ASTROPHYSICAL APPLICATIONS OF GRAVITATIONAL MICRO-LENSING

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ABSTRACT. Gravitational micro-lensing due to stars in the deflecting galaxy influences the brightness and the spectra of the macro-images. Thus differences in the spectra of different macro-images are not automatically an argument against gravitational lensing. Furthermore changes in the spectra due to micro-lensing may give informations on the quasar structure. From high amplification events the brightness profile of the source may be obtained. The time scale of the high amplification event is proportional to the source radius and inverse proportional to the transversal velocity. Due to the large brightness gradient by a high amplification event, a "parallax-effect" occurs, from which the transversal velocity may be obtained, and thereby the source radius ($R = \Delta t \cdot V_T$). We roughly estimate 0.3 high amplication events per year for all gravitationally lensed quasars. Frequent monitoring should be carried out in order to predict high amplification events as early as possible.

1. INTRODUCTION

Gravitational micro-lensing (GML) due to stars in an intervening galaxy (macro-lens) may lead to a split-up of the macro-images into several micro-images[1].
      Although the separation of this micro-images is of the order 10^{-6} arcsec (unobservable), observable effects occur.

Changes in brightness and in the spectra of the macro-images may lead to important informations on quasars.

2. SPECTRAL EFFECTS

2.1. Chromatic Effect

For an extended source the mean amplification <A> must be calculated by integration over the source. If the source radius depends on the wavelength, <A> depends on the wavelength, too.[1]
    Thus, the effect of GML is stronger for compact sources (e.g. quasar continuum source) than for more extended sources (e.g. quasar emission line regions).[2]

2.2. Equivalent Width

Since the source radius is different for continuum and emission lines, <A> is also different and GML can therefore change the equivalent width of the emission lines.[2]

2.3. Emission Line Profiles

If the emission line profile varies over the source (e.g. due to rotation) and if A varies over the source, different parts of the profile are differently amplified by GML, resulting in different emission line profiles for the macro-images.[2]

3. HIGH AMPLIFICATION EVENTS

3.1. Critical Curves

The curves in the source plane where A→ ∞ are called critical curves. If a compact source crosses a critical curve, two micro-images appear or disappear and a typical asymmetric peak occurs in the light curve[1] (High Amplification Event (HAE)).

3.2. Brightness Profile and Source Radius

By comparison of an observed light curve with the theoretical light curve of a HAE, the brightness profile of the source (perpendicular to the critical curve) can be obtained.[3] Especially, multiple sources may show up as multiple peaks in the light curve.[4]
    Since the HAE are eclipse-like events, their time scale is proportional to the source radius.[2]

3.3. Timescale of HAE

The time scale of a HAE for a typical lensed quasar (source
radius 10^{-4} pc, transversal velocity $V_T=1000$ km/s) is of the
order 0.1 yr. For more extrem cases (e.g. 2237 +0305) time
scales as short as 0.01 yr are possible.[2]

3.4. Brightness Gradient

The steepest slope in the light curve is typically of the
order 1 mag/week (1 mag/day for extrem cases). This slope
is due to a spatial brightness gradient at the observer :
0.25 mag/A.U. for a typical lensed quasar, 2.5 mag/A.U.
for extrem cases like 2237 +0305.[2]
    This gradient is easily observable by "space telescopes"
$\geqslant$ 0.1 A.U. away from the earth. From the time lag between
the light curves measured by three observers the transversal
velocity perpendicular to the critical curve can be
obtained[5]. Now the source radius can be obtained from the
time scale of the HAE ($R = \Delta t \cdot V_T$). For very small velocities
the annual motion of the earth may show up as oscillations
in the light curve.[5]

3.5. Frequency of HAE and Monitoring

We roughly estimate 0.1 HAE/yr for 2237 +0305[2] and 0.3 HAE/yr
for all known gravitationally lensed quasars.[2]
    In order to predict a HAE in time, we propose a
frequent monitoring of lensed quasars. The time interval
should be less than one third of the time scale of a HAE,
i.e. about 10 days for a typical lensed quasar, an 2 days
for 2237 +0305.

4. OBSERVATIONAL EVIDENCE FOR GML

If a lensed quasar shows intrinsic variations only on time
scales much larger than the time delay between two images,
the brightness ratio between this images would, without
micro-lensing, be fairly constant. Thus, if changes of the
brightness ratio are observed, they would be a clear
evidence for micro-lensing in one (or both) macro-images.
A variation of this kind has already been reported[6,7] for
the components A_1 and A_2 of the multiple quasar 1115+080
(separation 0.5"; estimated time delay a few days). This
gives evidence for GML, although further observations are
needed to exclude intrinsic short-time variability of the
object.

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DISCUSSION

TURNER: In complementary work, my Princeton colleague B. Paczynski has carried out Monte Carlo simulations of microlensing which often show substantial step function-like changes in the amplification. If microlensing affects continuum and emission line regions differently, this could easily produce large spectral differences between two macro lens images.