A CLOSE LOOK AT Q2237+0305 *

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ABSTRACT. CCD images of the lensed QSO candidate 2237+0305 in the blue and near-infrared are examined. At least two blue images of the QSO, separated by about 1 arcsec, are found. The inferred velocity dispersion of the lensing galaxy core of 150 km/sec implies that no dark matter is required for this case. Limits on the mass distribution of the lensing galaxy core and bar can be obtained from the data. Since the galaxy is so nearby, this lensed QSO is a good candidate for assisted lensing by individual stars in the galaxy core.

This sixth known gravitational lens system was discovered by John Huchra and collaborators. It is unlike the other five: the foreground galaxy that acts as a lens is nearby. The galaxy, 2237+0305, is a 15.7 magnitude spiral at a redshift of 0.0394. The discovery was made with spectroscopic observations of 2237+0305 that revealed a galactic spectrum contaminated with light from a quasar having a redshift of 1.695. Huchra, et.al. noted that the galaxy could produce either a single quasar image or a cluster of images which would not have been resolved in the 2 arcsecond seeing.

To confirm 2237+0305 as a strongly amplified quasar image, multiple images must be found, leading to eventual spectroscopy on each separately. Moreover, any multiple image structure would supply needed data on the mass distribution in the lensing object: is the nuclear bulge of the galaxy or a more compact object responsible for the lensed quasar image structure?

CCD frames of 2237+0305 were obtained in excellent seeing at Cerro Tololo Interamerican Observatory using the prime focus CCD camera, on 27 October, 1984. A bright star was included in the CCD field for use later as a comparison star. To avoid saturating on the quasar, four 100 sec exposures were taken through a J (blue) filter, and two 100 sec exposures through a special I filter (.78 - 1.1 micron), with the telescope offset slightly between exposures. The images were re-combined later after removal of any non-reproducible features.

The raw images were processed on the VAX 11/785 at Bell Labs. Examination of the full range of the raw images revealed something strange: the bright peaks of the quasar image on each CCD frame were triangular

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G. Swarup and V. K. Kapahi (eds.), Quasars, 551–552.

in shape. But the bright star in the field was circular at its peak. This was the first indication that lensed quasar multiple image structure had been resolved. Initial image processing removed bad pixels and cosmic rays, and, for each band, the frames were then registered to fractional pixel accuracy and averaged by taking the median intensity of each pixel.

The full-width at half-maximum of the triangle ensemble was larger than that of the comparison star. To reduce scattered light and sharpen the images near the quasar, the comparison star was smoothed with a gaussian filter until it was the same width, and then scaled and subtracted from the centroid of the quasar image combination. Three "stellar" images are seen.

One of the three "stellar" images has a different color than the other two. The fainter "third" image is much redder than the other two, and is presumably the galaxy core. Thus this is a likely example of a "double" quasar gravitational lens. The separation of the two quasar image components is about 1.2 arcsec, and is the closest spaced binary lensed quasar yet discovered. If the lensing mass has an isothermal distribution then the 1.2 arcsec quasar image separation would imply a line-of-sight velocity dispersion in the lensing mass of 150 km/sec. This is slightly smaller than a typical spiral galaxy's core dispersion. What distribution of mass is consistent with this image two-dimensional morphology and color data? The center of the galaxy does not lie on the line joining the two quasar images. In order to produce two misaligned images, the galaxy must have a mass distribution more complex than spherical. The CCD images show that the galaxy is a barred spiral with the bar oriented at 45 degrees to the east of north on the sky. It is possible that this bar represents mass that can account for the quasar image structure.

A composite color image formed from the blue and infrared CCD exposures shows, in addition to the relatively blue binary quasar images, a suggestion of a blue contribution near the third (red) component of the triangle. In collaboration with E. Falco and M. Gorenstein (CFA), we find that although the observed quasar image separation is easy to get, the displaced galaxy core (and possible third quasar image) is only consistent with a combination of galaxy core and extra quadrupole, aligned with the observed bar in the galaxy.

Paczynski has pointed out that 2237+0305 is a likely candidate for "mini-lensing": additional lensing by a star in the lens galaxy core. It is highly probable that some fraction of the lensing in this case is due to a star in the core of the lens galaxy. This predicts that (1) high resolution ST or speckle images of 2237+0305 may reveal higher multiplicity QSO images of spacing < 0.1 arcsec, and (2) the relative flux from the QSO components may vary on month to year timescales.

Based only on the positional coincidence of the relatively high redshift quasar and the nearby galaxy, 2237+0305 has been cited as a possible discrepant redshift object. However, its morphological similarity to other confirmed lensed quasars makes any non-cosmological redshift interpretation unlikely. ST offers an excellent opportunity to examine the spectrum of the two blue images, and search for fainter QSO images.