Observing Gravitational Microlensing with Parallax by OSIRIS

esa ESAC

Björn Grieger

Michael Küppers

MPS Max-Planck-Institut für Sonnensystemforschung

Horst Uwe Keller

Astrophysics Research Institute Liverpool JMU

Martin Burgdorf

University of St Andrews

Martin Dominik

ASTRONOMISCHES RECHEN-INSTITUT HEIDELBERG

Arnaud Cassan

Joachim Wambsganß

More than 20 years ago . . .

A parallax effect due to gravitational micro-lensing

B. Grieger, R. Kayser & S. Refsdal

Hamburger Sternwarte, Gojenbergsweg 112, D-2050 Hamburg 80, FRG

The astrophysical importance of gravitational micro-lensing due to stars in the deflecting galaxy is now well-known[1-7]. Each macro-image (caused by the corresponding smoothed-out galaxy) can be split up into several micro-images with typical angular distances measured in micro-arcseconds. Here we discuss a parallax effect due to gravitational micro-lensing (star disturbances). We show that such an effect would most favourably be observed during high amplification events when a compact source (quasar) crosses a critical curve. During such an event even a relatively small displace-

emphasis on the determination of (1) the size of the quasar and (2) the relative transversal velocities involved. It should be possible to observe such a parallax-effect with a relatively small telescope (10–20 cm) included in an interplanetary mission. In extreme cases, annual oscillations in the light curves of lensed quasars can be

Of particular interest among instances of gravitational micro-lensing are the high amplification events[2] that occur when a compact source crosses a critical curve[1]. These high amplification events where $\Delta m \approx 3$ are suddenly initiated (or terminated) by the appearance (or disappearance) of two bright micro-images[1,3,4].

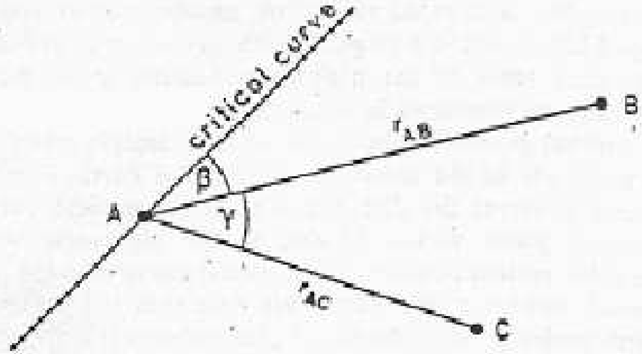


Fig. 1 Position of 3 observers, projected onto the observer plane.

are known, we can eliminate the angle β and determine the relative transverse velocity v_T (perpendicular to the critical curve) in the observer plane:

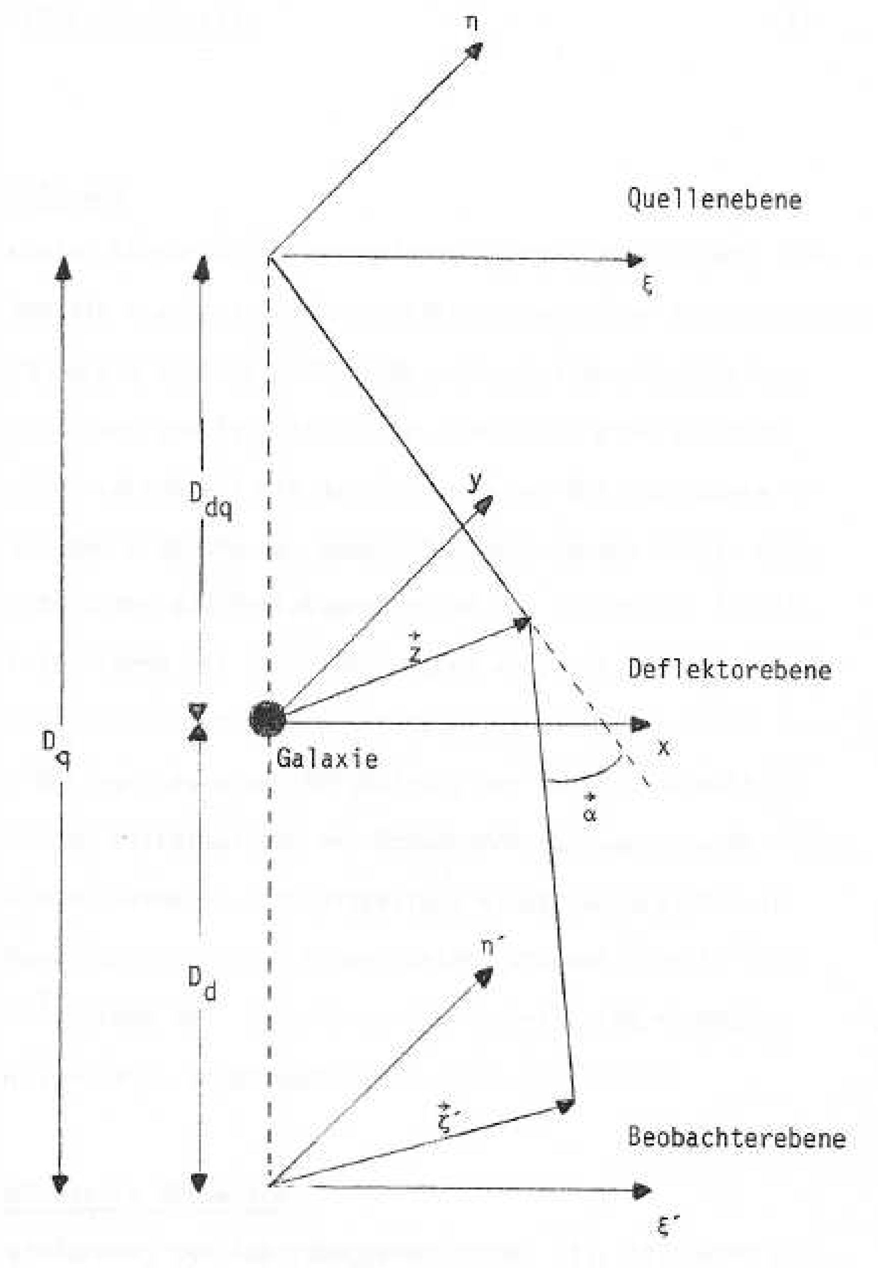
$$v_T = |\sin\gamma| \left\{ \left(\frac{\delta t_{AB}}{r_{AB}}\right)^2 + \left(\frac{\delta t_{AC}}{r_{AC}}\right)^2 - 2\cos\gamma \frac{\delta t_{AB}\delta t_{AC}}{r_{AB} r_{AC}} \right\}^{-1/2} \quad (2)$$

... the time lags δt are ... critical curve. ... sponding velocity V_T ... scale Δt of the high ... the time needed by ... d thereby the radius ... epends on the lumin- ... de of the event. This will be discussed in a subsequent paper.

If there are only two observers, A and B, a straightforward relation between the two unknowns v_T and $\sin\beta$ emerges (see Fig. 1).

$$v_T = r_{AB} \sin\beta / \delta t_{AB} \leq r_{AB}/\delta t_{AB} \quad (3)$$

Gravitational lensing

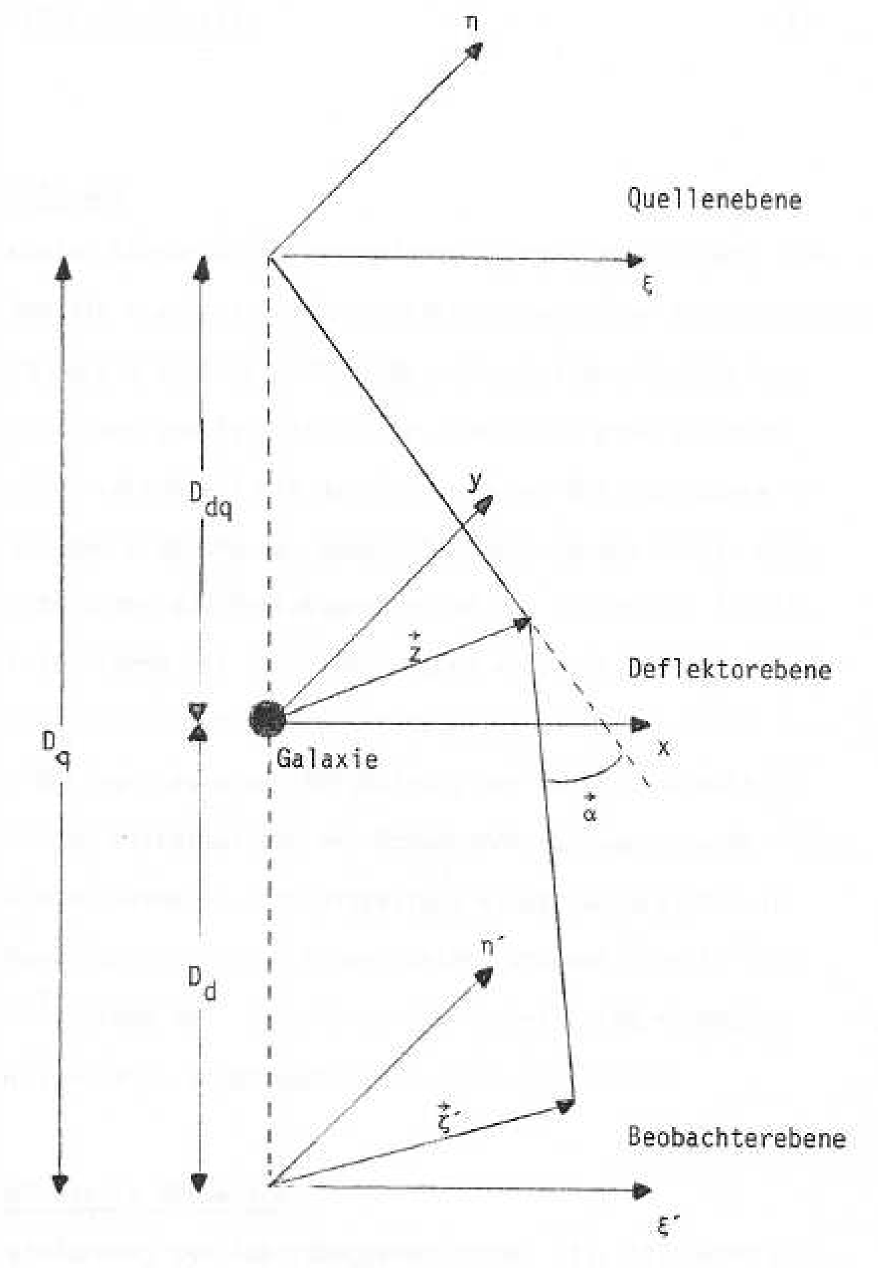


Source plane

Deflector plane

Observer plane

Extragalactic source



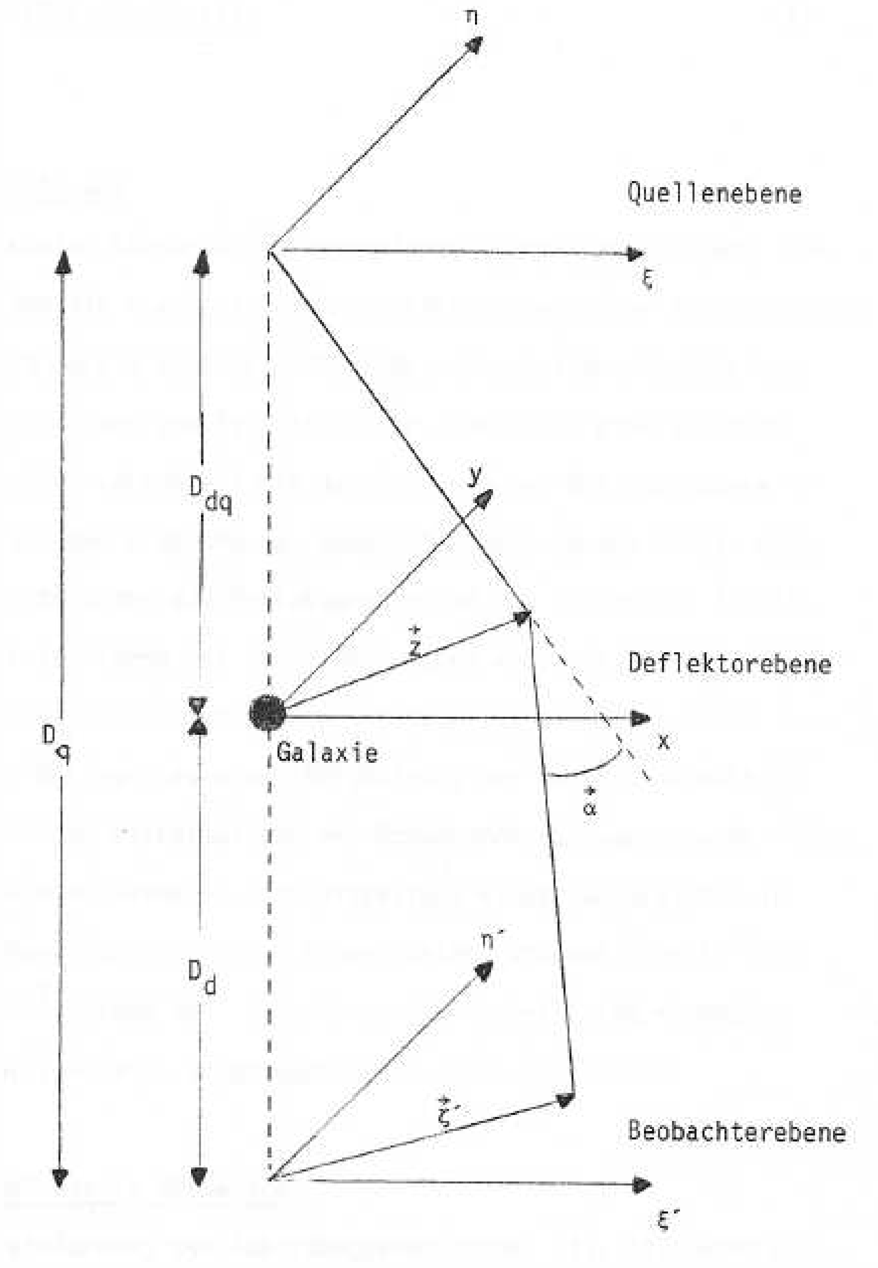
Quasar or galaxy

Lensing galaxy

Observer

Gravitationally distorted Galaxies (HST image)

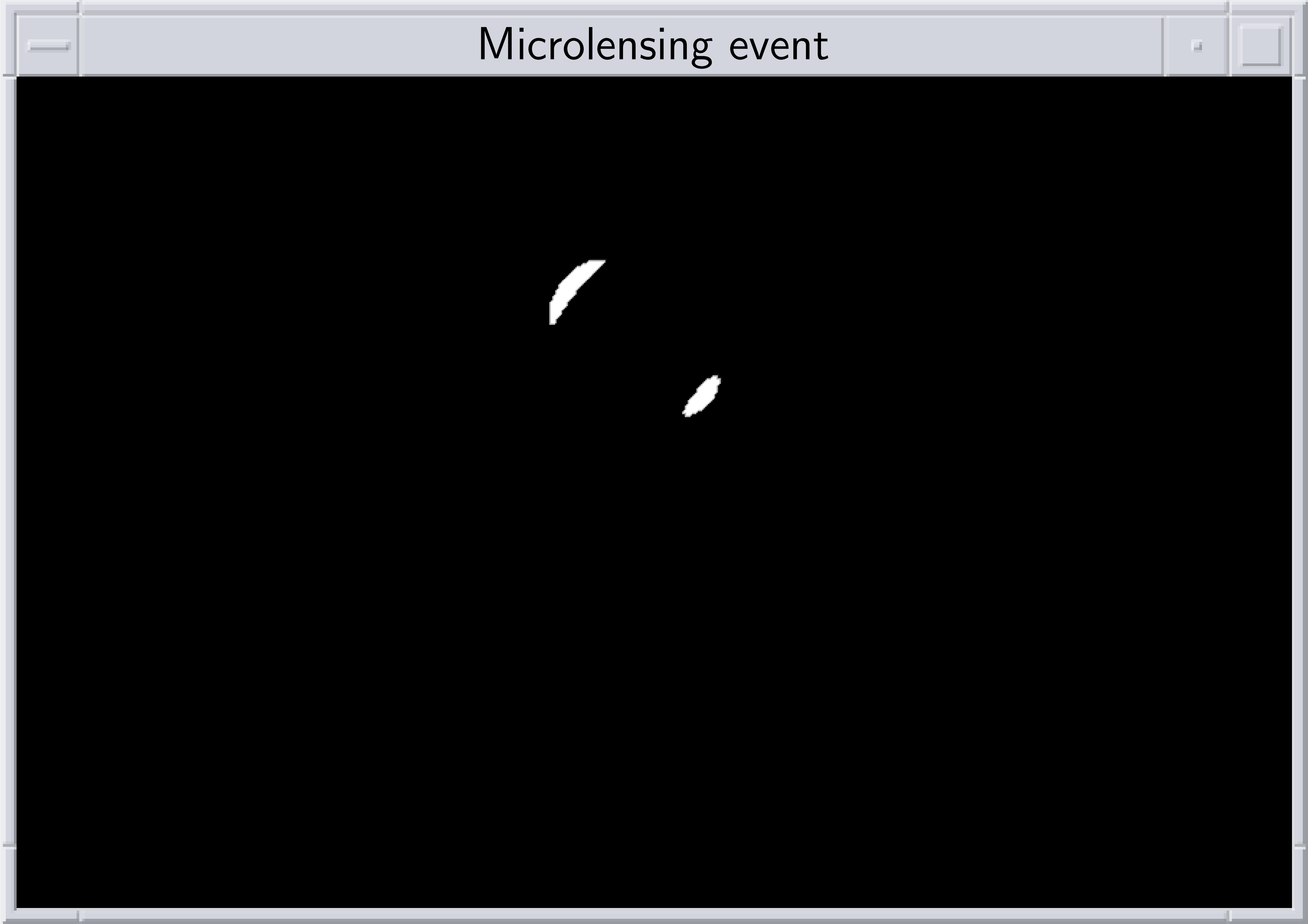
Stellar source



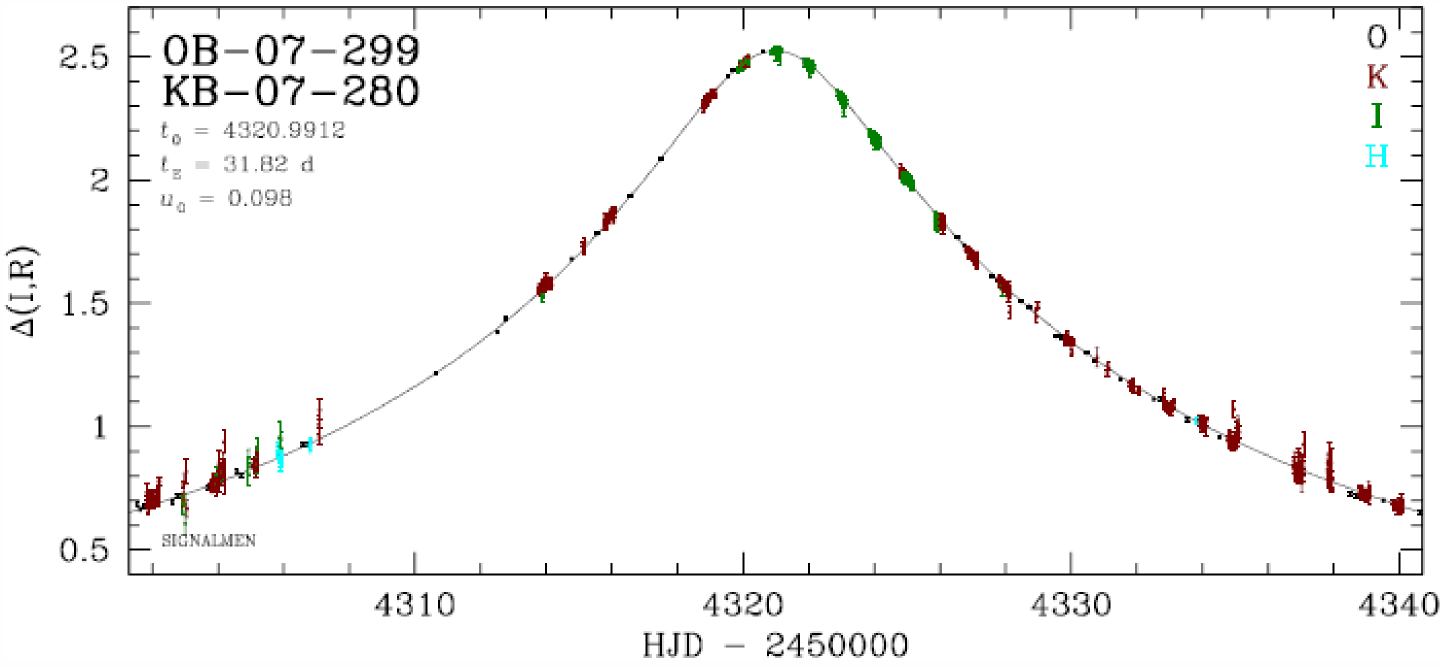
Star (most likely in the Galactic Bulge)

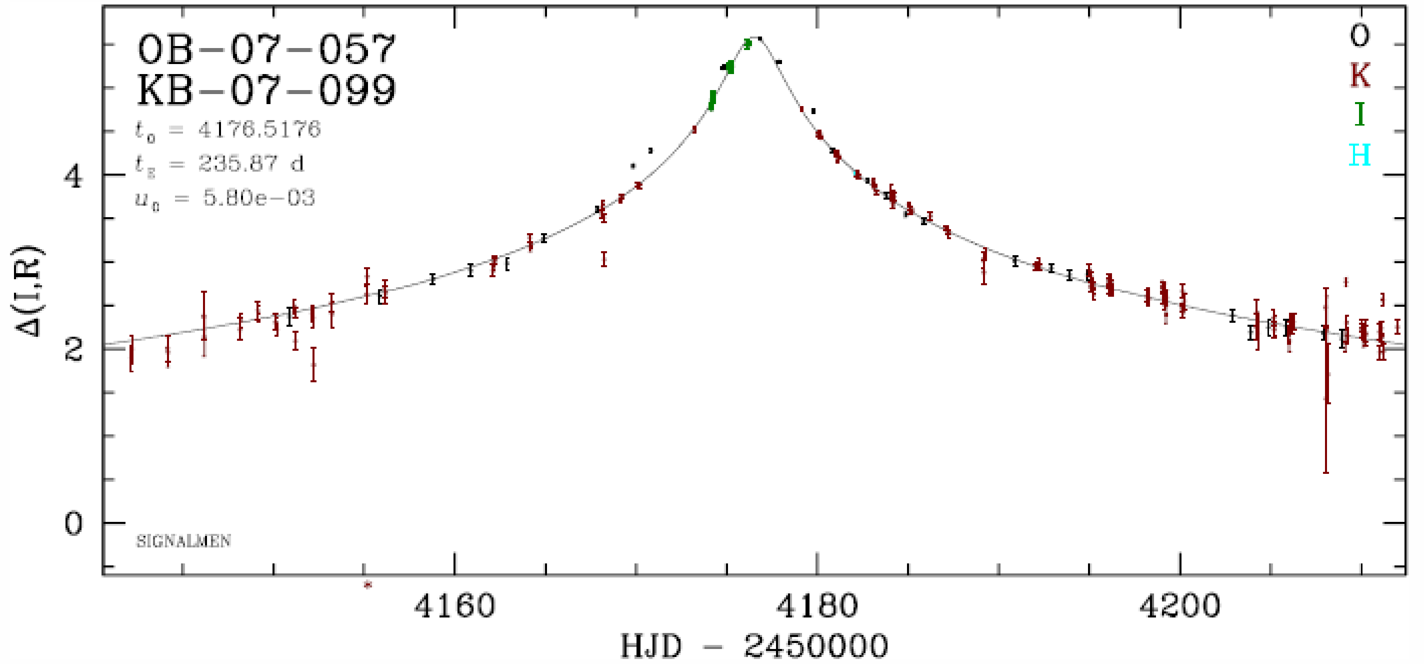
Lensing star (most likely an M-dwarf)

Observer


Microlensing event

Example light curves





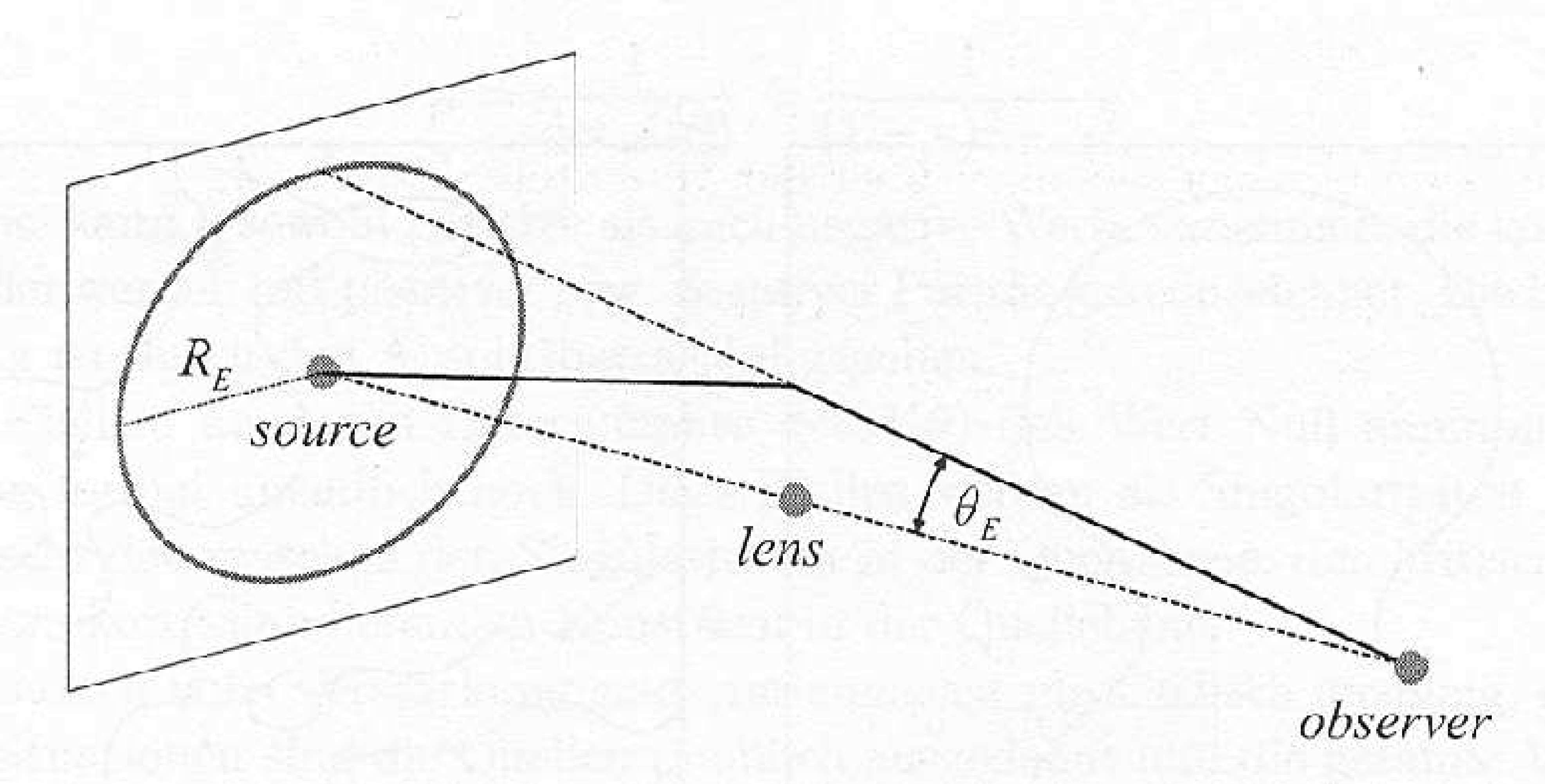
Microlensing surveys

Monitoring about 10^8 stars of the Galactic Bulge with

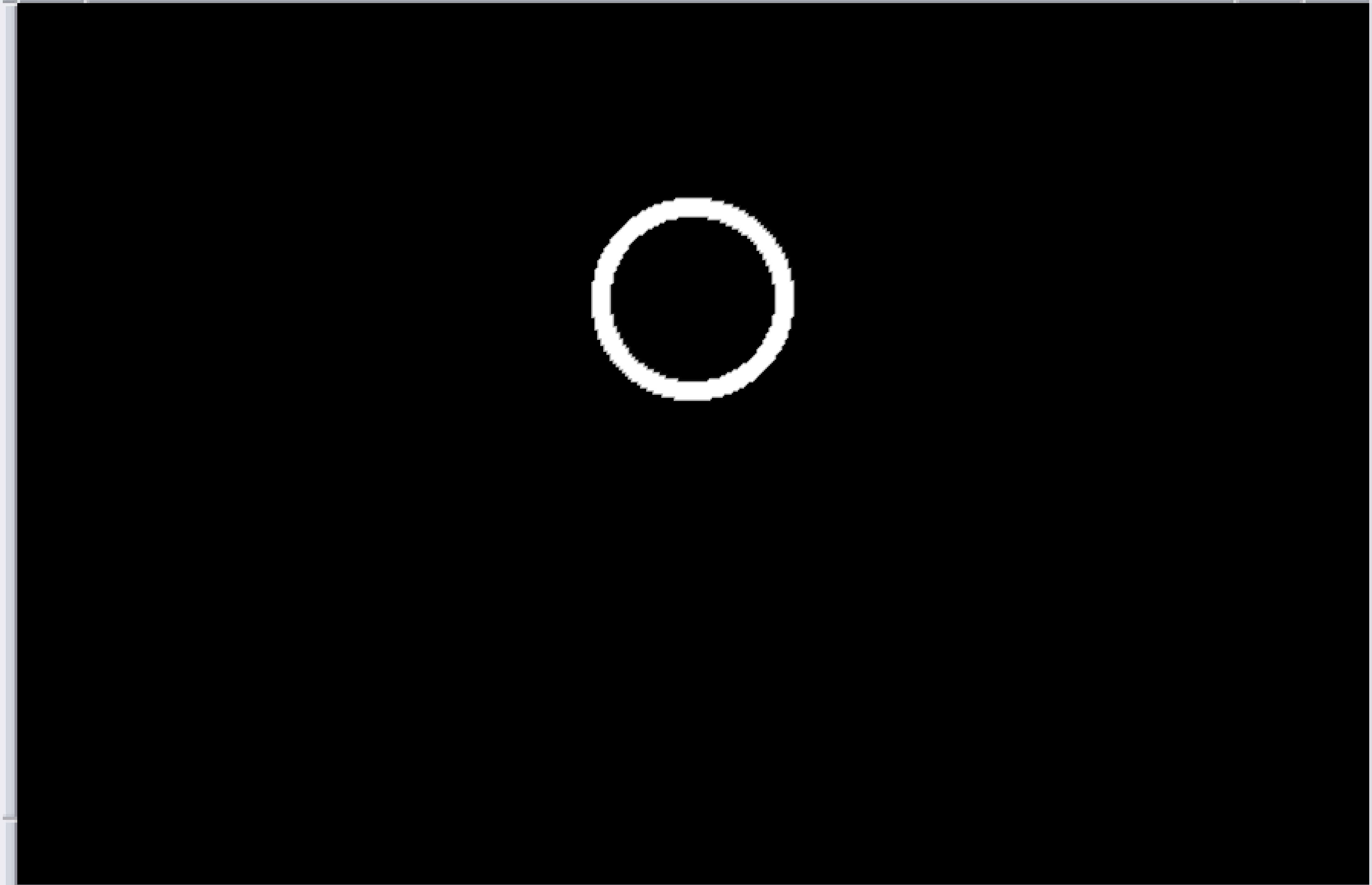
- OGLE: 1.3 m telescope at Las Campanas, Chile
- MOA: 1.8 m telescope at Mount John, NZ

$\longrightarrow$ About 700 events each season

The Einstein Ring



Microlensing event with perfect alignment



Radius of the Einstein Ring

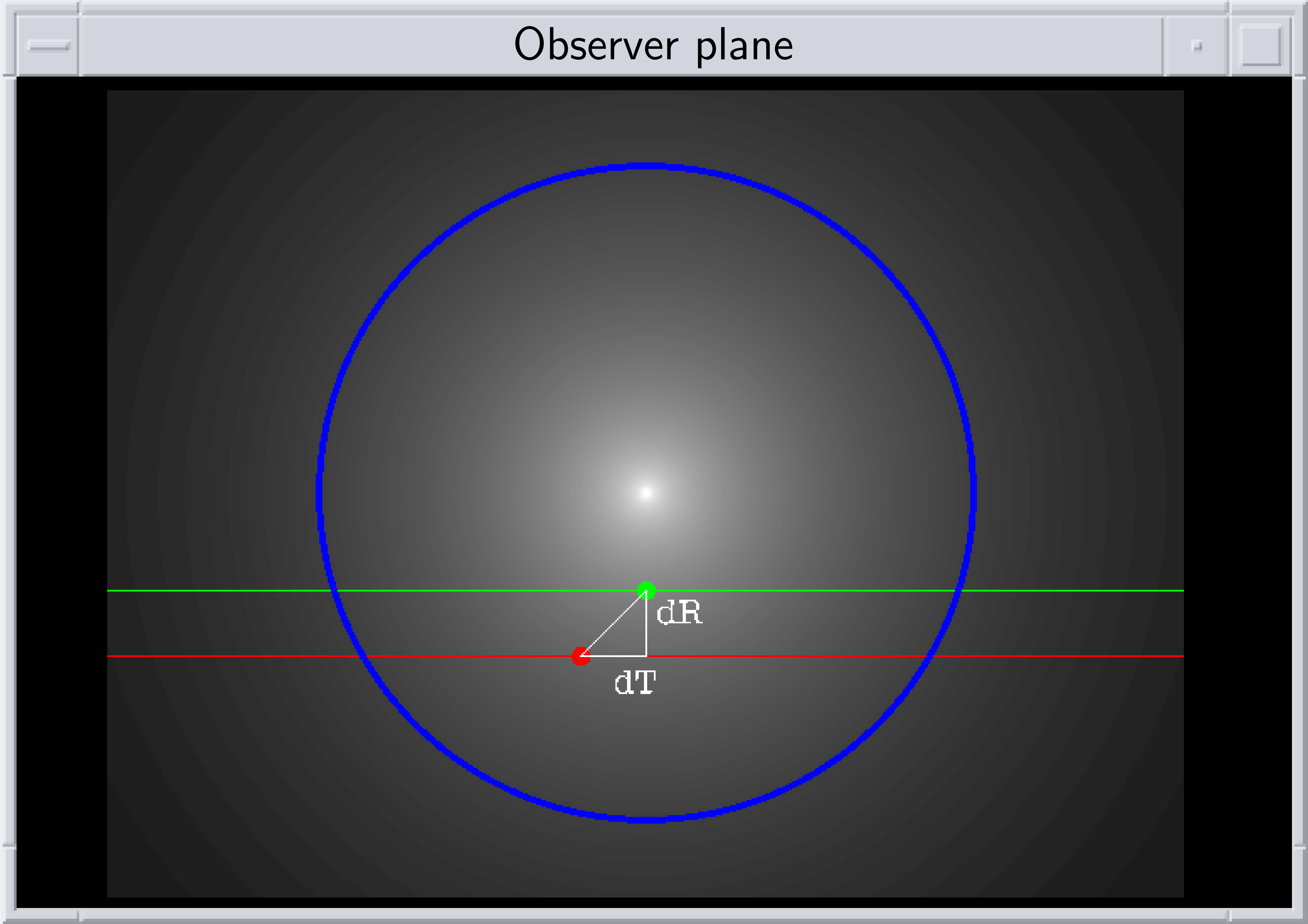
Assumptions: Source in the Galactic Bulge,
$D_L = D_{LS}$,
$M = 0.25\,M_\odot$

Viewing angle (scales with $\sqrt{M \cdot \frac{D_{LS}}{D_L \cdot D_S}}$):

$$\theta_E = 4.9 \cdot 10^{-4} \text{ arcsec}$$

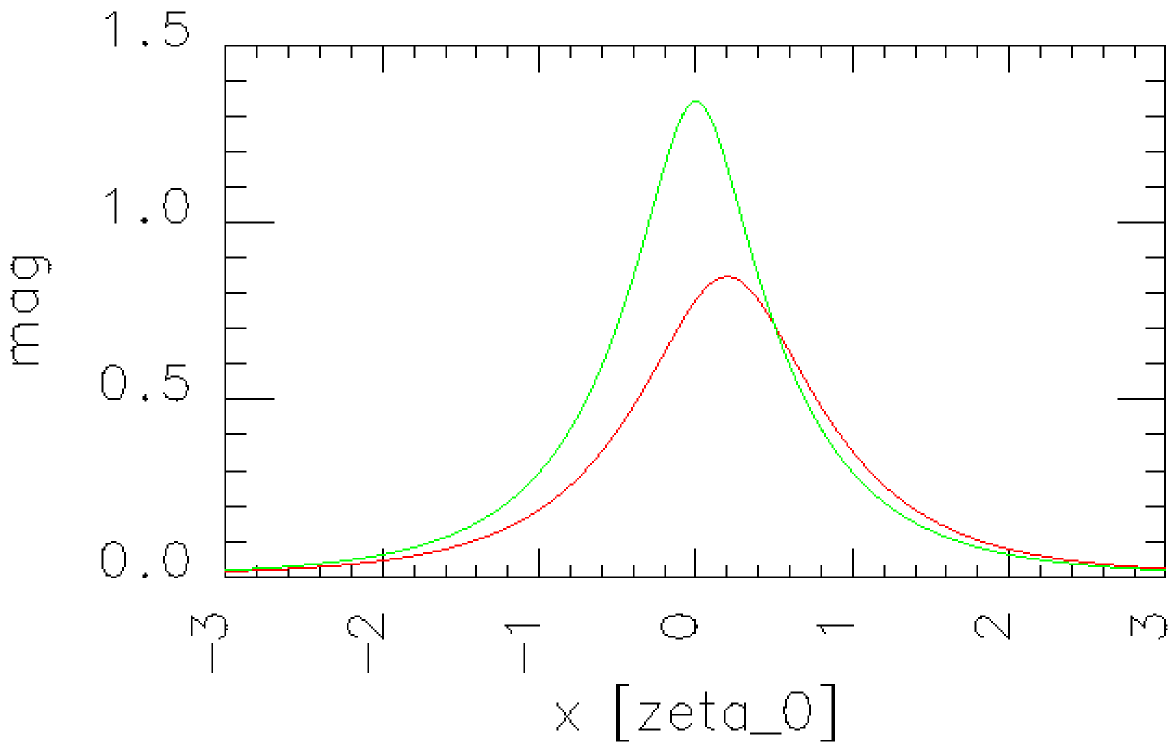
Radius in the observer plane (scales with $\sqrt{M \cdot \frac{D_L \cdot D_S}{D_{LS}}}$):

$$\boxed{R_E = 4.2 \text{ AU}}$$


Observer plane
dR
dT

Simulated lightcurves

- Two parameters have to be measured:



  – the time delay of the brightness peak,

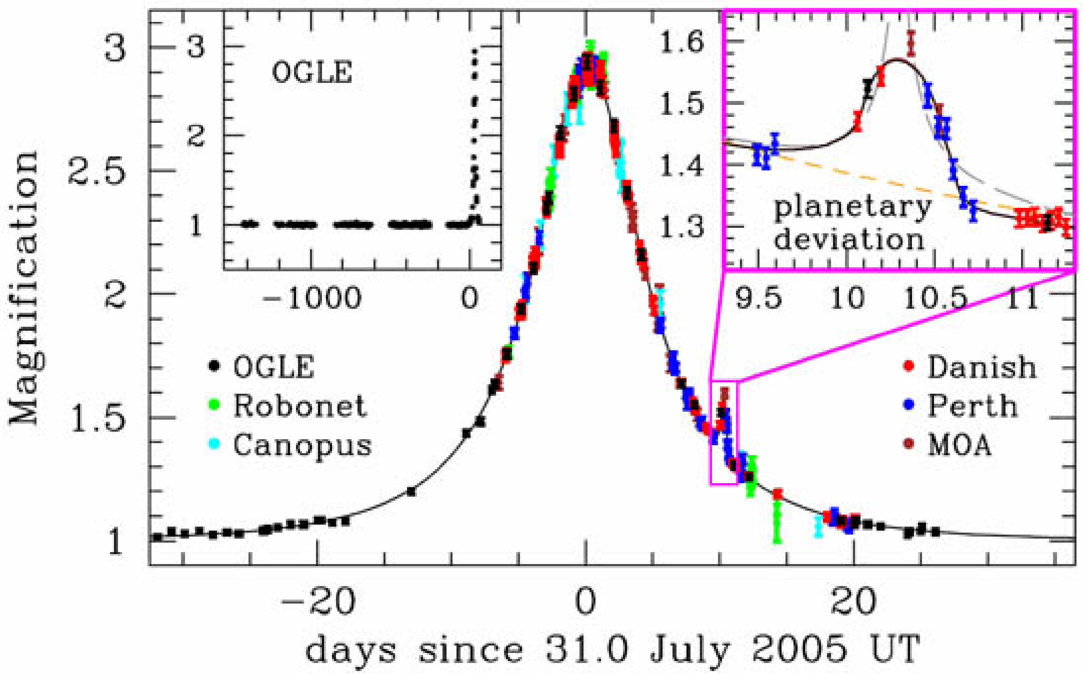
  – the different maximum amplifications.

- These determine the Einstein radius in absolute units.

Estimating the mass of the lensing star

- The Einstein radius scales with mass and distance of the lensing star, hence constrains these.
- The problem is still degenerated, but the uncertainty of mass estimations based on assumptions about the disk mass function is reduced from a factor of 2 to about 10 %.

The cream on top of the cake: an exoplanet event

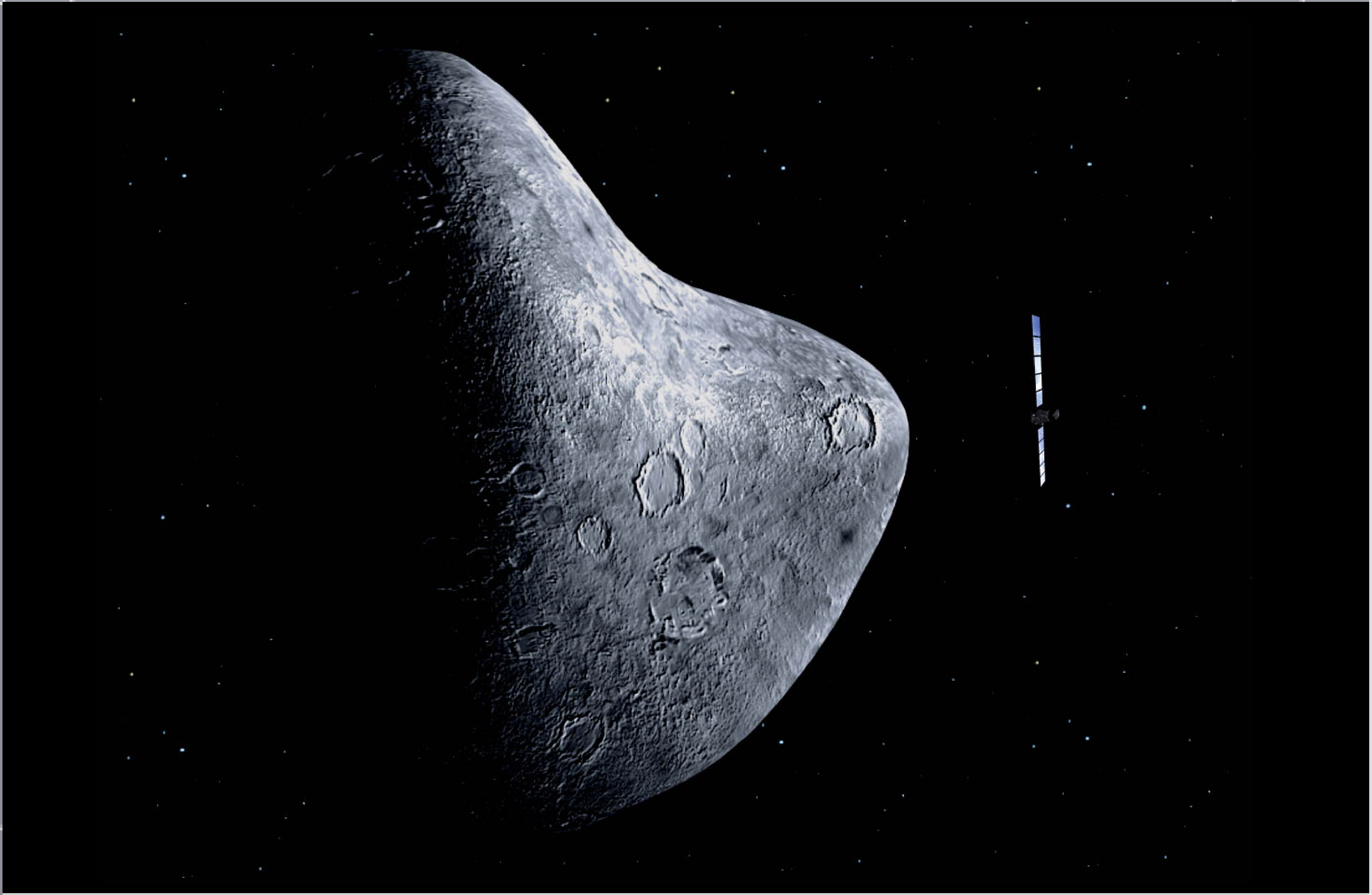


- Observation of a planetary deviation in a microlensing lightcurve provides the ratio of planet mass and lens star mass.

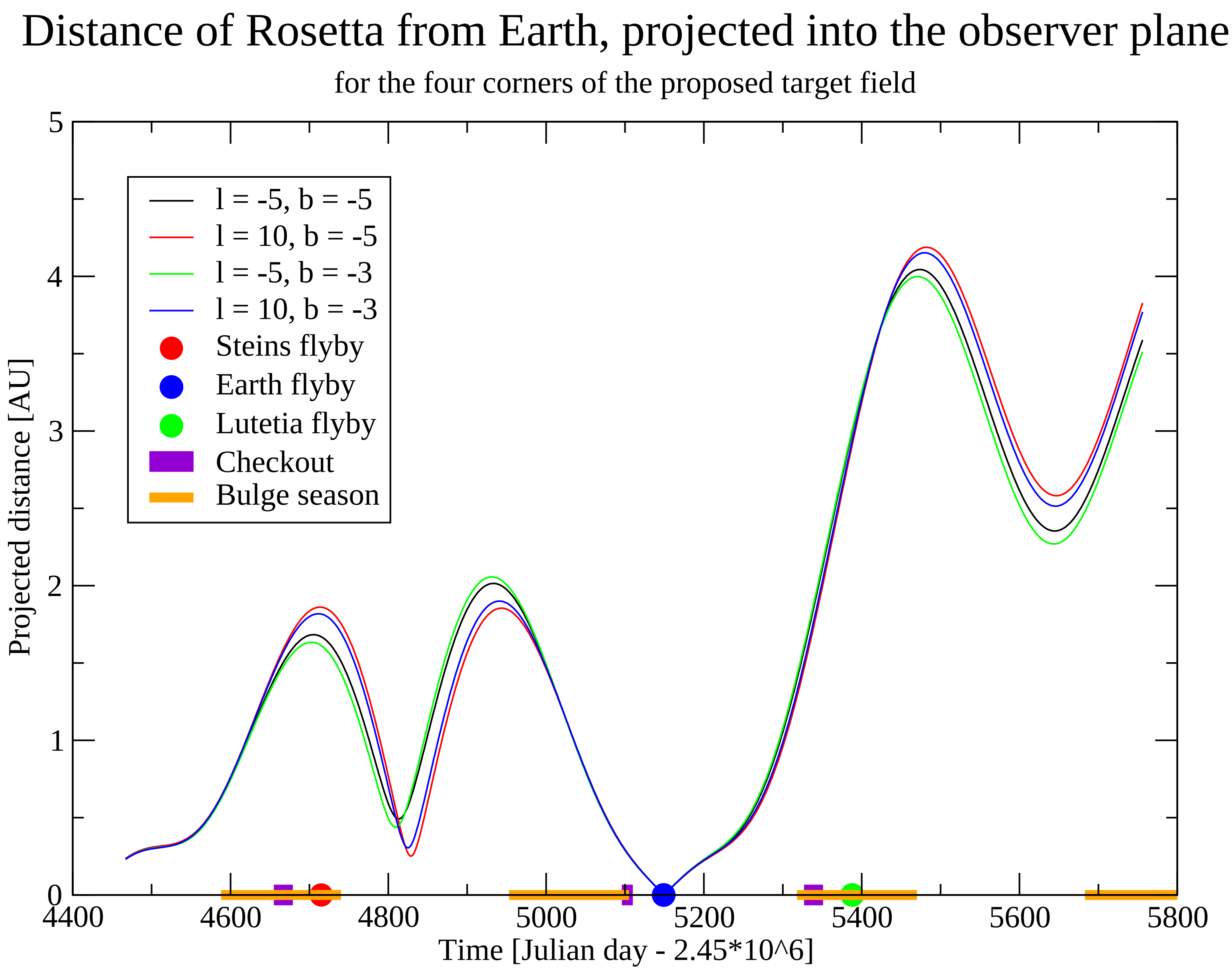
- Thus measuring the parallax constrains the absolute planet mass as well as the lens star mass.

- It is not necessary to measure the planetary deviation by both observers.

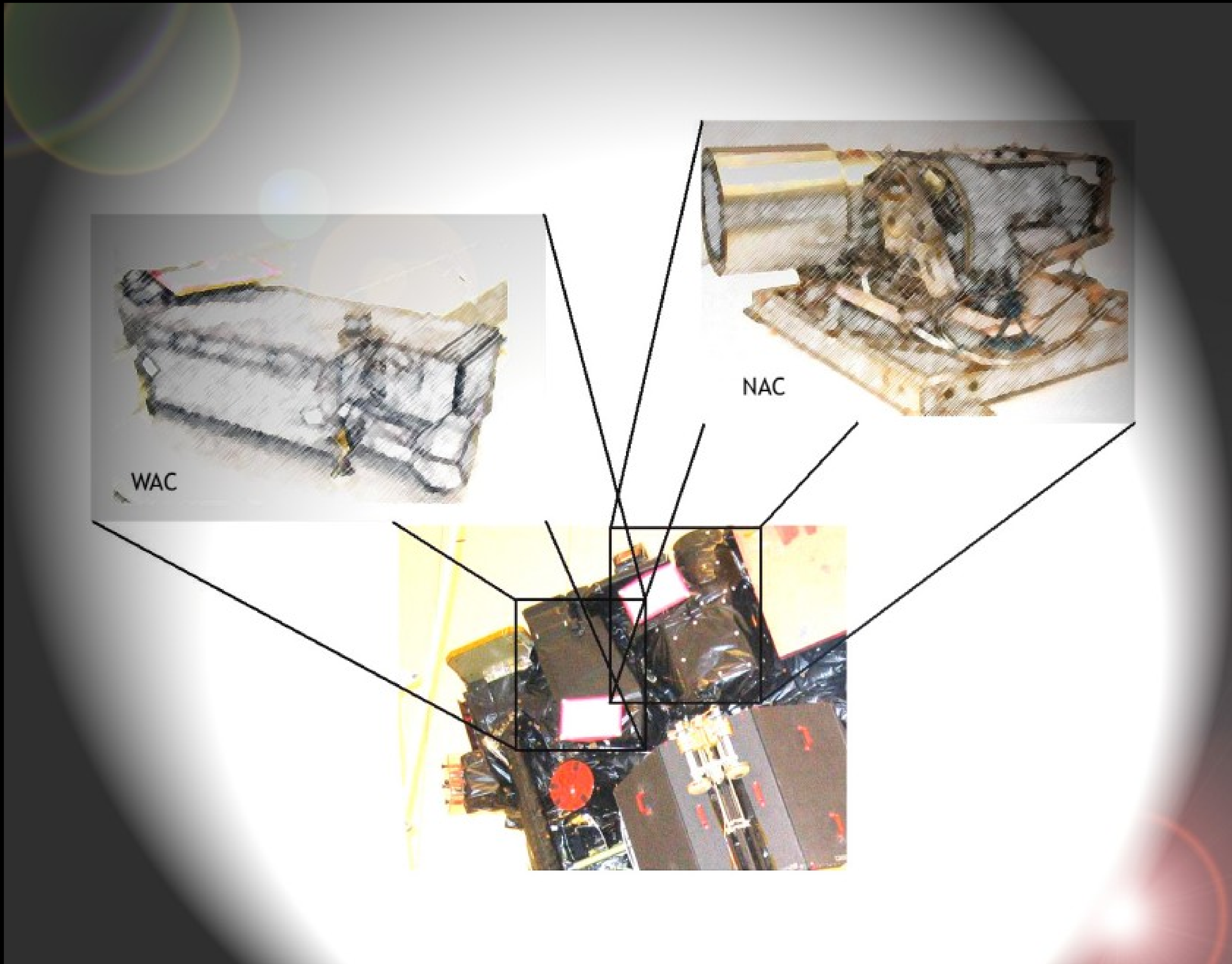
Rosetta Steins flyby (2008-Sep-05)



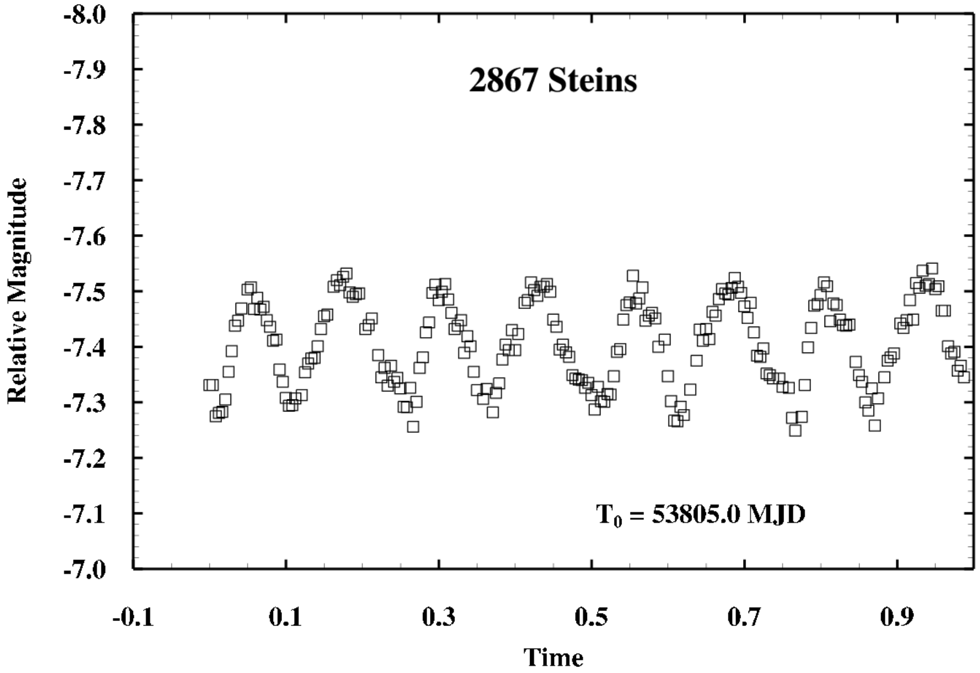
Distance of observers



The OSIRIS instrument



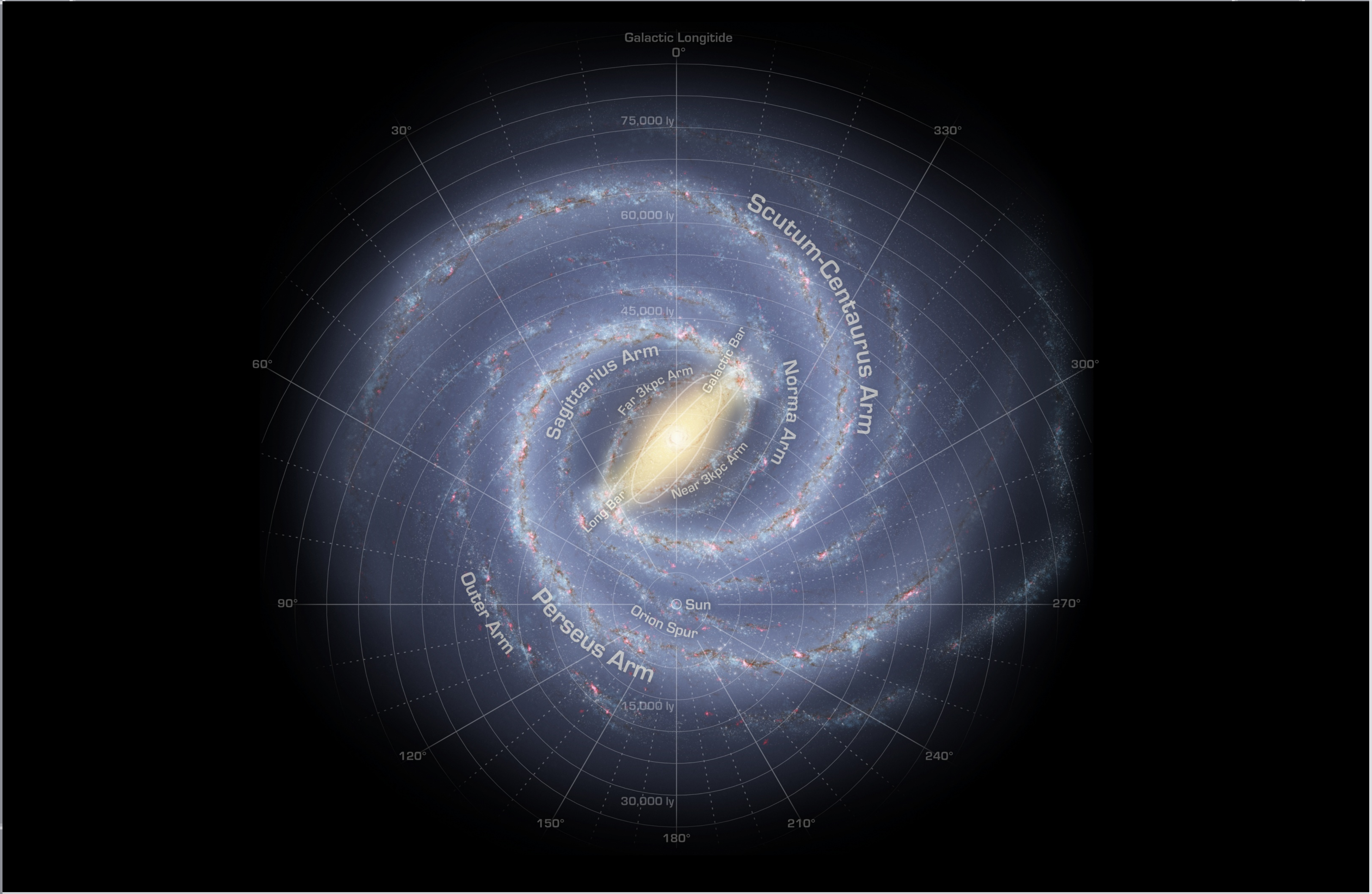
OSIRIS performance



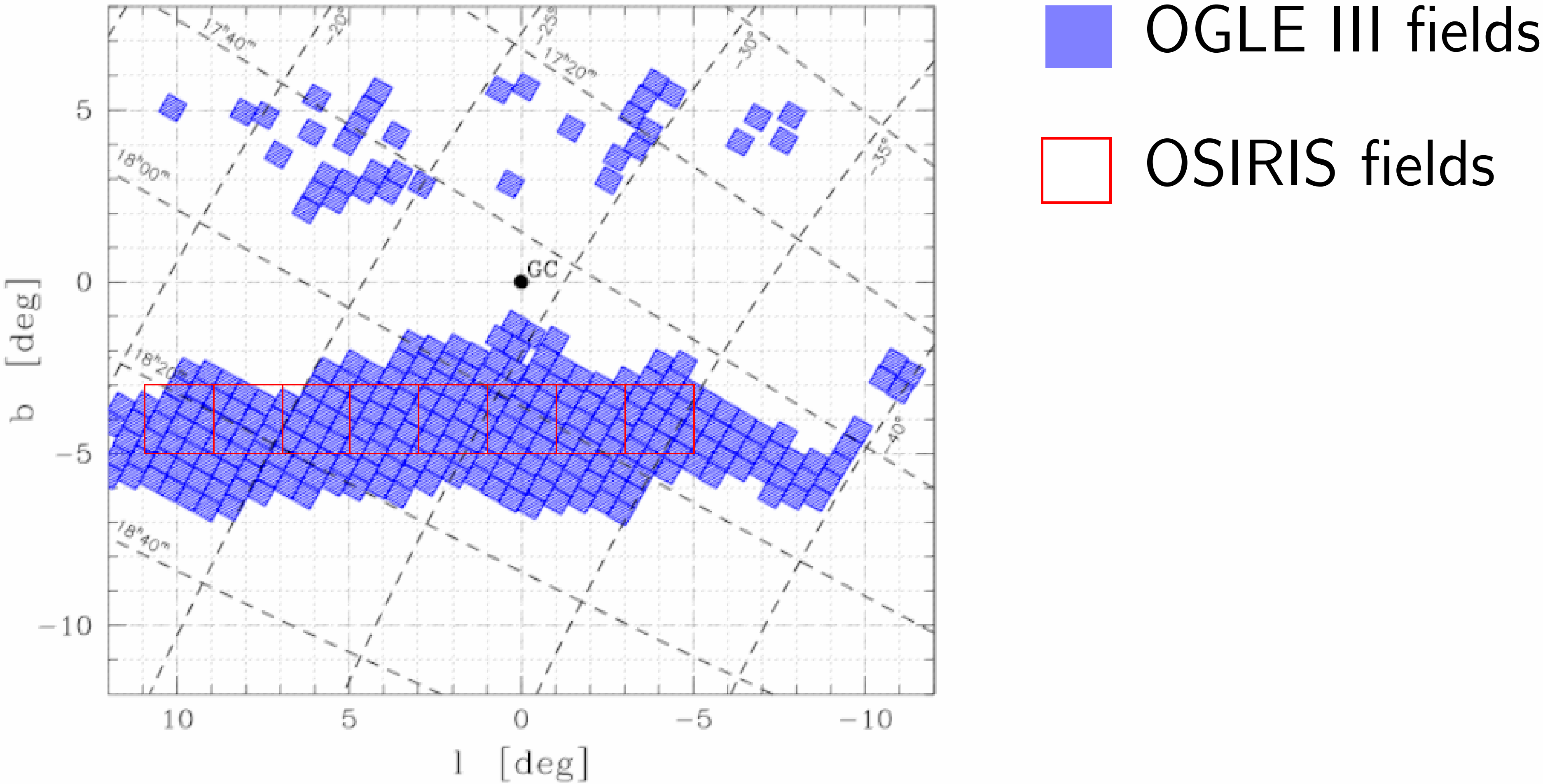
- OSIRIS performed photometry with a relative accuracy of 0.02 mag for Asteroid Steins (magnitude 16.6) with 5 minute exposures.

- A serendipitous OSIRIS image of a field close to the galactic centre isolates individual stars down to magnitude 16. Even fainter sources can be measured with adequate background subtraction.

Galactic coordinates



Scheduled OSIRIS observations



- We will image 8 different fields, each of it 7 times, over a 4 weeks period from Sep-07 to Oct-04.
- Dedicated ground based observation campaigns are simultaneously conducted in La Silla and in La Palma.

Expectations

- We expect to capture about 50 microlensing events.

Expectations

- We expect to capture about 50 microlensing events.
- The expected number of exoplanet events is 1 . . .