Gravitational Lensing as a Probe of Cosmology

LVIII Congresso SAIt - Milano
13/5/2014

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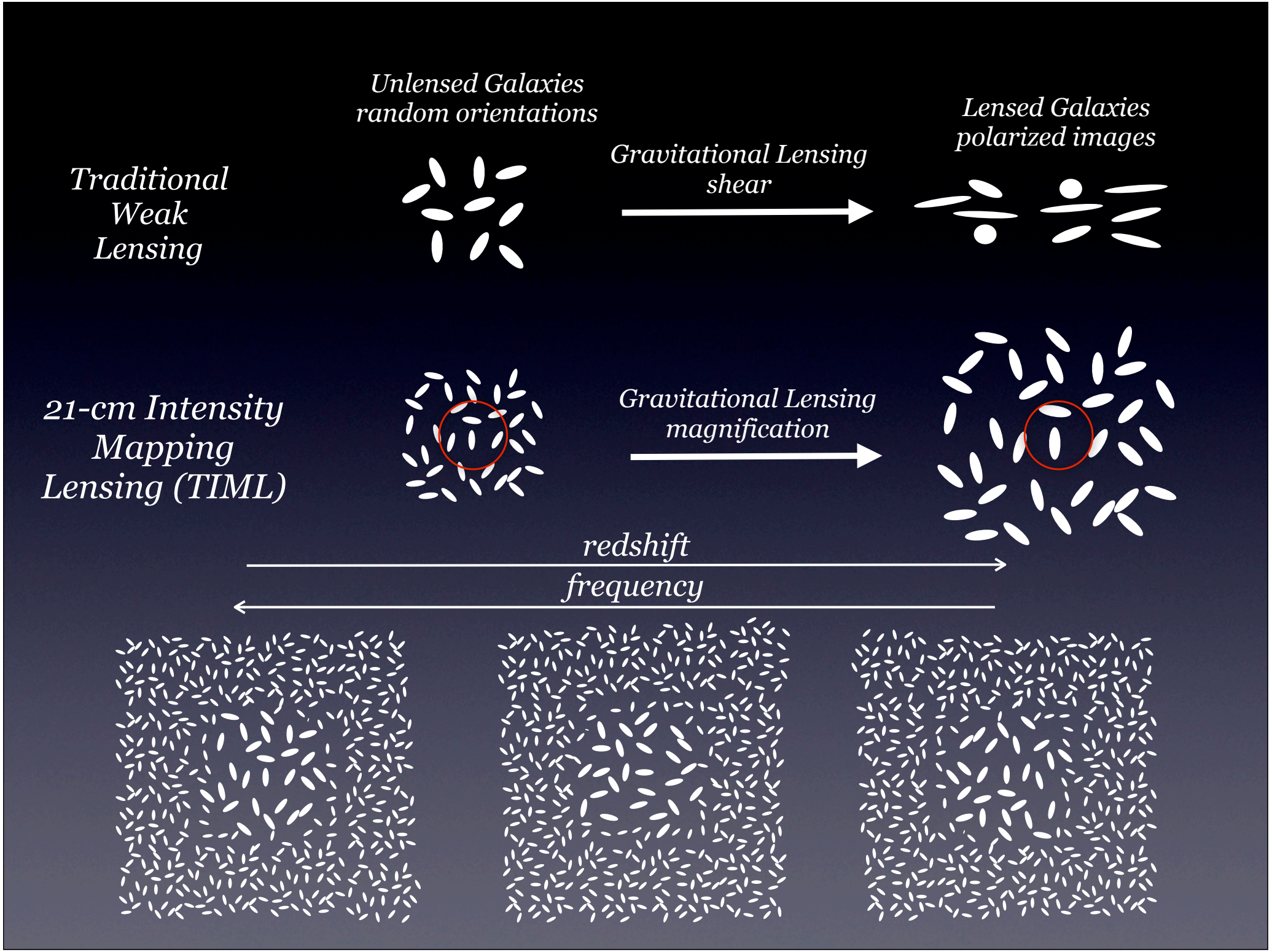
Outline:

Weak Lensing at high redshift in the radio

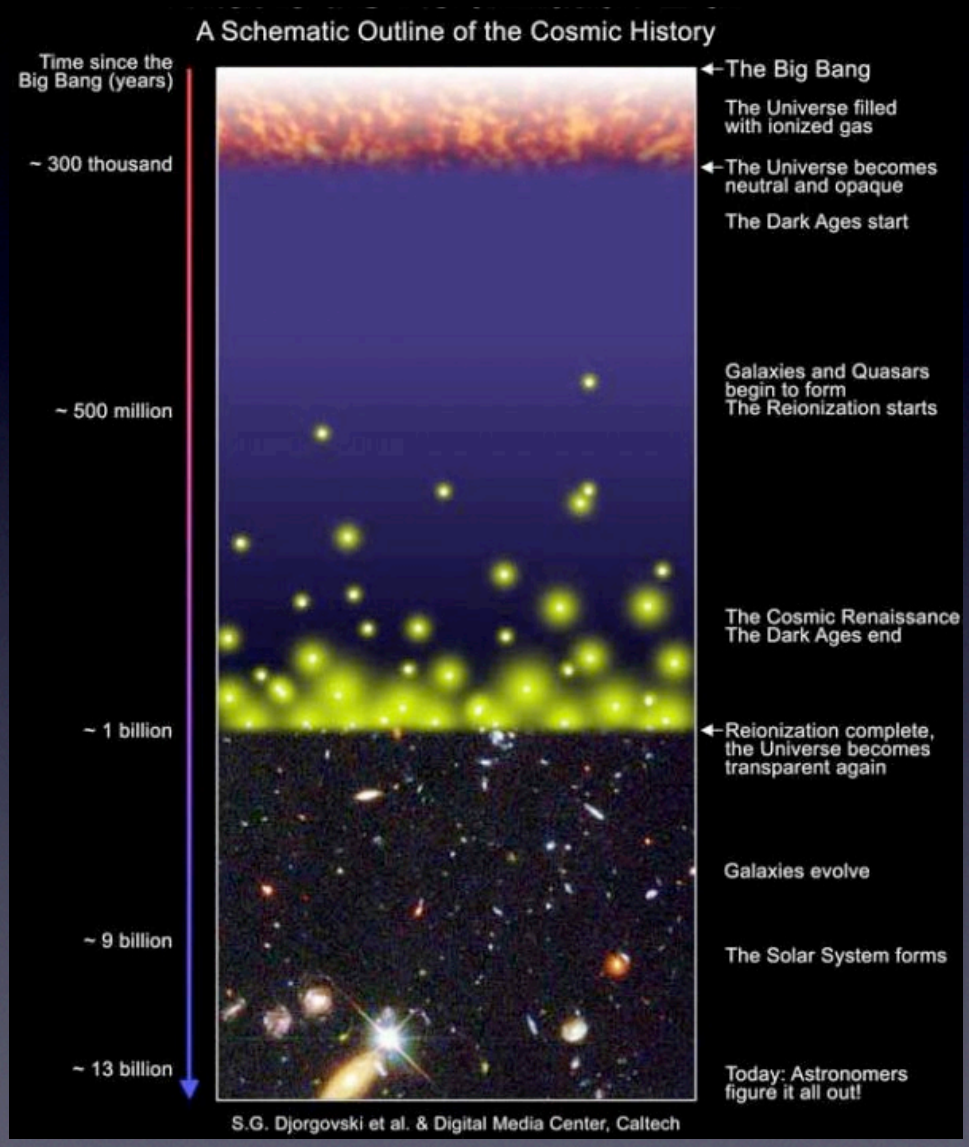
Lensing with 21 cm intensity mapping and the Square Kilometer Array (SKA)

Strong Galaxy Scale Gravitational Lenses

Cosmology and astrophysics from strong galaxy-galaxy lenses


Traditional Weak Lensing
Unlensed Galaxies random orientations
Gravitational Lensing shear
Lensed Galaxies polarized images
21-cm Intensity Mapping Lensing (TIML)
Gravitational Lensing magnification
redshift
frequency

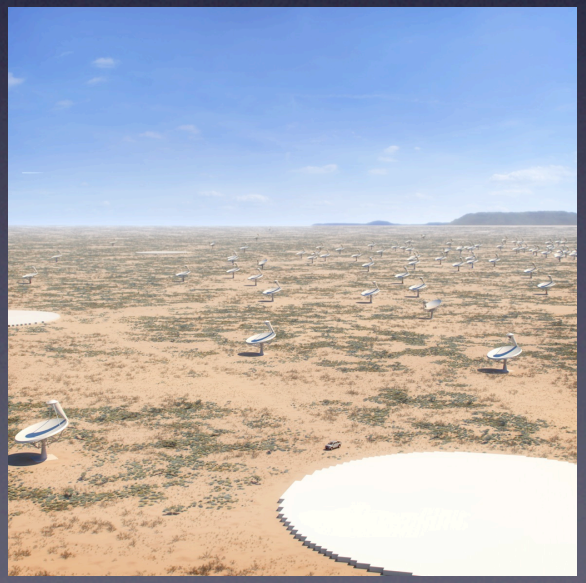
History of Neutral Hydrogen In the Universe



The Square Kilometer Array (SKA)

SKA-Low

Australian Murchison region
frequency: ~ 50 - 240 MHz
redshift for 21 cm: $z \sim 5 - 27$
survey area: 25 sq. deg.

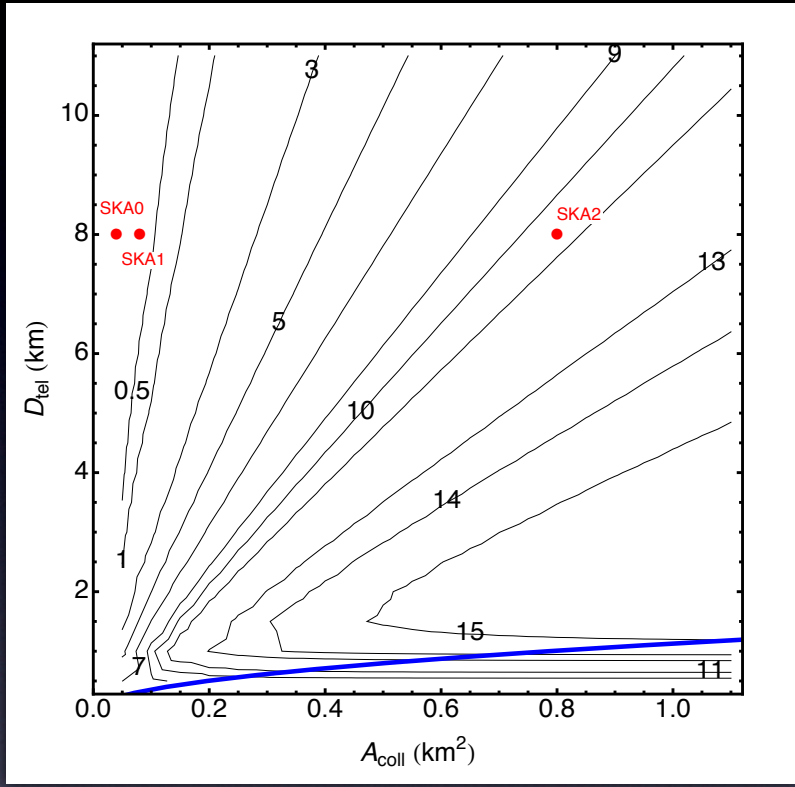


SKA-Mid

South Africa Karoo region
frequency: ~ 350 - 3050 MHz
redshift for 21 cm: $z \sim 0 - 3$
survey area: ~ 30,900 sq. deg.

TIML with SKA-Mid

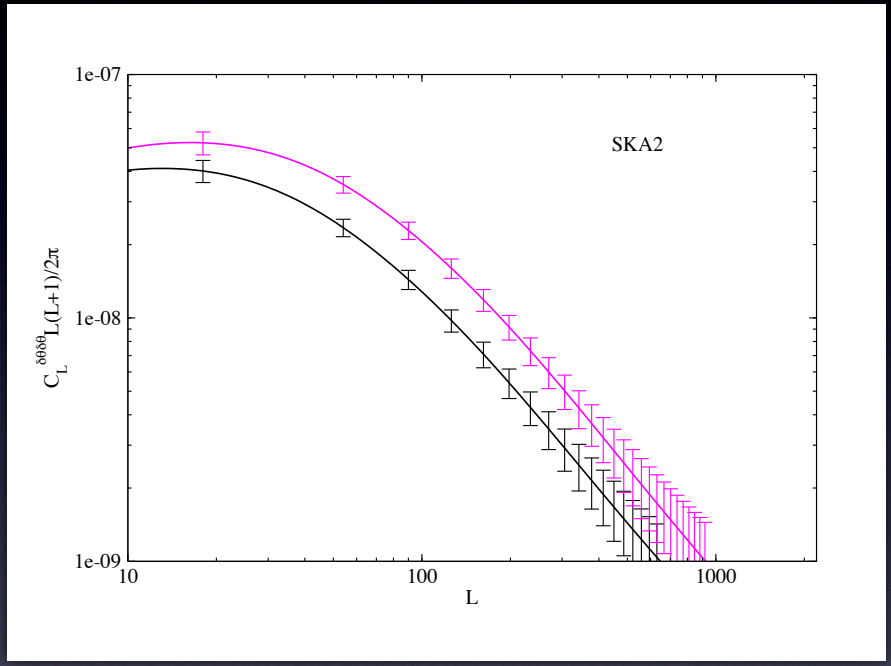
Lensing Signal to Noise



Array Diameter

Array Collecting Area

Lensing Power Spectrum



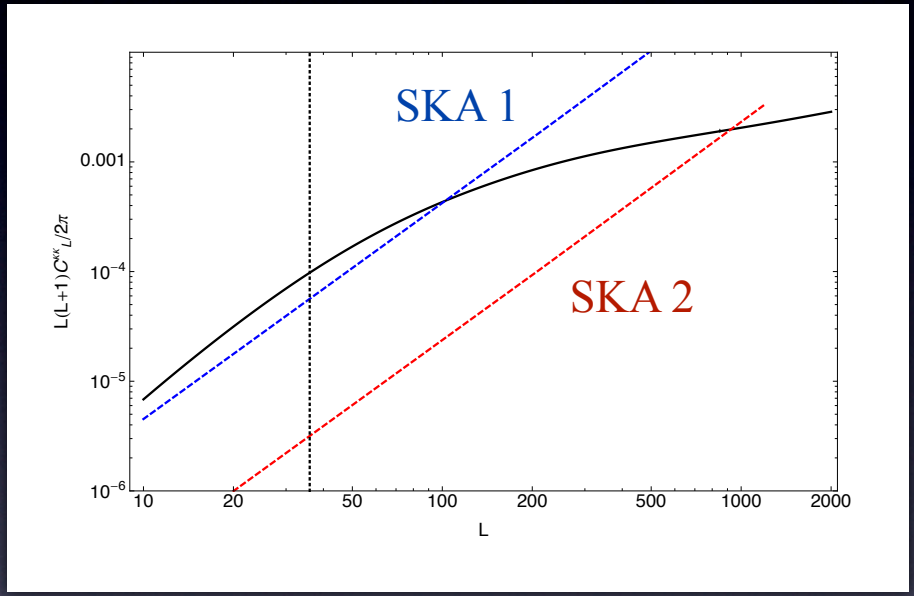
multipole on the sky

The evolution in the lensing power-spectrum will be measurable well above the redshifts where other forms of weak lensing studies are possible.

see Poursidou & Metcalf, 2014 and SKA Science Book (in preparation)

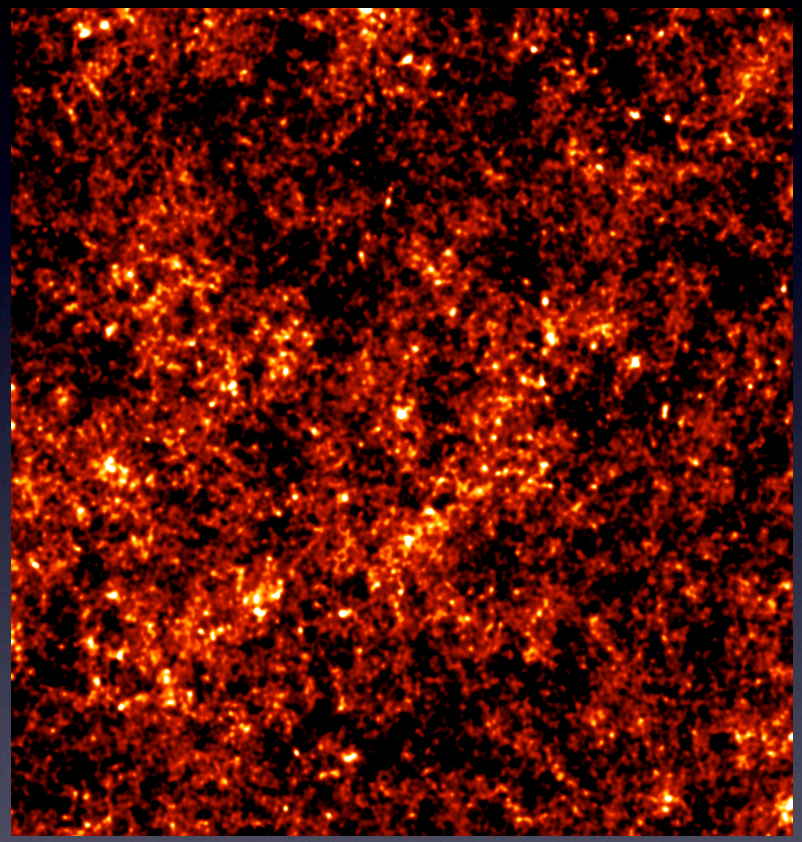
TIML with SKA-Low

Signal and Noise



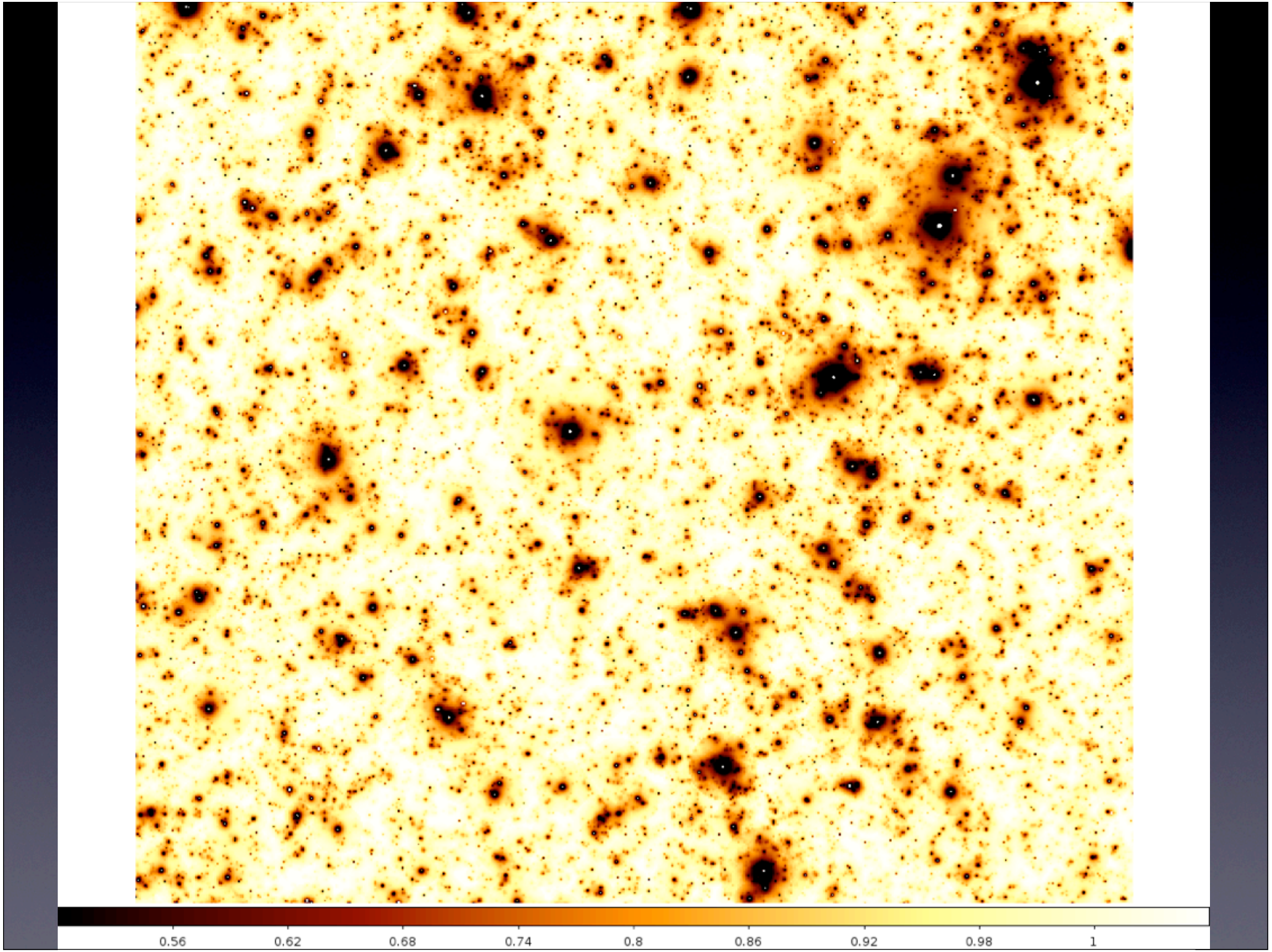
multipole on the sky

Simulated surface density in the light-cone



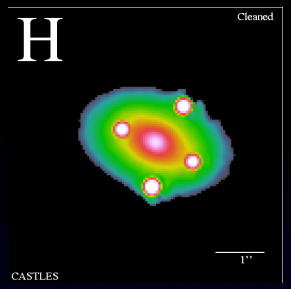
It should be possible to actually image the distribution of dark matter on the sky depending on when reionization occurs.

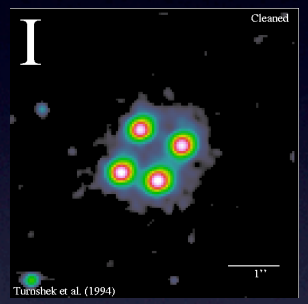
see Metcalf & White, 2009 and SKA Science Book (in preparation)

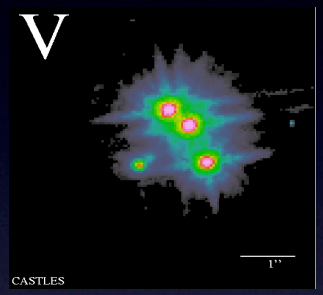

0.56
0.62
0.68
0.74
0.8
0.86
0.92
0.98
1

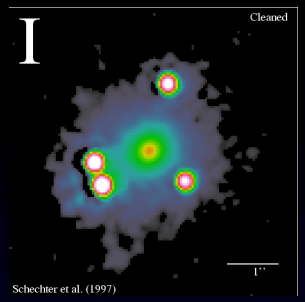
Galaxy Scale Strong Lenses

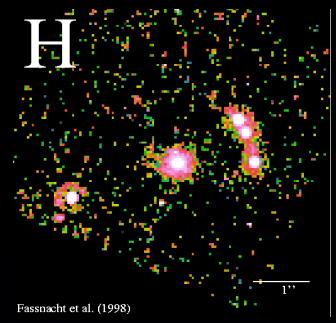
Galaxy - QSO Lenses

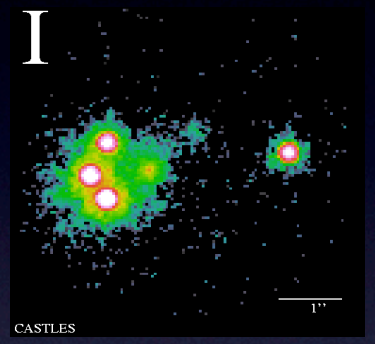




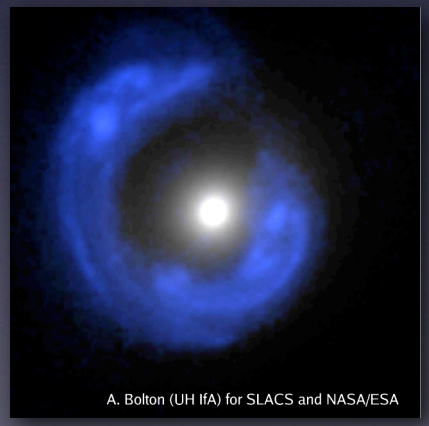


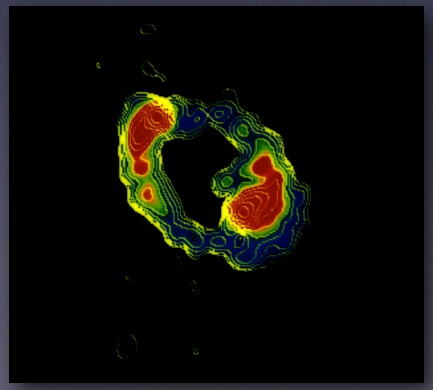


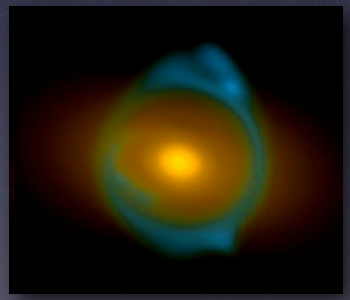


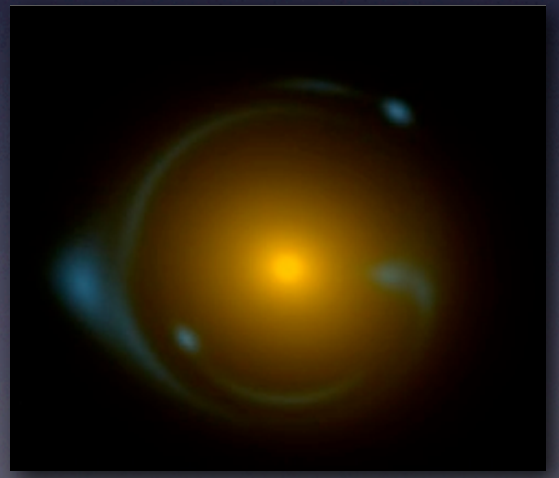


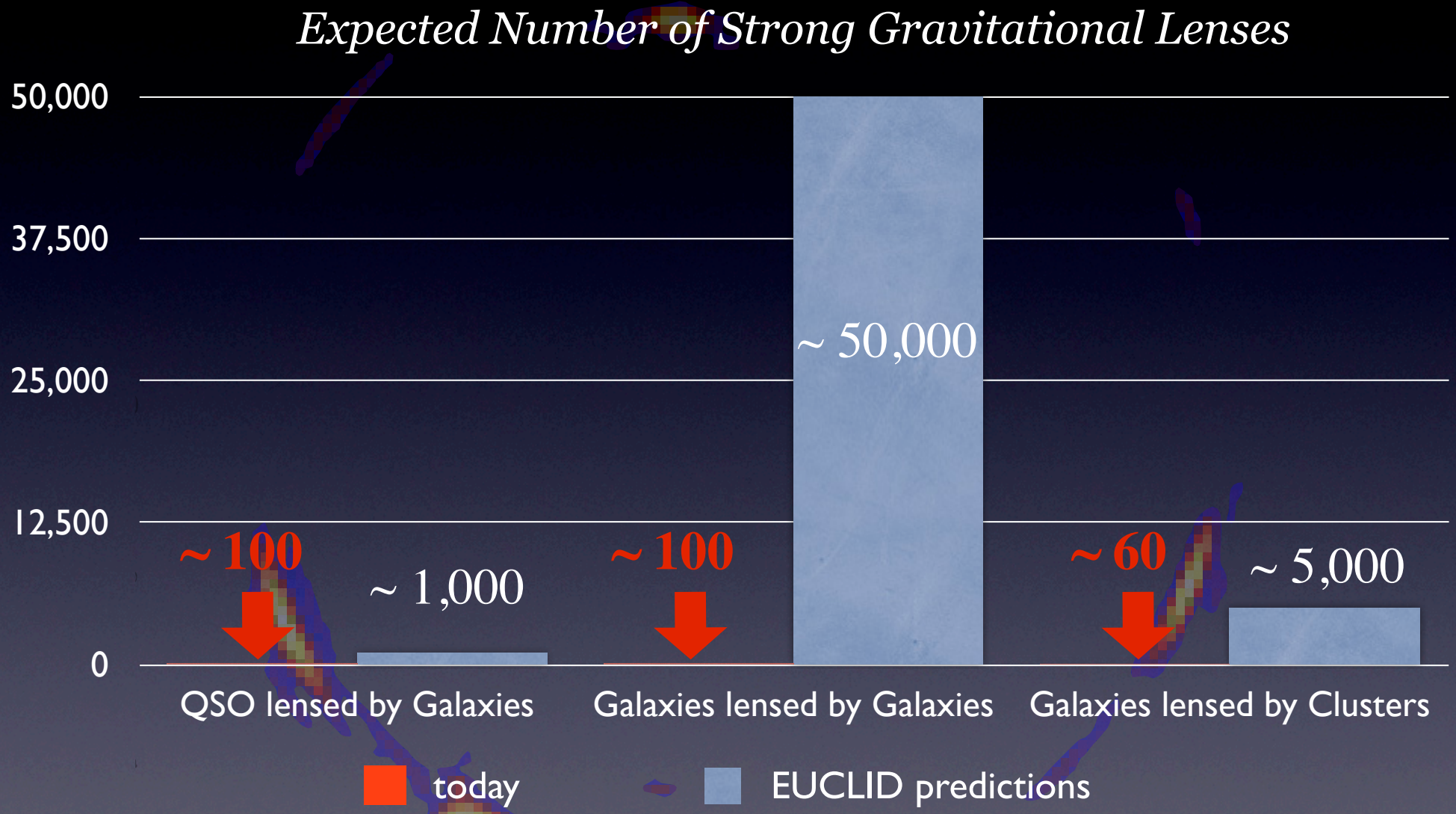
Galaxy - Galaxy Lenses











Future Data Sets : KIDS, DES, Pan-Starrs, LSST, Euclid

Uses for Strong Lenses in a Dark Universe

Distribution of dark matter around visible galaxies

- *dark matter halos' profile, ellipticity, correlation with visible galaxies, etc.*
- *mass and concentration of galaxy clusters*

Small-Scale structure in the dark matter distribution

- *missing dwarf galaxy problem*
- *mass of the dark matter particle*

Cosmography

- *time-delays*
- *geometrical constraints*

Challenges to Cosmology with Strong Lensing

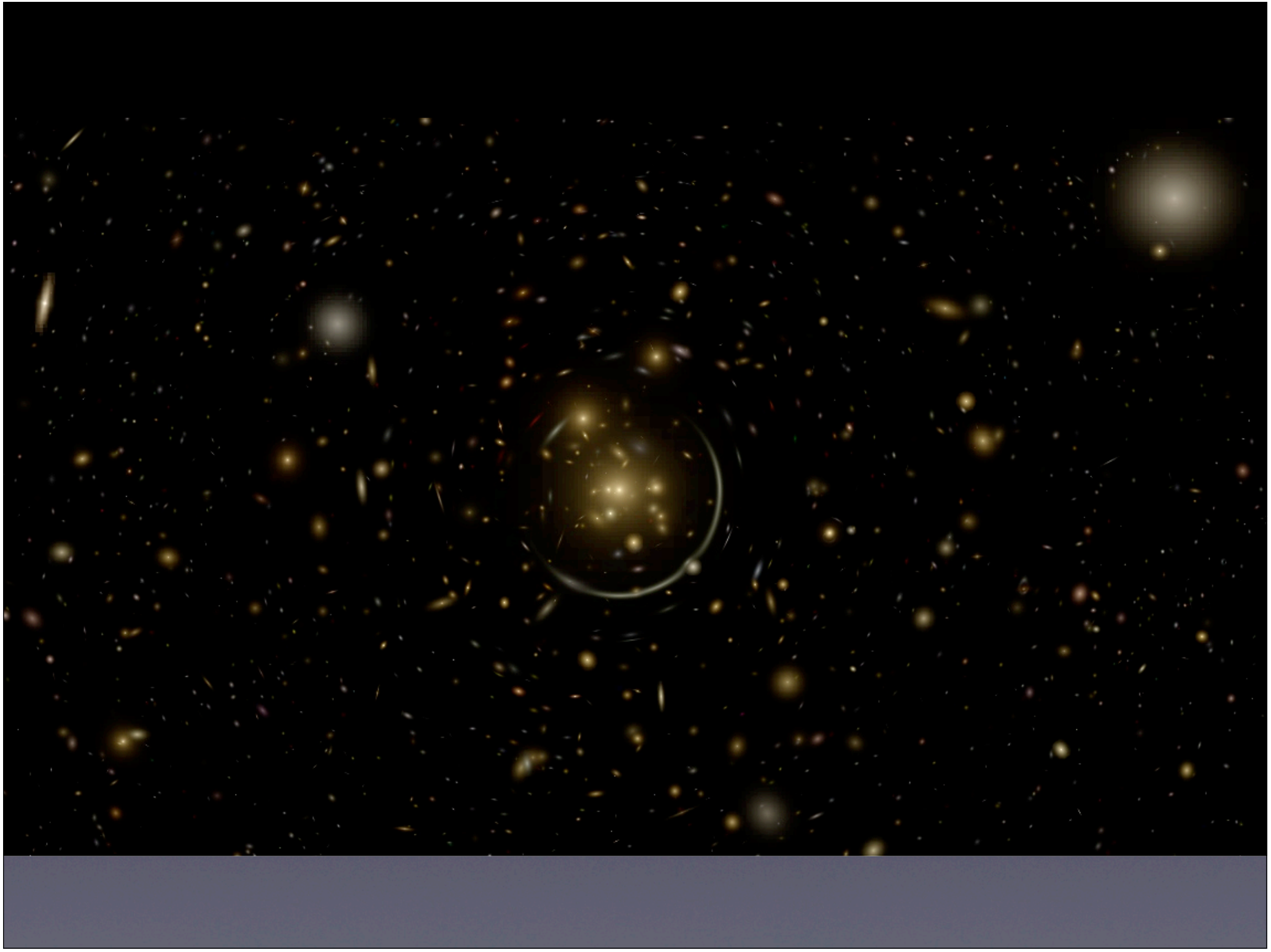
Finding Lensing

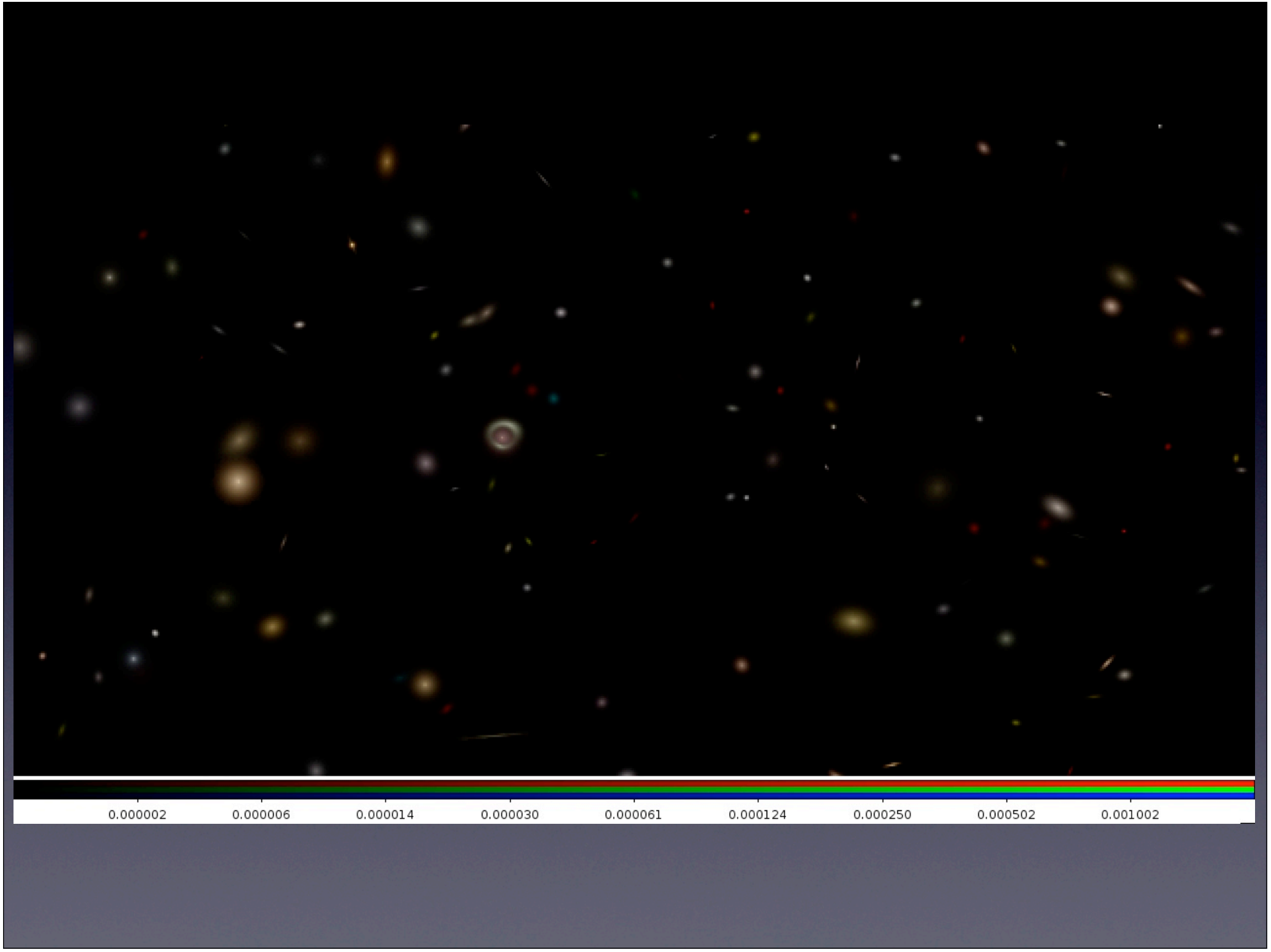
efficiency / selection bias
need for high quality simulations

Followup Information

high resolution deep images
long term monitoring for time-delays

Modeling Lenses

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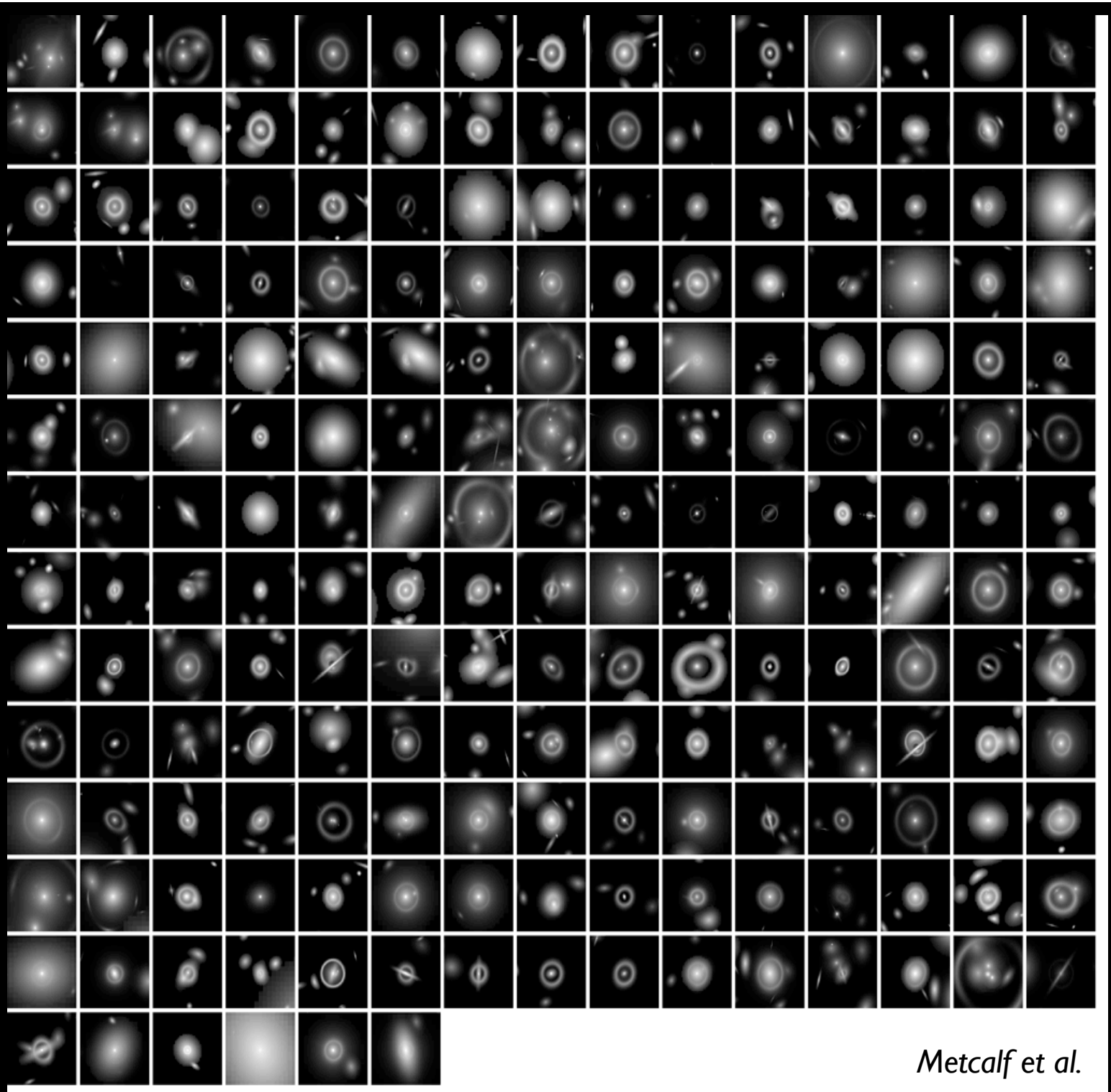
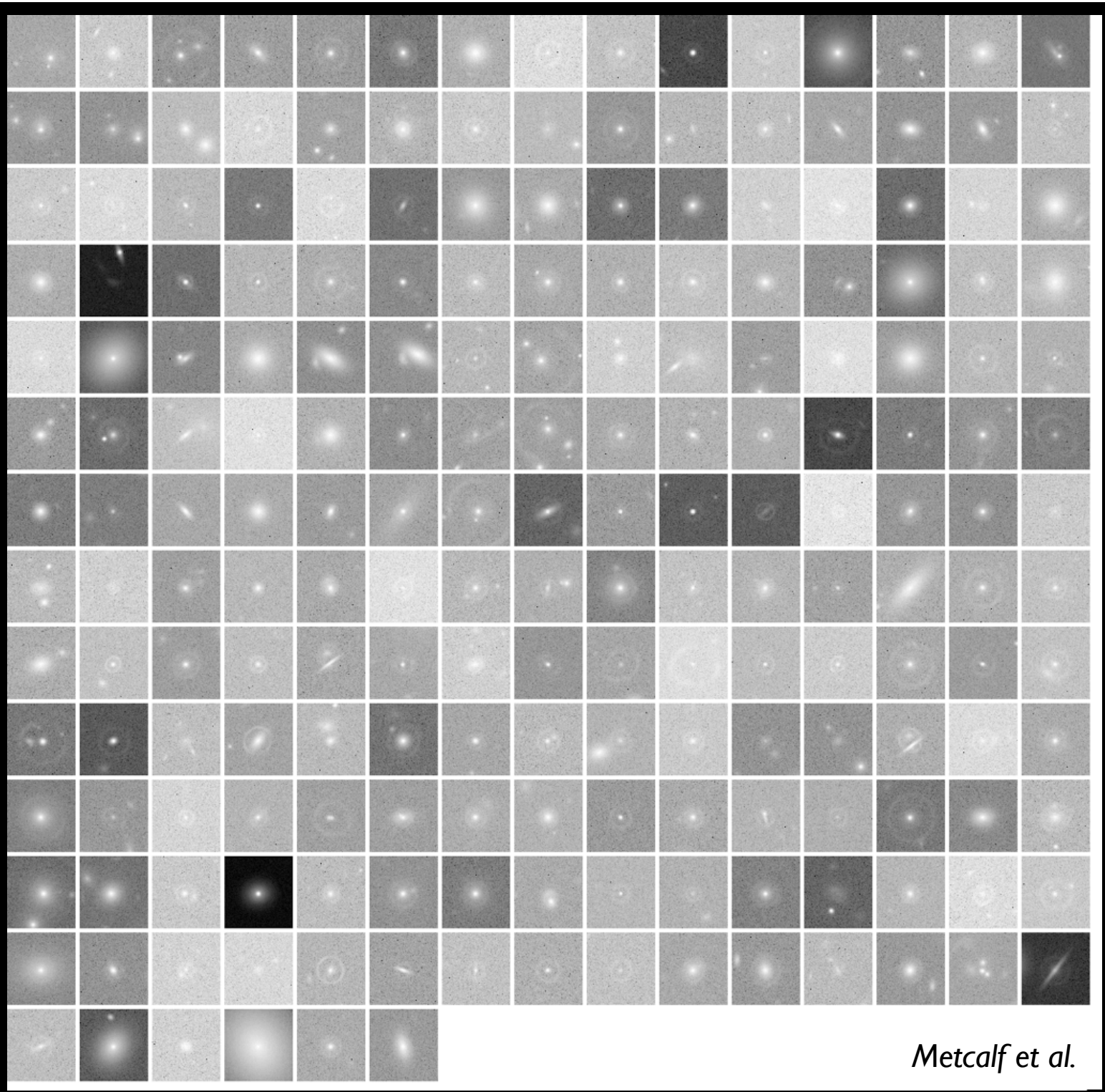
0.001002



Metcalf et al.


Metcalf et al.

The Bologna Lens Factory

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R. Benton Metcalf
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Gravitational lensing simulations - weak lensing, cluster lensing and galaxy lensing

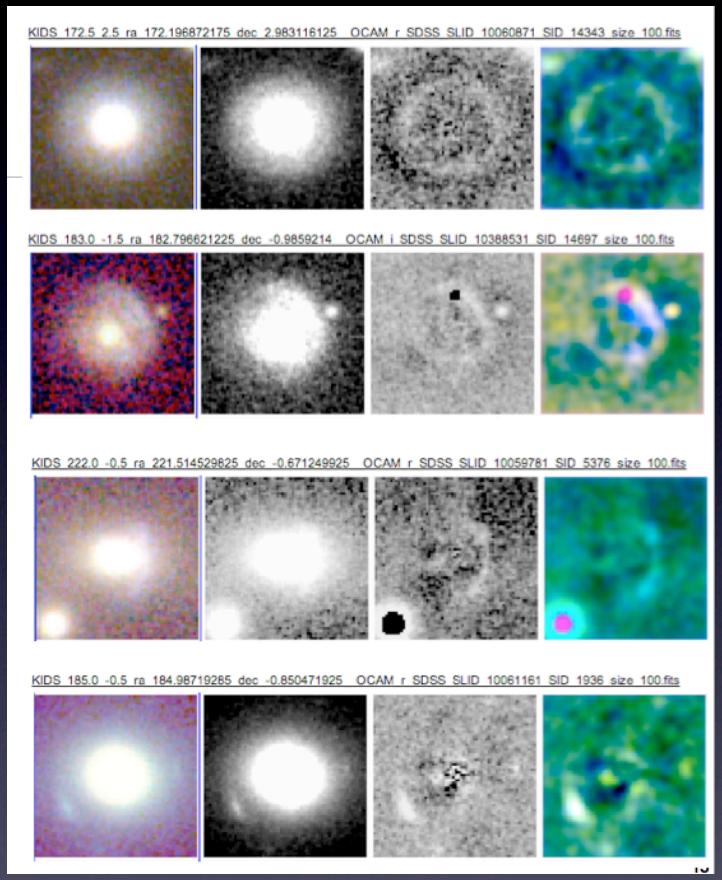
KiDS (the Kilo Degree Survey)
Strong Lensing Search

Lens candidates found two week ago.

~ 5,000 of an eventual ~ 200,000 galaxies (~1,500 sq.deg.) have been analyzed

Objective to fully characterize the detection efficiency and biases.

Precursor to Euclid



Using PCA ring finder method (Joseph, et al. 2014)

Using Arcfinder *(N. Jackson et al.)*

Conclusion

The TIML method will allow us to do weak gravitational lensing studies at redshifts well beyond traditional galaxy shear based methods.

Allow us to study early dark energy and modified gravity.

The number of known strong lenses will increase by orders of magnitude in the future.

They will become important probes of dark matter and cosmology.

To make these objects precise tools we are developing precise methods for finding and modeling them.