# Microlensing Constraints on Quasar X-ray Emission Regions

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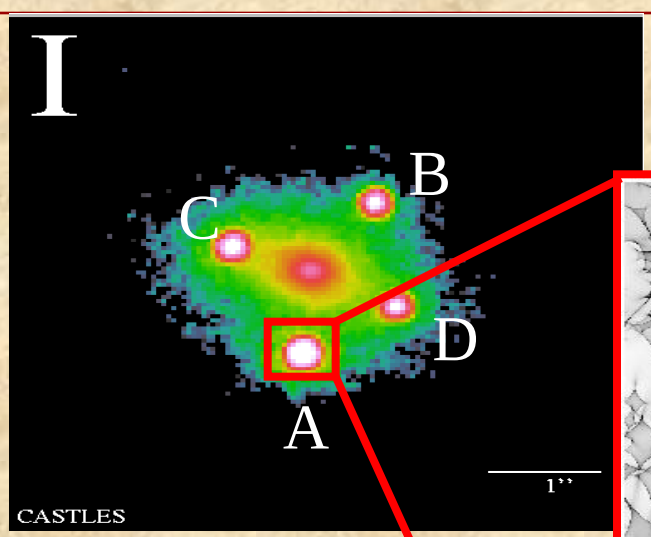
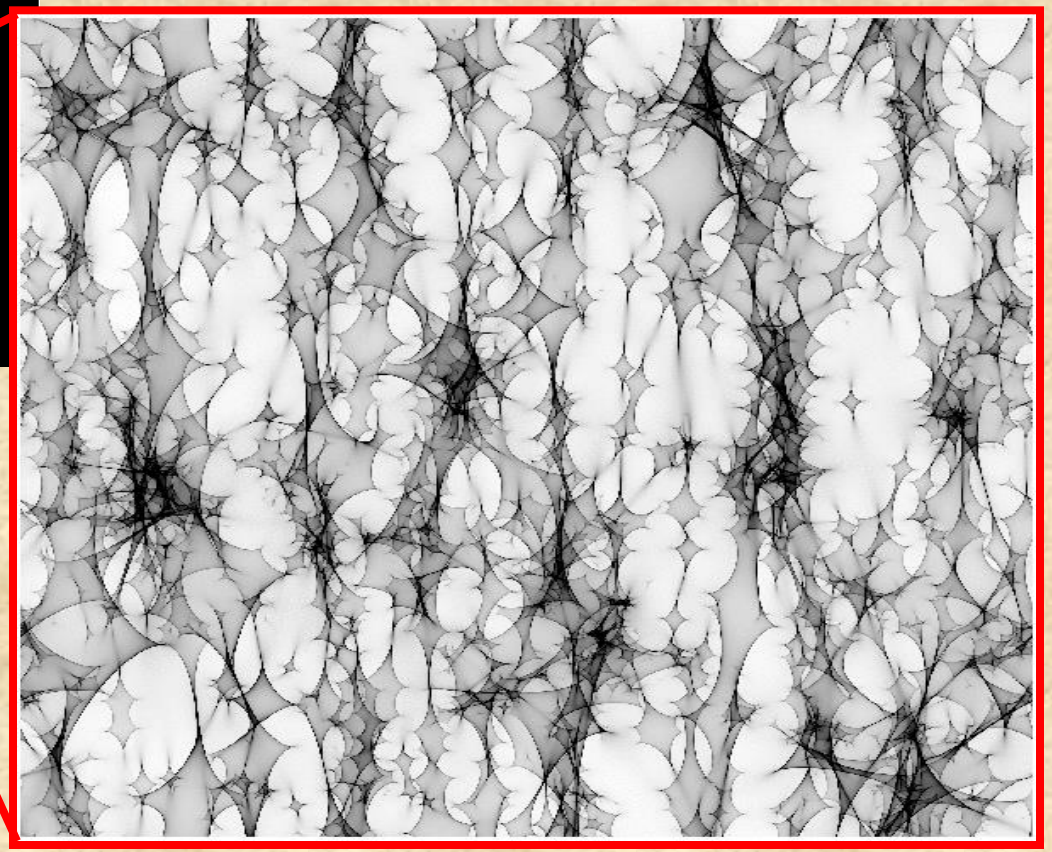
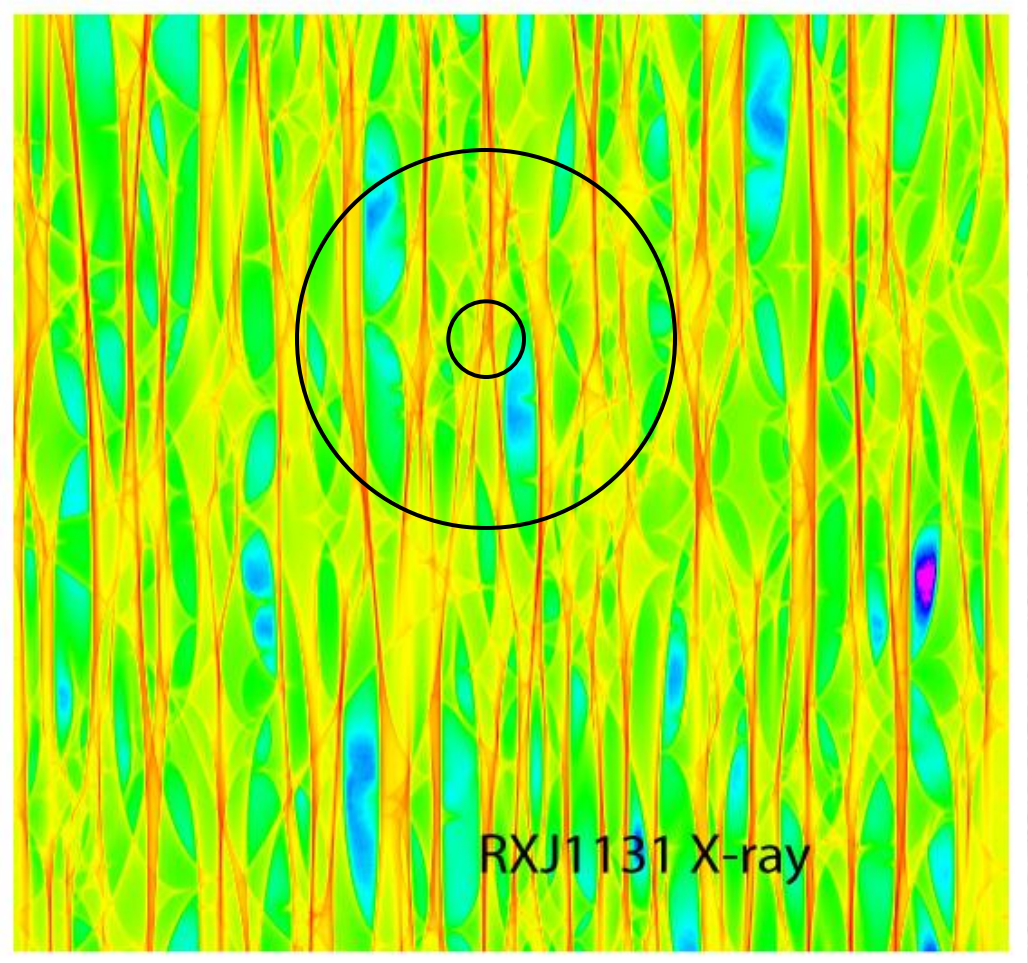
# Quasar Microlensing

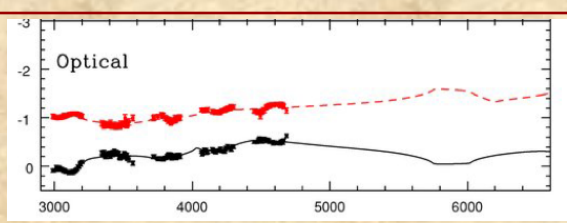


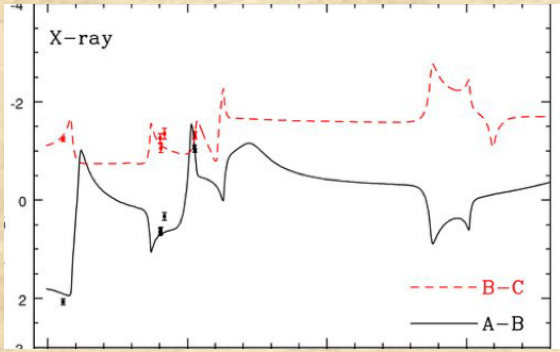



$$\alpha = \frac{4GM}{c^2 \xi}$$

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

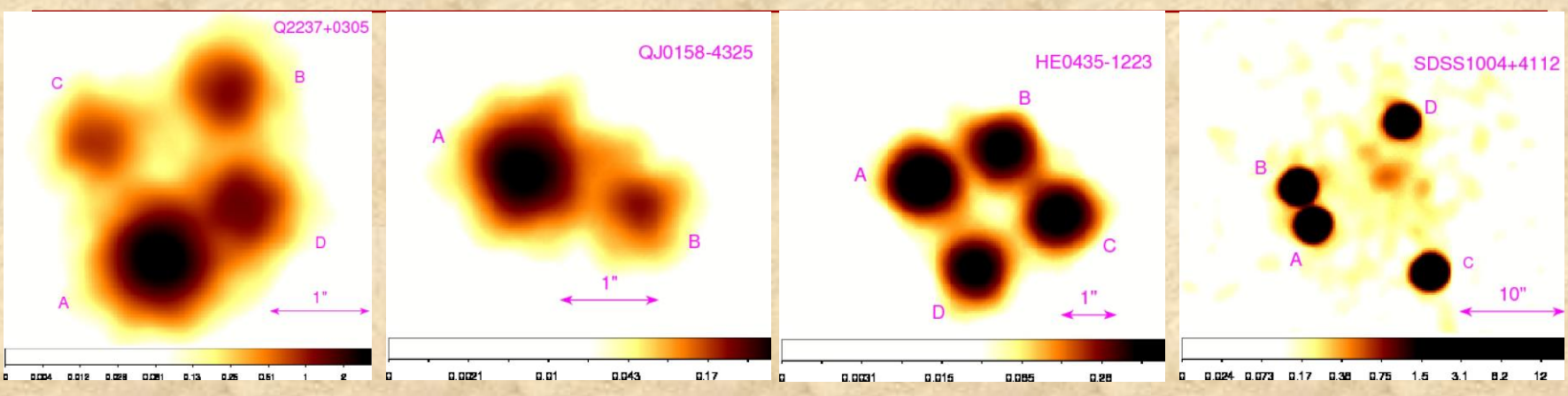


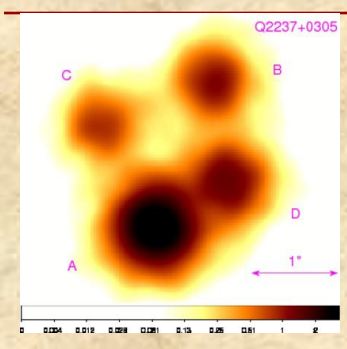

- **Larger sources** smooth the magnification pattern and have **smaller microlensing variability**.

# Chandra Monitoring of Gravitational Lenses

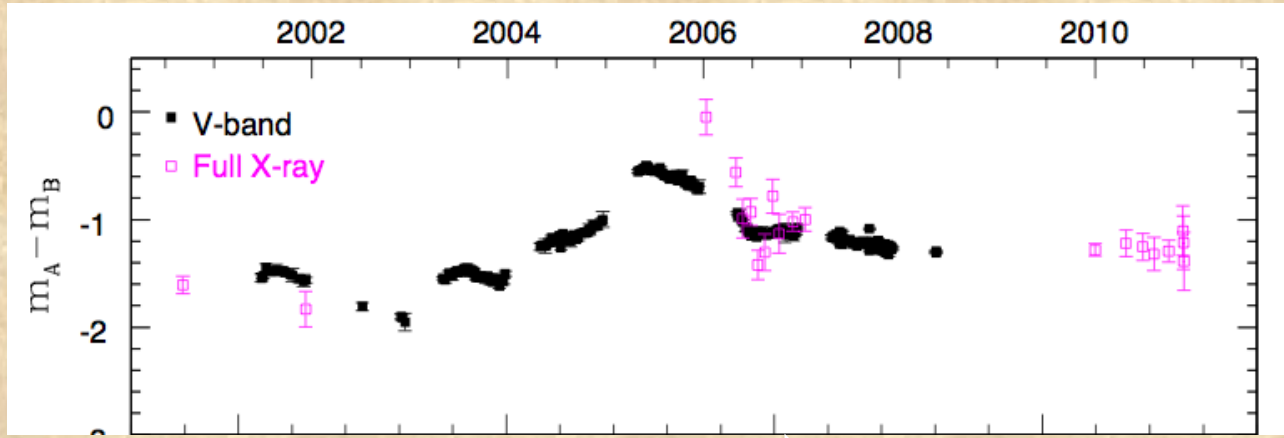



- Chandra resolves the lens images in X-rays
- ~20 lenses with total exp of ~1.5 Ms
- 7 lenses are intensely monitored in our Cycle 11 program ~700 ks.
- Ongoing Cycle 14/15 large program (800 ks, 6 lenses)

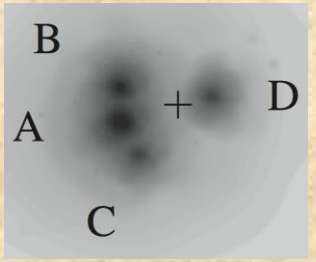
# X-ray and Optical Microlensing Variability



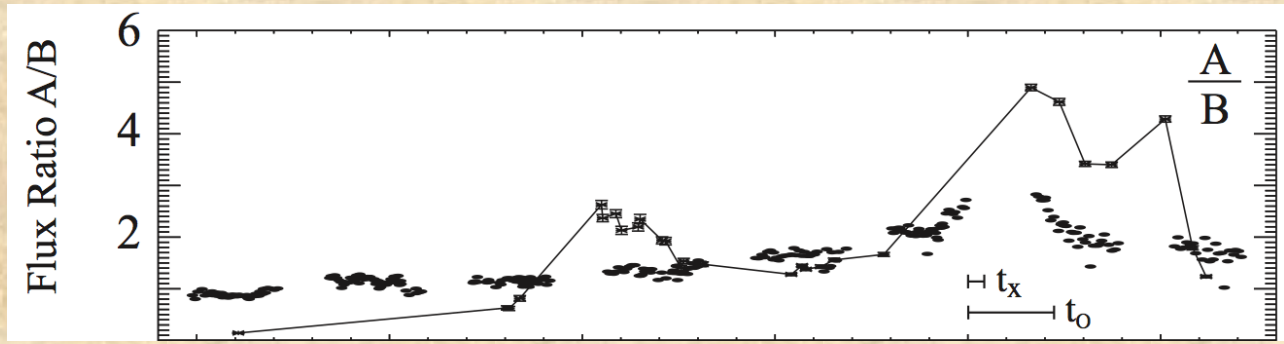

Q2237, Chen et al. (2011, 2012); Mosquera et al. (2013)



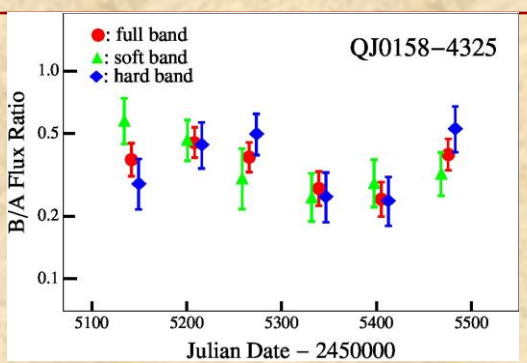

Time

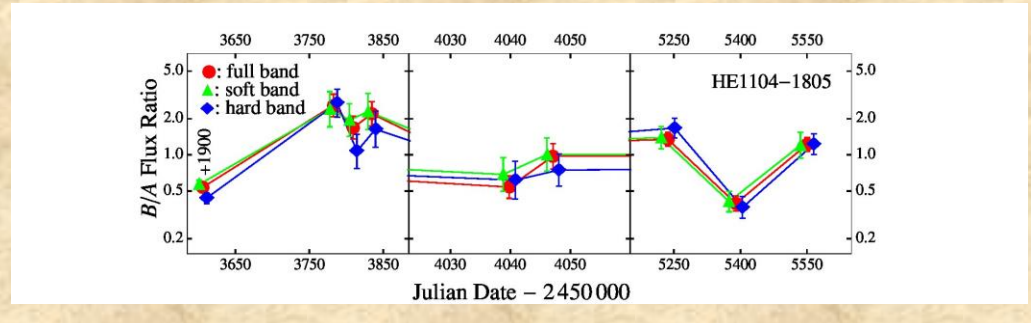


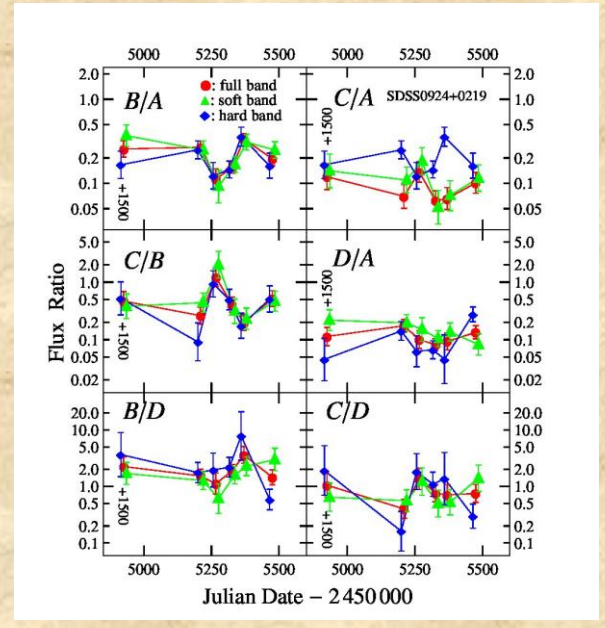

RXJ1131, Chartas et al. (2012)

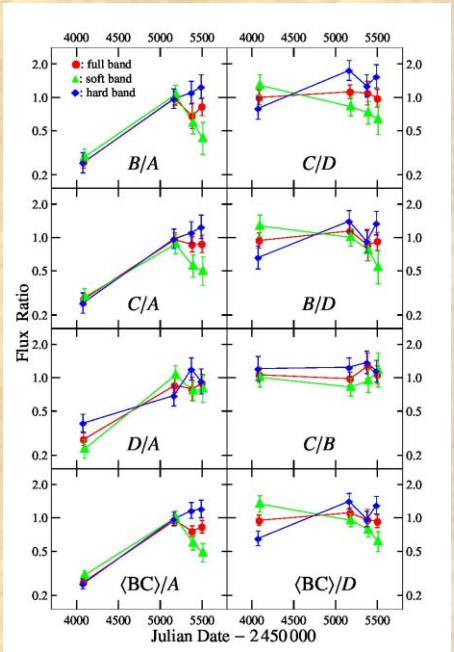


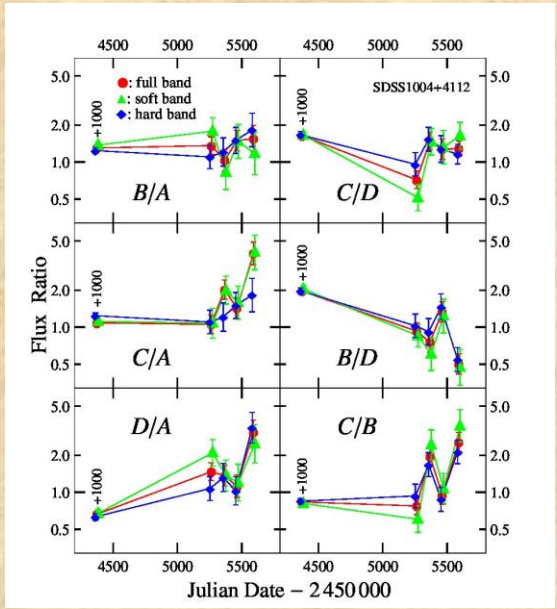
# X-ray Microlensing Light Curves (Chen et al. 2012)



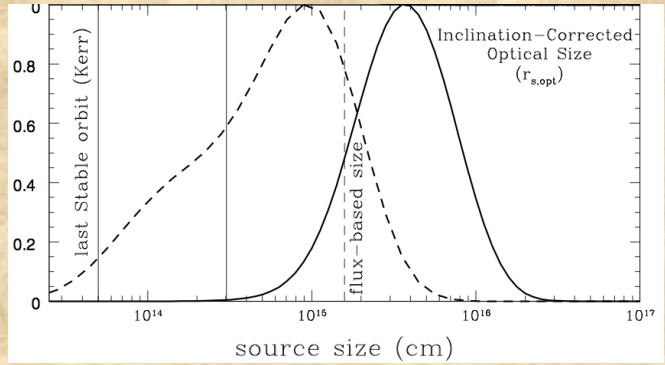



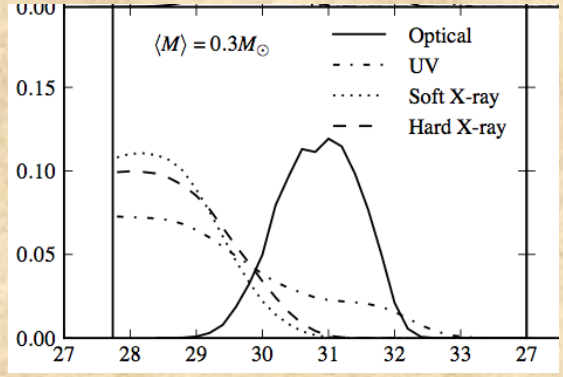



# X-ray and Optical Emission Sizes

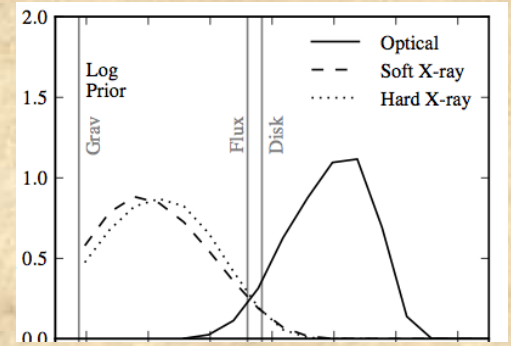
Probability



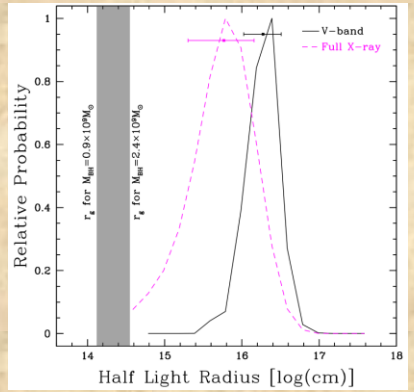

QJ0158, Morgan et al. (2012)




HE0435, Blackburne et al. (2011)



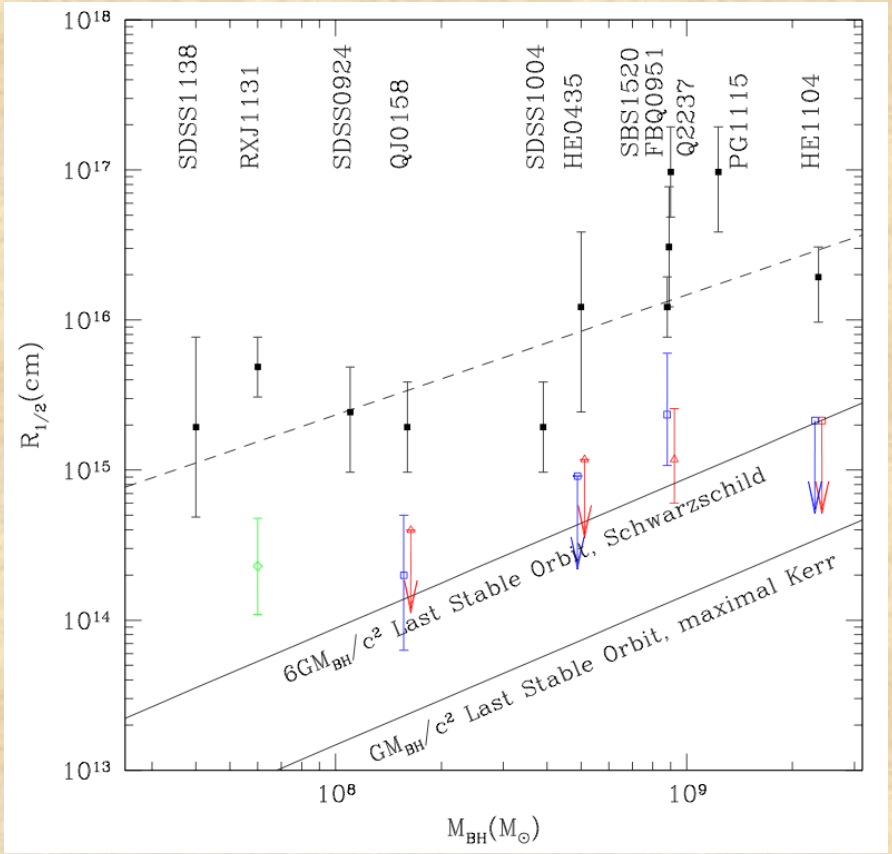

HE1104, Blackburne et al. (2013)

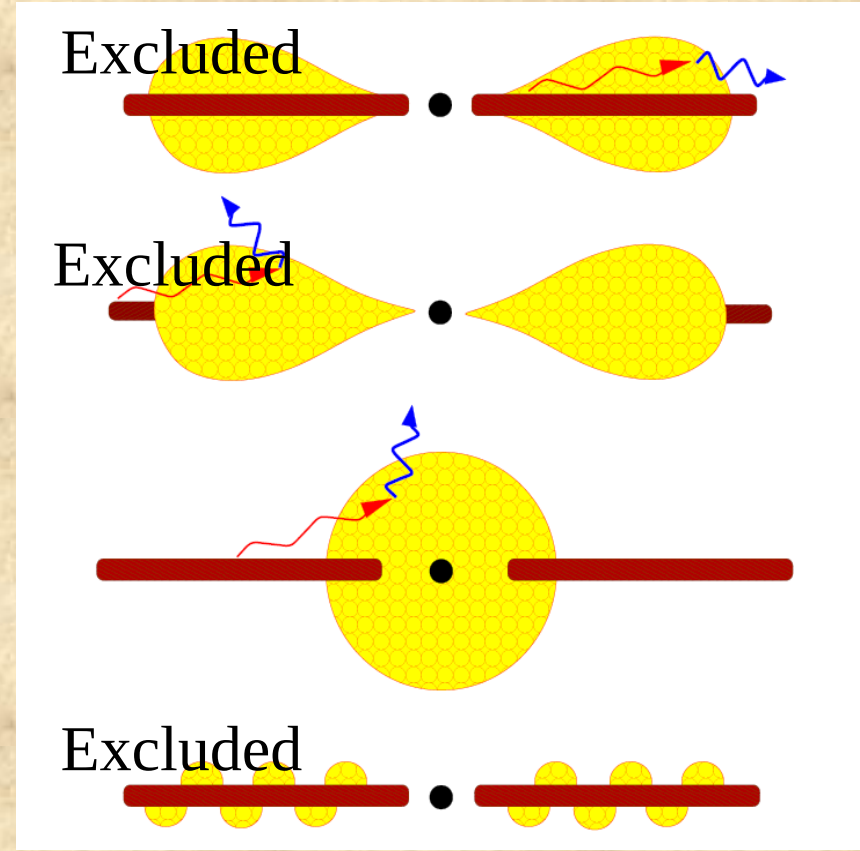



Q2237, Mosquera et al. (2013)

Size

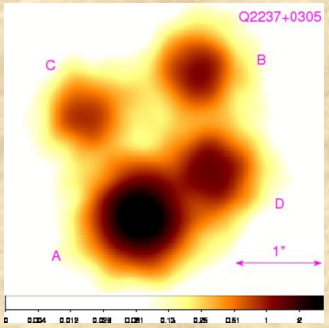
# X-ray and Optical Emission Sizes

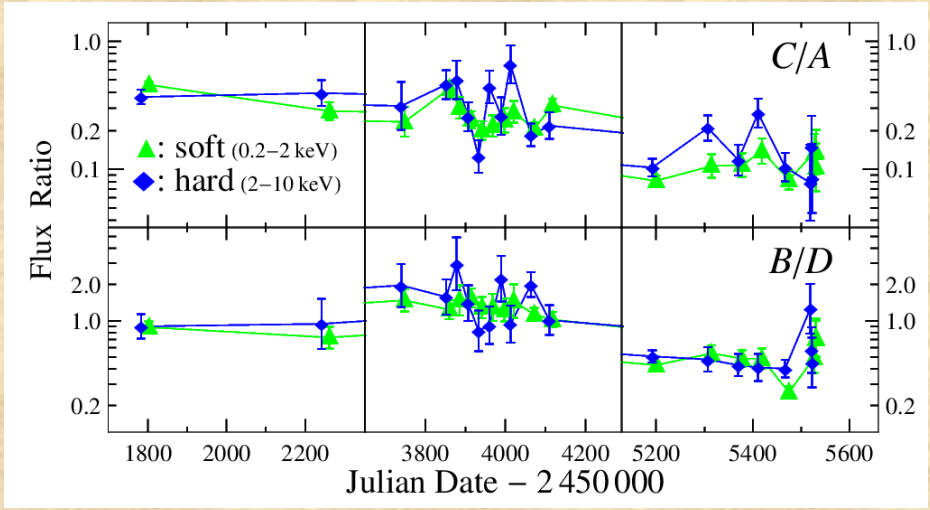


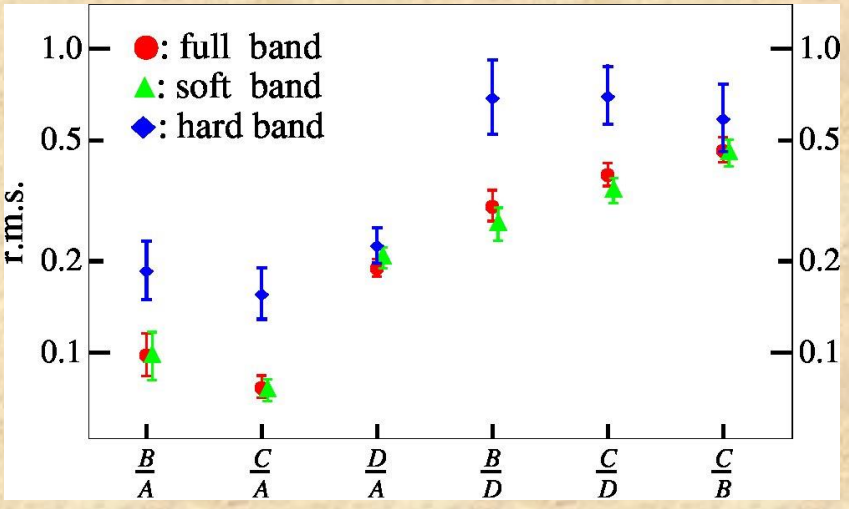



# Energy Dependent X-Ray Microlensing

- Q2237



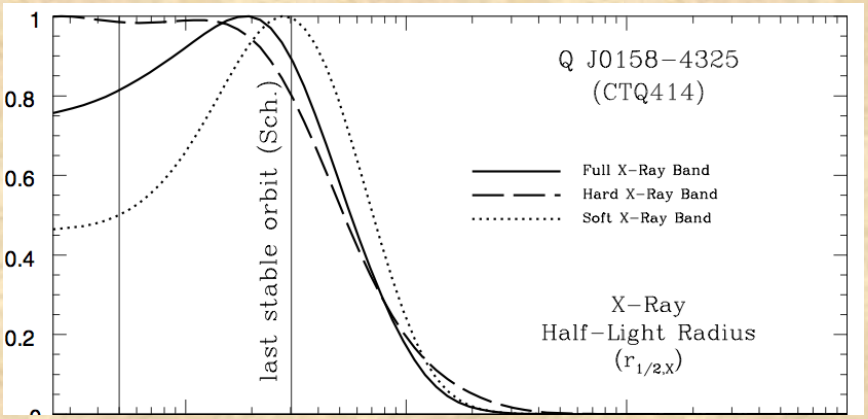



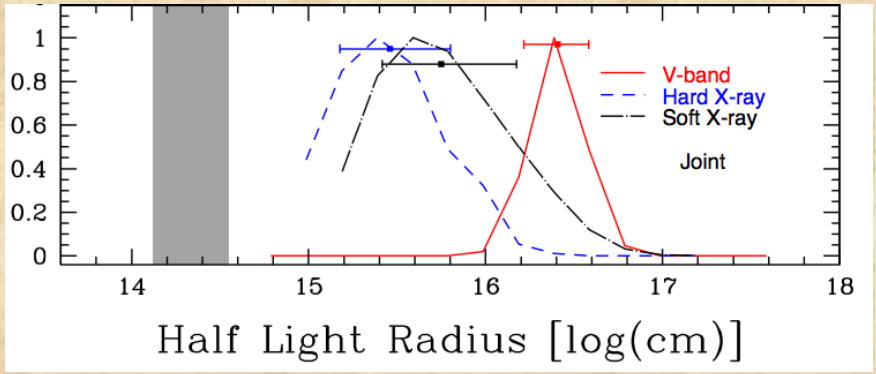

- Larger microlensing variability in hard band.
- Smaller hard source
- Temperature gradient in corona

Chen et al. 2011, ApJL, 740, 34

# Energy Dependent X-ray Microlensing



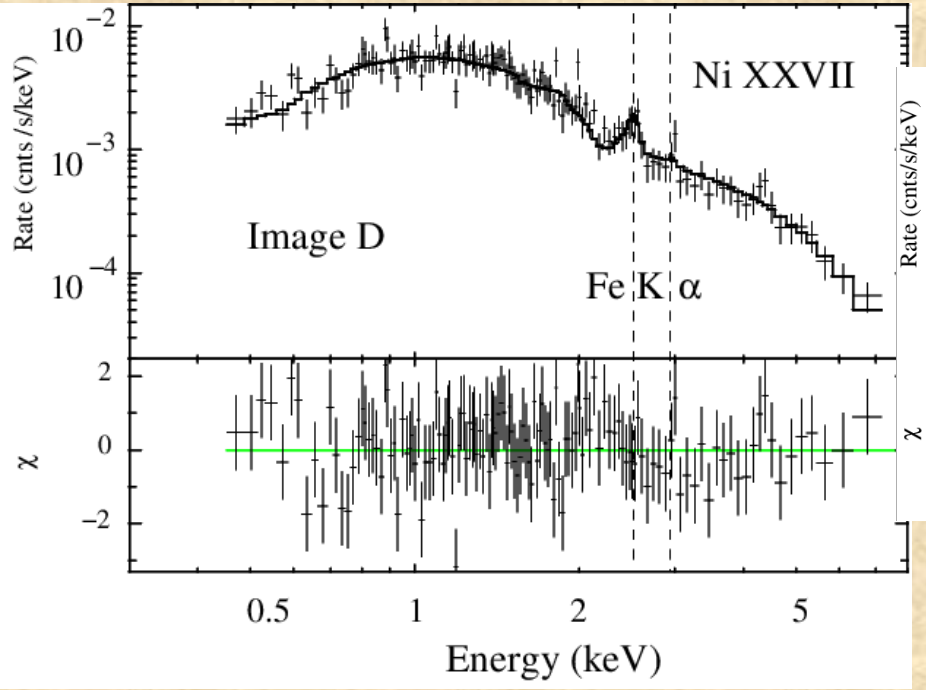

QJ0158, Morgan et al. (2012)

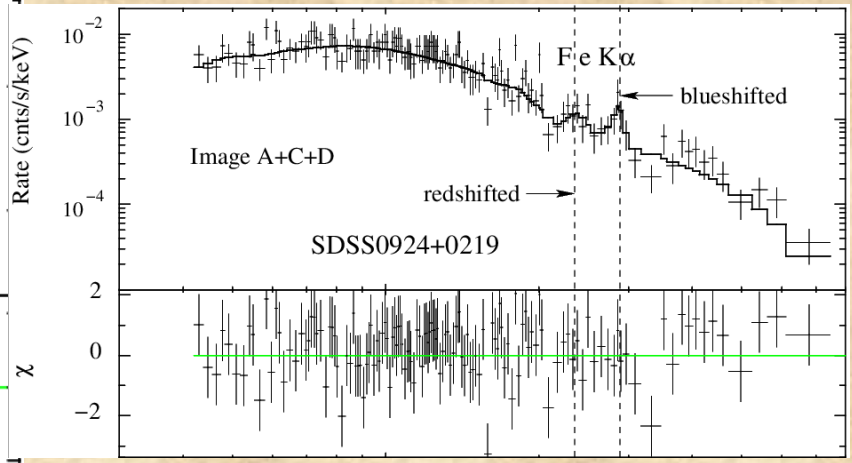


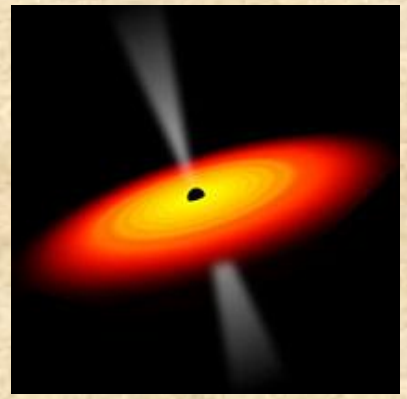

Q2237, Mosquera et al. (2013)

- Hard X-ray Smaller in 2 cases (QJ0158, Q2237).
- Consistent in 2 cases (could due to S/N)
- Hard X-ray larger in one case (RXJ1131).

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

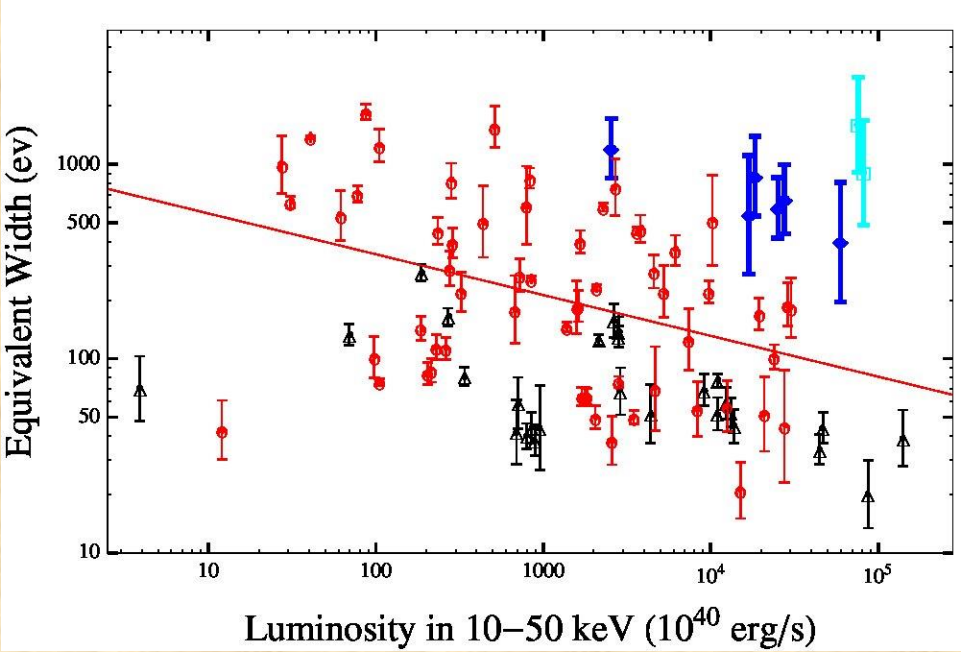


- Fe Lines are observed in almost all case.
- Sometime we see split of the line.

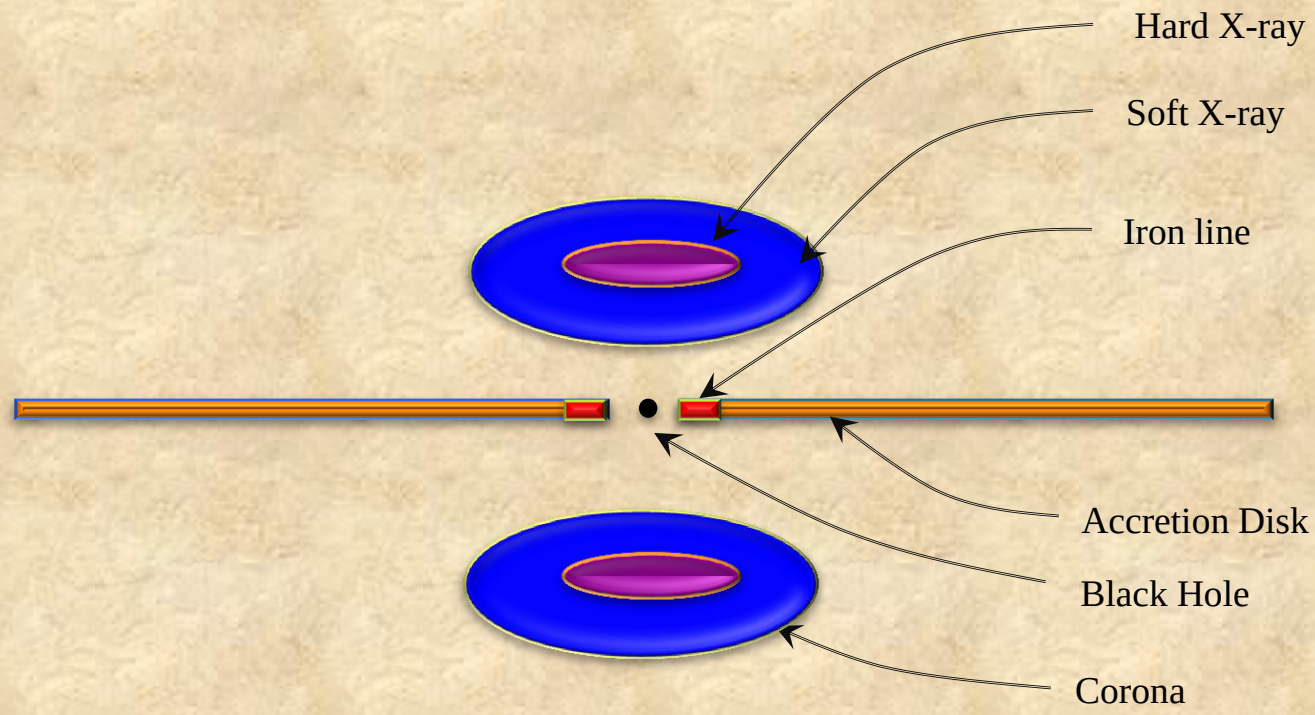
# Microlensing of Iron Lines




Chen et al. (2012a)

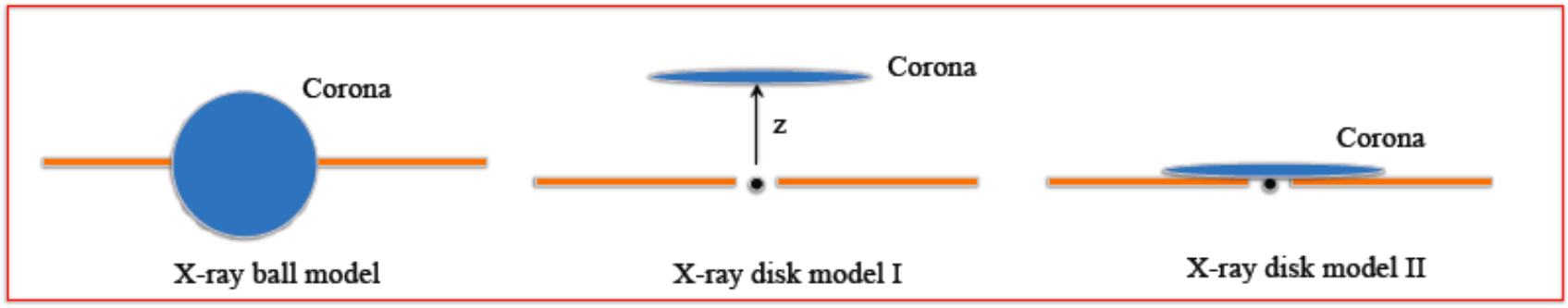
- Iron line EWs in lensed quasars are larger than those of normal AGN of same luminosities.
- Iron line size is even smaller than X-ray continuum.

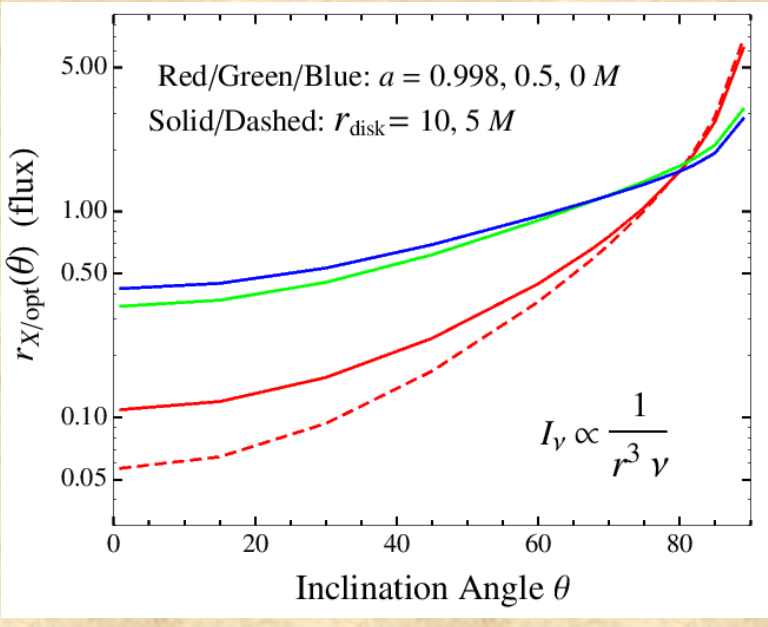
# Model of AGN Accretion Disk




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

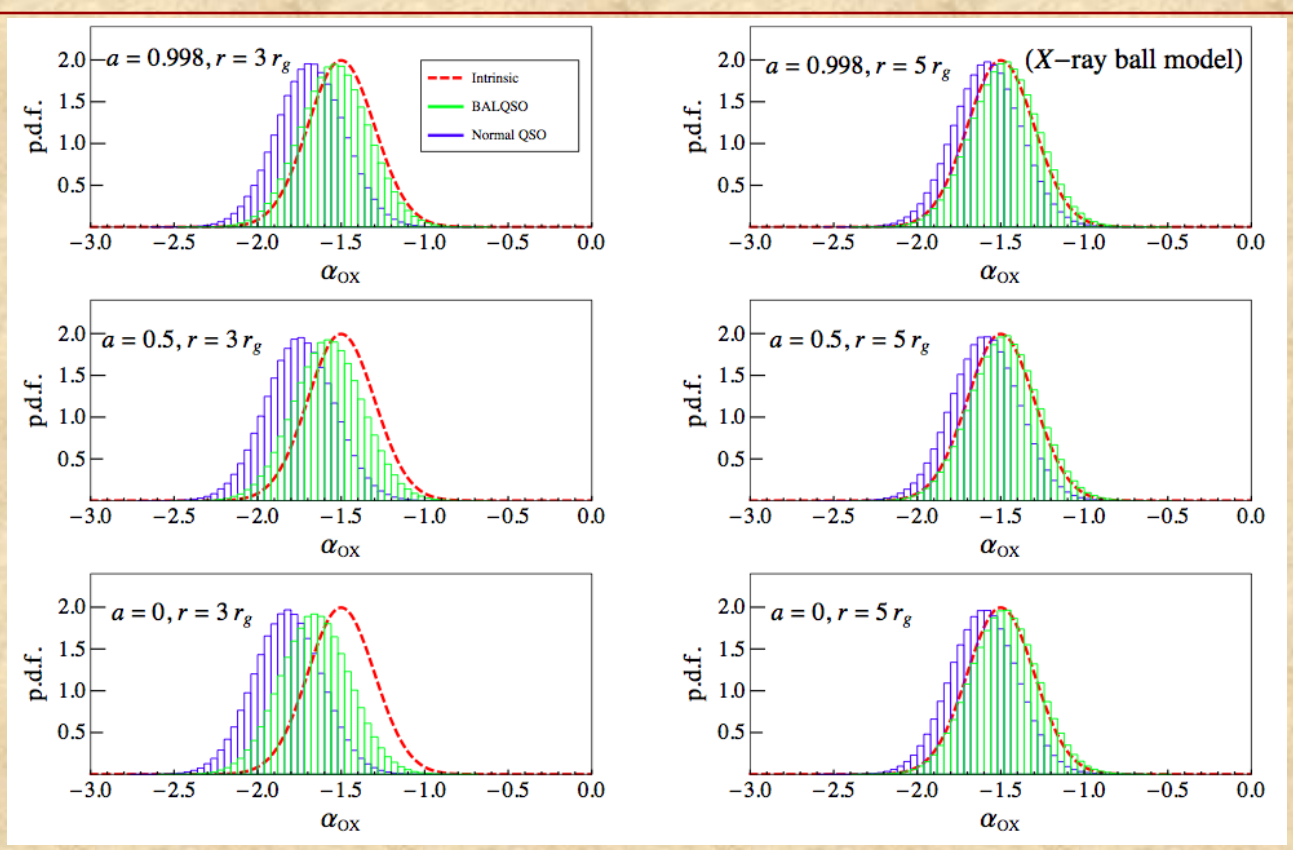
# X-ray Emission Under Strong Gravity



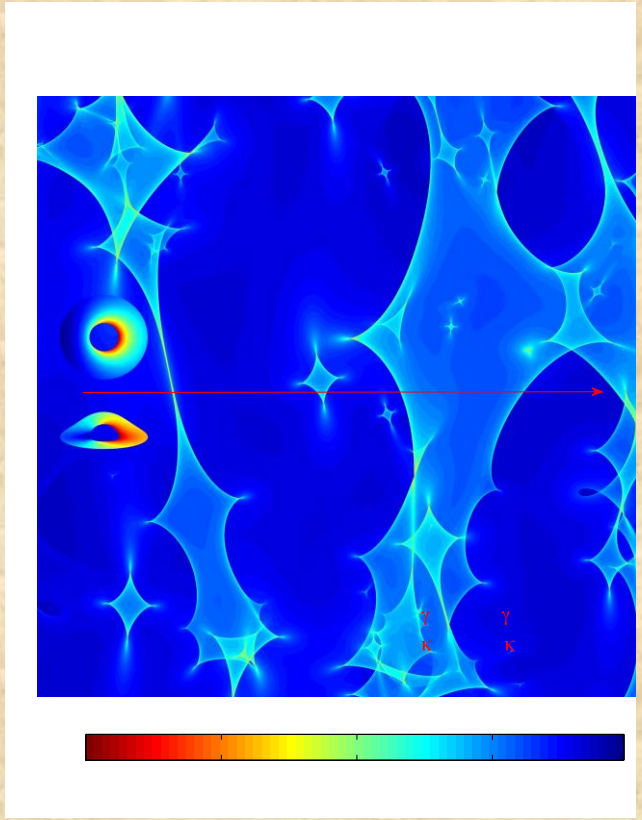

- Chen et al. 2013, ApJ, 762, 122.
- Poster 14x

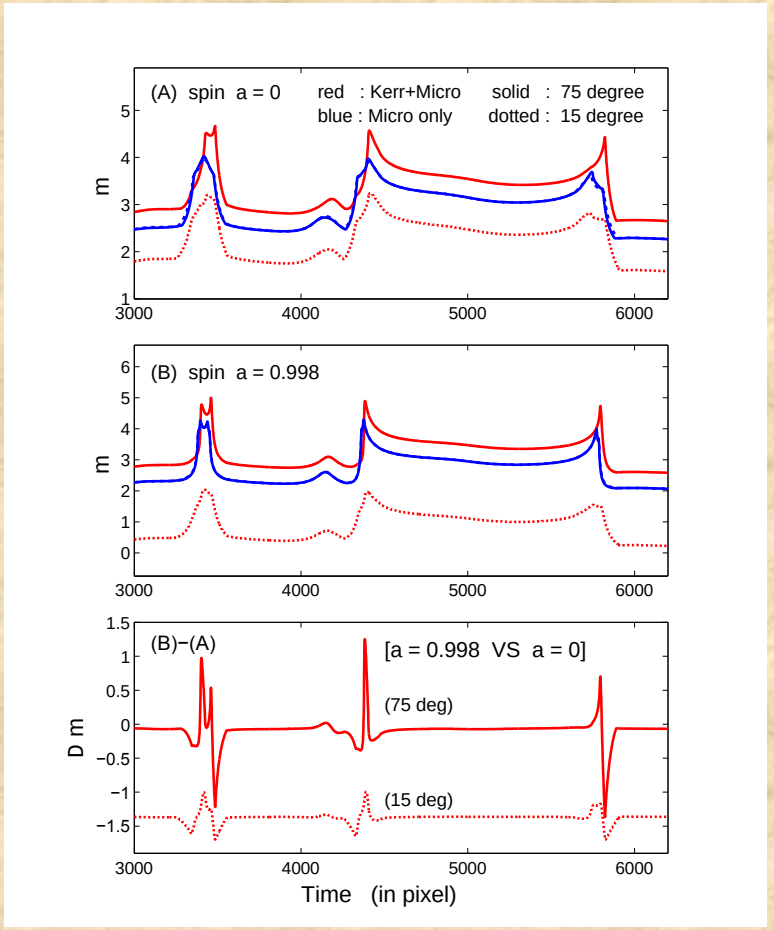
# Testing Unification Models




- Predicted aox distribution between BALs and non-BALs

# Potential New Spin Measurement Technique





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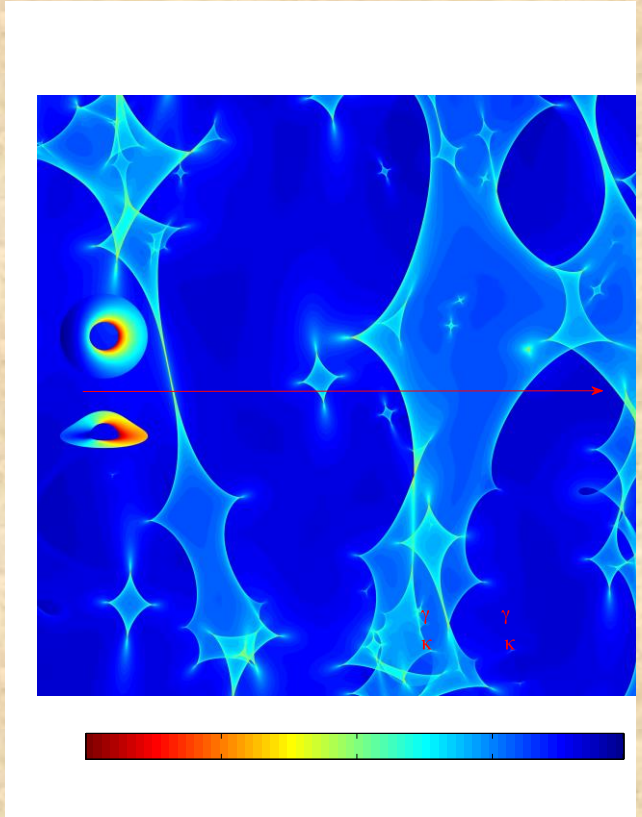

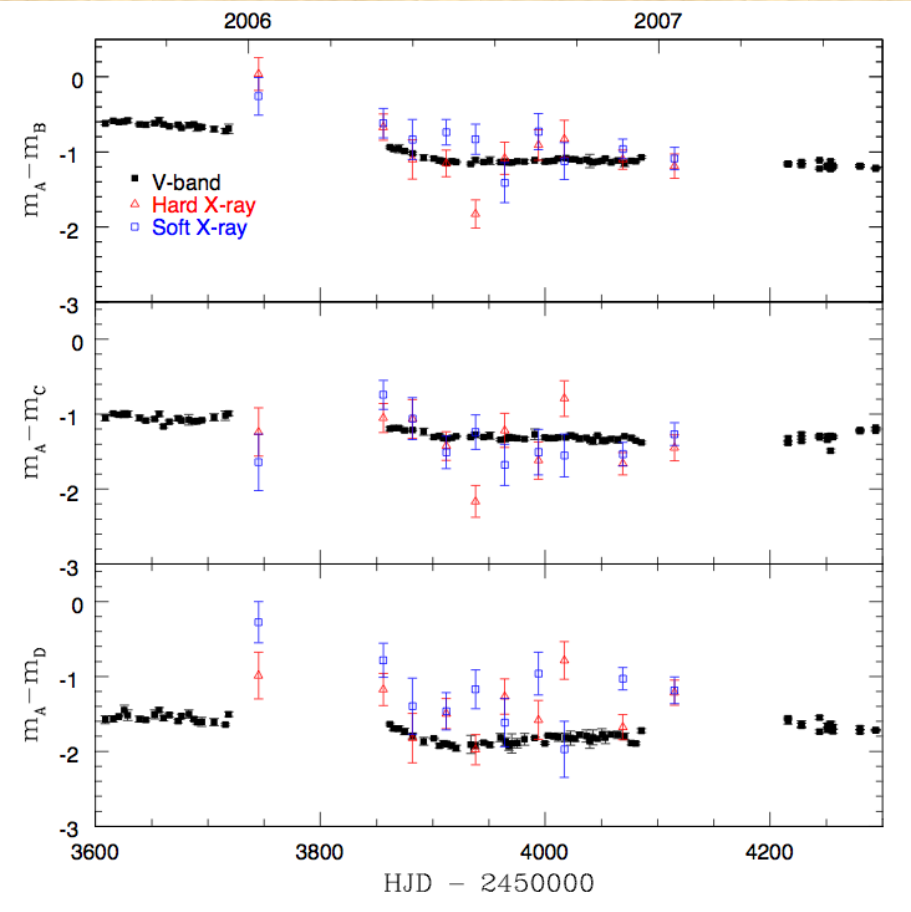

# Quasar Microlensing after Chandra Era

- Athena+: 2--2.5 $m^2$ effective area at 1 keV, 5--3'' angular resolution
- 10,000 Quasar-Galaxy lenses detected by DES, LSST, WFIRST
  - We will apply the technique to the large separation lens like SDSS1004.