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@Heraklion

X-ray reverberation lags of the Fe-K line due to AGN winds

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Hirokazu Odaka

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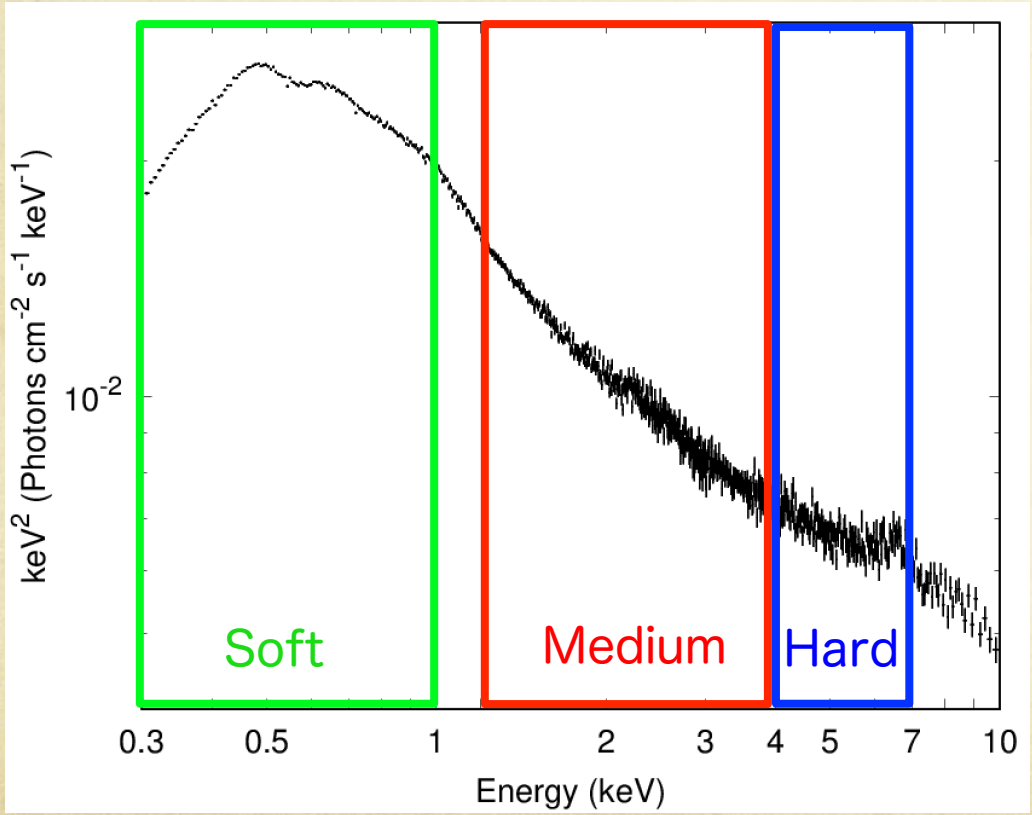
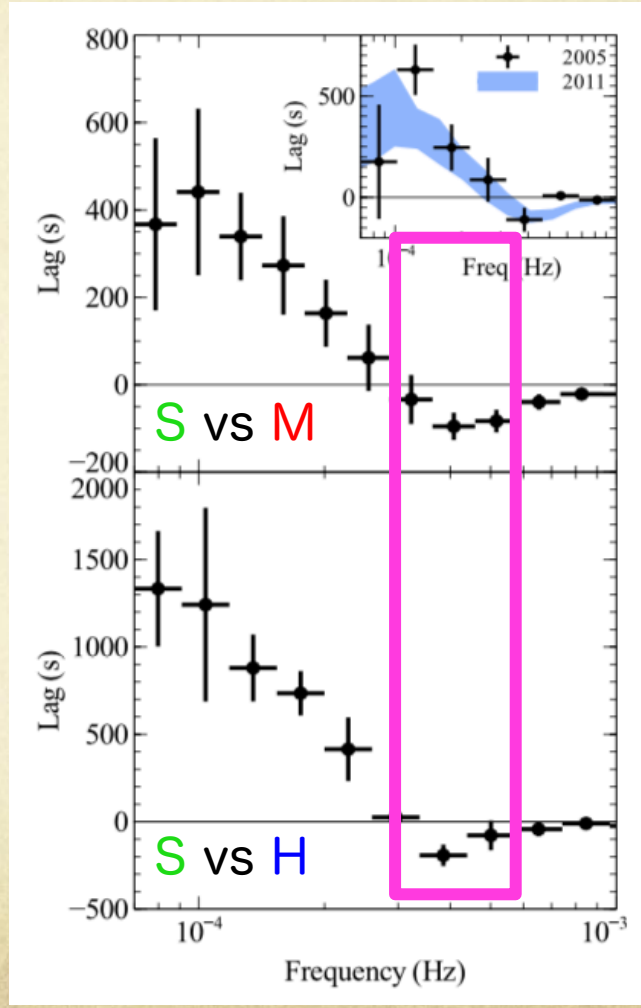
Energy spectrum



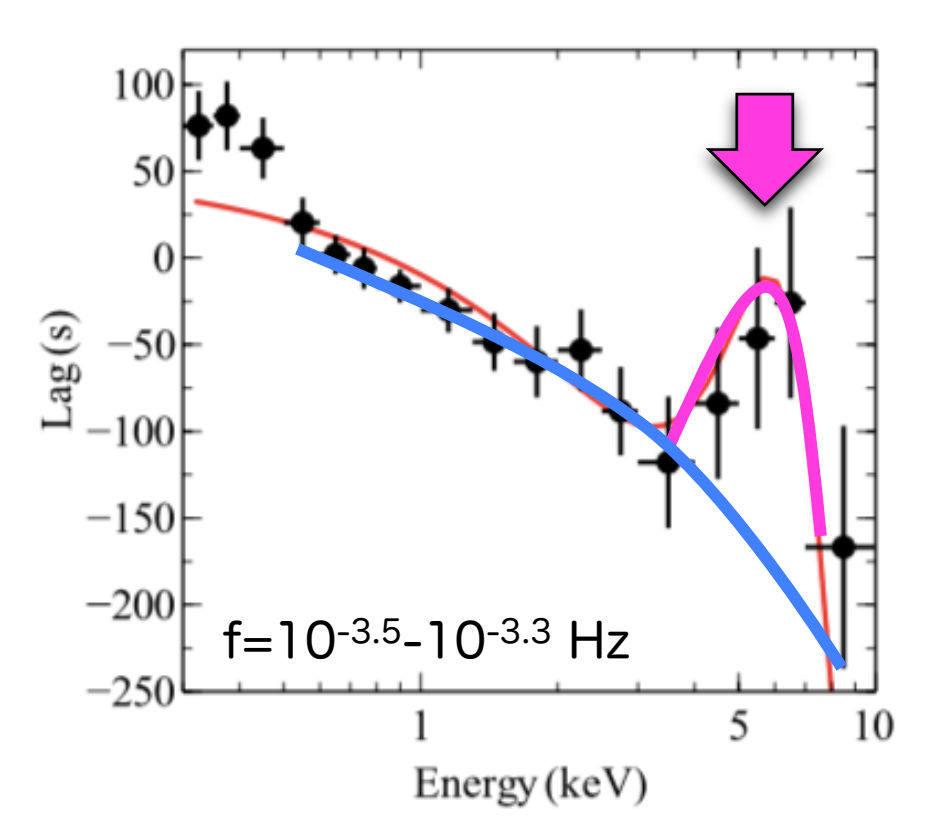
Lag vs freq. (Kara+13)



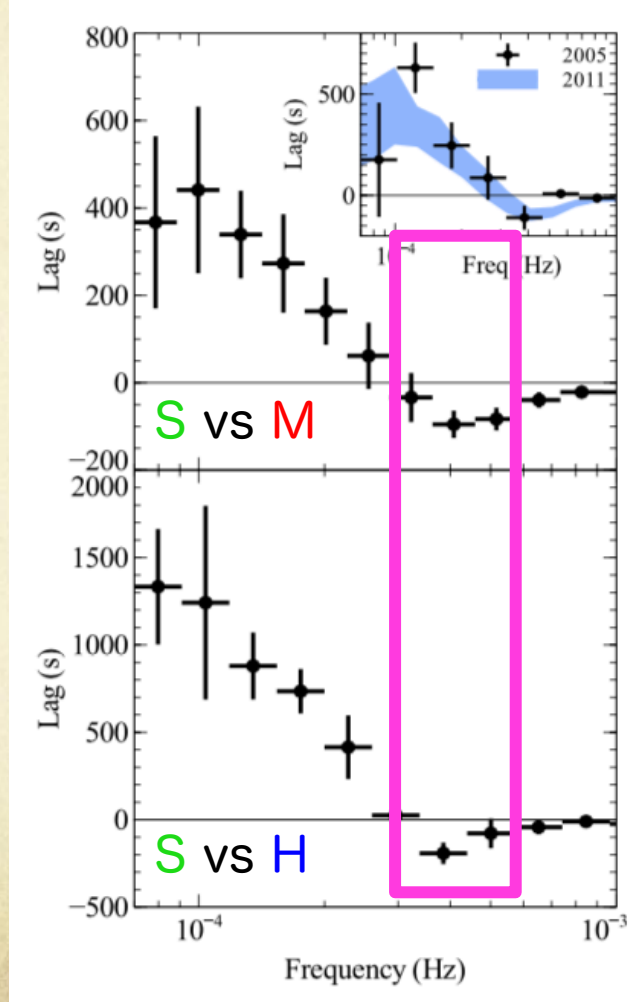
Fe-K lags in AGNs

Ark 564

Lag vs energy (Kara+13)



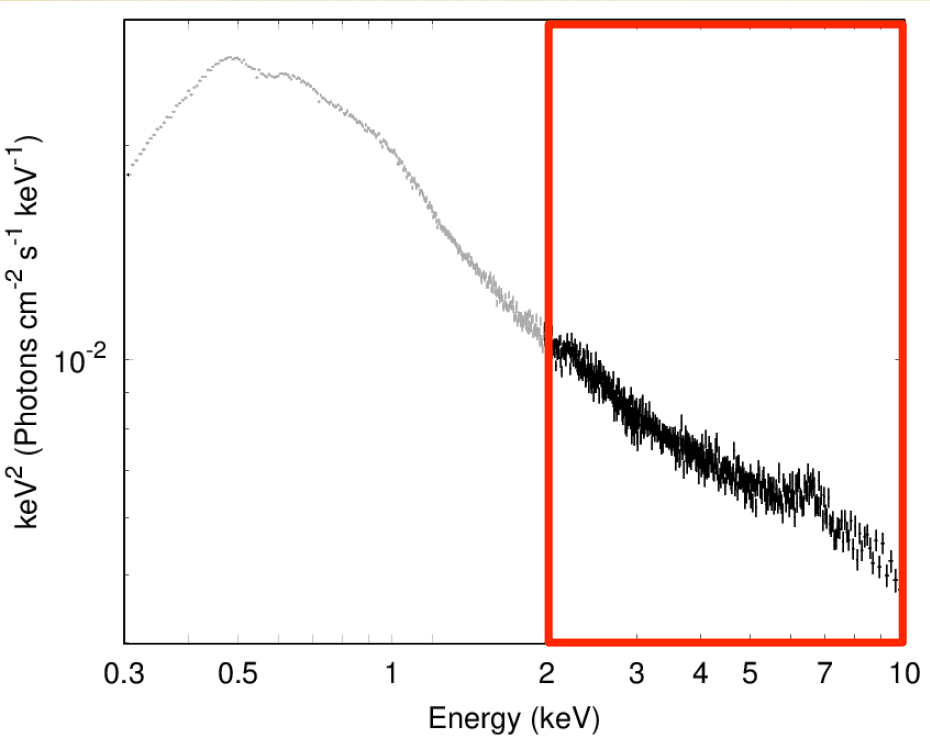
Lag vs freq. (Kara+13)



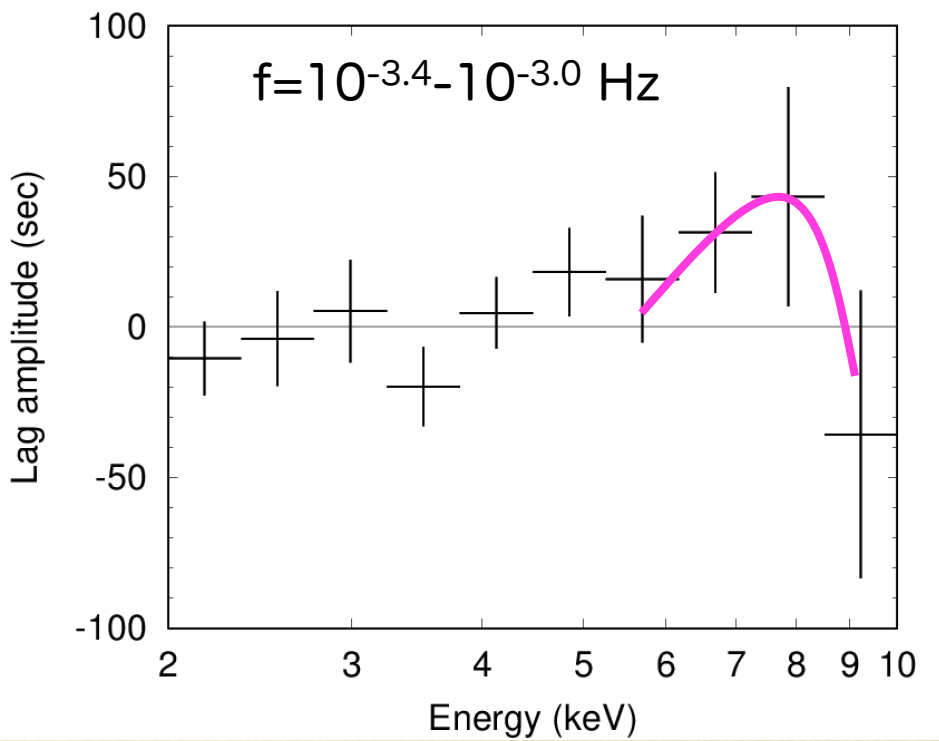
Fe-K lags in AGNs

Ark 564

Energy spectrum

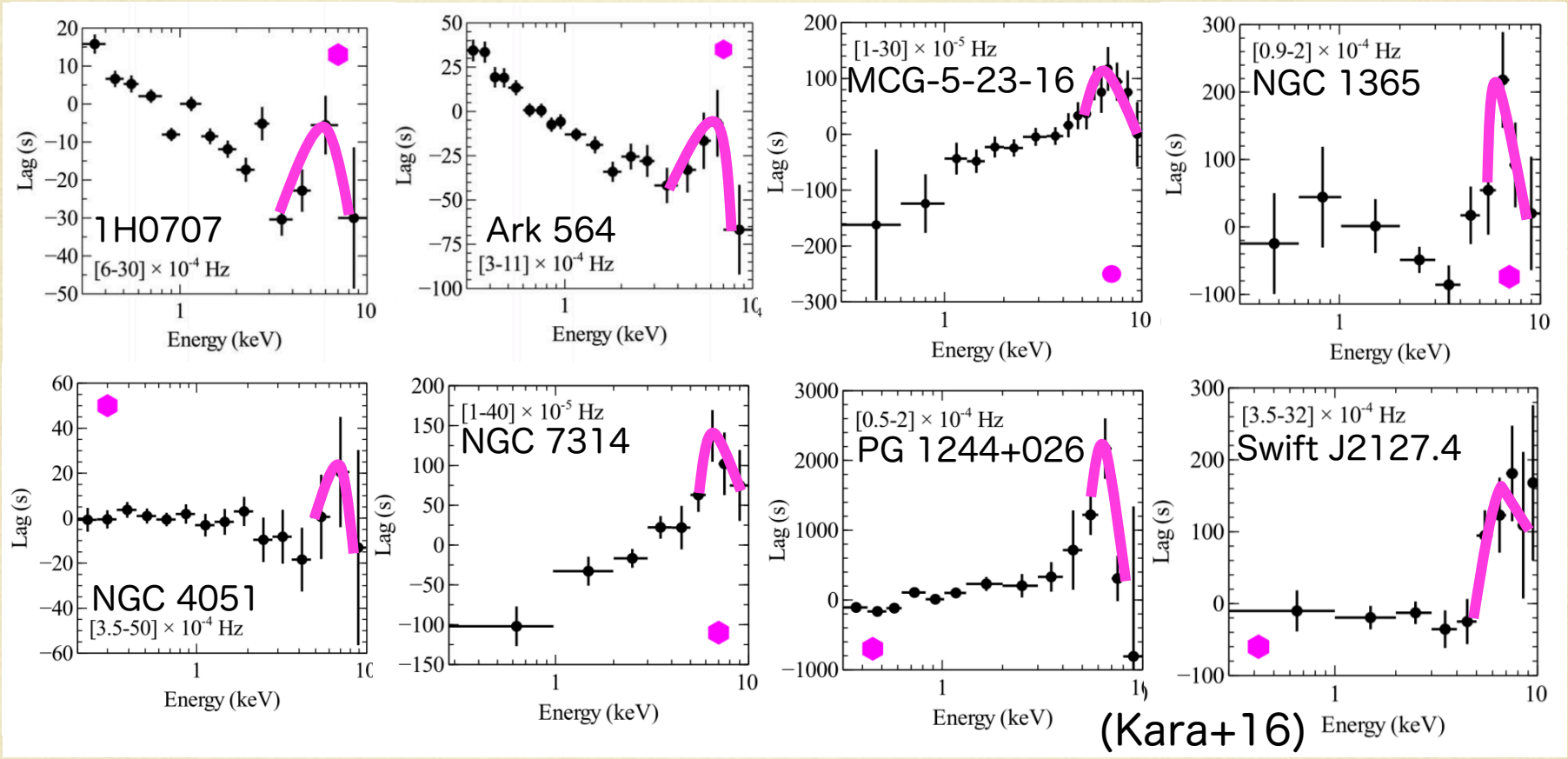


Lag vs energy



Broad Fe-K lags are seen in the high-frequency range.

Fe-K lags in AGNs

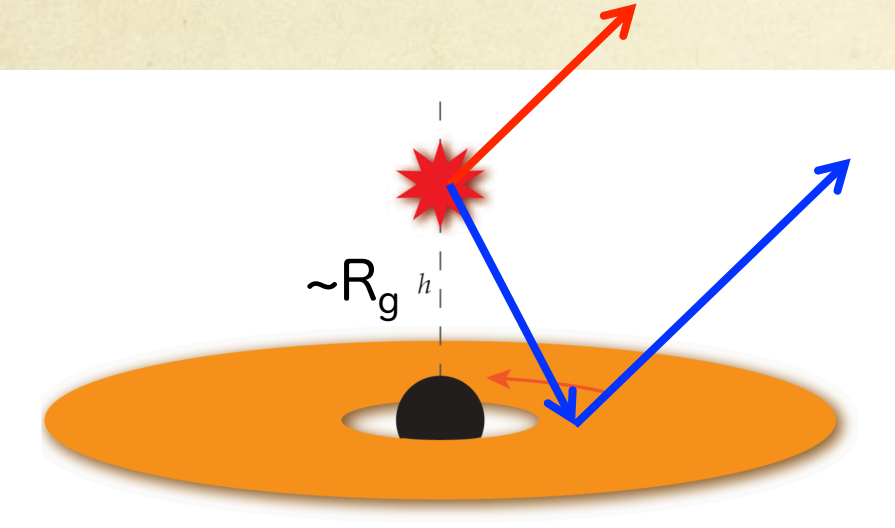


(Kara+16)

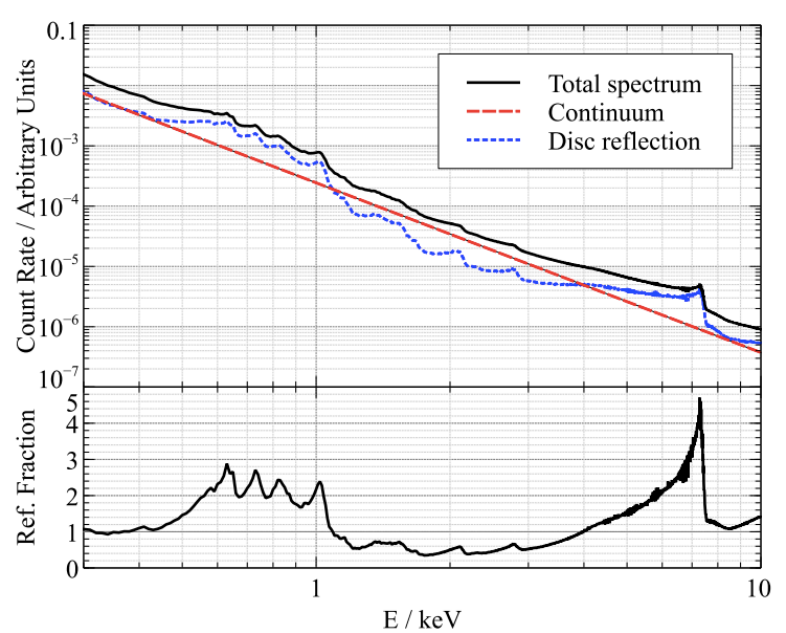
1. Lag amplitude: ~ several R_g/c
2. Frequency: ≤ $c/100R_g$
3. Fe-K lag profile: broad feature (6-9 keV)

Interpretation #1

Relativistic disc reflection



Wilkins+16

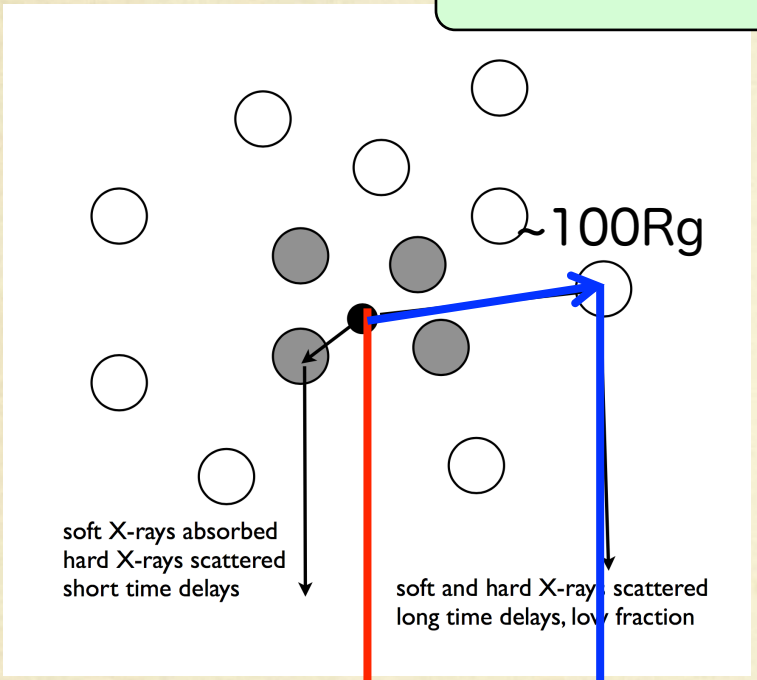


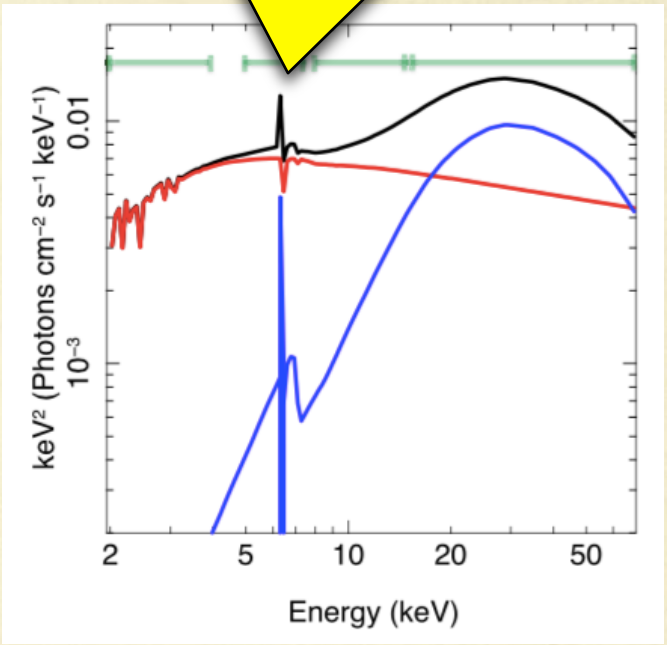
- Fe line is broadened by GR effect
- Short lag amplitude = short light-travel time
  (also see MM+18b, PASJ)

Interpreta

Primary photons are dominant
→ dilution effect

Cloud reflectio



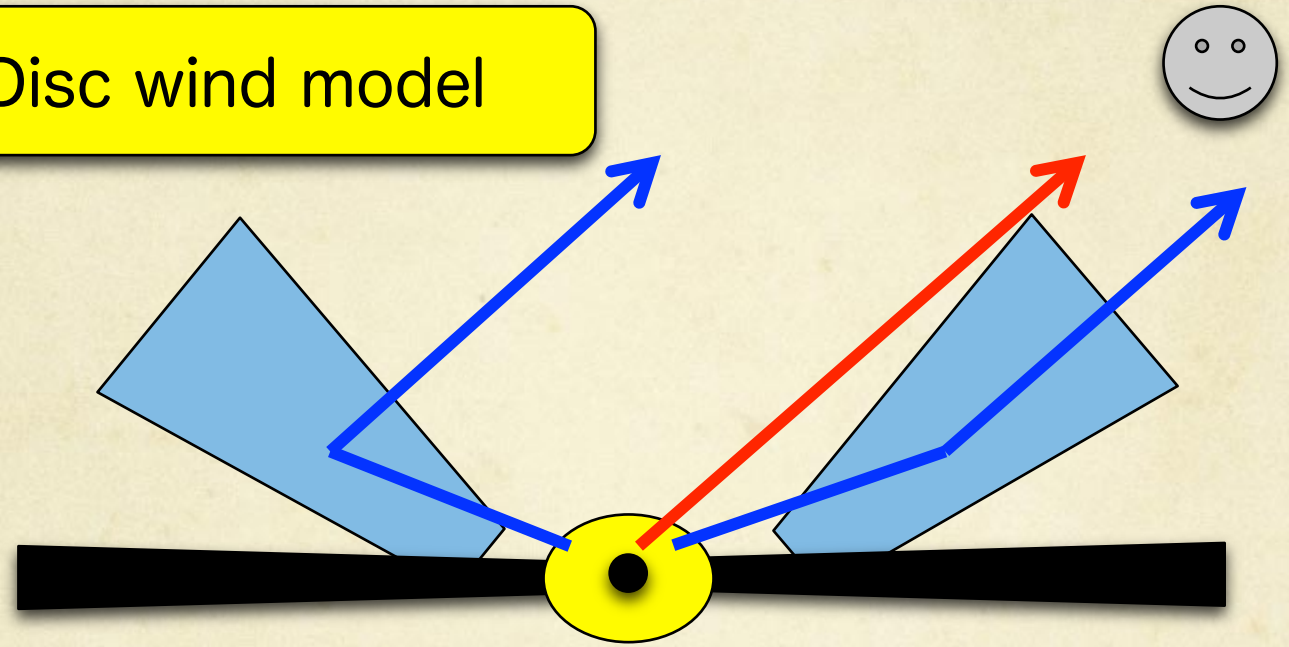


Turner+17

- Short lag amplitude: diluted by no-lagged primary photons (e.g., Miller+10a,b, MM+18)
- Fe line feature is broadened by velocity structure

Our interpretation

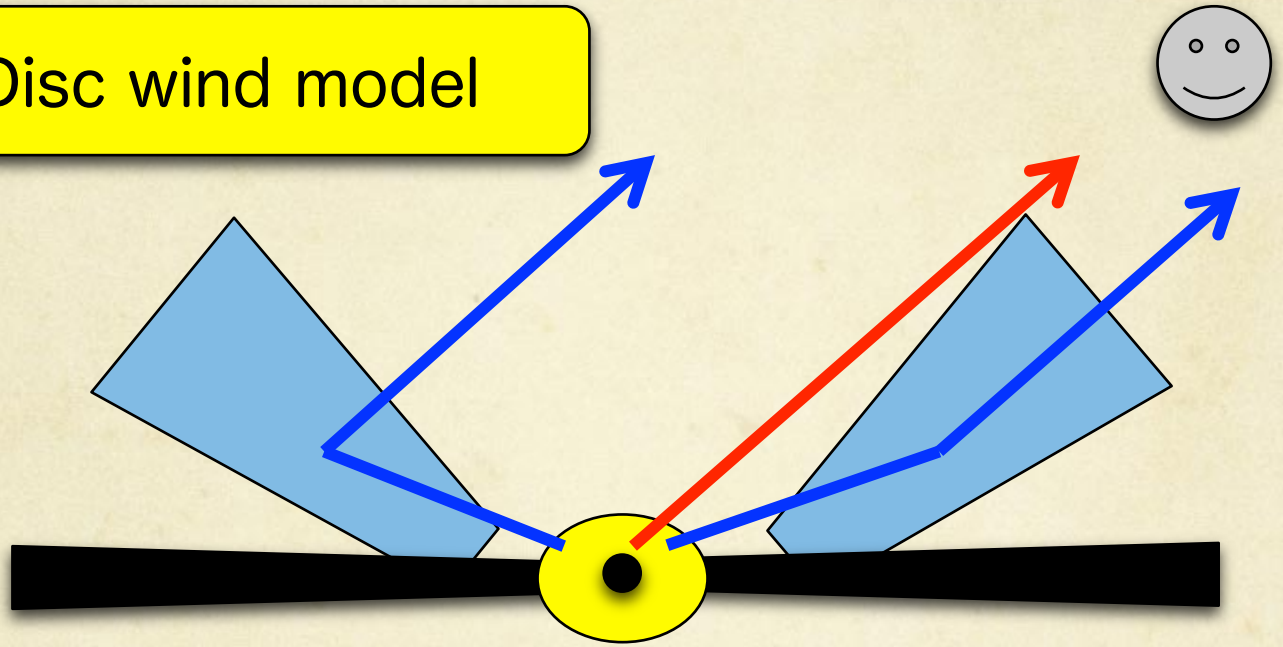
Disc wind model



- Short lag amplitude → Dilution by primary photons
- Frequency → $R<100R_g$
- Broad Fe-K feature → Outflowing velocity (+ orbital velocity)

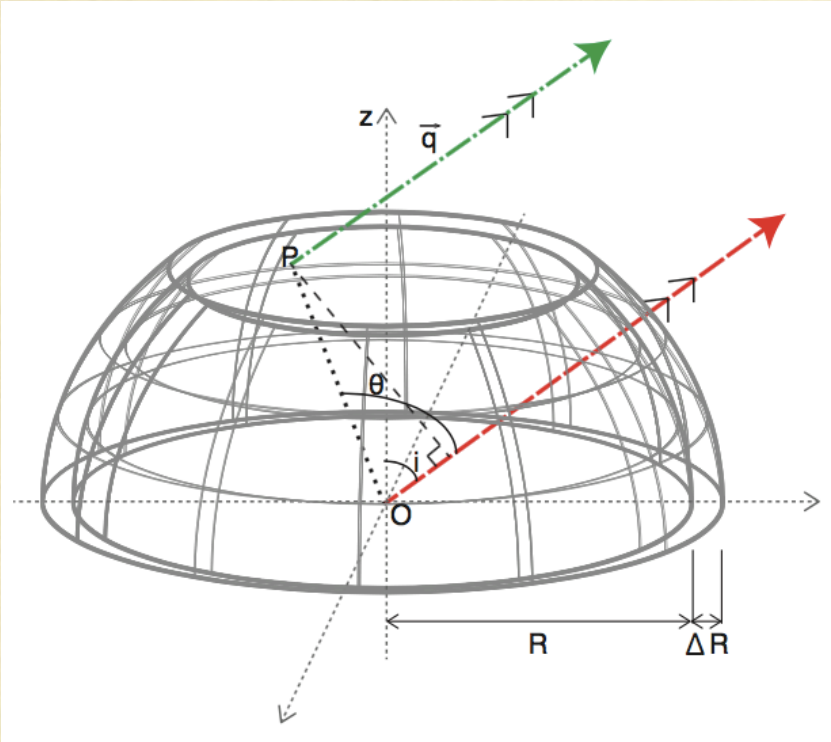
Our interpretation

Disc wind model



Motivation:
Can the disc wind quantitatively explain
the observed X-ray lags?

Simple (shell-like) geometry



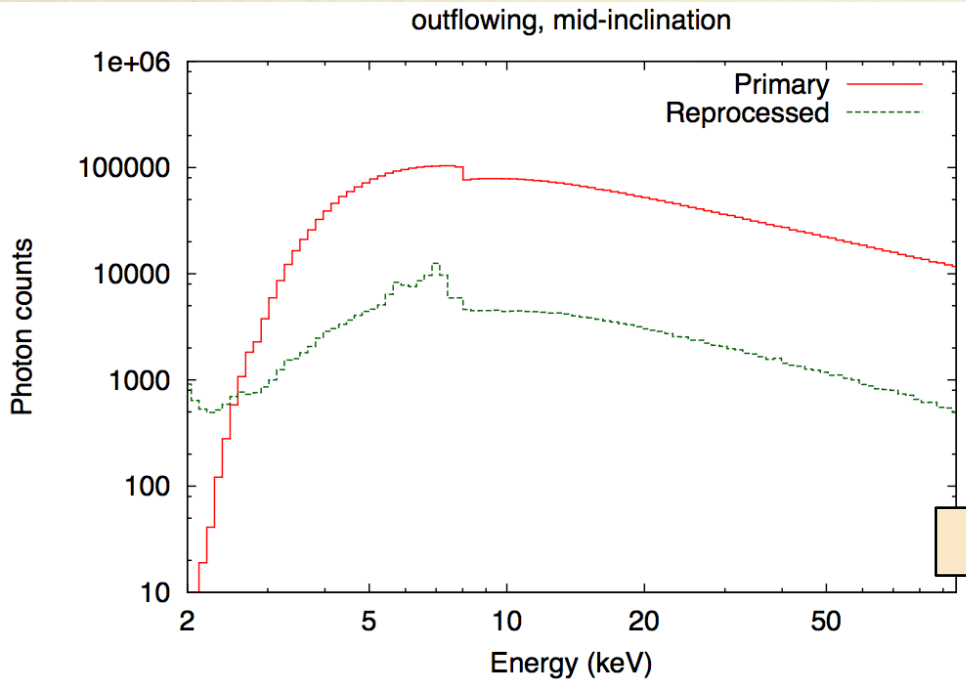
Monte-Carlo simulation with "MONACO" (Odaka+11)

- Smooth and neutral shell
- Shell thickness (ΔR) = R/10
- $R=100R_g$ ($M_{BH}=10^7 M_{solar}$) $=5000$ light-sec
- v=0.14c
- $N_H=2\times10^{23}$ cm^{-2}

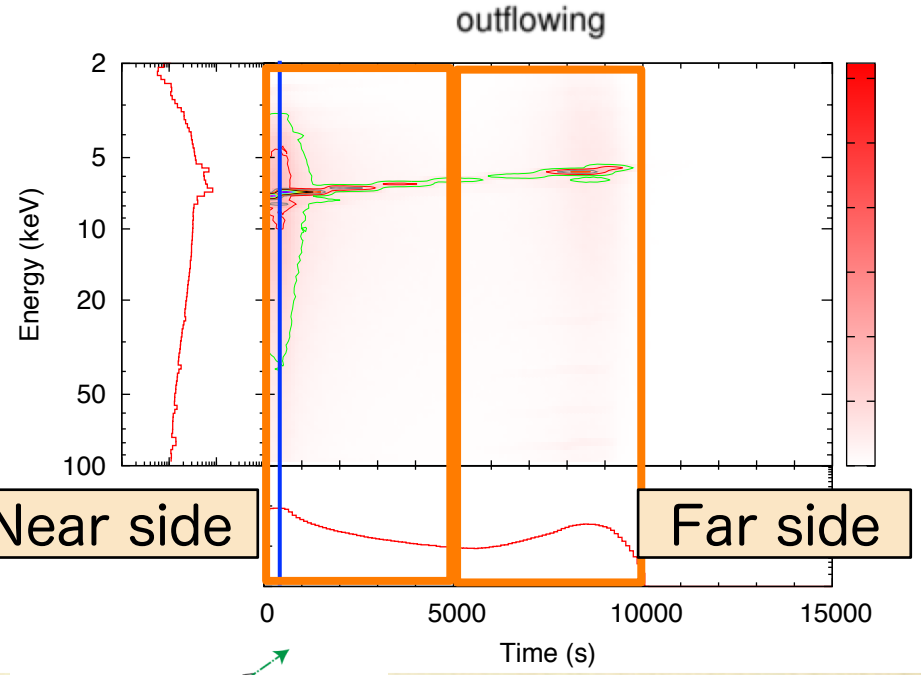
- Input spectra: power-law with $\Gamma=2$
- Inclination: $7/15 < \cos i < 8/15$
- 7×10^8 input photons
- $\Omega/4\pi=0.7$

Results #1

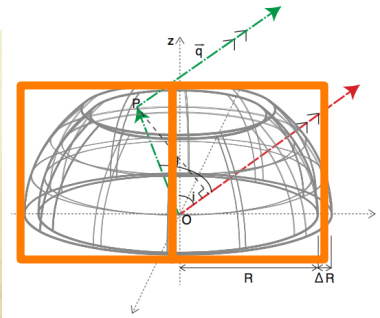
Energy spectra



2D transfer function



the average lag time:
~200s (=$4R_g/c$)

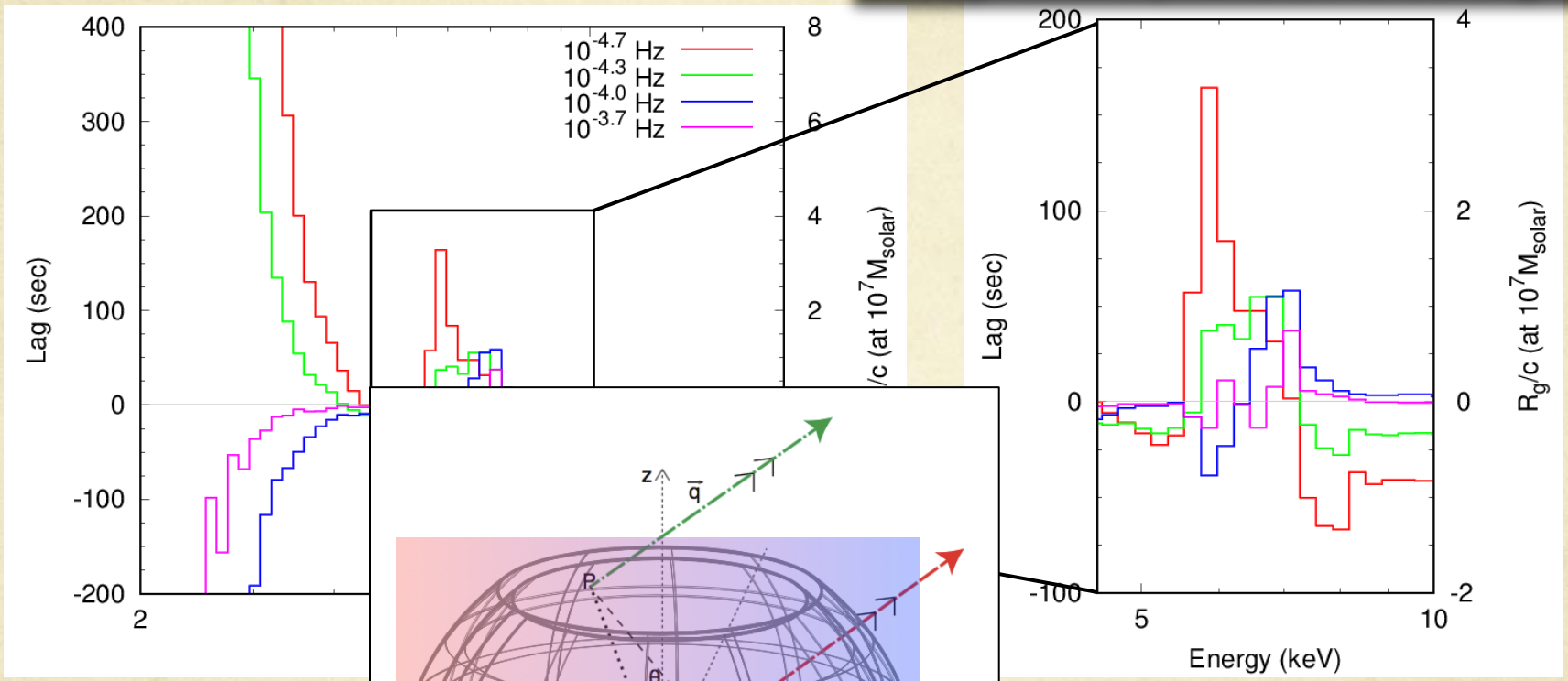


2. Monte-Carlo simulation

Results #2

Lag vs ene

lower freq. → red is strong
higher freq. → blue is strong



1. Lag amp
2. Frequen
3. Fe-K lag

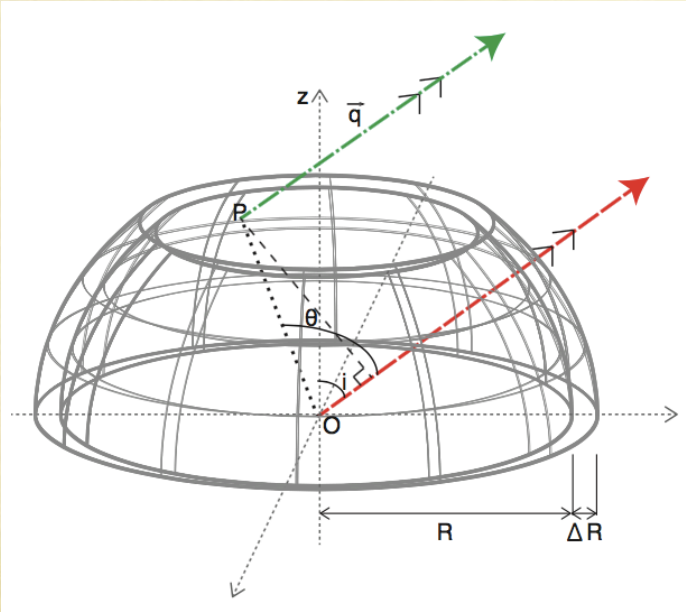
(6-9 keV)

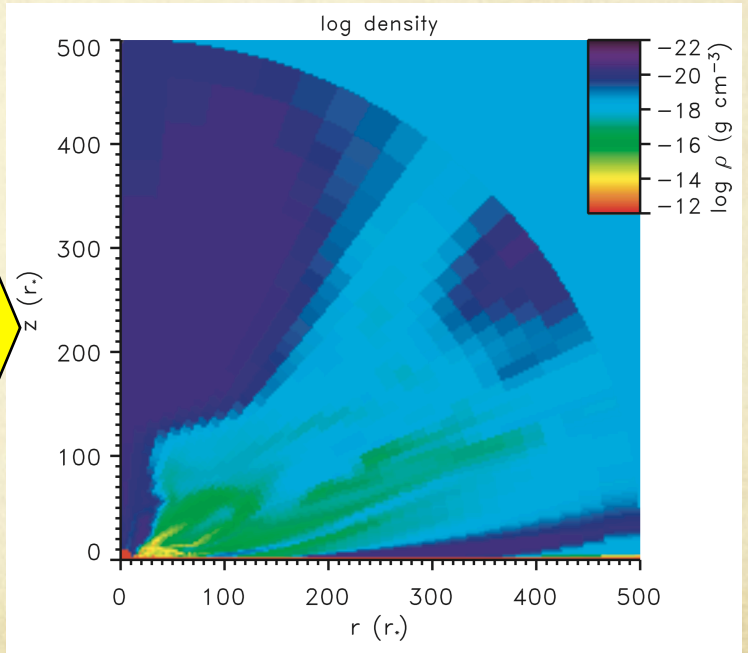
Disc-wind-like geometry

Outflowing clouds within $100R_g$ → AGN disc winds

Neutral shell

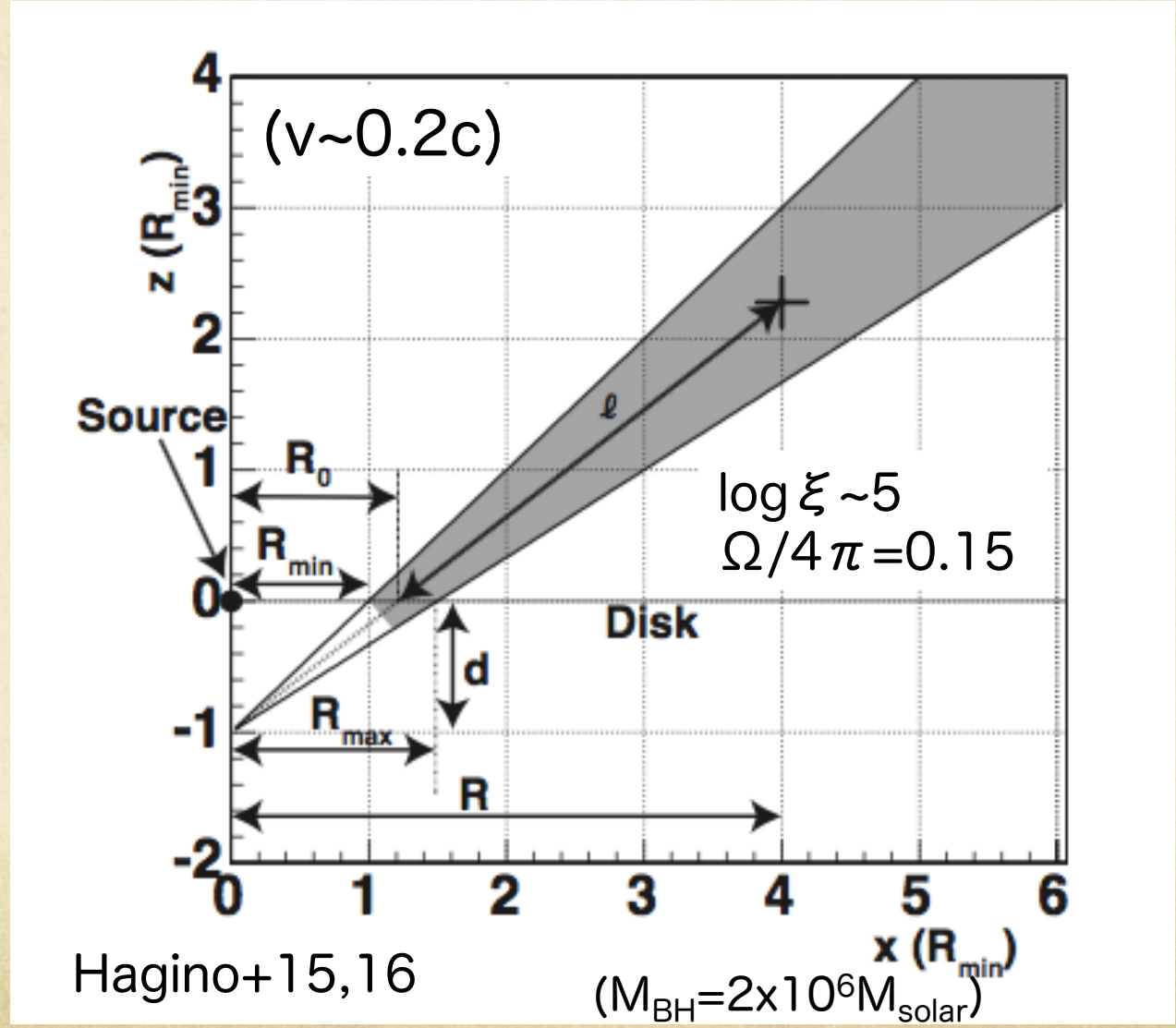
Ionised wind





Proga & Kallman 04

Biconical wind

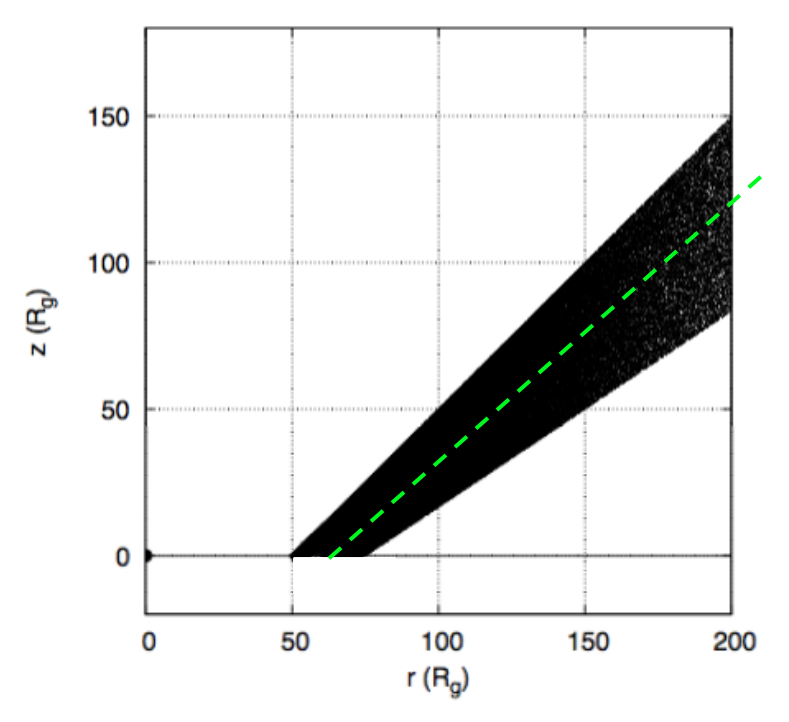


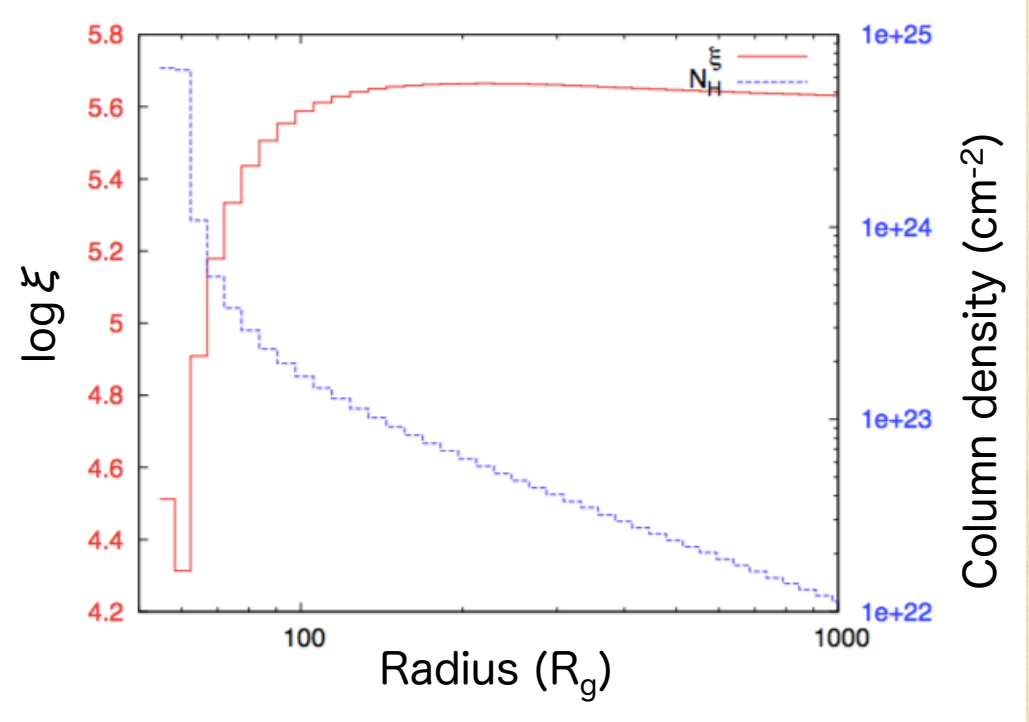
Wind parameters

Coordinates

Parameters

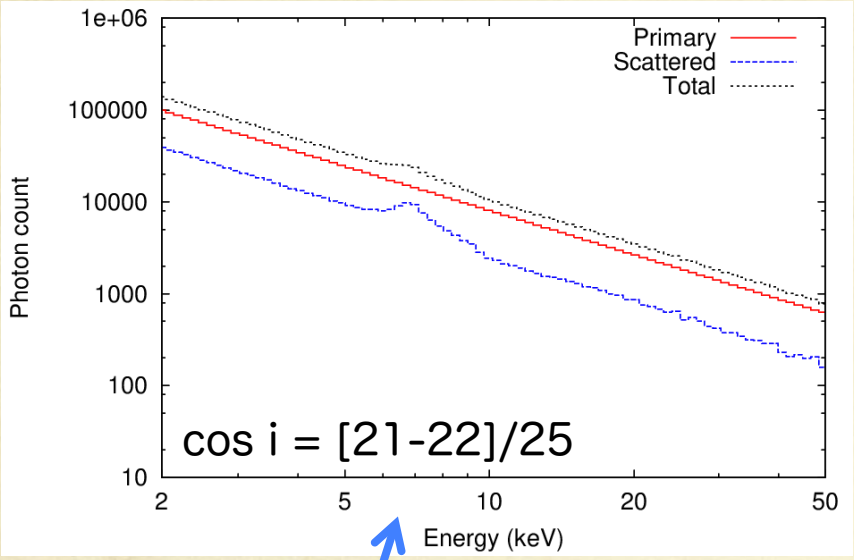
(along the green line)

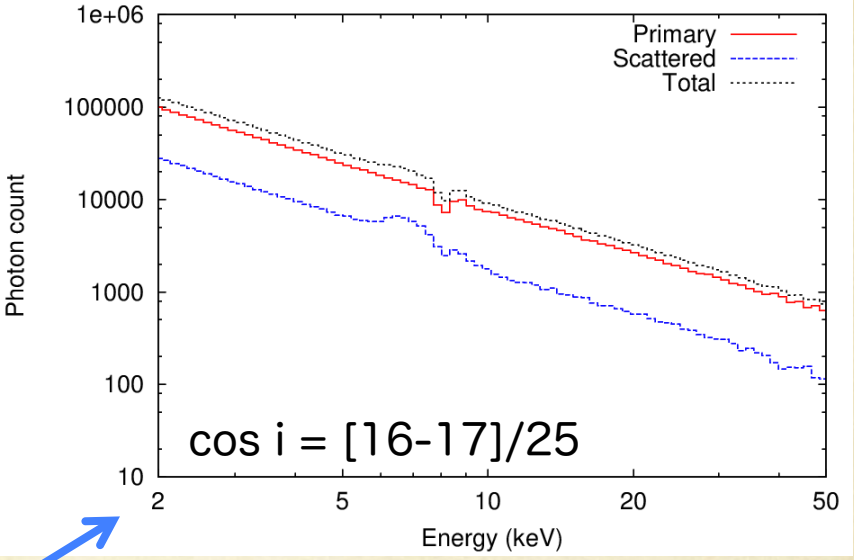


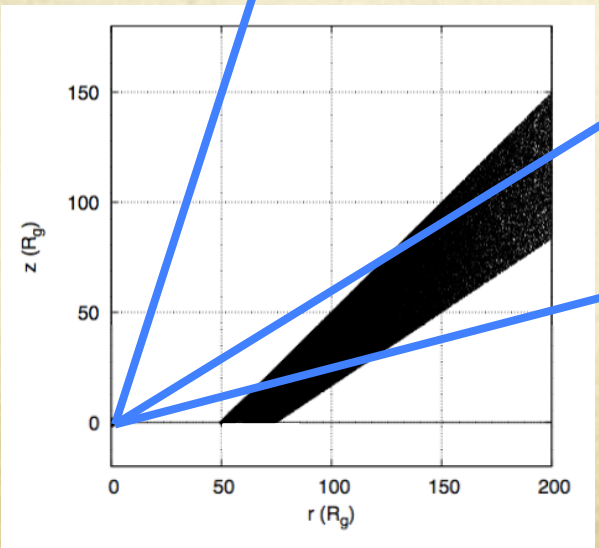


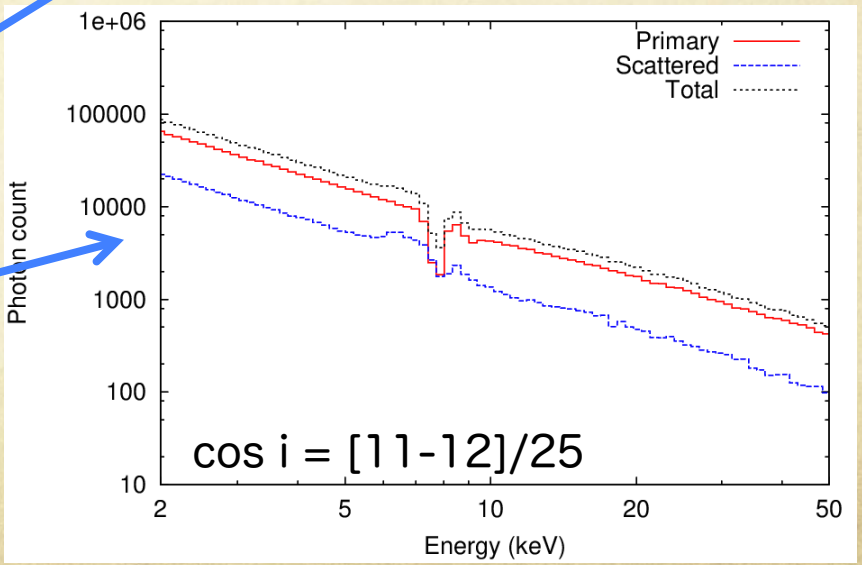
Resonance scattering within 100R_g

Energy spectra



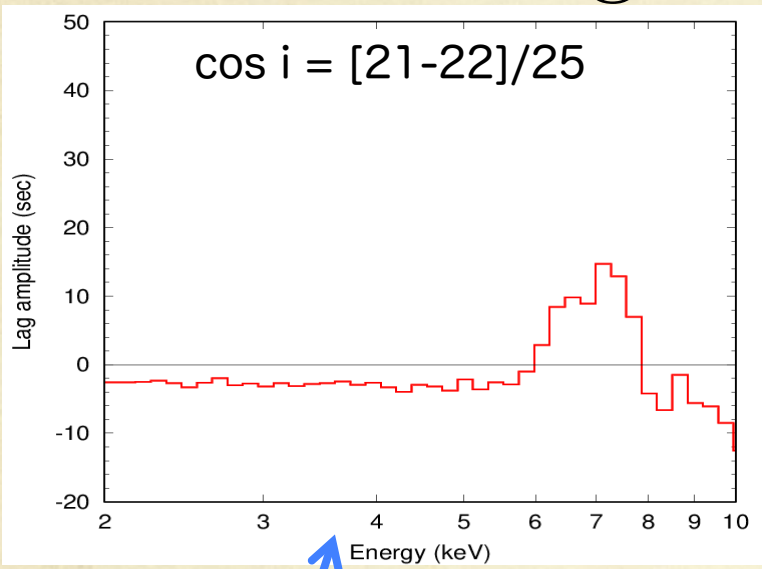


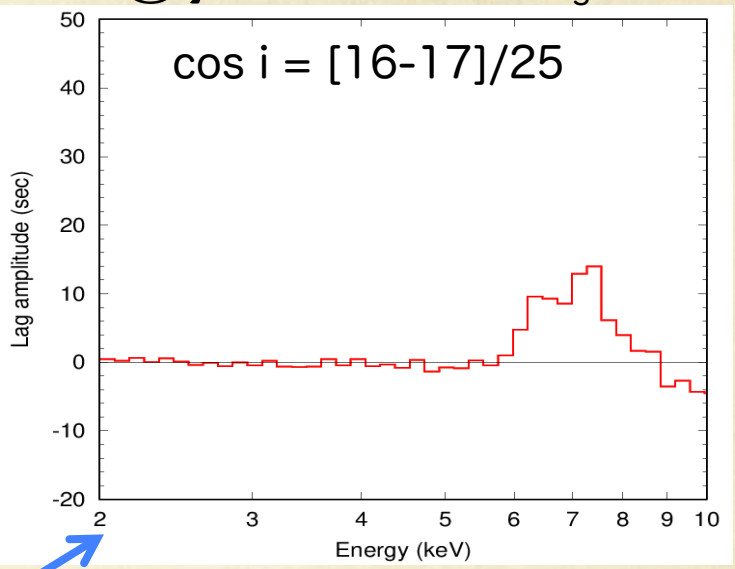


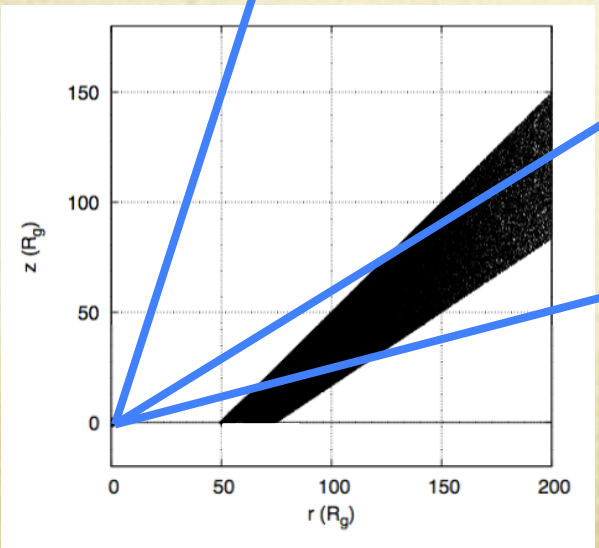


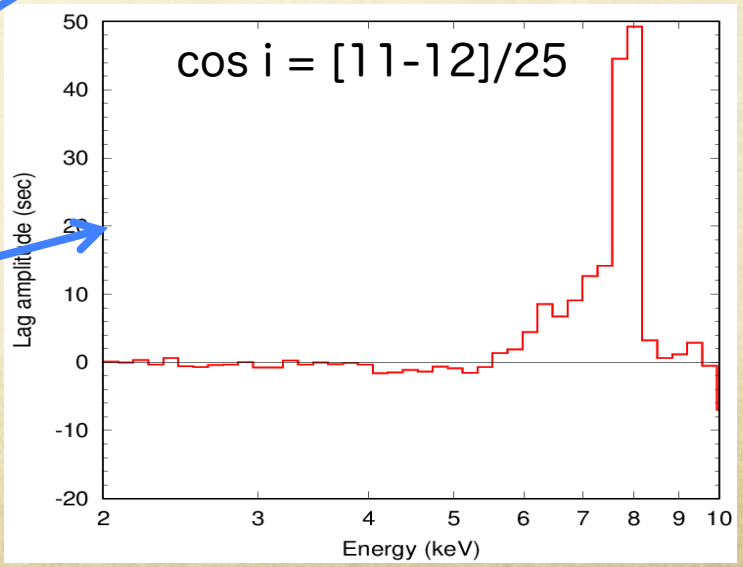
2. Monte-Carlo simulation

Lag vs energy ($f=c/250R_g$-$c/100R_g$)



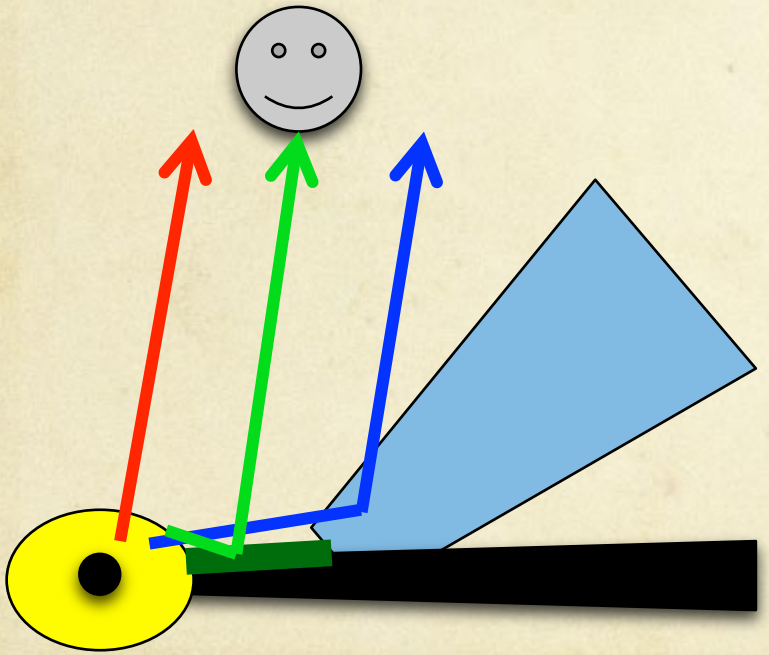




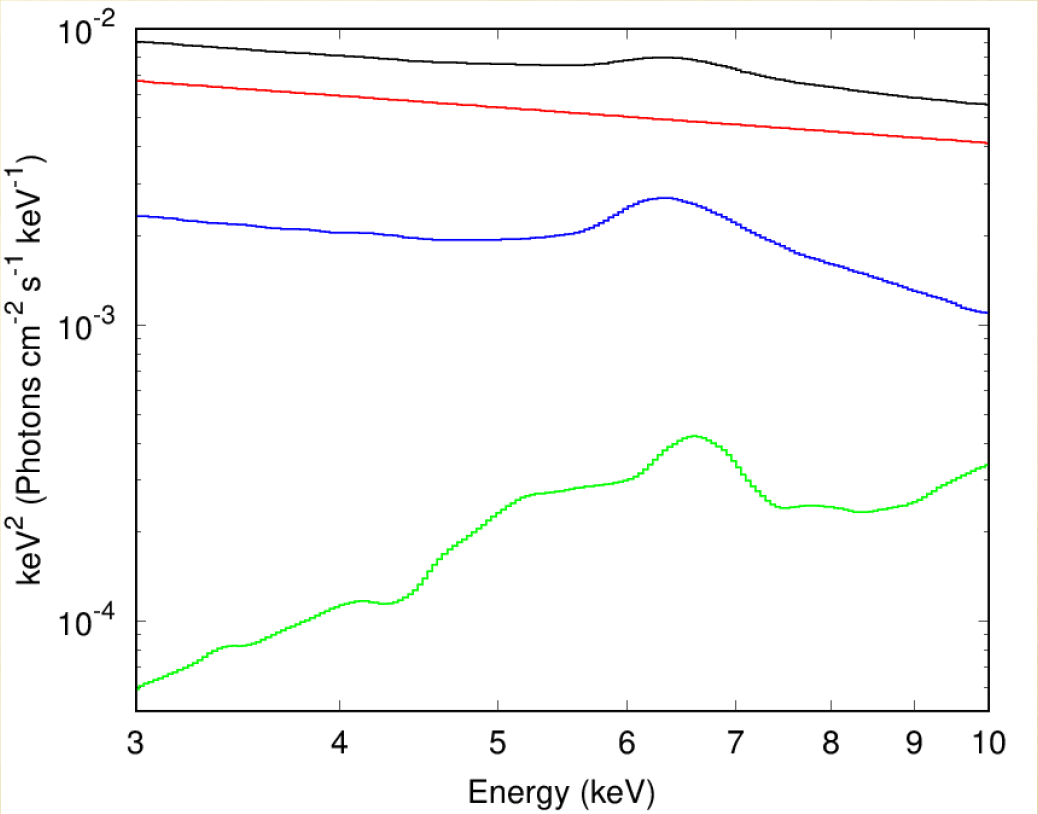


Disc reflection

Corona size: $5R_g$
Disc radius: $10R_g$-$50R_g$



Energy spectrum



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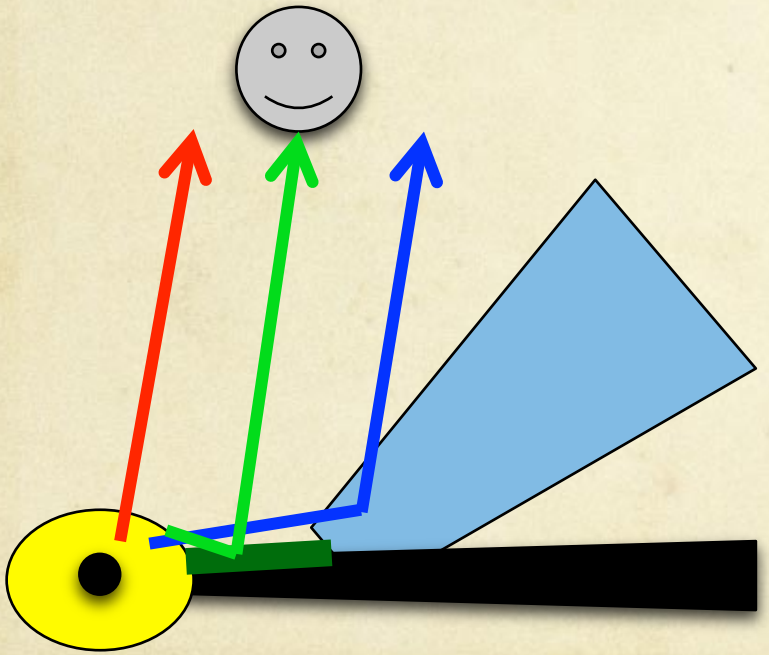
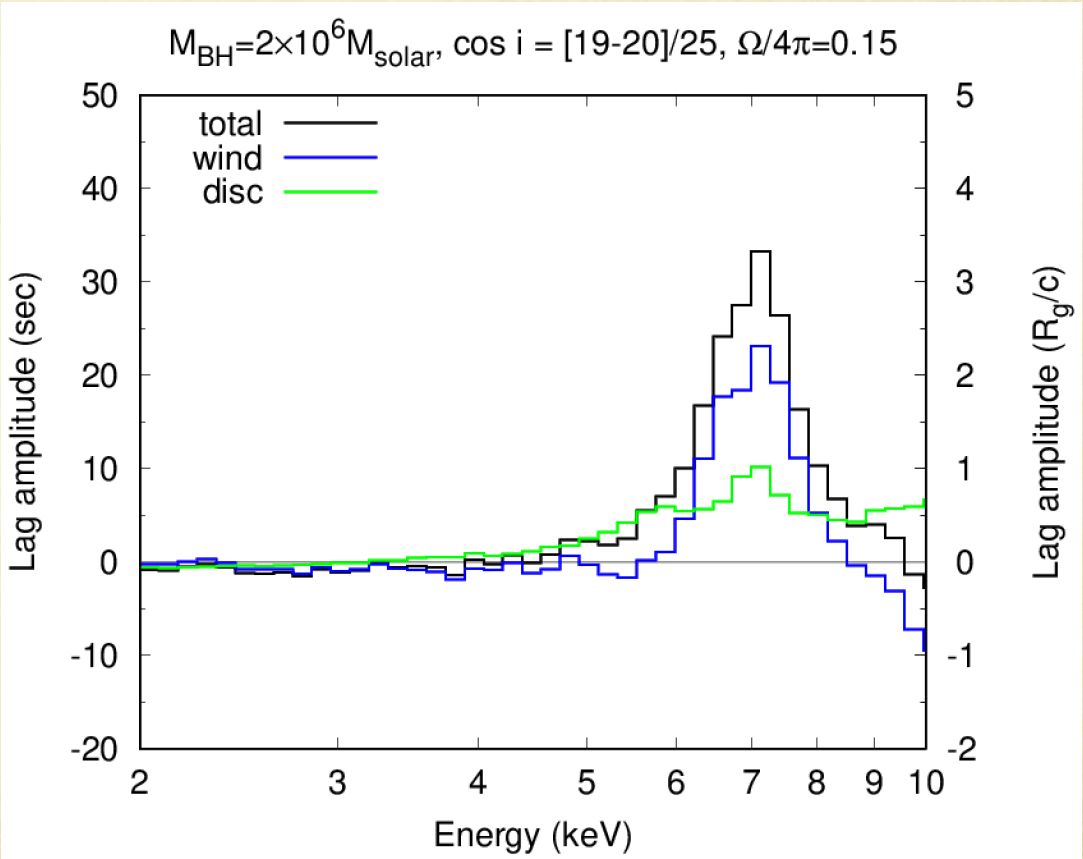


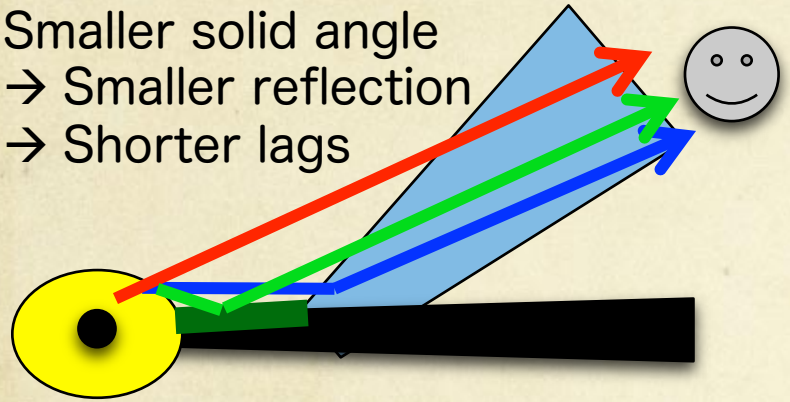
Lag vs energy



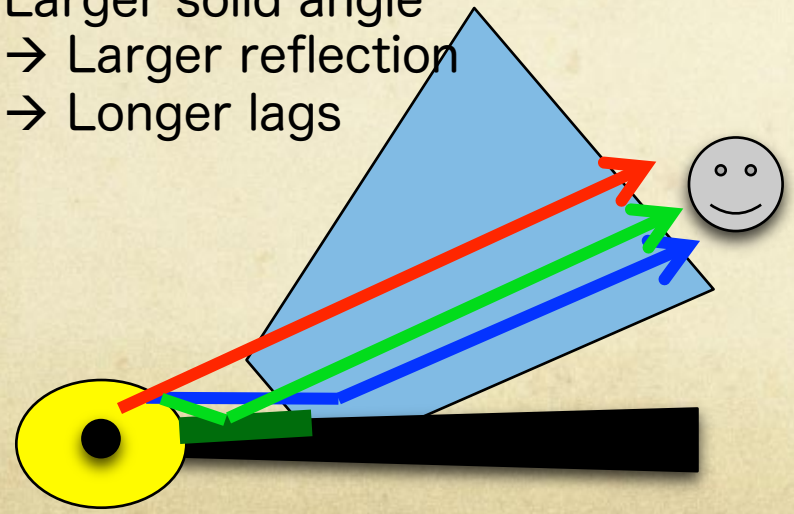
(freq=c/250R_g-c/100R_g)

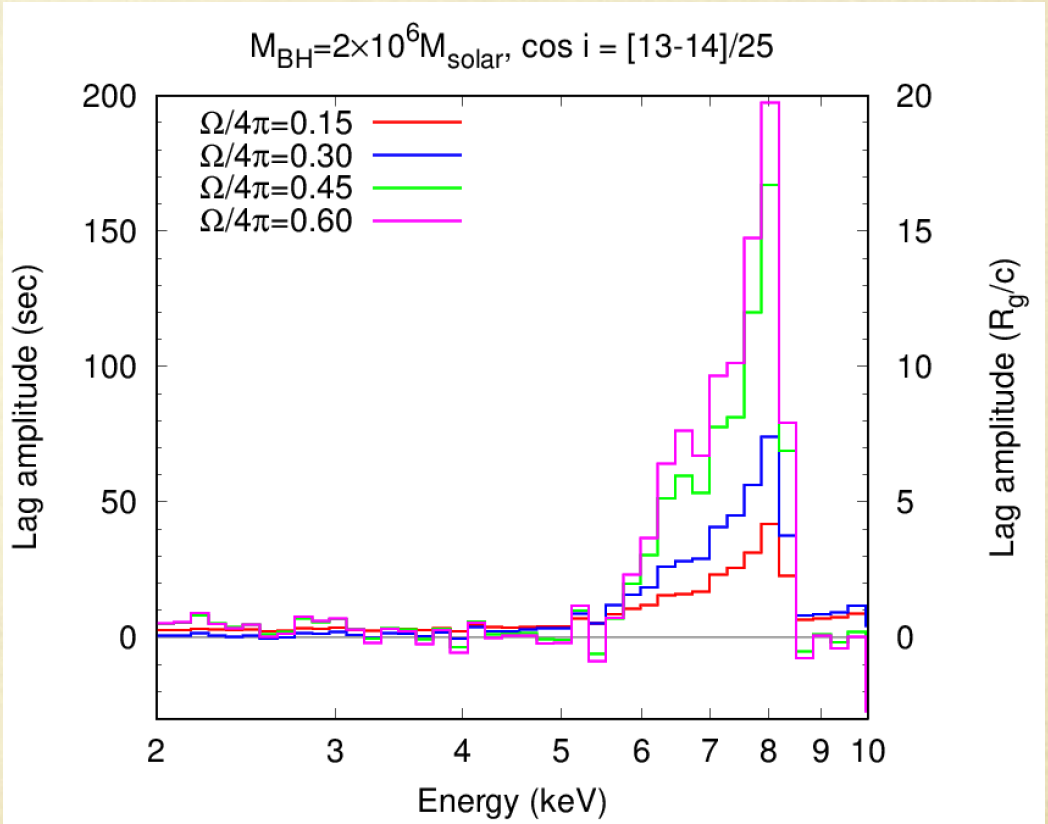
Solid angles of the wind

Smaller solid angle
→ Smaller reflection
→ Shorter lags



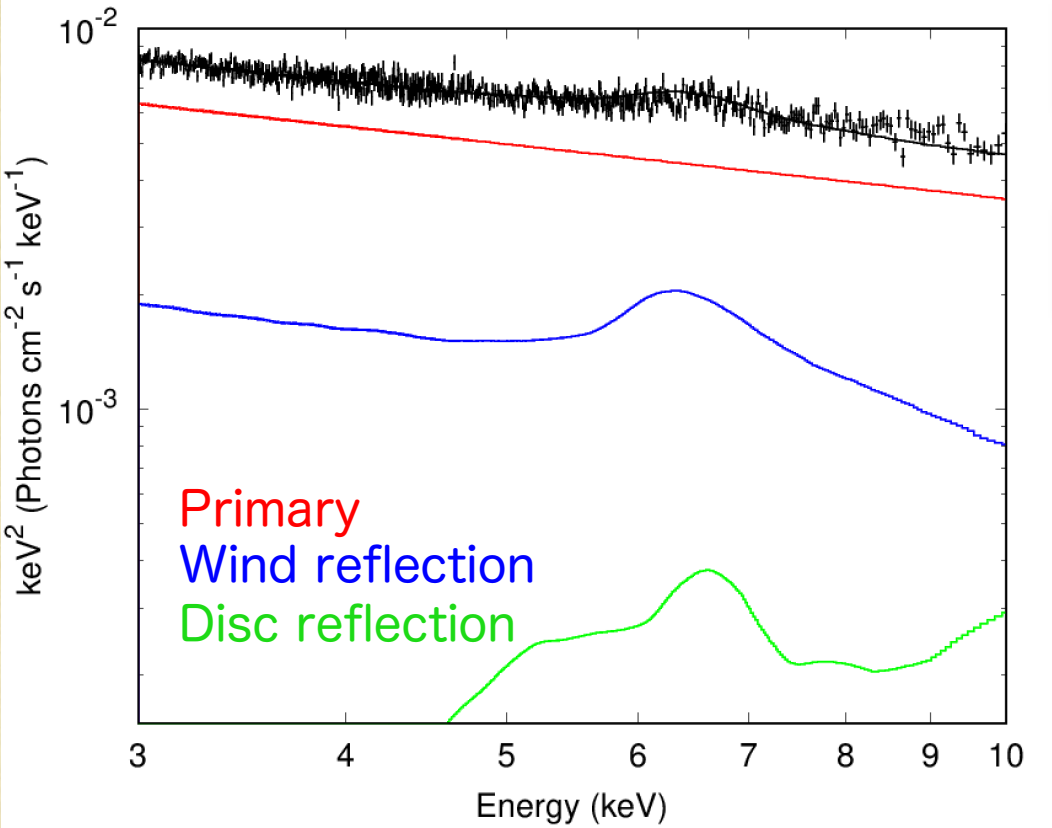
Larger solid angle
→ Larger reflection
→ Longer lags





(freq=c/250R_g-c/100R_g)

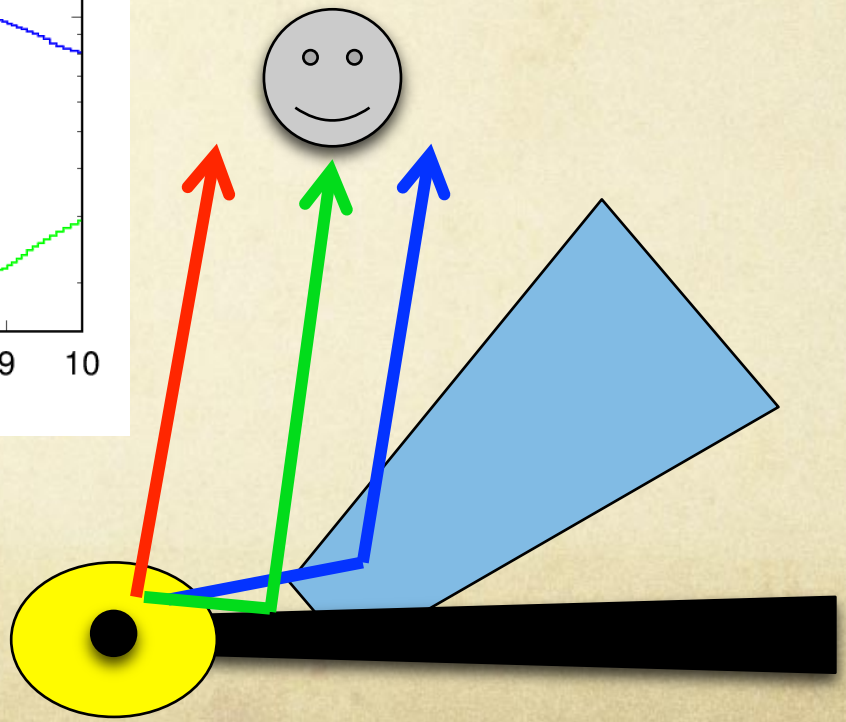
Ark 564



No absorption → face-on

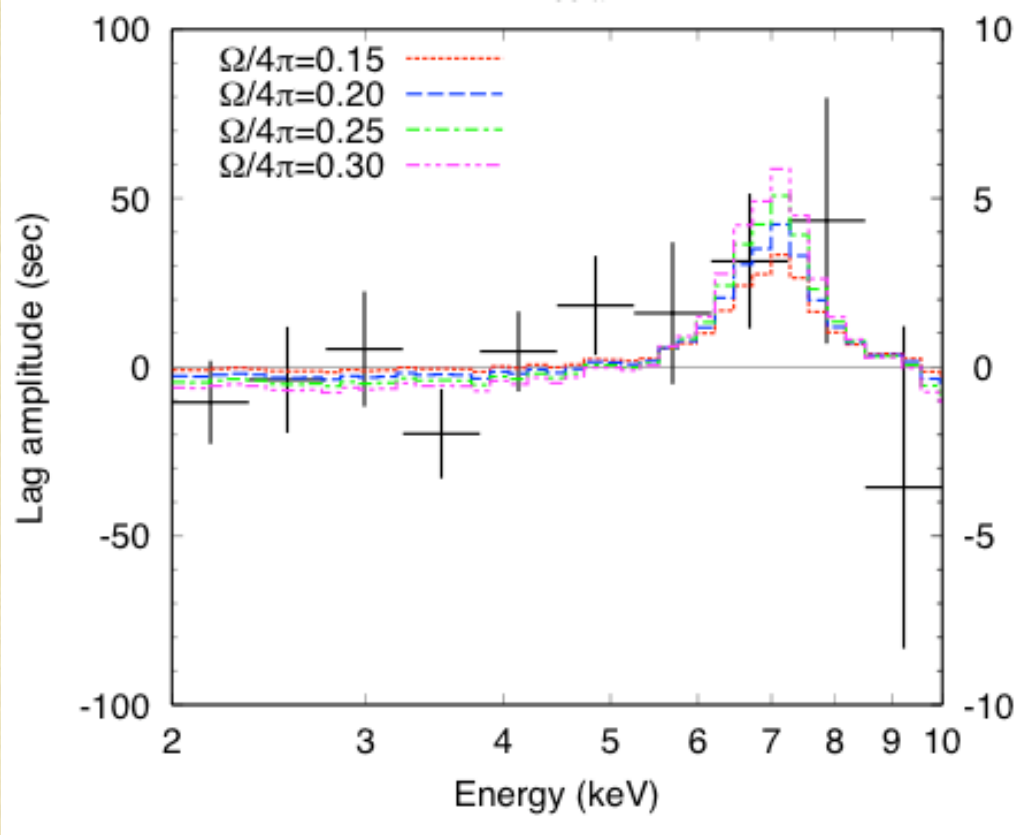
Moderate wind reflection

$\Omega/4\pi \sim 0.15$



3. Discussion

Ark 564

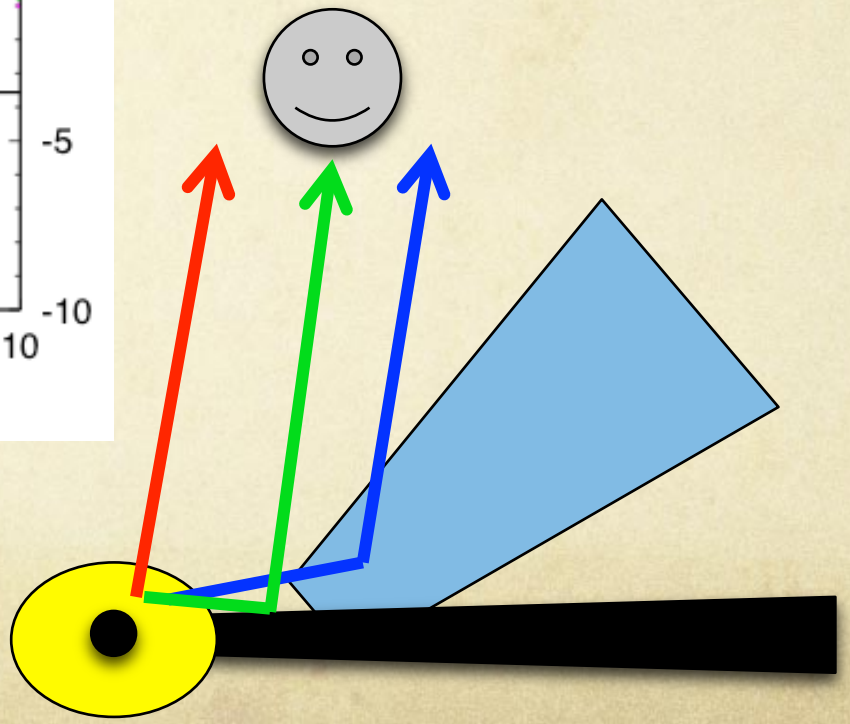


(f=c/250R_g-c/100R_g)

No absorption → face-on

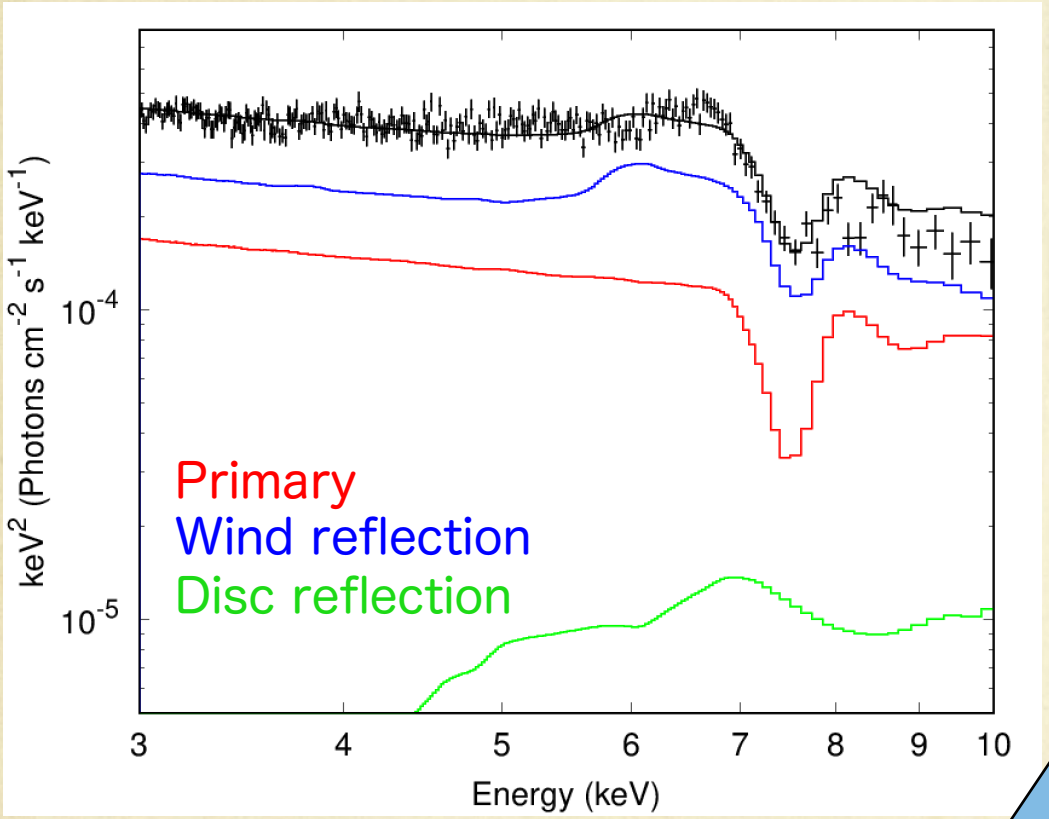
Moderate wind reflection

Ω/4π~0.15



3. Discussion

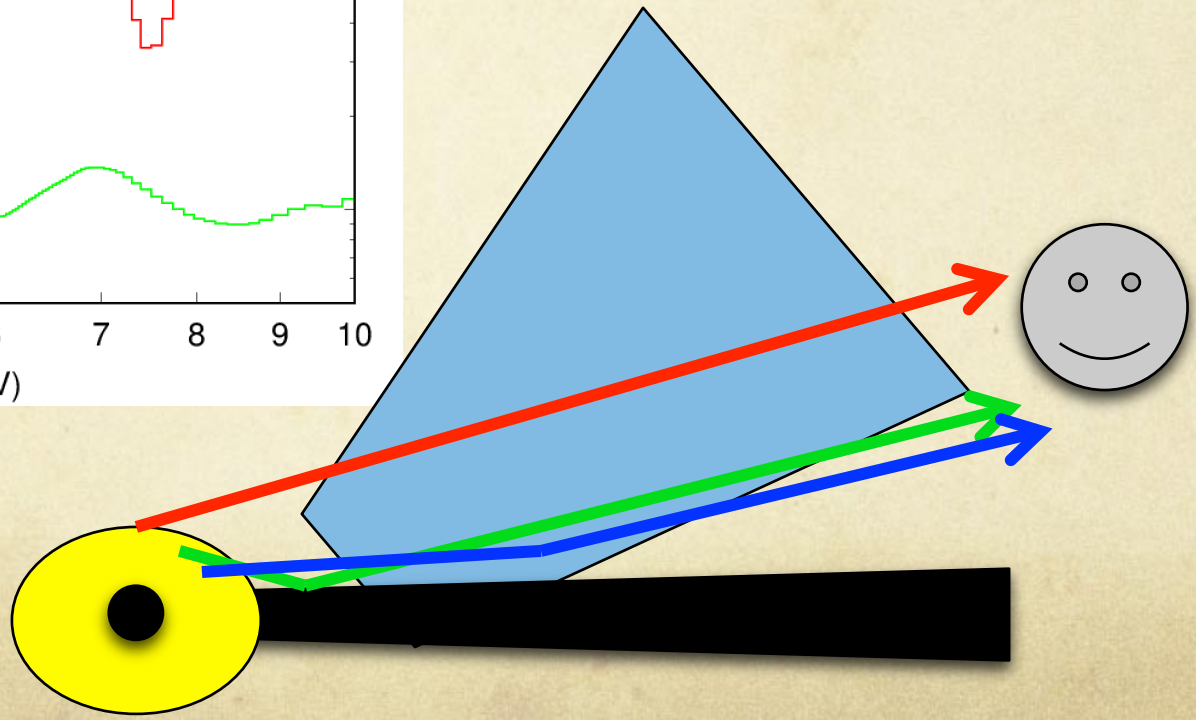
1H0707-495



Absorption → edge-on

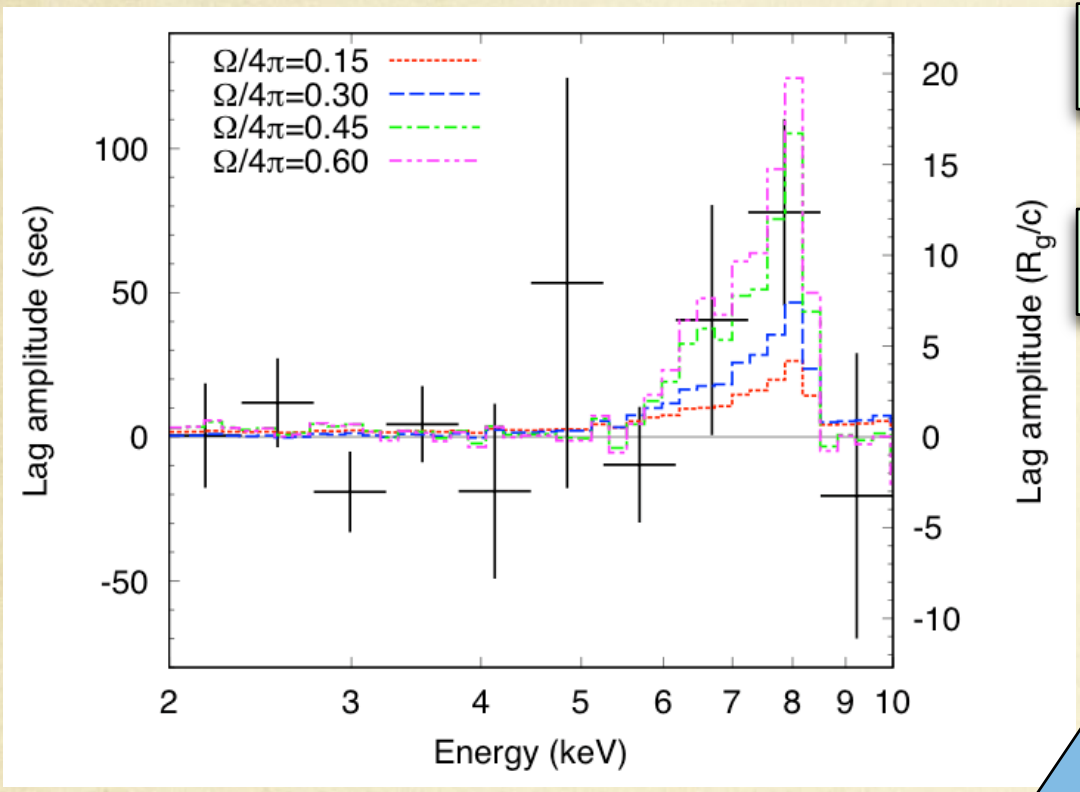
Strong wind reflection

$\Omega/4\pi \sim 0.6$



3. Discussion

1H0707-495

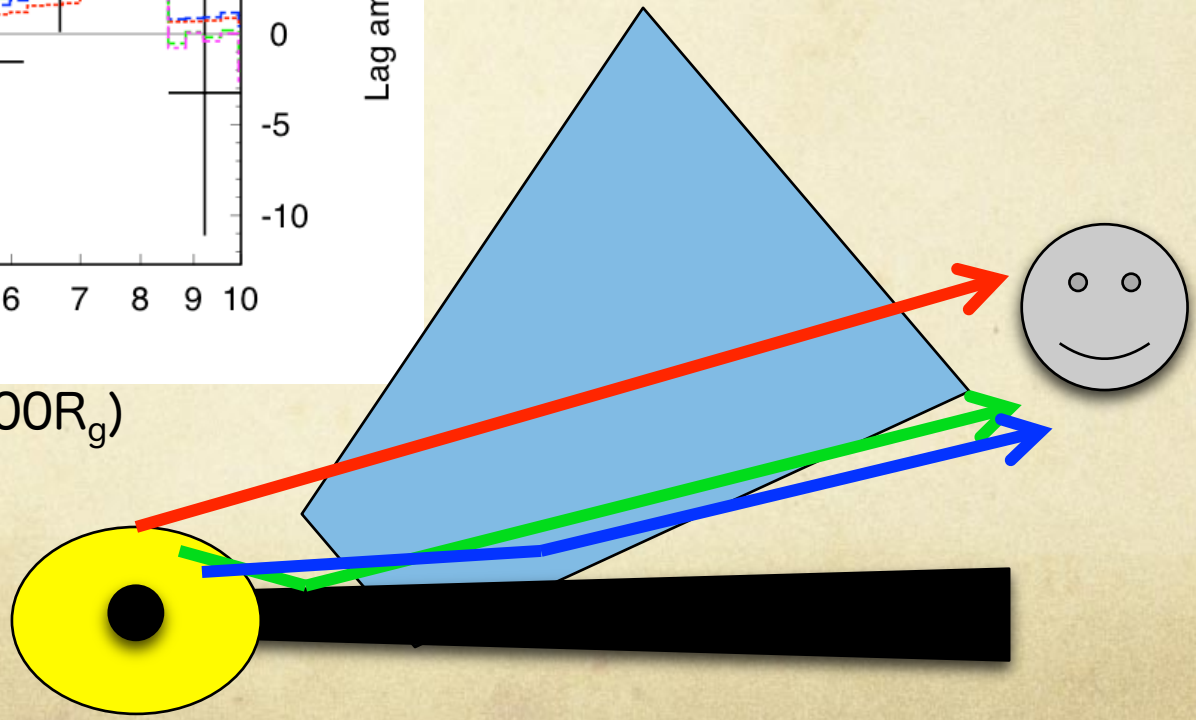


(f=c/250R_g-c/100R_g)

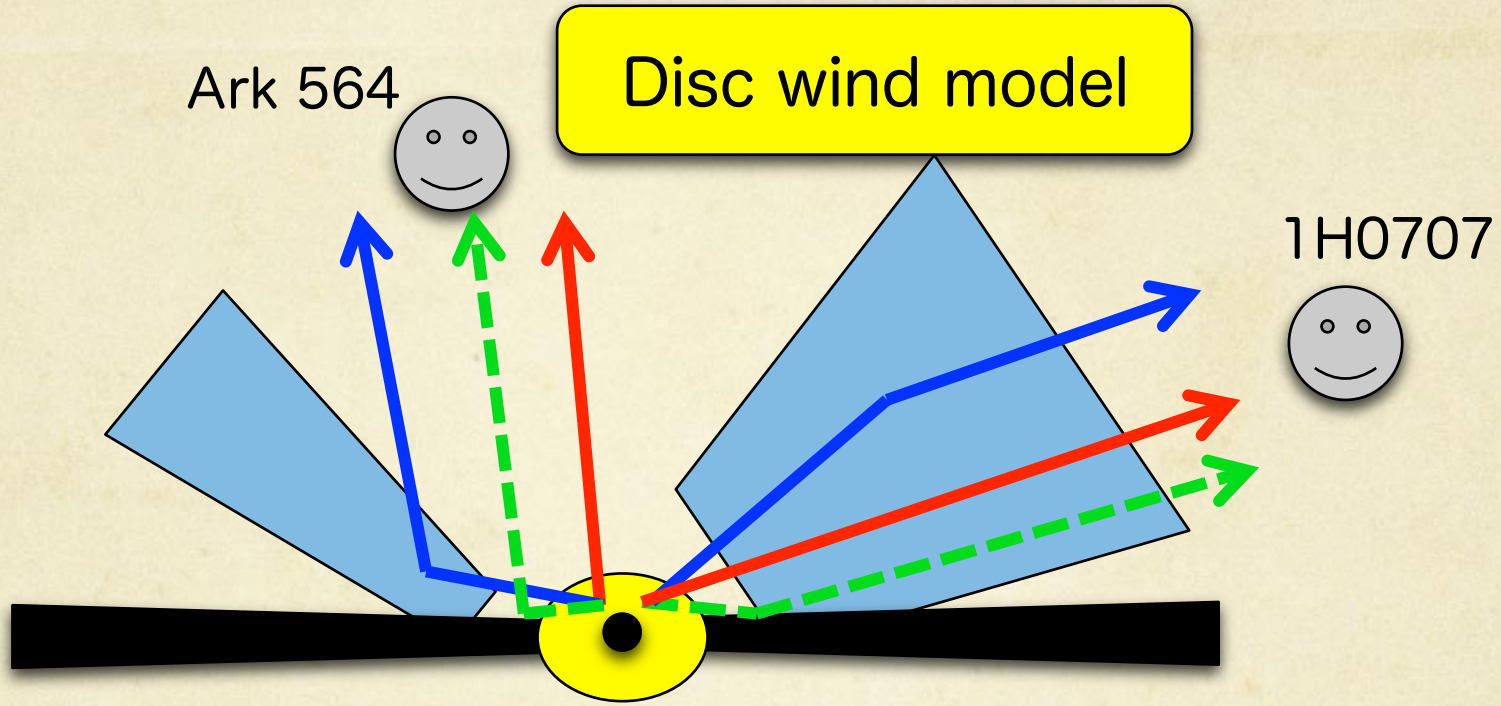
Absorption → edge-on

Strong wind reflection

Ω/4π~0.6



Conclusion



- X-ray reverberation lags in the Fe-K line can be explained by AGN winds.
- We can access winds “out of the line-of-sight”
  → can constrain solid angles

Please check our latest paper, arXiv:1805.00046

Thank you for your attention!