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AGN winds on the Georgia Coast

X-ray short time lags in the Fe-K band produced by disk winds in AGN

Misaki Mizumoto (JAXA/ISAS)

Collaborators: Chris Done[1], Kouichi Hagino[2], Ken Ebisawa[3], Masahiro Tsujimoto[3]

1: Univ. of Durham, 2: Tokyo Univ. of Sci., 3: JAXA/ISAS

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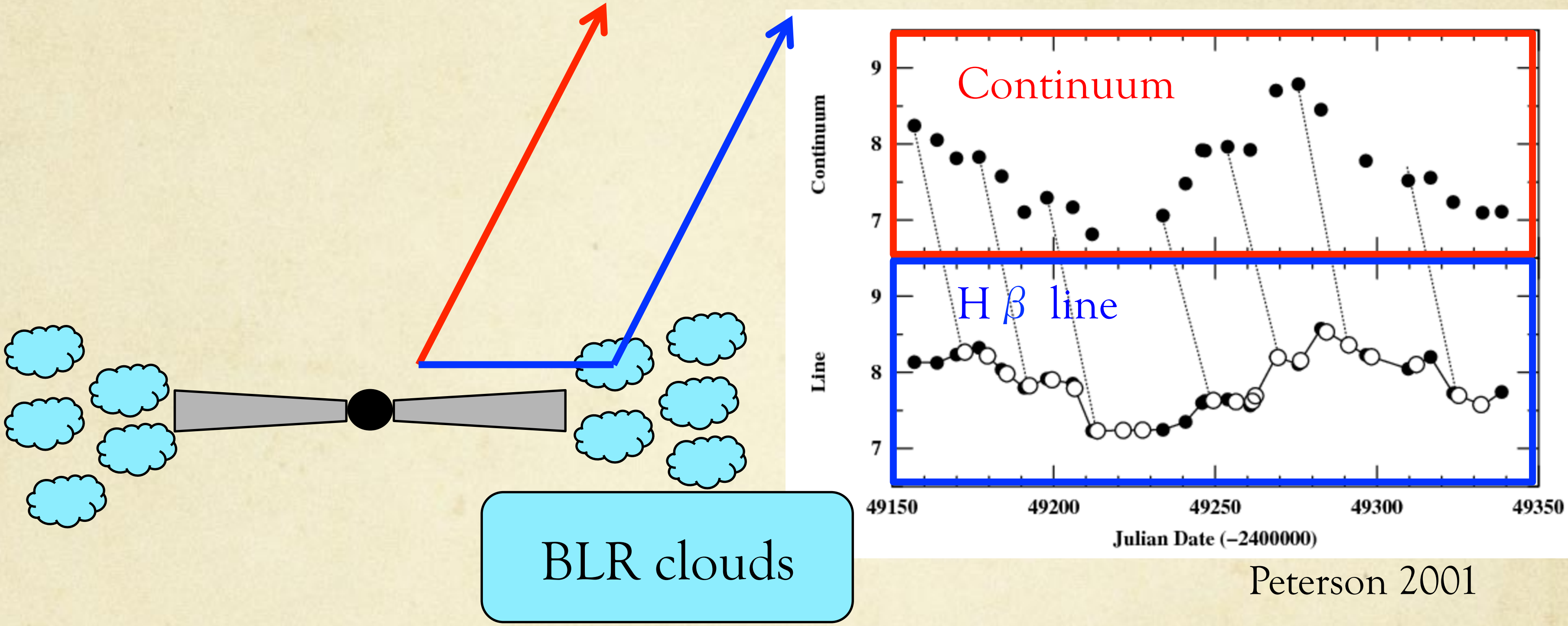
(Optical) reverberation mapping

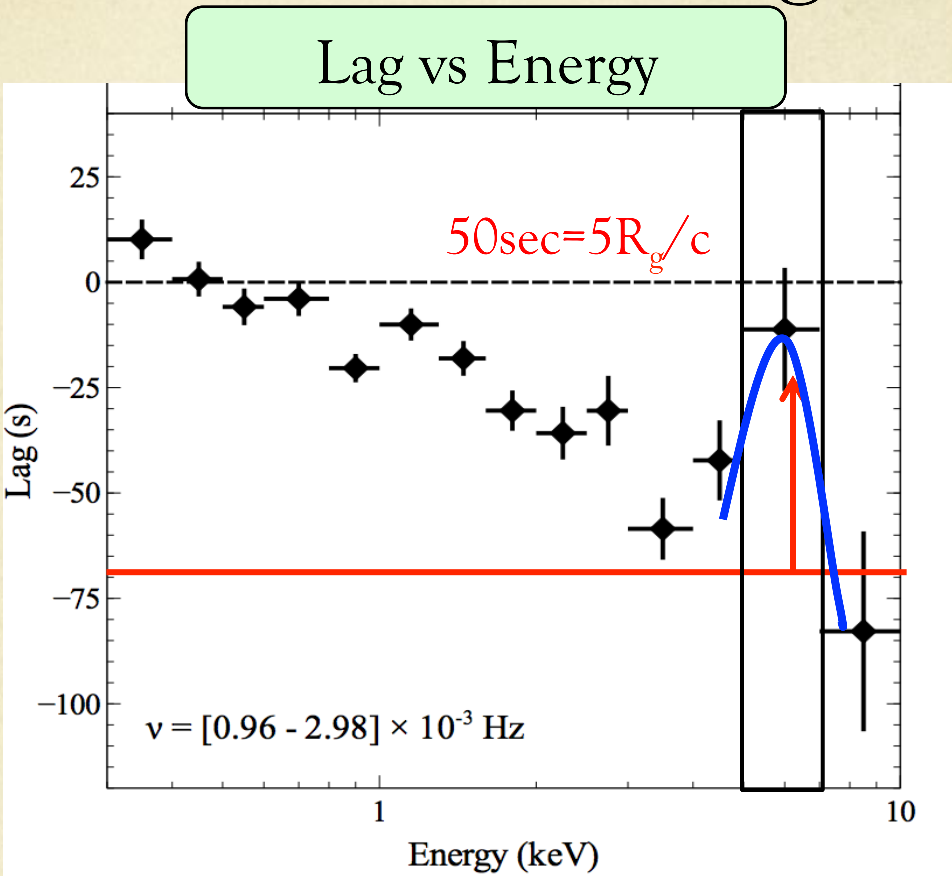


Peterson 2001

~10 light-days ($M_{BH}=10^7 M_{solar}$)

Reverberation lag is a key tool to investigate geometry around SMBH.

X-ray reverberation lags (Fe-K)

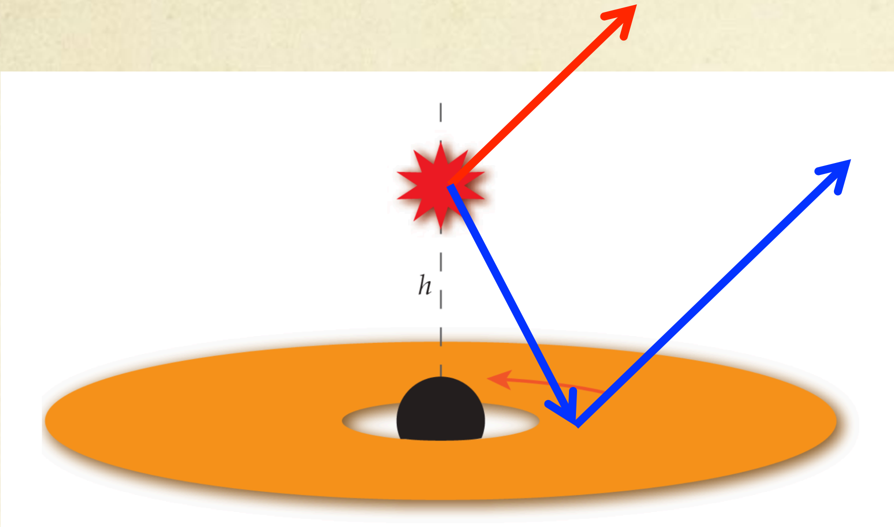


1H 0707-495 (Kara+13)

1. Lag amplitude: several R_g/c
2. Frequency: several × 10^{-3} Hz ($M_{BH}=10^6 M_{solar}$)
   several × 10^{-4} Hz ($M_{BH}=10^7 M_{solar}$)
3. Fe-K lag profile: broad feature (5-7 keV)

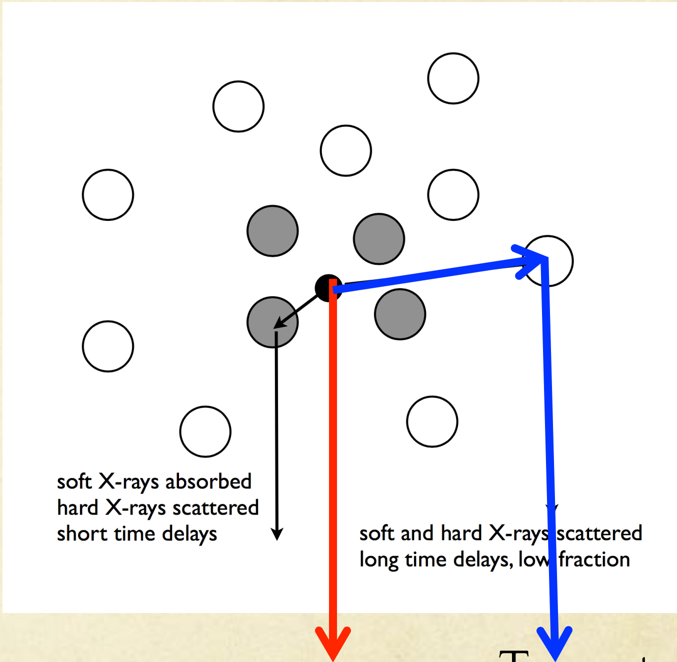
Interpretation

Disk reflection



Wilkins+16

Cloud reflection



Turner+ preprint

The scattered component lags behind the primary component.

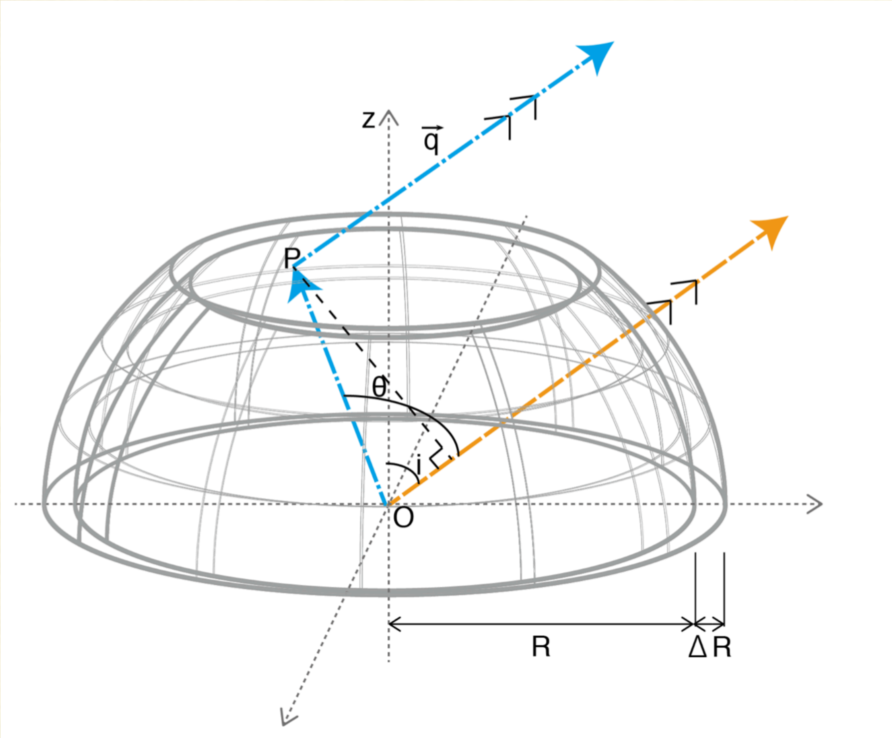
Motivation

- We focus on **Cloud reflection.**
- **Disk winds** can make X-ray reverberation lags.
- Explain the observed X-ray lags with disk winds
  1. Lag amplitude: several R_g
  2. Frequency: several × 10^{-4} Hz (@$M_{BH}=10^7 M_{solar}$)
  3. Fe-K lag profile: broad feature (5-7 keV)

Method

- Monte-Carlo simulations (using MONACO; Odaka+11)
- As a first step, a part of a spherical shell is assumed.

Setting (static)



- Input spectra: power-law with Γ=1.6
- Inclination: 7/15 < cos*i* < 8/15

- A static, smooth, and neutral shell
- Shell thickness (ΔR) = R/10
- $R=100R_g$ ($M_{BH}=10^7M_{solar}$) =5000 light-sec
- $N_H=2x10^{23}$ cm^{-2}

Each photon has information on

1. coordinate and time at the last time when it interacts with the cloud
2. velocity vector with which it moves toward the observer

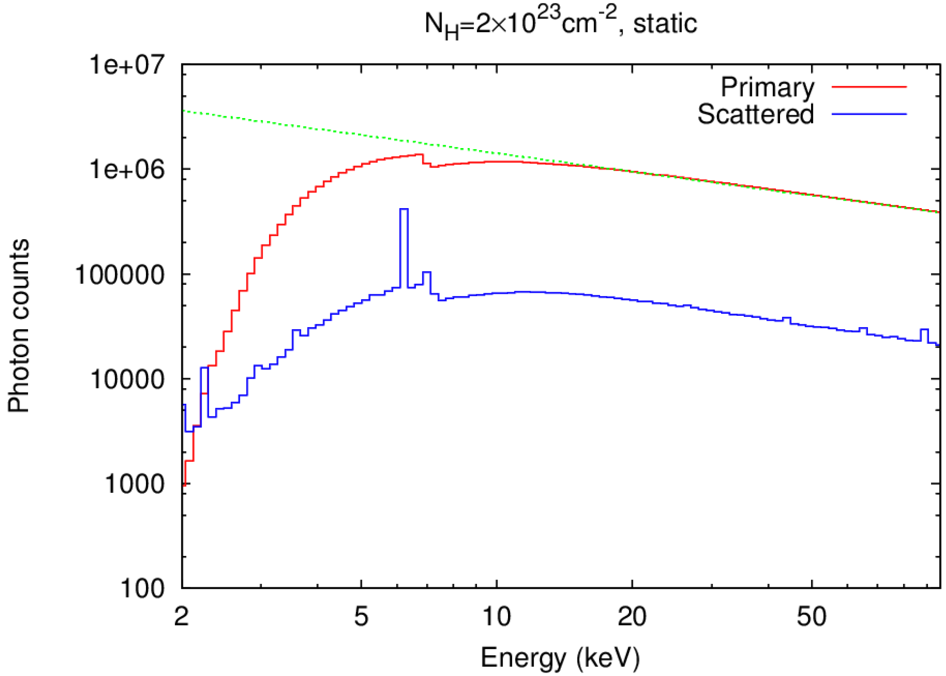
Lag calculation

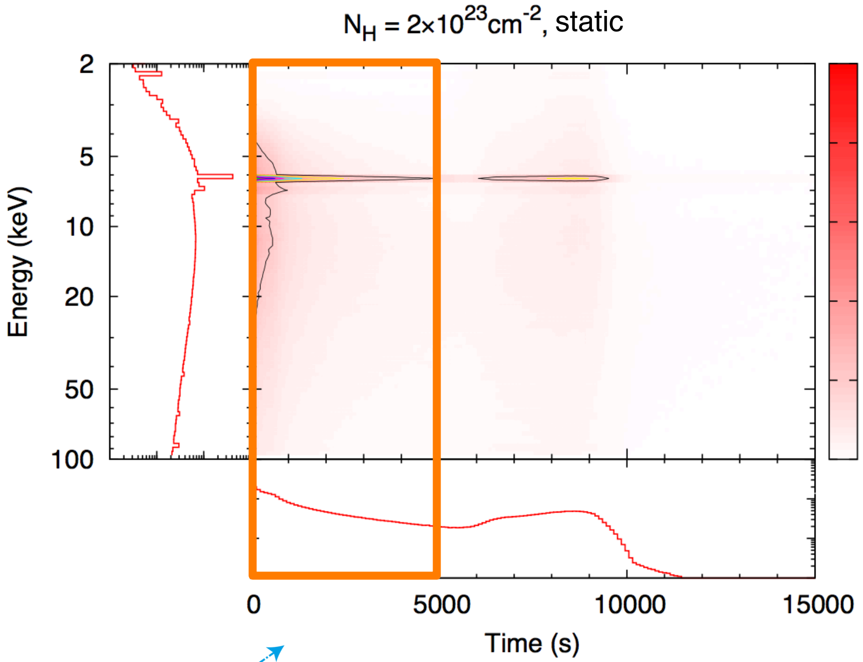
1. Compute model light curves assuming intrinsic X-ray flux variations of the central corona
   - PSD without any typical frequency
2. Definition: Phase difference of two light curves
   - Light curves in the soft/hard band: s(t)/h(t)
   - Fourier transformation of s(t)/h(t) → S(f)/H(f)
   - $C(f)=\langle S^*(f)H(f)\rangle$
   - Lag amplitude: $\tau(f)=\arg[C(f)]/2\pi f$

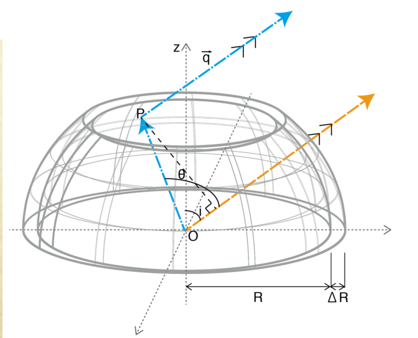
Results (static) #1

Energy spectra

2D transfer function





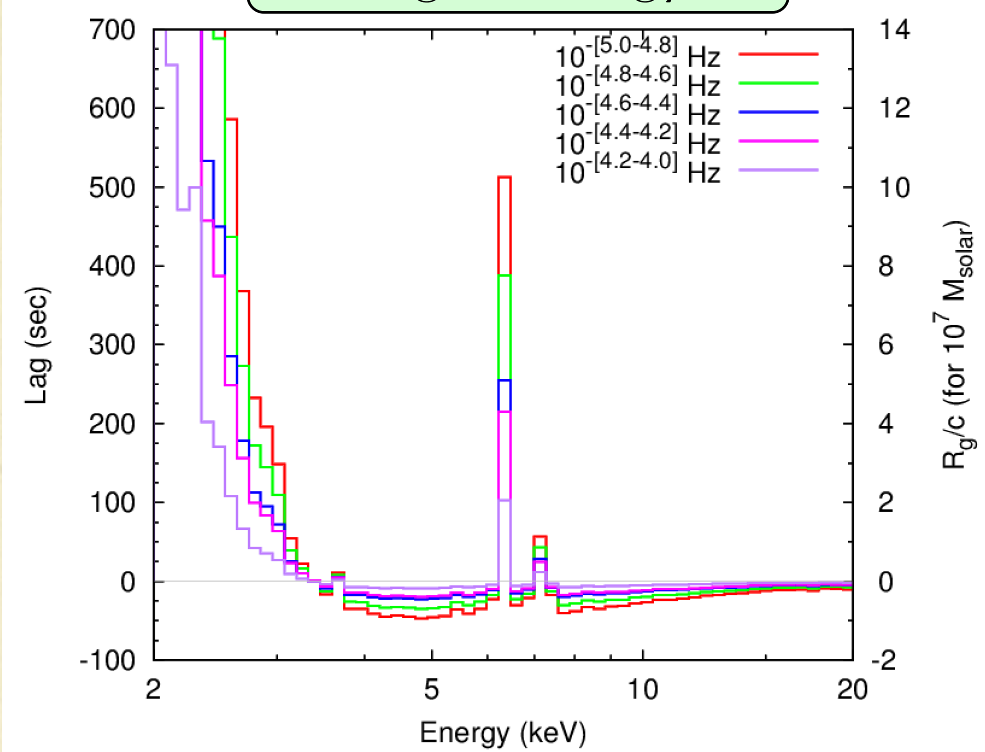


R=5000 light-sec

the weighted average lag time
(including primary photons)
=220s

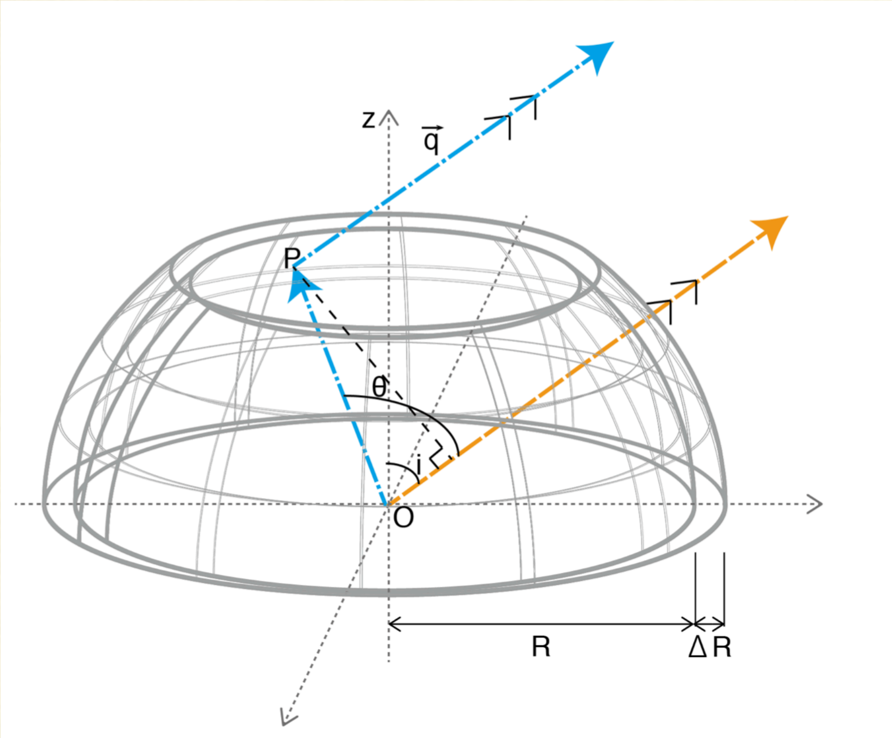
Results (static) #2

Lag vs energy



1. Lag amplitude: several R_g/c
2. Frequency: several × 10^{-4} Hz ($M_{BH}=10^7\ M_{solar}$)
3. Fe-K lag profile: broad feature (5-7 keV)

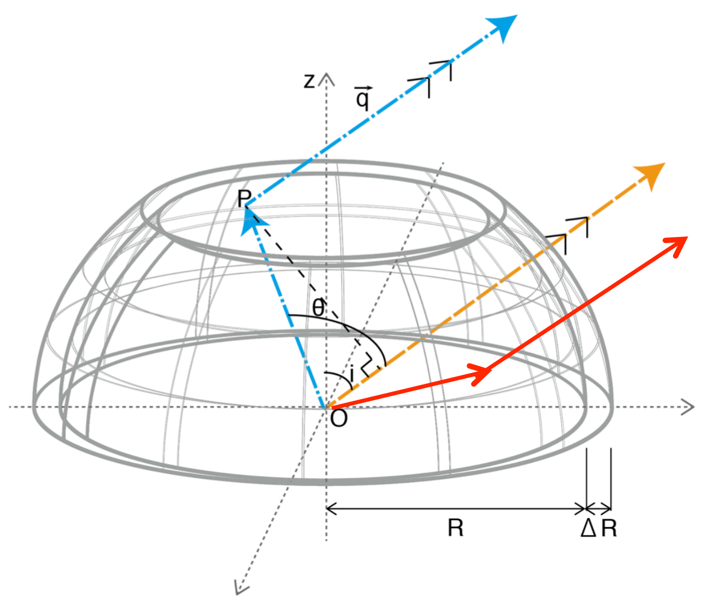
Setting (outflowing)

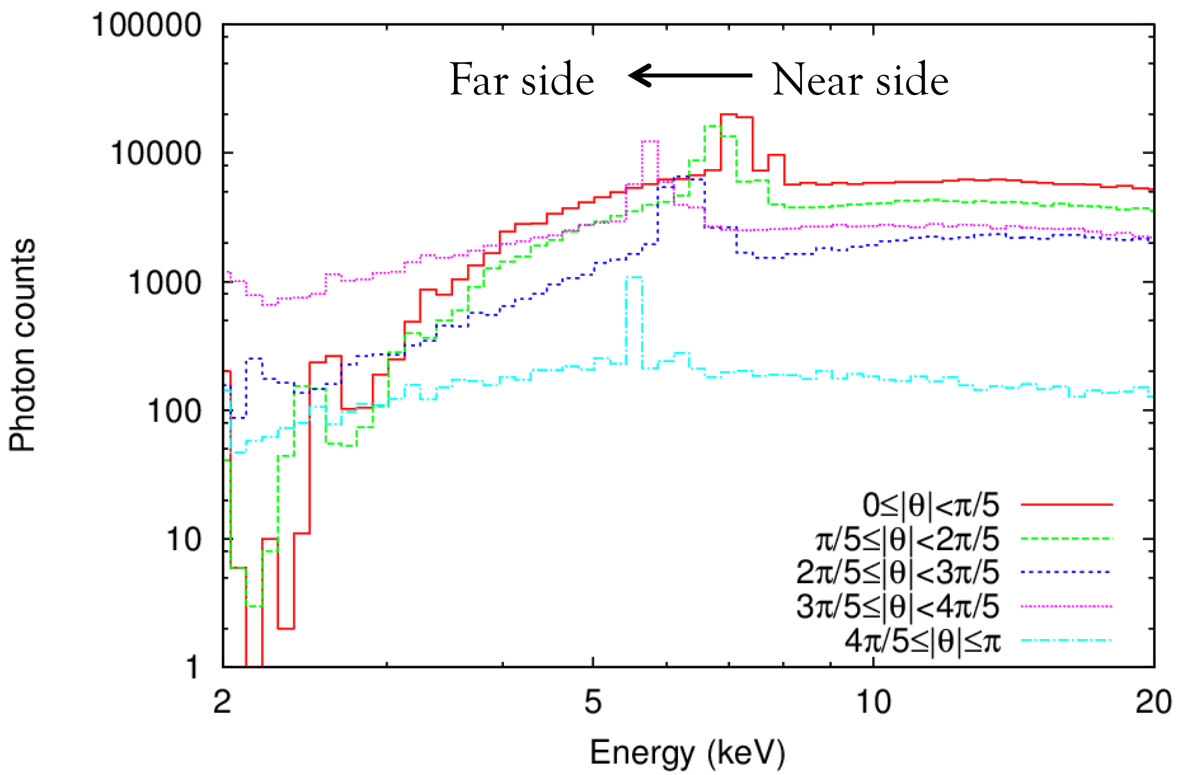


- An outflowing, smooth, and neutral shell
- Shell thickness (ΔR) = R/10
- $R=100R_g$ ($M_{BH}=10^7 M_{solar}$) $=5000$ light-sec
- $N_H=2\times10^{23}$ cm^{-2}
- Velocity=0.14c

- Input spectra: power-law with $\Gamma=1.6$
- Inclination: $7/15 < \cos i < 8/15$

Doppler broadening

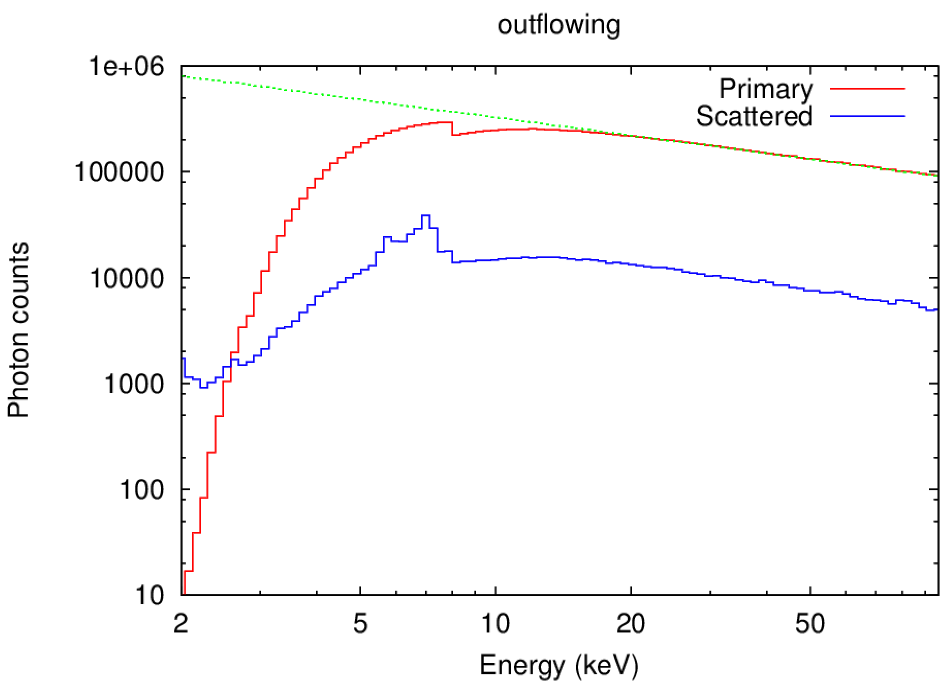


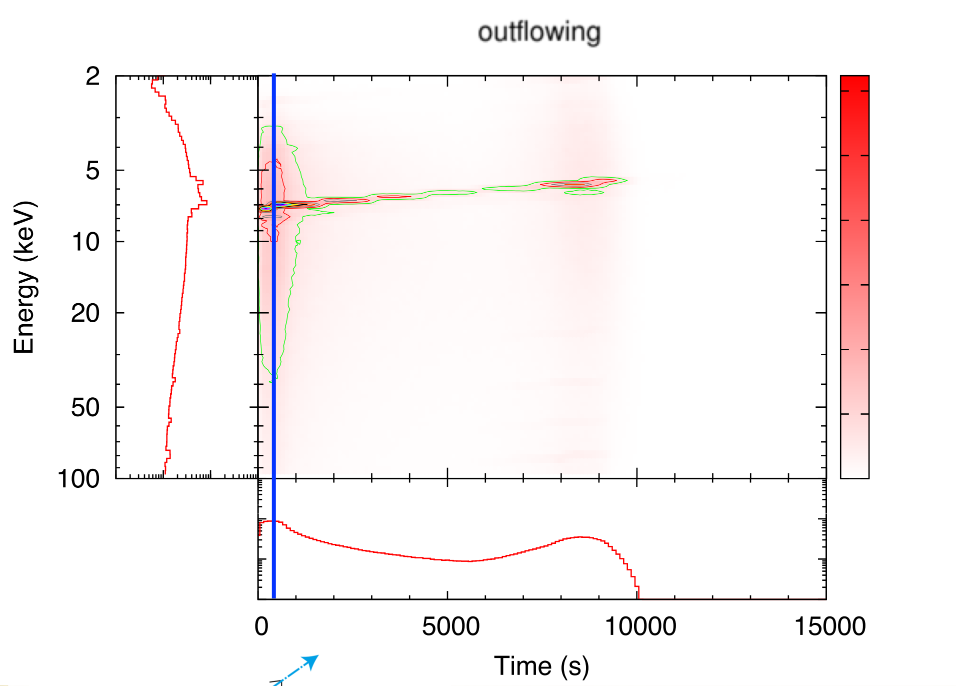


Results (outflowing) #1

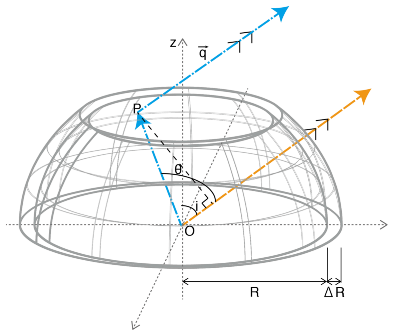
Energy spectra

2D transfer function



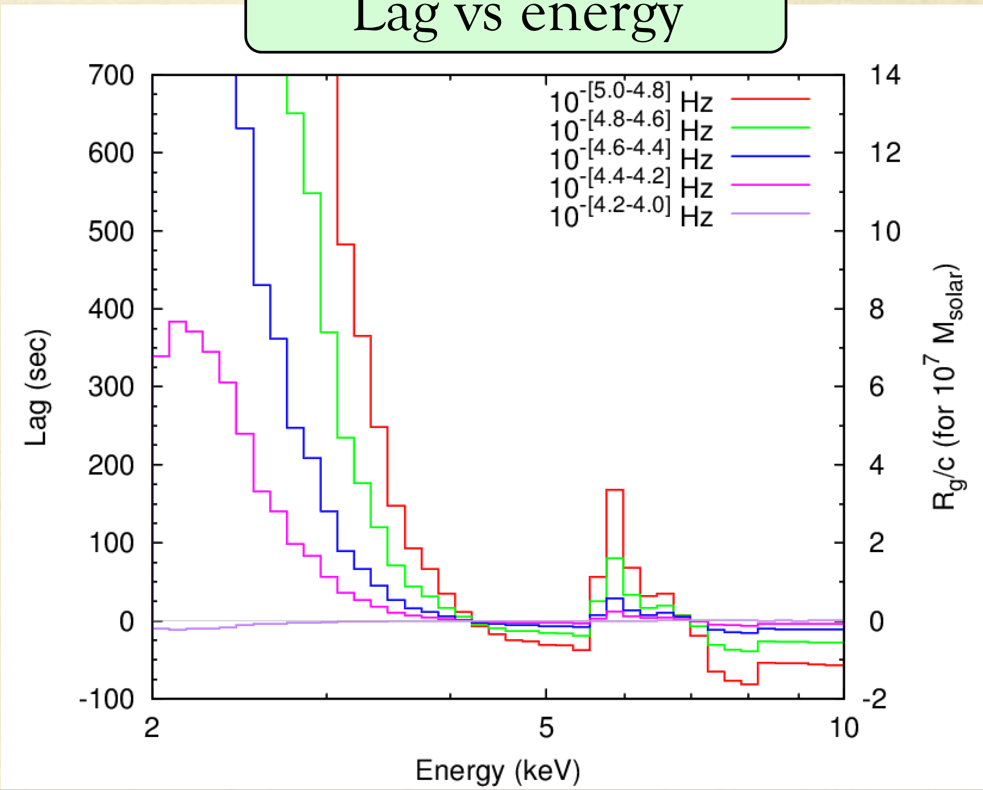


the weighted average lag time
(including primary photons)
=210s



Results (outflowing) #2

Lag vs energy

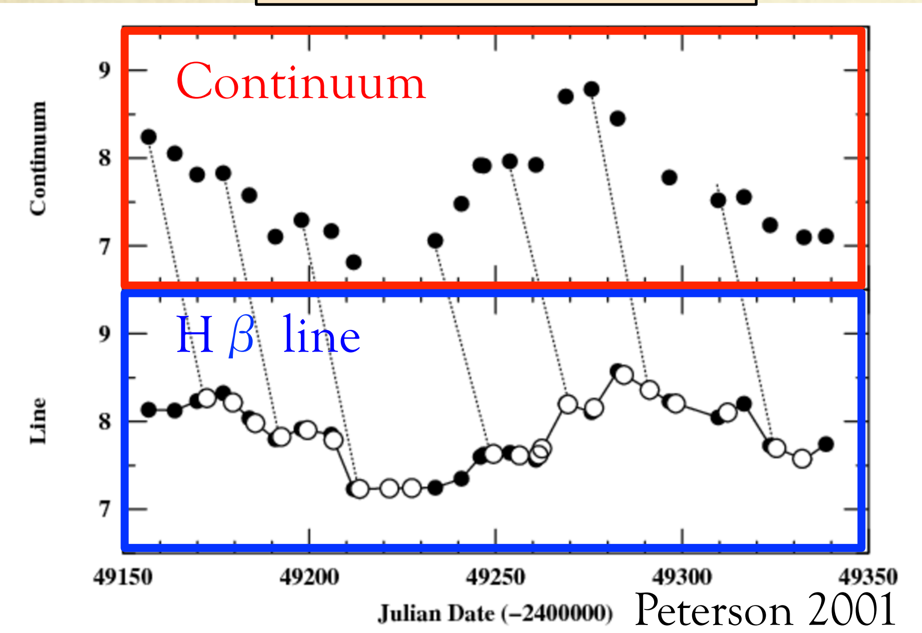


1. Lag amplitude: several R_g/c
2. Frequency: several × 10^{-4} Hz ($M_{BH}=10^7$ M_{solar})
3. Fe-K lag profile: broad feature (5-7 keV)

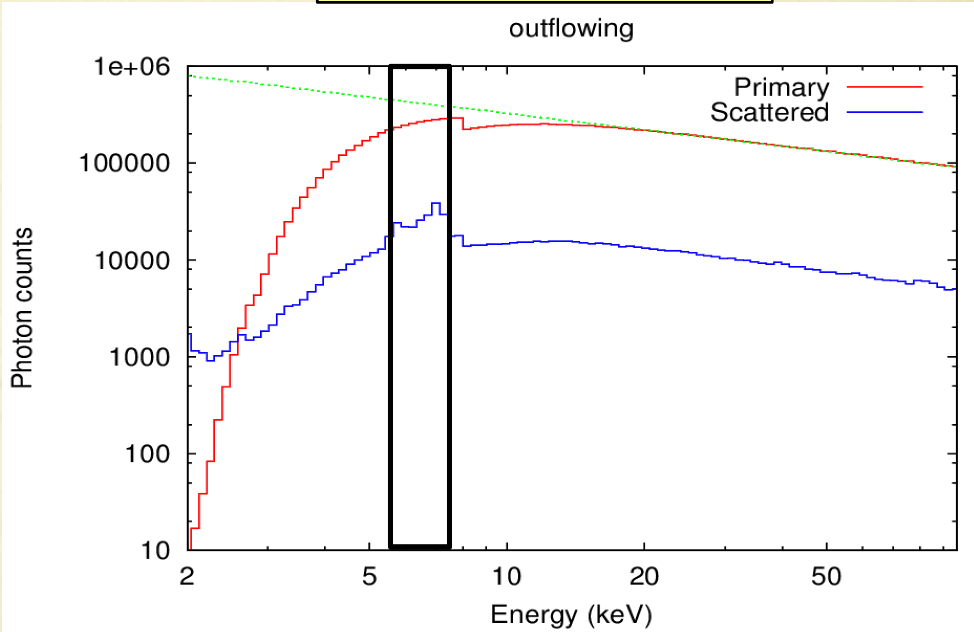
Why short lags in a distant cloud?

Dilution effect
(L. Miller+10a)

Optical



X-ray



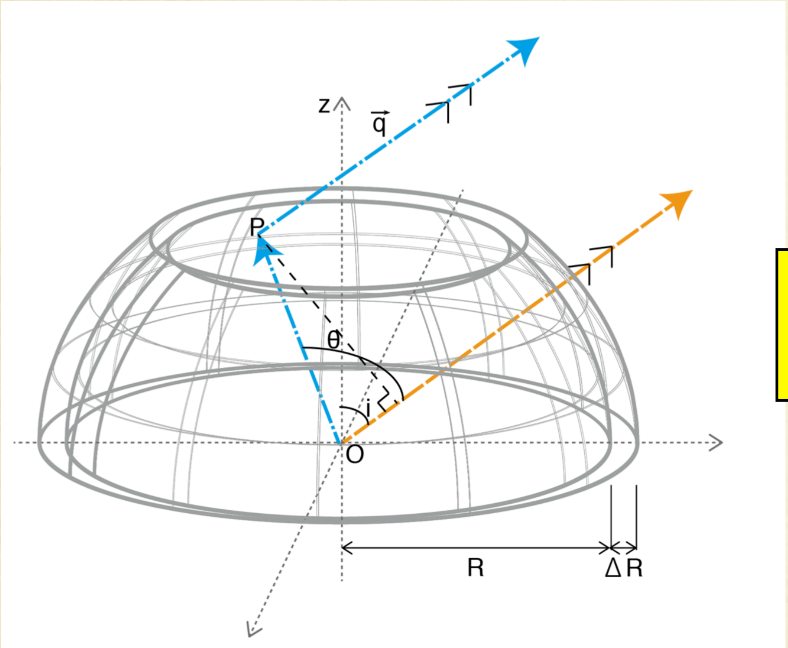
The two components can be perfectly distinguished.

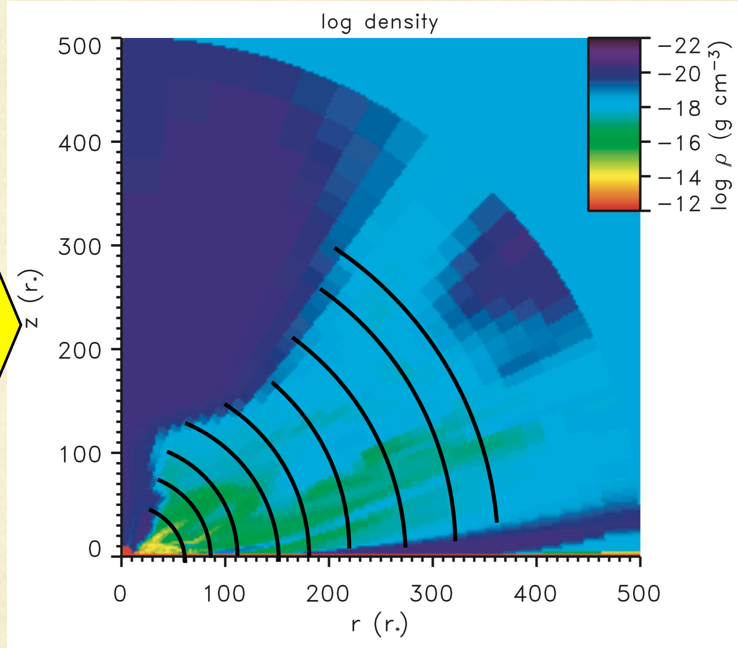
Both components share the same energy band.

Lags on disk winds

This work

Disk winds





Proga & Kallman 04

Disk winds can also make short-time X-ray lags.

Conclusion

- Outflowing clouds can produce X-ray reverberation lags.
  1. Lag amplitude: several Rg
  2. Frequency: several x 10^{-4} Hz ($M_{BH}=10^7 M_{solar}$)
  3. Fe-K lag profile: broad feature (5-7 keV)

- A disk wind is the plausible mechanism to produce X-ray reverberation lags.

- Future work
  1. Simulation based on realistic disk-wind geometry
  2. Physical picture to explain other observational features
     - e.g., energy spectra, root-mean-square spectra
  3. X-ray reverberation mapping of disk winds
     - Constrain location of disk winds