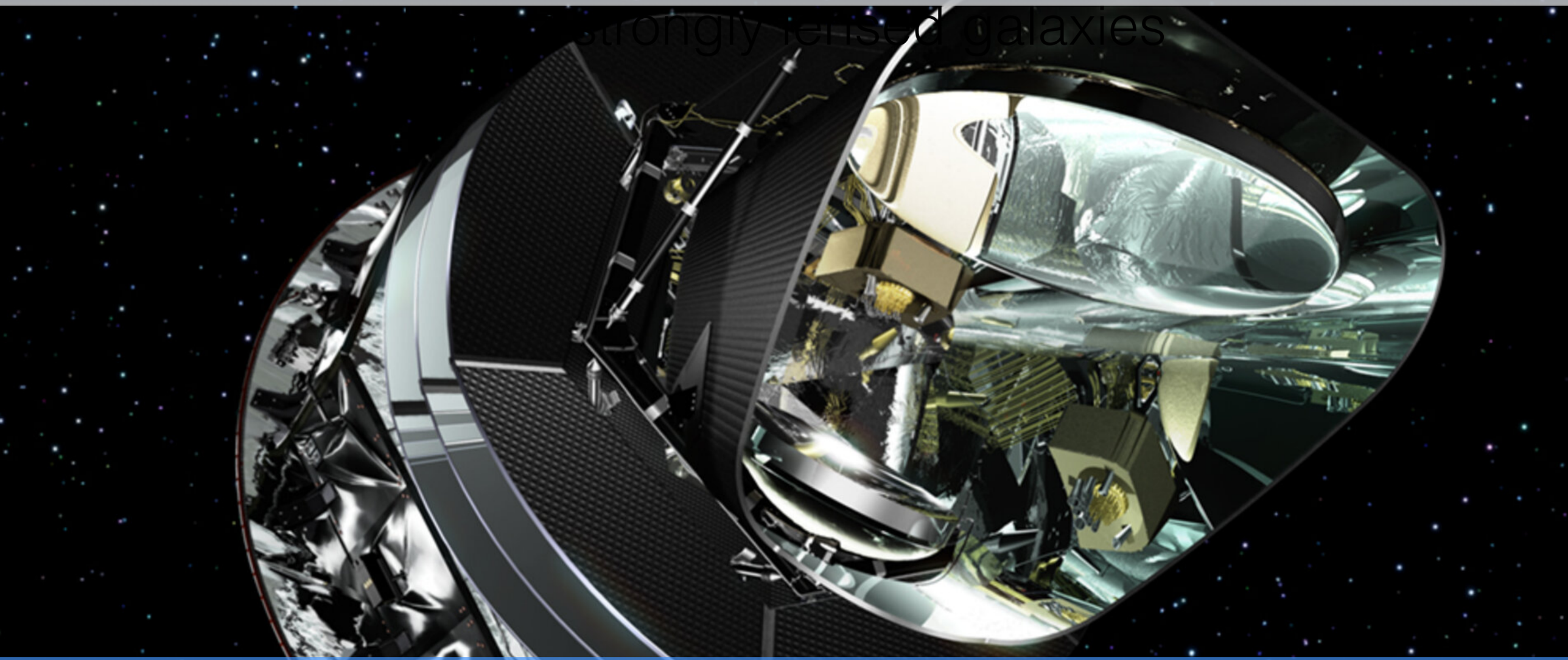
Using Planck maps for a systematic search of ultra-bright high-z strongly lensed galaxies



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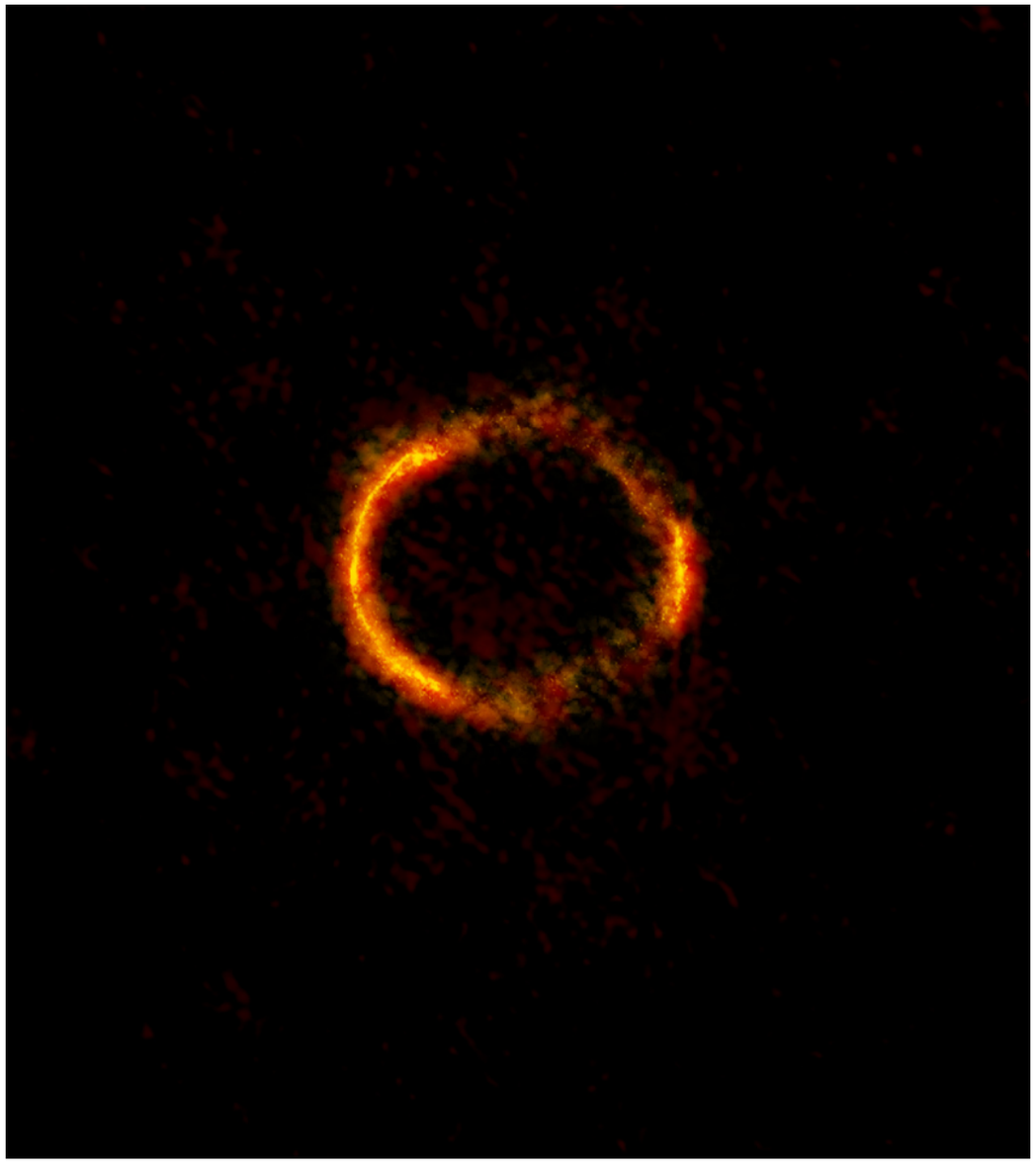
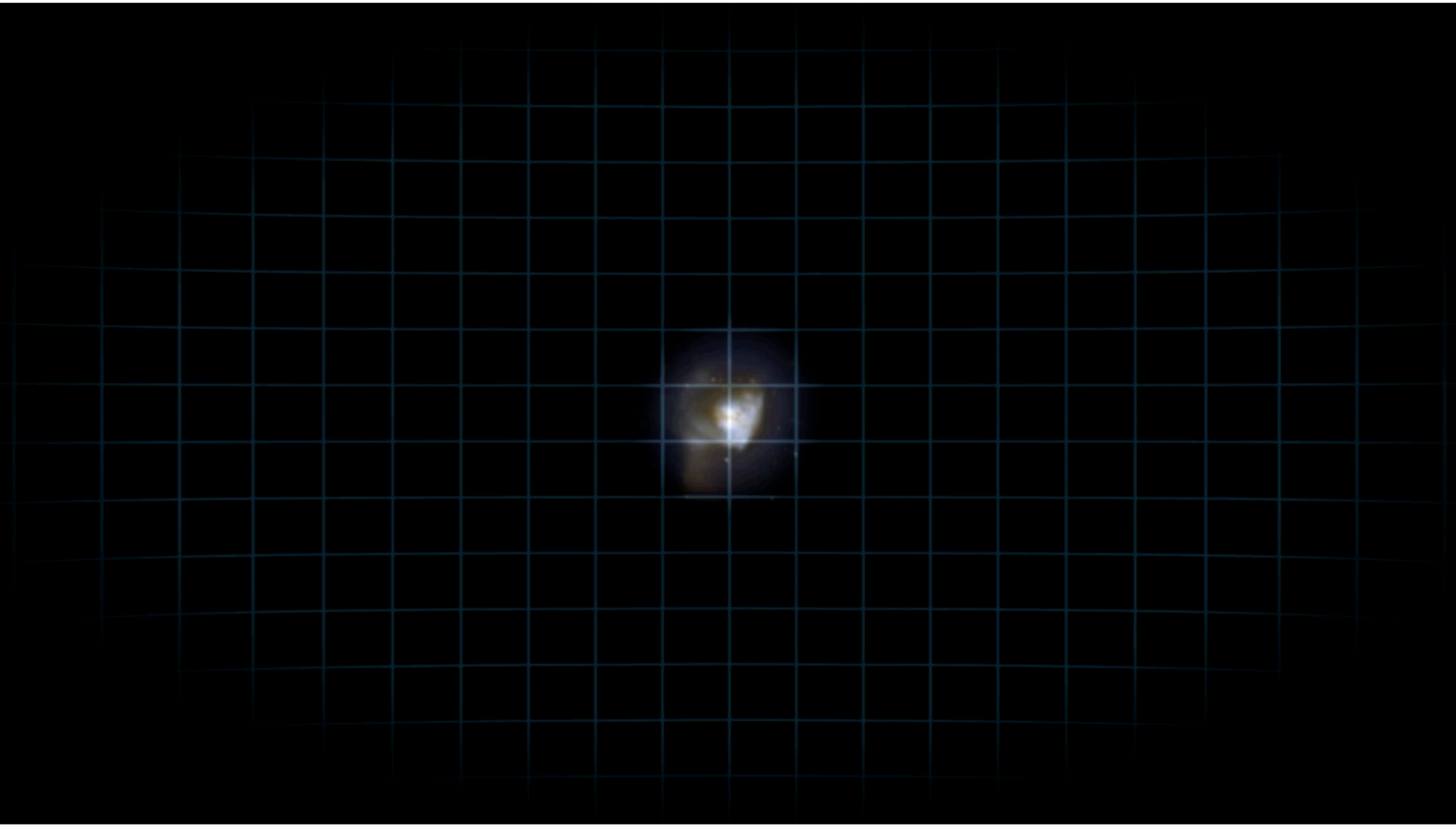
Seventeenth Marcel Grossmann Meeting
8 July 2024

Unveiling the Early Universe: Using Planck Maps to Find Ultra-Bright High-Redshift strongly lensed galaxies



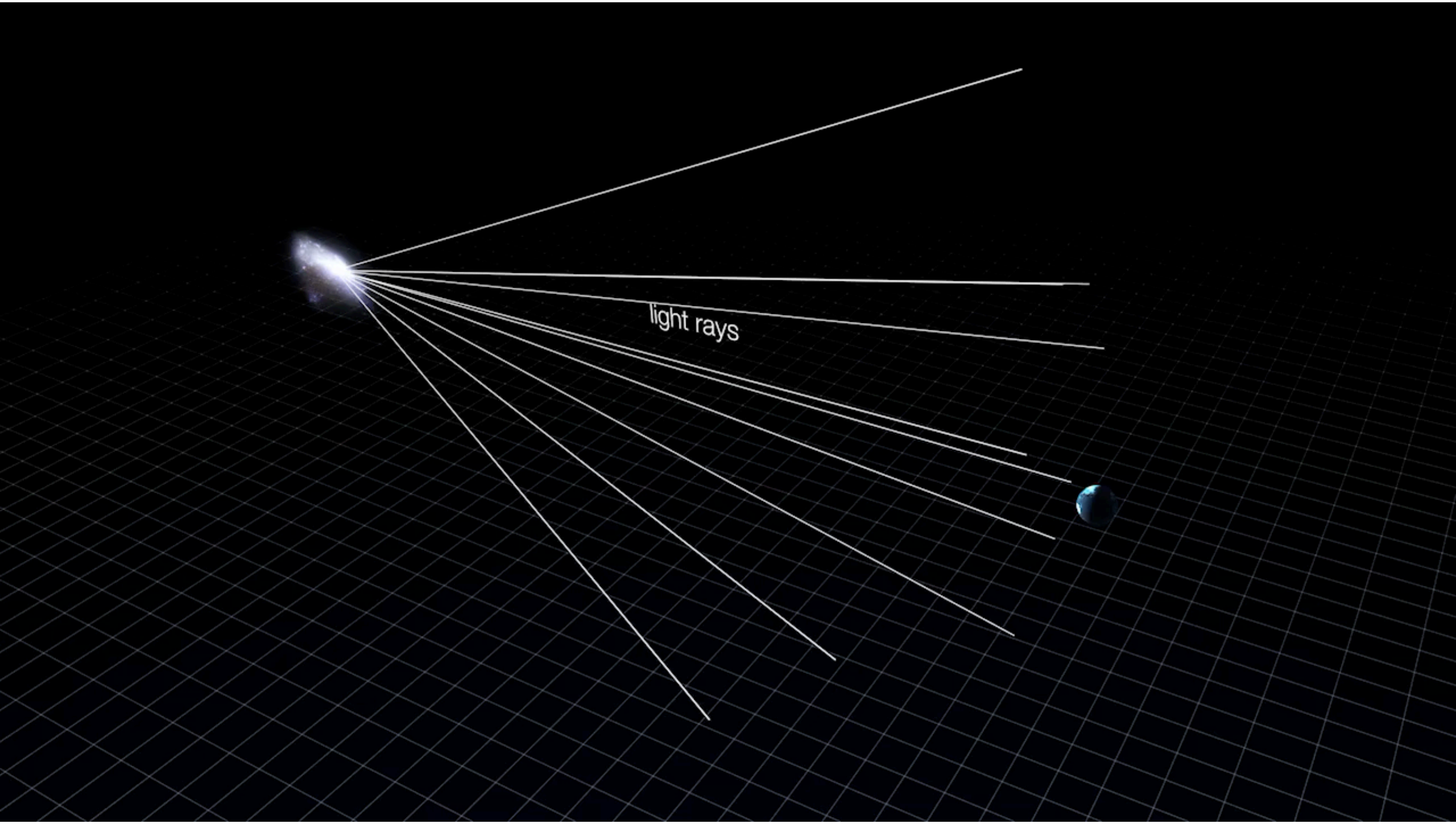
SDP.81 - Credit: ALMA (NRAO/ESO/ NAOJ); B. Saxton NRAO/AUI/NSF

Strong gravitational lensing



Credit: NRAO/AUI/NSF; ALMA (NRAO/ESO/NAOJ); Dana Berry / SkyWorks

Strong gravitational lensing



Credit: ESA/Hubble, NASA

Why lensed galaxies?

- Unique opportunity to get detailed information on the internal structure and kinematics of high-z galaxies during their most active, dust-enshrouded star-formation phase

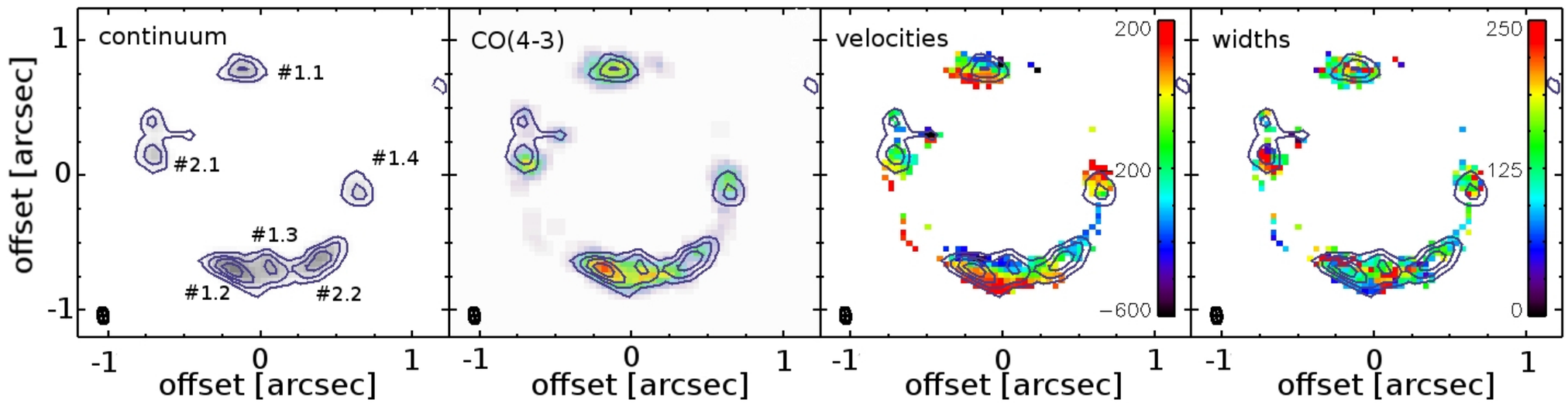
- This information is crucial to understand the key processes governing the galaxy formation and early evolution

- The only way to get direct information on physical processes at work is to look inside the high-z star-forming galaxies.

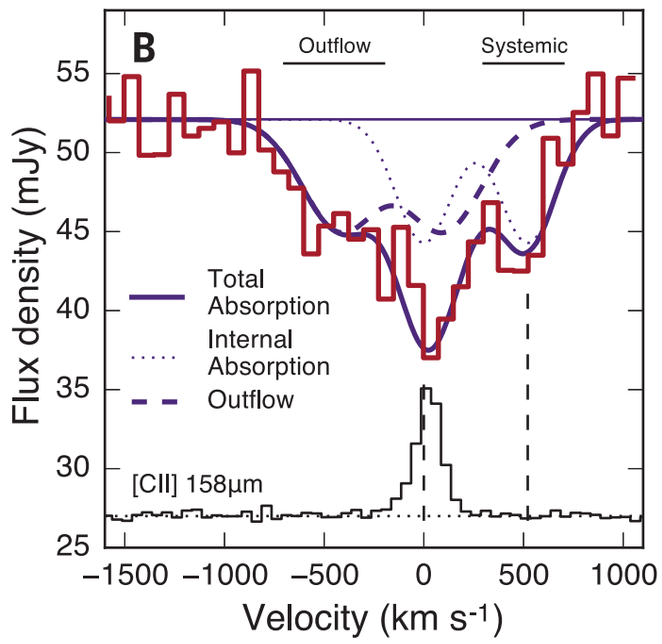
- Strong gravitational lensing allows us to study high-z galaxies in extraordinary detail, otherwise beyond reach of present-day instrumentation, thanks to the flux magnification combined with a stretching of images

Why lensed galaxies?

ALMA observation - Strongly lensed galaxy at z~3, μ~30, spatial resolution of ~60 pc



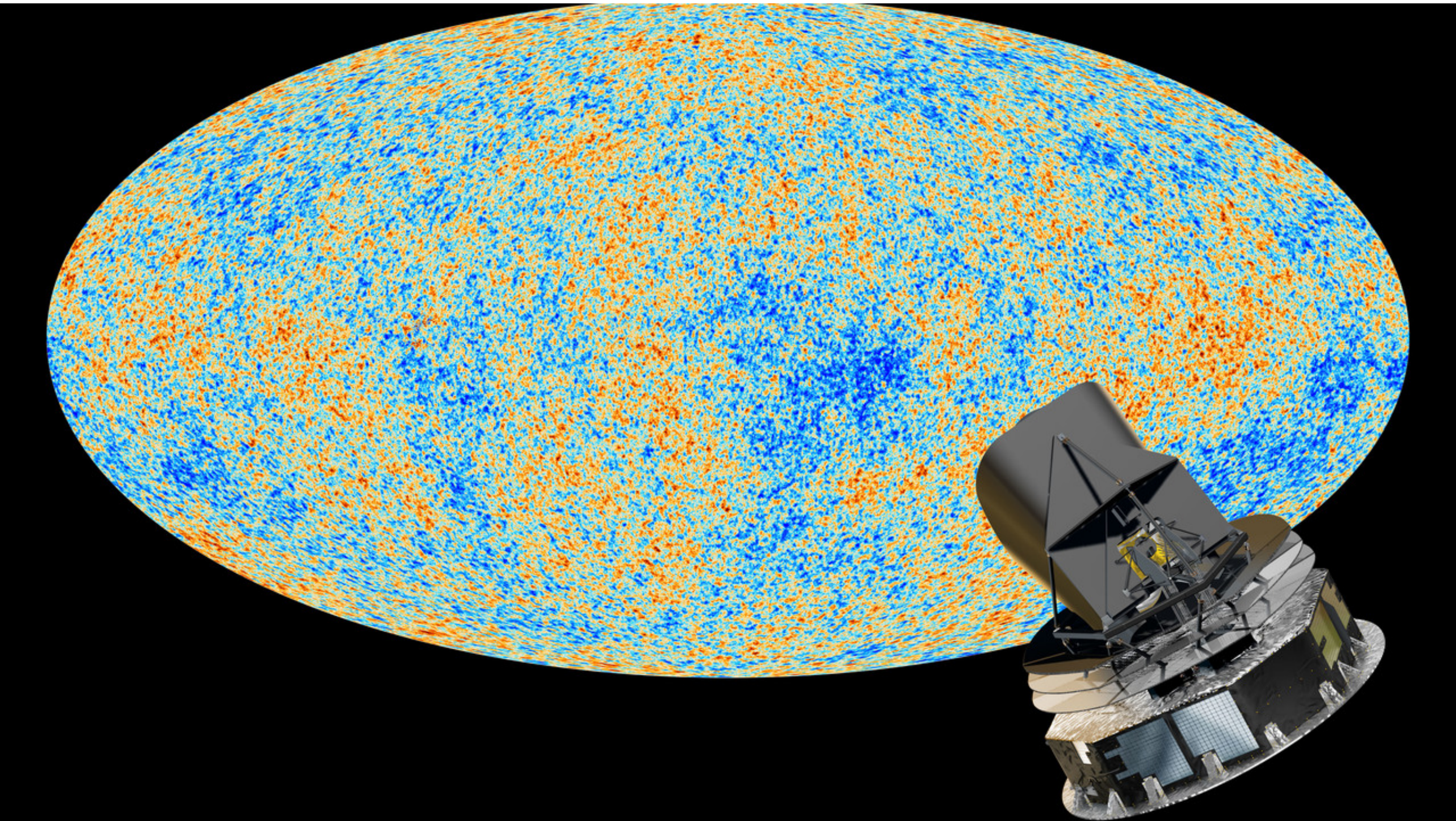
Cañameras et al. (2017)



Spilker et al. (2018)

ALMA observation - fast (800 kms/s) massive molecular outflows in a lensed galaxy at z~5.3

The Planck Mission and CMB



Lensed galaxies from Planck maps

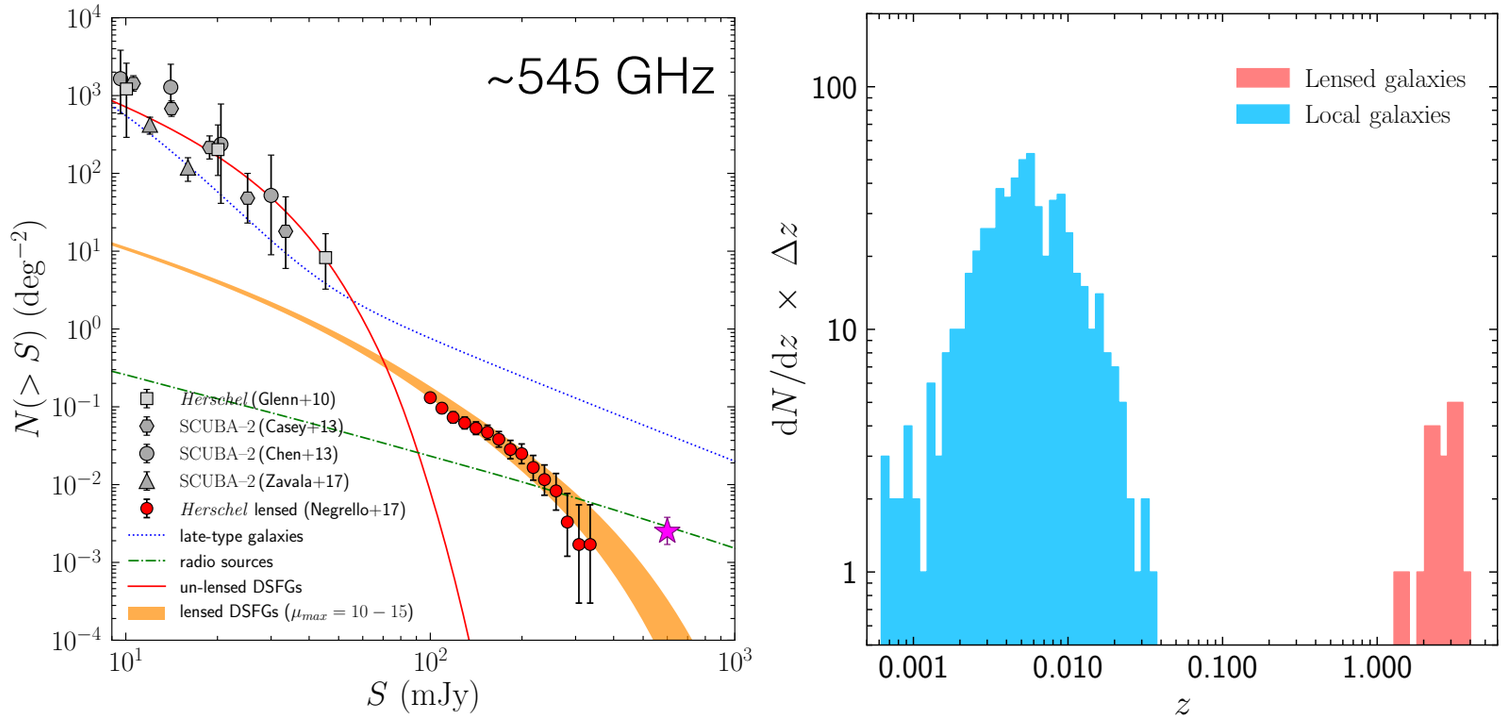
- So far about ~40 strongly lensed galaxies have been discovered from Planck catalogues

- But in the full high Galactic latitude Planck sky we expect a total number of ~150 lensed galaxies

- This sample would offer a unique opportunity for statistical studies of the foreground lensing population

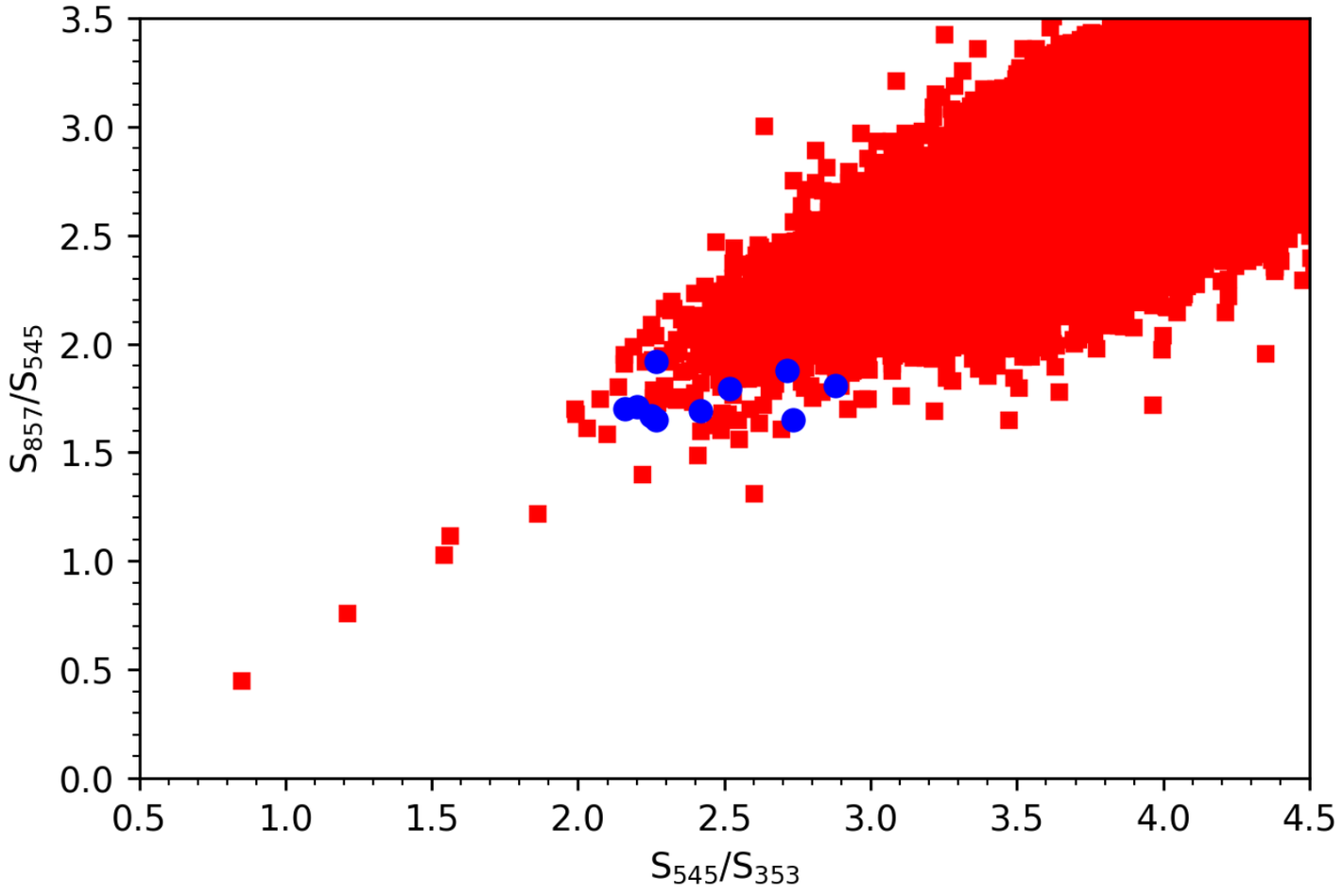
Selecting candidates from Planck maps

- Selecting at the three highest Planck frequencies: (353, 545, and 857 GHz)



Trombetti et al. (2021)

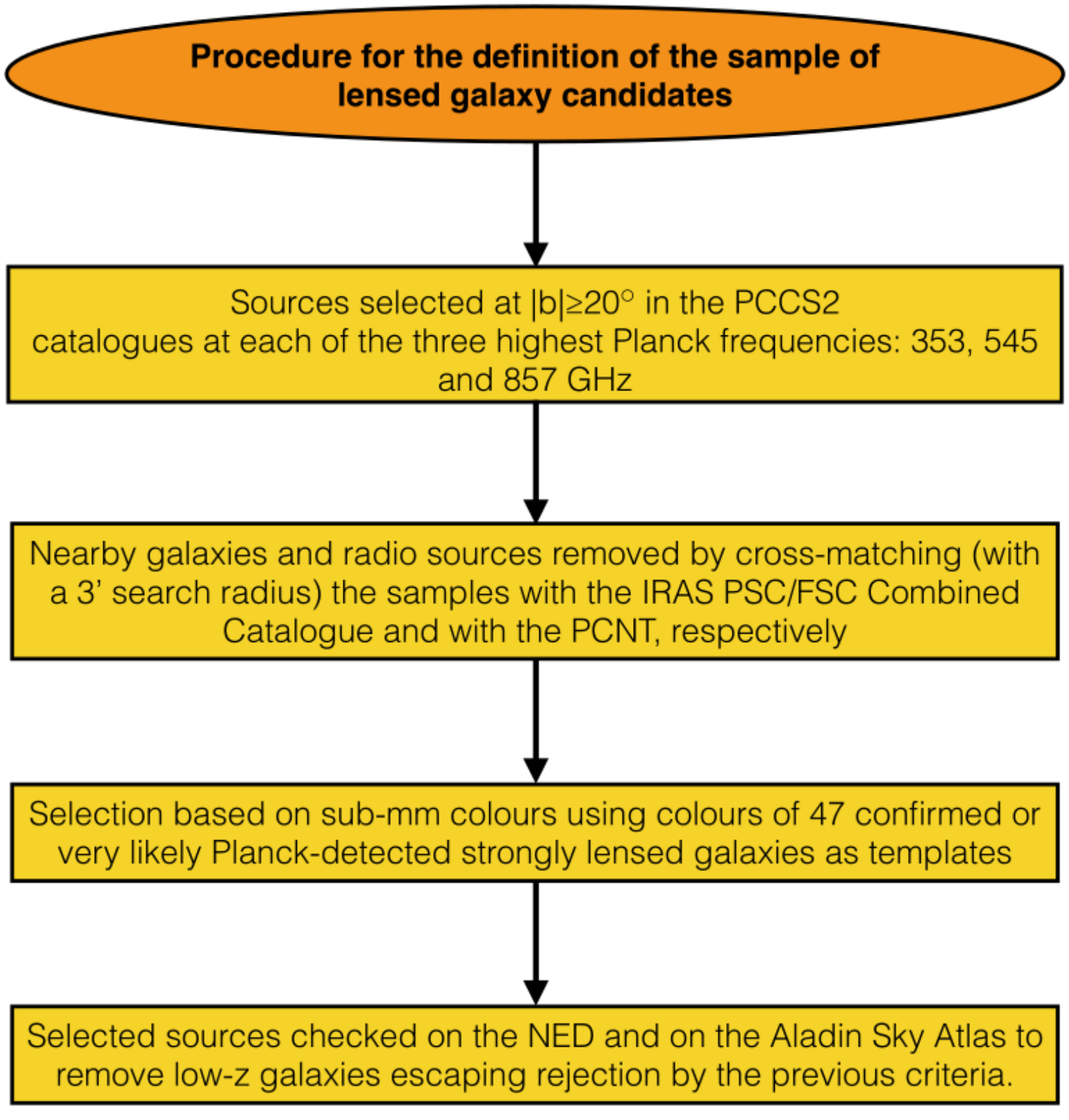
Different sub-mm colours



Trombetti et al. (2021)

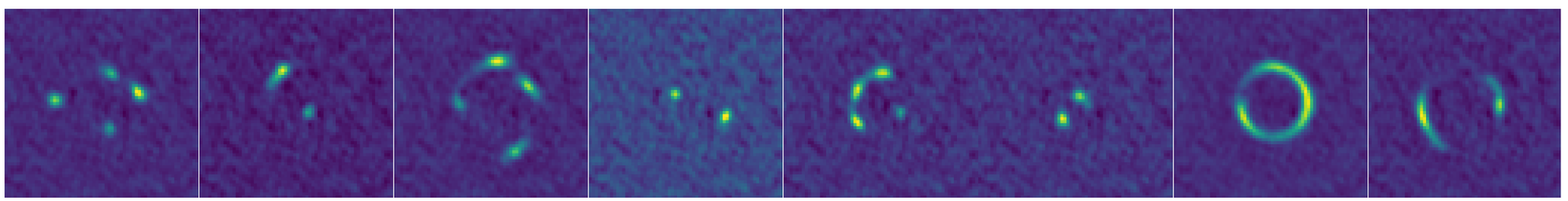
- High-z lensed galaxies are substantially redder

Candidate sample definition



Machine-learning approach

Another possibility: machine-learning
Massive simulations using the Planck Sky Model to produce a tailored training set.



Rezaei et al. (2023) - Machine learning based approach to gravitational lens identification with LOFAR

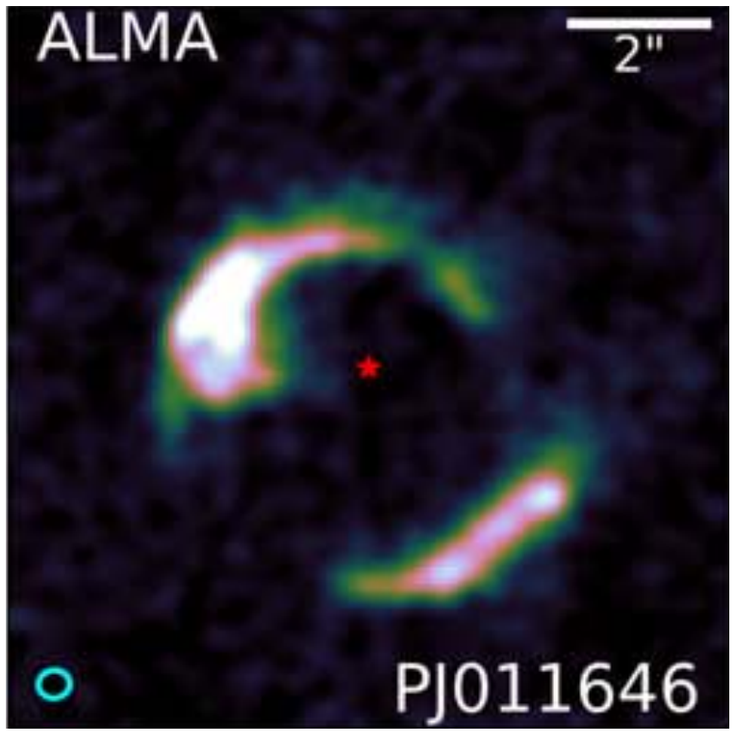
“Contaminants” in the final candidate sample

- Cold extended objects like cold clumps
- Proto-clusters of high-z dusty galaxies
- Positive fluctuations of the CIB

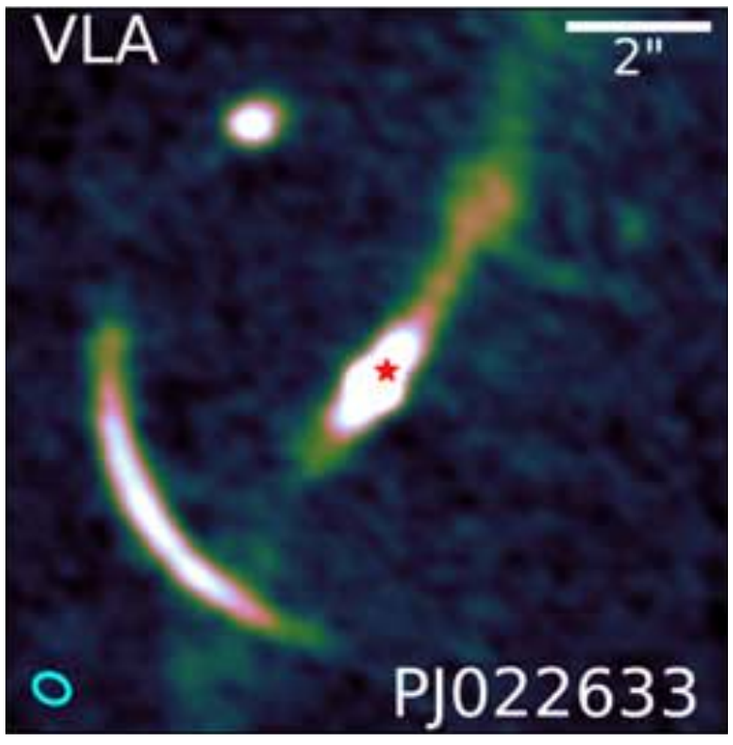
☞ 25-30% of the candidates are real gravitationally lensed galaxies

☞ **Need of Follow-up observation** (ATCA, NIKA2, SCUBA-2)

Highest resolution follow-up



Kamieneski et al. (2024)



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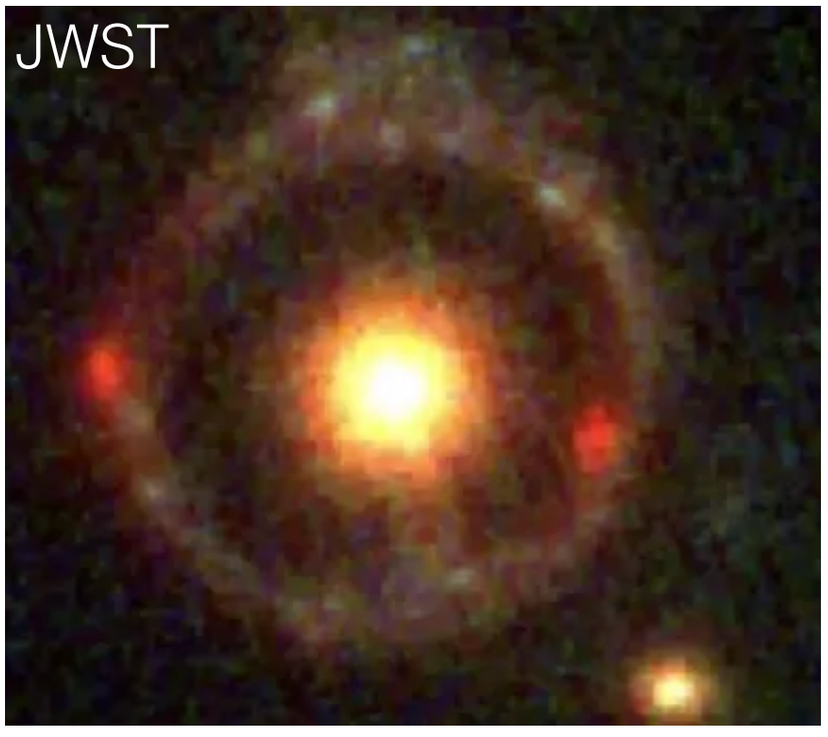

Van Dokkum et al. (2023)

Summary

- Using Planck data for discovering new high-z lensed galaxies
- These objects offer a unique opportunity to get detailed information on the internal structure and kinematics of high-z galaxies during their most active, dust-enshrouded star-formation phase
- This information is crucial to understand the key processes governing the galaxy formation and early evolution
- Strong gravitational lensing allows us to study high-z galaxies in extraordinary detail, otherwise beyond reach of present-day instrumentation
- We expect there are ~150 lensed galaxy in the full high Galactic latitude Planck sky
- Unique opportunity for statistical studies of the foreground lensing population

Summary

- We have developed a procedure for the selection of a sample of lensed galaxies candidates from the Planck maps

- We are observing them with ATCA, NIKA2, SCUBA-2 and NOEMA for verifying the existence of the sources and obtaining accurate positions. We have obtained preliminary results not public yet.

- Next step: observing the confirmed lensed galaxies with the highest resolution telescopes (ALMA, JWST, VLA…)

Ongoing project ✉ matteo.bonato@inaf.it

Thank you very much for your attention!

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