Search for MACHOS

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Outline

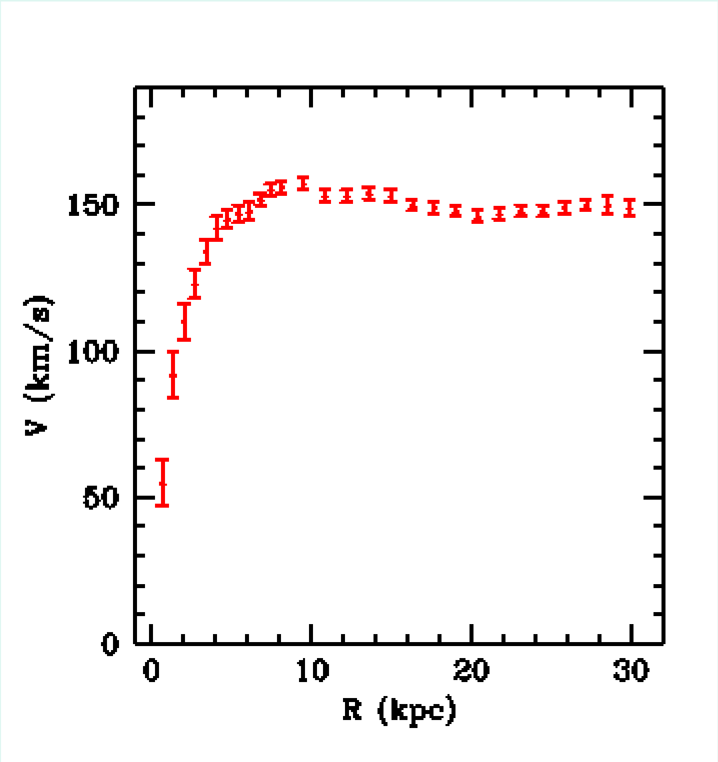
- What are MACHOS?
- Dark matter
- The need for baryonic dark matter
- Candidates
- Detection method
- Problems/concerns with detection
- Collaborations
- Findings
- Future work

What are MACHOS?

- Massive Compact Halo Object
- Any celestial mass that is both dense (not a diffuse gas cloud) and dark (not visible in any electromagnetic band)
- In some sense, defined by our inability to see it

Dark Matter

- First observed by Fritz Zwicky in 1933
- Galactic rotation curves do not fall off as quickly as expected



Galaxy NGC3198 from Begeman 1989
http://astro.berkeley.edu/~mwhite/darkmatter/rotcurve.html

Baryonic dark matter

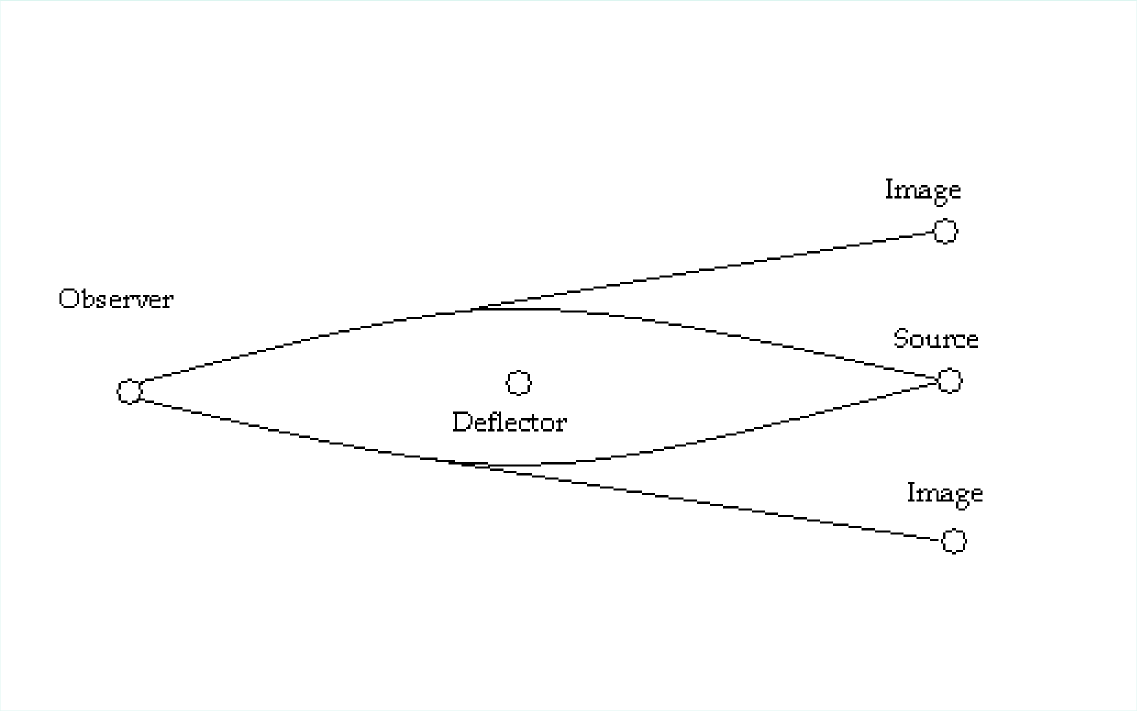
- Using Big Bang nucleosynthesis, the amount of baryonic matter in the universe can be estimated
- This is done by measuring the He/H ratio today, since most of the He was produced in the early big bang
- This happened when neutrons were first able to decay into protons – the density of baryonic matter determines how many neutrons found protons to turn into He before they decayed

Candidates

- Brown dwarfs
- Dim white dwarfs
- Neutron stars
- Black holes
- Planets (Jupiter like objects, aborted stars)
- Very dim stars

Detection

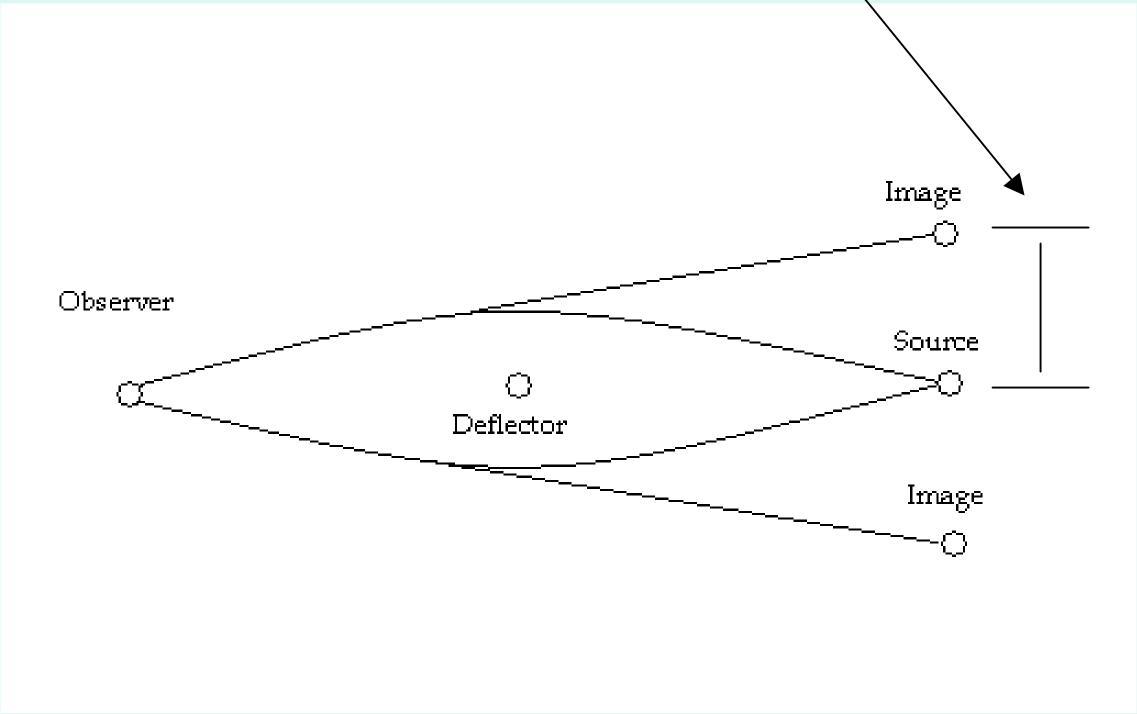
- First proposed by Paczynski
- Uses GR to get around the electromagnetic invisibility
- Gravitational lensing

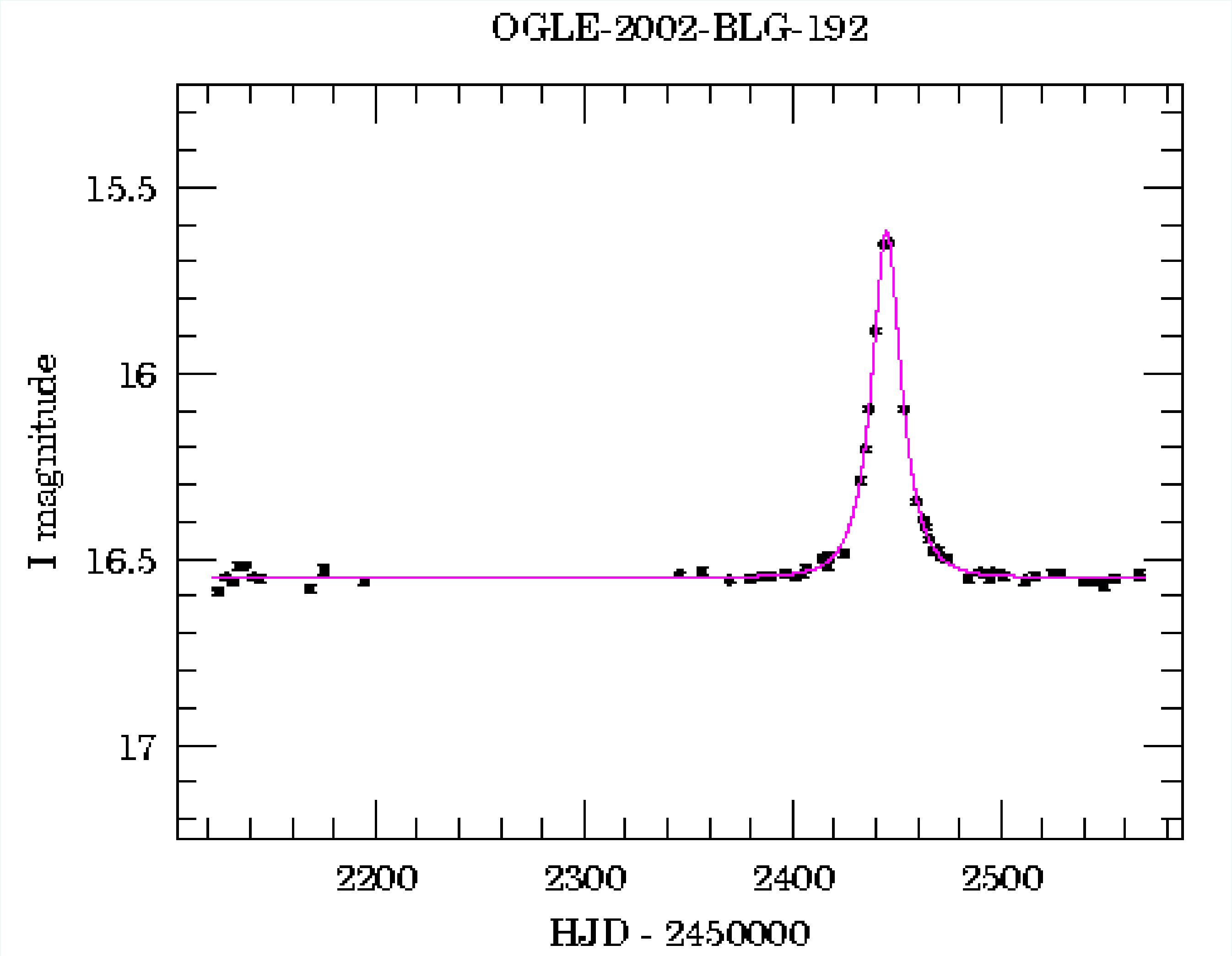


Detection

- “micro”lensing

$$R_E = \sqrt{\frac{4GM}{c^2}\frac{D_{OL}D_{LS}}{D_{OS}}}$$





A microlensing event observed by the OGLE collaboration

Problems with detection

- Proportional increase in brightness isn't very helpful
- So only real measured quantity is lensing *duration*
- Assuming you know where the source is, this quantity still varies with 3 variables
  - Lens distance
  - Lens transverse velocity
  - Lens mass

Efforts

- Most efforts have focused on the LMC (Large Magellanic Cloud) or SMC (Small Magellanic Cloud)
- They are distant enough to probe our own galactic halo, but close enough to resolve millions of stars
- Some effort has also been put into looking toward the Galactic bulge
- Probability of observing lensing/Optical depth
- Even if the whole halo was MACHOs, the optical depth would still be small enough to require that millions of stars be monitored

MACHO

- An American collaboration observing in Australia
- Monitored 8.6 million stars in the LMC
- In order to do this, they had little time coverage on each star – blind to short duration (low mass) events
- 528 events observed, 450 of which are clean and follow the model
- With 7 years worth of data, they measured

$$\tau \approx 2.1\times10^{-6}$$

EROS 2

- A French collaboration observing in Chile
- Monitored ~7 million stars for 6.7 years in the LMC
- Carefully accounting for backgrounds due to variable stars and source confusion, they observed only one microlensing event in this time
- This corresponds to $\tau < 0.36 \times 10^{-7}$
- This is at variance with the MACHO findings

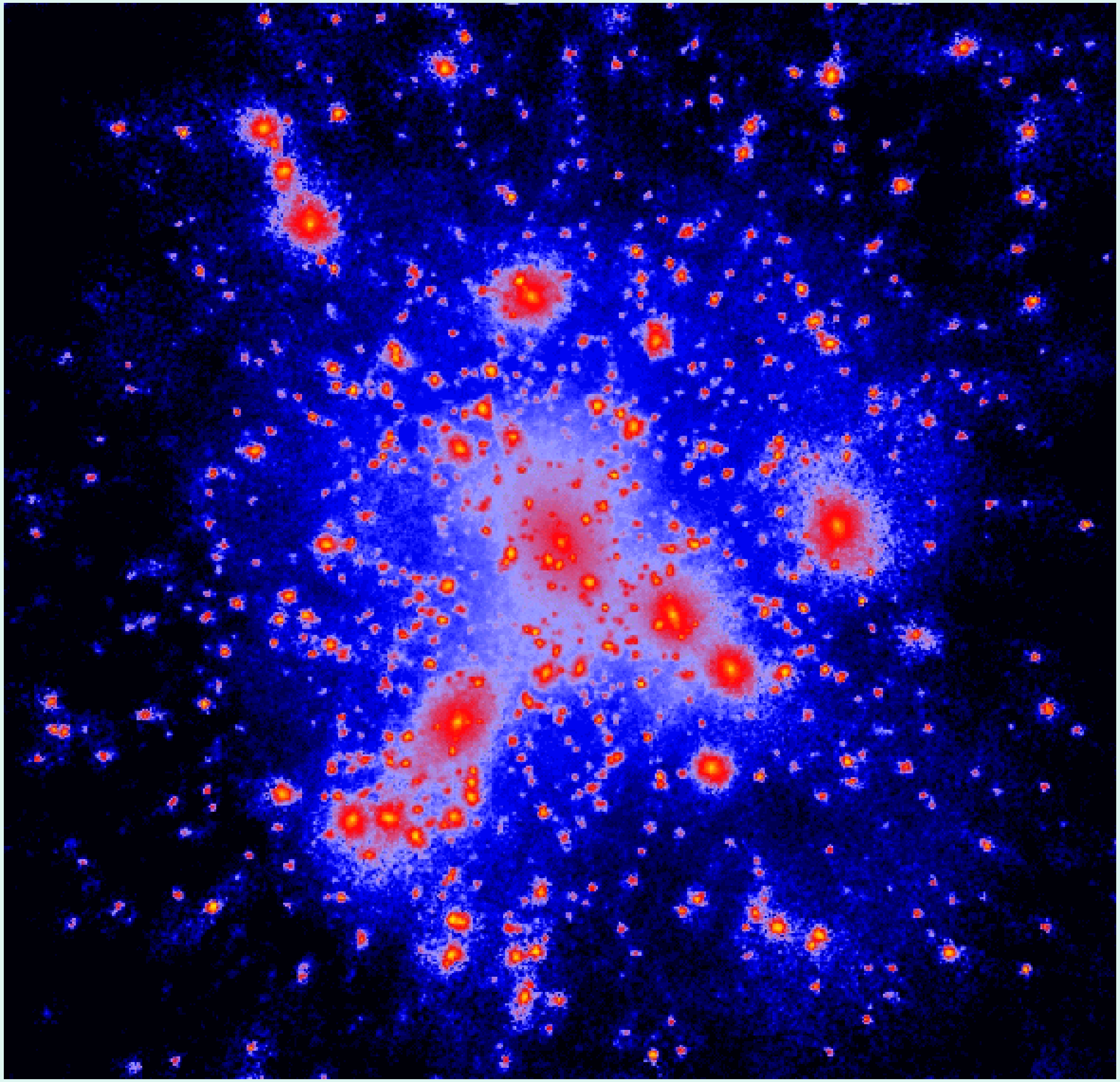
Others

- EROS 1, which monitored only ~150,000 stars but with high time sampling, to rule out any large contribution from low mass lenses
- OGLE 1 and 2: Polish experiments observing in Chile with similar methods and a wealth of publications

1.3m Warsaw Telescope - Las Campanas Observatory, Chile
http://bulge.princeton.edu/~ogle/

Findings

- Despite disagreements in the data, all collaborations seem to agree that MACHOs do not compose all of the dark matter in the galactic halo
- Current estimates are below 30% for the mass fraction of the halo composed of MACHOs
- Most common mass for MACHOs is ~0.5 solar masses
- Data also suggests that the galactic dark matter halo may not be perfectly spherical



N-body simulation of a galactic dark matter halo

http://relativity.livingreviews.org/open?pubNo=lrr-2002-4&page=node7.html

Future work

- The collaborations will continue to collect more data
- Now focusing in on the SMC and galactic bulge as well
- Trying to correct for problems like variable stars, achromatic events, reconcile experimental differences

References

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