Microlensing Constraints on Quasar Emission Regions: Athena's Perspective

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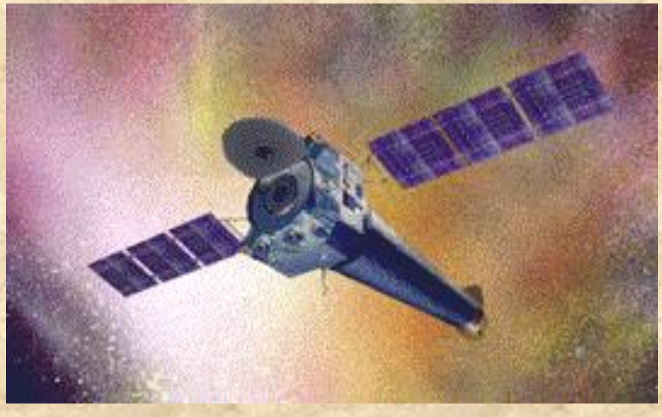
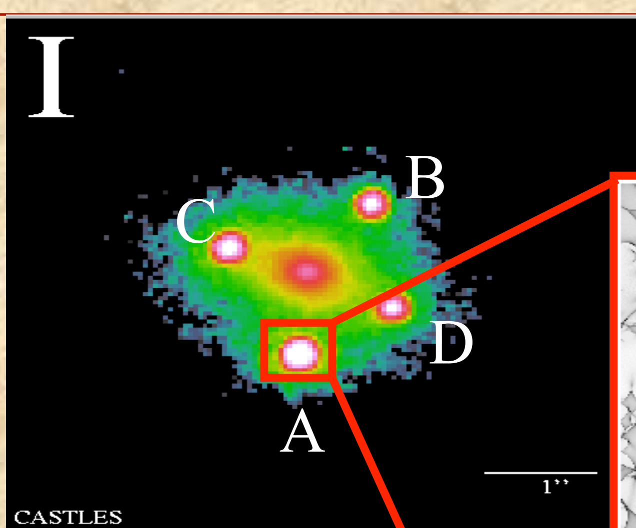
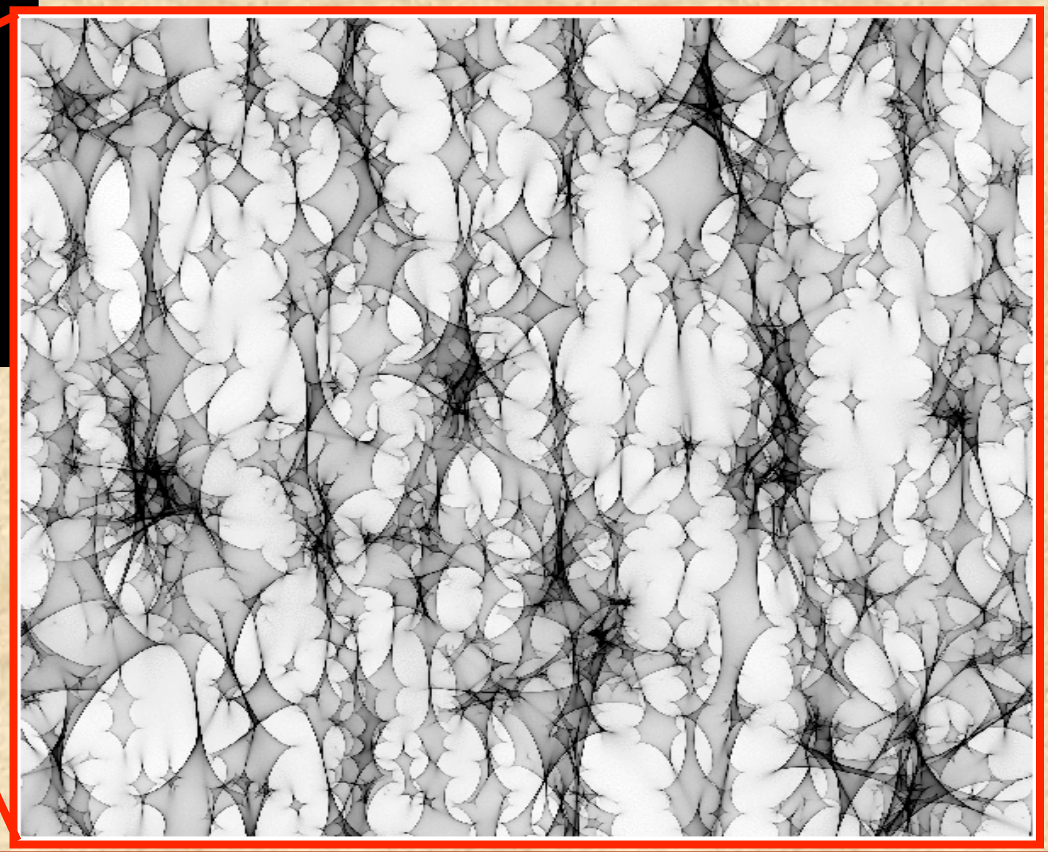


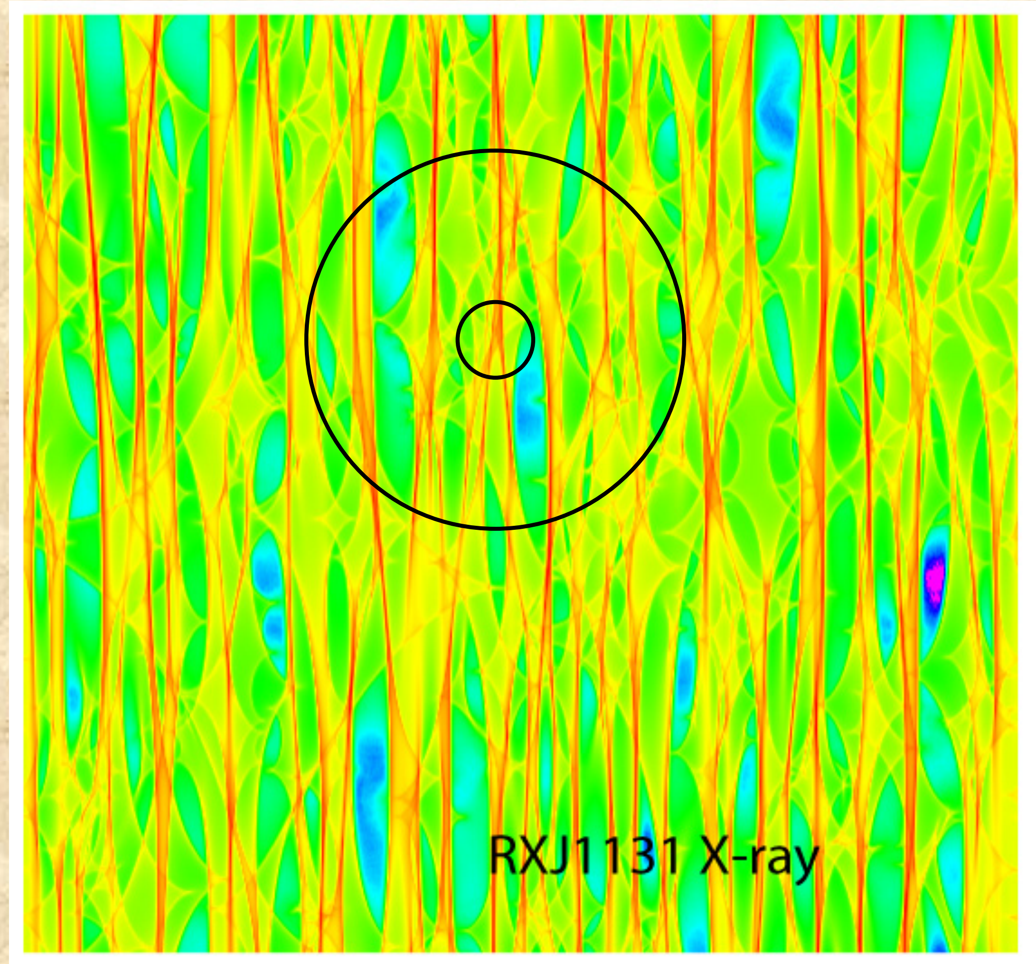
Quasar Microlensing (nano-arcsec resolution)

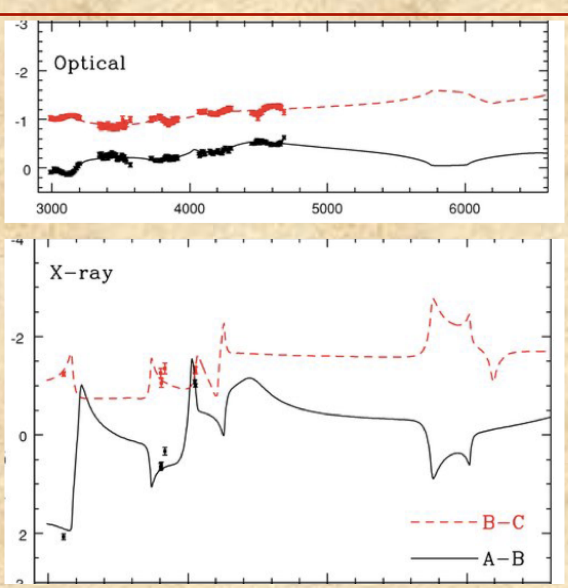




$$\alpha = \frac{4GM}{c^2 \xi}$$

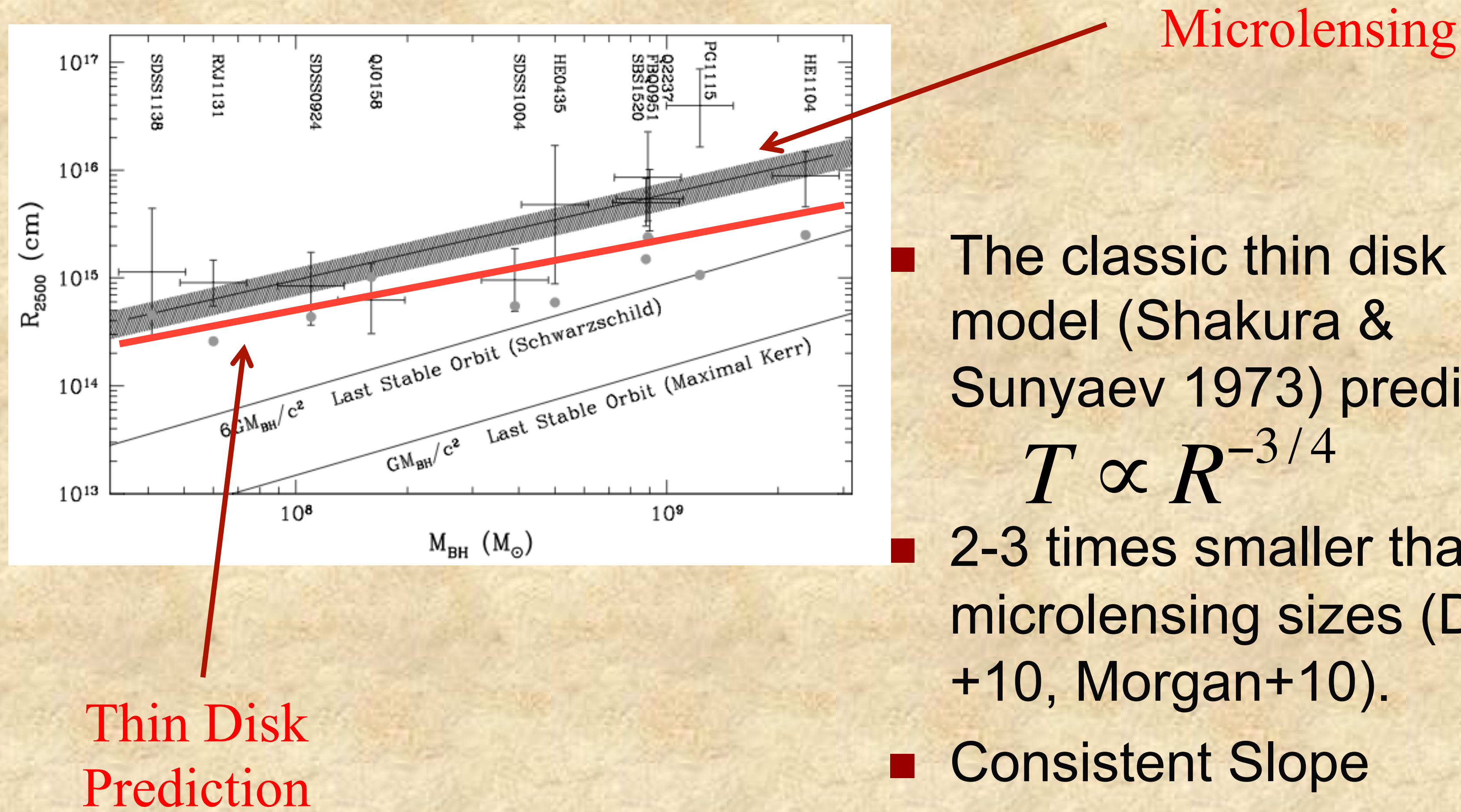
How to use microlensing to measure the source size? — Qualitative Approach





- **Larger sources** smooth the magnification pattern and have **smaller microlensing variability**.

Optical bands: Challenge Thin Disk Models

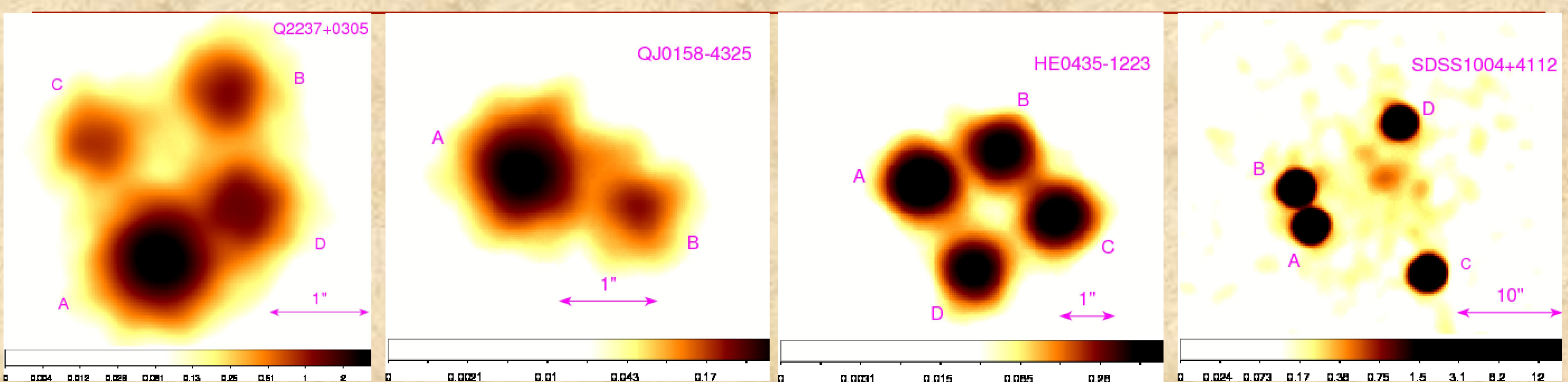


- The classic thin disk model (Shakura & Sunyaev 1973) predicts

$$T \propto R^{-3/4}$$

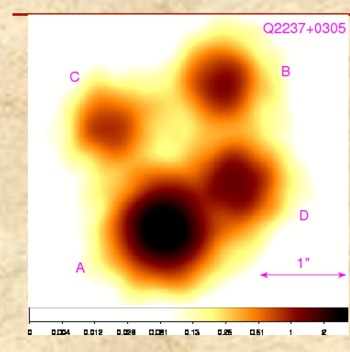
- 2-3 times smaller than microlensing sizes (Dai +10, Morgan+10).
- Consistent Slope

Chandra Monitoring of Gravitational Lenses

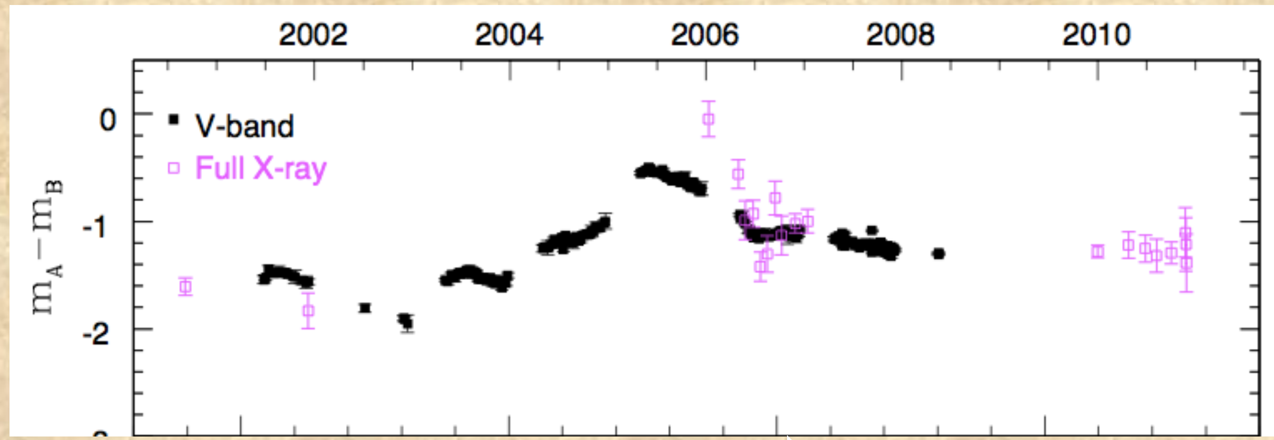


- Chandra resolves the lens images in X-rays
- ~20 lenses with total exp of ~3 Ms
- 7 lenses were intensely monitored in our Cycle 11 program ~600 ks.
- Cycle 14/15 large program (800 ks, 6 lenses)

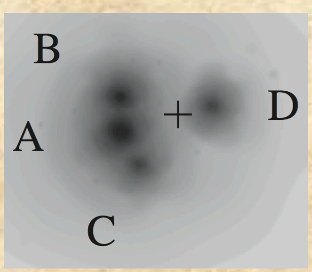
X-ray and Optical Microlensing Variability



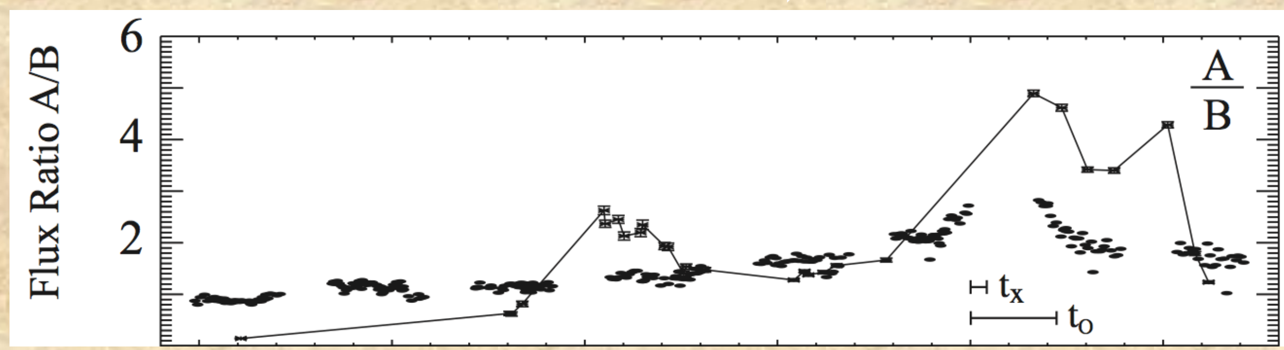
Q2237, Chen et al. (2011, 2012); Mosquera et al. (2013)



Time

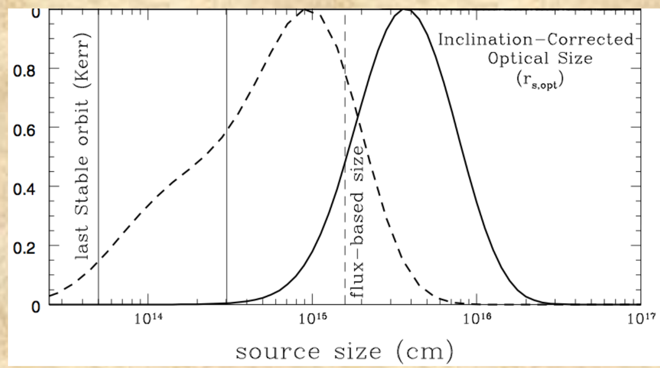


RXJ1131, Chartas et al. (2012)

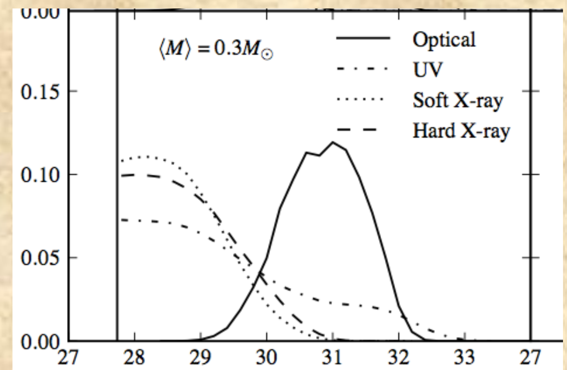


X-ray and Optical Emission Sizes

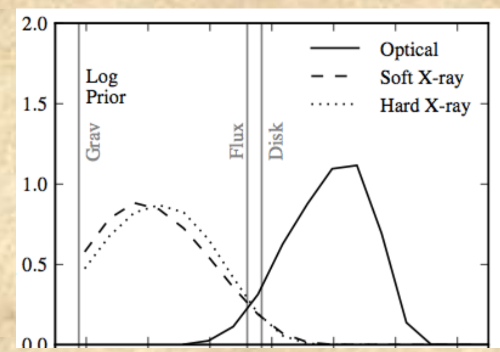
Probability



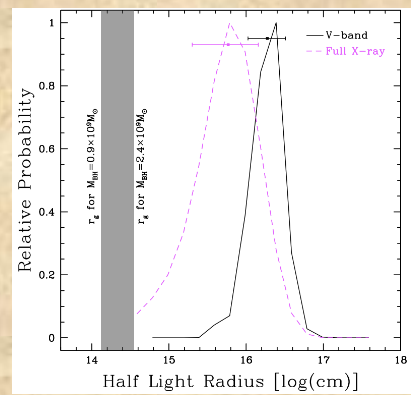
QJ0158, Morgan et al. (2012)



HE0435, Blackburne et al. (2011)



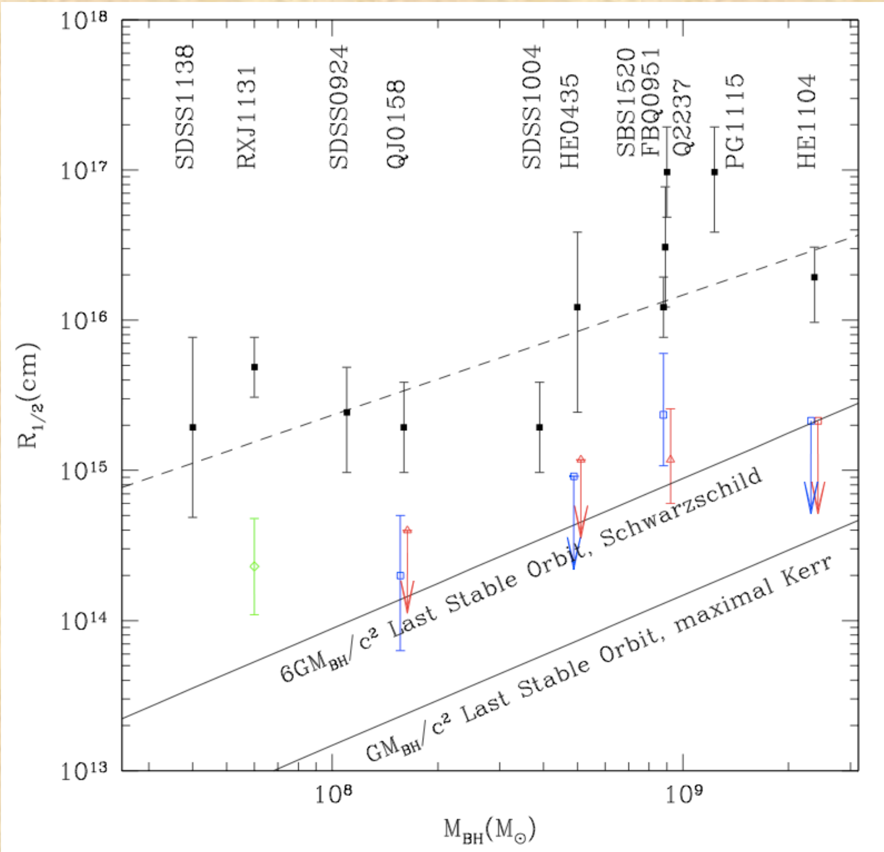
HE1104, Blackburne et al. (2013)

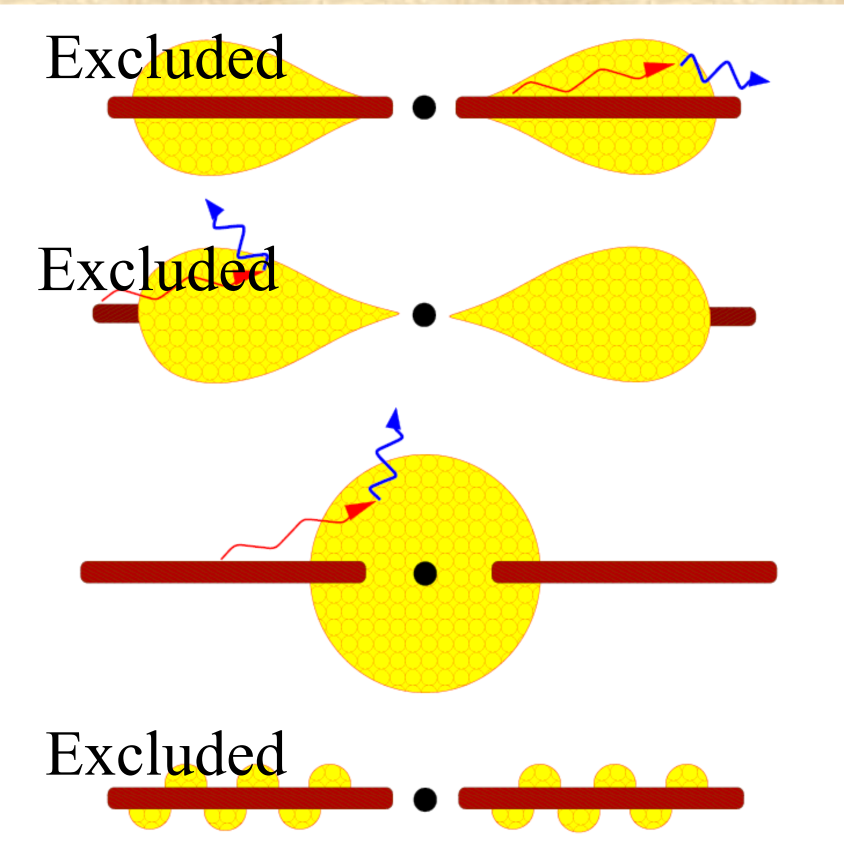


Q2237, Mosquera et al. (2013)

Size

X-ray (~10 Rg, smallest 6Rg) and Optical Emission Sizes

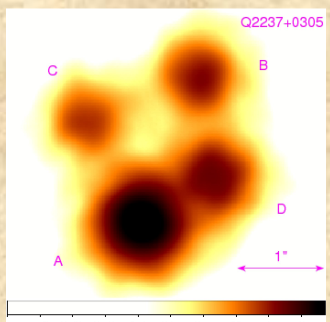


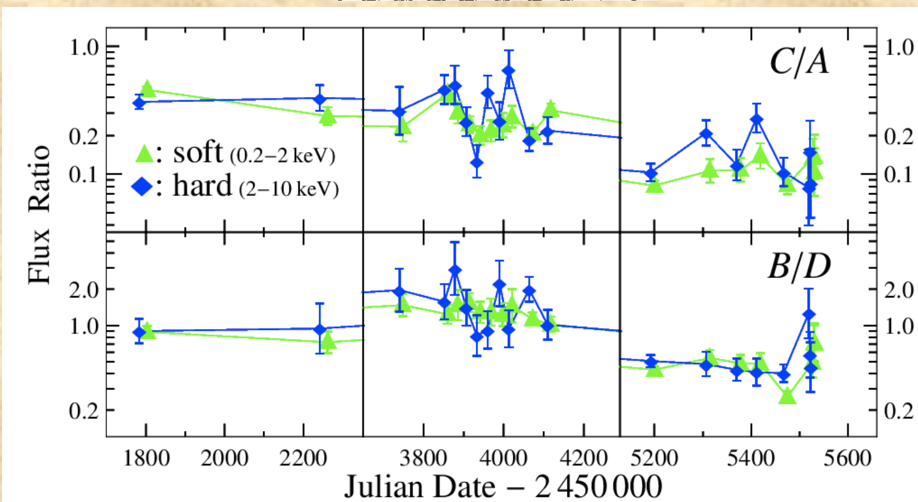


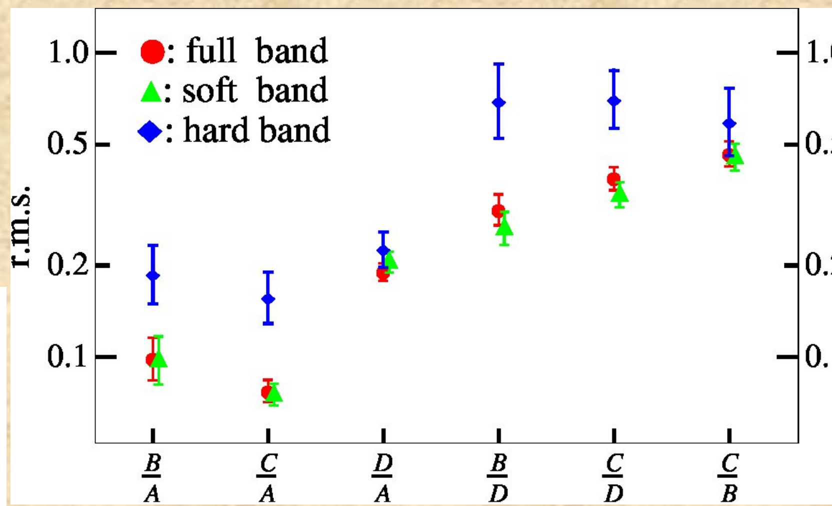
Mosquera et al. (2013)

Energy Dependent X-Ray Microlensing

- Q2237



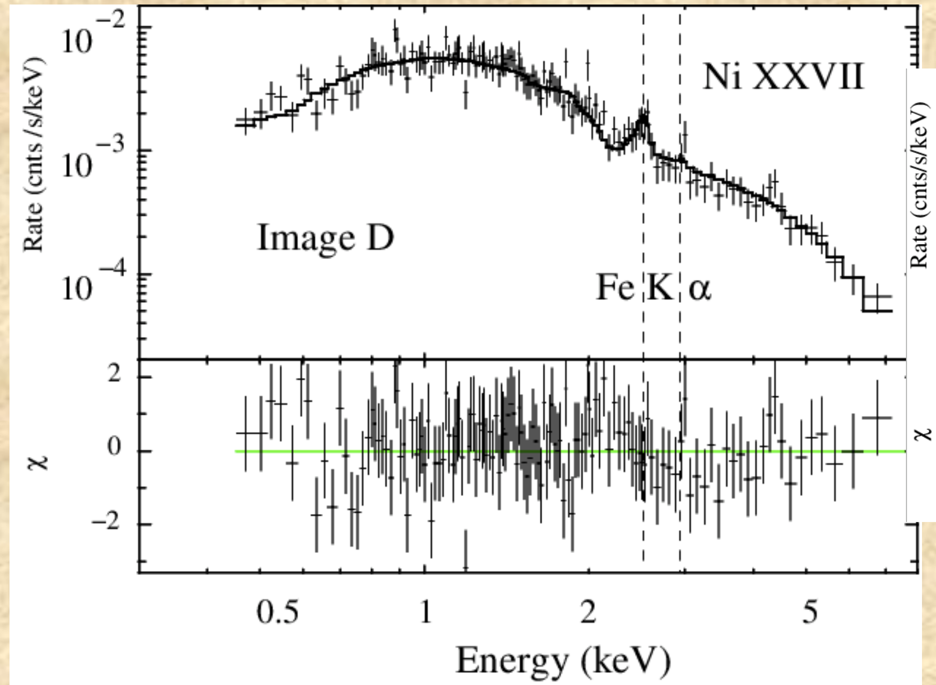


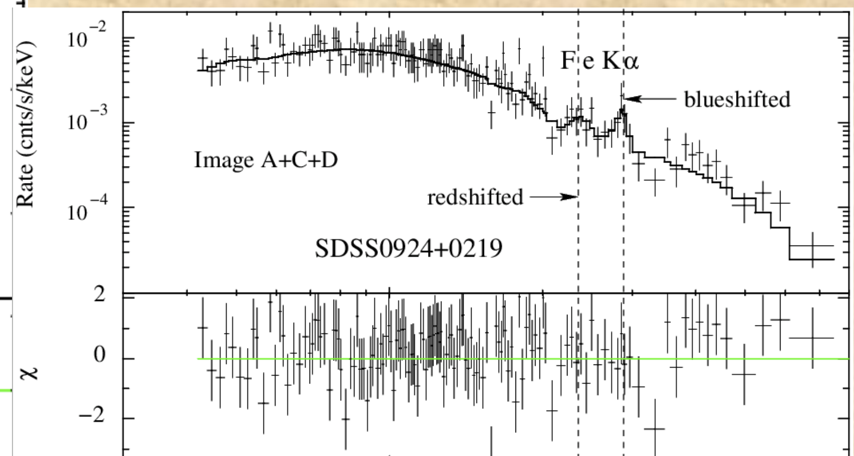


- Larger microlensing variability in hard band.
- Smaller hard source
- Temperature gradient in corona

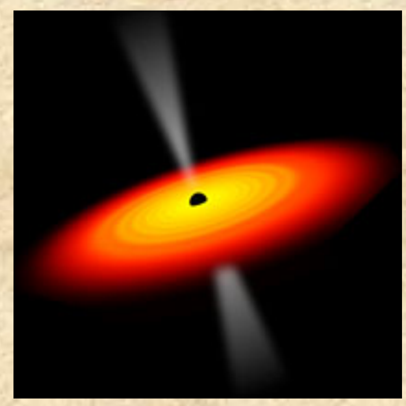
Chen et al. 2011, ApJL, 740, 34

Microlensing of Iron Lines (Chen et al. 2012a)

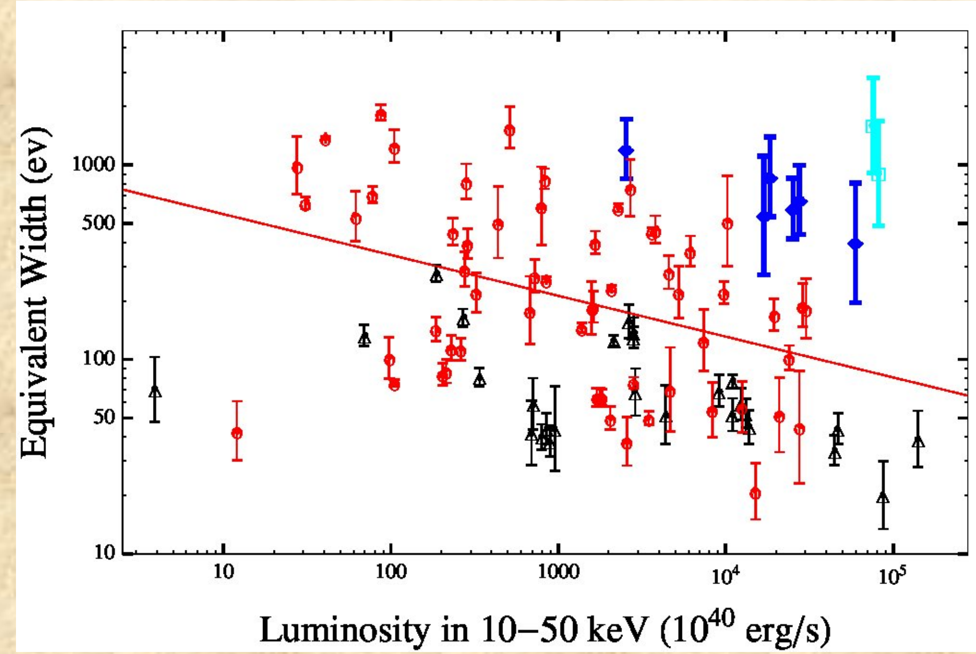




- Fe Lines are observed in almost all case.
- Sometime we see split of the line.



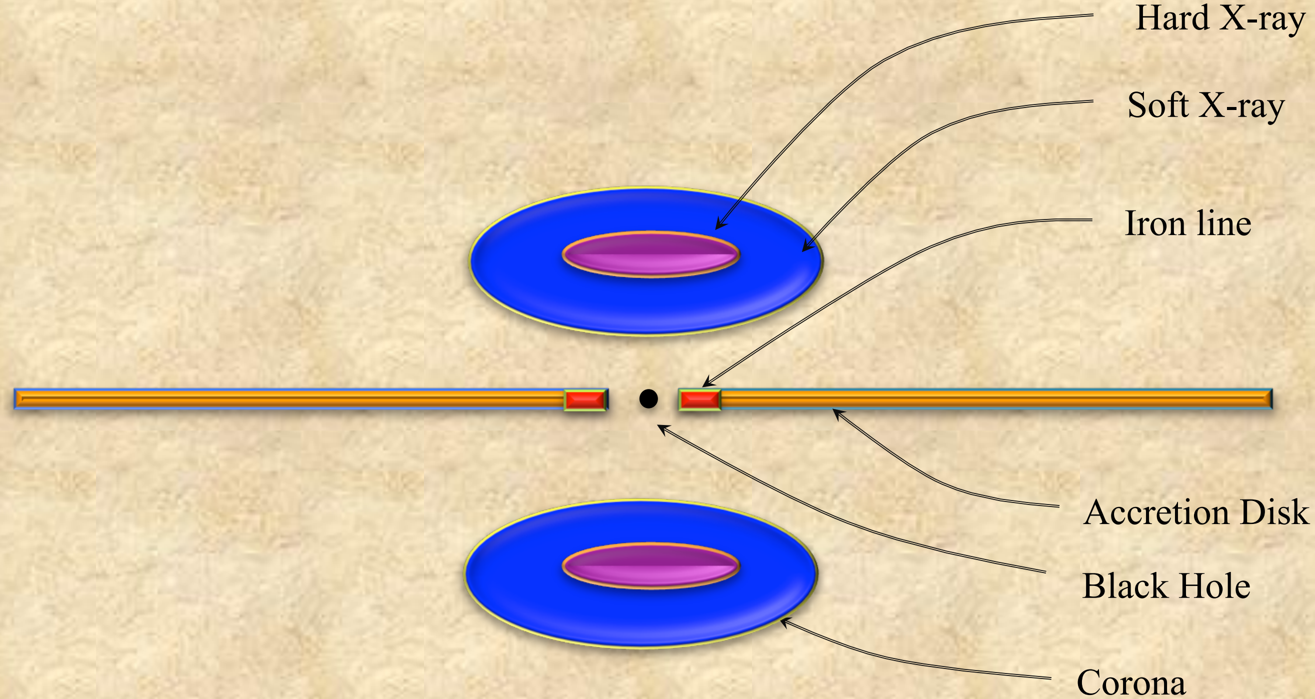
Microlensing of Iron Lines



Chen et al. (2012a)

- Iron line EWs in lensed quasars are larger than those of normal AGN of same luminosities.
- Iron line size is even smaller than X-ray continuum.

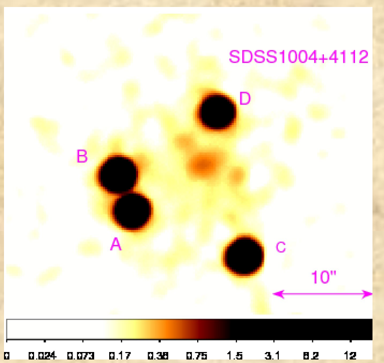
Model of AGN Accretion Disk



- Cycle 14/15 800 ks program.
- Calibrating all data from Cycle 1 to 15.

Athena's Perspectives: N of Suitable Lenses

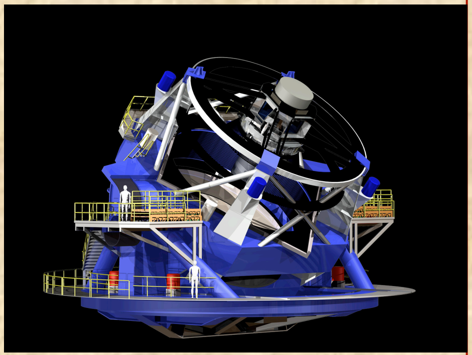
- Athena+: 1.5 -- 2.5 m^2 effective area at 1 keV, 5'' angular resolution



Chen+12

10,000 Quasar lenses detected by DES, LSST WFIRST

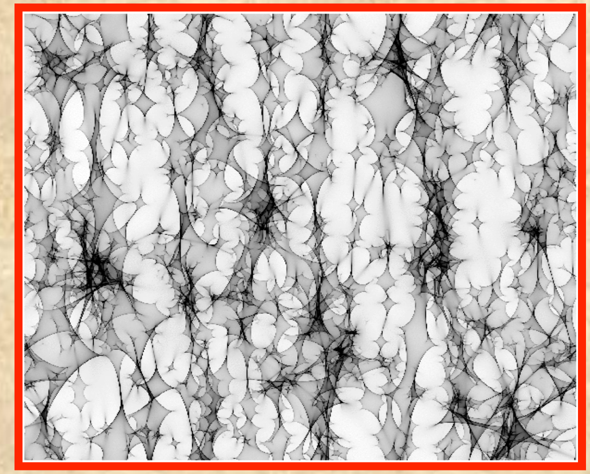
~200 lenses > 5'' image separations

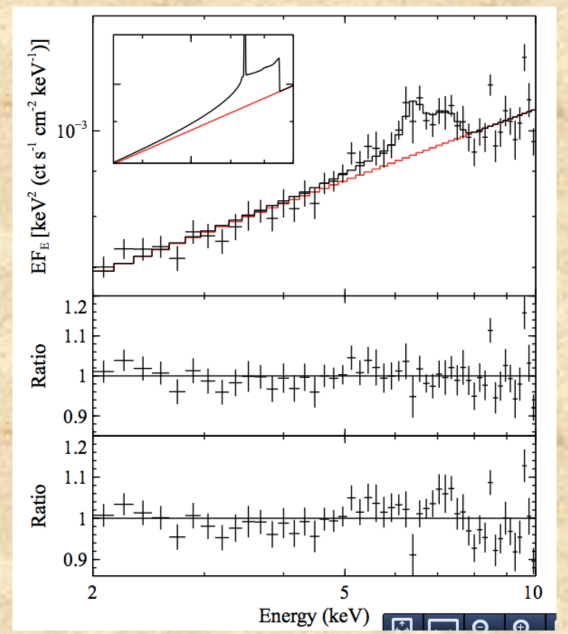


- R_X, R_hard, R_soft, R_Ka for a large sample of quasars spanning M and m_dot

Athena: Event Horizon (approaching)

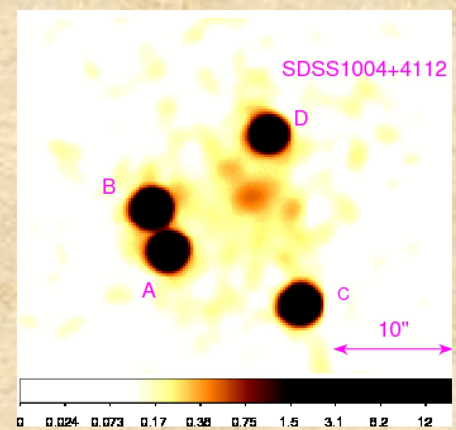
- No theoretical limit on the smallest size that microlensing can measure.
- Red wing of FeKa line



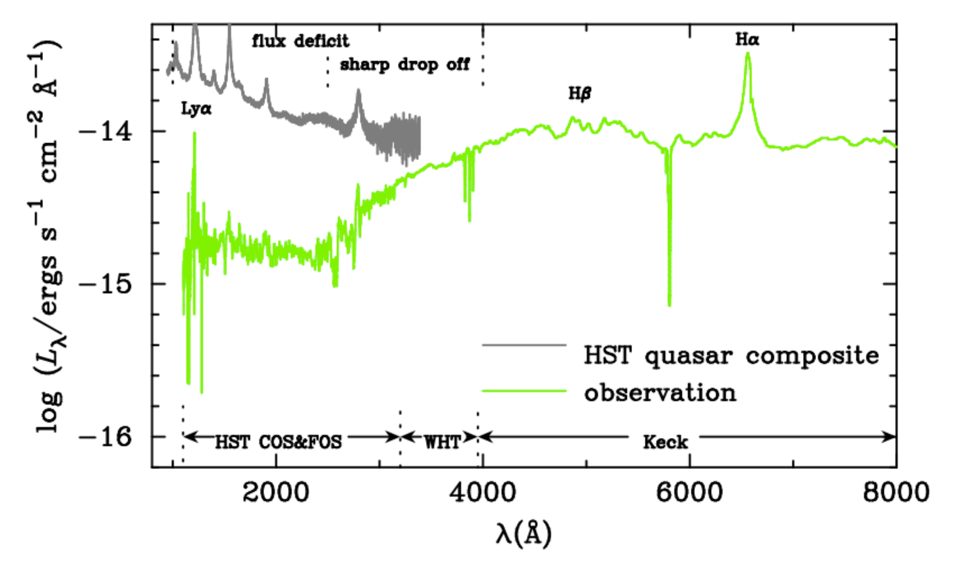


1.7Ms Chandra (Walton+15)

- 2Ms Athena: 25 monitoring obs of a single lens with this S/N.
- 4-5 keV FeKa size.
- 5 objects for 10Ms



Probable Binary Black Hole in Mrk231 (Yan+15)



Yan, Lu, Dai, Yu 2015, ApJ, 809, 117
arXiv: 1508.06292