Effect of Microlensing on the Quasar Iron-Line Profile

Lukáš Ledvina[1], David Heyrovský[1], Michal Dovčiak[2]

[1]Institute of Theoretical Physics, Charles University in Prague, Czech Republic
[2]Astronomical Institute of the Academy of Sciences, Prague, Czech Republic

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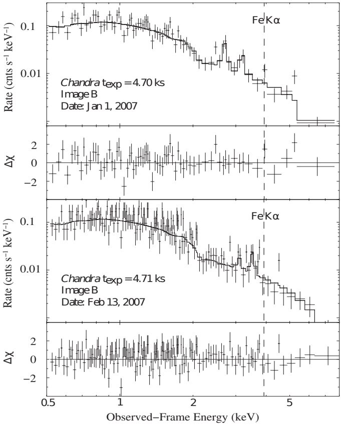
Observational data

Quasar RXJ1131–1231

- Microlensing variability of X-ray spectrum in lensed image B
- Chartas et al. 2012, ApJ, 757, 137



Disk model (Dovčiak et al. 2004)

- Kerr black hole (spin a) + thin disk, inclination i.
- local emission: photon specific intensity
  continuum: $I_{E,\mathrm{e}}^{\mathrm{cont}} = I_0^{\mathrm{cont}} E_{\mathrm{e}}^{-\Gamma} r^{-q}$
  iron line: $I_{E,\mathrm{e}}^{\mathrm{Fe}} = I_0^{\mathrm{Fe}} r^{-q} \delta[E_{\mathrm{e}} - E_{\mathrm{Fe}}]$
  E_{e}. . . emitted photon energy
- observed photon energy $E_{\mathrm{obs}} = E_{\mathrm{e}} g$
  g . . . Doppler + gravitational shift
- transformation disk $(r, \varphi)_{B-L}$ $\Rightarrow$ plane of the sky (α, β)

Gravitational lensing

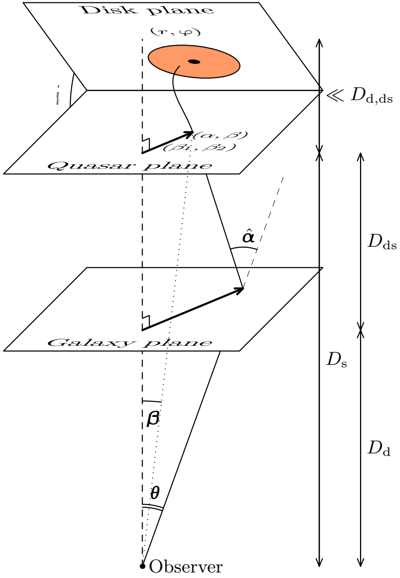
- Deflection angle $\hat{\boldsymbol{\alpha}}$
- Lens equation

$$\boldsymbol{\beta} = \boldsymbol{\theta} - \frac{D_{\rm ds}}{D_{\rm s}} \hat{\boldsymbol{\alpha}}(\theta)$$

- Typical deflection scale: Einstein radius

$$\theta_{\rm E} = \sqrt{\frac{4GM}{c^2} \frac{D_{\rm ds}}{D_{\rm d} D_{\rm s}}}$$

- In quasar microlensing $\theta_{\rm E} \approx 1\,\mu\text{arcsec}$



Caustic model

Straight fold caustic

- Amplification of point source at $(\tilde{x}, \tilde{y})$ by caustic at $\tilde{y} = 0$

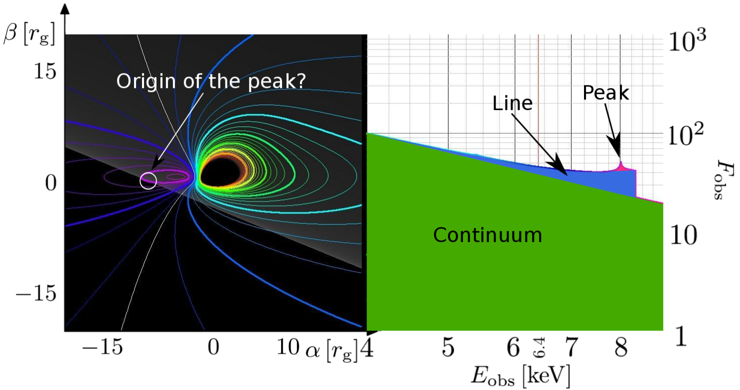
$$A(\tilde{x}, \tilde{y}) = A_0 + \begin{cases} 0 & \text{for} \quad \tilde{y} \leq 0 \\ \sqrt{\tilde{y}_0/\tilde{y}} & \text{for} \quad \tilde{y} > 0 \end{cases}$$

- A_0 – background amplification
- $\tilde{y}_0$ – caustic strength

Observed flux

$$F_{\mathrm{obs}}(\alpha_0, \beta_0) = \int_{\mathrm{disk}} I_{\mathrm{obs}}(\alpha, \beta) A(\alpha - \alpha_0, \beta - \beta_0) \mathrm{d}\alpha \mathrm{d}\beta$$

Decomposition of spectrum model

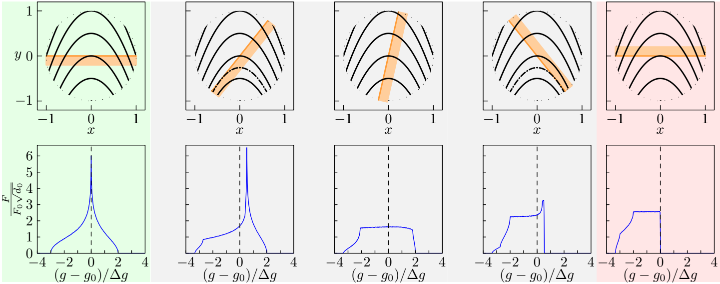


Peak modeling

g-factor: $g(x,y) = g_0 + g_y y + \frac{1}{2} g_{xx} x^2$

Caustic orientation

Line profile excess



Internally tangent contour to the caustic

$$\Delta F(E) \approx -I_0 \sqrt{\frac{2}{g_{xx} g_y}} \log |E - g_0 E_{\mathrm{Fe}}|$$

Externally tangent contour to the caustic

$$\Delta F(E) \approx I_0 \sqrt{\frac{2\pi^2}{g_{xx} g_y}} H(E - g_0 E_{\mathrm{Fe}})$$

Summary

- New method for studying central part of accretion disk
- Demonstrated generation of peaks and edges on iron line profile

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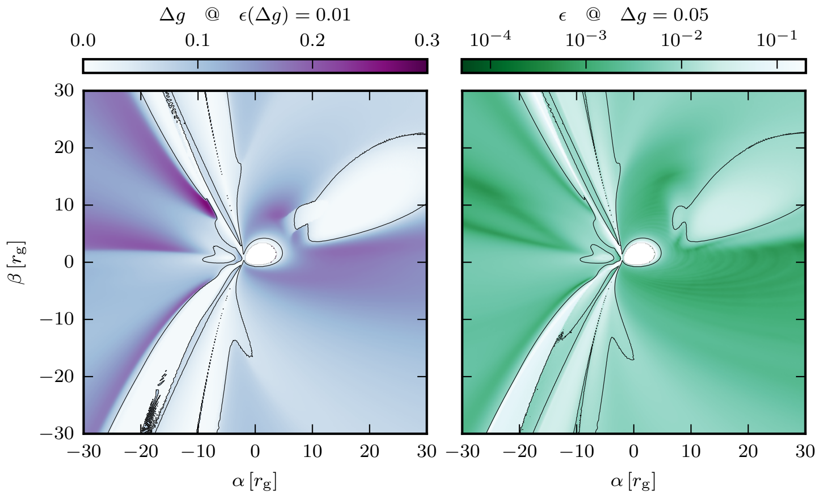
Thank you for your attention!

Peak width maps – inclination 70°



$$\varepsilon(\Delta g) = \sqrt{\frac{\int (F(g) - F_{\mathrm{m}}(g))^2 \mathrm{d}\, g}{\int F(g)^2 \mathrm{d}\, g}}\,, \qquad F_{\mathrm{m}}(g) = C + Dg - P \log|g - g_0|$$