Simulations of Gravitational Lensing of Galaxies for Use in Cosmological Catalogs

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Introduction

I will describe a project creating simulations of gravitationally lensed galaxies in collaboration with the Legacy Survey of Space and Time Dark Energy Science Collaboration (LSST-DESC). These lensed galaxies are hosts of lensed active galactic nuclei and lensed supernova. The lensed point sources (AGN/Supernovae) embedded in host galaxies are important as the cosmology-focused DESC is primarily interested in lensing time delays provided by these point sources. The lensed host galaxies we are adding make the systems more realistic as opposed to having only AGN and supernovae.

A gravitational lens creates a distorted image of a more distant object as light is bent around a nearer massive body. This distortion appears as a ring, arc or multiple images around the image of the lensing body. The simulations are being generated in order to be used in Data Challenge 2 (DC2) of the LSST-DESC. The DC2 sky survey covers six optical bands in a wide-fast-deep (WFD) area of approximately 300 deg^2 as well as a deep drilling field (DDF) of approximately 1 deg^2. The strong lenses are included in the DDF.

Our project is specifically working to produce several thousand simulated images of strongly lensed host galaxies using the Flexible Image Transport System (FITS) file type commonly used in astronomical data storage. Utilizing the Image Simulator (imSim) software, the generated FITS stamps will be put into large-scale cosmological simulations. These FITS stamps will be part of a set of simulated images used to test other software and scientific algorithms. Part of my work was in testing and running the code used to generate the FITS stamps and creating full-system images for data quality checks. As part of this project I will display the resultant images on a website I wrote hosted by Github.

What are AGN and Supernovae?

An **Active Galactic Nucleus (AGN)** is a region at the center of a galaxy with a much higher than normal luminosity in some EM band that wouldn't be produced just by stars.

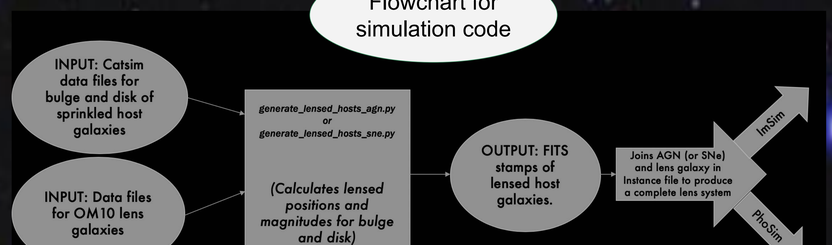
Supernovae are stellar explosions that can be caused when a degenerate star begins runaway nuclear fusion, causing a violent shedding of the star's outer layers, or the sudden gravitational collapse of a massive star's core, where gravity overpowers the nuclear fusion pushing out and the gravitational energy is released as a supernova.

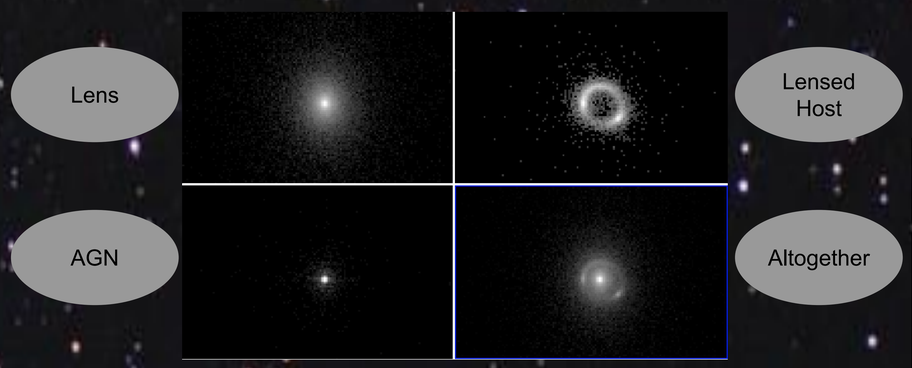
Gravitational lensing time delays occur when an object of variable brightness (like an AGN or supernova) is lensed. The multiple images of the object will change brightness at different times. The delay in brightness change depends on Hubble parameter H and thus time delays can be used to measure H, the expansion rate of the universe.

The FITS Stamps

These are all simulated bulges for AGN hosts produced by our code. Every simulated galaxy has a bulge and a disk component.

Flowchart for simulation code





The Websites

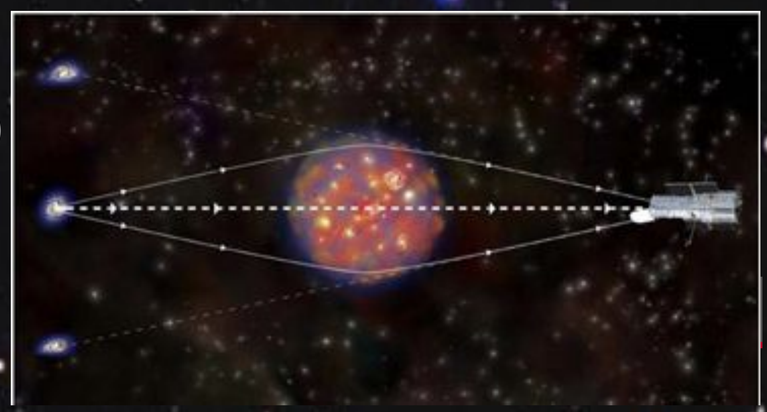
https://smtomsky.github.io

https://lsstdesc.org/

https://www.vro.org/

Gravitational Lensing

This is the Cosmic Horseshoe, a strong gravitational lens discovered in 2007 in the Sloan Digital Sky Survey. The foreground len galaxy is a type of very massive galaxy called a luminous red galaxy (LRG). The background source galaxy forms an almost complete Einstein ring. This image is from the Hubble Space Telescope and is a combination of images in the F475W, F606W, F814W filters. (From the Hubble Legacy Archive.)



A schematic of gravitational lensing showing the **source galaxy** on the left, the **lensing mass** in the middle (in this image a galaxy cluster), and then the **observer** on the far right. Notice how the path of the light is distorted by the lensing mass in a characteristic tangential pattern, leading to observed images like the Cosmic Horseshoe we show above.

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