00:14:19.30	-30:24:32.13					0.68	
4.4	00:14:22.37	-30:24:17.69					0.57	
4.5	00:14:22.46	-30:24:18.38					0.53	
6.1	00:14:23.65	-30:24:06.48	2.02[2]	···	···	···	0.28	0.48
6.2	00:14:22.57	-30:24:28.84					0.10	
6.3	00:14:20.74	-30:24:33.74					0.25	
7.1	00:14:23.58	-30:24:08.35	···	0.3-3.4	$2.69^{+0.23}_{-0.12}$	2.5-3.7	0.11	0.45
7.2	00:14:22.85	-30:24:26.73					0.18	
7.3	00:14:20.30	-30:24:35.33					0.28	
8.1	00:14:21.53	-30:23:39.62	···	···	$4.57^{+0.87}_{-0.45}$	3.0-6.5	0.29	0.51
8.2	00:14:21.32	-30:23:39.20					0.24	
9.1	00:14:21.21	-30:24:18.98	···	0.6-2.8	$2.99^{+0.39}_{-0.13}$	1.0-4.0	0.77	0.87
9.2	00:14:20.91	-30:24:22.47					0.81	
9.3	00:14:24.04	-30:23:49.75					0.67	
10.1	00:14:21.22	-30:24:21.16	···	1.8-3.2	$3.83^{+0.51}_{-0.27}$	1.8-5.0	0.64	0.66
10.2	00:14:20.97	-30:24:23.33					0.36	
10.3	00:14:24.17	-30:23:49.56					0.15	
11.1	00:14:21.93	-30:24:13.89	···	0.4-2.8	$2.82^{+0.18}_{-0.20}$	1.4-3.3	0.13	0.59
11.2	00:14:23.34	-30:24:05.23					0.52	
11.3	00:14:19.87	-30:24:32.09					0.37	
11.4	00:14:22.69	-30:24:23.55					0.28	
12.1	00:14:22.47	-30:24:16.09	···	1.4-3.1	$4.51^{+0.62}_{-0.30}$	1.4-6.0	0.61	0.68
12.2	00:14:22.38	-30:24:11.72					0.47	
12.3	00:14:22.70	-30:24:10.76					0.26	
12.4	00:14:19.07	-30:24:35.83					0.44	
13.1	00:14:22.17	-30:24:09.21	···	0.6-2.6	$1.44^{+0.06}_{-0.04}$	0.5-2.6	0.37	0.65
13.2	00:14:22.51	-30:24:07.79					0.41	
13.3	00:14:19.87	-30:24:28.96					0.47	
14.1	00:14:21.54	-30:23:40.69	···	1.8-3.2	$3.66^{+0.49}_{-0.43}$	1.8-5.0	0.35	0.58
14.2	00:14:21.23	-30:23:39.97					0.33	
16.1	00:14:13.57	-30:22:32.91	···	2.6-3.6[4]	···	···	0.12	0.50
16.2	00:14:13.53	-30:22:36.36					0.41	
16.3	00:14:13.10	-30:22:45.51					0.10	
18.1	00:14:21.78	-30:23:44.02	···	1.5-5.4	$3.56^{+0.84}_{-0.49}$	2.0-6.0	0.13	0.33
18.2	00:14:21.21	-30:23:44.29					0.09	

[1]Johnson et al. (2014)

[2]Richard et al. (in prep.).

[3]BPZ measured from *HST* preliminary data reductions.

[4]Image system fixed to $z = 3$ (see Johnson et al. (2014), §5.1).

Table 3. MACS J0416.1-2403 image constraints

Image system	R.A.	Dec.	Spec z	Photo z [3]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	04:16:09.80	-24:03:41.81	1.89[1]	···	···	···	0.15	0.53
1.2	04:16:10.43	-24:03:48.56					0.42	
1.3	04:16:11.37	-24:04:07.21					0.22	
2.1	04:16:09.86	-24:03:42.48	1.89[2]	···	···	···	0.29	0.53
2.2	04:16:10.34	-24:03:47.10					0.34	
2.3	04:16:11.39	-24:04:07.74					0.21	
3.1	04:16:07.38	-24:04:01.63	1.99[2]	···	···	···	0.73	0.74
3.2	04:16:08.46	-24:04:15.55					0.44	
3.3	04:16:10.03	-24:04:32.61					0.42	
4.1	04:16:07.39	-24:04:01.99	1.99[2]	···	···	···	0.72	0.73
4.2	04:16:08.44	-24:04:15.61					0.33	
4.3	04:16:10.04	-24:04:32.98					0.48	
5.1	04:16:07.77	-24:04:06.28	···	2.1-2.8	$1.79^{+0.11}_{-0.24}$	1.0-3.0	0.29	0.49
5.2	04:16:07.84	-24:04:07.15					0.23	
5.3	04:16:08.05	-24:04:10.00					0.20	
6.1	04:16:09.61	-24:03:42.62	···	6-8	$5.87^{+1.97}_{-1.39}$	4.0-8.0	0.01	0.15
6.2	04:16:09.95	-24:03:45.32					0.03	
7.1	04:16:09.55	-24:03:47.11	2.09[2]	···	···	···	0.42	0.84
7.2	04:16:09.76	-24:03:48.91					0.95	
7.3	04:16:11.30	-24:04:15.98					0.65	
8.1	04:16:08.78	-24:03:58.03	···	2.0-2.6	$1.78^{+0.23}_{-0.21}$	1.2-2.6	0.08	0.28
8.2	04:16:08.84	-24:03:58.83					0.07	
9.1	04:16:06.49	-24:04:42.87	···	1.8-3.0	$2.37^{+0.23}_{-0.28}$	1.0-3.5	0.13	0.36
9.2	04:16:06.60	-24:04:44.71					0.14	
10.1	04:16:06.25	-24:04:38.13	2.30[2]	···	···	···	0.70	0.78
10.2	04:16:06.82	-24:04:47.06					0.50	
12.1	04:16:09.25	-24:04:25.92	···	1.0-2.1	$1.62^{+0.17}_{-0.10}$	1.0-2.3	0.06	0.25
12.2	04:16:08.98	-24:04:23.39					0.06	
13.1	04:16:06.62	-24:04:21.60	3.22[2]	···	···	···	0.37	0.57
13.2	04:16:07.72	-24:04:30.37					0.35	
13.3	04:16:09.68	-24:04:53.32					0.24	
14.1	04:16:06.30	-24:04:27.60	2.05[2]	···	···	···	0.82	0.92
14.2	04:16:07.45	-24:04:44.22					0.29	
14.3	04:16:08.60	-24:04:52.74					1.20	
16.1	04:16:05.78	-24:04:51.20	1.96[2]	···	···	···	0.76	0.88
16.2	04:16:06.80	-24:05:04.34					0.65	
16.3	04:16:07.59	-24:05:08.73					0.89	
17.1	04:16:07.16	-24:05:10.91	2.21[2]	···	···	···	0.98	0.80
17.2	04:16:06.86	-24:05:09.45					0.44	
17.3	04:16:05.60	-24:04:53.69					0.31	

[1]Zitrin et al. (2013)

[2]Grillo et al. (2013, in prep.), obtained from VLT program 186.A-0798 (Balestra et al. 2013).

[3]Jouvel et al. (2013), 95% confidence levels on BPZ for entire image system from CLASH imaging.

Table 4. MACS J0717.5+3745 image constraints

Image system	R.A.	Dec.	Spec z[1]	Photo z[2]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	07:17:34.88	+37:44:28.22	2.90	···	···	···	0.45	0.63
1.2	07:17:34.52	+37:44:24.33					0.59	
1.3	07:17:33.84	+37:44:17.82					0.27	
1.4	07:17:32.24	+37:44:12.97					0.29	
1.5	07:17:37.39	+37:45:40.94					0.29	
3.1	07:17:35.65	+37:44:29.39	1.80	···	···	···	0.16	0.64
3.2	07:17:34.67	+37:44:21.01					0.62	
3.3	07:17:37.72	+37:45:13.78					0.28	
4.1	07:17:31.41	+37:45:00.42	···	1.7-2.0	$1.85^{+0.03}_{-0.04}$	1.7-2.0	0.10	0.37
4.2	07:17:30.35	+37:44:40.89					0.12	
4.3	07:17:33.86	+37:45:47.84					0.17	
5.1	07:17:31.17	+37:44:48.70	···	4.4-4.8	$4.02^{+0.20}_{-0.16}$	3.5-4.8	0.30	0.52
5.2	07:17:30.70	+37:44:34.09					0.32	
5.3	07:17:36.00	+37:46:02.63					0.17	
6.1	07:17:27.44	+37:45:25.53	···	2.2-2.8	$1.99^{+0.05}_{-0.05}$	1.8-2.8	0.39	0.57
6.2	07:17:27.05	+37:45:09.64					0.11	
6.3	07:17:29.73	+37:46:10.94					0.39	
7.1	07:17:27.98	+37:45:58.83	···	1.2-3.0	$1.80^{+0.11}_{-0.11}$	1.0-3.0	0.04	0.20
7.2	07:17:27.61	+37:45:50.85					0.04	
8.1	07:17:28.00	+37:46:10.80	···	2.7-3.6	$2.23^{+0.07}_{-0.06}$	2.0-3.5	0.15	0.33
8.2	07:17:26.90	+37:45:47.29					0.06	
8.3	07:17:25.56	+37:45:06.96					0.09	
12.1	07:17:32.44	+37:45:06.63	···	1.4-1.8	$1.66^{+0.03}_{-0.02}$	1.4-1.8	0.49	0.55
12.2	07:17:30.63	+37:44:34.38					0.19	
12.3	07:17:33.89	+37:45:38.24					0.02	
13.1	07:17:32.56	+37:45:02.59	2.50	···	···	···	0.27	0.64
13.2	07:17:30.61	+37:44:22.67					0.38	
13.3	07:17:35.09	+37:45:47.96					0.54	
14.1	07:17:33.31	+37:45:07.81	1.85	···	···	···	0.67	0.73
14.2	07:17:31.12	+37:44:22.95					0.54	
14.3	07:17:35.08	+37:45:37.51					0.37	
15.1	07:17:28.24	+37:46:19.41	2.40	···	···	···	0.30	0.48
15.2	07:17:26.07	+37:45:36.45					0.10	
15.3	07:17:25.57	+37:45:16.69					0.25	
16.1	07:17:28.60	+37:46:23.80	···	4.0-4.7	$3.04^{+0.11}_{-0.11}$	2.5-4.5	0.31	0.58
16.2	07:17:26.06	+37:45:34.34					0.41	
16.3	07:17:25.66	+37:45:13.36					0.28	
17.1	07:17:28.65	+37:46:18.71	···	3.0-4.7	$2.42^{+0.08}_{-0.05}$	2.0-3.5	0.38	0.85
17.2	07:17:26.25	+37:45:31.65					0.64	
17.3	07:17:25.98	+37:45:12.96					1.00	
18.1	07:17:27.42	+37:46:07.06	···	1.6-3.7	$1.76^{+0.18}_{-0.04}$	1.6-3.3	0.51	0.71
18.2	07:17:26.69	+37:45:51.61					0.51	

[1]Limousin et al. (2012)

[2]Jouvel et al. (2013), 95% confidence levels on BPZ for entire image system from CLASH imaging.

Table 5. MACS J1149.5+2223 image constraints

Image system	R.A.	Dec.	Spec z[1]	Photo z[2]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	11:49:35.28	+22:23:45.60	1.48	···	···	···	0.97	0.83
1.2	11:49:35.86	+22:23:50.78					0.62	
1.3	11:49:36.82	+22:24:08.78					0.31	
2.1	11:49:36.58	+22:23:23.10	1.89	···	···	···	0.37	0.66
2.2	11:49:37.45	+22:23:32.92					0.51	
2.3	11:49:37.58	+22:23:34.39					0.41	
3.1	11:49:33.78	+22:23:59.45	2.50	···	···	···	0.26	0.49
3.2	11:49:34.25	+22:24:11.09					0.28	
3.3	11:49:36.31	+22:24:25.88					0.15	
4.1	11:49:34.32	+22:23:48.57	···	2.7-3.1	$2.83^{+0.16}_{-0.15}$	2.6-3.1	0.51	0.83
4.2	11:49:34.65	+22:24:02.65					0.87	
4.3	11:49:37.00	+22:24:22.06					0.63	
5.1	11:49:35.94	+22:23:35.02	···	2.4-2.9	$3.23^{+0.22}_{-0.30}$	2.4-3.5	0.35	0.63
5.2	11:49:36.26	+22:23:37.77					0.57	
5.3	11:49:37.90	+22:24:12.79					0.19	
6.1	11:49:35.93	+22:23:33.16	···	0.1-3.3	$3.13^{+0.16}_{-0.30}$	2.0-3.3	0.37	0.67
6.2	11:49:36.44	+22:23:37.89					0.67	
6.3	11:49:37.93	+22:24:09.02					0.17	
7.1	11:49:35.75	+22:23:28.82	···	2.5-3.2	$3.06^{+0.31}_{-0.27}$	2.5-3.5	1.09	0.95
7.2	11:49:36.82	+22:23:39.37					0.70	
7.3	11:49:37.82	+22:24:04.47					0.88	
8.1	11:49:35.64	+22:23:39.66	···	1.1-2.8	$3.31^{+0.17}_{-0.28}$	1.1-3.5	0.79	0.84
8.2	11:49:35.95	+22:23:42.16					0.90	
8.3	11:49:37.69	+22:24:19.99					0.16	
9.1	11:49:37.24	+22:25:34.44	···	0.6-1.7	$1.35^{+0.32}_{-0.35}$	0.6-1.7	0.19	0.53
9.2	11:49:36.93	+22:25:38.03					0.35	
9.3	11:49:36.78	+22:25:38.02					0.27	
10.1	11:49:37.08	+22:25:31.85	···	1.0-2.2	$1.61^{+0.56}_{-0.43}$	1.0-2.2	0.32	0.51
10.2	11:49:36.87	+22:25:32.29					0.28	
10.3	11:49:36.53	+22:25:35.85					0.13	
13.1	11:49:36.89	+22:23:52.03	···	0.7-1.4	$1.20^{+0.05}_{-0.02}$	0.7-1.4	0.15	0.60
13.2	11:49:36.68	+22:23:47.96					0.46	
13.3	11:49:36.01	+22:23:37.89					0.40	
14.1	11:49:34.00	+22:24:12.56	···	0.7-4.0	$2.57^{+0.21}_{-0.15}$	2.0-4.0	0.29	0.51
14.2	11:49:33.80	+22:24:09.53					0.22	

[1]Spectroscopic redshifts reported by Smith et al. (2009).

[2]Jouvel et al. (2013), 95% confidence levels on BPZ for entire image system from CLASH imaging.

Table 6. Abell S1063 image constraints

Image system	R.A.	Dec.	Spec z	Photo z[3]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	22:48:46.68	-44:31:37.13	1.24[1,2]	...	...	...	0.50	0.68
1.2	22:48:47.01	-44:31:44.22					0.44	
1.3	22:48:44.74	-44:31:16.32					0.43	
2.1	22:48:46.25	-44:31:52.28	1.26[1,2]	...	...	...	0.16	0.69
2.2	22:48:46.11	-44:31:47.39					0.62	
2.3	22:48:43.16	-44:31:17.62					0.53	
3.1	22:48:46.93	-44:31:55.70	...	1.8-2.3	$2.08^{+0.11}_{-0.19}$	1.2-2.3	0.24	0.45
3.2	22:48:46.54	-44:31:43.43					0.16	
4.1	22:48:46.49	-44:31:48.58	...	0.9-1.8	$1.25^{+0.04}_{-0.06}$	0.9-1.8	0.09	0.32
4.2	22:48:46.40	-44:31:45.91					0.10	
5.1	22:48:43.01	-44:31:24.92	1.40[1,2]	...	...	...	0.73	0.73
5.2	22:48:45.08	-44:31:38.32					0.56	
5.3	22:48:46.36	-44:32:11.51					0.04	
6.1	22:48:41.82	-44:31:41.99	1.43[1,2]	...	...	...	0.50	0.93
6.2	22:48:42.20	-44:31:57.14					1.25	
6.3	22:48:45.23	-44:32:24.00					0.66	
7.1	22:48:40.65	-44:31:38.10	...	1.8-2.8	$1.92^{+0.05}_{-0.03}$	1.8-2.7	0.82	0.77
7.2	22:48:41.82	-44:32:13.60					0.60	
7.3	22:48:43.64	-44:32:25.80					0.18	
8.1	22:48:40.31	-44:31:34.32	...	2.4-3.2	$2.84^{+0.12}_{-0.07}$	2.4-3.1	0.63	0.65
8.2	22:48:41.91	-44:32:18.20					0.33	
8.3	22:48:43.39	-44:32:27.17					0.18	
9.1	22:48:40.27	-44:31:34.61	...	2.4-3.1	$2.87^{+0.08}_{-0.09}$	2.4-3.1	0.50	0.63
9.2	22:48:41.95	-44:32:19.00					0.36	
9.3	22:48:43.27	-44:32:26.92					0.29	
11.1	22:48:42.01	-44:32:27.71	3.12[1]	...	...	...	0.20	0.67
11.2	22:48:41.56	-44:32:23.93					0.24	
11.3	22:48:39.74	-44:31:46.31					0.72	
12.1	22:48:45.37	-44:31:48.18	6.11[4]	...	...	...	1.10	0.98
12.2	22:48:43.45	-44:32:04.63					1.10	
12.3	22:48:45.81	-44:32:14.89					0.50	
12.4	22:48:41.11	-44:31:11.32					0.98	
j7.1	22:48:42.92	-44:32:09.13	...	3.1-3.6	$3.22^{+0.16}_{-0.15}$	2.9-3.6	0.93	0.81
j7.2	22:48:44.98	-44:32:19.28					0.31	
j7.3	22:48:40.96	-44:31:19.52					0.59	
j8.1	22:48:46.01	-44:31:49.87	...	2.8-3.3	$2.47^{+0.08}_{-0.11}$	2.0-3.1	1.38	1.17
j8.2	22:48:46.21	-44:32:03.91					1.51	
j8.3	22:48:42.22	-44:31:10.74					1.21	
j10.1	22:48:39.90	-44:32:01.14	...	3.0-3.5	$3.12^{+0.10}_{-0.13}$	2.8-4.0	0.28	0.65
j10.2	22:48:40.03	-44:32:05.75					0.25	
j10.3	22:48:42.68	-44:32:35.05					0.62	
j11.1	22:48:44.60	-44:32:19.86	...	3.5-4.0	$3.09^{+0.34}_{-0.18}$	2.5-3.9	0.21	0.48
j11.2	22:48:42.92	-44:32:12.23					0.25	
j12.1	22:48:41.32	-44:32:11.83	...	0.5-4.3	$3.70^{+0.50}_{-0.29}$	0.5-4.5	0.31	0.57
j12.2	22:48:44.35	-44:32:31.42					0.35	

[1] Johnson et al. (2014)

[2] Richard et al. (in prep).

[3] Jouvel et al. (2013), 95% confidence levels on BPZ for entire image system from CLASH imaging.

[4] Balestra et al. (2013); Boone et al. (2013).

1. Model parameters

Table 7. Abell 370 image constraints

Image system	R.A.	Dec.	Spec z	Photo z[3]	Model z	z prior	Image plane individual rms ($''$)	Image plane system rms ($''$)
1.1	02:39:52.09	-01:34:37.28	0.81[1]	···	···	···	1.37	1.15
1.2	02:39:54.31	-01:34:34.11					1.37	
1.3	02:39:52.48	-01:34:36.20					1.25	
2.1	02:39:53.72	-01:35:03.56	0.72[1]	···	···	···	0.12	0.47
2.2	02:39:53.03	-01:35:06.65					0.23	
2.3	02:39:52.50	-01:35:04.60					0.38	
2.4	02:39:52.65	-01:35:05.36					0.15	
2.5	02:39:52.70	-01:35:05.79					0.07	
3.1	02:39:51.75	-01:34:01.10	1.42[2]	···	···	···	0.23	0.59
3.2	02:39:52.44	-01:33:57.35					0.54	
3.3	02:39:54.54	-01:34:02.25					0.14	
4.1	02:39:55.11	-01:34:35.15	1.27[2]	···	···	···	1.47	1.05
4.2	02:39:52.98	-01:34:34.94					0.37	
4.3	02:39:50.86	-01:34:40.95					1.17	
5.1	02:39:53.63	-01:35:21.05	···	1.0-1.8	$1.15^{+0.03}_{-0.03}$	1.0-1.8	1.79	1.17
5.2	02:39:53.07	-01:35:21.66					0.17	
5.3	02:39:52.51	-01:35:20.91					1.54	
6.1	02:39:52.67	-01:34:38.28	1.06[2]	···	···	···	0.22	0.66
6.2	02:39:51.48	-01:34:42.10					0.62	
6.3	02:39:55.11	-01:34:38.10					0.39	
7.1	02:39:52.74	-01:34:49.88	···	2.8-3.2	$2.07^{+0.11}_{-0.06}$	0.9-3.2	0.74	0.90
7.2	02:39:52.76	-01:34:51.06					0.62	
7.3	02:39:52.51	-01:35:08.60					0.87	
7.4	02:39:50.77	-01:34:48.44					0.95	
7.5	02:39:56.11	-01:34:41.09					0.80	
8.1	02:39:51.47	-01:34:11.64	···	2.8-3.4	$2.26^{+0.07}_{-0.06}$	2.0-3.4	0.87	0.90
8.2	02:39:50.85	-01:34:25.65					0.65	
8.3	02:39:56.18	-01:34:24.46					0.88	
9.1	02:39:50.98	-01:34:40.84	···	1.0-1.7	$1.50^{+0.05}_{-0.03}$	1.0-1.7	0.25	0.46
9.2	02:39:52.67	-01:34:34.94					0.16	
9.3	02:39:55.68	-01:34:35.98					0.23	

[1]Richard et al. (2010).

[2]Richard et al. (in prep.).

[3]BPZ measured from *HST* preliminary data reductions.

Table 8. Abell 2744 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$12.9^{+1.3}_{-3.8}$	$47.9^{+8.5}_{-5.8}$	[0]	···	[20.0]	[1500]	504^{+89}_{-58}
cluster halo #2	$1.25^{+1.2}_{-1.4}$	$-5.45^{+1.9}_{-2.7}$	[0]	···	57.7^{+15}_{-16}	[1500]	549^{+76}_{-77}
cluster halo #3	$19.7^{+1.4}_{-0.73}$	$-18.3^{+0.98}_{-0.64}$	$0.538^{+0.059}_{-0.041}$	$33.7^{+7.5}_{-6.7}$	$25.5^{+6.3}_{-4.9}$	[1500]	516^{+44}_{-43}
cluster halo #4 (N)	-34.8^{+11}_{-15}	133^{+17}_{-15}	[0]	···	[150]	[1500]	890^{+140}_{-220}
cluster halo #5 (NW)	[-102]	[84.7]	0.12 (< 0.23)	44.1^{+17}_{-21}	$88.6^{+14}_{-3.7}$	[1500]	885^{+82}_{-31}
cluster galaxy #1	[0.000]	[0.000]	[0.800]	$57.8^{+8.5}_{-6.2}$	[1.35]	457^{+150}_{-270}	359^{+23}_{-18}
cluster galaxy #2	[18.0]	[-20.1]	$0.551^{+0.23}_{-0.21}$	93.1^{+14}_{-13}	[0.159]	363^{+110}_{-130}	290^{+46}_{-33}
$L^\star$ galaxy	$m_\star = 18.50, z = 0.308$ (ACS F814W)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=00:14:20.70, δ=-30:24:00.62, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

Table 9. MACS J0416.1-2403 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$16.2^{+1.1}_{-0.9}$	$16.6^{+2.0}_{-1.3}$	$0.618^{+0.094}_{-0.056}$	$-34.1^{+3.7}_{-2.7}$	91.3^{+13}_{-20}	[1500]	938^{+69}_{-130}
cluster halo #2	$-9.03^{+6.0}_{-6.9}$	$-23.2^{+6.9}_{-8.7}$	$0.731^{+0.07}_{-0.21}$	$-41.7^{+5.3}_{-6.6}$	68.3^{+48}_{-22}	[1500]	521^{+250}_{-78}
foreground galaxy*	[-20.7]	[-50.7]	[0.143]	[-44.4]	93.4^{+14}_{-23}	[1500]	774^{+75}_{-210}
cluster galaxy #1	[-9.02]	[-21.0]	[0.0710]	[-44.7]	[0.152]	[30.4]	320^{+55}_{-59}
cluster galaxy #2	[-7.48]	[11.2]	[0]	···	[0.5]	[250]	58.0^{+23}_{-16}
$L^\star$ galaxy	$m_\star = 19.33, z = 0.396$ (ACS F775W)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=4:16:08.331, δ=-24:04:17.74, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

*Parameters intrinsic to galaxy ($r_{\rm core}$, $r_{\rm cut}$, and σ) derived by arbitrarily placing the galaxy at cluster redshift, $z = 0.396$.

Table 10. MACS J0717.5+3745 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$-5.70^{+0.81}_{-1.2}$	$6.39^{+1.1}_{-1.3}$	$0.314^{+0.088}_{-0.074}$	$82.6^{+8.3}_{-7.3}$	48.1^{+17}_{-20}	[1500]	832^{+67}_{-67}
cluster halo #2	$-34.9^{+1.0}_{-0.4}$	$-12.8^{+0.5}_{-1.5}$	$0.869^{+0.039}_{-0.030}$	$55.2^{+0.8}_{-2.2}$	$28.3^{+9.8}_{-19}$	[1500]	694^{+33}_{-35}
cluster halo #3	$-73.6^{+5.8}_{-2.6}$	$39.3^{+0.88}_{-2.9}$	$0.822^{+0.040}_{-0.040}$	$10.1^{+2.0}_{-1.5}$	156^{+20}_{-38}	[1500]	1080^{+55}_{-120}
cluster halo #4	$-117^{+3.5}_{-4.8}$	$72.3^{+2.4}_{-2.3}$	$0.565^{+0.22}_{-0.14}$	$9.64^{+5.8}_{-9.1}$	$73.5^{+53}_{-9.4}$	[1500]	790^{+170}_{-31}
foreground galaxy*	[19.6]	[-21.8]	[0]	···	110^{+54}_{-33}	336^{+43}_{-150}	854^{+160}_{-79}
cluster galaxy	[0.929]	[32.6]	[0.329]	[-20.0]	[0.315]	$18.1^{+35}_{-7.8}$	1010^{+310}_{-360}
$L^\star$ galaxy	$m_\star = 20.66, z = 0.545$ (ACS F814W, Limousin et al. 2012)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=07:17:35.57, δ=+37:44:44.80, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

*Parameters intrinsic to galaxy ($r_{\rm core}$, $r_{\rm cut}$, and σ) derived by arbitrarily placing the galaxy at cluster redshift, $z = 0.545$.

Table 11. MACS J1149.5+2223 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$6.79^{+2.8}_{-2.8}$	$-5.14^{+2.1}_{-1.8}$	$0.701^{+0.021}_{-0.097}$	$29.8^{+1.3}_{-2.2}$	$64.9^{+8.6}_{-10.}$	[1500]	812^{+55}_{-65}
cluster halo #2	$-12.6^{+1.1}_{-1.9}$	$26.3^{+3.7}_{-2.8}$	[0]	···	107^{+31}_{-18}	[1500]	919^{+130}_{-88}
cluster halo #3 (N)	$16.9^{+0.39}_{-0.55}$	$101^{+0.93}_{-1.1}$	[0.800]	$-60.1^{+4.3}_{-6.9}$	[0.261]	[300]	371^{+57}_{-40}
BCG	[0]	[0]	[0.2]	[124]	[1]	[200]	299^{+23}_{-58}
cluster galaxy	[25.6]	[-32.2]	[0.205]	[47.0]	[0.233]	[40.2]	544^{+32}_{-28}
$L^\star$ galaxy	$m_\star = 20.3, z = 0.543$ (K band, Smith et al. 2009)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=11:49:35.695, δ=+22:23:54.70, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

Table 12. Abell S1063 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$-0.826^{+0.59}_{-0.32}$	$0.0556^{+0.38}_{-0.35}$	$0.573^{+0.025}_{-0.026}$	$-36.2^{+0.56}_{-0.52}$	$84.9^{+8.7}_{-8.5}$	[1500]	1190^{+24}_{-29}
cluster halo #2 (NW)	386^{+170}_{-67}	212^{+89}_{-22}	[0]	···	[50.0]	[1500]	1820^{+650}_{-260}
cluster halo #3 (S)	$12.9^{+31}_{-9.9}$	-111^{+24}_{-87}	[0]	···	[50.0]	[1500]	592^{+390}_{-180}
BCG	[0]	[0]	[0.269]	[-37.7]	[0.208]	[41.5]	356^{+77}_{-76}
cluster galaxy #1	[31.6]	[17.6]	[0.246]	[-86.3]	[0.107]	[21.4]	115^{+68}_{-99}
cluster galaxy #2	[-29.4]	[-34.7]	[0.635]	[89.2]	[0.0580]	[11.6]	85.8^{+67}_{-81}
cluster galaxy #3	[-42.6]	[-14.1]	[0.250]	[4.90]	[0.0410]	[8.23]	$74.2^{+25}_{-7.5}$
$L^\star$ galaxy	$m_\star = 18.82, z = 0.348$ (ACS F814W)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=22:48:43.970, δ=-44:31:51.22, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

Table 13. Abell 370 model parameters

Component	ΔRA (″)	ΔDec (″)	e	θ (°)	$r_{\rm core}$ (kpc)	$r_{\rm cut}$ (kpc)	σ (km s^{-1})
cluster halo #1	$0.143^{+0.56}_{-0.28}$	$34.9^{+2.4}_{-0.8}$	$0.0913^{+0.023}_{-0.062}$	$89.4^{+10.}_{-3.9}$	$94.7^{+3.7}_{-15}$	[1500]	1040^{+45}_{-120}
cluster halo #2	$-2.46^{+0.27}_{-0.30}$	$1.96^{+2.4}_{-1.3}$	$0.473^{+0.024}_{-0.027}$	$80.8^{+0.99}_{-0.74}$	$88.2^{+8.7}_{-5.7}$	[1500]	969^{+100}_{-46}
BCG	[0]	[0]	[0.373]	[-83.8]	[0.196]	[39.2]	405^{+25}_{-26}
cluster galaxy	[-7.95]	[-9.80]	[0.8]	121^{+31}_{-19}	[0.0790]	[15.8]	114^{+18}_{-15}
$L^\star$ galaxy	$m_\star = 19.04, z = 0.375$ (ACS F814W)				0.15	30	120

Note. — Parameters for best fit-model and errors representing the 95% confidence level of the parameter values from the MCMC chain. Values in brackets are not optimized, or fixed parameters. ΔRA and ΔDec are measured with respect to the galaxy at α=2:39:53.125, δ=-1:34:56.420, position angles are measured north of west, ellipticity is defined as $e = (a^2 - b^2)/(a^2 + b^2)$.

Table 14. List of Delivered Files

File name	Deliverable	Source redshift	Size [pixels]	Pixel scale [″]
...mag-z1 ...	magnification map (μ)	1	5004×5004	0.06
...mag-z2 ...	magnification map (μ)	2	5004×5004	0.06
...mag-z4 ...	magnification map (μ)	4	5004×5004	0.06
...mag-z9 ...	magnification map (μ)	9	5004×5004	0.06
...deflect-x ...	deflection matrix (x, units=arcsec)	9	5004×5004	0.06
...deflect-y ...	deflection matrix (y, units=arcsec)	9	5004×5004	0.06
...kappa ...	convergence map (κ)	9	5004×5004	0.06
...gamma ...	shear map (γ)	9	5004×5004	0.06
kappa**.fits	low rez convergence from MCMC	9	1251×1251	0.24
gamma**.fits	low rez shear from MCMC	9	1251×1251	0.24

Note. — All high-resolution FITS files are named with the same format: hlsp_frontier_model_[clustername]_sharon_[column 1]_v2.fits.