

NIKKI ARENDSE

Oskar Klein Centre, Stockholm University

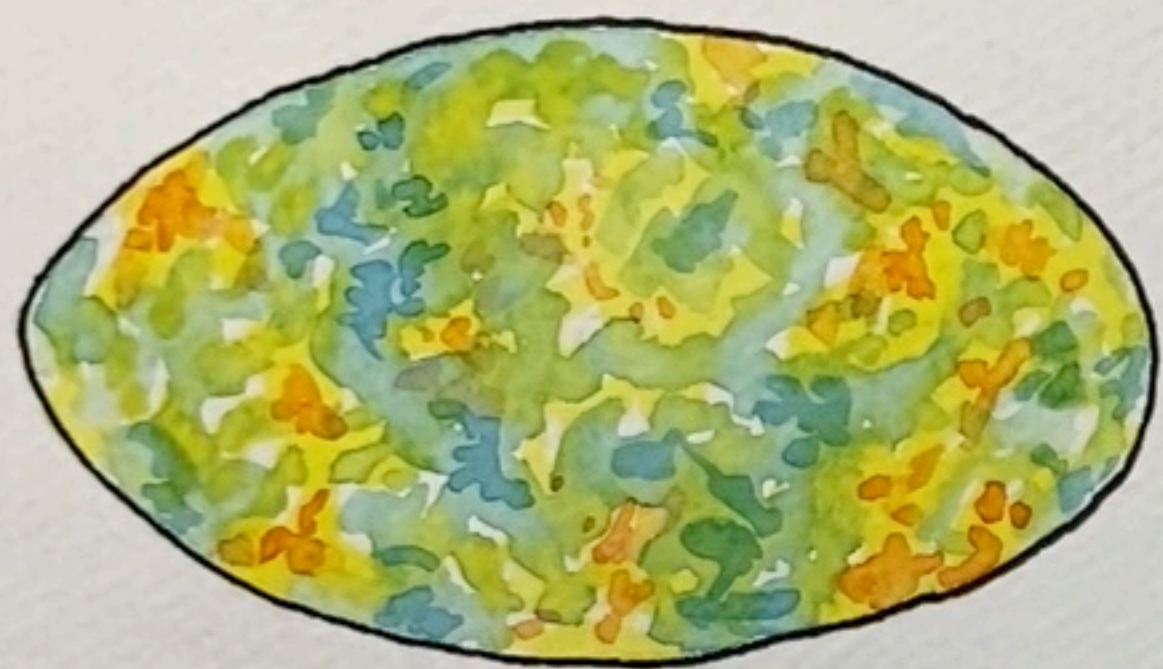
# Inferring the Hubble constant from gravitationally lensed supernovae

**Collaborators:** Doogesh Kodi Ramanah, Radek Wojtak, Hiranya Peiris, Ariel Goobar, Rémy Joseph, Justin Alsing, Simon Huber, Sherry Suyu, Catarina Alves



# CMB

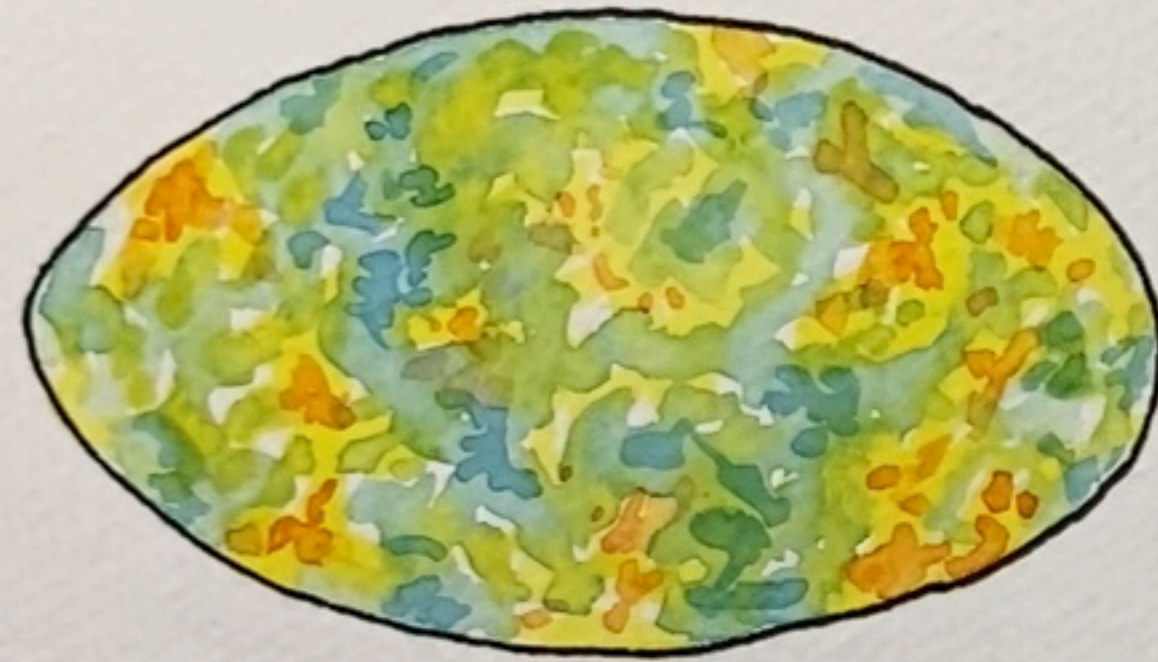
(model-dependent)





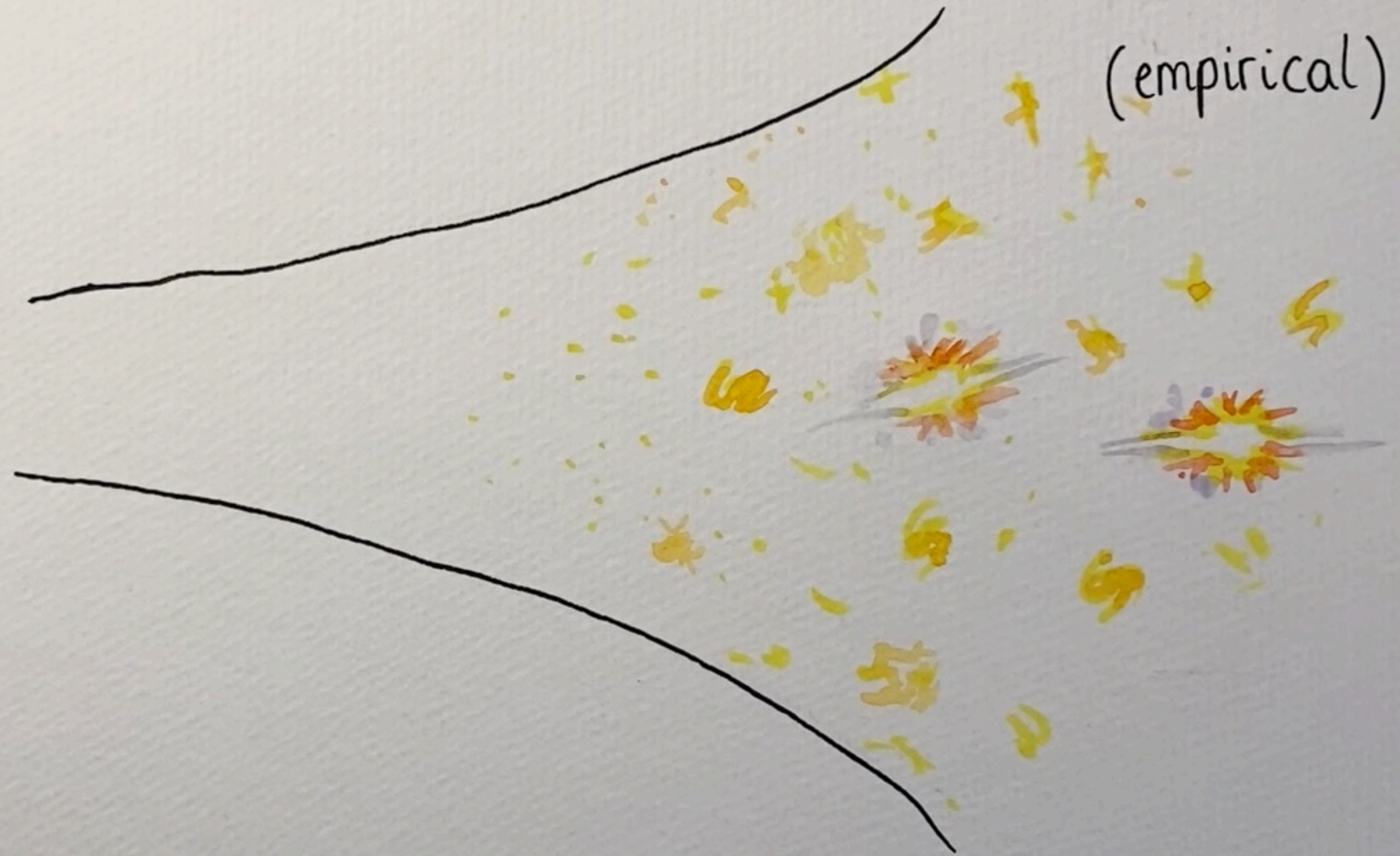
CMB

(model-dependent)



local

(empirical)

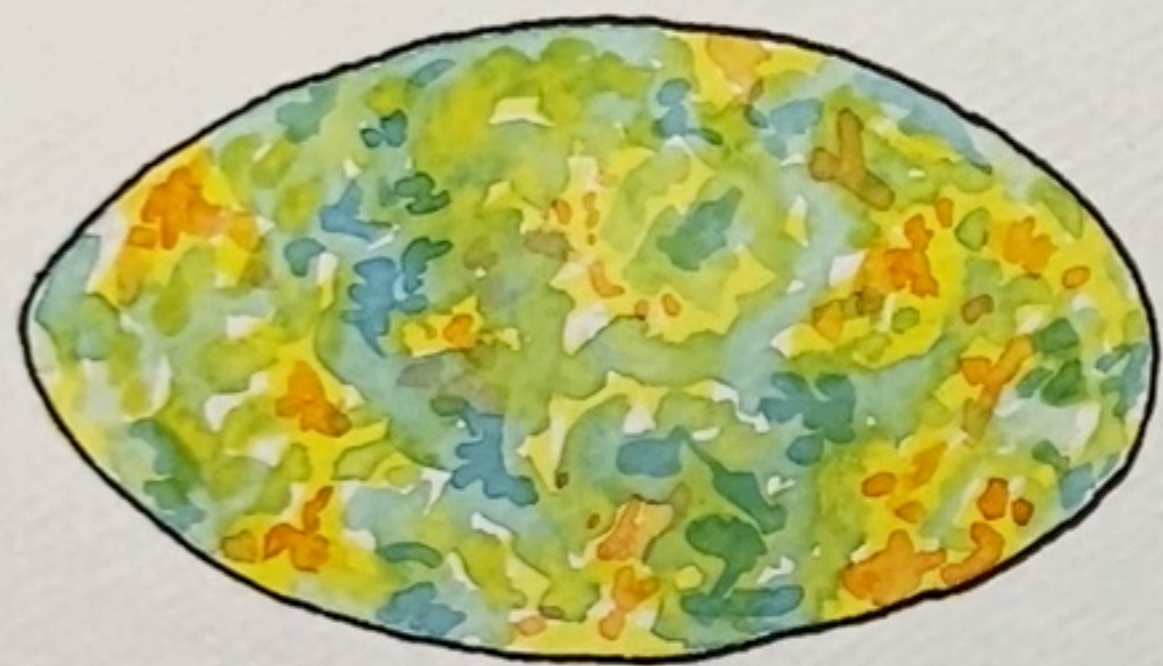


There is a tension between two types of methods to measure the Hubble constant



CMB

(model-dependent)

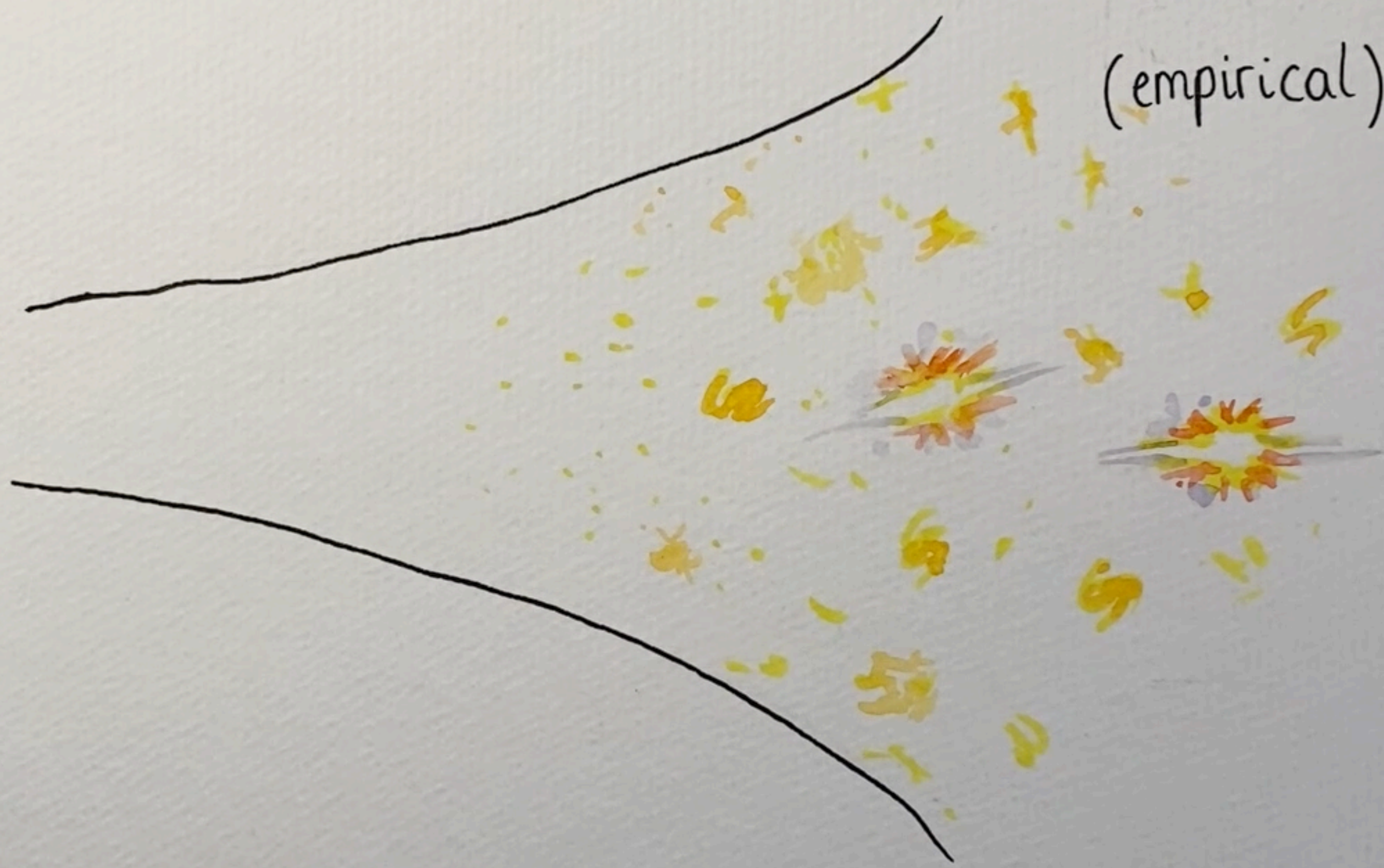


67.4

$\pm 0.5$  km/s/Mpc

from Planck

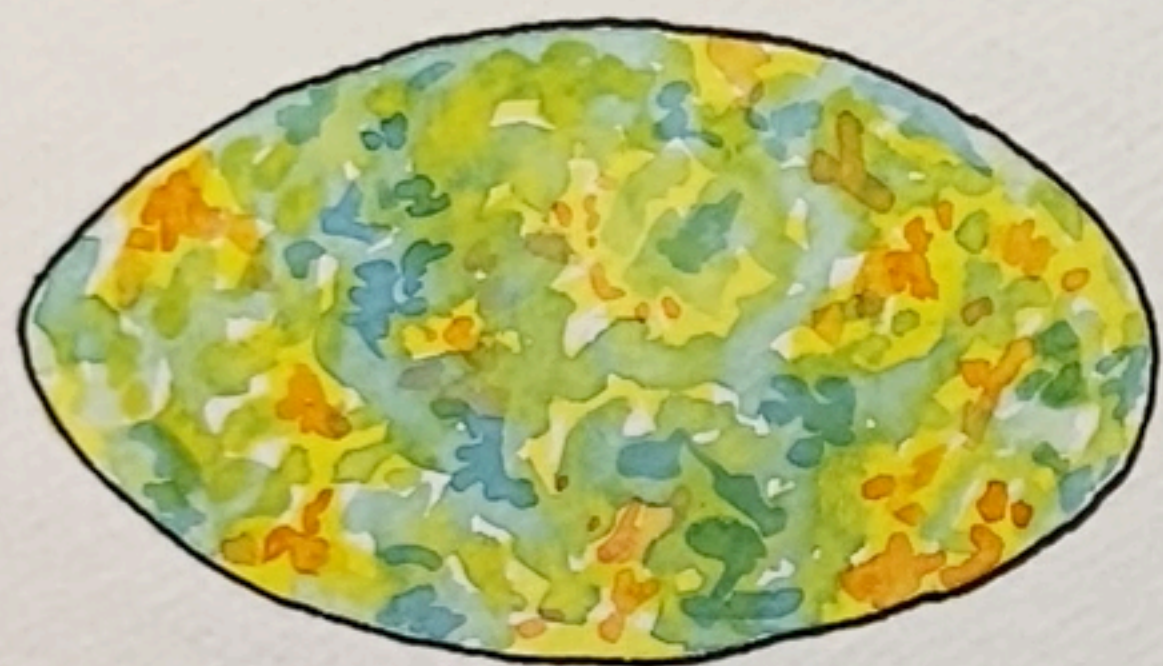
local  
(empirical)





CMB

(model-dependent)



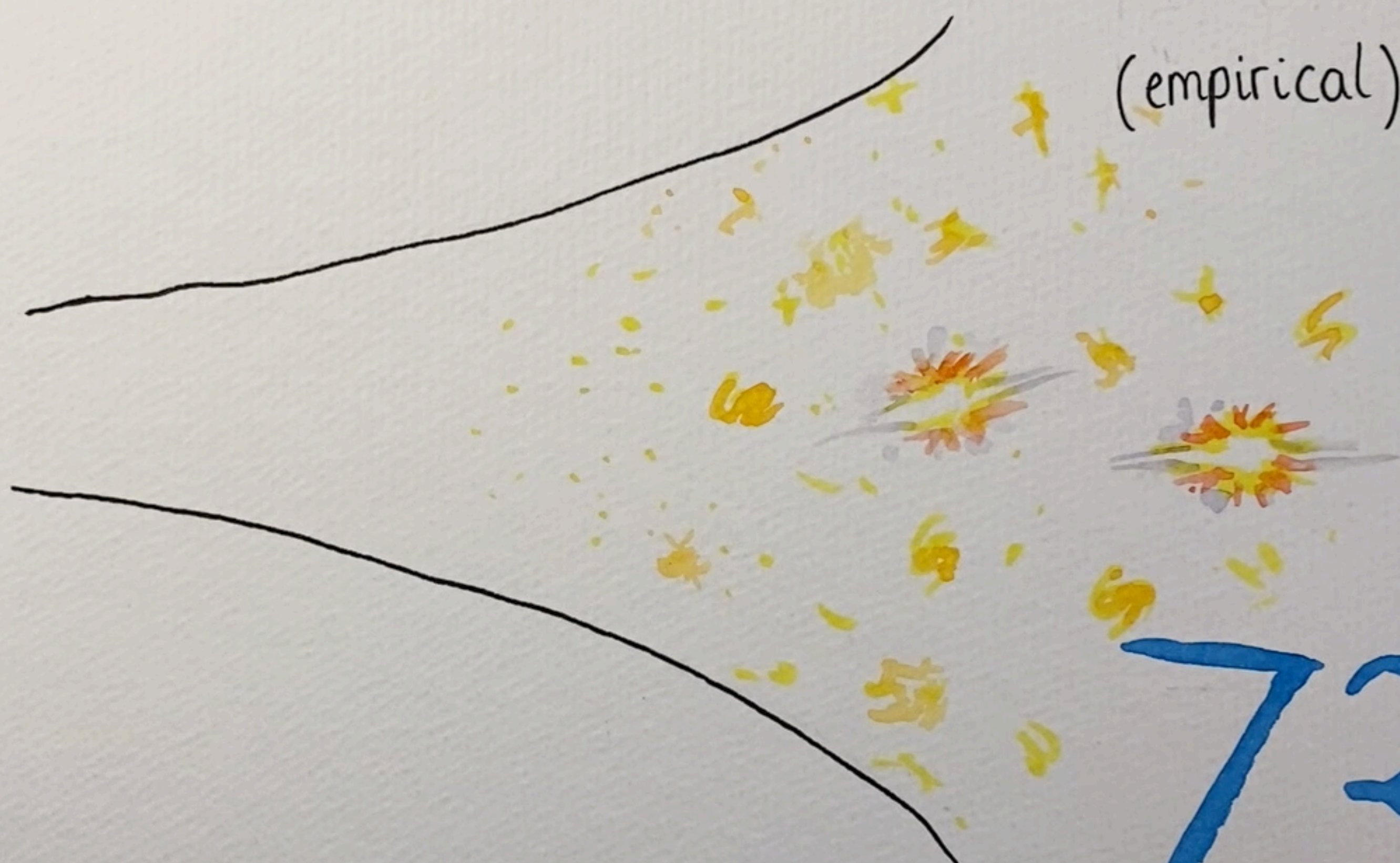
67.4

$\pm 0.5$  km/s/Mpc

from Planck

local

(empirical)

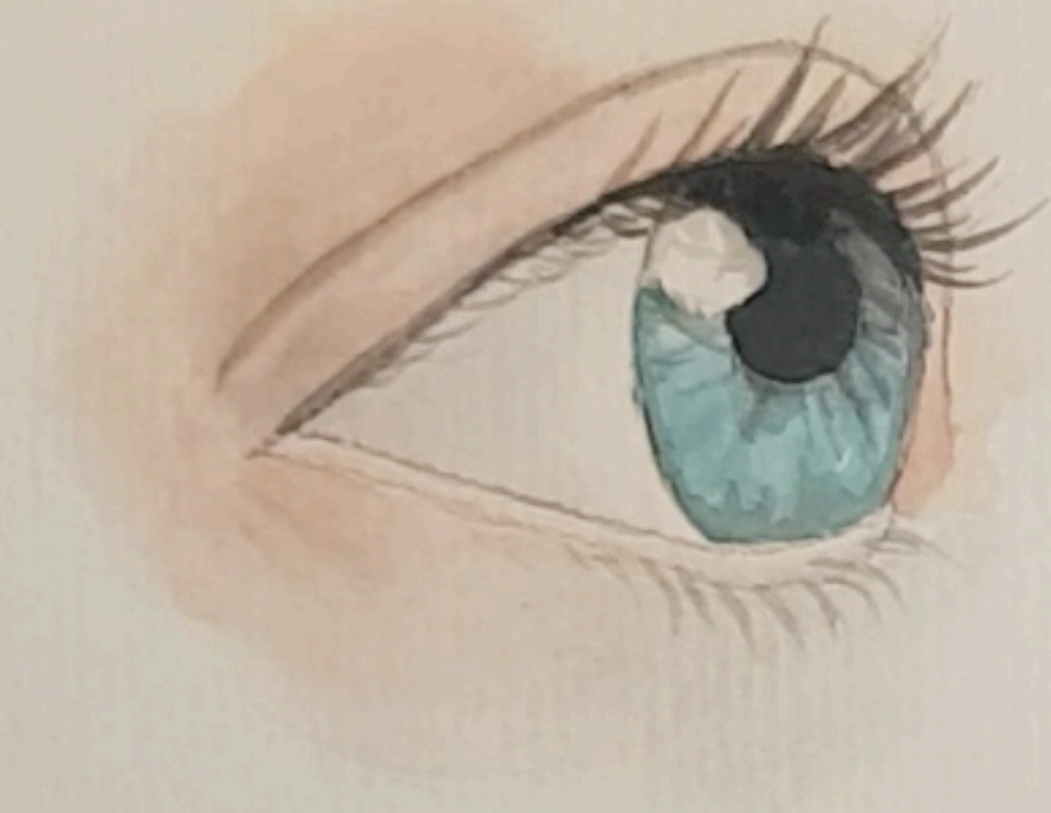


73.0

$\pm 1.0$  km/s/Mpc

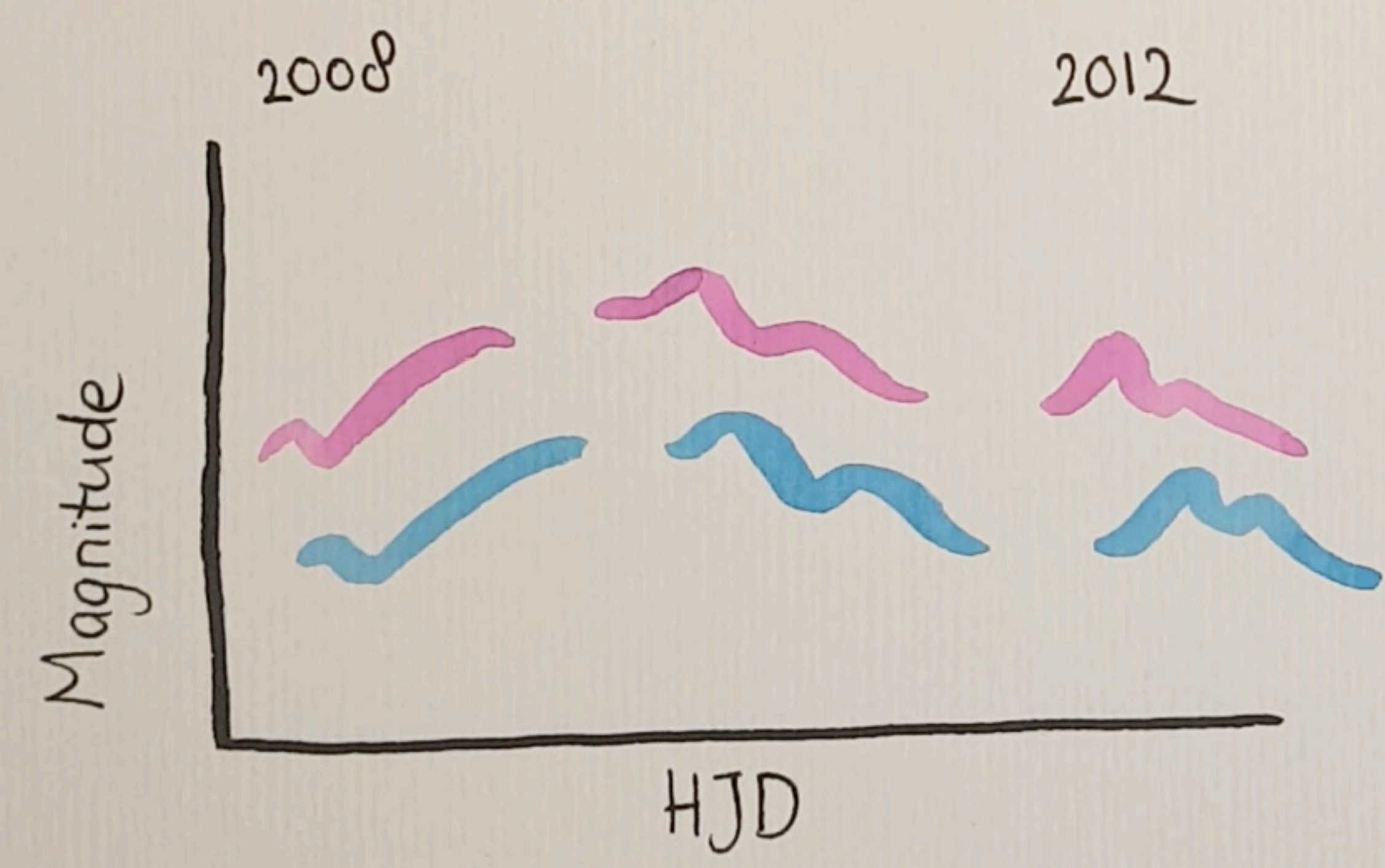
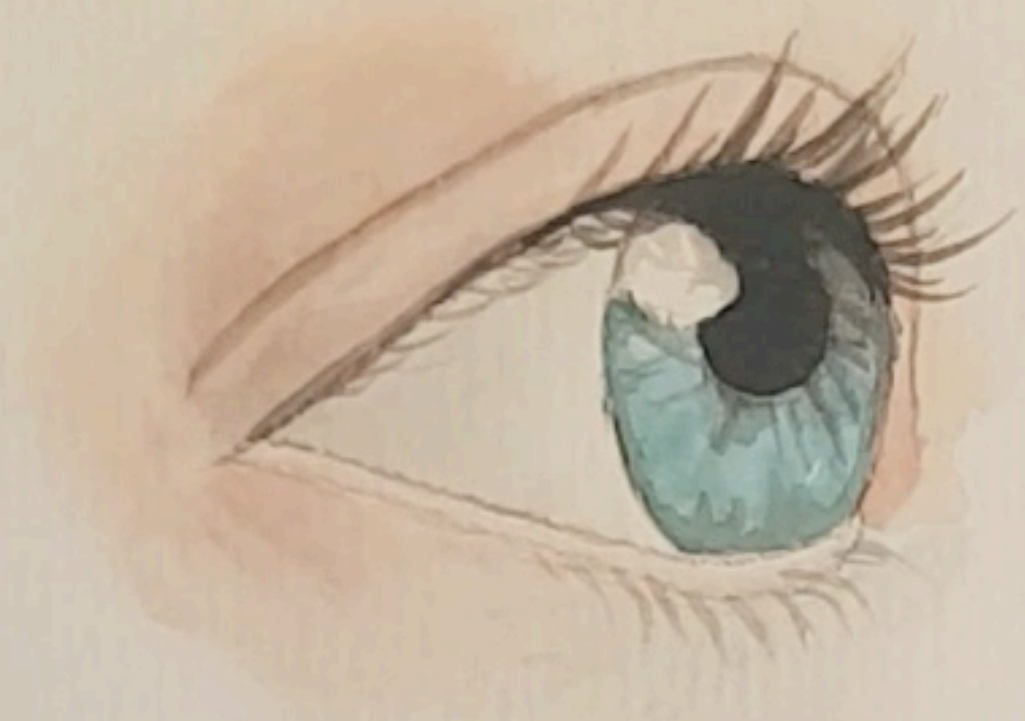
from Cepheid





Promising candidate for new, independent measurements of the Hubble constant: **gravitational lensing**

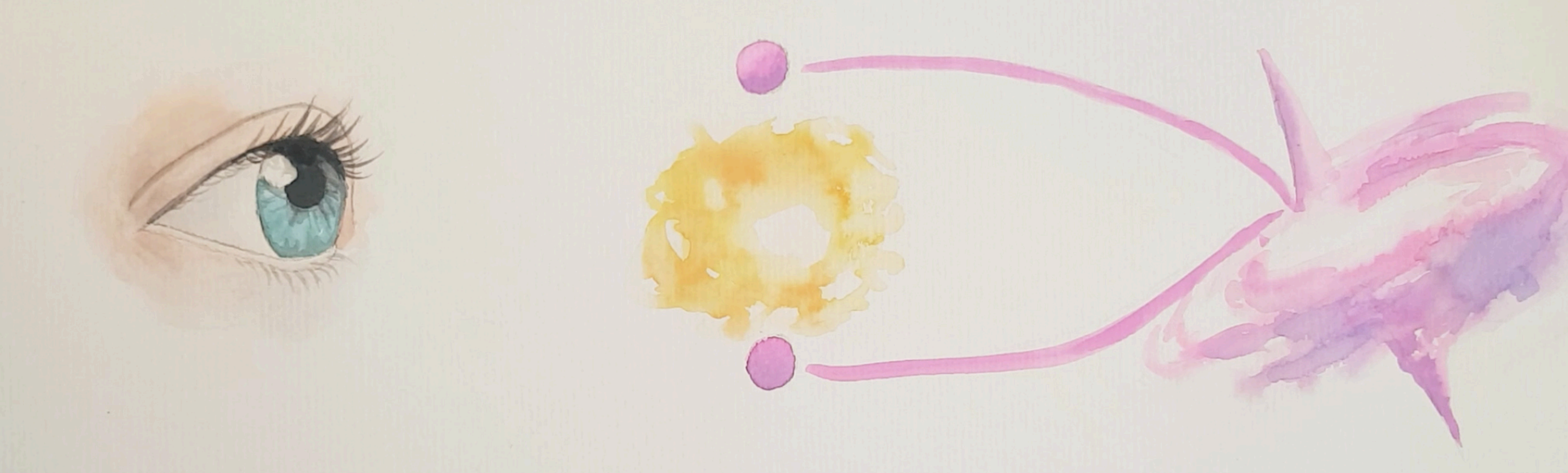




$$\Delta t \propto \phi_{\text{lens}} \left( \frac{D_L D_S}{D_{LS}} \right)$$

$D_{\Delta t}$

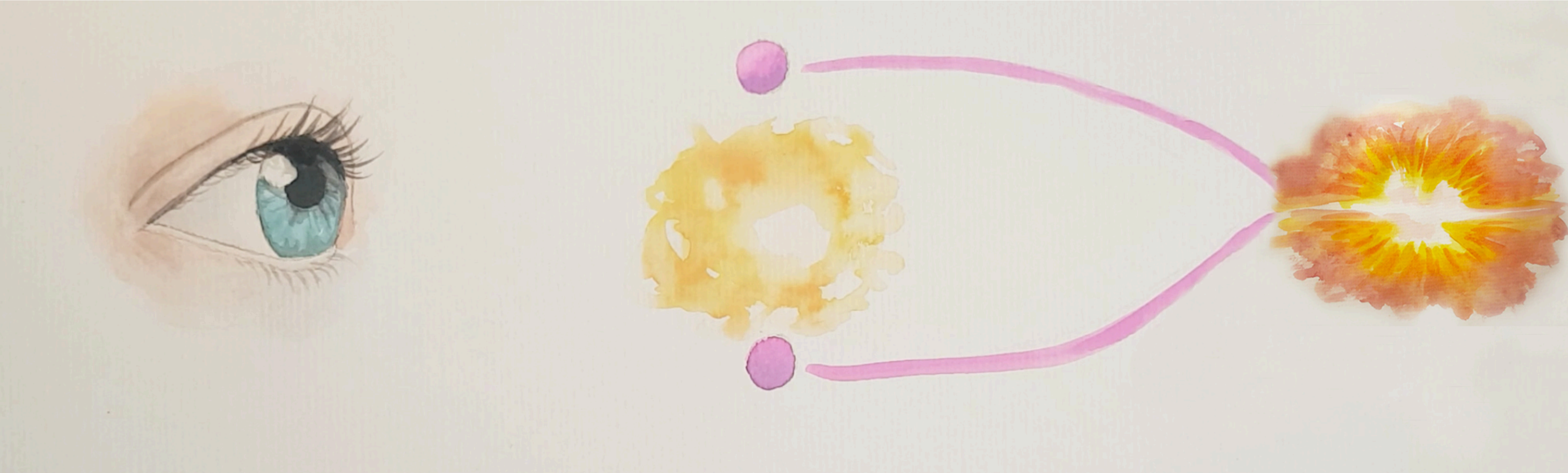




# Gravitationally lensed **quasars**

have been used successfully to measure  $H_0$





# Gravitationally lensed **supernovae**

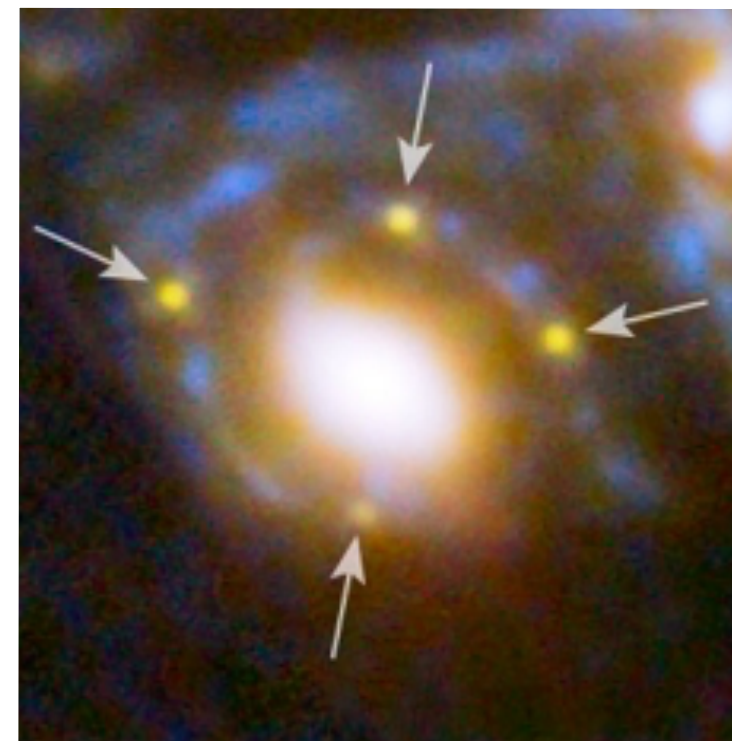
are at the start of their potential for cosmological analyses



# Gravitationally lensed **supernovae**

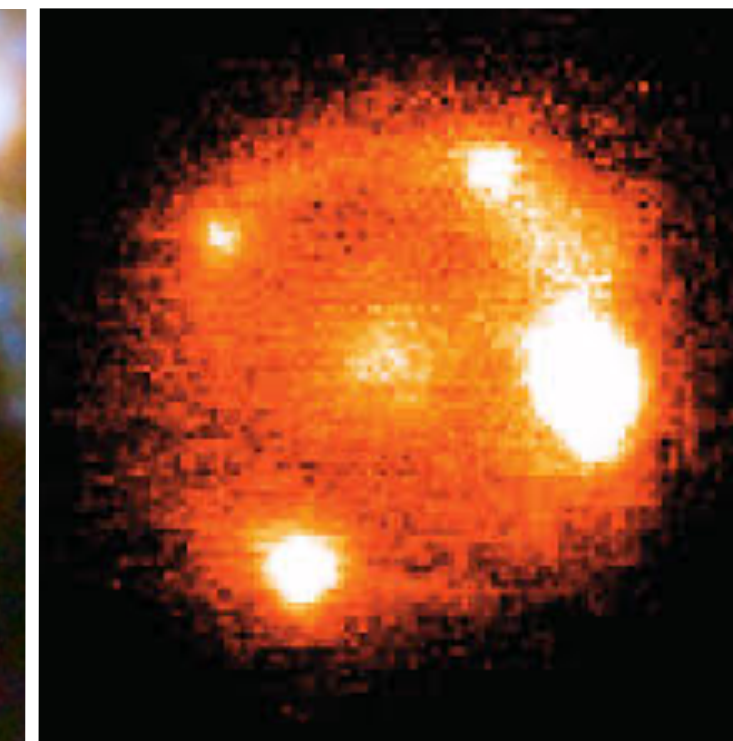
As of date: 3 discoveries

SN Refsdal



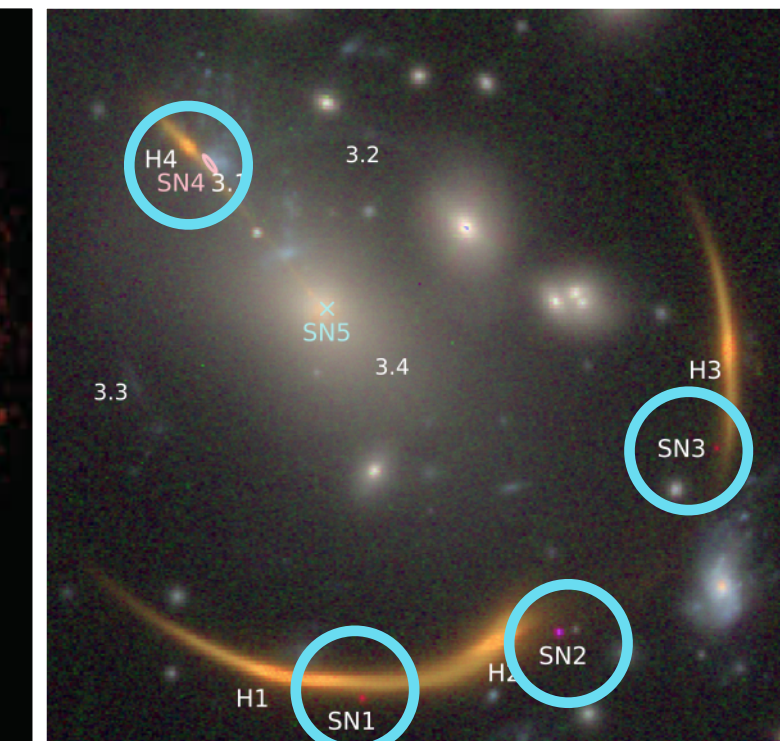
Kelly et al (2015)

iPTF16geu



Goobar et al (2017)

SN Requiem



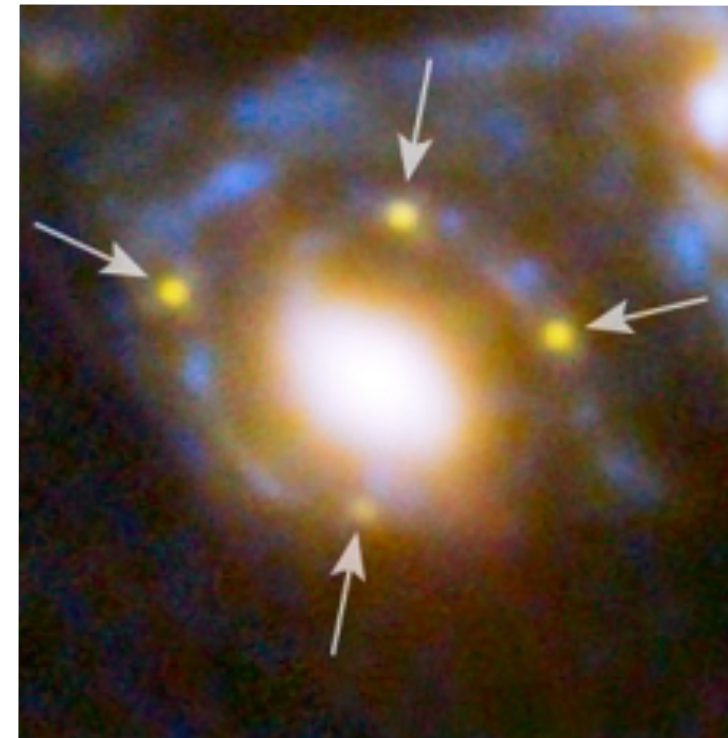
Rodney et al (2021)



# Gravitationally lensed **supernovae**

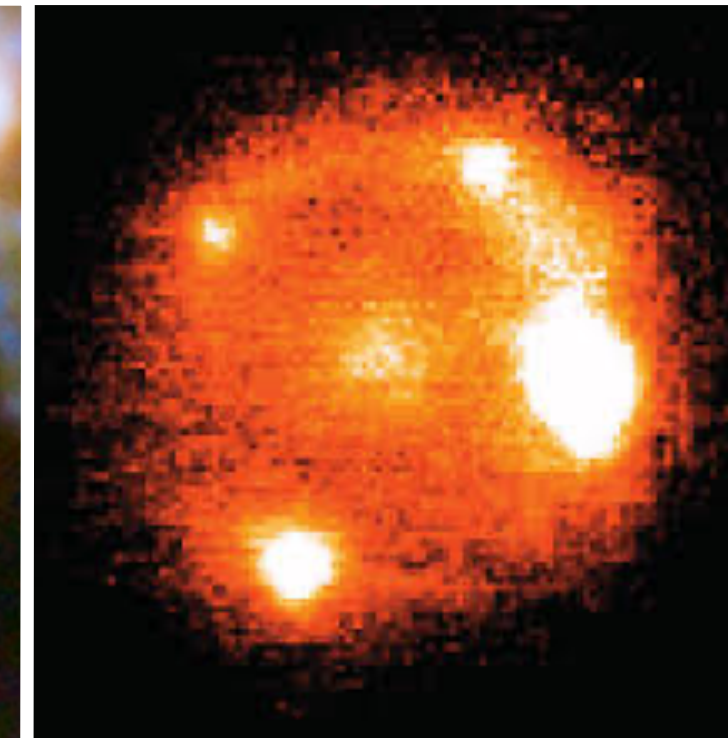
As of date: 3 discoveries

SN Refsdal



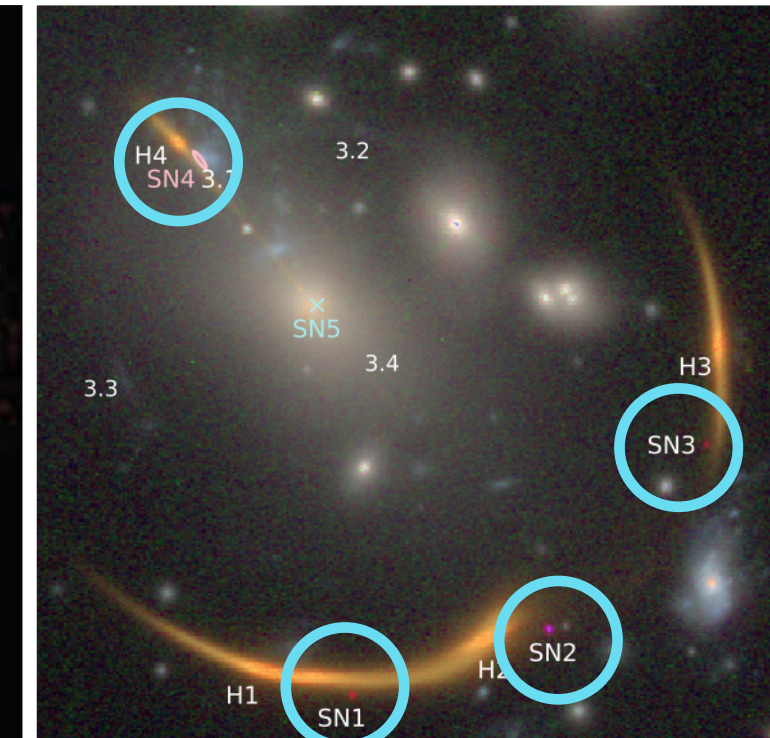
Kelly et al (2015)

iPTF16geu



Goobar et al (2017)

SN Requiem



Rodney et al (2021)



**VERA  
RUBIN  
OBSERVATORY  
(LSST)**

Expected yields per year:  
**89 Ia and 250 CC**

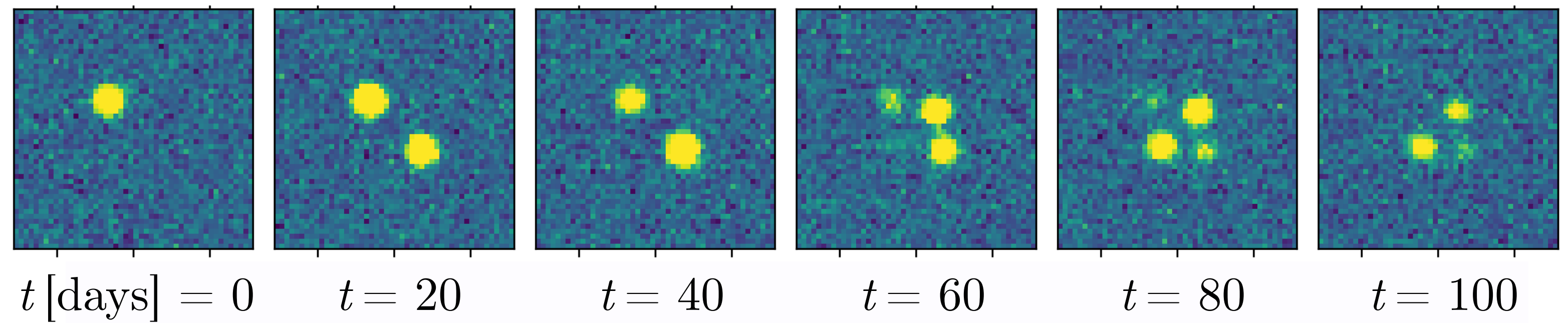
Wojtak et al (2019)



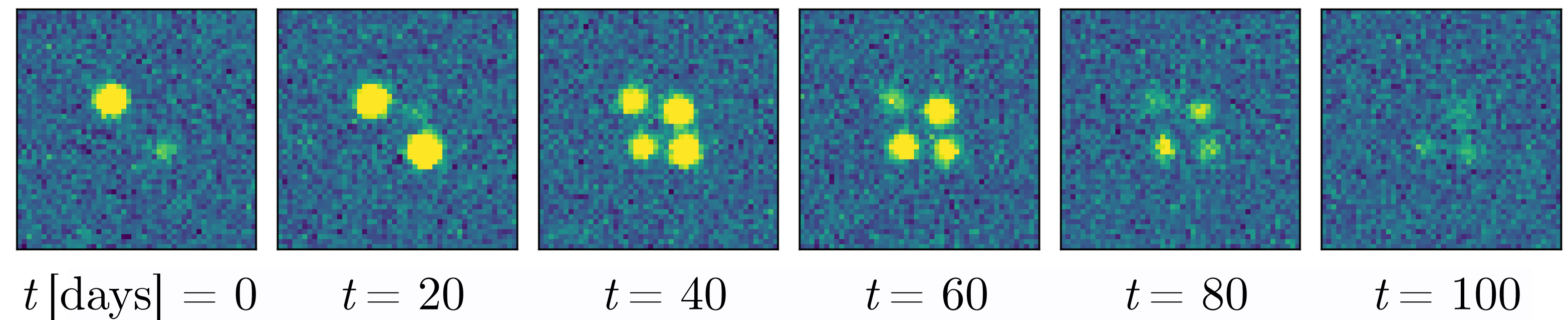
# Inferring $H_0$ from lensed supernovae

Simulated LSST-like lensed supernova difference images

$H_0 = 50 \text{ km/s/Mpc}$



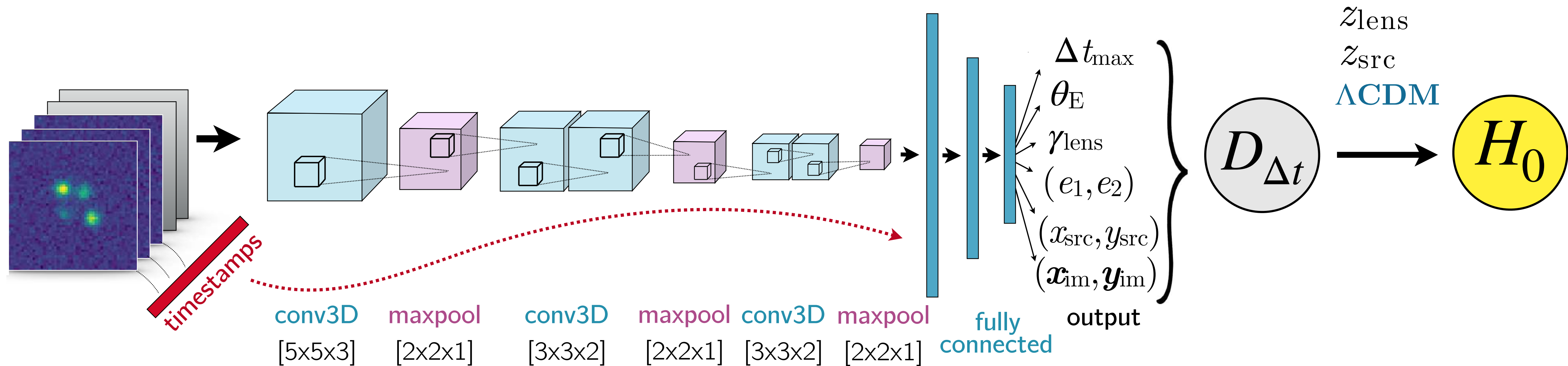
$H_0 = 90 \text{ km/s/Mpc}$





# Inferring $H_0$ from lensed supernovae

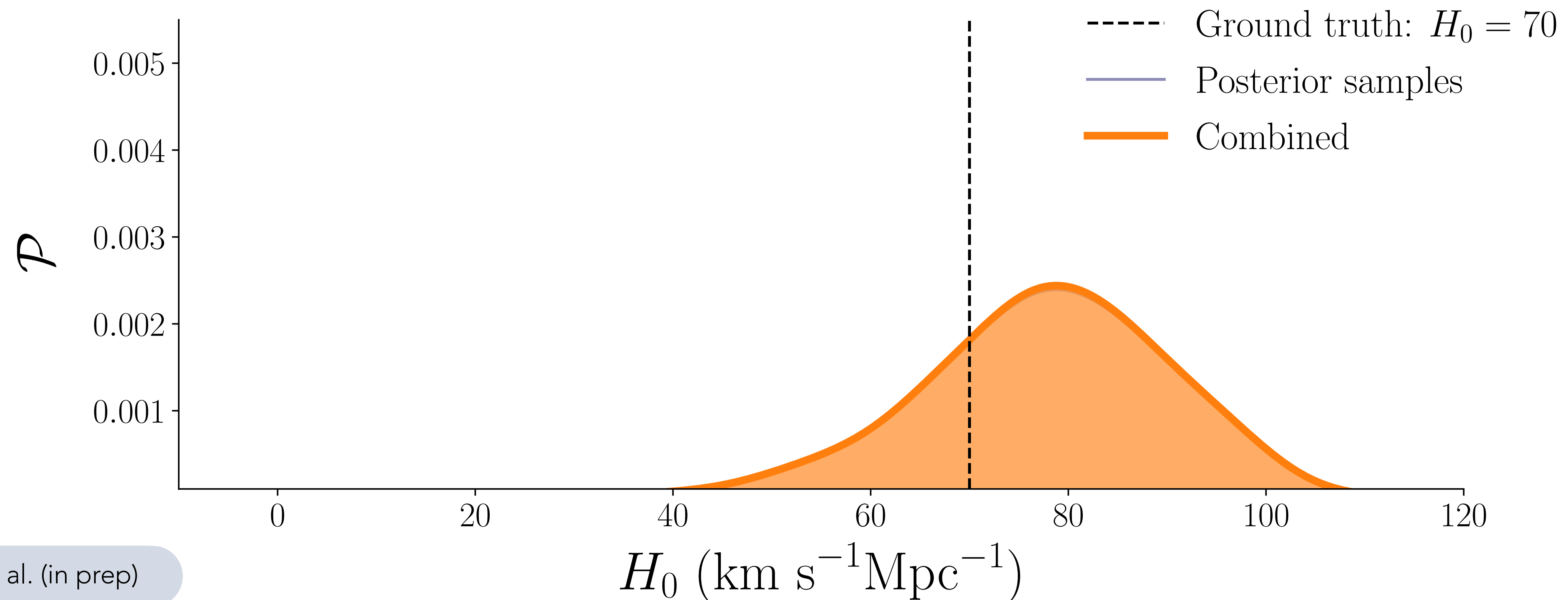
A 3D CNN extracts the lens parameters and time delays of the input data:





# Inferring $H_0$ from lensed supernovae

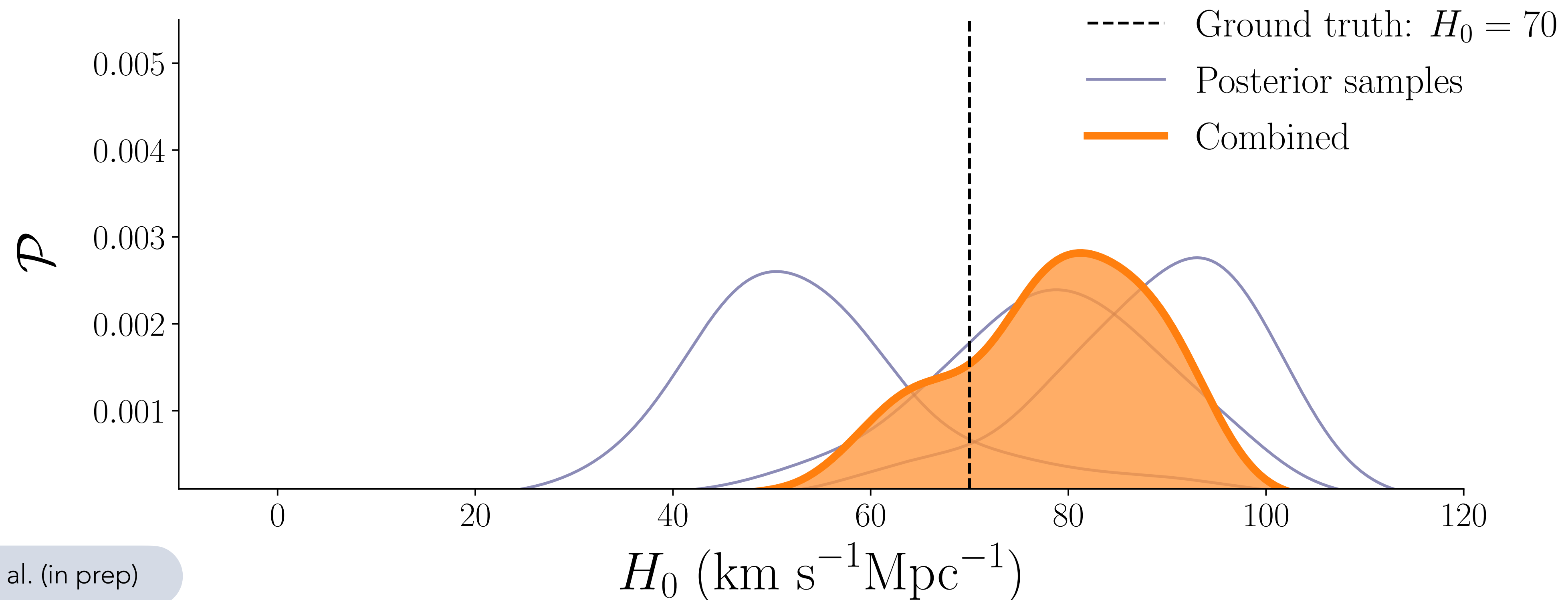
Preliminary: Joint analysis





# Inferring $H_0$ from lensed supernovae

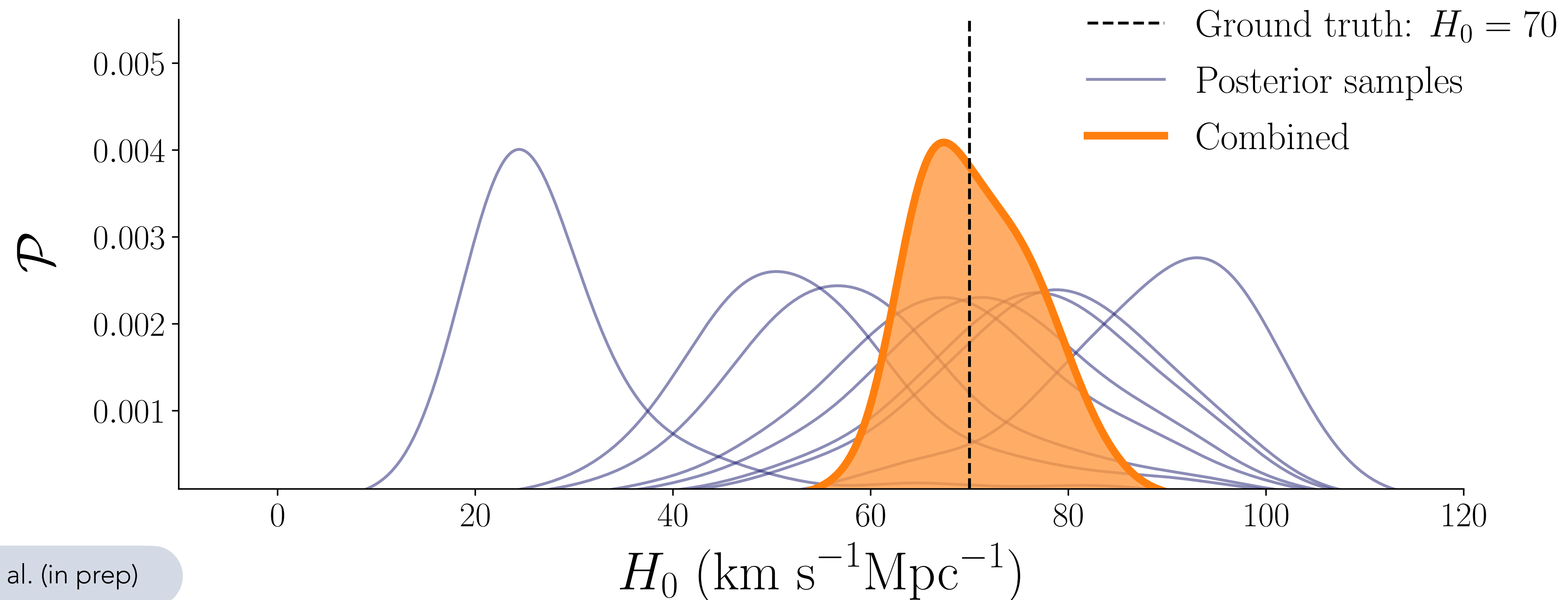
Preliminary: Joint analysis





# Inferring $H_0$ from lensed supernovae

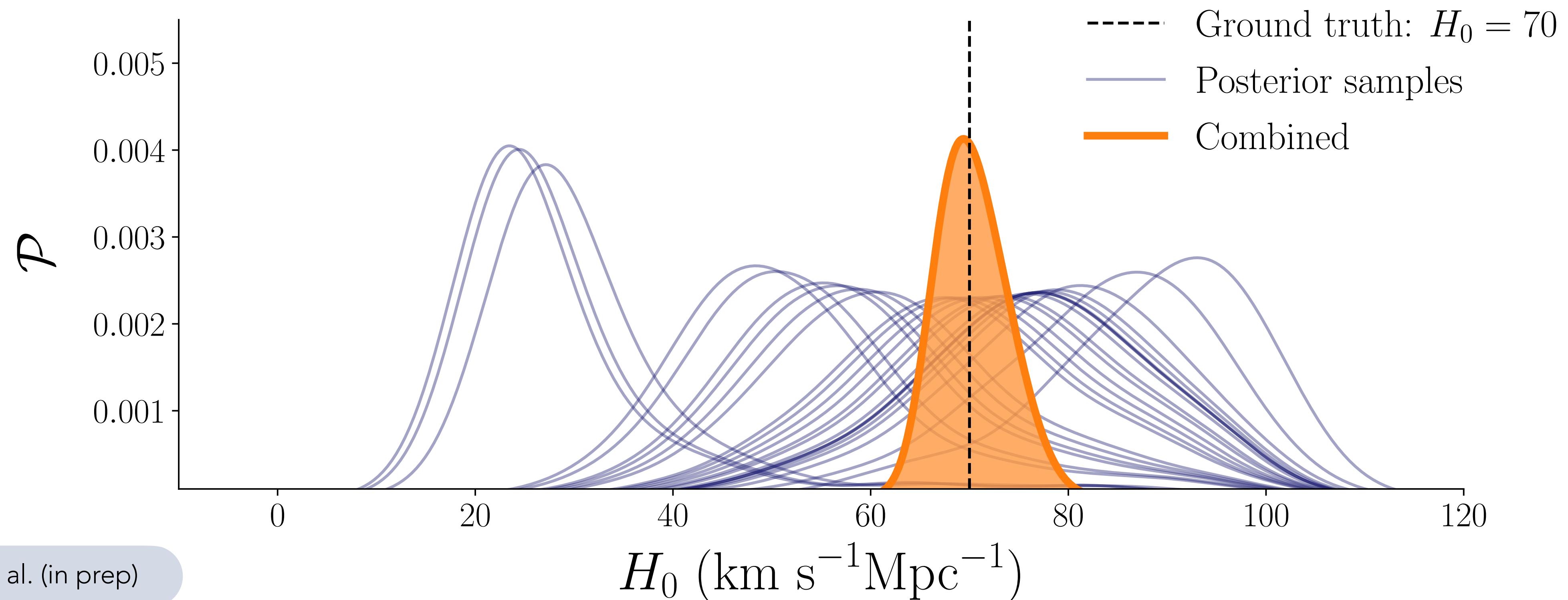
Preliminary: Joint analysis





# Inferring $H_0$ from lensed supernovae

Preliminary: Joint analysis





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Preliminary: Joint analysis

