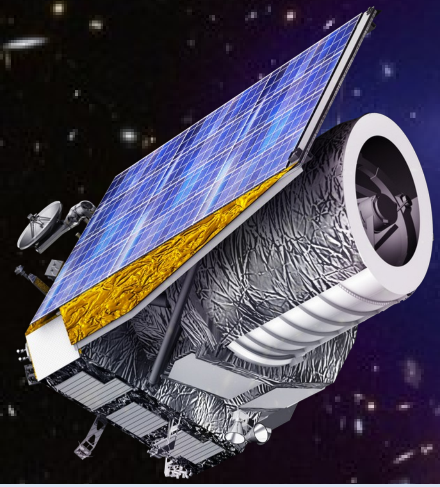
Euclid weak lensing cosmic shear measurement on IRIS/gridPP

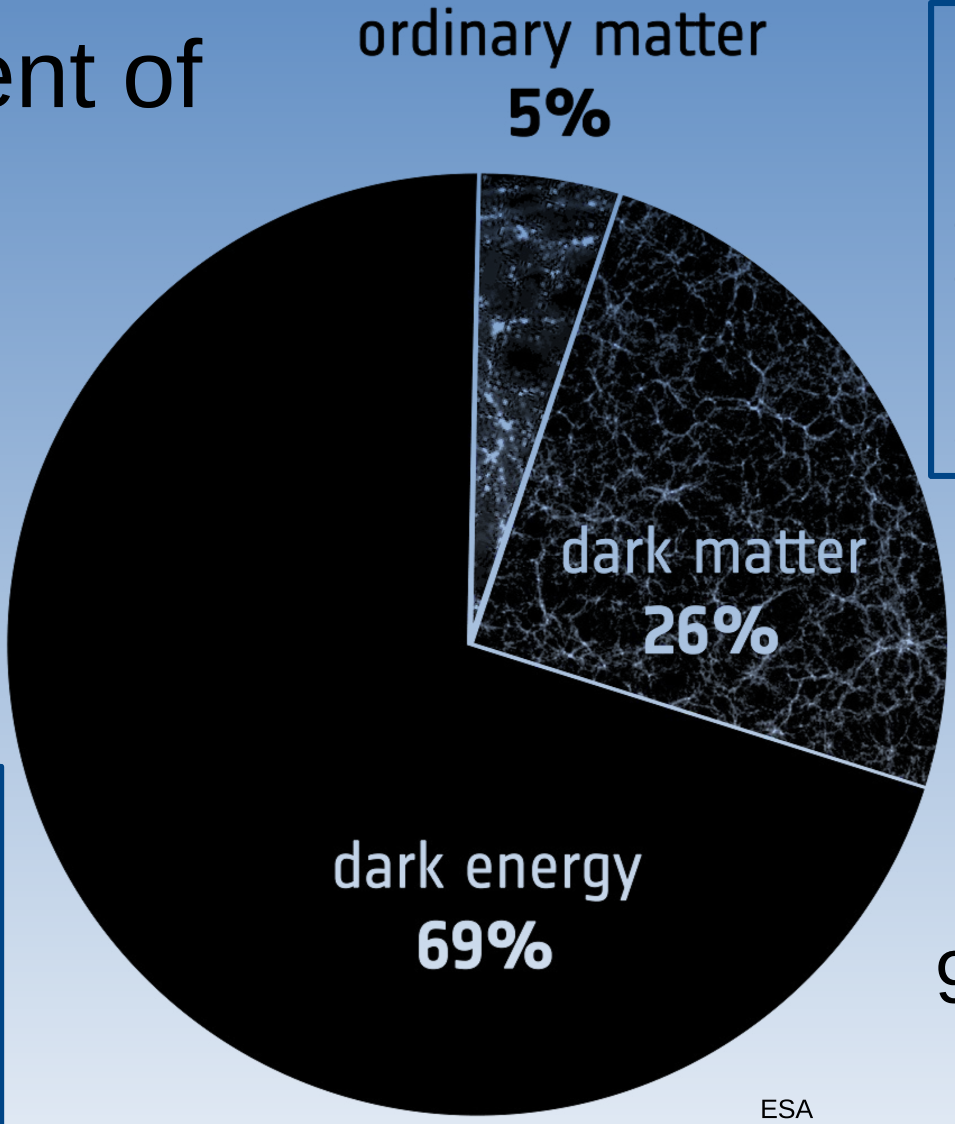
Giuseppe Congedo
(Senior Researcher)



ESA & Ma, Ebeling, Barrett (2009)

11 Oct 2022

energy content of the universe



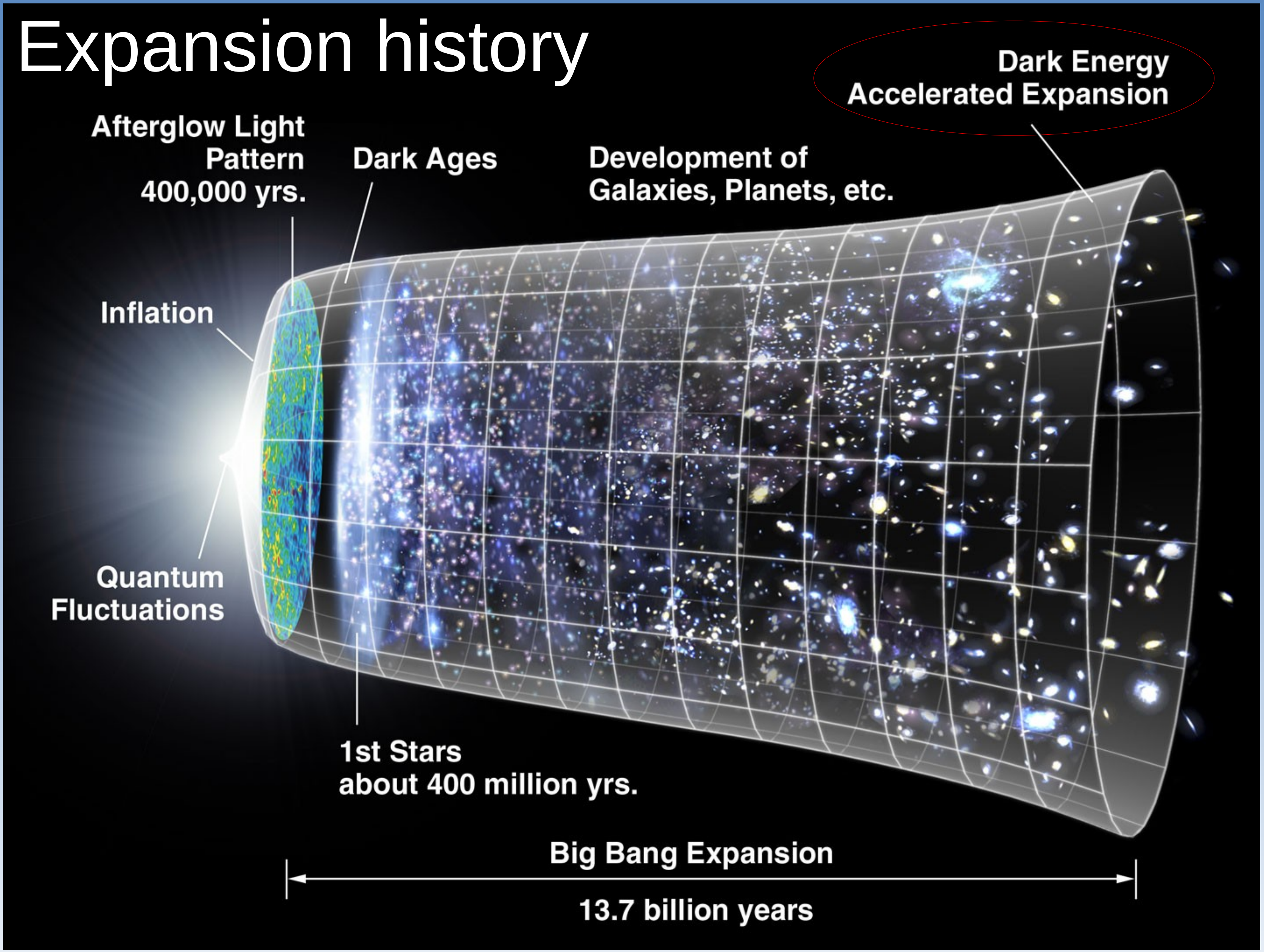
ESA

dark matter
- responsible for the rotation speed of galaxies (constant with distance from the centre)
- new particle?
- galaxies live at the centre of DM halos

dark energy
- responsible for the accelerated expansion of the universe
- deviation from general relativity?
- cosmological constant?

95% is unknown!

Expansion history

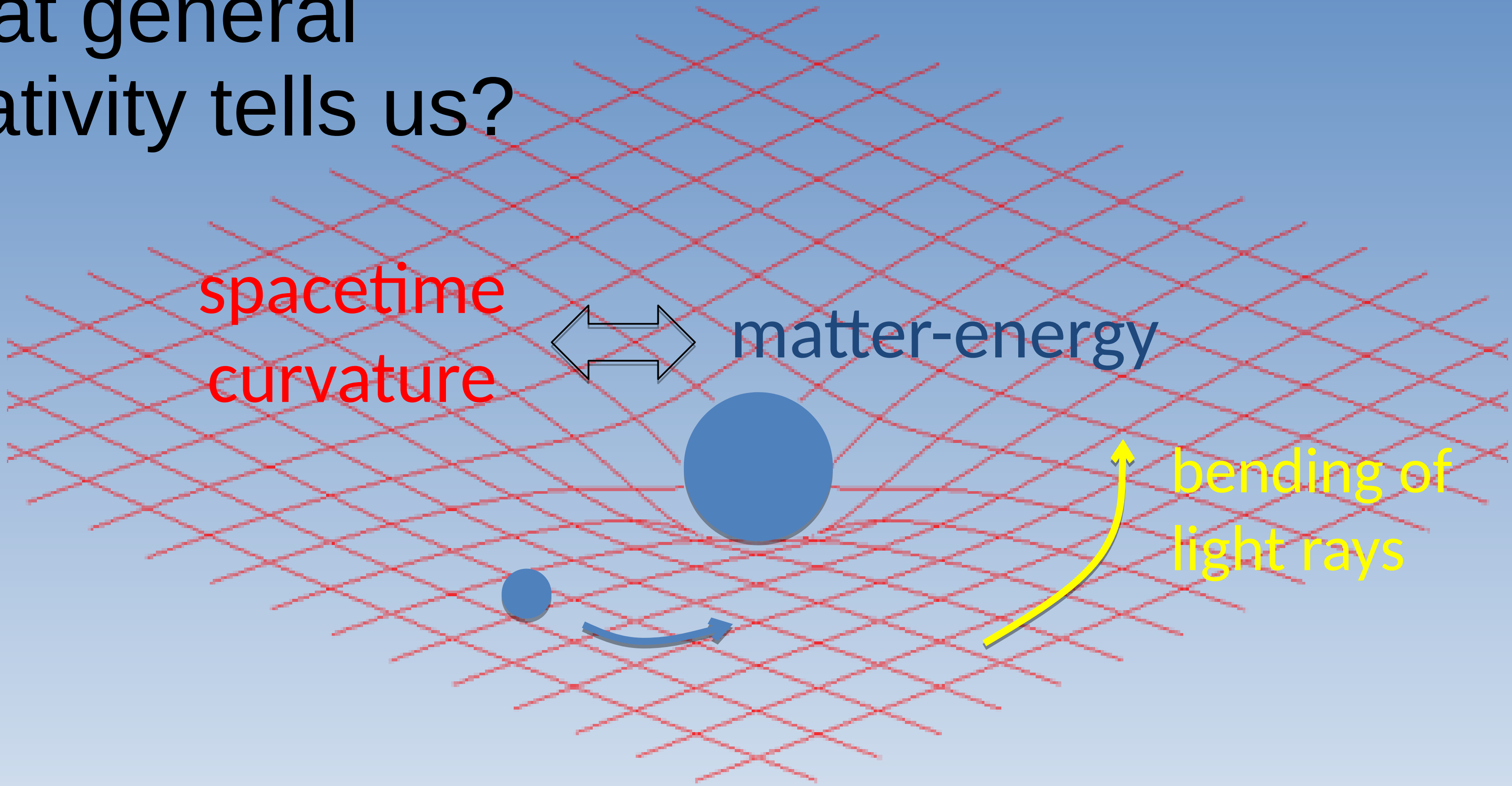


size / scale

time

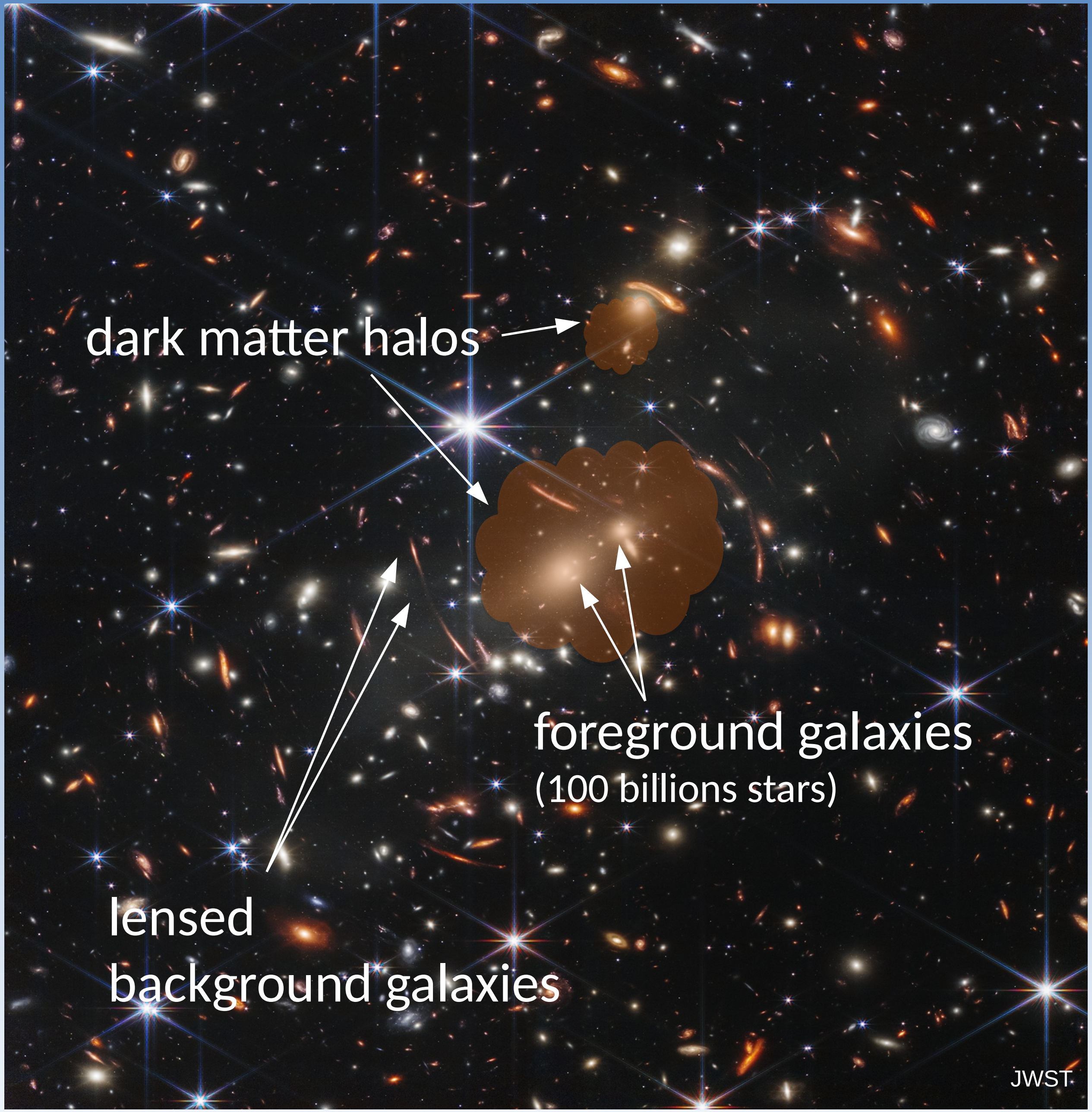
ESA

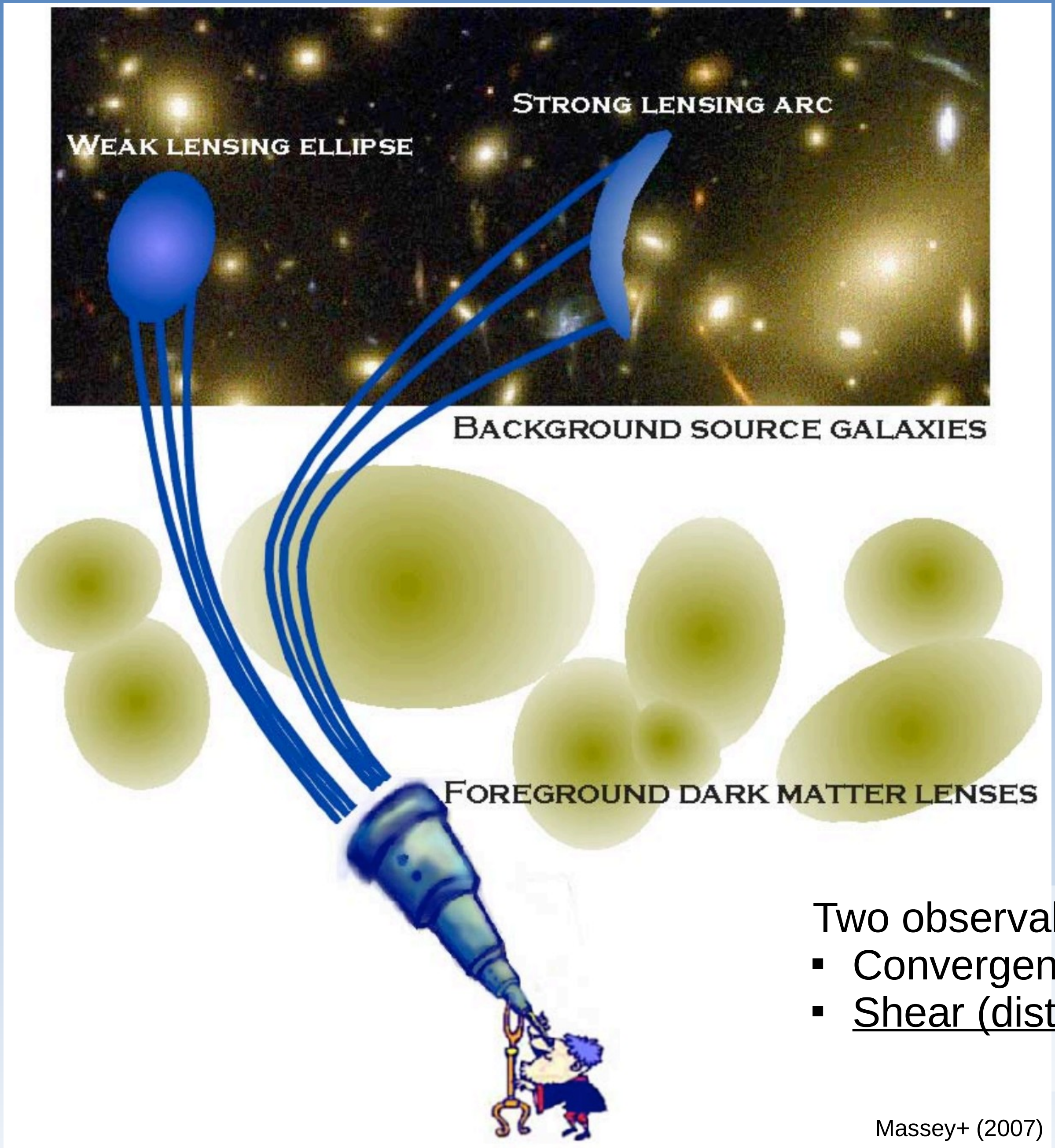
what general relativity tells us?



- *Spacetime tells matter how to move; matter tells spacetime how to curve* (J. Wheeler)
- Spacetime also tells light how to bend!


JWST


dark matter halos
foreground galaxies
(100 billions stars)
lensed
background galaxies
JWST

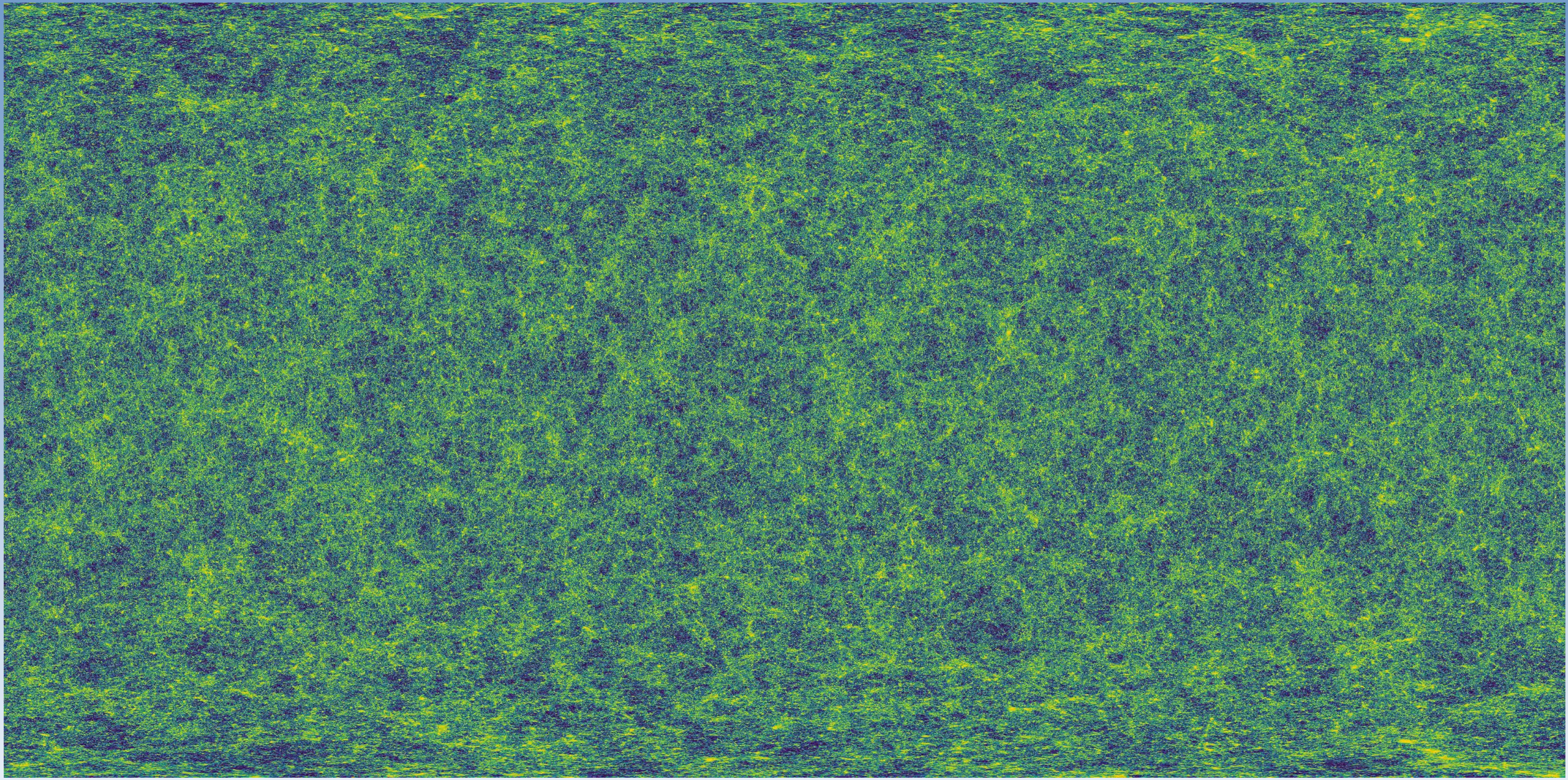


Two observables:

- Convergence (magnification)
- Shear (distortion)

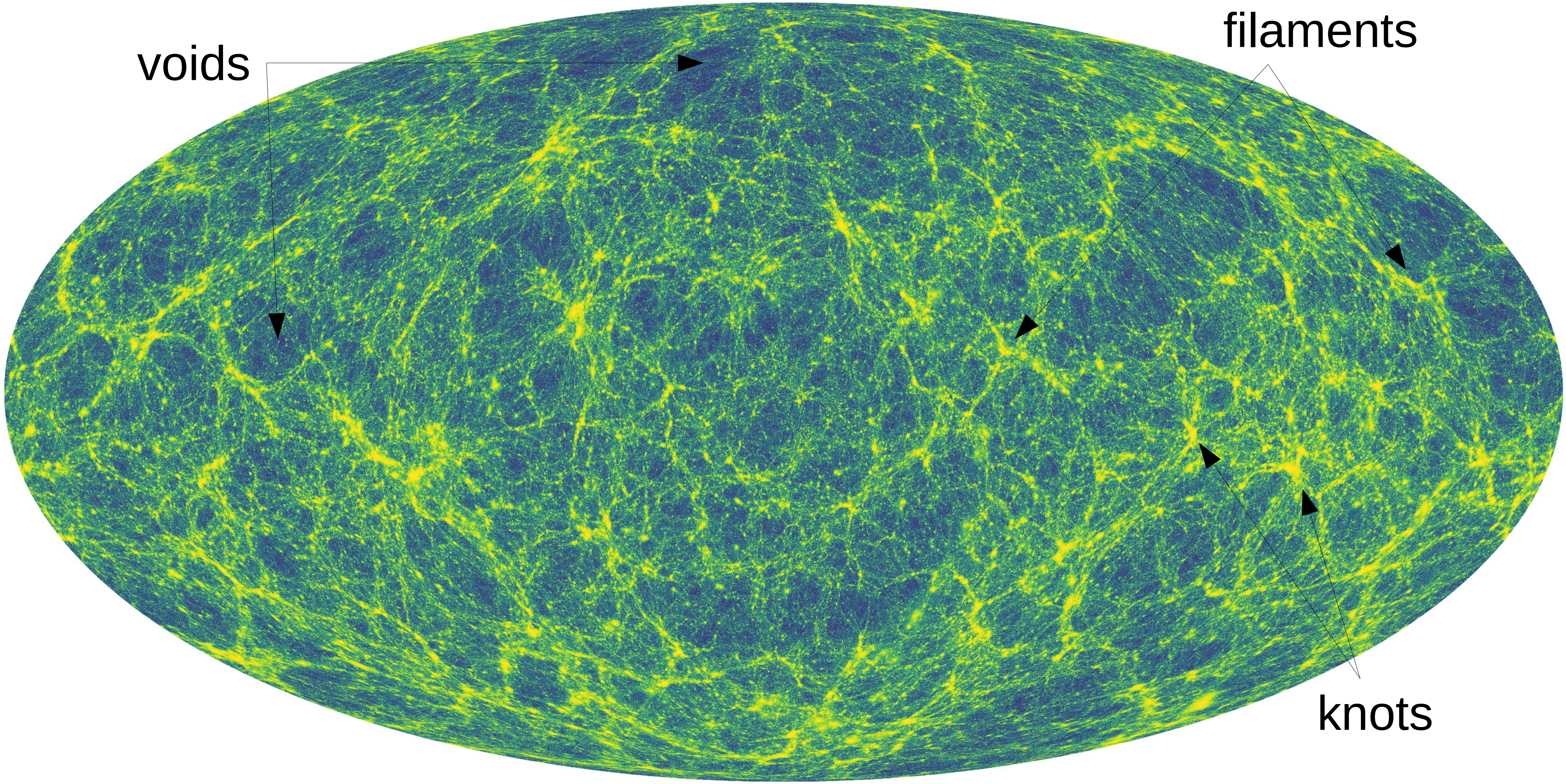
Massey+ (2007)

Full-sky convergence map (dark matter distribution)



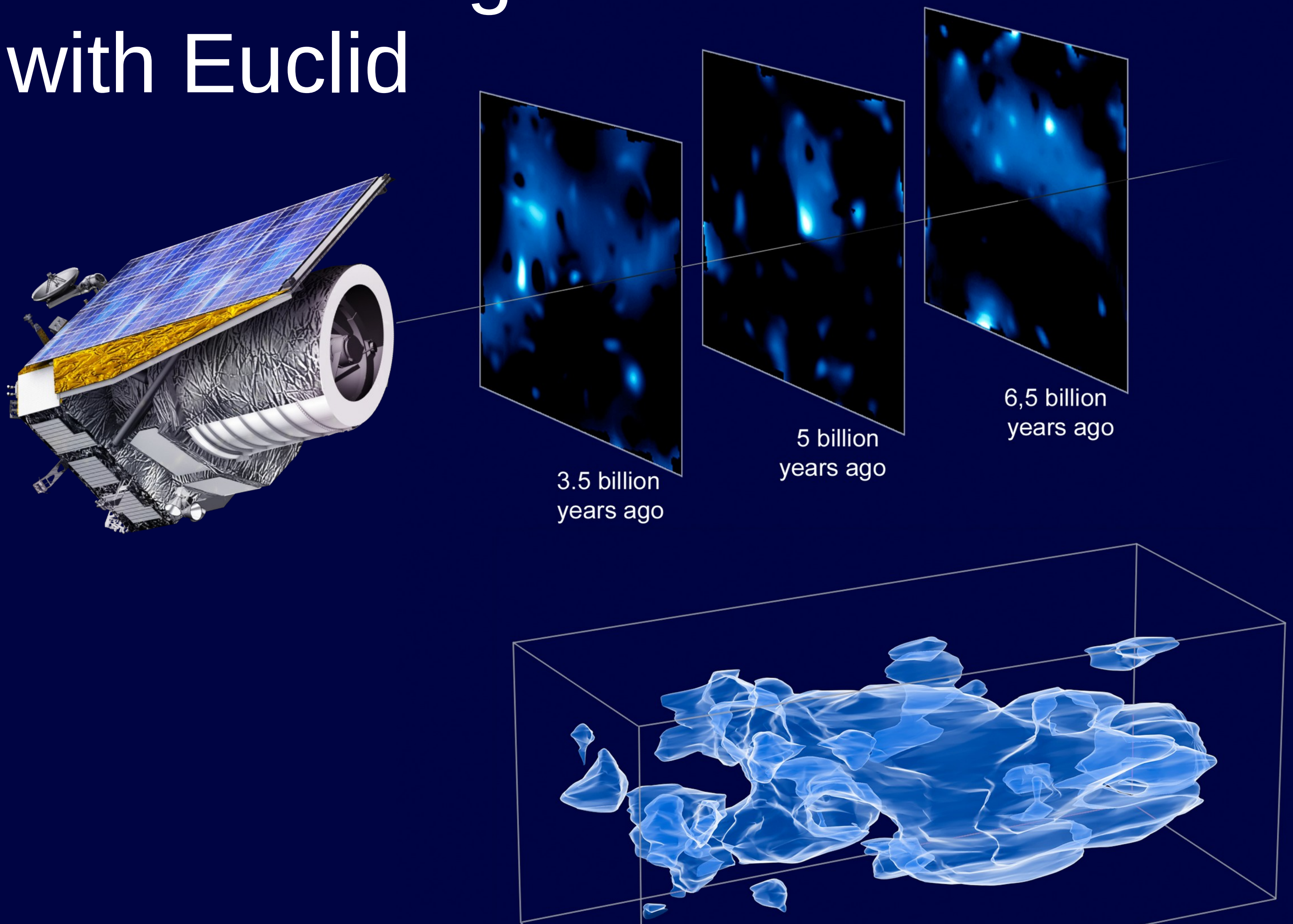
Timelapse and maps made by GC using Takahashi simulations

Full-sky convergence map (dark matter distribution)



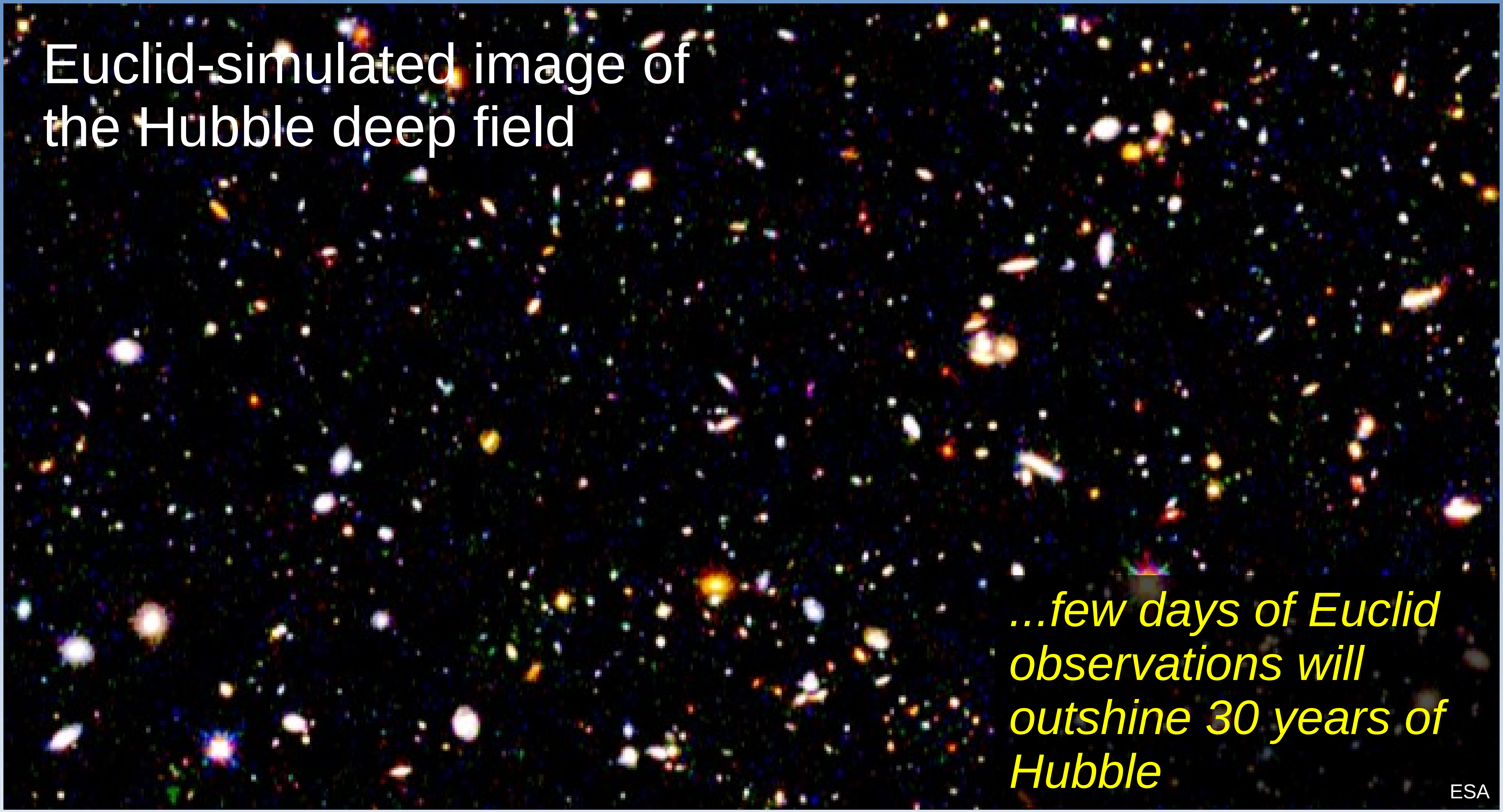
Map made by GC using Takahashi simulations

Weak lensing with Euclid



- Reconstruct the properties of dark matter
- Take snapshots back in time
- Study how dark energy interacts with dark matter
- Ultimately, understand what dark energy and dark matter are

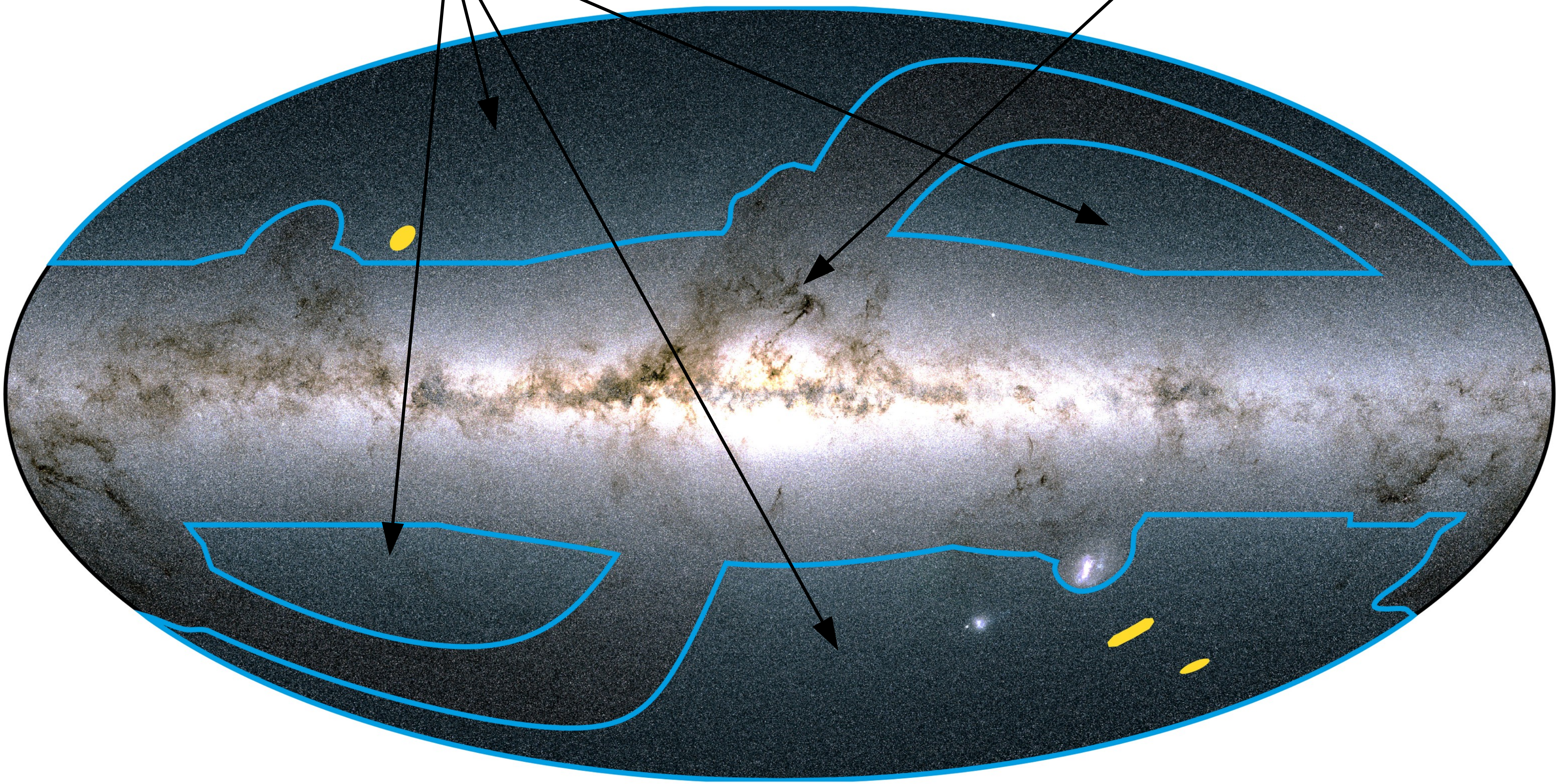
adapted from ESA



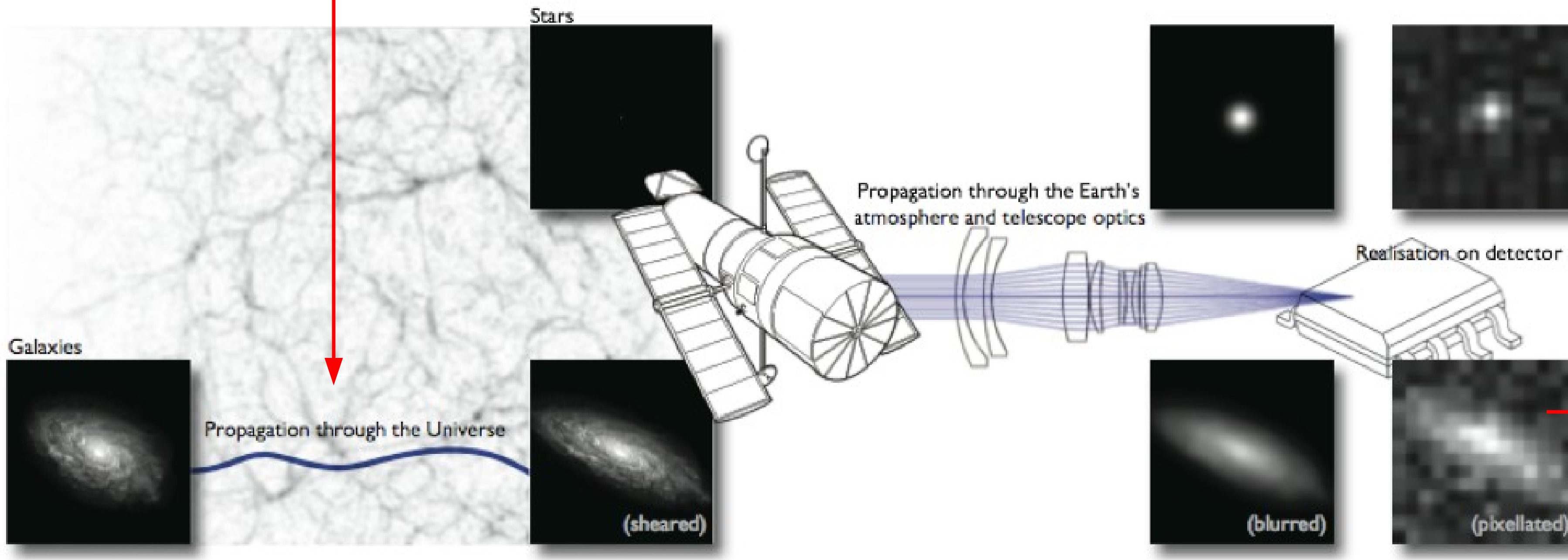
1/30th of the full Moon

Extra-galactic sky:
billions of distant galaxies

our galaxy

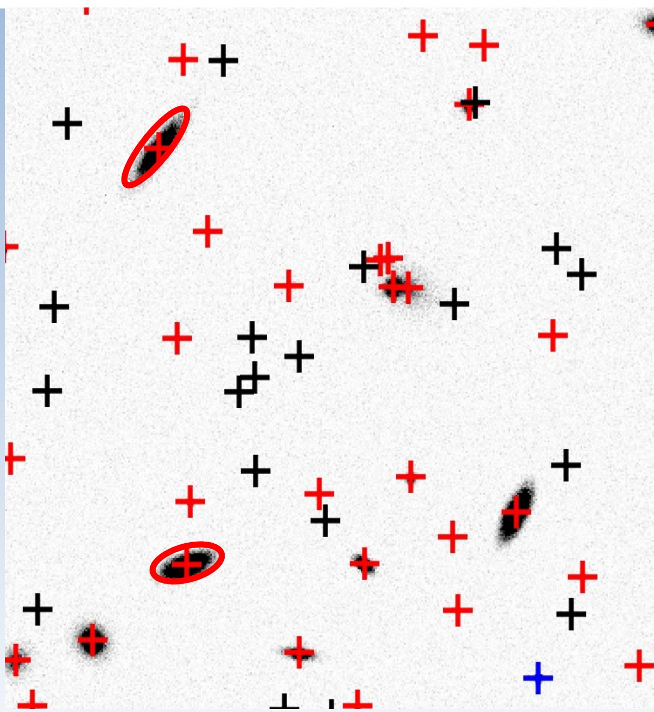


ESA

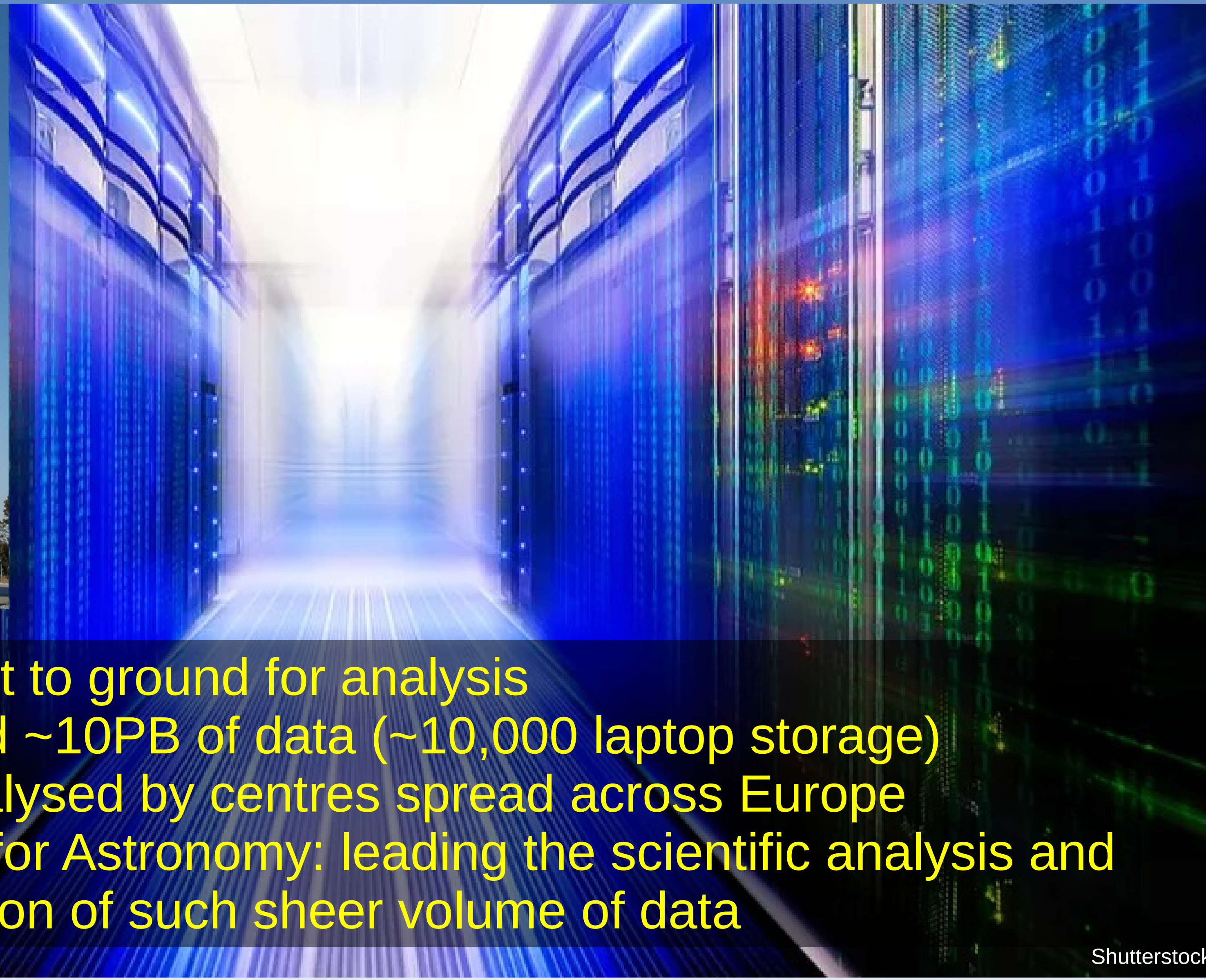


Courtesy of L. Miller, adapted from Bridle, Kitching+ (2010)

- The shape of distant galaxies gets distorted by the large scale structure (cosmic shear)
- Our goal is to recover the cosmic shear through the observation of blurred, pixellated images
- Challenging task: do it for 1.5 billion galaxies (my main job in the project)
- LensMC – official measurement method



Cebreros,ESA



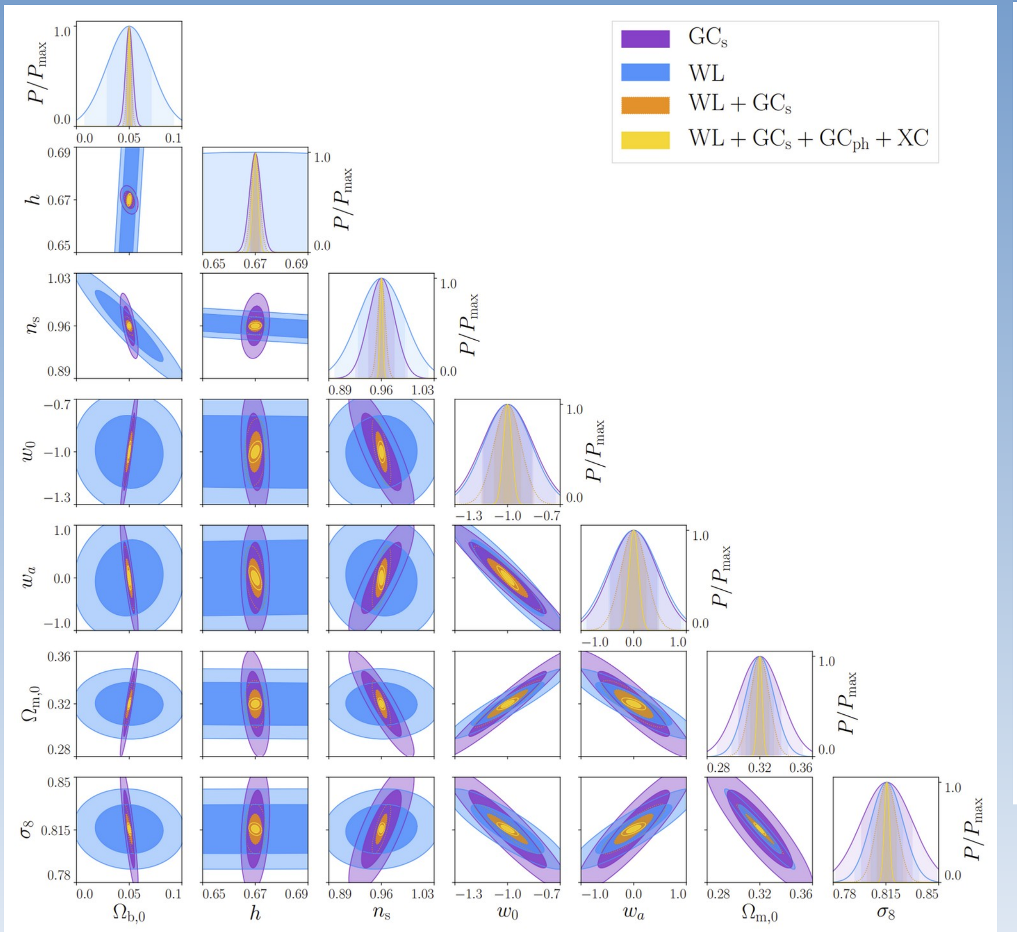
- Data sent to ground for analysis
- Expected ~10PB of data (~10,000 laptop storage)
- Data analysed by centres spread across Europe
- Institute for Astronomy: leading the scientific analysis and exploitation of such sheer volume of data

Shutterstock

Challenges

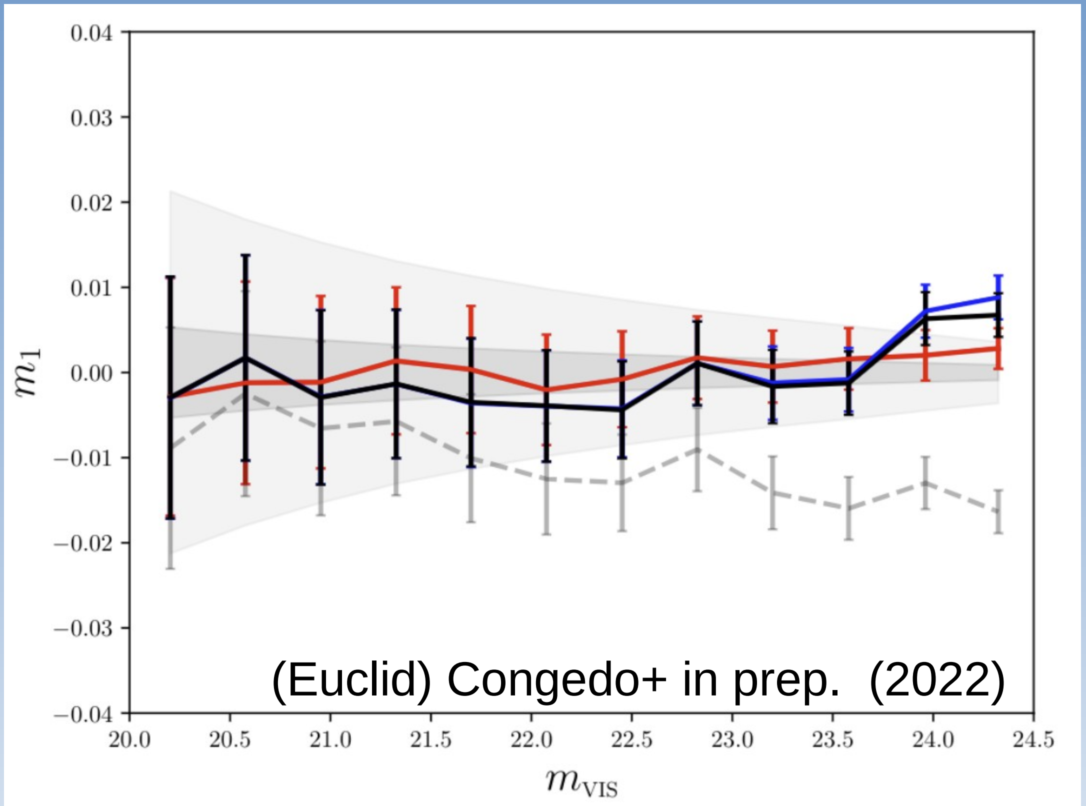
- Cosmological measurements with percent-level precision: measure a cosmic shear of 1% with an accuracy of 0.2%
- Correct for PSF errors ~10^{-4}
- Galaxies down to S/N>5, 30/sq.arcmin, median z=2
- Need 10^8-10^9 galaxies to beat down shape noise (~0.3), g=<e>
- Euclid:
  - 15,000 sq.deg across the extra galactic sky (37% of the full sky)
  - Mag<24.5 for wide survey; +2 for deep survey
  - Diffraction limited with a resolution of 0.1”
- Estimate 2p-correlation/ power spectra of:
  - Weak Lensing: shape-shape
  - Galaxy Clustering: position-position
  - Cross-correlation: shape-position

Science objectives



(Euclid) Blanchard+ (2020)

for cross-correlation with CMB see:
(Euclid) Ilic+ (2021)



$g_{meas} = (1 + m)\, g_{true} + c$

$\sigma_m < 2 \times 10^{-3}$

$\sigma_c < 3 \times 10^{-4}$

How can IRIS and GridPP help?

- Lots of help through many cores up and down the country
- Lots of CPUh to reduce measurement uncertainty
- Demonstrate performance of LensMC shear measurement method (the official method) at Euclid requirement level
  - very hard to meet with clusters
  - in fact, been using IRIS resources (e.g. Cambdrige, RAL) for testing, but now need to scale up
  - cores made available by IRIS to gridPP will be crucial

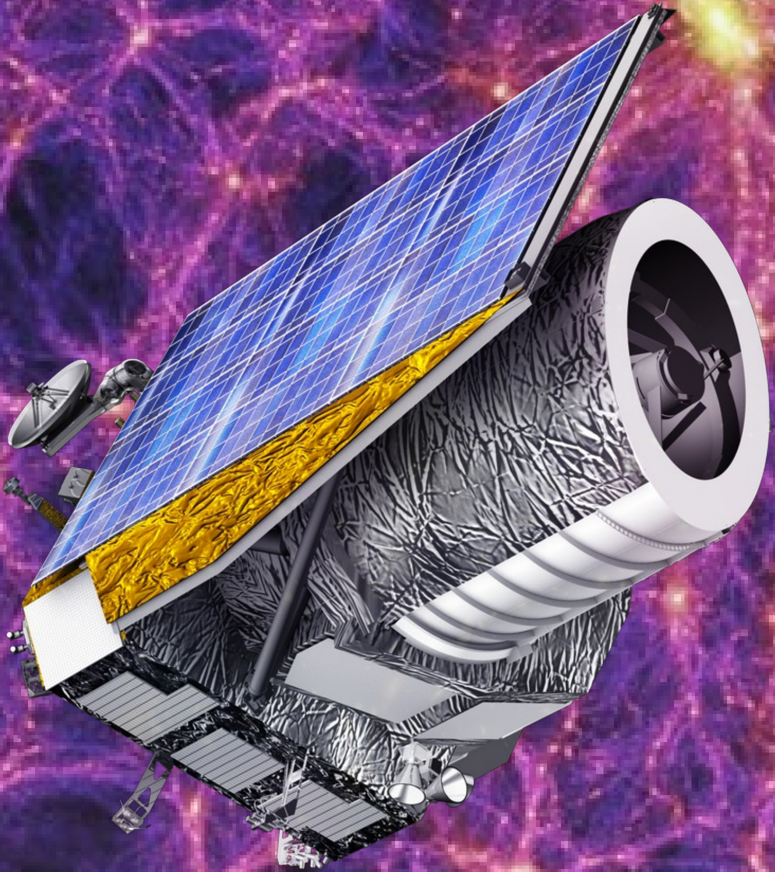
LensMC-gridPP

- Take large simulation of the sky
- Split in small patches of ~9 sq.arcmin
- Emulate Euclid images and run measurement
- Compile all results
- Estimate bias/errors
- Meet requirements

LensMC-gridPP

- The job:
  - take in small patch of sky, simulate image, and run measurement
  - Conda environment installer, code, Python script, wrapper script, and ancillary data on storage
  - jobs retrieve data before running, results saved back to storage
- Successful at running all of this for a couple of months on gridPP VO (70% complete):
  - very low memory footprint (~1GB), runtime ranging from few hours to few days
  - often 10,000 cores/day with very low downtime or failure rate
- Moving on:
  - new Euclid VO for tracking/accountability
  - Any further help from IRIS very much appreciated!
- Outcome: key Euclid publication (with gridPP+IRIS stamp) ready for submission to the board hopefully by the end of the year

Thank you



coming up in 2023...