Zooming In on Quasar Accretion Disks through Chromatic Microlensing

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Abstract

Gravitational lensing ought to be achromatic, yet X-ray flux ratios differ from optical ratios in several quadruple quasar lenses. The best explanation is that the X-ray accretion disk of the quasar is fully microlensed, while the larger optical disk experiences less extreme microlensing. This is in conflict with the standard Shakura-Sunyaev thin disk model, which predicts a smaller optical disk. Simulations suggest that there will be strong evolution in the flux ratios of microlensed images in the optical regime. We have begun a survey of twelve quad lenses in broadband filters from 0.4 to 2.2 microns, to find this evolution and characterize the size of the disk as a function of wavelength. We will use microlensing to "zoom in" on the accretion disk.

Chromatic Microlensing

AGN accretion disks appear larger at red wavelengths and smaller at blue wavelengths. If the size of a lensed quasar is large enough relative to the Einstein ring of a perturbing mass, it will attenuate flux variations caused by the perturber.

For several lensed quasars, X-ray flux ratios are more anomalous than optical ratios, indicating that at optical wavelengths the accretion disks have sizes nearly comparable to stellar microlens Einstein radii (or a few 10^{16} cm). One example of this is PG 1115+080 (see Figure 1).

These sizes are, in general, larger than are predicted by the standard Shakura-Sunyaev thin accretion disk model.

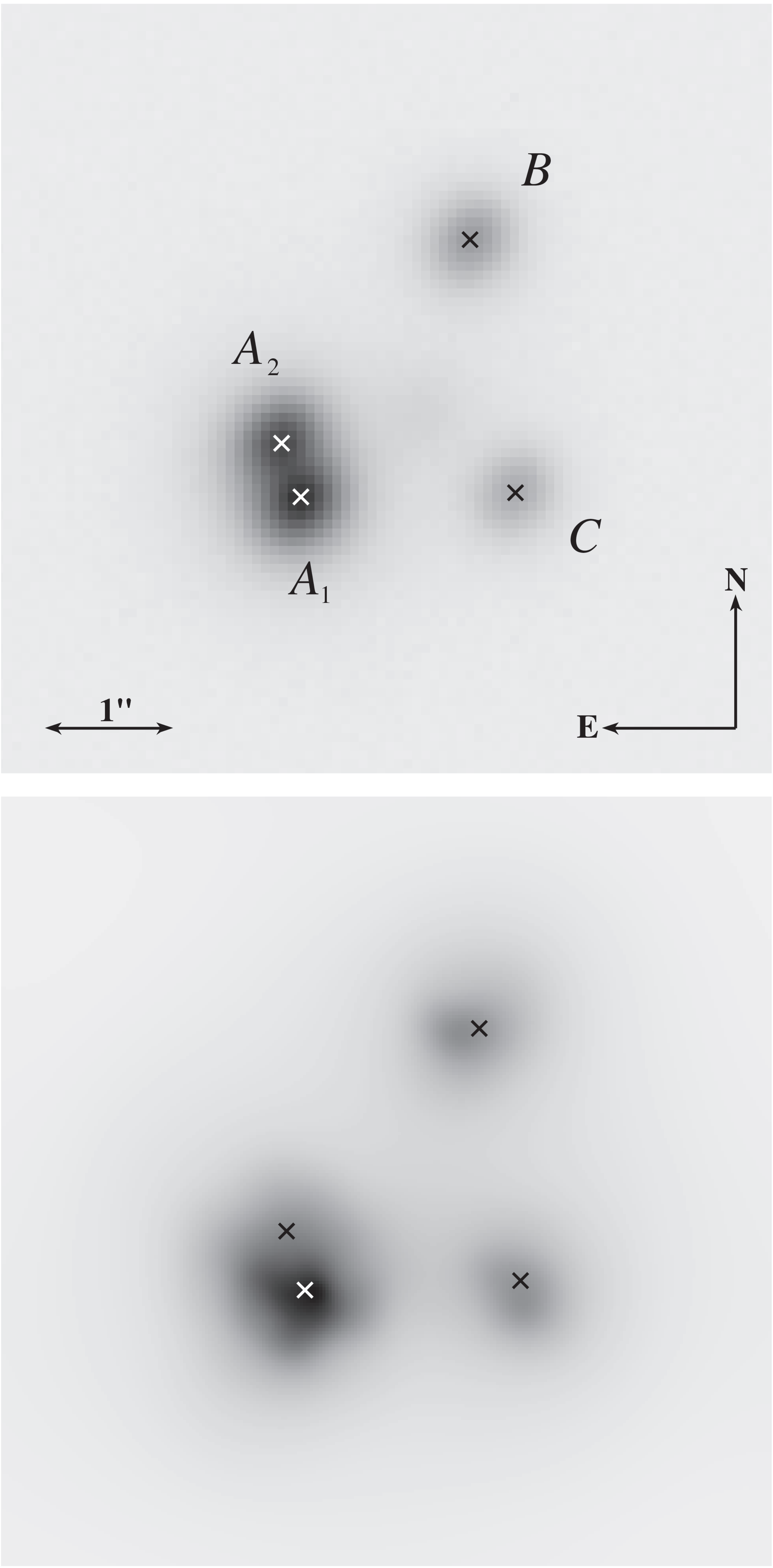

Figure 1: Optical and X-ray views of PG 1115+080. The A1/A2 ratio is much higher in X-rays than at optical wavelengths. Figure from Pooley et al. (2006, ApJ 648, 67)

Microlensing "Sweet Spot"

Though optical flux ratios usually do not match those predicted by smooth lens models, X-ray flux ratios are often even more anomalous.

The simplest explanation is that the X-ray emission region is much smaller than the Einstein radius of a microlens star, but the optical region is a significant fraction of an Einstein radius, in the "sweet spot" for observations.

There ought to be strong evolution of flux ratios with wavelength in the optical regime, according to simulations (e.g., Mortonson et al. 2005, ApJ 628, 594). See Figure 2.

A multiwavelength survey of a sample of lenses from near-UV to near-IR would test the chromatic microlensing scenario and provide information on the temperature profile of the accretion disks.

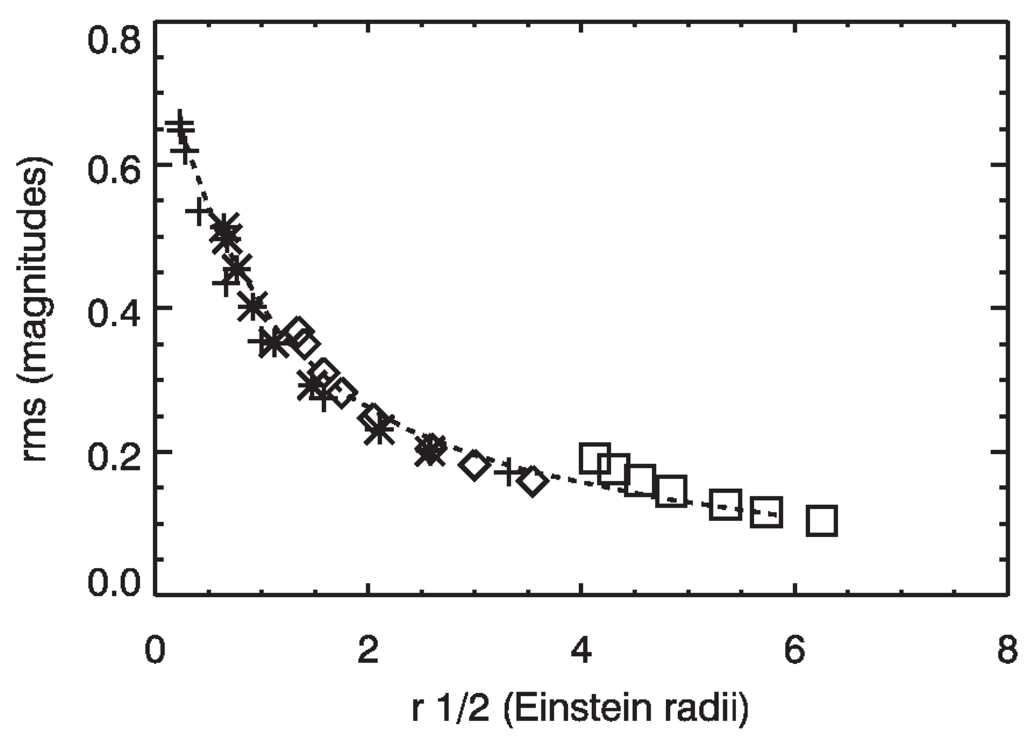

Figure 2: Microlensing flux variations as a function of source size. Figure based on simulations by Moronson et al. (2005, ApJ 628, 594). At source sizes near 1 micro-Einstein radius, flux variations change rapidly with source size.

Optical Chromaticity Survey

We have begun an optical survey of 12 quadruple lenses in several broadband filters, using the Magellan Telescopes at Las Campanas Observatory. We will also obtain complementary X-ray data from *Chandra*.

Preliminary results are beginning to arrive. Figure 3 shows one ratio from the quad RXS J0911+0551. There is clear evidence for chromatic microlensing in this flux ratio.

Future work will increase the number of flux ratios (three per lens), better characterize uncertainties, and explore implications for accretion disk profiles.

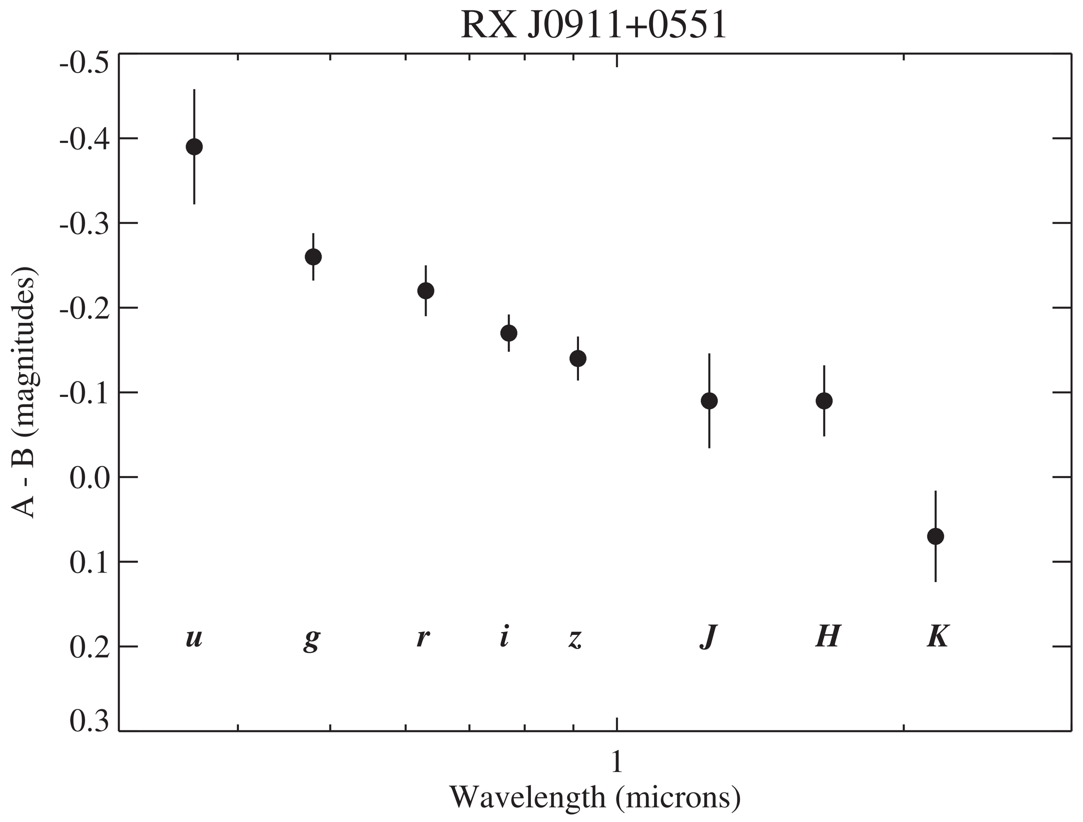

Figure 3: Preliminary result for the quad lens RX J0911+0551. The high-magnification A–B flux ratio varies monotonically with wavelength. It is closer to the model-predicted ratio at redder wavelengths, and closer to the X-ray ratio at bluer wavelengths. Error bars indicate statistical uncertainties, multiplied by 2 to reflect systematics which are not yet characterized.

Conclusions & Further Work

Chromatic microlensing can provide a magnifying glass to "zoom in" on the accretion disks of lensed quasars. To this end, we are surveying 12 quad lenses in eight broadband filters.

More lenses mean better statistics. This work could be extended to doubly lensed quasars as well, though they are not such a rich source of information (only one flux ratio per lens). This is another reason to find lenses!