Energy spectra of X-ray quasi-periodic oscillations in the Lense-Thirring precession model

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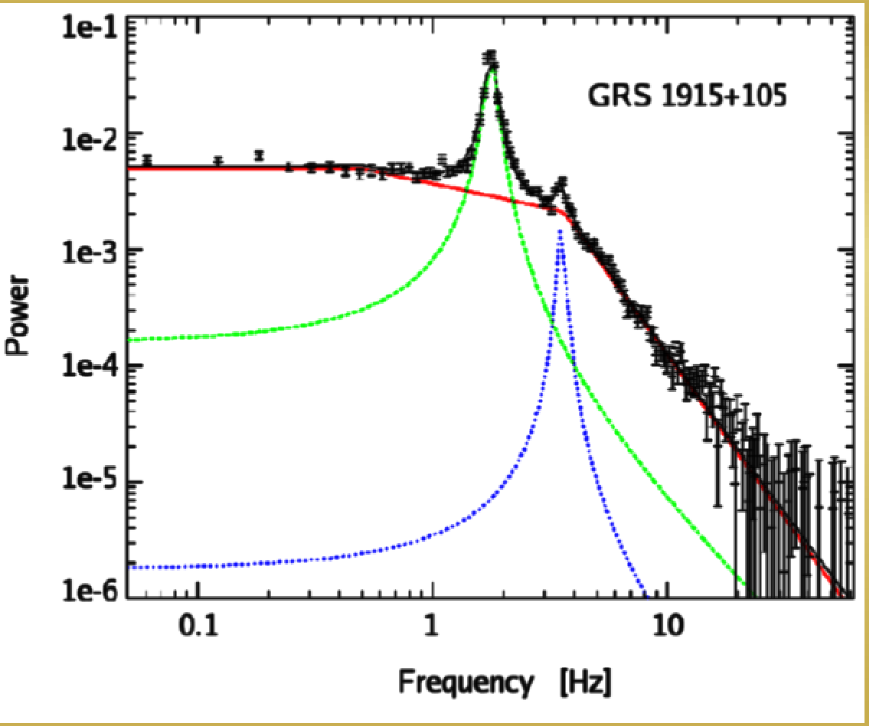
SEVENTH FRAMEWORK PROGRAMME

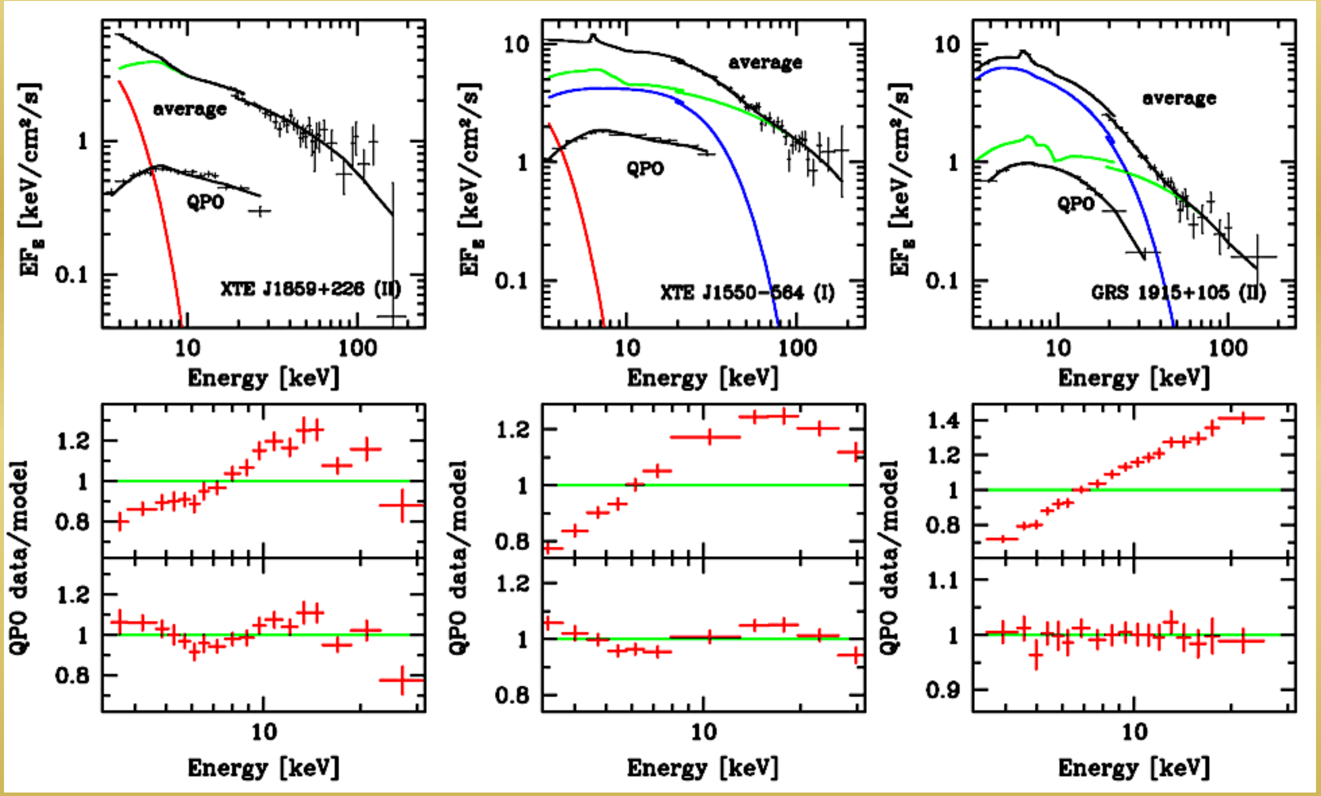
NATIONAL SCIENCE CENTRE

X-ray QPO

Low-*f* QPO



Observed energy spectra of QPO



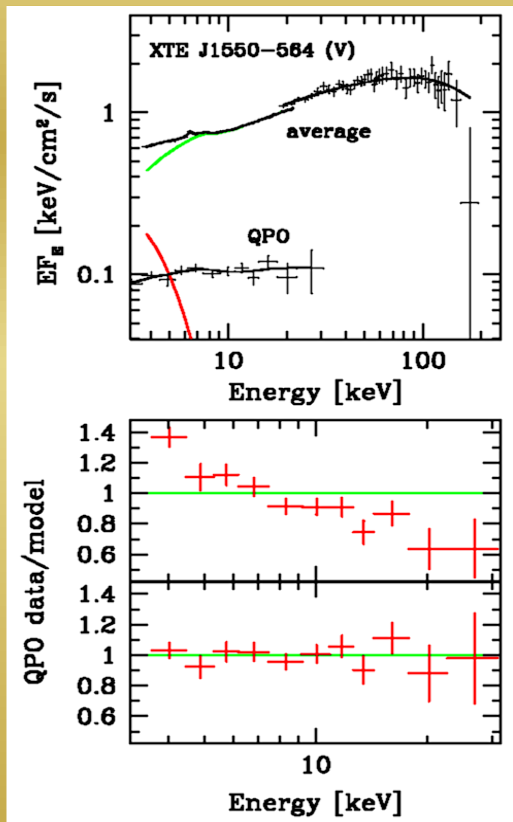
Sobolewska & Życki 2006

Disk emission is ***not*** present in the QPO spectra.

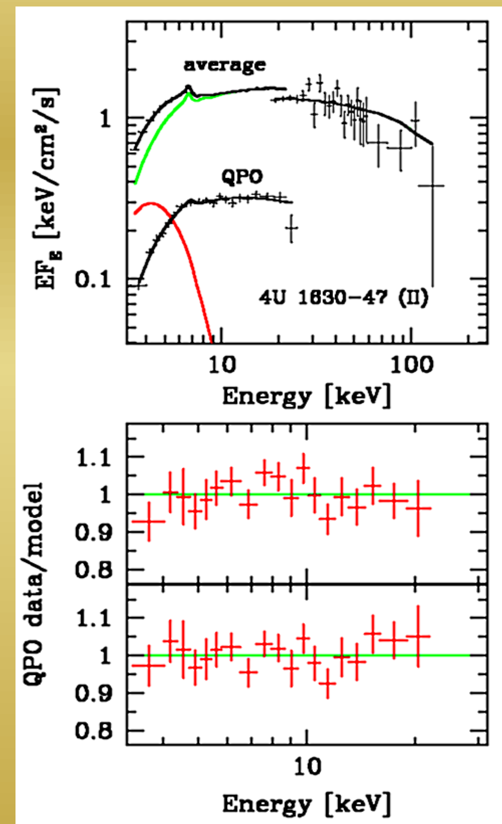
When time averaged spectra are soft, the QPO spectra are *harder* than the time averaged spectra.

Observed energy spectra of QPO

Hard spectral state



Intermediate state



Sobolewska & Życki 2006

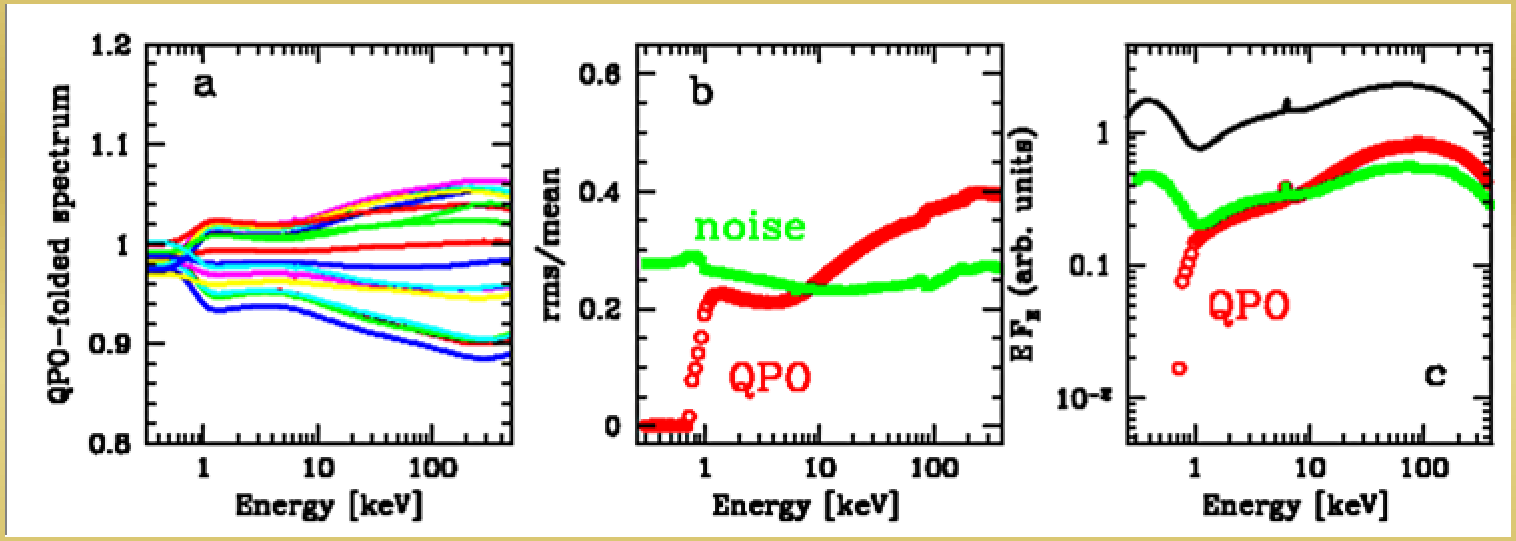
When the time averaged spectra are hard, the QPO spectra are *softer* than the time averaged spectra

Generic Comptonization models

(Thermal) Comptonization is described by two main parameters: heating rate and cooling rate of the plasma. Spectral slope determined by the ratio of the two quantities. Variability (broad-band or QPO) may be driven by variations of $l_{\rm h}$ and/or $l_{\rm s}$.

In the specific situation of multi-phas accretion flows (soft photons from reprocessing) one can also imagine variations of the geometry of the flow, leading to variations of the viewing geometry (e.g. viewing angle), heating-to-cooling ratio and/or reflection amplitude.

Modulation of heating rate



Spectral variability folded with QPO period

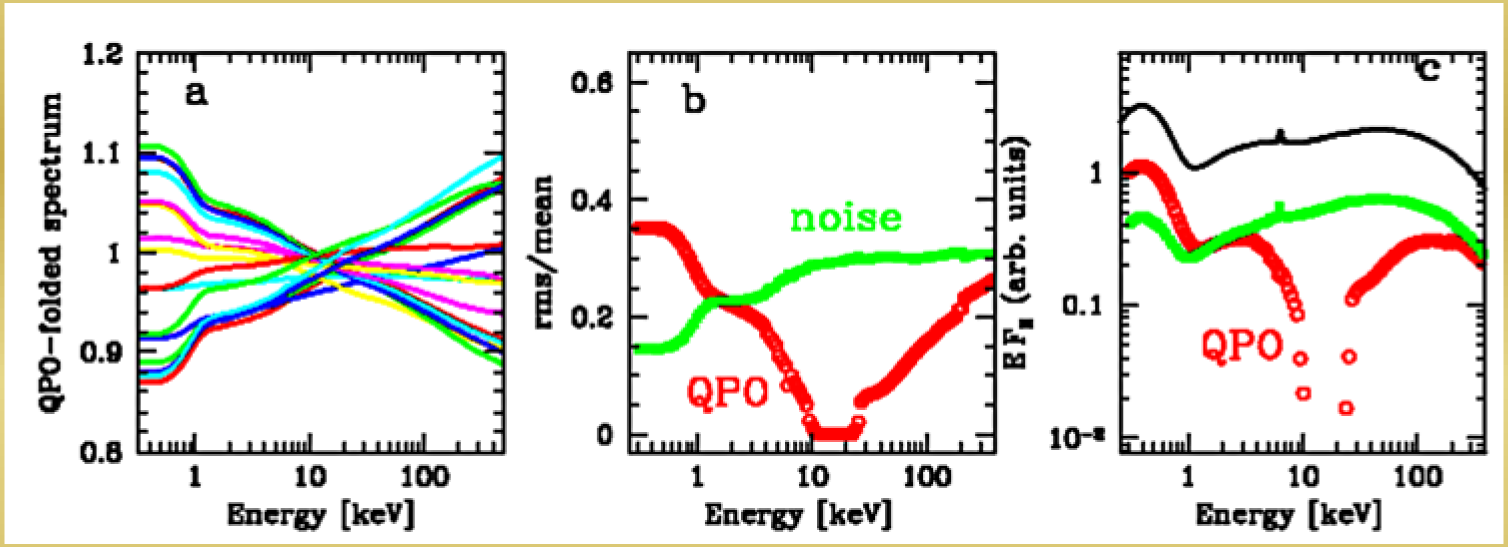
r.m.s./mean variability

Energy spectra

QPO energy spectrum is *harder* than the time averaged spectrum

Życki & Sobolewska 2005

Modulation of cooling rate



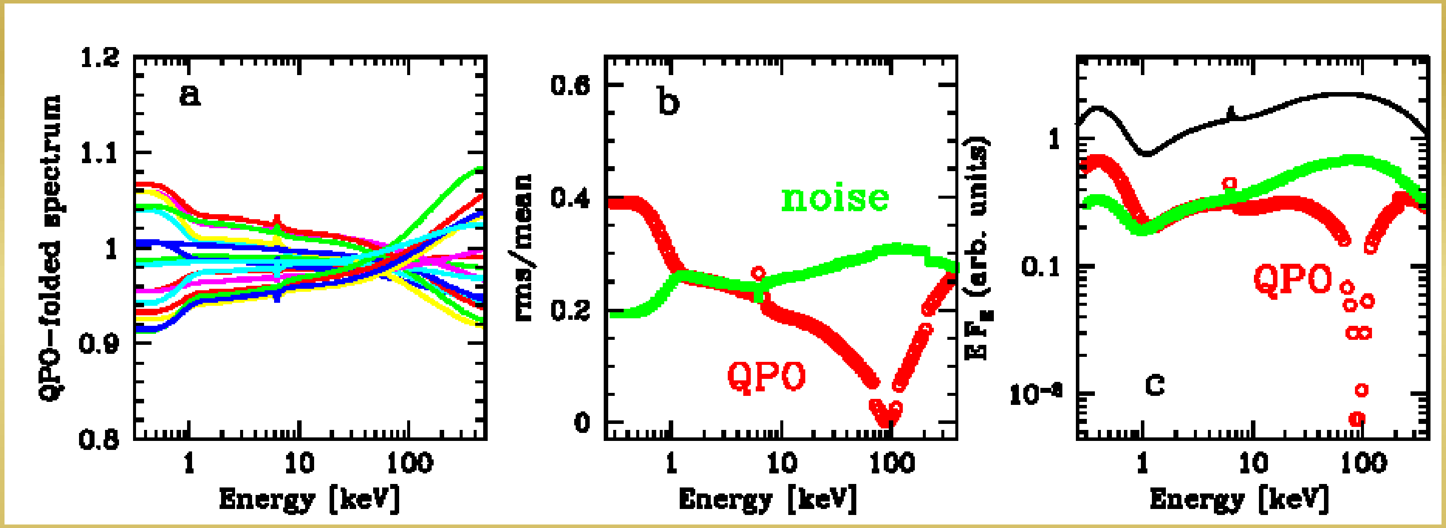
Spectral variability folded with QPO period

r.m.s./mean variability

Energy spectra

QPO energy spectrum is *softer* than the time averaged spectrum

Modulation of the covering factor of the cold matter



Fe Kα line present in the QPO spectrum

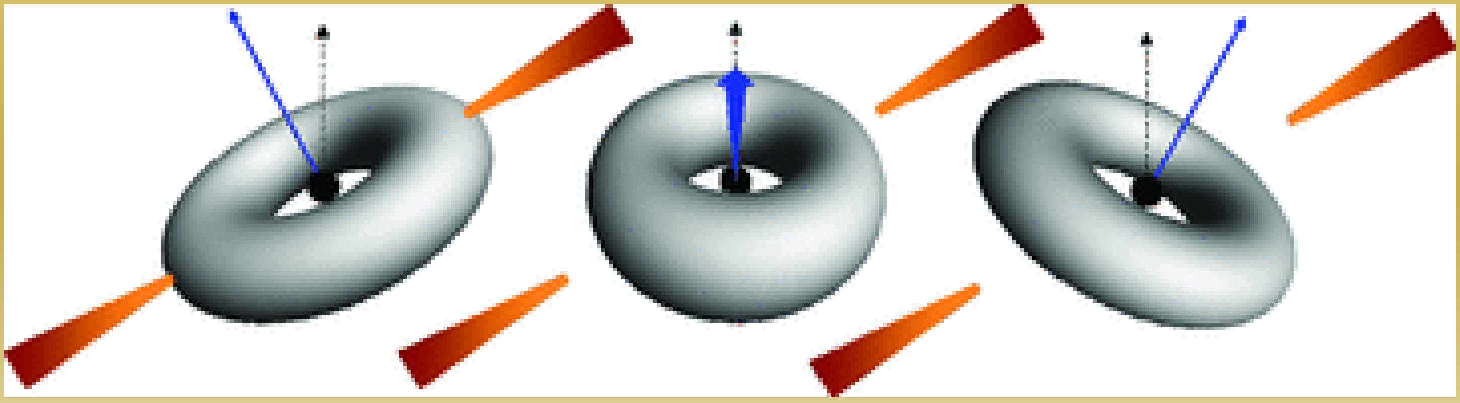
Lense-Thirring precession model for low-*f* QPO

Formulated by Stella & Vietri (1998)

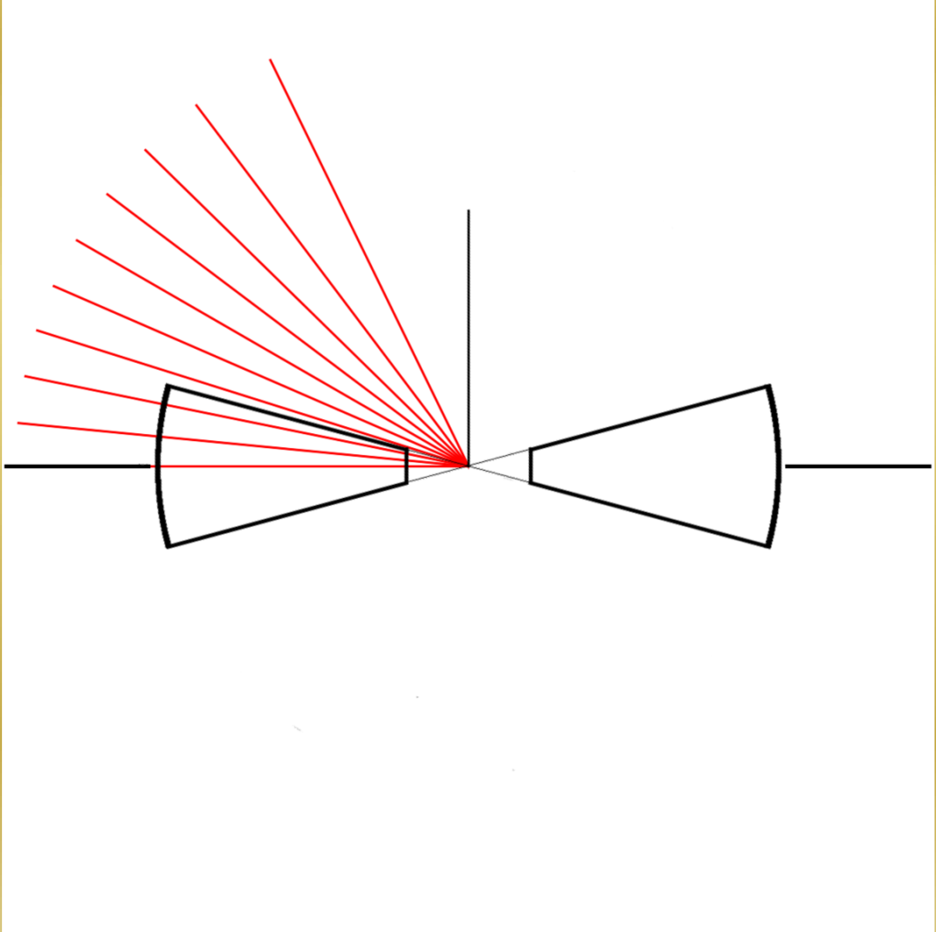
Recent hydrodynamical simulations suggest that the hot flow behaves (precesses) like a solid body.

Inner radius of the flow is determined by properties of the bending waves. It is approximately independent of the spin of the black hole. As a result the maximum precession frequency does not depend on the spin)

(C. Done, A. Ingram, C. Fragile)



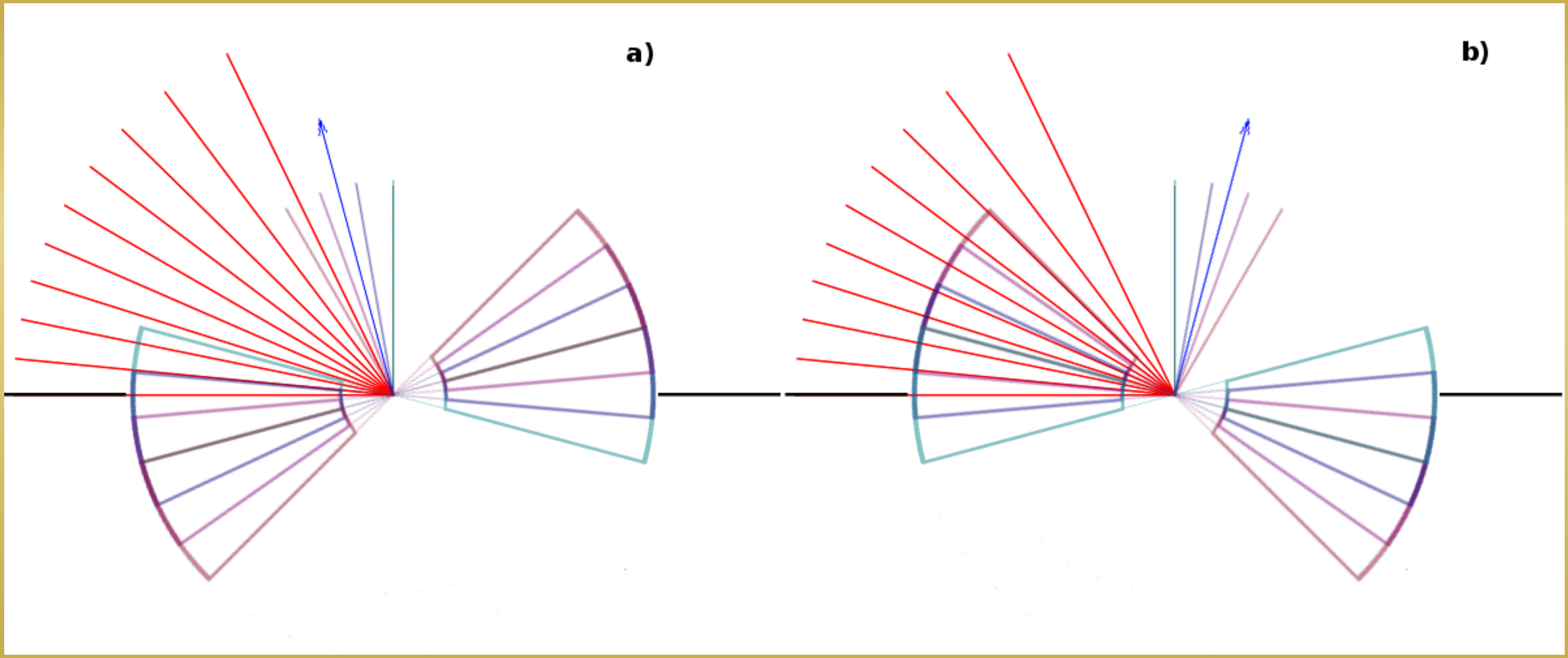
Geometry

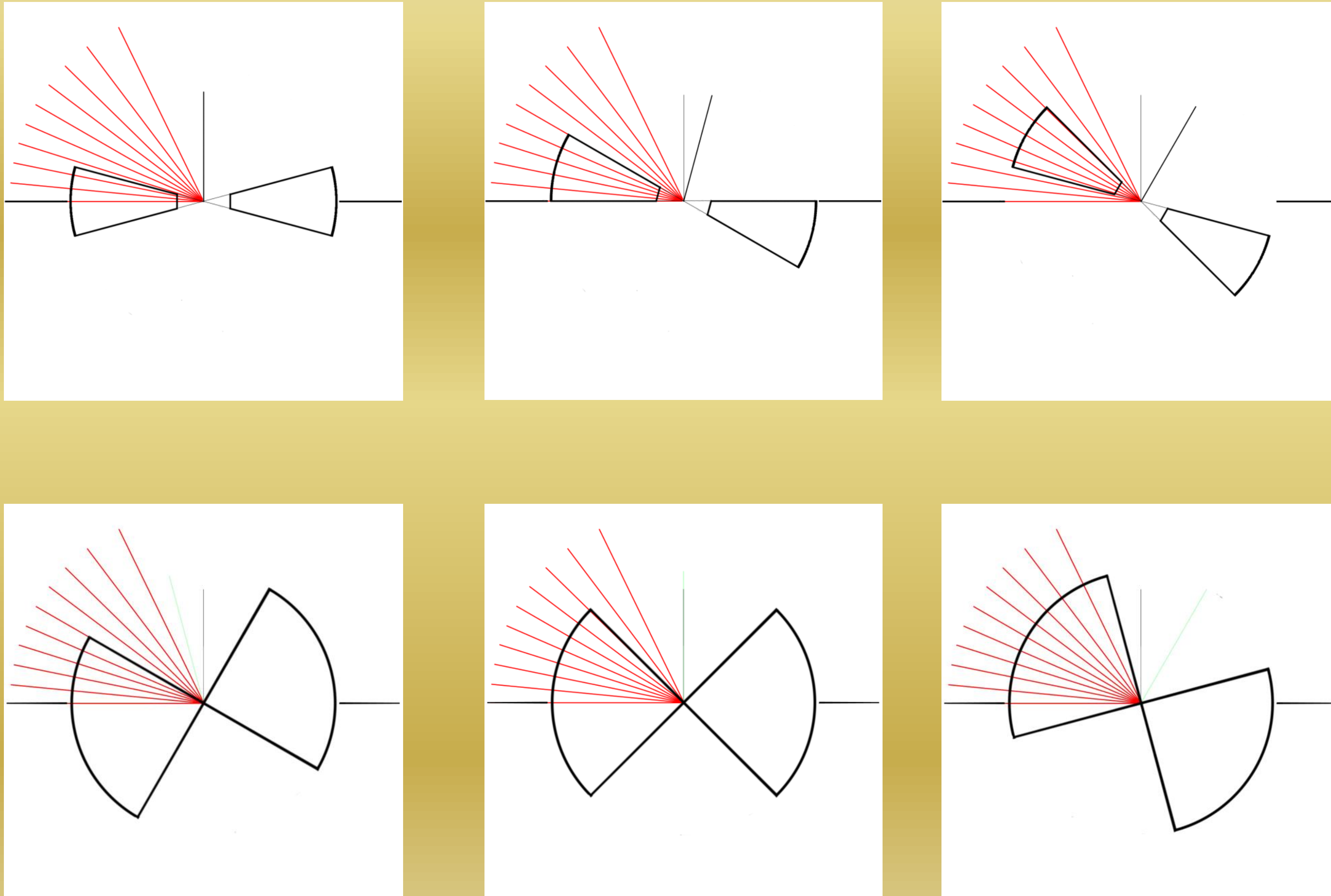


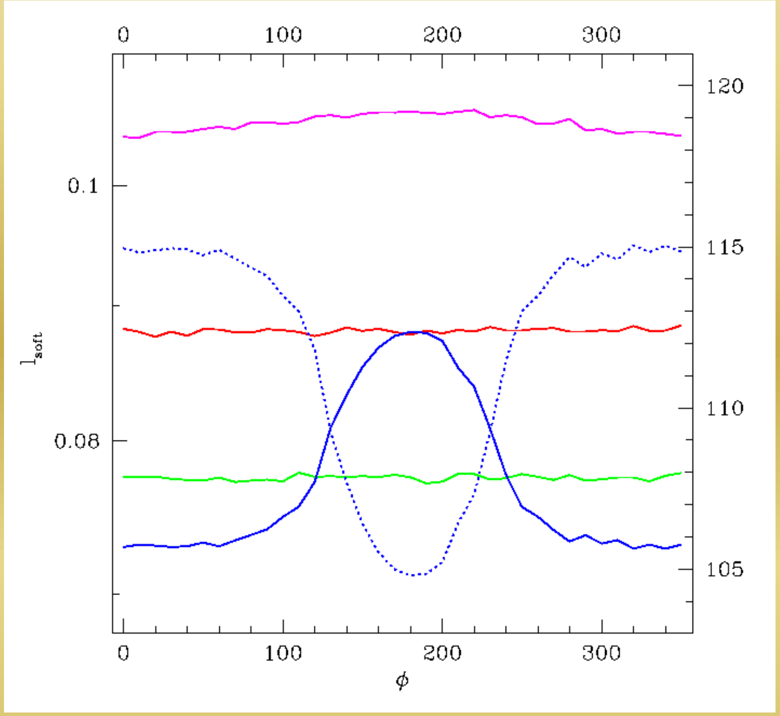
Two geometrical scenarios:

1. precession axis perp. to the outer disk
2. Precession axis inclined to the outer disk (based on Bardeen-Peterson effect)

Geometry







geometrically thick torus; to be compared with the blue curve

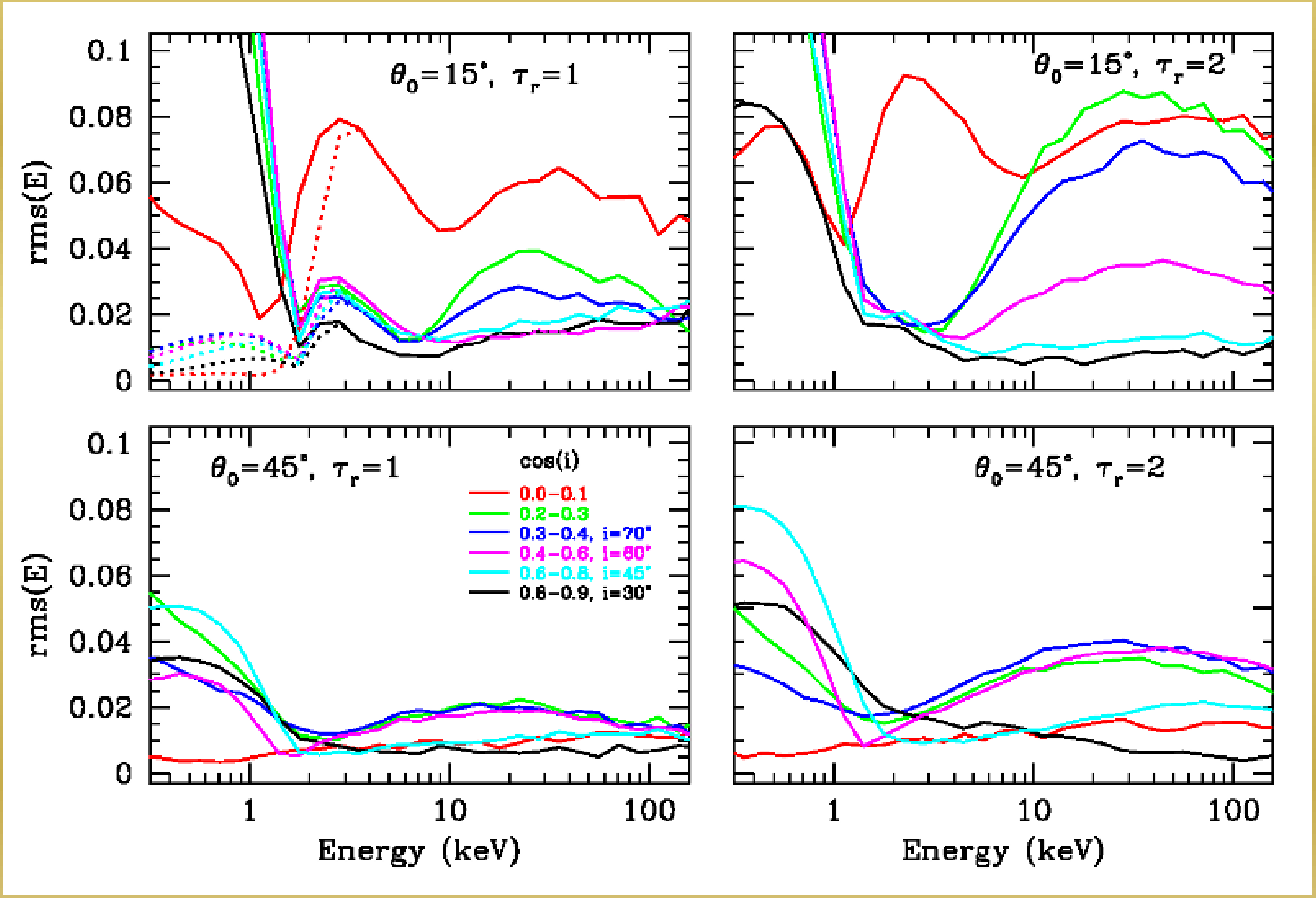
coplanar config.

prec. axis perp. to the outer disk

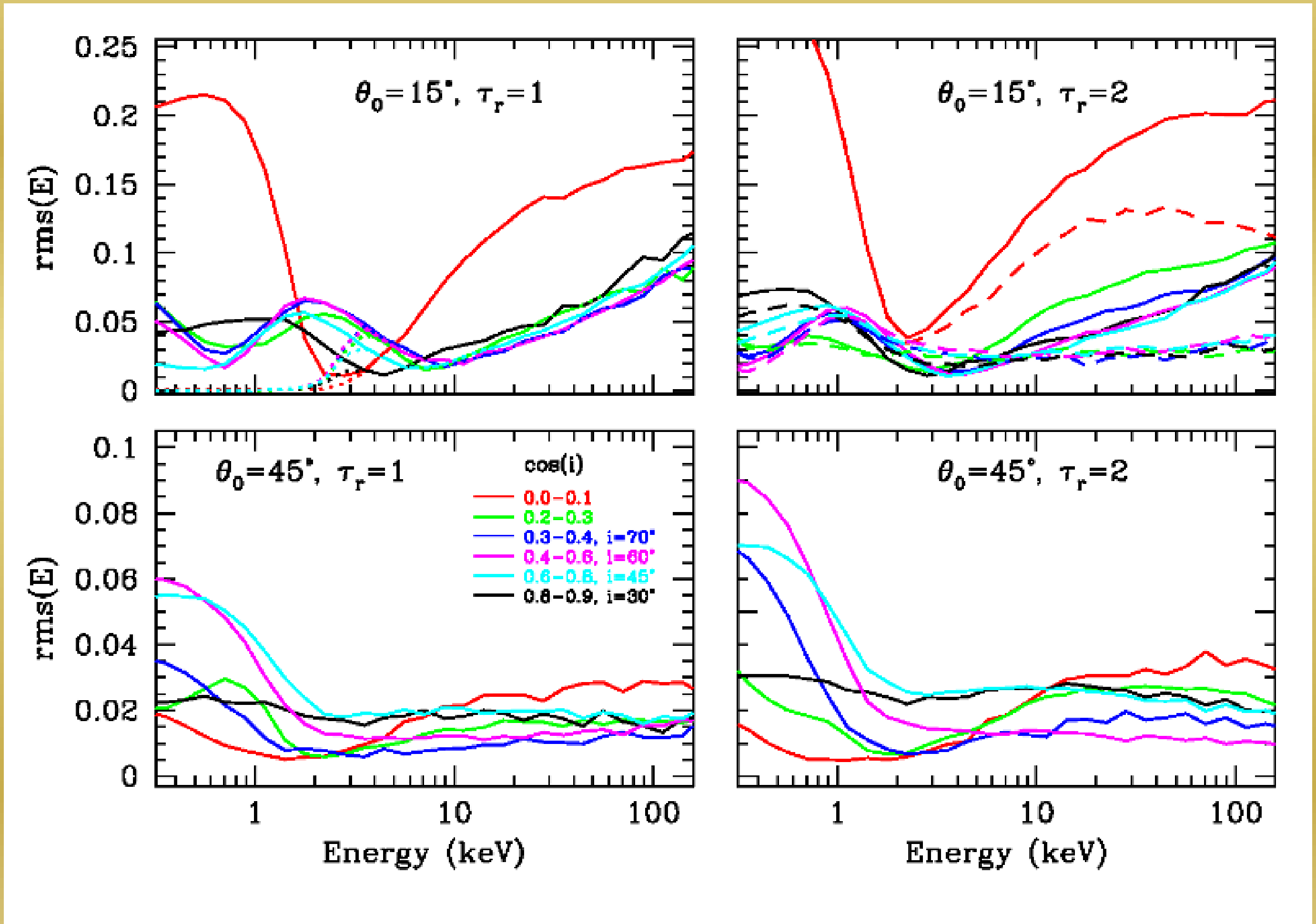
prec. axis inclined to the outer disk

Results

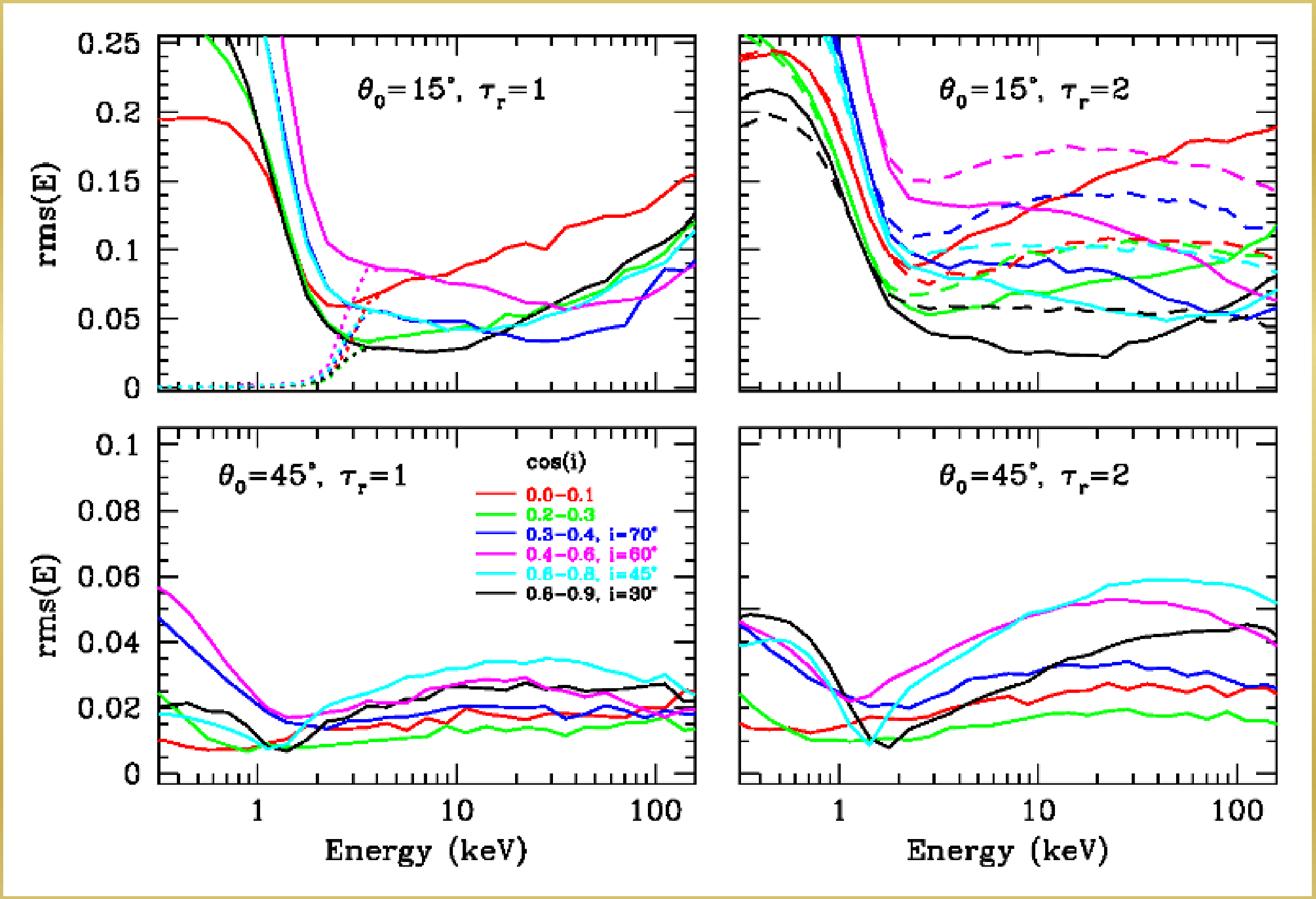
Precesion scenario **1** (precession axis *perpendicular* to the outer disk axis)



Precesion scenario **2** (precession axis *inclined* to the outer disk axis)
precession axis *towards* the observer



Precesion scenario **2** (precession axis *inclined* to the outer disk axis)
precession axis *away from* the observer



Variations of the iron K_α line

Ingram & Done 2012