The Dark Universe with the Subaru Telescope

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2025/11/17 Physics of the Two Infinities@U.Tokyo

https://subarutelescope.org/en/

Subaru Telescope

https://www.naoj.org/jp/

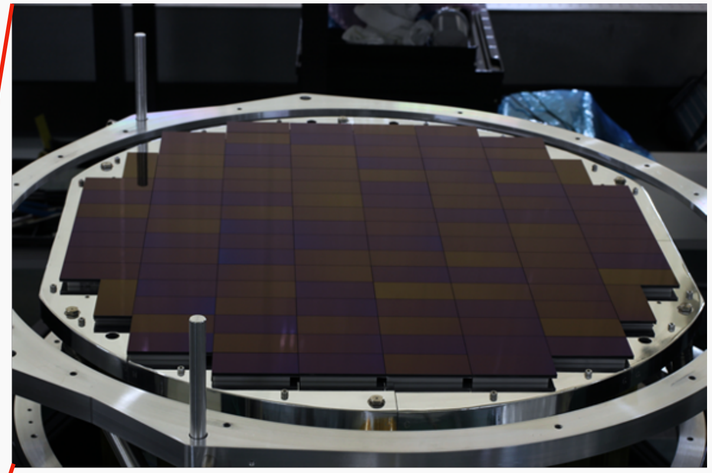
- 8.2-meter optical-infrared telescope at Mauna Kea, Hawaii
- operated by National Astronomical Observatory of Japan
- uniqueness: capability to mount large instruments at prime focus
  → **wide-field observations**

Hyper Suprime-Cam (HSC)

https://www.naoj.org/jp/

Subaru Telescope

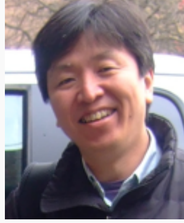
Hyper Suprime-Cam at prime focus



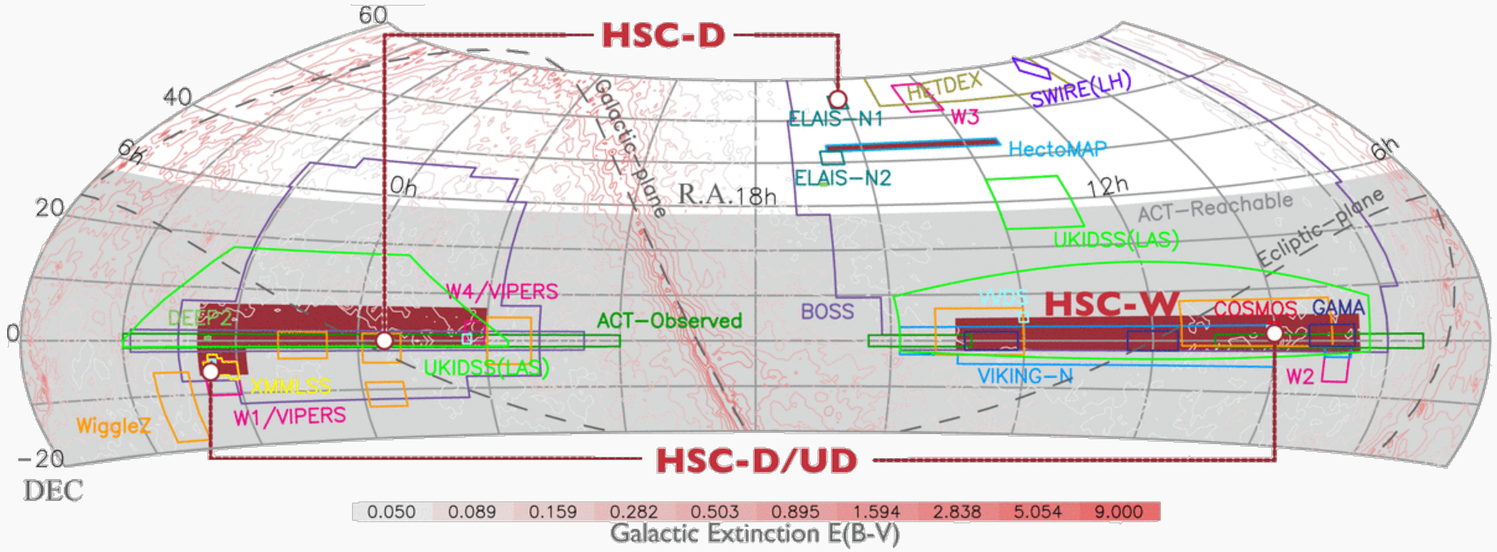
116 CCD
→ 0.9 billion pixels

most powerful imaging survey instrument in the world (before Rubin/LSST)

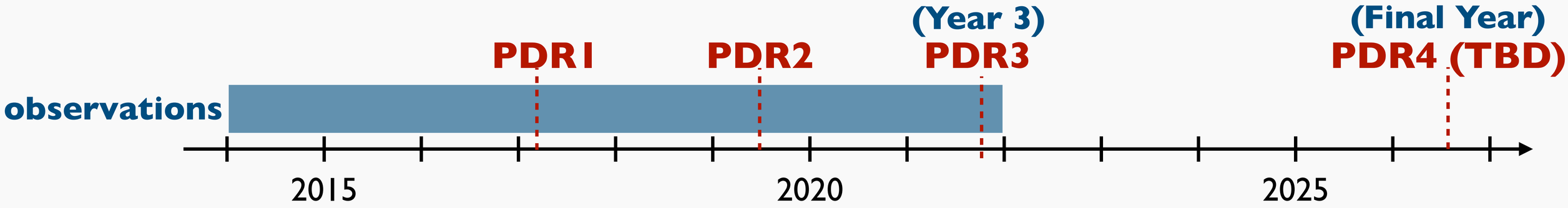
PI: Satoshi Miyazaki



HSC Subaru Strategic Program (HSC-SSP)

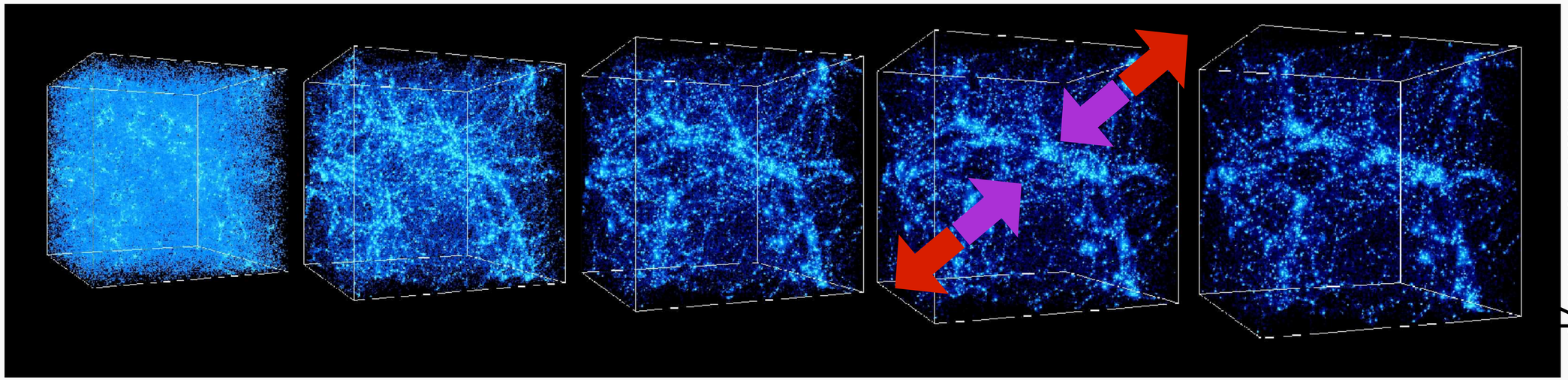


1400 deg² of sky
grizy-band
down to 26 mag



(currently analyzing the final year data within the collaboration)

Evolution of density fluctuations



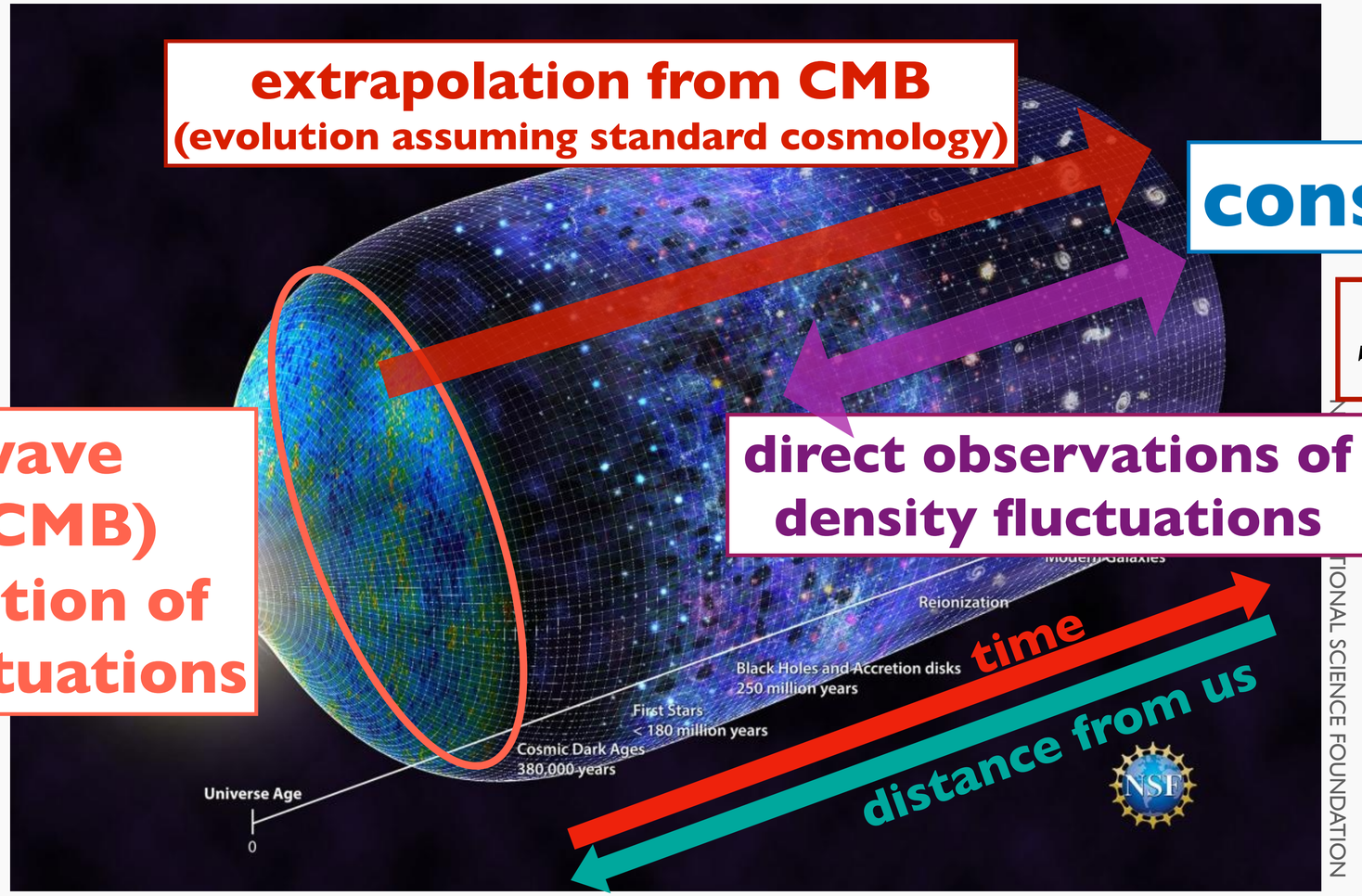
evolution equation
of density fluctuations

$$\delta \equiv \frac{\rho - \bar{\rho}}{\bar{\rho}}$$

$$\frac{d^2\delta}{dt^2} + \underbrace{2H}_{\text{cosmic expansion (dark energy?)}}\frac{d\delta}{dt} - \underbrace{4\pi G\bar{\rho}\delta}_{\text{gravitational attraction (modified gravity?)}} = 0$$

rich cosmological information!

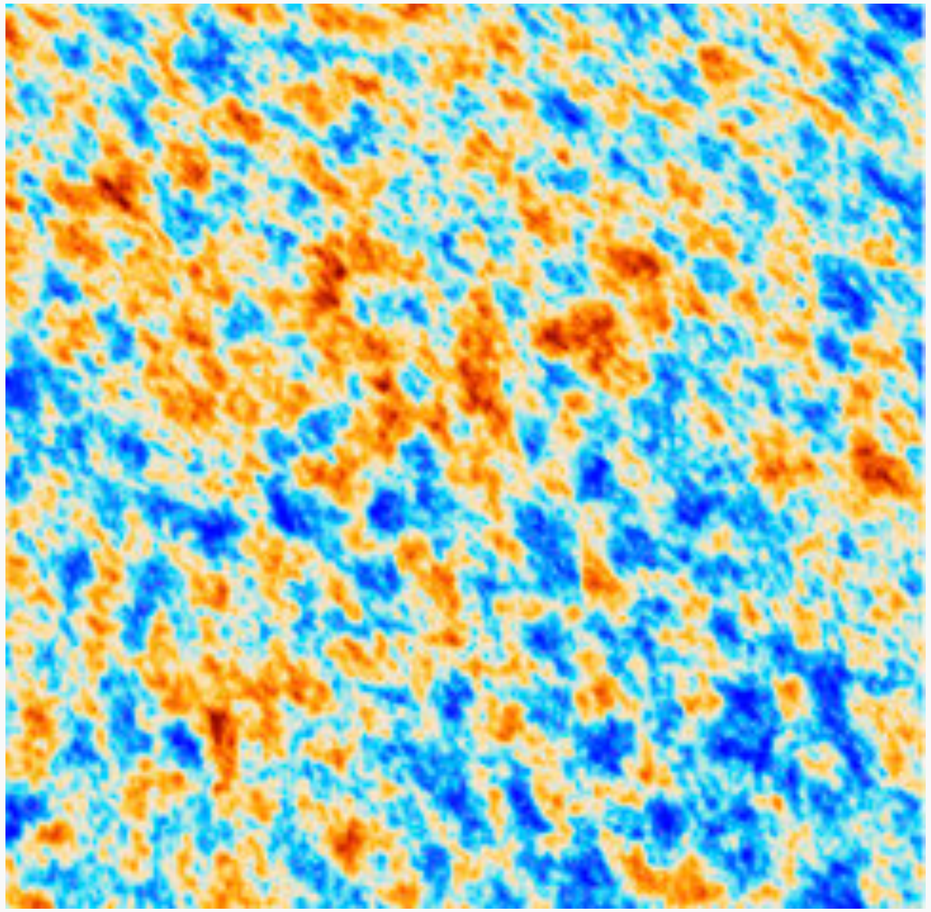
Specific focus: S_8 tension?



$$S_8 = \sigma_8(\Omega_m/0.3)^{0.5}$$

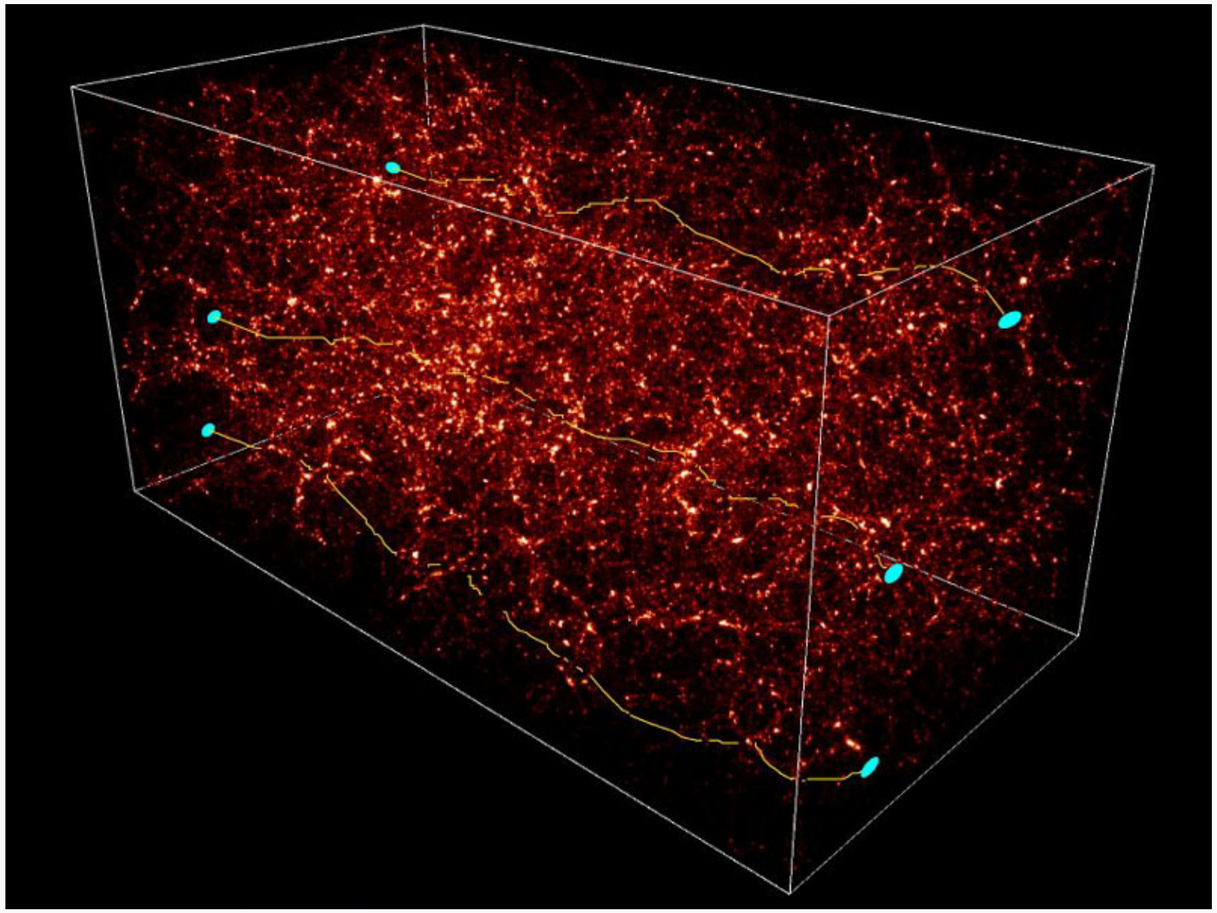
'lumpiness' of Universe at present

Measuring S_8 in two ways



EAS and the Planck collaboration

↓Subaru Telescope measures this



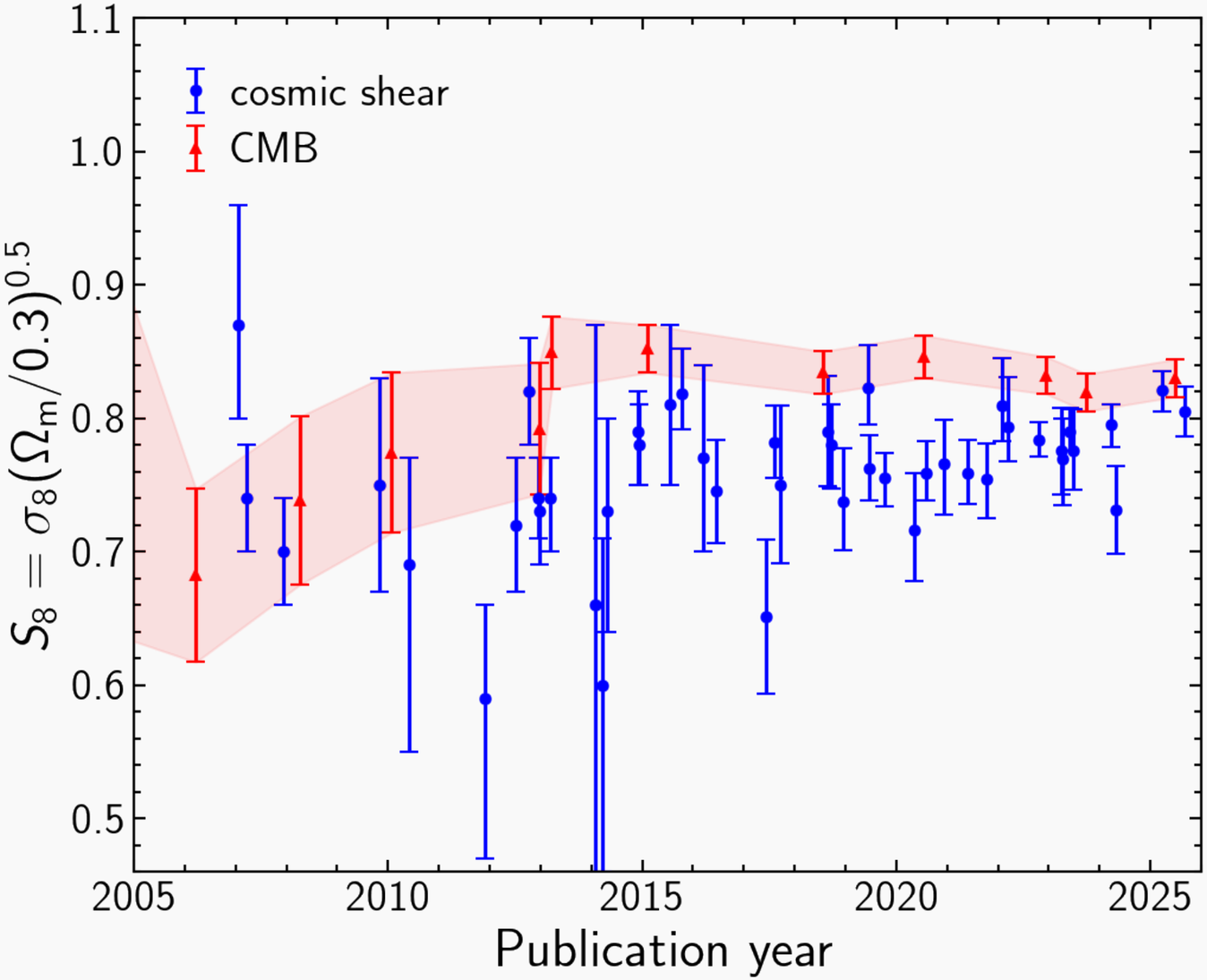
S. Colombi, CFHT Team

CMB $\frac{\Delta T}{T} \longrightarrow \Phi, \rho_{\mathrm{DM}} \xrightarrow[\text{extrapolate}]{} S_8$

cosmic shear galaxy shapes $\longrightarrow S_8$

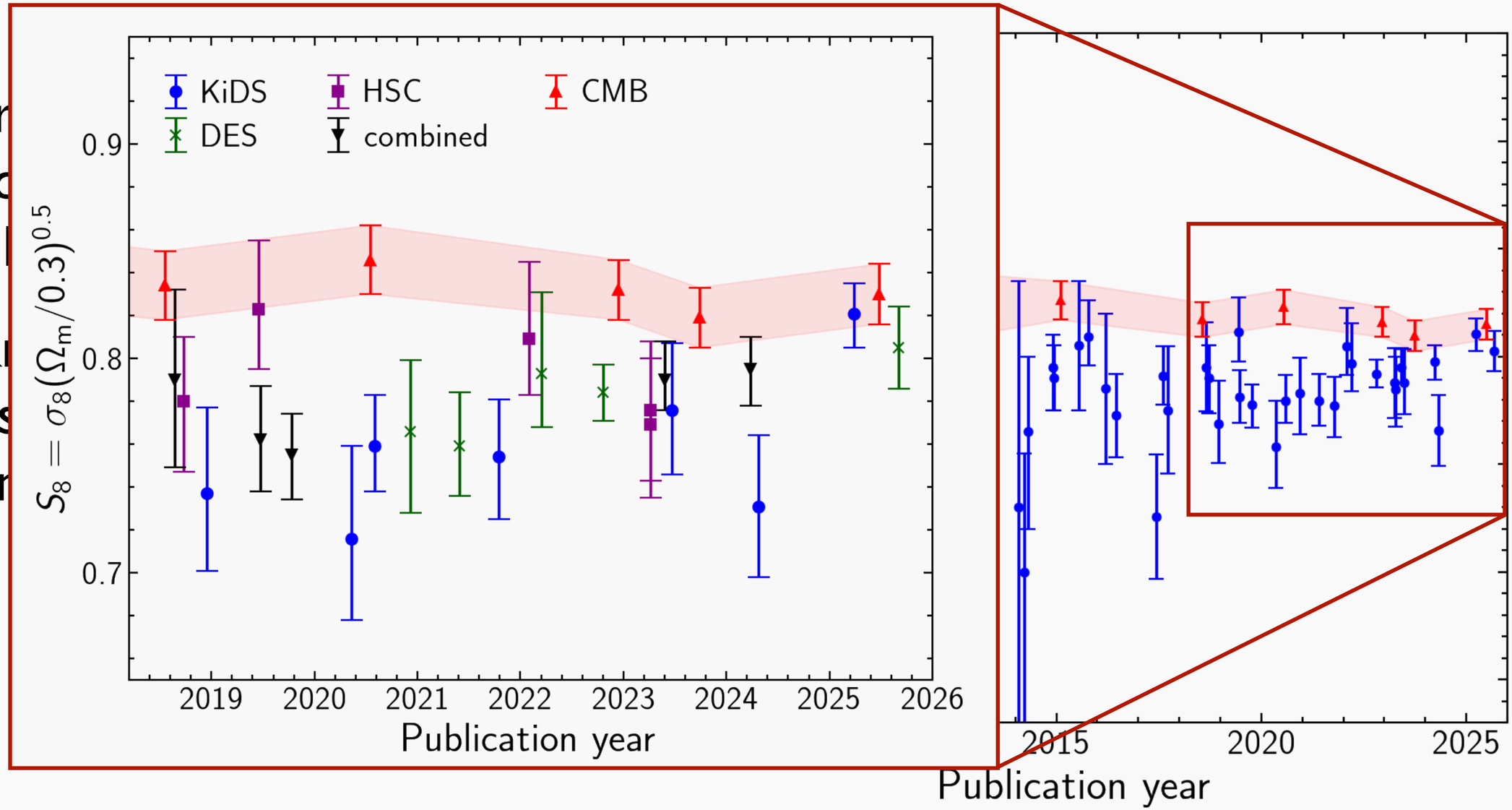
S_8 tension?

- S_8 from cosmic shear tends to be lower than CMB
- unknown systematics or physics beyond standard cosmological model?



S_8 tension?

- S_8 fr
  tenc
  CMI
- unkn
  phys
  cosr



S_8 tension?

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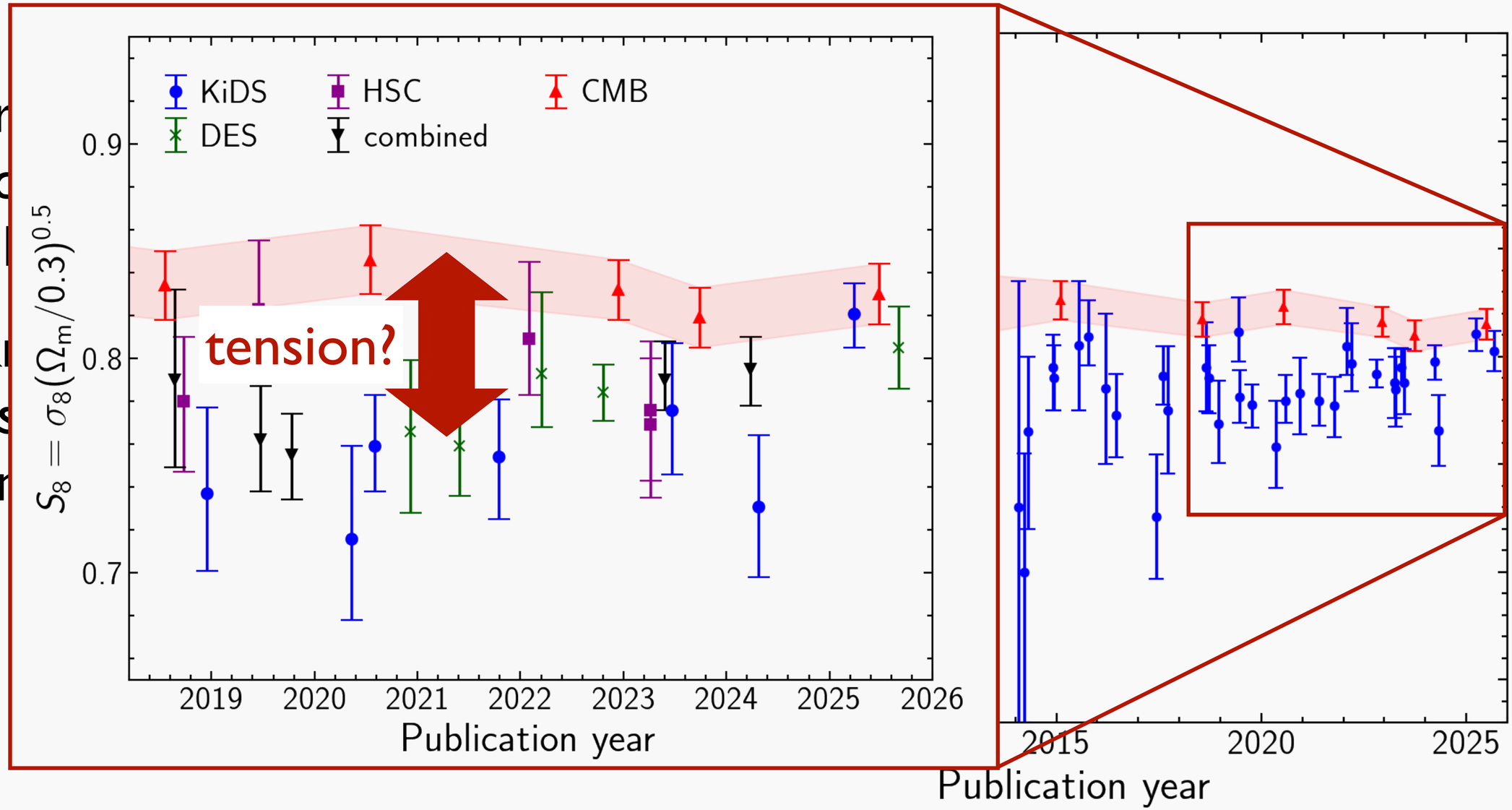

S_8 tension?

- S_8 fr
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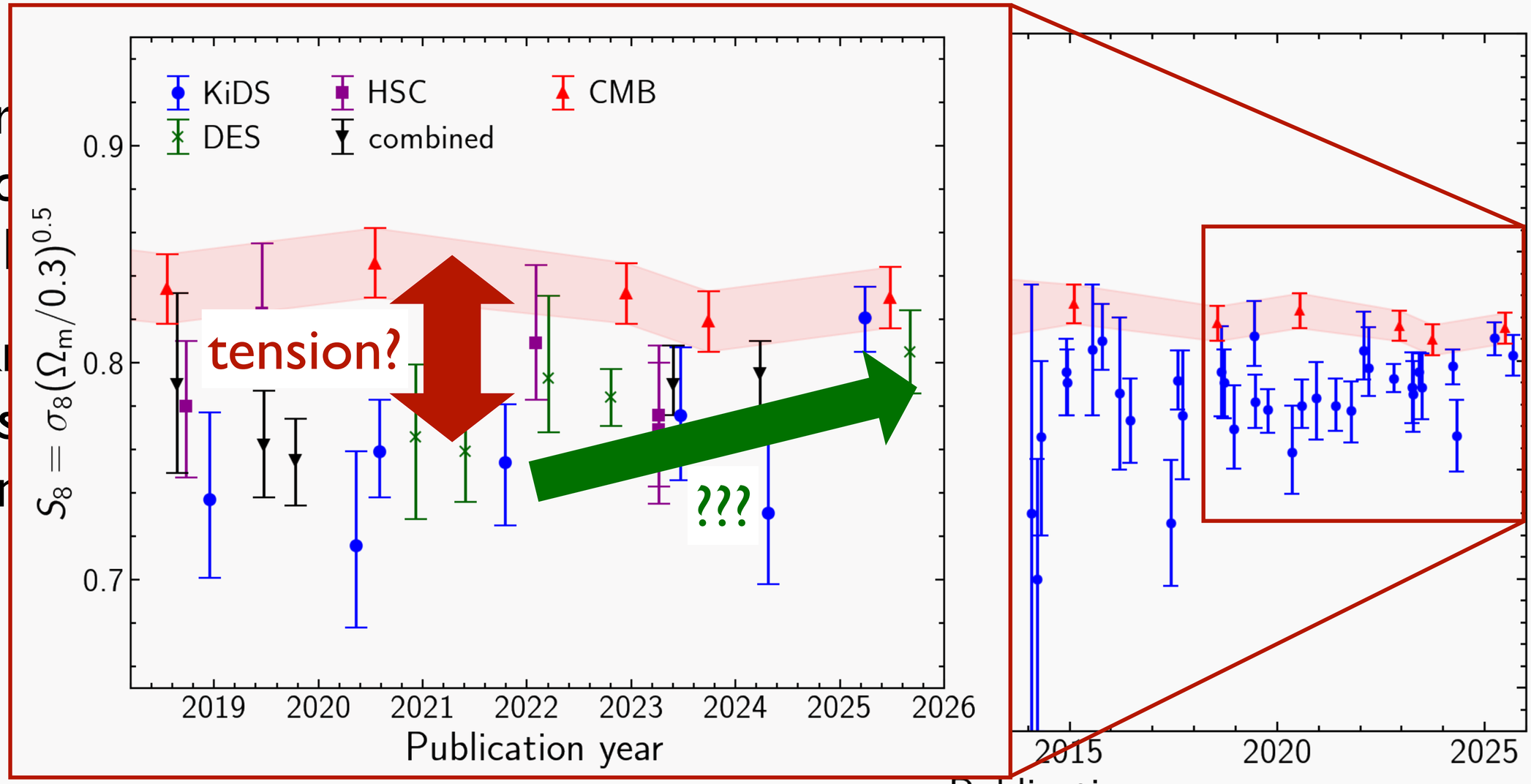
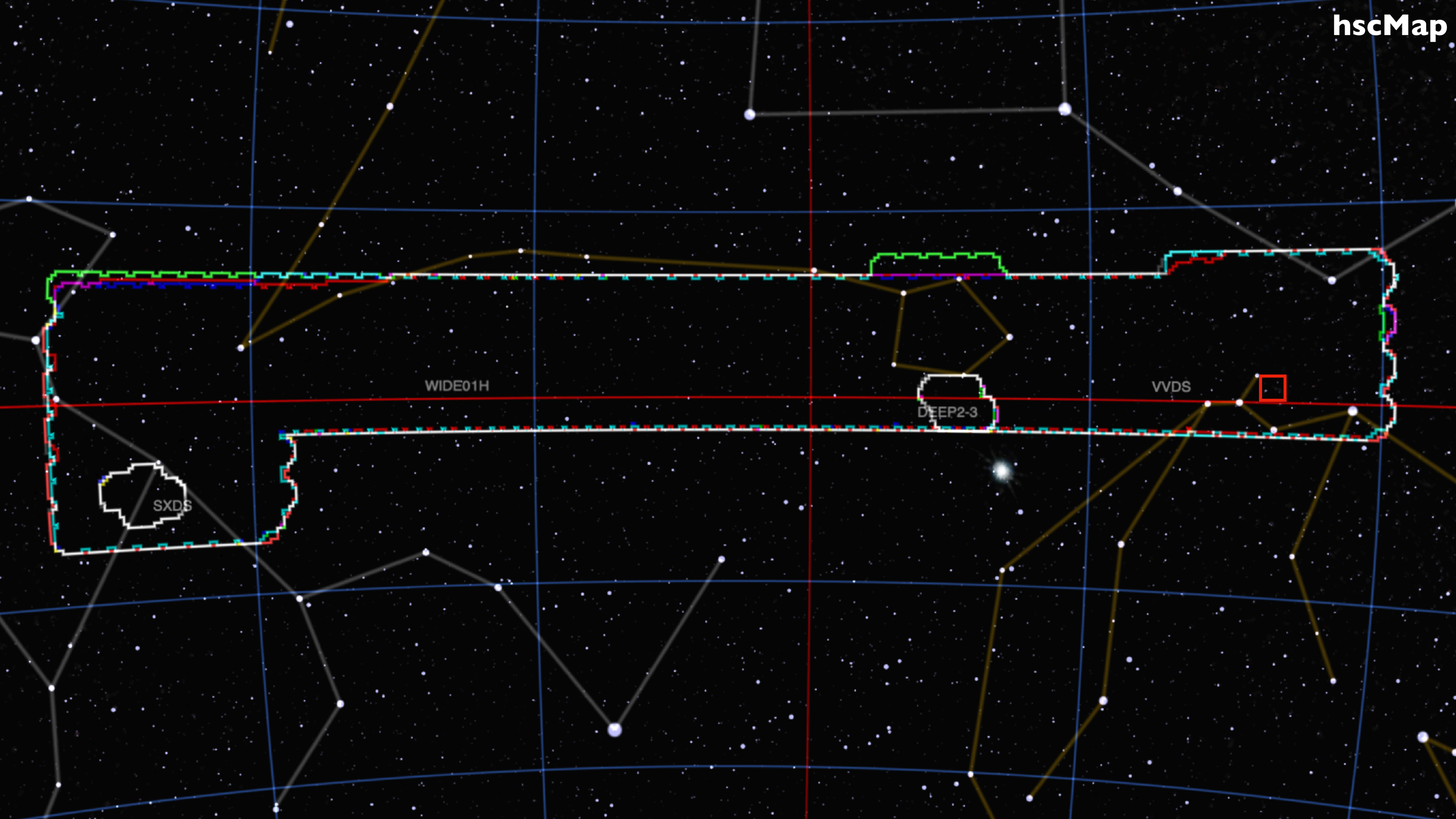
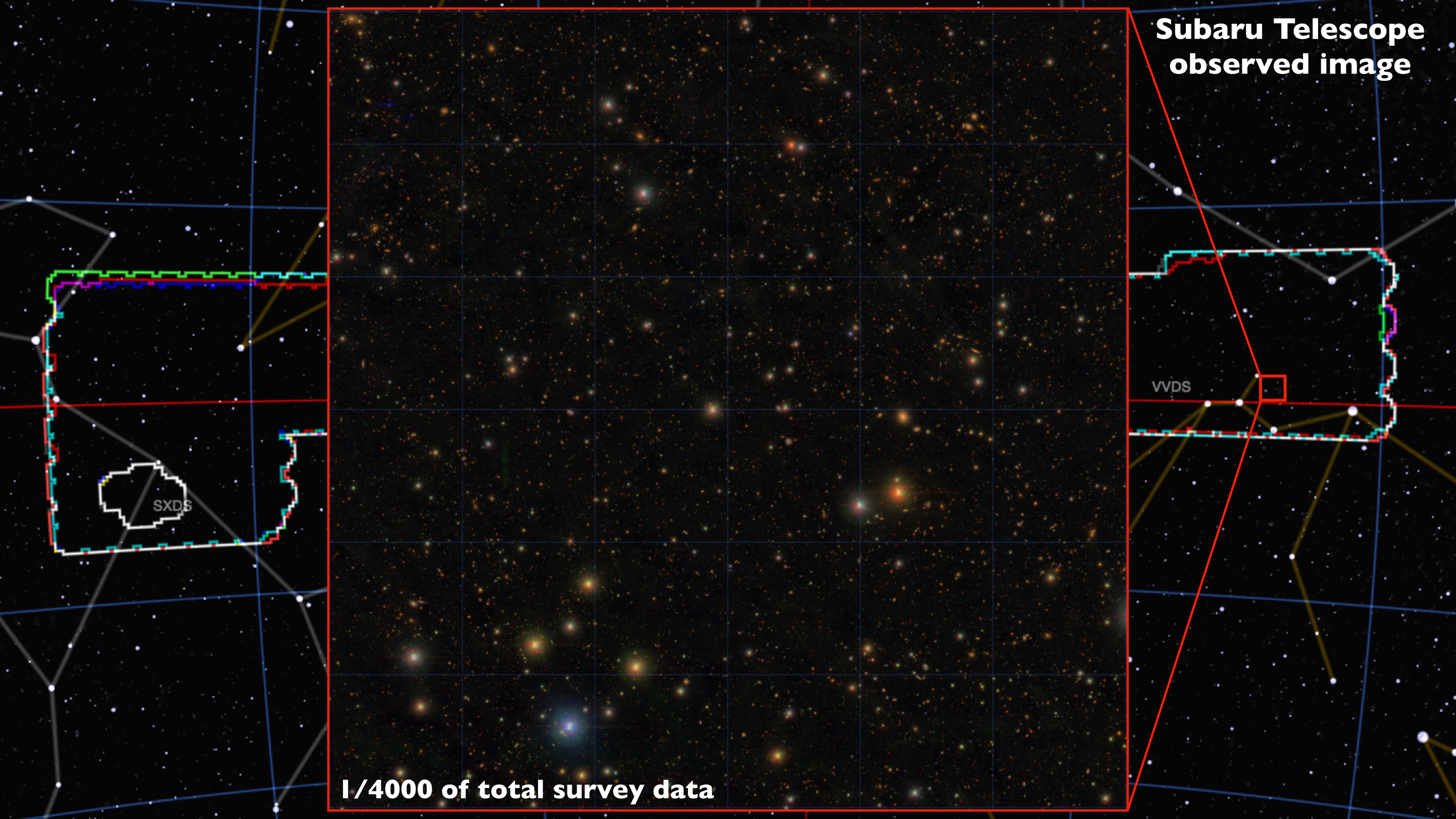
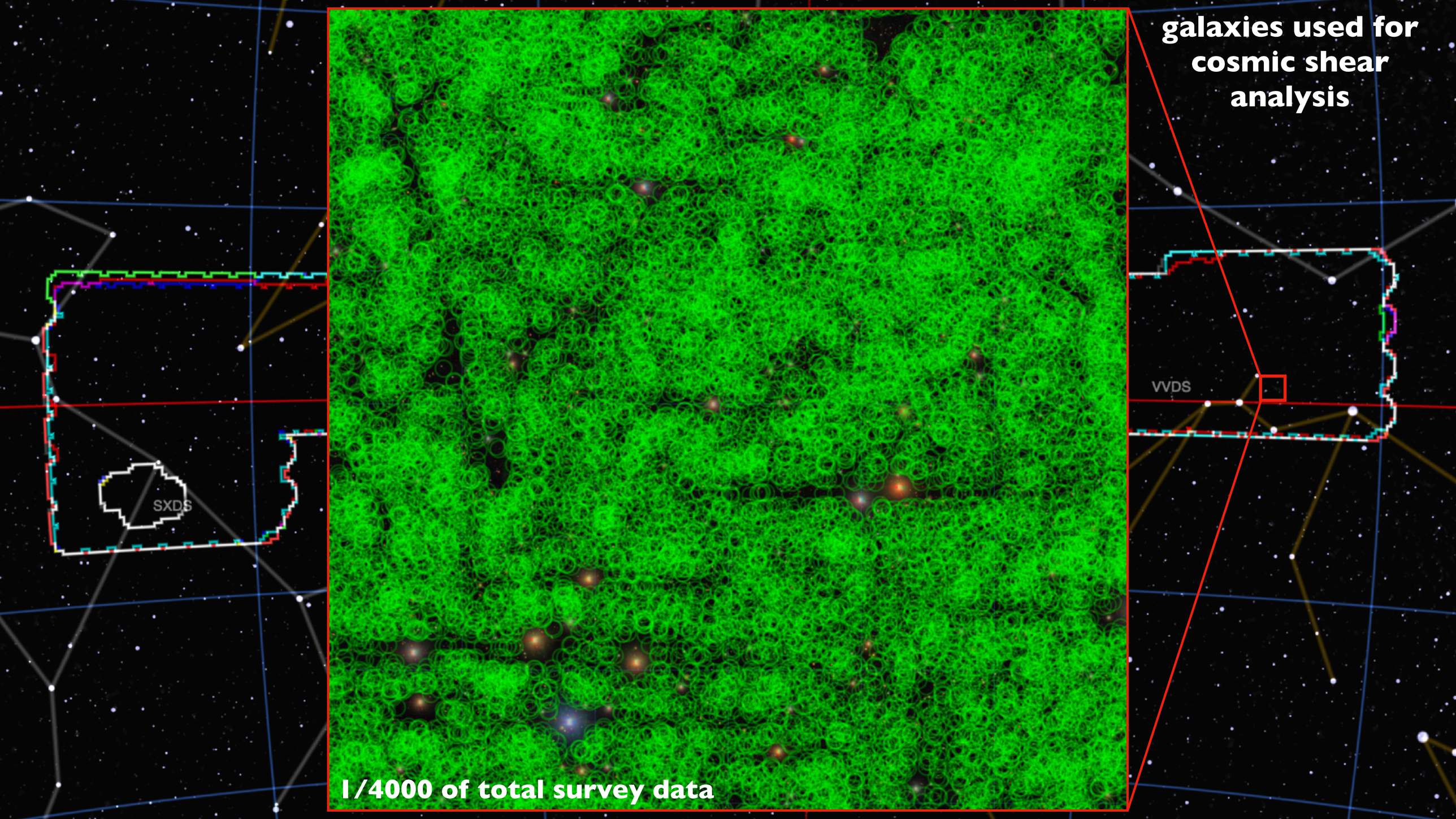
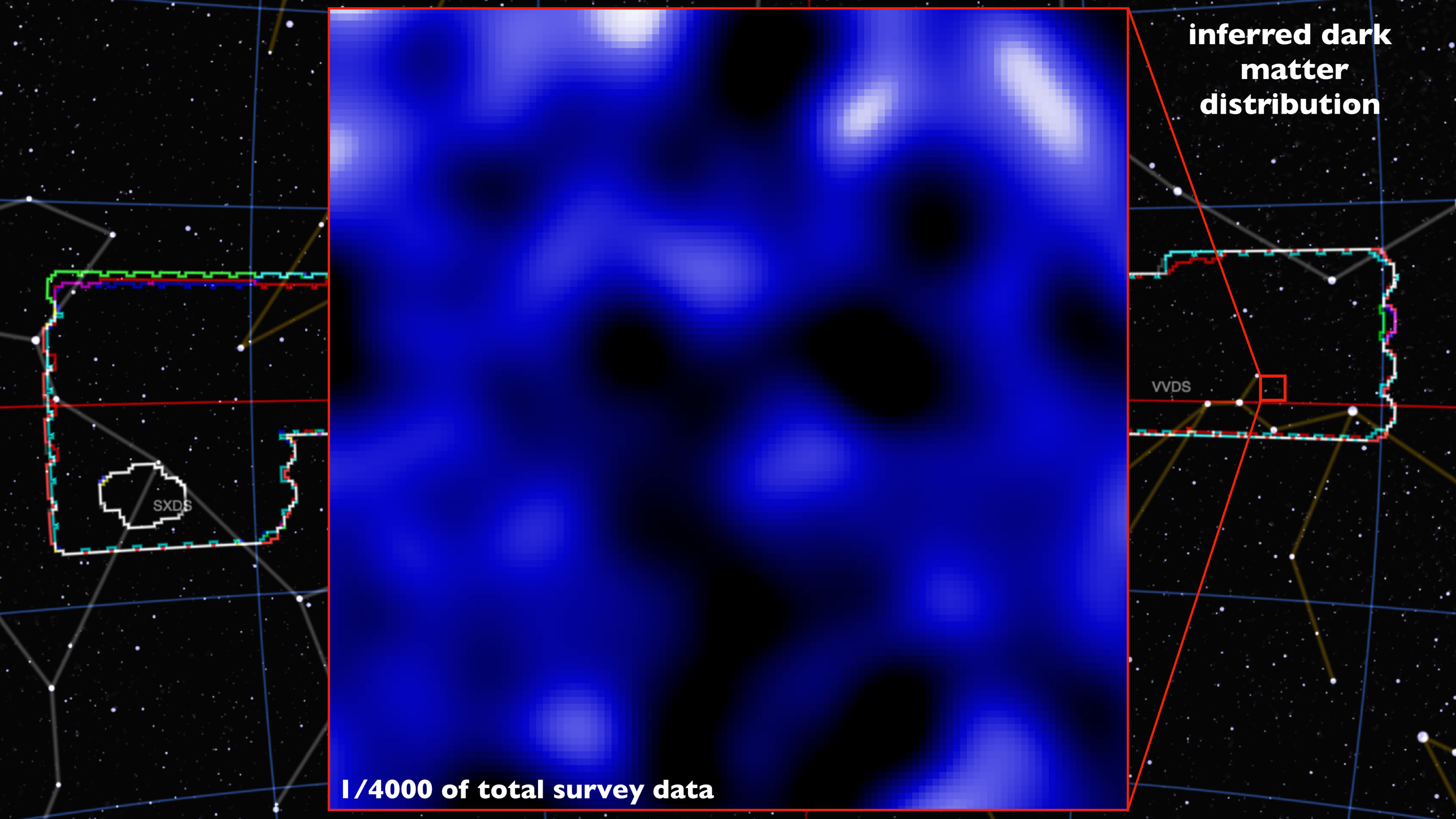


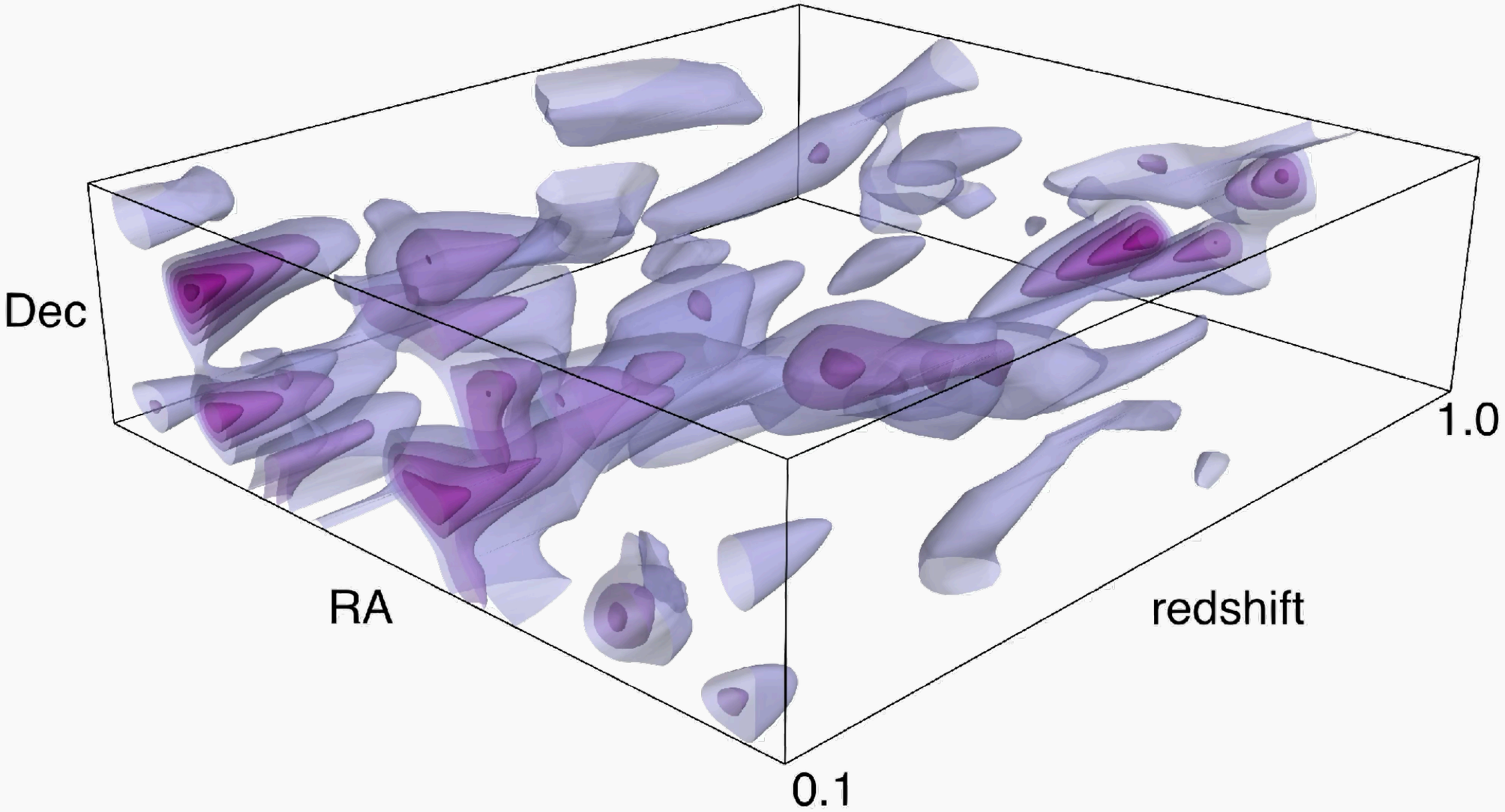

hscMap
WIDE01H
DEEP2-3
VVDS
SXDS


Subaru Telescope
observed image
SXDS
VVDS
1/4000 of total survey data

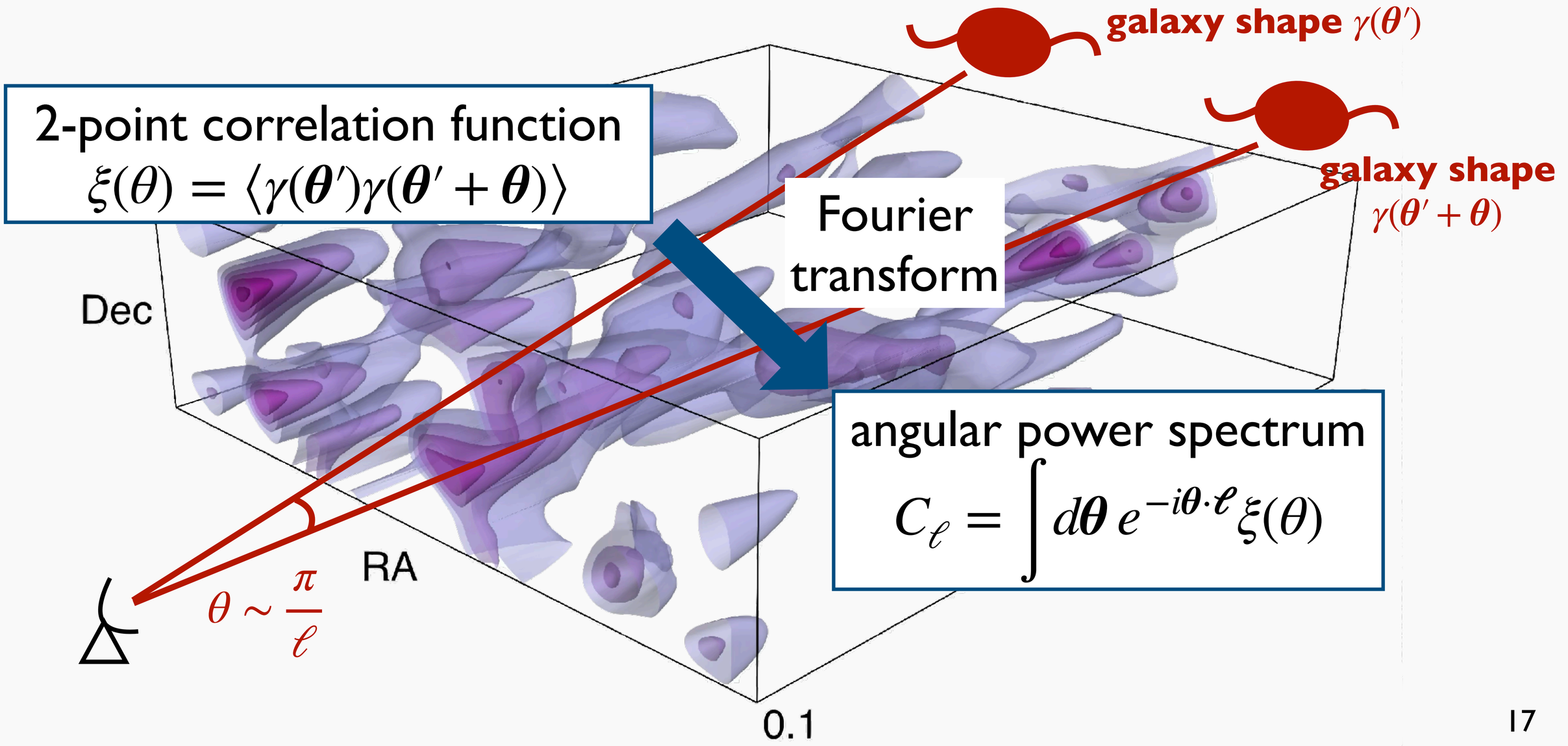

galaxies used for cosmic shear analysis
SXDS
VVDS
1/4000 of total survey data


inferred dark matter distribution
SXDS
VVDS
1/4000 of total survey data

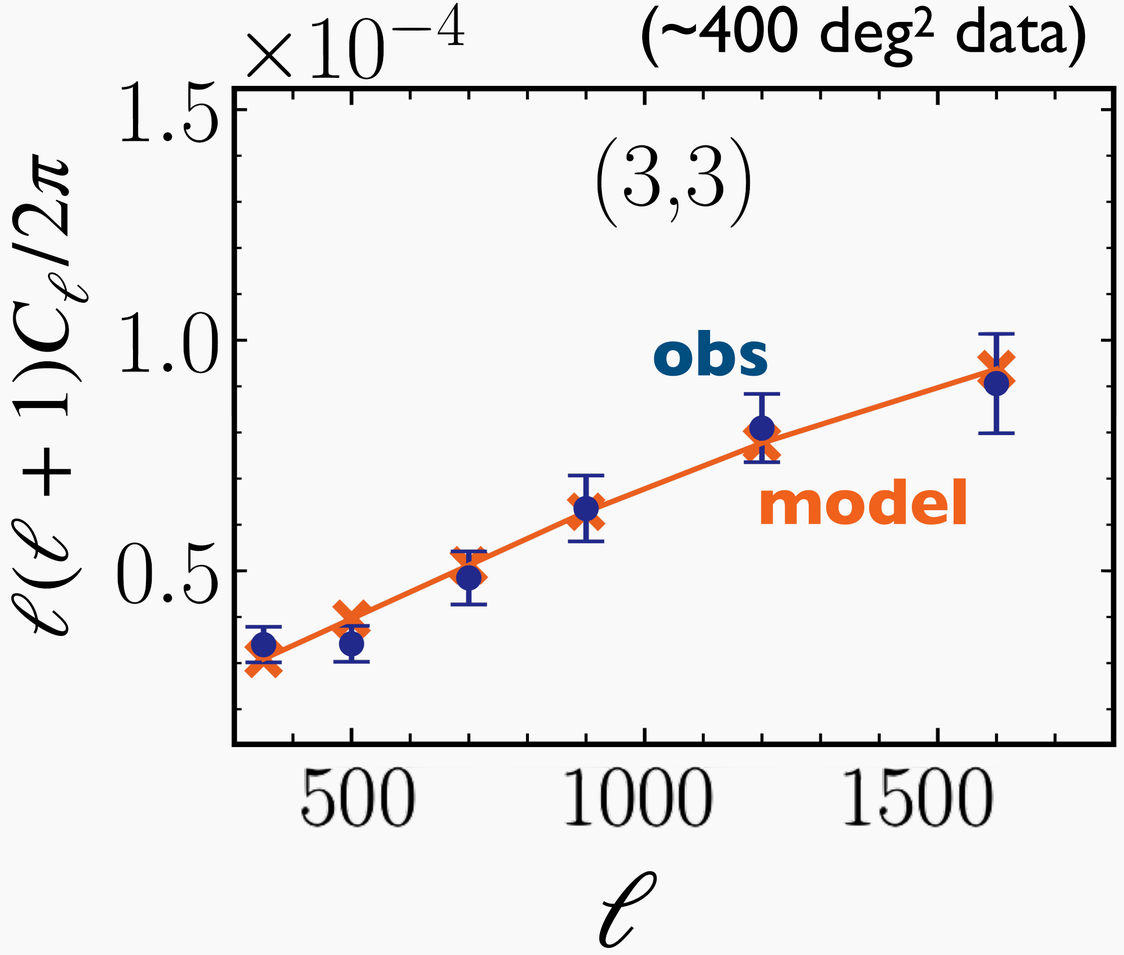
3D map of dark matter



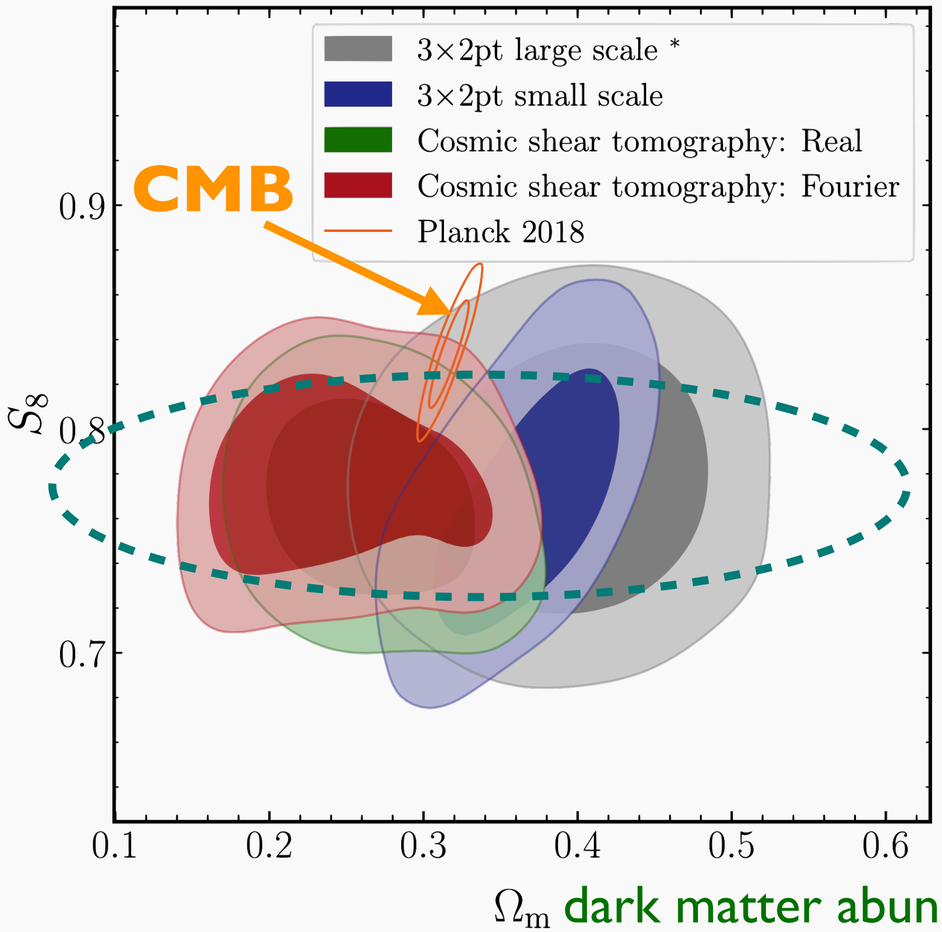
Quantifying density fluctuations



HSC-SSP Year 3 result



Dalal+ (incl. MO) PRD **108**(2023)123519

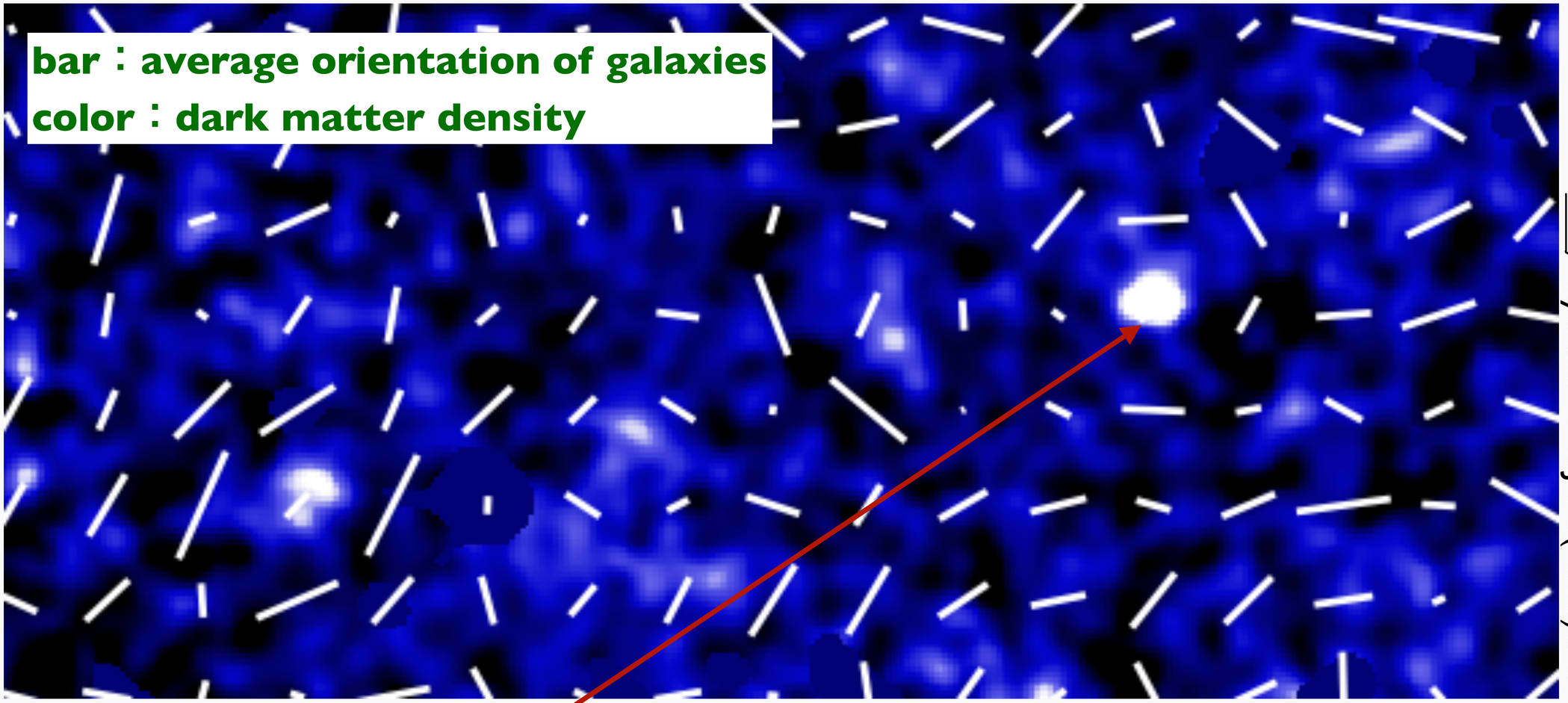


Sugiyama+
Miyatake+
Li+
Dalal+

cosmic shear

Miyatake+ (incl. MO) PRD **108**(2023)123517

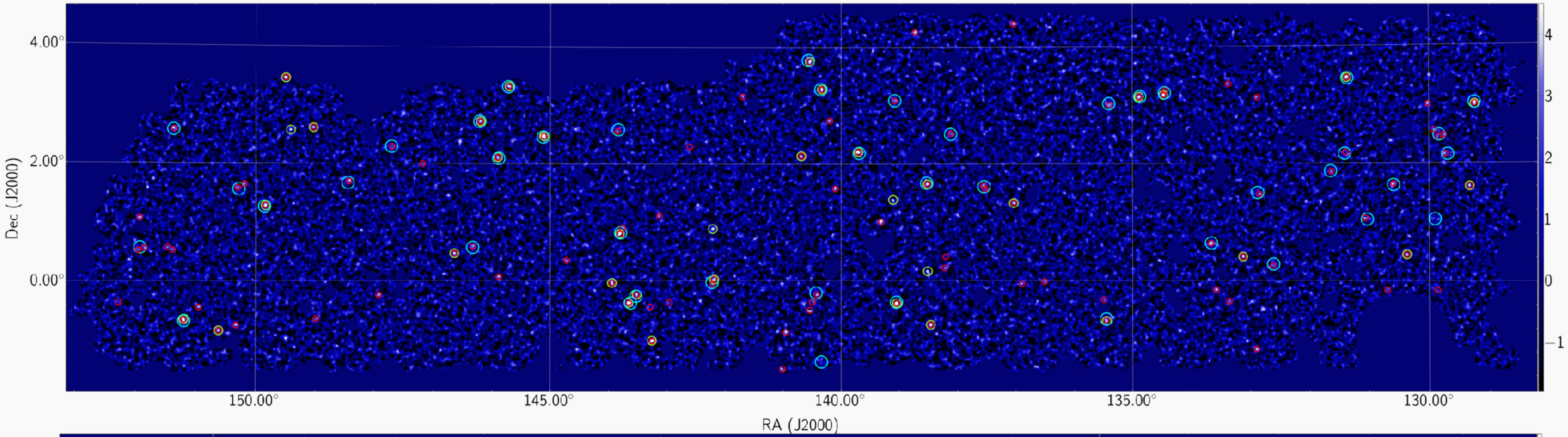
New approach: peaks in dark matter maps

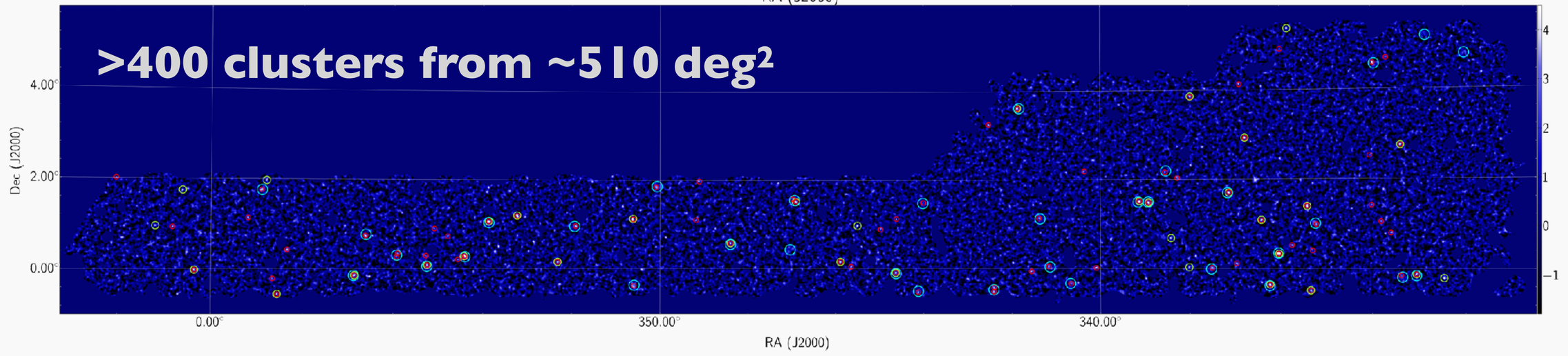


MO, Miyazaki+ PASJ **70**(2018)S26

peaks in dark matter map = clusters of galaxies

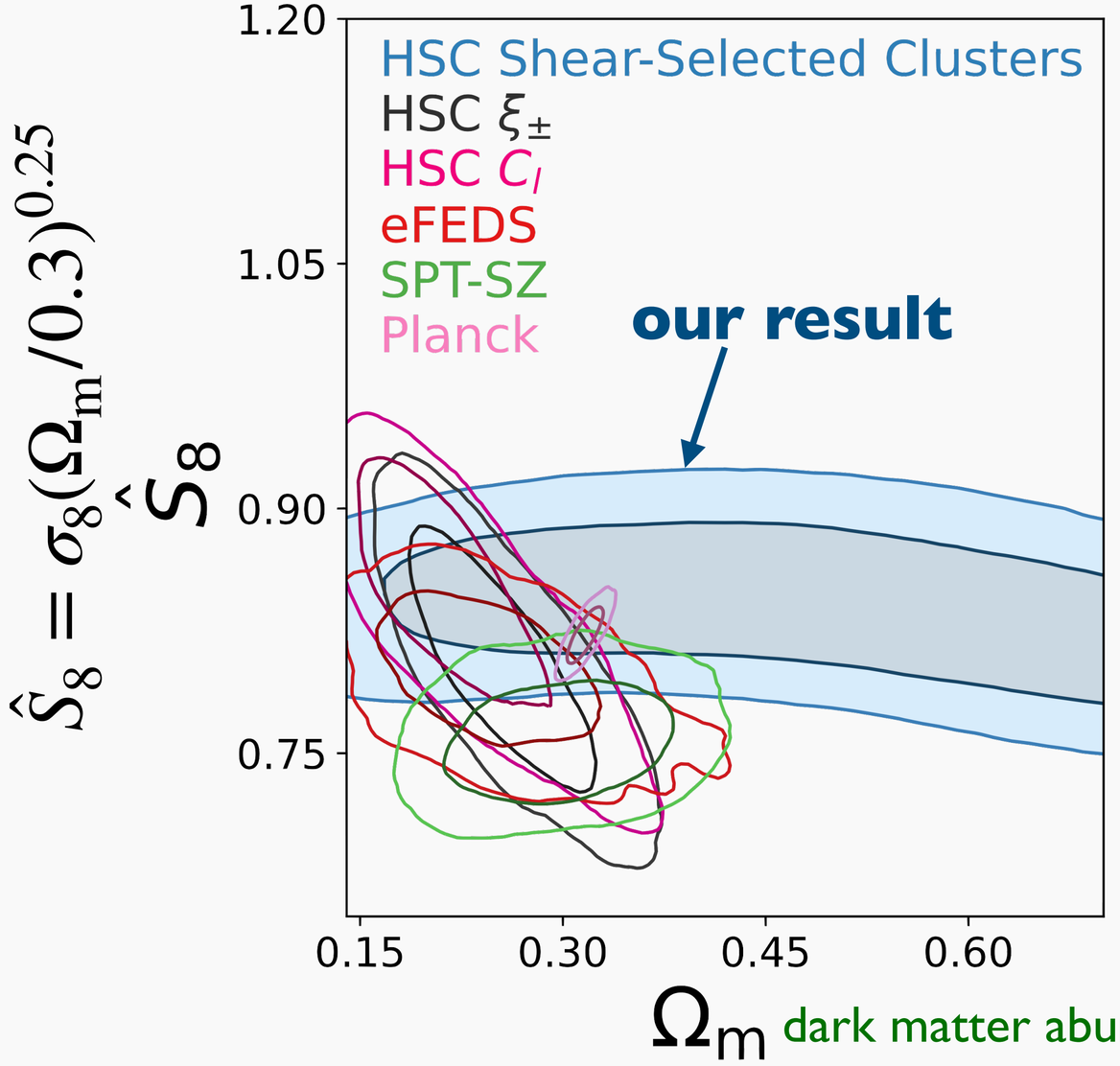
HSC Y3 shear-selected cluster search





Chiu, Chen, MO+ OJAp **7**(2024)90

HSC Y3 cosmological constraints



- brand new approach to constrain S_8 with shear-selected clusters
- intensive injection simulations in real dark matter maps to derive selection functions
- S_8 consistent with CMB
- new avenue of cosmological analysis that can be applied to future cosmological surveys

HSC final year analysis

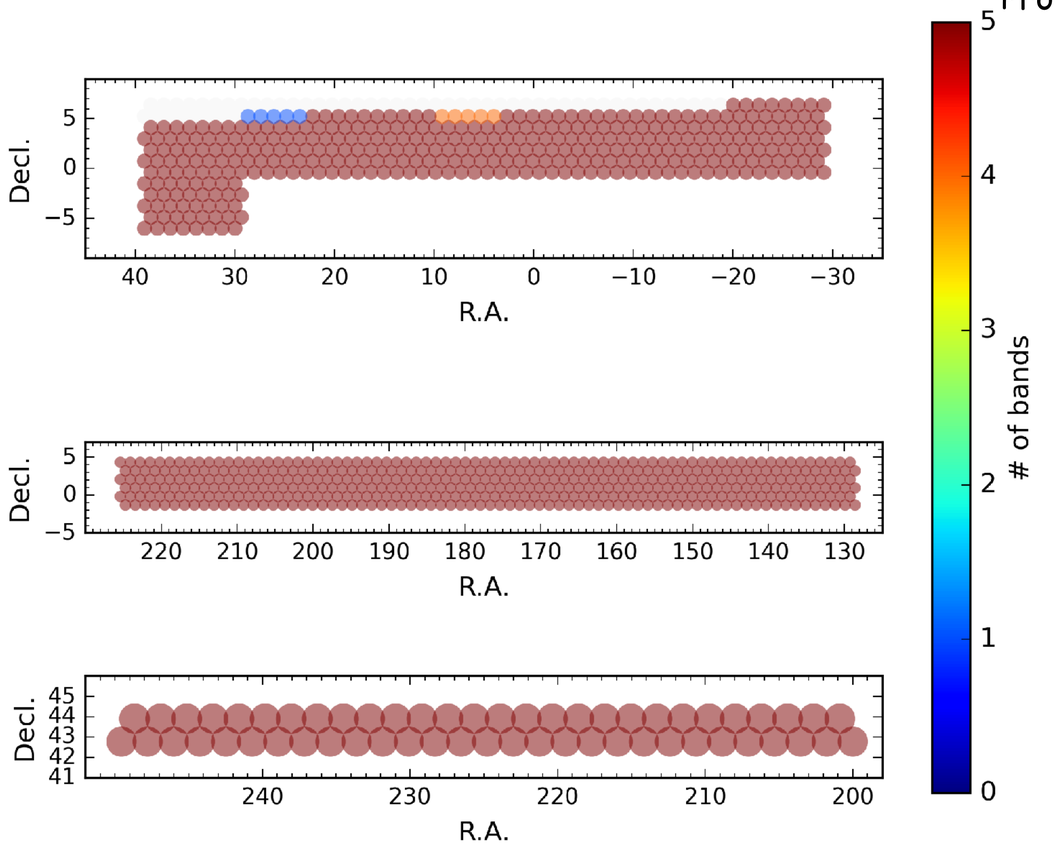
- released internally, active scientific analysis ongoing
- public release around mid-2026 (?)

slide by S. Miyazaki

Field Coverage (Wide)

Full depth area (5) Created at 2021-12-09 21:28:29

Prof. Yasuda

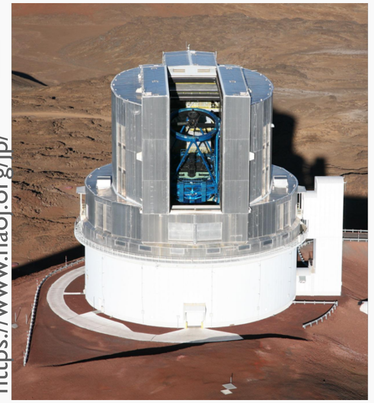


full-depth full-color 1086.8 deg2

Deep:27 deg^2
UD: 3.5 deg^2

Future: strong synergy with other missions

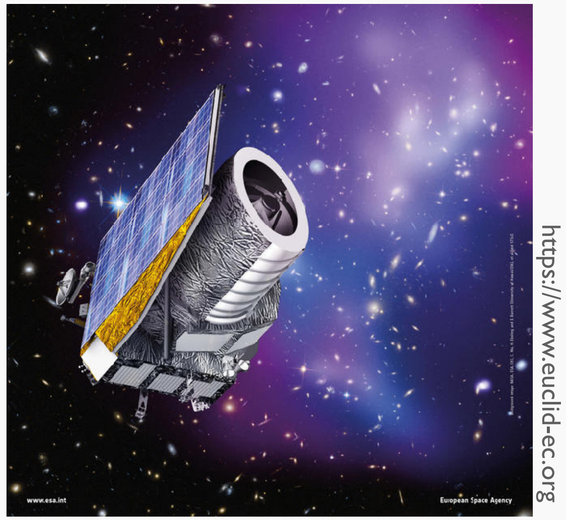
Subaru



https://www.naoj.org/jp/

synergetic HSC imaging
(WISHES/WHIGS/UNIONS)

Euclid Consortium
membership



https://www.euclid-ec.org

Euclid satellite

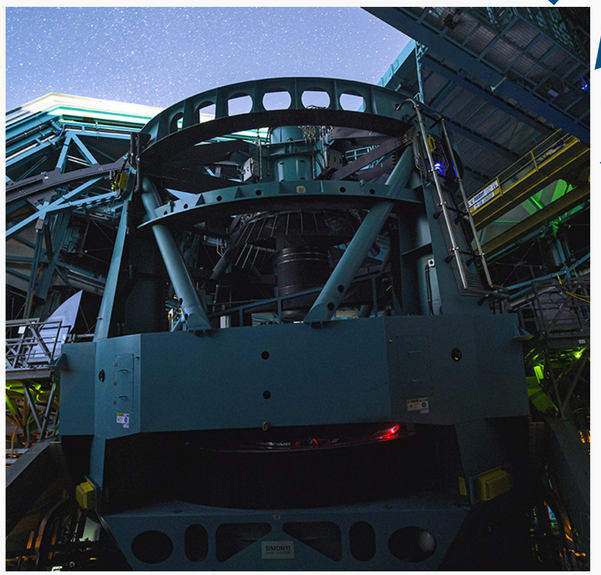
see talks by Francis Bernardeau, Linda Blot

see talk by Enya Van den Abeele

data access right

observing time

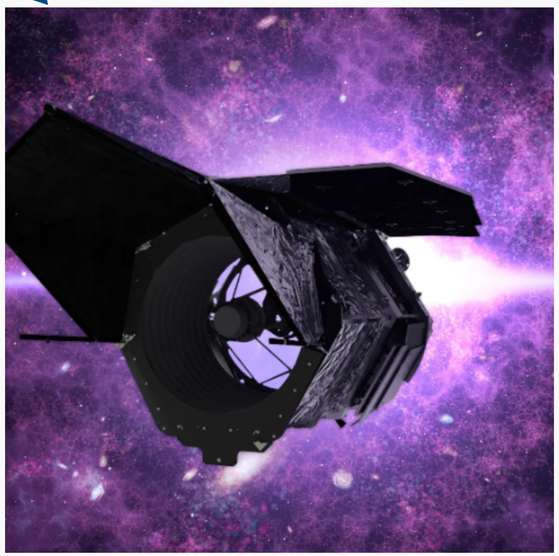
Rubin Observatory



https://www.nao.ac.jp/news/topics/2025/20250624-rubin.html

synergetic observations

right to join science activities



https://www.nasa.gov/news-release/nasa-telescope-named-for-mother-of-hubble-nancy-grace-roman/

Roman Space Telescope

Summary

- Subaru Telescope is a powerful telescope for cosmology
- with HSC-SSP imaging survey we can measure density fluctuations S_8 precisely and accurately using cosmic shear (weak lensing)
- HSC Y3 cosmology results show some hint of S_8 tension but not conclusive
- HSC final year cosmology analysis is ongoing
- (topic that I didn't cover today: Prime Focus Spectrograph (PFS) survey just started!)