Probing interactions between the Be star and the compact object in the TeV gamma-ray binary HESS J0632+057

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- Introduction
- Previous analysis & Motivation
- Swift/XRT analysis ~ deriving the orbital period~
- Comparison between X-ray and Hα
- Summary & future work
- Introduction of Hiroshima University group

Introduction ~gamma-ray binaries~

- Most of their radiated power is emitted beyond 1 MeV
- Compact object and massive star (>10 M_{solar})
- 5 systems
  - 1 system: pulsar

    Be star: PSR B1259-63
  - 4 systems: compact object of unknown nature

    O(f) stars: LS 5039, 1FGL J1018.6-5856

    Be stars: HESS J0632+057, LS I +61 303

The origins of high energy emission of gamma-ray binaries and the particle acceleration mechanism are still unsolved

Introduction ~gamma-ray binaries~

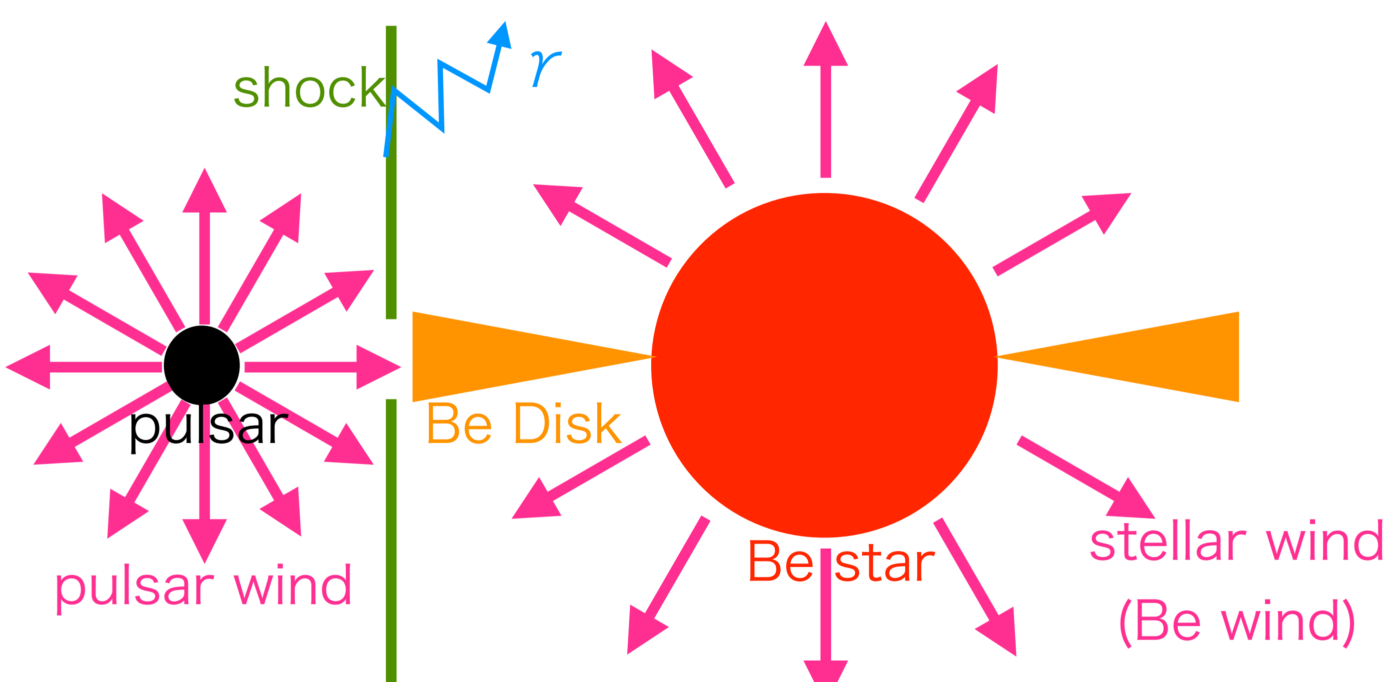
2 theories to explain the emissions of gamma-ray binaries

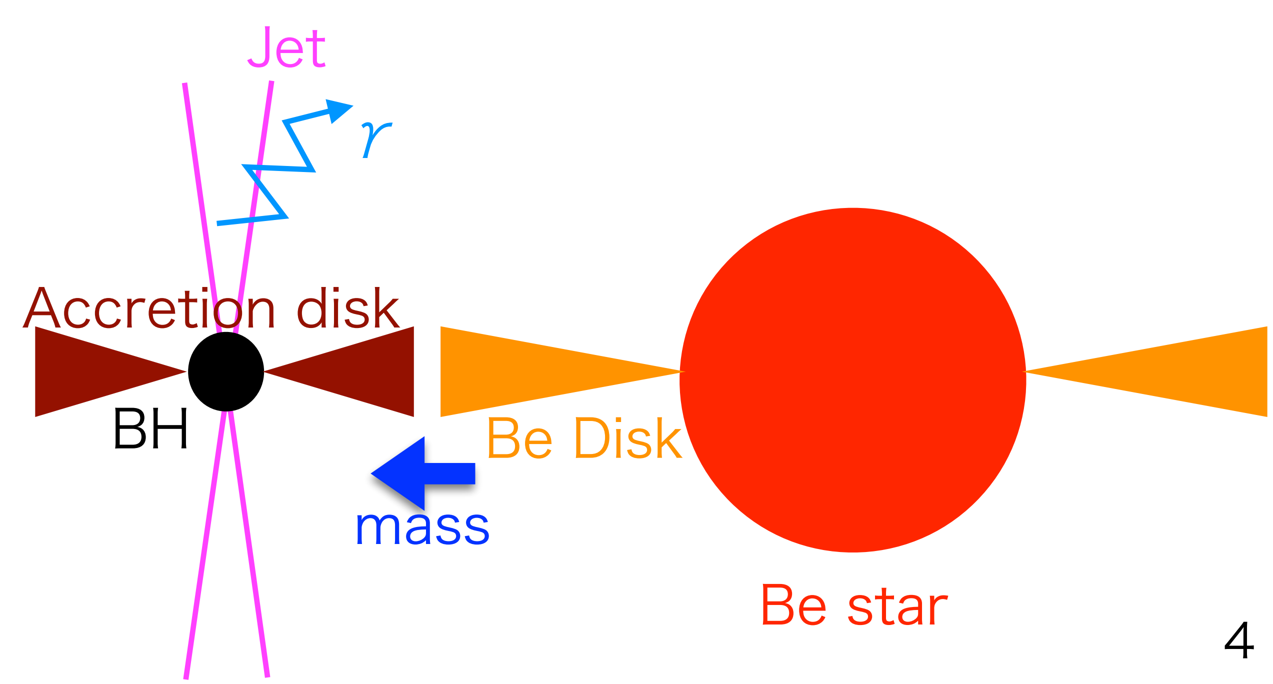
Pulsar Wind model

- Compact object: pular
- Collision between stellar wind (or Be disk) and pulsar wind →shock
- Particle acceleration originate from shock → gamma-ray emission

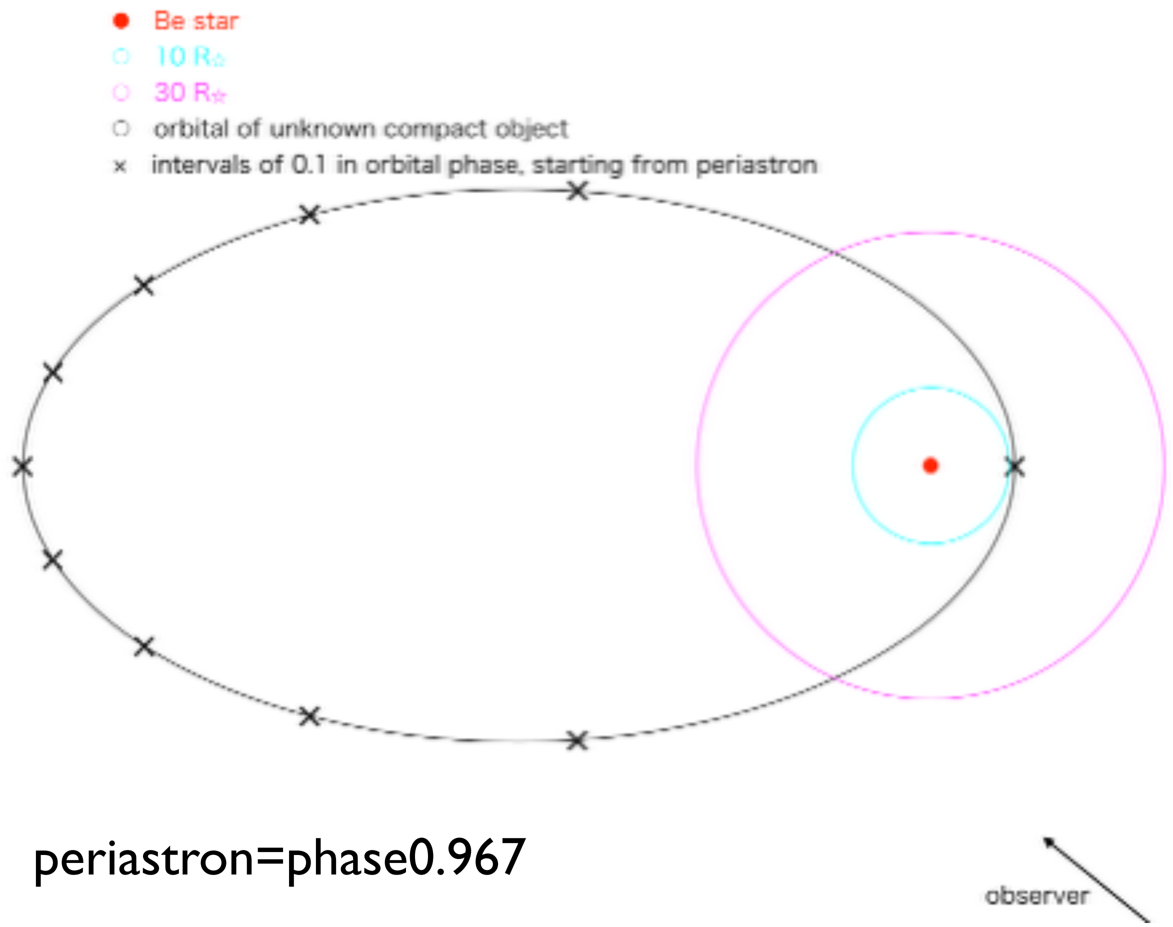
Accretion (Microquasar) model

- Compact object: BH (or NS without pulsar wind)
- Enormous gas from star (or Be disk) → jet
- Particle acceleration originate from shock in jet → gamma-ray emission





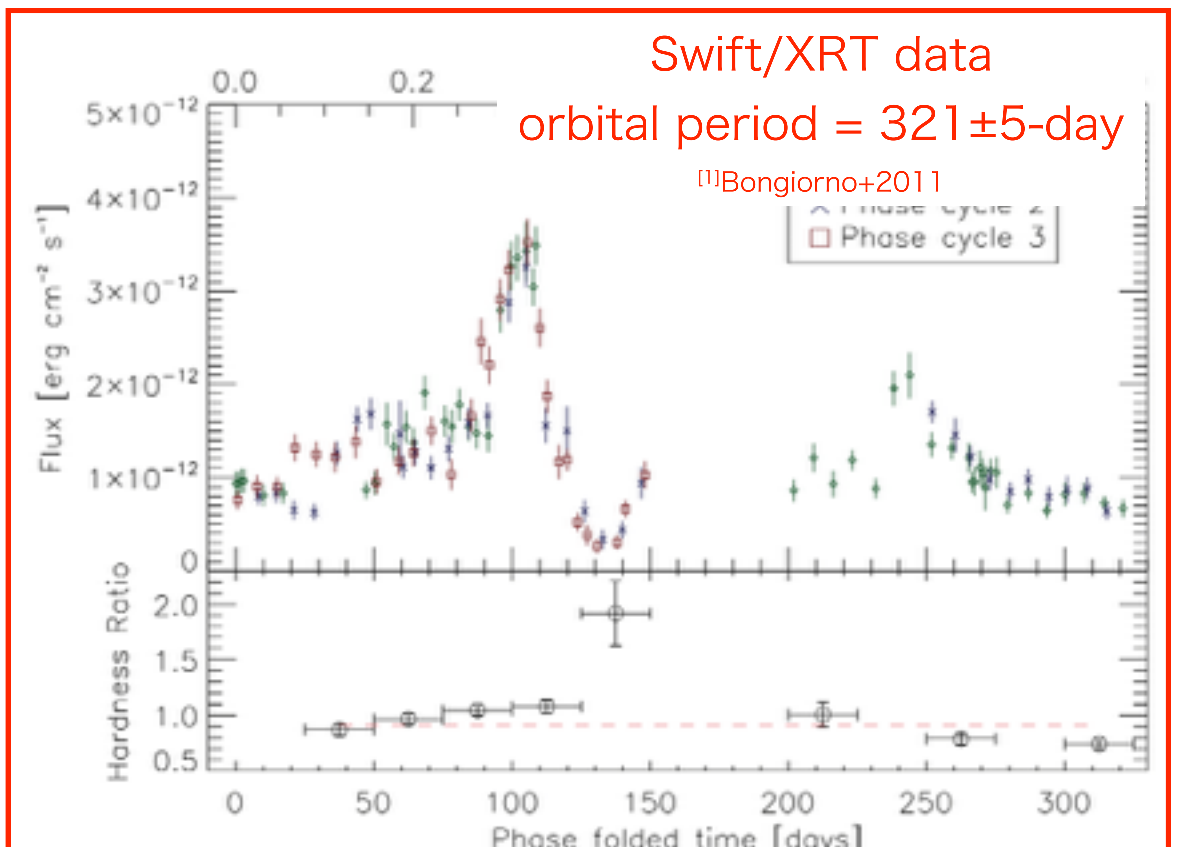
Previous analysis — HESS J0632+057

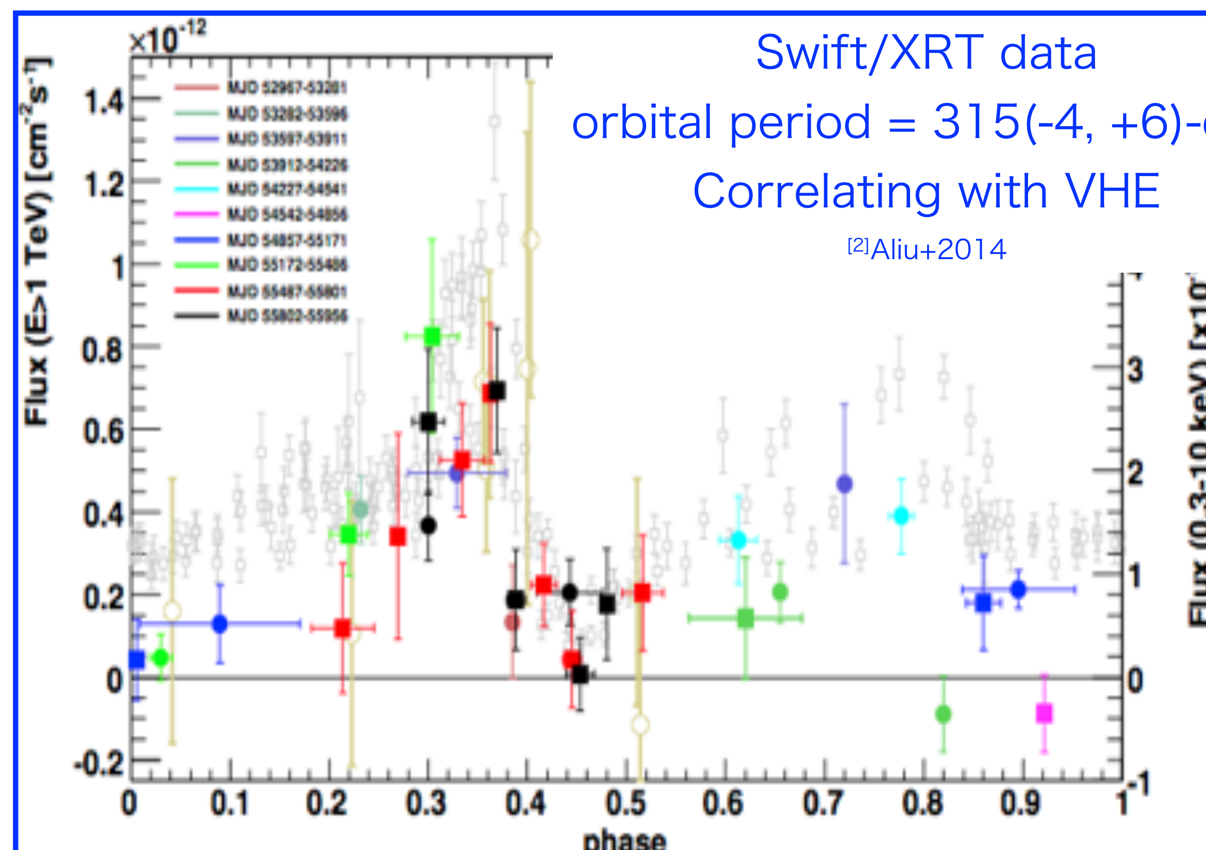


periastron=phase0.967

- Highly eccentric orbit: 0.83(7)
- Long orbital period: ~320-day
- Sharp peaks around apastron

highly eccentric system
→the compact object has a high velocity around periastron
→important to predict a periastron
⇒a few-day uncertainly in the orbital period
~6-week uncertainty in the next periastron passage





[1]Bongiorno S.D. et al., 2011, ApJ, 737, L11, [2]Aliu et al. 2014, ApJ, 780, 168

Motivation — HESS J0632+057

✓ To identify the nature of the compact object

- What is the origin of the high energy emission??

- X-ray light curve

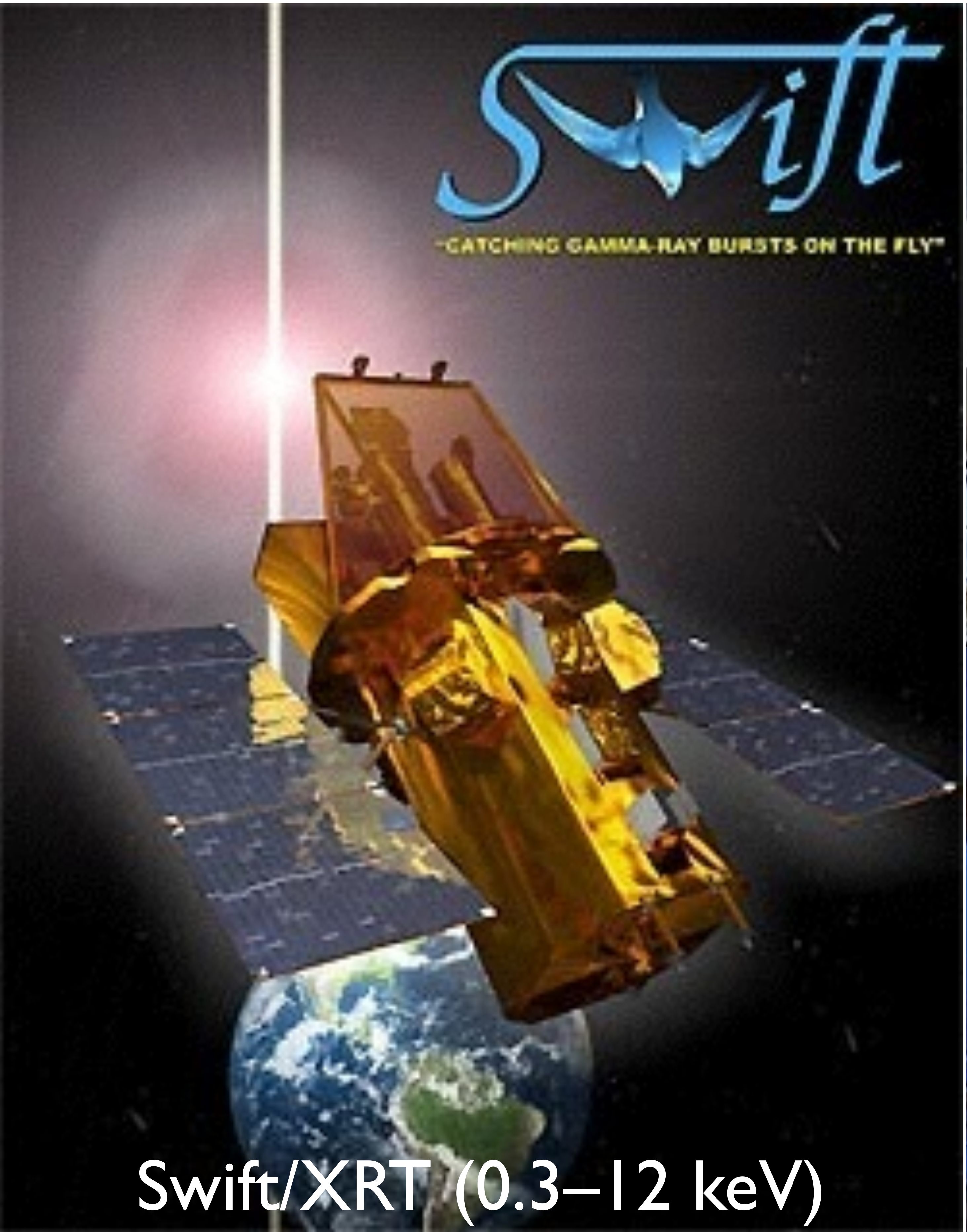
  →To determine the most plausible orbital period

- Multi-wavelength observation & hydrodynamic simulation

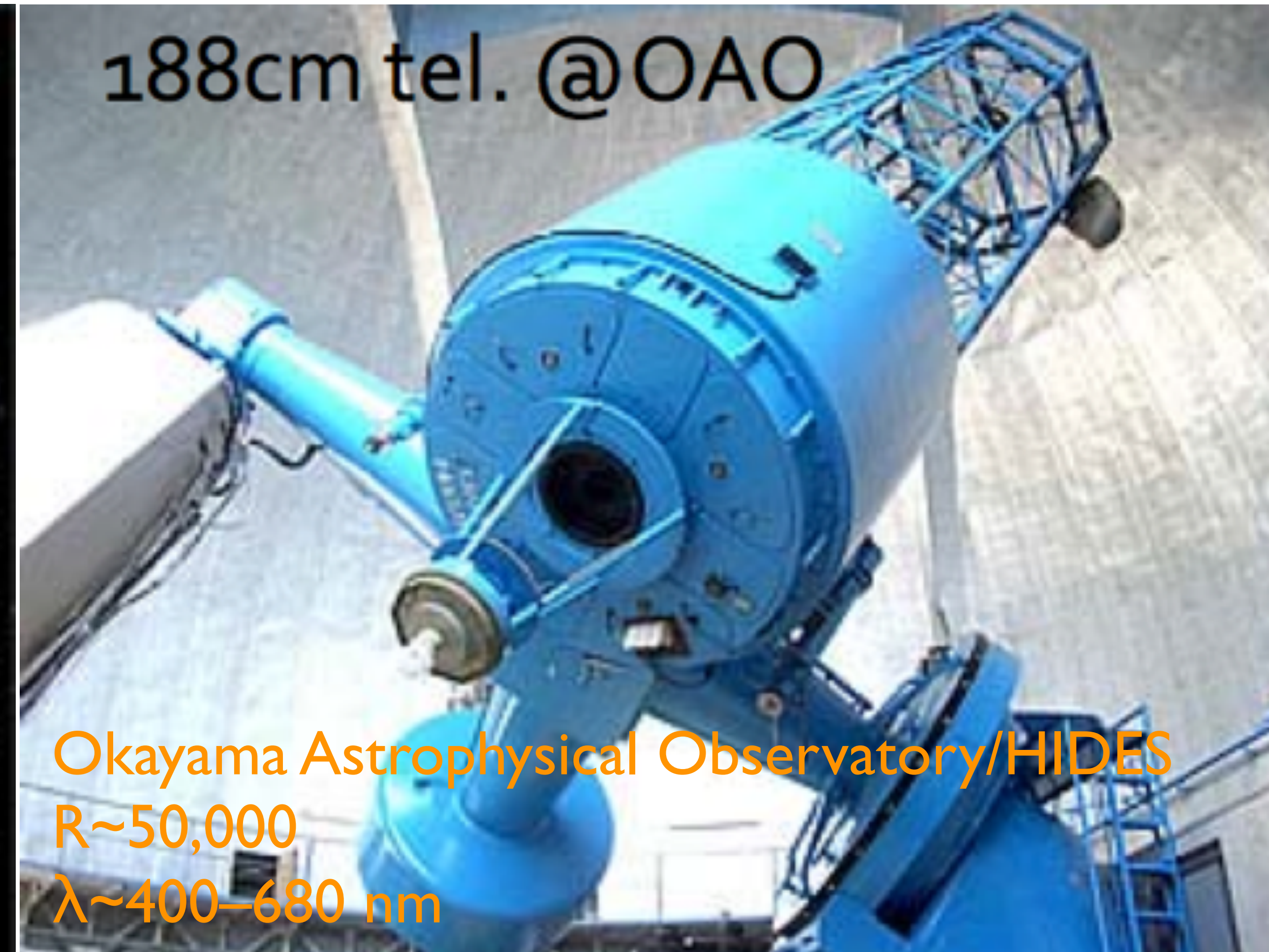
  →Study of the interactions between the Be star and the compact object

  →Unveiling the nature of the compact object & the origin of the high energy emission

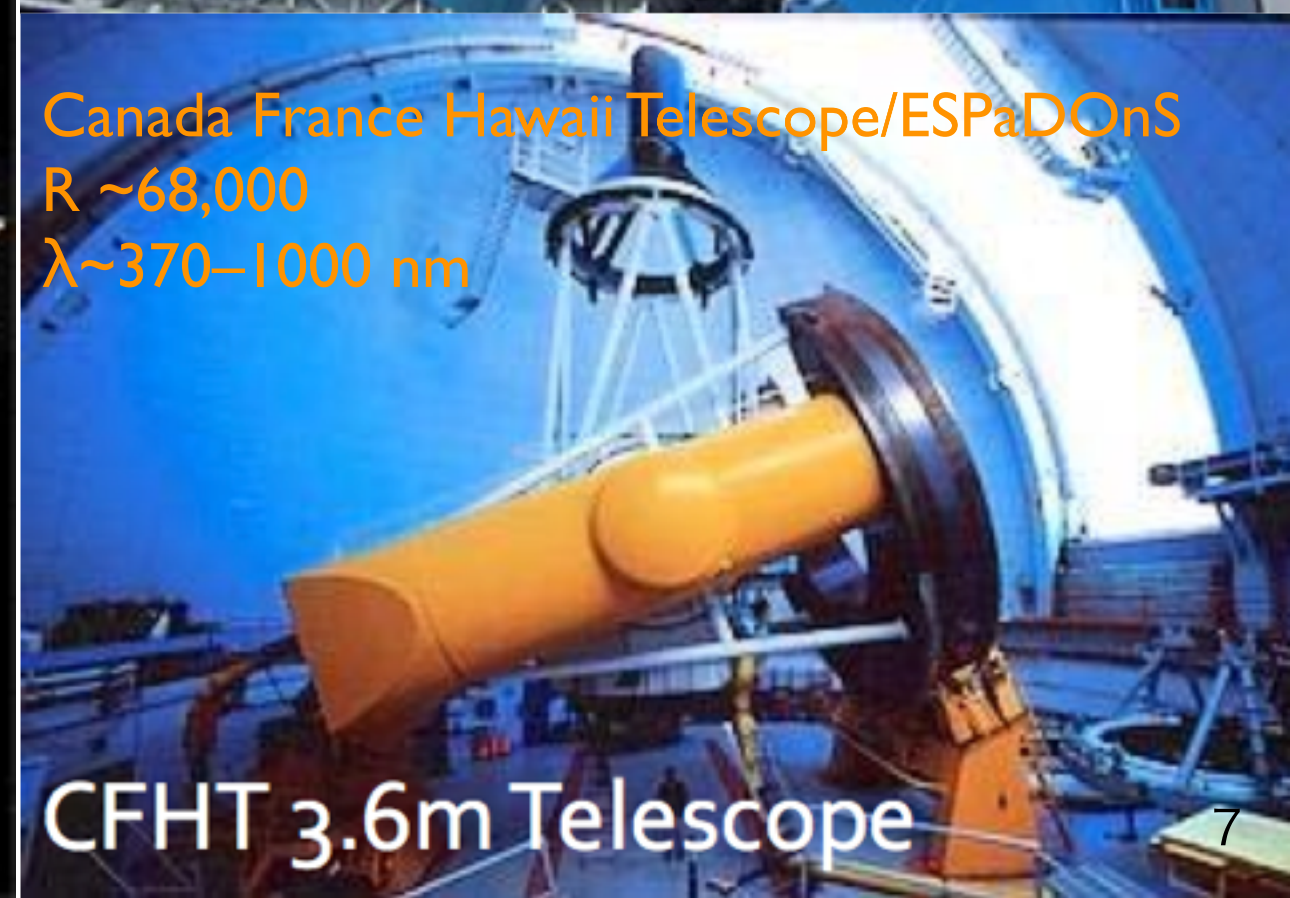
Approach from X-ray and Optical wavelengths



Swift/XRT (0.3–12 keV)

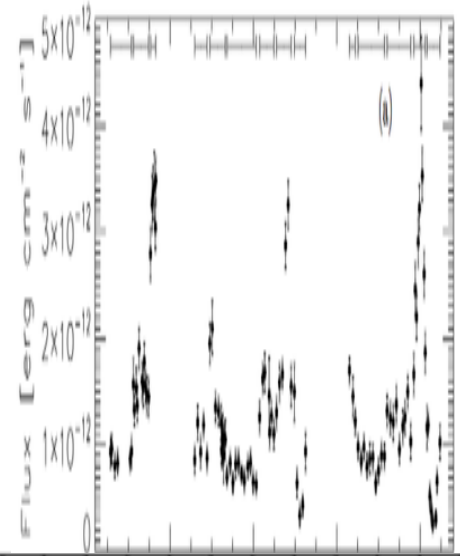


Okayama Astrophysical Observatory/HIDES
R~50,000
λ~400–680 nm

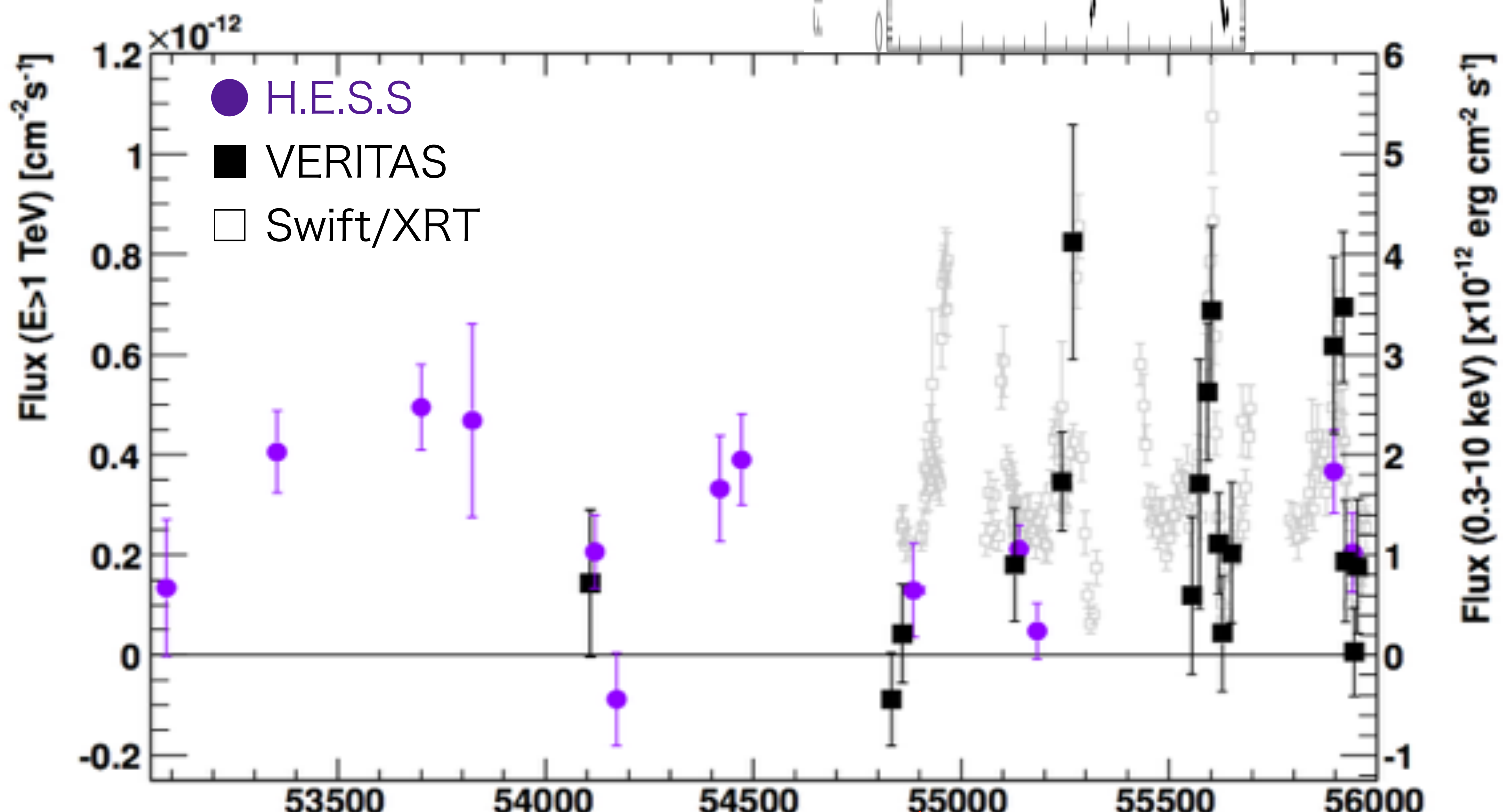


Canada France Hawaii Telescope/ESPaDOnS
R ~68,000
λ~370–1000 nm

Long term light curve ~Swift/XRT~



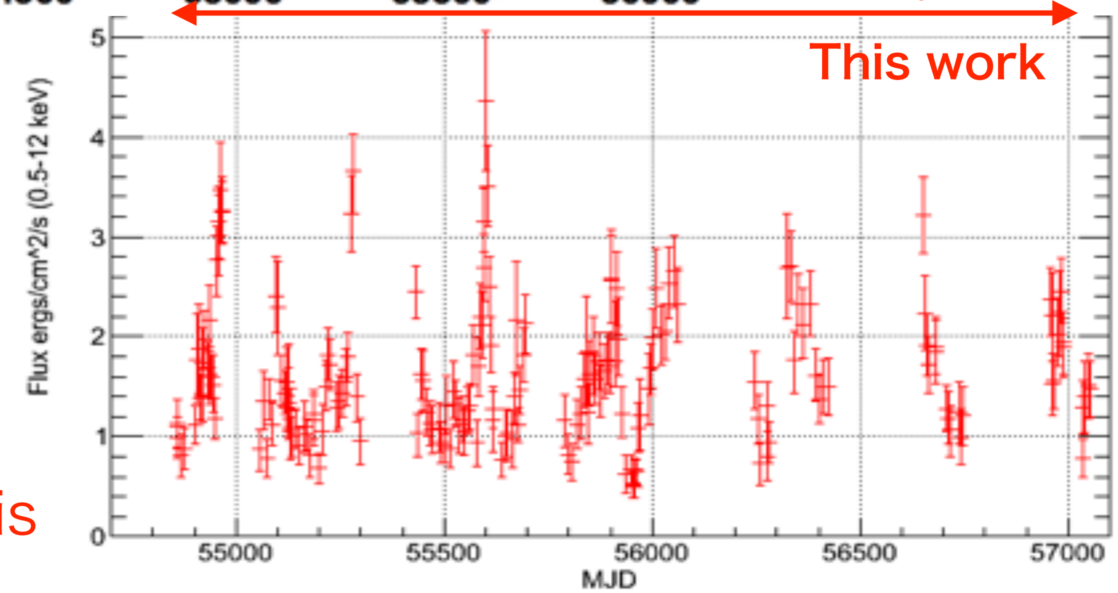
Bongiorno+2011



Aliu+2014

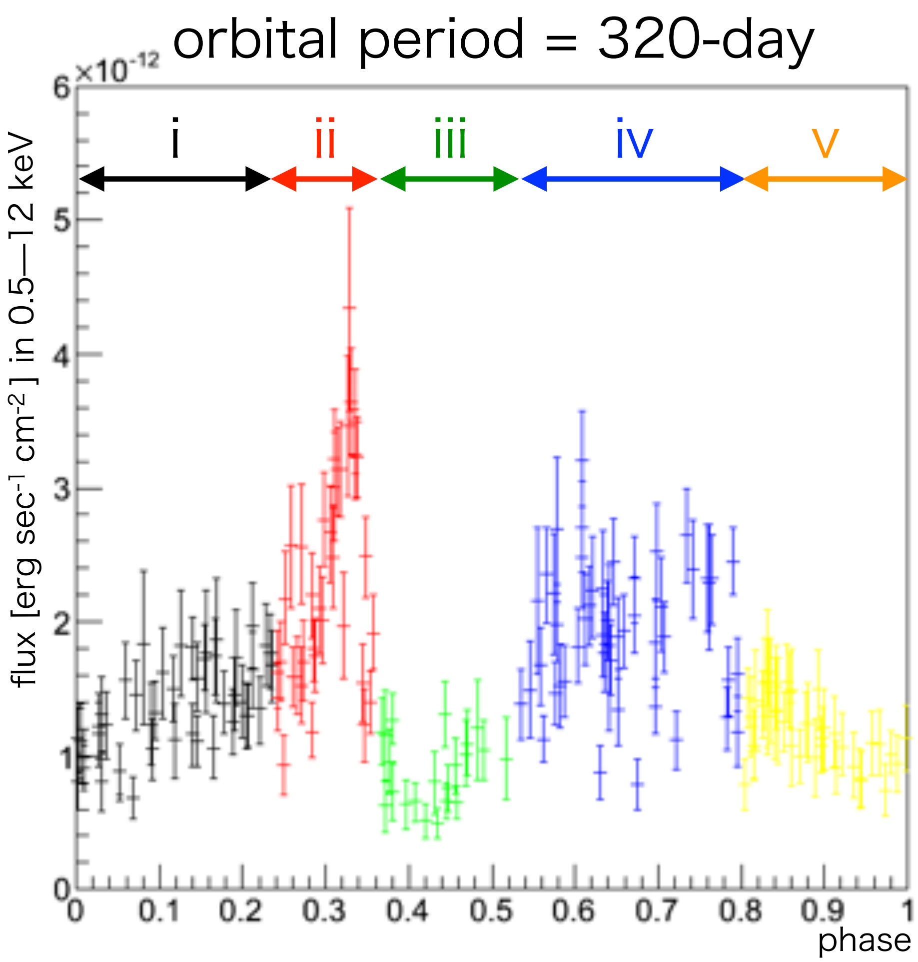
about 6 years
2009/Jan./26-2015/Jan./30

This work

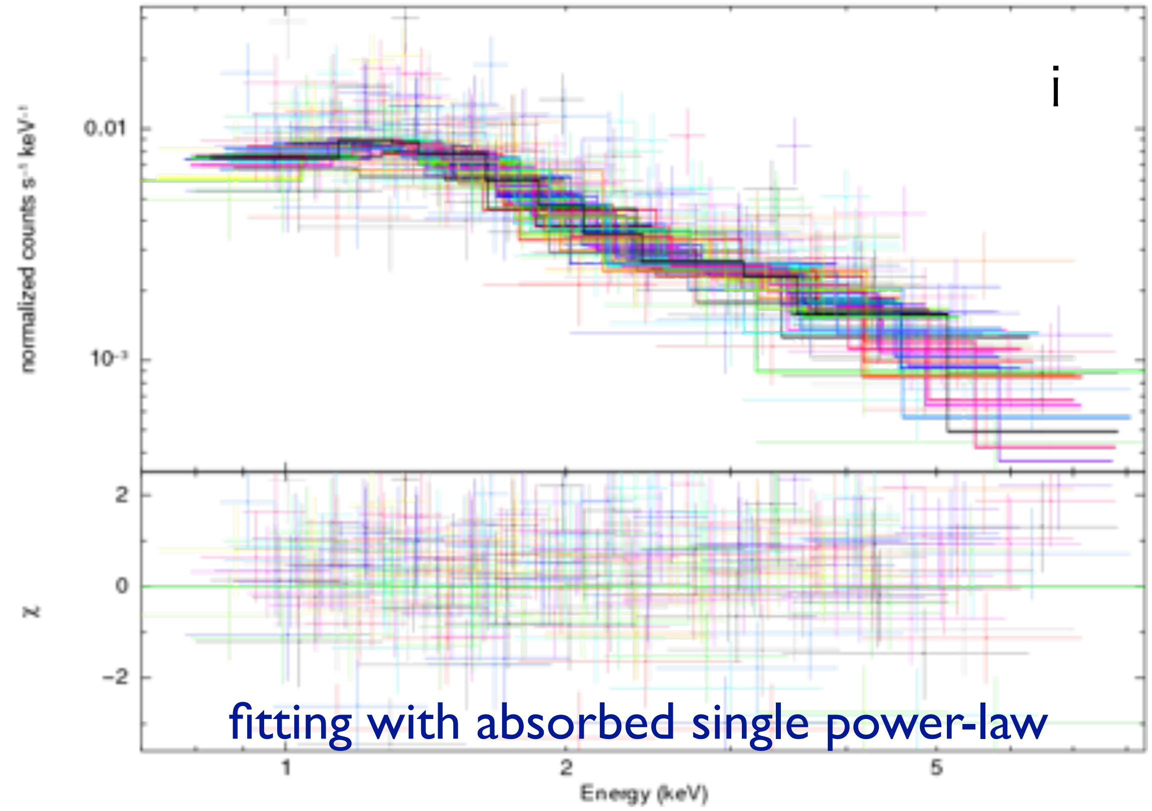


better statistics than the previous analysis

First step: Analyzing the X-ray spectra



Also tried 313-day and 317-day



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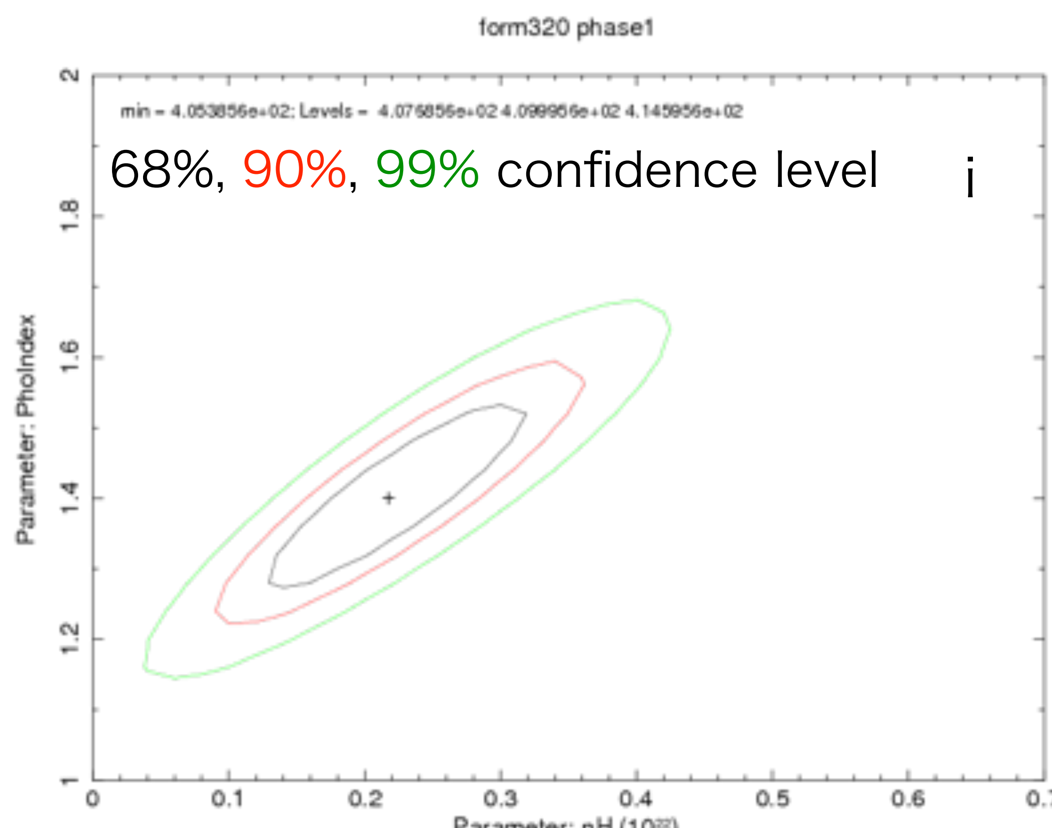

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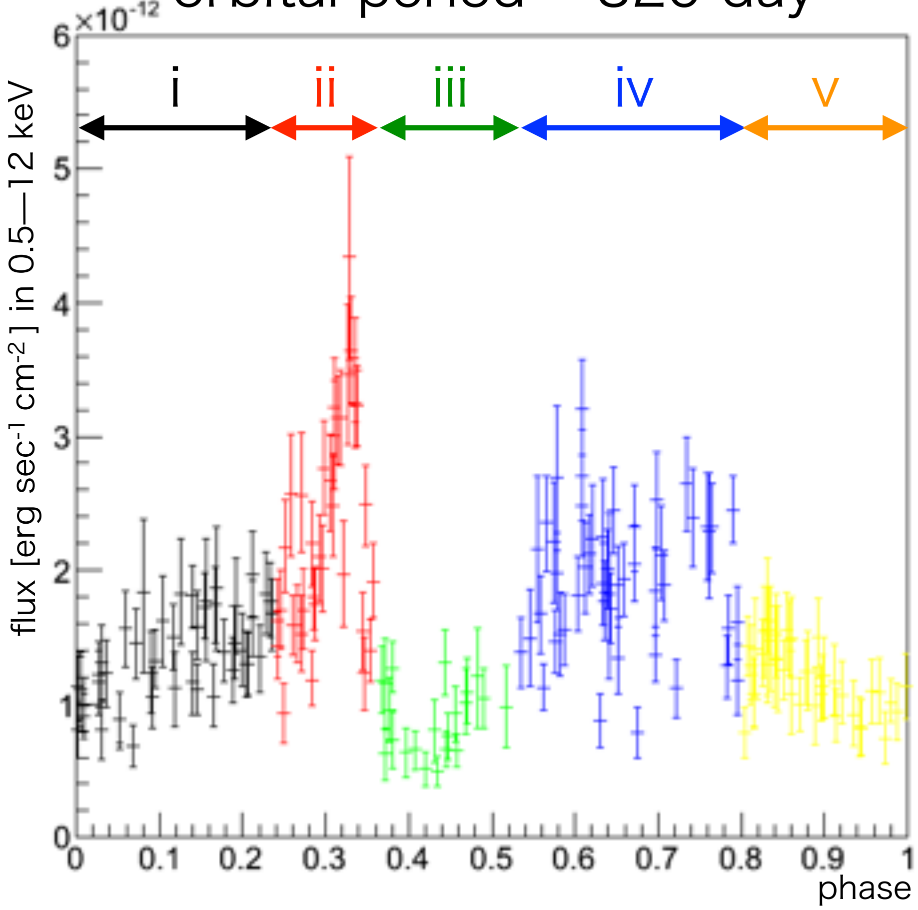
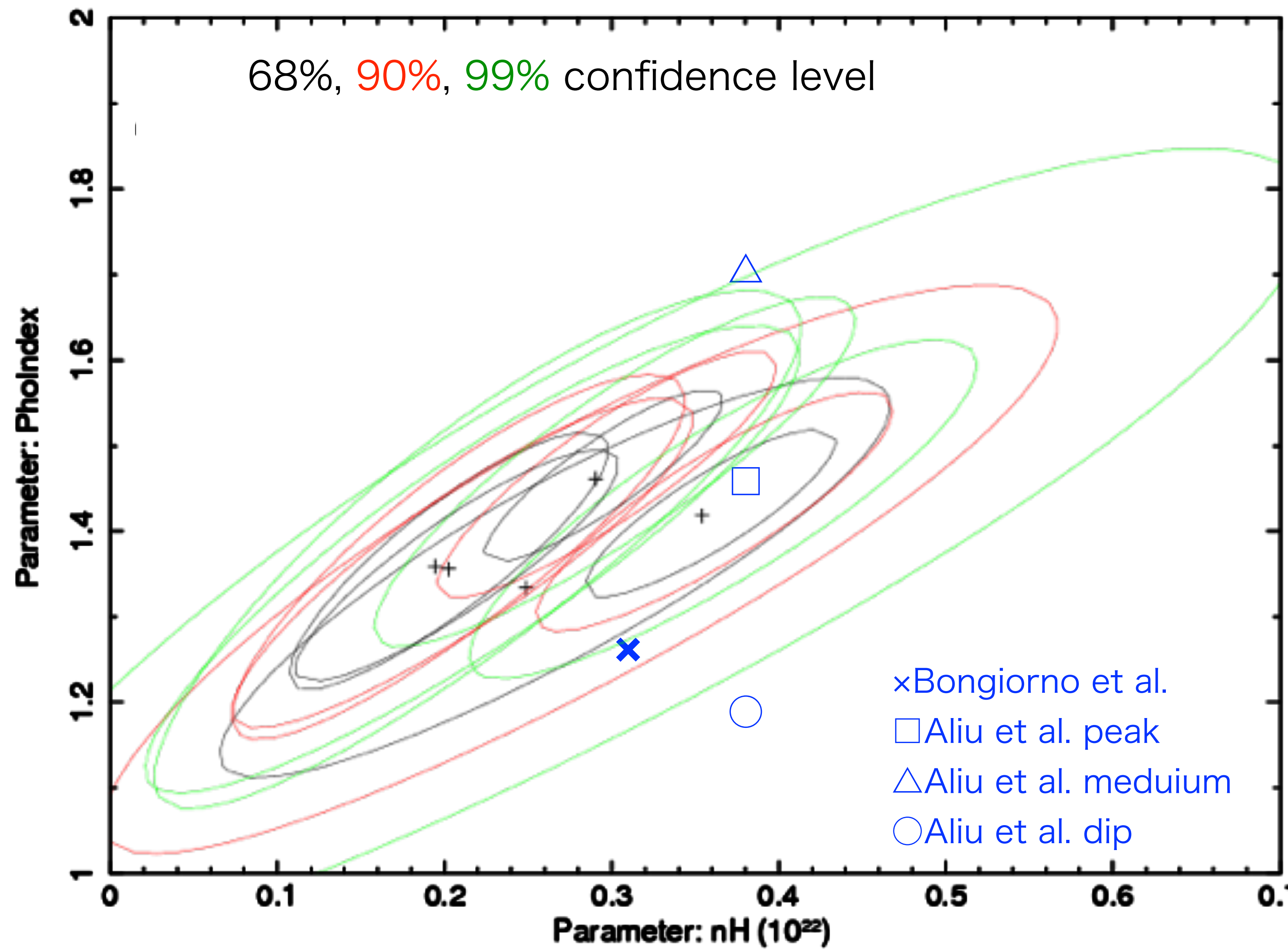
fitting with absorbed power-law,
and created contours of nH vs. Photon Index

First step: Analyzing the X-ray spectra



Also tried 313-day and 317-day



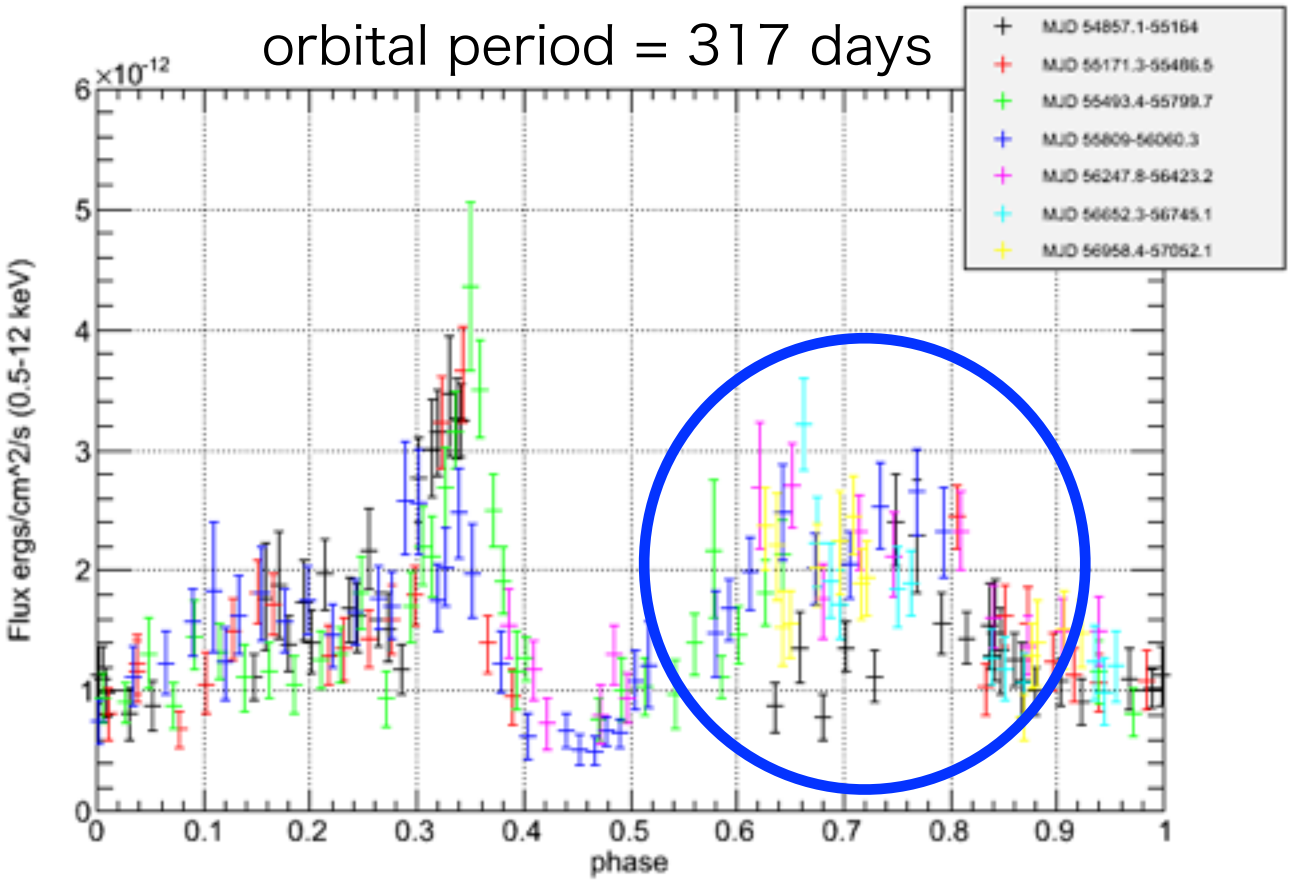
nH & photon index are not different significantly

→Utilized all data set to determine nH & photon index

nH: 1.8 (±0.4)×10^{21} cm^{-2}

photon index: 1.31(±0.06)

Second step: deriving the orbital period



2-peak structure? in the secondary peak

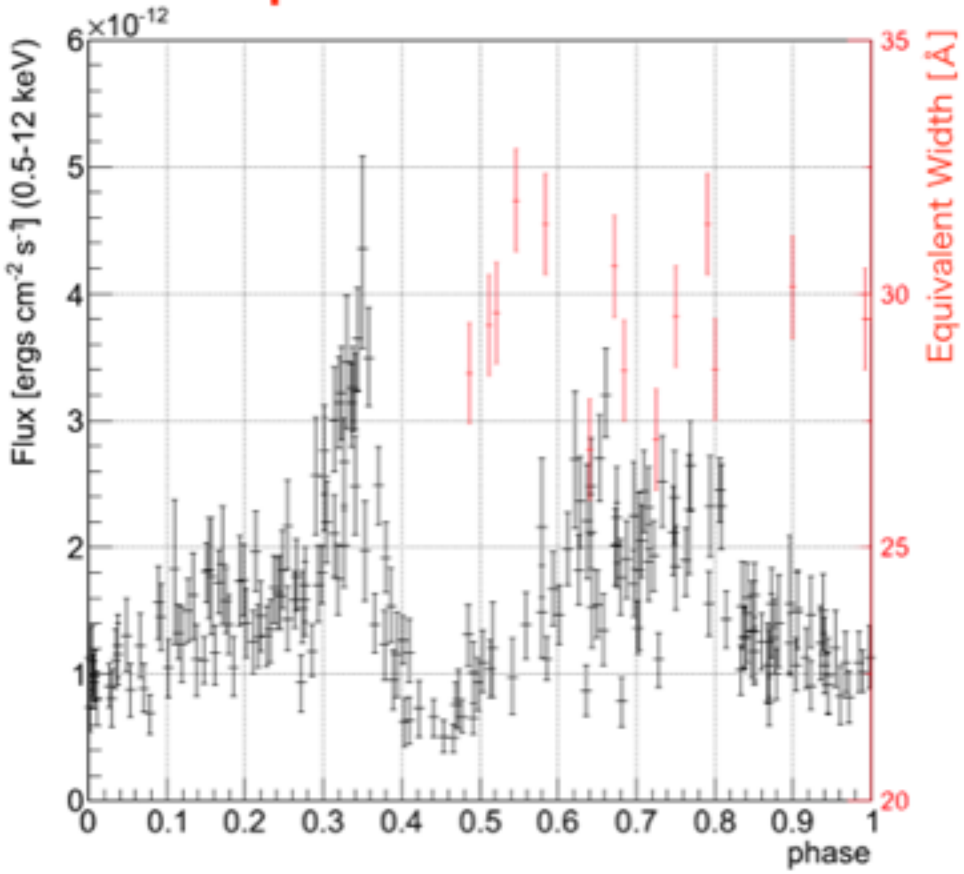
- Used Z-DCF to determine the orbital period
  - Z-DCF (Z-transformed discrete correlation functions, Alexander 1997, Edelson & Krolik 1997).
  - Based on Monte Carlo-based method, using simulated light curve, and assuming them to be normally distributed.
  - The errors correspond to 1σ sampling errors.
- Estimated orbital period=317(-4, +6) days

Bongiorno et al. : 321±5 days
Aliu et al. : 315 (-4, +6) days

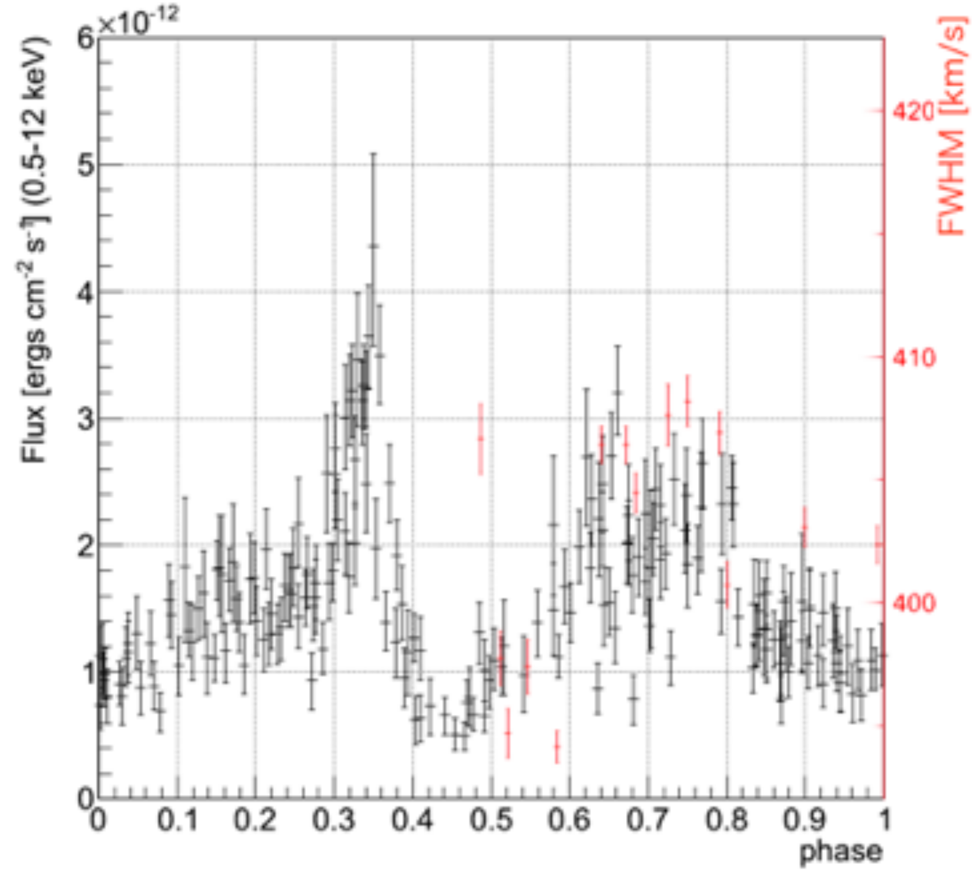
The accuracy of the orbital period is not different significantly from previous statistics using Swift/XRT data & Z-DCF

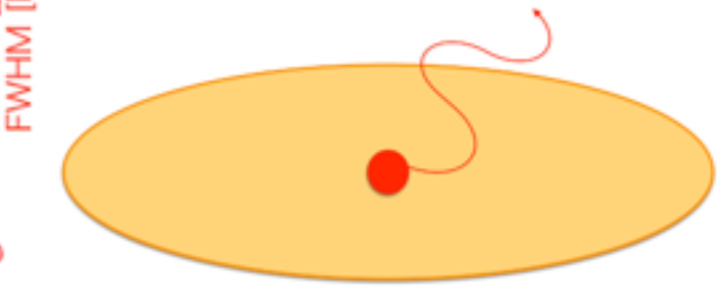
Swift/XRT(0.5–12 keV) vs. Hα

Equivalent Width



FWHM





	Correlation
EW	×
FWHM	○

- ✓ EW (strength of Be disk emission)
  - Not correlated with the X-ray variability
- ✓ FWHM (dependent on Be disk structure)
  - Seems to be correlated with the X-ray variability

→May suggest a correlation between the structure variation of the Be disk and the X-ray variability

Summary

- X-ray
  - Analyzed Swift/XRT data 2009/Jan./26-2015/Jan./30, and found that 317-day is the most plausible orbital period.
  - Two (three?) peaks around apastron
- Comparison between X-ray & Optical/near-infrared band
  - FWHM of Hα seems to be correlated with X-ray variability

  →May suggest a correlation between the structure variation of the Be disk and the X-ray variability

Future work

- X-ray
  - More robust method to determine the orbital period
- GeV gamma-ray
  - Analyzing ~6-year data of Fermi/LAT
- HESS J0632+057 with multi-wavelength (X, gamma, Opt, NIR)

★ Studying the broad band spectrum to unveil the emission mechanism

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○Kanata Telescope & HONIR ~Introduction of Hiroshima university group~

Kanata Telescope

- 1.5-m diameter optical infrared telescope
- Located at Hiroshima, Japan

HONIR (Hiroshima Optical and Near-InfraRed camera)

- Two cameras (an optical CCD and a near-infrared array) cover the wavelength range 0.5 - 2.4 μm
- Optical - NIR simultaneous imager and spectrograph in two band with **polarimetry** capability.

Science target: Optical & NIR Transients

GRBs, SNe, AGNs, X-ray binaries **and gamma-ray binaries**

☆Plan to observe HESS J0632+057 and LS I +61 303 with HONIR (V, Rc, J, Ks bands)

NIR polarimeter is a very powerful tool for studying Galactic transients!!

Info.: http://hasc.hiroshima-u.ac.jp/telescope/kanatatel-e.html

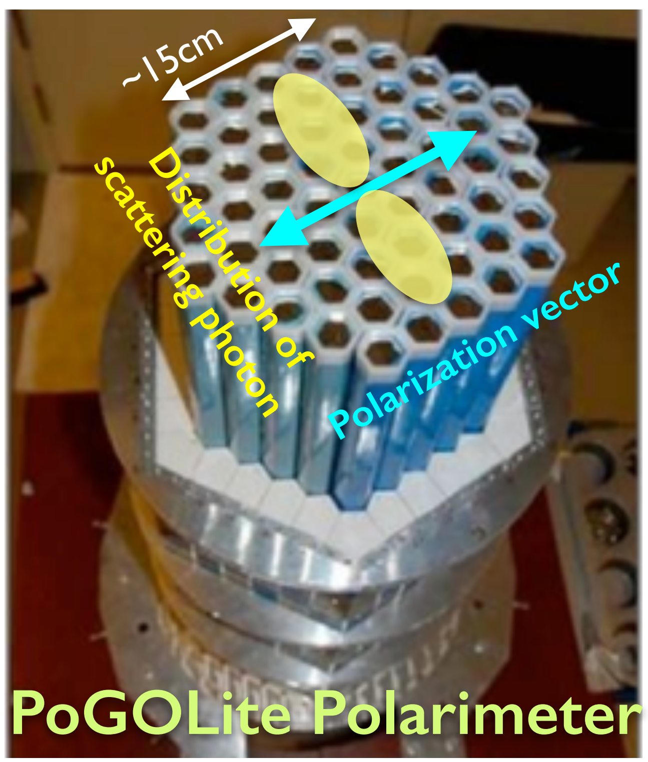
Contact: M. Yoshida (yoshidam at hiroshima-u.ac.jp)
R. Itoh (itoh at hep01.hepl.hiroshima-u.ac.jp)

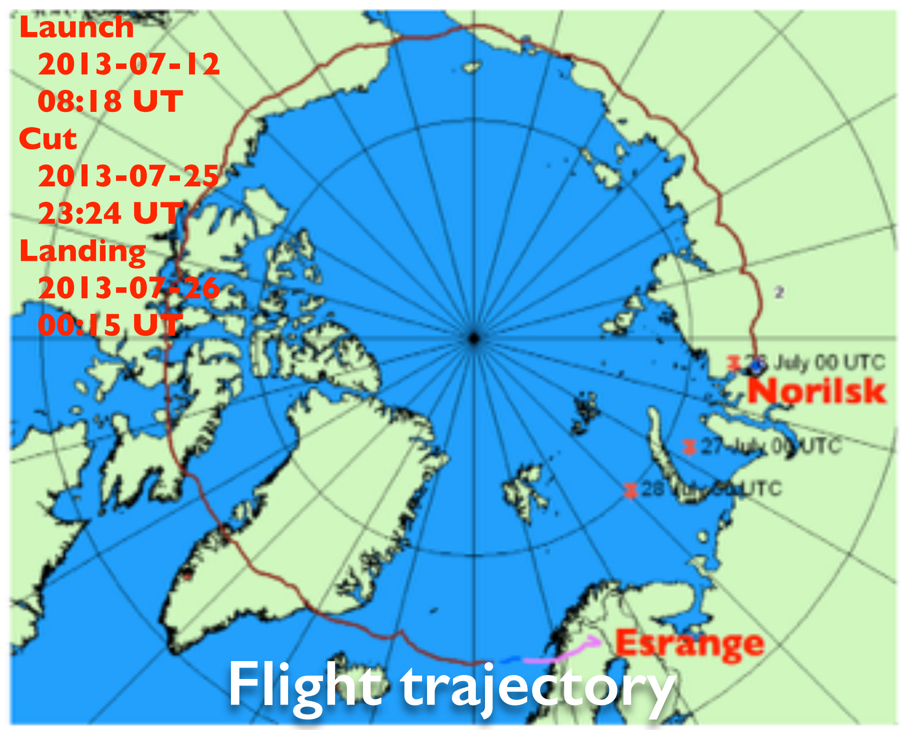
Kanata 1.5 m telescope and HONIR

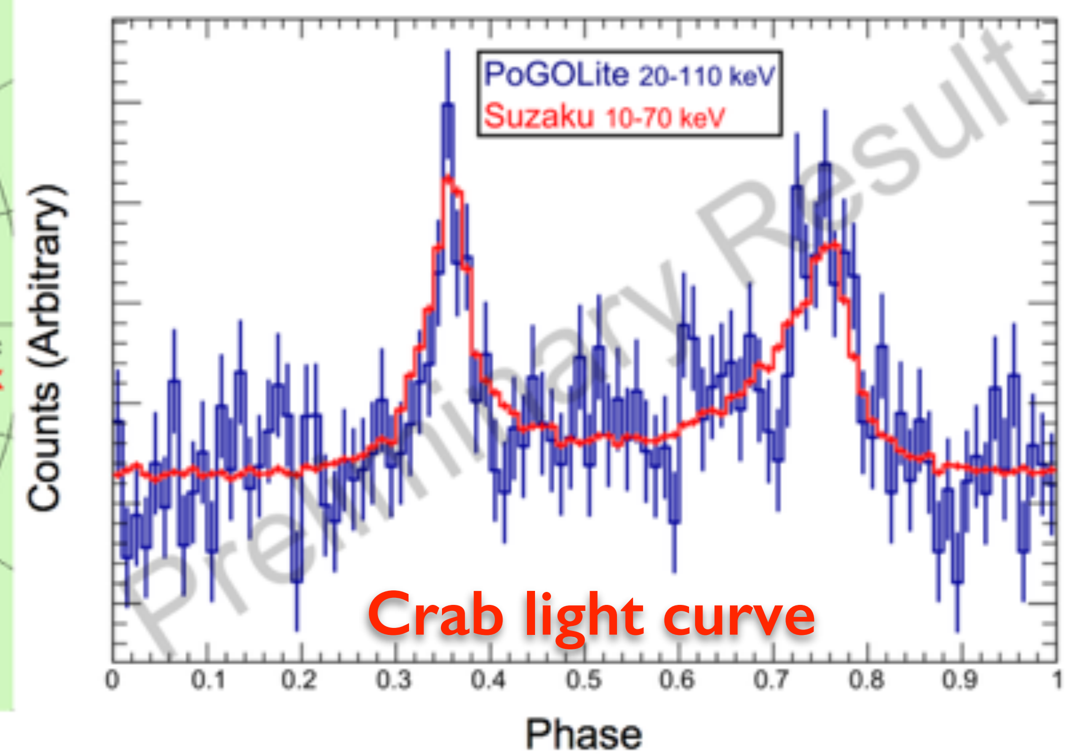
○PoGOLite ~Introduction of Hiroshima university group~

Polarized Gamma-ray Observer Light-weight version (PoGOLite)

- Collaboration campaign among Sweden, Japan and USA
- Balloon-borne Compton polarimeter
- Measuring the polarization of hard X-rays/soft gamma-rays
- Energy range: 25–240 keV
- Target objects: Crab, Cygnus X-1

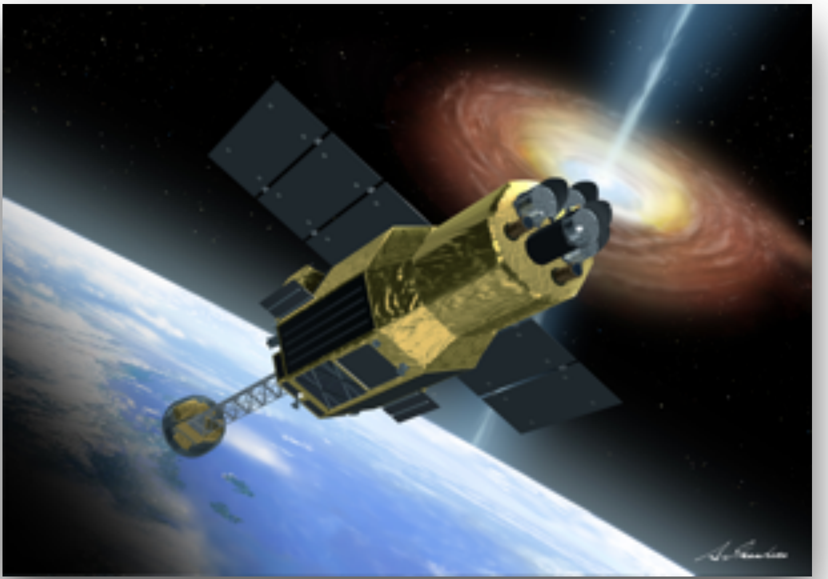




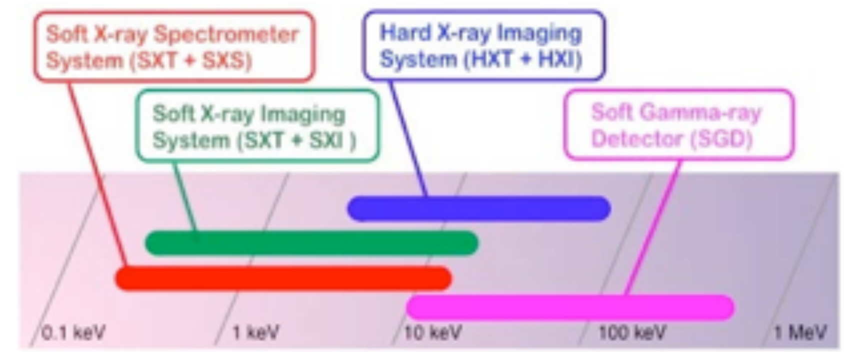


- During July 12-26 of 2013, a successful near-circumpolar pathfinder flight was conducted.
- During this two-week flight, several observations of Crab were made
- We have confirmed that Crab X-rays are registered by polarimeter
- Reflight is proposed for summer in 2016

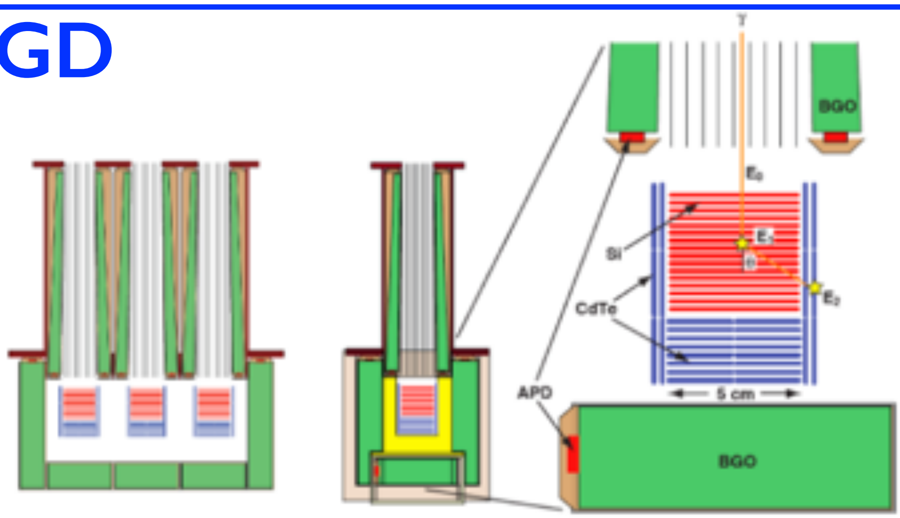
○ASTRO-H ~Introduction of Hiroshima university group~



- 6th in the series of the X-ray observatories from Japan
- Will be launched in 2015 JFY
- Four Instruments achieve wide band (0.3-600 keV) & high energy resolution (<10keV)
  - Soft X-ray Spectrometer
  - Sof X-ray Imager
  - Hard X-ray Imager
  - Soft Gamma-ray Detector

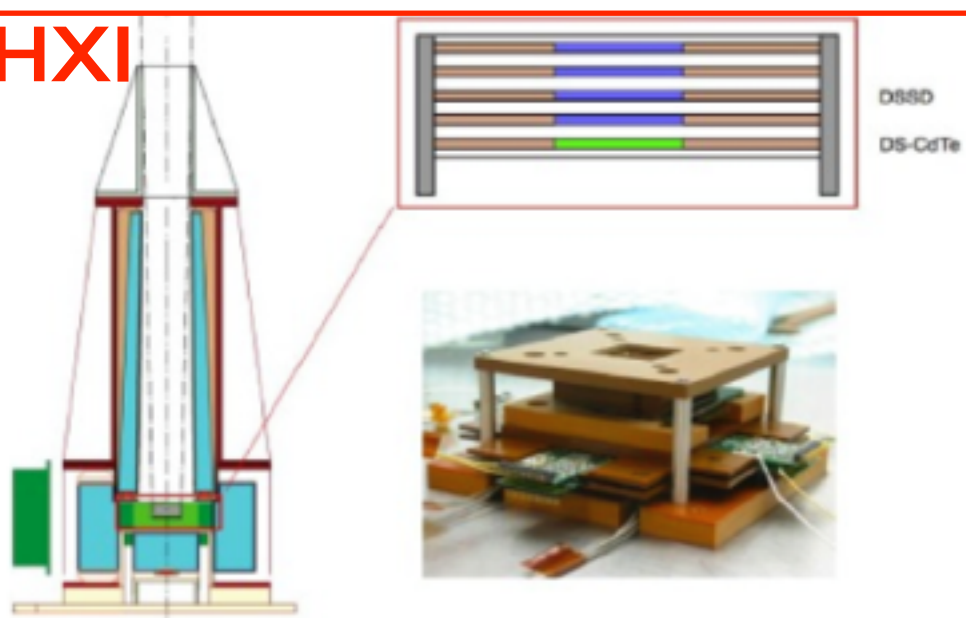


SGD

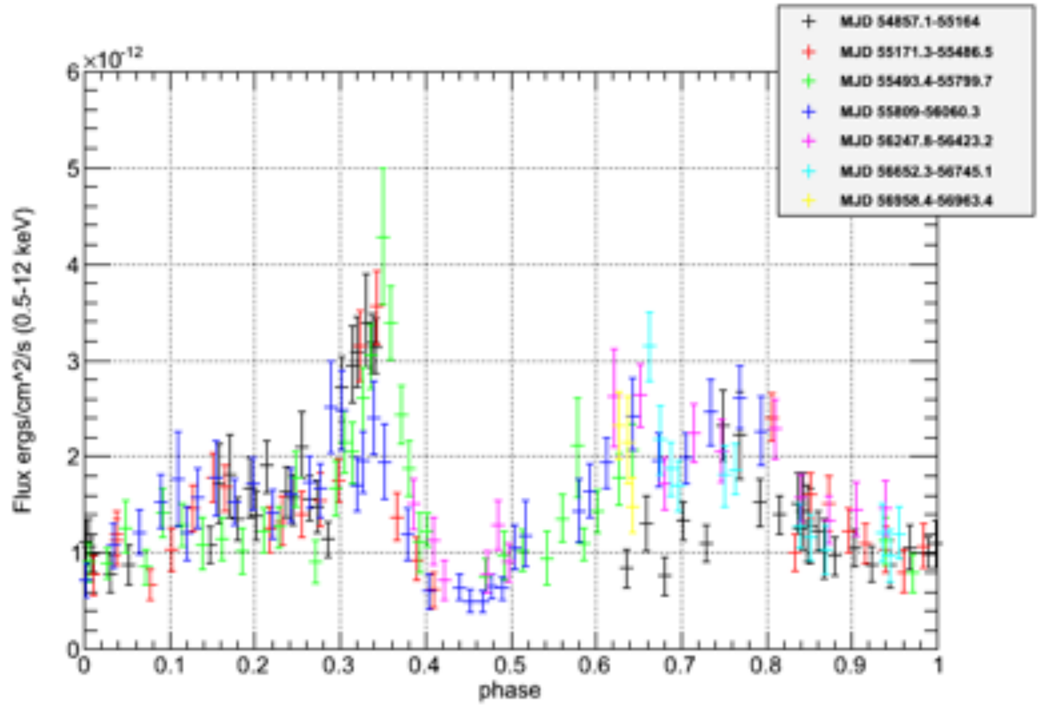


- Si/CdTe Compton Gamma Camera and Well-type shield (60 - 600 keV)
- Achieved ultimately low background.
- Measuring polarization (Modulation Factor=58%)
- GRB monitoring using BGO shield.

HXI



- Si and CdTe Hybrid Imager (5 - 80 keV)
- Imaging with hard X-ray optics: ~100 times higher sensitivity than Suzaku.
- 30-50% of the cosmic X-ray background will be resolved into hidden super-massive black holes.



assuming orbital period = 317-day

phase1: MJD 54857.1-55164
phase2: MJD 55171.3-55486.5
phase3: MJD 55493.4-55799.7
phase4: MJD 55809-56060.3
phase5: MJD 56247.8-56423.2
phase6: MJD 56652.3-56745.1
phase7: MJD 56958.4-56963.4

average
each