Mapping the Dark Matter Universe with CSST

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In the Age of AI

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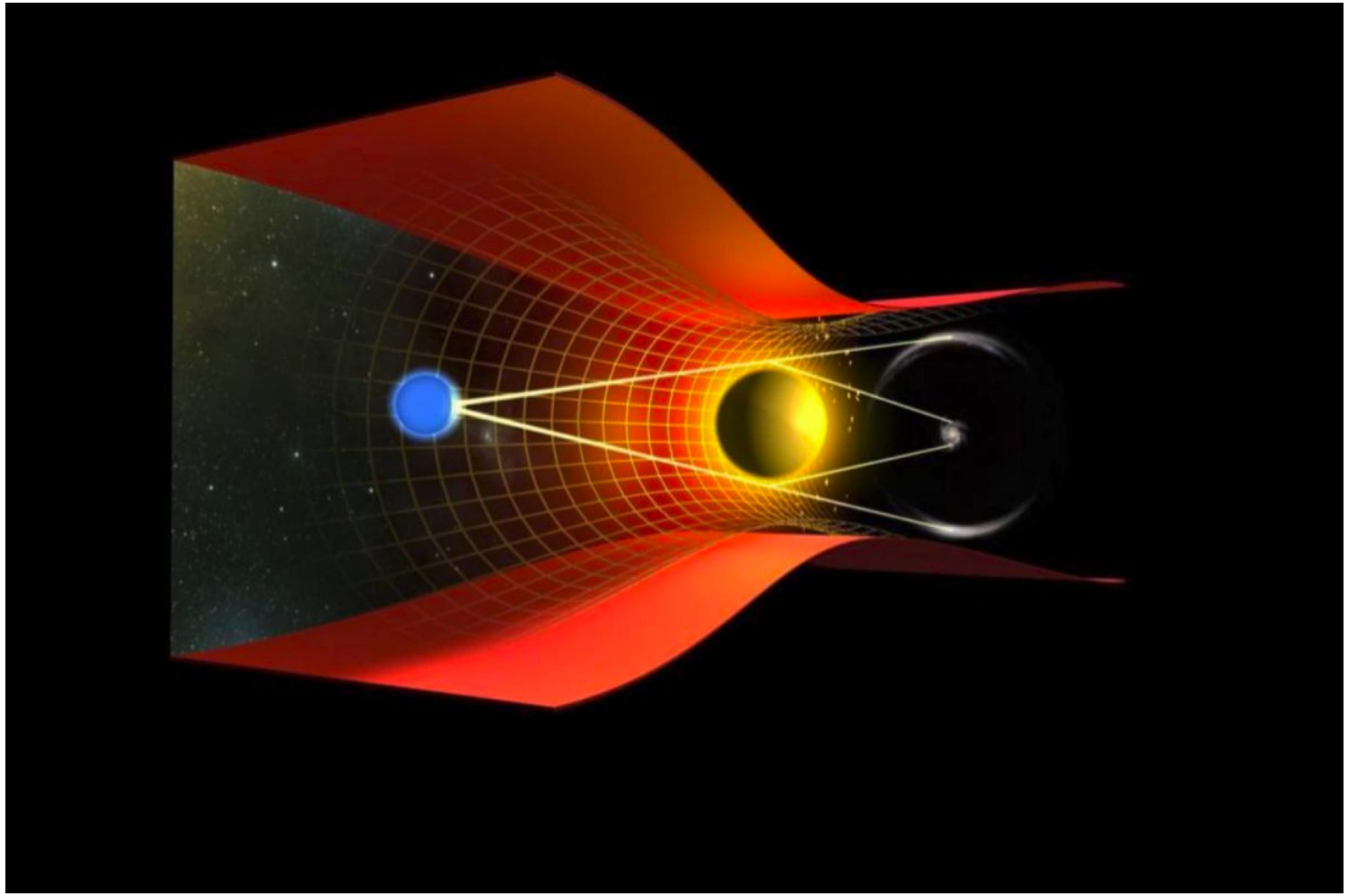
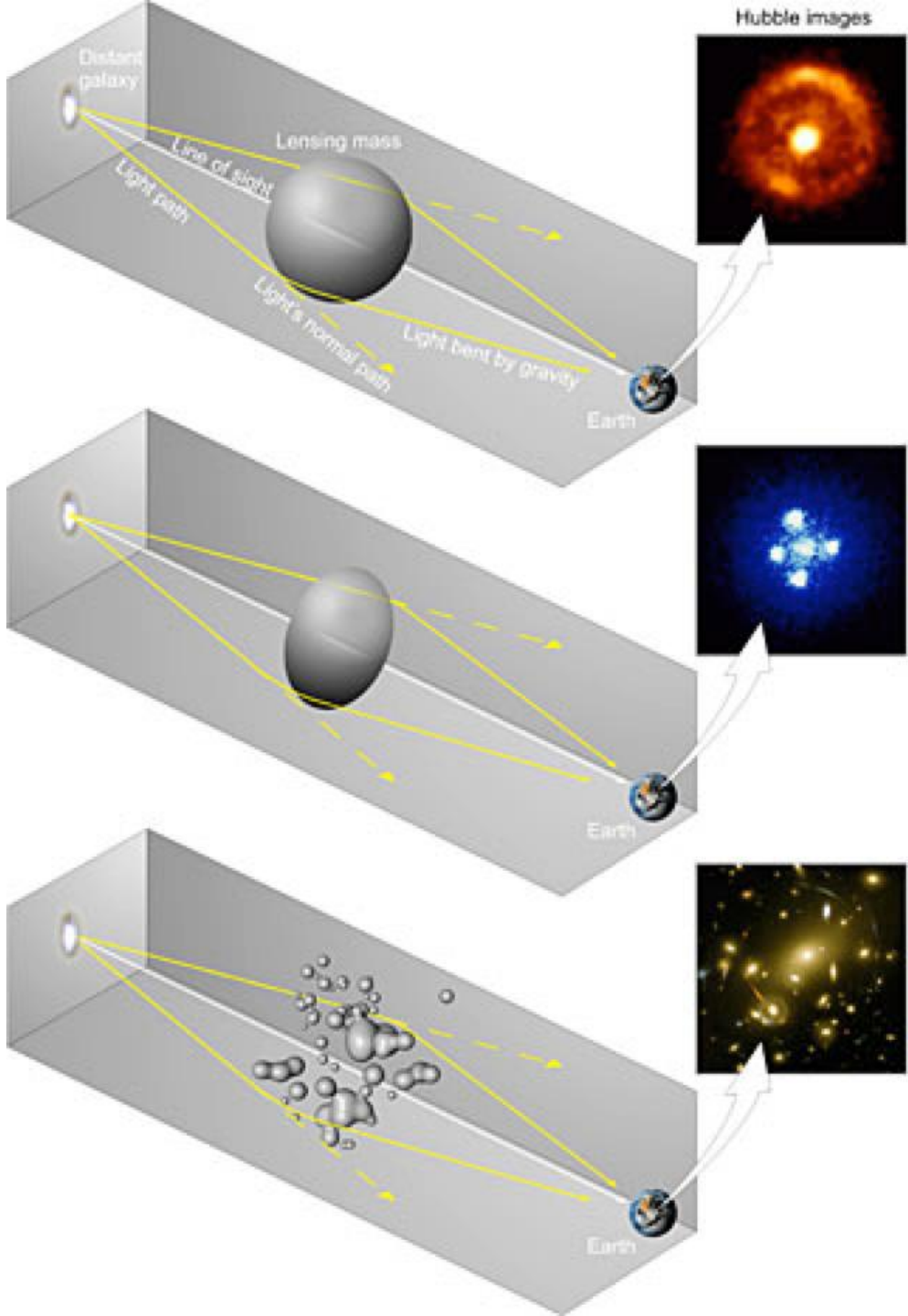
Dark Matter Dominates the Structure
Formation and Evolution of Our Universe

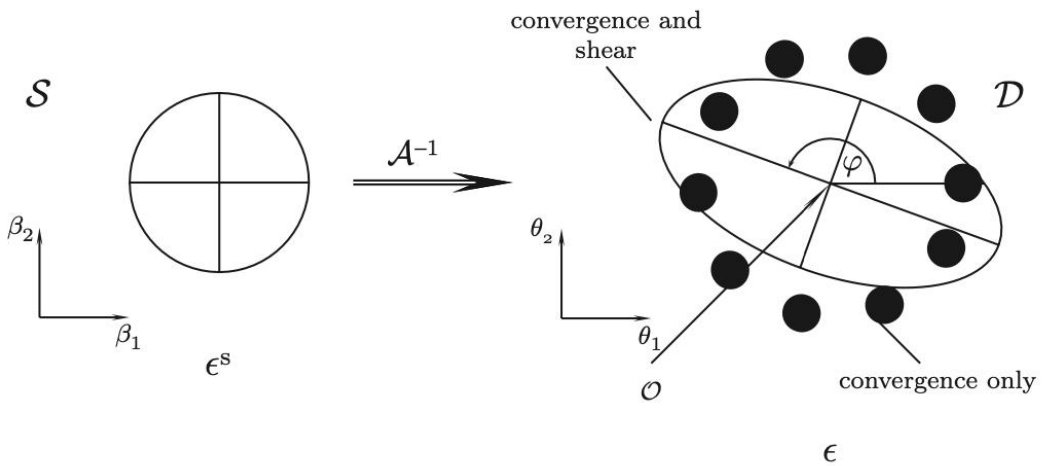
Mapping the Dark Matter with Gravitational Lensing



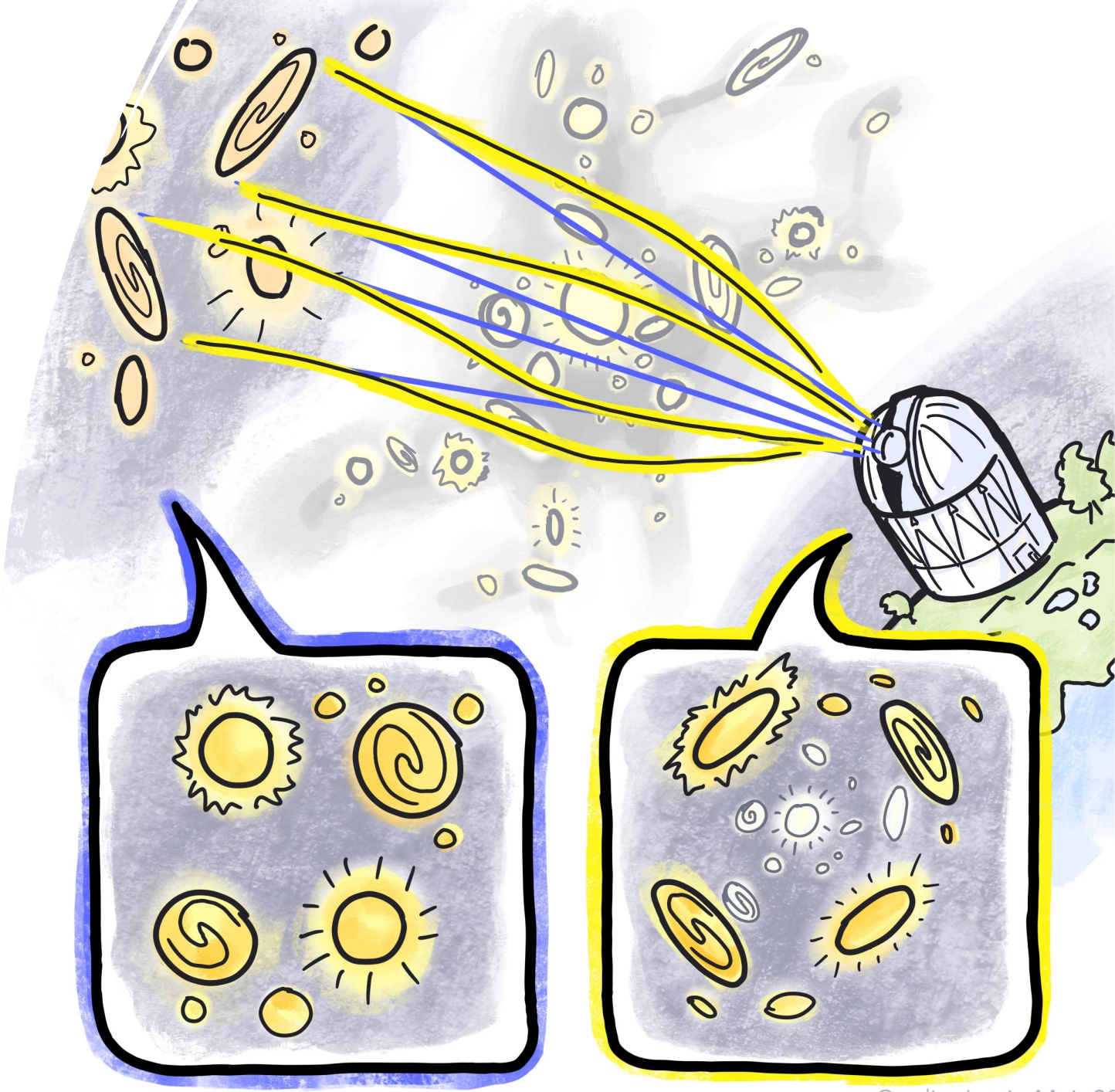


Weak Lensing Shear (γ)

$$\mathcal{A}(\boldsymbol{\theta}) = (1-\kappa)\begin{pmatrix} 1-g_1 & -g_2 \\ -g_2 & 1+g_1 \end{pmatrix}, \text{ where } g(\boldsymbol{\theta}) = \frac{\gamma(\boldsymbol{\theta})}{[1-\kappa(\boldsymbol{\theta})]}$$

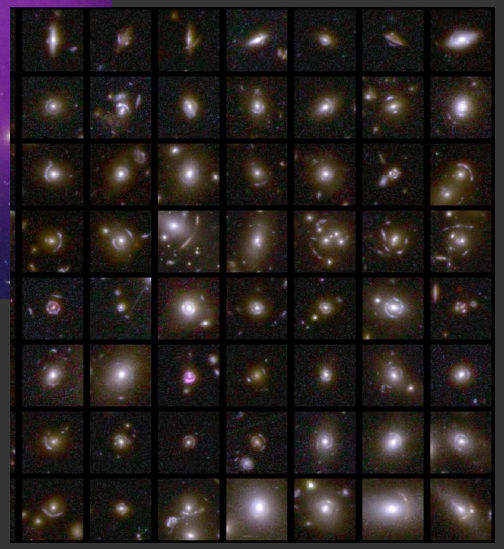


M. Bradac



Credit: Jessie Muir 20

Ongoing and Upcoming Space Optical Surveys



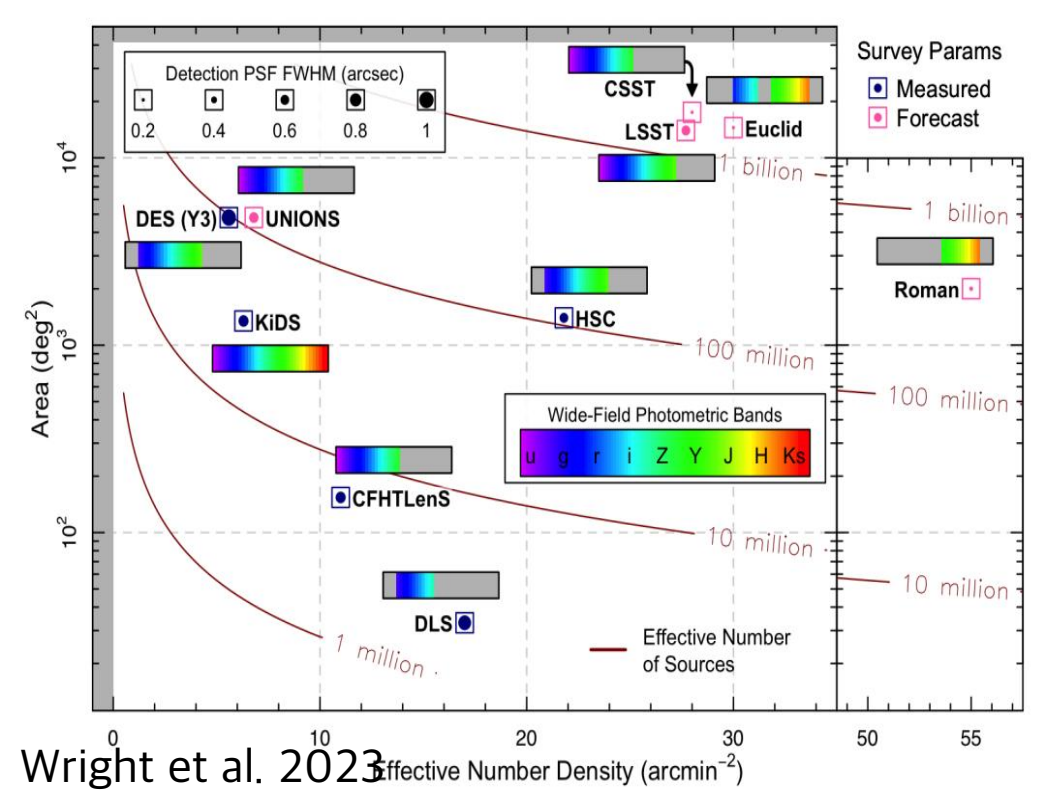
Euclid Telescope
and Q1 Lenses

- Chinese Space-station Survey Telescope (CSST)
- 2-Meter Nuv-Optical Telescope
- Launch ~2027

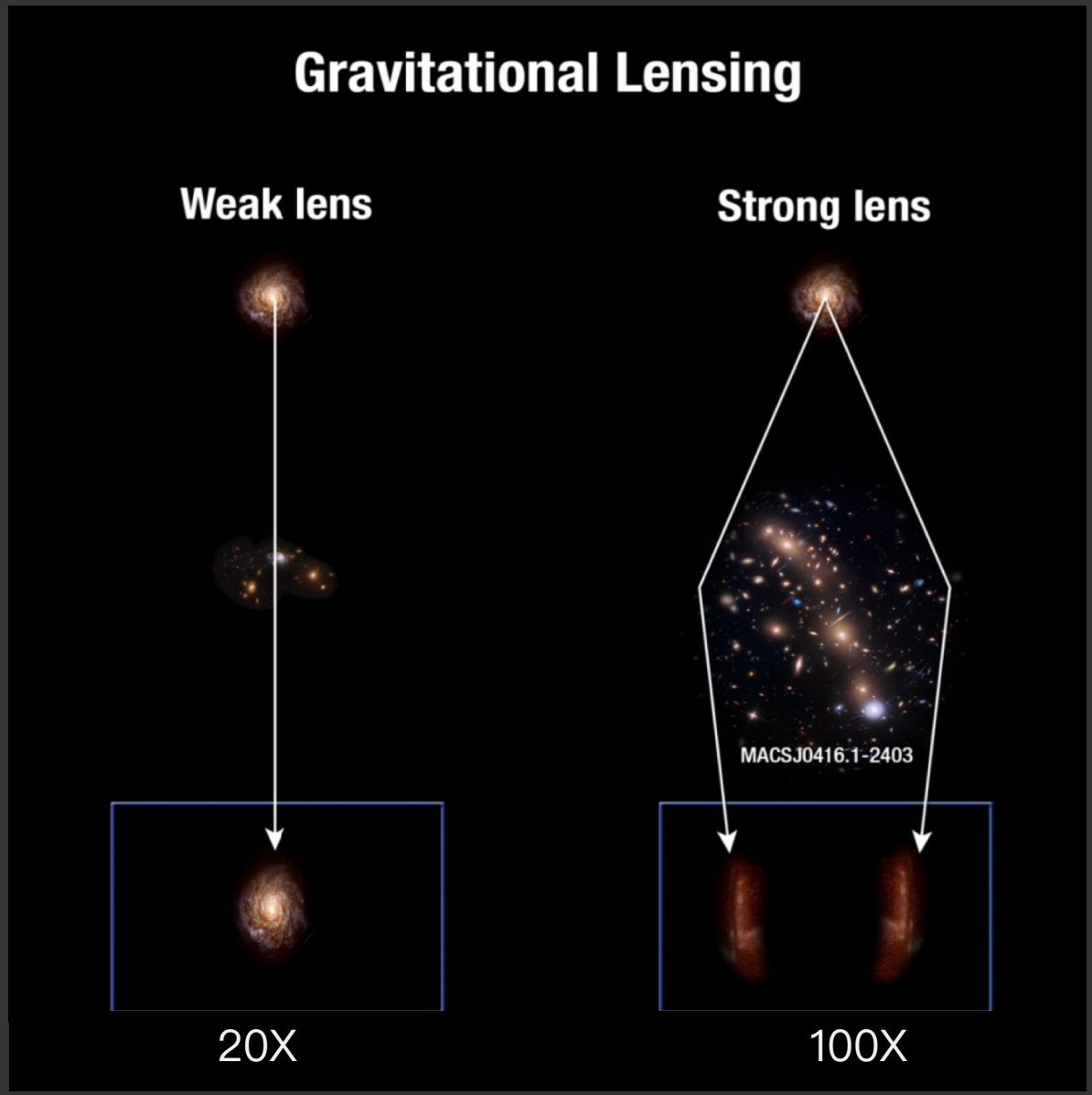
CSST Wide Survey

17500□°imaging : 255–1000nm, ⩾6 filters, avg ⩾25.5m (5σ, point source, AB mag)

17500□°slitless spect: 255–1000nm, 3 bands, R⩾200, ⩾22–23m



Wright et al. 2023

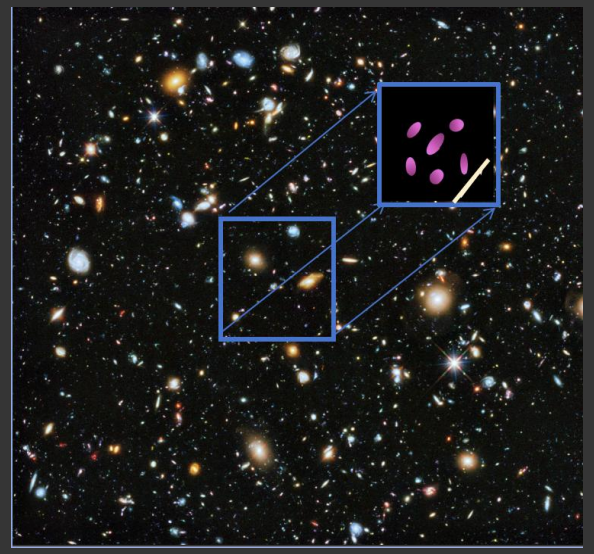


Credit: Nastassia Grimm

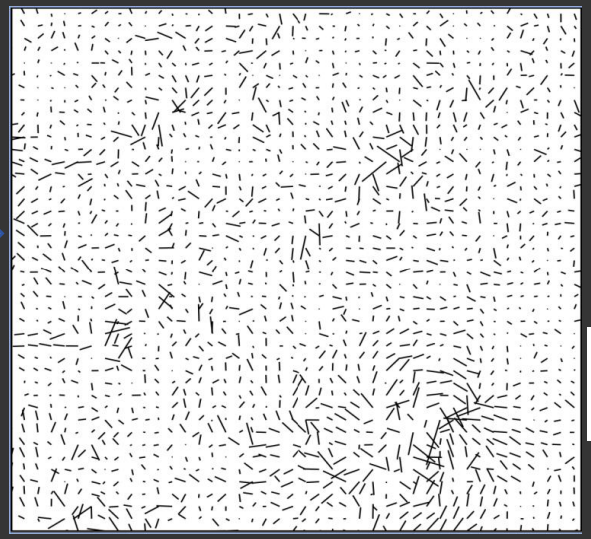
How can AI help?

Constructing the dark matter map

Galaxy shapes

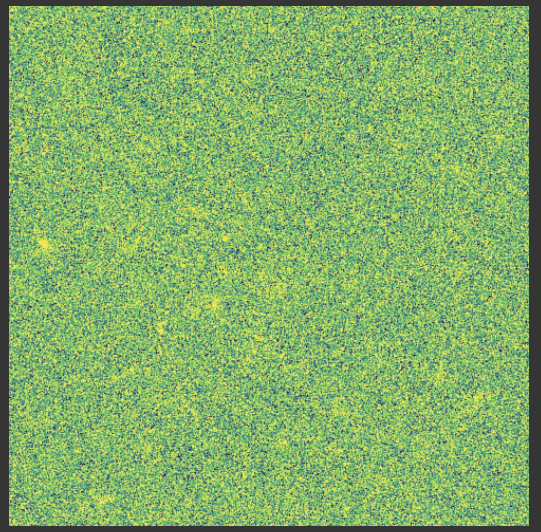


Shear（γ） Field
Derived from galaxie shapes



$$\frac{1}{\pi}\int_{\mathbb{R}^2} \mathrm{d}^2\theta'\, \mathcal{D}^*(\boldsymbol{\theta}-\boldsymbol{\theta}')\,\gamma(\boldsymbol{\theta}')$$

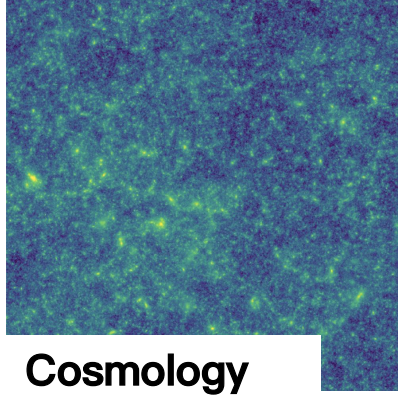
Convergence k
(Dimensionless DM Durface Density)



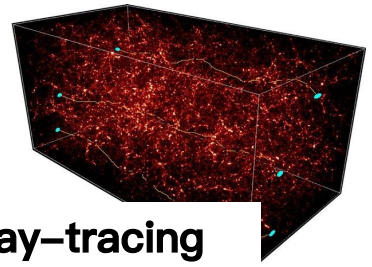
Traditional KS method:

- Noise–dominated on small scales
- Mask–induced artifacts and spurious structures
- Rigid objective: no physics priors, no multi–probe inference

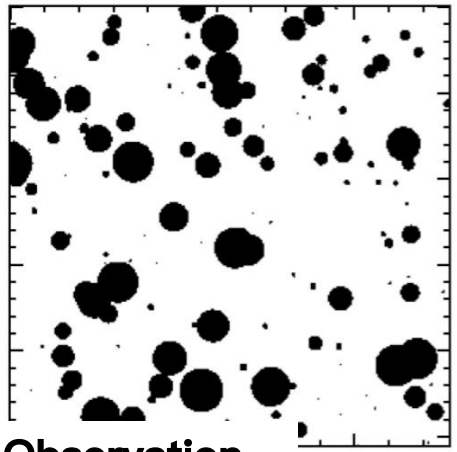
Dark Matter Mass Map with U2Net



Cosmology Simulation



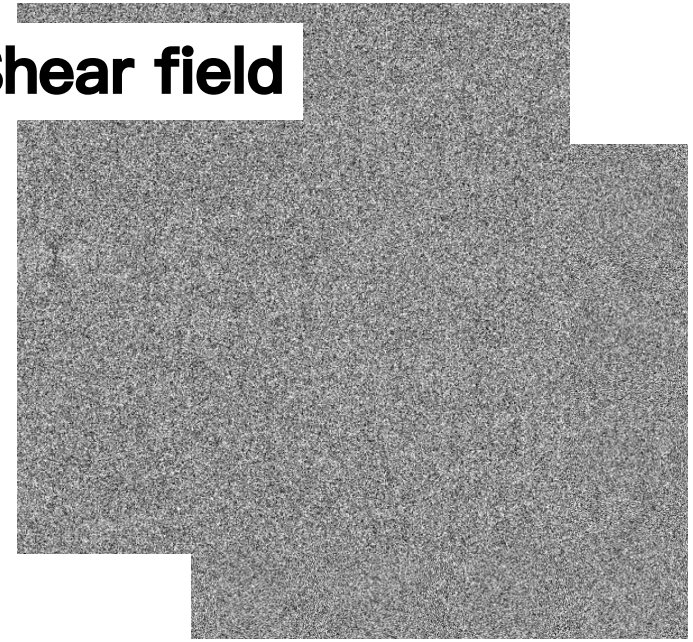
Ray-tracing



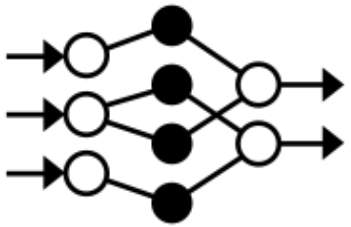
Observation Mask

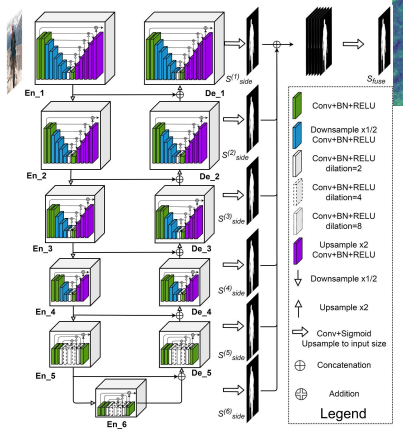
x 20000

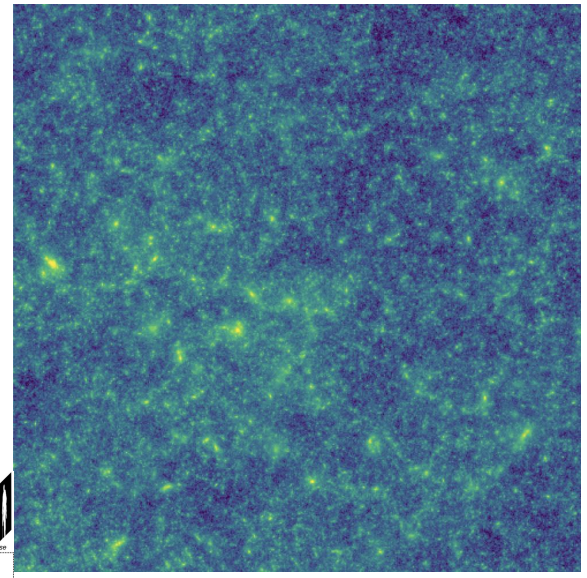
Shear field



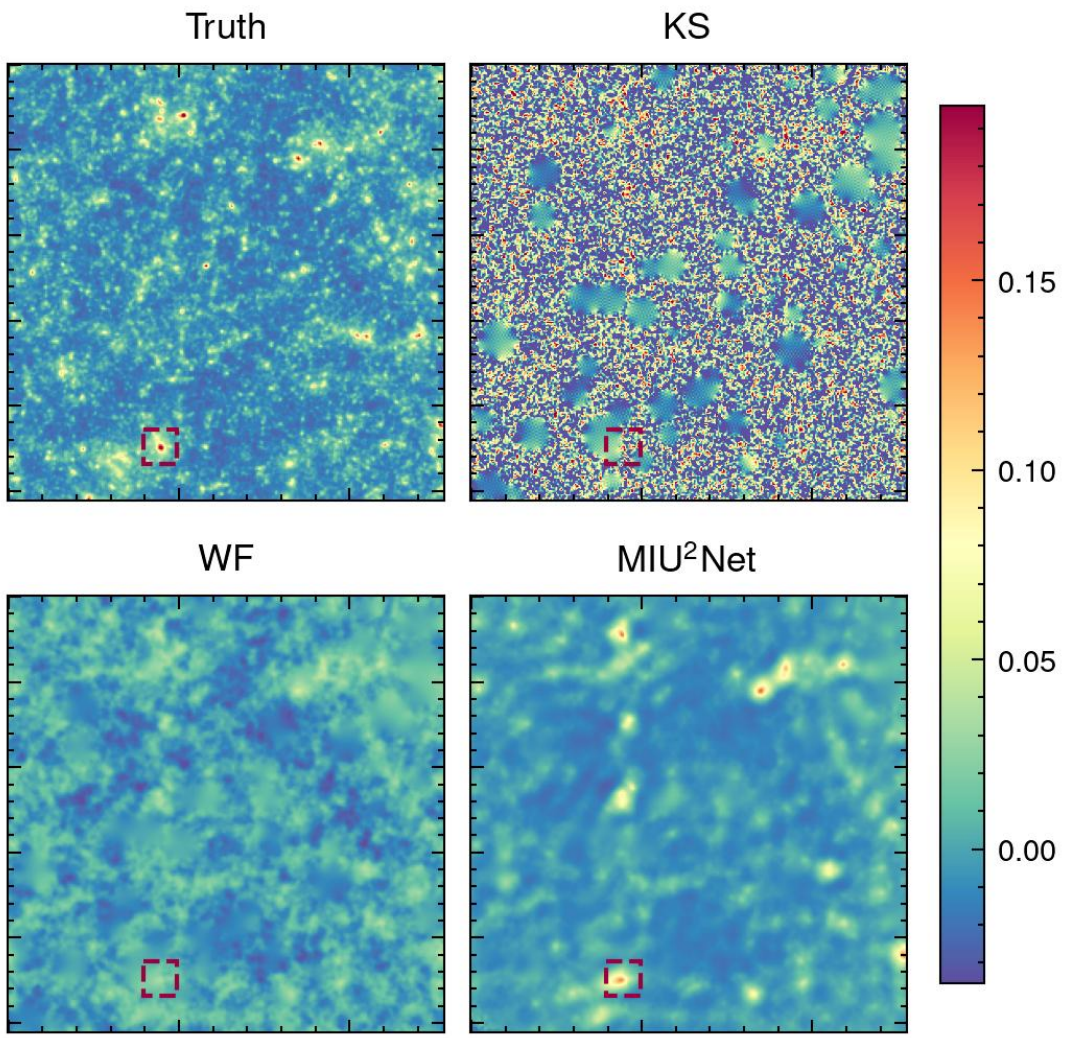
$\mathcal{F}(\gamma)$

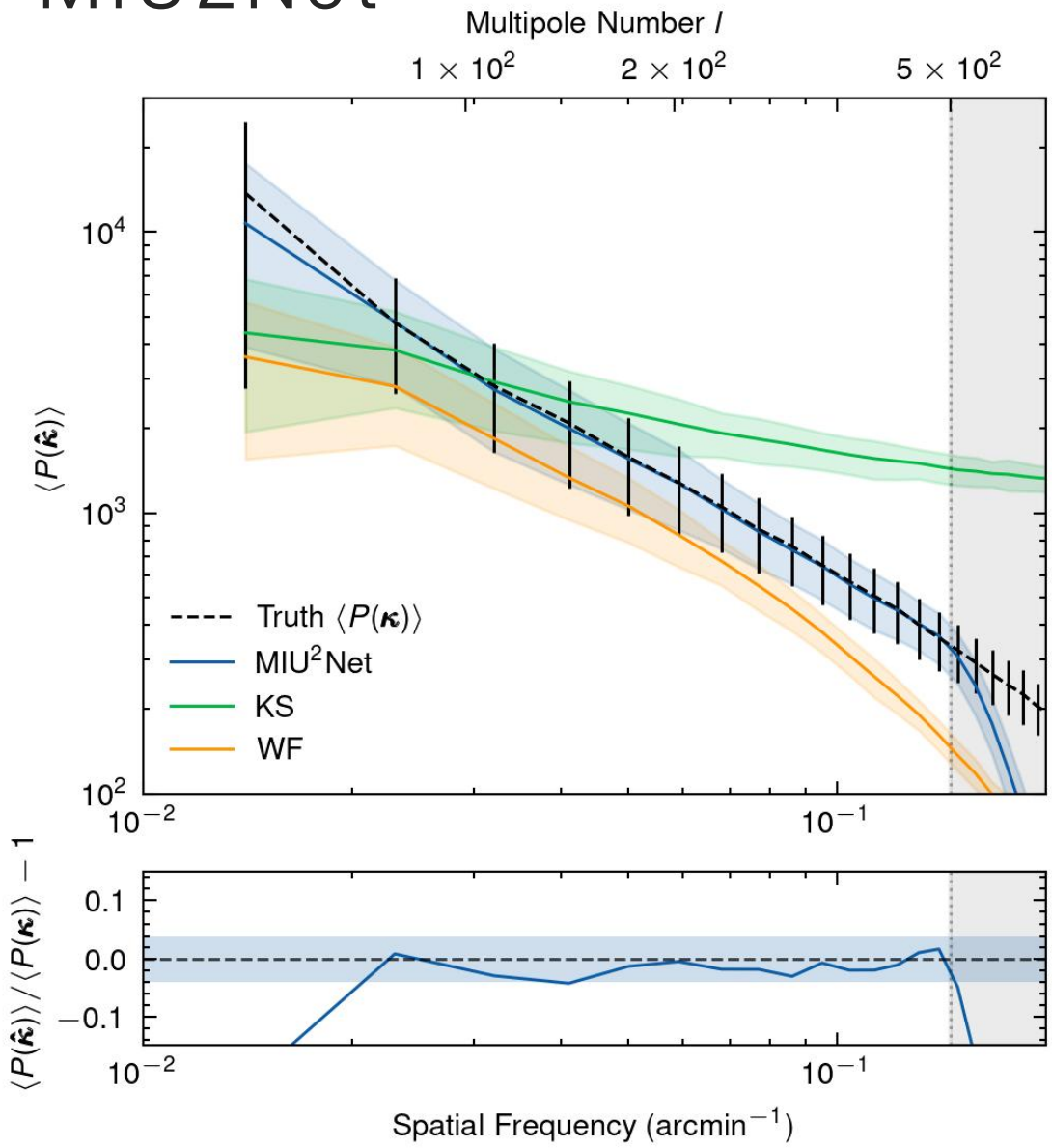






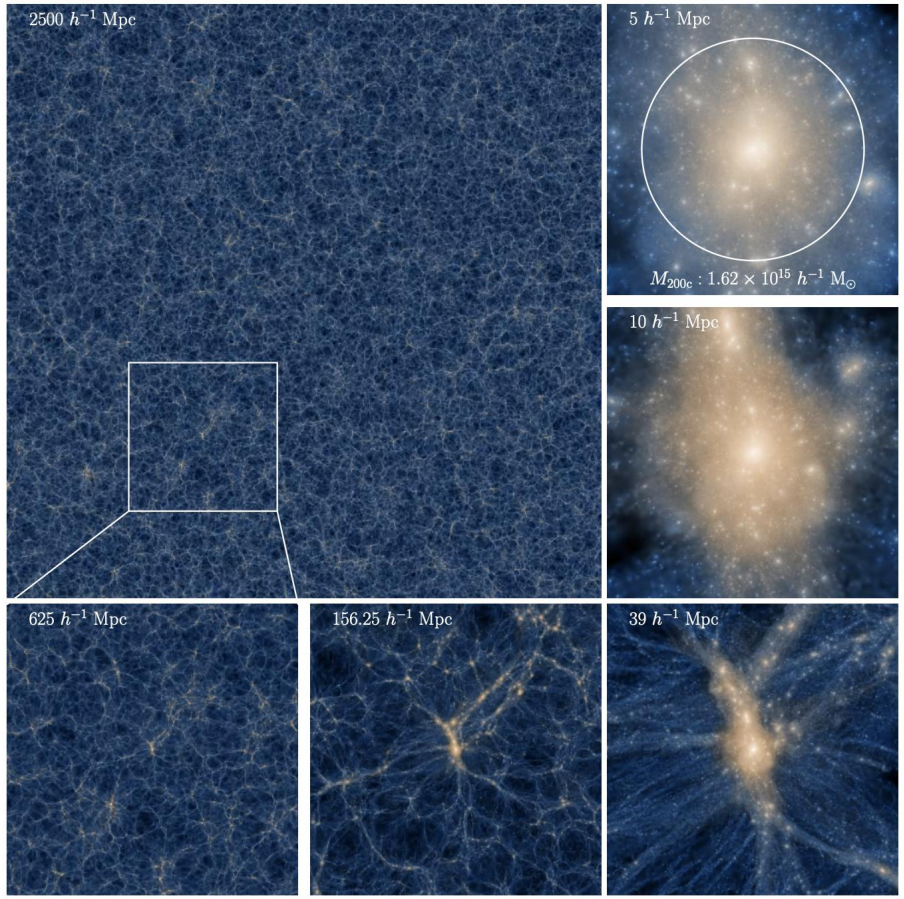
Dark Matter Mass Map with MiU2Net

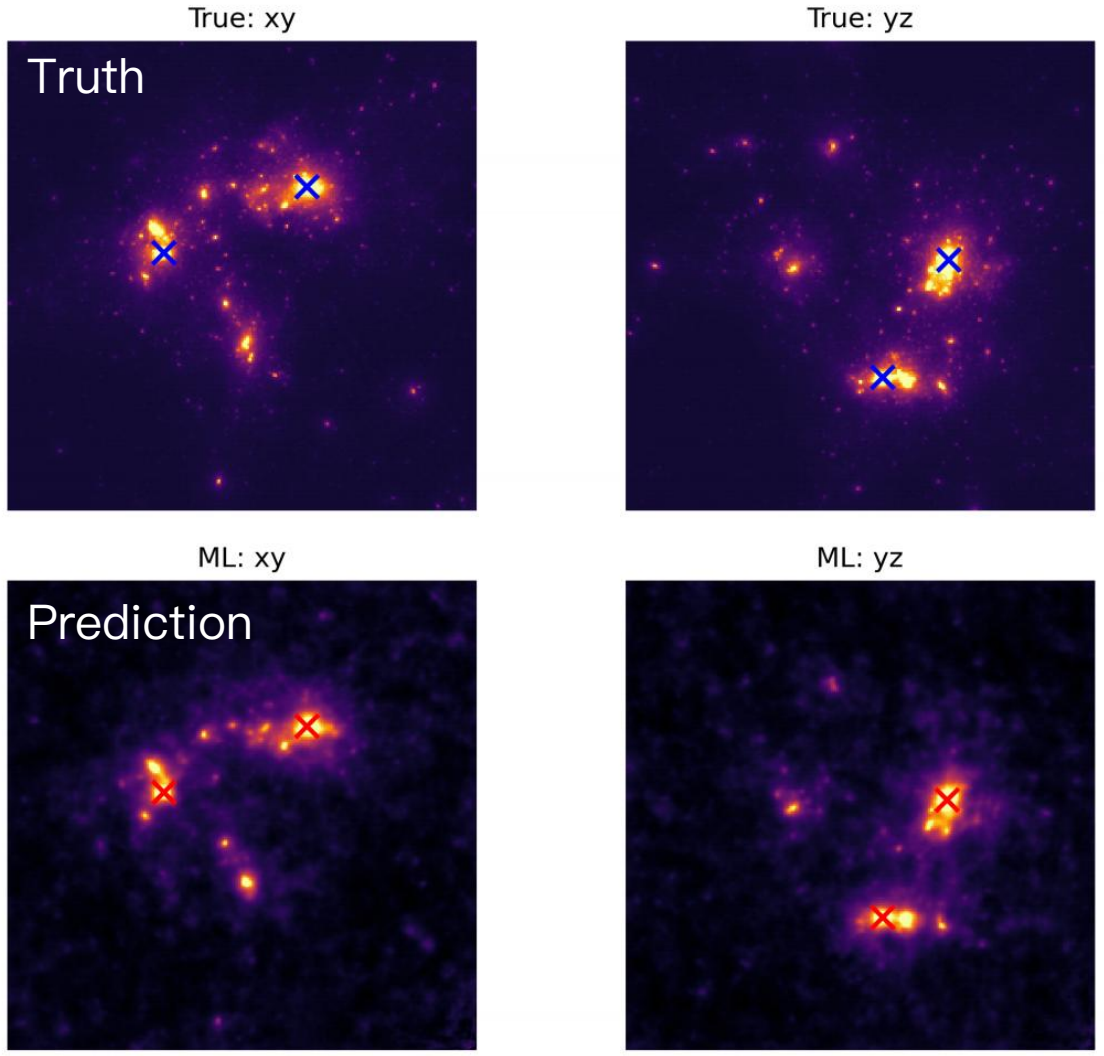




Miu2Net, Han... RL et al. 2026

Cluster–Cluster Pair mass mapping

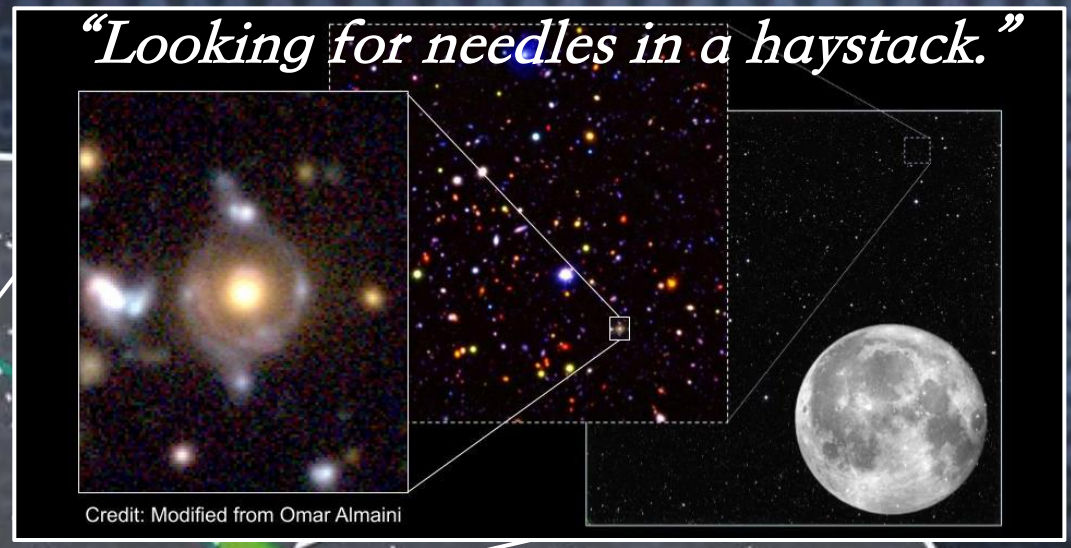




Enhance the training set with HyperMillennium simulation of $(2.5\ \mathrm{Gpc})^3$ box

Chen XY et al. in prep

Strong Lensing

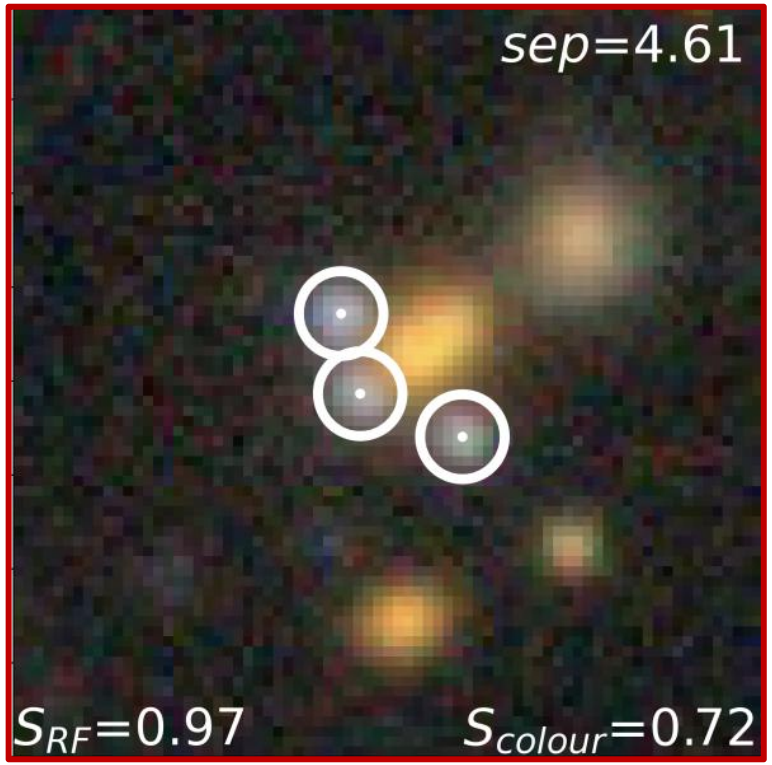


How to identify and model tens of thousands of strong lenses from tens of billions of astronomical objects in the big data era ? ? ?

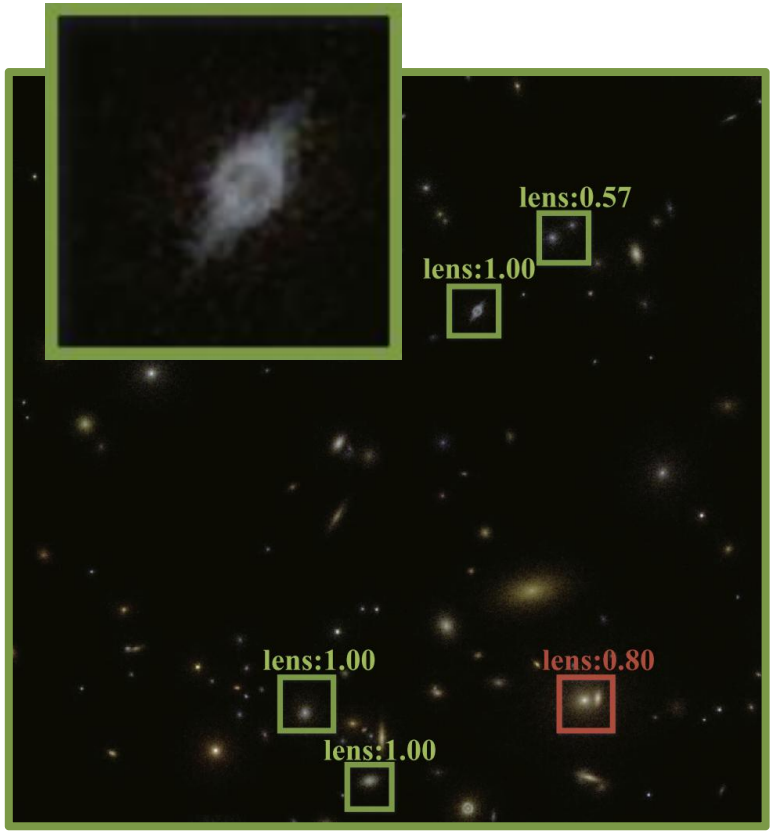
Slides from Nan Li

Identifying Strong Lenses from Gigantic Datasets

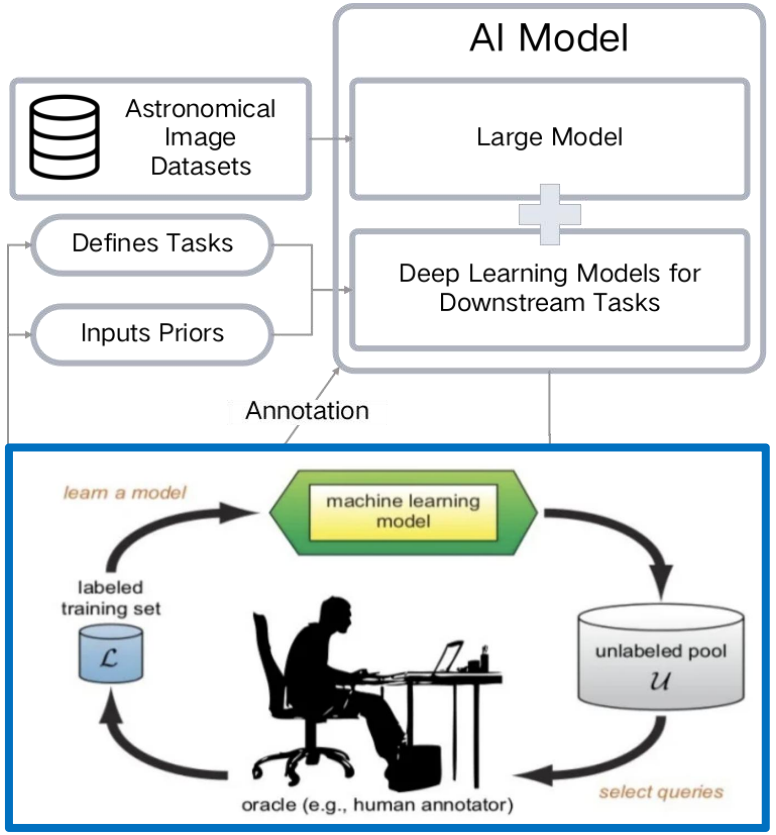
1. Catalog Based Pattern Match



2. Deep Learning Empowered

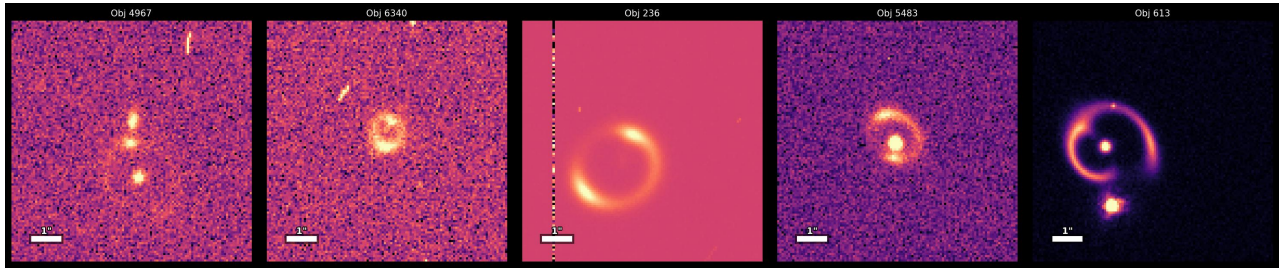


3. Human & AI in the Loop

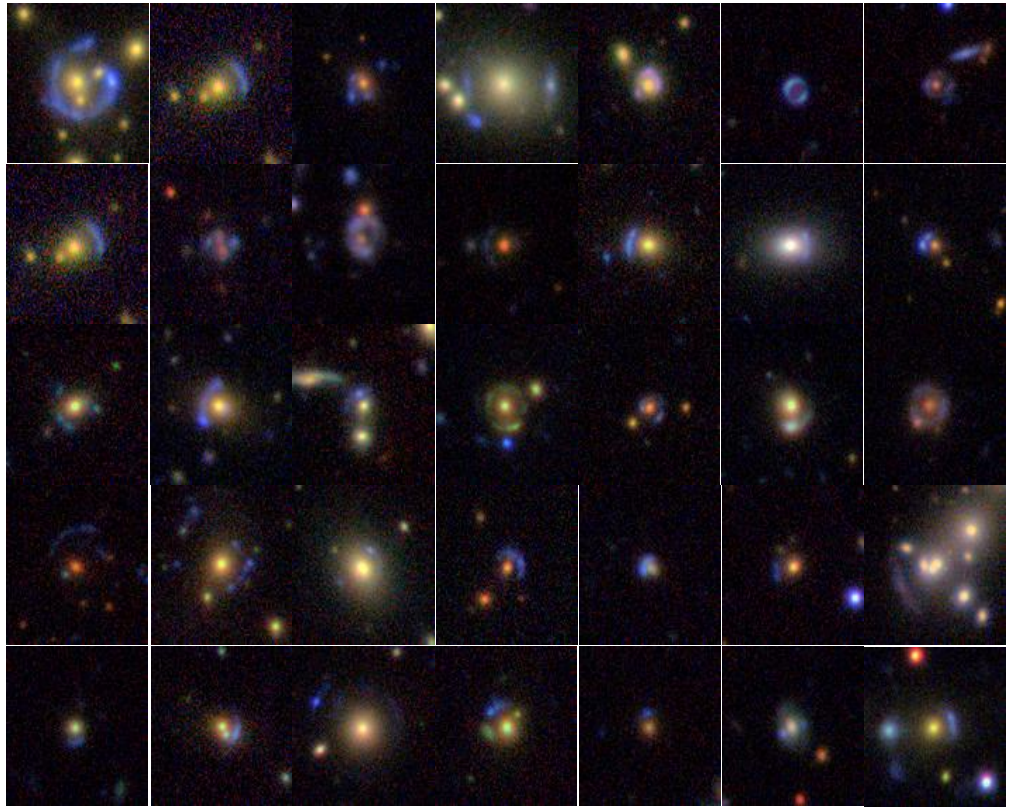


Slides from Nan Li

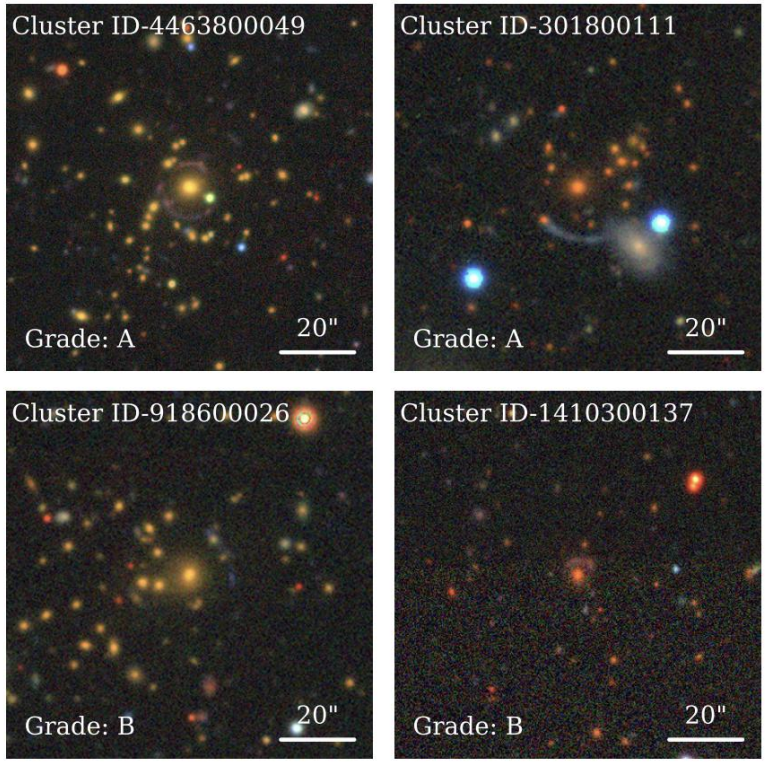
CSST Mock Lenses, Liu P., RuiLi, Cao XY, RL in prep

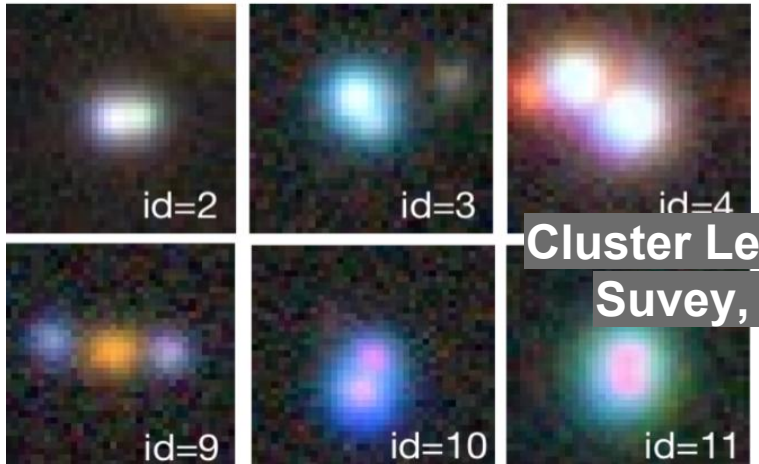


Lens in KiDS DR5(Li Rui et al. 2021)

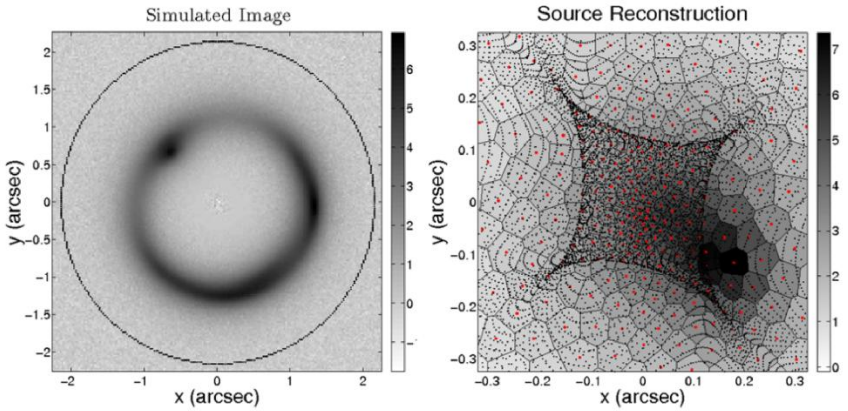


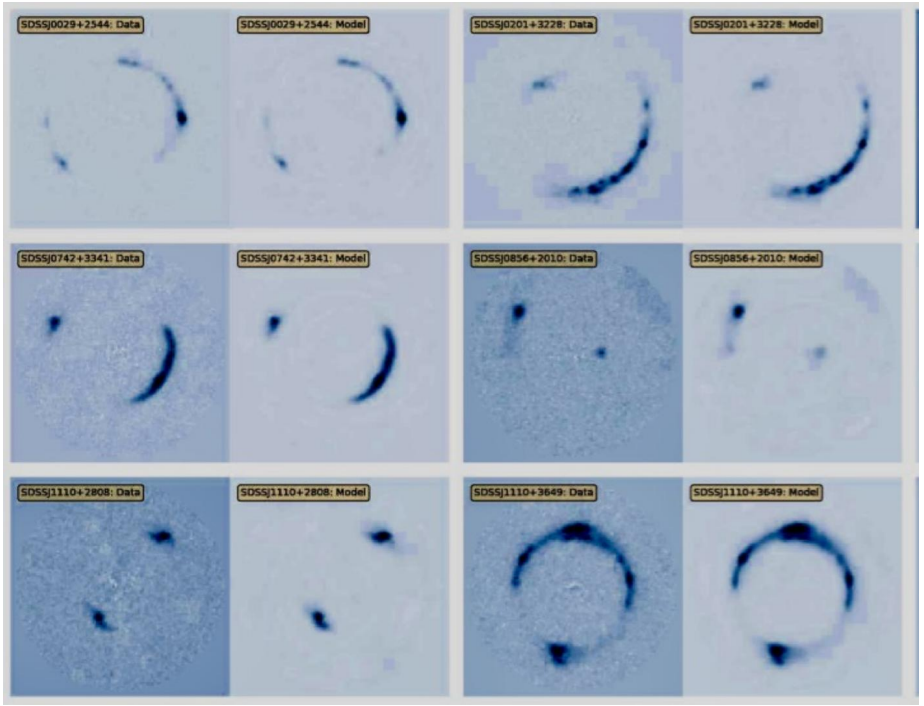
Cluster Lens in DESI Legacy Suvey, Zhang, *NL** et al. 2025



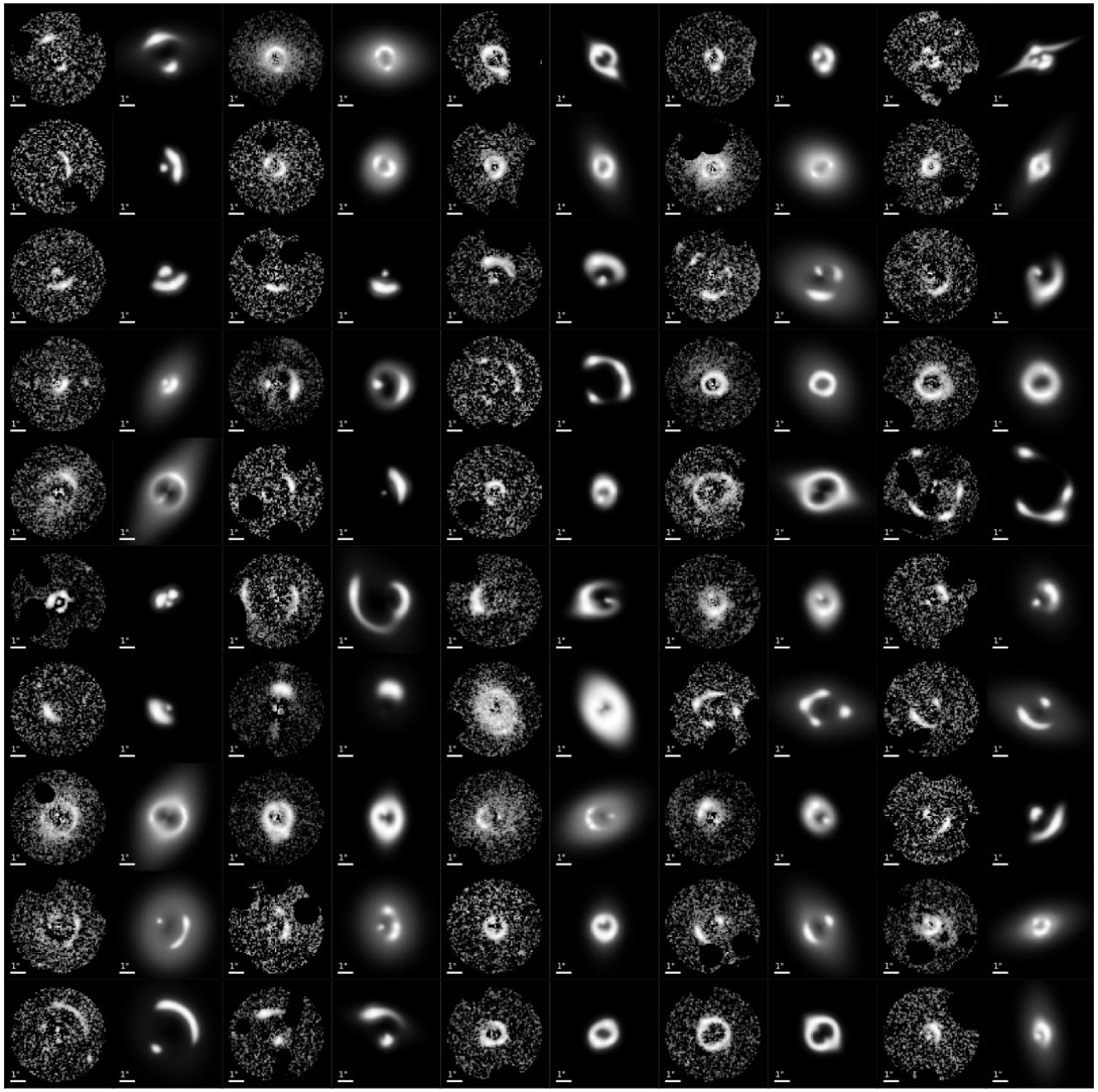


Cluster Lens in DESI Lega Suvey, He, *NL** et al. 20

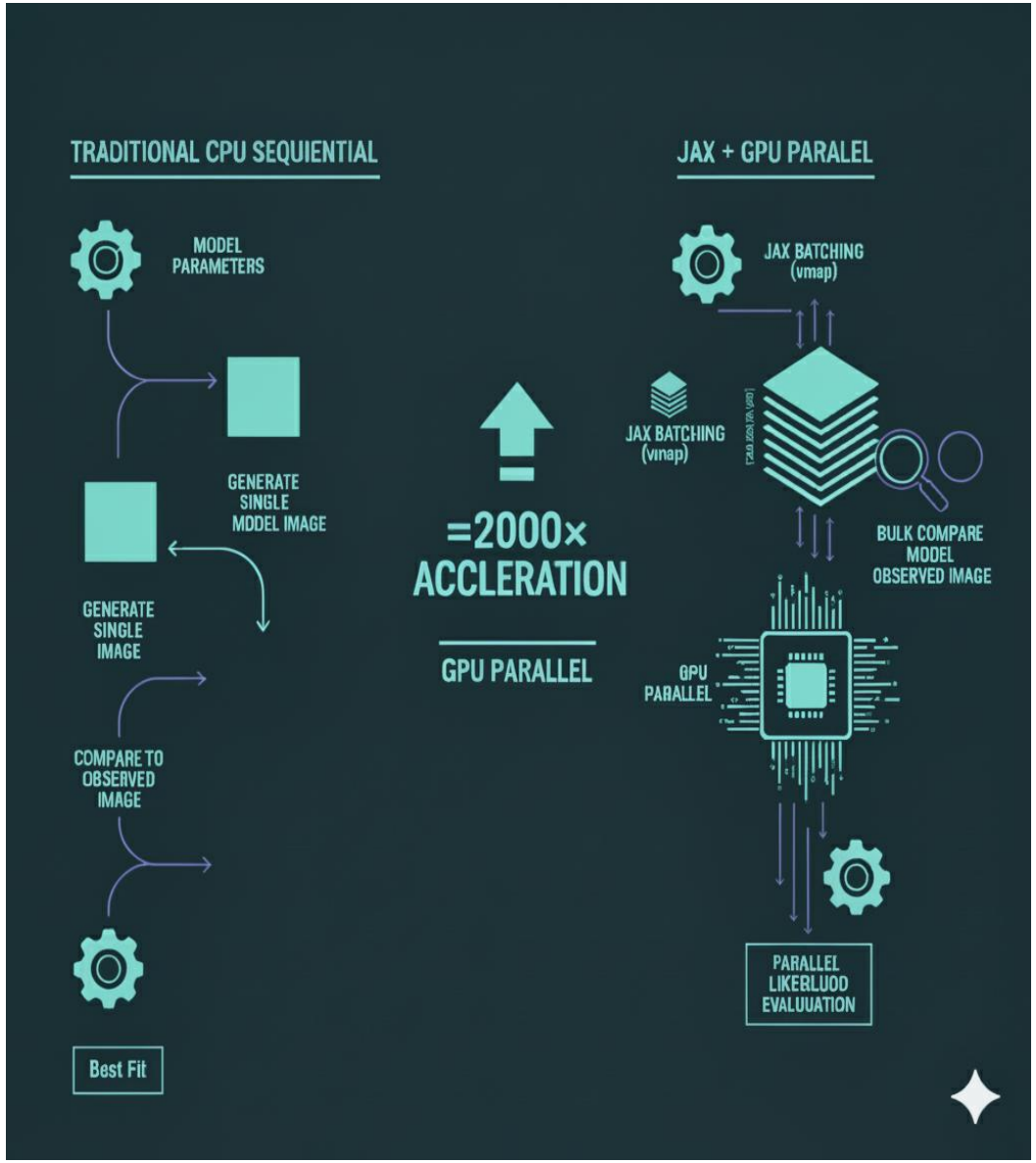


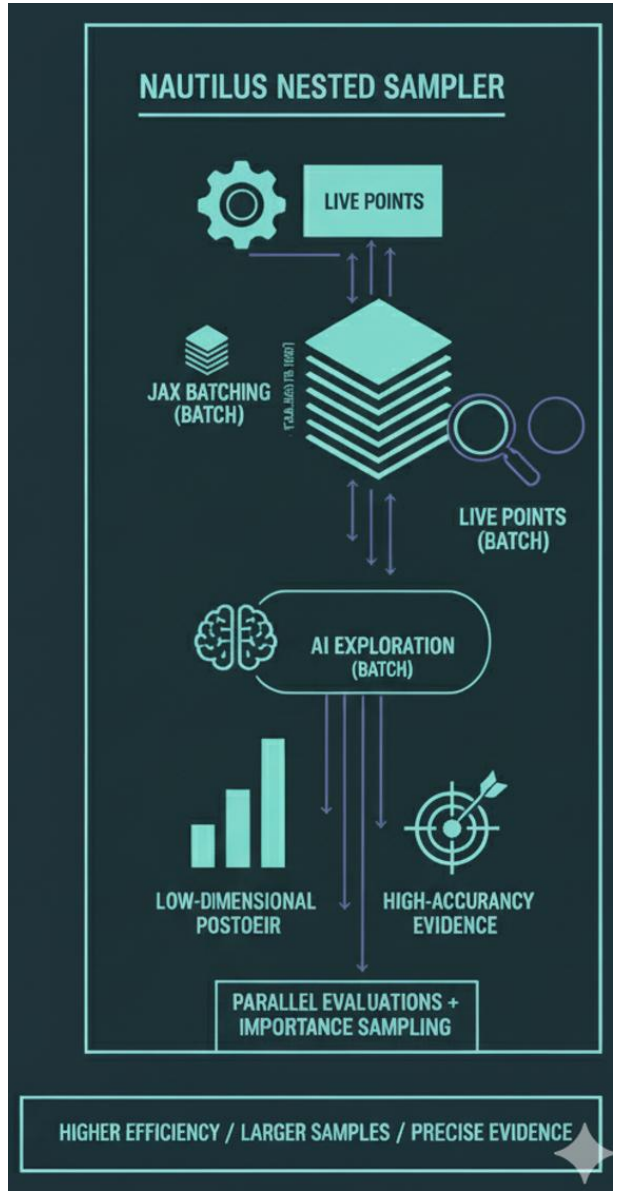


Bells Gallery Lens from Hubble



Euclid Q1 lenses model by TINYLENS

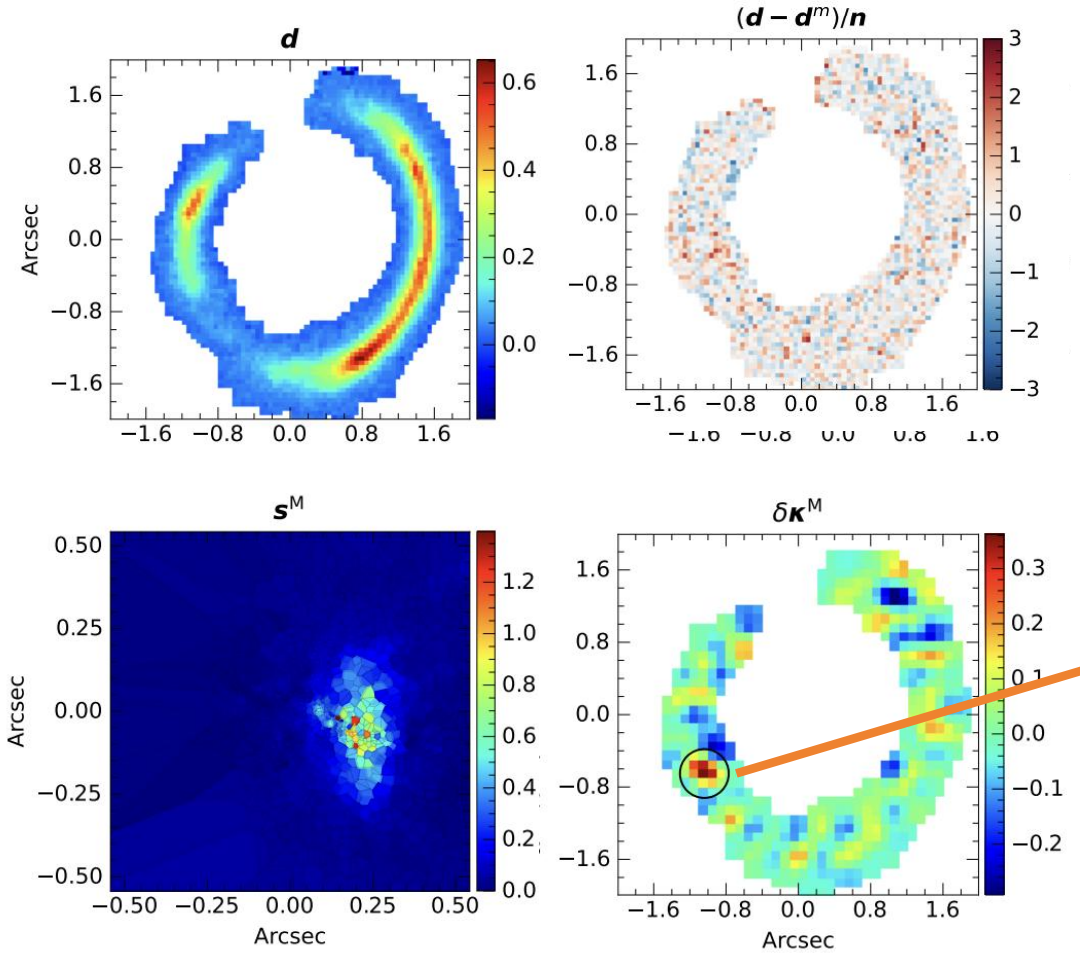




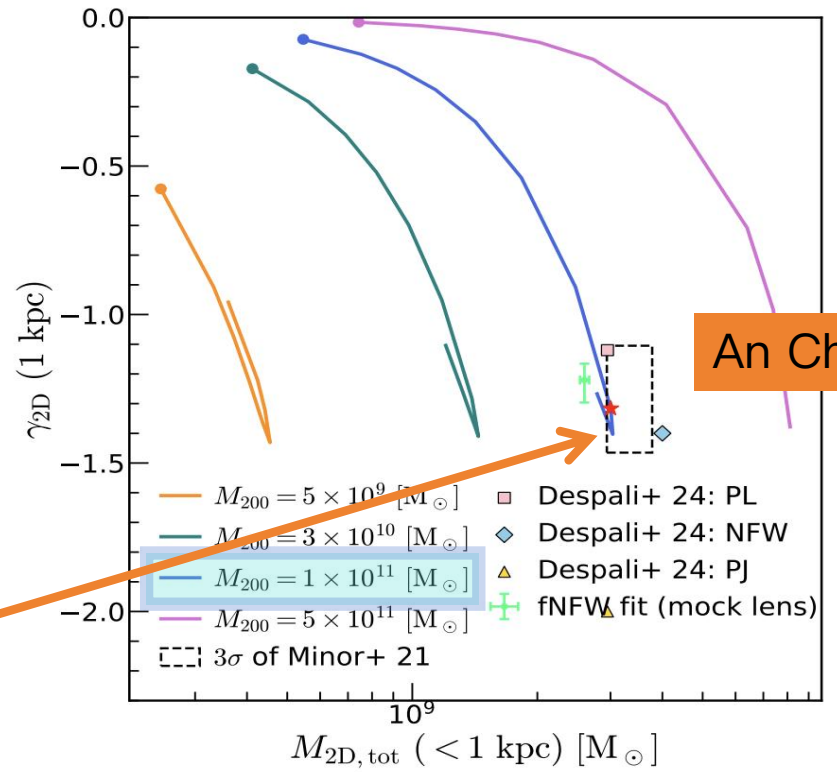
TINYLENS–GPU XY Cao , RL et al. 2025

Reveal the low mass dark matter perturber

SLACS 0946+1006 with Hubble Imaging



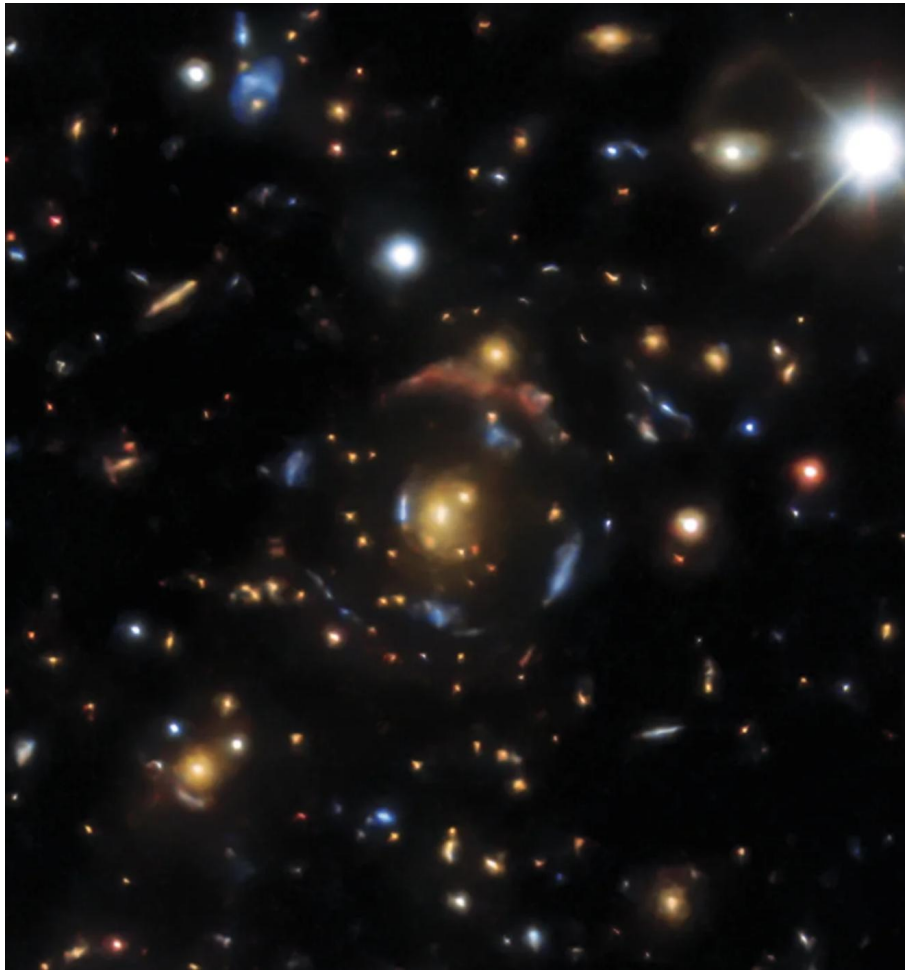
Cao XY, RL et al. 2025
https://arxiv.org/pdf/2504.19177



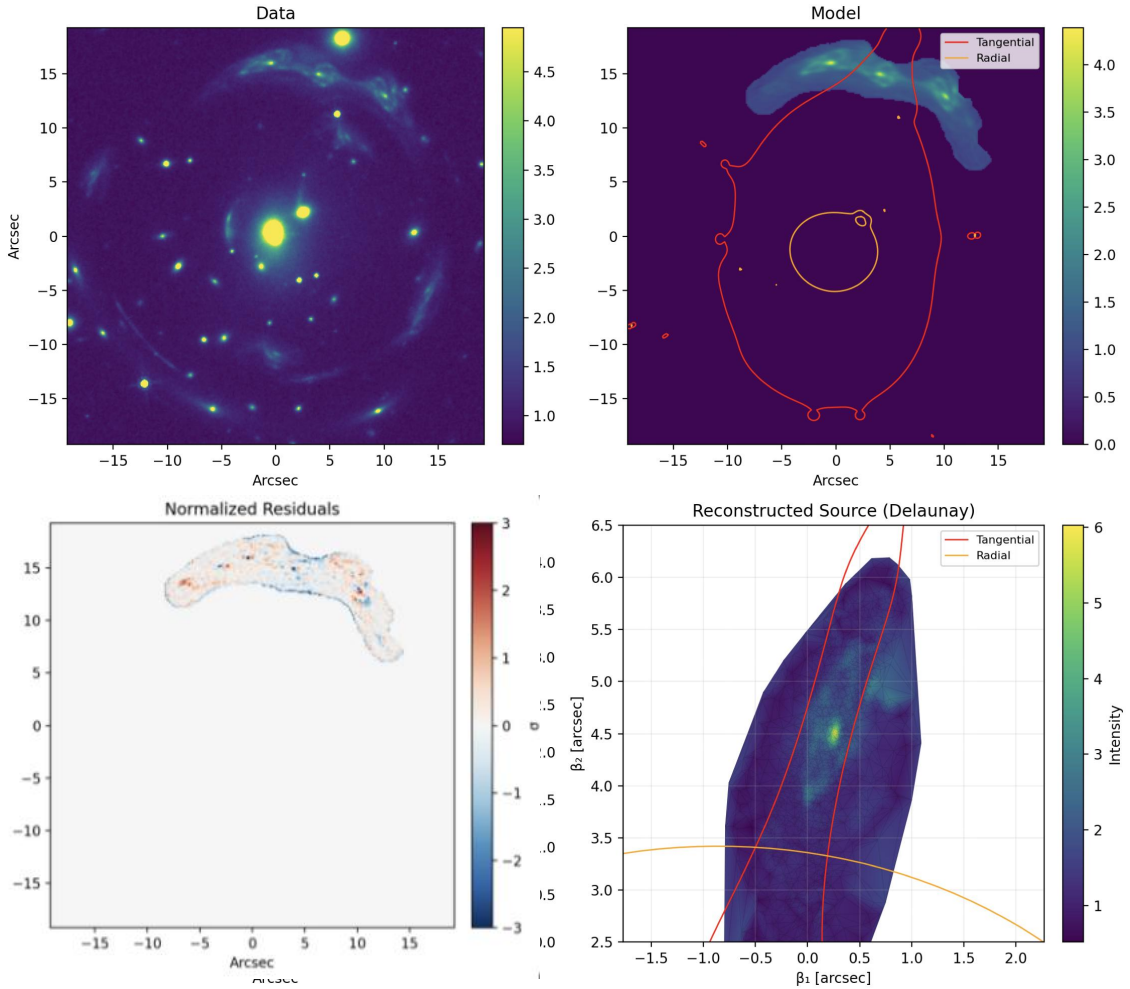
An Challenge for CDM ?

SHB Li, Ran Li + 2025, ApJ, arxiv: 2504.11800

Cluster Giant Arc Modelling



Carousel cluster



Ma XH, RL et al. in prep


AI Language Model for Coding Assistance
How to fit a strong lens model?
Accelerated Learning
• Code Suggestions
• Debugging Help
OpenCode Open Source Coding Agent
LensMod: Strong Lens Modelling Project Plan
Discuss Project Requirements
Let's Discuss Project Requirements
Let's discuss the requirements for your strong lens modelling project...
Develop Project Plan
Great! Here's a plan for your project
Define API Interfaces
I will generate the API interfaces
Assine with Codings
Assist with Coding
Assist Lsing Coding
Help Design & Test
• Quick Project Setup
• Ready to Use Notebooks
Before: 1-2 Years of Technical Training
Now: 1-2 Months of Learning

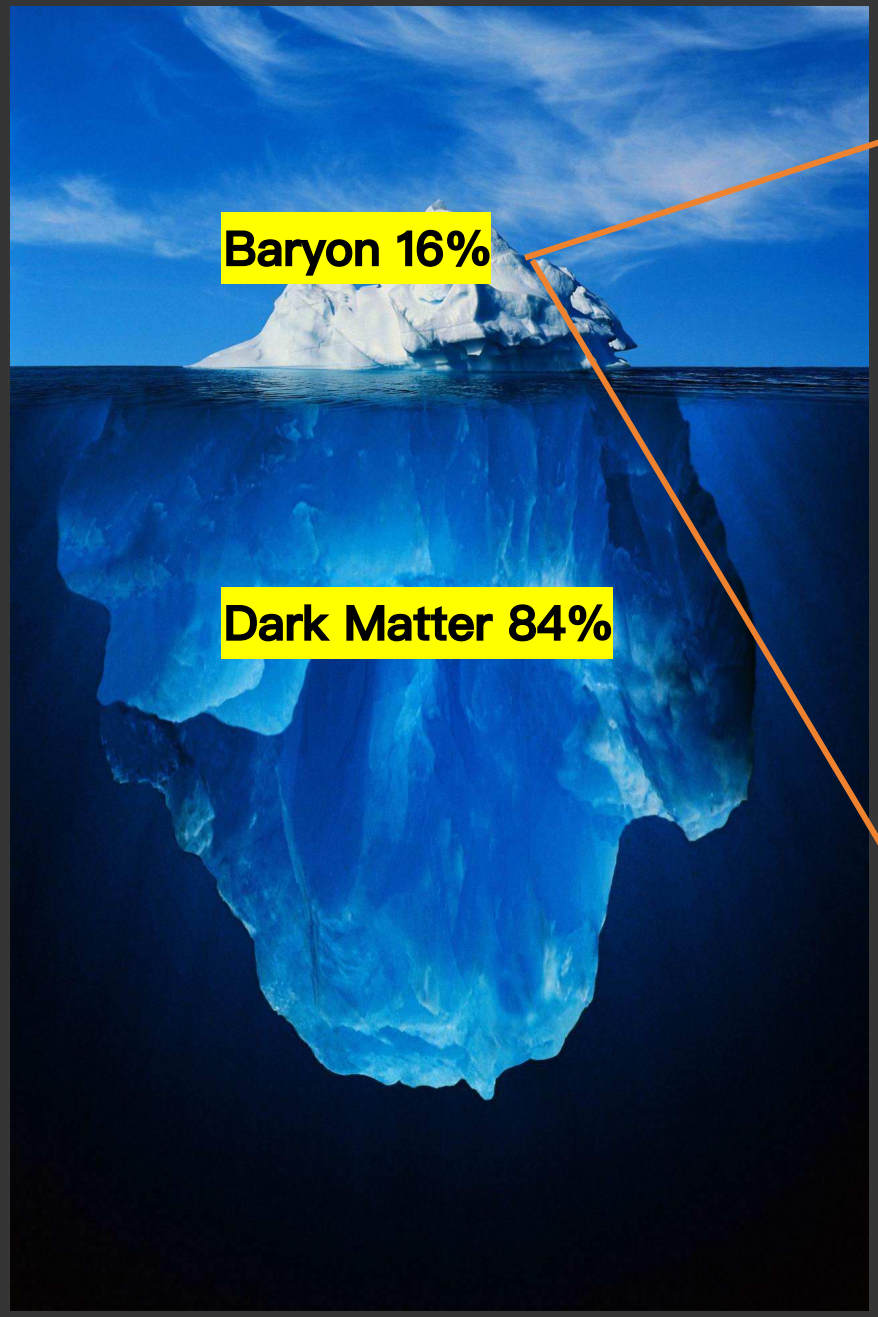
AI CAN DO

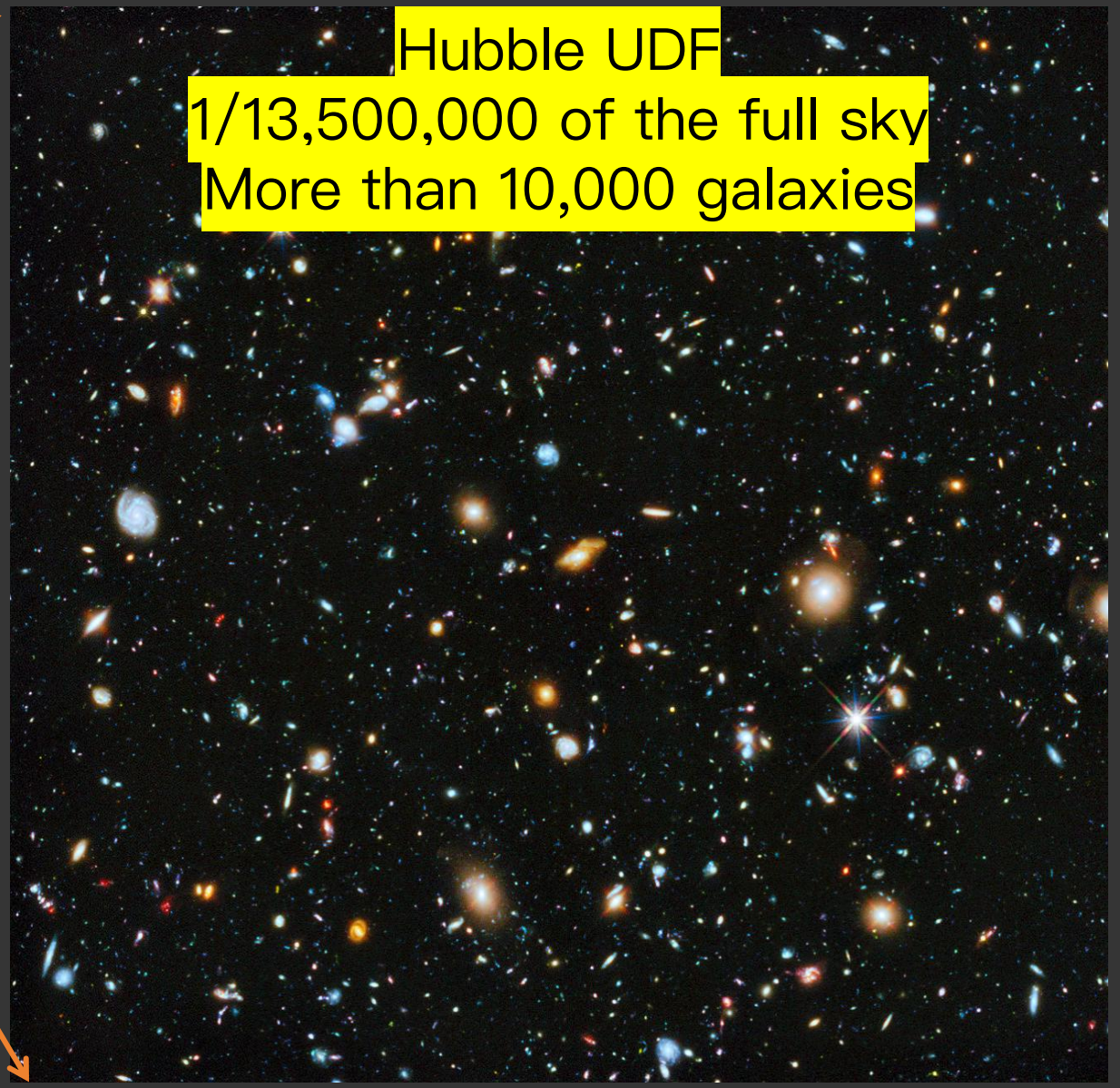
- High-fidelity dark matter reconstruction
- “Needle in a haystack” into scalable discovery
- Democratizes high-performance computing
- AI Agents redefine how science is done

AI CANNOT DO

- AI does not own reality
  - Reality is not a dataset — it is a messy, constrained system
- AI alone cannot guarantee precision at the level cosmology demands
- AI can not define what is scientifically interesting


In the age of AI, the bottleneck is no longer computation
— it is curiosity


Baryon 16%
Dark Matter 84%


Hubble UDF
1/13,500,000 of the full sky
More than 10,000 galaxies