A Novel View of AGN Accretion Flows Revealed by X-ray & Optical Monitoring

Noda *et al*. (2016), *ApJ* 828, id 78

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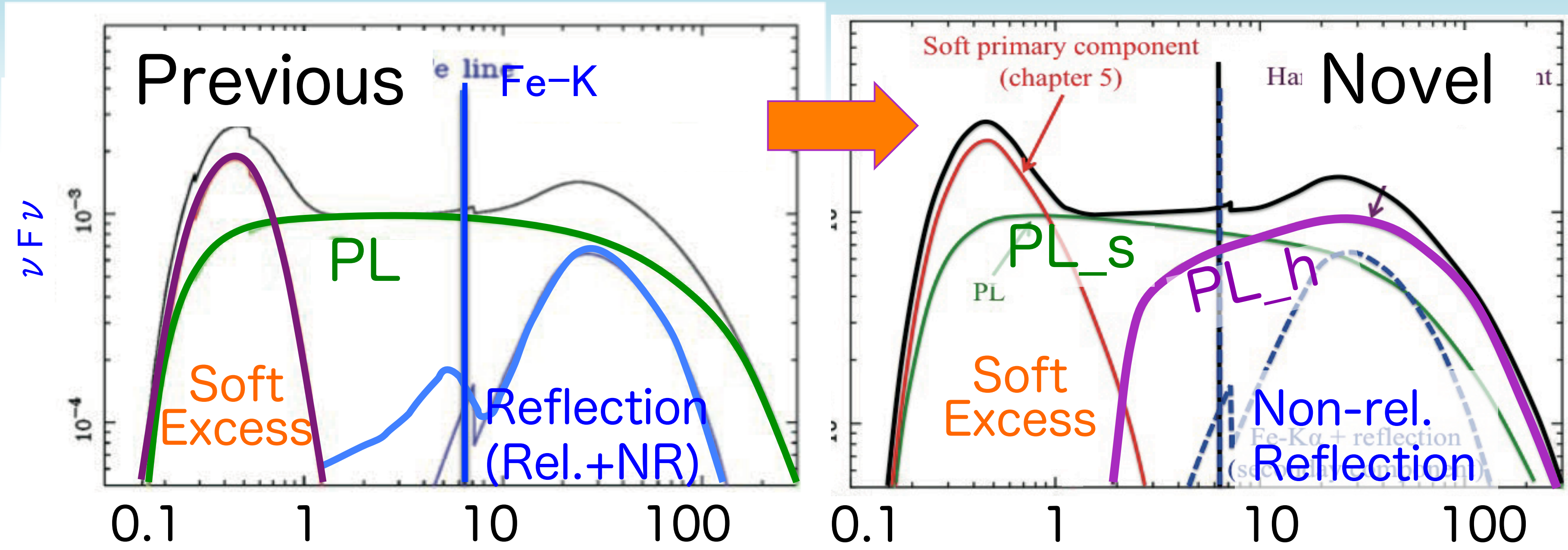
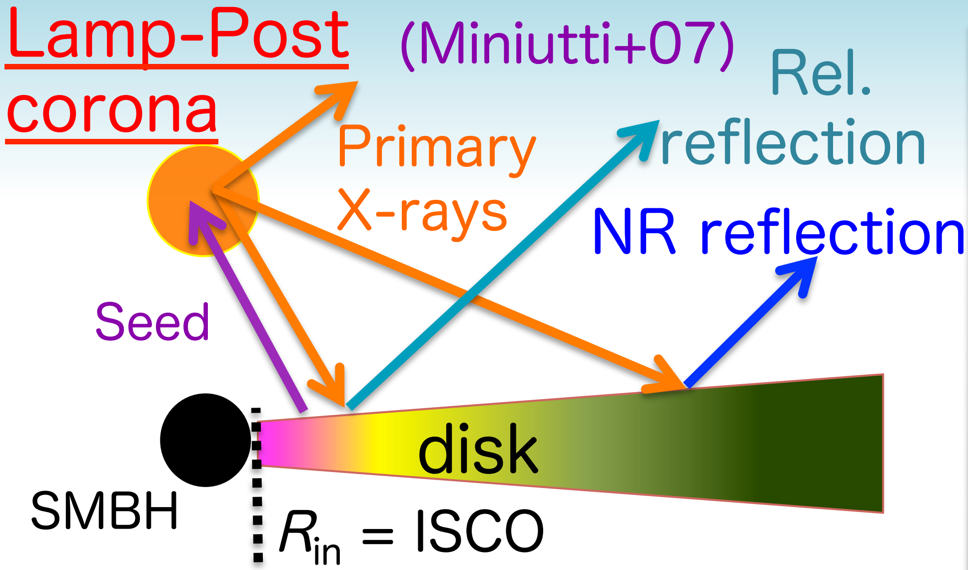
1. The AGN Central Engine: a Paradigm Shift



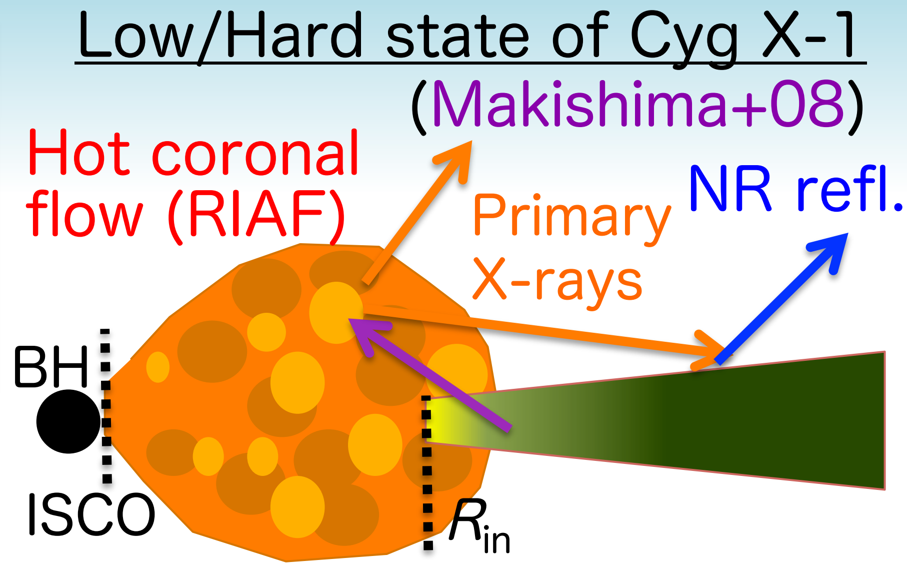
✧ Previous (e.g, Miniutti+07)
Single PL primary + Rel. & NR. reflection+Soft Excess

✧ Novel (Noda+11a, 11b, 13a, 13b, 14; Miyake+16; Miyake+P32, Seino+P31)
Variable soft PL primary +Absorbed hard PL primary +NR. reflection + Soft Excess

2. Two Geometries of the Central Engine



Employed widely w/o clear basis.
- ✧ An opt.thick disk reaching ISCO
- ✧ A Lamp-Post type PL source
- ✧ Strong reprocessing near ISCO



- ✧ A truncated disk: R_{in}>>ISCO
- ✧ Hot coronal flow at < R_{in}
- ✧ X-ray reflection at large radii
- ✧ Another corona ?

- ✧ Analogous to the High/Soft state of BHBs, or Low/Hard state?
- ✧ Information in the visible band is important, because

  $T_{in}\sim 30\ (M_{BH}/10^7 M_{\odot})^{-1/4}\eta^{1/4}$ eV ; $\eta \equiv$ Eddington ratio = L_{bol}/L_{Edd}

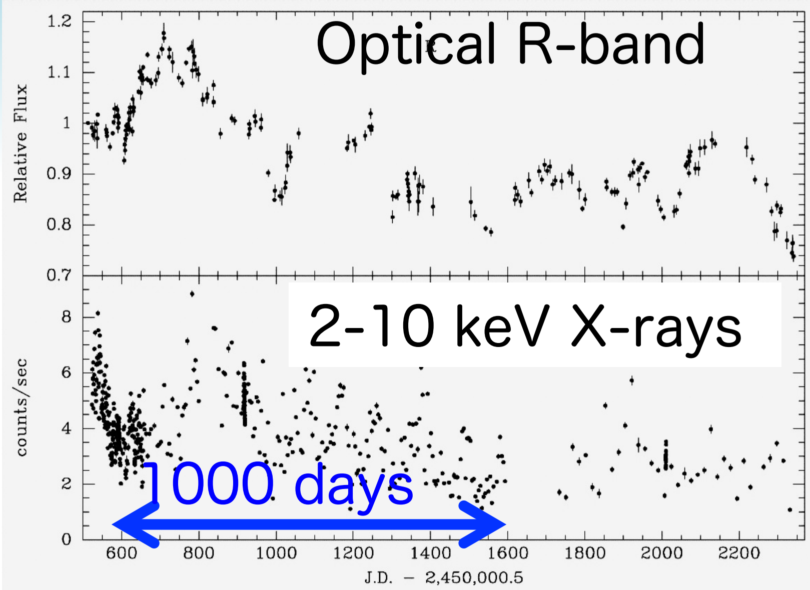
  if R_{in}=ISCO=3 R_s.

3. X-ray/Optical Simultaneous Observations

✧Many attempts were so far made on various AGNs.

✧Correlation was poor in some cases 🡐 because the two PL components mixed up?

✧We expect the harder PL to correlate with the optical, whereas the softer PL not.

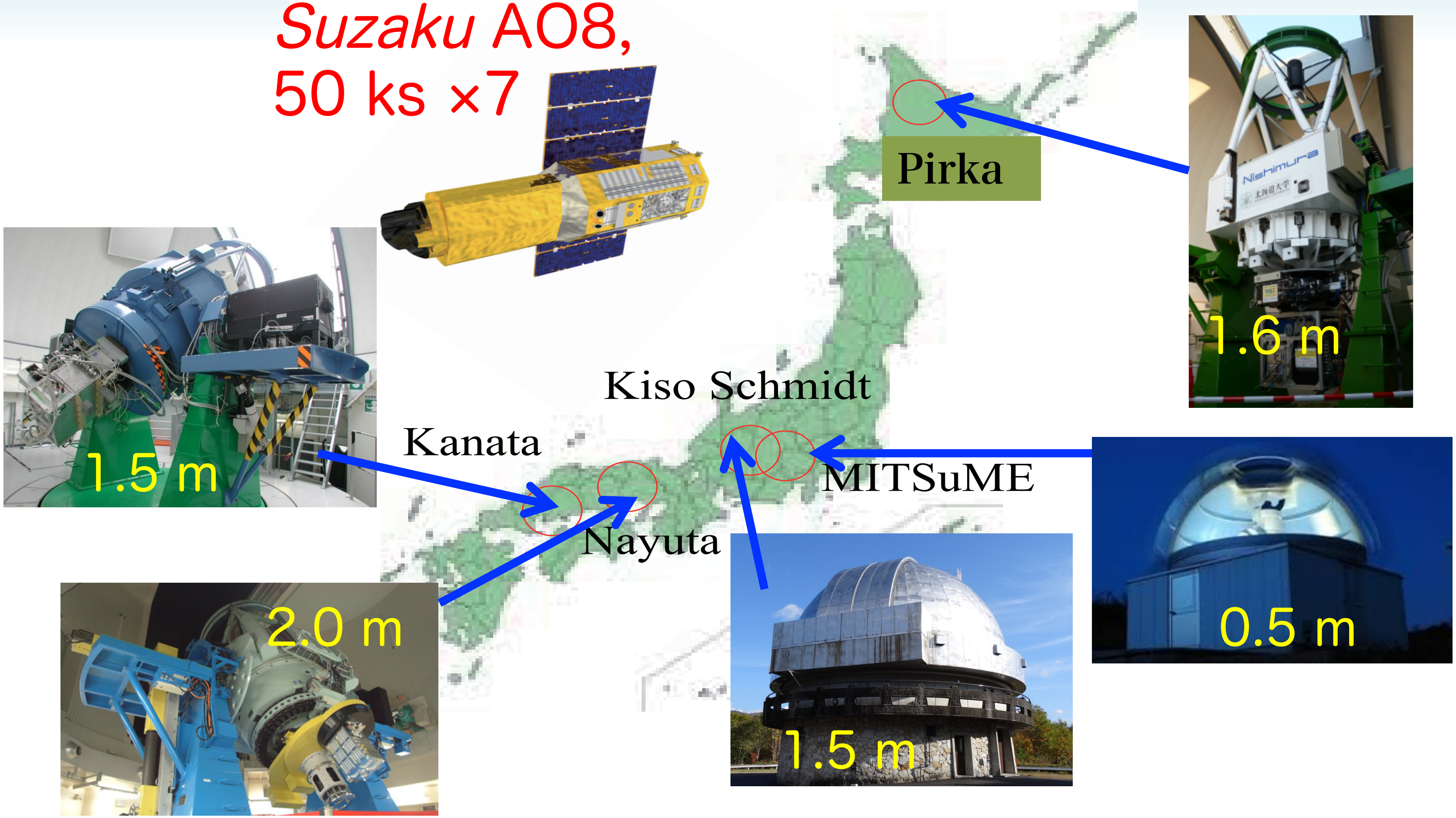


Results of an extensive motoring campaign of NGC 3516 using *RXTE* (Maoz+02)

✧Selected NGC 3516 for our target, because of
- Detailed X-ray information with *Suzaku* (Noda+13)
- Dec=72 deg → high visibility from Japan

4. X-ray/Optical Monitoring Campaign of NGC 3516 (2013-2014), led by H. Noda

Suzaku AO8,
50 ks ×7



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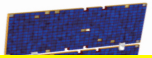
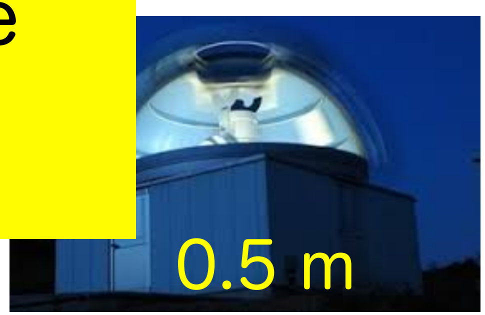
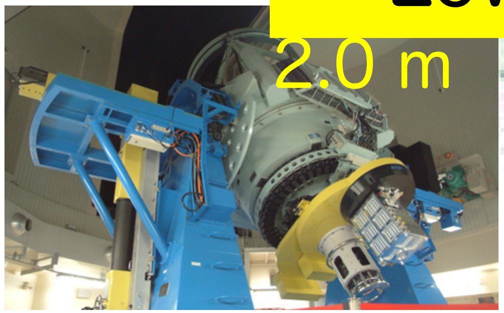
Suzaku AO8,
50 ks ×7



1. Which X-ray component correlates with optical?
2. Can we constrain the central engine geometry?
3. Is NGC 3516 similar to the High/Soft state or the Low/Hard state of BHBs?

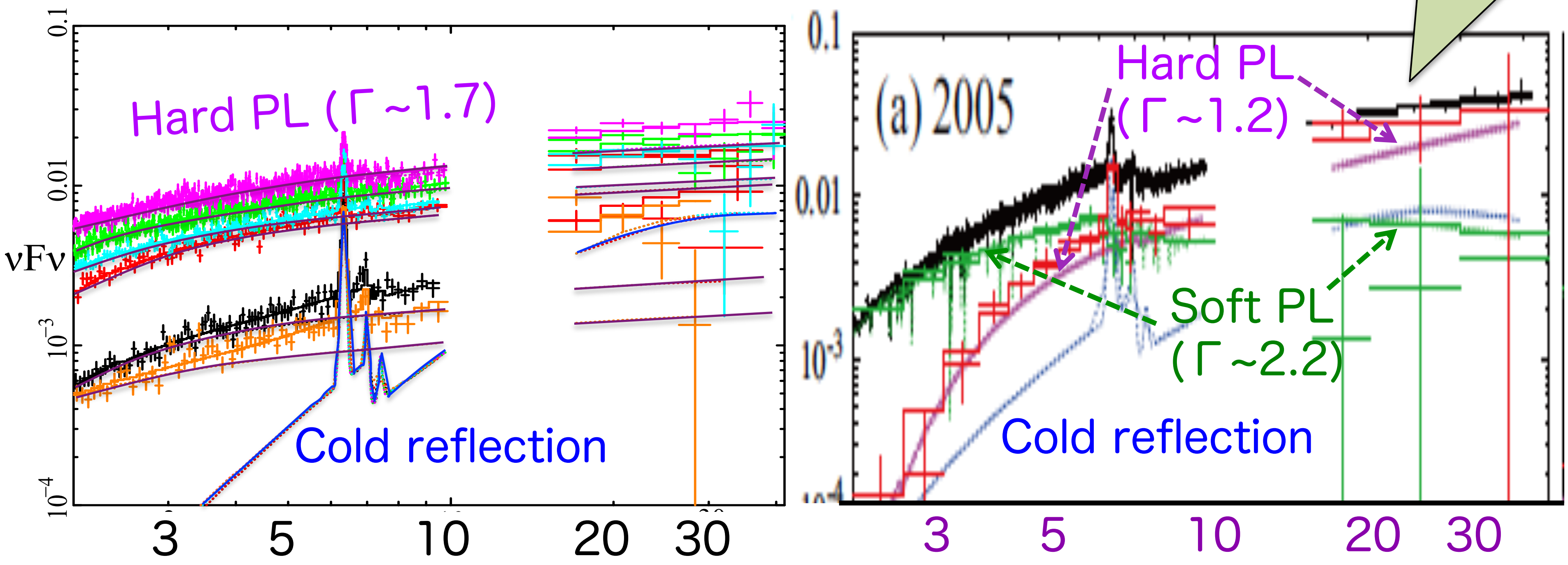




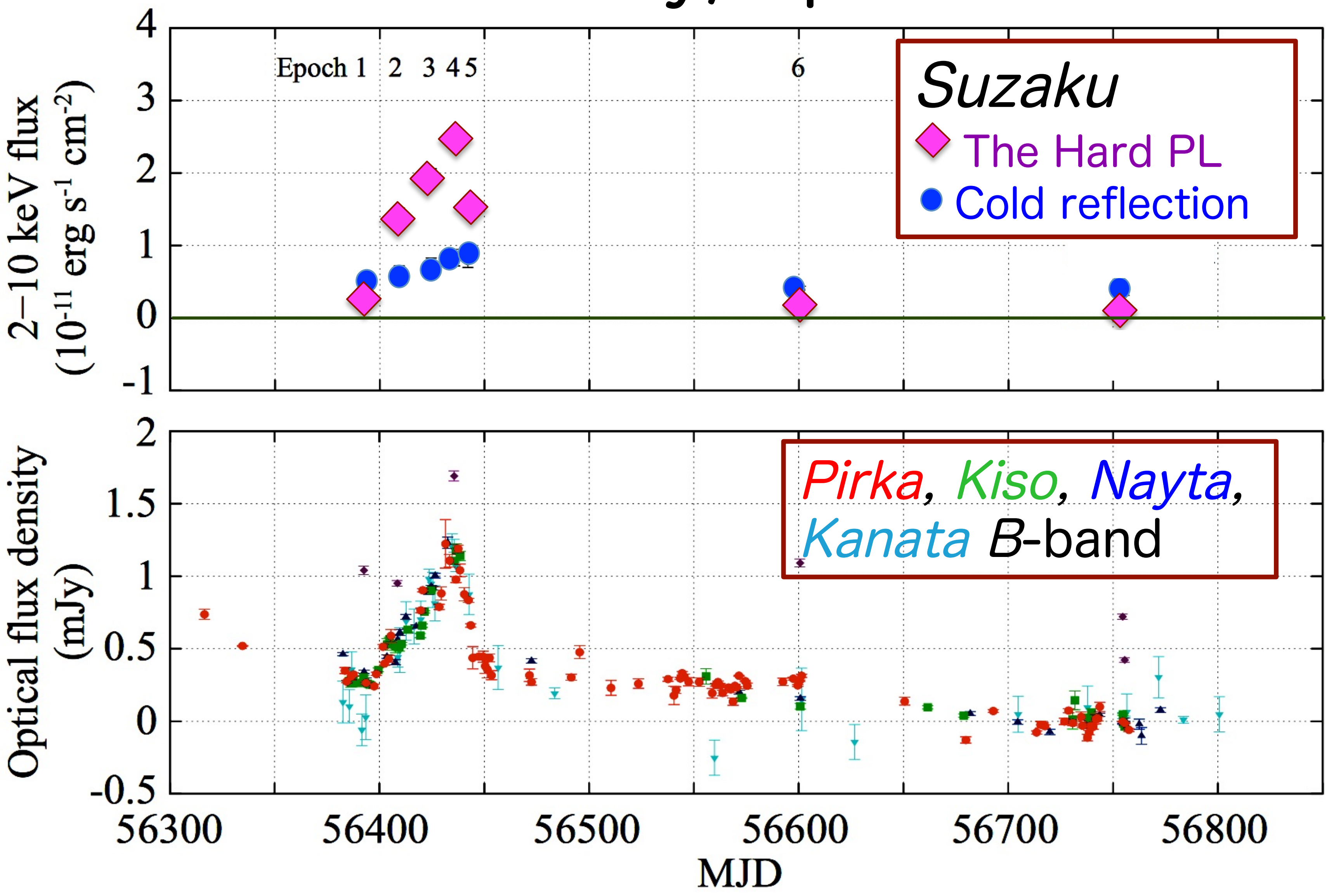
5. X-ray Results from the Campaign

- ✧ On the 7 occasions across ~1 yr, NGC 3516 was faint with η=1e-3~0.01, and varied by an order of magnitude.
- ✧ The 2-45 keV spectra consisted of a hard PL with Γ~1.7 and cold reflection.
- ✧ Unlike in the 2005 brighter state (Noda+13), the soft variable PL (Γ~2.2) was absent.

Comparison: *Suzaku* data in 2005 (Noda+13)



6. Correlated X-ray/Optical Variations



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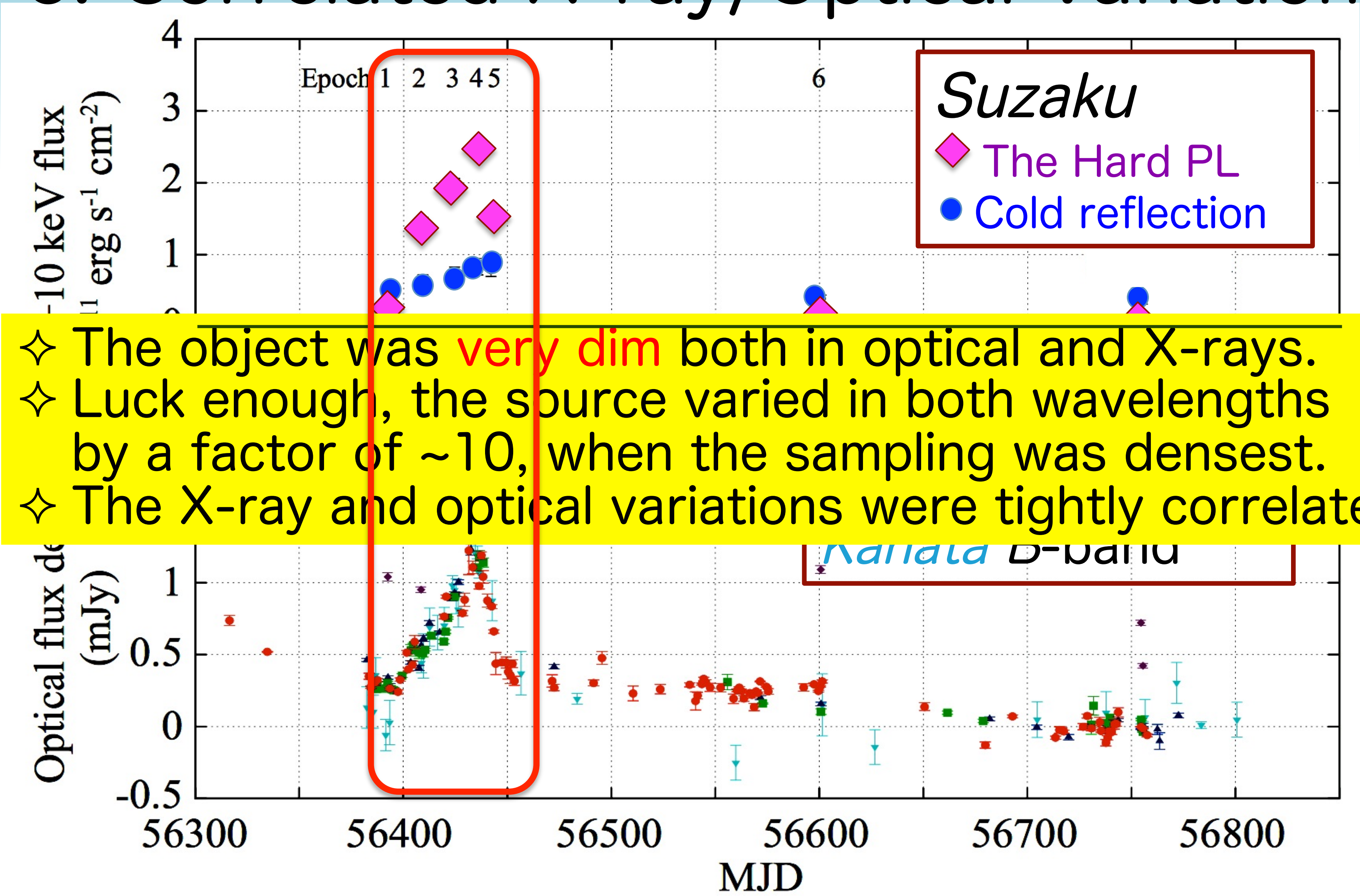

- ✧ The object was very dim both in optical and X-rays.
- ✧ Luck enough, the source varied in both wavelengths by a factor of ~10, when the sampling was densest.
- ✧ The X-ray and optical variations were tightly correlated.

7. Optical Time Lag behind X-rays

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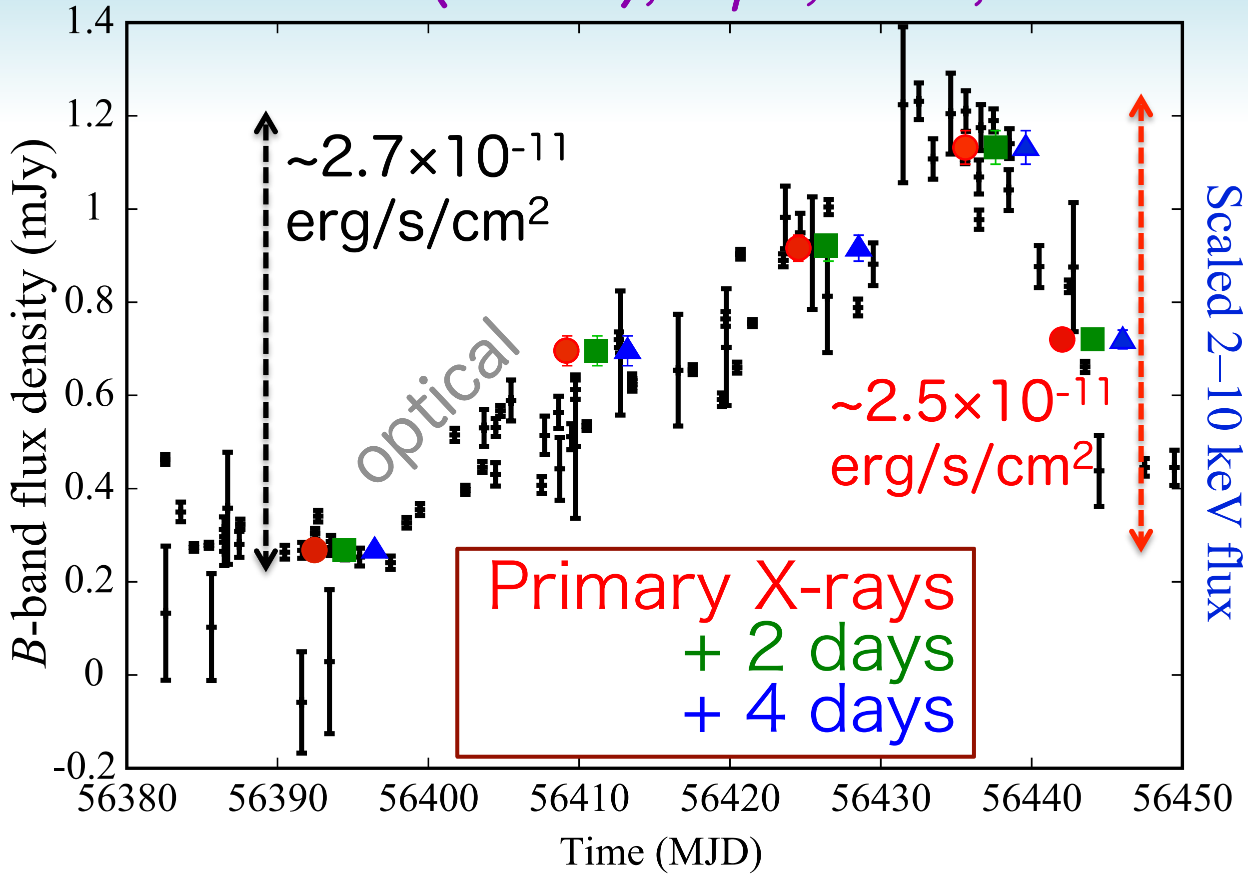
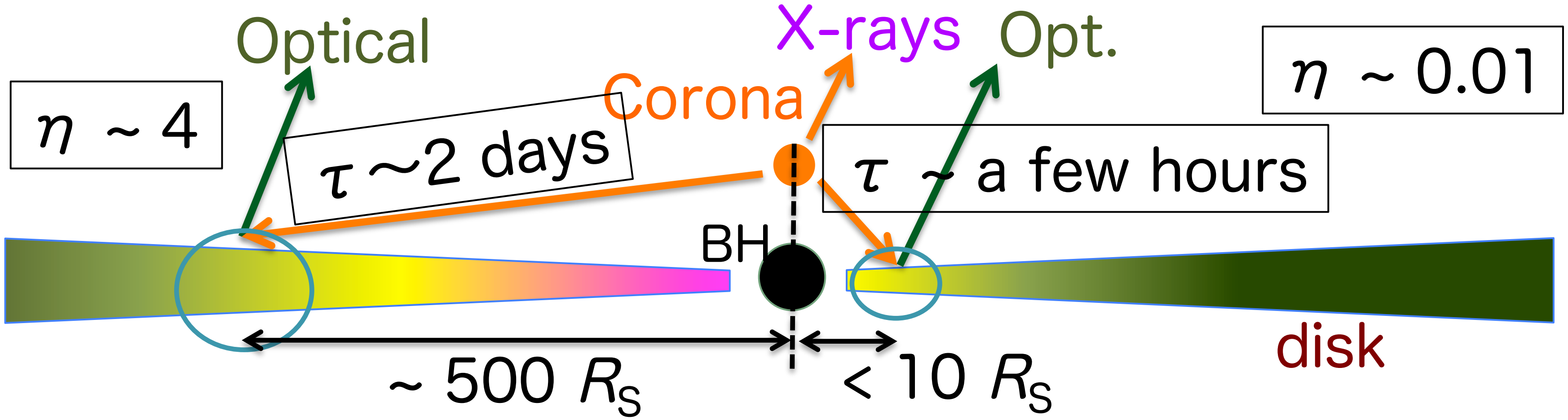


- ✧ X-ray flux derived by carefully removing absorption and reflection.
- ✧ The optical flux increment was comparable to that in the X-rays.
- ✧ Optical variations were delayed by 2.0±0.7 days behind X-rays.

The optical variation resulted via X-ray reprocessing, at locations ~2 lt-days (~500 R_s for M_{BH}=3.2×10^7 $M_{\odot}$) from the Hard X-ray emission region.

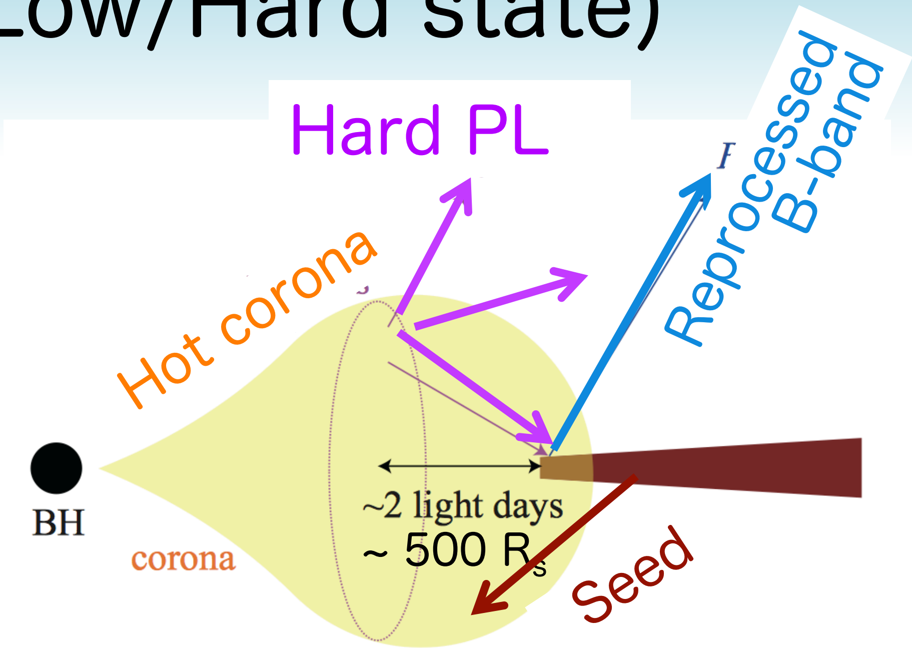
8. Difficulty with the "Lamp-Post" Geometry

- ✧ X-rays irradiate the disk at τ~2 lt-day = 500 R_s, and produce optical variations via reprocessing.
- ✧ If, furthermore, the disk continued to ISCO (~3R_s) as assumed in the "Lamp Post" scenario, we expect T_{in}~40 eV → the source would be too luminous, η~4.
- ✧ If instead we assume η~0.01 → τ~ a few hours
- ✧ The Lamp-Post geometry cannot reconcile the large τ and the low η → unlikely!



9. The Truncated-Disk Geometry (similar to the Low/Hard state)

- ✧ The disk is truncated at a radius of 500 R_s or larger.
- ✧ There, the flow turns into an optically-thin hot corona, which Comptonizes disk seed photons to produce the hard PL.
- ✧ The PL photons irradiate the disk at > 500 R_s to cause the optical variation.
- ✧ If the corona is in a RIAF (Radiatively Inefficient Accr. Flow) condition, the low η is readily explained.



Similar "large τ and low η" conditions were reported on other AGNs (e.g., Cackett +07); NGC 4051, 3C390.3, Mrk 509, MCG+8-11-11, NGC 5548

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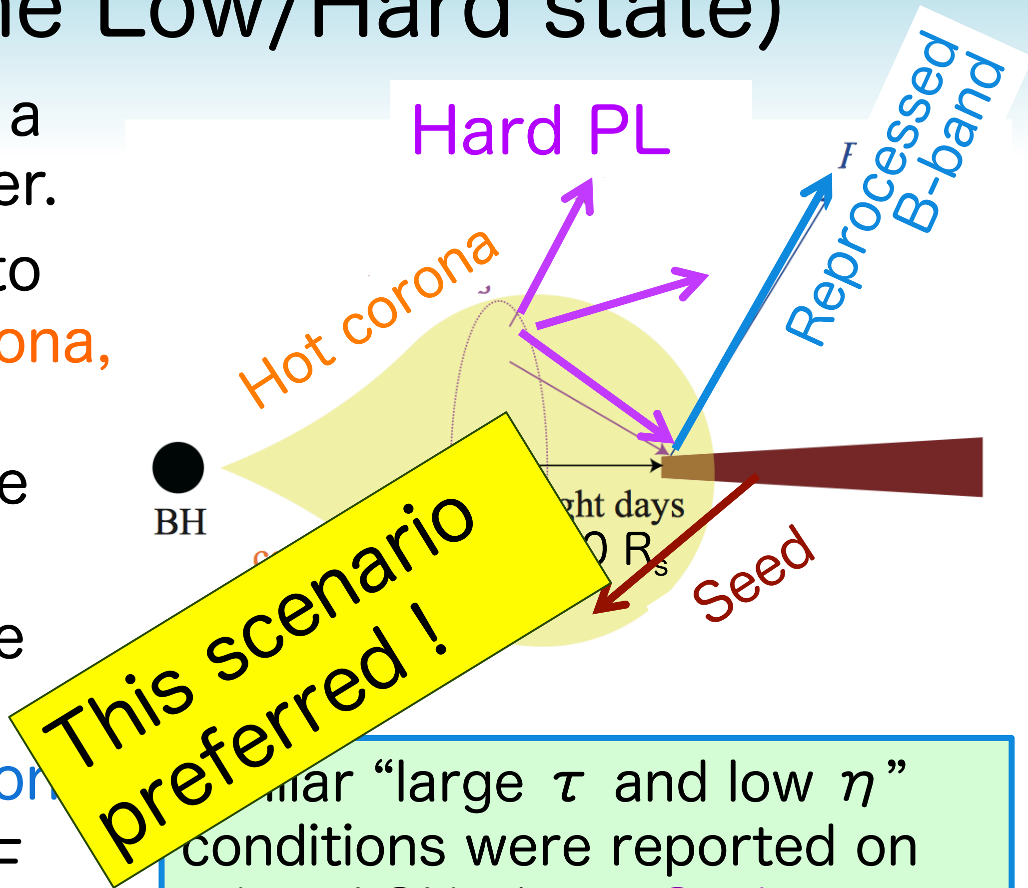

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10. Conclusion

- ✧ When NGC 3516 was dim (η=1e-3~0.01), the optical correlated closely with the newly identified harder PL. (The softer PL is presumably uncorrelated with optical.)
- ✧ The optical variation, delayed by τ~2 days, must result from X-ray reprocessing at this large distance.
- ✧ The low η and large τ cannot be reconciled by the Lamp Post geometry which assumes R_{in}= ISCO, but can be explained if the disk is truncated and turns into RIAF.
- ✧ The hard PL is likely to emerge from the RIAF region.
- ✧ Low-η AGNs are similar to BHBs in the Low/Hard state.
- ✧ No room for the "relativistic reflection."

Confirming the scenario among other Seyferts will be an excellent subject for future X-ray All Sky Monitors.