SpaghettiLens

Gravitational Lens Modelling

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Motivation

- Gravitational Lenses (GL) hard to find
- Let volunteers help find them: SpaceWarps
- But post processing? SpaghettiLens

Outline

Fermat's Principle

Fermat's Principle[1]

Rays of light traverse the path of stationary optical length with respect to variations of the path.

Fermat's Principle

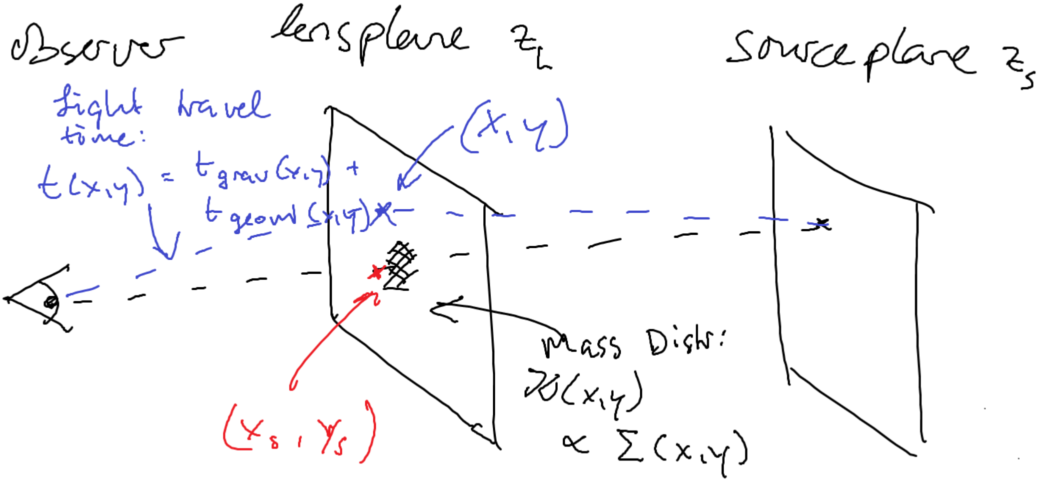
Time t for path X:

$$t[X] = \frac{1}{c} \int_{t_1}^{t_2} n(\vec{x}(t)) \sqrt{1 + \left(\frac{\mathrm{d}\vec{x}(t')}{\mathrm{d}t'}\right)^2} \mathrm{d}t'$$

Path X where t stationary.

[1] Ghatak, Ajoy (2009), Optics

Setup

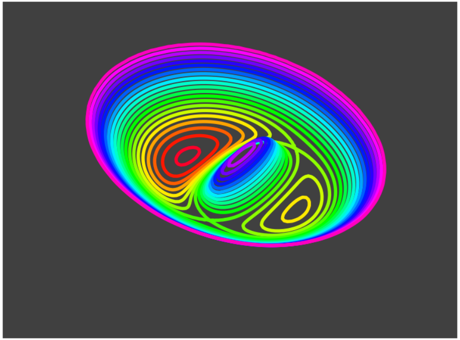

Observer
lensplane z_L
Sourceplane z_S
light travel time:
$t(x,y) = t_{grav}(x,y) + t_{geom}(x,y)$
(x,y)
(x_s, y_s)
Mass Distr:
$\kappa(x,y)$
$\propto \Sigma(x,y)$

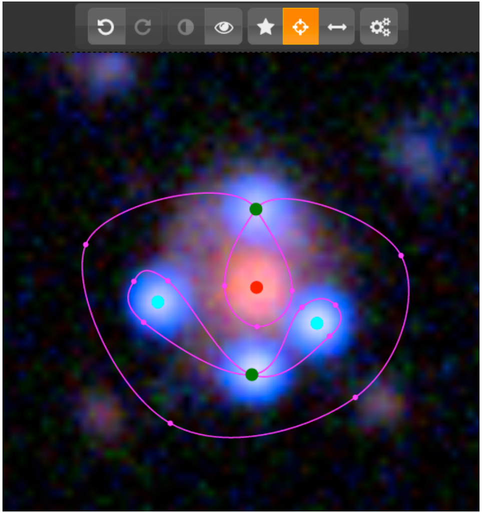
light travel time

Fermat's Principle

$$
\begin{aligned}
t(x,y) &= t_{\text{geom}} + t_{\text{grav}} && (1)\\
t_{\text{geom}} &\propto (x - x_s)^2 + (y - y_s)^2 && (2)\\
t_{\text{grav}} &= \langle t_{\text{grav}}(x_\circ, y_\circ)\rangle + (1 + z_L)\frac{2G}{c^3} M(x_\bullet, y_\bullet) && (3)
\end{aligned}
$$

Arrival Time Surface

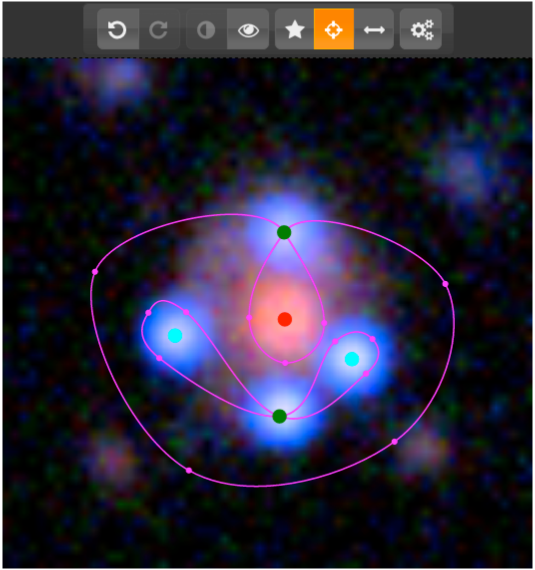




SpaghettiLens

- Extremal Points (Images)
- Self Intersecting Contour Lines

`http://labs.spacewarps.org/spaghetti/`



SpaceWarps Setup & Results

- CFHT Legacy Survey
- about 11 million classifications
- 29 promising (59 total) new lens candidates

SpaceWarps: II New Gravitational Lens Candidates...[2]

SPACE WARPS: II. New Gravitational Lens Candidates from the CFHTLS Discovered through Citizen Science

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[2] arxiv:1504.05587

SpaghettiLens Results: Tests of Perfomance

- use simulated lenses
- let volunteers model them
- recover Einstein Radii
- Volunteers perform well!

Gravitational Lens Modelling in a Citizen Science Context[3]

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Gravitational Lens Modelling in a Citizen Science Context

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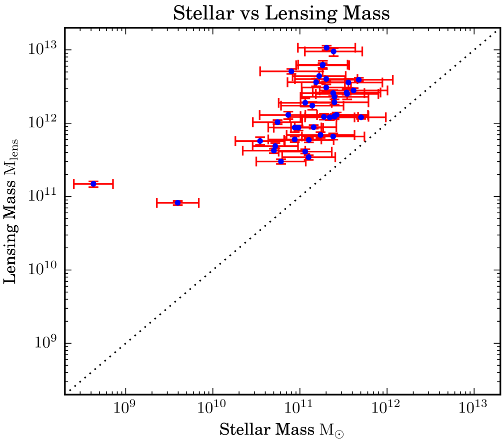
SpaghettiLens Results: Stellar vs Lensing Mass

- lensing mass against the stellar mass of the candidate lens galaxies
- stellar mass fraction of order 20 percent
- with decreasing trend for the most massive galaxies
- expected for early type galaxies
- outliers? Maybe non-lenses (not yet spectroscopically confirmed)



Outlook

We are currently working on:

- fit parametrized models to the free-form mass distributions (Lucy Oswald)
- determination of photometric red shifts
- estimate stellar populations (using galfit, SExtractor)

Questions?

Questions?
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Appendix

$$A_t = A_{\mathrm{geom}} + A_{\mathrm{grav}} \tag{4}$$

$$A_{\mathrm{geom}} = \frac{1}{2}\left(x^2 + y^2\right) \tag{5}$$

$$\nabla^2 A_{\mathrm{grav}}\left(x, y\right) = -2\kappa\left(x, y\right) \tag{6}$$

$$A = \frac{cD_L}{(1+z_L)^2}\frac{D_{LS}}{D_S} \times t \tag{7}$$

$$\kappa(x, y) = \frac{4\pi G}{c^2}\frac{D_L}{1+z_L}\frac{D_{LS}}{D_S} \times \Sigma(x, y) \tag{8}$$