# Combining ground- and space-based photometric surveys for deblending and shear measurement

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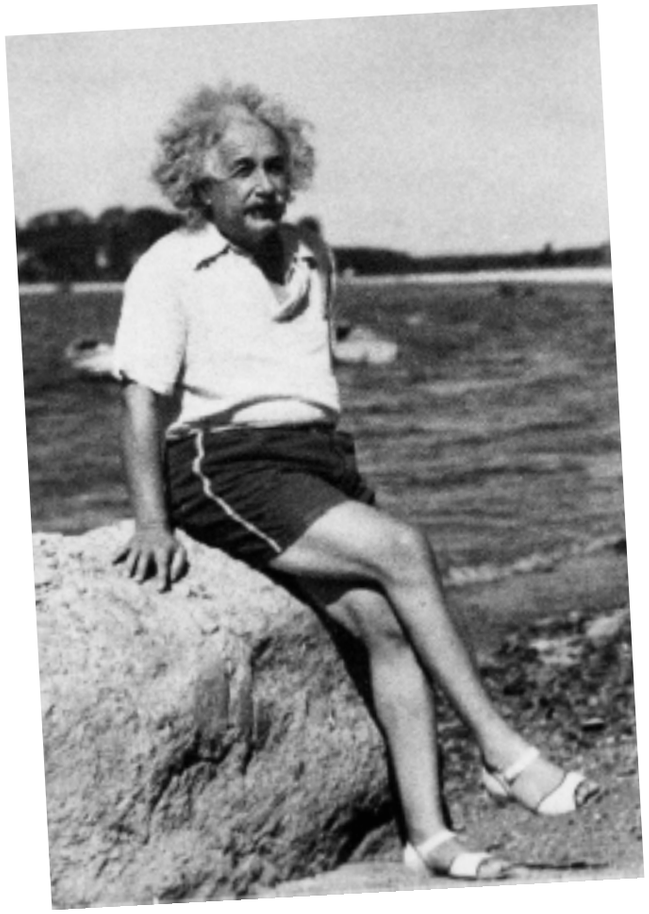
*Laboratoire AstroParticule et Cosmologie*

Workshop Deblending with Deep Learning, FACe, June 28th, 2017


# WEAK LENSING 101

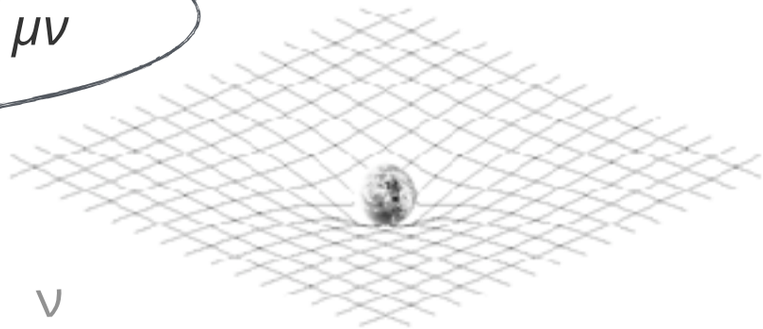


$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

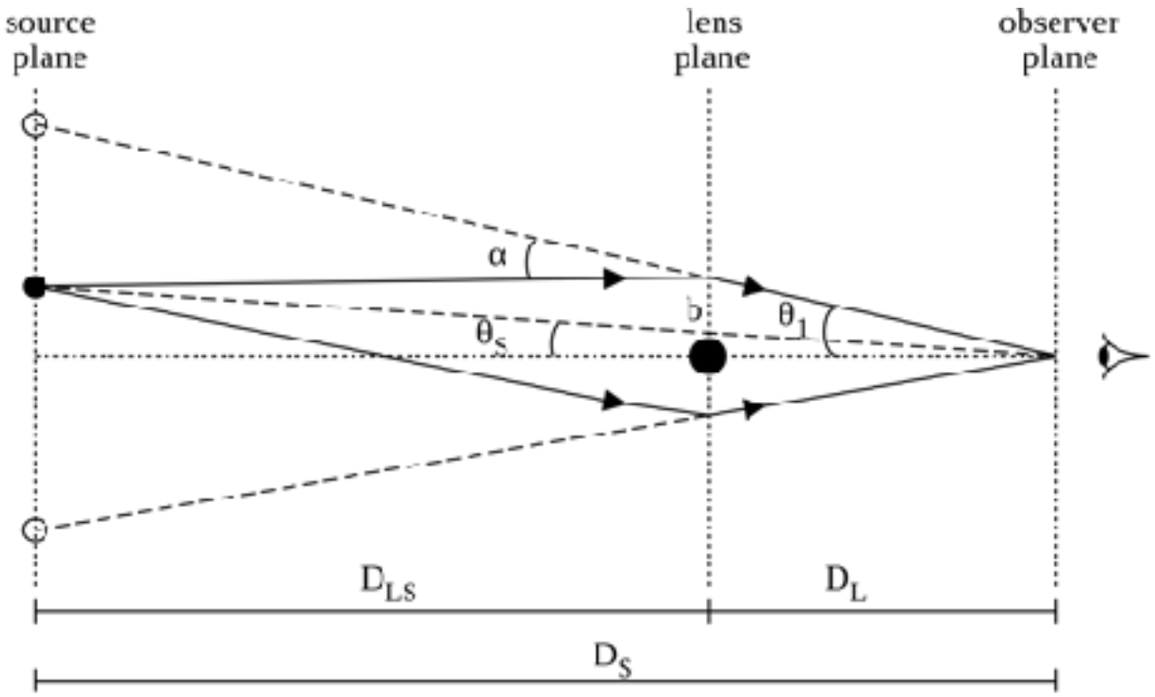
geometry

stuff

DM $b$ $\nu$ $\gamma$ ...



**HENCE** matter bends light rays

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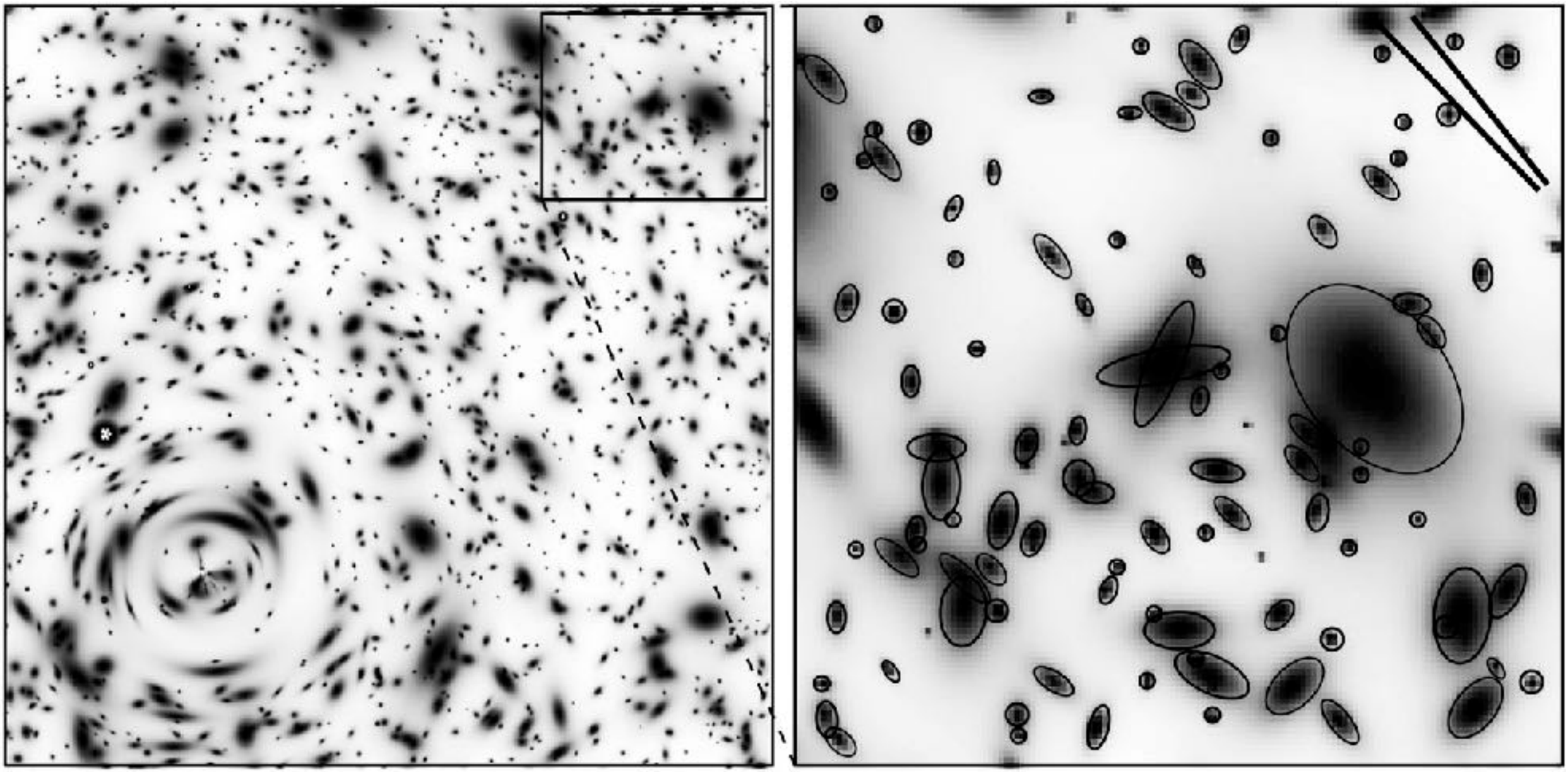

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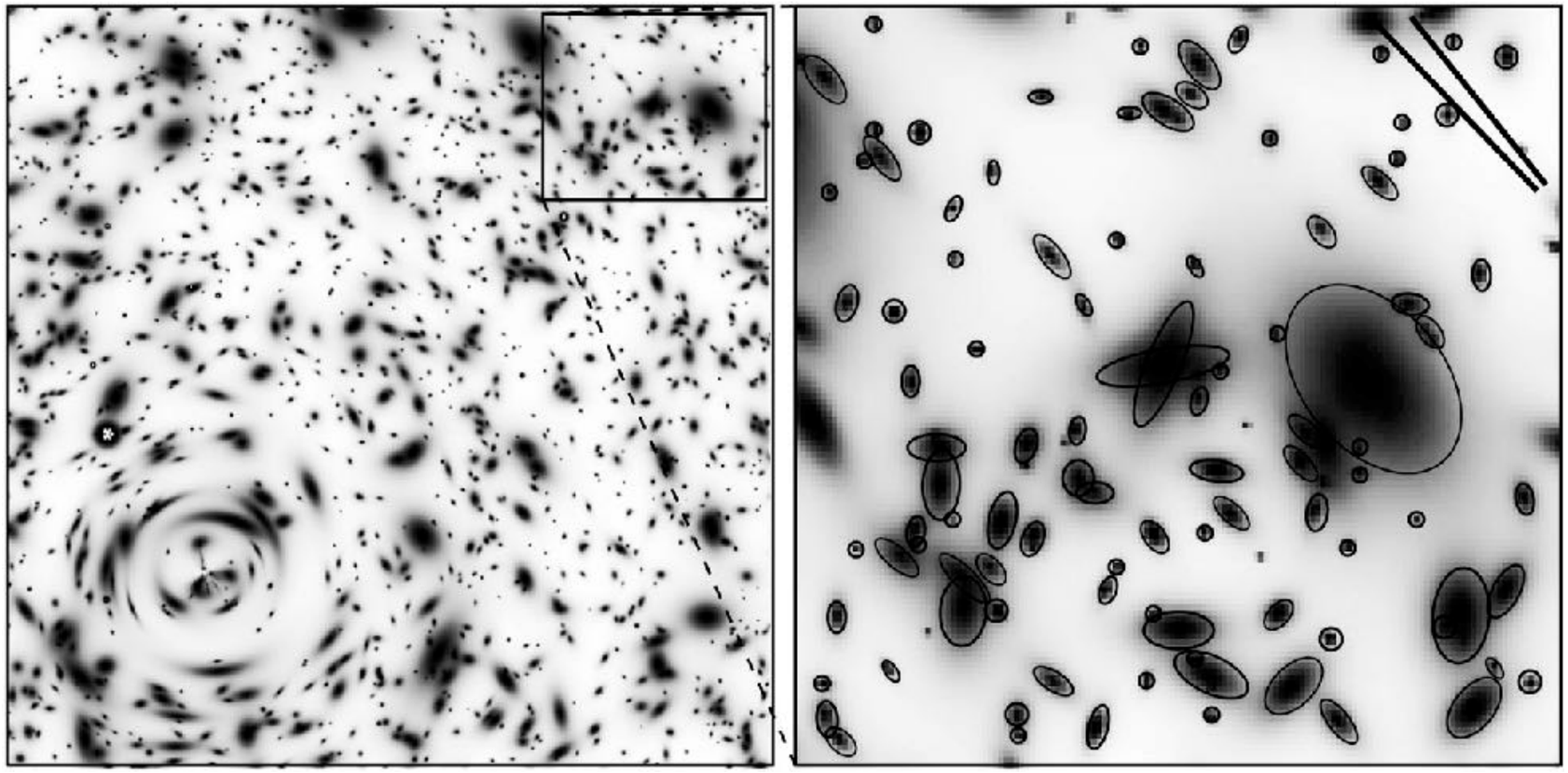
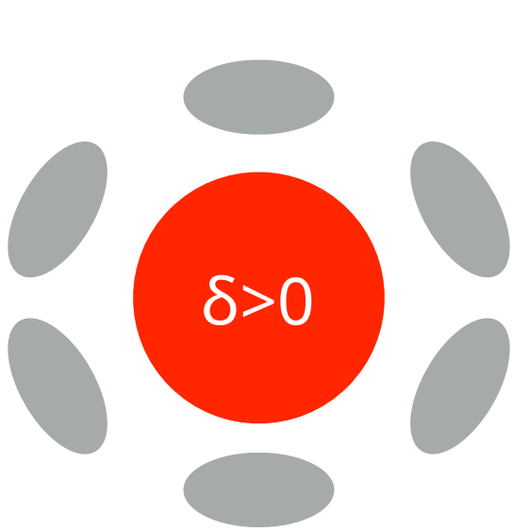
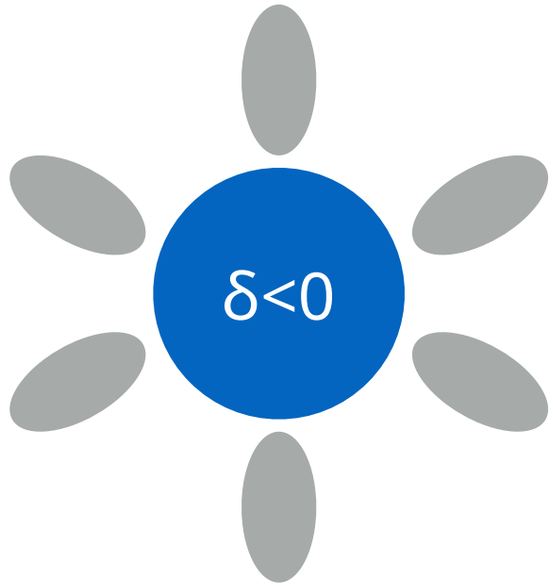


SHAPES → MASS :



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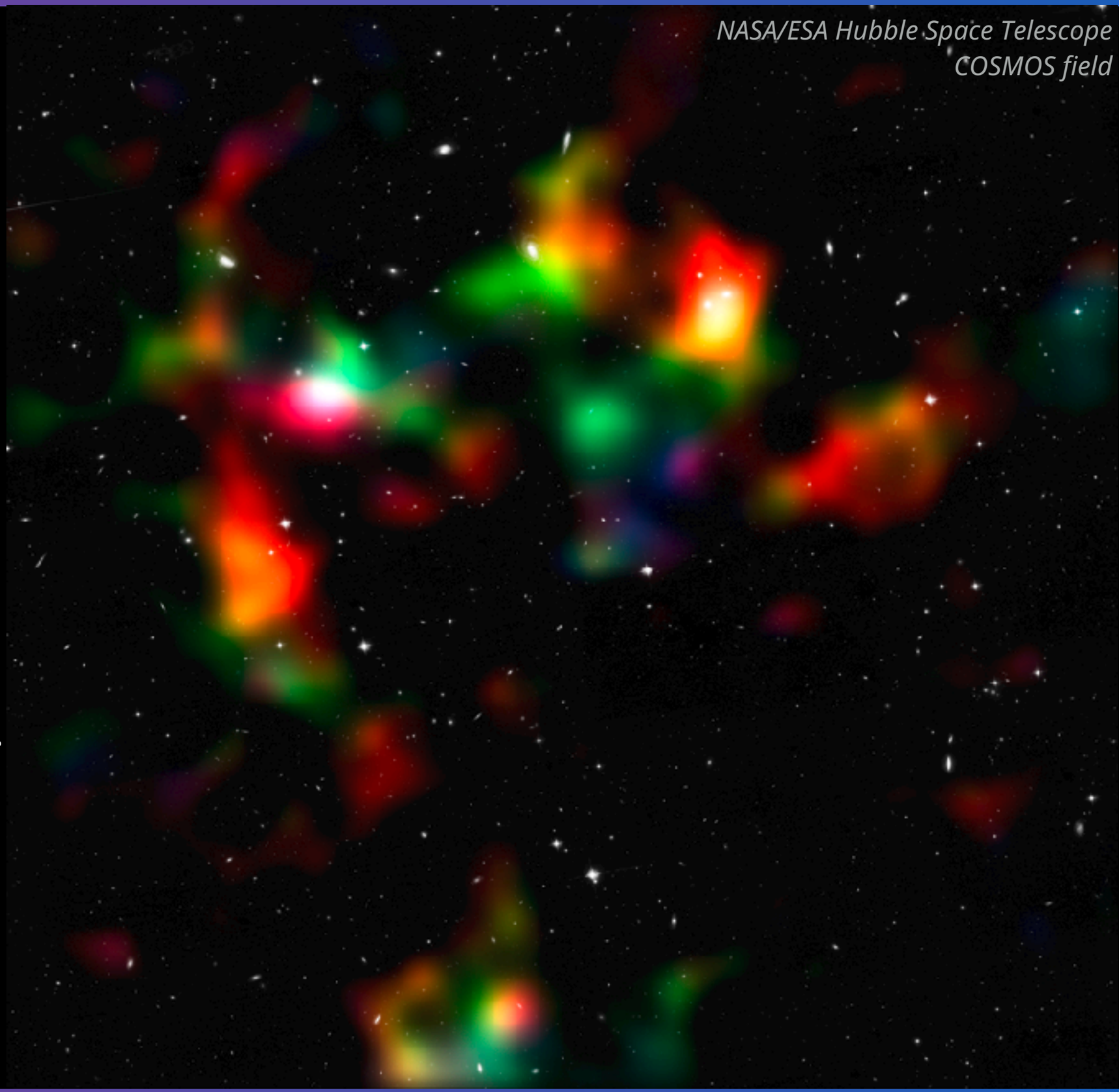


*NASA/ESA Hubble Space Telescope*
*COSMOS field*

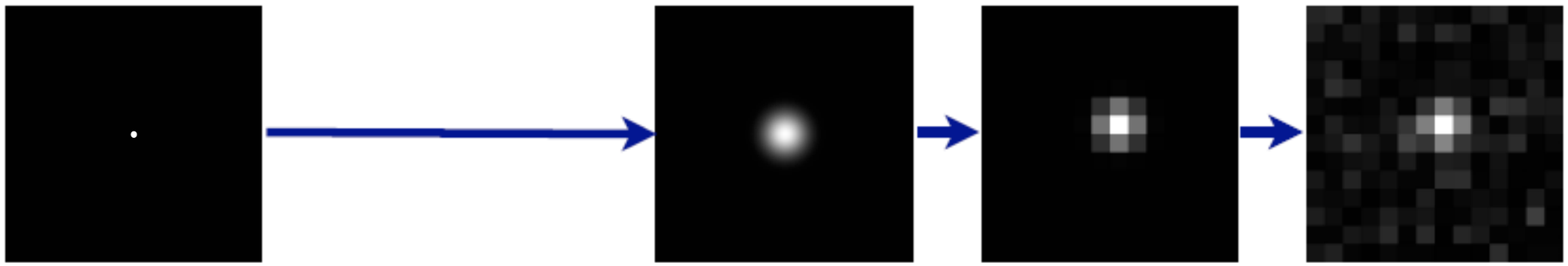
# REASONS WHY IT'S HARD

## The Forward Process.

**Galaxies:** Intrinsic galaxy shapes to measured image:

Intrinsic galaxy (shape unknown) → Gravitational lensing causes a ***shear (g)*** → Atmosphere and telescope cause a convolution → Detectors measure a pixelated image → Image also contains noise

**Stars:** Point sources to star images:



Intrinsic star (point source) → Atmosphere and telescope cause a convolution → Detectors measure a pixelated image → Image also contains noise

*Bridle+09*

→ **IDEA** : same galaxy observed with different **PSFs** (no atmosphere in space!) and color filters

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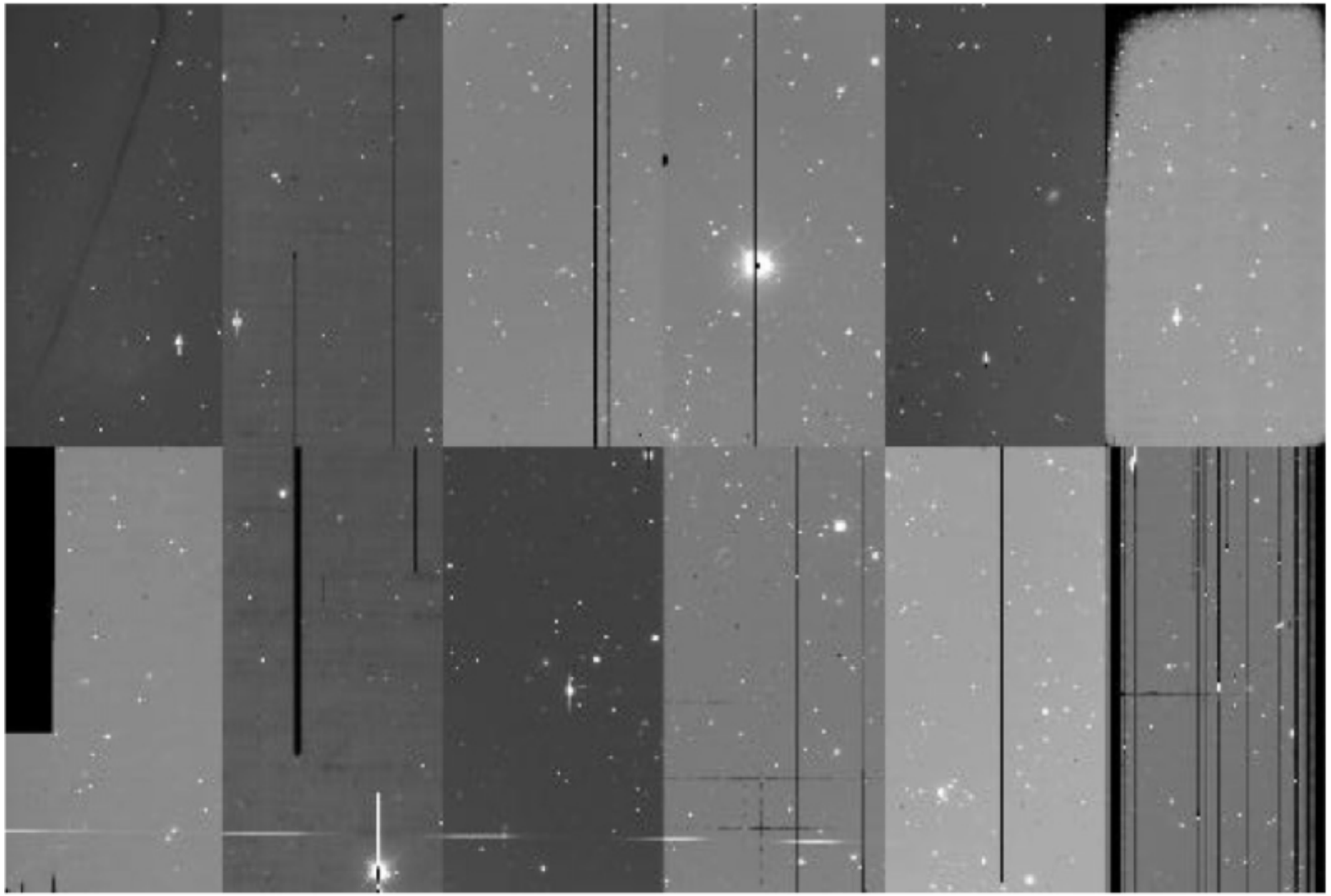
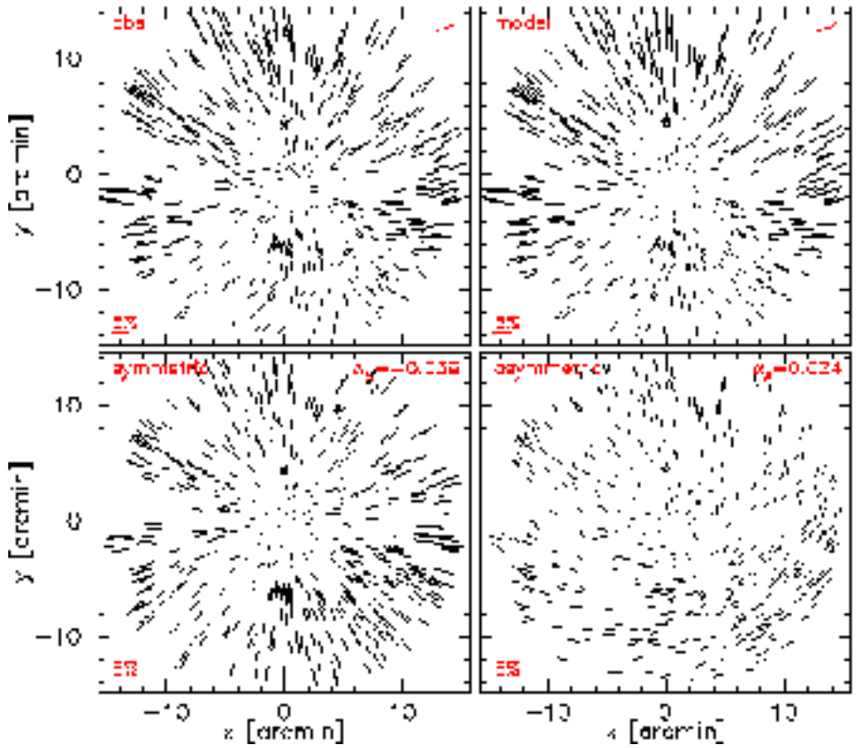


*Raw data from CFH12K, from Schneider, P., Kochanek, C. & Wambsganss, J. Gravitational Lensing: Strong, Weak and Micro.*

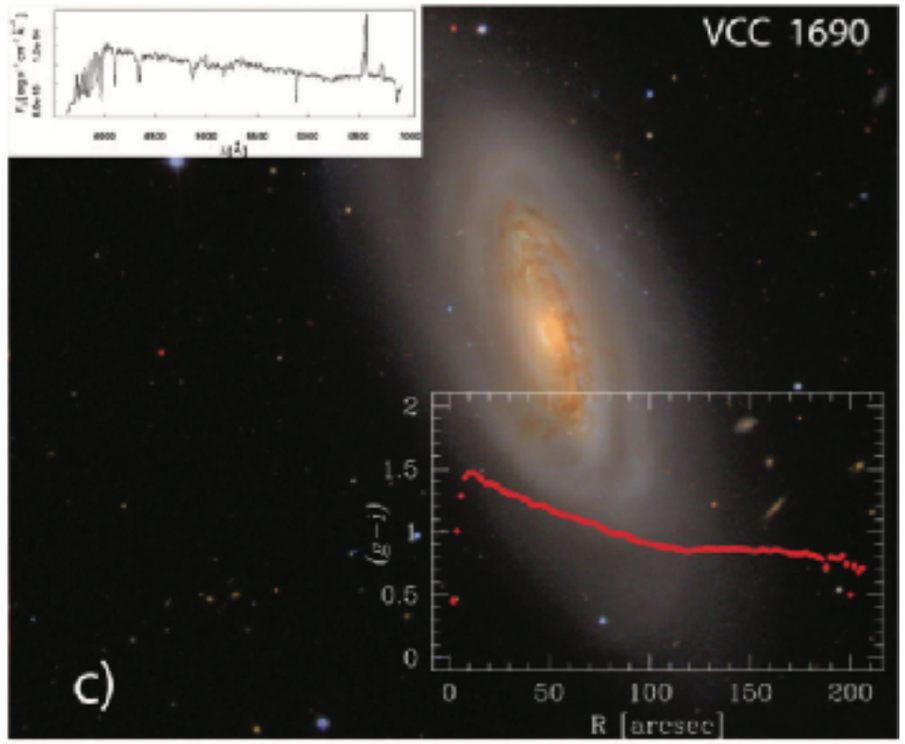
# REASONS WHY IT'S HARD

→ PSF anisotropies



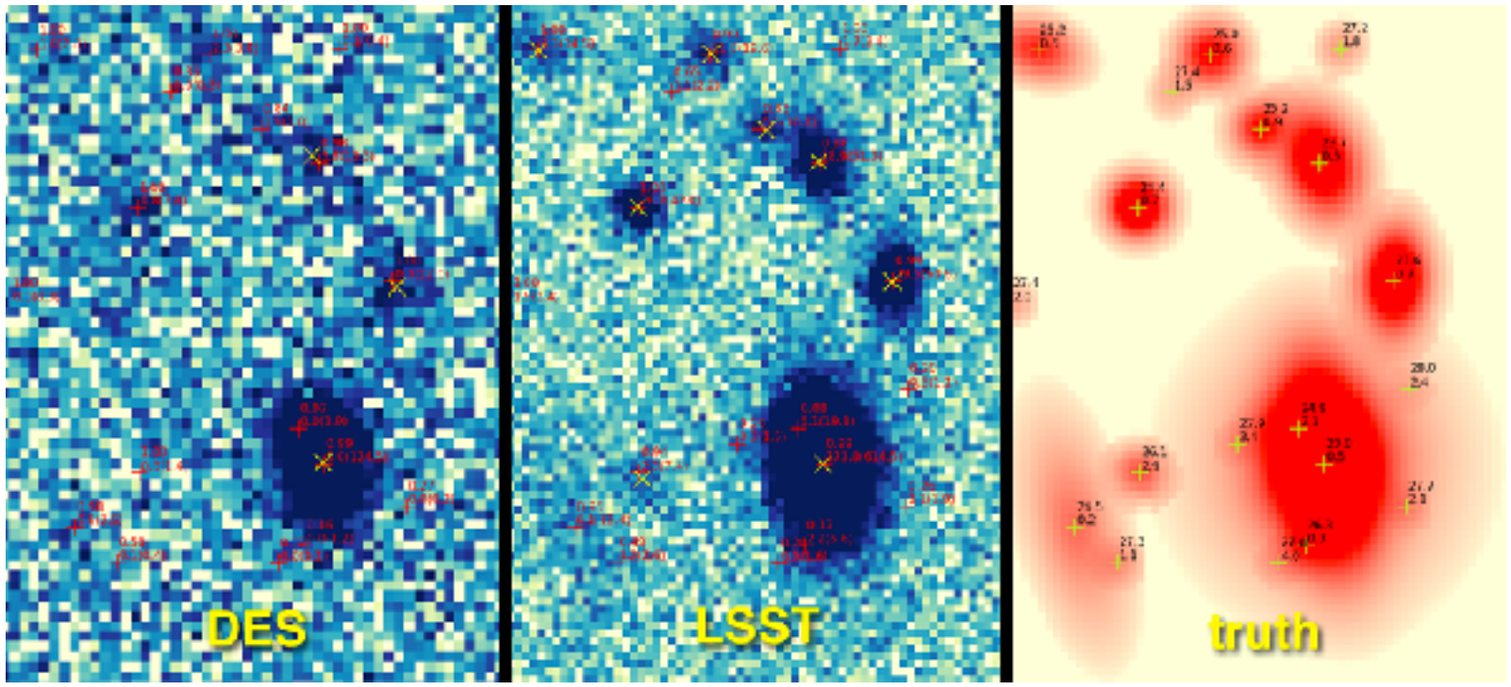

*Consolandi+16*

→ color gradients




*Dawson+16*

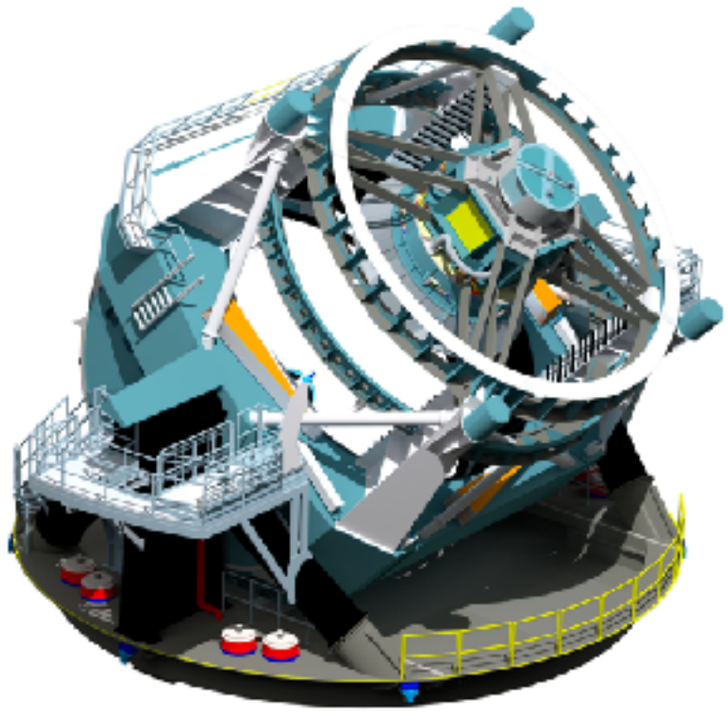
→ blending



# LSST IN A NUTSHELL

- **A few numbers**
  - 10 years of observations ~2022-2032
  - 15s exposures of wide field (1°), observed 1000 times, 1/3 of the sky
  - 9 Gpx camera, 100 PB of raw data
  - 30 000 000 000 objects detected (stars, galaxies, transients)

- **Scientific goals** include:
  - dark energy : tomographic shear+clustering measurement
  - transients (SNIa, asteroids, *etc*)
  - clusters and IGM physics
  - strong lensing
  - …



# WHAT WILL LSST DATA LOOK LIKE?

A lot like HSC data (hsc-release.mtk.nao.ac.jp/hscMap2/) !

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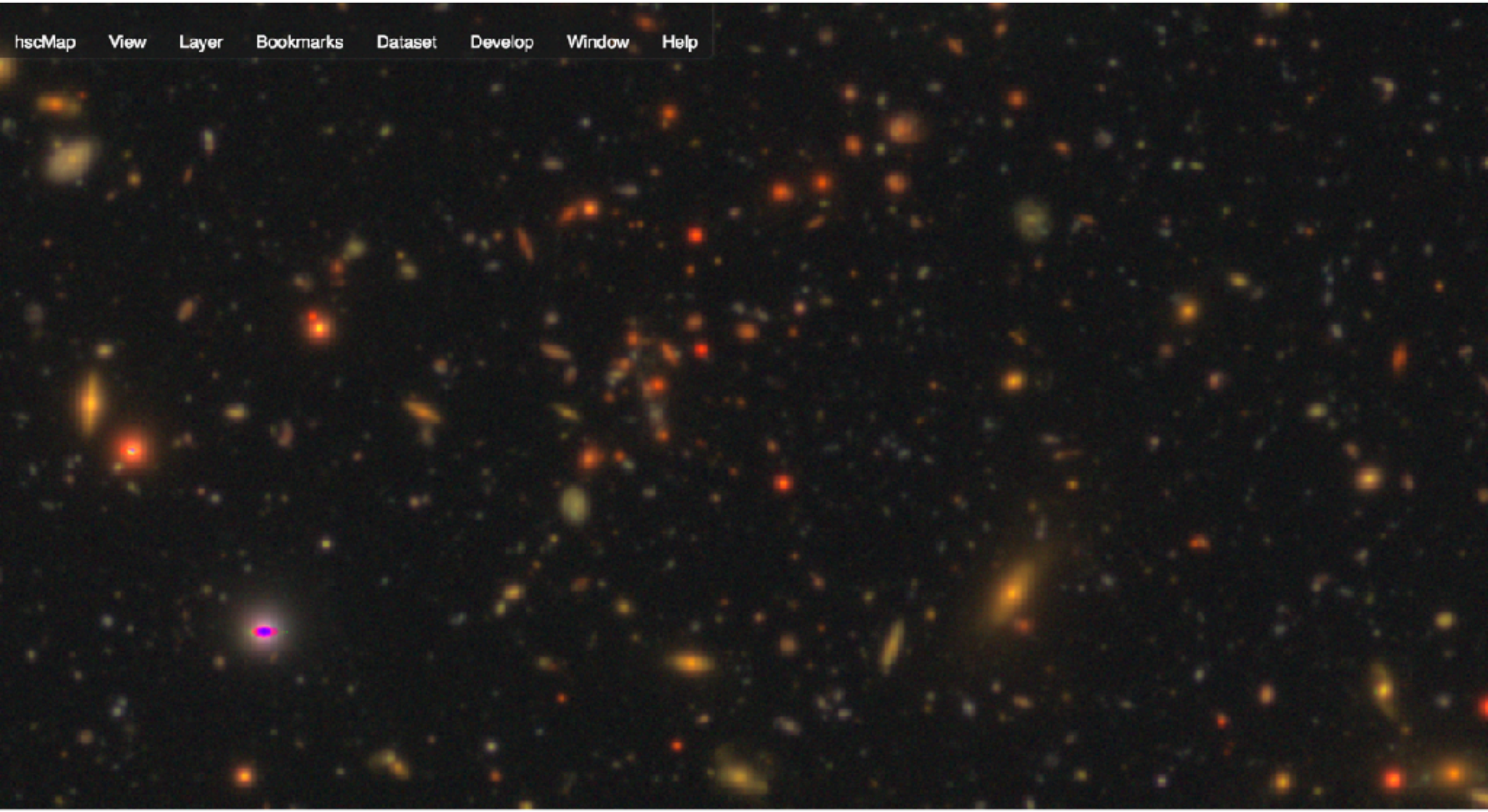

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# THE DEBLENDING PROBLEM

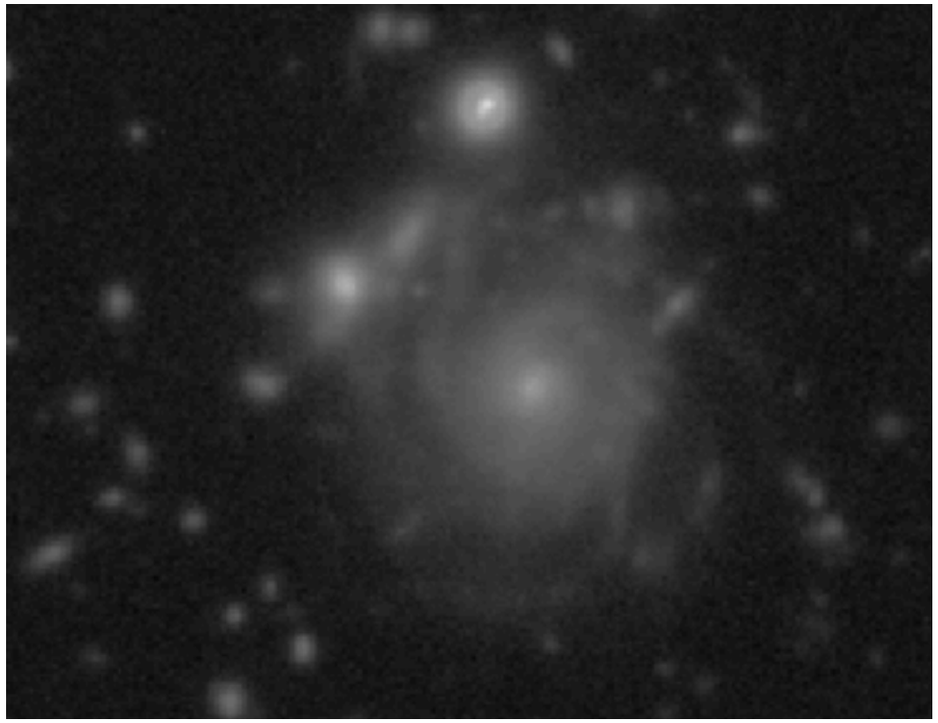
- **Is it an issue ?**
  - Yes !
  - *deep* survey: maybe up to 40% of blended objects (so says R. Lupton !)
  - depends on your definition of "*blended*"

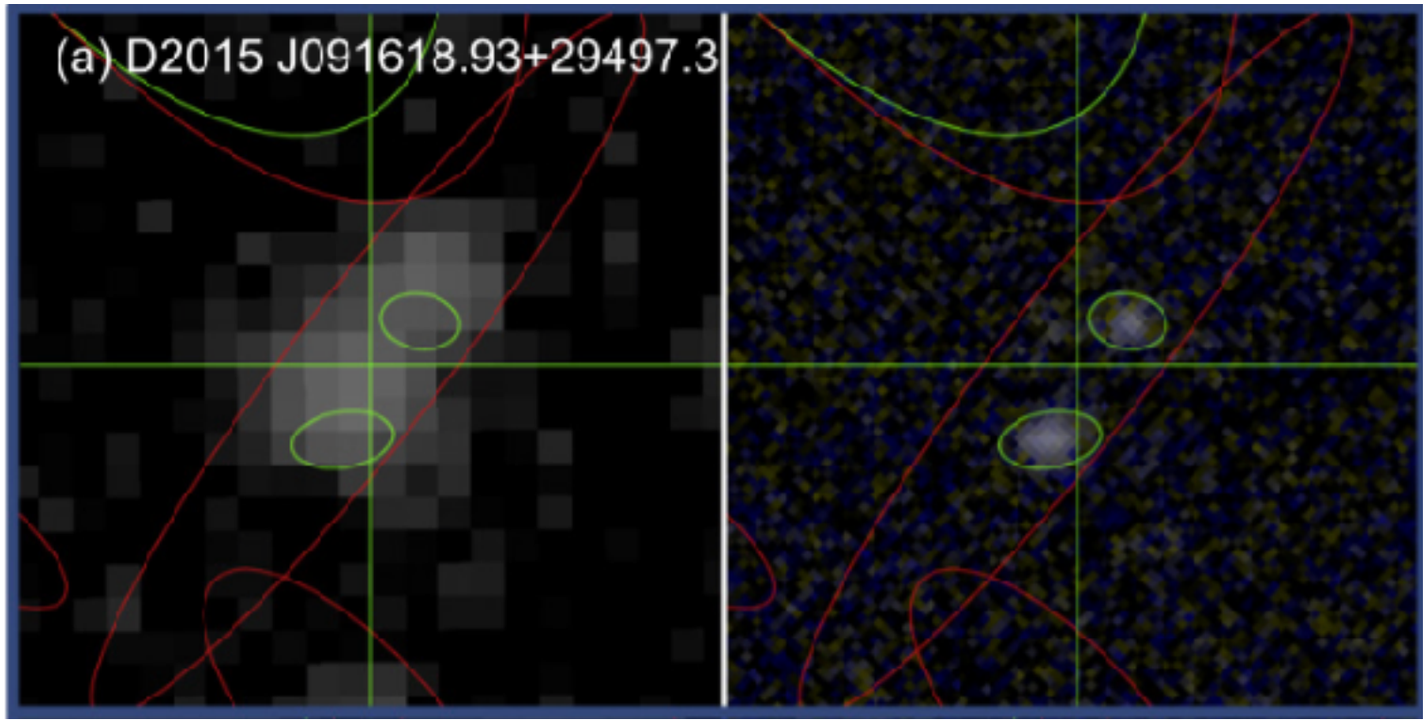
- **Why ?**
  - it affects all measurements :
    - fluxes of extended objects per band > colors > redshift
    - shapes > cosmic shear
    - morphology
    - …

# WHAT CAN YOU DO ABOUT IT?

- Use **colors** (*ugrizy* bands)
- Use **space** observations (Euclid, WFIRST !) ⇒ diffraction-limited PSF
- Learn what *real* galaxies look like *vs* symmetries

↳ *neural networks can do that very well!*






Ground : HSC Space : HST

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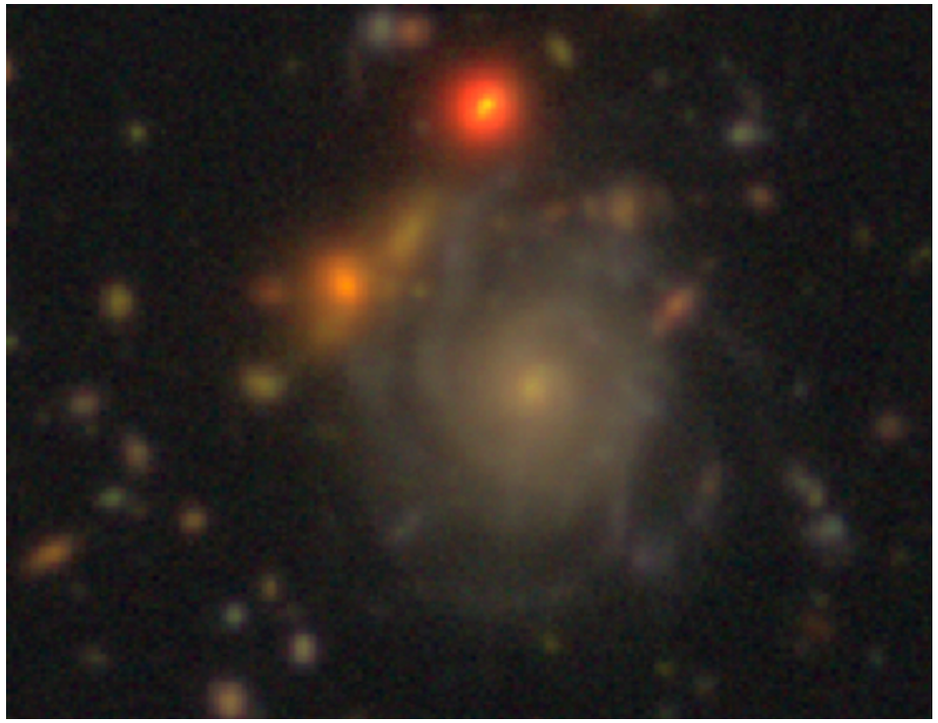
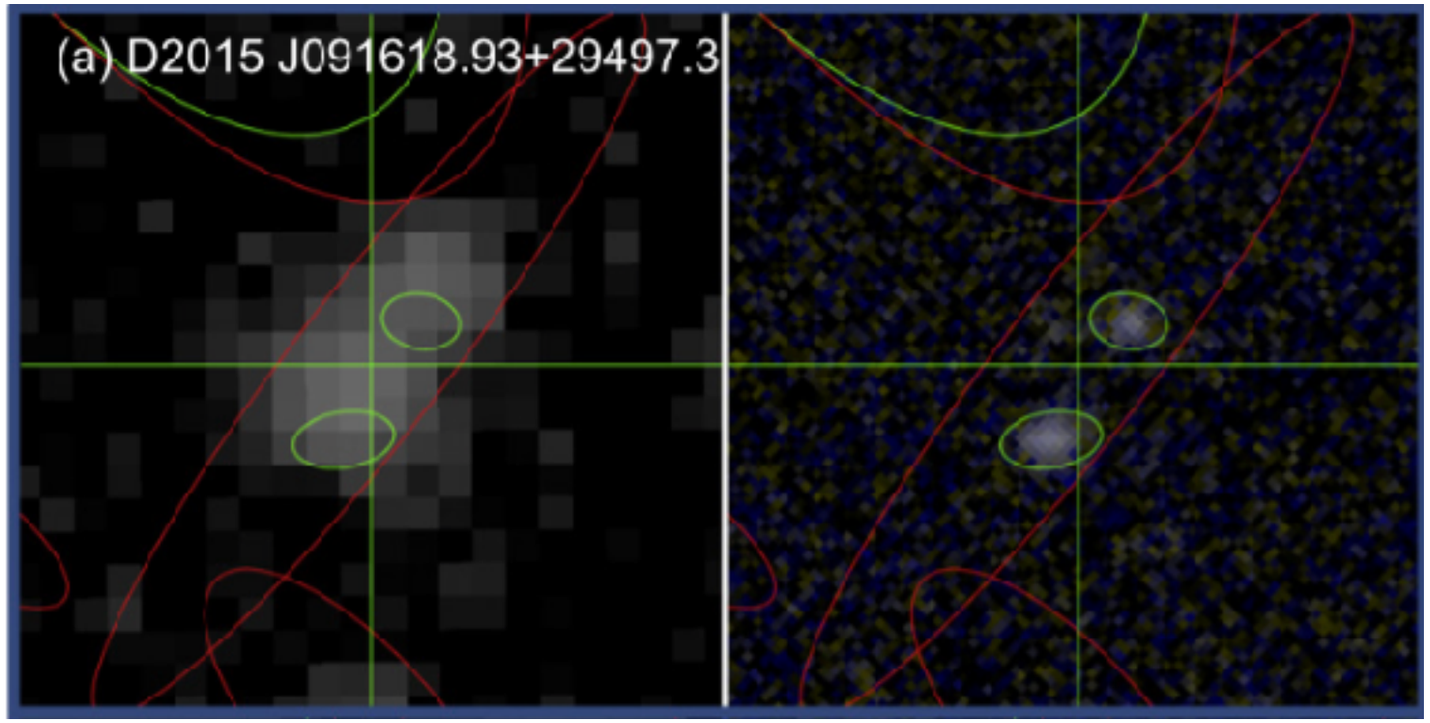
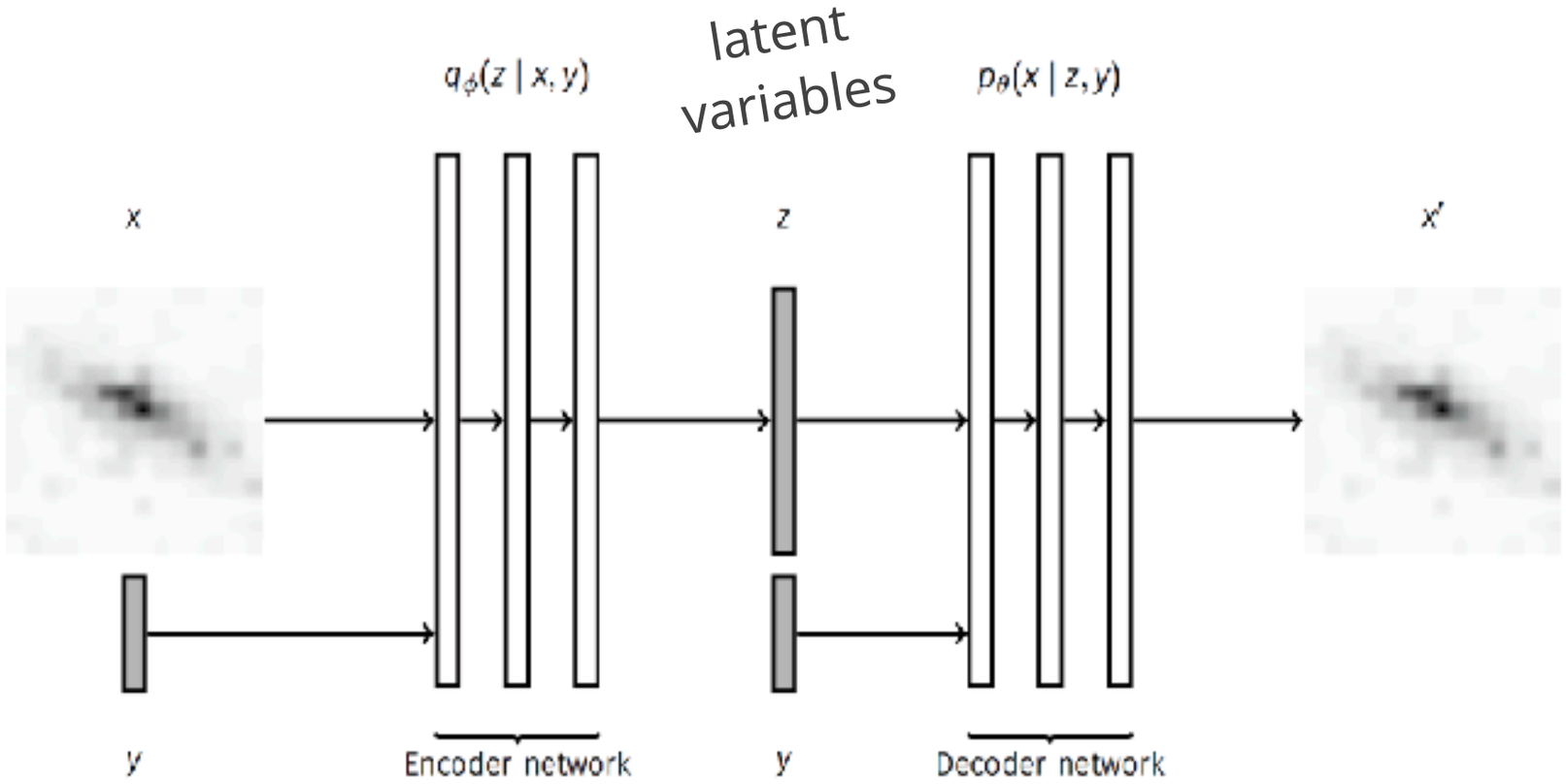





Ground : HSC Space : HST

# GENERATING REALISTIC GALAXY IMAGES

→ learn what real galaxies look like : (conditional) variational auto encoders



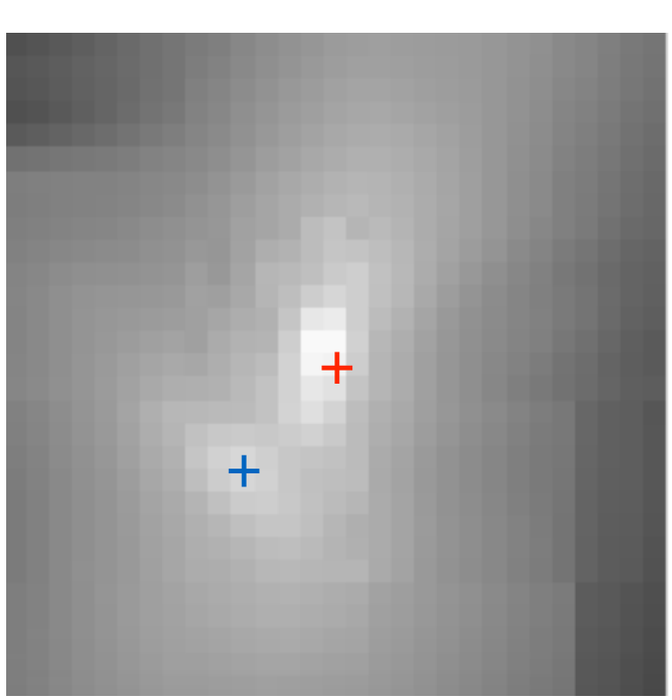

$$\log(p_\theta(x \mid y)) \geq \underbrace{-\mathbb{D}_{\mathrm{KL}}(q_\phi(z \mid x, y) \| p_\theta(z \mid y))}_{\text{Code regularisation}} + \underbrace{\mathbb{E}_{z \sim q_\phi(\cdot \mid x, y)}[\log p_\theta(x \mid z, y)]}_{\text{Reconstruction error}}$$

*©François Lanusse*

→ draw z~$\mathcal{N}(0,\mathbb{1})$ to produce new realistic images

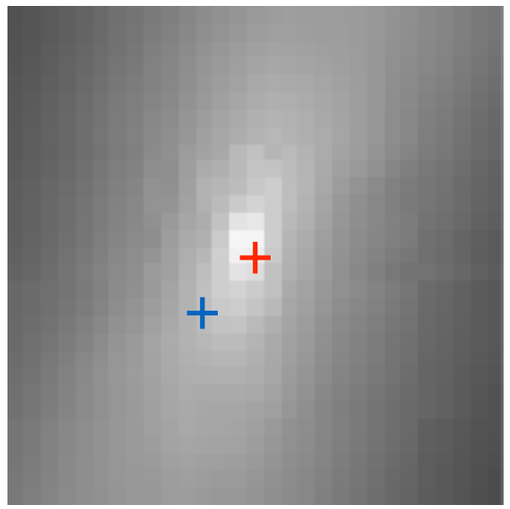
# DEBLENDING GALAXIES

- deep neural networks to perform deblending
  - adapted VAE-type networks ? preliminary work : monochromatic, shape only
  - hierarchical networks using pre-trained encoders ?
  - use latent variables encoding shear ?

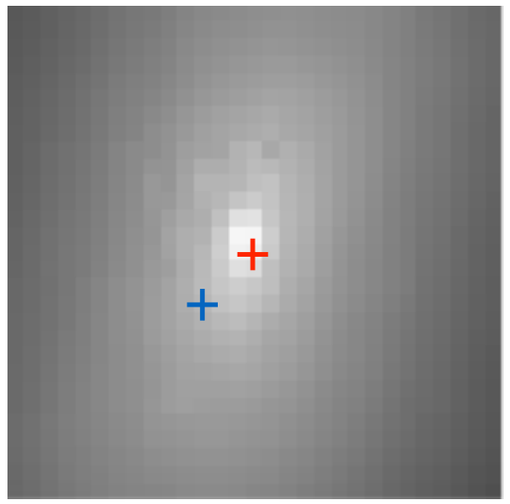


input
(blended)

desired output
(deblended)



output
(deblended)



# THE CASE FOR GROUND & SPACE

DES data - deliberately stolen from Peter Melchior's slides

# THE CASE FOR GROUND & SPACE

CLASH WFC3/IR data - deliberately stolen from Peter Melchior’s slides

# ASKING THE GOOD QUESTIONS

- Deblending is a *necessity*, not a *purpose*
- **Scientific goal(s)** sets the deblending *score*
  - shape
  - colors/redshift
  - morphology
  - ?

  *cosmic shear needs both!*

- **How to proceed ?**
  - define the question: what task should NN learn?
    - do you care about single objects ? or statistical measurements ?
    - where can they outperform good ol' algorithmic? see Alpha Go
  - build a test data base (COSMOS field?)
  - test algorithms for different scores (RAMP ?)