Argonne NATIONAL LABORATORY

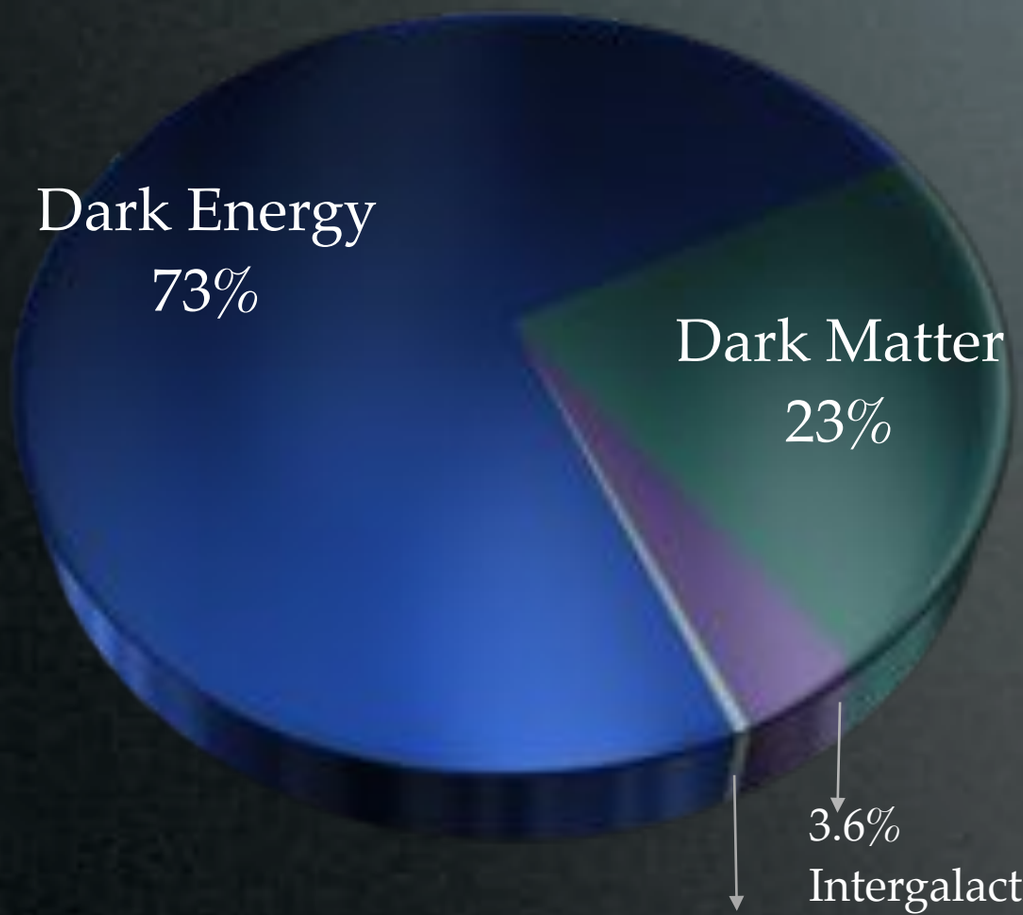
CLUSTER LENSING IN THE ERA OF SURVEYS

Sanghamitra Deb
Argonne National Laboratory

SF12

07/10/2012

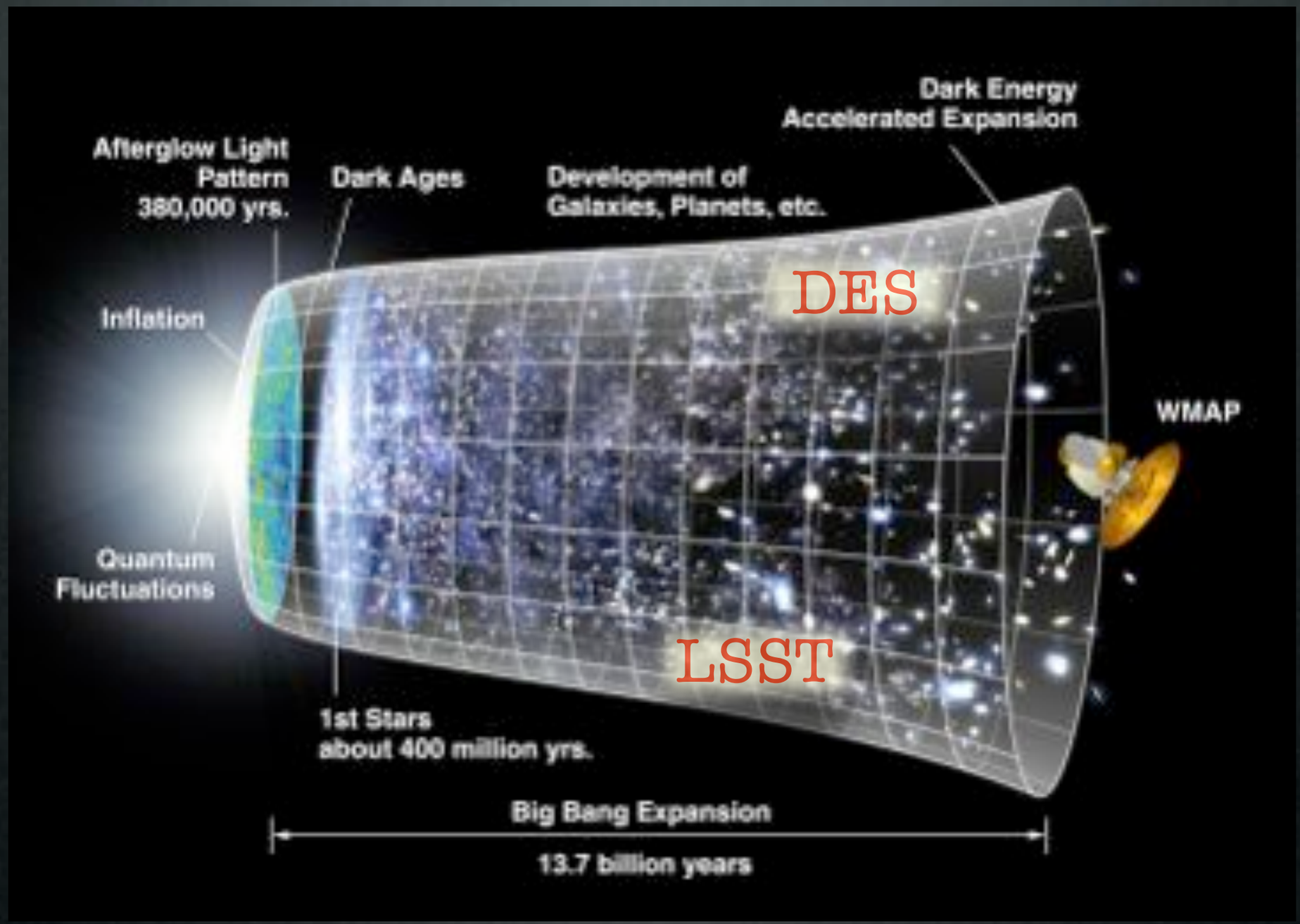
Energy Budget of the Universe



Cluster cosmology will be one of the key techniques to unveiling the "Dark" part of our universe.

Current surveys (DES, HSC LSST, EUCLID, ...) are aimed at understanding Dark Energy and Dark Matter

CLUSTERS RESIDE IN THE LATE UNIVERSE



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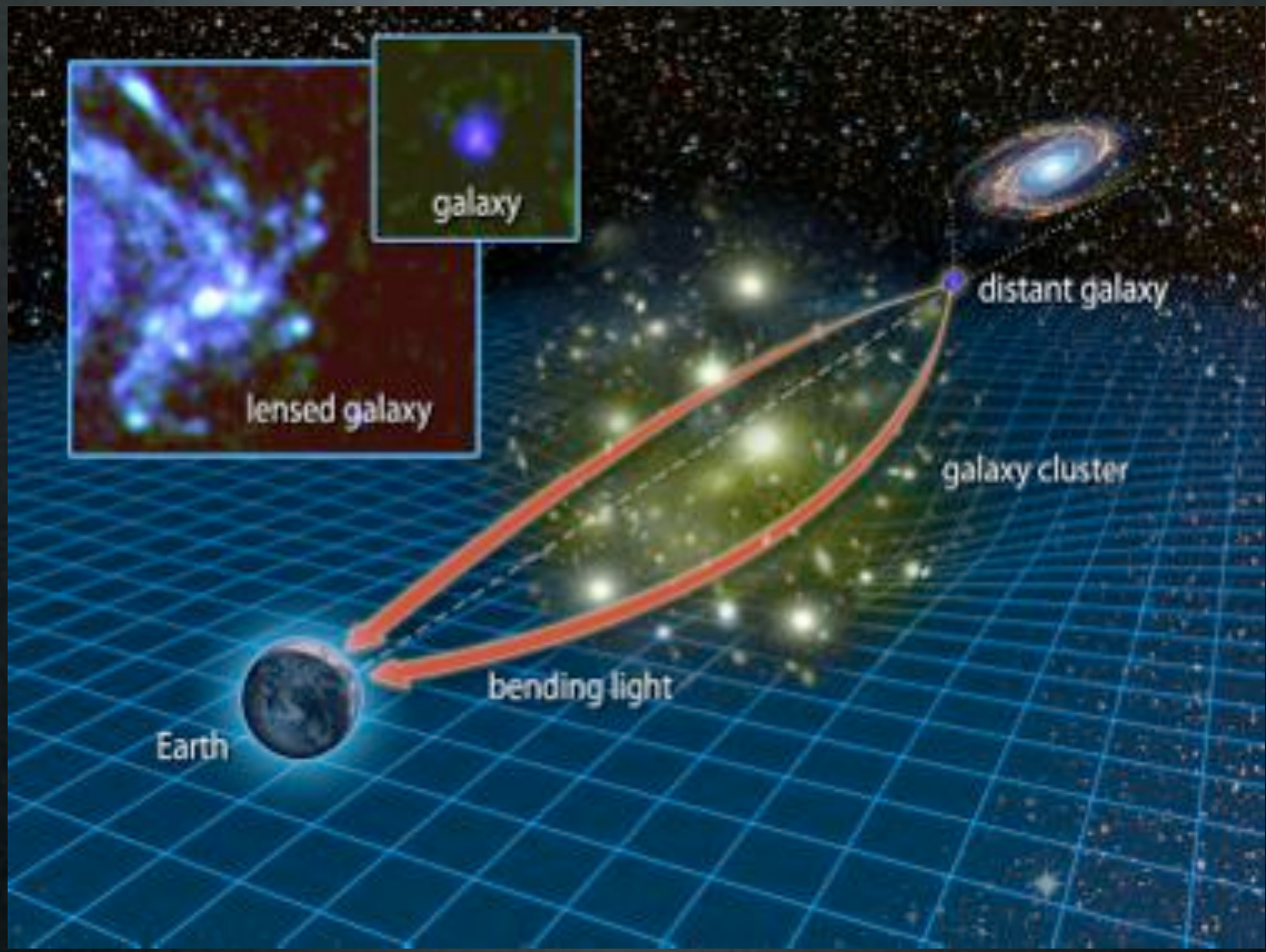
LENSING IS A COORDINATE TRANSFORMATION



http://keckobservatory.org/news/natures_best_magnifying_glass/

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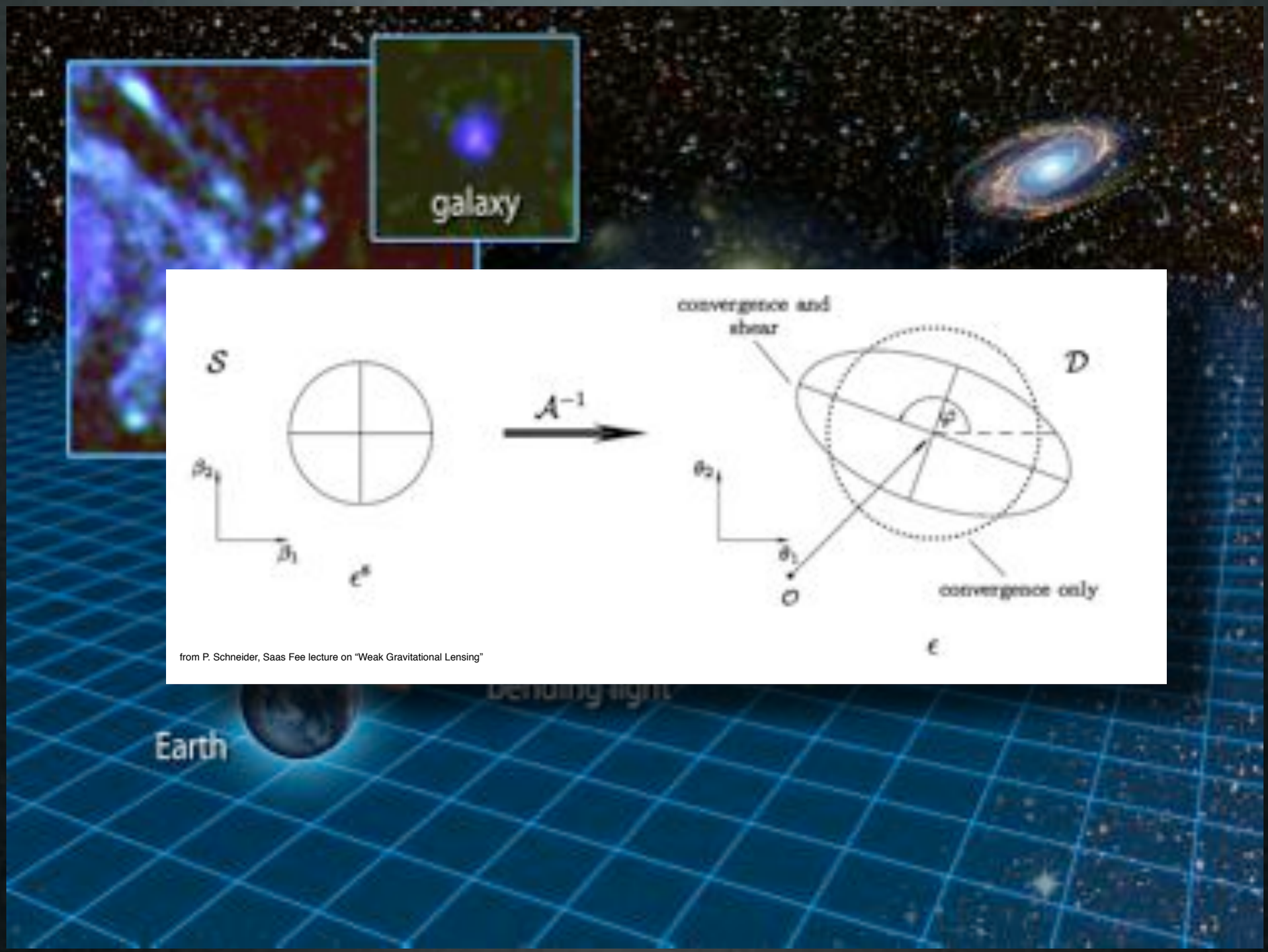
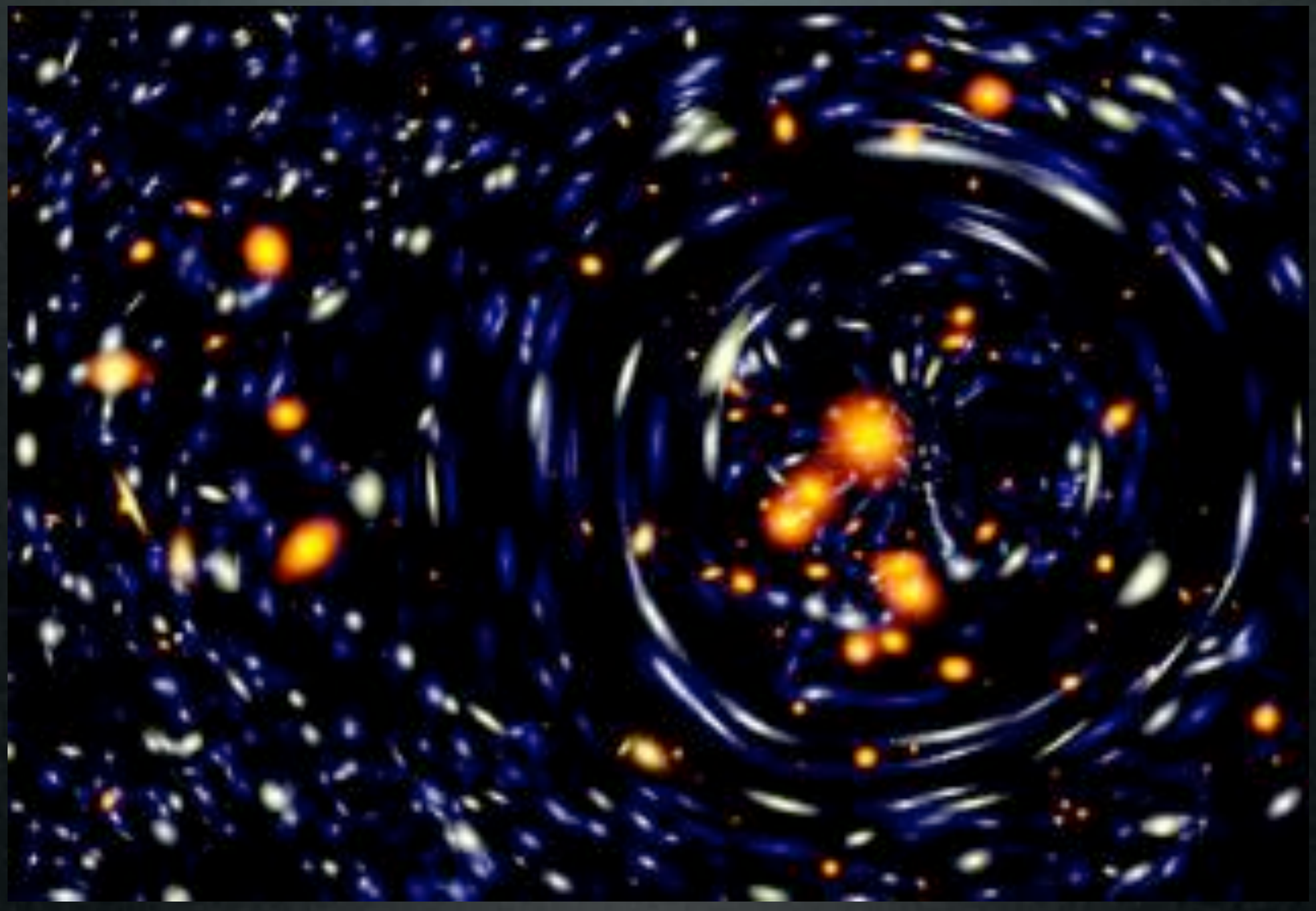
Lensing is a coordinate transformation



from P. Schneider, Saas Fee lecture on "Weak Gravitational Lensing"

http://keckobservatory.org/news/natures_best_magnifying_glass/

Looking at different lensing regimes



http://lsst.org/lsst/

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We are in the era of large cluster Surveys

MACS
The MAssive Cluster Survey

SL2S

SDSS

CFHTLS

Giant Arc Survey

200 groups+clusters

KIDS

DES

~50 SUBARU

LoCuss

KIDS

LSST, EUCLID, ...

SuperMassive Clusters

....and many more

CLASH

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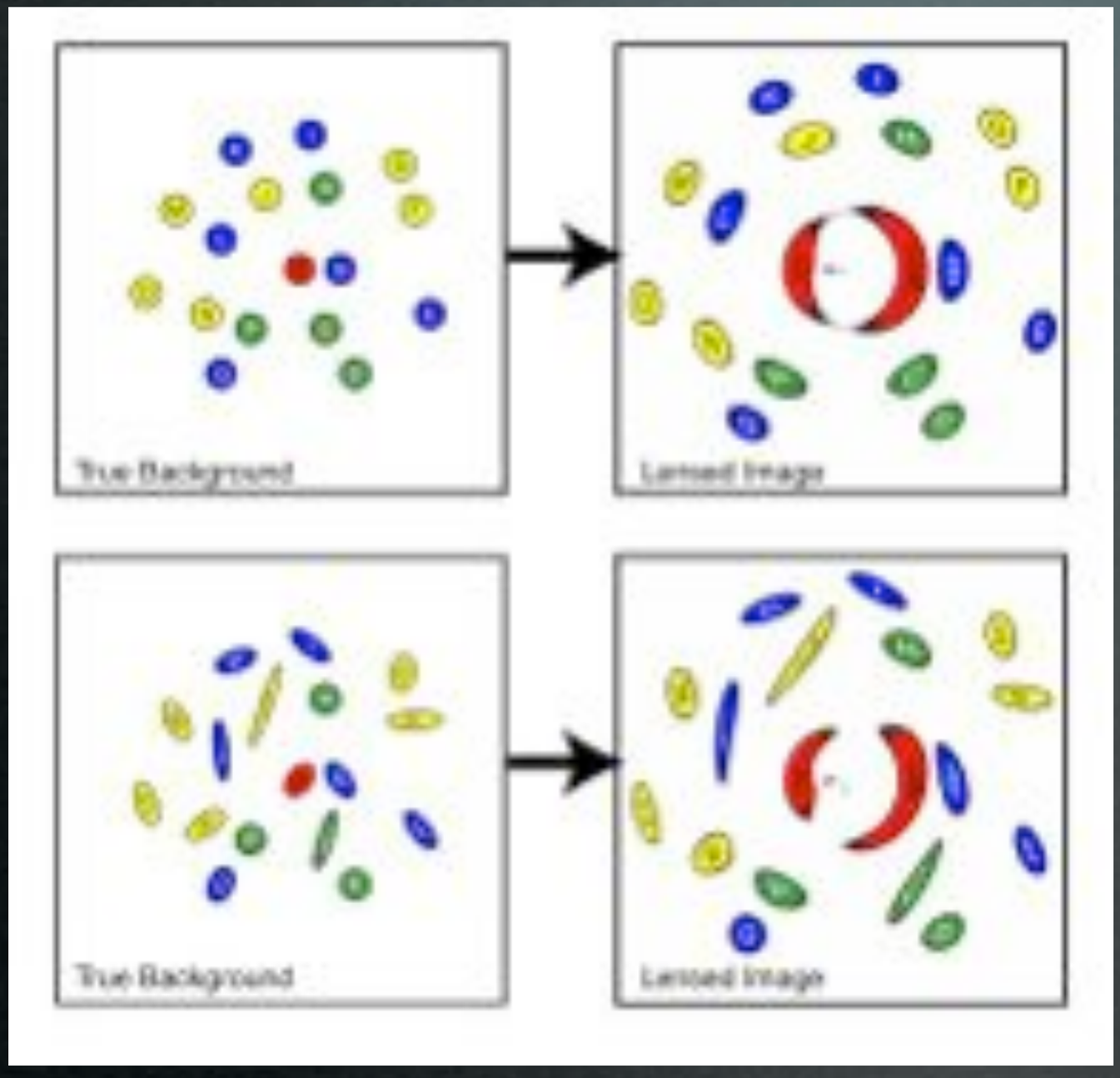
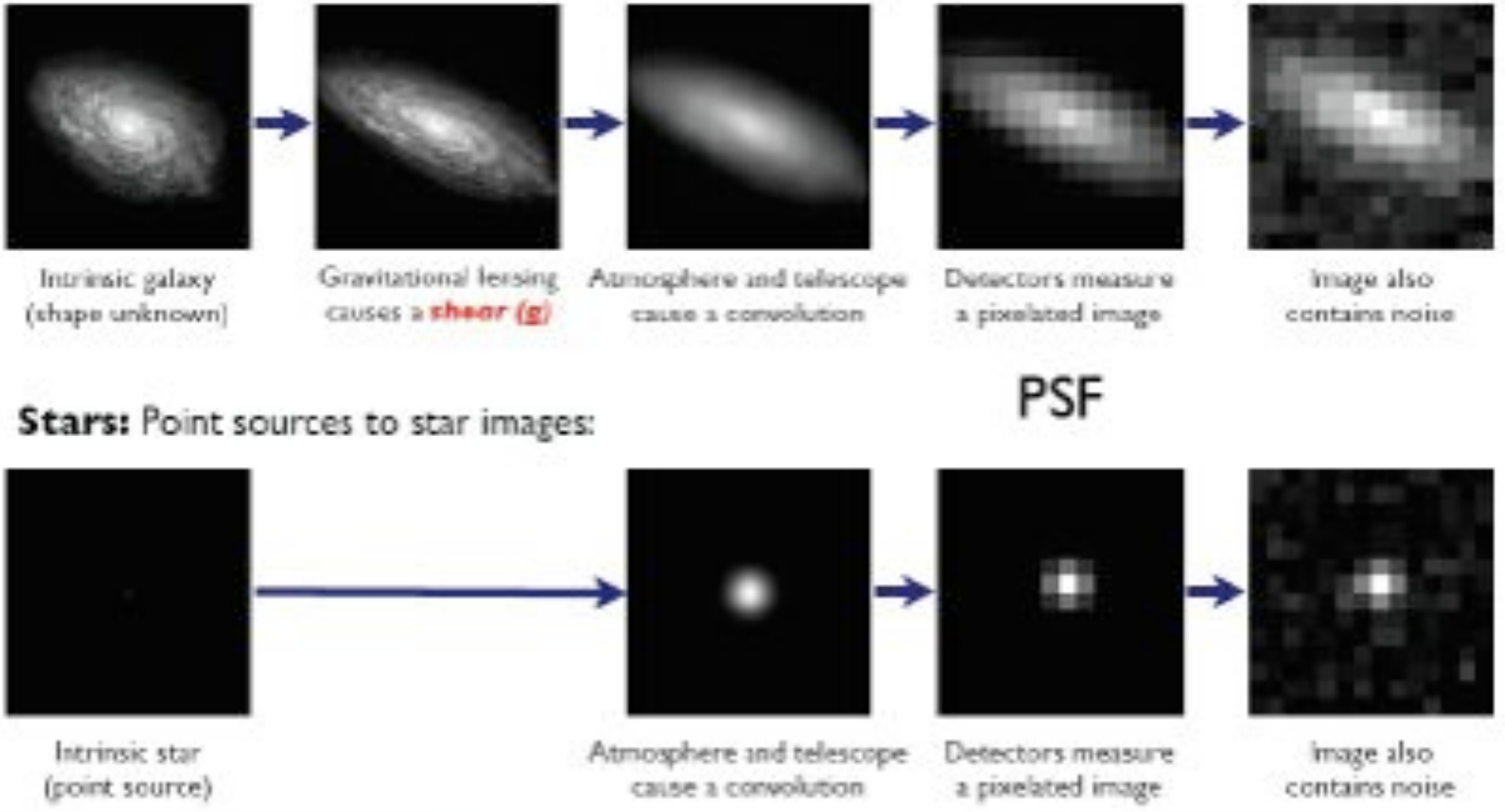
Gravitational Lensing causes coherent distortions



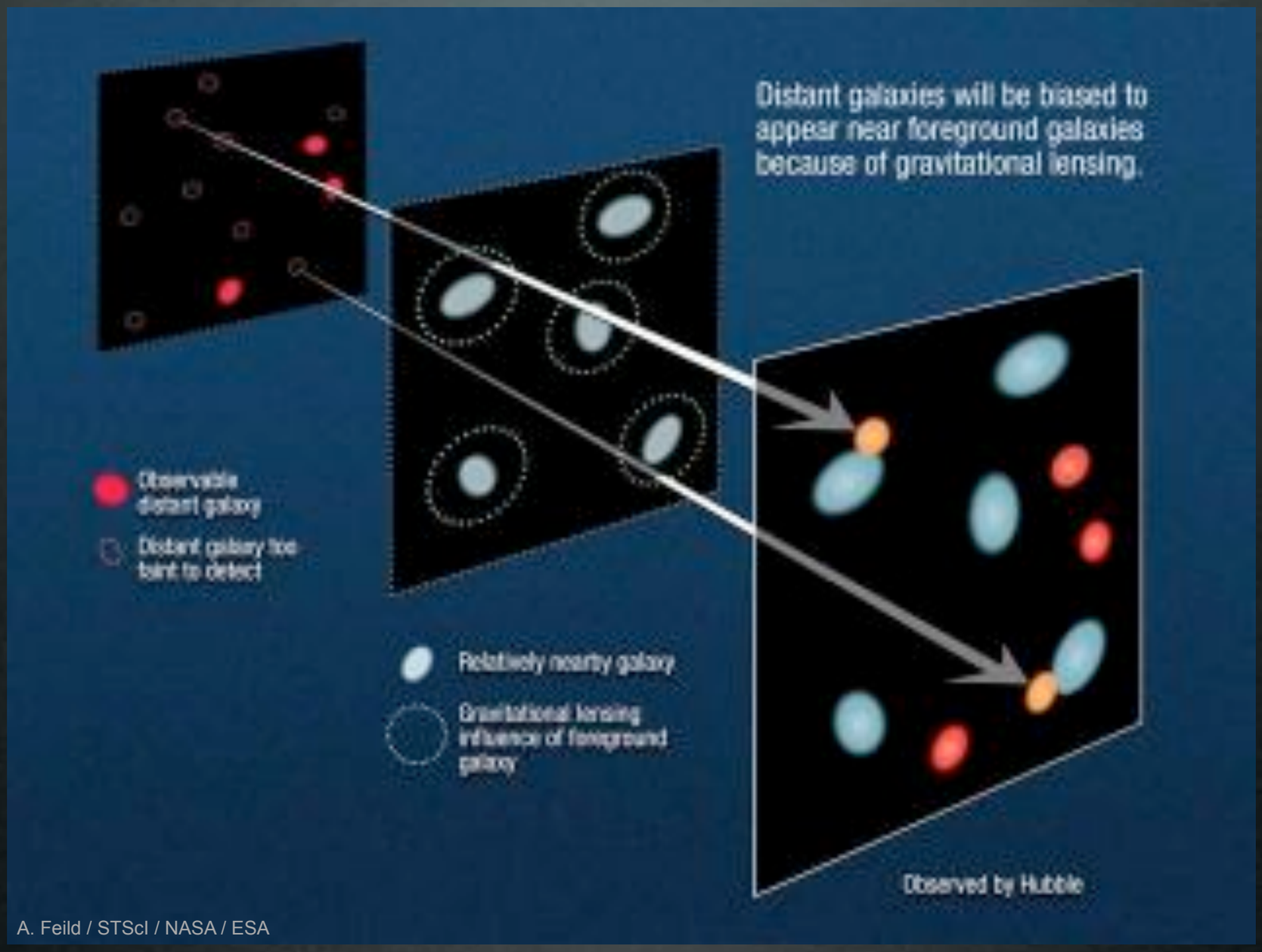
Williamson et al. 2007.

Weak lensing is a statistical measure of the distortion of background galaxies due to the intervening mass.

MEASURING GALAXY ELLIPTICITY IS DIFFICULT



Another weak lensing effect is magnification



A. Feild / STScI / NASA / ESA

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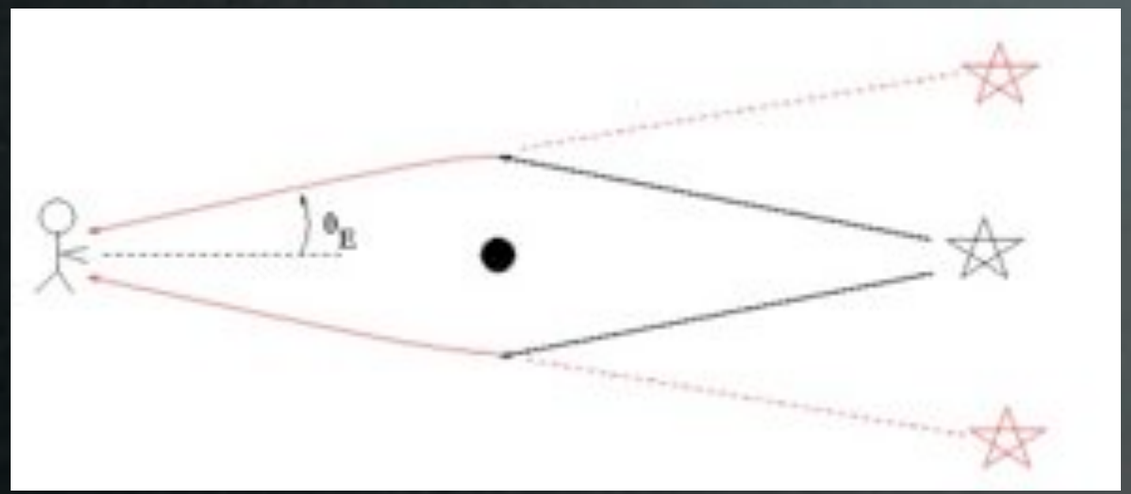
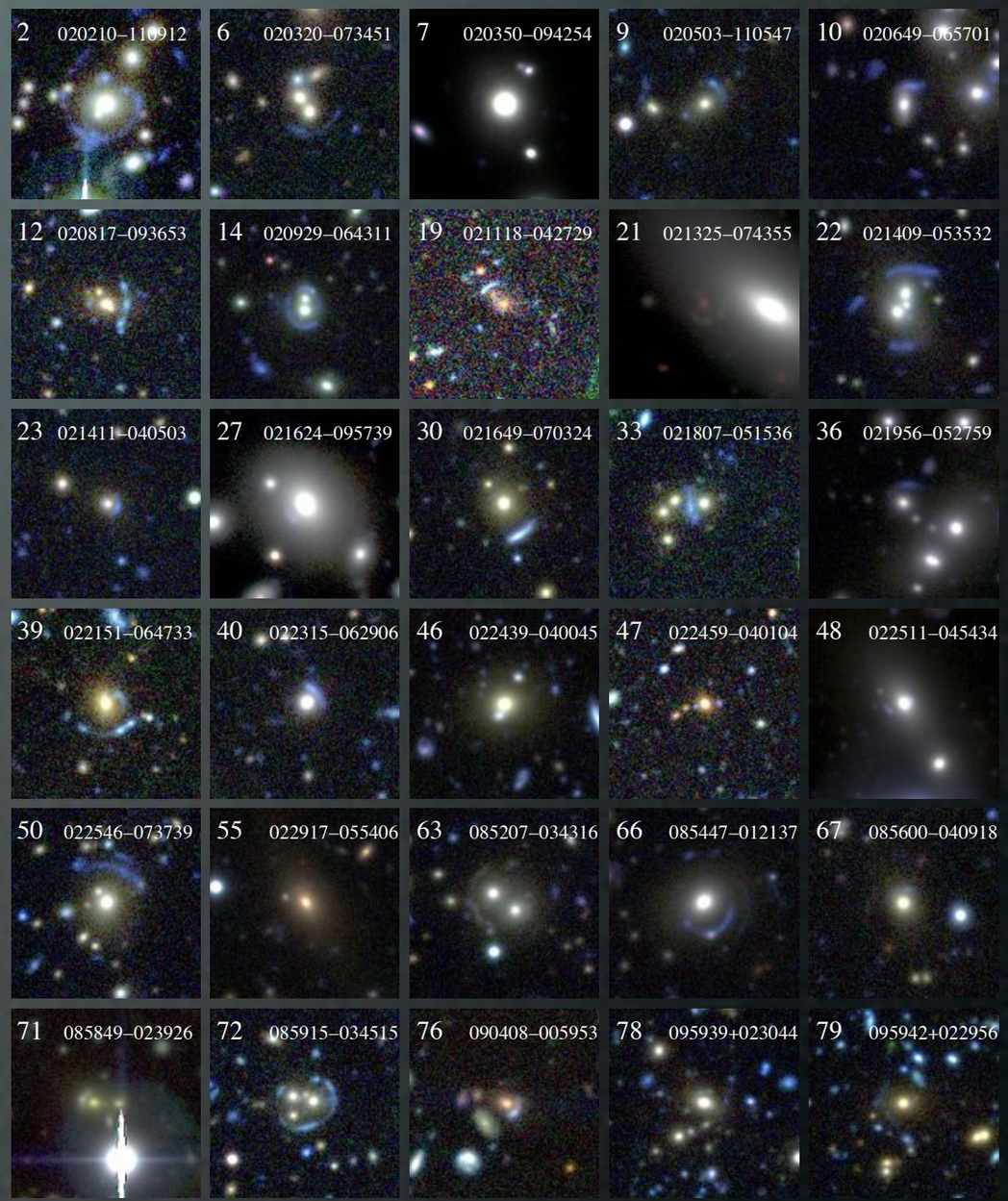
Lensing at its best: Strong Lensing





More et al. 2011.

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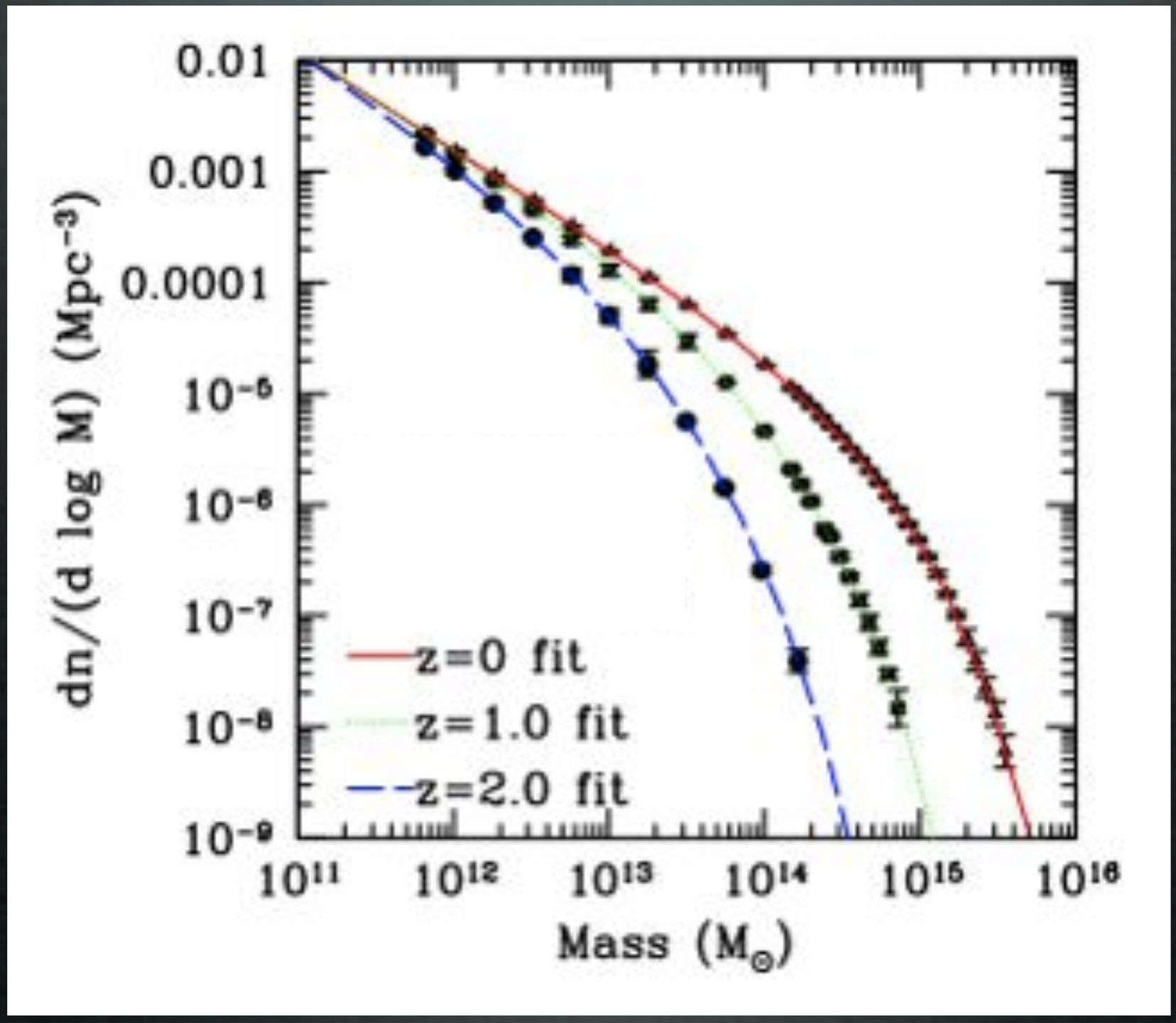
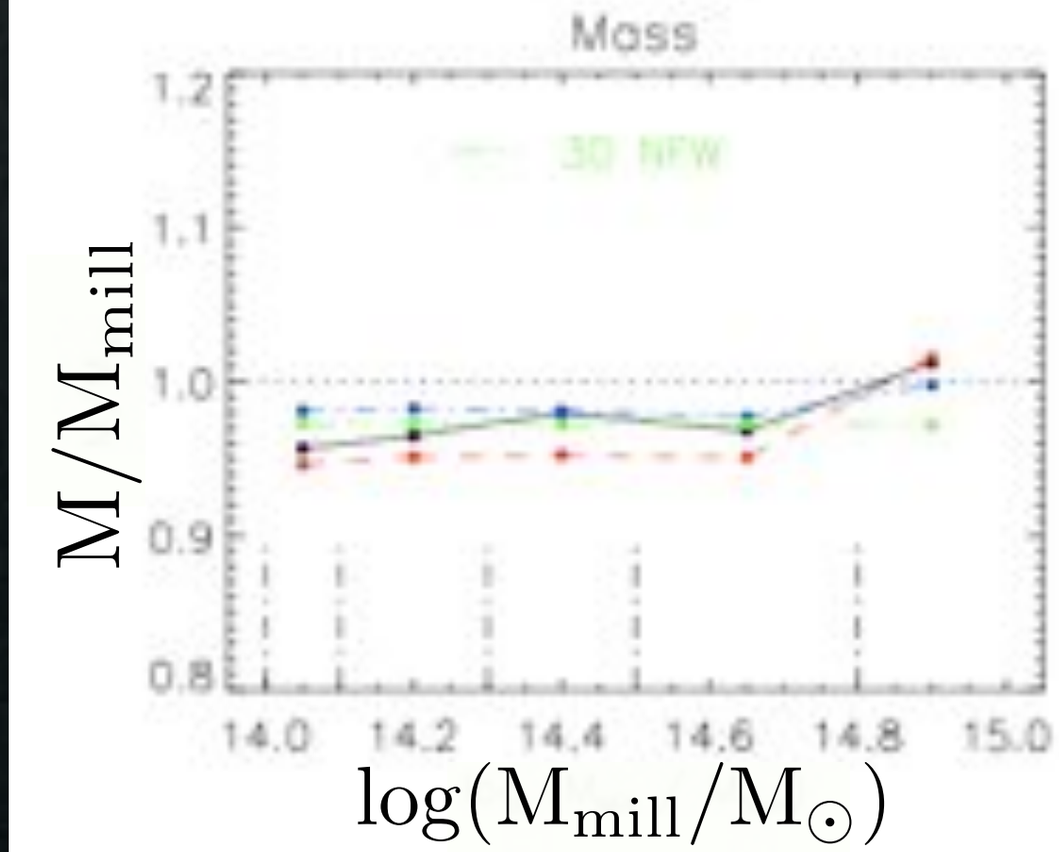
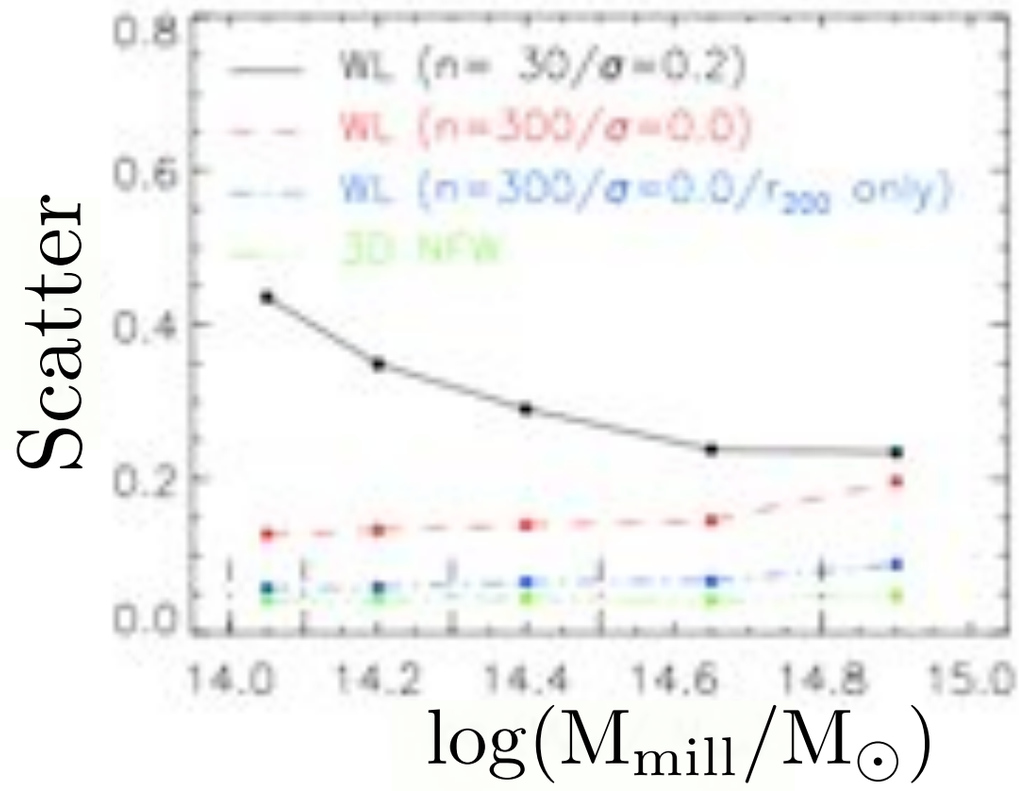
The Cluster Mass Function falls sharply

Bhattacharya et. al.



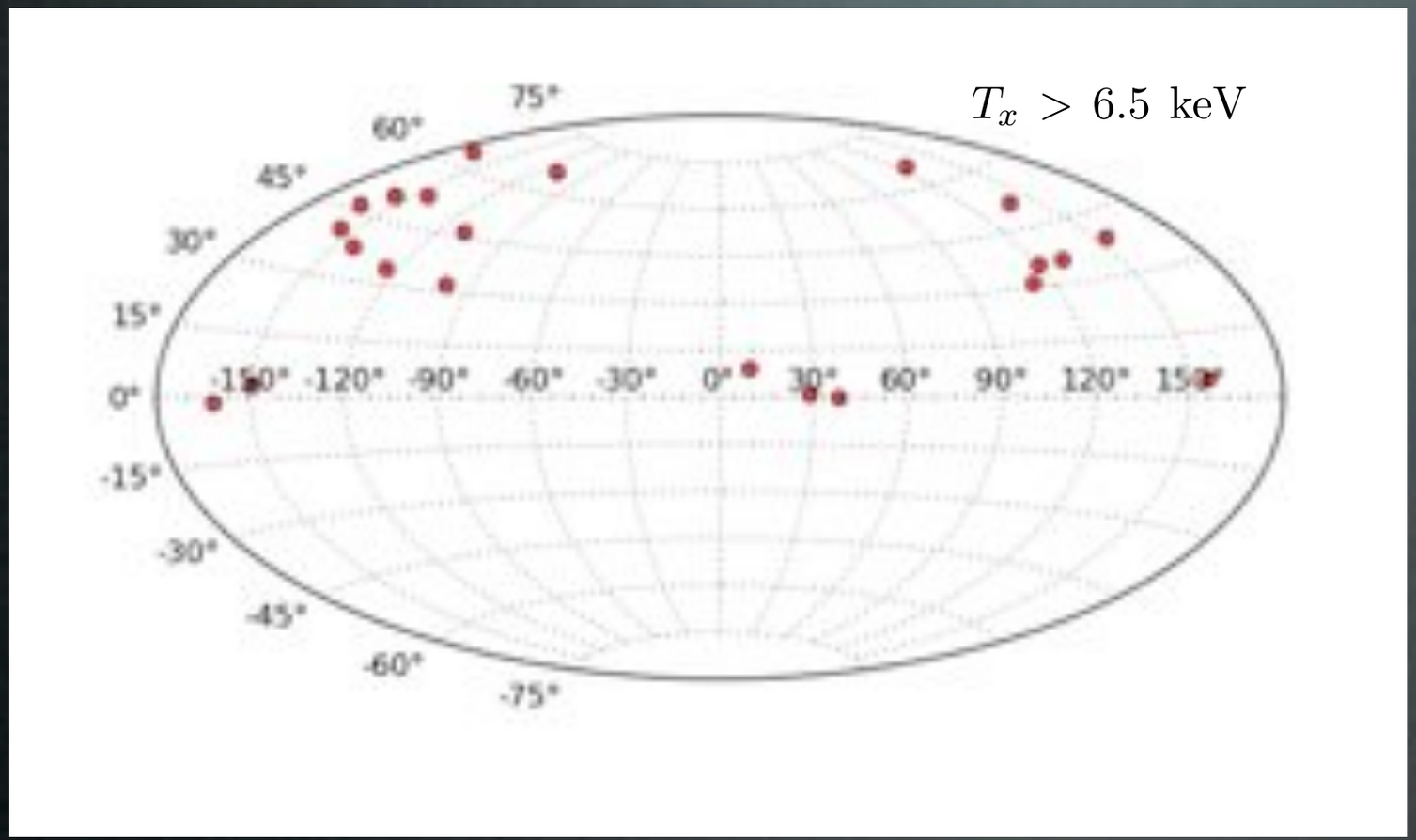
...THERE ARE CHALLENGES IN WEAK LENSING MASS MEASUREMENTS





Bahe et al. 2011

SuperMassive Clusters

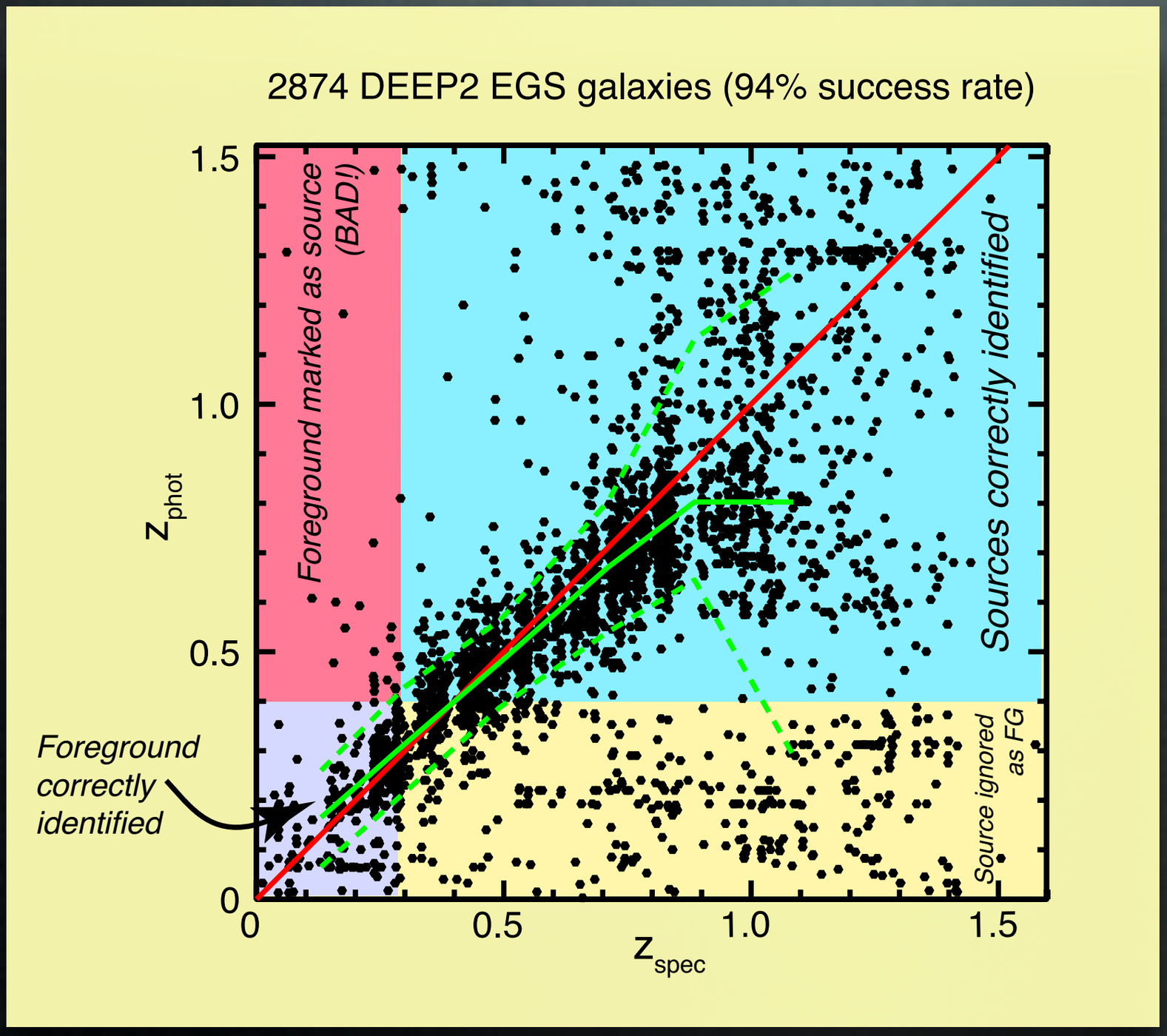


20 Clusters
0.15<z<0.3

Aim: *Constrain the intrinsic scatter in the mass-temperature relationship within 5%. This will be done by using excellent photozs and combining simulations to account for the foreground large scale structure. Massive clusters at low redshift are chosen to ensure accurate mass estimates.*

Existing data on X-rays and Strong Lensing

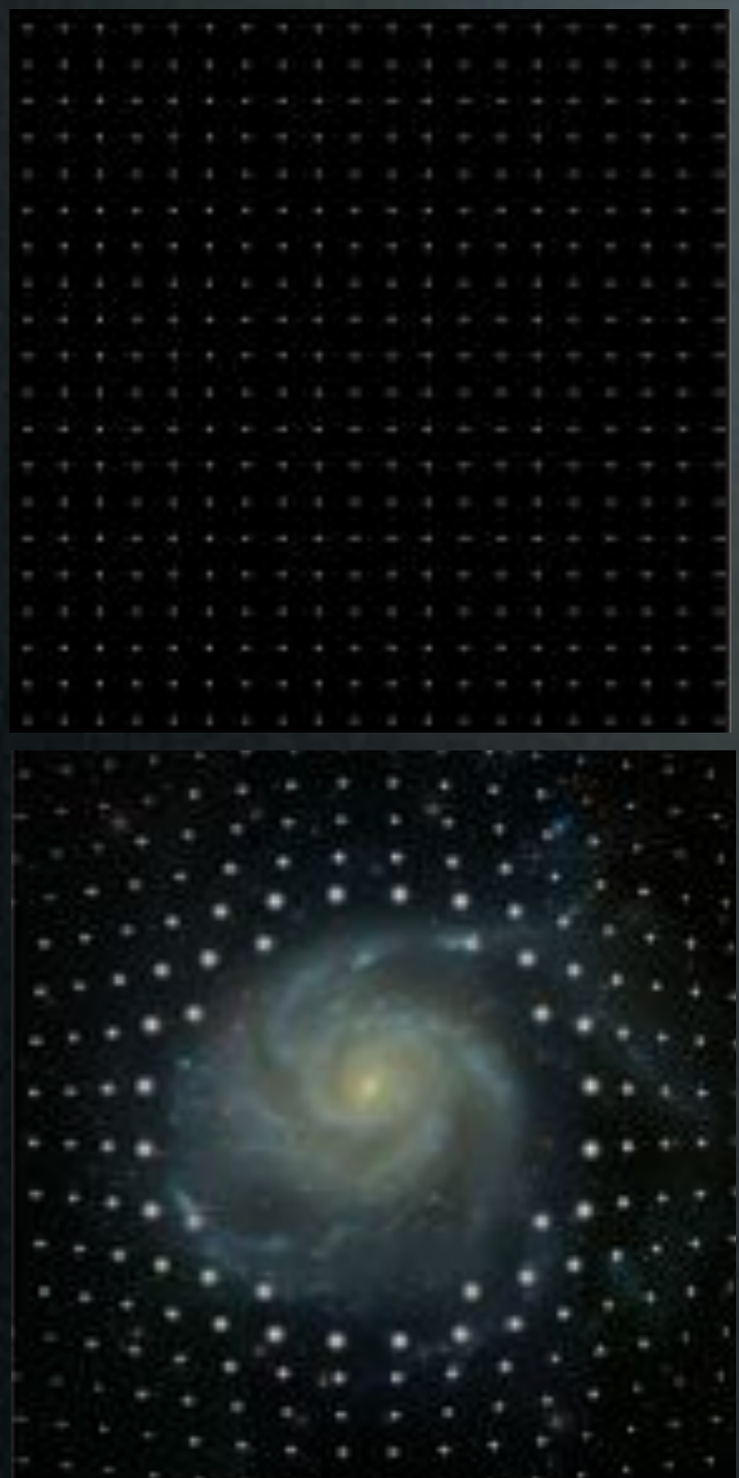
Separating foreground and background galaxies



For $z < 0.8$, scatter in $dz/(1+z) \sim 0.065$.

MacDonald et al. (in prep.)

Magnification changes source density



http://www.sdss.org/news/releases/20050426.magnification.html

$$N(m) = N_0(m)\mu^{2.5s(m)-1}$$

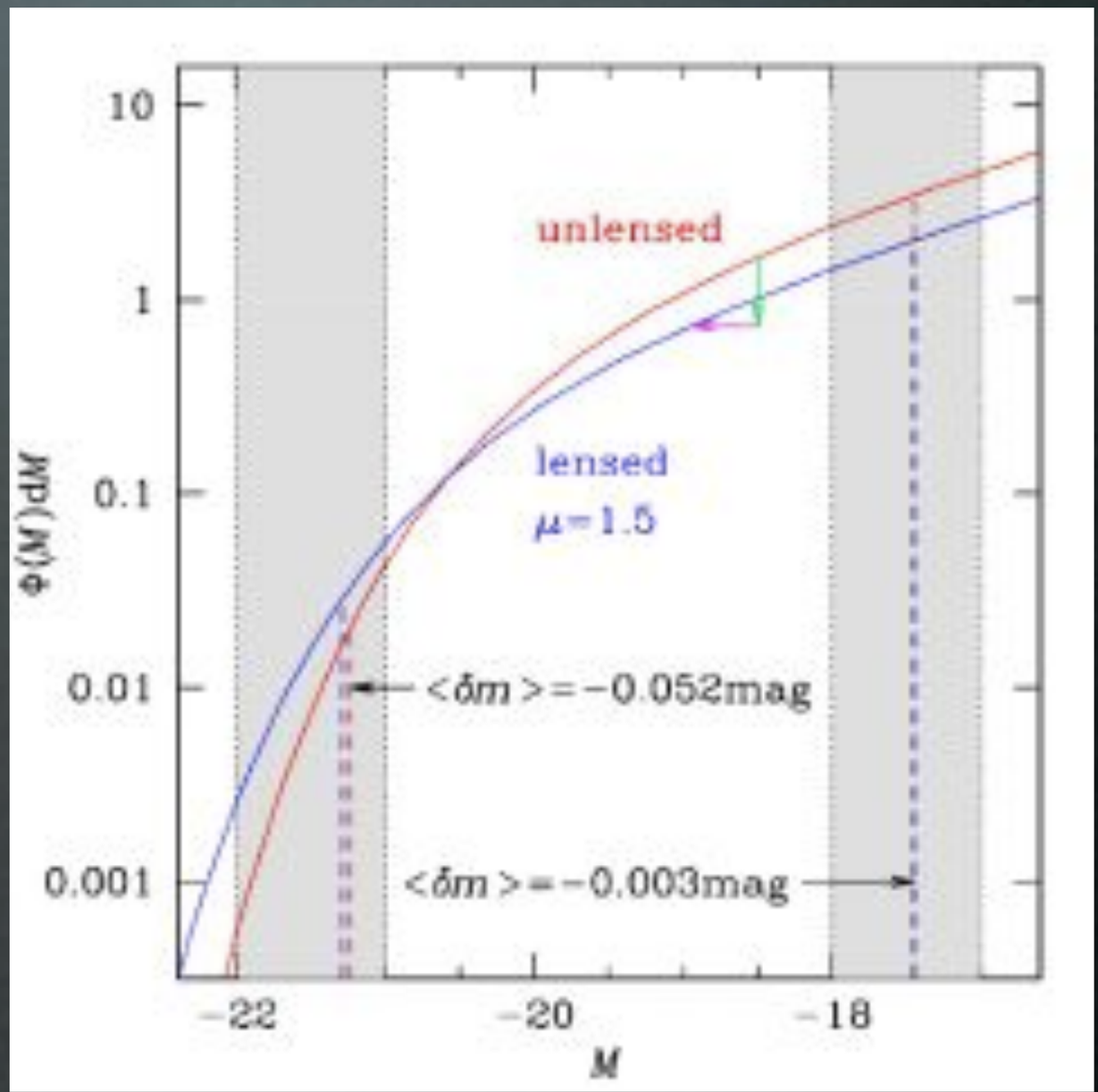


image credit: Hendrik Hildebrandt

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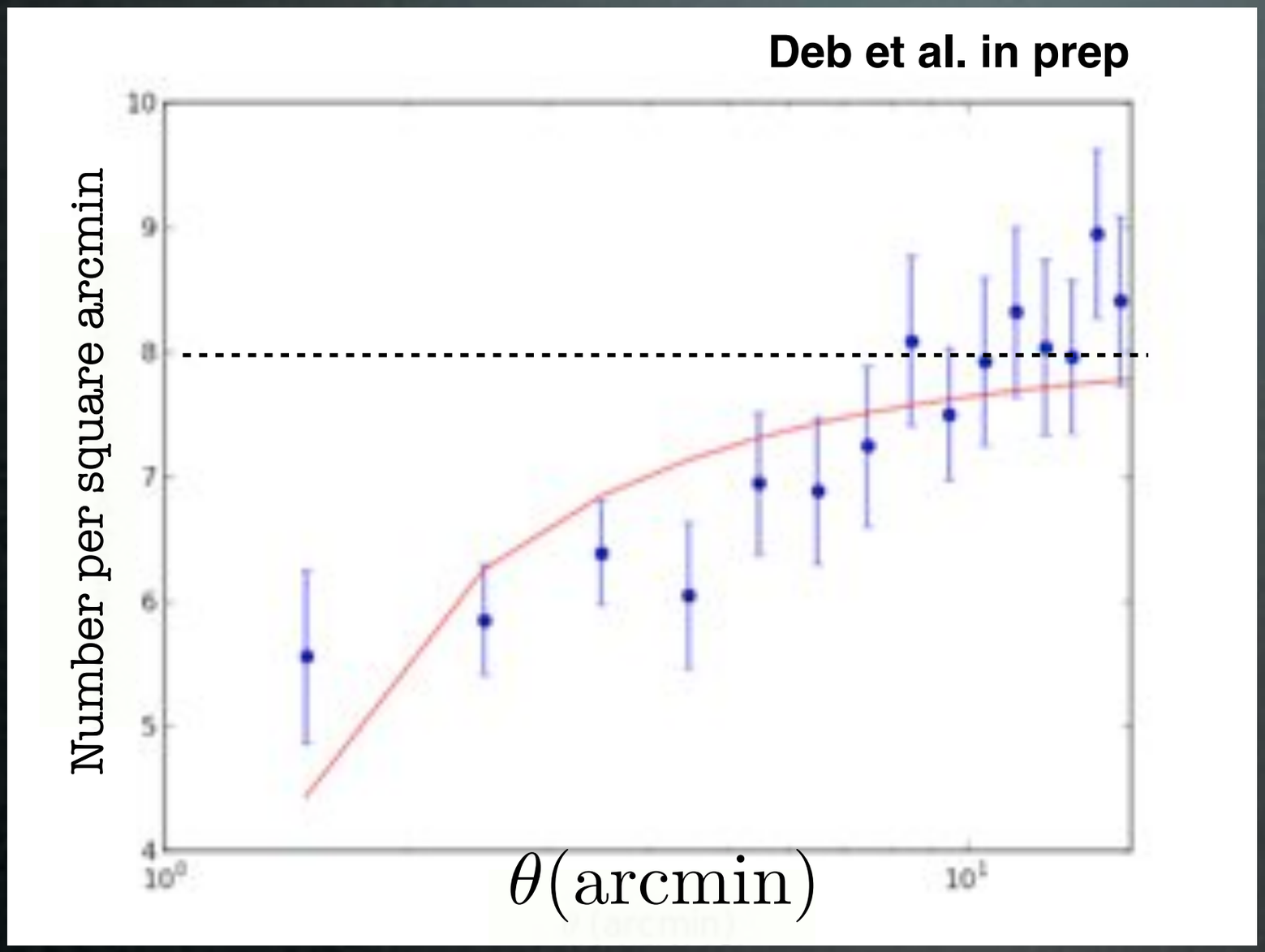
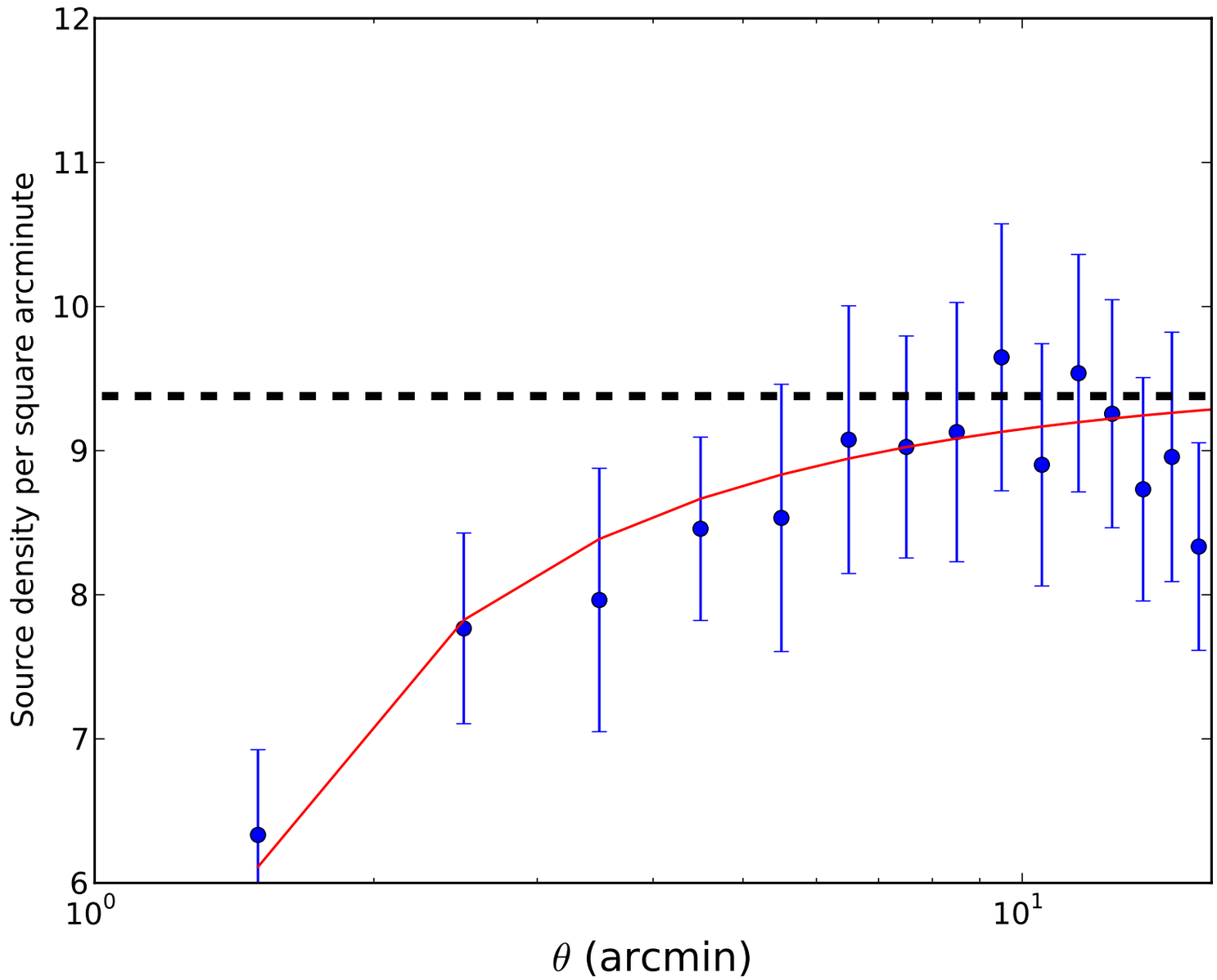
Magnification Depletion in A2261



$$\chi_\mu{}^2 = \Sigma_i \frac{(\hat{n}_\mu^i - n_\mu^i)^2}{\sigma_n^2}$$

Poisson +Clustering

Magnification Depletion in A2219



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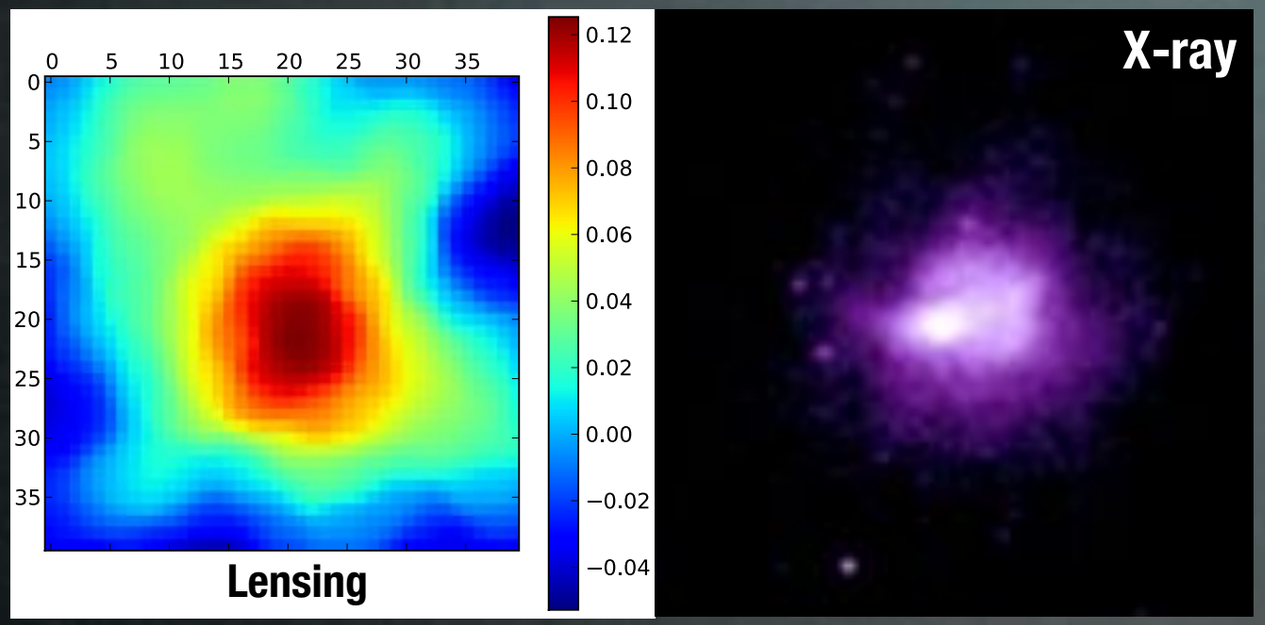
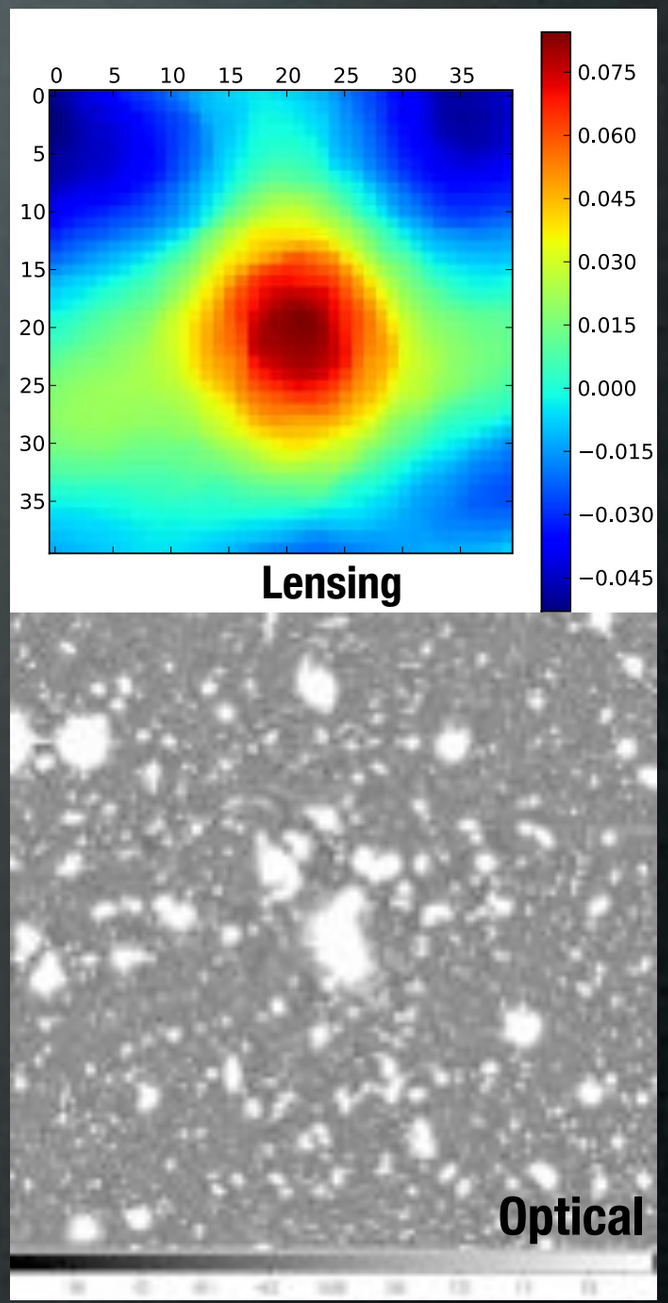
An ongoing study...

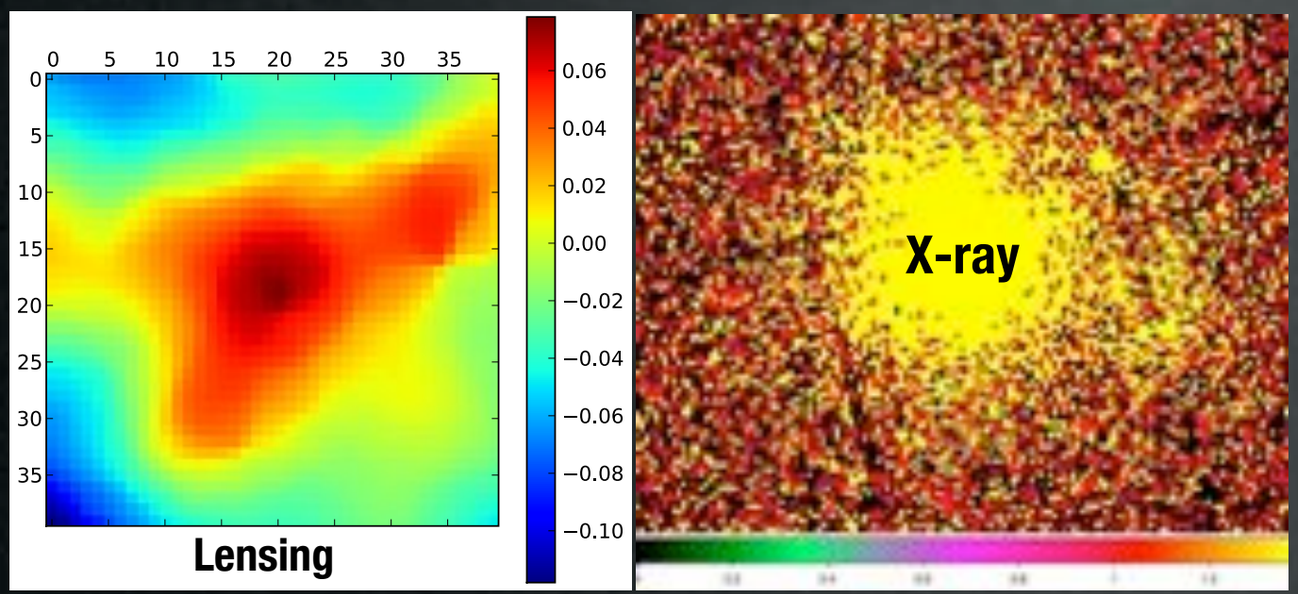
A1914



A2219



A2261



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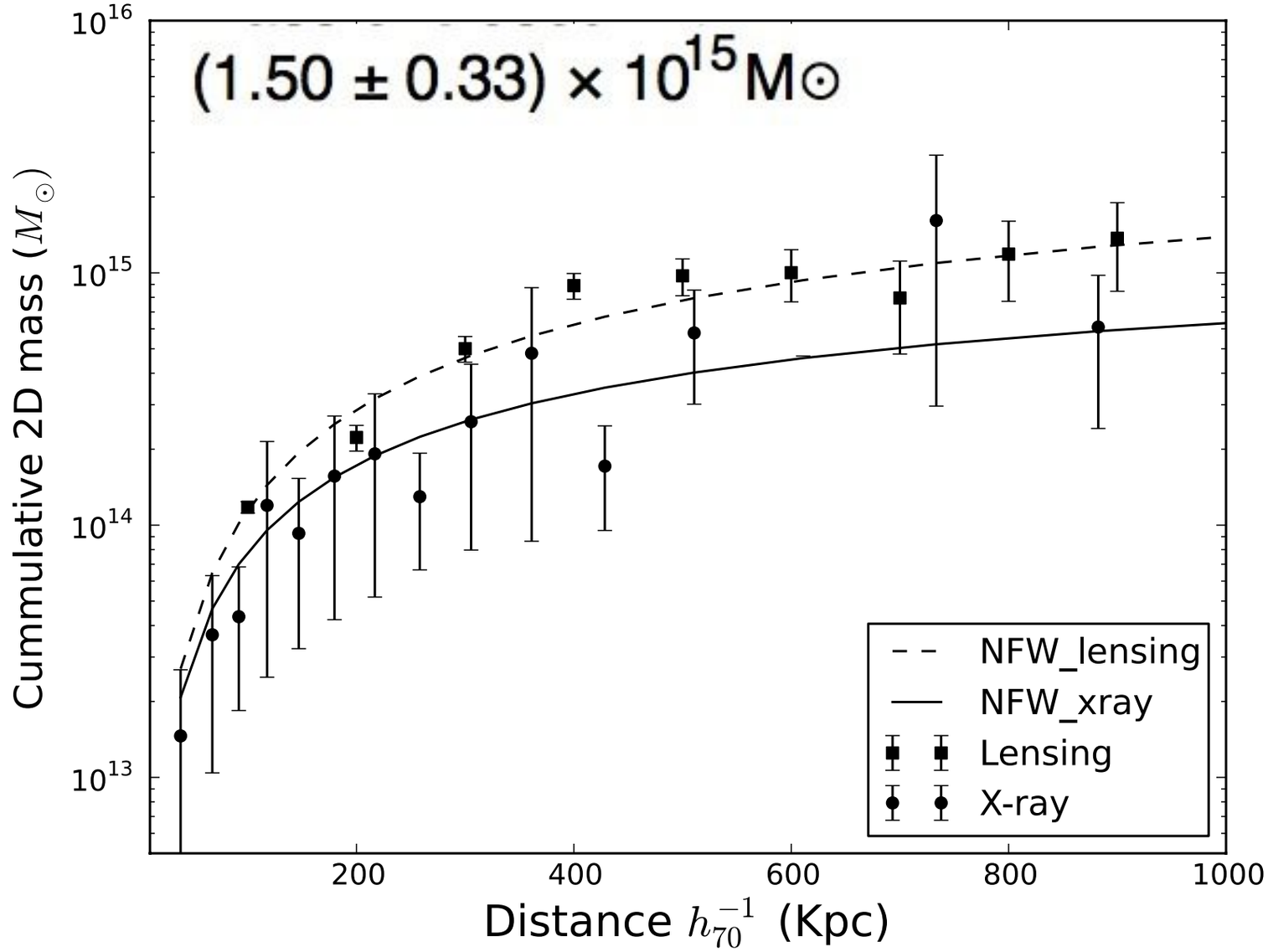
Profile Fitting: A1689

Deb et al. 2011



Shear vs. Magnification

Shear Advantages

- Higher S/N per galaxy.

$$\left(\frac{\mathrm{S}}{\mathrm{N}}\right) = \frac{|\gamma|}{\sigma_\epsilon}\sqrt{N}$$

- $\left\langle \epsilon^{(s)} \right\rangle = 0$

Disadvantages

- PSF, pixelization and Measurement Noise.
- Intrinsic Alignments.

Magnification Advantages

- Object detection is easier than shape measurement.
- More galaxies available, especially at high redshifts.

Disadvantages

- Lower signal-to-noise per galaxy.
- Prior knowledge of Luminosity Function.

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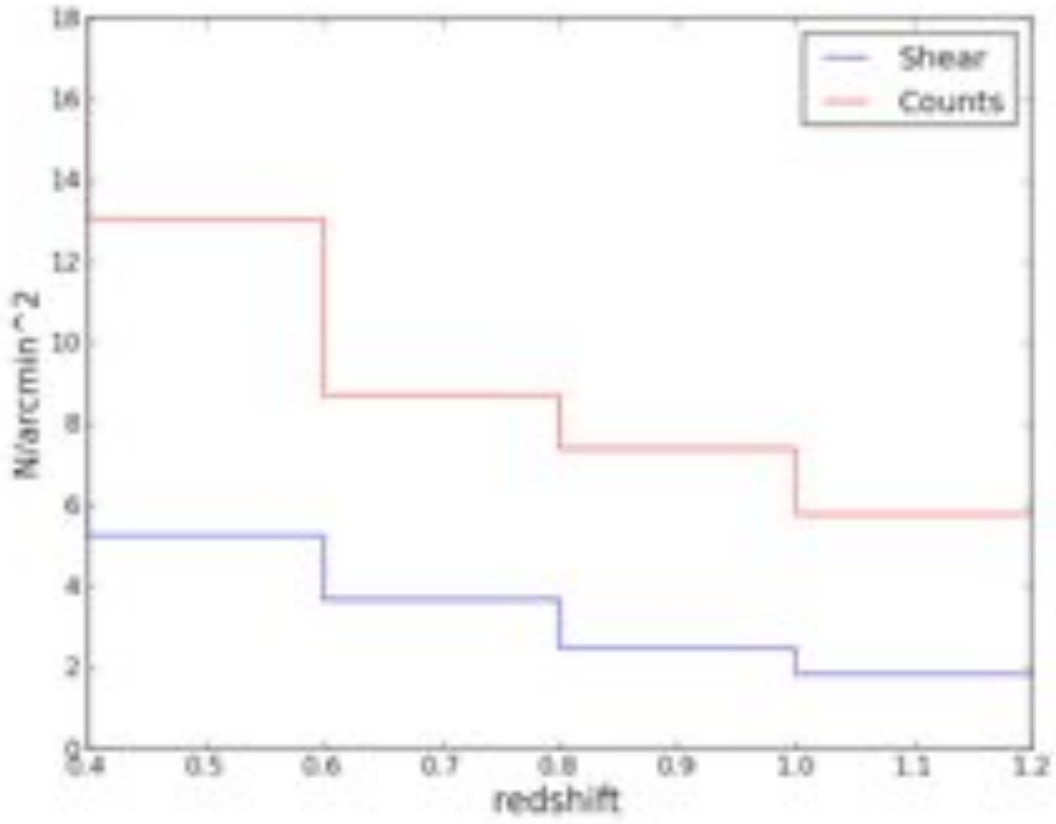
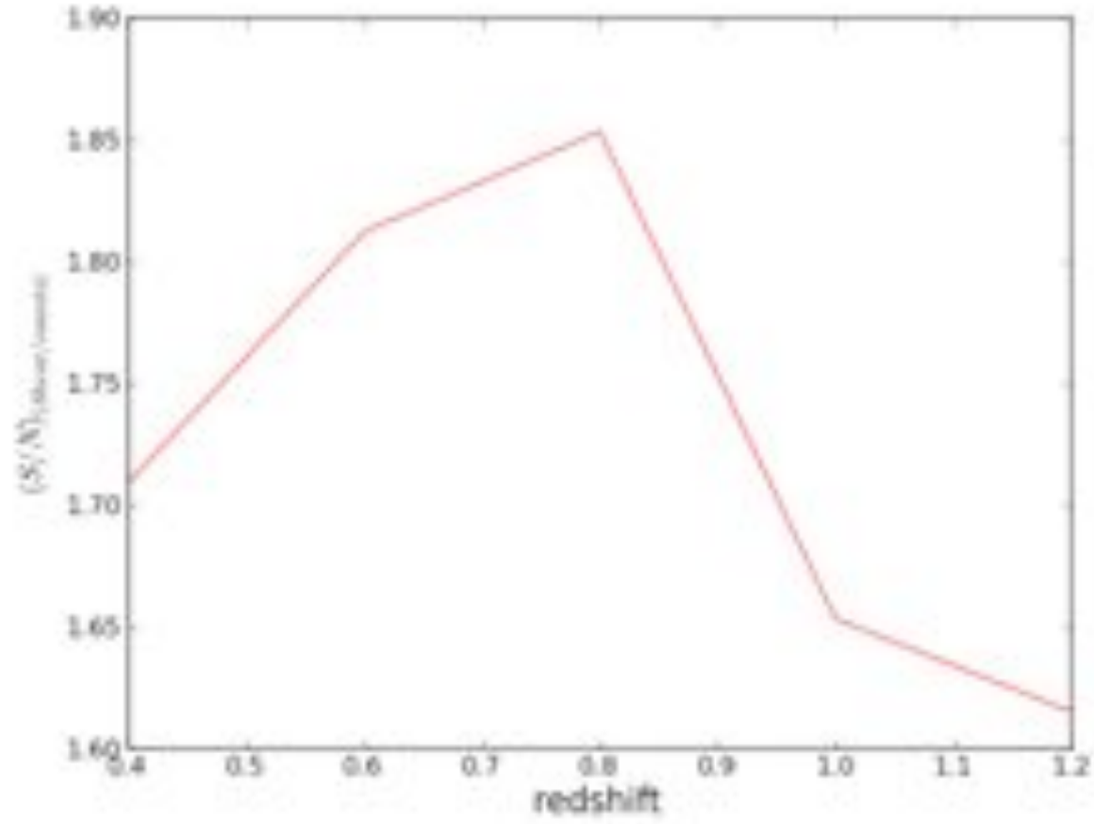
Shear + Magnification: Maximizes S/N

Shear vs. Magnification





$$(S/N)_{\frac{\gamma}{\mathrm{Mag}}} = \frac{1}{2\sigma_e|s-1|}\left(\frac{N_{shear}}{N_{counts}}\right)^{0.5}$$

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Looking ahead into the era of survey science

- **Cluster Cosmology:** From individual clusters to thousands of objects: a step toward measuring the mass function.

- **Shear + Magnification+Strong Lensing:** Maximum S/N from data.

Major Challenges: Systematics, systematics, ...

Collaborators

Salman Habib
Katrin Heitmann
Juliana Kwan
Adrian Pope
Suman Bhattachraya
Amol Upadhye

Reiko Nakajima
Rachel Mandelbaum
Gary Bernstein
Jonathan MacDonald

Thank You