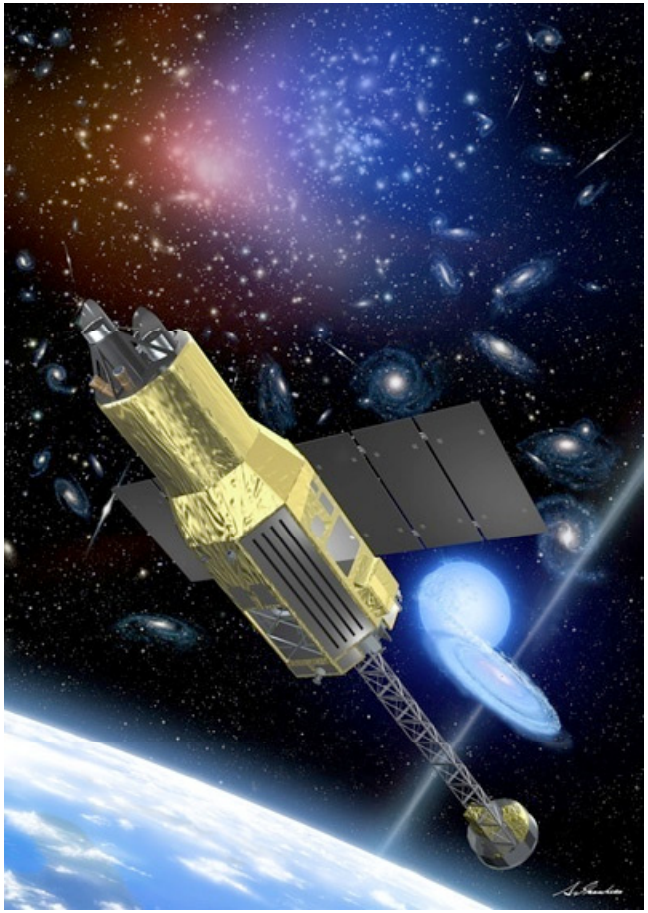
Probing Particle Acceleration with X-ray/Gamma-ray Polarimetry



Mar 22, 2012

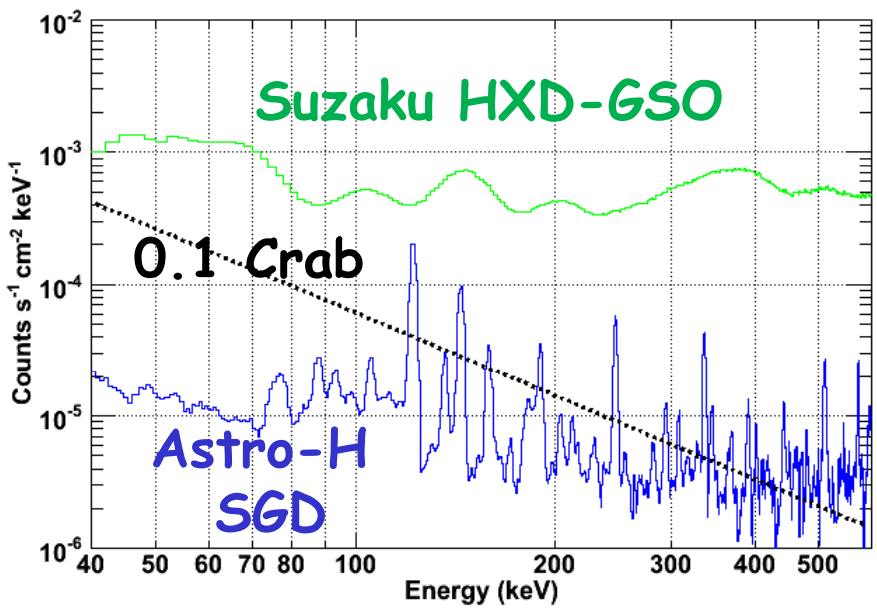
ASTRO-H Session, ASJ meeting

T. Mizuno, H. Takahashi, Y. Fukazawa (Hiroshima Univ), H. Tajima (Nagoya Univ.), T. Tanaka, Y. Uchiyama (KIPAC/Stanford), S. Takeda, H. Odaka, S. Watanabe, G. Sato, M. Kokubun, T. Takahashi (ISAS/JAXA), K. Nakazawa (Tokyo Univ.), P. Coppi (Yale Univ.) and T. Tamagawa (RIKEN)

ASTRO-H SGD

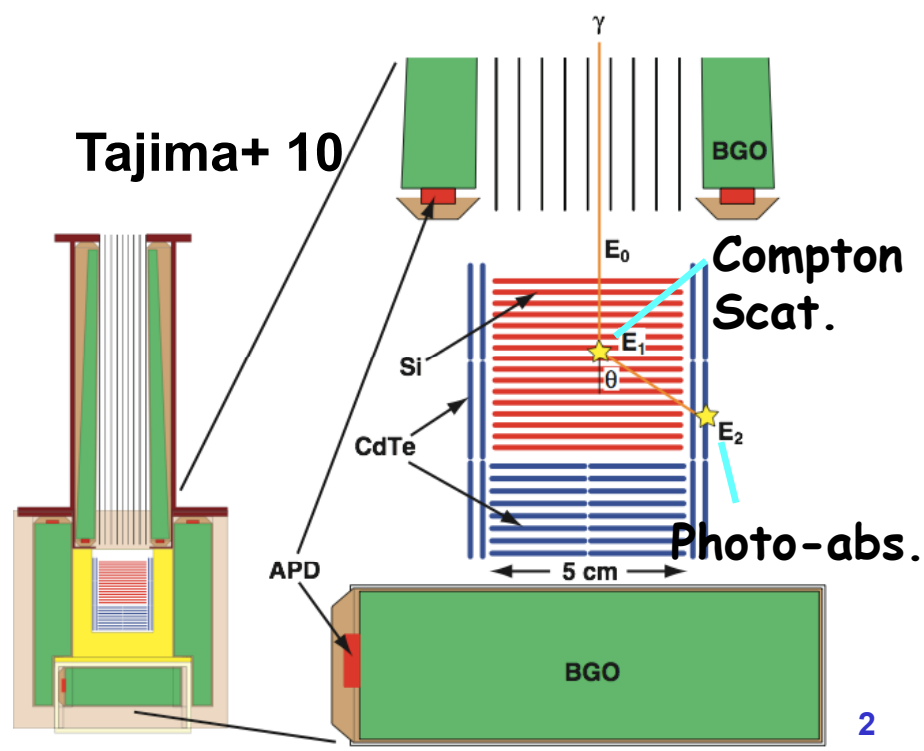
- Si-CdTe Compton Camera + BGO shiled
- Constrain incident angle using Compton kinematics
  - efficient background suppression

Background Level



BG<=100 mCrab

$$\cos\theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

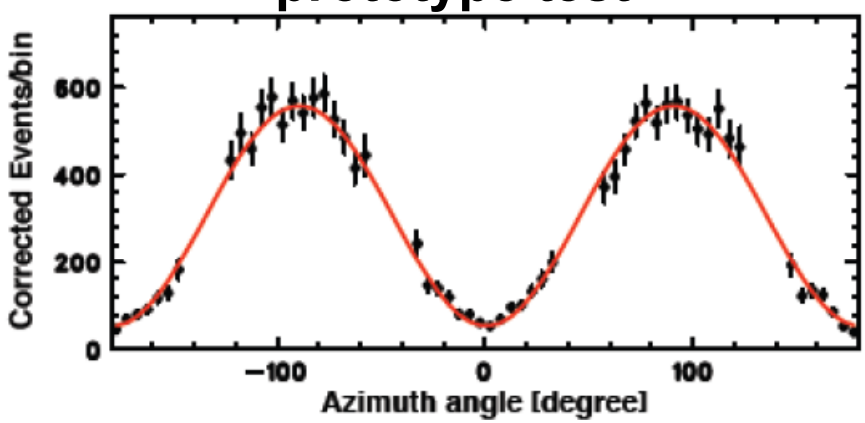


ASTRO-H SGD as a *Polarimeter*

- Si-CdTe Compton Camera + BGO shiled
- Constrain incident angle using Compton kinematics
  - efficient background suppression
  - polarization measurement

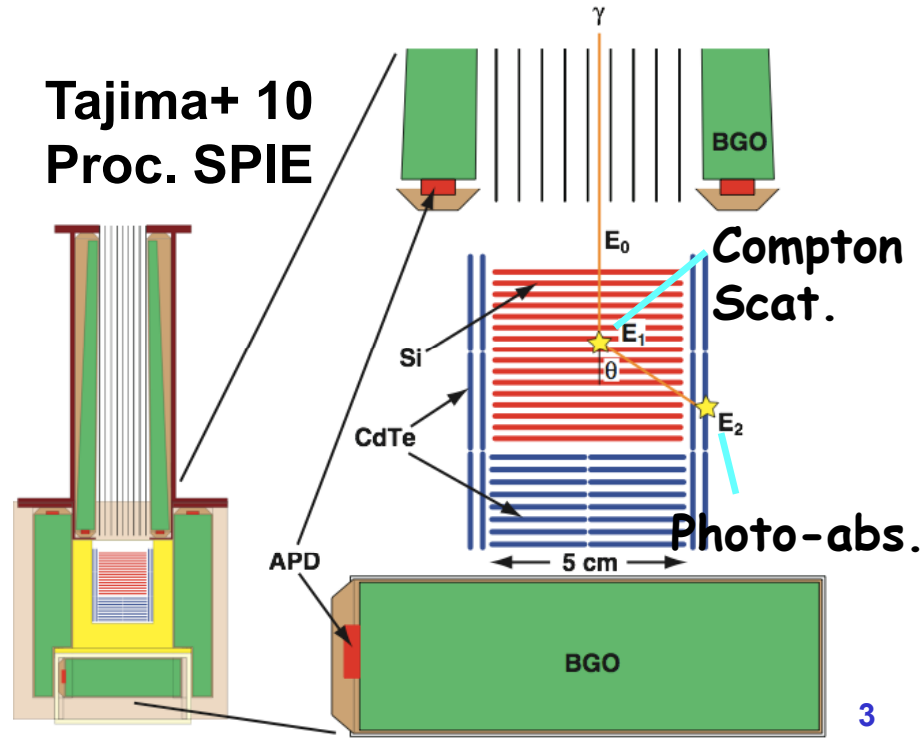
$$\cos\theta = 1 + \frac{m_e c^2}{E_1 + E_2} - \frac{m_e c^2}{E_2}$$

Takeda+ 10, NIMA
prototype test



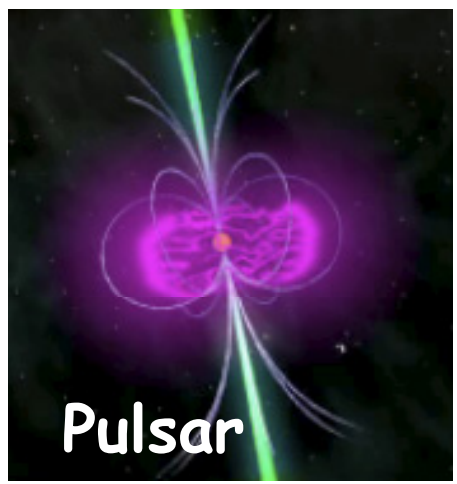
M=0.58 (80-300 keV)
w/ flight configuration

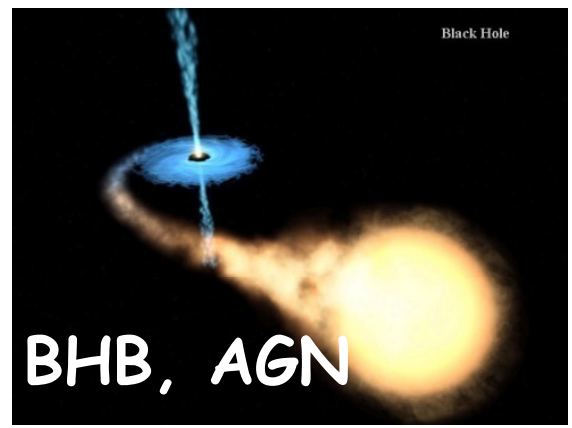
Tajima+ 10
Proc. SPIE



X-ray/Gamma-ray Polarimetry

- **Why polarization? (1) place constraints on source geometries (2) break model degeneracy**
  - **Synchrotron emission (magnetic field)**
  - **Compton up-scattering radiation (see photons, disk)**
  - **Pol. due to QED or general relativity (constraints on fundamental physics and compact object)**





Magnetic field,
Accelerated electrons

Pulsar emission model,
QED

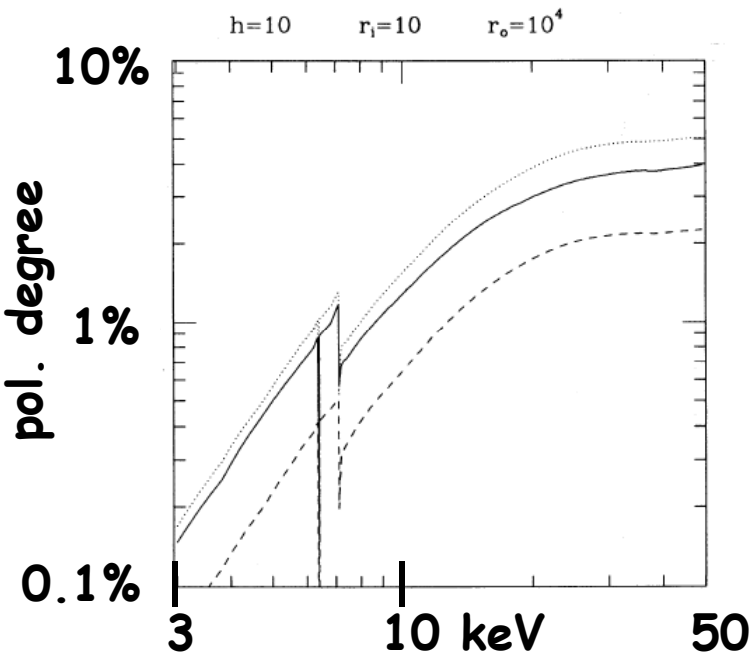
Accretion disk,
Jet

X/γ-ray pol. not subject to Faraday rotation/depolarization

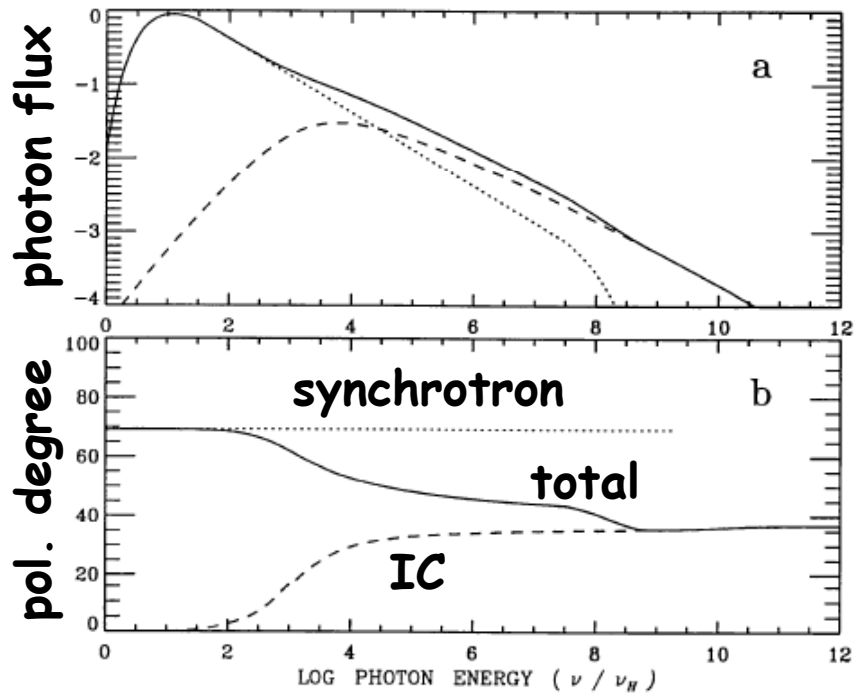
X-ray/Gamma-ray *SpectroPolarimetry*

- **Measuring energy dependent polarization is crucial to disentangle emission mechanisms**
  - **transition from one pol. generation process to another may occur over broad energy range**

disk reflection model (Matt+93)
pol. vector ⊥ disk



Blazar model (Poutanen94)



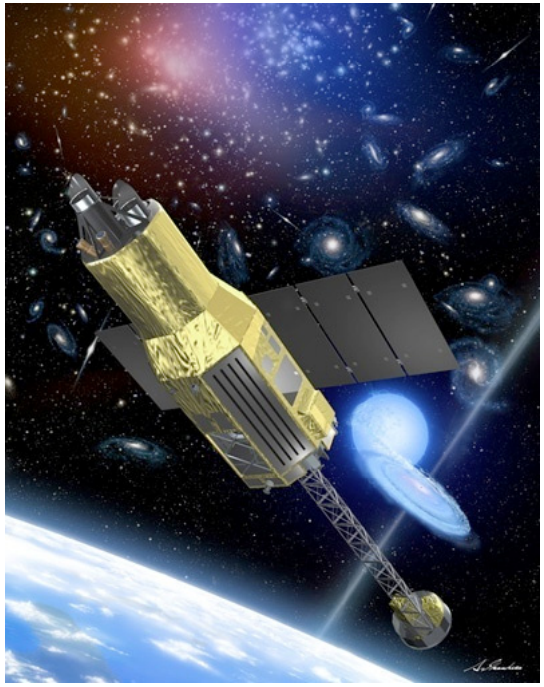
**** pol. may be low in EC ****

X-ray/Gamma-ray *SpectroPolarimetry*

- **Measuring energy dependent polarization is crucial to disentangle emission mechanisms**
  - **synergy with GEMS and PoGOLite will enhance science outputs**

GEMS (2014-)
2-10 keV
X-ray mirror+MPGD

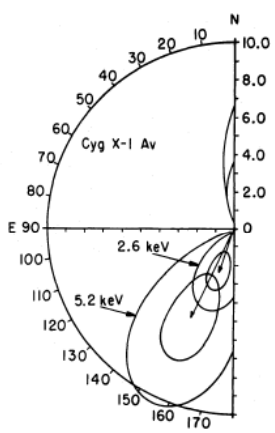
PoGOLite (2012)
30-80 keV
ballloon, Plasctic scint.



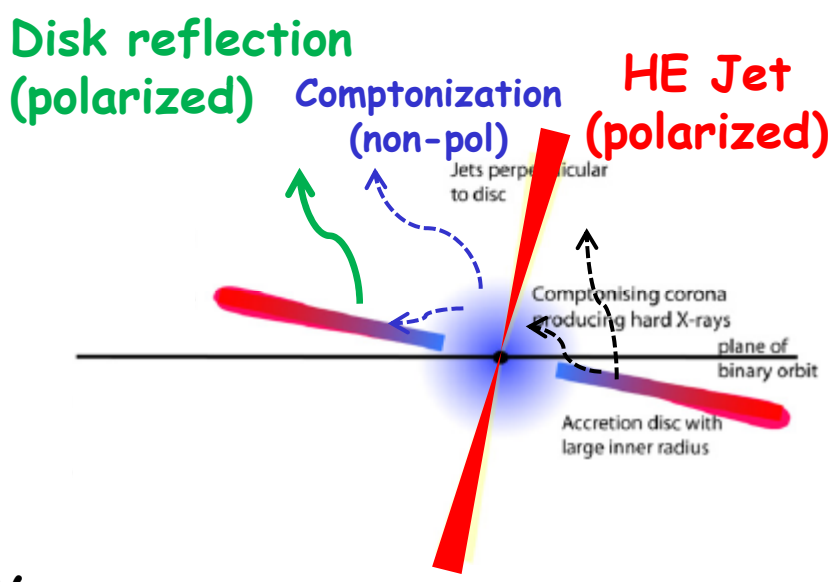
ASTRO-H SGD (2014-)
40-600 keV
Si/CdTe Compton Camera

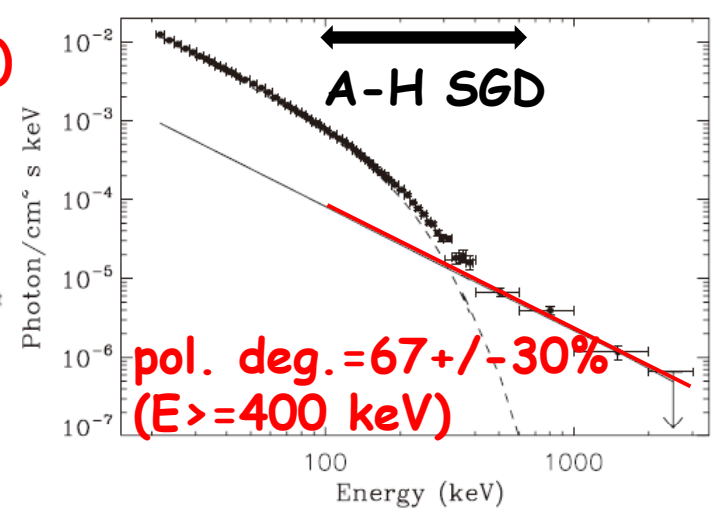
Case Study 1: Cyg X-1

- **A toy model of polarized emission**
  - **Polarized jet seen by INTEGRAL/IBIS (67% pol., ϕ=140eg, contributing in E>100keV)**
  - **Disk reflection (3% pol. in 2-10keV and 10% pol. in 30-60 keV, ϕ=162deg (Long+80))**
- **See how SGD (+others) can measure polarization**



Long+80
2.6/5.2 keV
hint of weak pol.



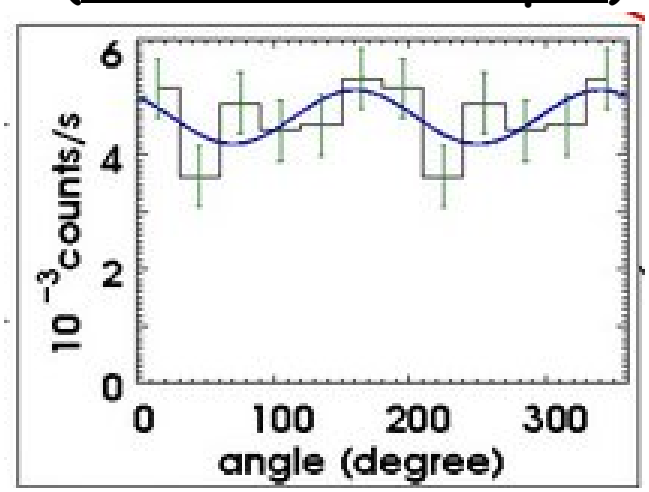


Laurent+11

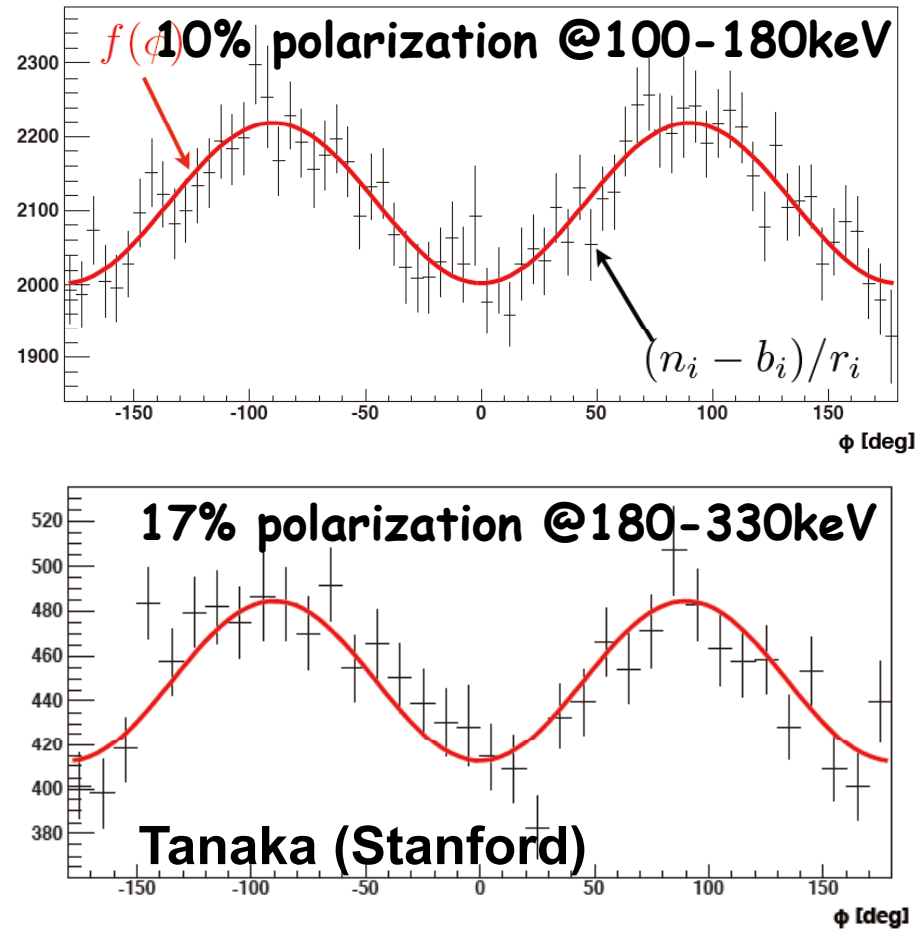
SGD Polarimetry of Cyg X-1

- **Energy dependent polarization measurement w/ ASTRO-H SGD**
  - **disclose jet component hidden in Comptonization down to 100 keV**

INTEGRAL IBIS
Modulation Curve@250-400 keV
(consistent with no pol.)



SGD Simulation, 300 ks

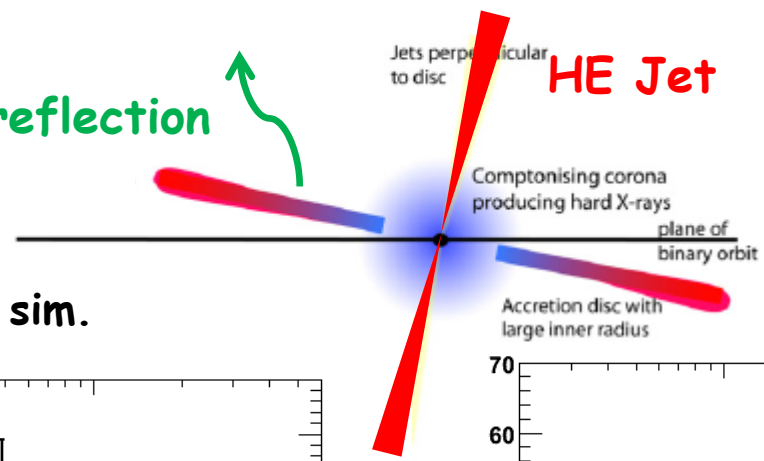


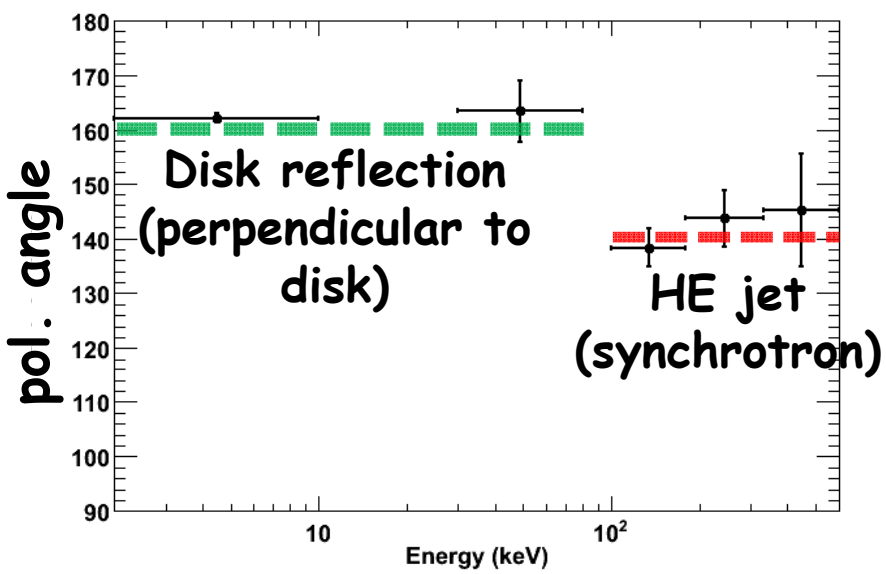
Tanaka (Stanford)

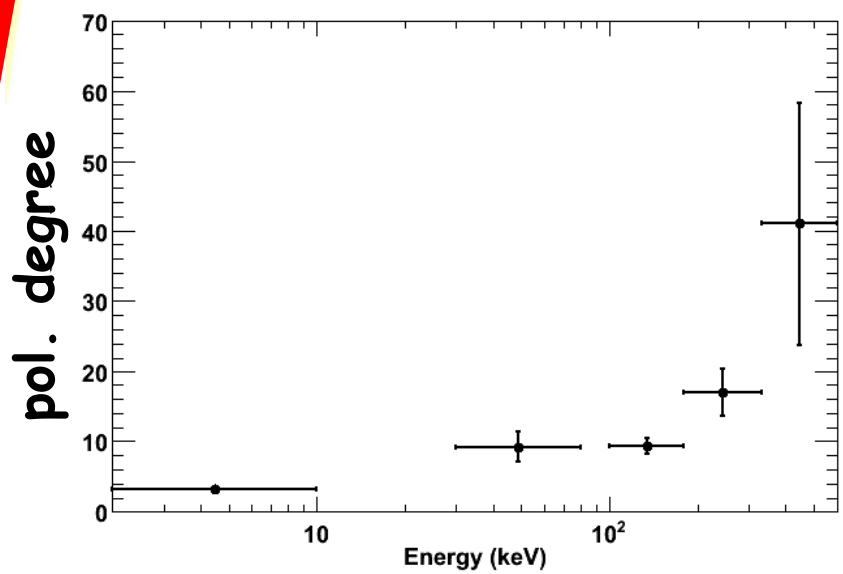
Wide-band Polarimetry of Cyg X-1

- **Coordination with soft/hard X-ray polarimetry**
  - **disentangle disk reflection and jet emission**
  - **Compare directions of magnetic field (soft γ), disk (X-ray) and jet (radio)**

assumption:
100 ks obs.
M=0.32 (GEMS, PoGO)
SGD scaled from 300ks sim.



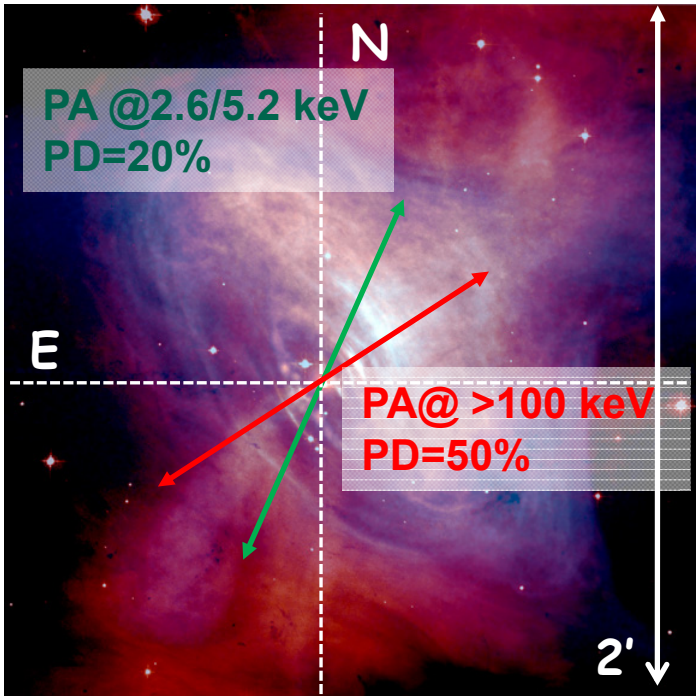




Case Study 2: Crab Nebula

- **A toy model based on the OSO-8/INTEGRAL data**

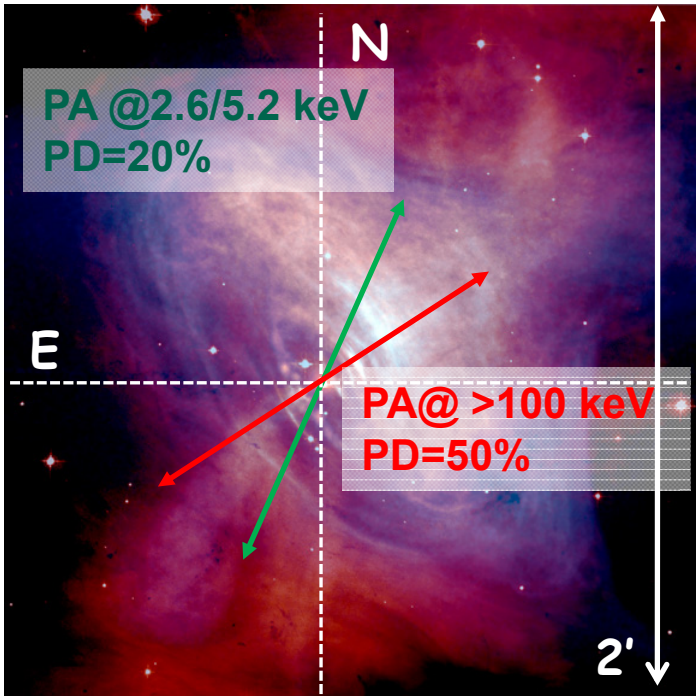
- PD=20%, PA=156deg (2.6/5.2keV): OSO-8, whole Nebula
- PD=50%, PA=124deg (>100keV): INTEGRAL, aligned with pulsar rot. axis
- Let's assume PD=30% and PA=138deg (30-80keV)

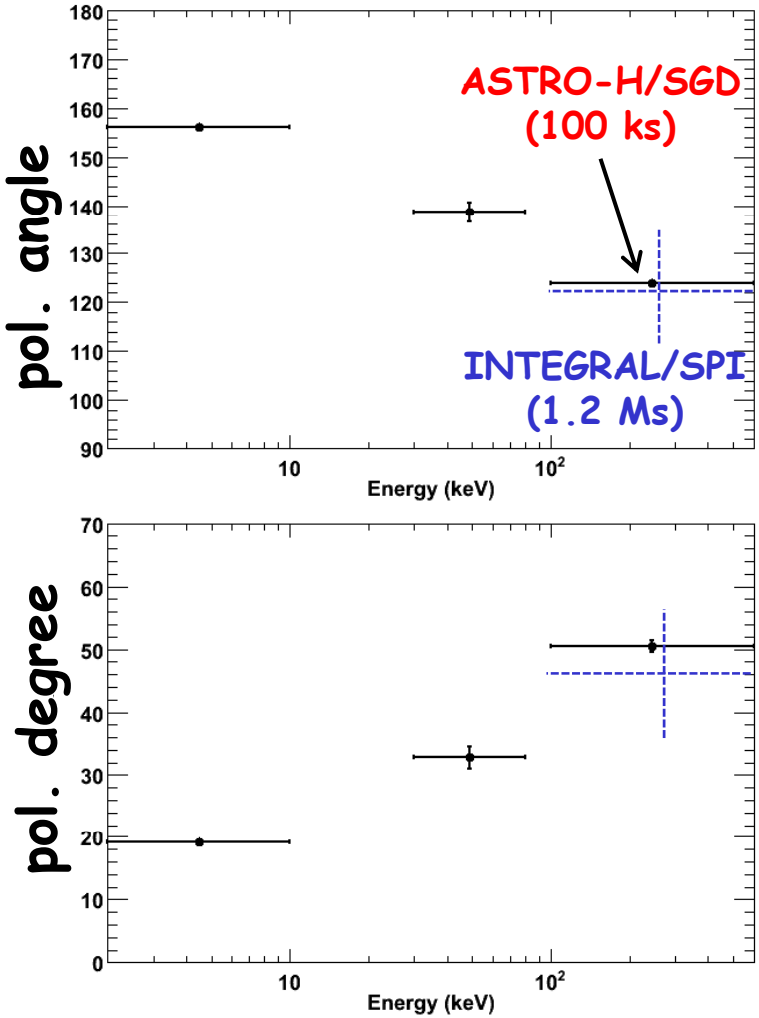


Case Study 2: Crab Nebula

- **A toy model based on the OSO-8/INTEGRAL data**

• SGD will confirm (or deny) the alignment with pulsar rot. axis
• Constraints on PWN model w/ soft-X and hard-X data





Summary and Prospect

- **Pol. measurement by A-H SGD can place constraints on source geometry and break model degeneracy (*qualitatively new type of information*)**
- **Synergy with X-ray polarimeters will enhance science outputs**
- **Two case studies are presented (Cyg X-1 and Crab; robust targets for SGD polarimetry)**
- **Pol. measurement of pulsars and AGN flares will also be possible (to understand BG anisotropy is important)**

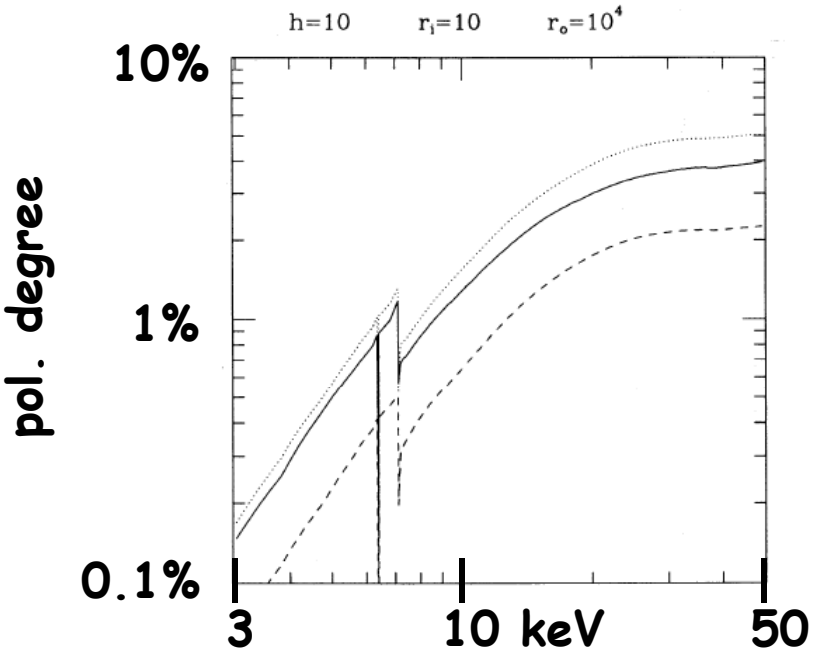
Thank you for your Attention

Backup Slides

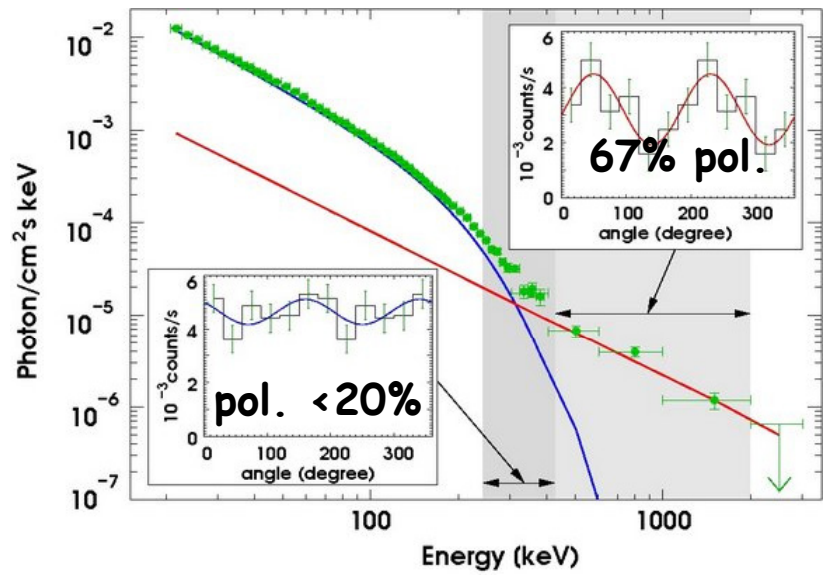
X-ray/Gamma-ray *SpectroPolarimetry*

- **Measuring energy dependent polarization is crucial to disentangle emission mechanisms**

disk reflection model (Matt+93)
pol. vector ⊥ disk

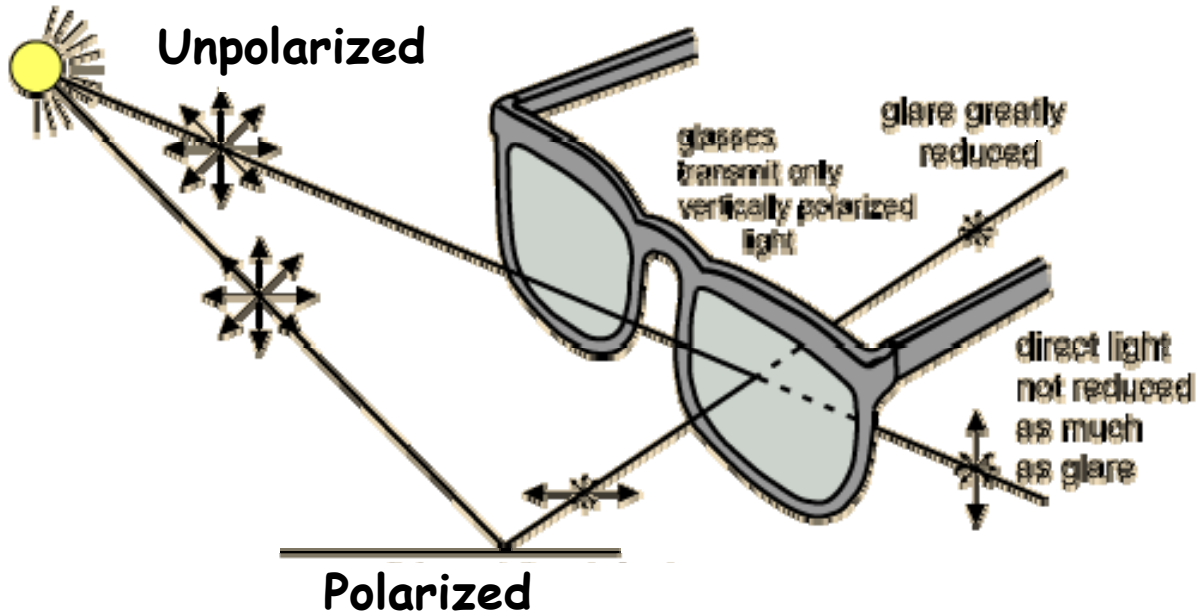


Strong polarization (67%) from Cyg X-1 jet in HE (Laurent+11)



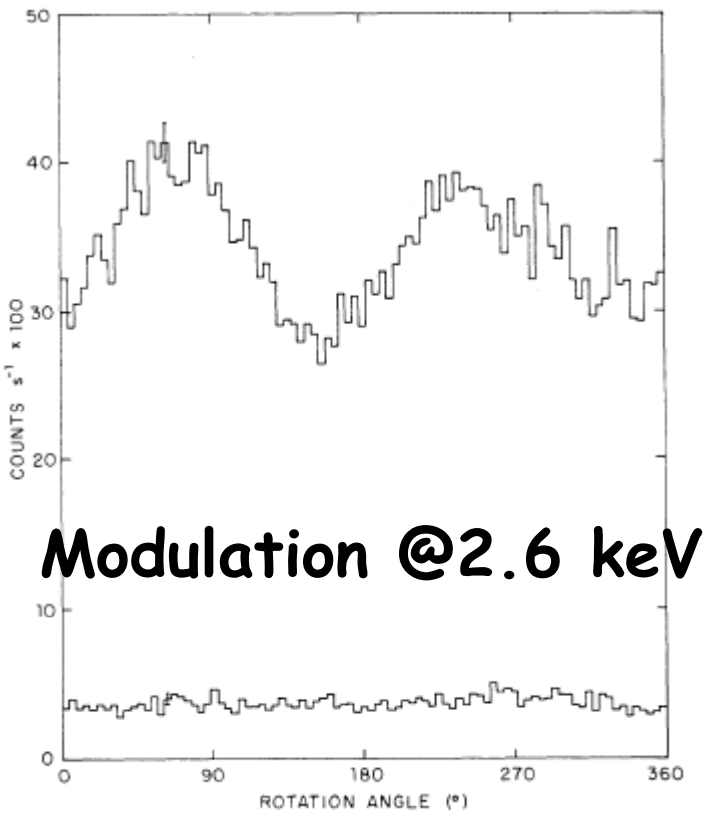
Polarization

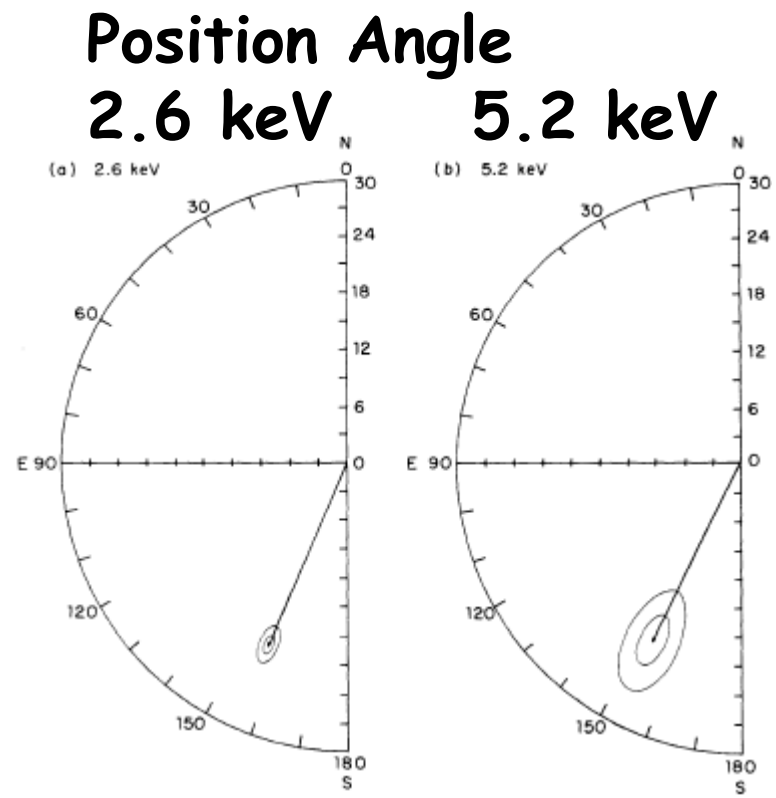
- 光源が非一様だと偏光が生じる
  - そろった磁場下でのシンクロトロン
  - 特定の面でのコンプトン散乱



Crab Nebula Polarization (X-ray)

- **Measured by OSO-8 (Bragg reflection)**

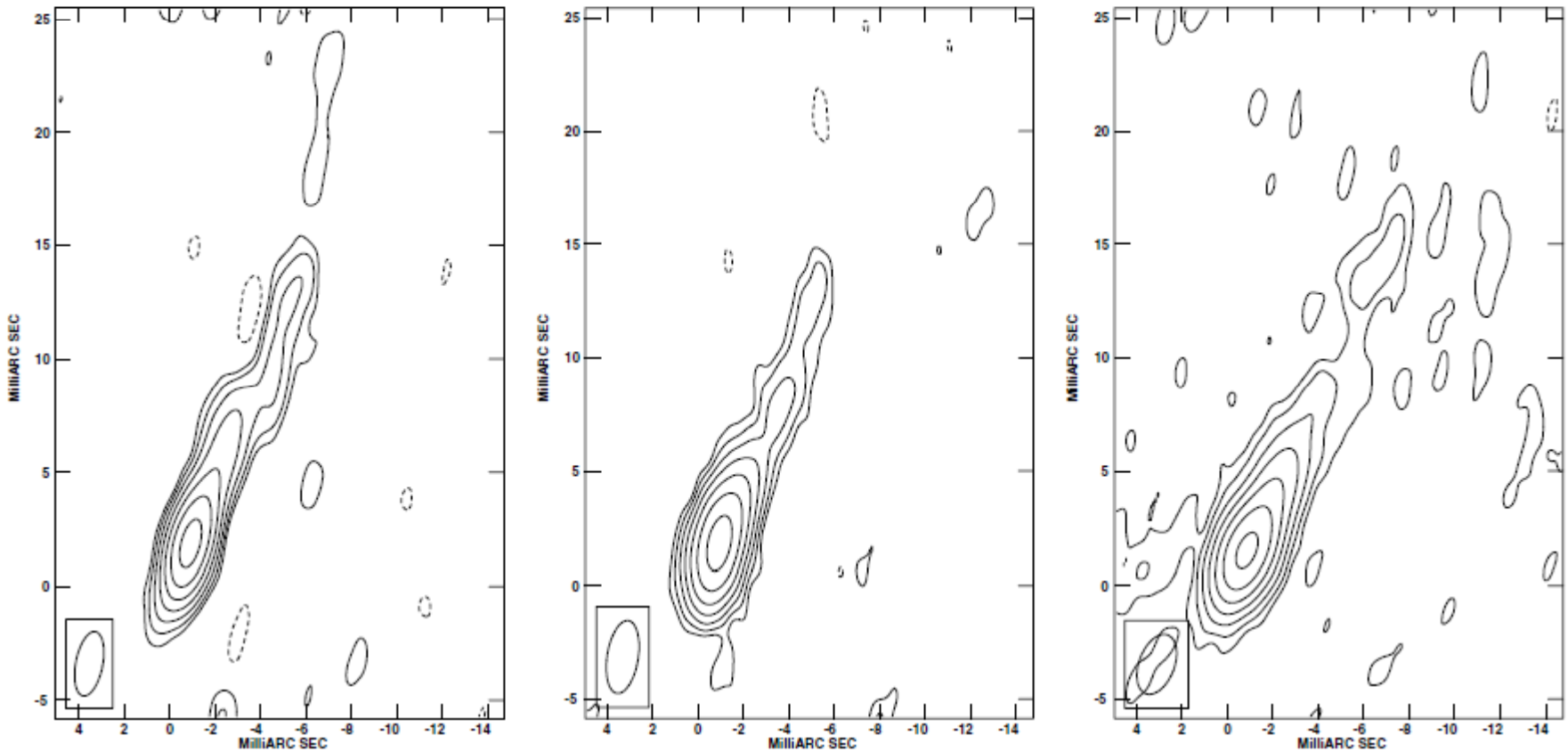




Weisskopf+78

Cyg X-1 Radio Jet

- **8 GHz images at three orbital phases (1998 August)**



Stirling+01