Kaiju Stars

The hunt for cosmic monsters ... and clues for dark matter

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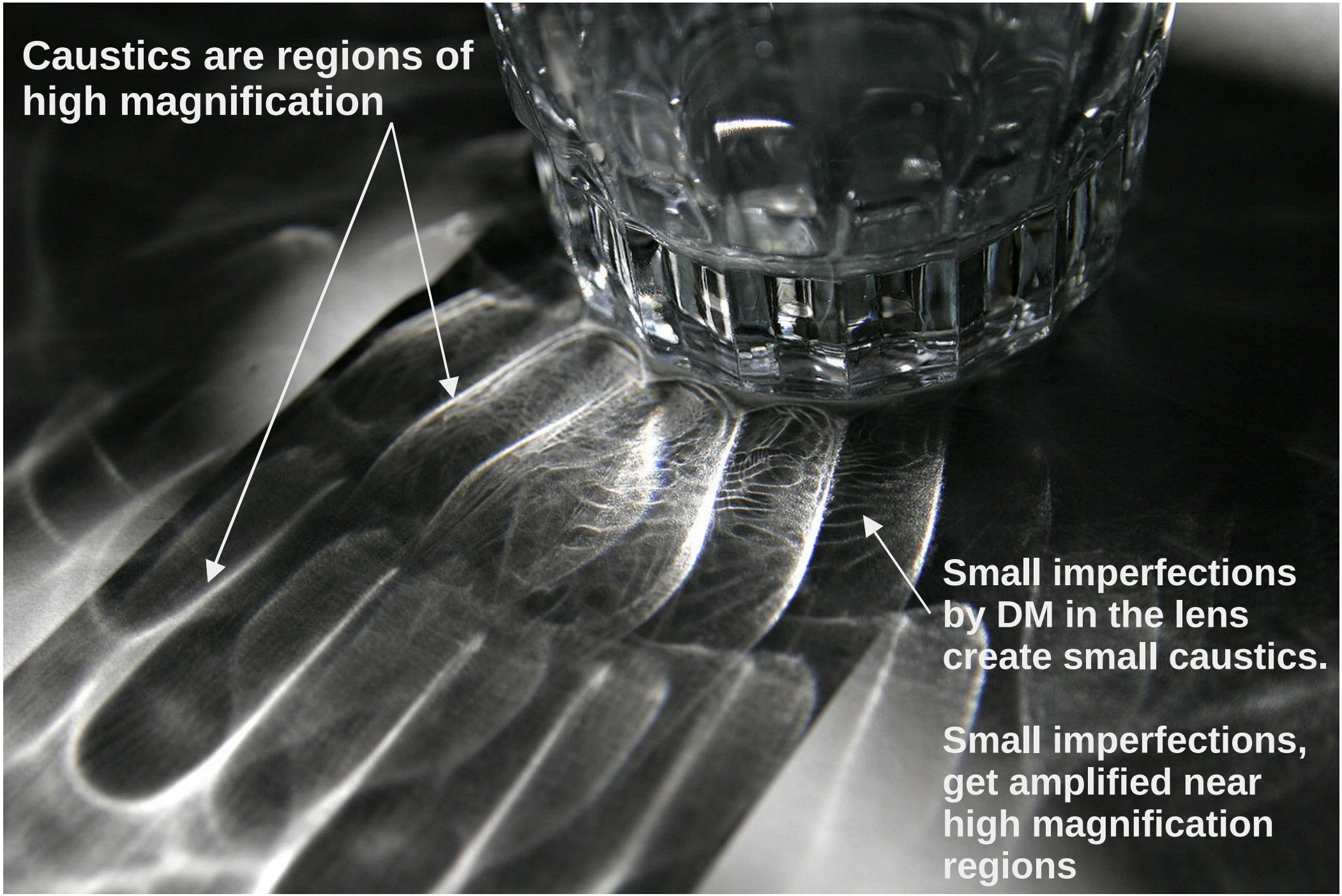
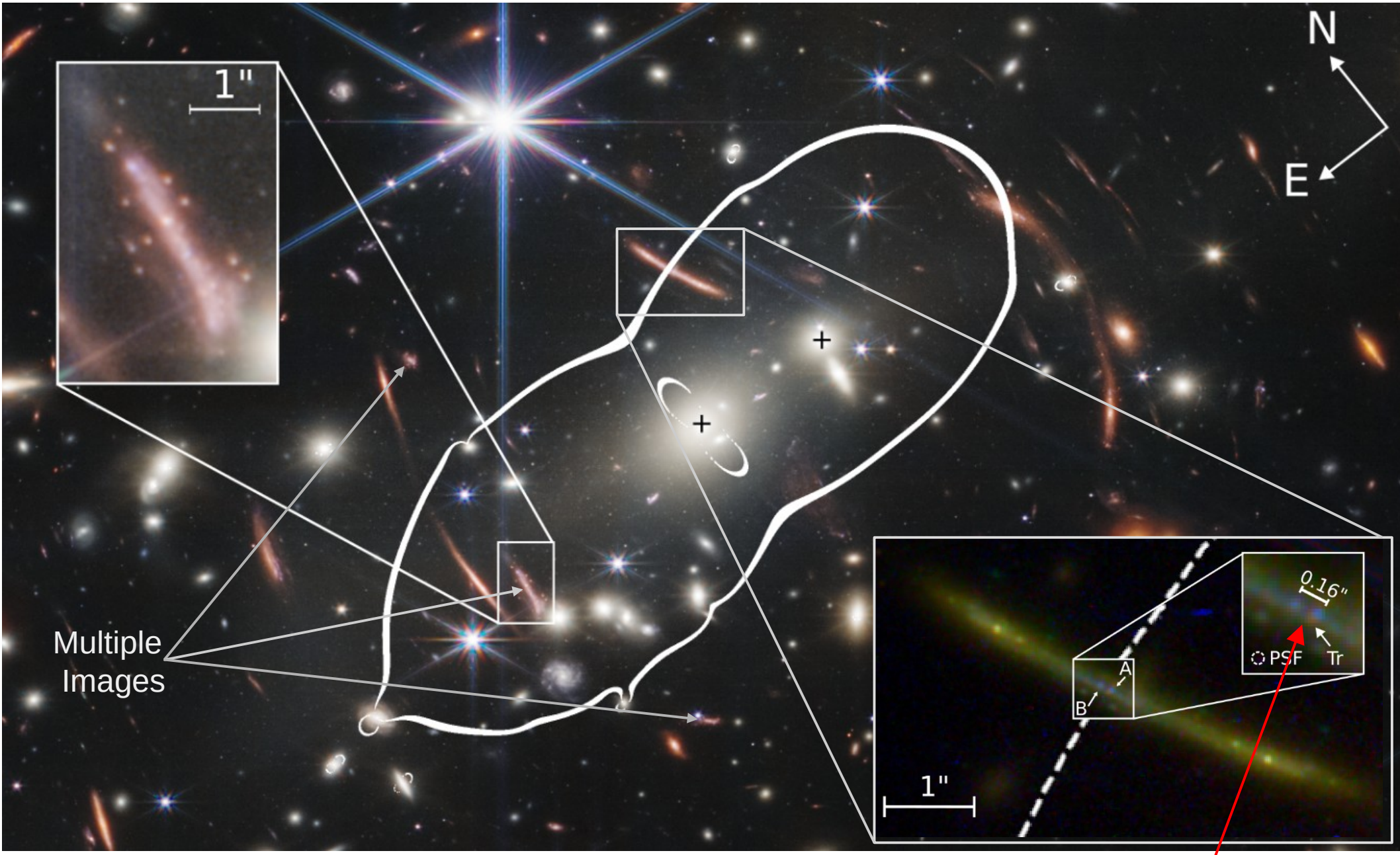
“What goes up, must come down”
Isaac Newton.

Santander, June 2th 2025


Caustics are regions of high magnification
Small imperfections by DM in the lens create small caustics.
Small imperfections, get amplified near high magnification regions

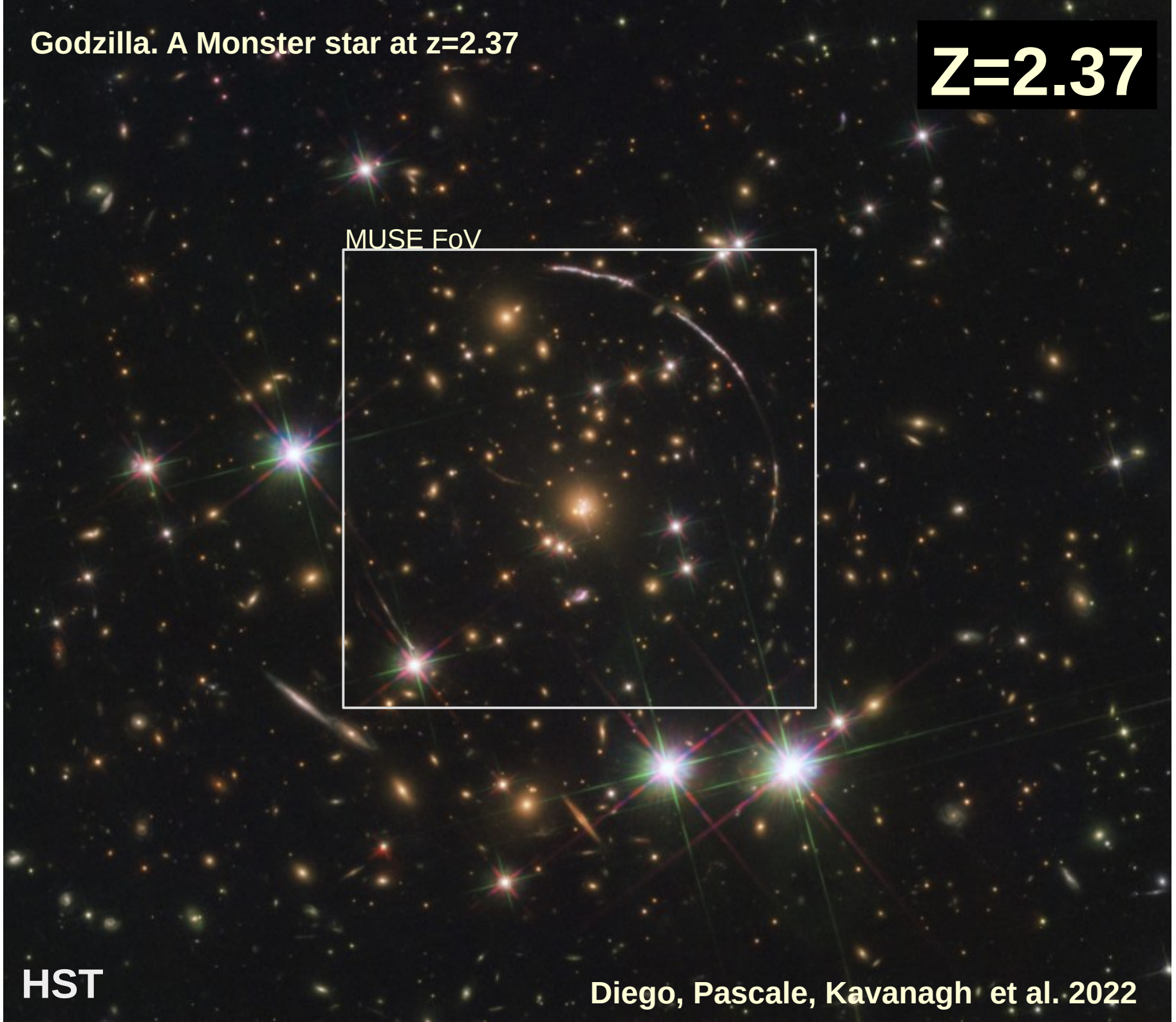
Strong Gravitational Lensing



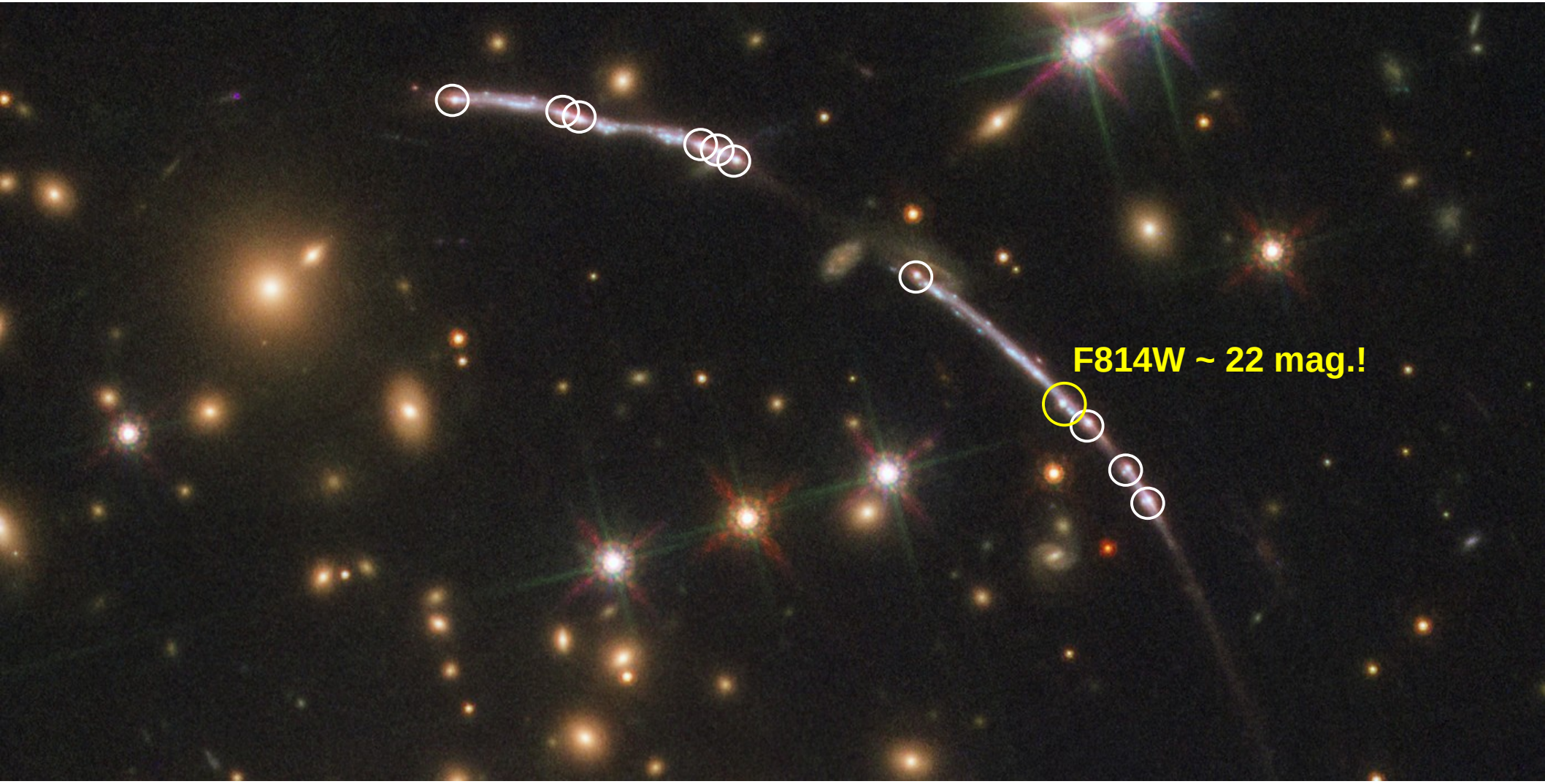
SMACS0723 by JWST

Pascale, Frye, Diego et al 2022

Extreme magnification (>500)


Godzilla. A Monster star at z=2.37
Z=2.37
MUSE FoV
HST
Diego, Pascale, Kavanagh et al. 2022

Godzilla. A Monster star at z=2.37

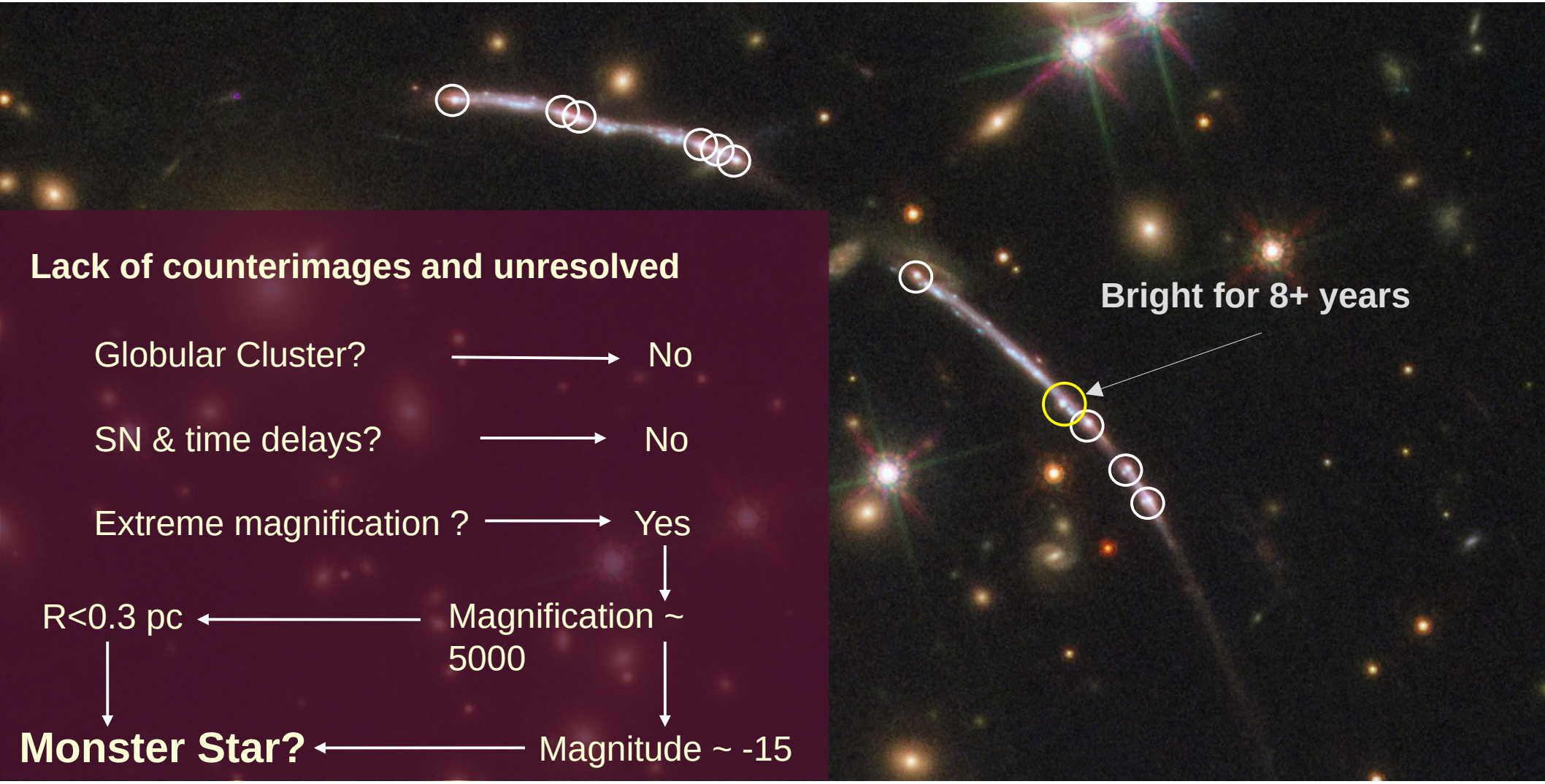


Multiple images of the same stellar cluster (white circles)

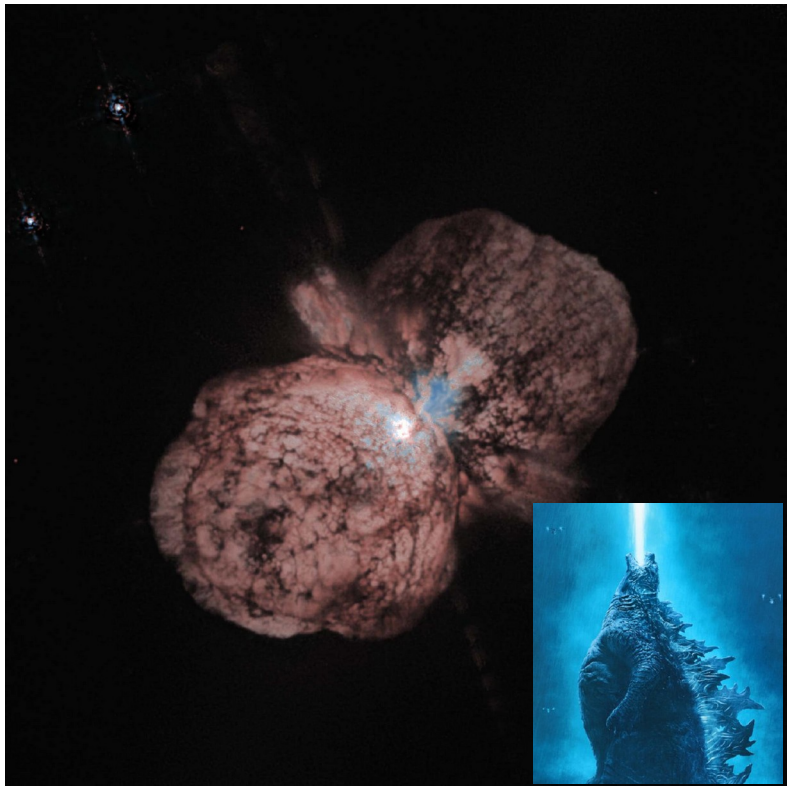
Godzilla is seen only once (yellow circle) which is unexpected (should be seen multiple times)

Godzilla is unresolved

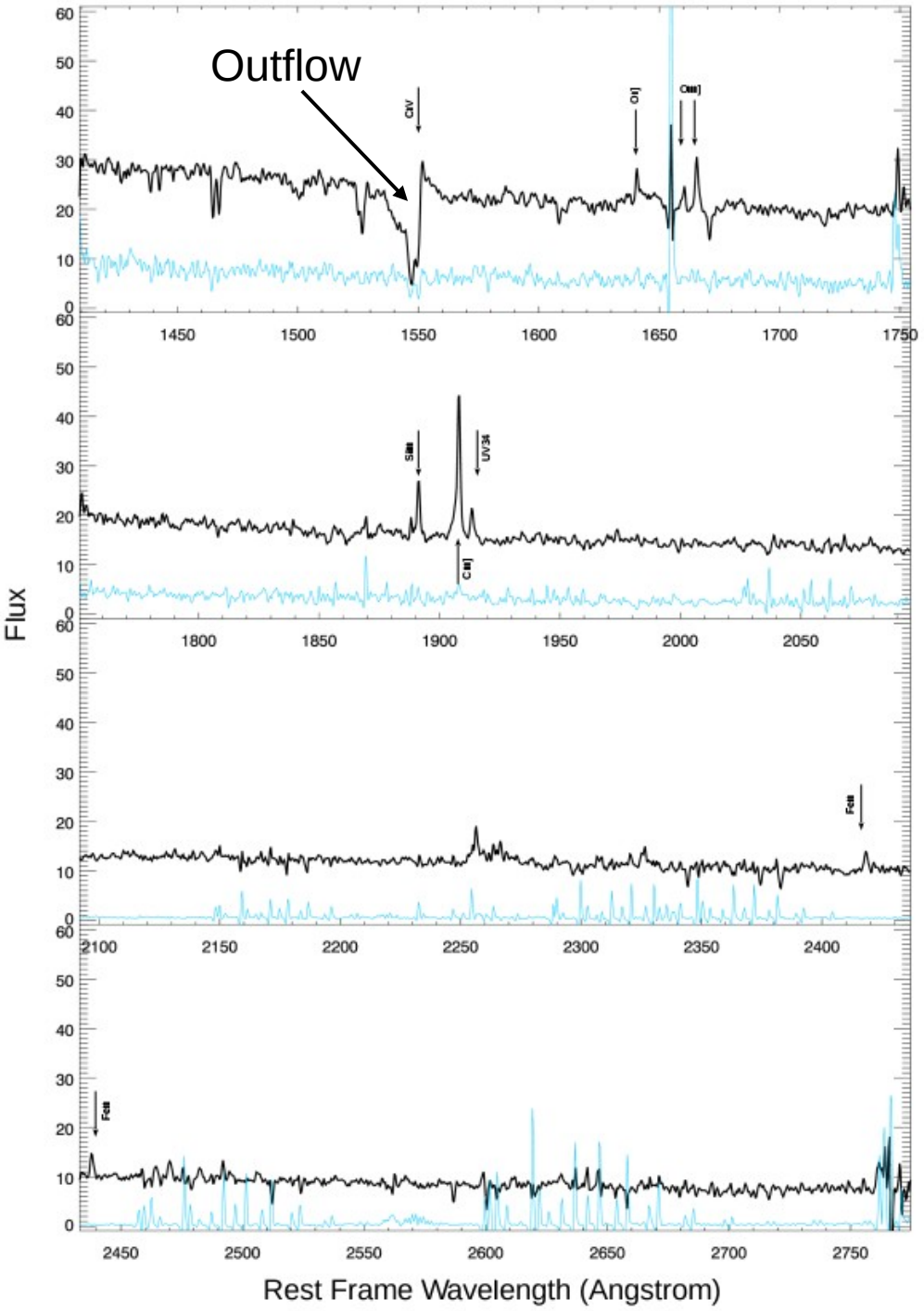
Godzilla. A Monster star at z=2.37

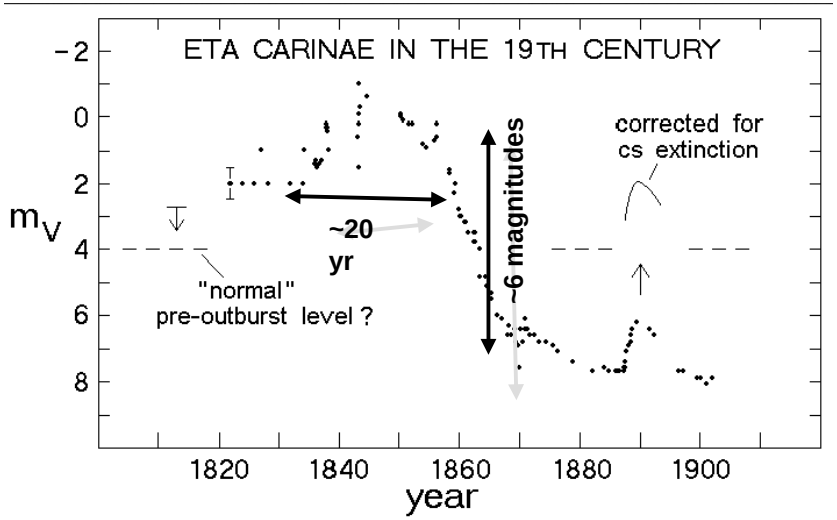


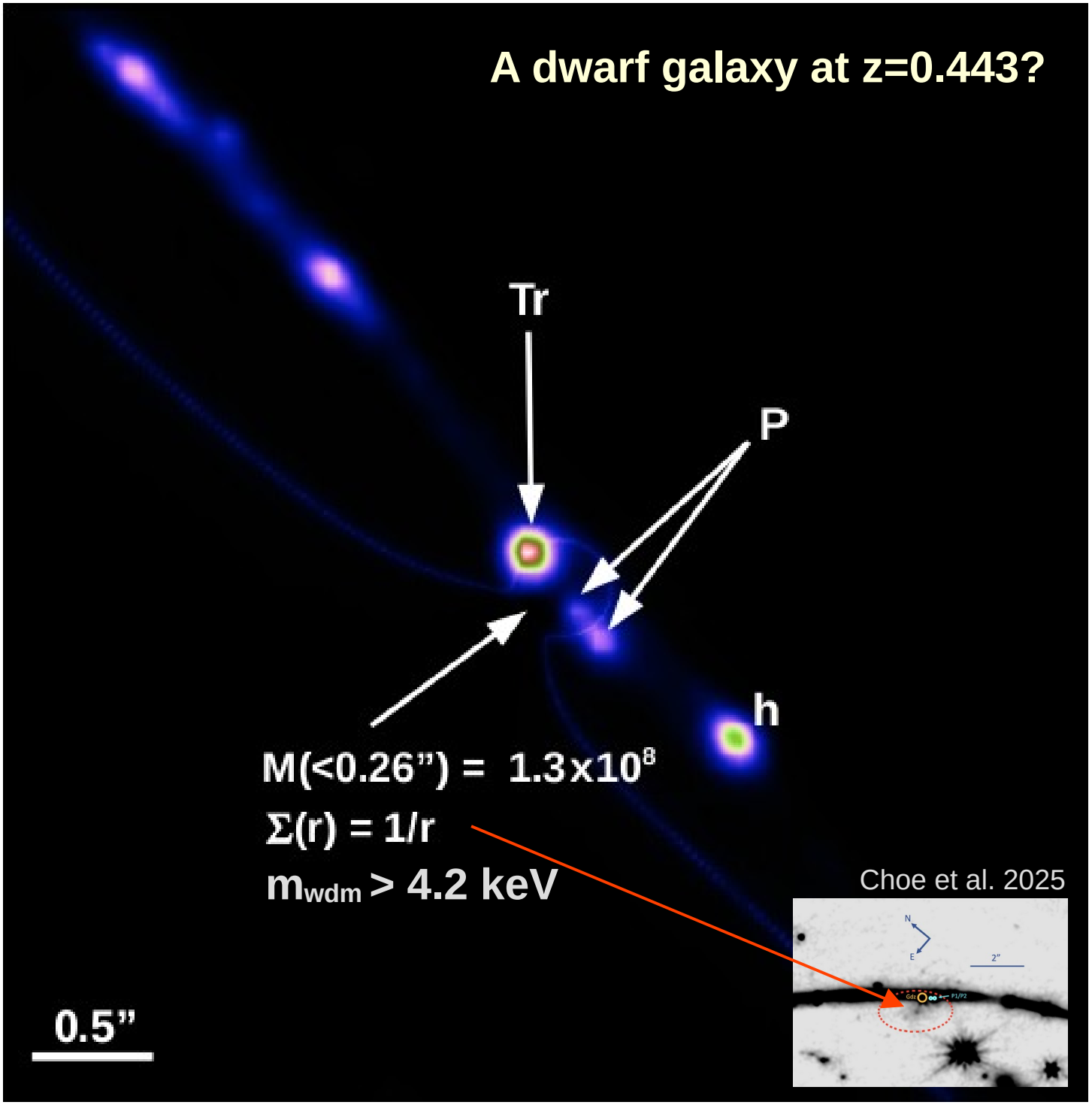
MUSE spectrum of Godzilla

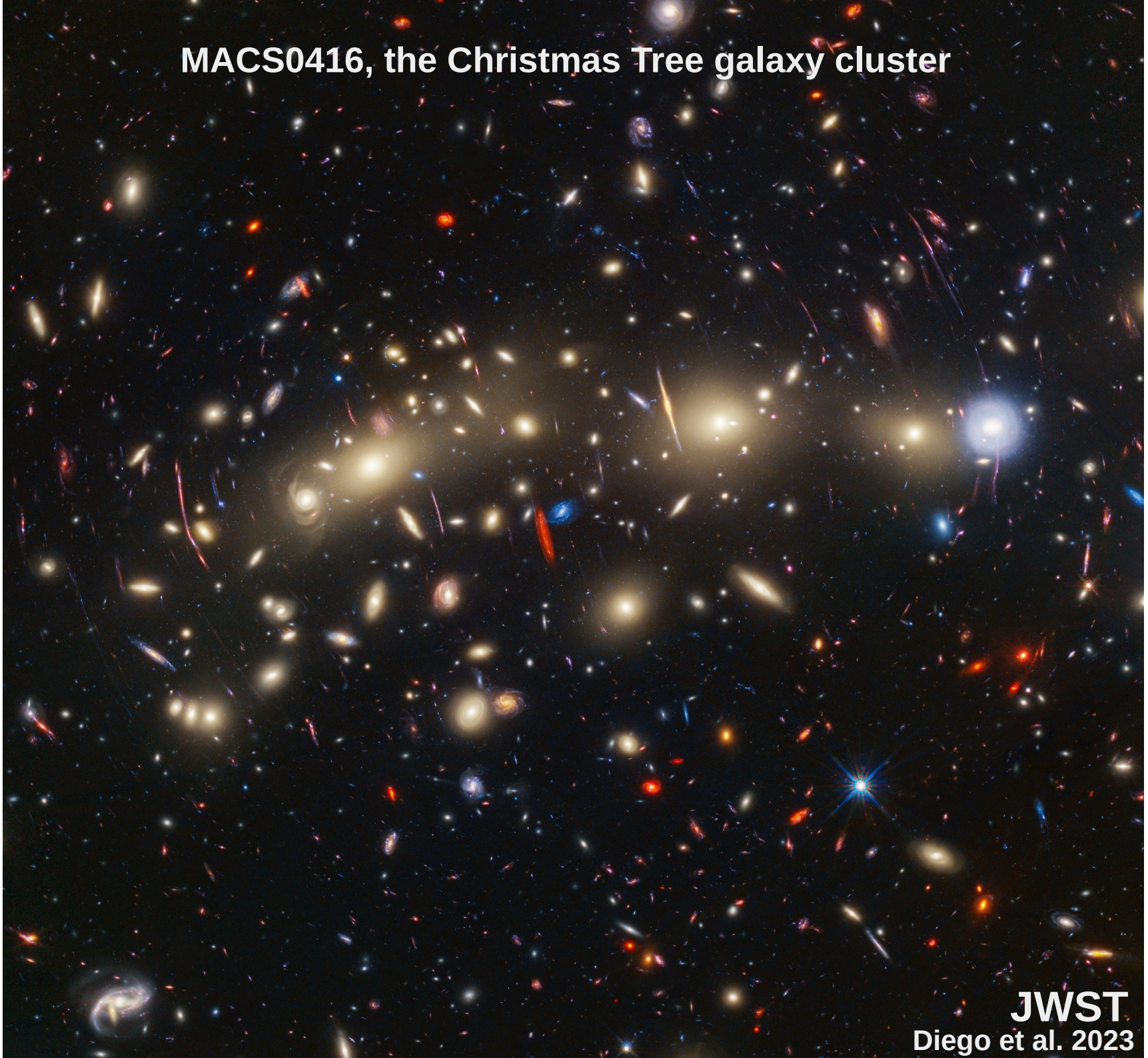


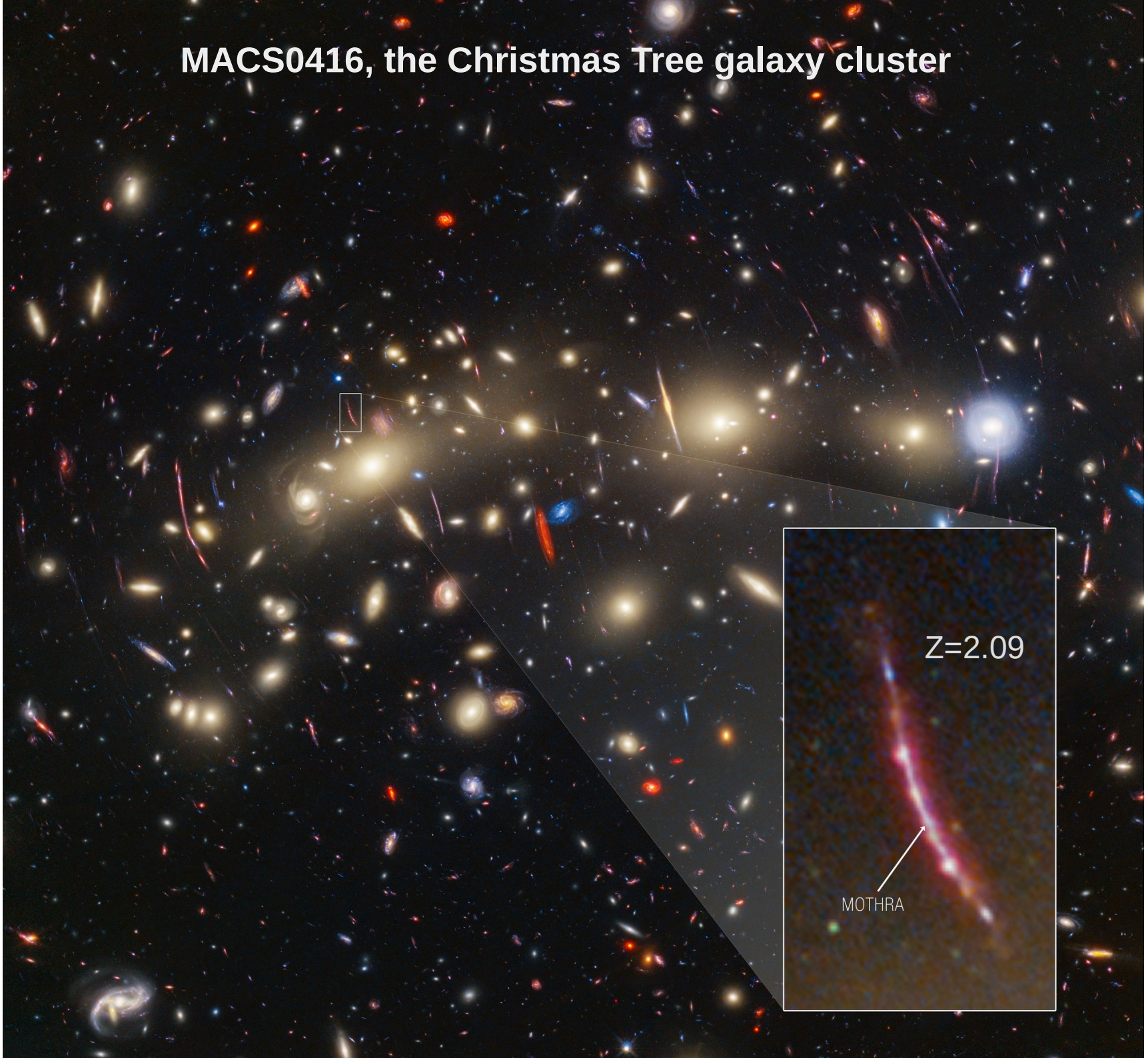
First ever spectrum of a single star at z>2



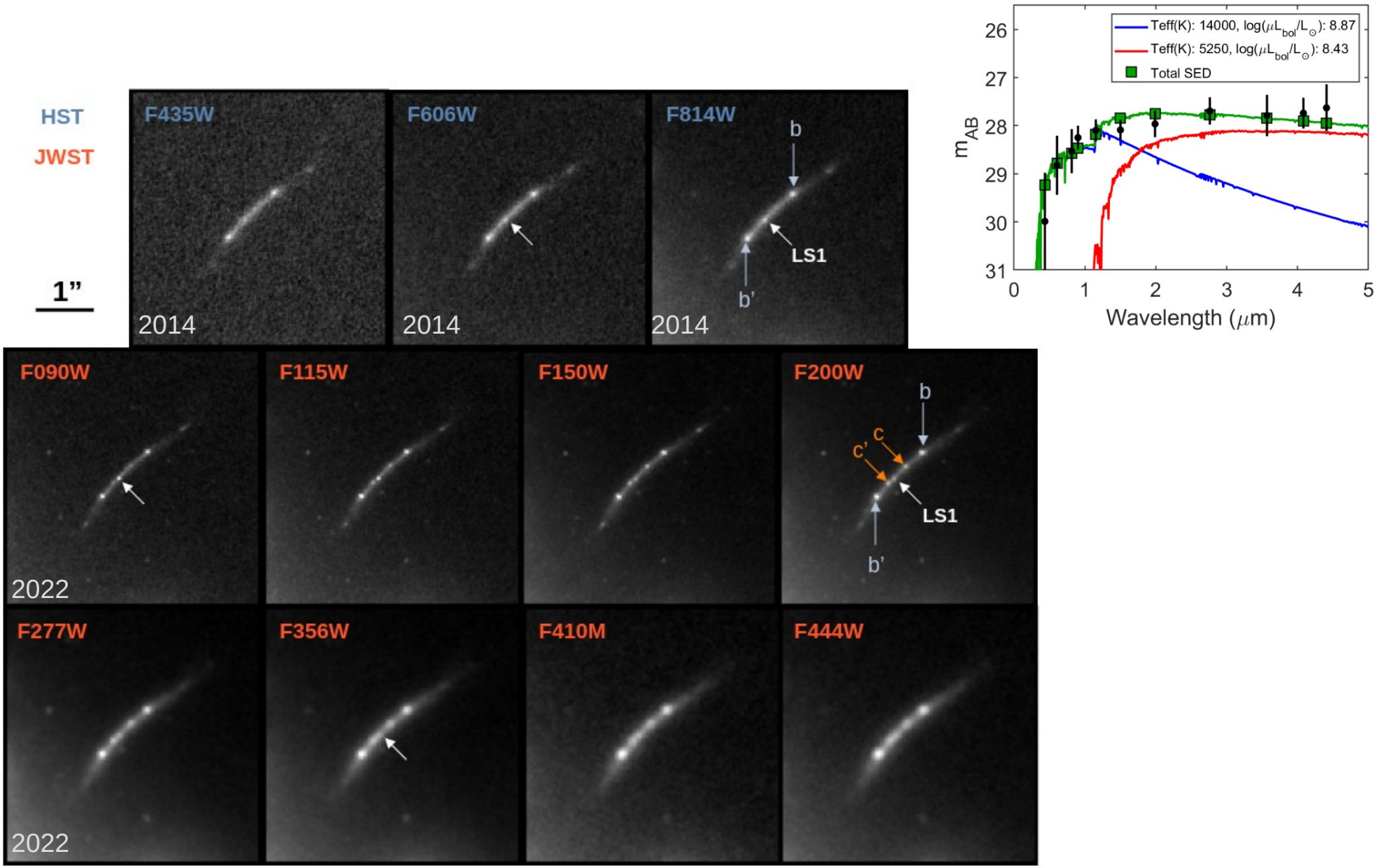



A dwarf galaxy at z=0.443?
Tr
P
h
M(<0.26”) = 1.3x10^8
Σ(r) = 1/r
m_wdm > 4.2 keV
0.5”
Choe et al. 2025
N
E
2”
Gdz
P1/P2


MACS0416, the Christmas Tree galaxy cluster
JWST
Diego et al. 2023

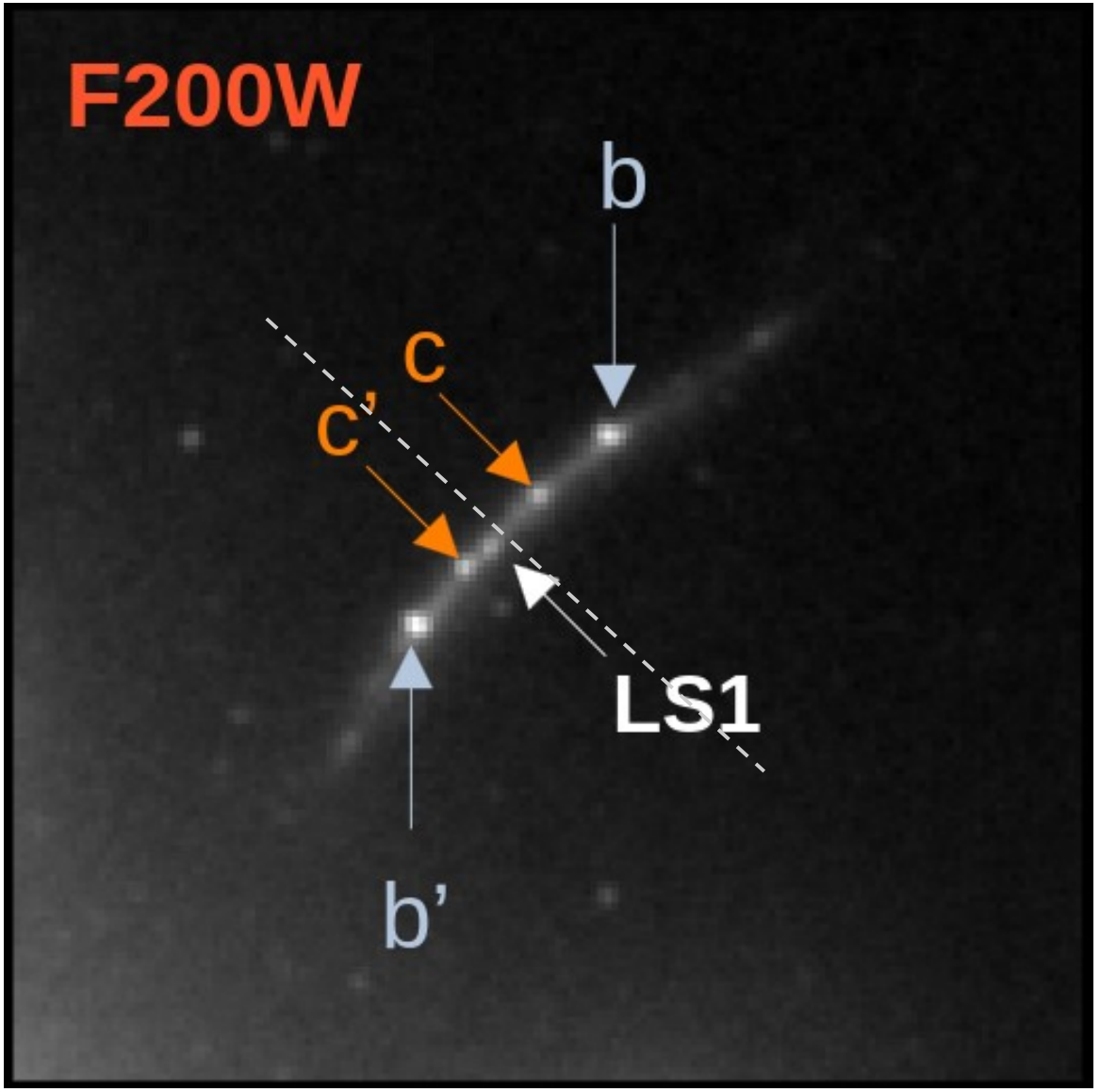

MACS0416, the Christmas Tree galaxy cluster
Z=2.09
MOTHRA

Mothra:
A binary star at z>2 with long lasting millilensing effects



Between HST and JWST images there is a 8 year gap. Mothra is seen in HST images as well

Mothra:
A binary star at z>2 with long lasting millilensing effects



For Mothra, the important thing is not what is seen, but what is not seen

Mothra: Likely interpretation and implications for DM models.

The millilens has to be then at least 10,000 solar masses (detected for 8+ years)

But it can not be more than 2.6 million solar masses. Otherwise the observed image of Mothra (and the millilens) would be resolved. Also, it would introduce unobserved perturbations in the relative magnification of c and c'.

- Warm DM models with **particles lighter than 8.7 keV are ruled out**.
- **Fuzzy DM** models are marginally **consistent** (but in tension with other cases)
- **CDM fully compatible** with expectations (wealth of small halos)

SUMMARY

- Lensed luminous stars act as pencil beams of small scale structure and are sensitive to masses down to few thousands solar masses.
- Currently Mothra holds the record for the smallest millilens detected so far, with halo mass less than 2e6 Msun. CDM consistent with observations. Light Warm DM in tension. DM mass > 8.7 keV.
- Globular clusters, seen by the thousands in galaxy cluster lenses, represent a major challenge since small ones remain undetected in JWST images and result in false positives for DM substrcutures.
- Outbursting lensed stars similar to Godzilla can be detected from ground-based facilities, and will be revealed in greater numbers by time-domain surveys such as Rubin-LSST, opening the door to new and tighter constraints.
- First HST, now JWST, and soon Roman & Rubin will provide a wealth of data to discover new Kaiju stars in the near future
- New tests for DM models (PBH, waveDM, SIDM, …) arxiv:2505.24373 Palencia et al. New tests of wDM