Gravitational Lensing and the Dark Energy Survey

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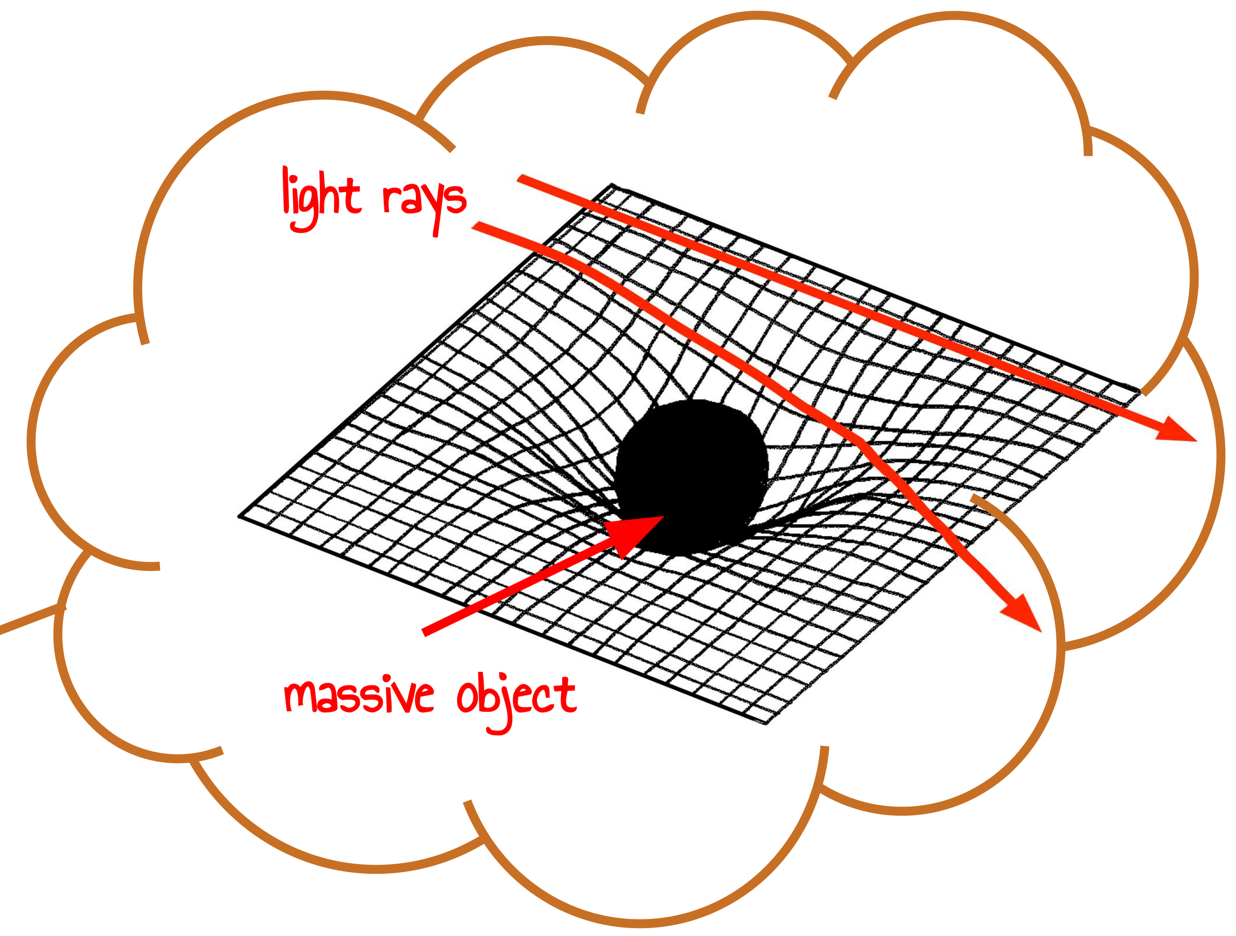
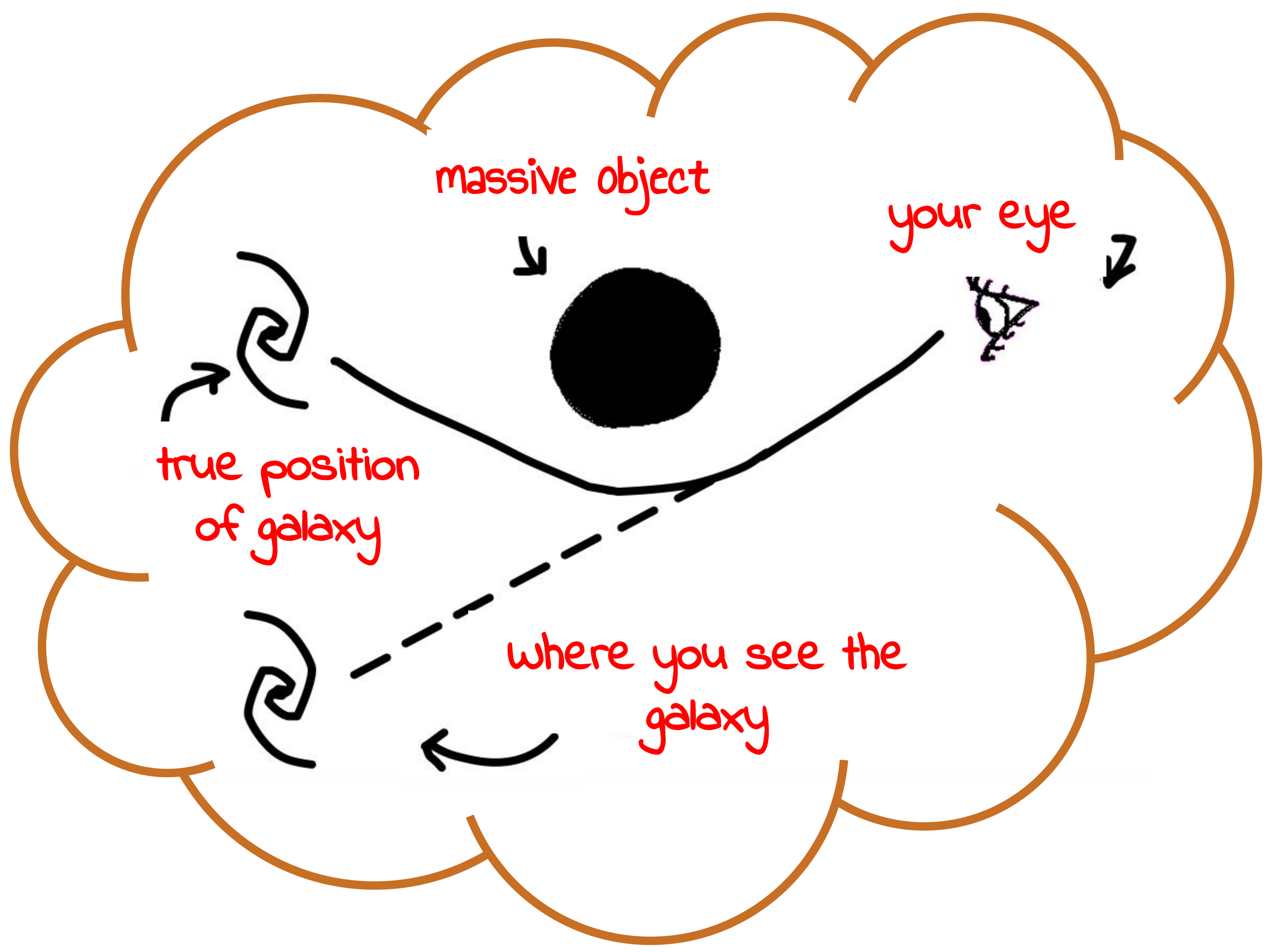
What is Gravitational Lensing?

- ★ Light is made of photons
- ★ Photons are massless particles that travel to our eyes by following the curvature of spacetime - *the fabric of our universe that changes shape in the presence of mass* (see right)
- ★ Very massive objects - like galaxy clusters and black holes - create large dips in spacetime like a bowling ball resting on a rubber sheet, though all mass has some effect (we call this gravity!)





- ★ As photons pass by the dip, they curve toward the mass ("lens")
- ★ When we see light from an object ("source") that is behind this dip, we don't know all the curves and bumps its photons encountered
- ★ Our eyes and brain perceive it as though it had travelled in a straight line. So we see an image (or images) of the source in a different place than it really is (see left)
- ★ This is called gravitational lensing because *gravity is bending the light* - much like a lens made of glass would

- ★ Gravitational lensing affects the appearance of galaxies in two ways -
  - they are magnified in all directions (by what we call "convergence")
  - and stretched along one axis (this is called "shear")
- ★ These effects are shown separately in the image to the right
- ★ The more massive the lens, the stronger this distortion will be

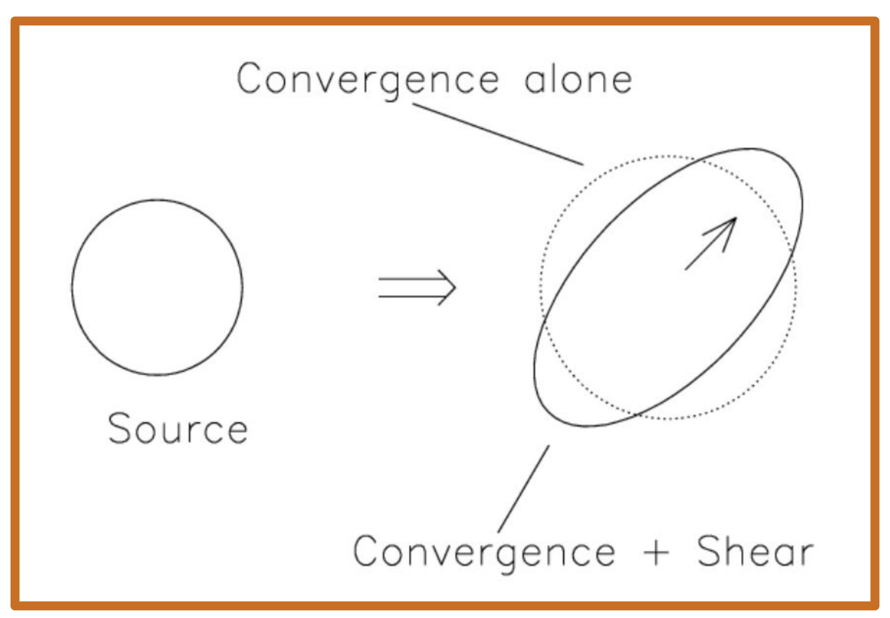


Image: Narayan & Bartelmann 1995

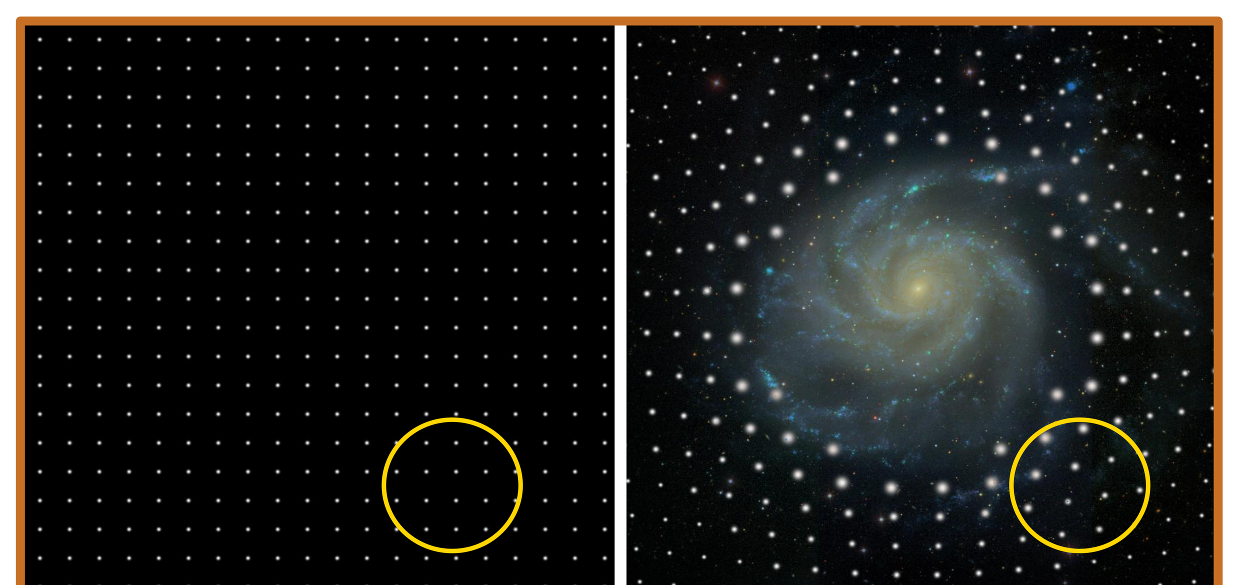


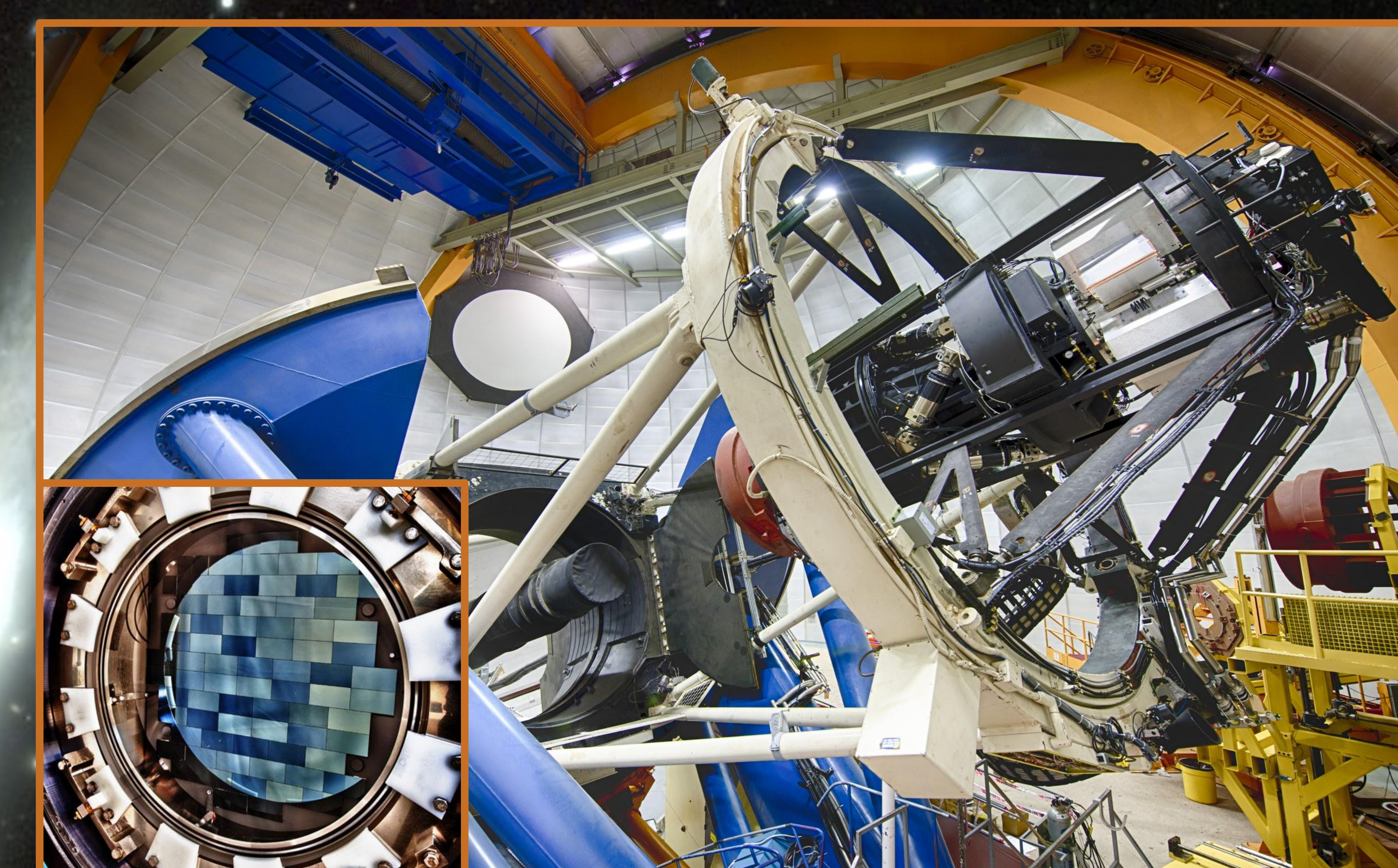
Image: J.Colberg, R. Scranton, R. Lupton, SDSS

Schematic of the magnification (related to convergence) of a grid of point-like sources by a foreground spiral galaxy. By counting the number of sources in a patch of sky around the lens galaxy (right) and comparing to an unaffected field (left), we can estimate the mass of the lens galaxy.

The thin arcs in this image are background galaxies that have been lensed by a foreground galaxy cluster called Abell 2218. **Inset:** When the source and lens are closely aligned, they create a special image called an "Einstein Ring," like the blue (source) and red (lens) galaxies shown here. *Images: NASA/ESA/Hubble*

The Dark Energy Survey

- ★ The Dark Energy Survey (DES) is a survey of 5,000 square degrees of sky in the Southern hemisphere over Chile
- ★ DES uses DECam (below, inset) to take pictures of hundreds of millions of stars and galaxies
- ★ With these images, we can use special software to estimate the shape, size, and brightness of each galaxy
- ★ If we can measure the distortion of galaxies due to gravitational lensing, we can "weigh" all of the mass that is in front of them
- ★ This is especially helpful for studying dark matter - matter which does not radiate light and only interacts gravitationally
- ★ It can also help us study "dark energy" - the name given to the mysterious vacuum energy causing the *accelerated expansion* of our universe



The 570 Megapixel Dark Energy Camera (DECam, inset) is mounted on the 1.4-meter diameter Blanco Telescope at the Cerro Tololo Inter-American Observatory in Chile. *Images: Reidar Hahn, Fermilab*

- ★ I use DES to study the magnification of *very* distant sources
- ★ We can probe higher distances with magnification than we can with shear because distant galaxies are too faint to determine their shape, only their size and brightness
- ★ I use the method shown in the schematic (left) to count source galaxies around lens galaxies we know to be nearby
- ★ I can then make estimates of the mass profiles of the lens galaxies, and compare my results with predictions from theory