ASTROPHYSICS

STUDY OF WEAK GRAVITATIONAL LENSING EFFECT

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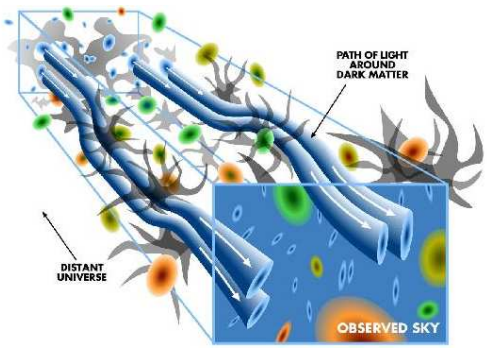
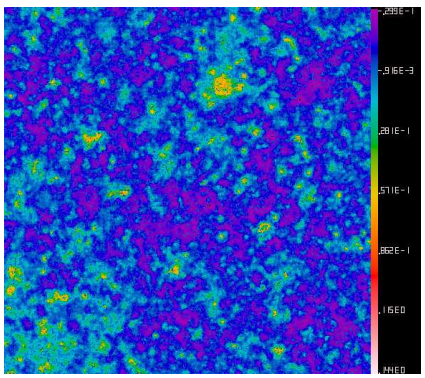
OBJECTIVES

- **Large-scale structure of universe:** as oppose to local structure of universe, eg. within clusters of galaxies, which can also be inferred by gravitational lensing, often by strong lensing.
- **Nature and distribution of dark matter:** Baryonic dark matter, Cold dark matter, Hot dark matter; how they are distributed in space, in the form of integration along line of sight.



The distorted universe. light rays from distant galaxies travel a tortuous path through a universe filled with clustering dark mass. Every bend in the path of a bundle of light from a distant galaxy stretches its apparent image. The orientation of the resulting elliptical images of galaxies contains information on the size and mass of the gravitational lenses distributed over the light path. The figure shows a schematic view of weak gravitational lensing by large-scale mass structure: distant galaxy orientation is correlated on scales characteristic of the lensing dark matter structures. *Above figure is taken from David M. Wittman et al, Detection of weak gravitational lensing distortions of distant galaxies by cosmic dark matter at large scales, Nature 405, 143-148 (11 May 2000)*



KAPA map: magnifying effect of foreground mass on background galaxies

GENERAL BACKGROUND

GRAVITATIONAL LENSING

- **Strong Lensing:** caused by extremely dense lenses, eg. black holes; produces multiple images or arcs.
- **Weak Lensing:** caused by less dense lenses, eg. "well-dispersed" dark matter; produces polarized single image.
- **Micro-Lensing:** caused by small lenses, eg. stars; increases intensity of source.

MATTER IN THE UNIVERSE

- **Baryonic matter:** matter which we see everyday
- **Dark matter:** eg. neutrino, WIMP; mass density is $\sim 30\%$ of critical density (At critical density, we have a flat universe)
- **Dark energy:** a form of matter which has repulsive gravity; mass density is $\sim 60\%$ of critical density

WEAK LENSING EFFECTS

- **Cosmic shear:** polarization (change of ellipticity) of background galaxies due to inhomogeneous gravitational lense.
- **Displacement:** image appears shifted since we assume linear propagation of light even though the light is bent.
- **Magnification:** image appears larger than source because light is refracted at different angles by the lense at different angular displacement.

WHAT HAVE I DONE?

- **Receive a map to be analyzed:** eg. diagrams shown; result of either simulation or observation
- **Smooth:** to take into account the different object sizes because they are not points like pixels/single data
- **Finding peak values:** relates to mass of large scale structures
- **Distribution of peak values:** infers distribution of dark matter

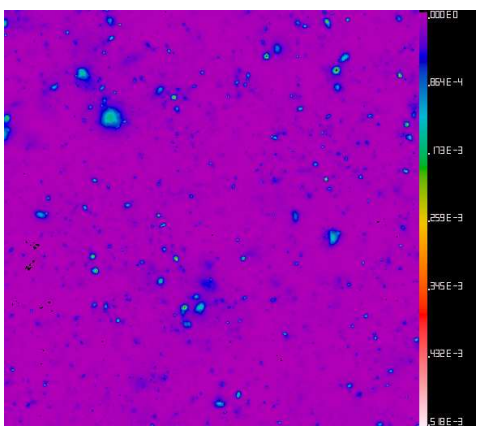
WEAK LENSING

DARK MATTER LENSES

- **Large-scale distribution of foreground mass:** unknown 3-D distribution; however, we can find the surface density of the lense.
- **How it acts as lenses:** long-range gravitation, relatively small curvature of space-time (compared to that of strong lensing), bends light light as optical lenses do.

BACKGROUND GALAXIES

- **Intrinsic ellipticity** of galaxies
- **Angular Displacement** in relation with lense and observer
- **Distance of source:** determined from red shifts
- **Bending of light:** according to general relativity, light, like any object, is susceptible to gravitation. Different mass density gives space-time curvature, and thus, different refractive index, and light takes the path of minimum optical distance.



The Sunyaev Zeldovich effect: Ionized electrons between galaxies scatter off cosmic microwave background (CMB) photons, causing secondary temperature fluctuation in the CMB.