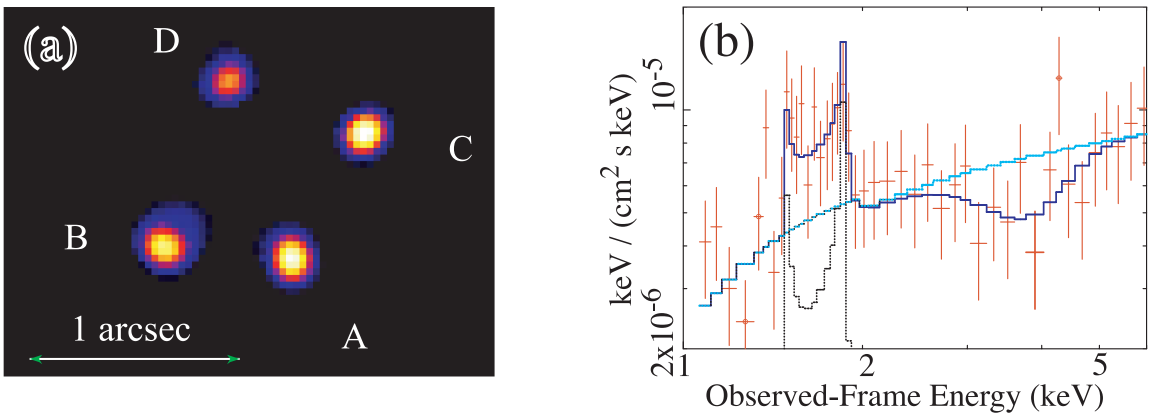

Figure 1: (a) Deconvolved images of the 89 ks *Chandra* observation of the lensed broad absorption line quasar H 1413+117 (b) Unfolded spectrum of all images of H 1413+117 showing the double-peaked Fe K emission line fit with an accretion disk model.

Imaging of the Environments of Supermassive Black Holes

Direct imaging of the immediate environments of black holes in Active Galactic Nuclei (AGNs) requires angular resolutions of the order of tens of nano-seconds at $z \sim 1$ and is beyond the capabilities of present day telescopes. We have recently developed an indirect method to probe the various emission regions of an accretion disk from scales of a few hundred gravitational radii (r_g) down to the event horizon of the black hole. This method is based on monitoring microlensing events in lensed quasars. In particular, as a magnification caustic is traversing the accretion disk we expect to detect changes in the line energy, intensity, and profile of microlensed Fe Kα lines in the X-ray spectra of lensed quasars. We reported the first detection of a such a microlensing event in the *Chandra* observations of the radio-loud quasar MG J0414+0534 (Chartas et al. 2002, ApJ, 568, 509). Based on our simulations of caustic crossings, we expect future detailed X-ray monitoring of microlensing events in quasars to reveal significant distortions of the iron line caused by special and general relativistic effects and Doppler effects as the caustic approaches near (a few r_g) the event horizon of the black hole.

We also detected a remarkable X-ray microlensing event in the Cloverleaf quasar (Chartas et al. 2007). The estimated time-scale of the microlensing event of 2000 days leads to a size-scale of the microlensed region of the order of $13r_{\rm g}$. In the combined spectrum of all images emission peaks at 5.35 $\pm$ 0.23 keV and $6.3^{+0.6}_{-0.3}$ keV are detected at the $>$ 95% significance level. We propose as a plausible origin of the double peaked emission line fluorescence from the far side of the accretion disk. We modeled the Fe Kα profile with an accretion disk line model and found an acceptable fit to the spectrum (see Figure 5). We note, however, that due to the low S/N of the spectrum we cannot obtain tight constraints on the parameters of such a disk-line model. Additional deeper observations are needed to determine the origin of the double peaked Fe emission line and constrain the parameters of a disk-line model.

A related project that is being performed in collaboration with Dr. Christopher Kochanek at OSU involves monitoring gravitationally lensed quasars for microlensing variability from the ground in the optical and with the *Chandra X-ray Observatory* in the X-ray band to obtain a geometric measurement of the relative sizes of the optical and X-ray emitting regions of the quasars. We are currently monitoring several lenses using the SMARTS 1.2m at Cerro Tololo and the MDM 2.4m at KPNO in the J, I, R and B bands with a cadence of roughly 1/week. We also have approved time to observe PG 1115+080 with the *Chandra X-ray Observatory* for the 2008-2009 cycle. Our plan is to simultaneously monitor microlensed quasars in the X-ray and optical bands. If the X-ray emission is more compact than the optical emitting region we expect more variability in the X-ray flux ratios than in the optical flux

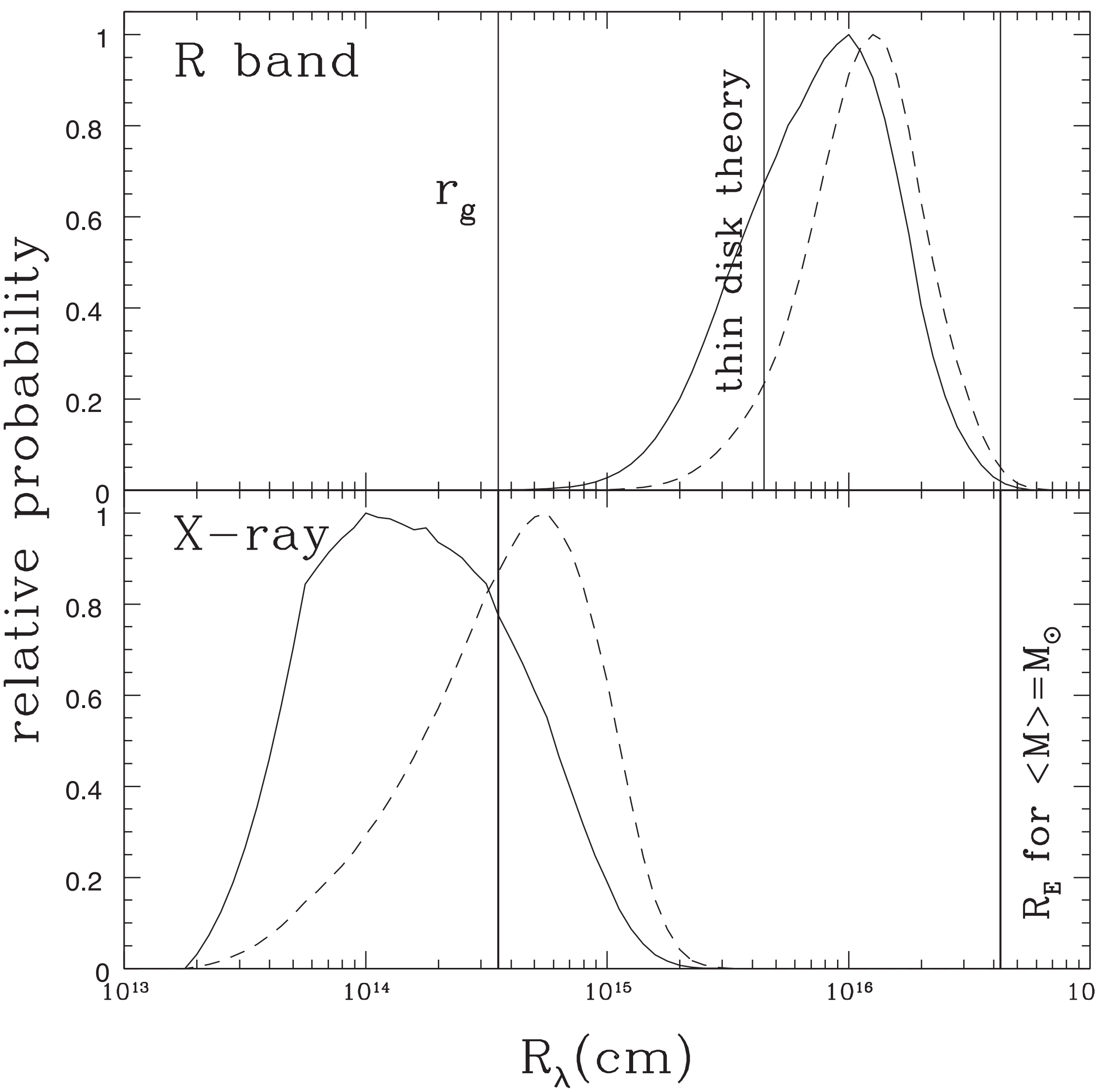

Figure 2: Disk size at 2000Å (top) and X-ray (bottom) for HE 1104−1805, where the solid (dashed) curves assume logarithmic (linear) priors on the source size. We show the values of R_λ for the assumed surface brightness profile so that the size ratios will be correct. Physically, the disk size at 2000Å can be increased by a factor of $(\cos i)^{-1/2}$ for the inclination of the disk i, and the X-ray size should be regarded as a measurement of the half-light radius with $R_{1/2} = 2.44 R_\lambda$. Vertical lines mark the gravitational radius $r_g = GM_{BH}/c^2$ and accretion disk size given the wavelength, the estimated black hole mass, and Eddington limited accretion with an efficiency of $\eta = 0.1$. The final vertical line marks the Einstein radius for solar mass stars.

ratios. We presented the first results from our X-ray and optical monitoring campaign of microlensing events at the AAS High Energy Astrophysics Division (HEAD) meeting in San Francisco. Following the recommendation of the organizers of the HEAD meeting we gave a press release on our results (see http://www.science.psu.edu/alert/GarmireChartas10-2006.htm).

In Figure 6 I show the rest-frame UV and X-ray source sizes derived from applying a microlensing analysis to the UV and X-ray light-curves of gravitational lens HE 1104−1805 (Chartas et al. 2009, ApJ in press) We find that the X-ray emitting region of HE 1104−1805 is compact with a half-light radius $\lesssim 6r_g$, where the gravitational radius is $\mathrm{r_g} = 3.6 \times 10^{14}$ cm, thus placing significant constraints on AGN corona models. We also find that the microlensing in HE 1104−1805 favors mass models for the lens galaxy that are dominated by dark matter.