The Search for Primordial Black Holes

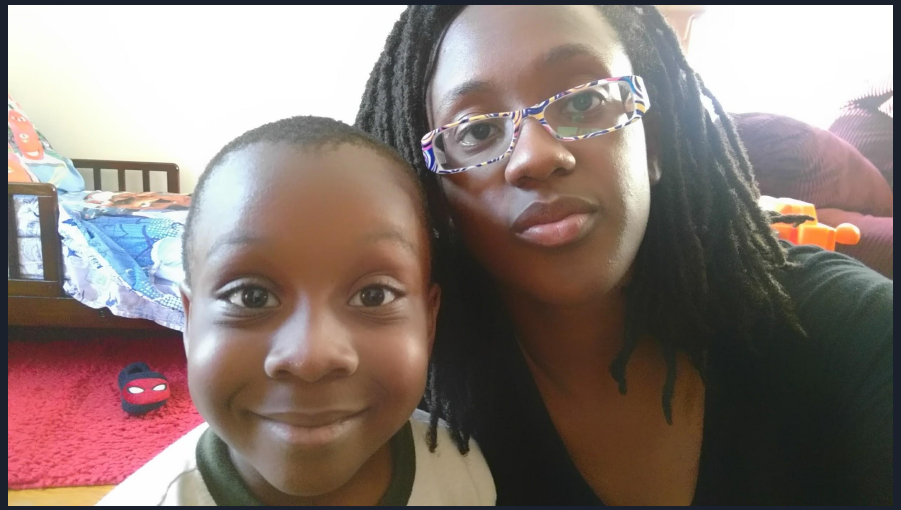
Marika Erin McGhee
University of Wisconsin - Milwaukee

with Jim Annis (FNAL); Celeste Keith (UW-Madison); Mishelle Mironnov (ISTA)

Agenda

- About Me
- Background
  - Dark Matter
  - Primordial Black Holes
- Gravitational Lensing
  - Strong/Weak Lensing
  - Microlensing
- Microlensing Generator Code
- Output Examples
- Future Work
- Questions/Comments

About Me



Education

- Computer Science, Technical Theatre
  - DePauw University, 2011
- Astrophysics, Mechanical Engineering
  - University of Wisconsin - Milwaukee, 2018

Work

- Harley - Davidson Motor Company
- United Technologies Corporation - Aerospace Systems
- Arecibo Remote Command Center
- Montevideo Technology Inc. - Torque Systems

Organizations

- National Society of Black Engineers
- National Society of Black Physicists
- Society of Women Engineers

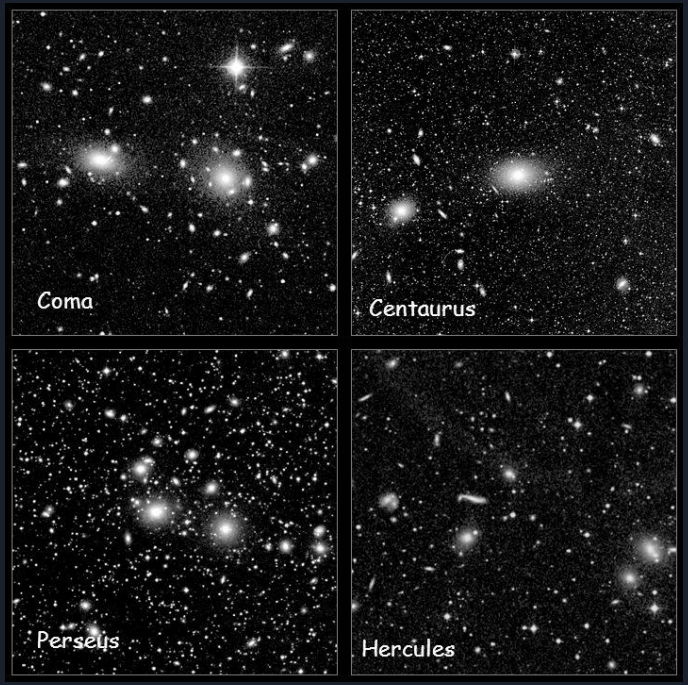
Background

Dark Matter & Black Holes

Dunkle Materie

Galaxy Clusters

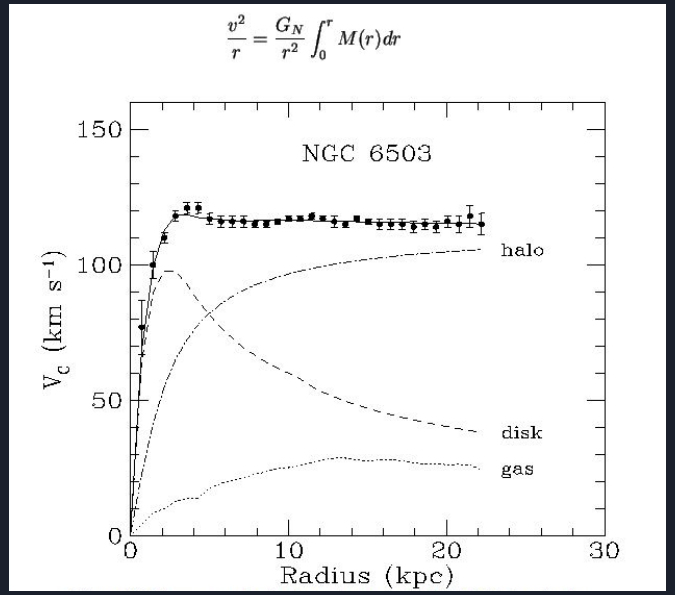
- 1933 || Swiss astrophysicist Fritz Zwicky
- Virial theorem to the Coma galaxy cluster
  - Compared mass based on velocity, and mass based on brightness.
- Has ~400x more mass than was visually observable.
- The gravity effect of the visible galaxies was far too small for such fast orbits, thus mass must be hidden from view.
- Based on these conclusions, Zwicky inferred that some ***unseen matter*** provided the mass and associated gravitation attraction to hold the cluster together.
- This was the first formal inference about the existence of dark matter.[32] Zwicky's estimates were off by more than an order of magnitude, mainly due to an obsolete value of the Hubble constant[33]



http://slideplayer.com/slide/6061190/20/images/39/Gravity+holds+clusters+together.jpg

Dark Matter

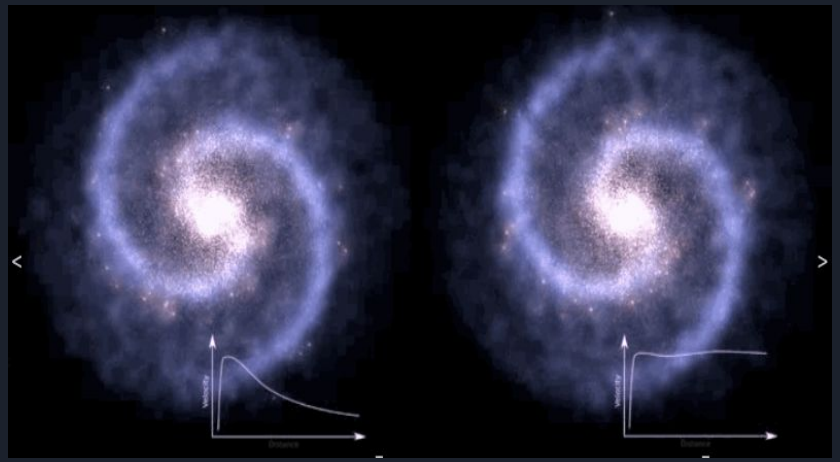
Flat Rotation Curves



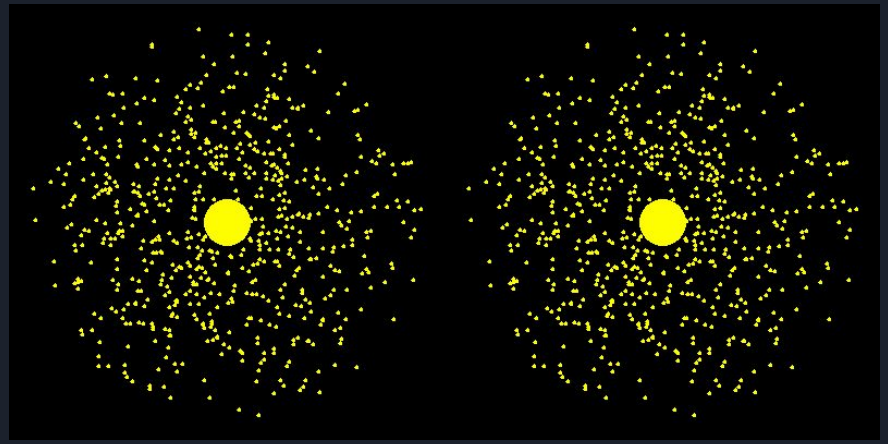
Location: The Local Void
Distance: 17,000,000 ly
Diameter: 30,000 ly

Dark Matter

Flat Rotation Curves



https://media.giphy.com/media/pvVVhQg2syJk4/source.gif

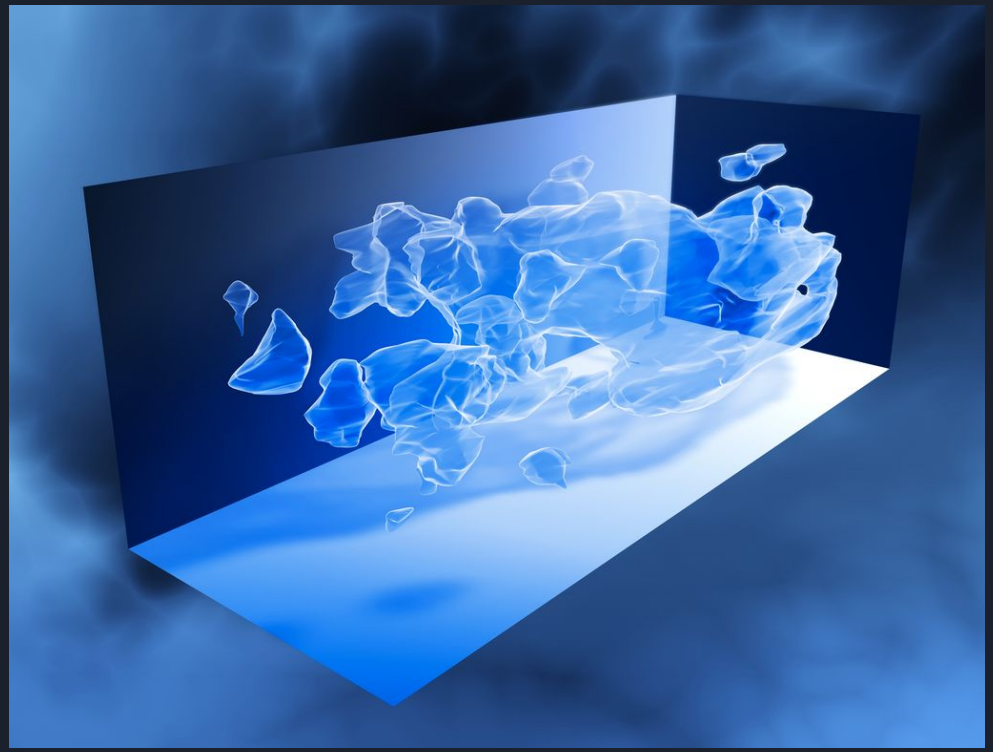


http://ircamera.as.arizona.edu/NatSci102/NatSci102/movies/galrot_anim.gif

Dark Matter

Recap

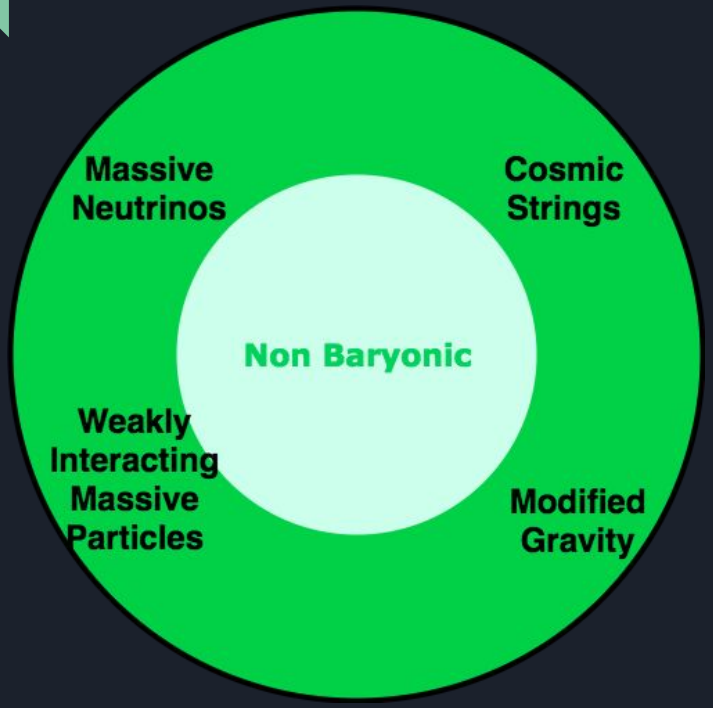
- Interacts with gravity
- Does not interact with electromagnetic radiation (light)



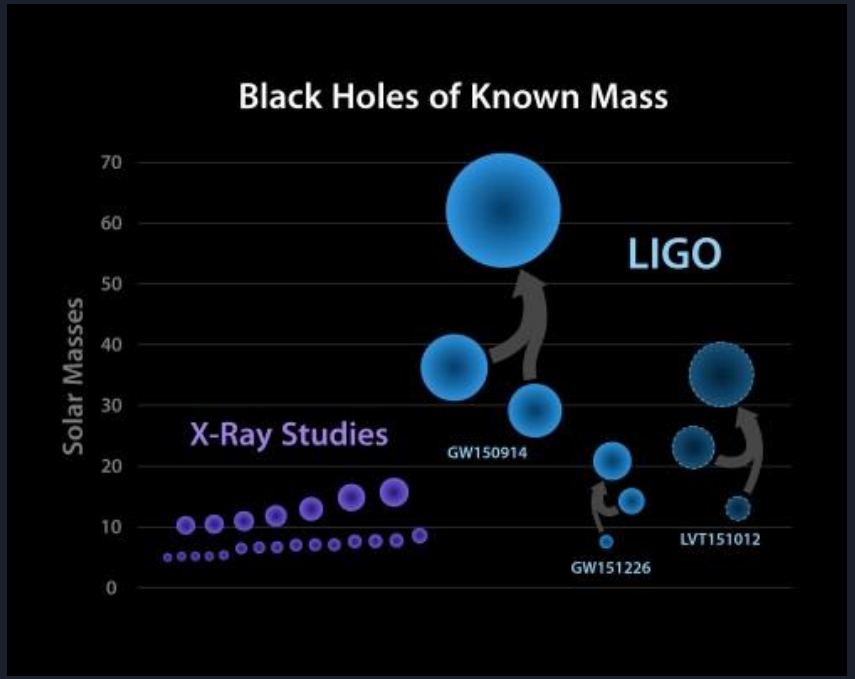
https://upload.wikimedia.org/wikipedia/commons/thumb/3/31/COSMOS_3D_dark_matter_map.png/1024px-COSMOS_3D_dark_matter_map.png

Dark Matter

Candidates



Black Holes



http://scienceblogs.de/astrodicticum-simplex/files/2016/06/Black_Hole_Mass_Chart-500x400.jpg

First proposed by Hawking in 1971

Formed at 10^{-5} s after big bang

Initial masses of ~1-10^{3} solar masses

Idea rekindled by LIGO's announcement of the merger of two 30M black holes

Gravitational Lensing

Strong, Weak, Micro

Gravitational Lensing

Strong Lensing

Weak Lensing

Micro Lensing

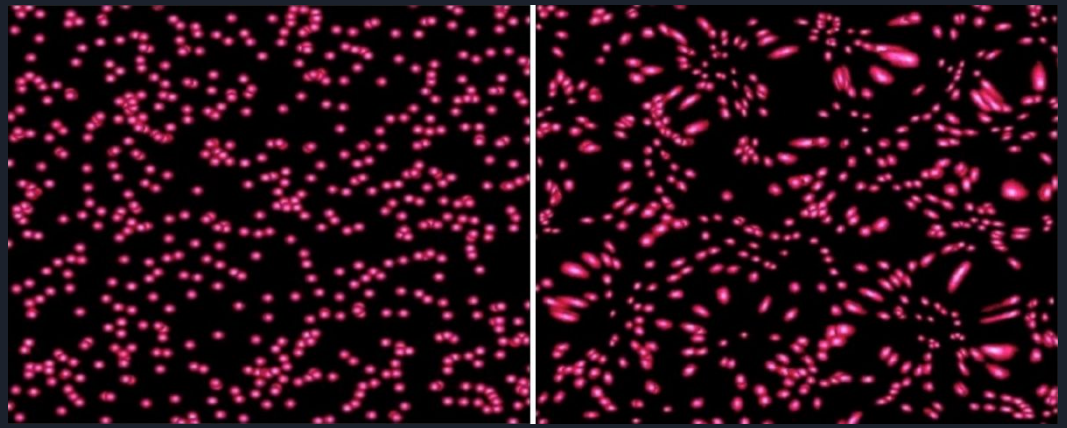
https://upload.wikimedia.org/wikipedia/commons/thumb/0/03/Black_hole_lensing_web.gif/120px-Black_hole_lensing_web.gif

Gravitational Lensing

Strong Lensing

https://upload.wikimedia.org/wikipedia/commons/1/11/A_Horseshoe_Einstein_Ring_from_Hubble.JPG

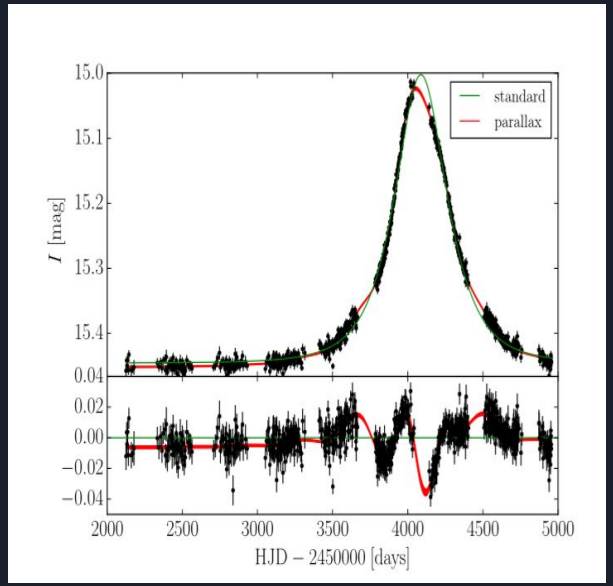
Weak Lensing

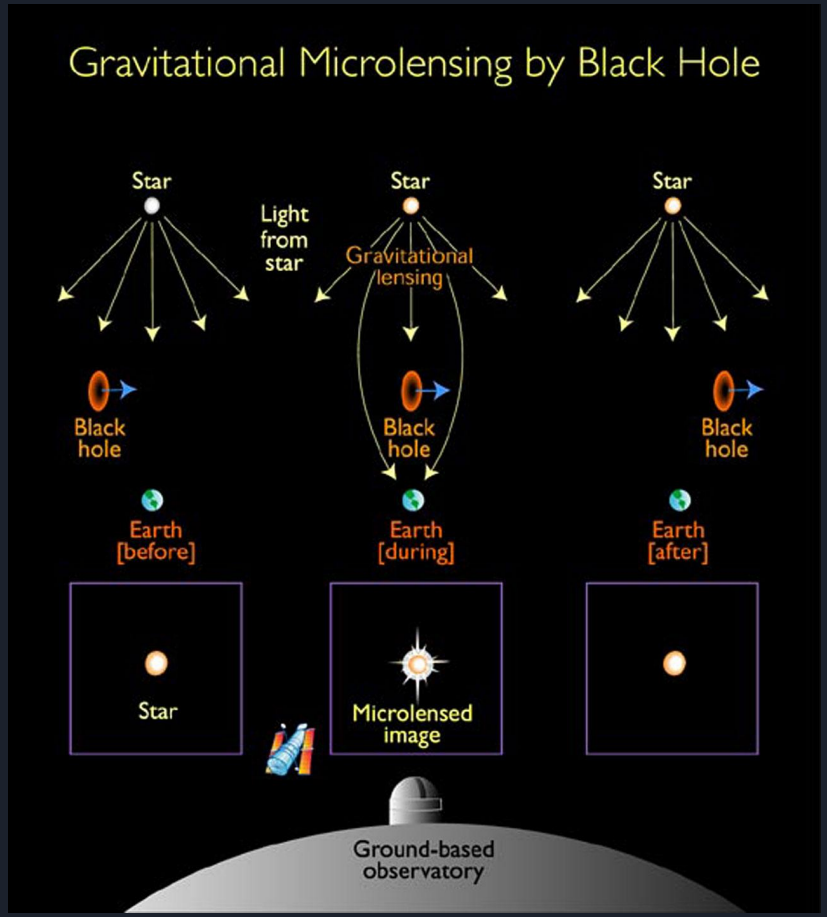


https://i.stack.imgur.com/nIECi.jpg

Micro Lensing

1986 - Paczynski suggests using this to search for massive compact halo objects (MACHOs)



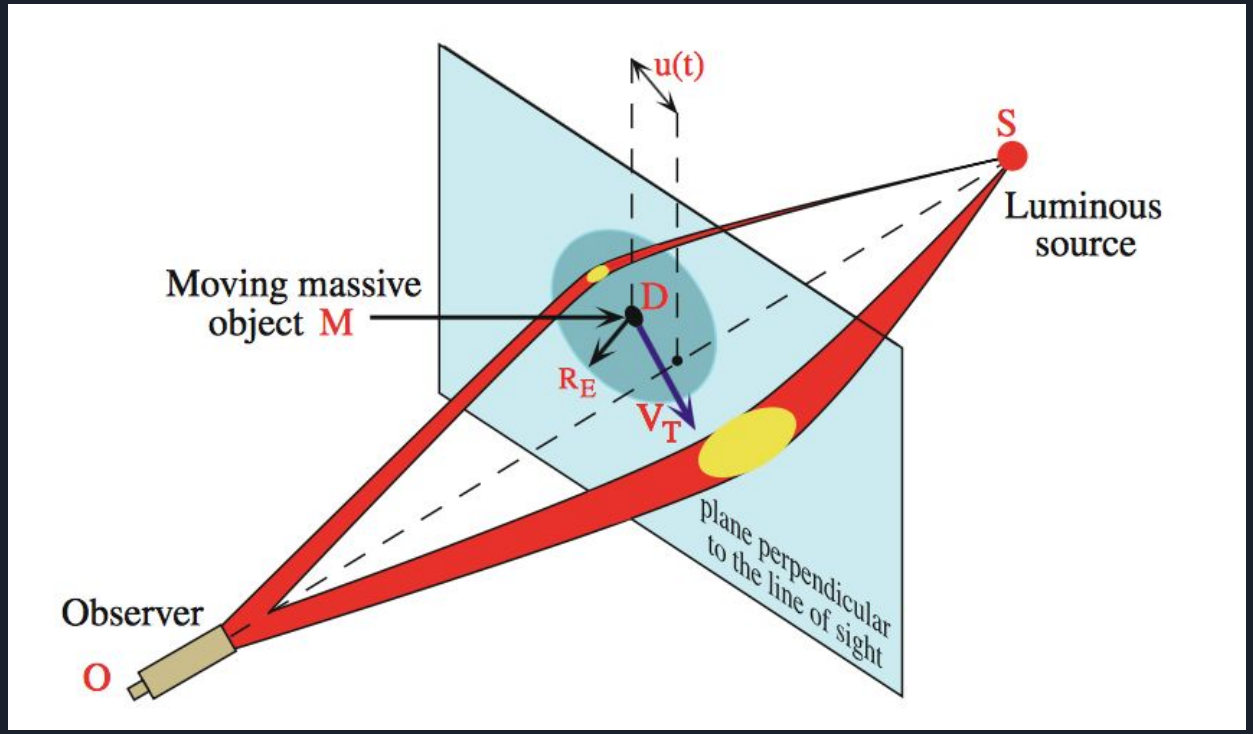


https://i.stack.imgur.com/mWNqQ.jpg

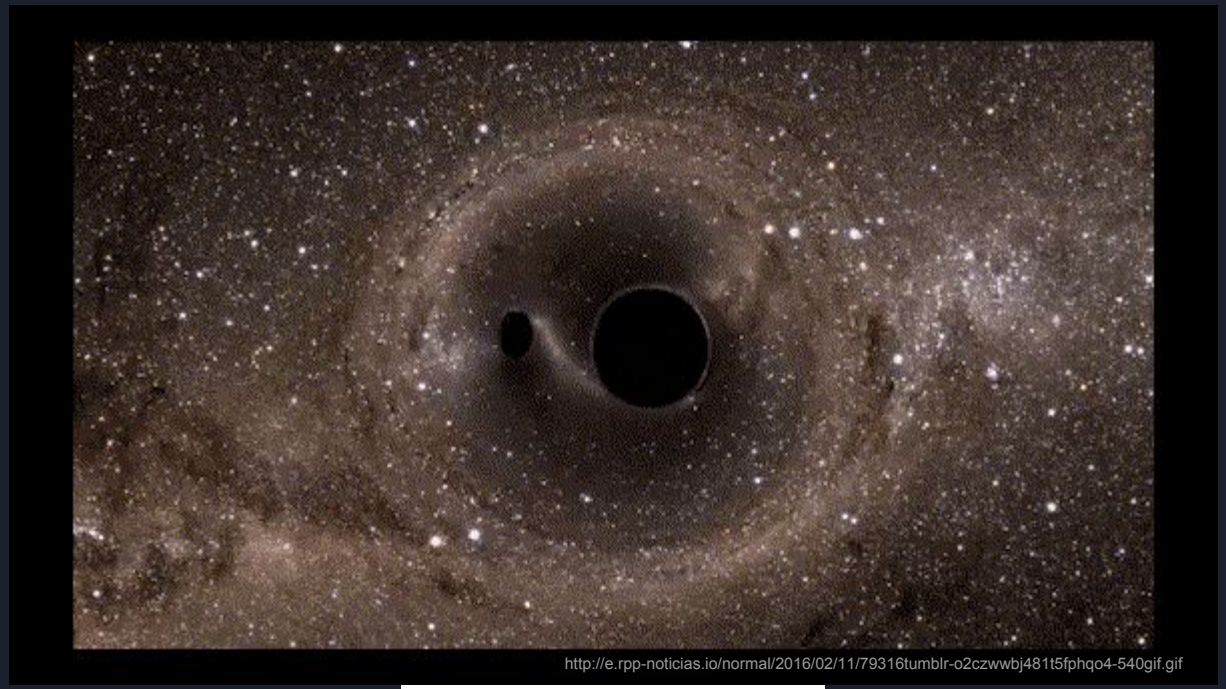
Microlensing Generator

The Code

The Model


u(t)
S
Luminous source
Moving massive object M
D
R_E
V_T
plane perpendicular to the line of sight
Observer
O

Calculations


http://e.rpp-noticias.io/normal/2016/02/11/79316tumblr-o2czwwbj481t5fphqo4-540gif.gif

$$R_{\mathrm{E}} = \sqrt{\frac{4GM}{c^2} D_S x(1-x)}$$

$t_E = R_E/v_t$; R_E

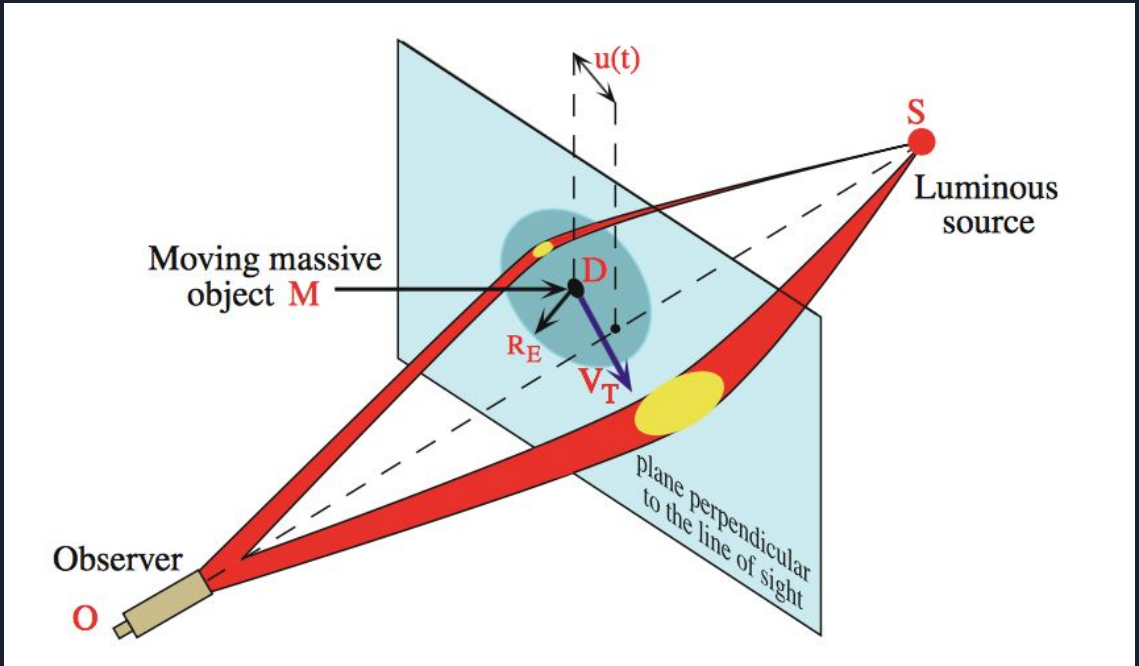
Calculations

$$R_E = \sqrt{\frac{4GM}{c^2} D_S x(1-x)}$$

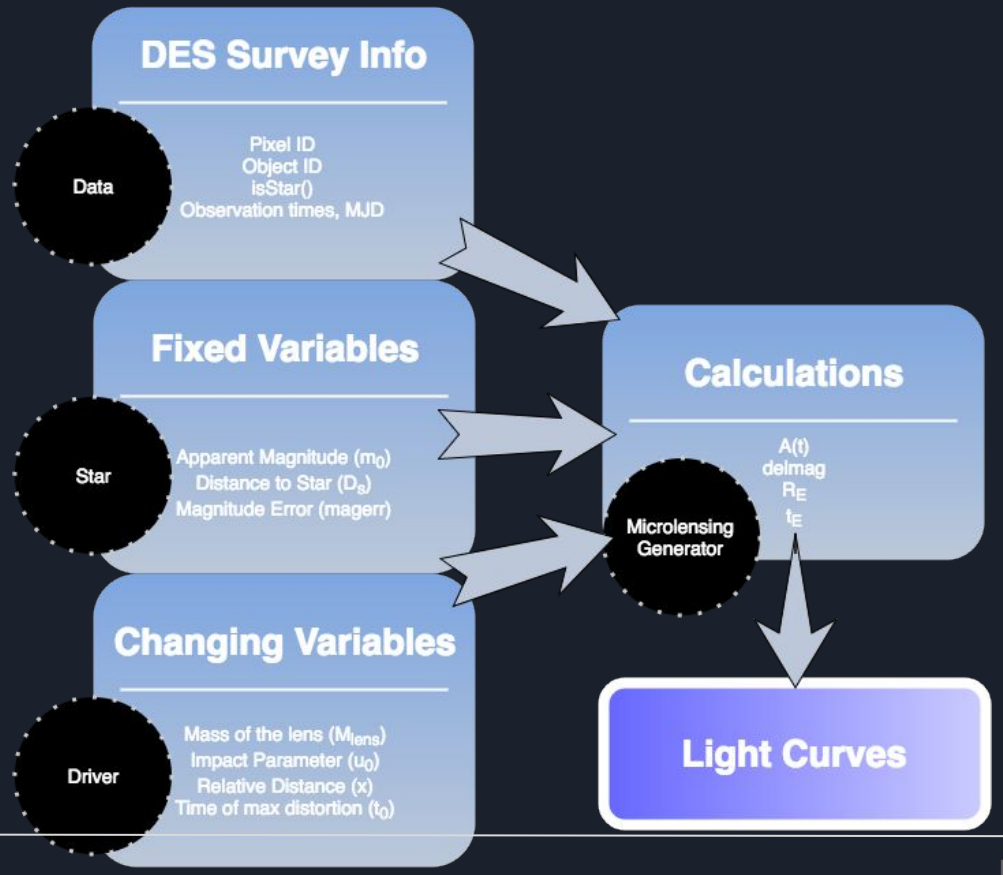
$$t_E = R_E/v_t$$

$$u(t) = \sqrt{u_0^2 \left(\frac{(t-t_0)}{t_E}\right)^2}$$

$$A(t) = \frac{u(t)^2 + 2}{u(t\sqrt{u(t)^2+4})}$$



Generating Light Curves

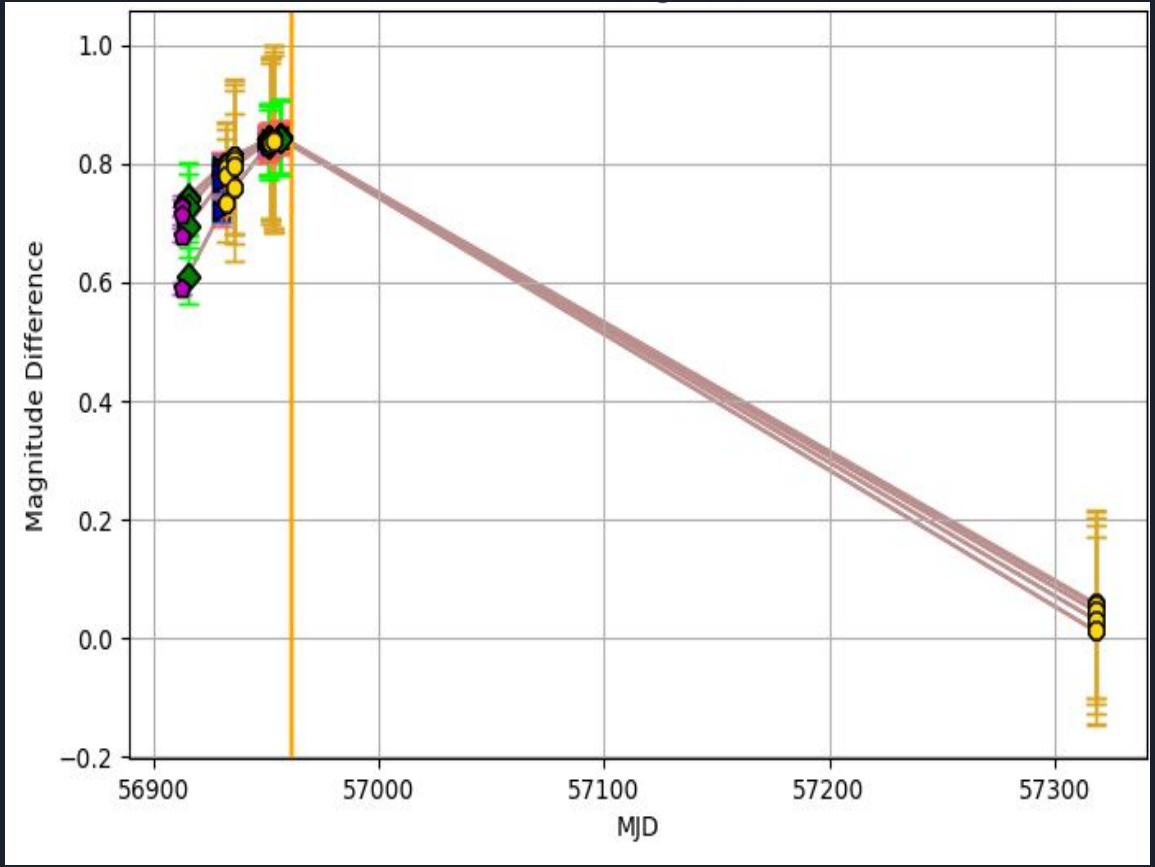


Light Curves

HPIX = 11737
objID = 11173700000001

$M = 50\ M_{\odot}$
$u_0 = 1$
$t_0 = 56965$

Changing x
$0.1 < x < 0.9$

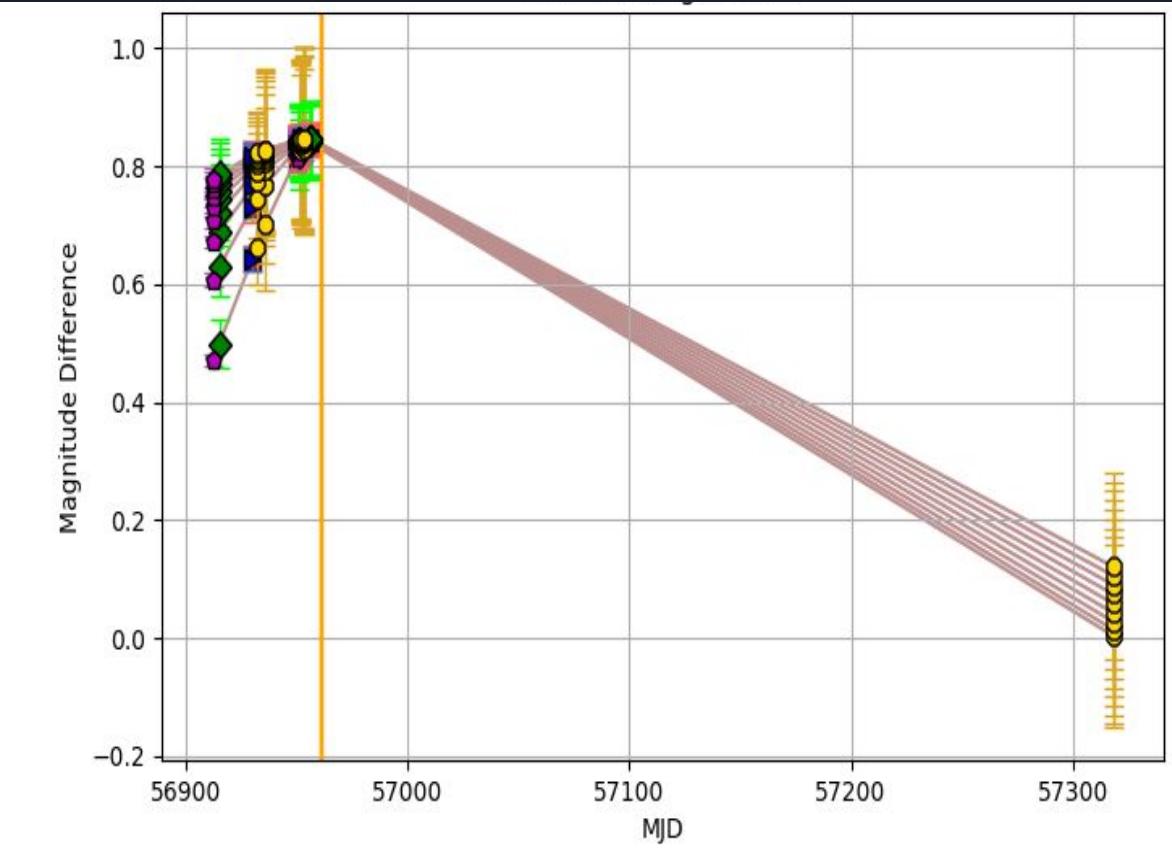


Light Curves

HPIX = 11737
objID = 11173700000001

x = 0.5
$u_0 = 1$
$t_0 = 56965$

Changing M
$10M_\odot < M < 100M_\odot$

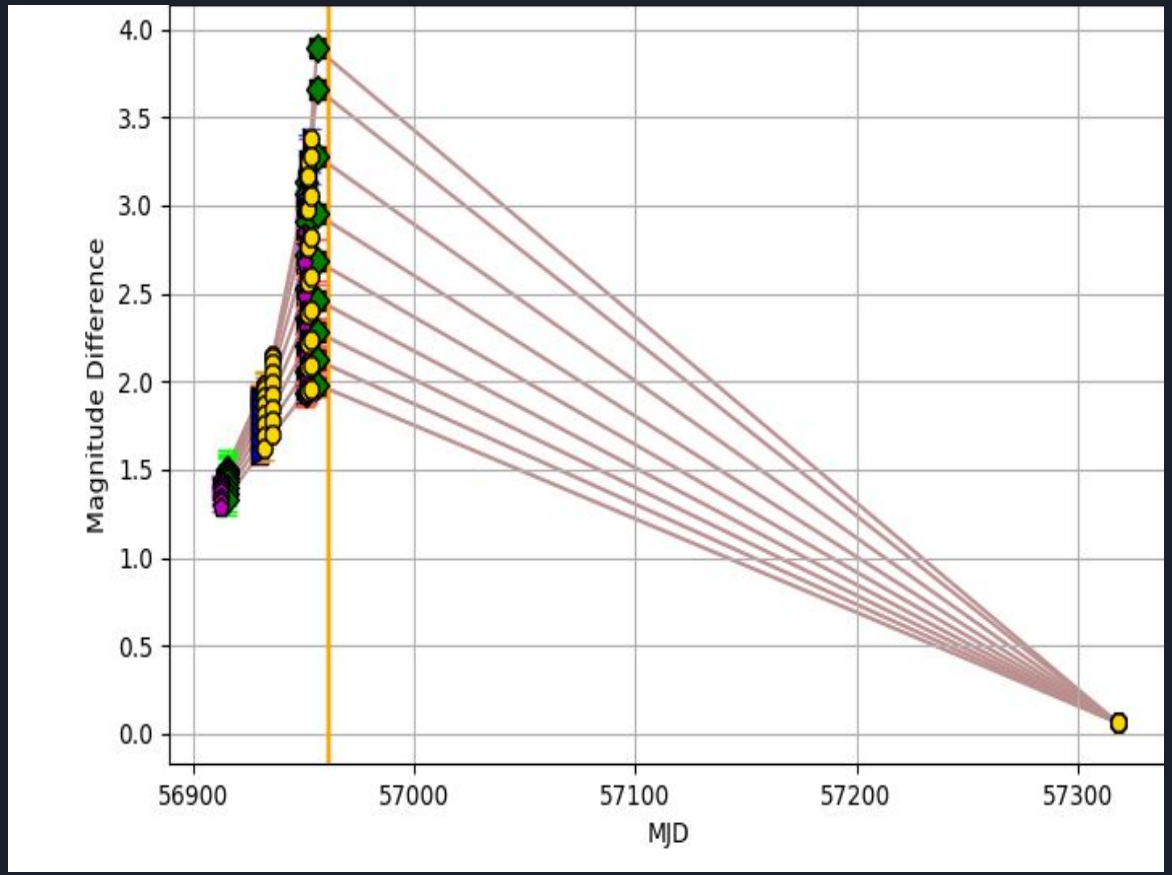


Light Curves

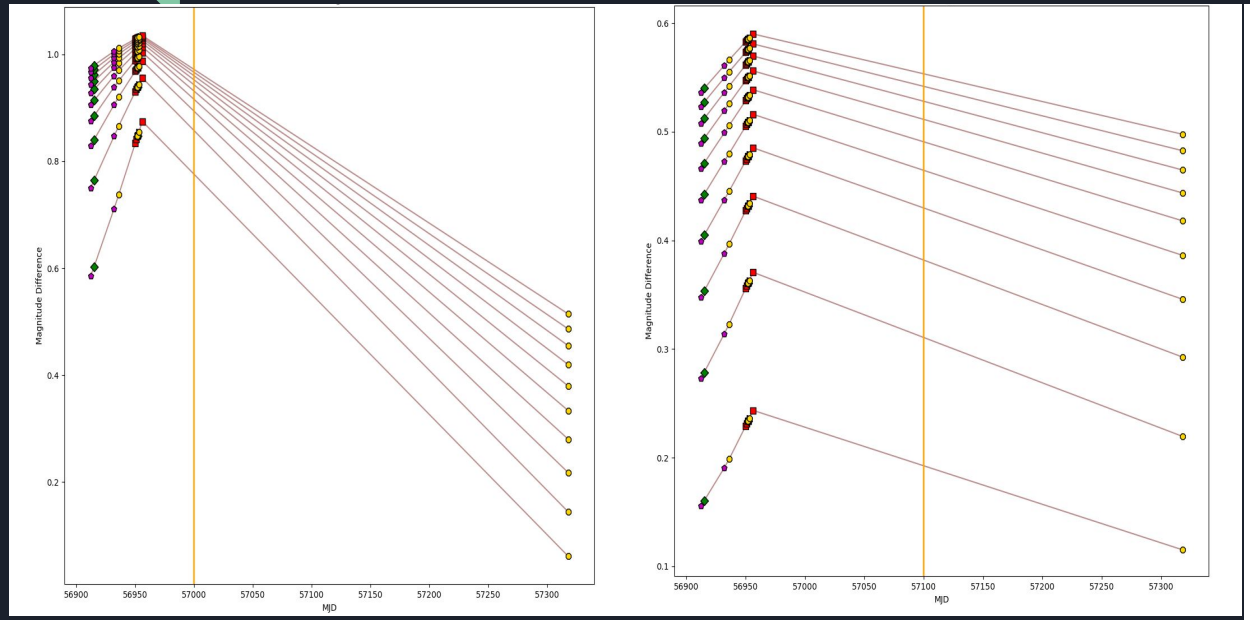
HPIX = 11737
objID = 11173700000001

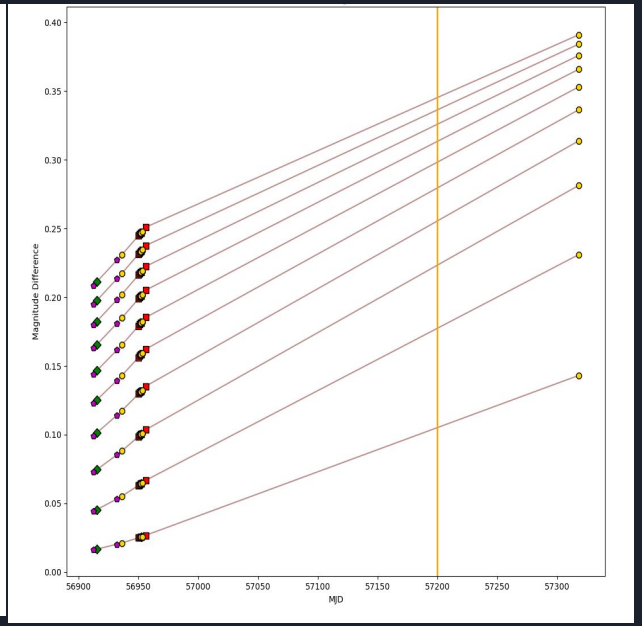
$M = 50\ M_{\odot}$
$x = 0.5$
$t_0 = 56965$

Changing u_0
$0 < u_0 < 1$



Light Curves

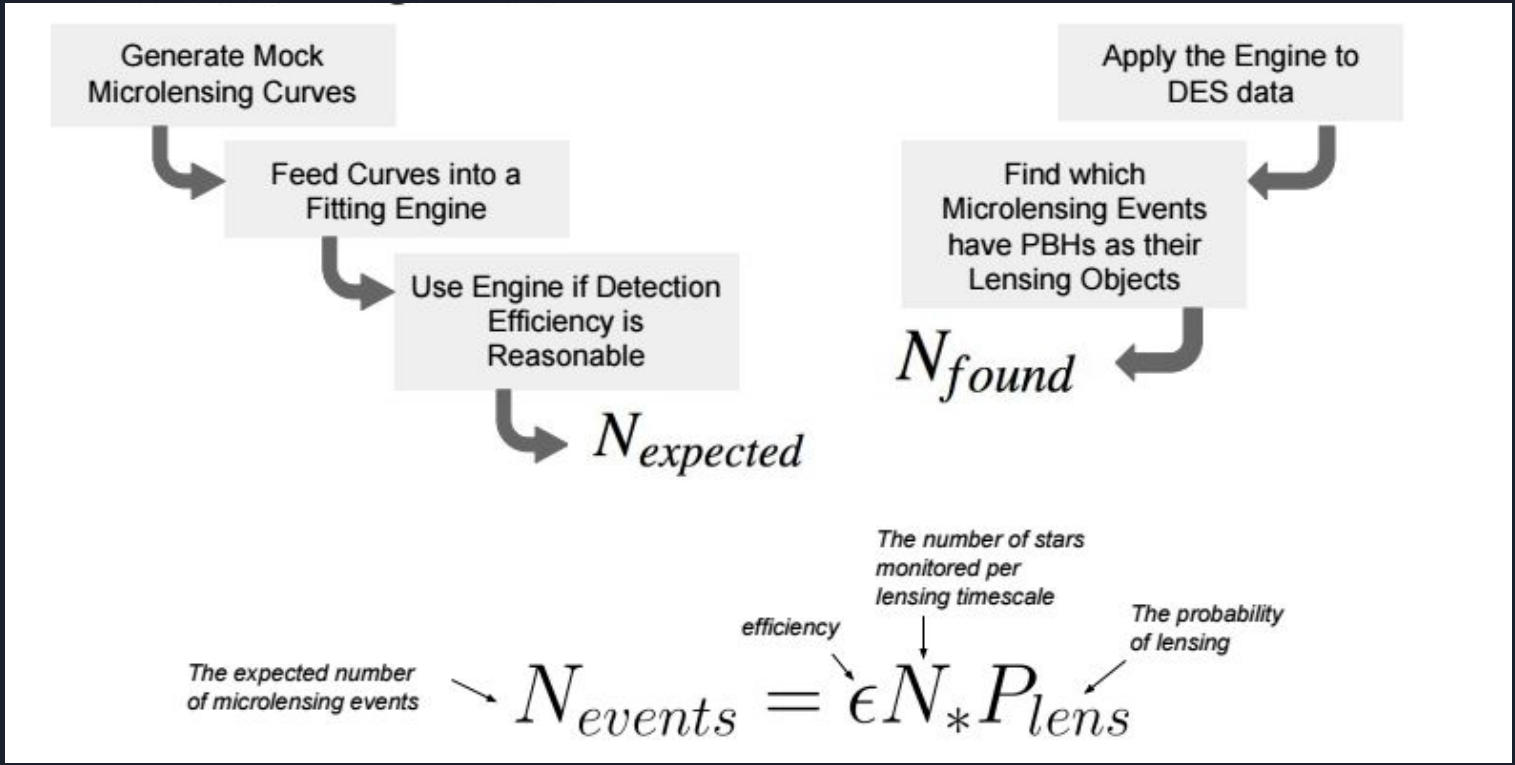




The Next Steps

Fitters & Efficiency Maps

Efficiency


Generate Mock Microlensing Curves
Feed Curves into a Fitting Engine
Use Engine if Detection Efficiency is Reasonable
$N_{expected}$
Apply the Engine to DES data
Find which Microlensing Events have PBHs as their Lensing Objects
N_{found}
The number of stars monitored per lensing timescale
efficiency
The probability of lensing
The expected number of microlensing events
$N_{events} = \epsilon N_* P_{lens}$

More Robust Mock Light curves

Sources

[1]Schmitz, Henning Peter. “Constraining The Contributions of Large Black Holes to Dark Matter.” The University of Queensland Australia, 2017.

[2]Moniez, Marc. “Microlensing as a Probe of the Galactic Structure: 20Â Years of Microlensing Optical Depth Studies.” General Relativity and Gravitation, vol. 42, no. 9, Sept. 2010, pp. 2047–2074., doi:10.1007/s10714-009-0925-4.

[3]Ogle: Wyrzykowski et al, 2016
https://arxiv.org/pdf/1607.06077.pdf

Images:
https://upload.wikimedia.org/wikipedia/commons/thumb/3/31/COSMOS_3D_dark_matter_map.png/1024px-COSMOS_3D_dark_matter_map.png
https://upload.wikimedia.org/wikipedia/commons/thumb/0/03/Black_hole_lensing_web.gif/120px-Black_hole_lensing_web.gif
https://upload.wikimedia.org/wikipedia/commons/1/11/A_Horseshoe_Einstein_Ring_from_Hubble.JPG
https://i.stack.imgur.com/nIECi.jpg
https://lco.global/files/spacebook/Gravitational%20Microlensing%20timeline.png
https://i.stack.imgur.com/mWNqQ.jpg
http://imgsrc.hubblesite.org/hu/db/images/hs-2015-23-a-full_jpg.jpg

Thank You!

Questions?