Quasar Microlensing: Polarization and Iron Lines as a Probe of Accretion Disk Physics

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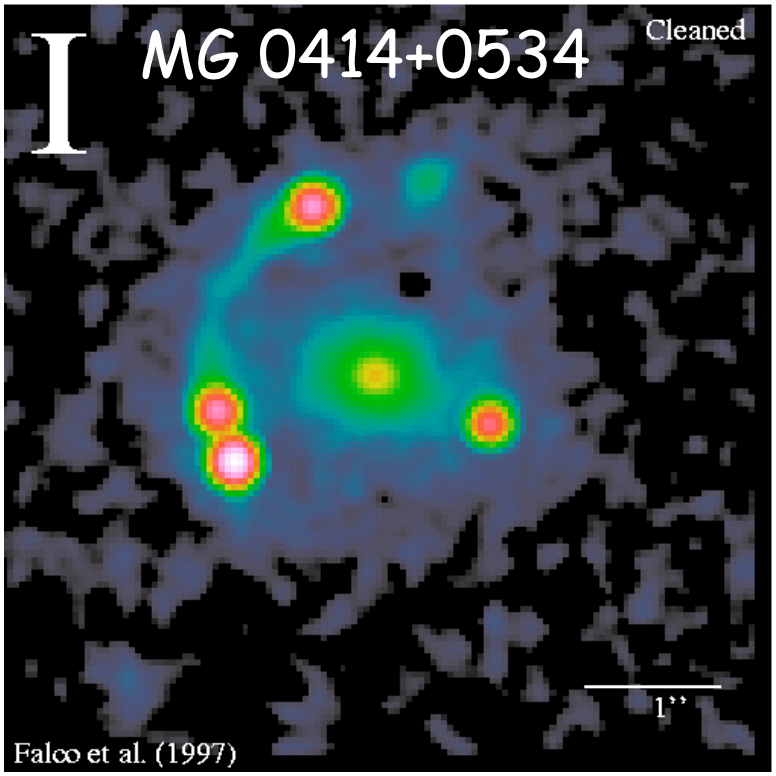
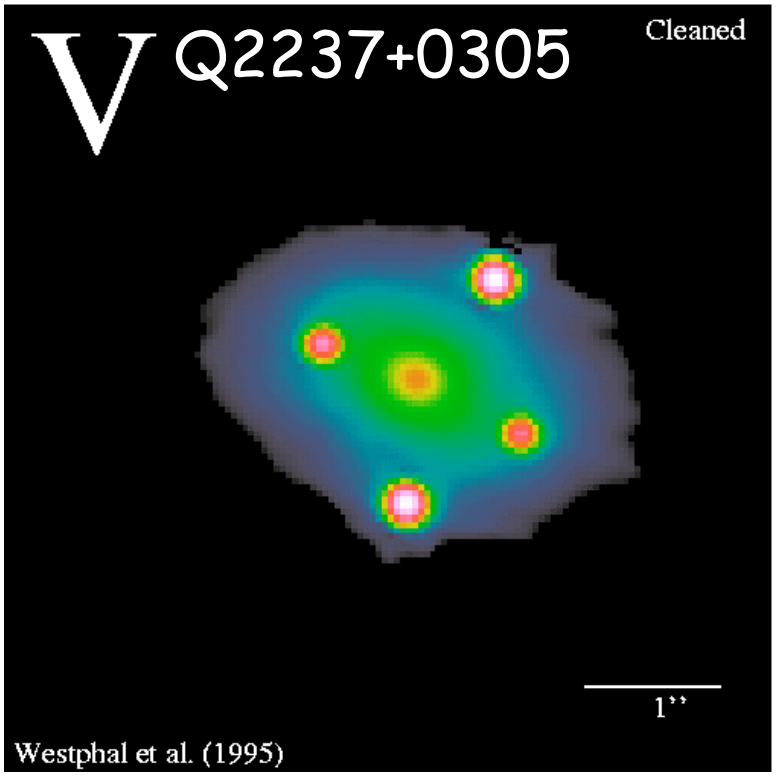




Dependence of fluctuations on source size:

Small sources are amplified by as much as ~$(R_E/R_s)^{1/2}$, while large sources vary by only ~(R_s/R_E)

Wyithe, Agol, & Fluke (2001)

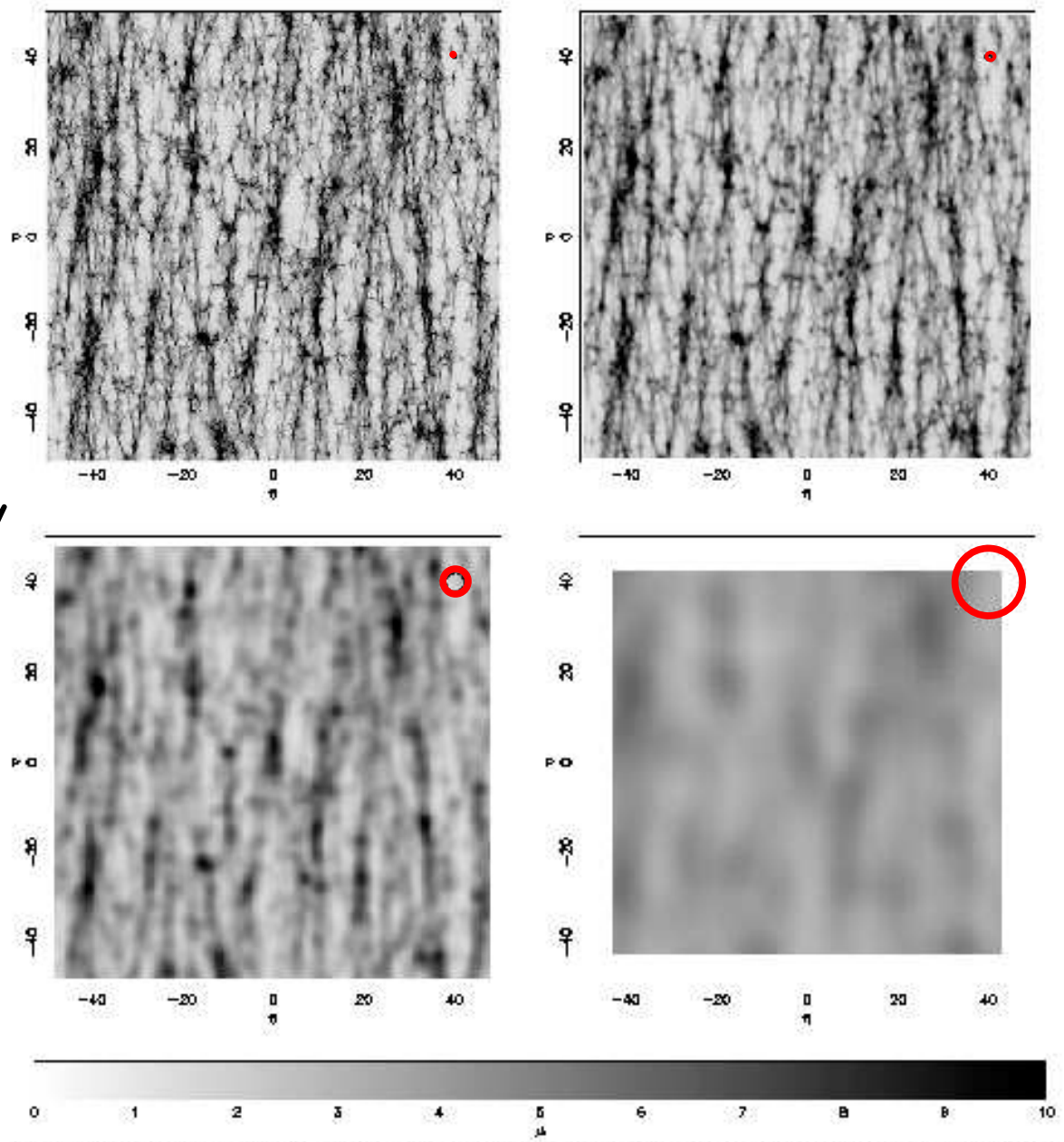
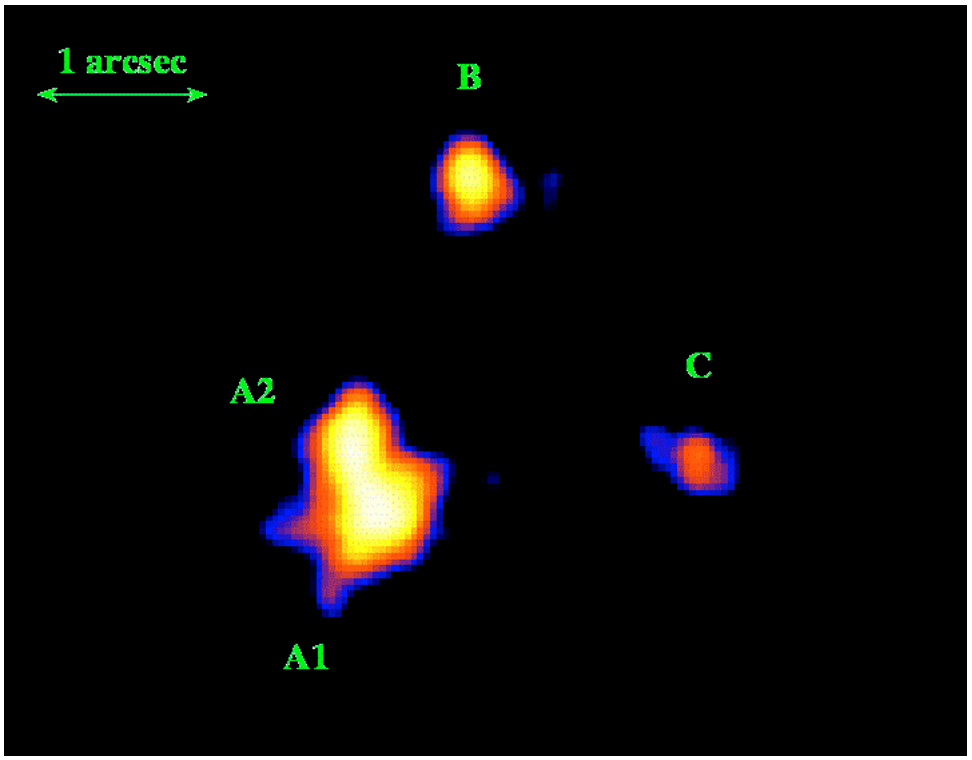
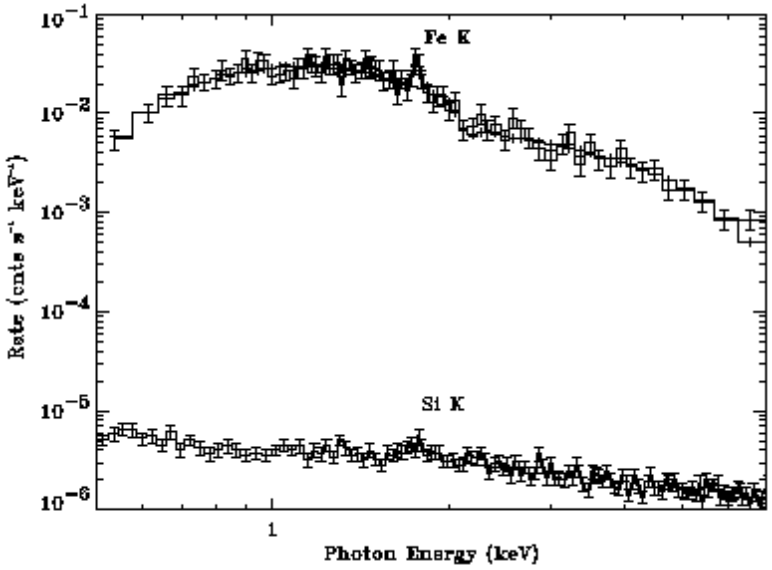


Figure 2. Convolution of a magnification map with source discs of 4 different sizes (shown by the circles in the upper right corner of each panel. The grey-scale bar shows the corresponding magnification. The macrolensing parameters were $\kappa = 0.35$, $\gamma = 0.40$.

Deconvolved Chandra Image of MG 0414+0534 (Chartas et al. 2001)



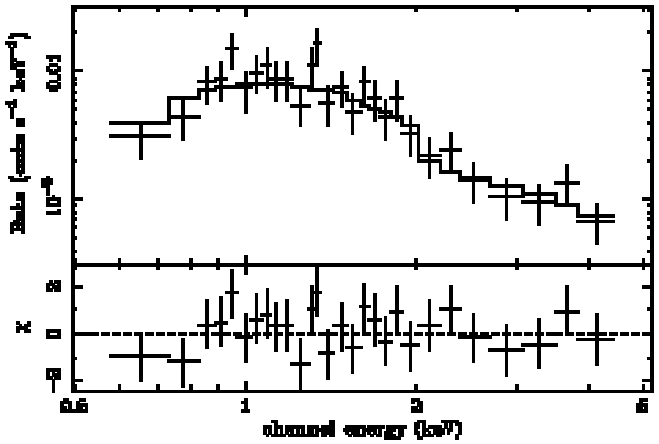


- 5 obs, 7 ksec each over 13 months
- Fe line at 1.7 keV with 200 eV EW (z=2.64)

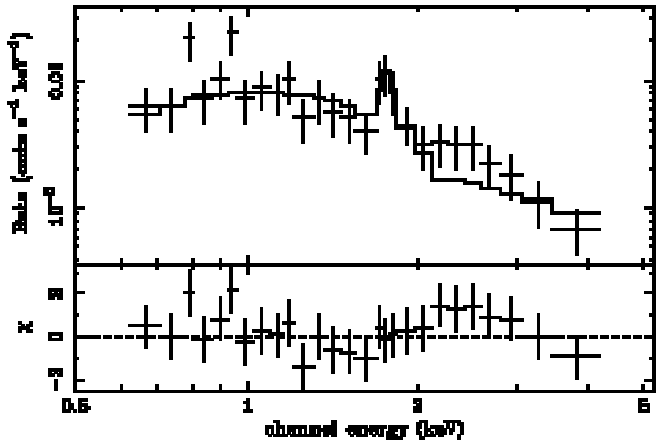
Variability in Image B

The iron line appears to have varied in Image B

first 3 observations:

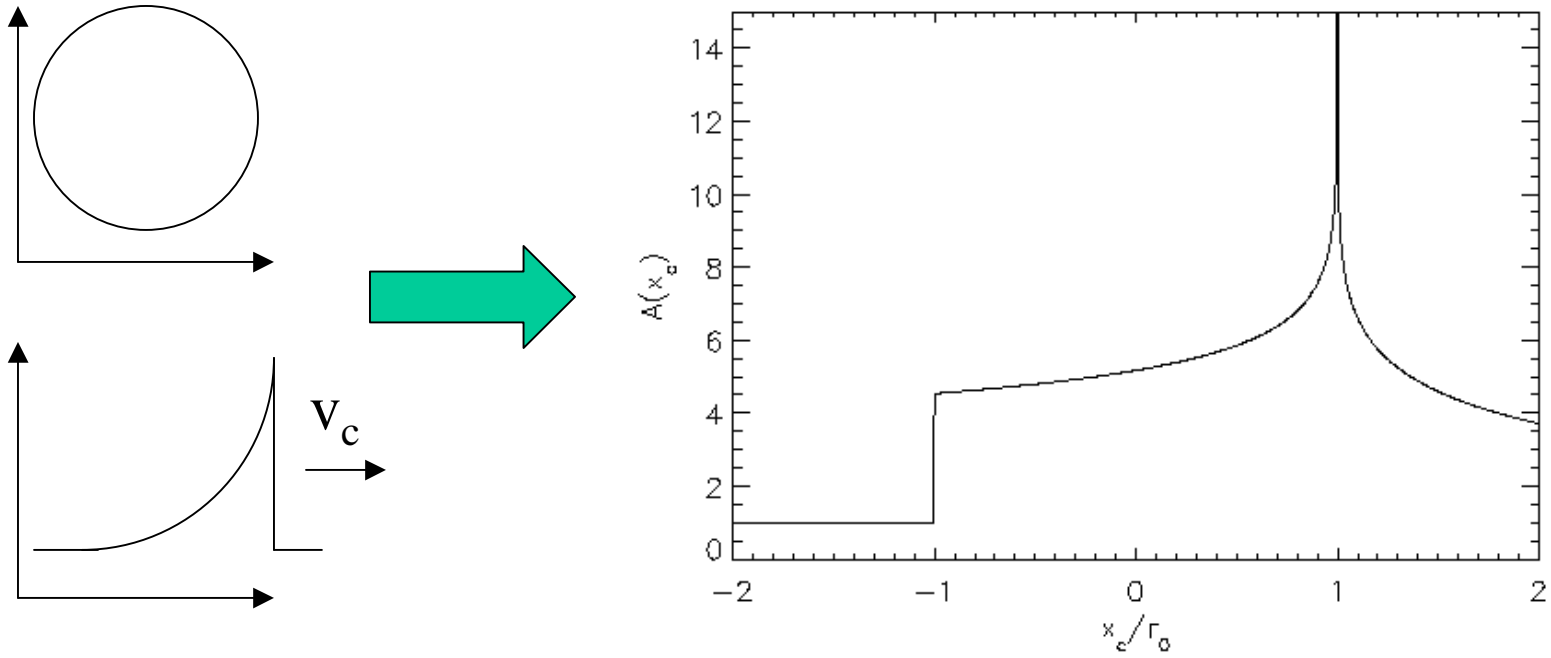


last 2 observations:

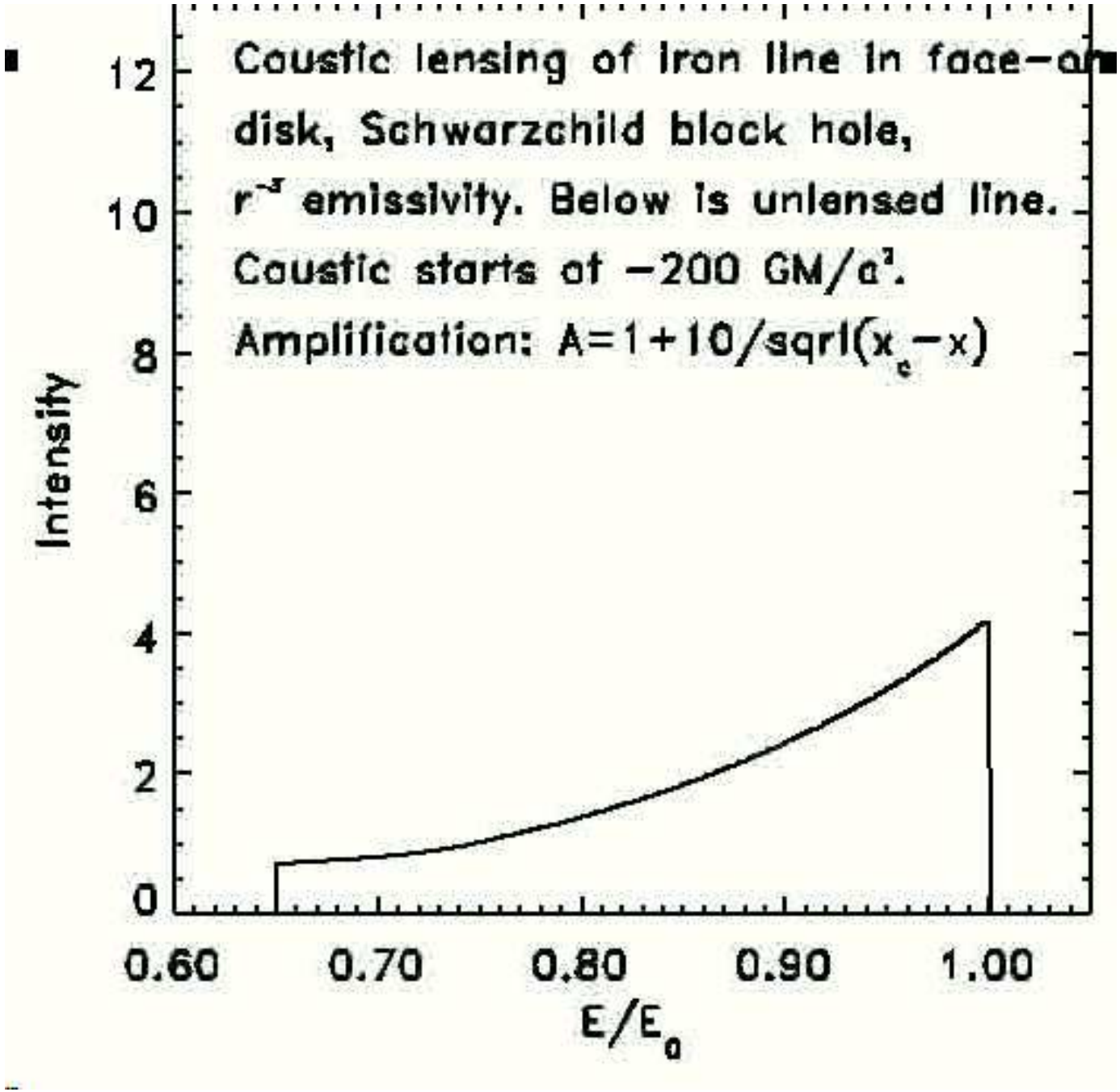


- The left spectrum consistent with 200 eV EW
- The right spectrum is 910 eV at 6 sigma confidence, while continuum is unchanged and other images are unchanged.
- Microlensing of iron line emission region?
  DD time has been awarded to confirm

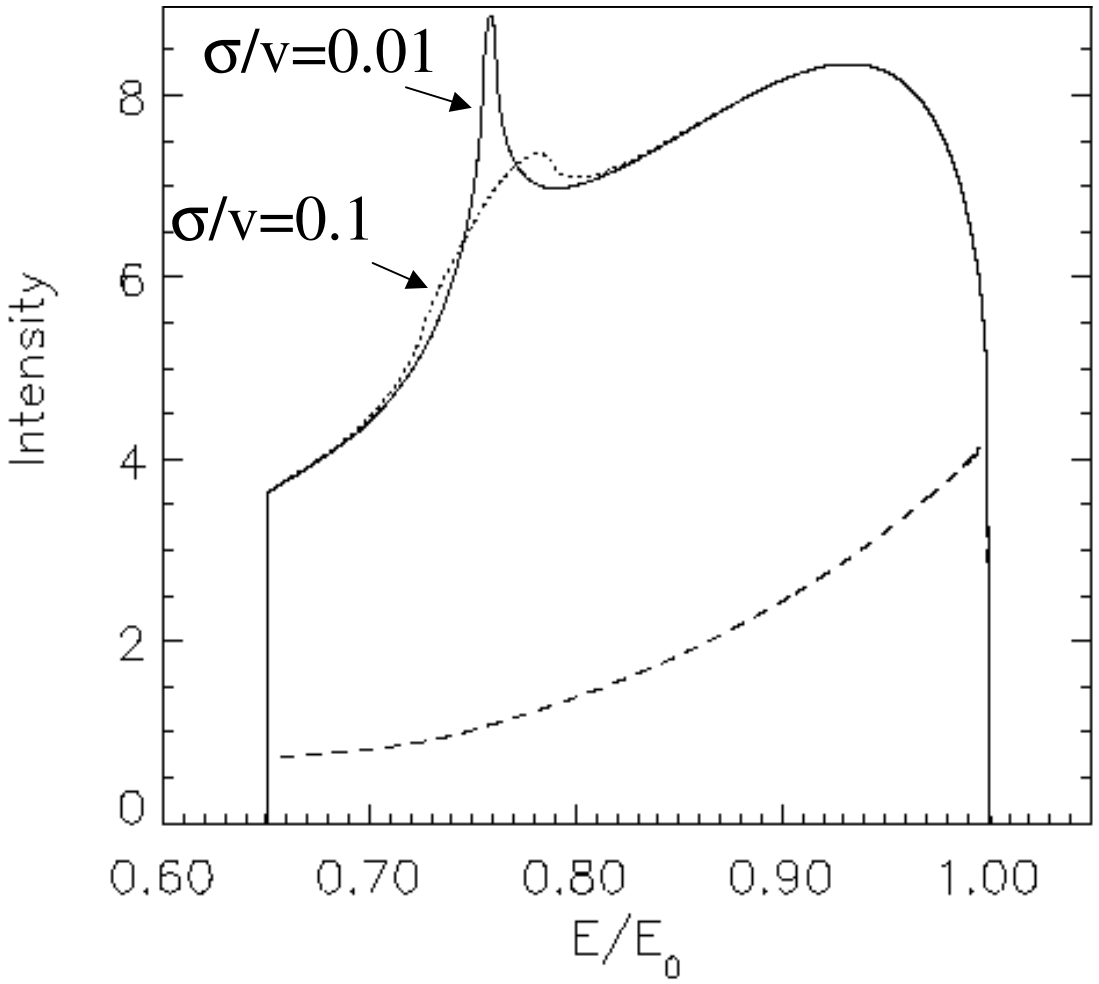
Microlensing of a ring by a caustic



- If MG 0414 line is microlensed, then
  $r < 4 \times 10^{-4}$ pc to achieve high EW
- $M < 10^6 M_\odot$ to be consistent with line being unbroadened so far...


Coustic lensing of iron line in face-on
disk, Schwarzchild black hole,
r^{-3} emissivity. Below is unlensed line.
Coustic starts at $-200\ GM/c^2$.
Amplification: $A=1+10/sqrt(x_c-x)$
Intensity
0
2
4
6
8
10
12
0.60
0.70
0.80
0.90
1.00
E/E_0

Peak of microlensing depends on turbulence in disk



The Intrinsic Polarization of QSOs

Radio-quiet QSOs are typically polarized ~ 0.5-1%

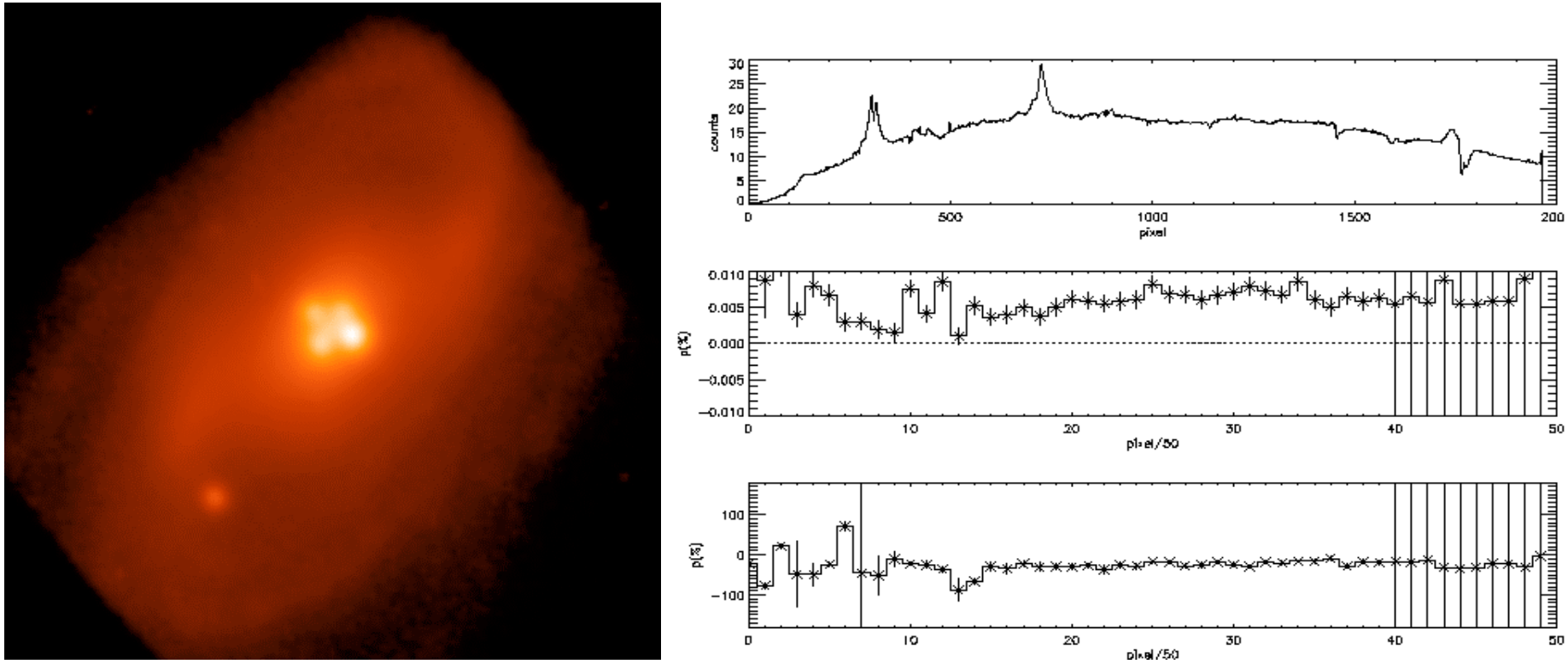
At least two possible origins of the polarization:

- The optical emission region, thought by some to be an accretion disk, is *intrinsically* polarized from scattering by disk electrons or from non-thermal synchrotron
- Polarization is created *extrinsically* by electron or dust scattering on larger scales.

With two measurements of the polarized flux of a microlensed QSO at different epochs, one can measure the intrinsic polarization, p_{int}, and constrain the size of the scattering region.

MHD simulations of accretion disks show that the magneto-rotational instability naturally produces near-equipartition magnetic fields (Miller & Stone 2000), which should Faraday depolarize the thermal disk emission (Agol & Blaes 1996), so $p_{int} \sim 0$. A measurement of p_{int} will test this hypothesis; non-zero p_{int} will provide evidence for weak magnetic fields or non-thermal emission.

Polarimetry of the Einstein Cross



Left: V-band image with LRISp on Keck I taken on Sept. 21, 2001. We will follow up with observations next Fall.

Right: Spectrum and polarization of images A & D of 2237; data is uncalibrated. The average p=0.56±0.02%.

Summary

- Microlensing may allow one to probe QSO accretion disk physics:
  - Broad emission lines will show peak which depends on disk turbulence, as well as disk inclination, black hole mass, and spin.
  - Polarization will depend on magnetic field strength and non-thermal nature.
- MG 0414+0534 may show iron line variations due to microlensing
- Q2237+0305 shows some polarization; monitoring should reveal the size of the polarized emission region