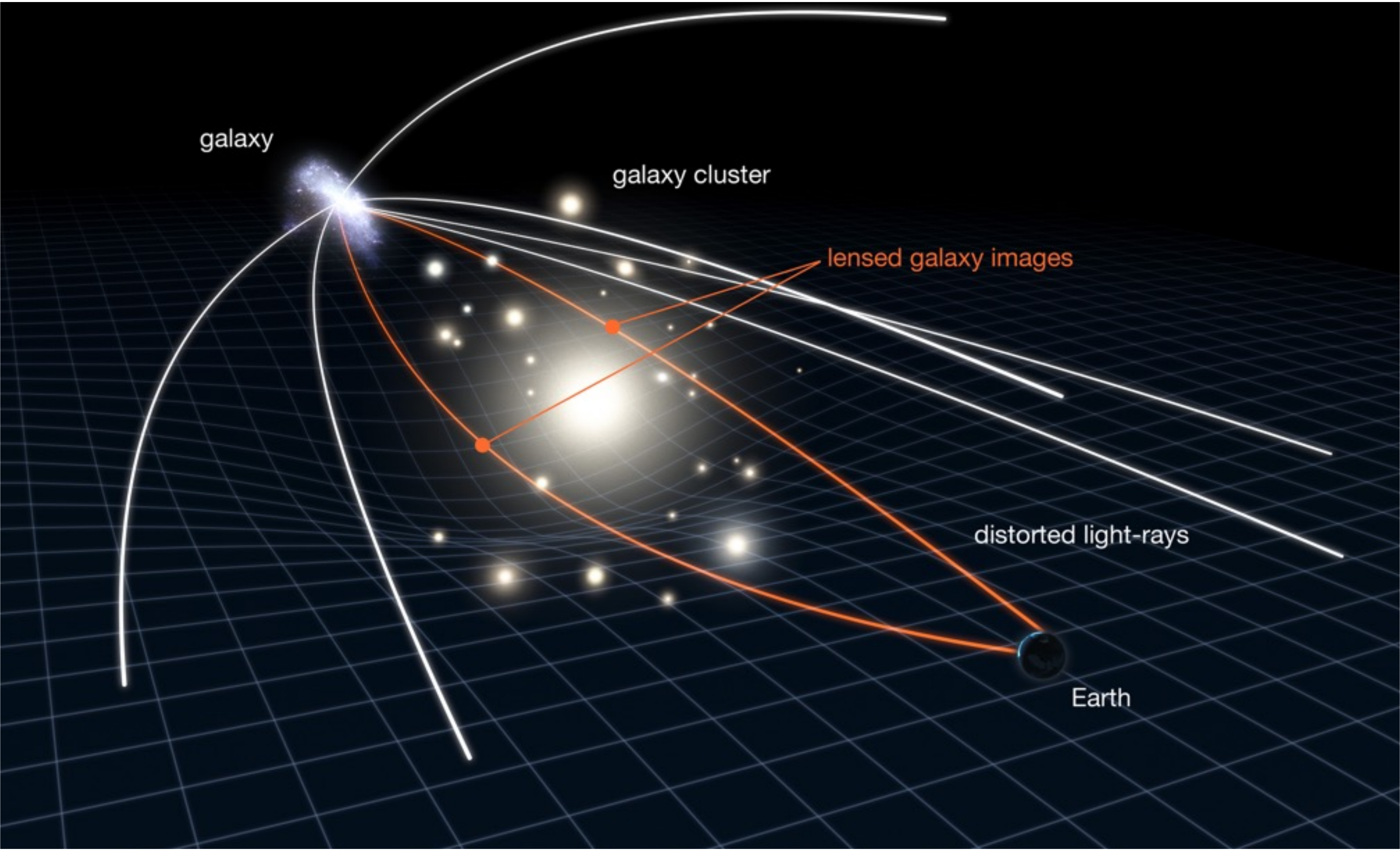
Strong Lensing with CSS-OS:

Ran Li (李然） NAOC

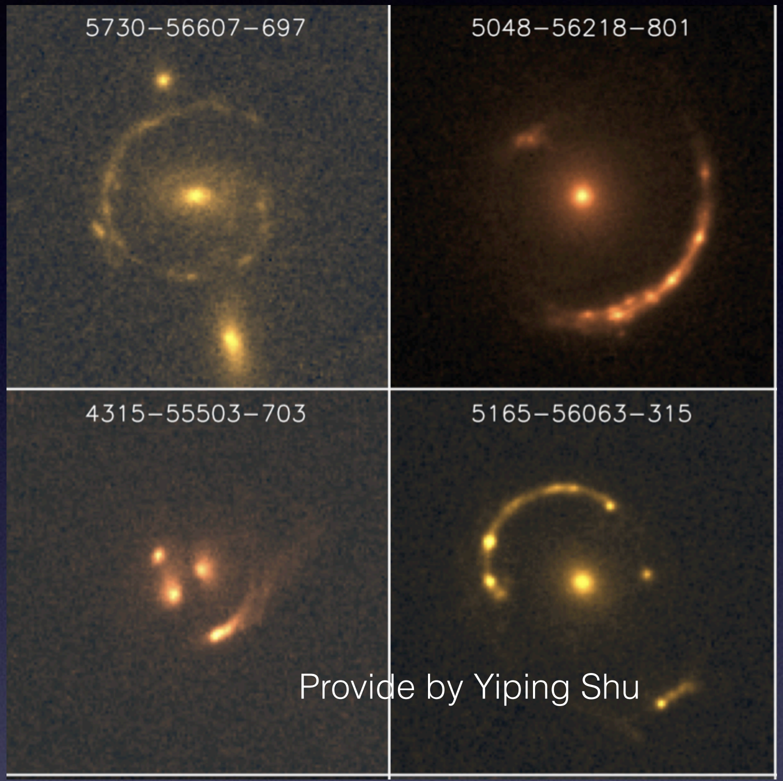
On behalf of Strong Lensing Working Group:

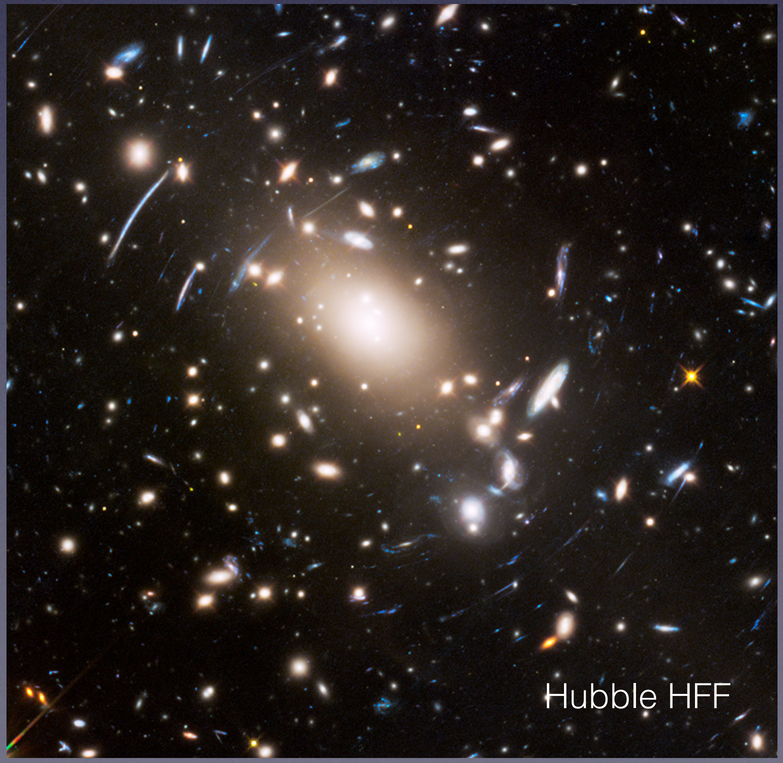
Ran Li, Nan Li, Huanyuan Shan, Yun Chen,
Dezi Liu, GuoLiang Li, Xiaoyue Cao, Xinzhong Er,
Yiping Shu, Xin Wang, Ye Cao, XiaoLei Meng, Wei Du


galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth

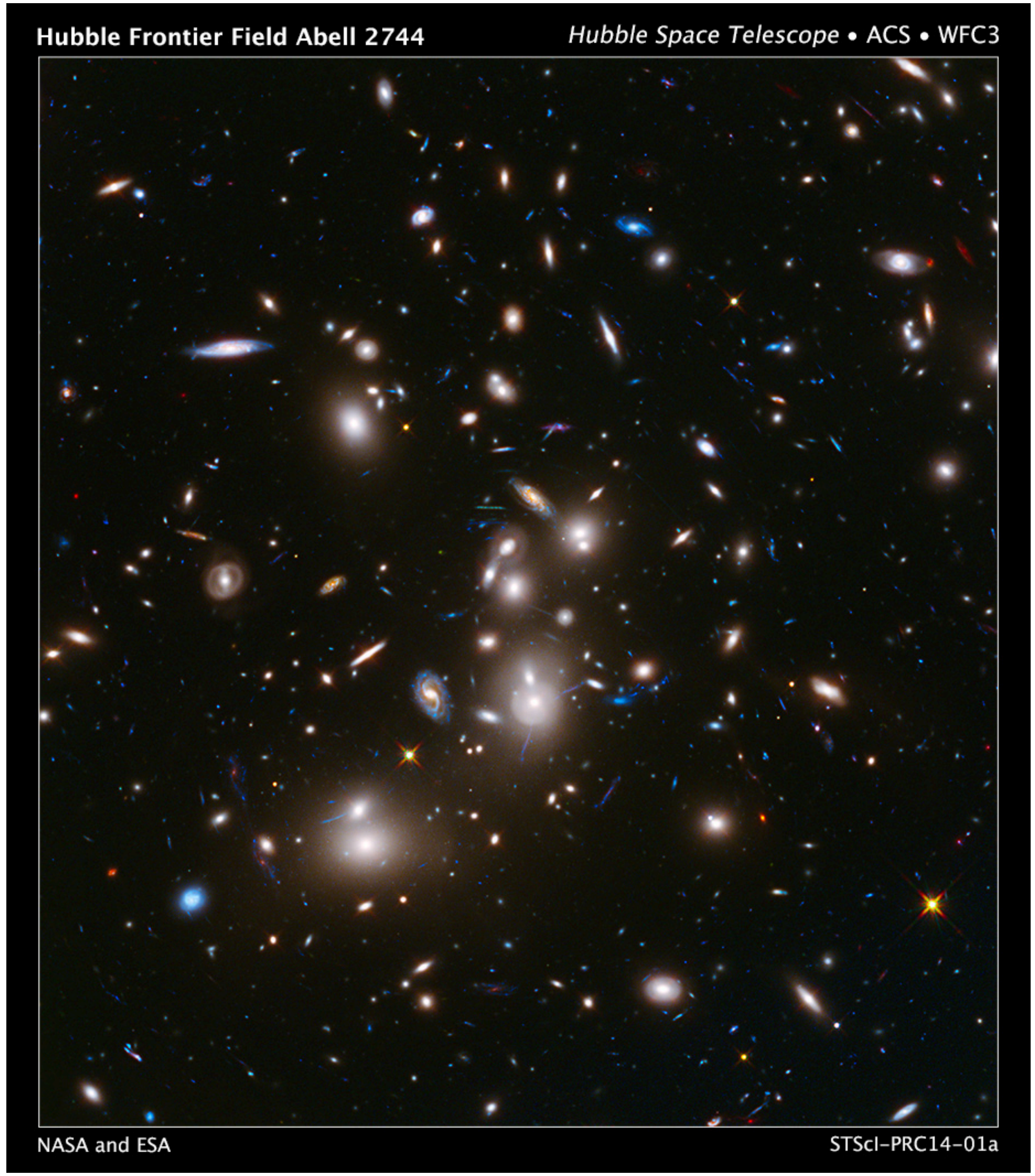
Expectation for CSS-OS

- ~100000 galaxy scale strong lens systems (currently ~400), Including ~1000 double lens system
- Hundreds of massive clusters with many multiple images
- Accurate photo-z for both lens and source.



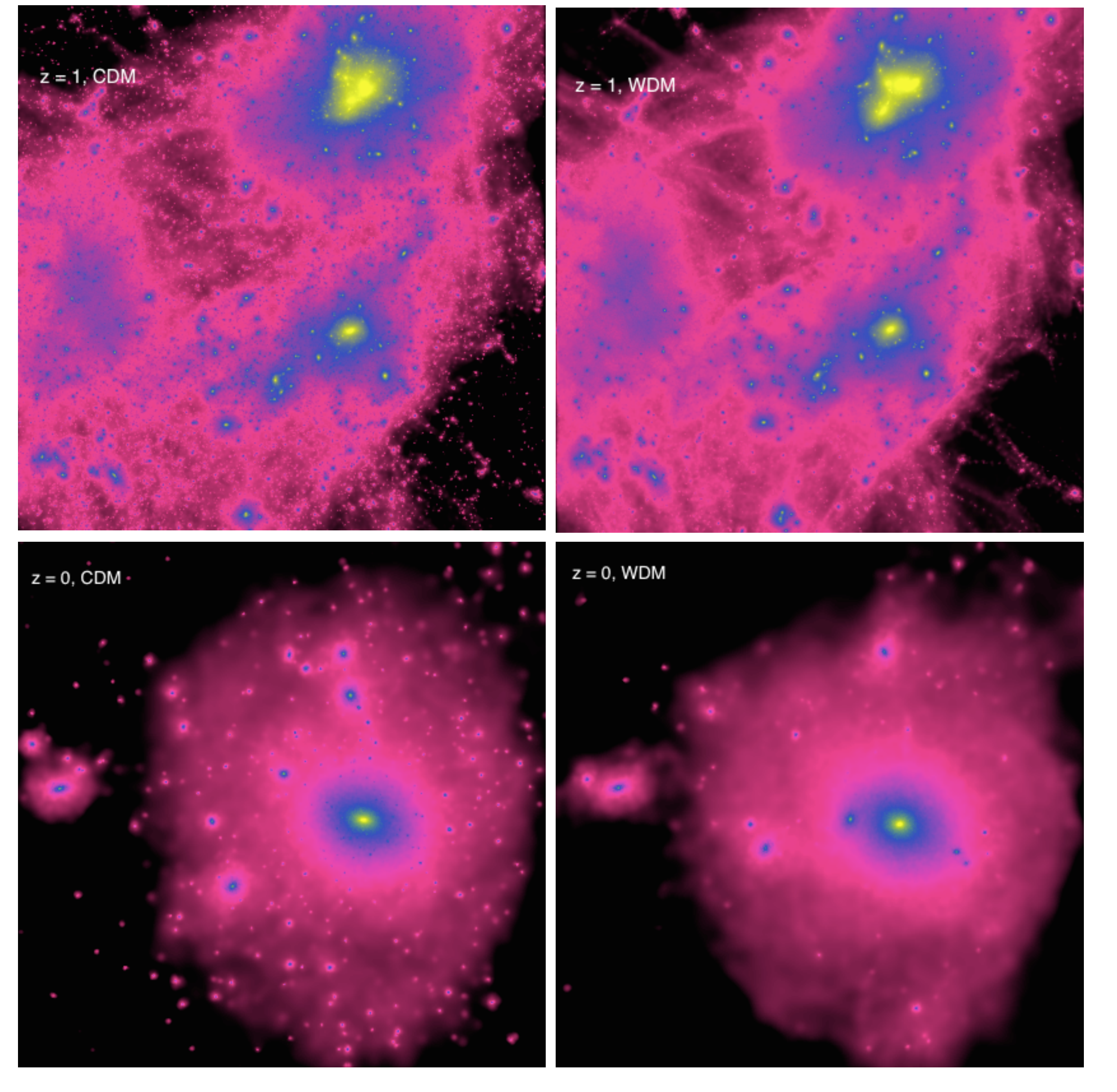


Deeps fields

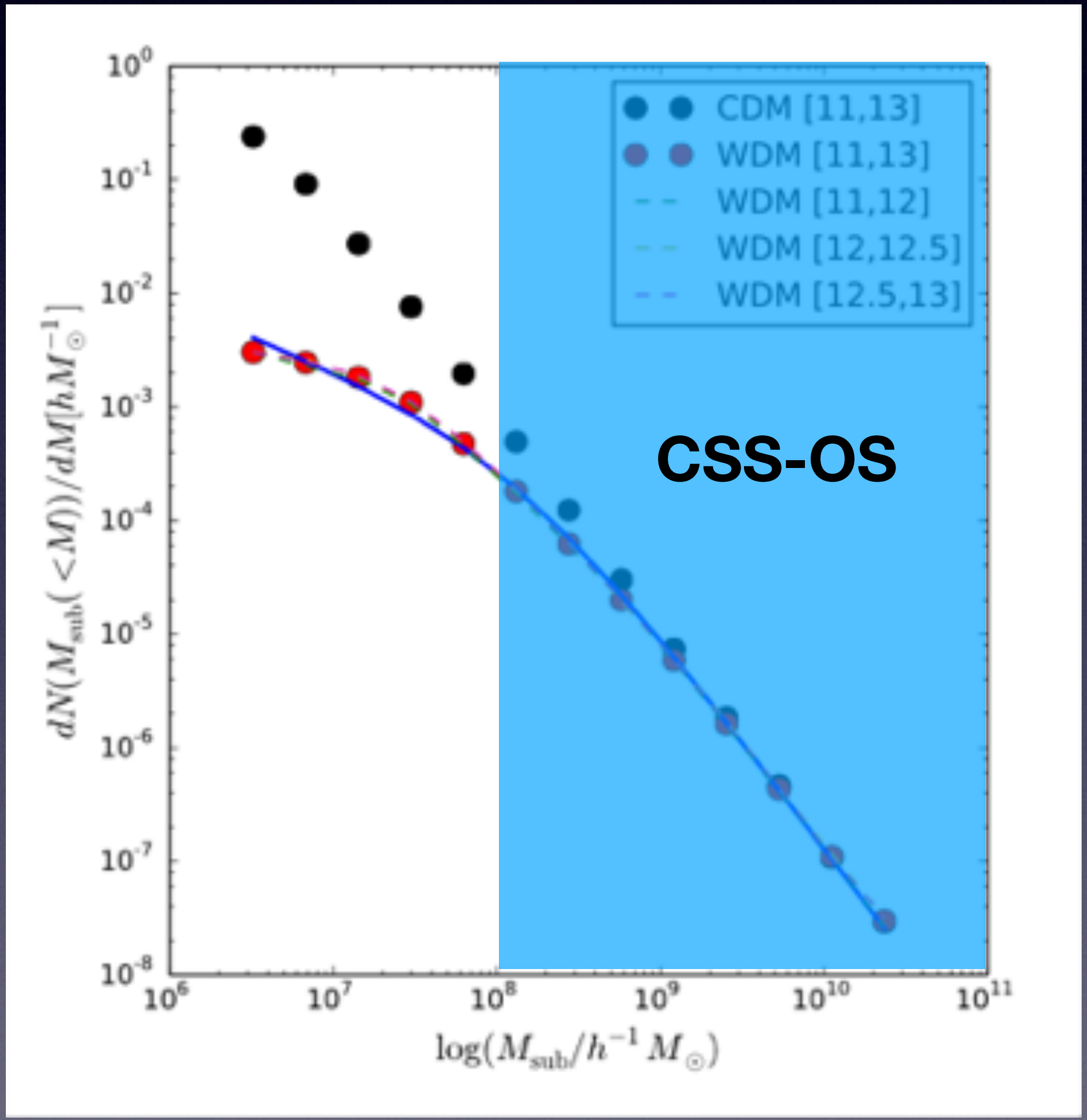


Main survey: 300-400 deg^2 to 27th, 10 deg^2 to 28th,
MCI: 3 clusters to 30th in g band

Identity of Dark matter

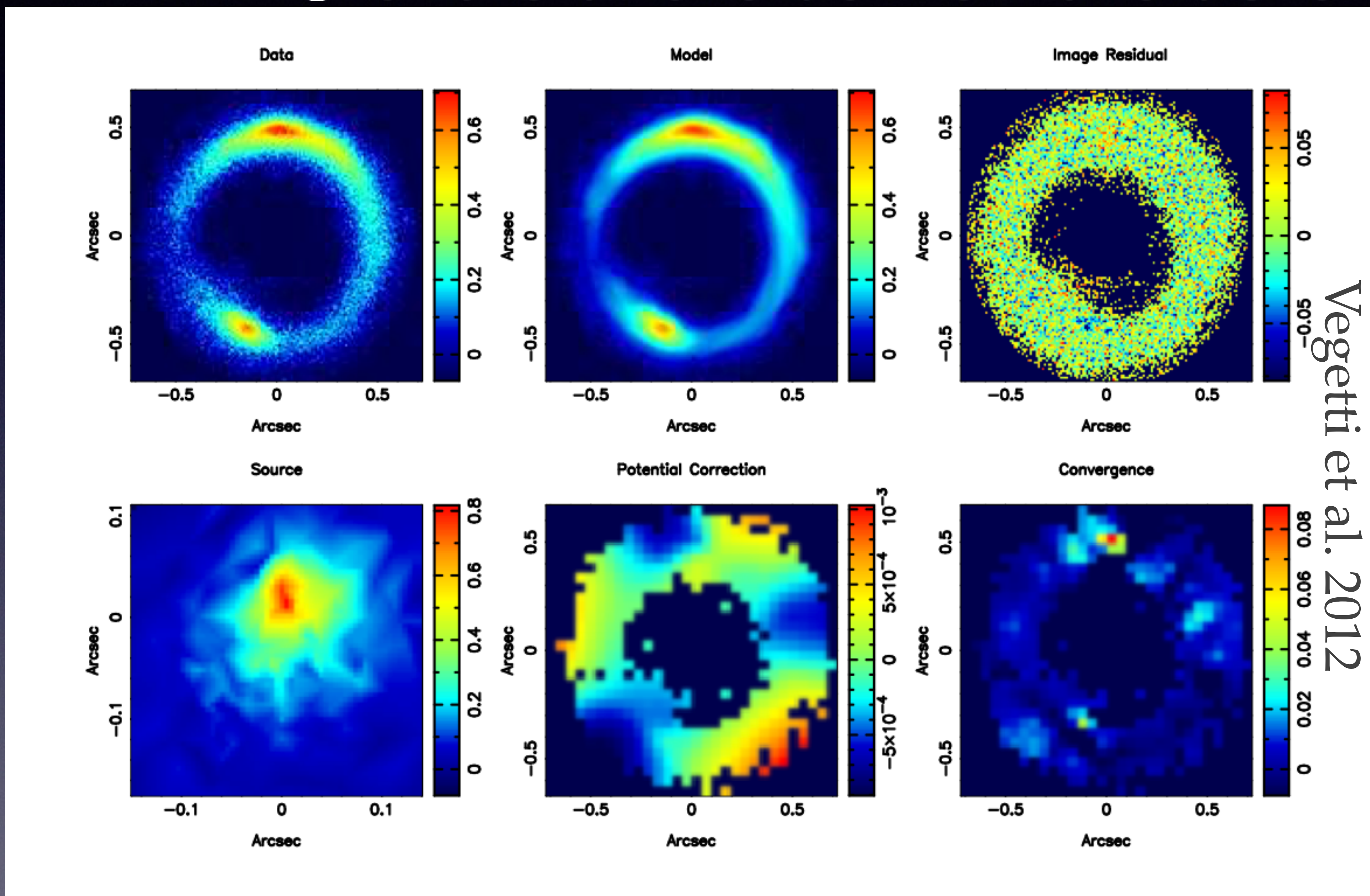


COCO simulations Bose+ 2016

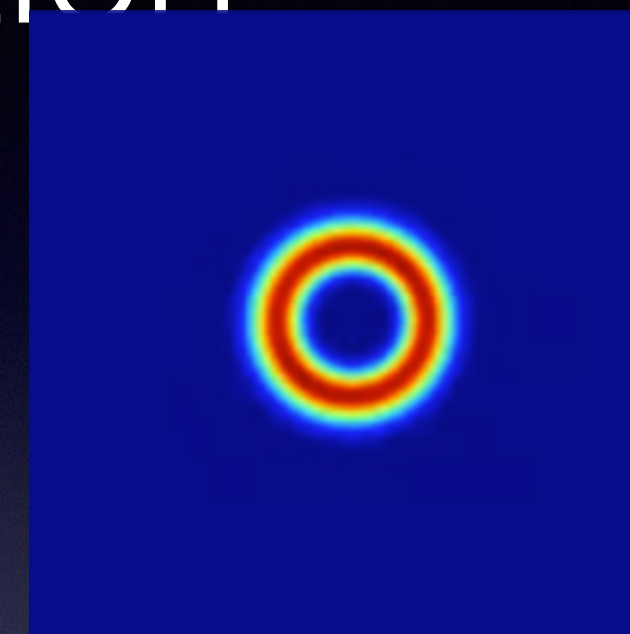


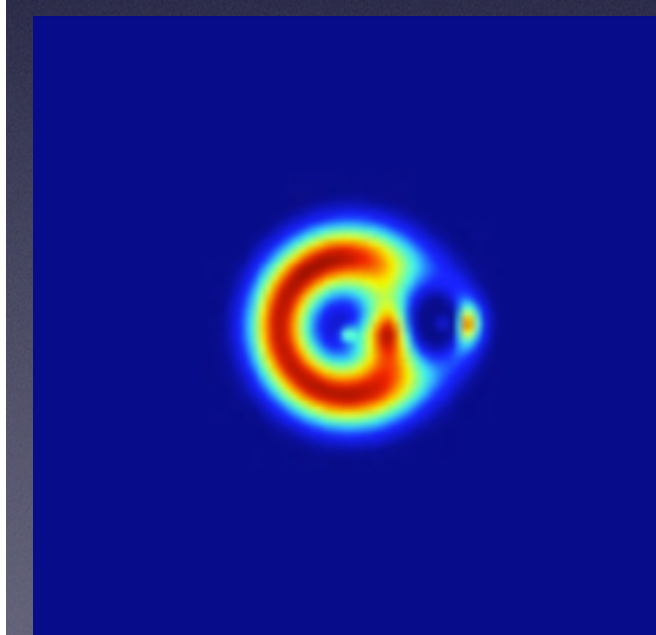
Li et al. 2016 arxiv 1512.06507

DM on small scales: Substructure detection

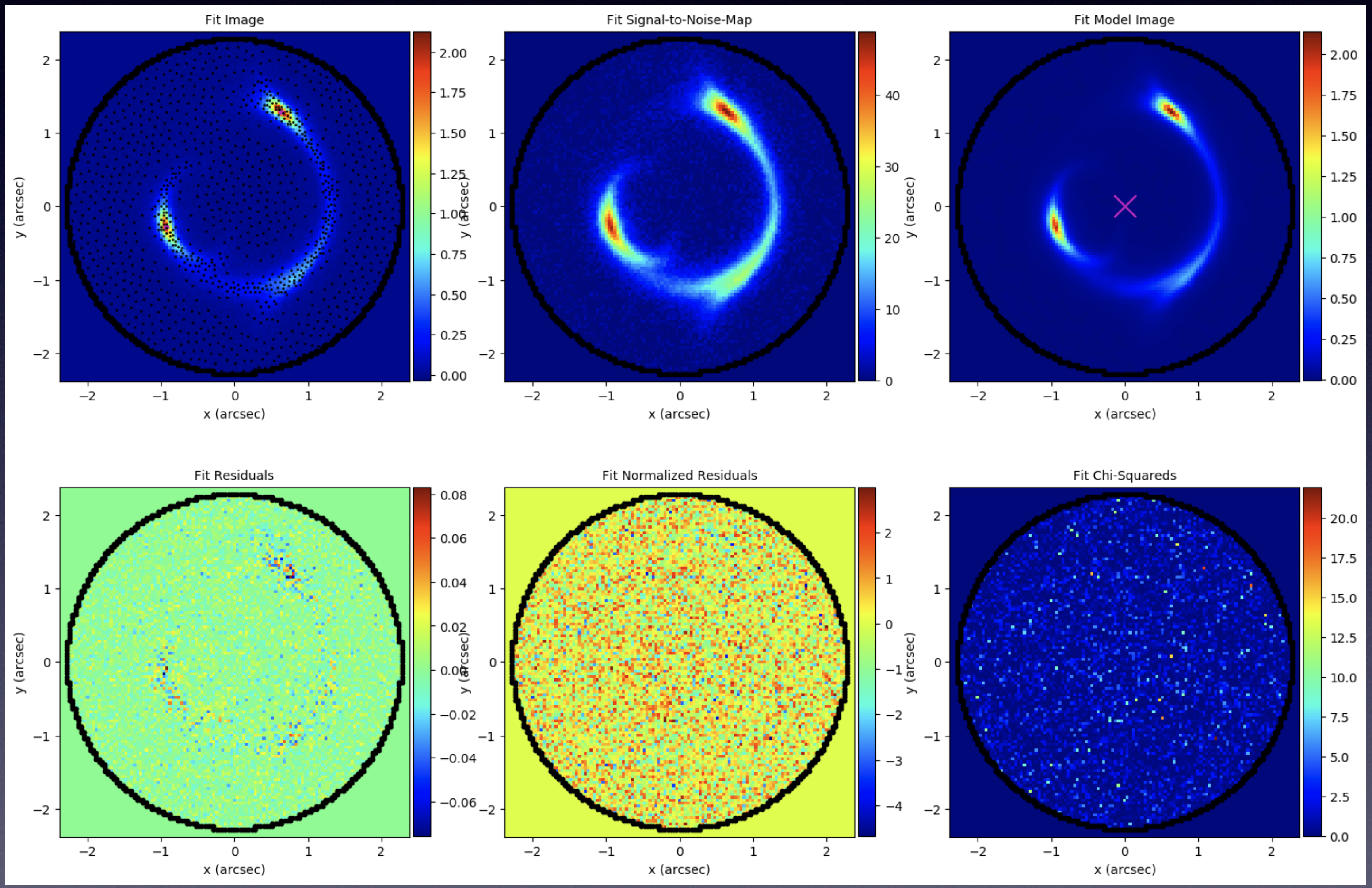


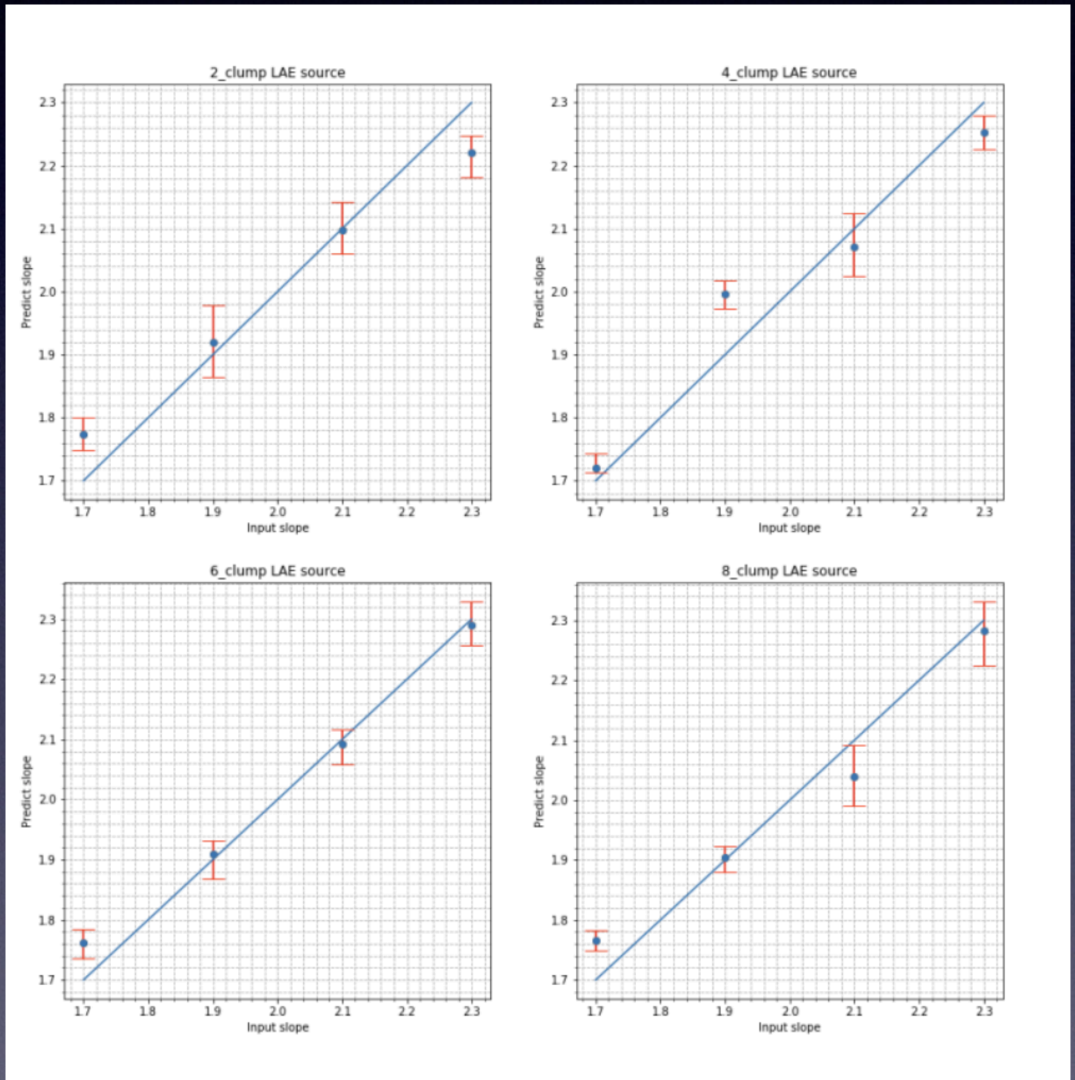
Vegetti et al. 2012





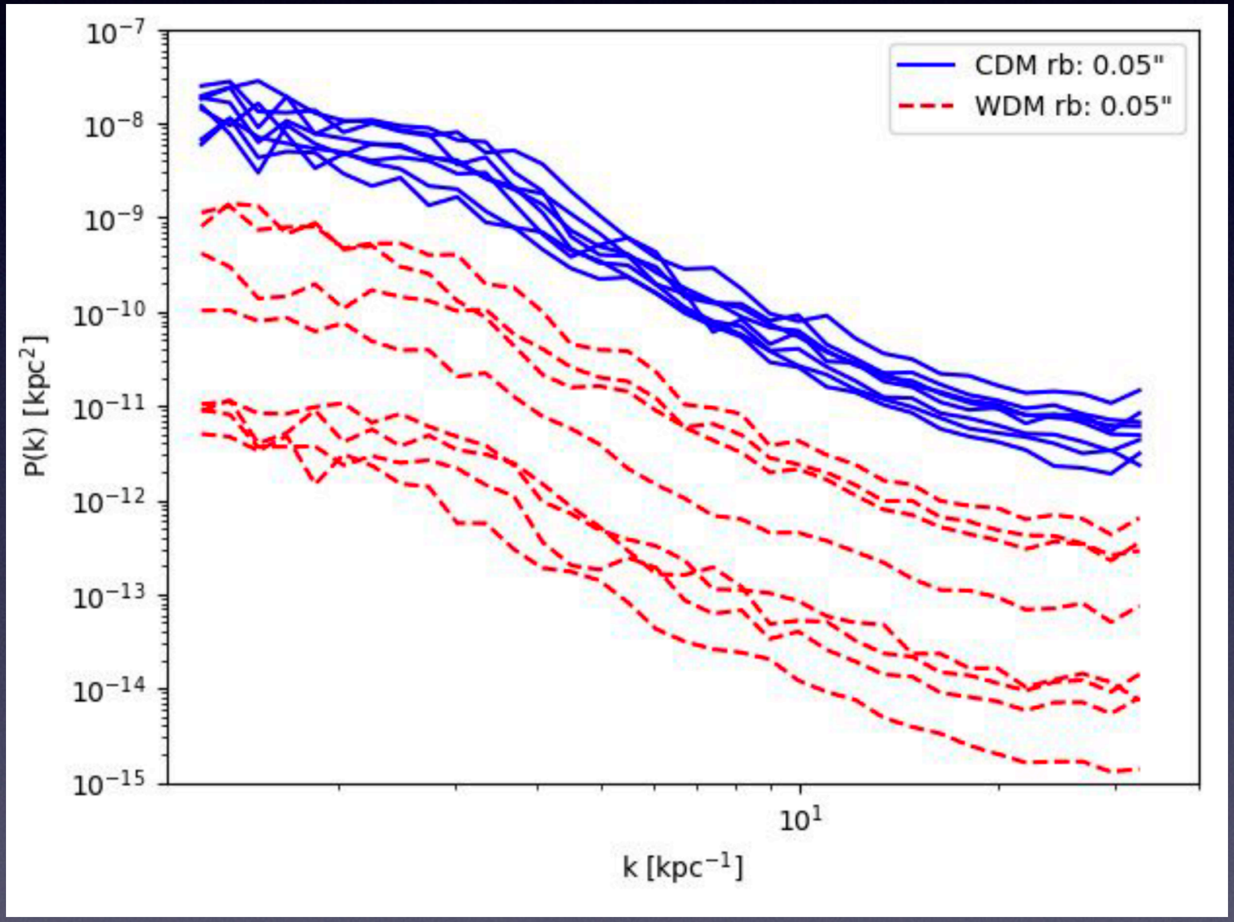
Galactic Lens Modeling

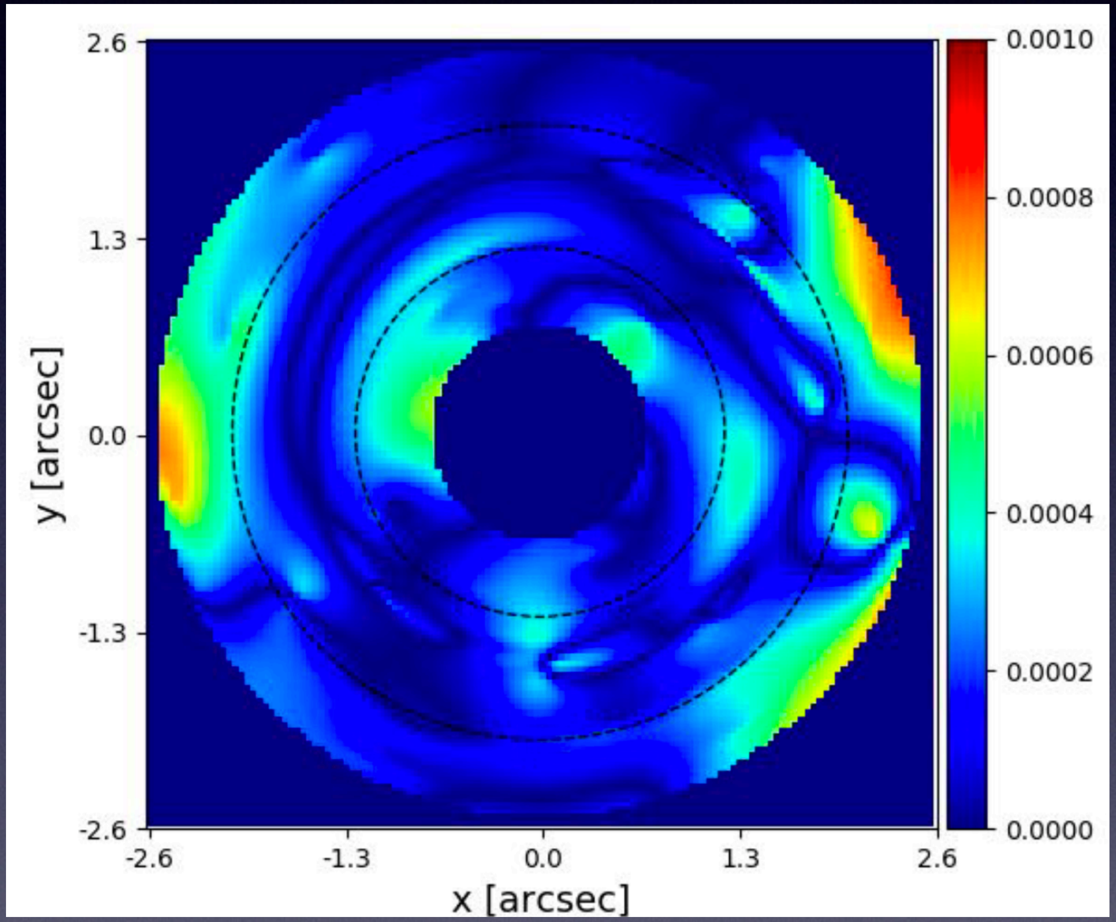




By Xiaoyue Cao with PyAUTOLENS

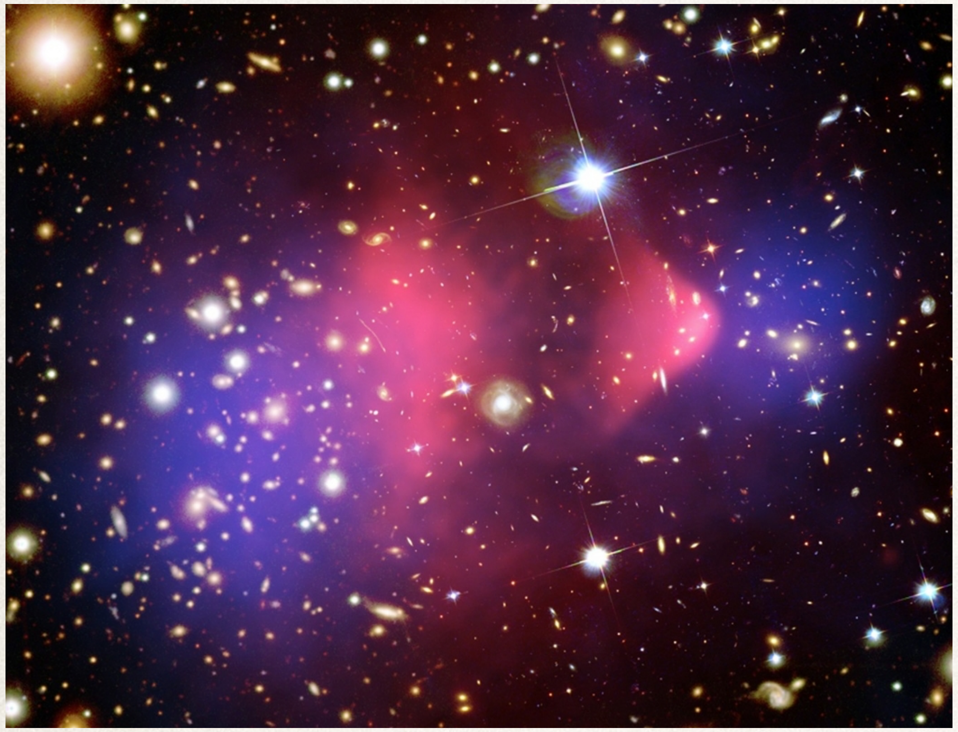
Power spectrum of subhalo

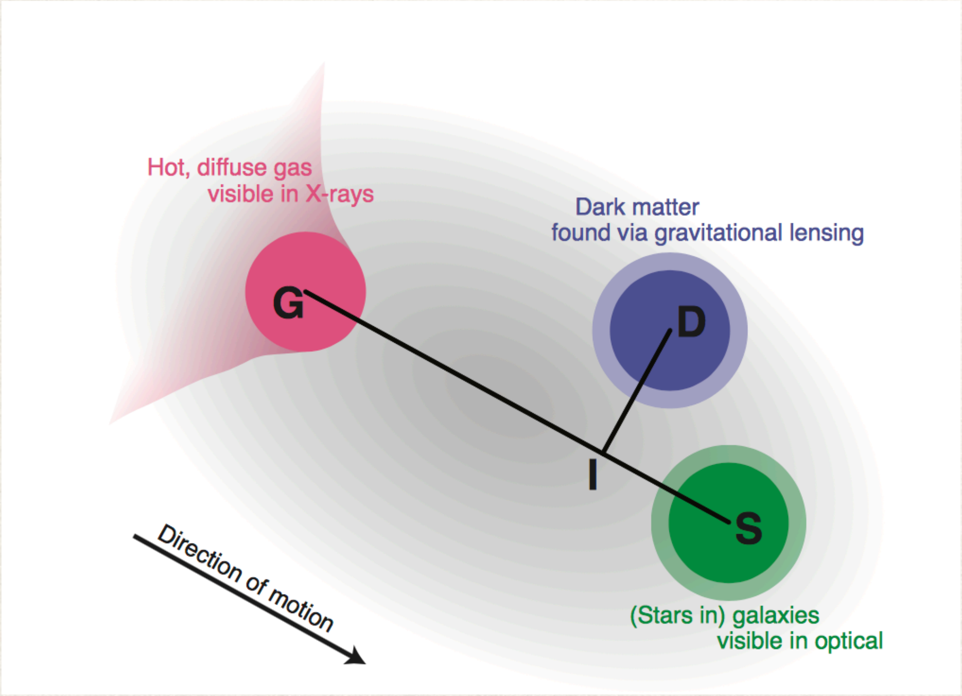


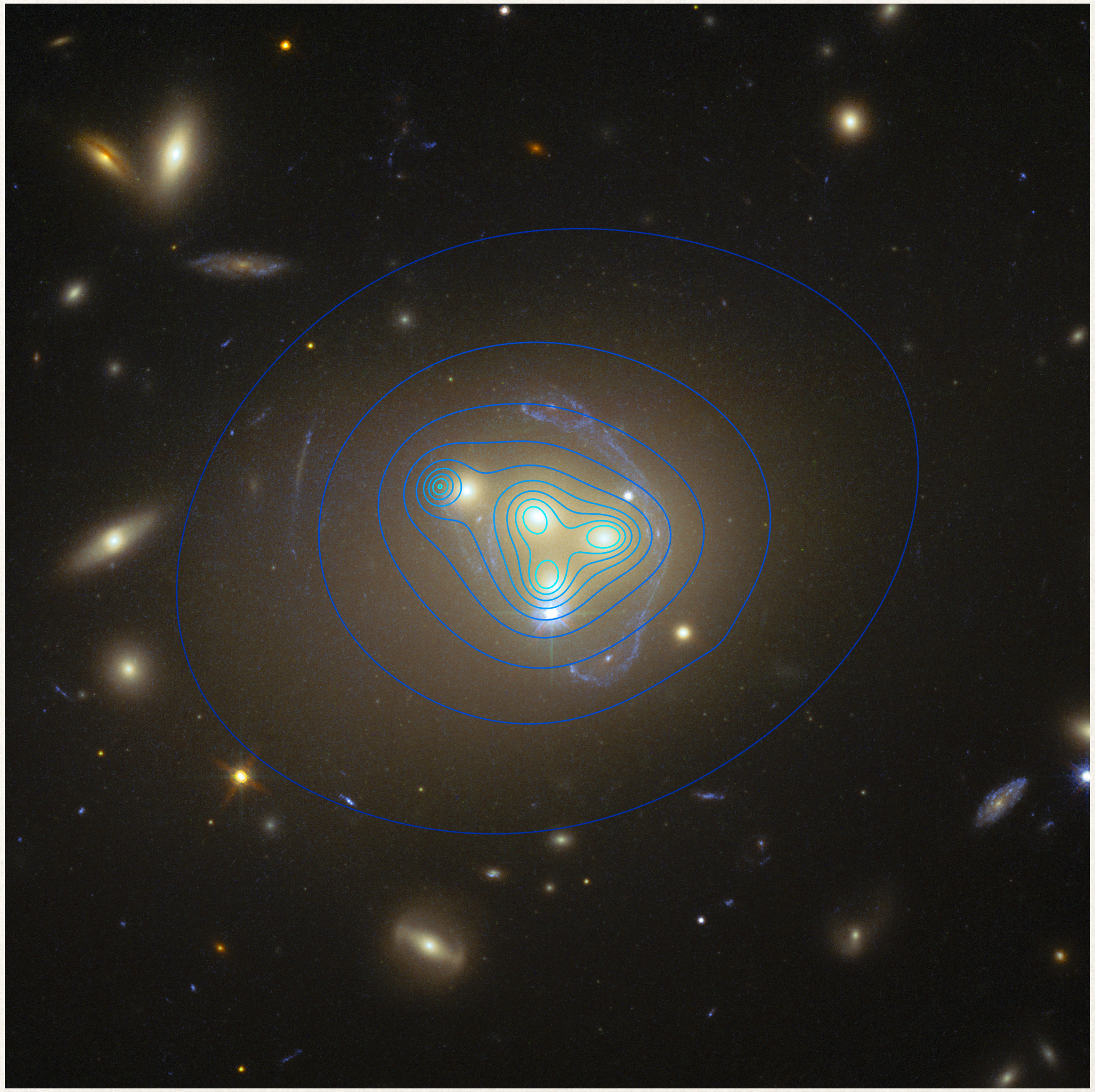


He et al. in prep

Self-interacting dark matter?





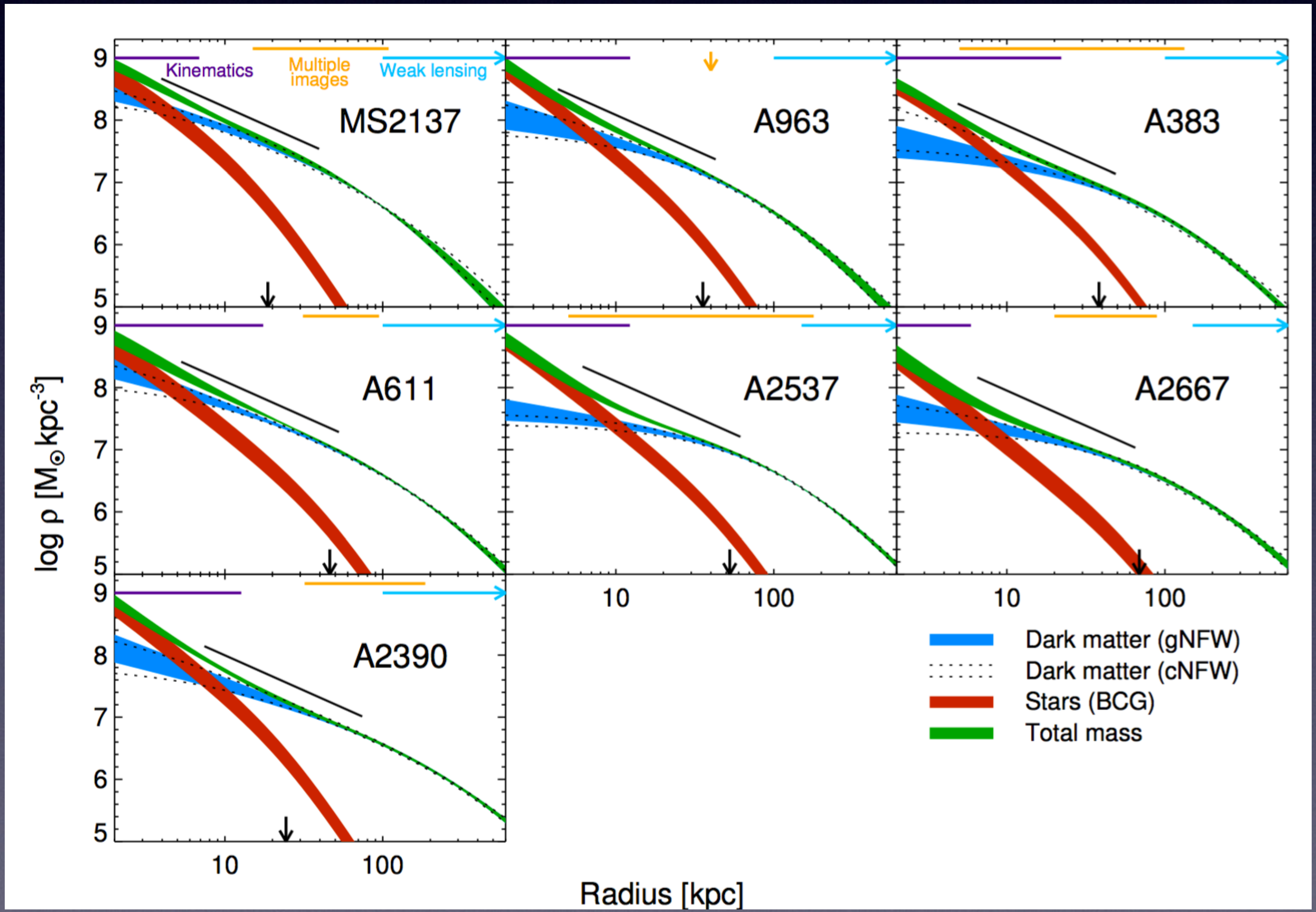


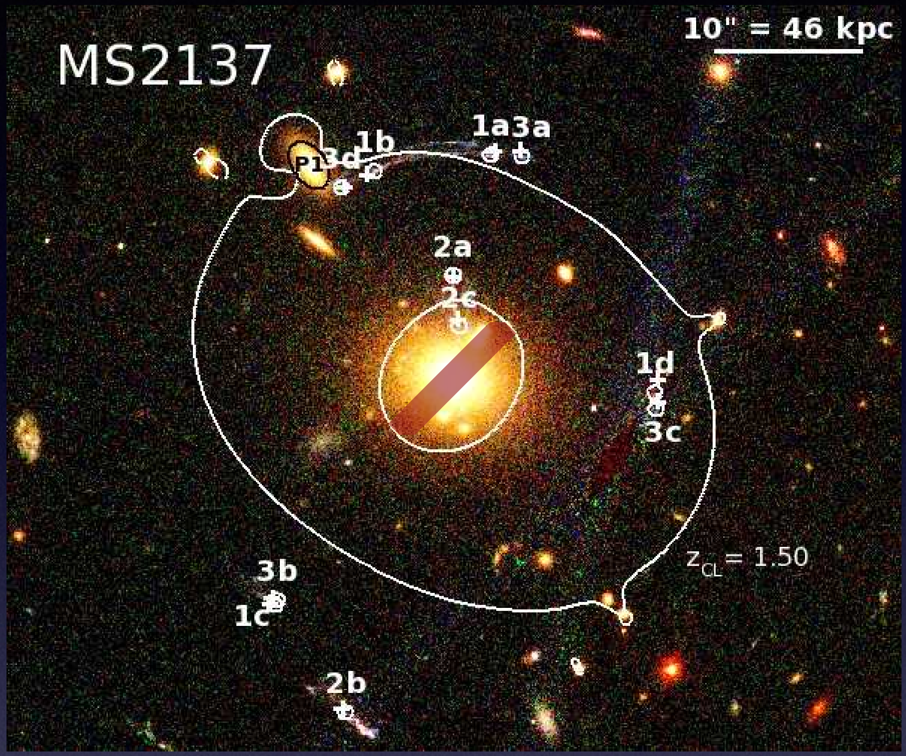
Galaxy cluster Abell 3827
offset is 1.62+0.47 kpc ?

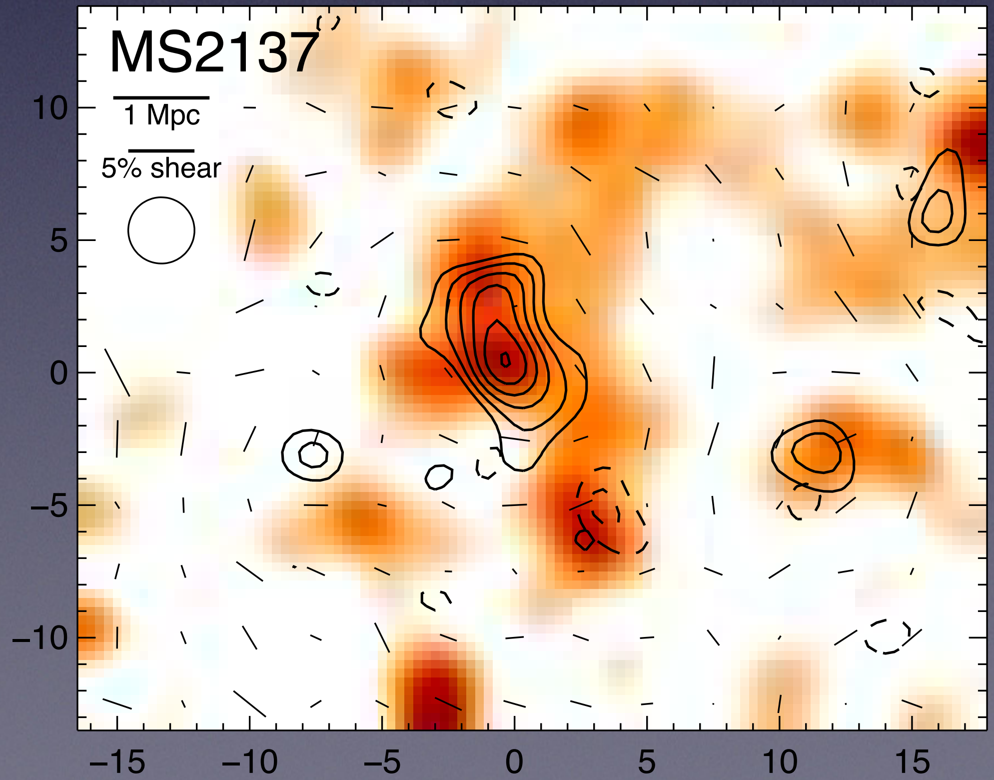
Massey et al. 2015

Density profile at the cluster center

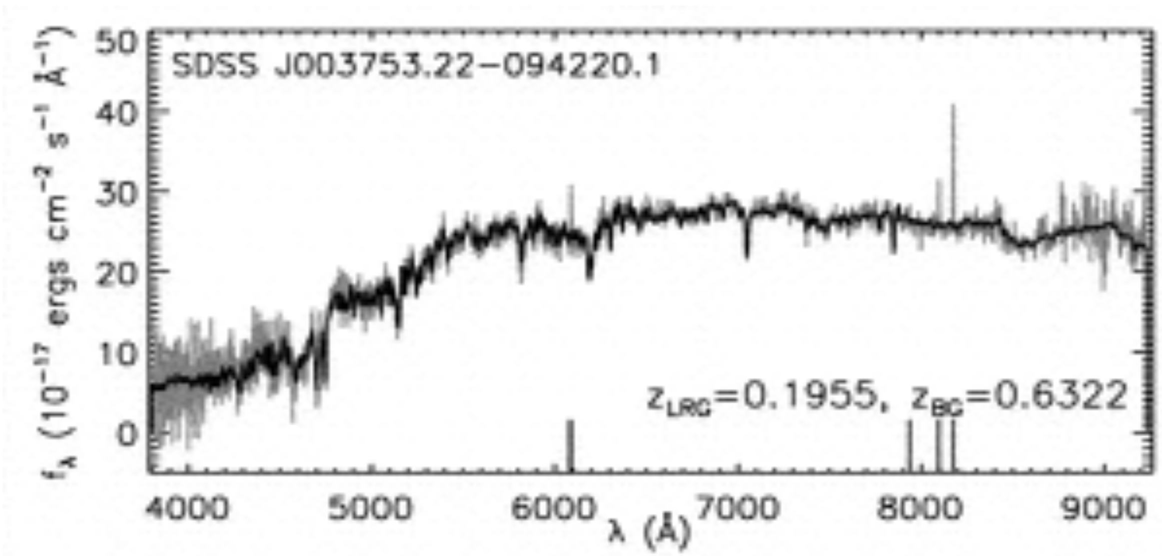
Newman et al . 2012

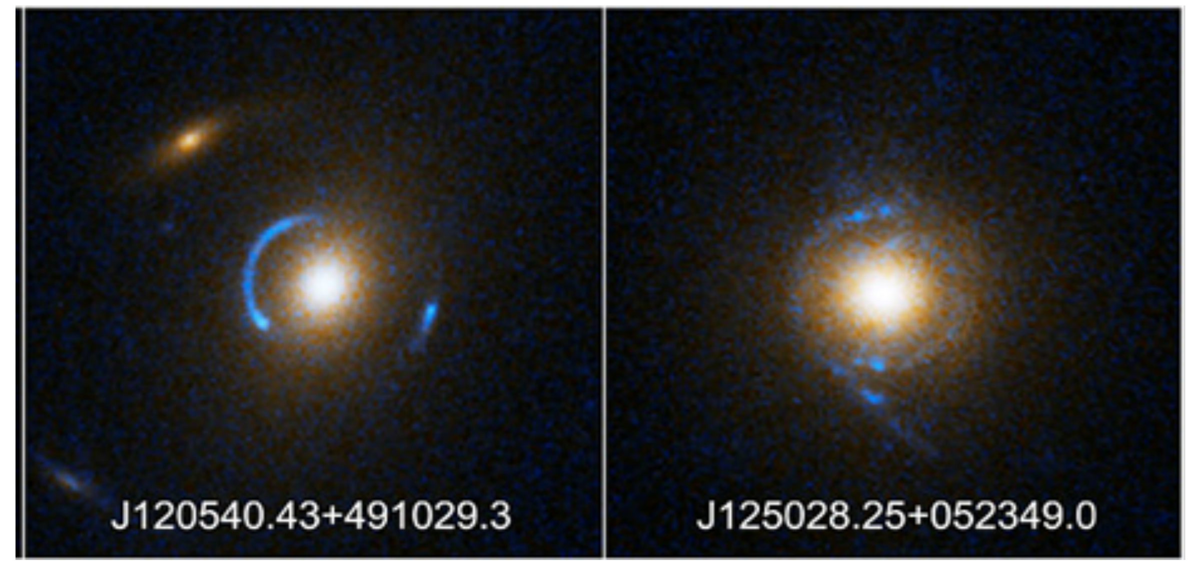






Testing gravity





Velocity dispersion → Dynamical mass

Gravitational mass

$$ds^2 = -(1+2\Psi)dt^2 + (1-2\Phi)\delta_{ij}dx^i dx^j$$

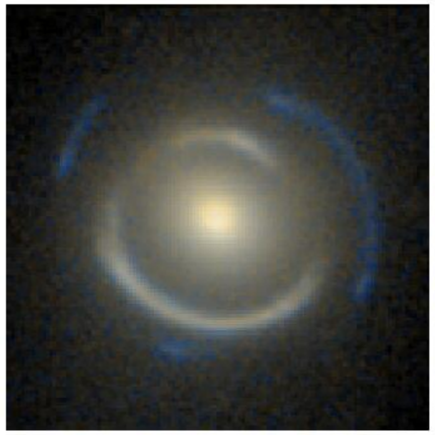
Ψ : Newtonian dynamical potential

Φ : space curvature potential

In GR, $\Phi = \Psi$

Slides by Wei Du

Cosmological constraints from double source plane strong lensing (DSPL)



SLACS
J0946+1006

The observable: $$\eta = \frac{\theta_{\mathrm{E},1}}{\theta_{\mathrm{E},2}}$$

In the ideal case of neglecting the effect of the intermediate source (source 1) on the background source (source 2):

$$\theta_{E,1} = \frac{4G}{c^2}\alpha\sigma^2_{(\leqslant\theta_1)}\frac{D_{ls1}}{D_{s1}}$$

$$\theta_{E,2} = \frac{4G}{c^2}\alpha\sigma^2_{(\leqslant\theta_2)}\frac{D_{ls2}}{D_{s2}}$$

The factor α depends on the **lens mass model**

$$\frac{D_{ls1}/D_{s1}}{D_{ls2}/D_{s2}} = \frac{\theta_{E,1}}{\theta_{E,2}}\frac{\sigma^2_{(\leqslant\theta_2)}}{\sigma^2_{(\leqslant\theta_1)}}$$

The factor α is cancelled out, that alleviates the dependence on the lens model to some extent.

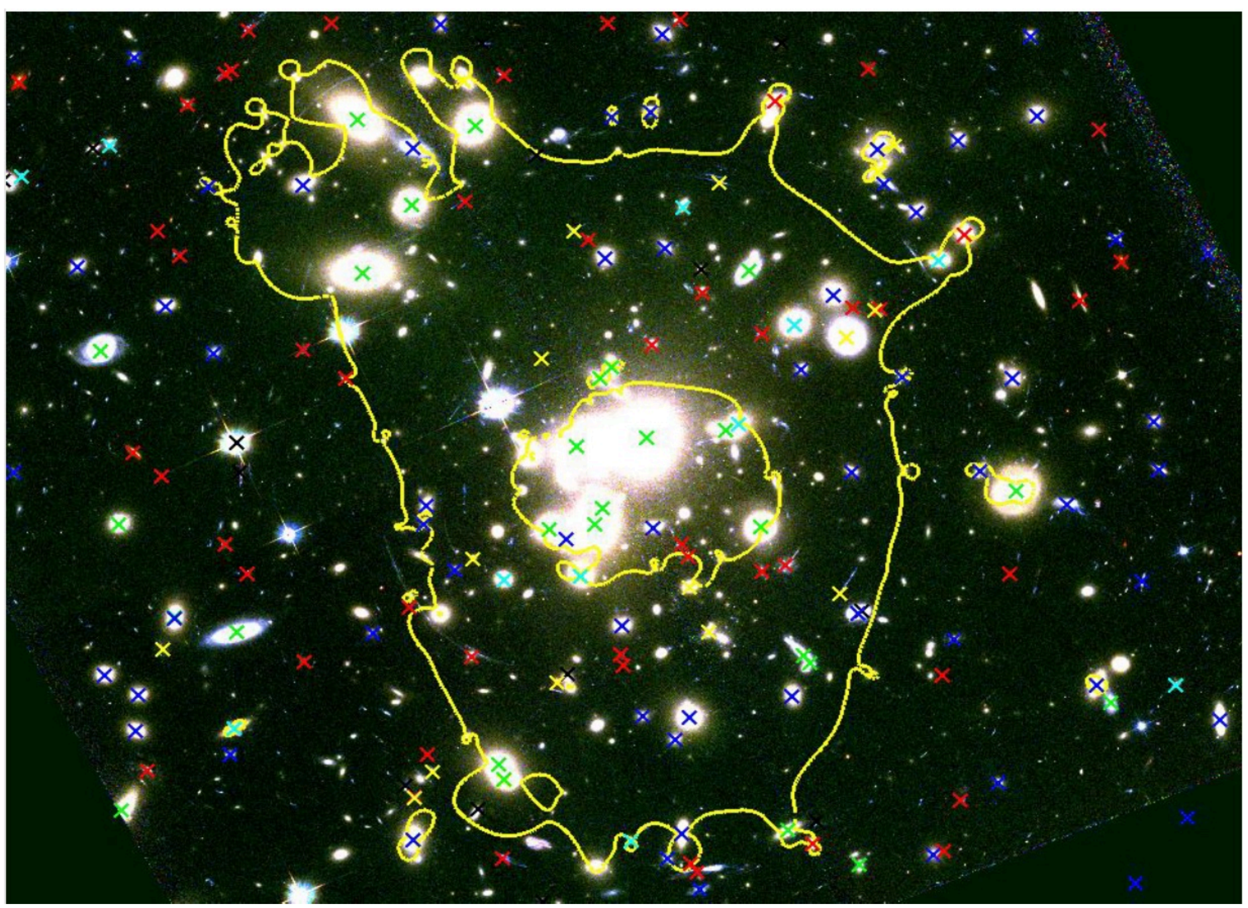
Prediction: ~ 10^3 galaxy-scale DSPL systems (**based on Gavazzi et at. 2008 , about one lens galaxy in ~ 40 - 80 could be a DSPL**)

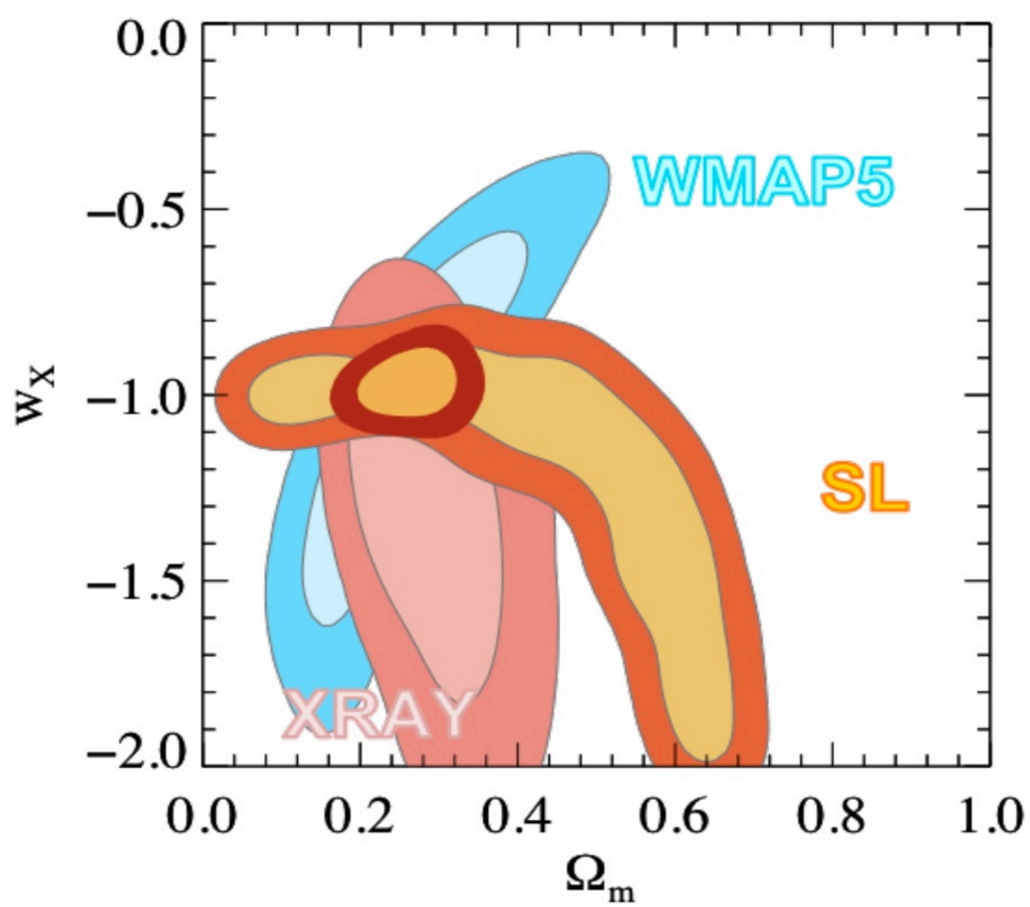
In SIS lens model, the stellar velocity dispersion is invariable with radius, that leads to

$$\eta^{\mathrm{SIS}} = \frac{D_{\mathrm{ls}1}/D_{\mathrm{s}1}}{D_{\mathrm{ls}2}/D_{\mathrm{s}2}} = \frac{\theta_{\mathrm{E},1}}{\theta_{\mathrm{E},2}}$$

Slides by Yun Chen

SL Cluster Cosmology





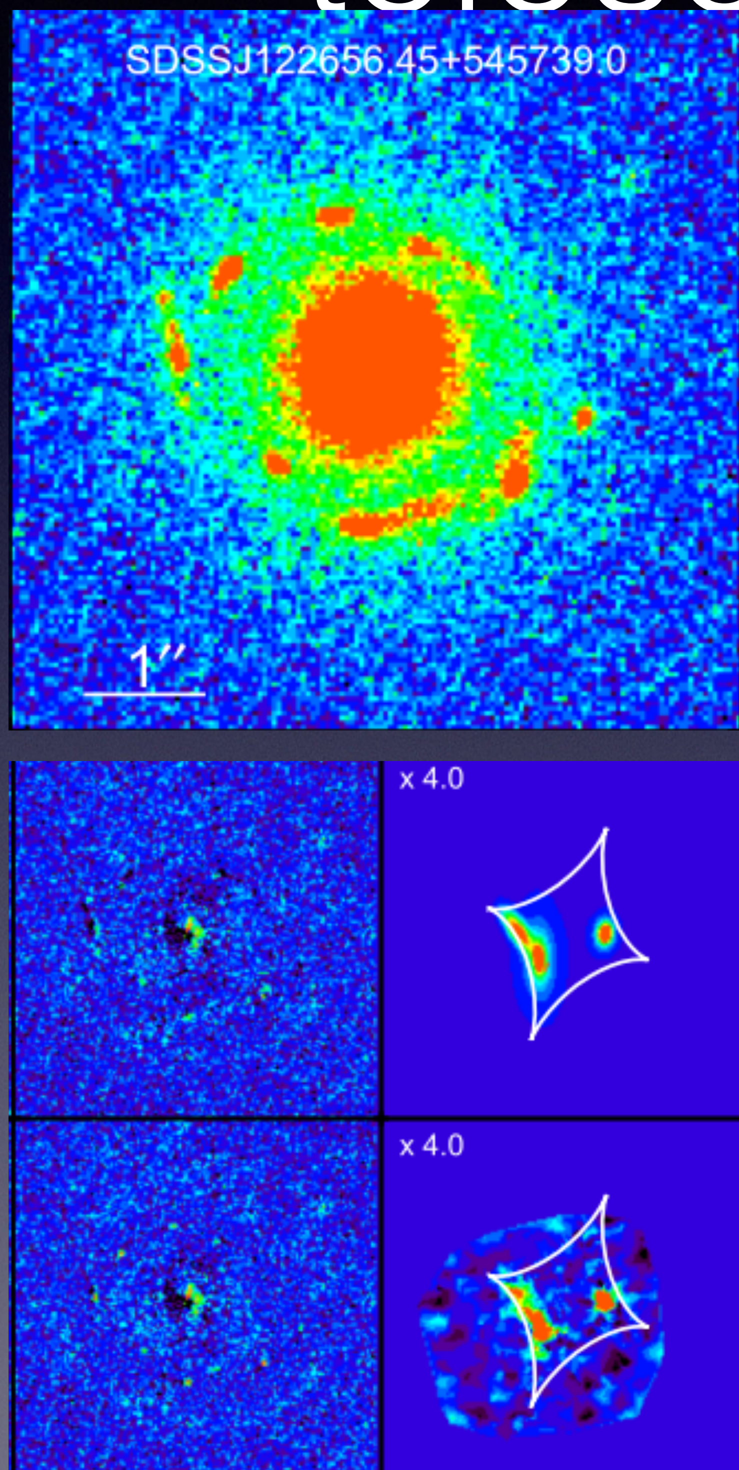
Slides from Huanyuan

Jullo et al. 2010

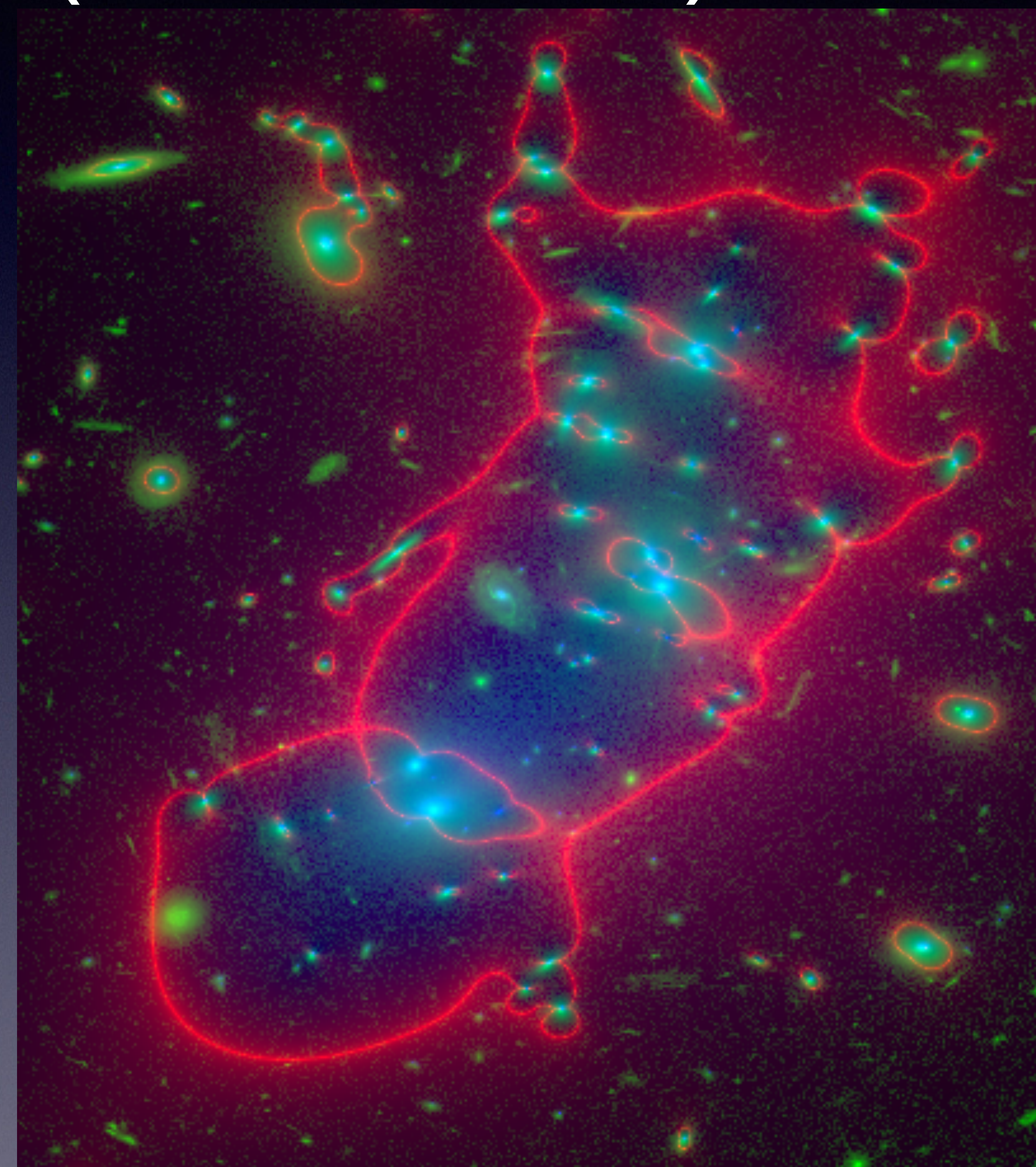
Galaxy science (SL+SSP+Kinematics)

- Galaxy mass and structure
- Dark matter fraction within galaxies and clusters
- Shape of dark matter haloes at center
- Evolution of Early type galaxies
- IMF variation of late type lenses
- Synergy with time domain surveys
- ……

Galaxy lensing as a telescope (DF, UDF)

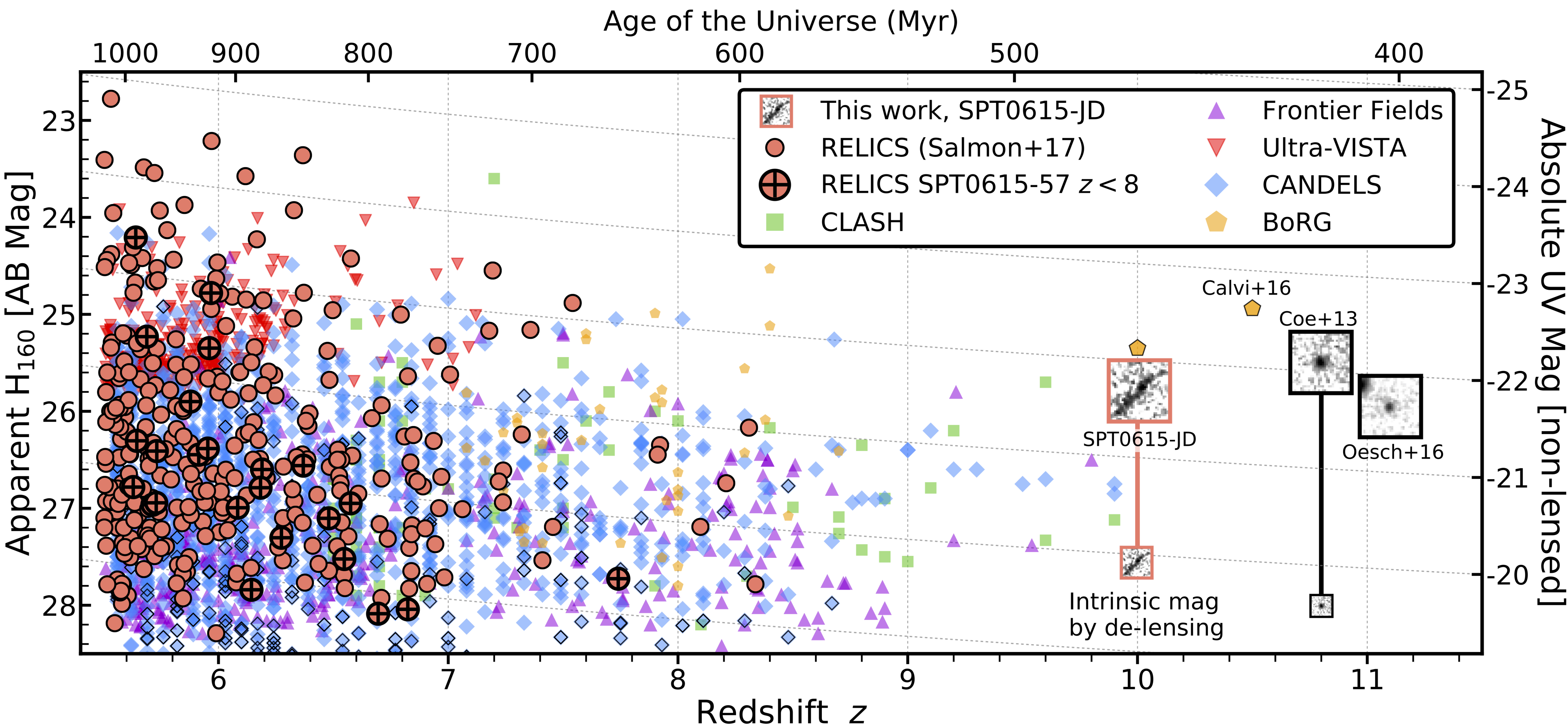


Lensd LAEs, Shu et al. 2016



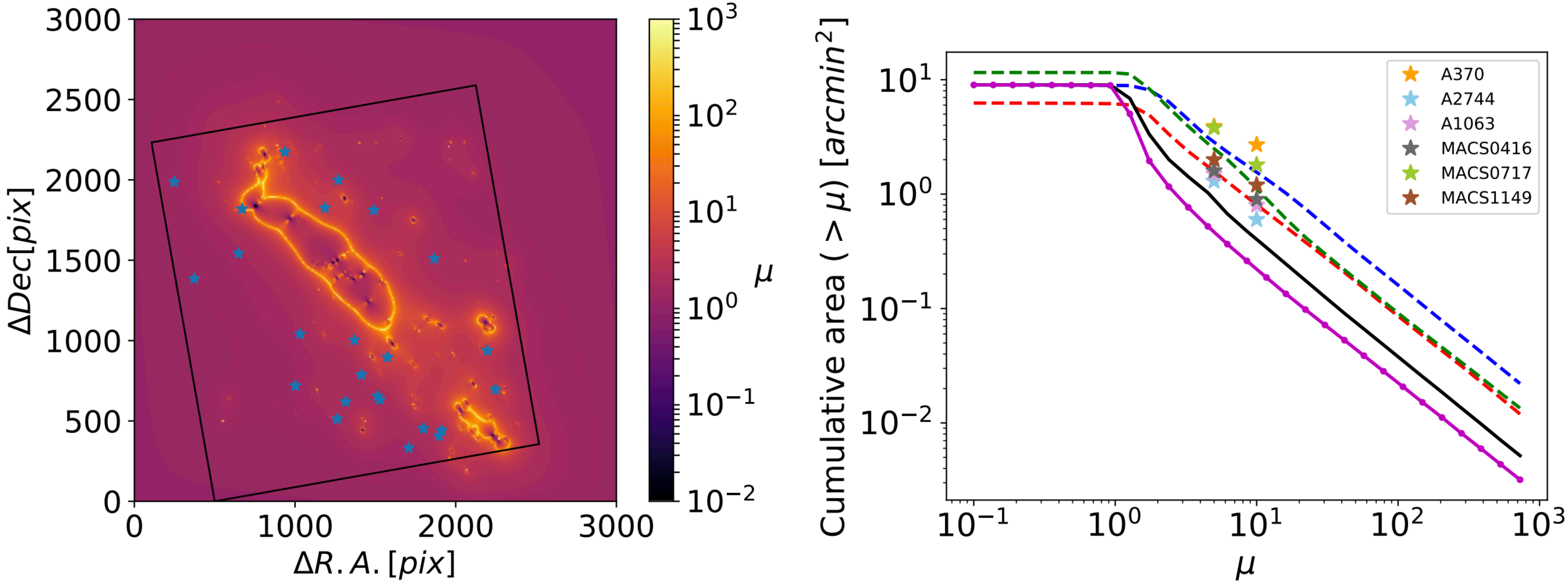
Abell 2744, magnification map by CATS team

High-redshift galaxies



Salman et al. 2018

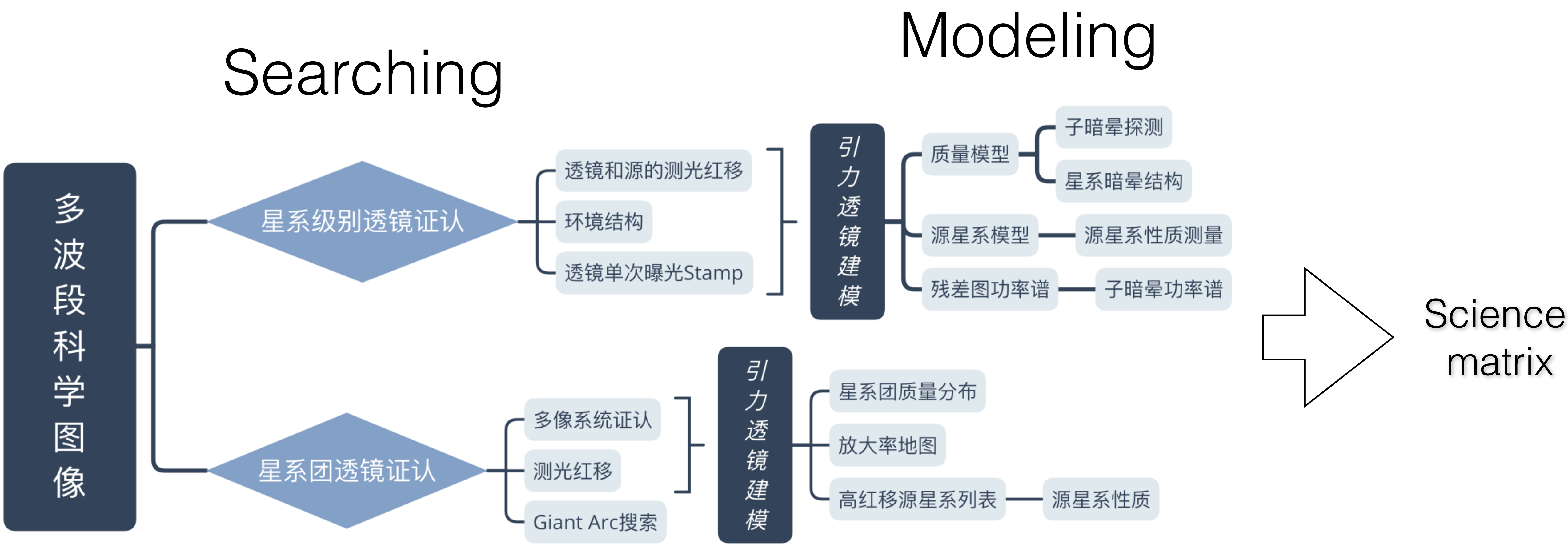
Slide from Huanyuan Shan



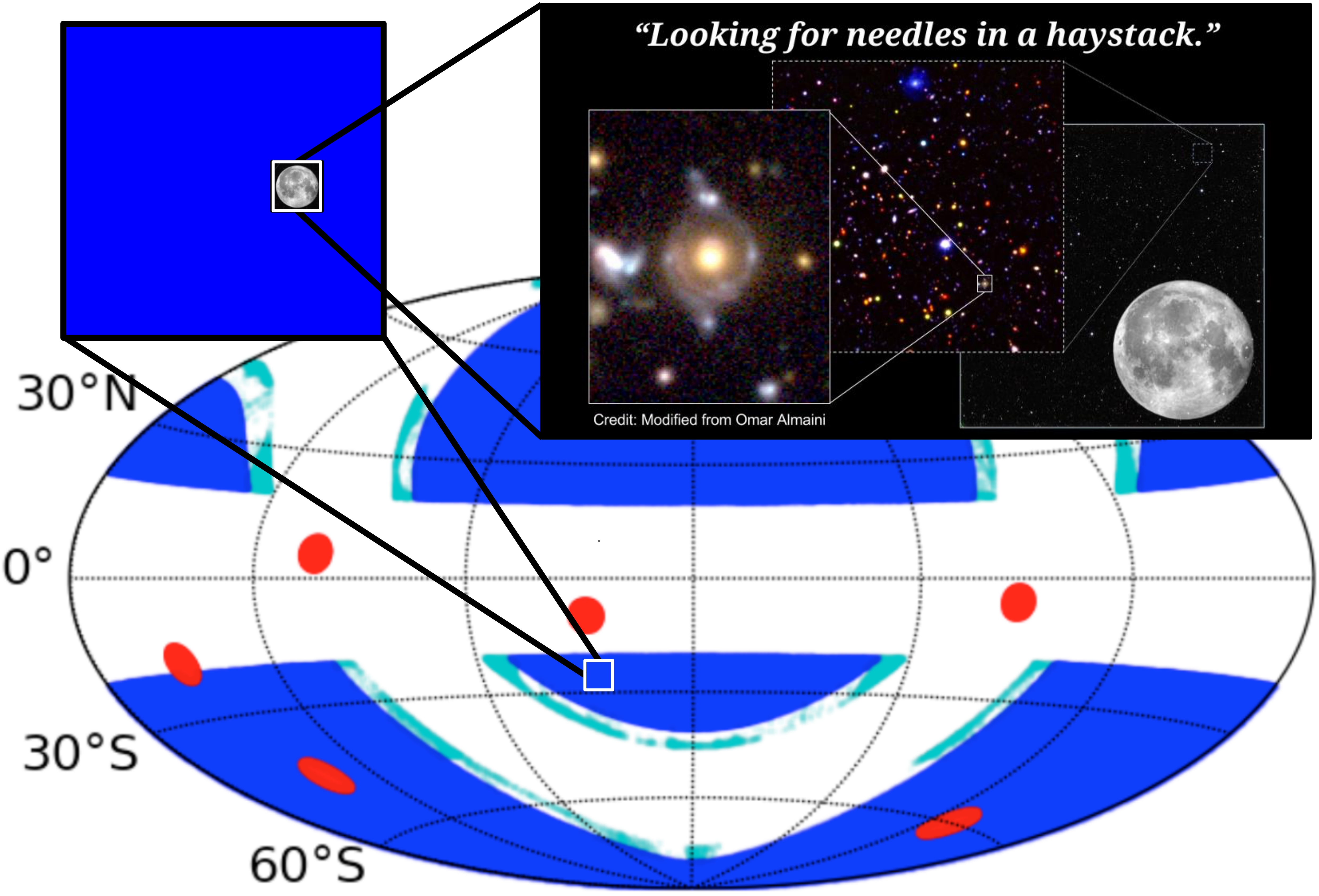
Acebron et al. 2018

Slide from Huanyuan Shan

Strong lensing Road map

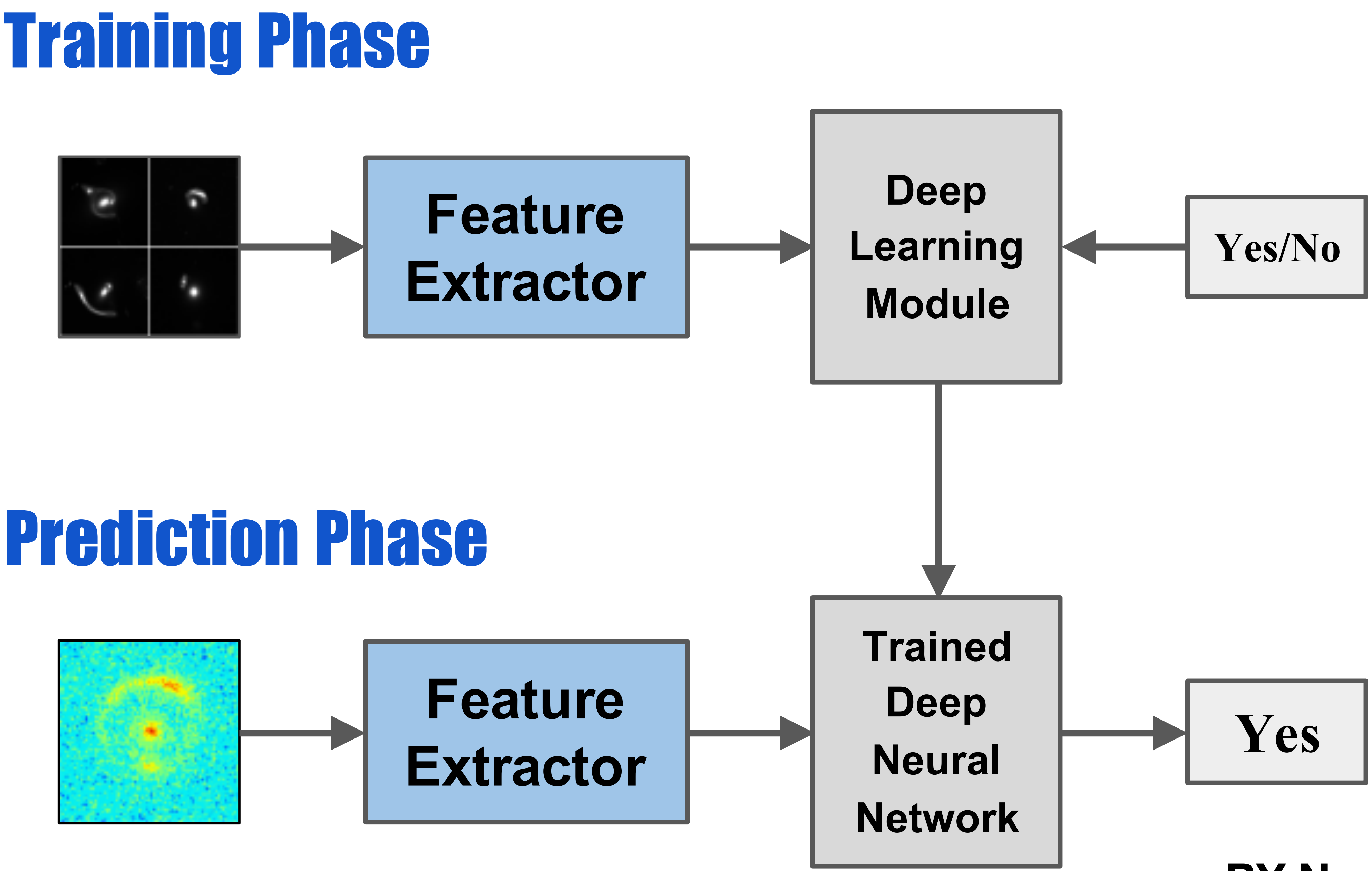


	A	B	C	D	E	F	G	H
1	Science Goal	Probe	Targets	Measurement	CSST Impact/comparing with current and future survey	Complementary Instruments	Complications	ref/demo with simulation data/observation data
2	Distinguish dark matter models: WDM vs. CDM	subhalo/halo mass function at low mass end	Galactic Einstein ring/arc system (~100 high S/N)	Detecting the flux perturbation on the Einstein ring; require lens modelling with Pixelized source reconstruction	Increasing the number of suitable lenses; High angular resolution imaging; accurate photoz for large sample of galactic lenses;	Ground base Laser AO imaging follow-up; spectroscopy follow-up	Distinguishing false detection; estimating sensitivity map	
3		subhalo powerspectrum	Galactic Einstein ring/arc system	Measuring the powerspectrum of residual flux after subtracting the macro model	Increasing the number of suitable lenses; High angular resolution imaging; accurate photoz for large sample of galactic lenses;		linking power spectrum of residual to that of subhalo	
4	Dark matter Self-interaction	off-set between center of distribution of galaxies and dark matter mass center	Coliding clusters	Constructing dark matter mass map of cluster	Hudreds of coliding clusters with high resolution imaging; accurate photo-z for source galaxies; weak lensing at large scales	X-rays; MCI follow-up to 27 mag	Accurate measurement of dark matter centre from limited multi-image systems	
5		Core of dark matter at centre of clusters	relaxed clusters	Constructing mass map of cluster at ~kpc	Increasing the number of clusters with strong lensing multi-images	IFS measurement of velocity map of central galaxy; weak lensing at larger scale; X-rays	AGN feedback effect; Dry merger effect; Accury of dynamical analysis	

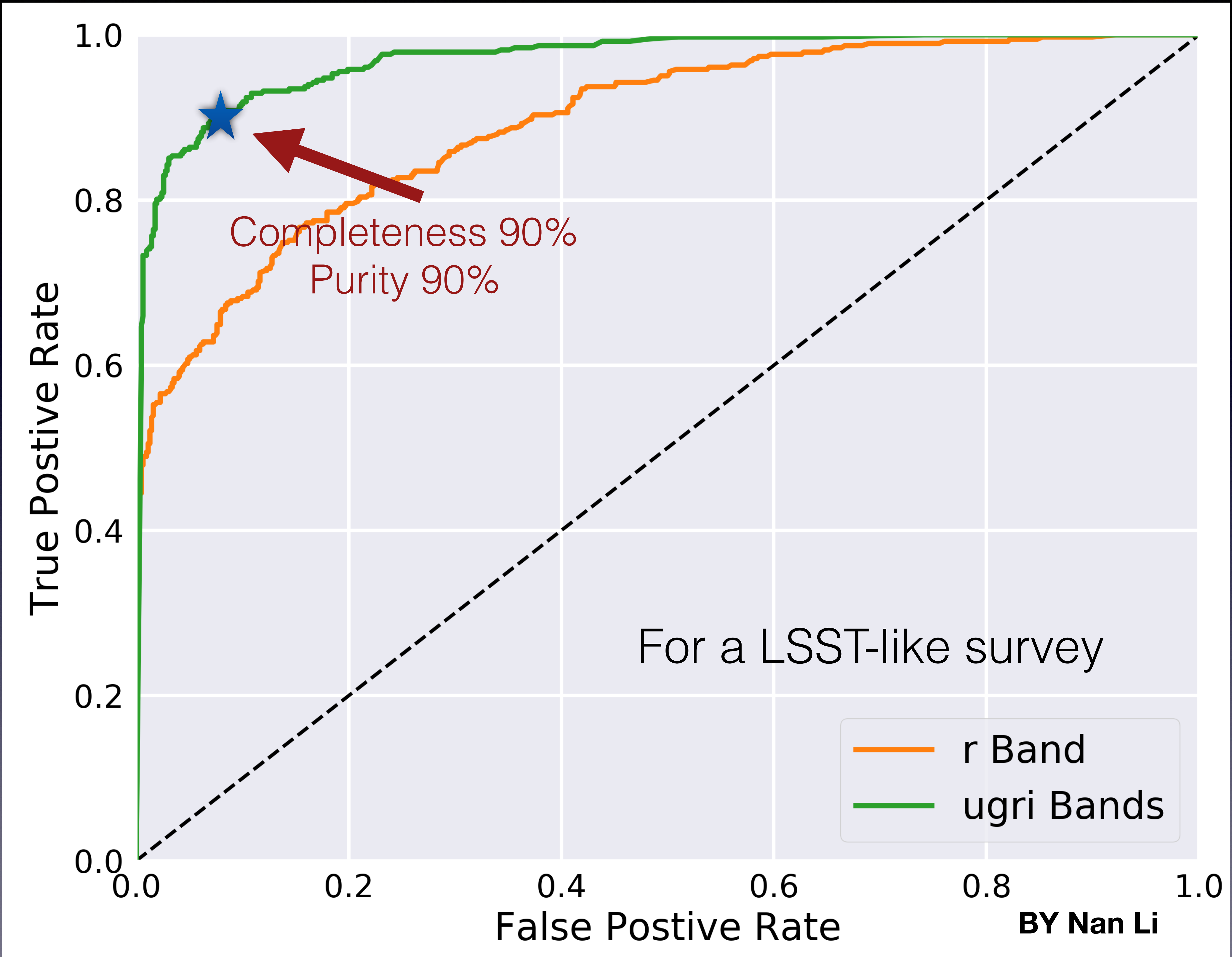


Mining more than 10000 lenses from one billion objects

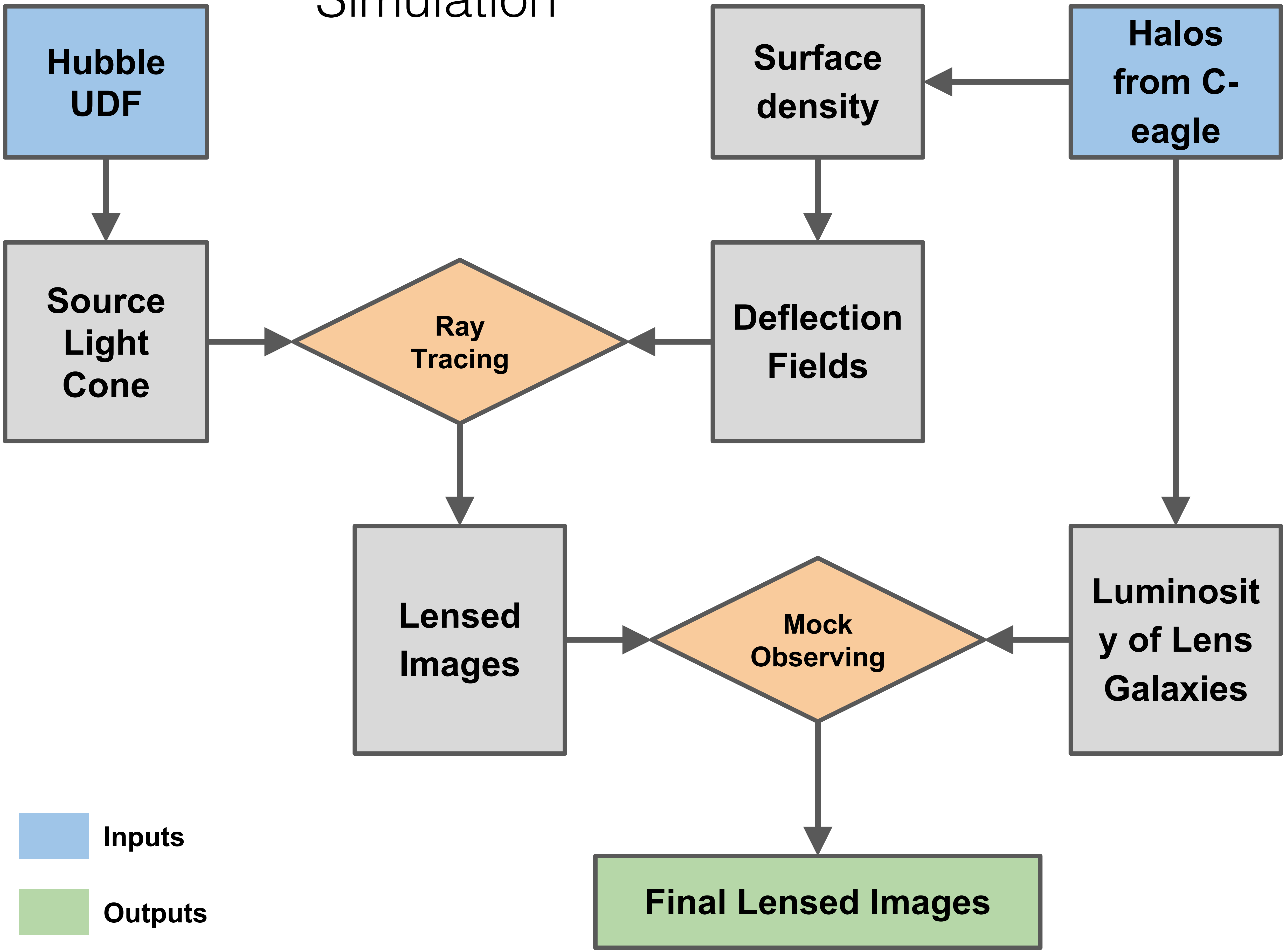
Lens search: ML

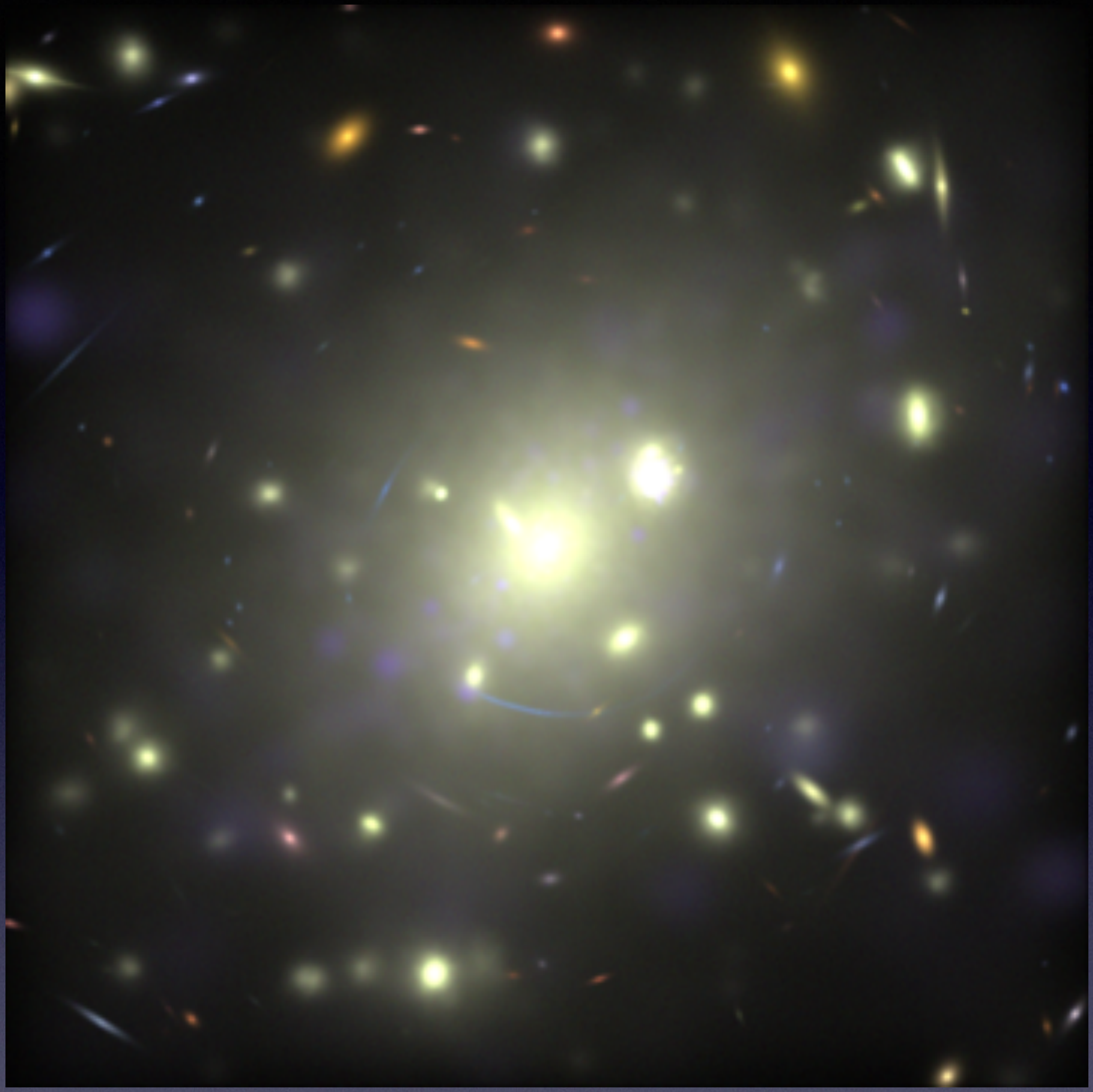
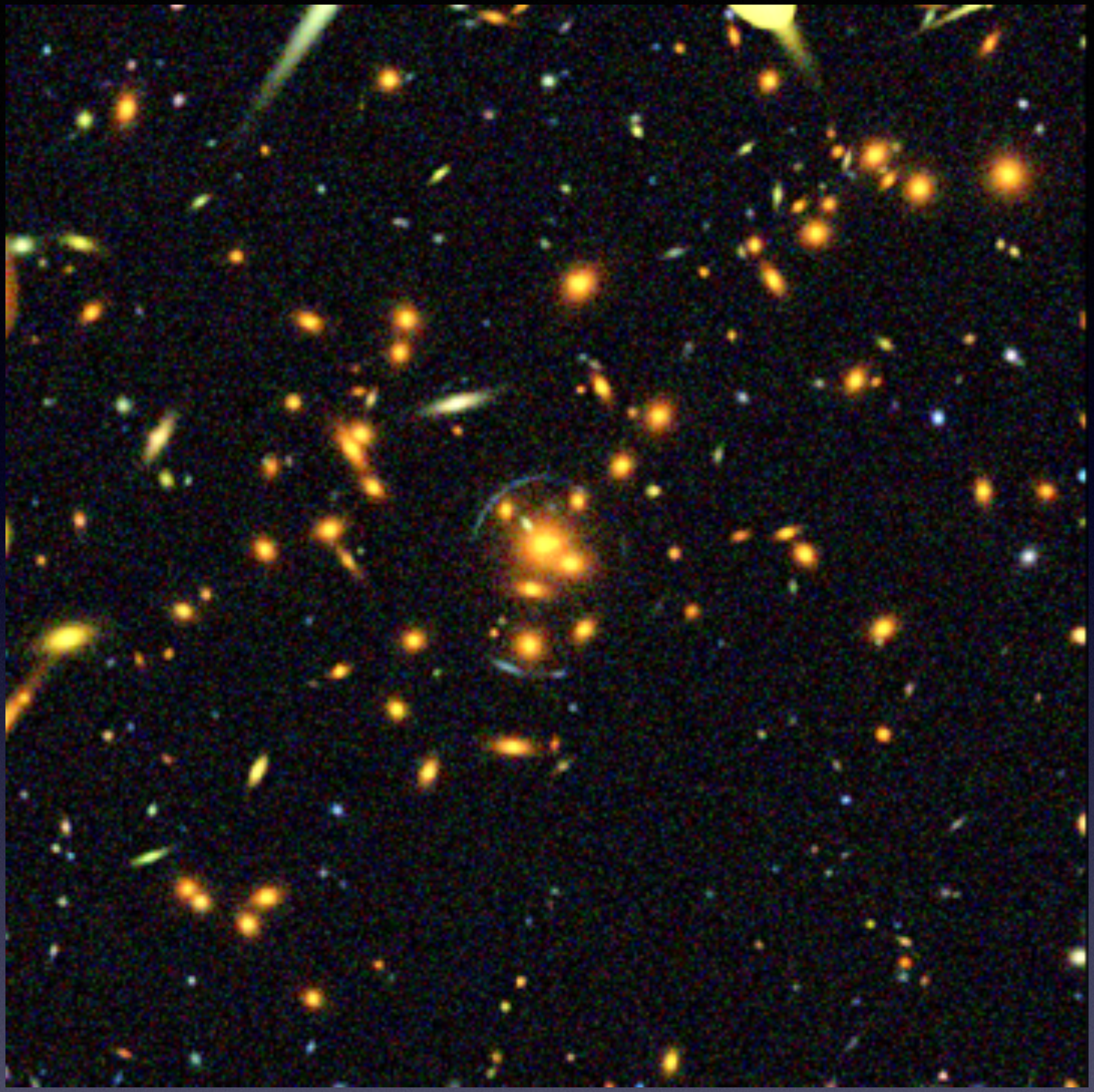


BY Nan Li


1.0
0.8
0.6
0.4
0.2
0.0
True Postive Rate
0.0
0.2
0.4
0.6
0.8
1.0
False Postive Rate
Completeness 90%
Purity 90%
For a LSST-like survey
r Band
ugri Bands
BY Nan Li

Simulation


Hubble UDF
Surface density
Halos from C-eagle
Source Light Cone
Ray Tracing
Deflection Fields
Lensed Images
Mock Observing
Luminosity of Lens Galaxies
Final Lensed Images
Inputs
Outputs

27 simulated cluster lenses using the data of C-Eagle clusters (left); hundreds of simulated cluster lenses based on a semi-analytic model named CosmoDC2 (right). Include both Strong and Weak Lensing.

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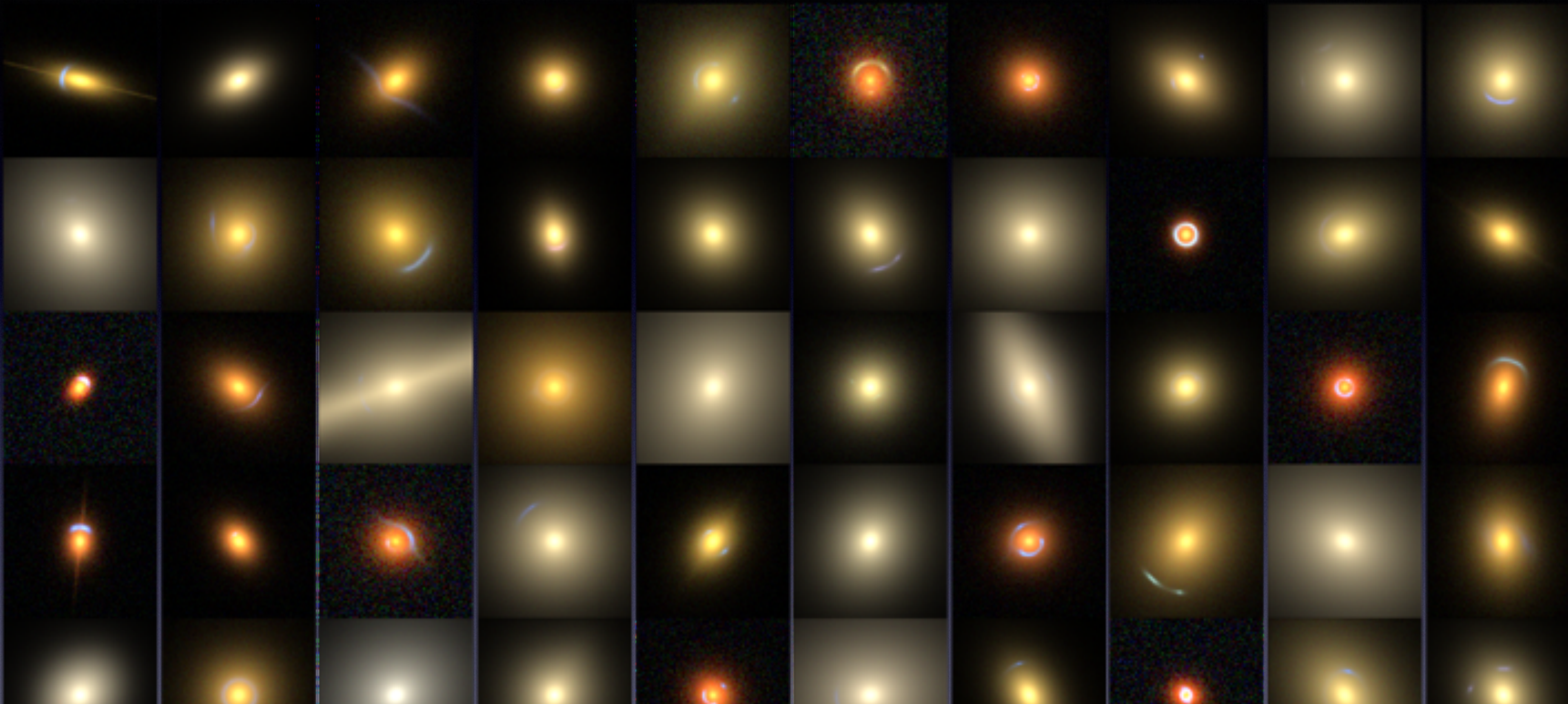

500k simulated galaxy-galaxy strong lenses based on CosmoDC2. Each image includes the flux in gri-bands, and the morphological model of the galaxies (both lens and source) is bulge + disk in the form of Sersic profile.

By Nan Li, Dezi Liu, Ran Li

Summary

- Strong gravitational lensing will be greatly benefit from CSS-OS
- Novel opportunities on different topics: dark matter identity, cosmology, galaxy formation, high redshift galaxies
- Need to model 100000 lenses fast and accurately
- A lot of work to be done. Welcome to join us!