Strong lens modeling of clusters with JWST data

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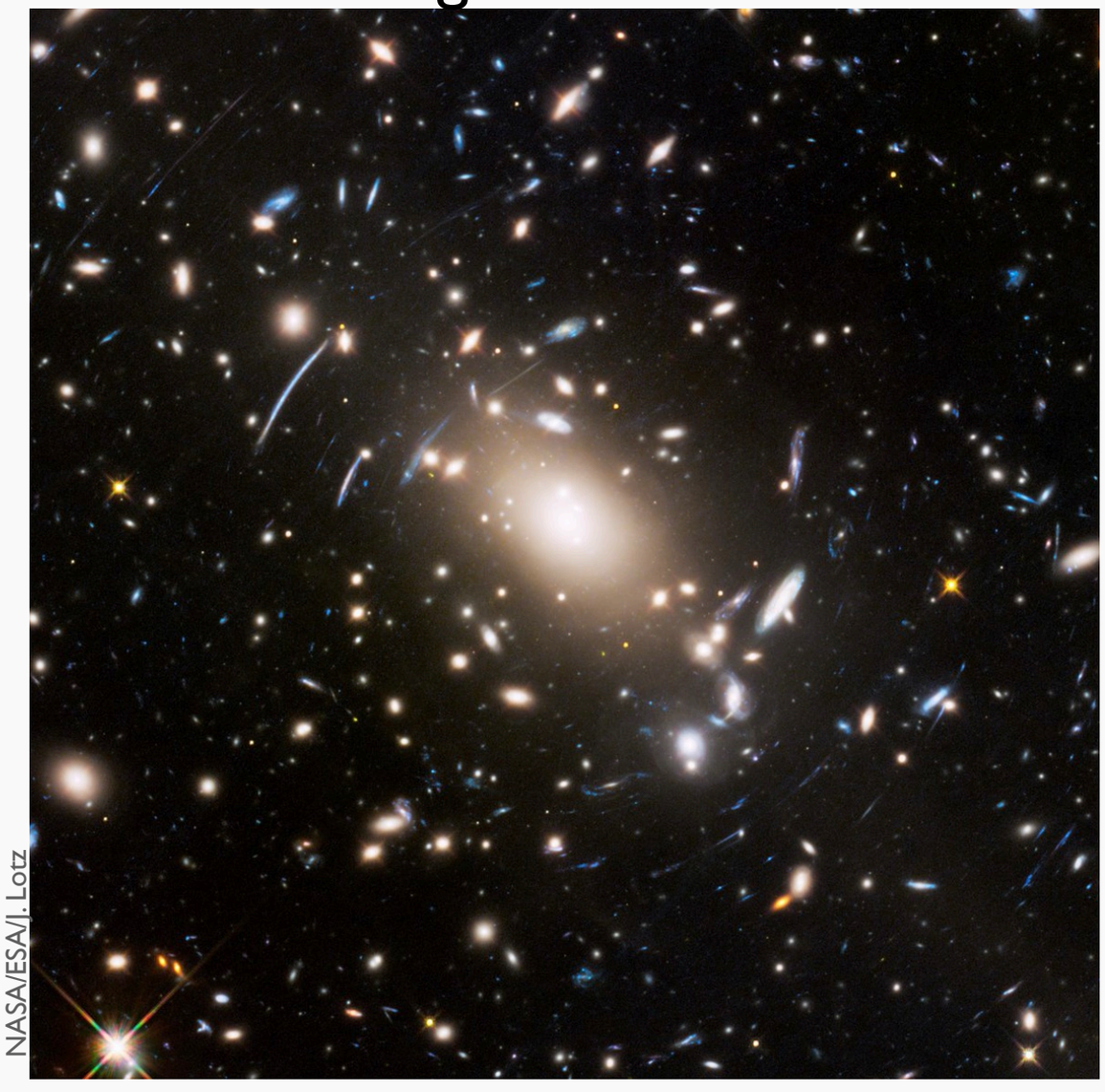
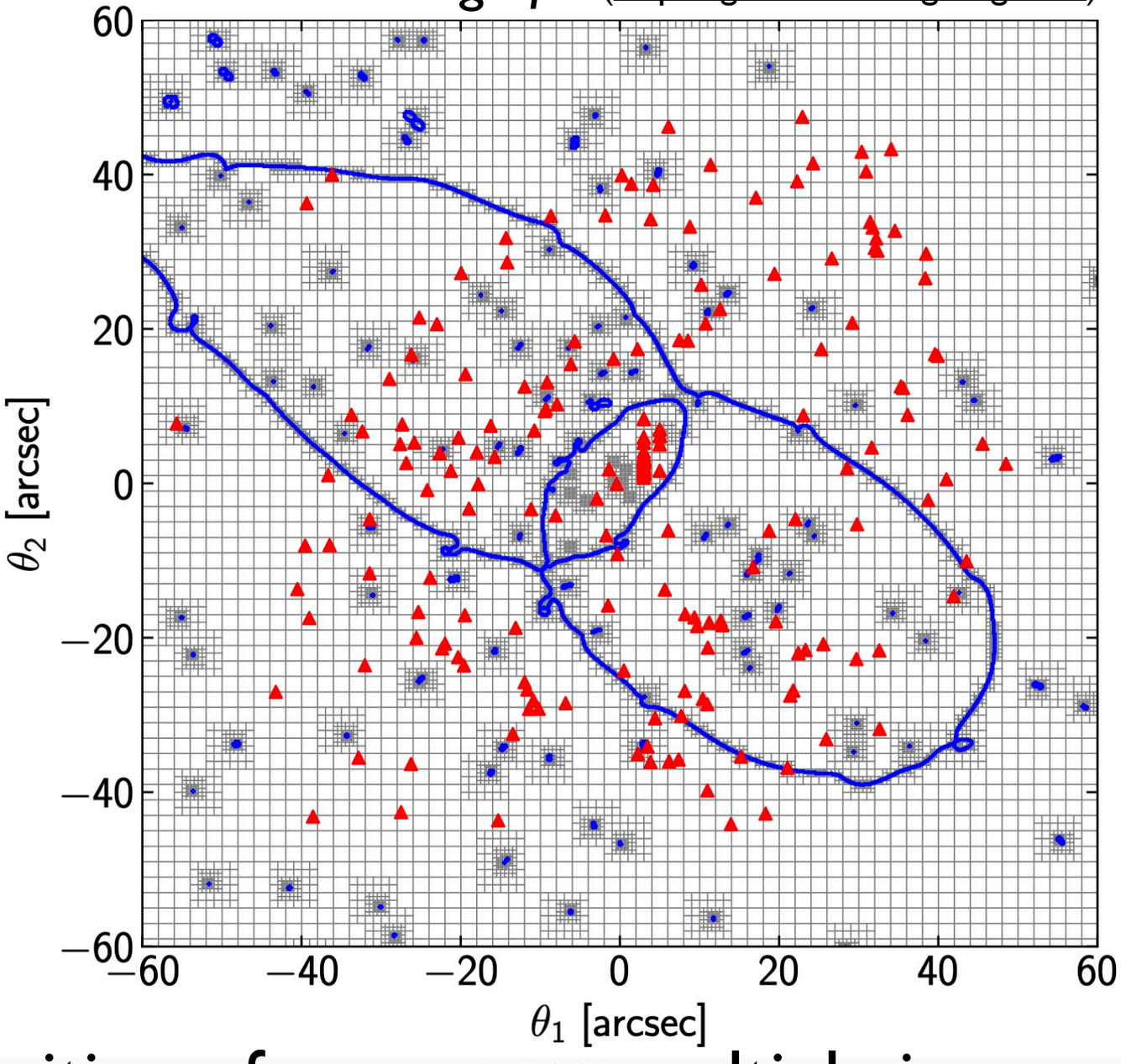
Strong lens modeling of clusters

HST image of Abell S1063



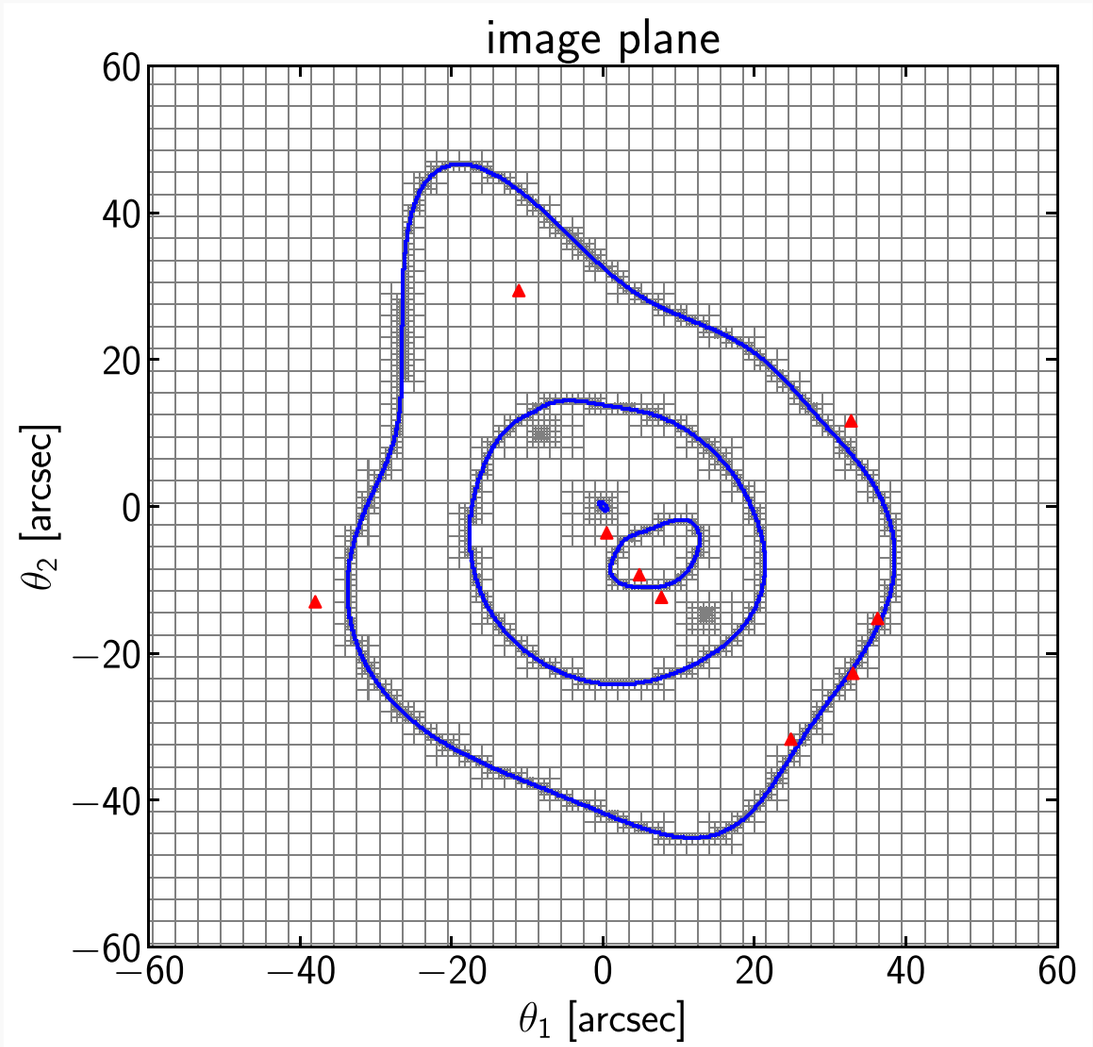
model with *glafic* (https://github.com/oguri/glafic2)



construct models reproducing position of many (≳100) multiple images

MO PASP, 133, 074504 (2021)

Fast calculation in elliptical density

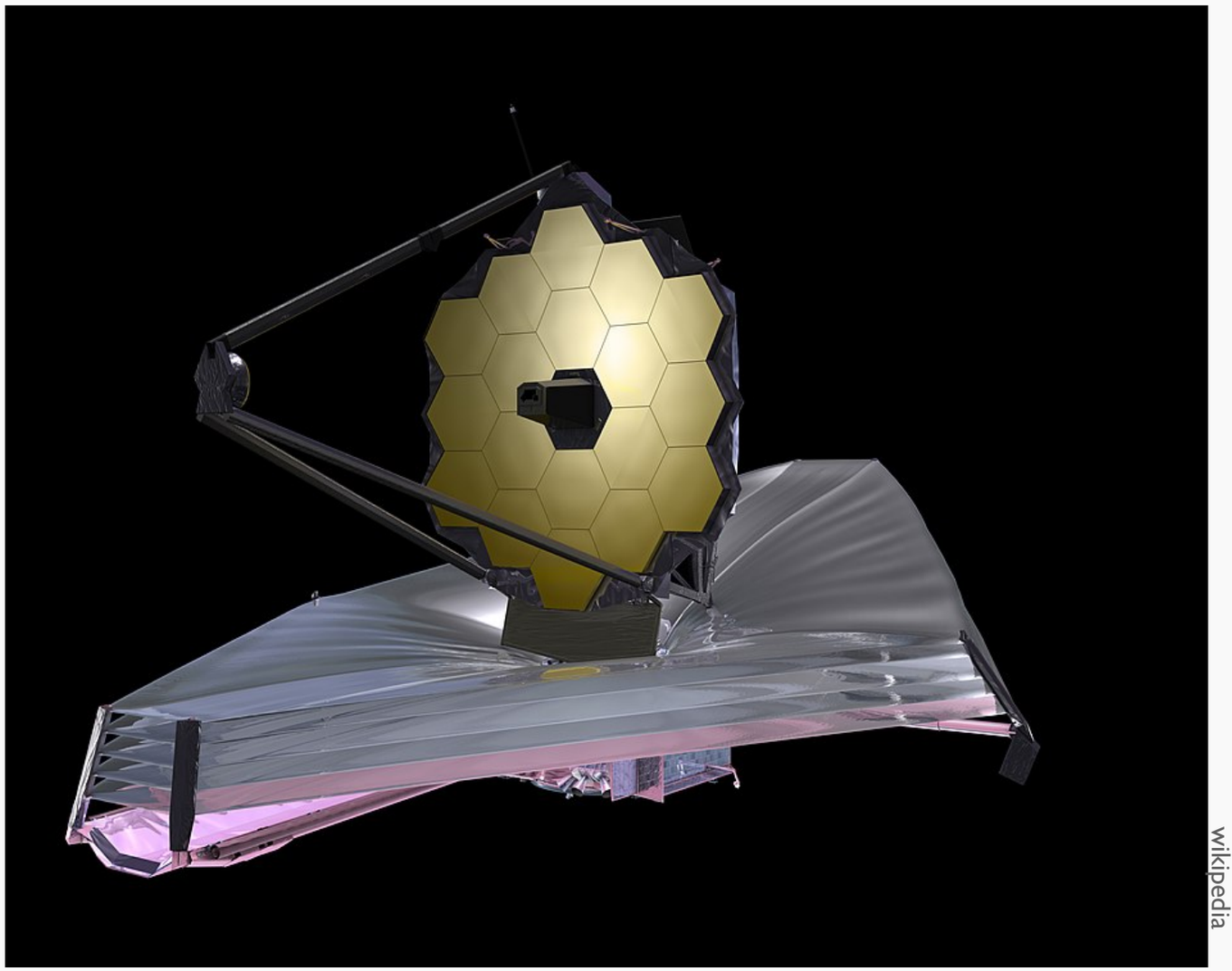


- a new fast method to compute lensing properties of **elliptical NFW** and **Hernquist** density profiles
- **~300 faster** in this example
- already implemented in public *glafic* code

Example: three lens plane at z=0.3, 0.6, 0.9, a source at z=3 lensed into 9 images

JWST launch

wikipedia



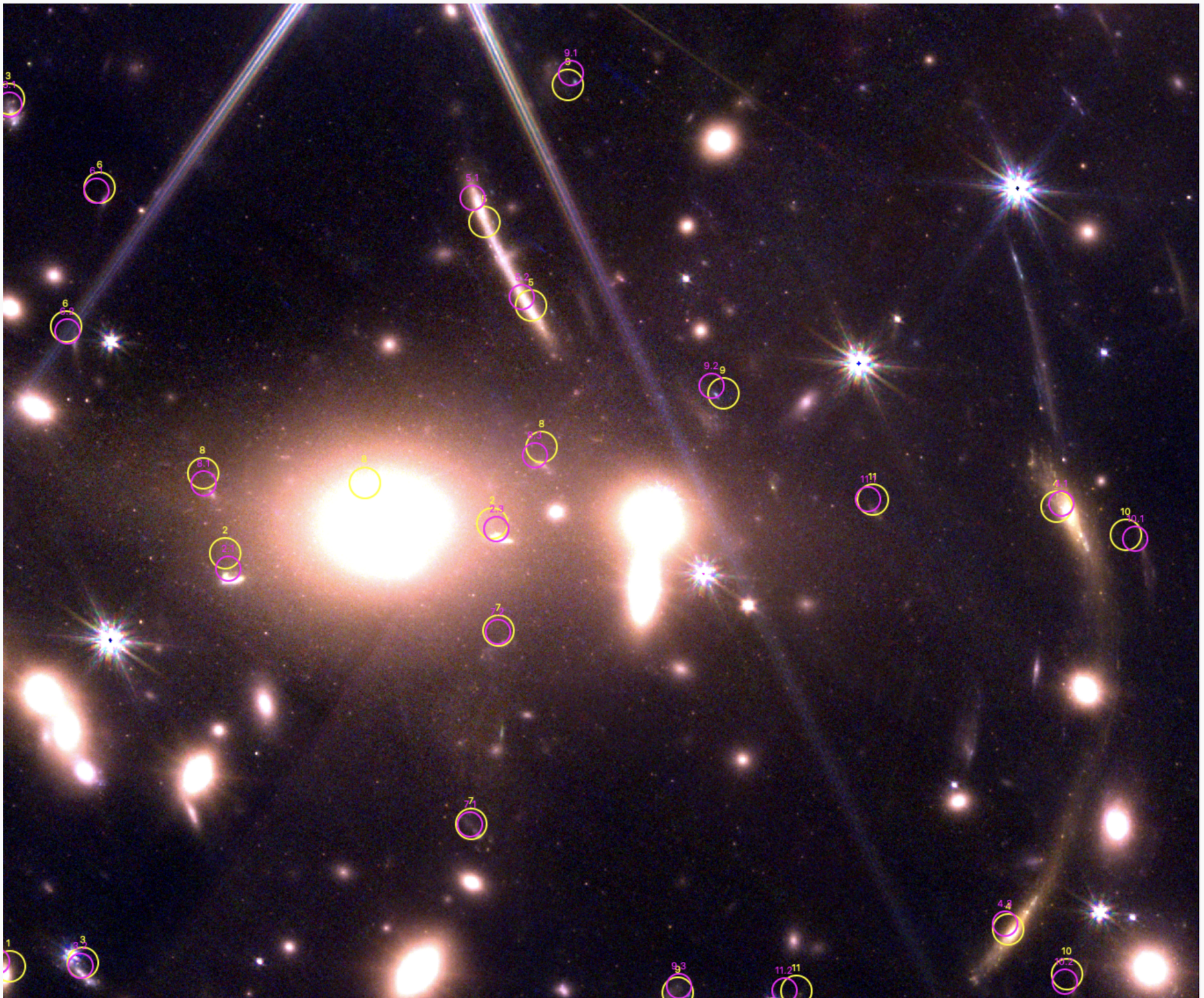
wikipedia

launched on 2021 Dec 25

SMACS0723 HST

SMACS0723 JWST

Imperfect modeling?



magenta: observed positions

yellow: predicted positions

(w/ *glafic*)

small, but significant mismatch!

Imperfect modeling?

- strong lens modeling of clusters searches for models that reproduce observed multiple image positions
- best-fitting models usually cannot reproduce observed multiple image positions perfectly
- **RMS has been used to quantify "goodness" of fit**

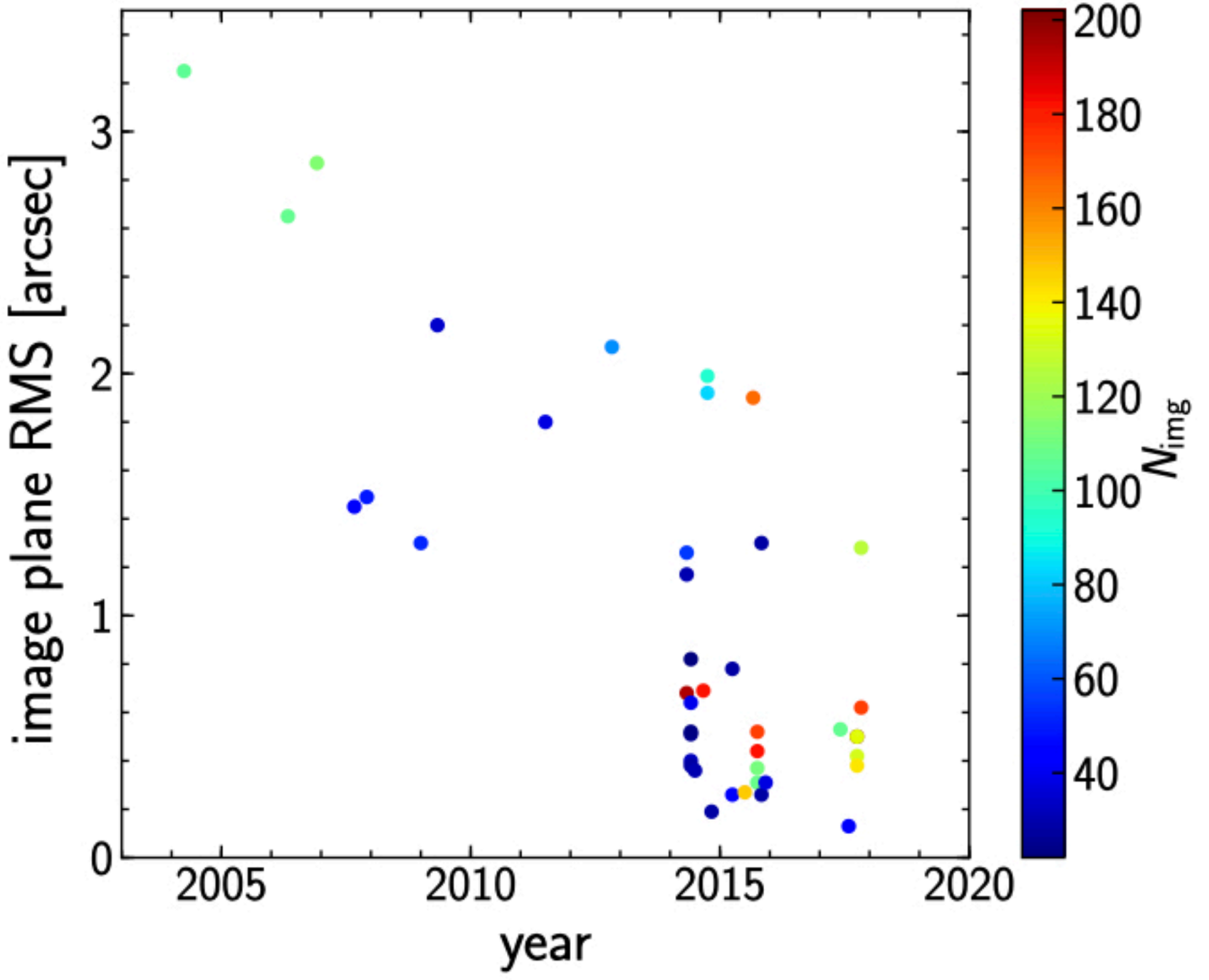
$$\mathrm{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left|\vec{\theta}_{i,\mathrm{obs}} - \vec{\theta}_{i,\mathrm{model}}\right|^2}$$

presentations by P. Rosati, P. Bergamini, S. Cha, …

my talk@Milan, 2018 Sep

Improvements of RMS

- mass modeling of clusters w/ ≳50 multiple images
- plotted data not complete
- RMS getting better….



my talk@Milan, 2018 Sep

Improvements of RMS

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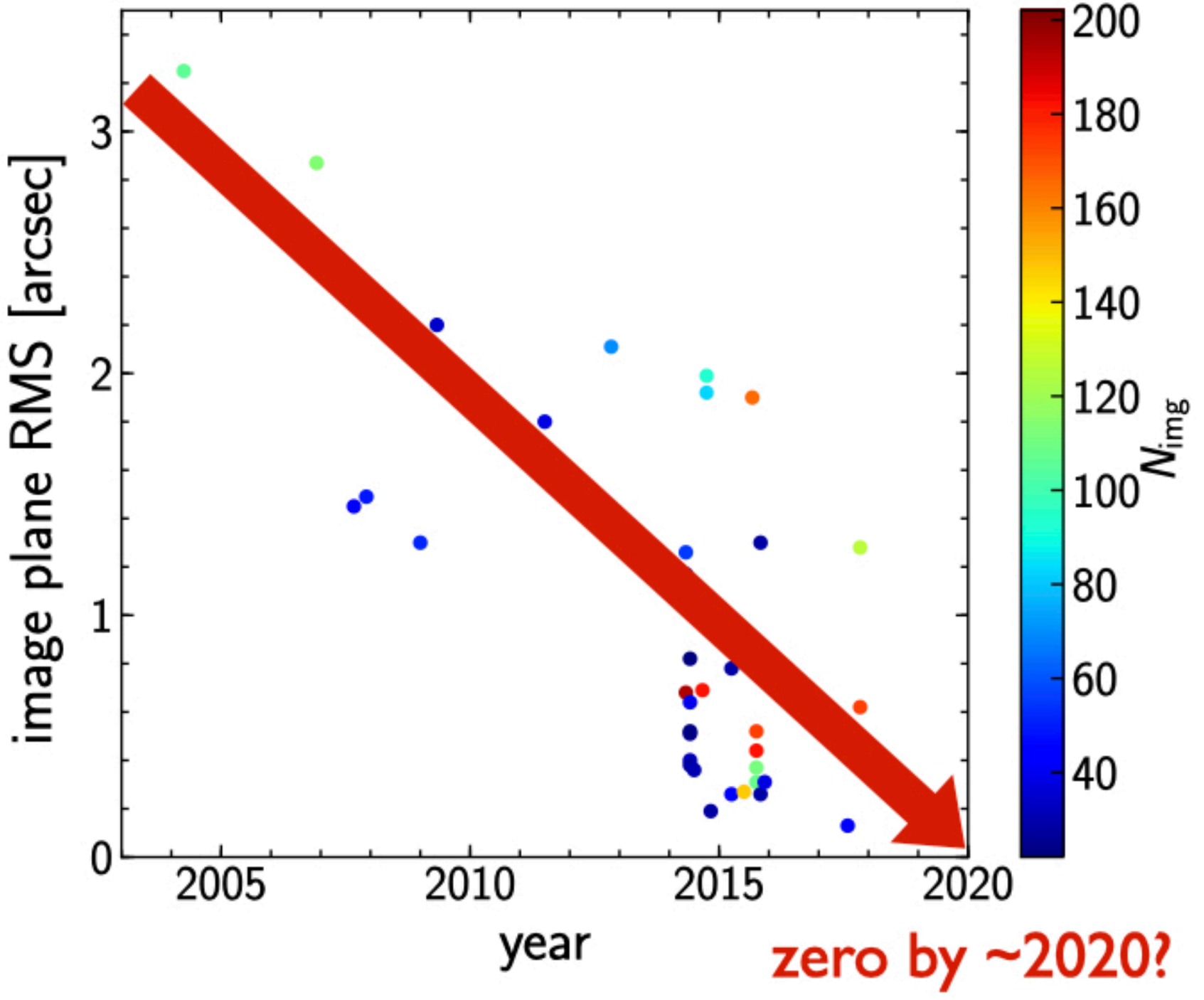
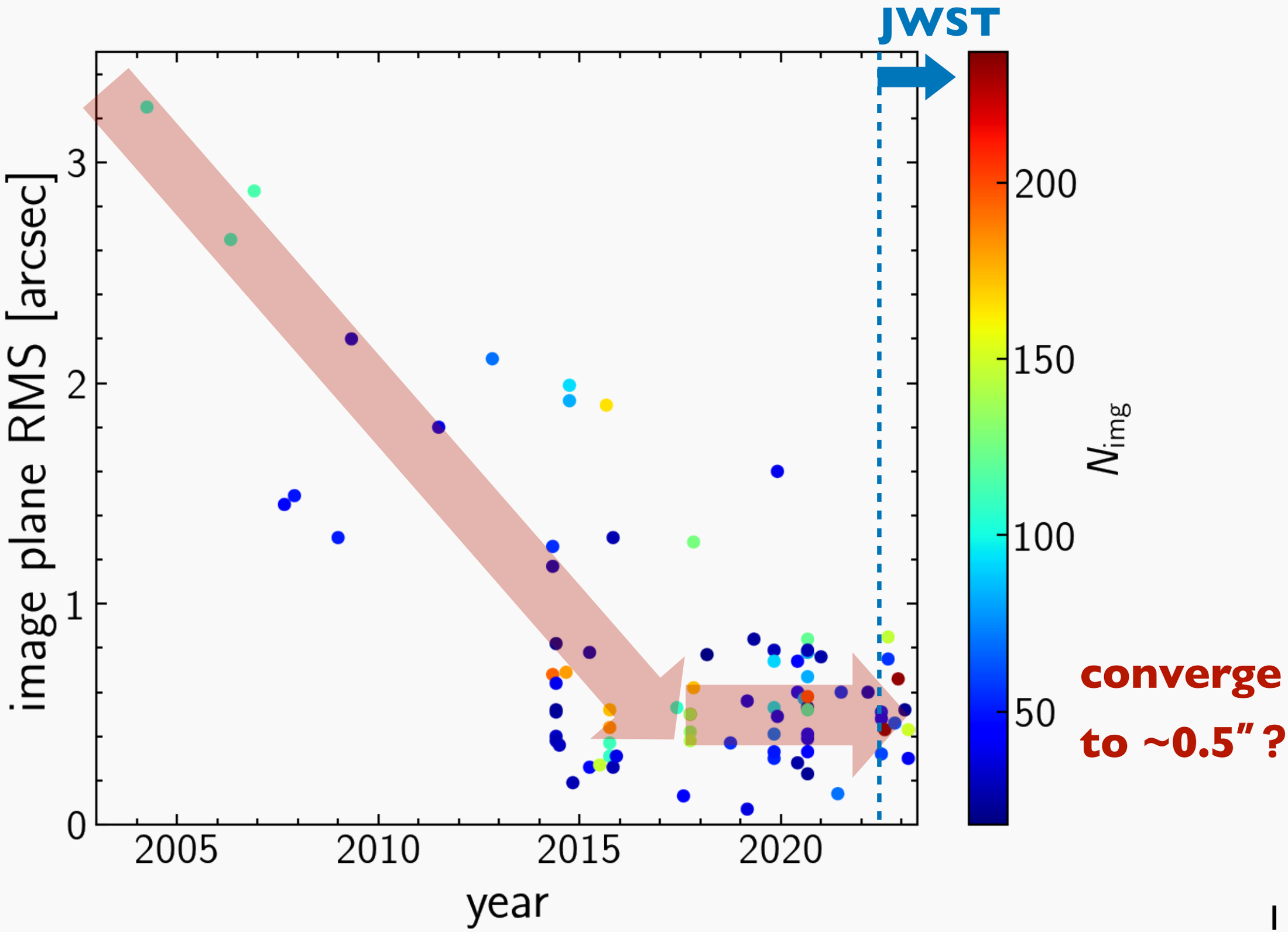


zero by ~2020?

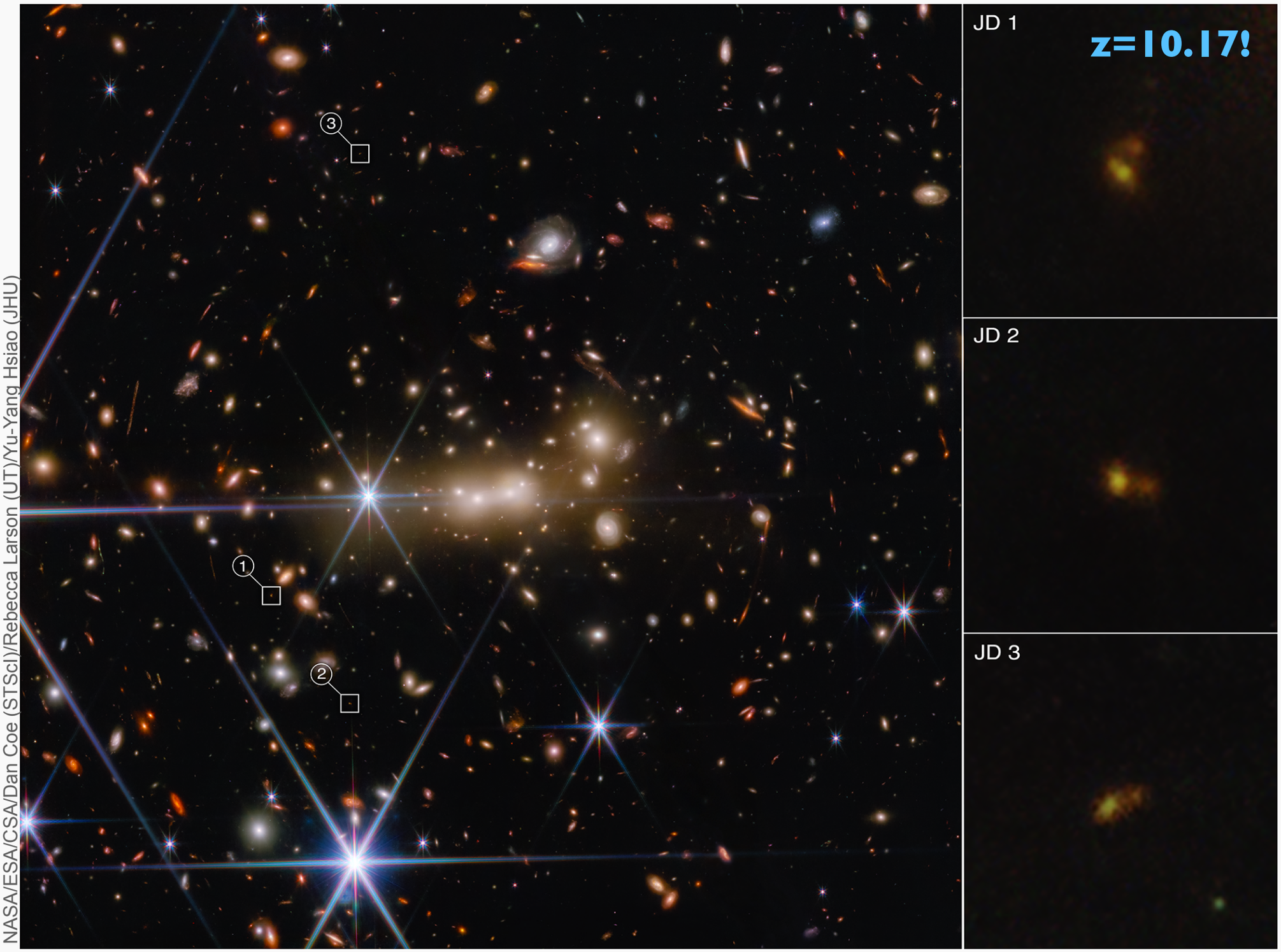
Answer?


JWST
image plane RMS [arcsec]
0
1
2
3
2005
2010
2015
2020
year
200
150
100
50
N_{img}
converge
to ~0.5″?

Origin of RMS?

- we expect non-zero RMS coming from substructure, line-of-sight fluctuations, …
- **but, what is the reasonable value of RMS?**
- how do we know that they are not overfitted?

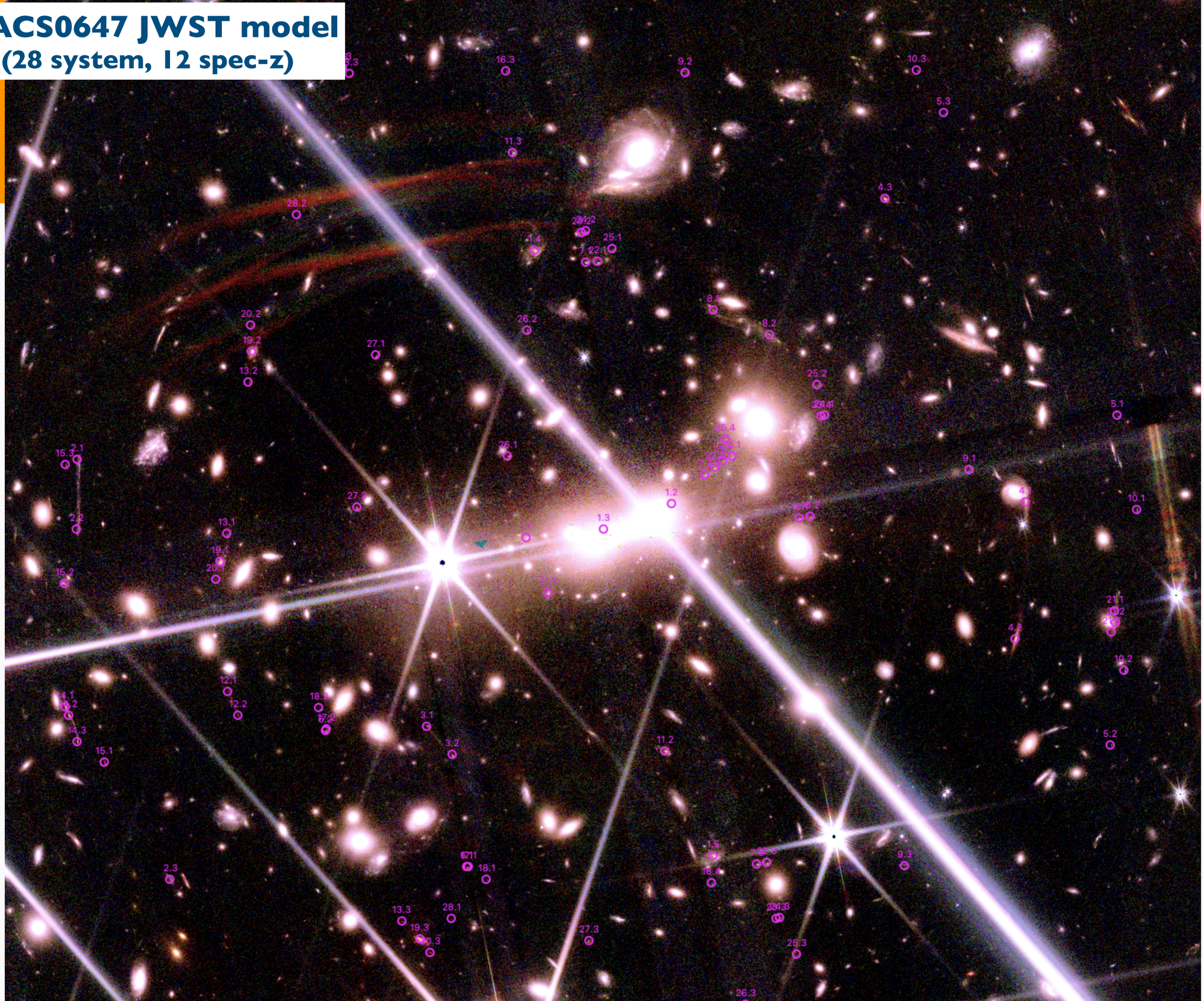
Lesson from MACS0647



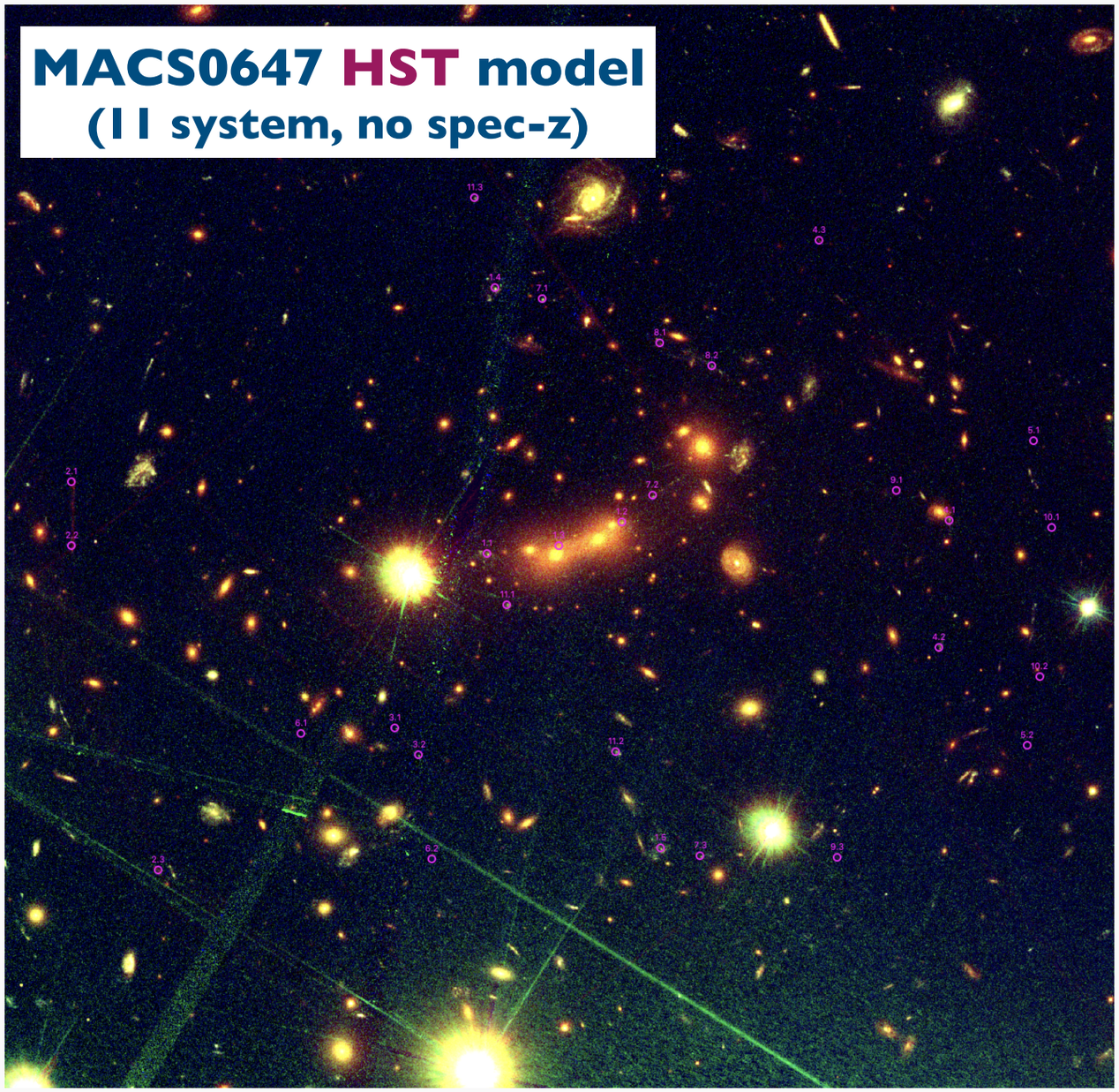
Coe+2013
Hsiao+2023a,b
Abdurro'uf+2023
Meena+2023
....

MACS0647 HST model
(11 system, no spec-z)

MACS0647 JWST model
(28 system, 12 spec-z)



RMS values (for *glafic* mass models)



RMS=0.32"

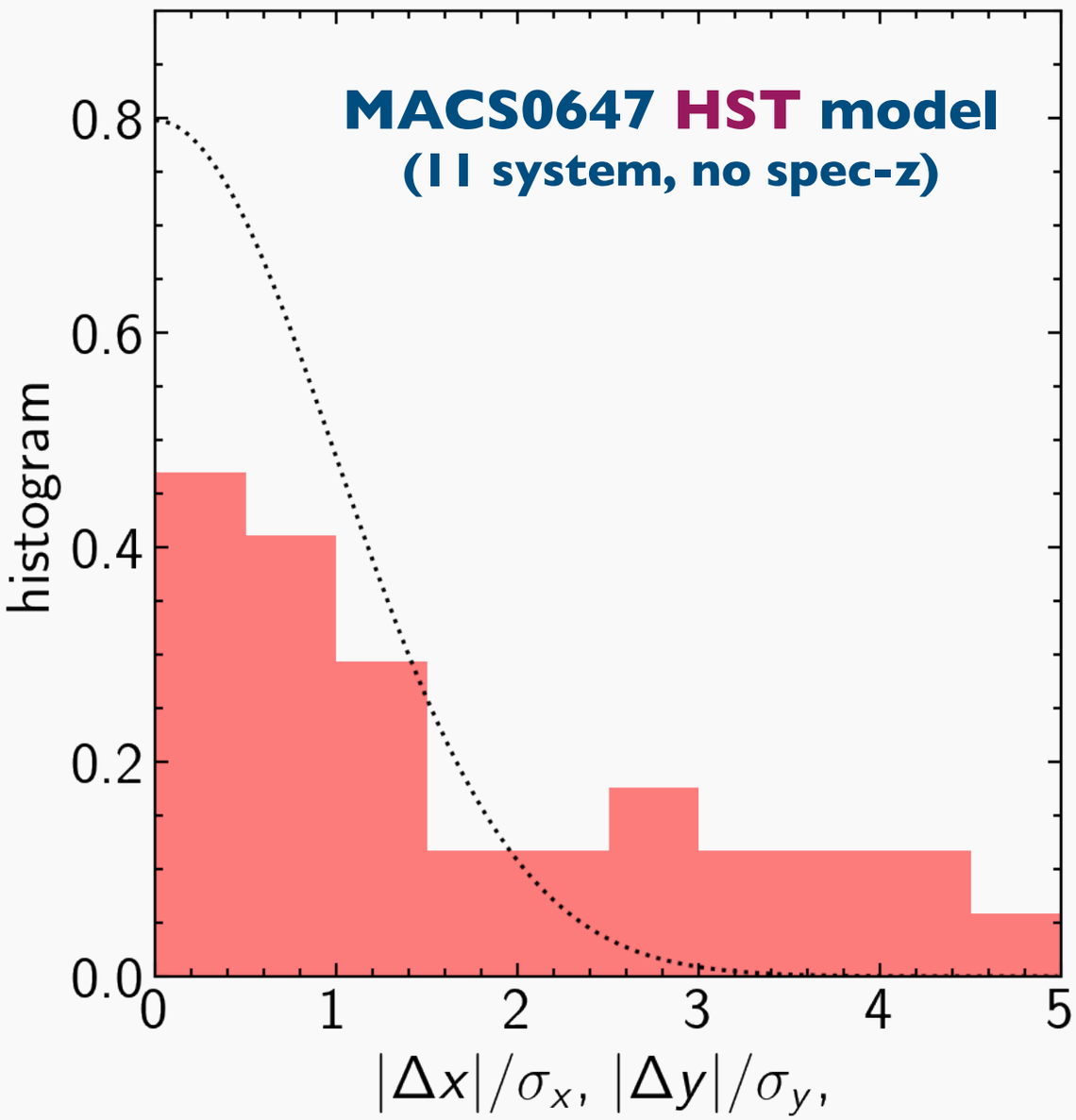
RMS=0.49"

overfitted?

Exercise: jackknife cross-validation

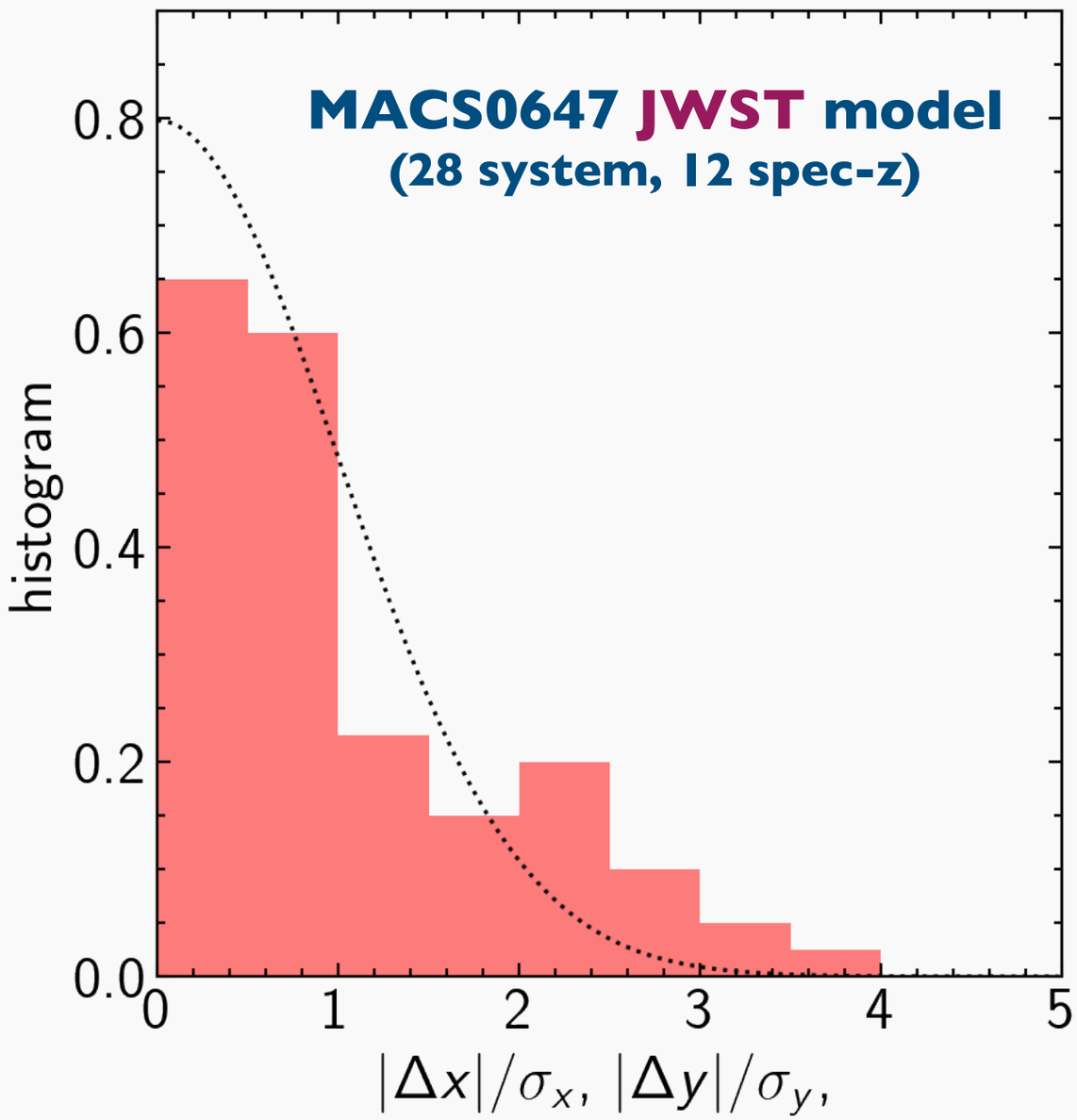
- remove one of multiple image sets and derive a best-fit mass model
- check and see how well that best-fit model predicts positions of the multiple images that were removed
- repeat this for all multiple image sets

Jackknife cross-validation result



Jackknife errors significantly larger than assumed errors

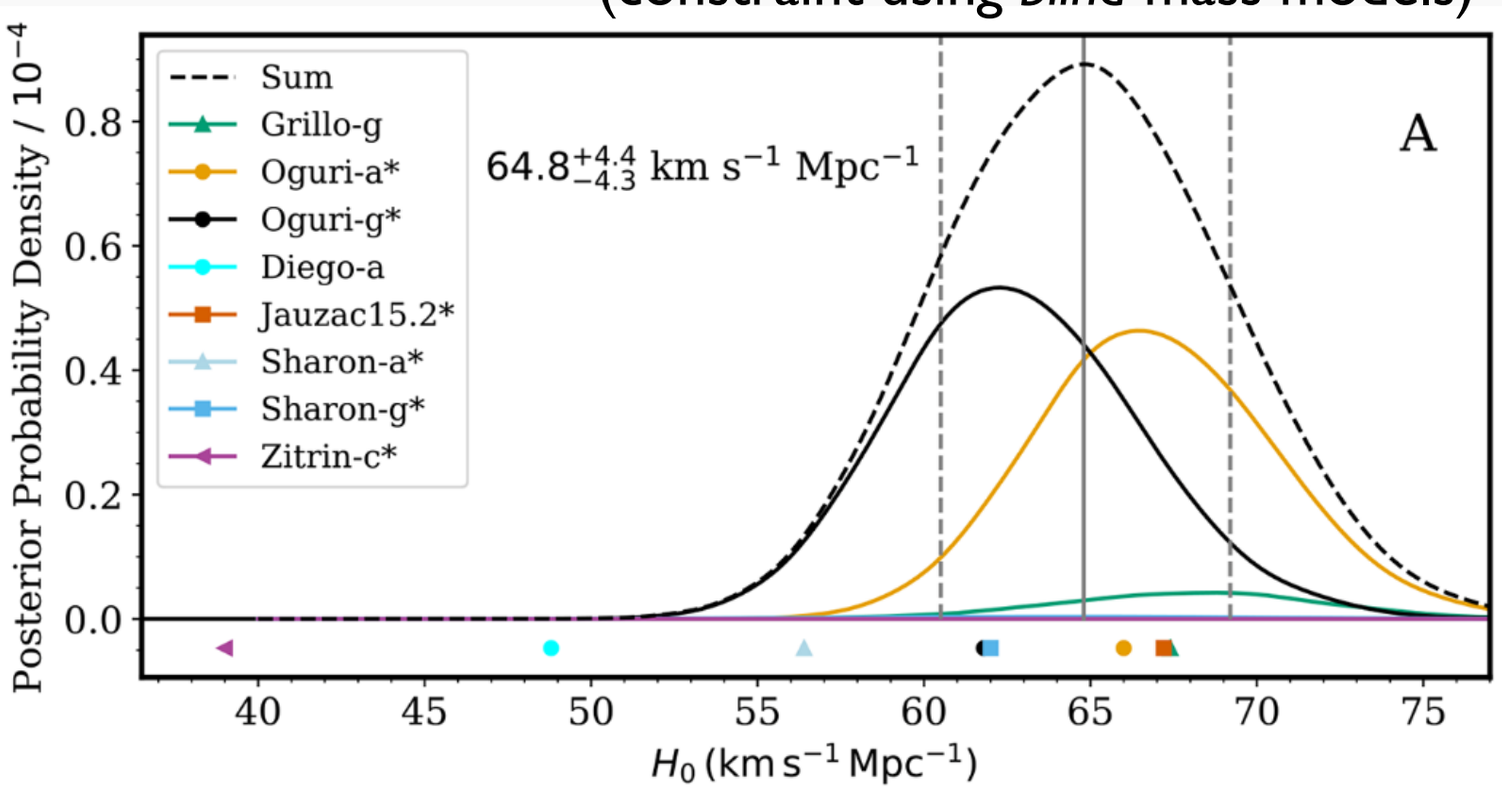
overfitting!



Jackknife errors roughly consistent w/ assumed errors

Accurate model needed for H_0

(constraint using *blind* mass models)



Kelly, Rodney, Treu, MO+ Science, in press

- having an ***accurate*** (rather than ***precise***) mass model and its reliable error are crucial for H_0
- your ideas welcome!

presentations by S. Suyu, A. Acebron, G. Caminha, H. Dahle, S. Schuldt, …

Summary

- with JWST data we can have many multiple images w/ spec-z for each cluster
- how to get *accurate* (rather than *precise*) mass models? how to to assign reliable errors on them?
- with many multiple images one can in principle cross-validate models to see if they are overfitted
- more ideas welcome!