Variability Analysis of the Seyfert 1 Galaxy MCG-6-30-15 observed by ASCA and Suzaku

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Abstract

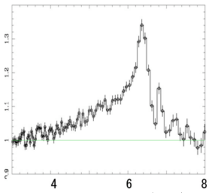
We analyzed long observations of the Seyfert 1 Galaxy MCG-6-30-15 in 1999 and 2006 using ASCA and Suzaku, respectively. We carried out model independent RMS (Root Mean Square) variability analysis, and confirmed that the RMS variability spectrum in 1999 indicates a significant decrease in the Fe line energy band more rapidly than those in other energy bands, when time-scale increases from 10^4 to 10^5 sec, as already reported by Matsumoto et al. (2003). On the other hand, the RMS variability spectrum in 2006 does not show such a dramatic decrease at the Fe line energy band. Examining the structure function (variability time-scale vs RMS variability), we found a common characteristic in 1999 and 2006 that RMS variability is most significant on a time-scale of ~10^3 sec in all the energy bands. Our results of differential spectral analysis are also consistent with the results of the structure function analysis.

1. Introduction

■Active Galactic Nucleus MCG-6-30-15
◇Mass ～ 10^6 solar mass (McHardy et al. 2005)
◇Having been observed for more than 10 years, using ASCA(Tanaka et al. 1995 etc), XMM-Newton, Suzaku satellite, and so on.

■Long exposure with ASCA and Suzaku
◇Exposure time about 405 ksec in 1999 (ASCA)
◇Exposure time about 346 ksec in 2006 (Suzaku)

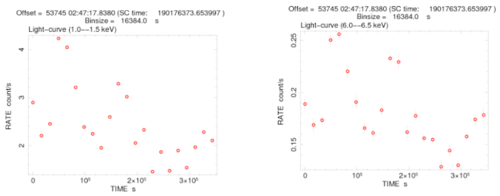
■We have studied spectral variation.
In particular, iron line region.



X-ray Energy (keV)
<Observed spectrum by Suzaku>
(Miniutti et al 2007)

2. Observation & Data analysis

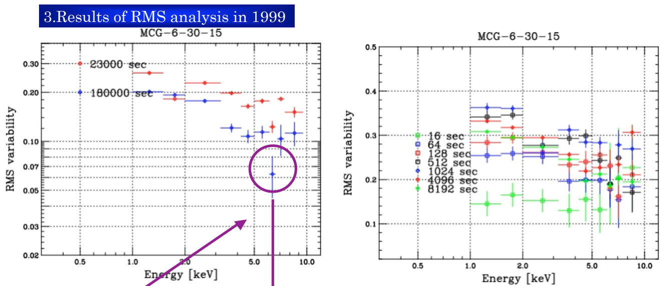
Suzaku satellite ：<2006>Jan 9—14th (ID:70007010),23—26th(ID:70007020), 27—30th(ID:70007030) Total about 346 ksec (exposure time)
※Total operating time is about 781 ksec.
ASCA satellite :<1999>July 19—29th (ID:77003000) Total about 405 ksec (exposure time)



<Figure: Light curve of the observed data in 2006. Time bin width is 16384 sec.
These figures are light curves of 1.0—1.5 keV (left) and 6.0—6.5 keV (right), respectively. >

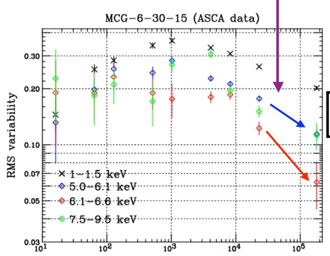
<RMS analysis>
◇ Root Mean Square (RMS) variability
For data set of {xi ± δxi}I=1…N
(where {xi}: observed data, {δxi}: their errors, N: number of the data)
RMS variability is defined as $(V_{intrinsic}/(N-1))^{0.5}/x_{ave}$
$(x_{ave} = \Sigma x_i/N,\ V_{intrinsic} = \Sigma(x_i - x_{ave})^2 - \Sigma \delta x_i^2)$

3.Results of RMS analysis in 1999



<The RMS variability as a function of energy>

The RMS variability in the disk-line energy band goes down to ∽ 5 %. (as already reported from Matsumoto et al 2003)



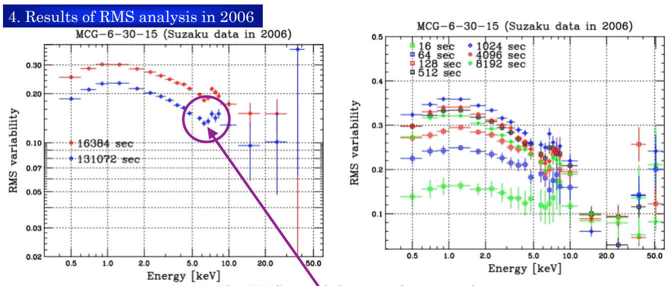
<The RMS variability VS time bin width>

The RMS variability in the disk-line energy band (5.0—6.6 keV) decreases more rapidly than those in the other energy band as time bin width increases from 10^4 to 10^5 sec (Matsumoto et al. 2003)

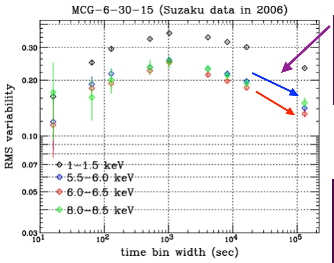
We have analyzed the RMS variability in 10—10^5 sec, including the RMS variability of 10 —10^3 sec.

Examining the structure function (variability time scale vs RMS variability), we found a common characteristic in 1999 and 2006 that RMS variability is most significant on a time scale of ∽10^3 sec in all the energy bands.

4. Results of RMS analysis in 2006



<The RMS variability as a function of energy>

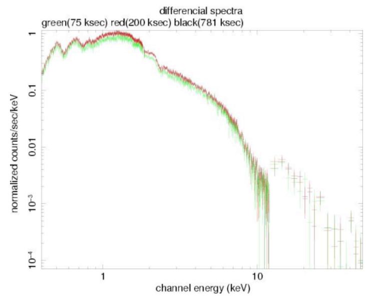


<The RMS variability VS time bin width>

The RMS variability spectrum in 2006 does not show such a dramatic decrease at the Fe line energy band as observed with ASCA in 1999.

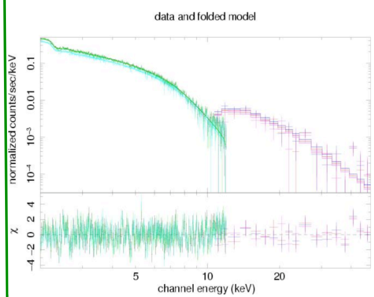
We found a common characteristic in 1999 and 2006 that RMS variability is most significant on a time scale of ∽10^3 sec in all the energy bands.

5. Data analysis with differential spectrum



◇How to make differential spectra

1. Divide the entire observation period into a series of short-periods of time of which length is T [sec].
2. Create light curves for the individual T [sec].
3. Calculate the average count rate for each period.
4. Create spectrum when the count rates are higher and lower than the average for each period.
5. Subtract the low spectrum from the high spectrum to create the “differential spectrum” for each period .
6. Combine the differential spectra from all the periods.



$N_H = (3.6\pm0.7)\times10^{21} cm^{-2}$
Photon index = 2.19±0.03

χ^2/d.o.f = 1.03
(=1053/1018)

All the spectra in 2--50 keV are fitted with a power-law model.

6. Summary

■We confirmed that the RMS variability in 1999 indicates a significant decrease in the Fe energy band when time-scale increases from 10^4 to 10^5 sec, as already reported by Matsumoto et al. (2003).
■The RMS variability in 2006 does not show such a dramatic decrease in the Fe line energy band.
■We found a common characteristic in 1999 and 2006 that RMS variability is most significant on a time scale of ~10^3 sec in all the energy bands.
■We have analyzed the differential spectra in 2—50 keV on time scale of 10^4—10^5 sec, and found that all spectra are fitted with power-law model. Photon index is constant at ∽ 2.2 .

7. References

<1>. Tanaka et al (1995), Nature, 375, 659
<2>. Matsumoto et al (2003), PASJ, 55, 615
<3> McHardy et al. (2005), MNRAS, 359, 1469
<4>. Fabian et al (2002), MNRAS, 335, 1
<5>. Fabian et al (2004), MNRAS, 348, 1415
<6>. Miniutti et al (2007), PASJ, 59, 315

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