H0LiCOW XIII. A 2.4% measurement of H_0 from lensed quasars: 5.3 sigma tension between early and late-Universe probes

Monthly Notices of the Royal Astronomical Society, in press
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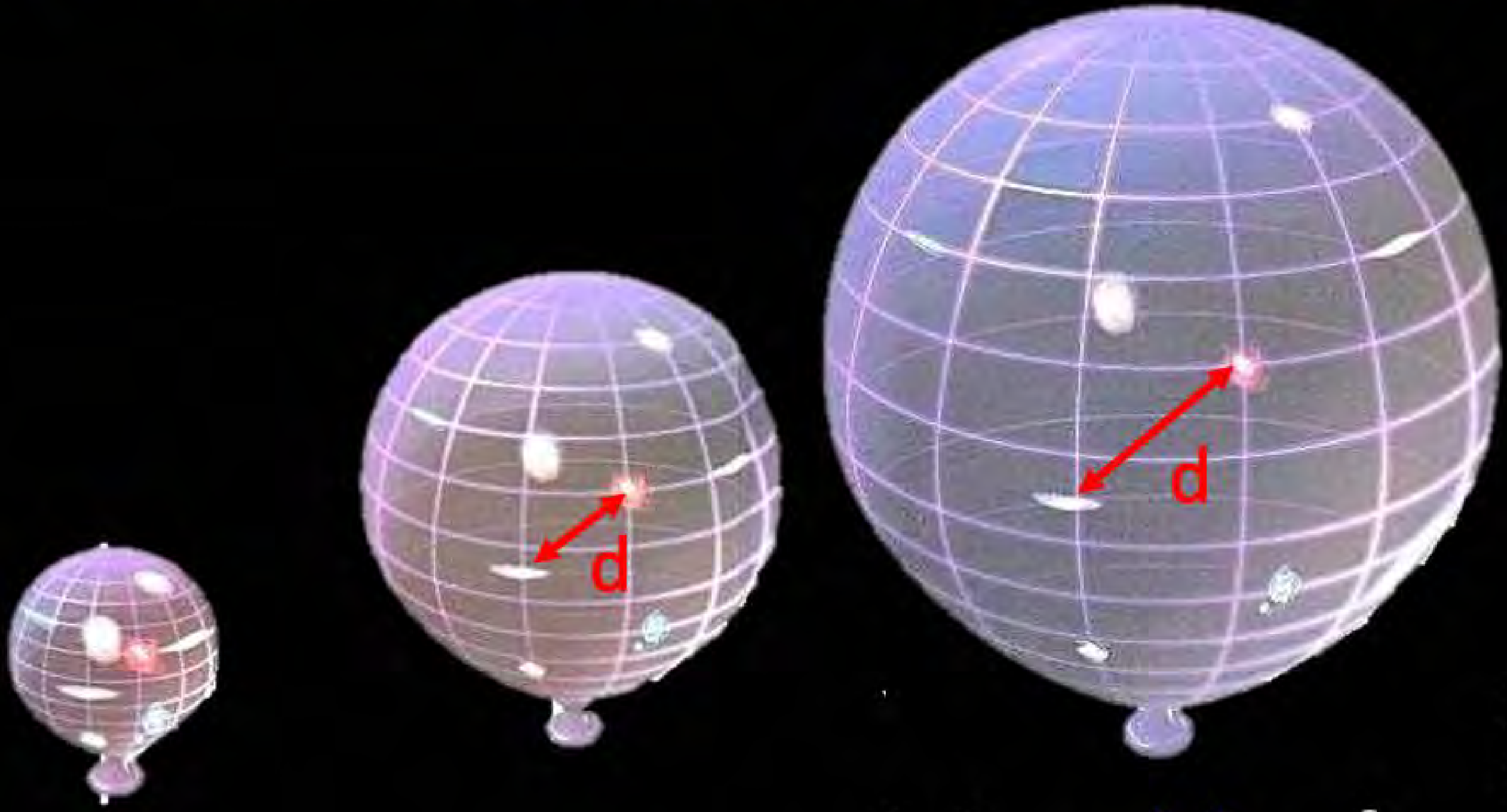
What we found!

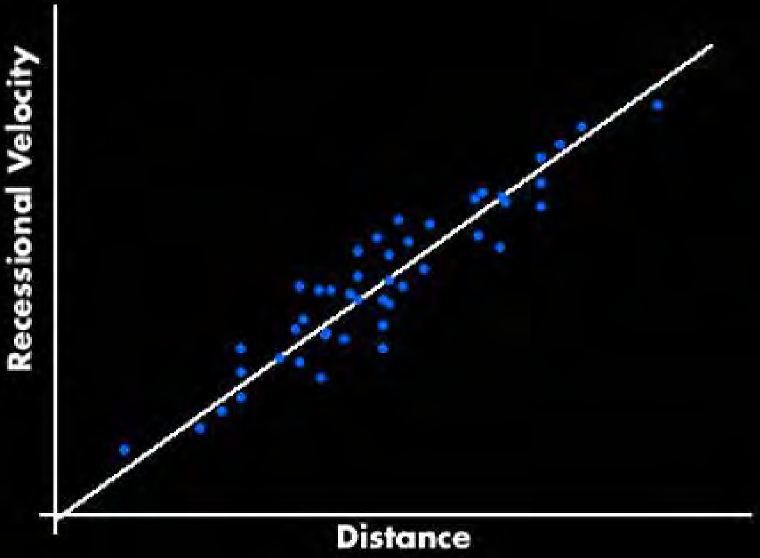
- We have used a completely independent method to measure the Hubble constant.
- Our result agrees with the local measurements by the traditional distance ladder technique (Riess et al. 2019; Freedman et al. 2019).
- The consequence is that the tension is very likely real between local expansion rate and the prediction from the standard cosmological model.

Hubble constant: the current expansion rate of the Universe

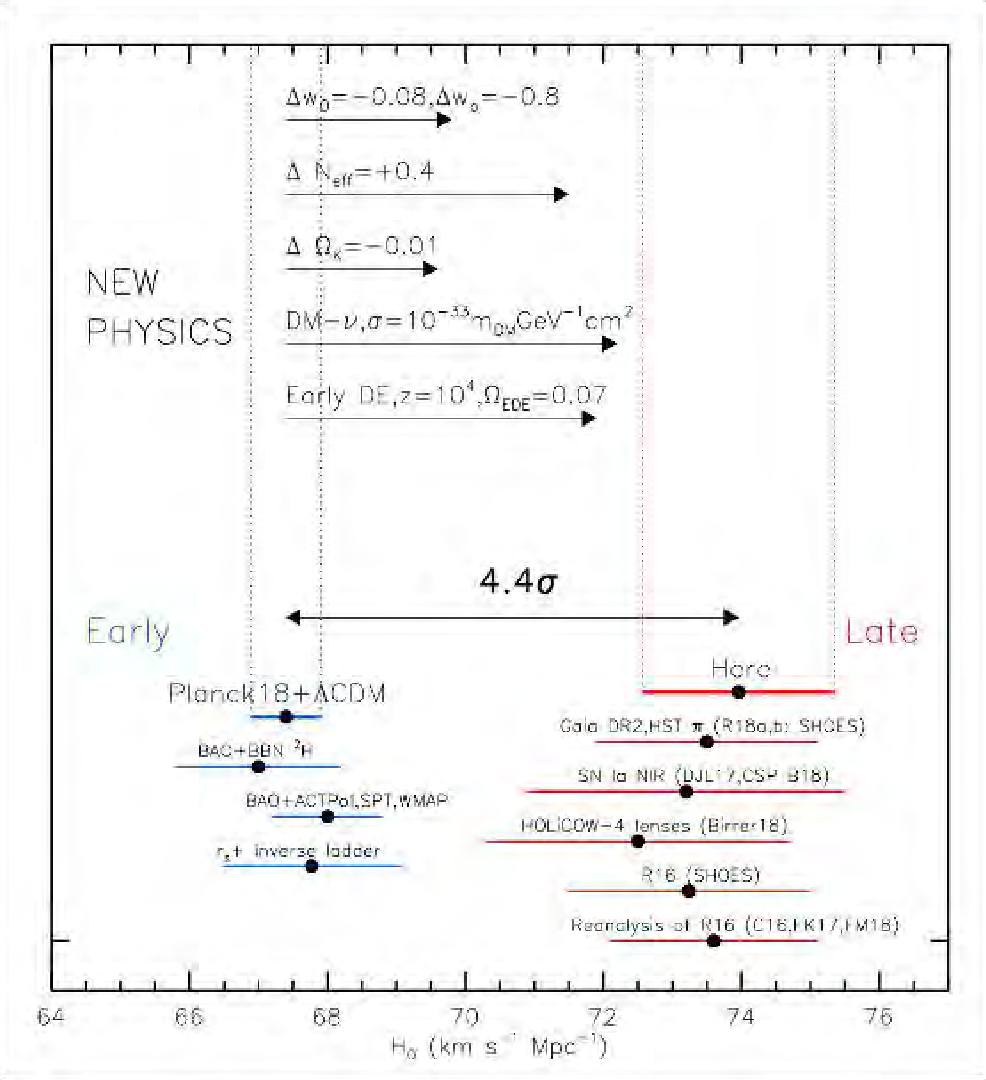


$$V = H_0 d$$

Hubble constant



H_0 tension



Riess et al 2019

$$H = H(\rho_m, \rho_r, \rho_\Lambda, \rho_k)$$

Cosmic microwave background data

\+

ΛCDM model

=

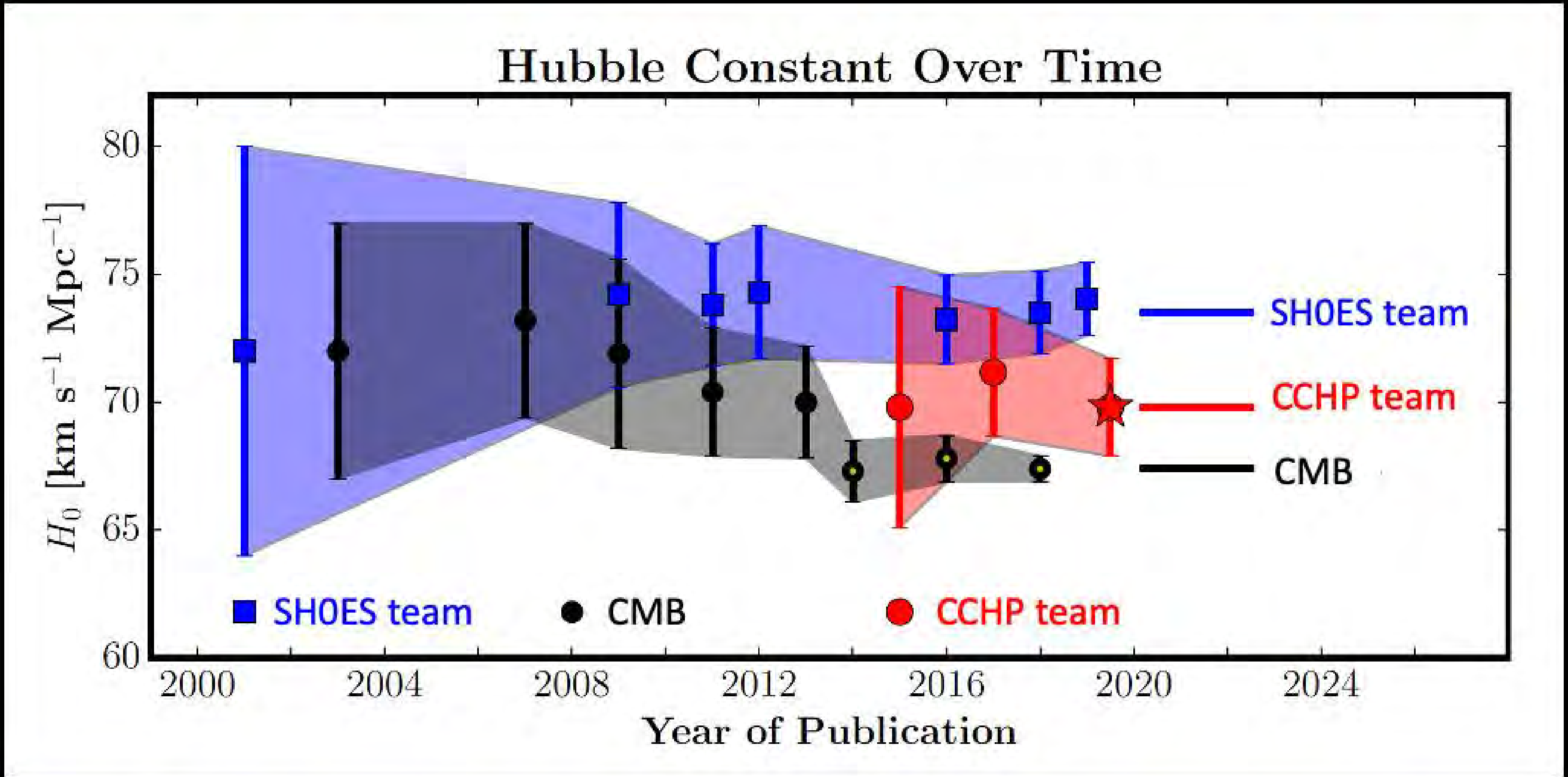
Planck team derives

H_0 = 67.4±0.5 km s^-1 Mpc^-1 (Planck 2018)

Assumptions made in ΛCDM model

- No spatial curvature
- Constant dark energy (Λ)
- Effective number of neutrino species inferred from the standard model

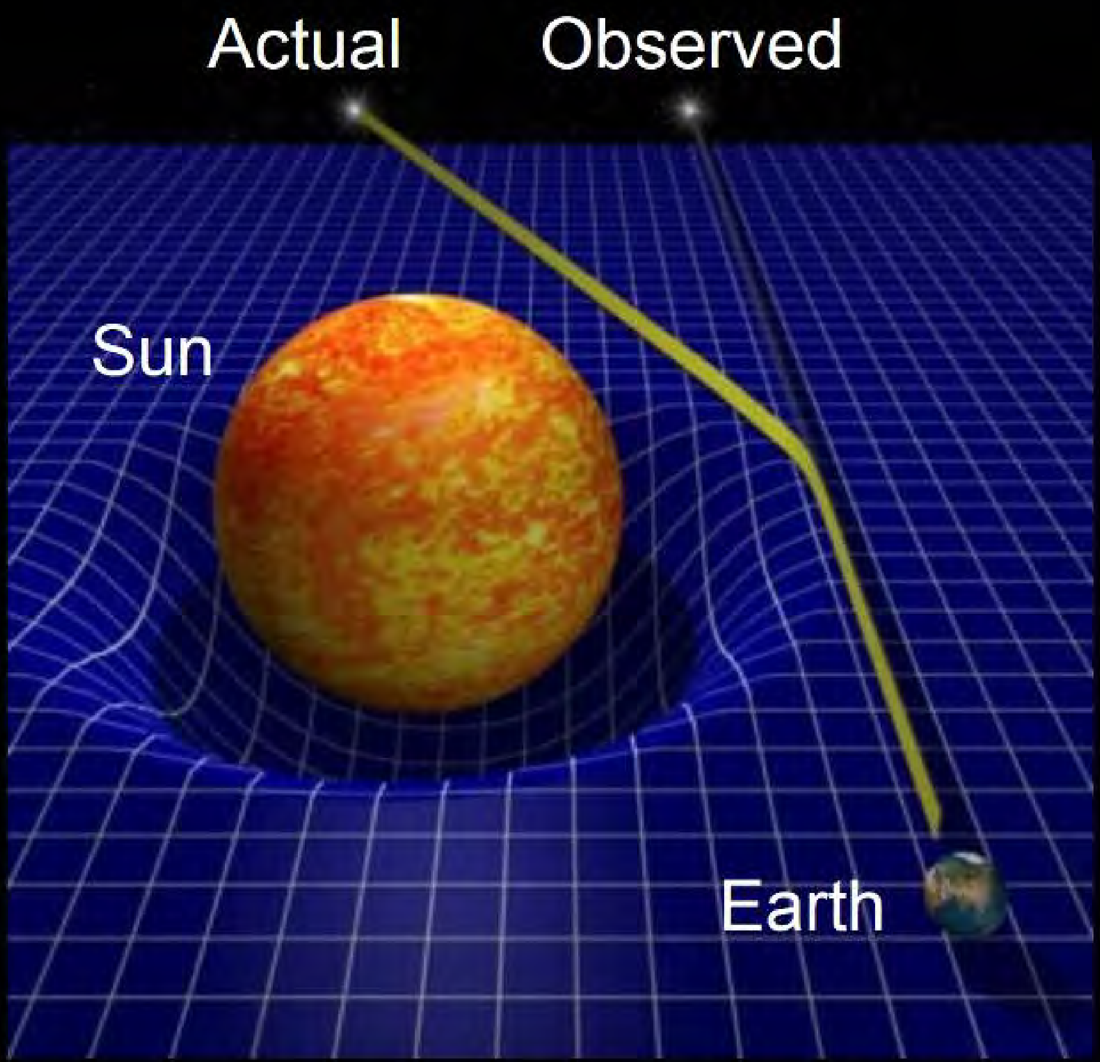
Extraordinary claims require extraordinary evidence



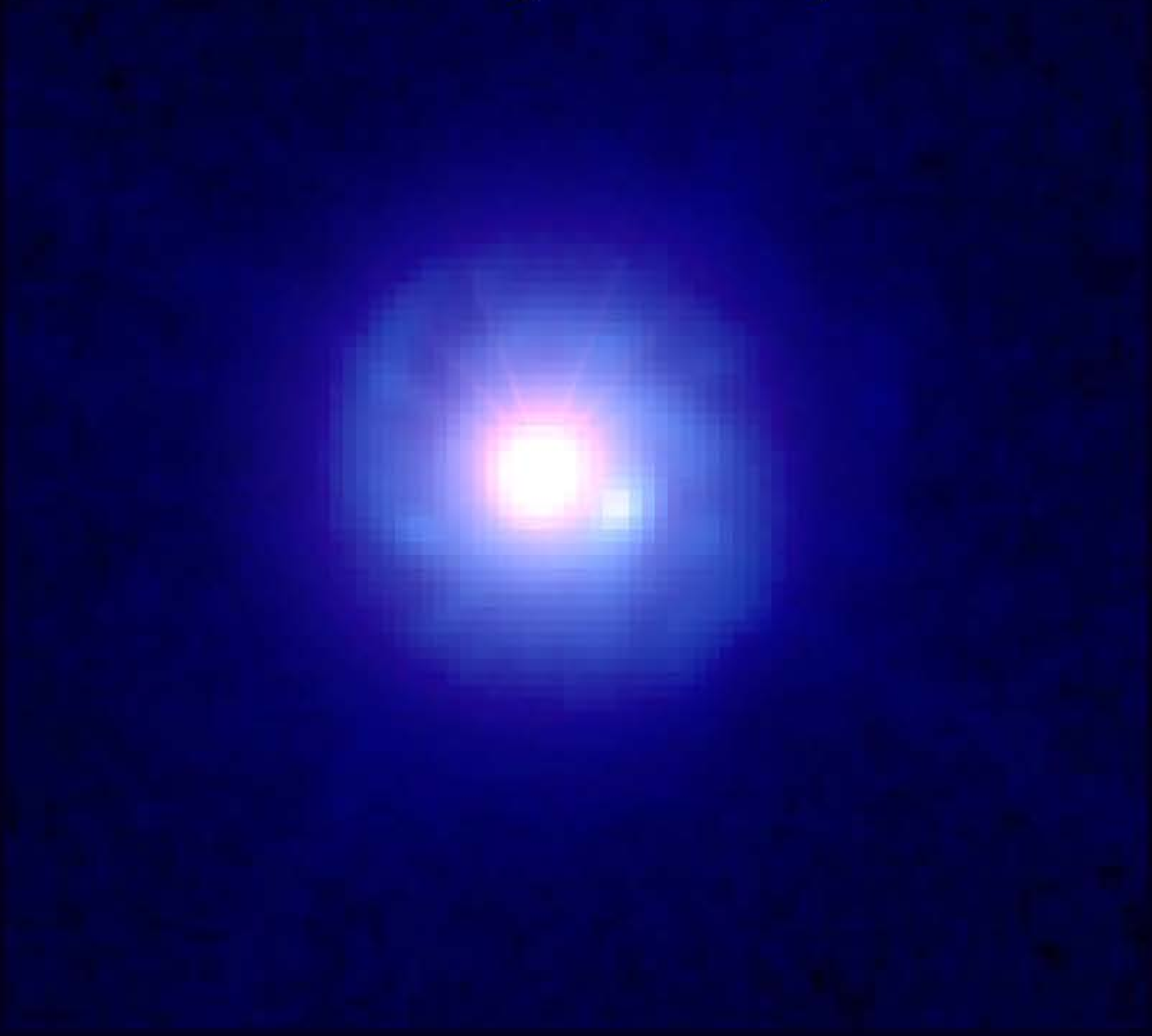
Need independent methods and data to overcome systematics, especially the unknown unknowns

Freedman et al. 2019

Independent methodology: Gravitational lensing



Gravitationally lensed quasars

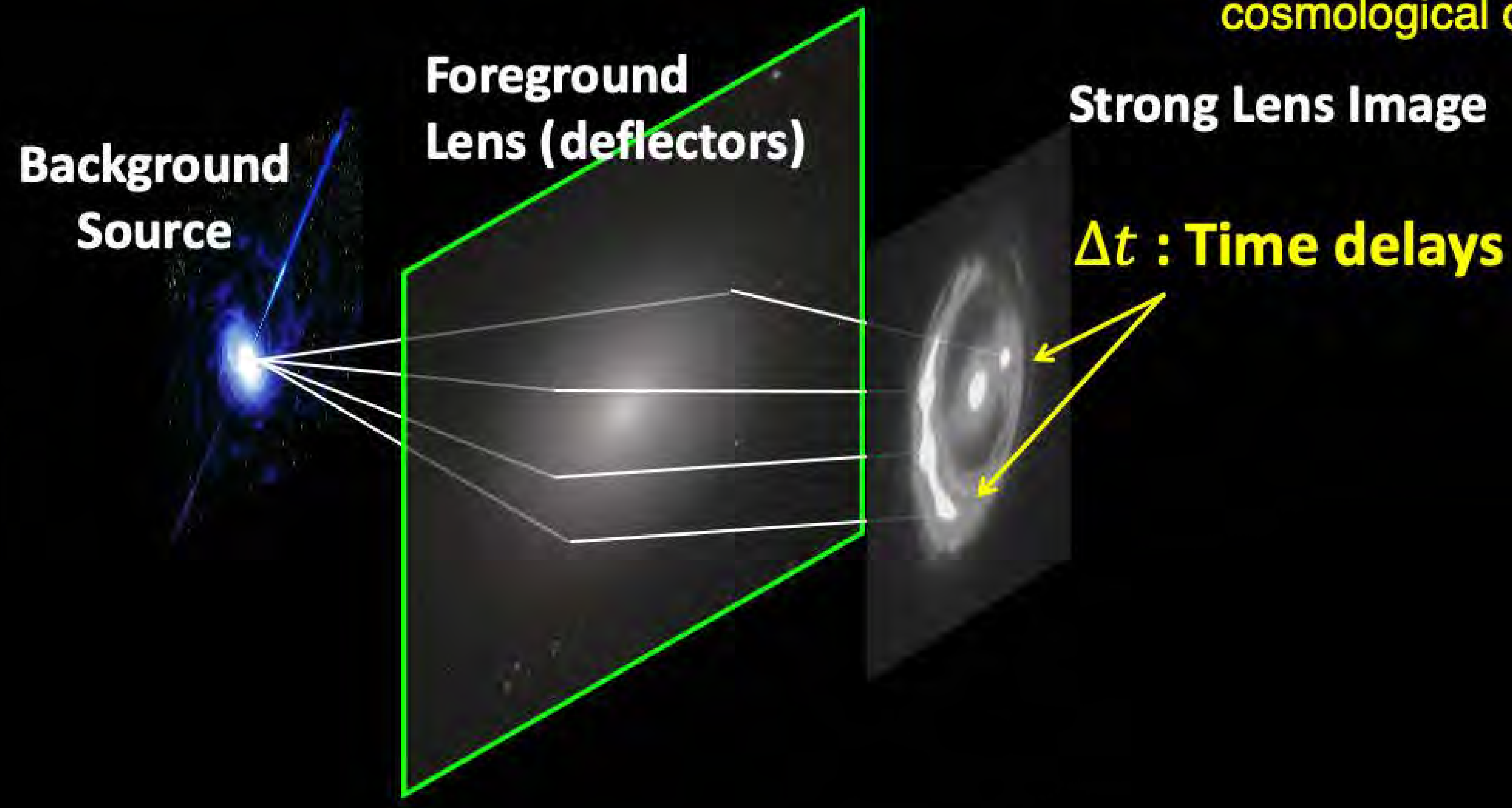


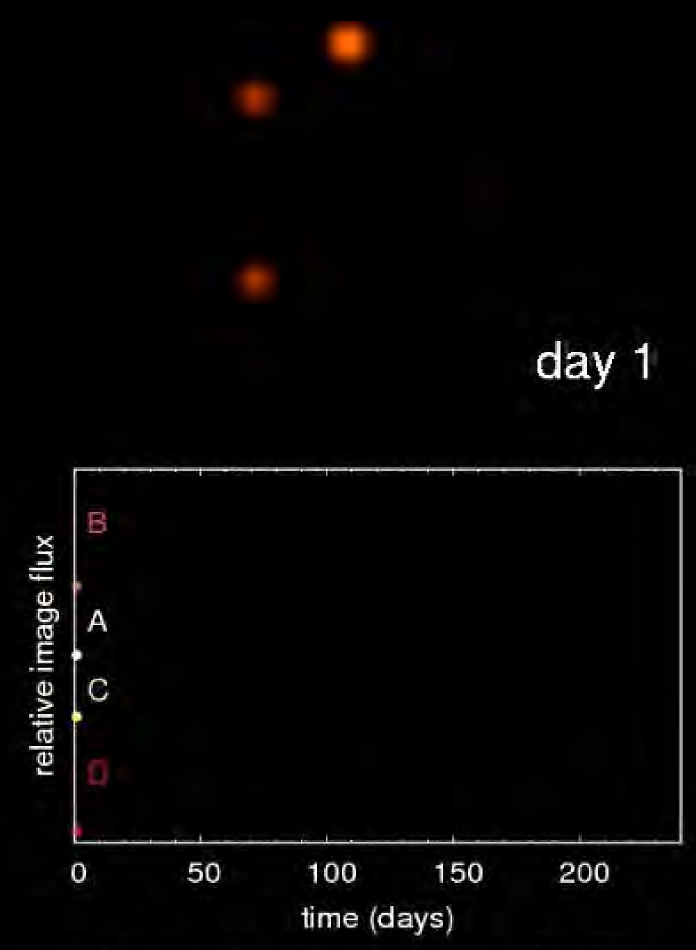
[Credit: ESA/Hubble, NASA]

Time-delay cosmography

Advantages:

(1) simple geometry & well-tested physics
(2) one-step physical measurement of a cosmological distance





S. H. Suyu, C. D. Fassnacht, NRAO/AUI/NSF

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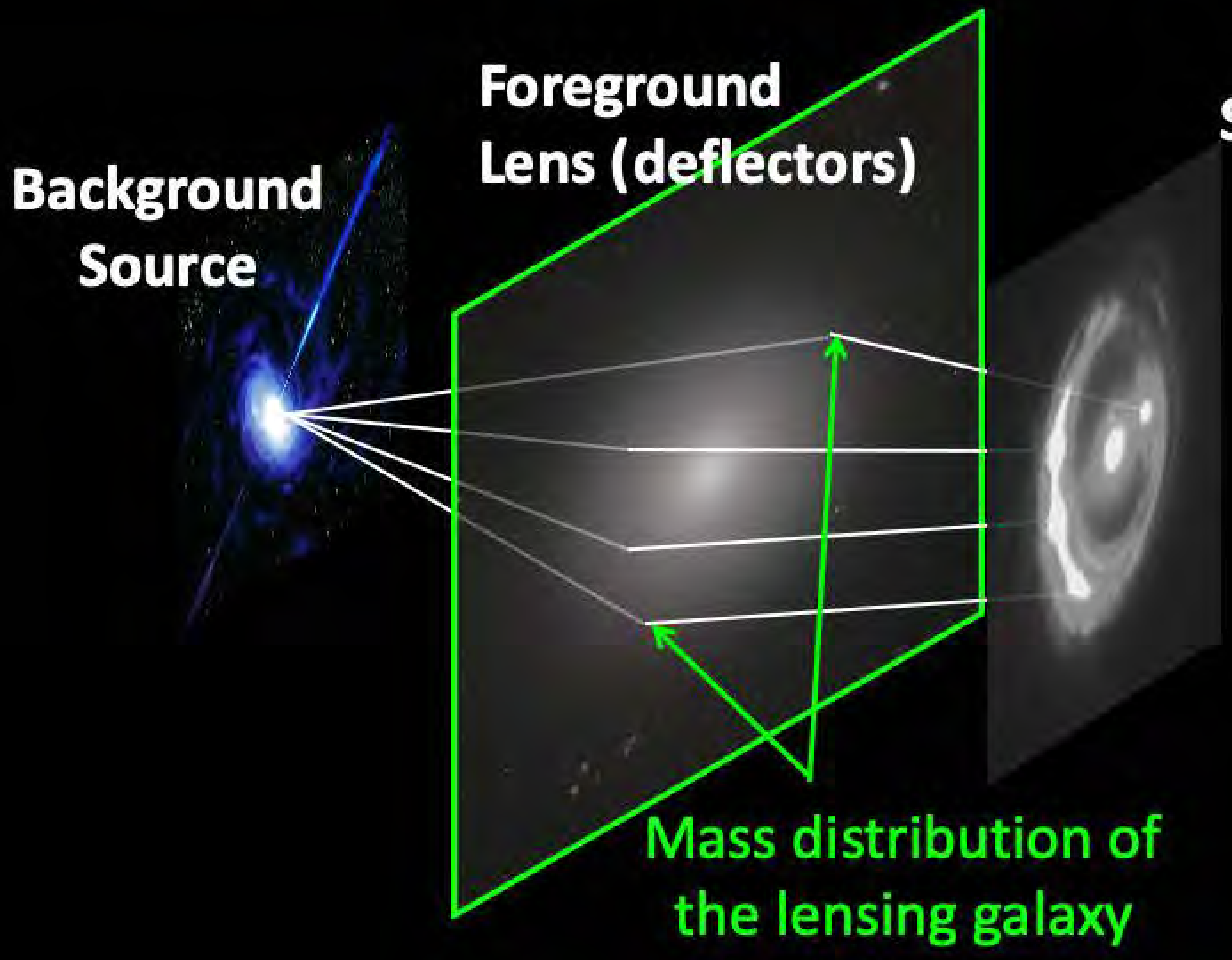

Suyu et al. 2014

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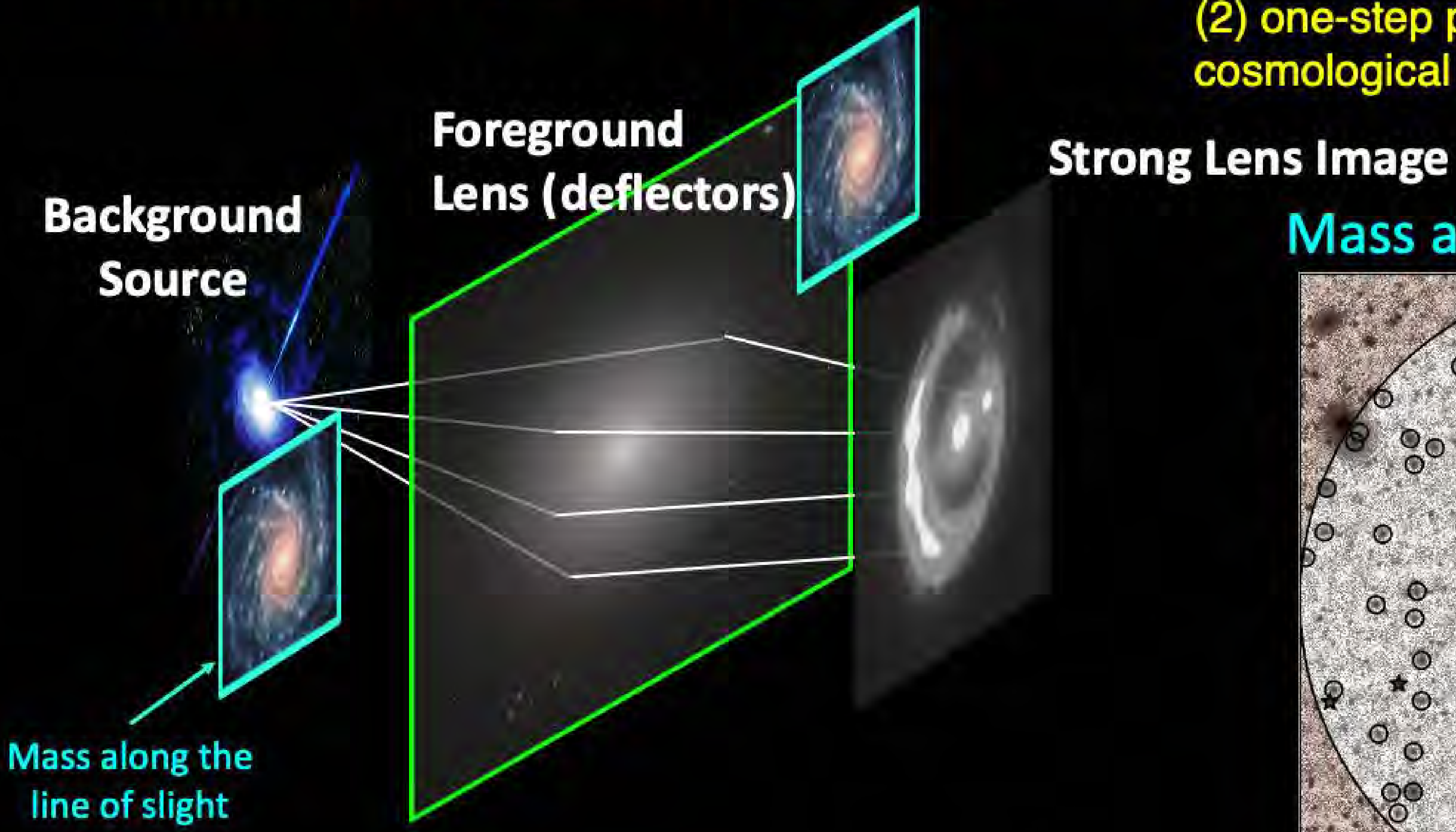
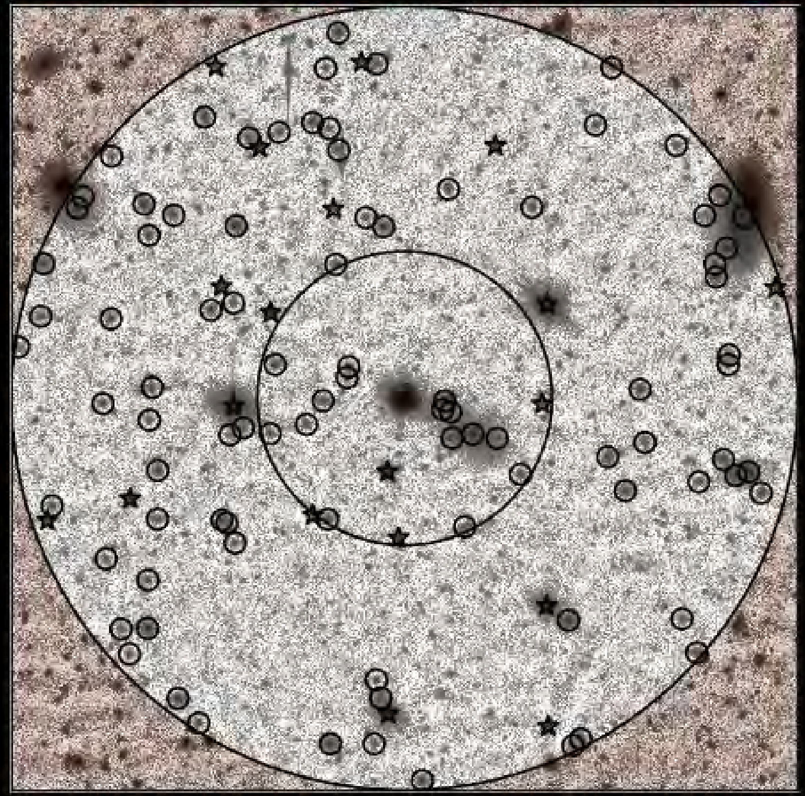


Mass along the line of slight



Chen et al. 2019

Time-delay cosmography

Advantages:

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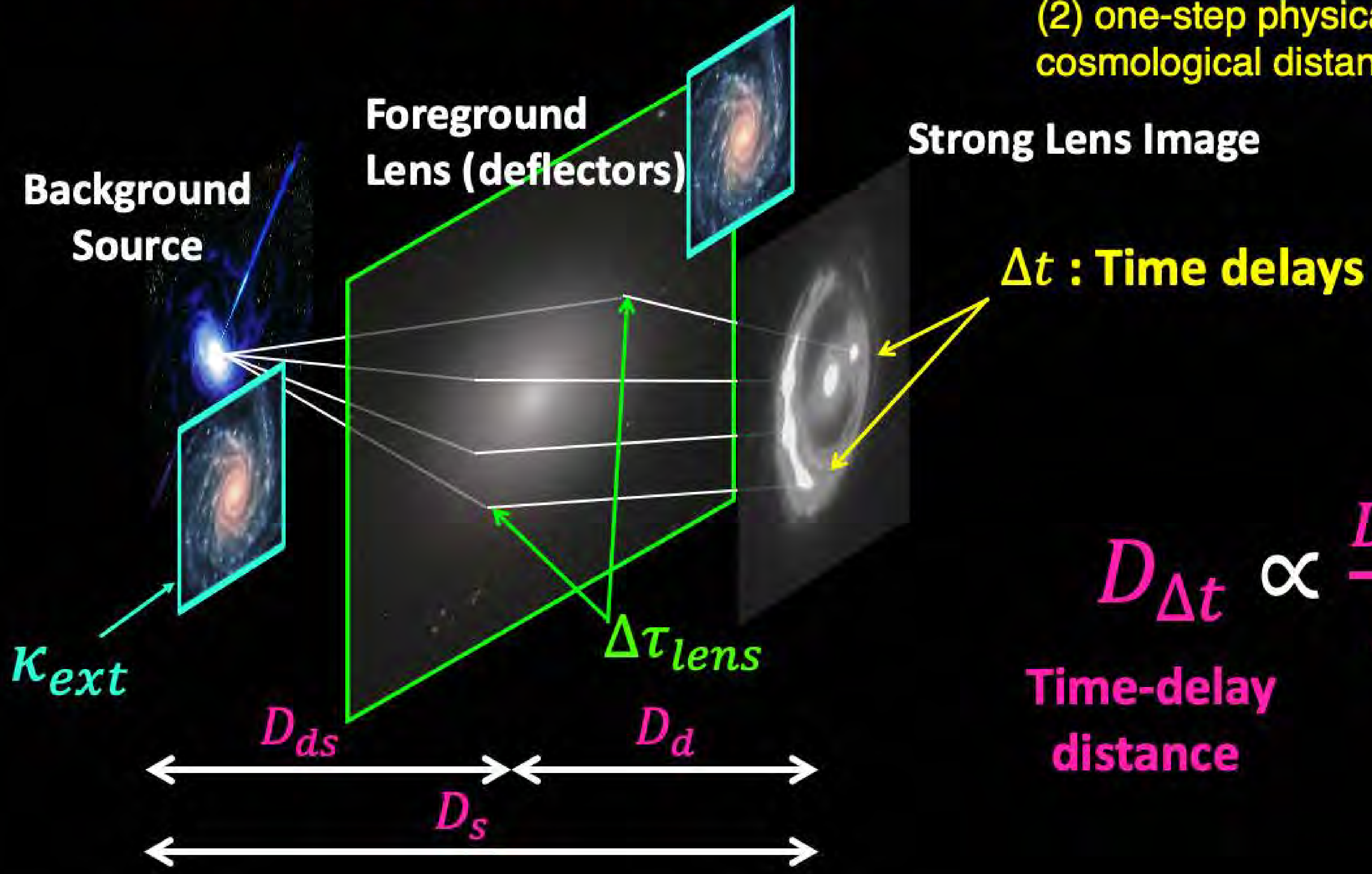


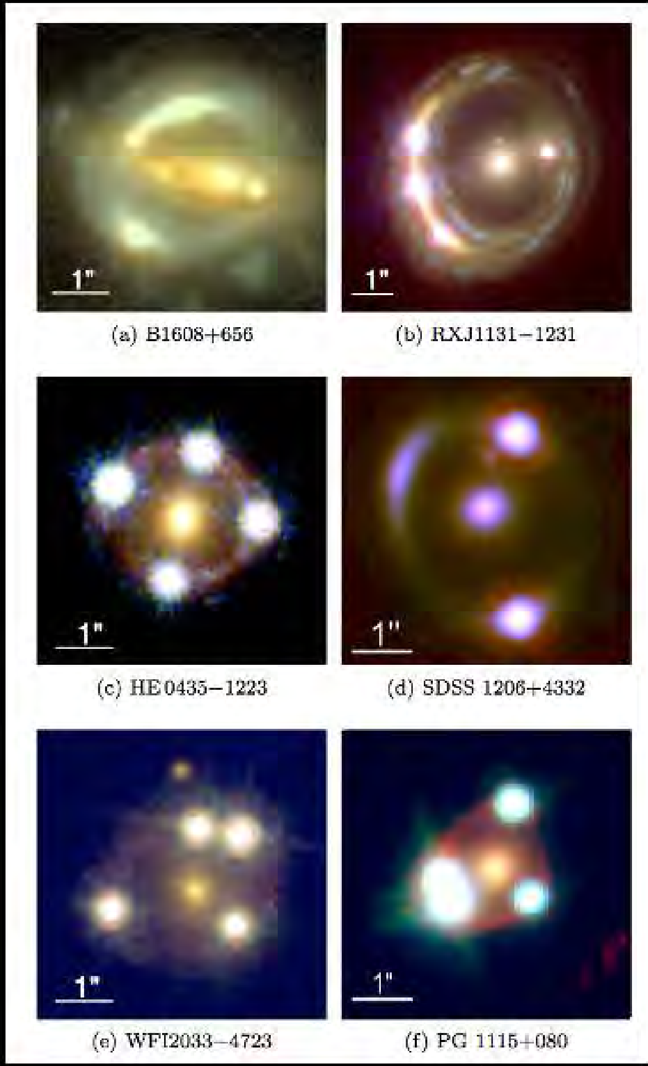
$$D_{\Delta t} \propto \frac{D_d D_s}{D_{ds}} \propto \frac{1}{H_0}$$

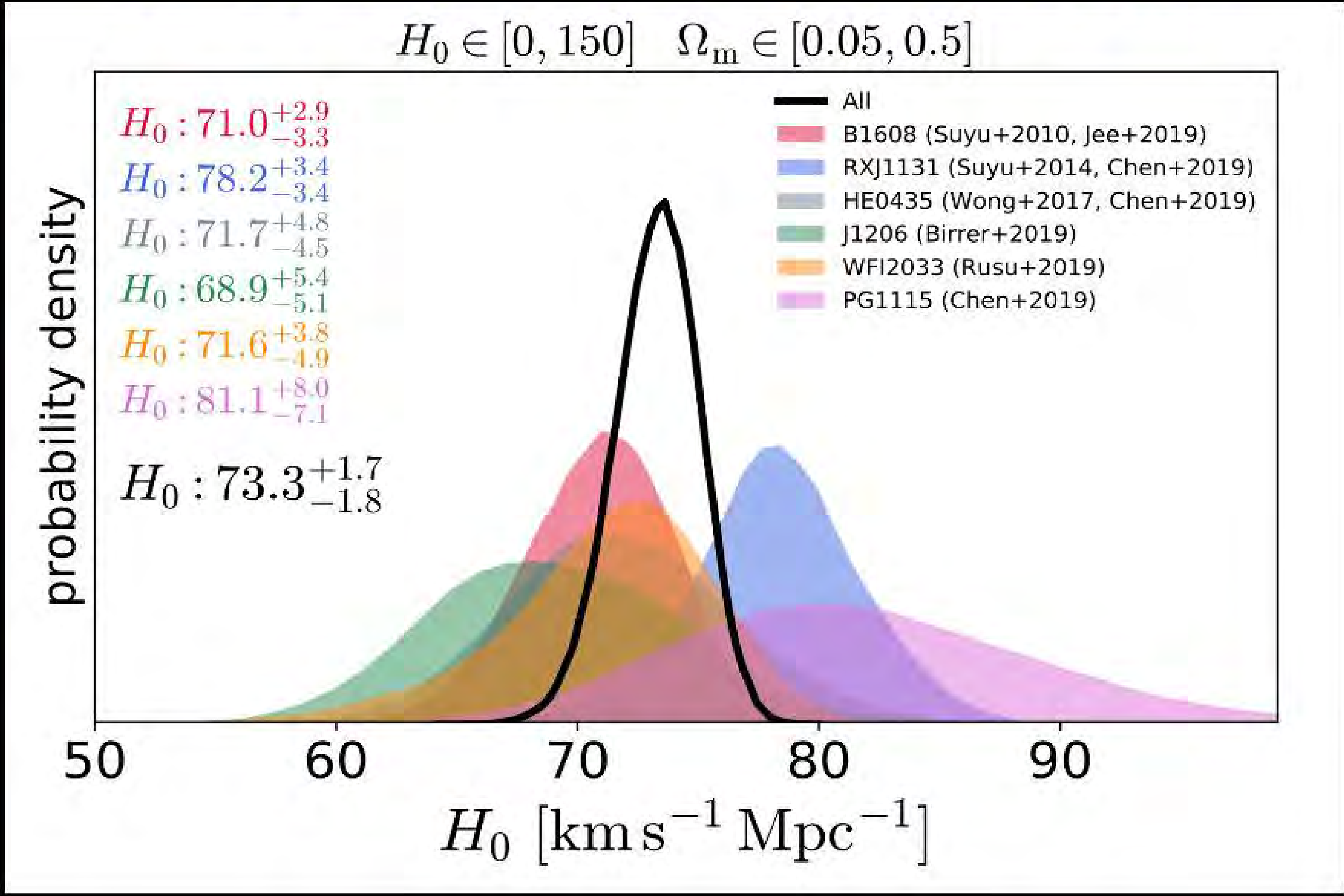
Time-delay distance

Hubble constant

H0LiCOW collaboration: A 2.4% measurement of H_0

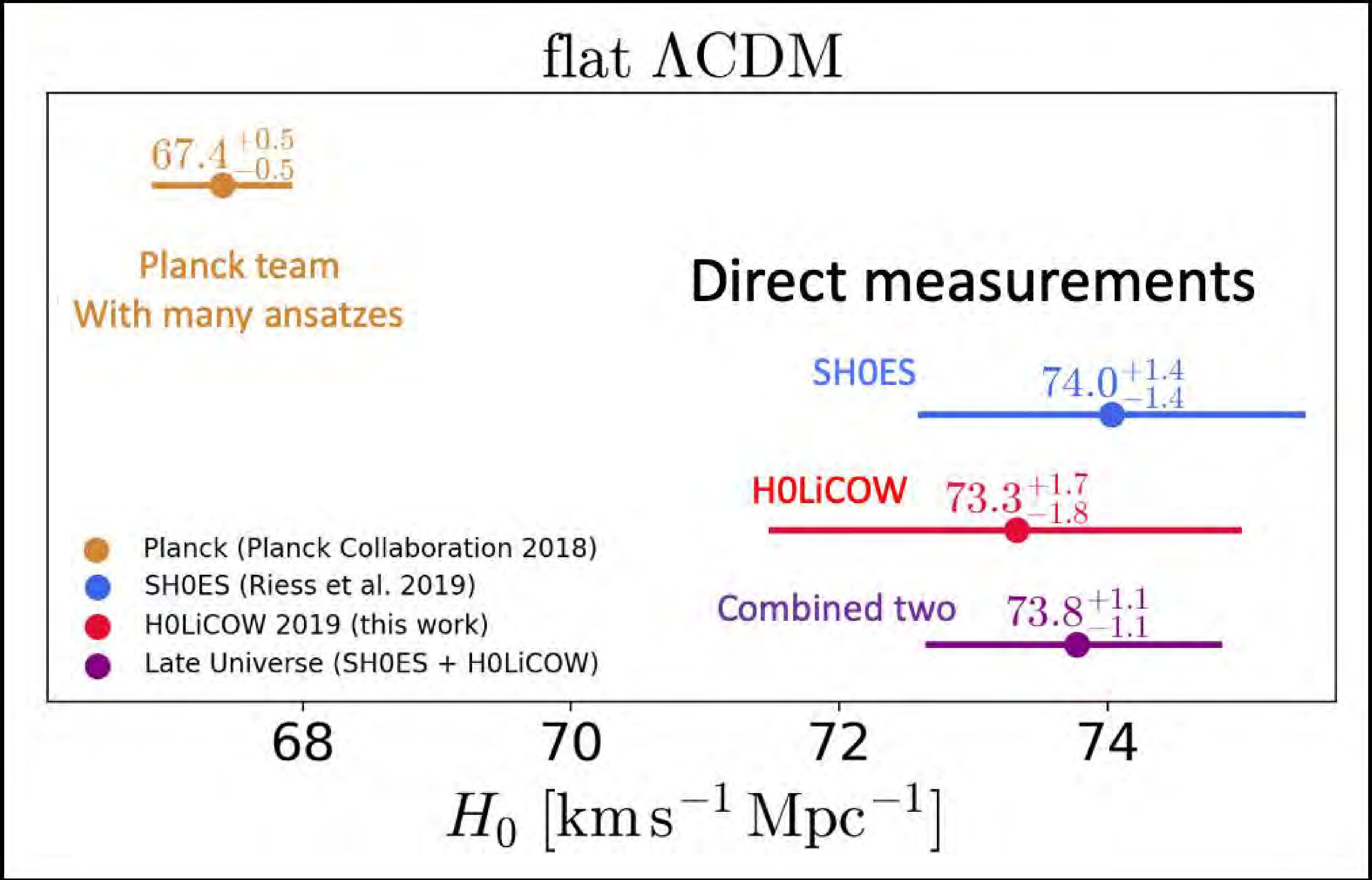
Blind analysis to avoid confirmation bias





H0LiCOW Paper XIII

5.3 sigma tension between early and late-Universe probes



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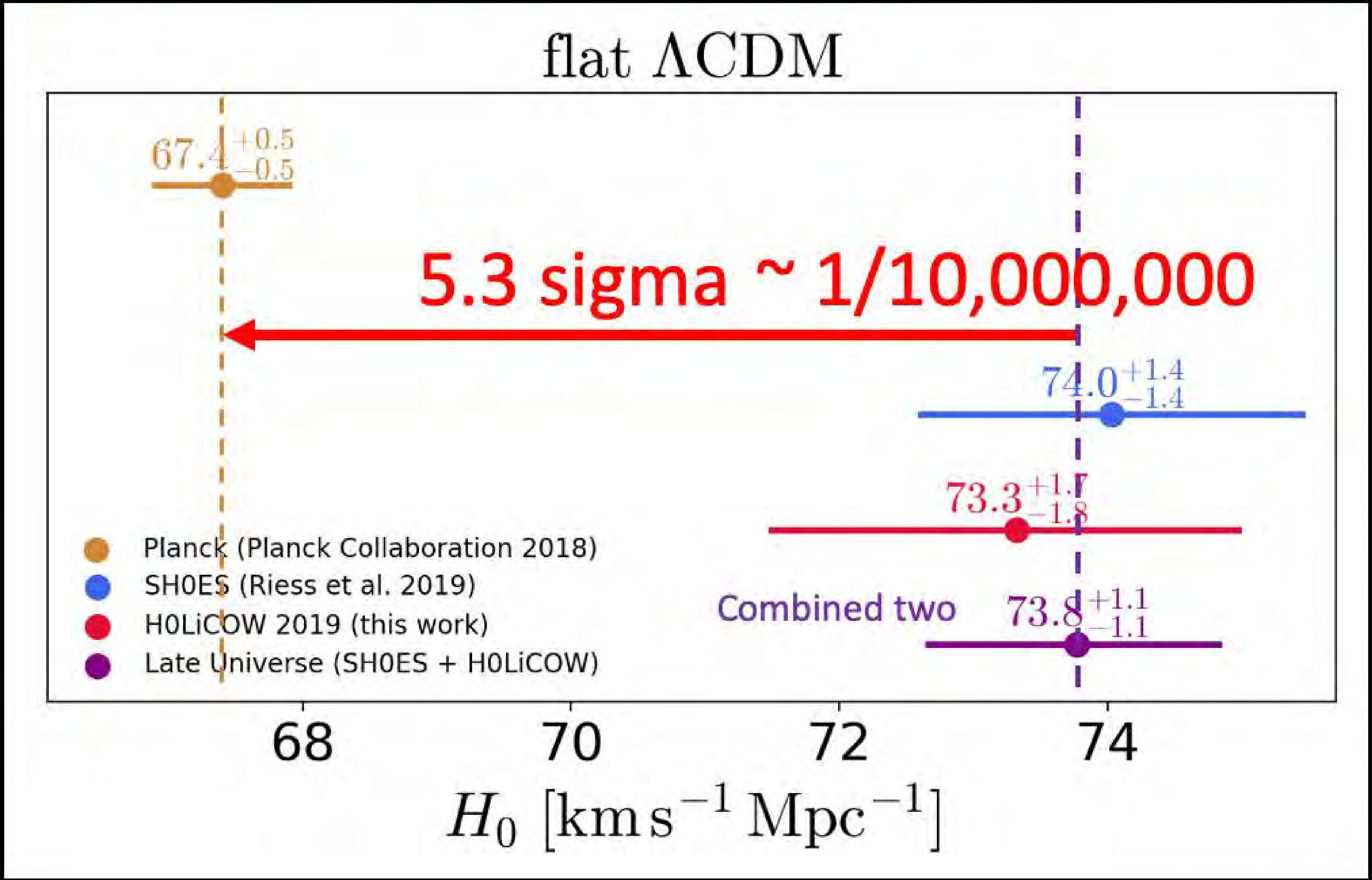

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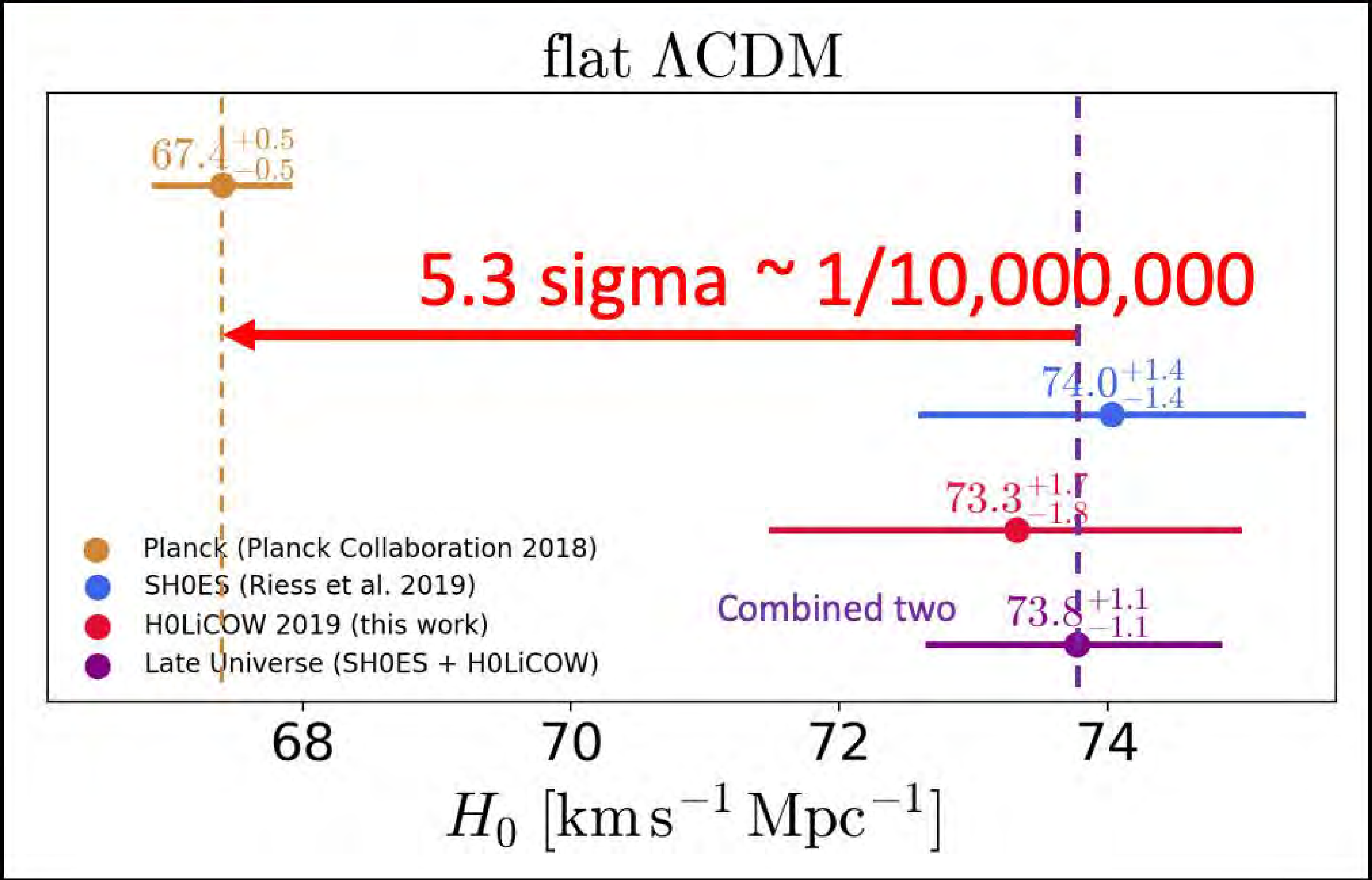
Terminology

$\sim 0\sigma$	Too good to be true
$\sim 1\sigma$	Consistency
$>2\sigma$	**Curiosity**
$>3\sigma$	Tension/Discrepancy
$>4\sigma$	Problem
$>5\sigma$	Crisis?

Crisis?

5.3 sigma tension between early and late-Universe probes



H0LiCOW Paper XIII

Summary

- Time-delay strong lensing achieves a 2.4% uncertainty in the H_0 measurement with 6 gravitationally lensed quasars.
- Two independent and direct H_0 measurements yield the consistent results indicating a crisis in the modern cosmology
- Only 0.00001% chance that the true value is located at the prediction from the LCDM model (caveat: no any systematics)
- New cosmological model may very well be needed to resolve the tension

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https://hubblesite.org/contents/news-releases/2020/news-2020-04

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