The Evaluation of the relation between Quasi-Periodic Oscillation and mass of the black hole candidates
(ブラックホール候補天体における準周期的振動-質量の関係性の評価)

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May 9, 2018 @Ando Lab

About this talk

・I talk about my graduation thesis in Tokyo University of Science.
・I explain the overall view of my theme and don’t mention everything.
・The theme is “QPO (Quasi-Periodic Oscillation)”, which is seen in compact objects.

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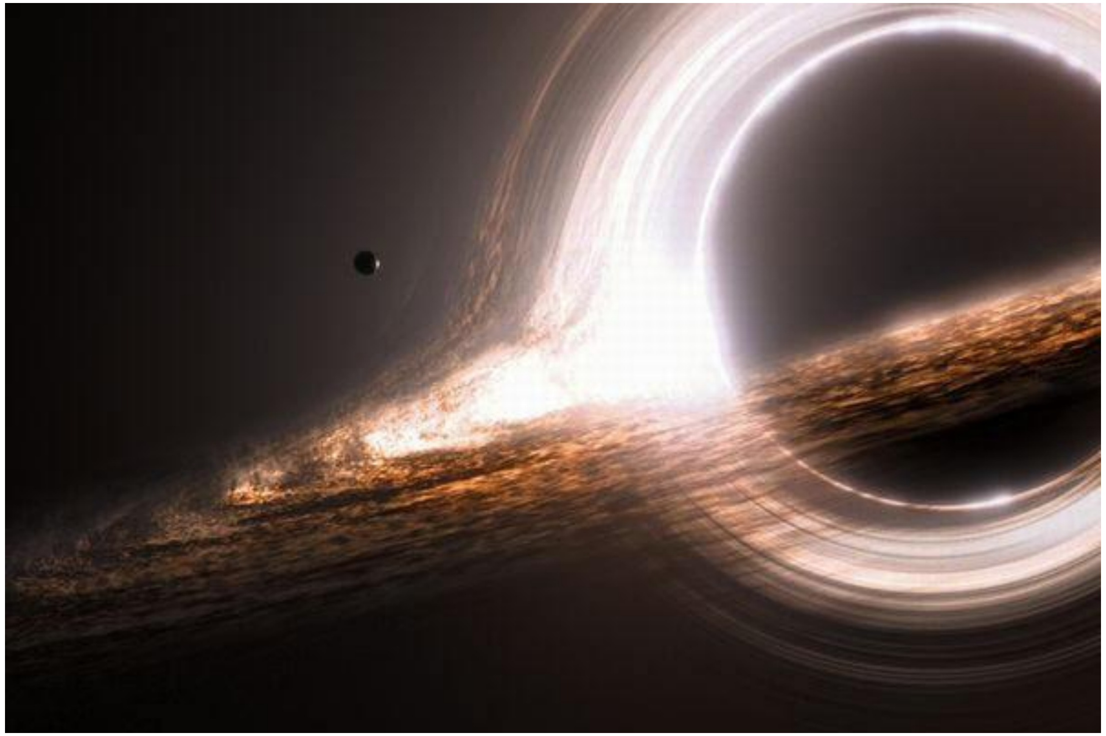
    ・Matsushita Lab
2. Principles
    ・QPO(Quasi-Periodic Oscillation)
3. Analysis
    ・Power Spectrum
4. Conclusion



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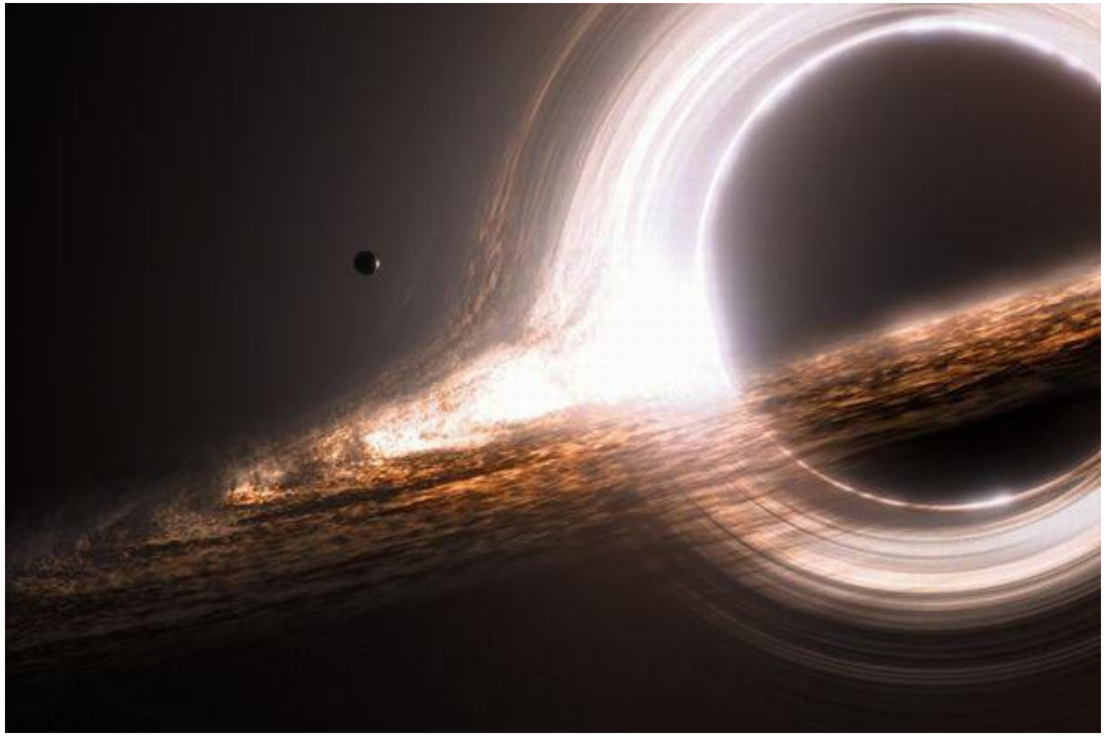

Introduction

5 years old

~My life~

18 years old

I was born

Skip !

2014 Enroll in the Tokyo University of Science

2018 Graduate from the Tokyo University of Science

Enrole in the University of Tokyo

22 years old

Matsushita Lab

- X-ray Astronomy Lab

Why X-ray?
⇒There are many kinds of electromagnetic waves.
Especially X-ray and γ-ray are suitable for high-energy objects.
How to research?
⇒Analysis the data from the X-ray observatories.
What main target?
⇒Galaxy, Cluster of Garaxies, Black Hole, AGN, NS and so on…

How to get data

1. Retreival object name
2. Choose observatory
3. Choose date

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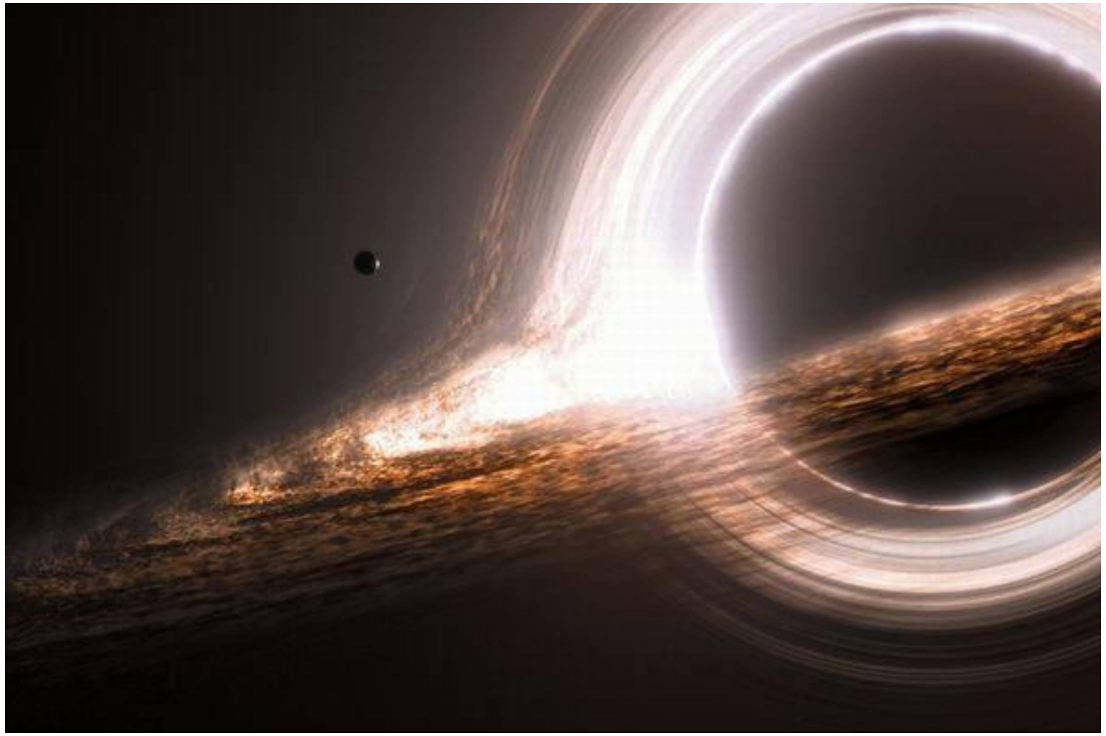


Accretion Disk

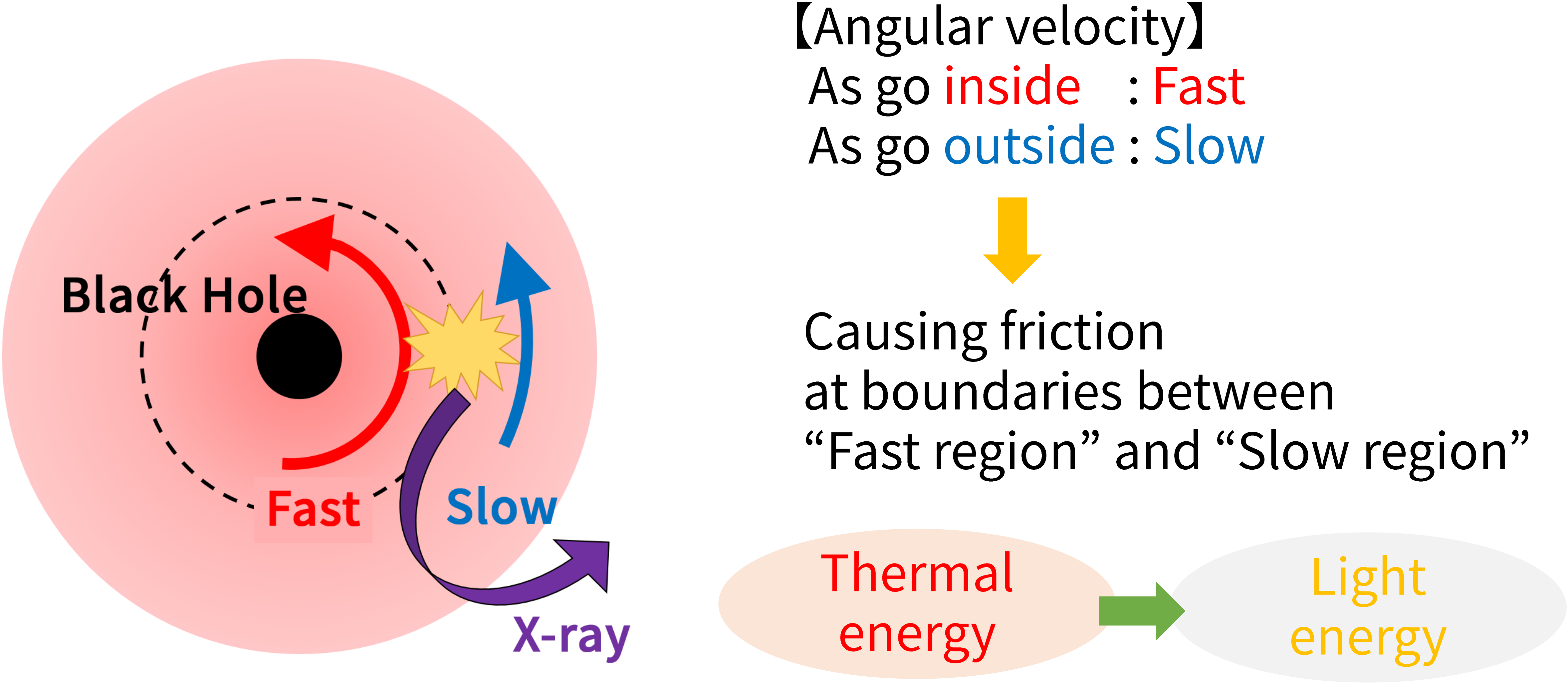


Fig1. X-ray emission mechanism of black hole

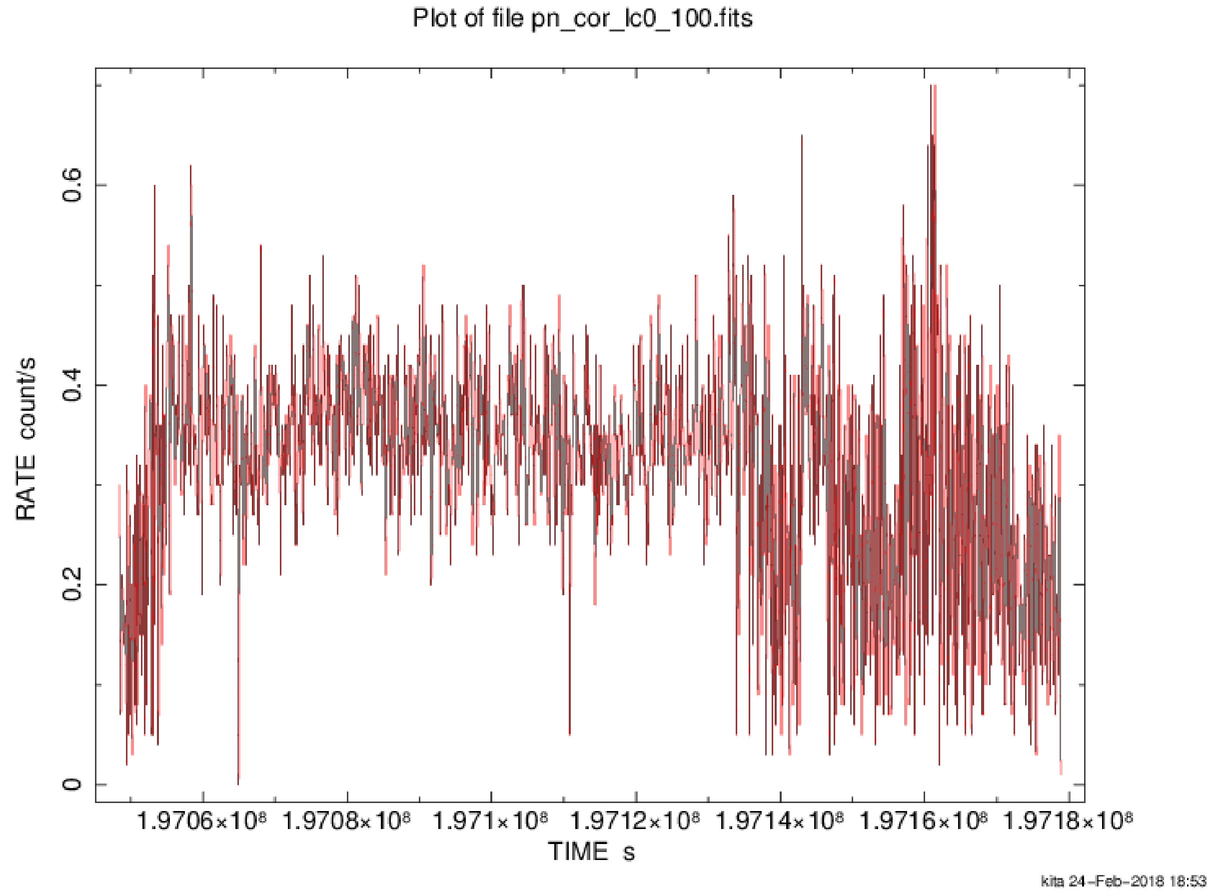
Types of black hole

Stellar-mass BH	Intermediate-mass BH	Massive BH
mass: $5 - 15\ M_{\odot}$	mass: $10^2\ M_{\odot}$~	mass: $10^6 - 10^9\ M_{\odot}$
This type is generated from supernova of fixed stars.	This type is generated from the union of two Stellar-mass BHs. The candidates is called "ULX", Ultra-Luminous X-ray source.	This type is generated from mass accretion around intermediate-mass BHs. But this is one of hypotheses and the existence is almost unknown.

States of stellar-mass black hole

state	features
very high state	Very bright and high energy by Inverse Compton sacattering
high/soft state	Rate of accretion and radiation efficiency is high
intermediate state	The state in transition between high and low states
low/hard state	Rate of accretion and radiation efficiency is low
quiescent state	Low state features + lower luminosity

Light Curve



Light Curve is...

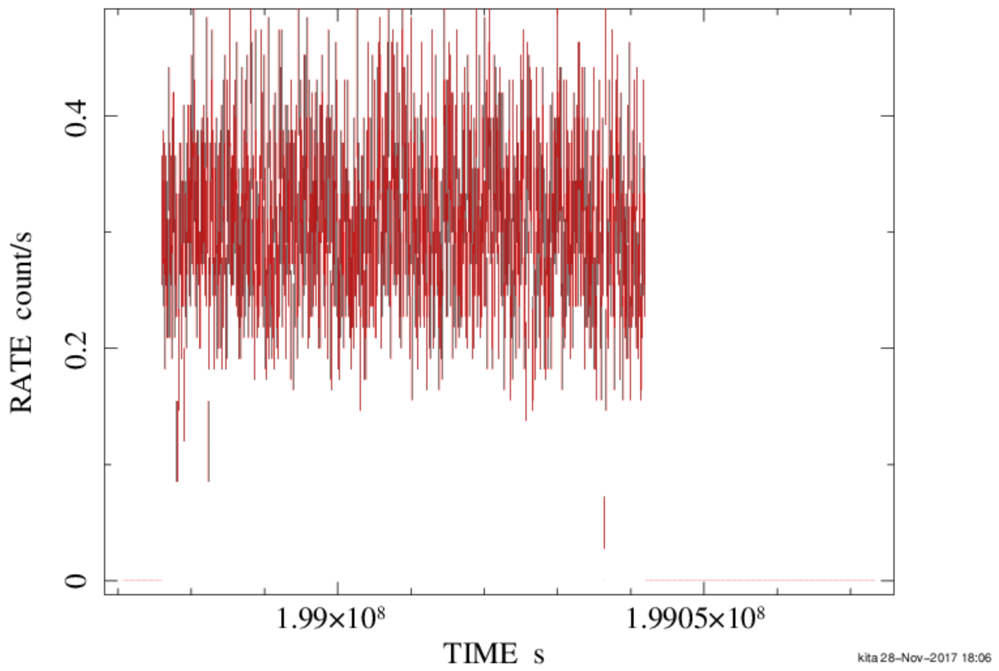
the plot which shows
the relation between
Time[s] and Count Rate[count/s]

Count Rate shows
the number of incident photons
per second

Timing Analysis

We apply Fourier Transform to Light Curve and get Power Spectrum.

Light Curve



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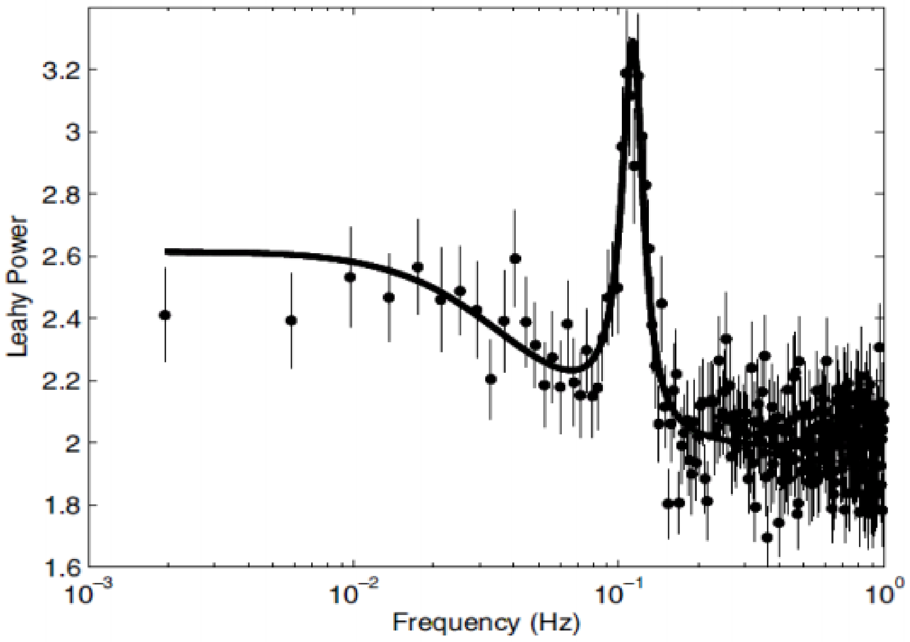
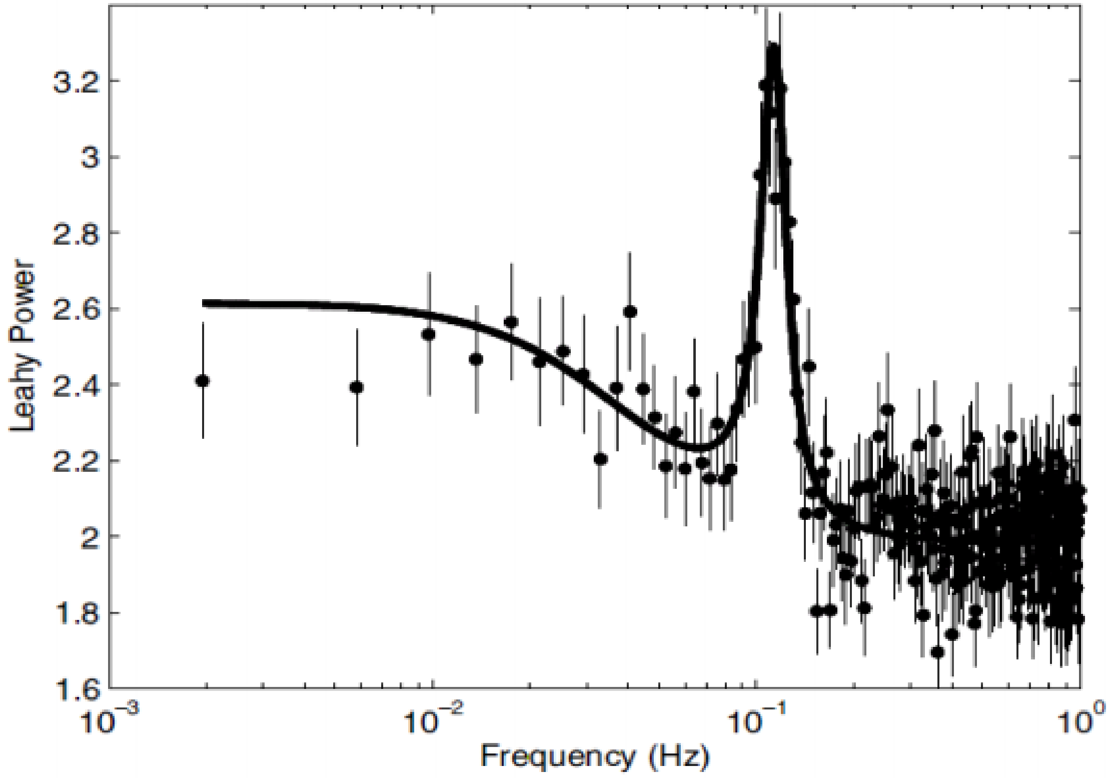
Power Spectrum



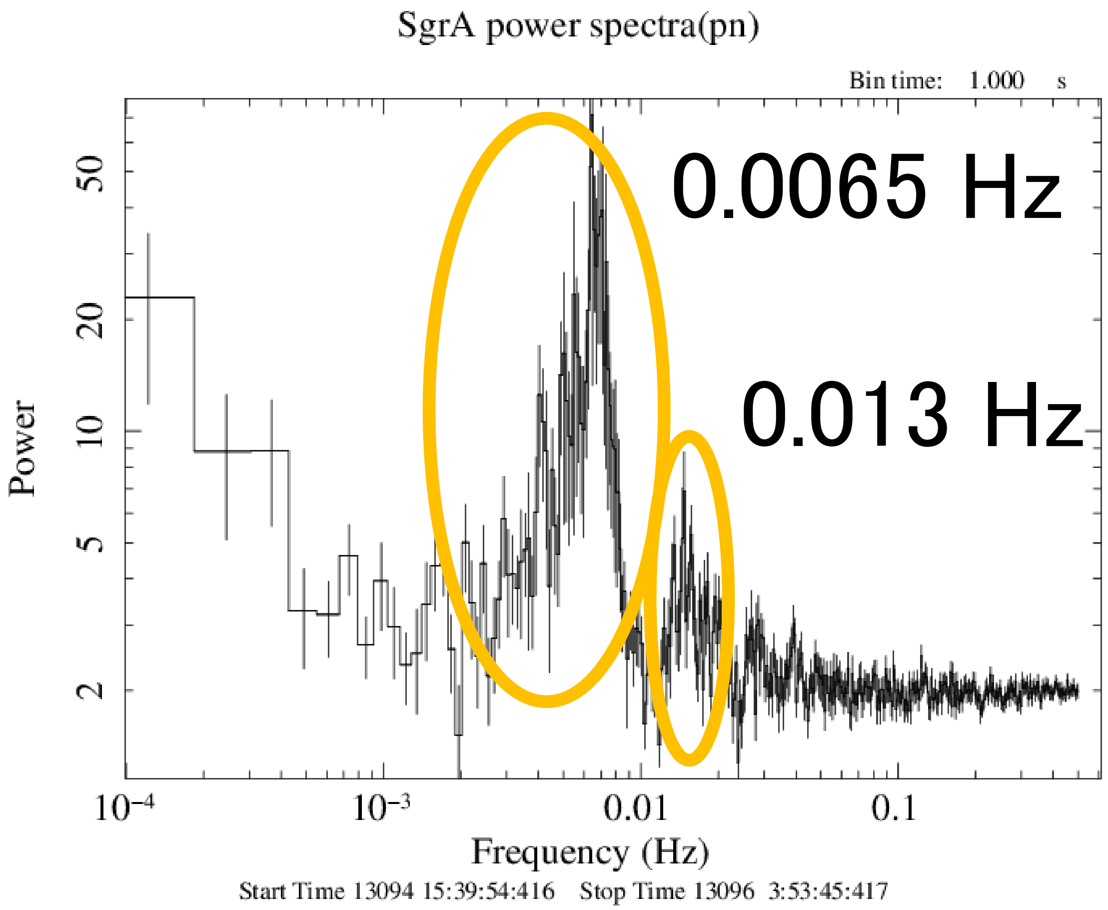
QPO(Quasi-Periodic Oscillation)



QPO is a phenomenon which have one or some peak(s) with width in power spectrum.

In respect to stellar-mass BH,
it is considered that
1.Variability of accretion disk itself
2.Instabilty of gas in the disk
cause QPO.

Twin-peak QPO



It is considered that Twin-peak QPO is strongly related to mass of objects.

Vibration period of blightness

↕

Size of radiation area

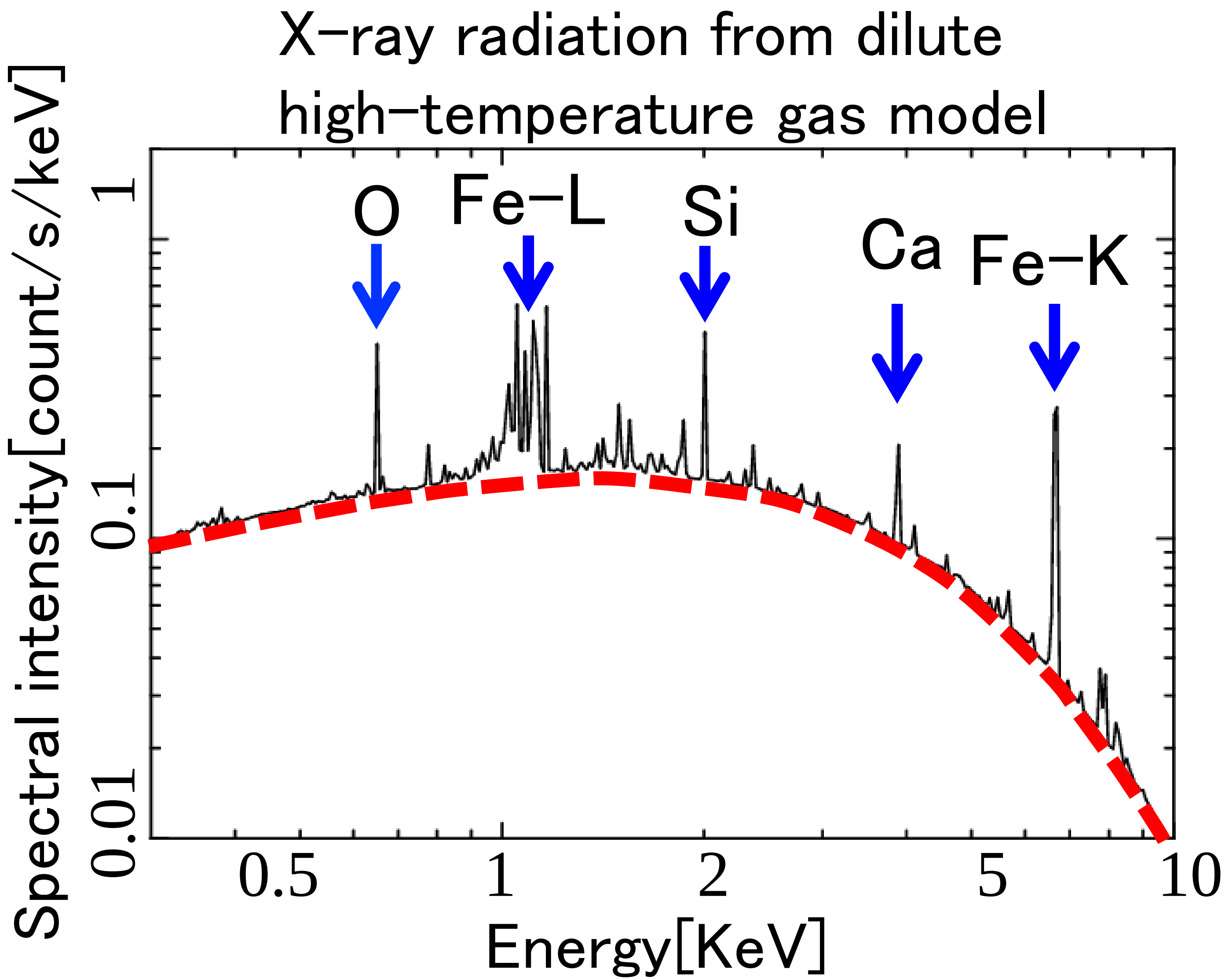
↕

Schwarzschild radius

↕

Mass of BH

Energy Spectrum



Fitting energy spectrum needs Many models.

e.g)thermal bremsstrahlung,
synchrotron radiation,
black body radiation,
each blight line spectrum

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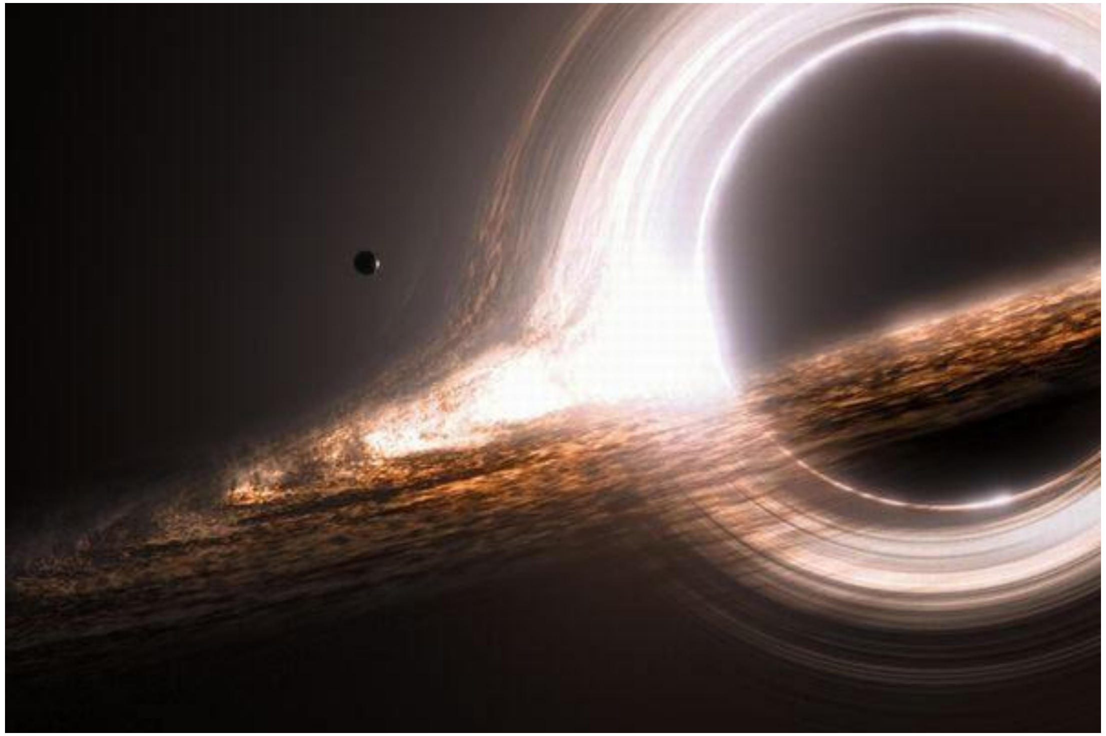
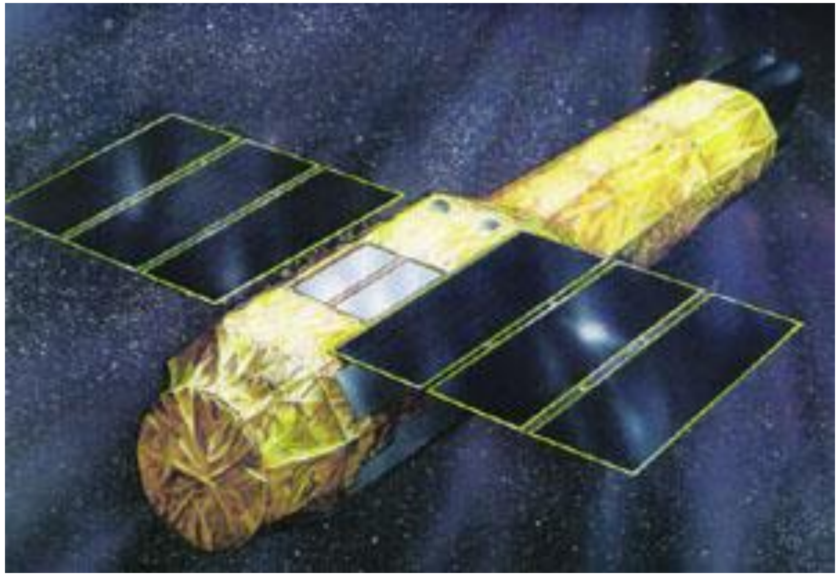


X-ray observatory part1

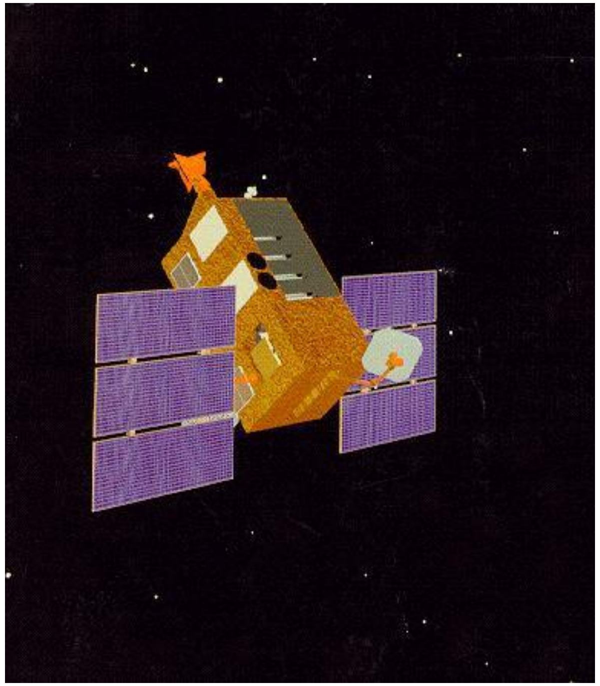
XMM-Newton

Chandra



Suzaku

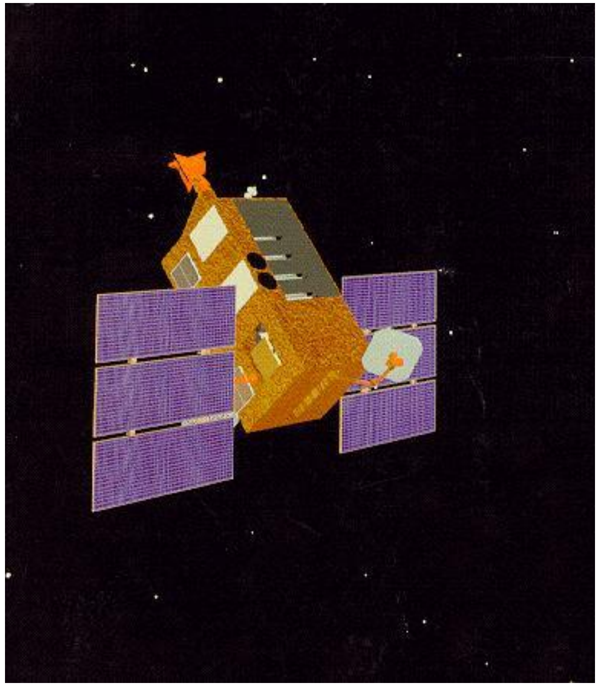
X-ray observatory part2



RXTE

ASTRO-H ひとみ

X-ray observatory part2



RXTE

ASTRO-H ひとみ

XMM-Newton

XMM-Newton was launched by ESA on December 10th 1999.

Time resolution: 12 arcseconda
Effective area: $3000cm^2$ to 6keV
Grating: reflective
Hight of perigee: 7000km
Orbital period: 47.8h

Detectors of XMM-Newton

MOS[1 pixel = 1.1"]	Time Resolution [s]	Live Time[%]	Max count rate difuse(total) [s^{-1}]	Max count rate (flux) point source [$mCrab^4 s^{-1}$]
Full frame(600 × 600)	2.6	100.0	150	0.50(0.17)
Large window(300 × 300)	0.9	99.5	110	1.5(0.49)
Small window(100 × 100)	0.3	97.5	37	4.5(1.53)
Timing uncompressd (100 × 600)	0.00175	100.0	N/A	100(35)

PN [1 pixel = 4.1"]	Time Resolution [s]	Live Time[%]	Max count rate difuse(total) [s^{-1}]	Max count rate (flux) point source [$mCrab^4 s^{-1}$]
Full frame(376 × 384)	73.4	99.9	1000	2(0.23)
Extended Full frame(376 × 384)	199.1	100.0	370	0.3(0.04)
Large window(198 × 384)	47.7	94.9	1500	3(0.35)
Small window(63 × 64)	5.7	71.0	12000	25(3.25)
Timing(64 × 200)	0.03	99.5	N/A	800(85)
Burst(64 × 180)	0.007	3.0	N/A	60000(6300)

XMM-Newton has 3 detectors, MOS1・MOS2 and PN.
Time resolution of PN is very high.
So I adopt

1. MOS1+MOS2
2. PN only

as data set .

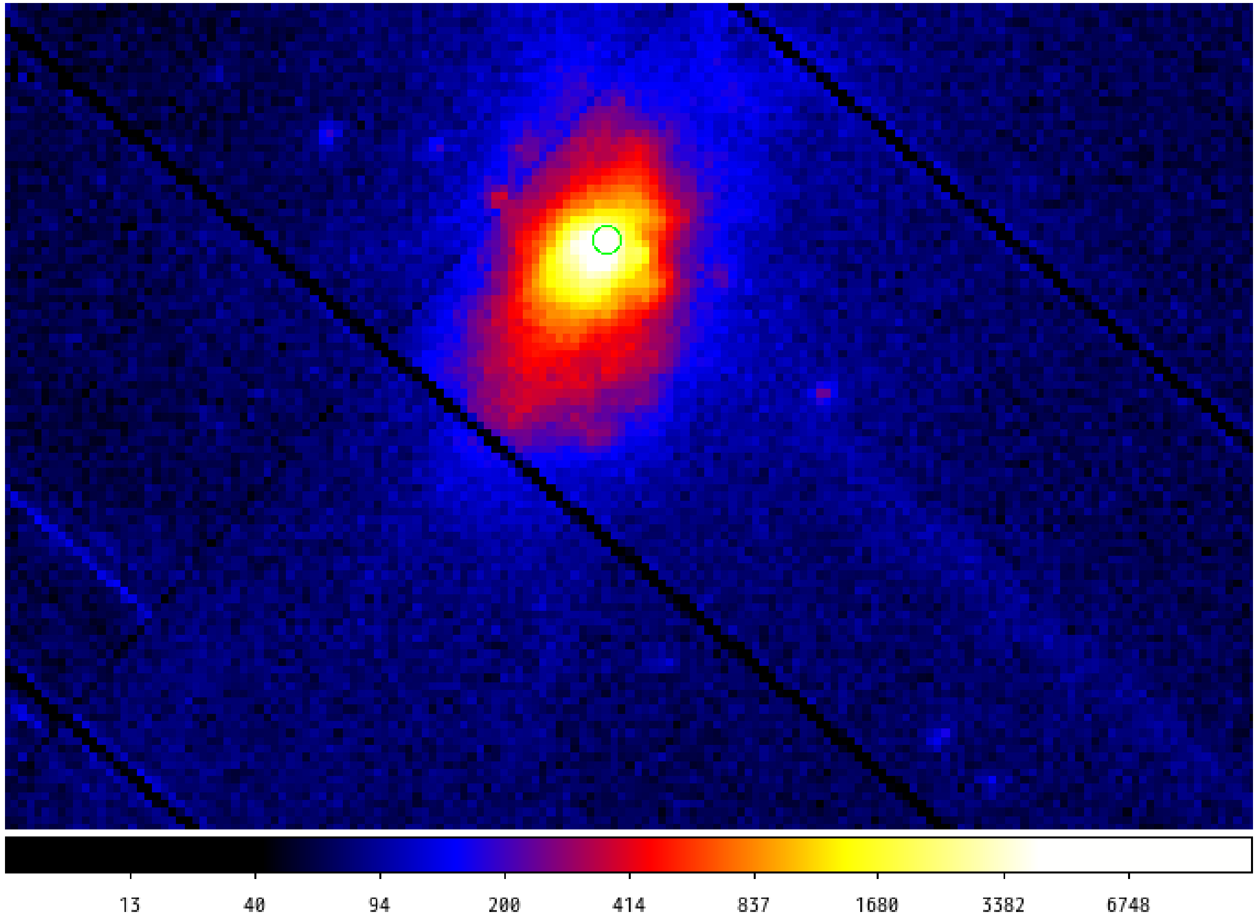
Objects

object	obs ID	time
GROJ1655-40	0112460201	2001-08-30 02:37:53
	0112921301	2005-02-27 07:46:53
	0400890201	2007-03-26 15:18:27
XTEJ1550-564	0204270101	2004-08-11 06:24:43
	0400890101	2007-02-25 10:03:06
GRS1915+105	0112990501	2003-10-17 00:10:08
	0144090101	2004-04-17 14:18:56
	0506161201	2007-09-29 23:55:48
H1743-322	0724401901	2014-09-23 19:15:51
	0783540201	2016-03-13 03:25:57
M82 X-1	0206080101	2004-04-21 21:36:32
NGC5408 X-1	0302900101	2006-01-13 18:41:00
	0500750101	2009-01-13 19:05:27
	0723130401	2014-02-13 00:23:35
NGC6946 X-1	0200670401	2006-06-25 16:28:06
	0500730201	2007-11-02 21:53:24
	0691570101	2012-10-21 17:50:58
Swift J1644+57	0678380201	2011-04-30 07:31:07
	0700381601	2012-10-05 19:06:15
	0784790101	2016-10-18 14:20:23
Sgr A*	0202670601	2004-03-30 14:46:36
	0202670701	2004-08-31 03:12:01
	0762250301	2015-09-27 15:48:39
REJ1034+396	0506440101	2007-05-31 19:47:14
	0561580201	2009-05-31 01:44:37
	0655310201	2010-05-11 05:32:56

Region File

Make region files for each objects.

e.g.)M82 X-1



Software

・Ciao command
⇒program for analysis of CHANDRA　e.g.)deflare
・Sas command
⇒program for analysis of XMM-Newton　e.g.)evselect
・ds9
⇒make region files
・XRONOS(ver 5.22)
⇒TF program for Timing Analysis

Fitting model

Different from energy fitting, we mainly use 3 models for Timing Analysis.

【Lorentzian】

$$L(x) = \frac{LN}{1 + \left(\frac{2(x - x_0)}{\Delta x}\right)^2}$$

【Power-law】

$$A(E) = KE^{-\alpha}$$

Exponential model

【Constant】

C=C

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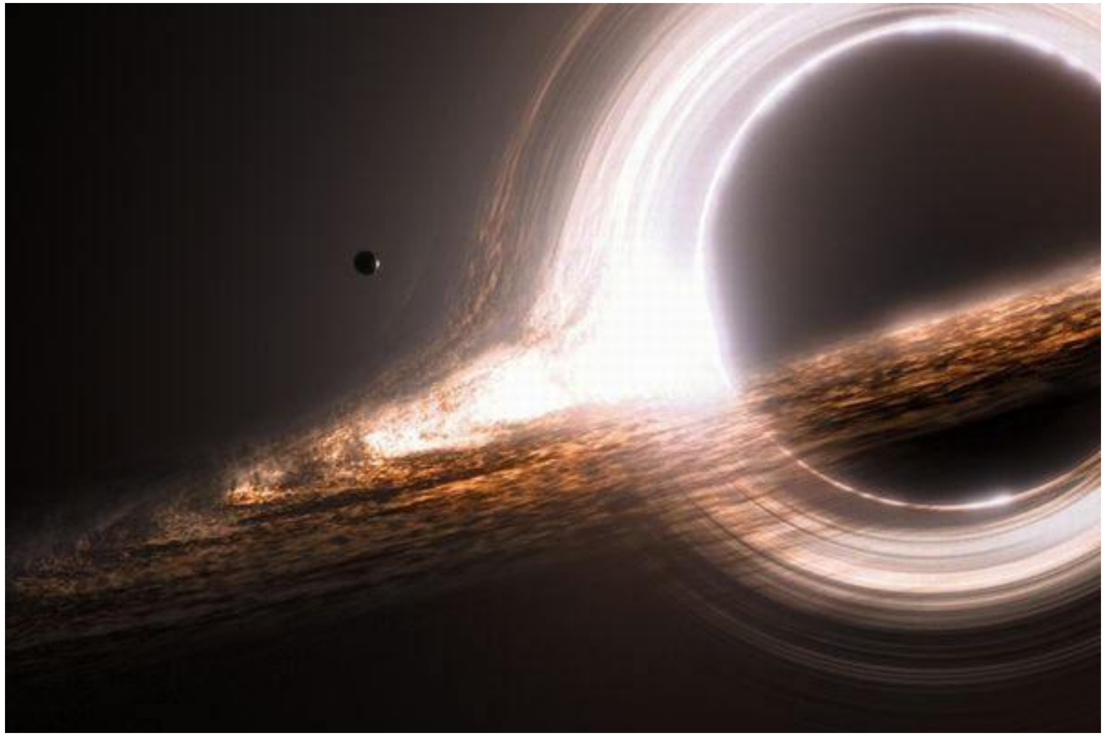
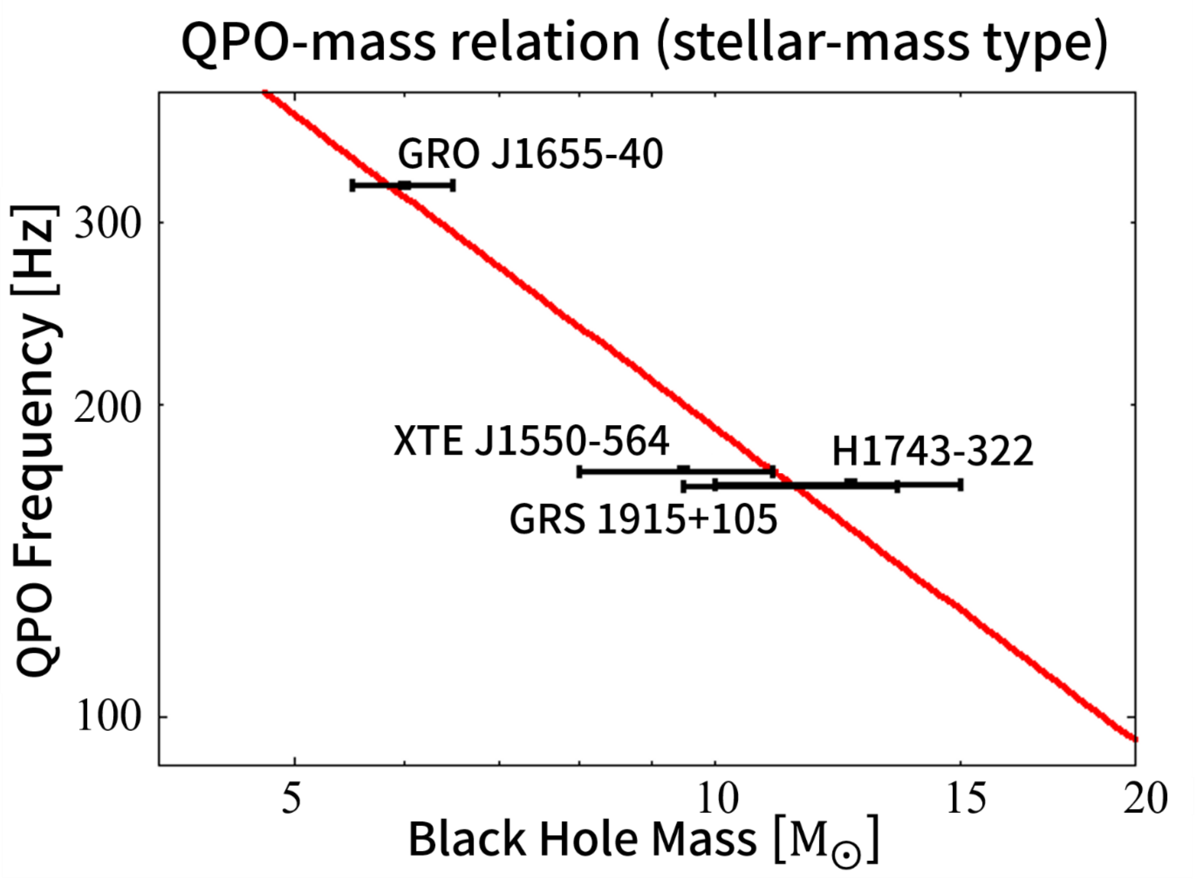


Conclusion



$$f\ [\mathrm{Hz}] = 1903.28\left(\frac{M}{M_\odot}\right)^{-1}$$

inverse proportionality

If we can adopt the relation to other type BH candidates, Their QPO frequency should be much smaller…?

Fig1. The relation between QPO-mass of the stellar-mass black holes

Conclusion

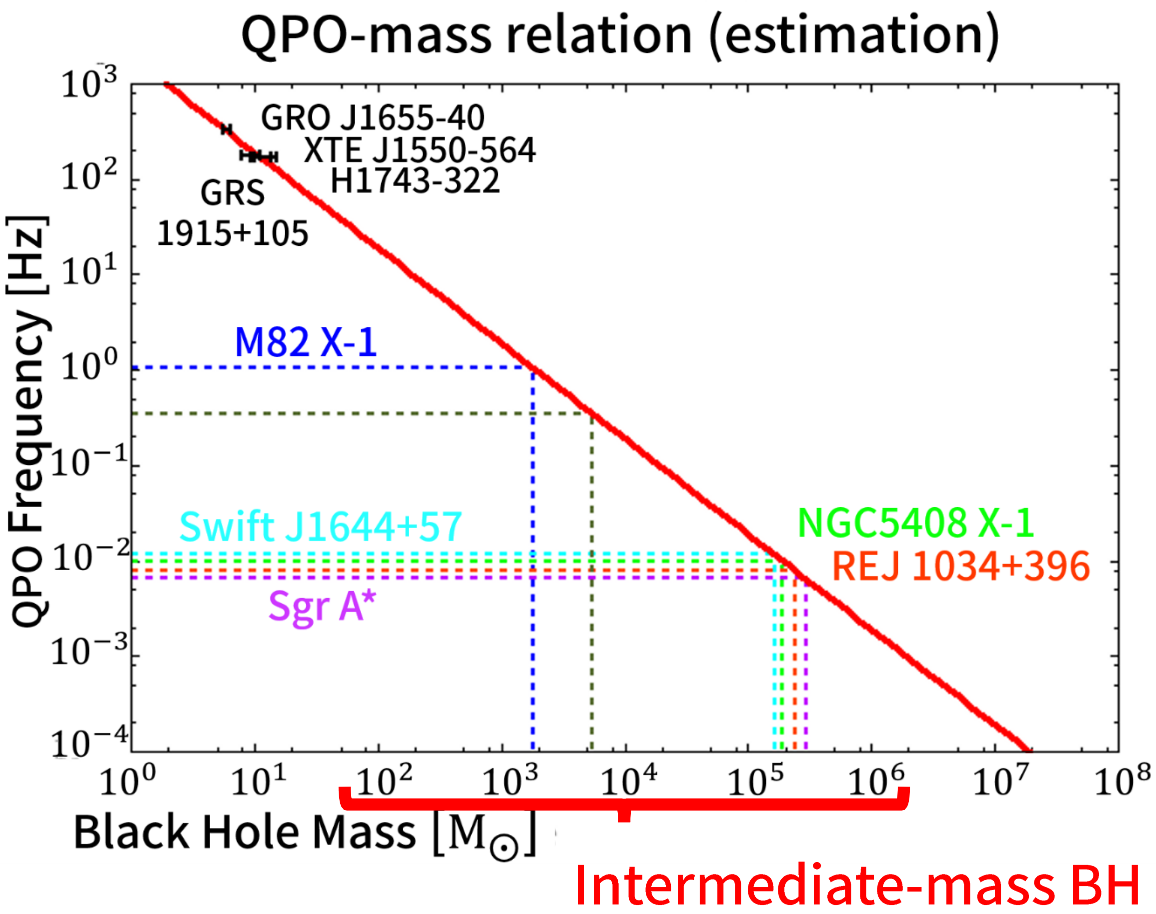


Fig2. Estimation of the mass of the black hole candisates
from QPO-mass of the stellar-mass black holes

Analysis QPO of 6 candidates and
Adopt the relation

$$f\ [\mathrm{Hz}] = 1903.28 \left(\frac{M}{M_\odot}\right)^{-1}$$

Then...
The mass of all objects are included in Intermediate-mass BH region!!

Summary

- I applied the relation between QPO and mass of the stellar-mass black holes to intermediate-mass or massive black hole candidates.
- As a result, it is suggested that the candidates

  M82 X-1 , Swift J1644+57 , NGC5408 X-1
  NGC6946 , REJ1034+396 , Sgr A*

  are intermediate-mass black holes
  with respect to QPO.


Thank you for listening !