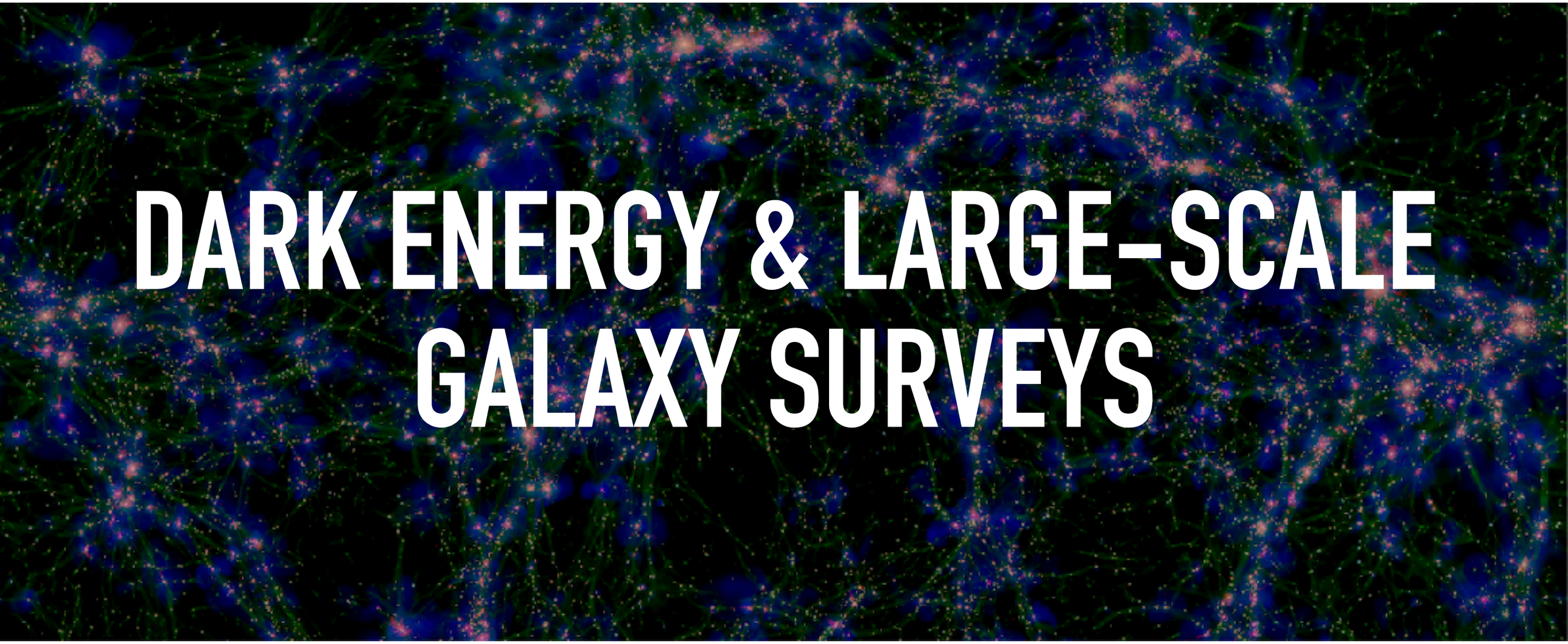


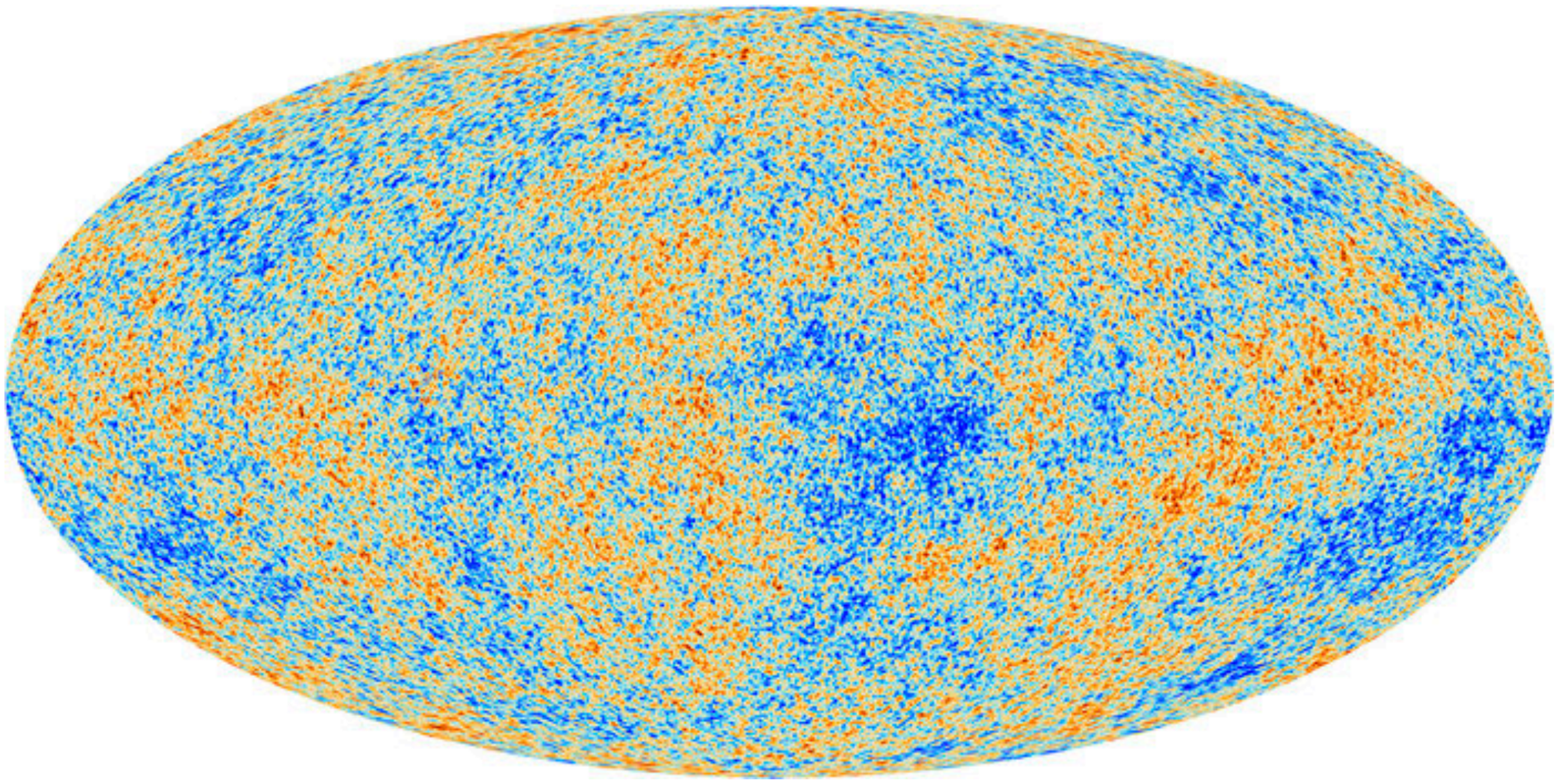
DARK ENERGY & LARGE-SCALE GALAXY SURVEYS

Elisa Chisari

Royal Astronomical Society Research Fellow

University of Oxford

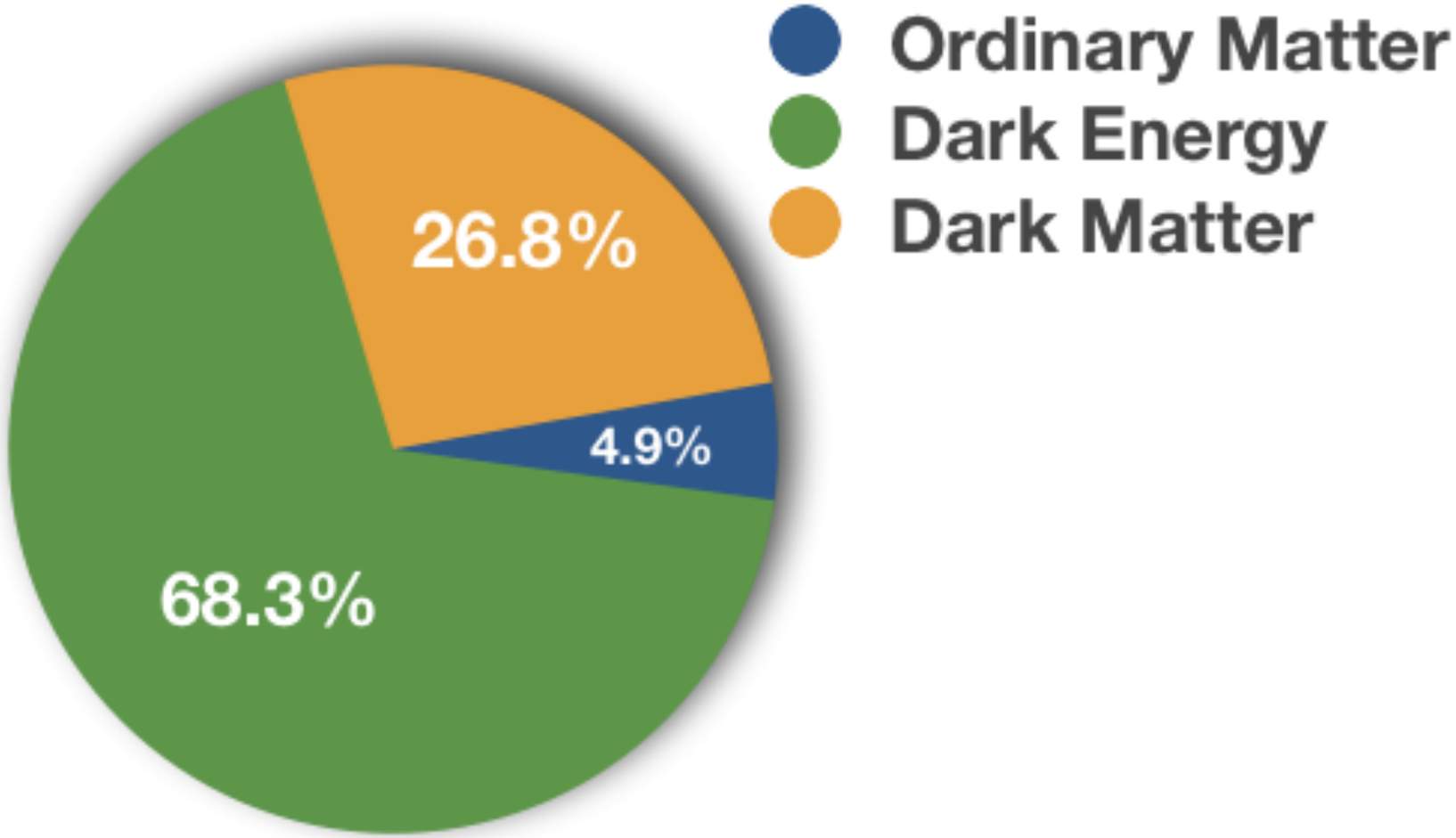
PRECISION COSMOLOGY



The cosmic microwave background (CMB)
400,000 years after the Big Bang

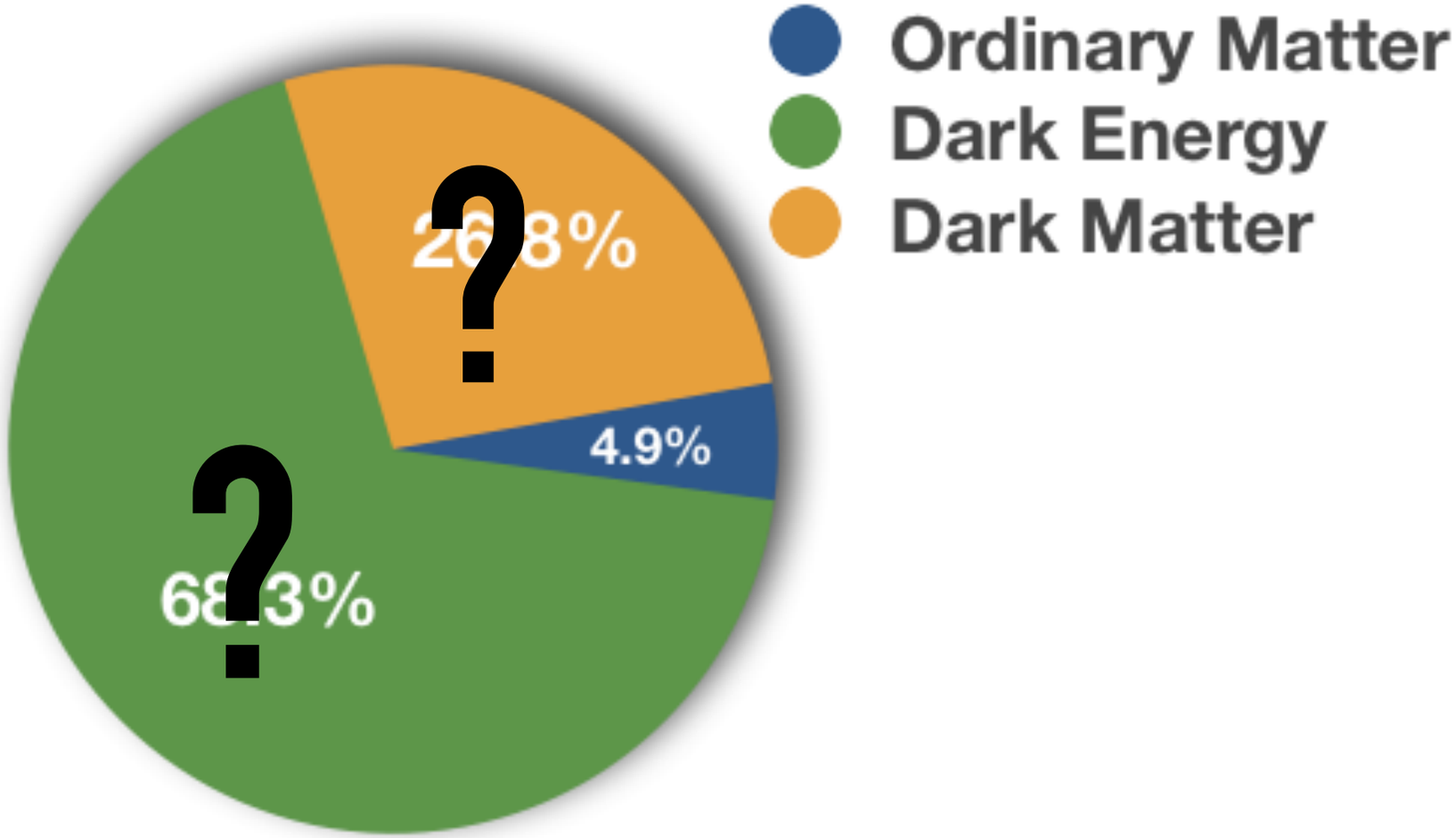
Image: ESA & the Planck Collaboration

PRECISION COSMOLOGY



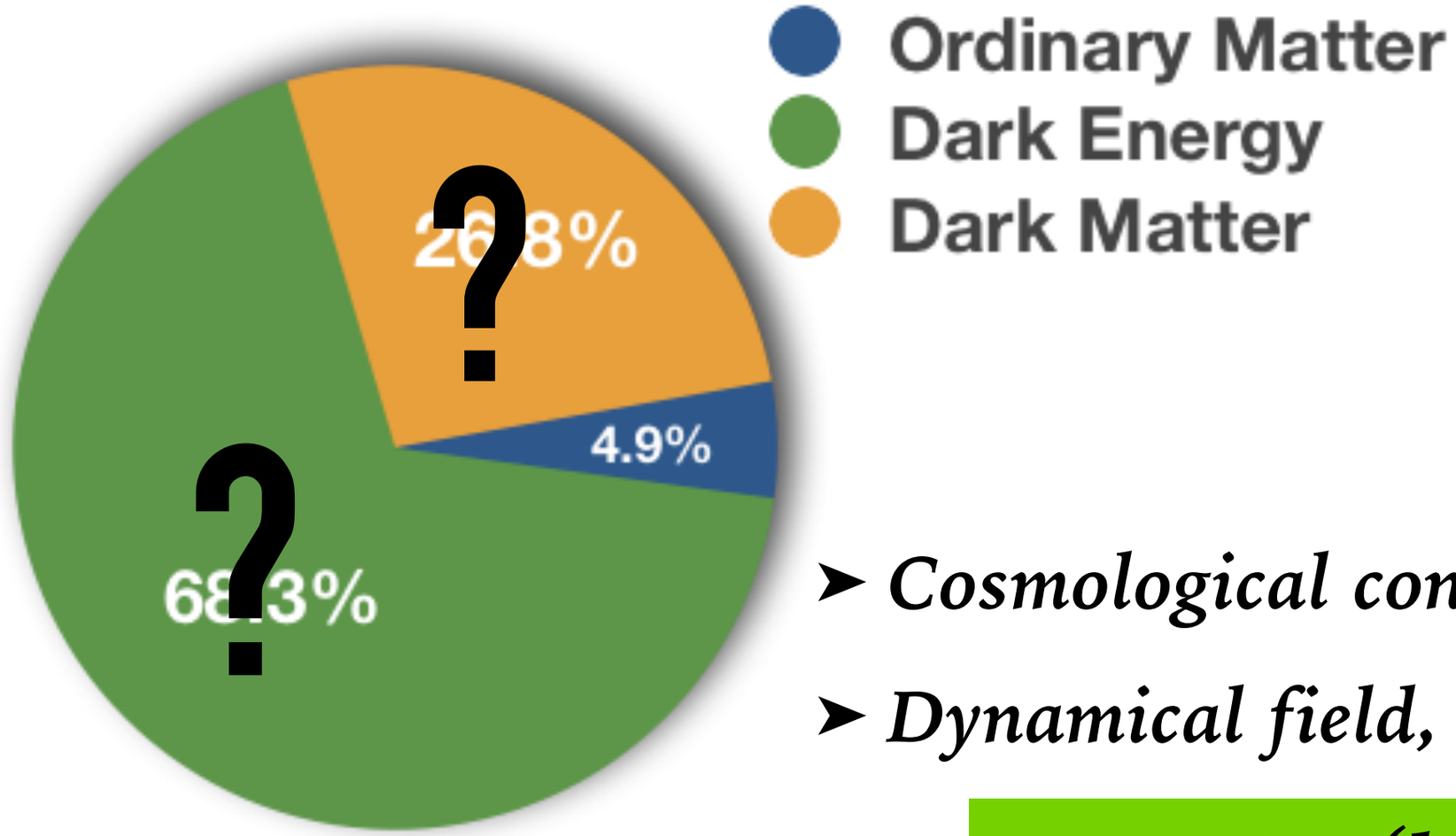
Planck Collaboration

PRECISION COSMOLOGY



Planck Collaboration

PRECISION COSMOLOGY



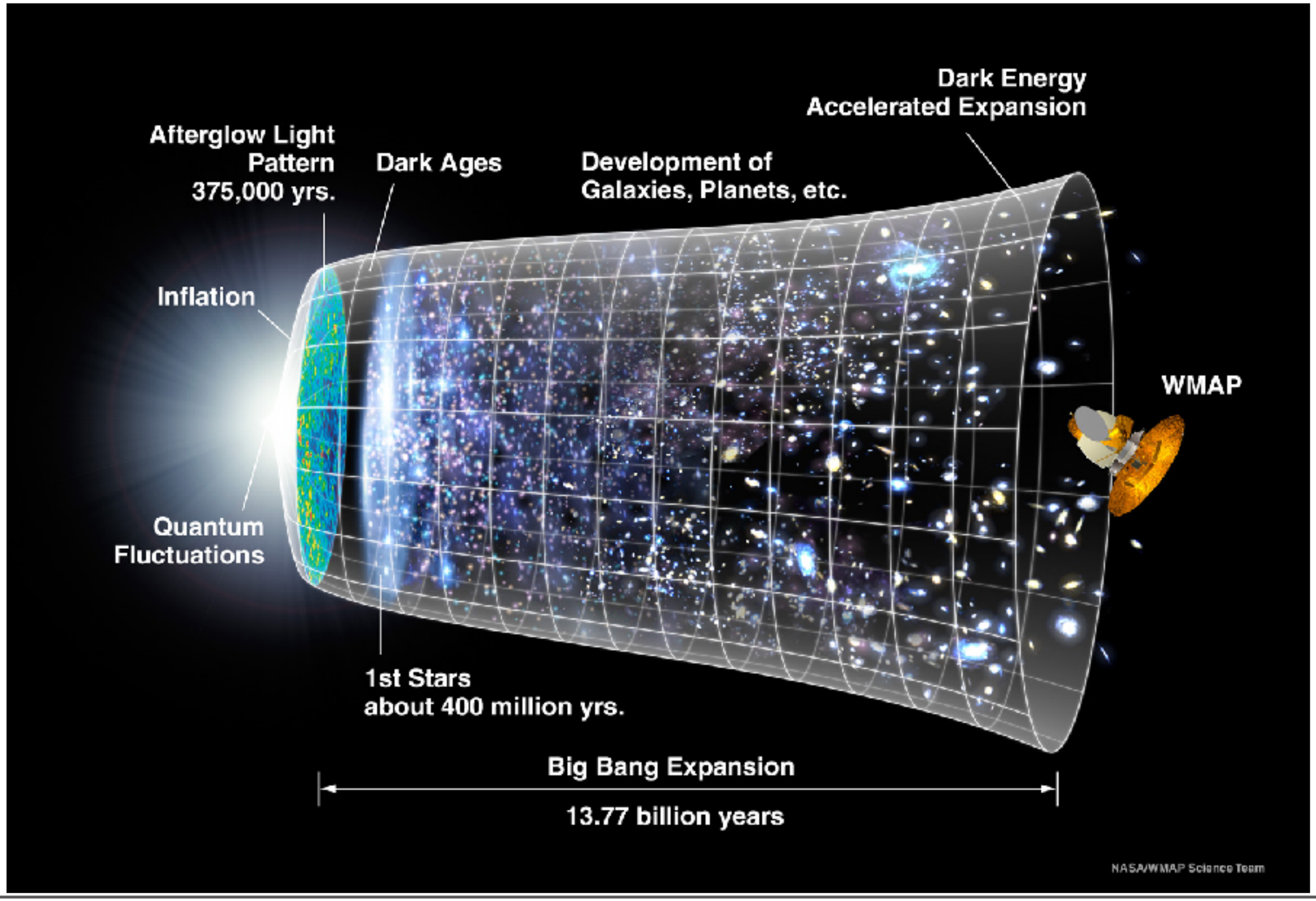
- ***Cosmological constant,*** Λ
- ***Dynamical field,*** $p = w\, c^2 \rho$

$$w = w_0 + w_a(1-a)$$

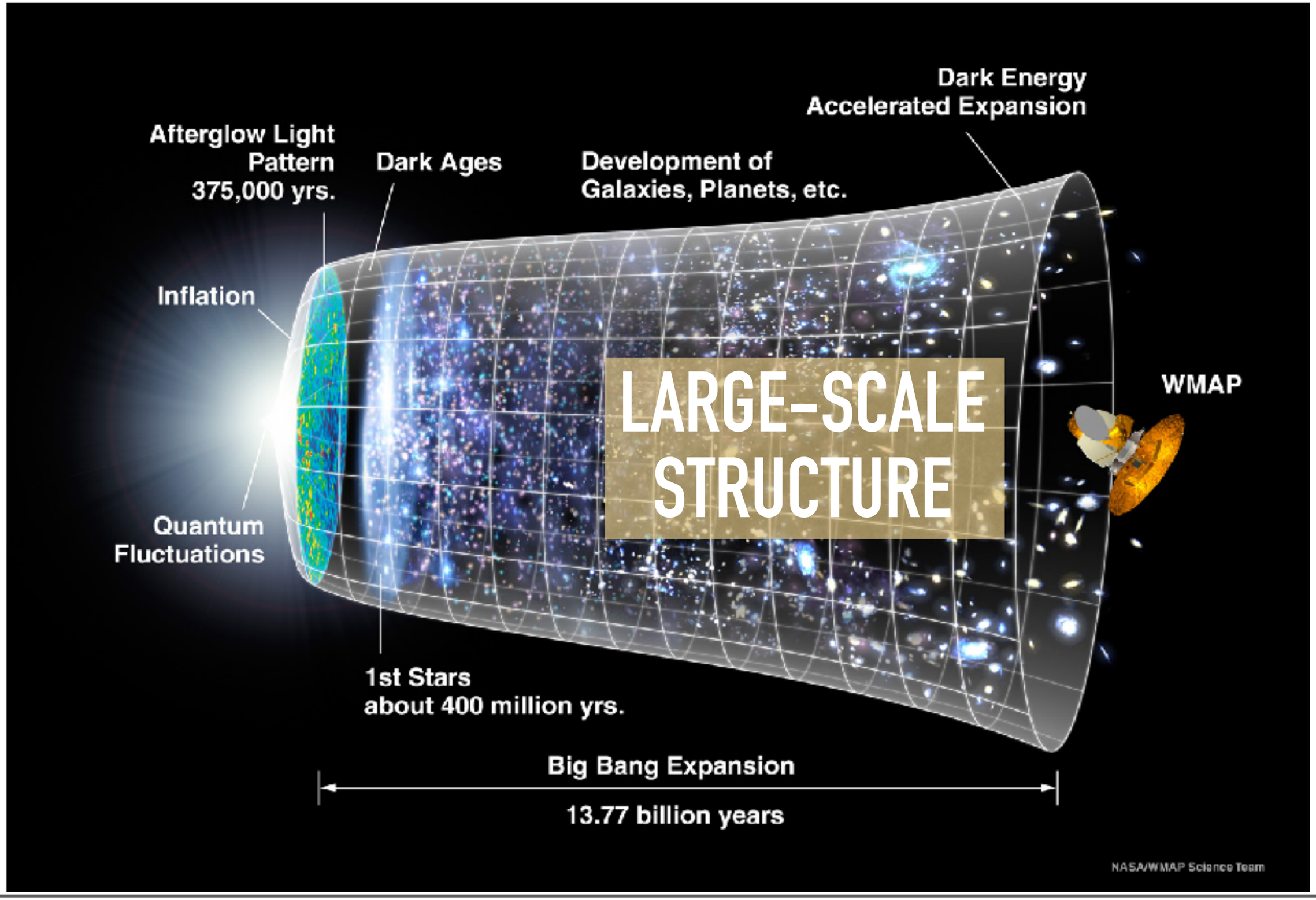
- ***Modification of gravity.***

Planck Collaboration

PRECISION COSMOLOGY



PRECISION COSMOLOGY



OUTLINE

Precision cosmology with galaxy surveys

Gravitational lensing

OUTLINE

Precision cosmology with galaxy surveys

Gravitational lensing

Challenges

I. Observational

II. Theoretical

OUTLINE

Precision cosmology with galaxy surveys

Gravitational lensing

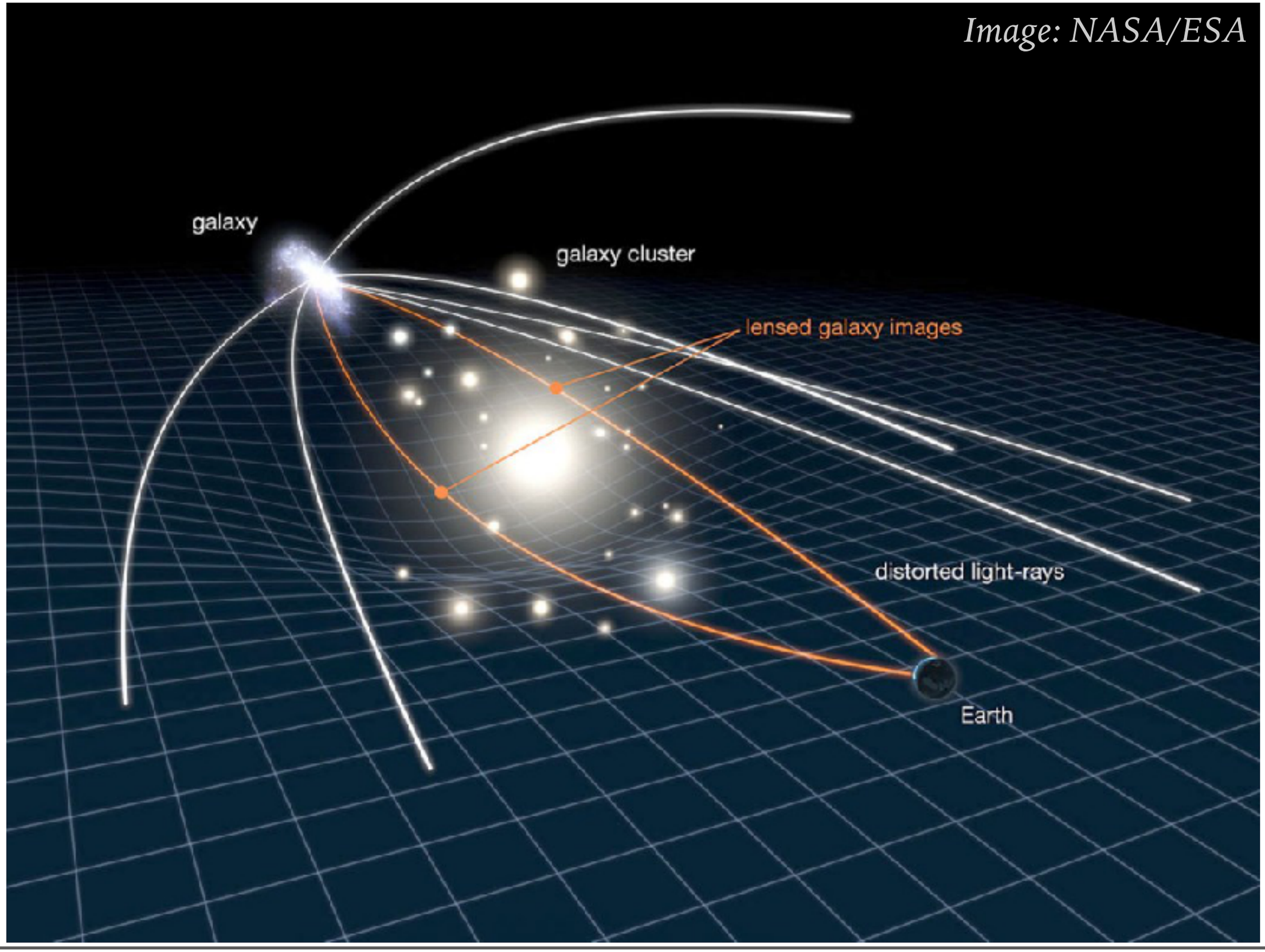
Challenges

I. Observational

II. Theoretical

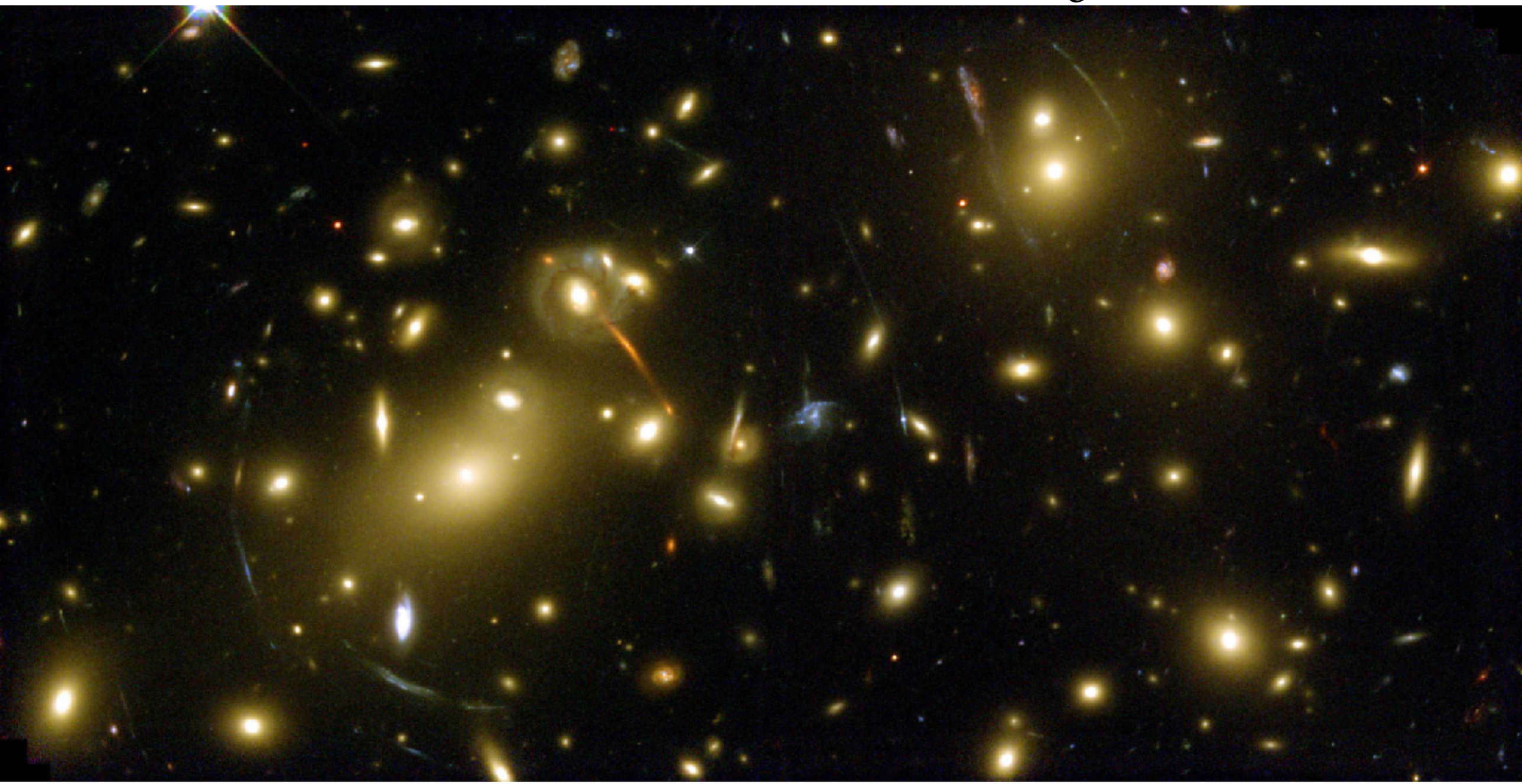
Current & future surveys

GRAVITATIONAL LENSING



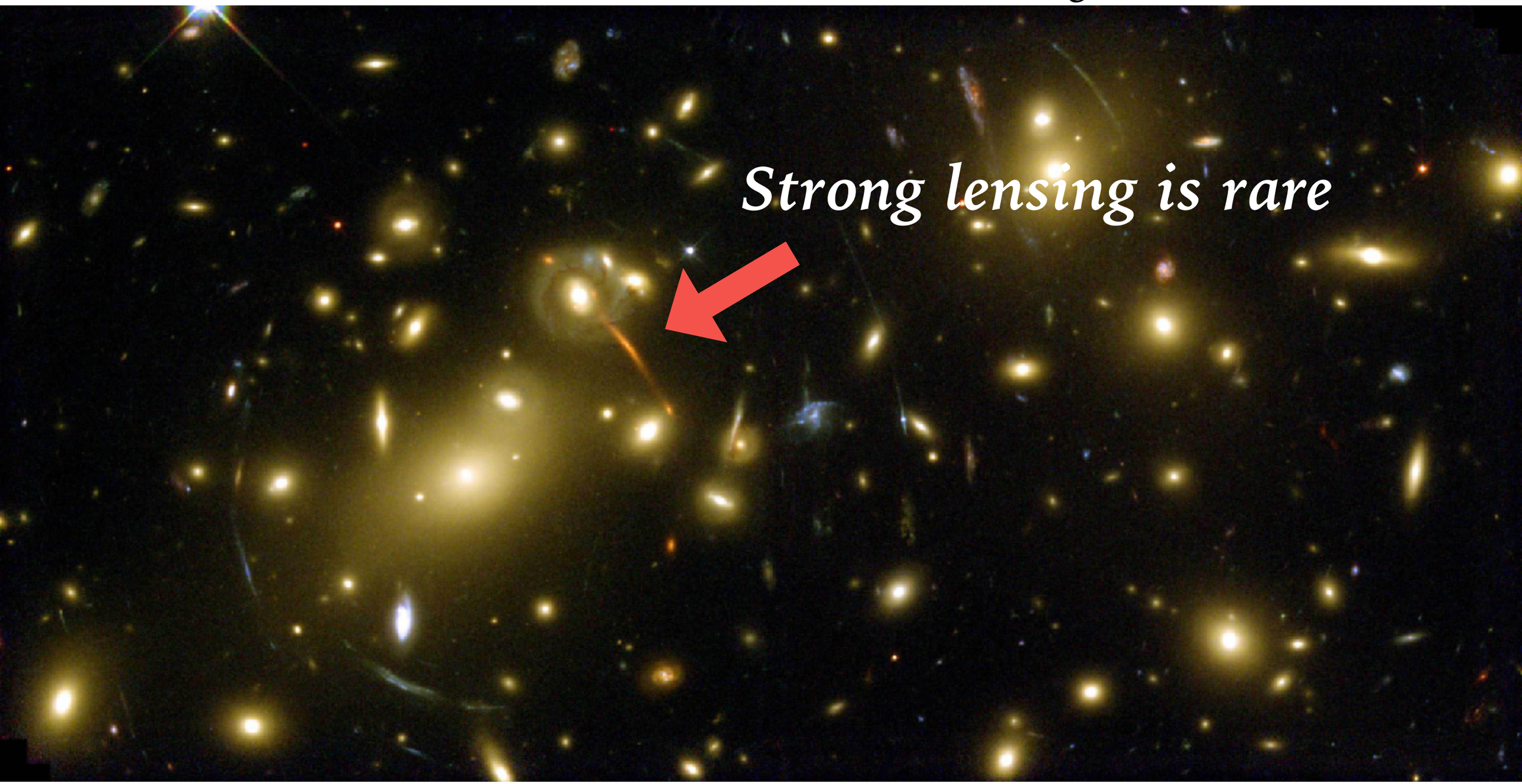
GRAVITATIONAL LENSING

Image: Abell 2218, NASA/ESA



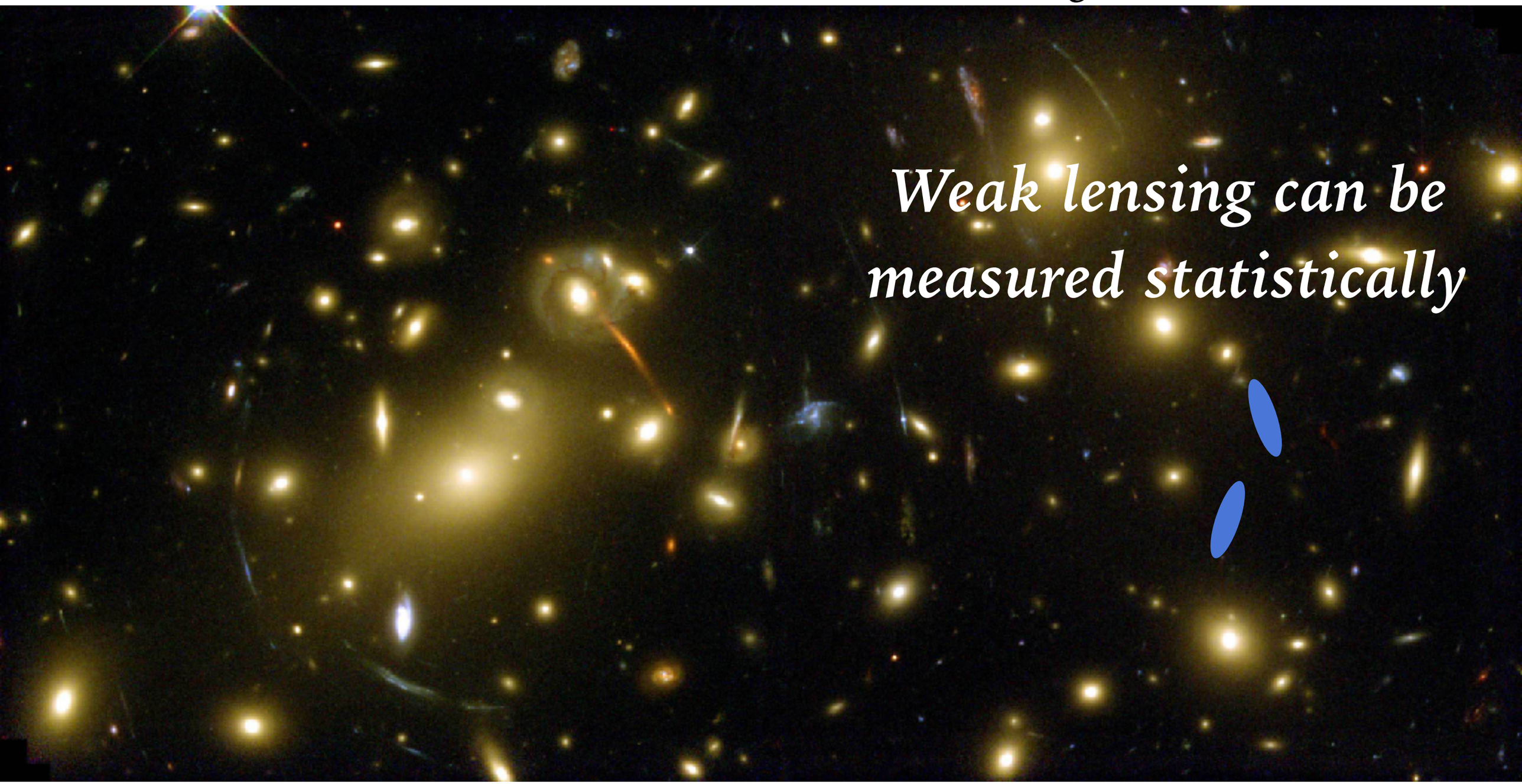
GRAVITATIONAL LENSING

Image: Abell 2218, NASA/ESA



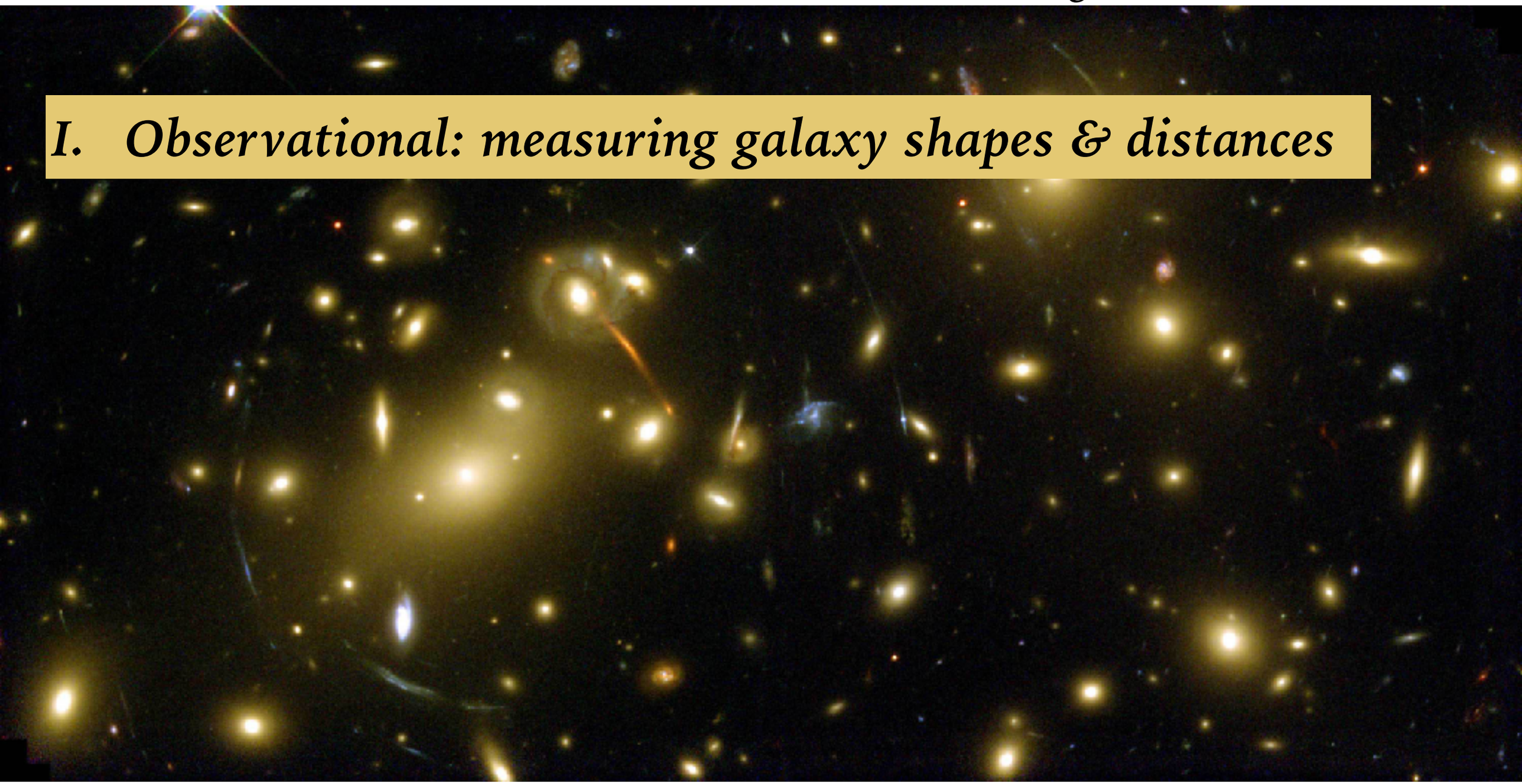
GRAVITATIONAL LENSING

Image: Abell 2218, NASA/ESA



CHALLENGES IN WEAK LENSING

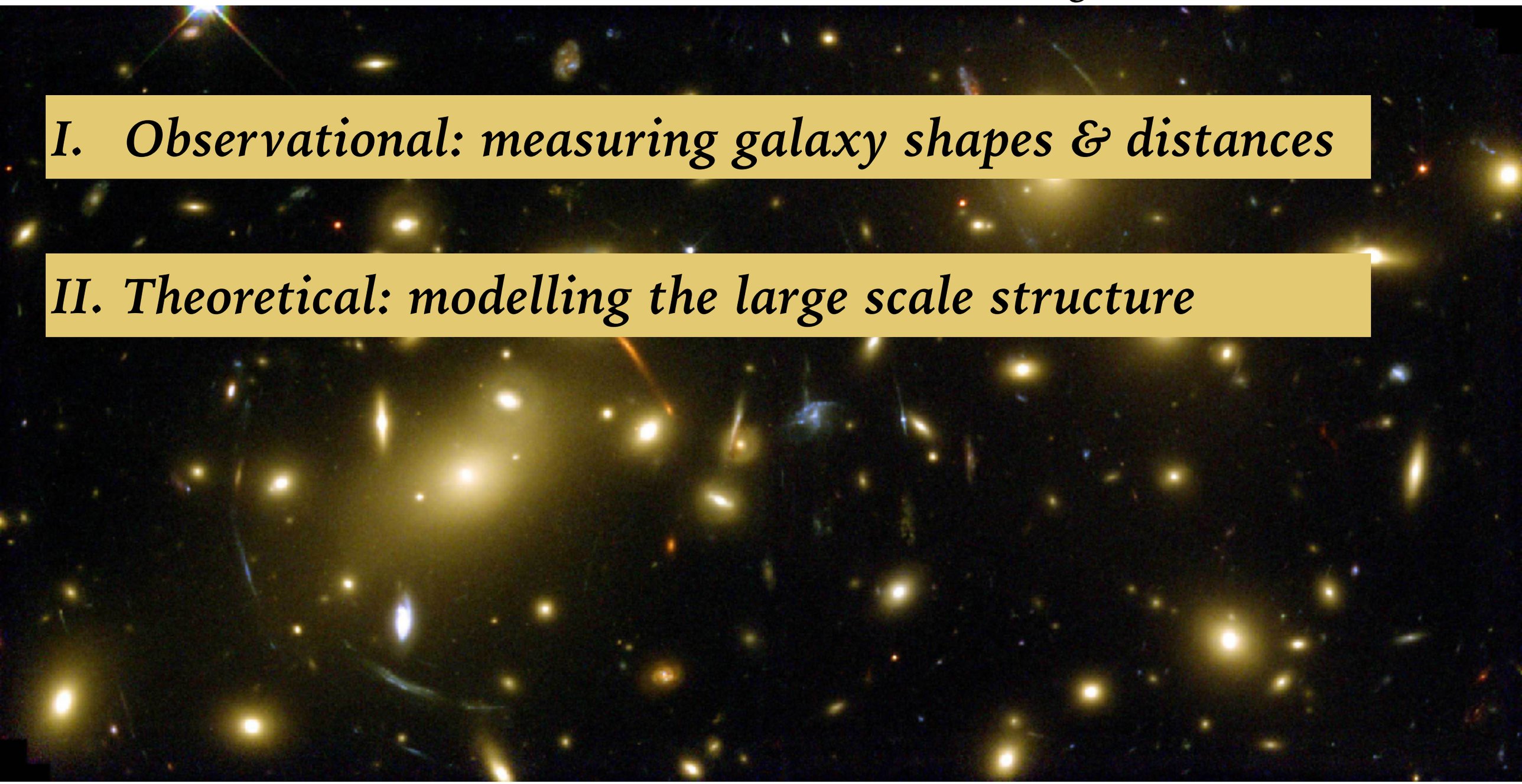
Image: Abell 2218, NASA/ESA



I. Observational: measuring galaxy shapes & distances

CHALLENGES IN WEAK LENSING

Image: Abell 2218, NASA/ESA



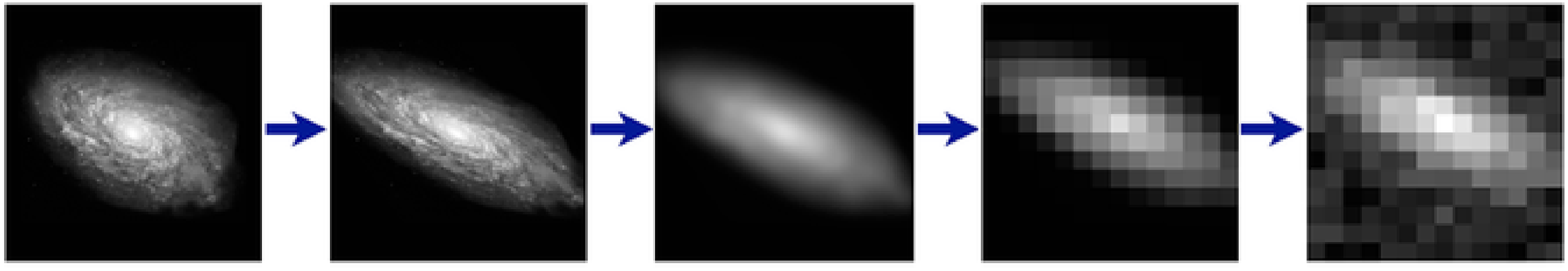
I. Observational: measuring galaxy shapes & distances

II. Theoretical: modelling the large scale structure

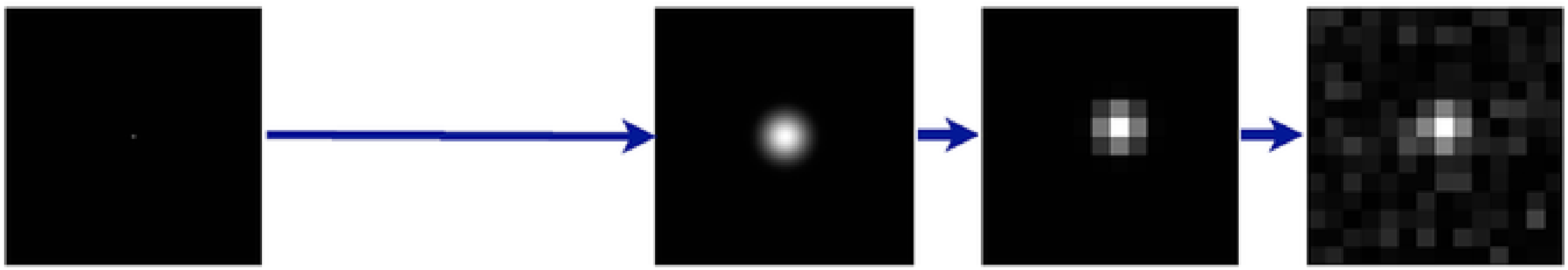
OBSERVATIONAL CHALLENGES

The Forward Process.

Galaxies: Intrinsic galaxy shapes to measured image:



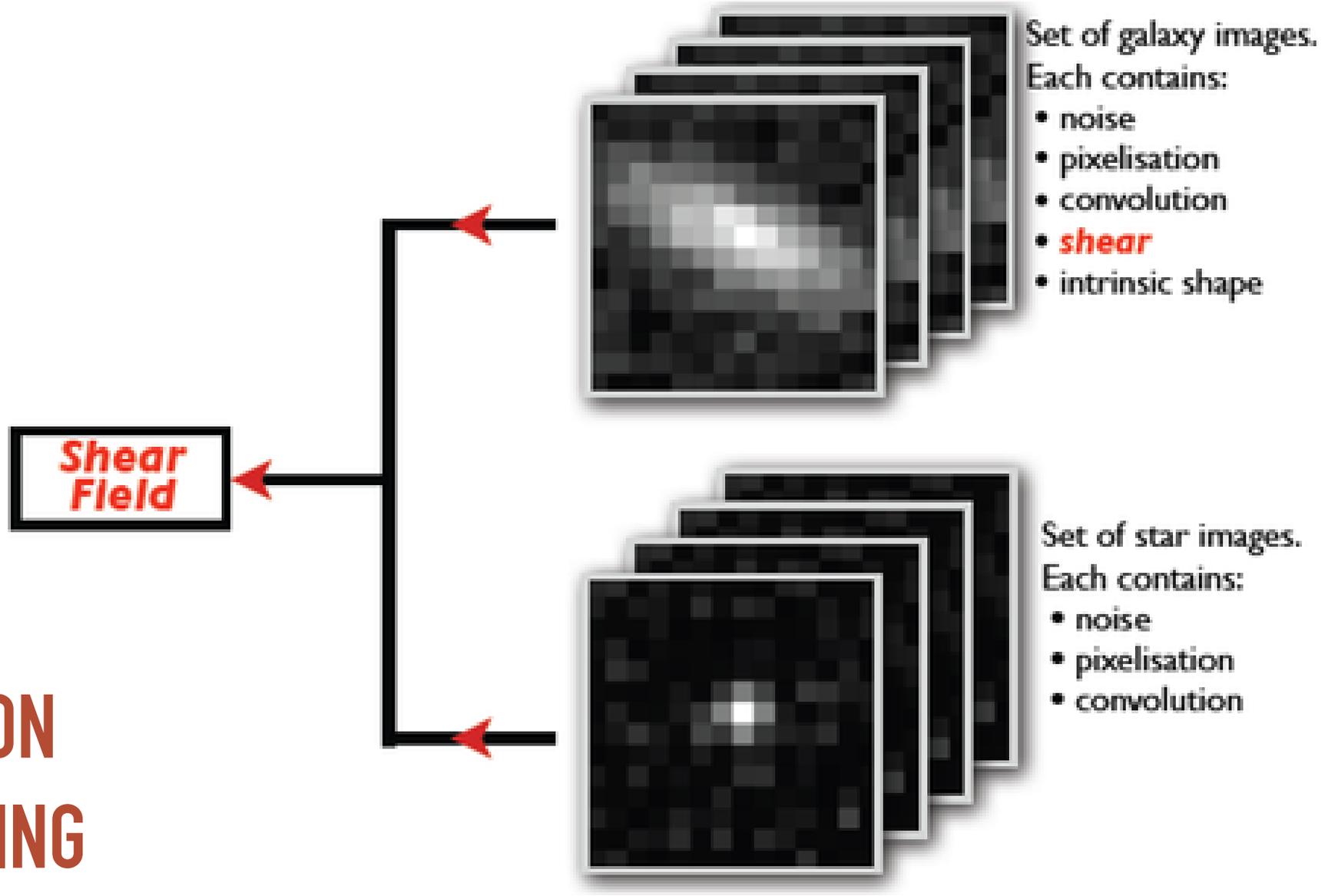
Stars: Point sources to star images:



GREAT08 challenge handbook, Bridle+ (2008)

OBSERVATIONAL CHALLENGES

The Inverse Problem:
Measured images to *shear*

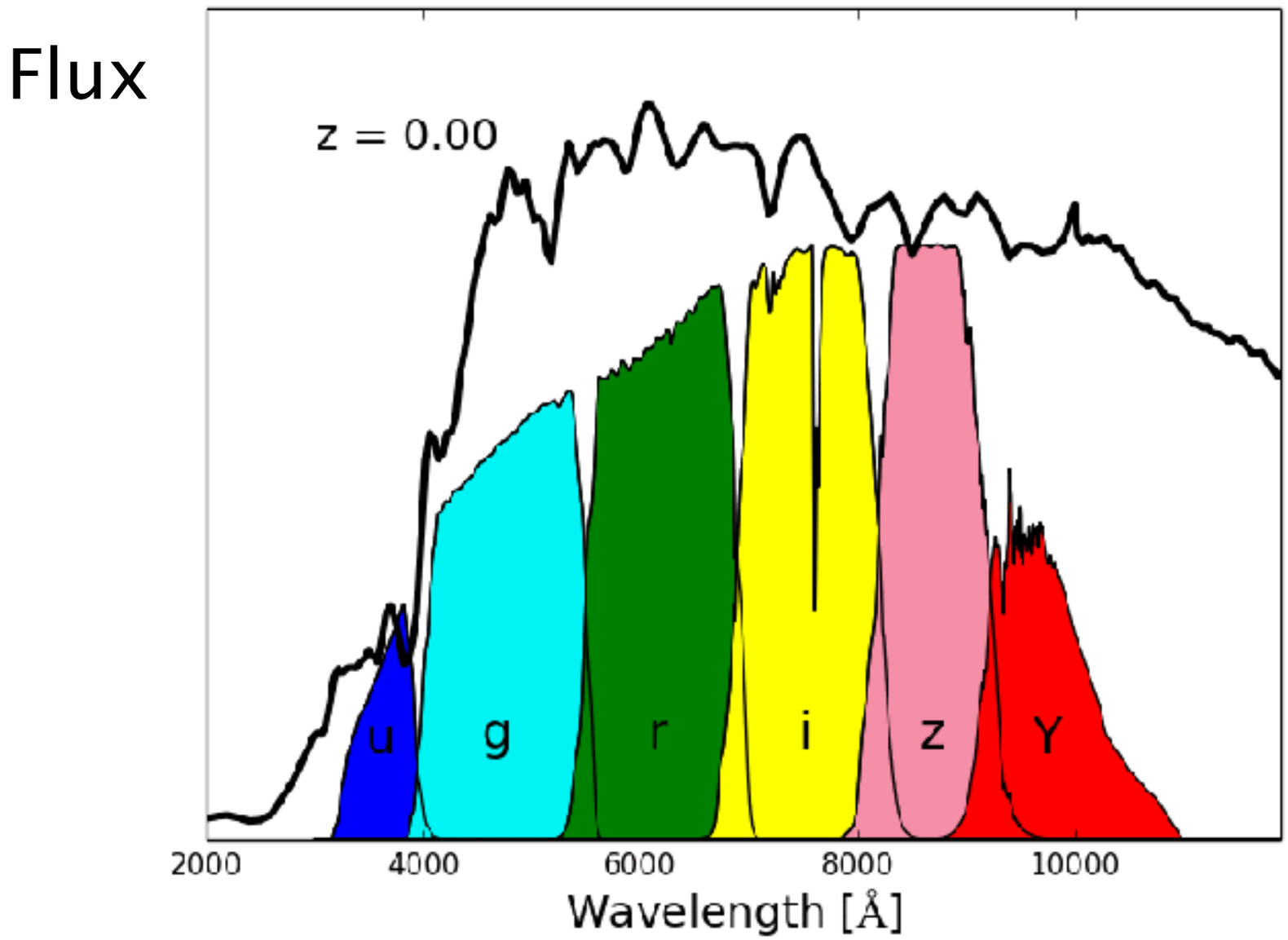


- SHEAR CALIBRATION
- IMPACT OF BLENDING
- STAR-GALAXY SEPARATION

GREAT08 challenge handbook, Bridle+ (2008)

OBSERVATIONAL CHALLENGES

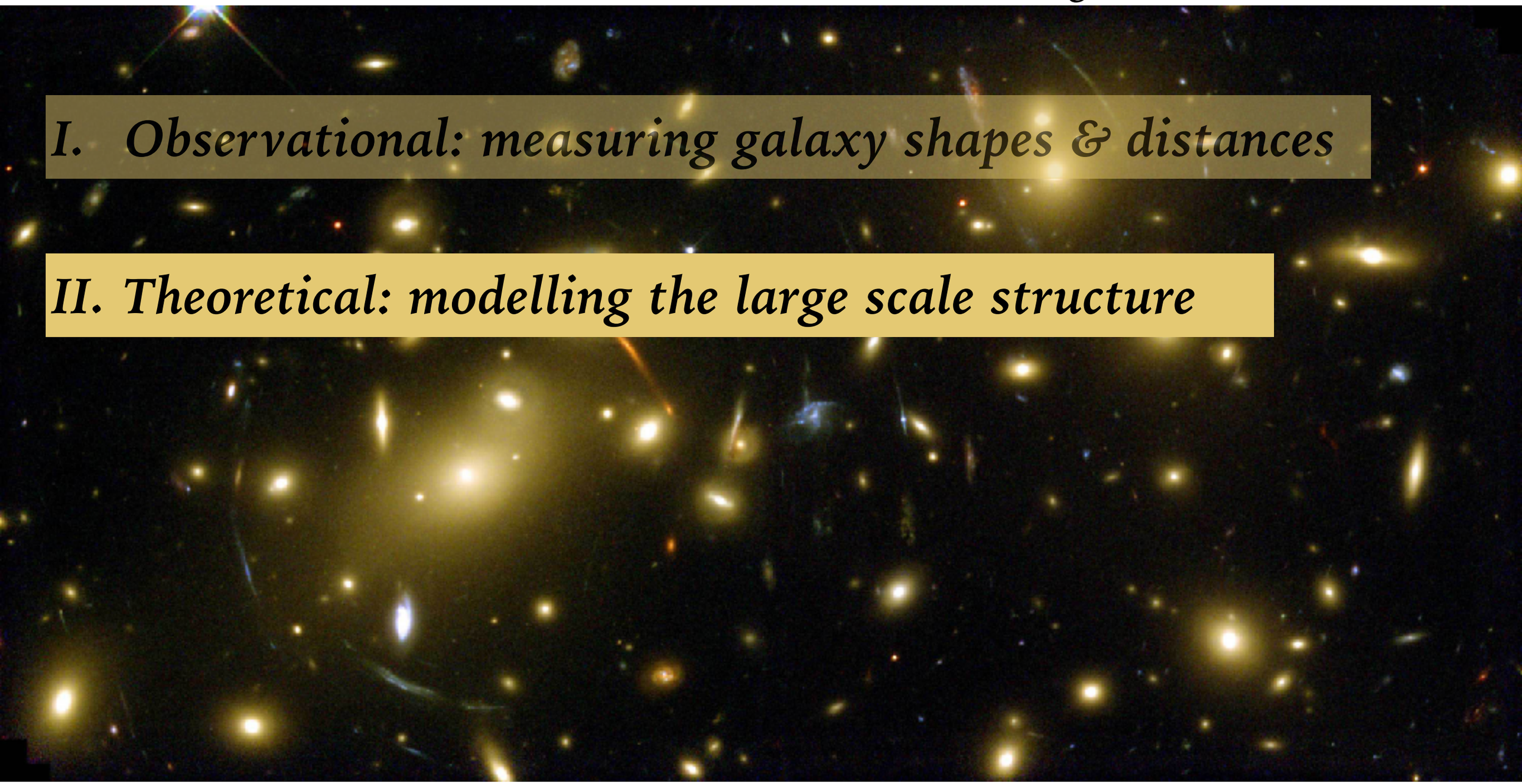
PHOTOMETRIC REDSHIFTS



Credit: LSST DESC Photo-z working group

CHALLENGES IN WEAK LENSING

Image: Abell 2218, NASA/ESA



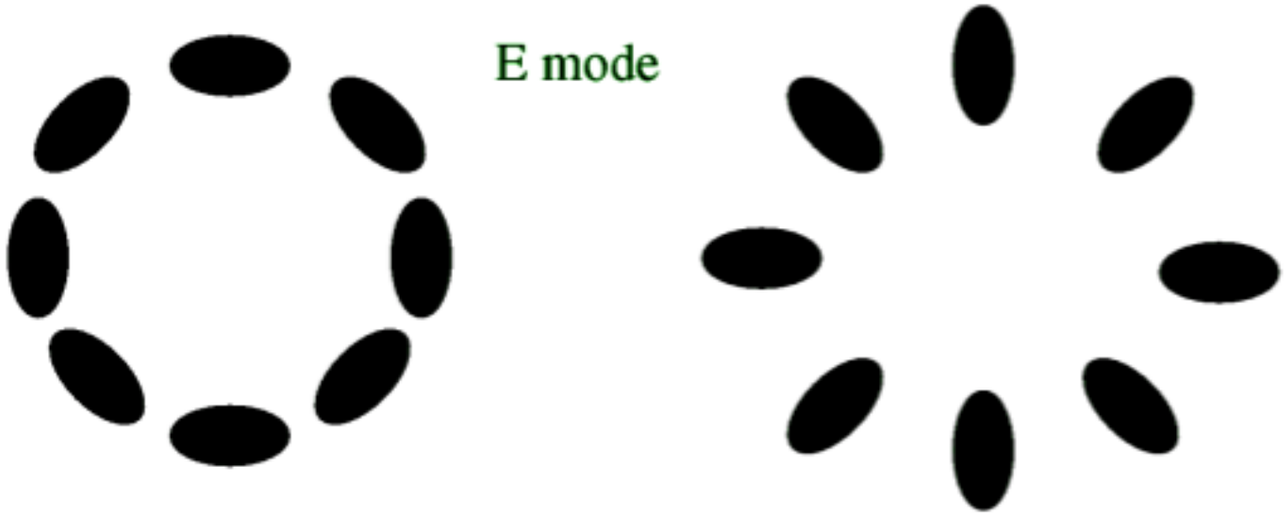
I. Observational: measuring galaxy shapes & distances

II. Theoretical: modelling the large scale structure

THEORETICAL CHALLENGES

OBSERVABLES:

CORRELATIONS OF GALAXY POSITIONS AND SHAPES

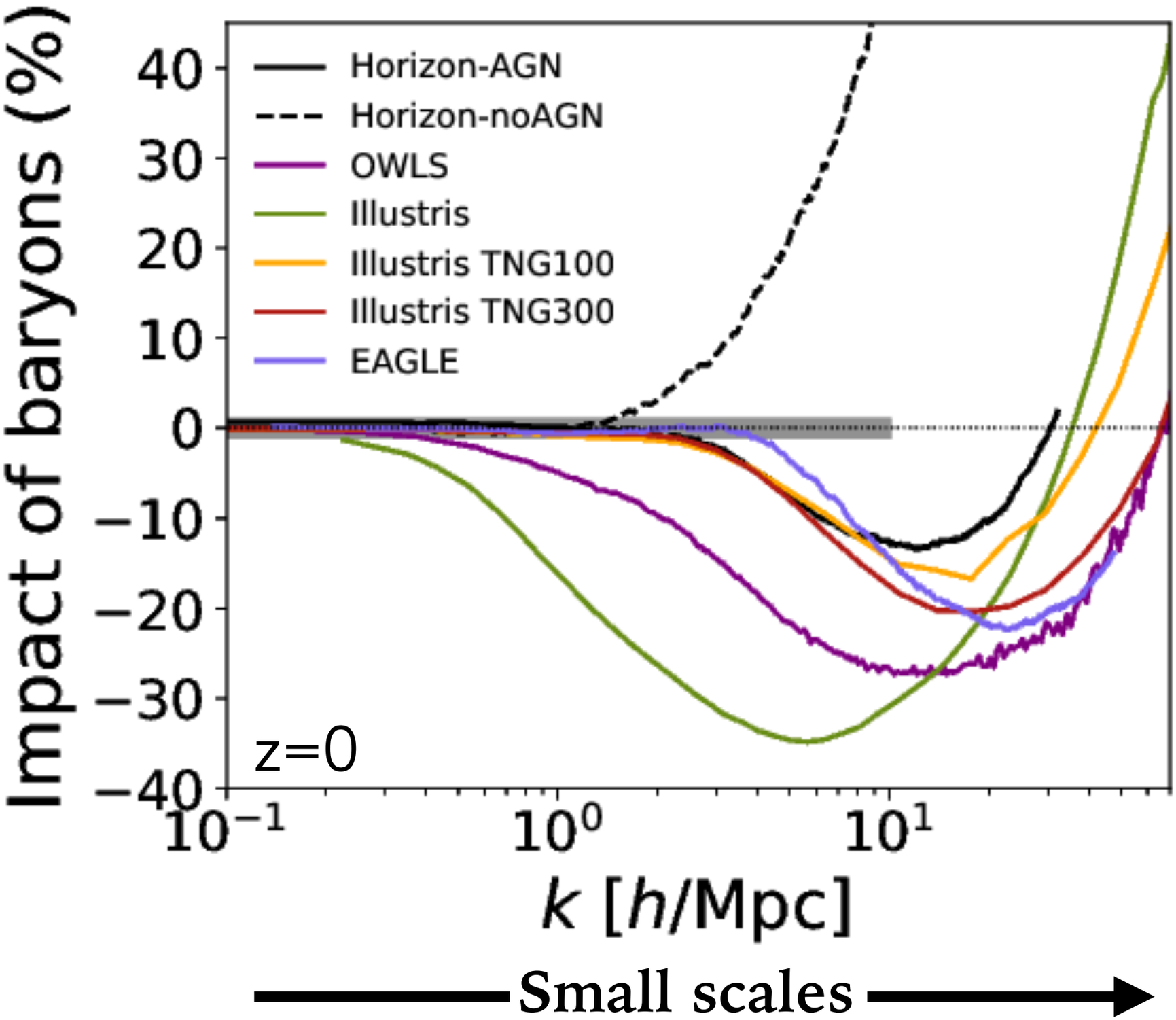


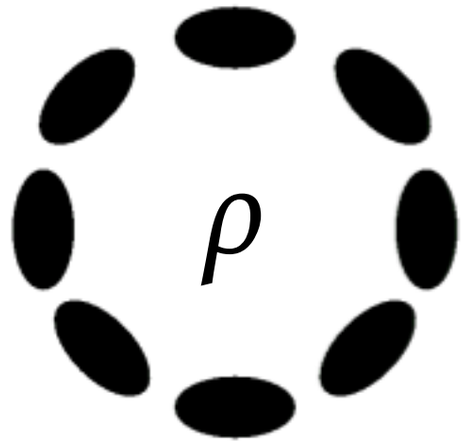
van Waerbeke & Mellier (2003)

APPROACHES

- ANALYTICAL MODELLING
- NUMERICAL SIMULATIONS

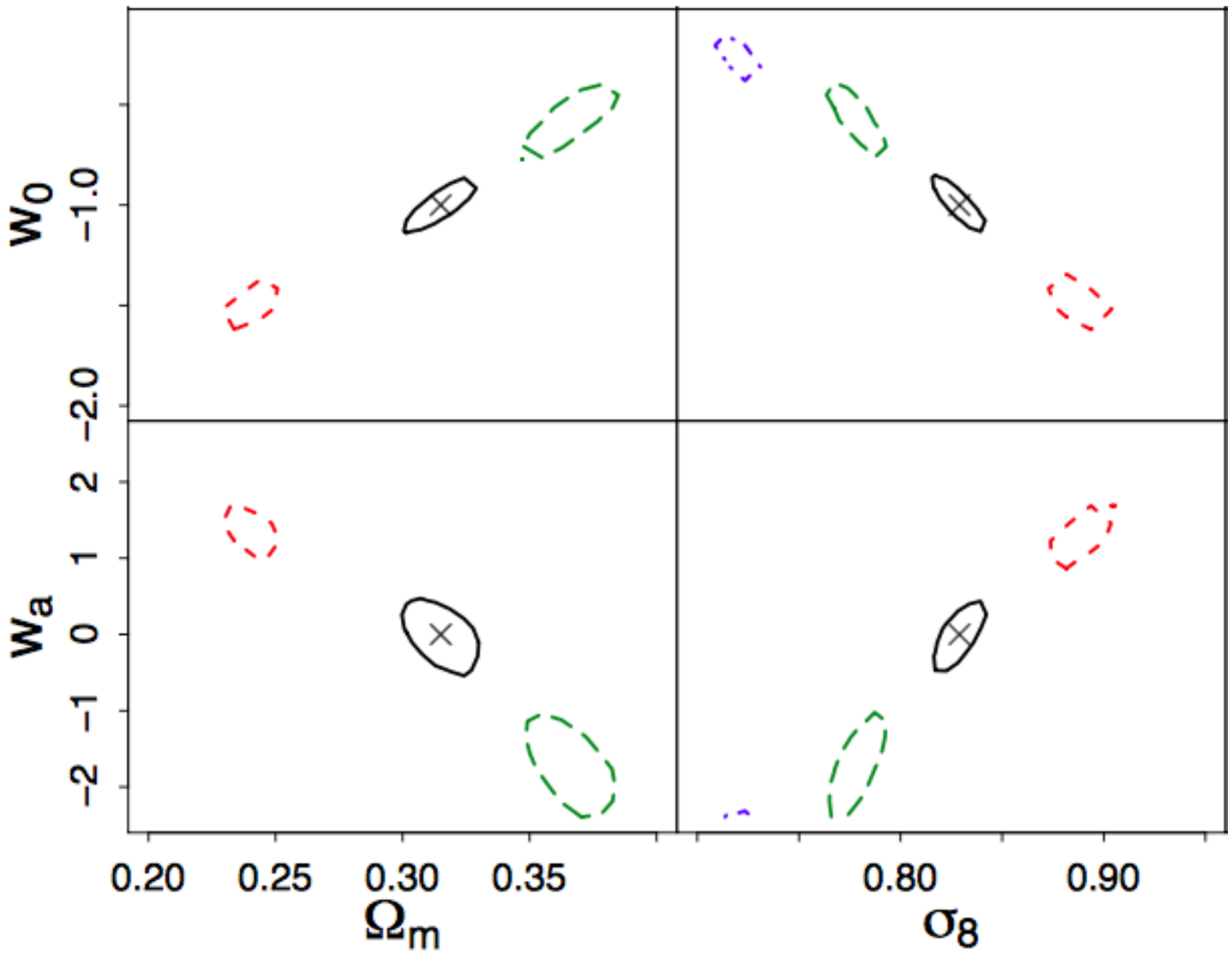
THEORETICAL CHALLENGES





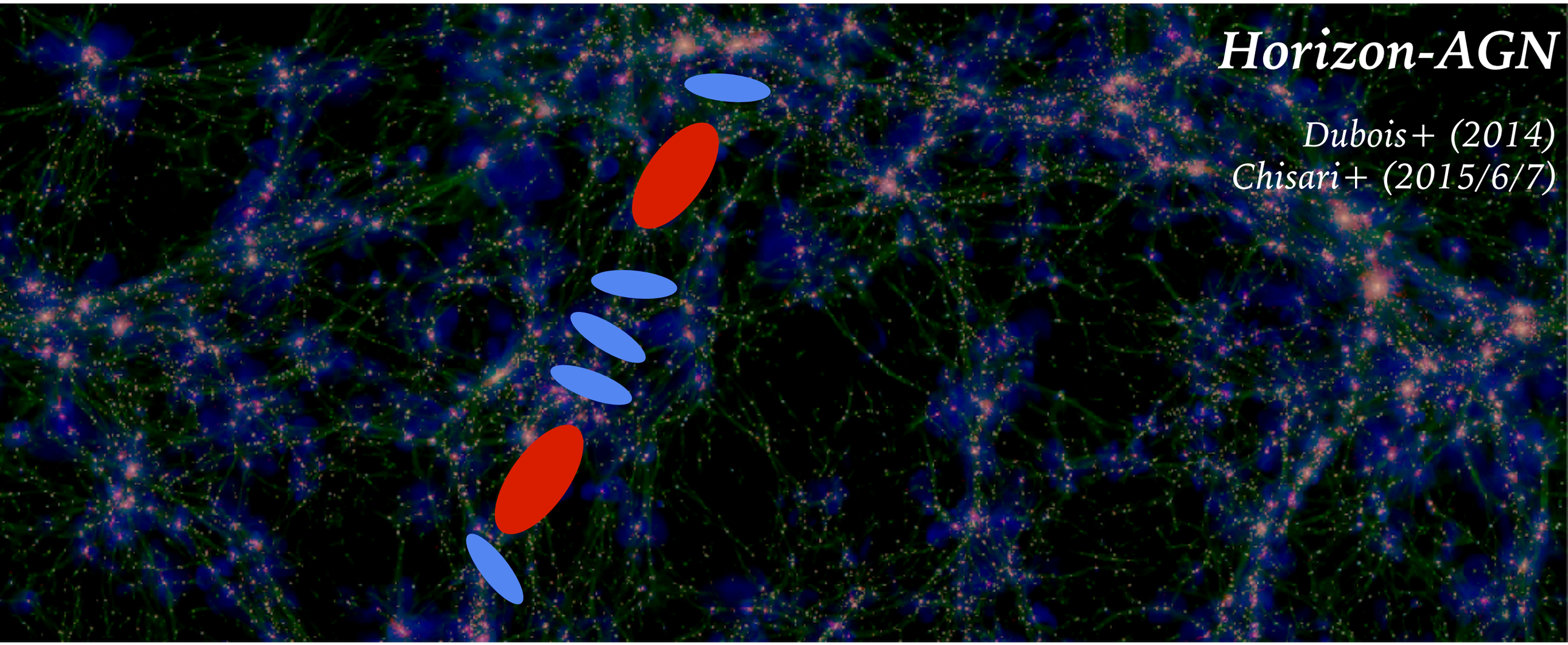
Chisari+, in prep
van Daalen+ (2011)
Vogelsberger+ (2014)
Hellwing+ (2016)
Springel+ (2017)

THEORETICAL CHALLENGES



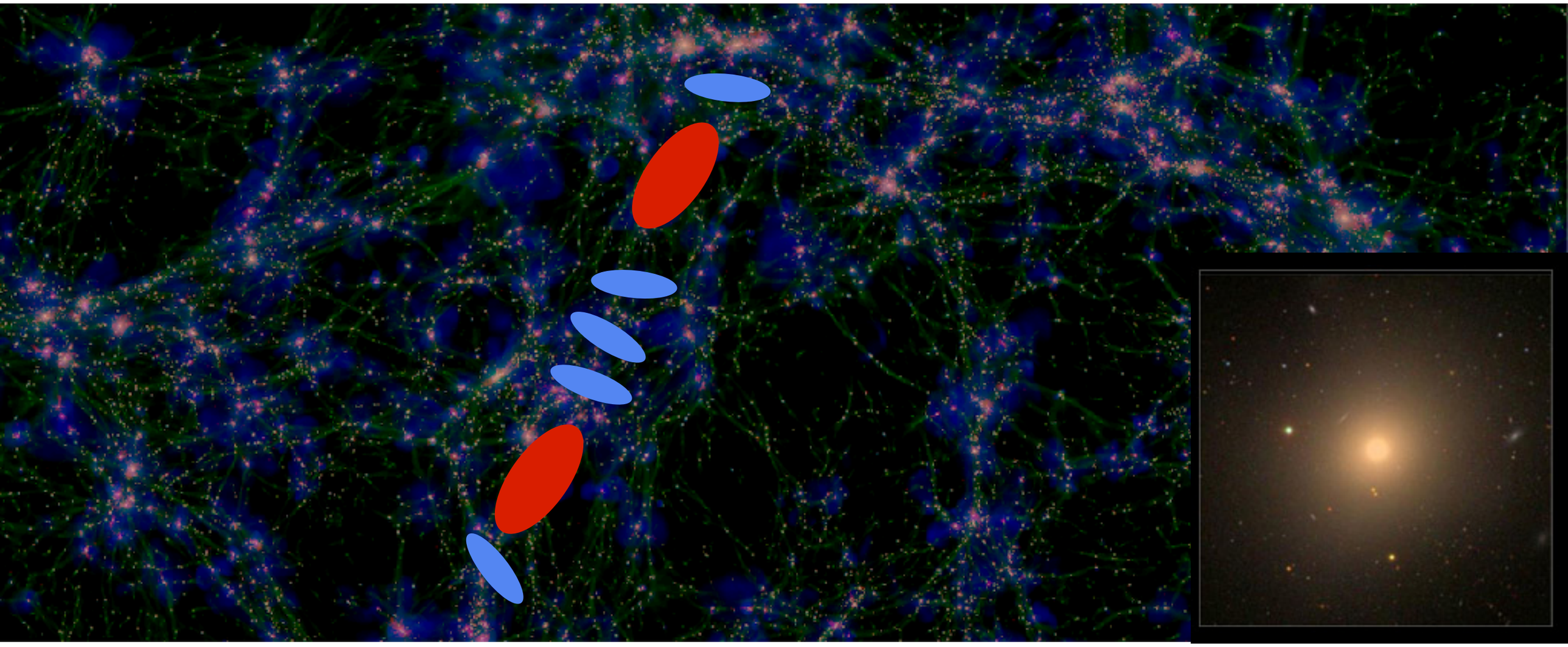
Eifler+ (2015)

THEORETICAL CHALLENGES



$$\textit{Galaxy shapes} = \textit{Lensing} + \textbf{\textit{Intrinsic alignment}} + \textit{Noise}$$

THEORETICAL CHALLENGES

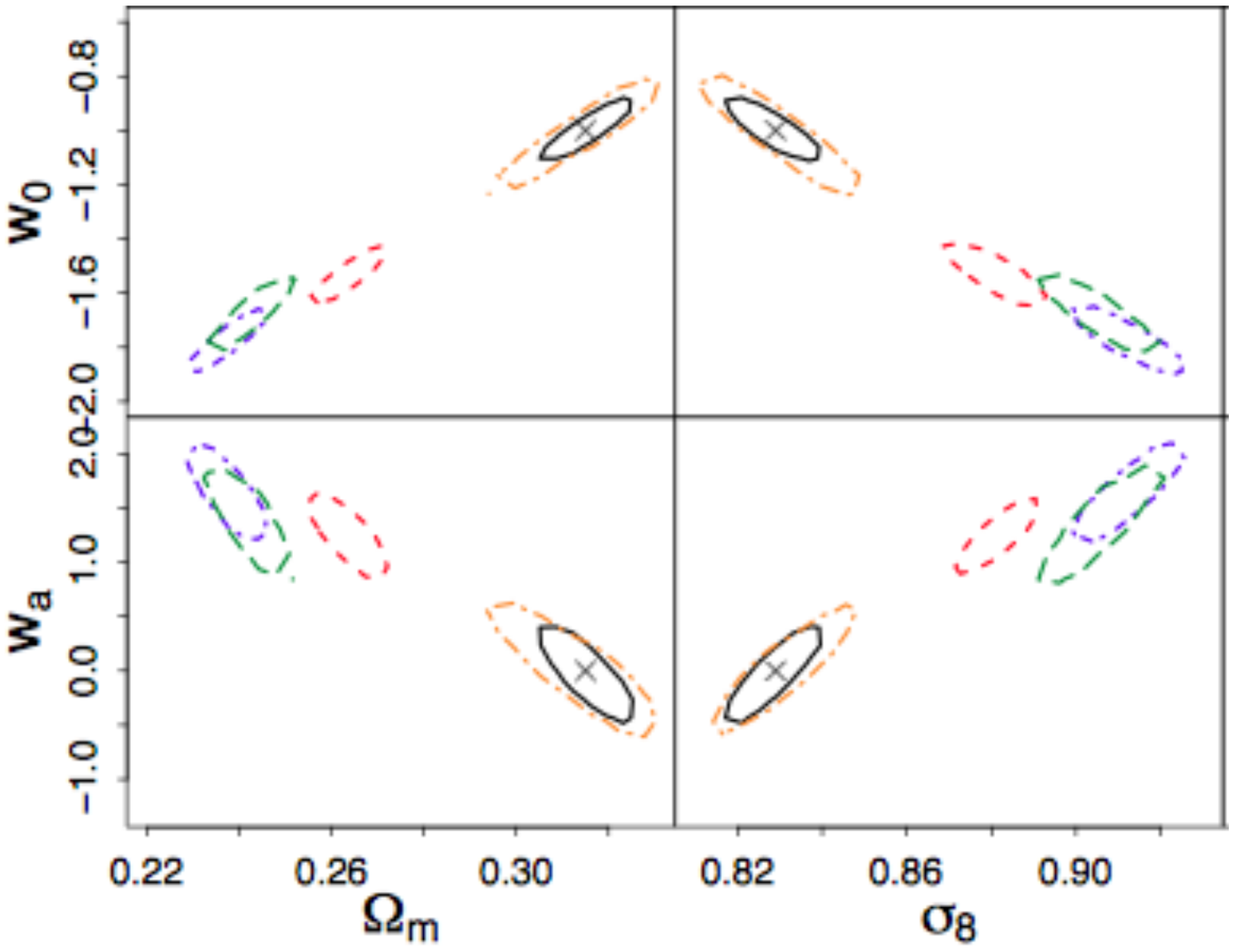


Intrinsic shapes ~ *Tidal field of the large-scale structure*

Catelan+ (2001)

THEORETICAL CHALLENGES

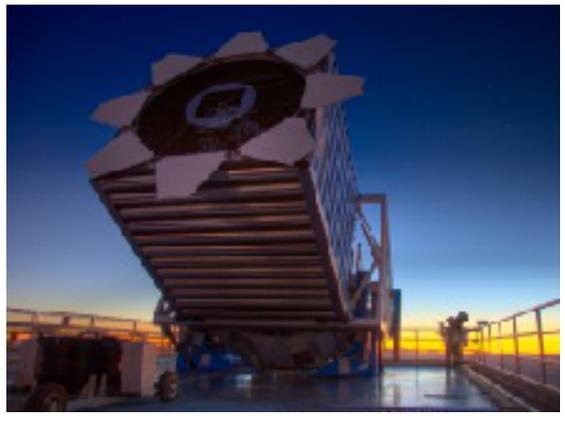
Bias in cosmology due to galaxy alignments



Krause+ (2015)

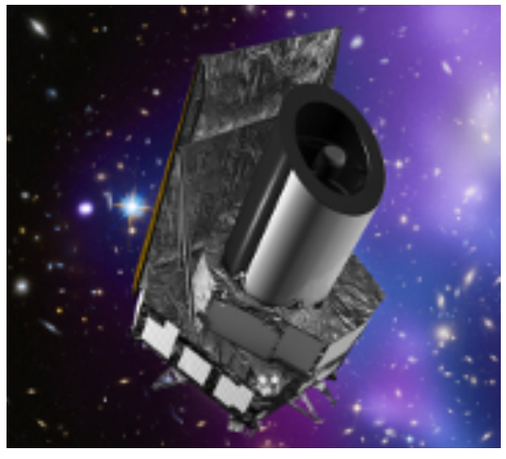
PAST, PRESENT & FUTURE GALAXY SURVEYS

SDSS



Kilo-Degree Survey

Euclid (2021)



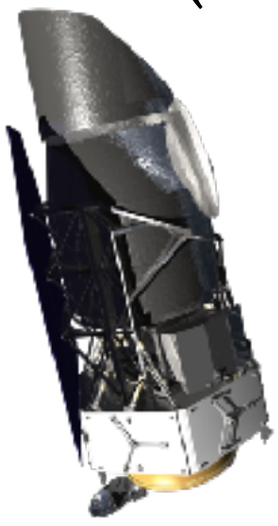
LSST (2021)

CFHTLenS

DES

HSC

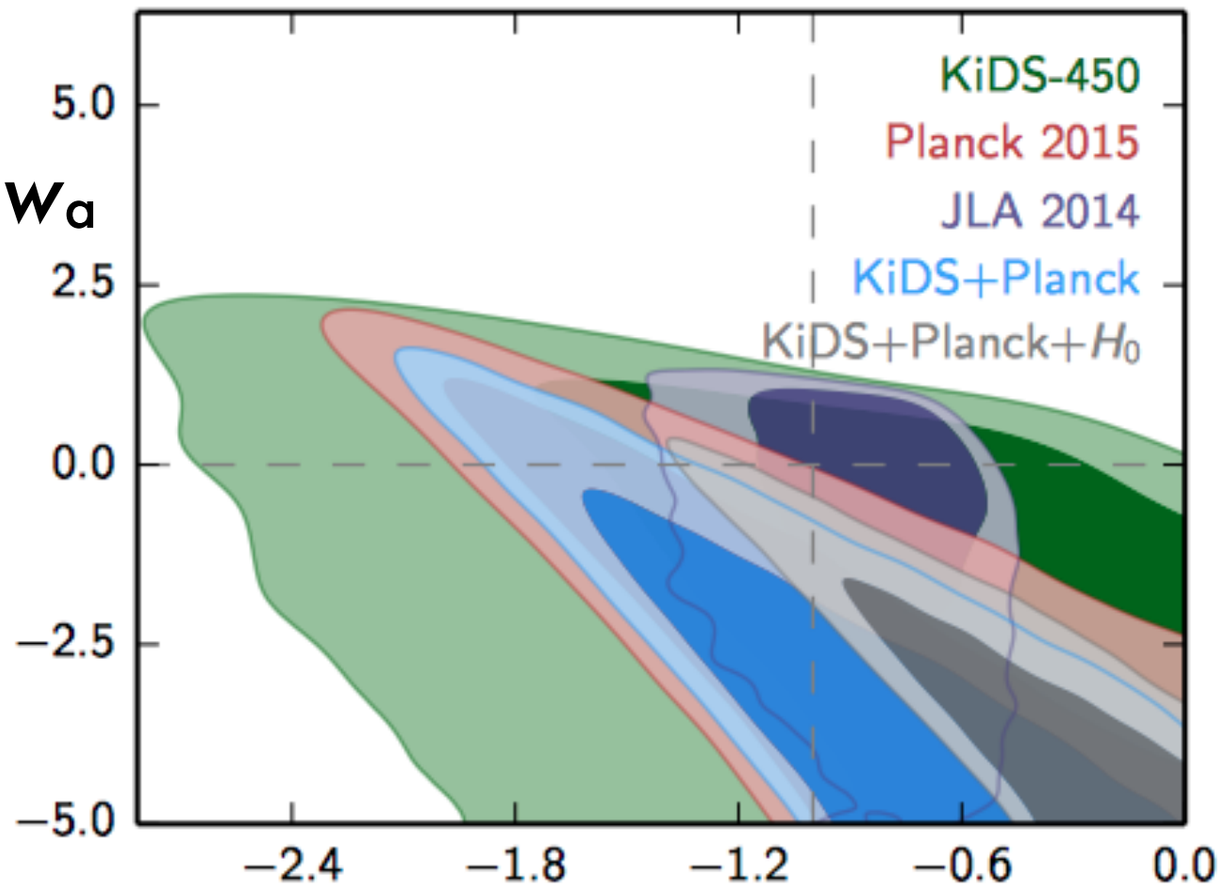
WFIRST (2025)



COSMOLOGY WITH GALAXY SURVEYS

$$w = w_0 + w_a(1-a)$$

KiDS-450

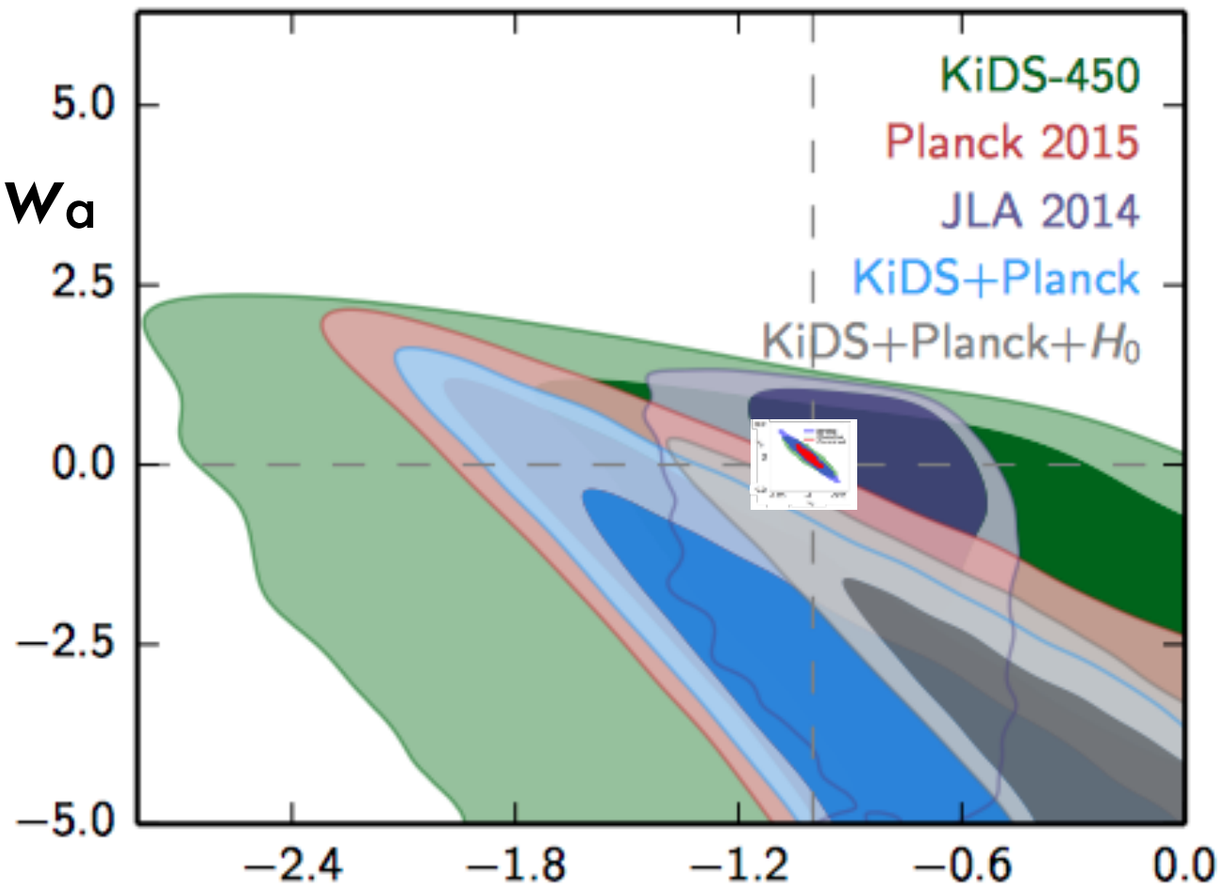


Joudaki+,
KiDS collaboration, 2016

COSMOLOGY WITH GALAXY SURVEYS

$$w = w_0 + w_a(1-a)$$

KiDS-450



Joudaki+,
KiDS collaboration, 2016

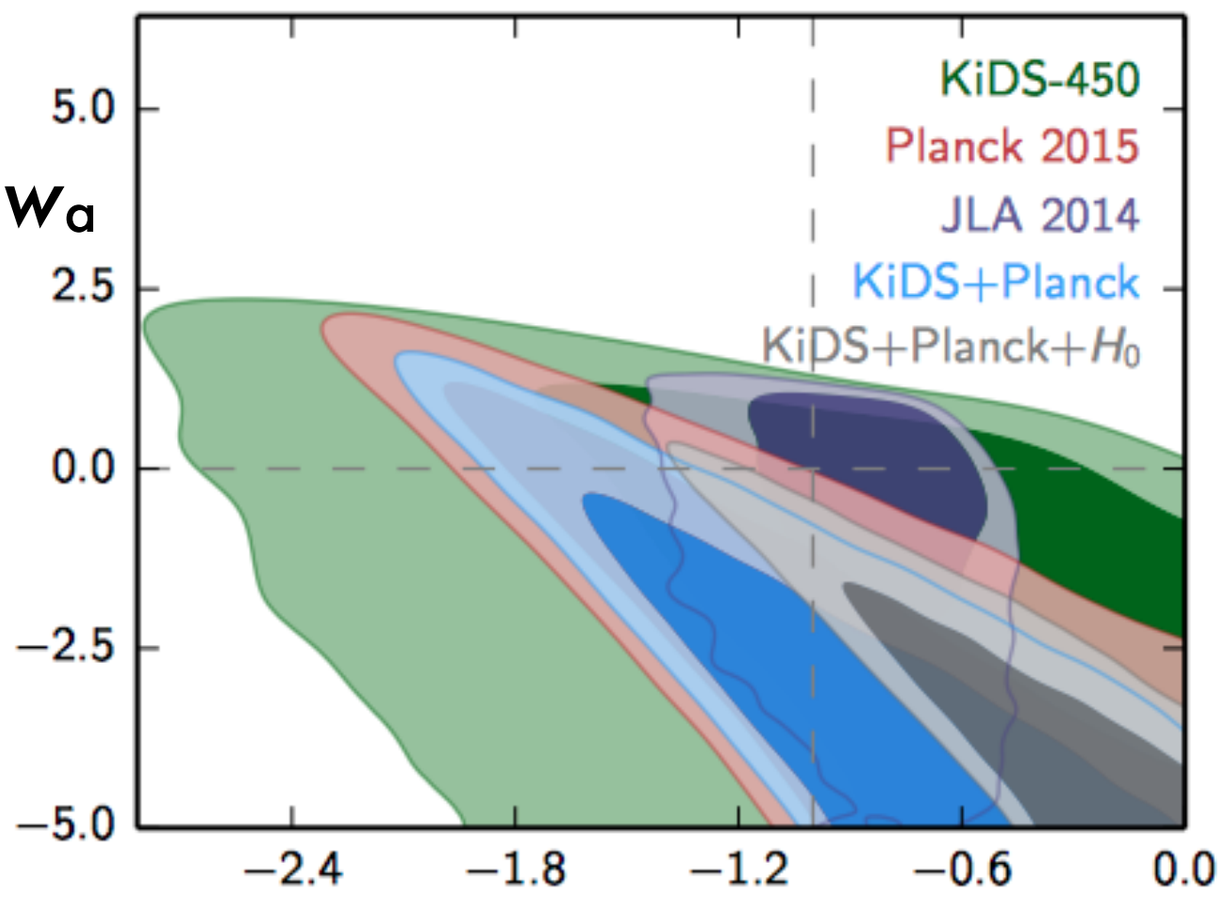
LSST expected

D. Alonso, E. Chisari+
LSST-DESC Code Comparison

COSMOLOGY WITH GALAXY SURVEYS

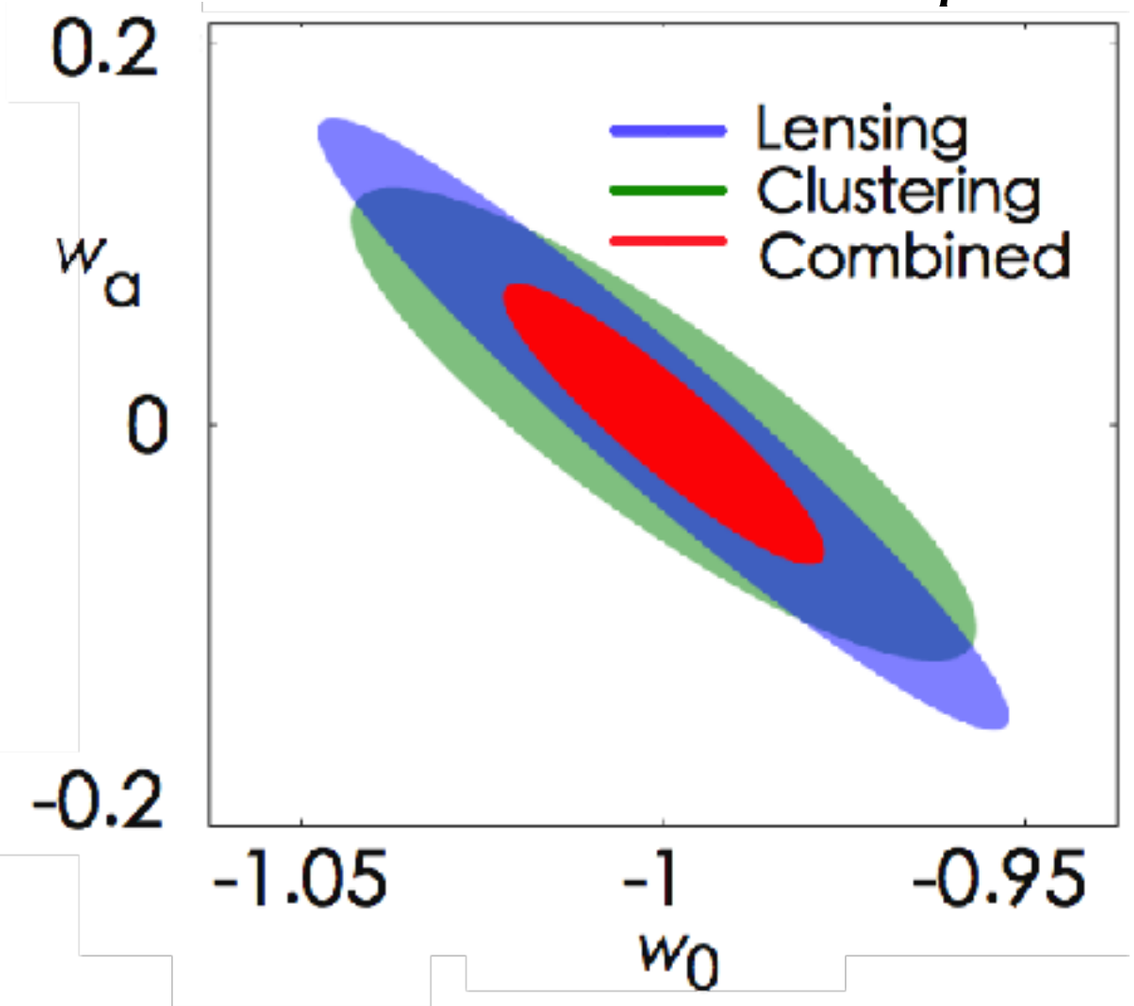
$$w = w_0 + w_a(1-a)$$

KiDS-450



Joudaki+,
KiDS collaboration, 2016

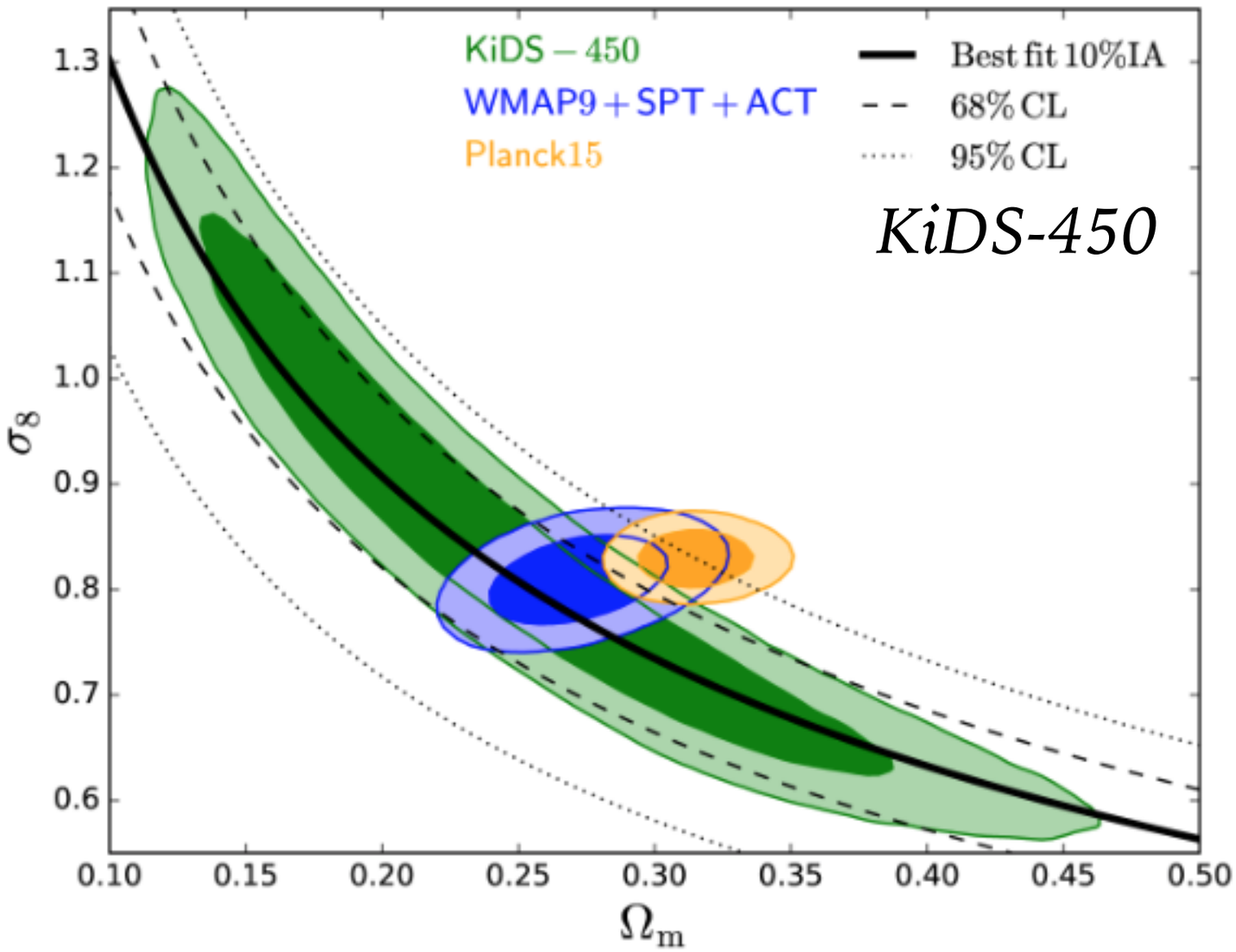
LSST expected

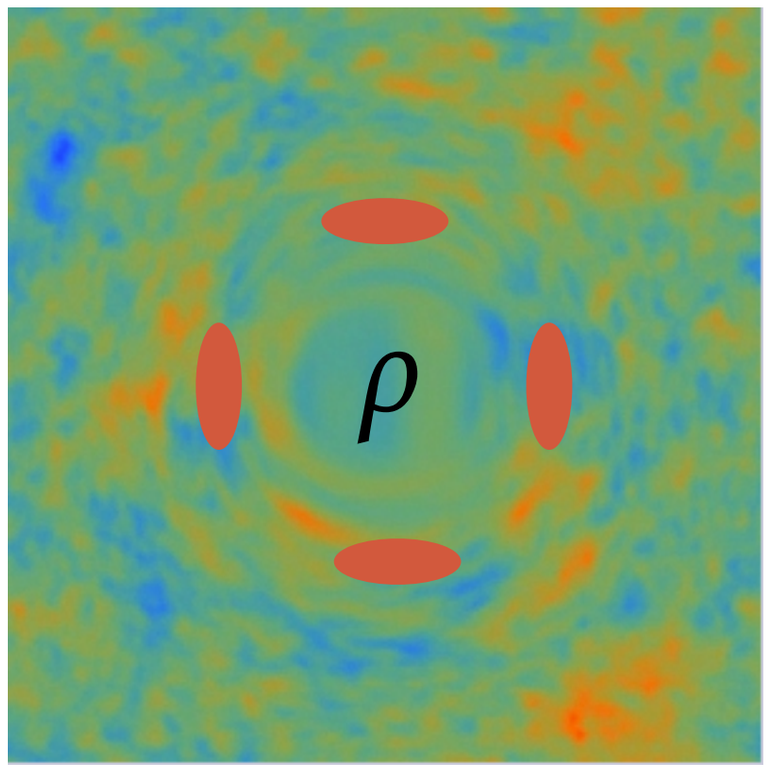


D. Alonso, E. Chisari+
LSST-DESC Code Comparison

COSMOLOGY WITH GALAXY SURVEYS

Combining probes: cross-correlation with CMB lensing





Credit: W. Hu

Harnois-Déraps+ (KiDS collaboration, 2017)

CONCLUSIONS

- *Gravitational lensing is one of the most promising probes of dark energy in the next decade.*

- *The main observational challenges to cosmology with gravitational lensing are accurate estimation of galaxy shapes and distances.*

- *The main theoretical challenges in modelling the large-scale structure of the Universe are associated with the role of baryons and galaxy formation.*

- *Preparation is underway to enable the next generation of lensing experiments (LSST, Euclid) which will drive a next era in precision cosmology.*