

***cipher*** :  
**a CubeSat-Based  
Hard X-ray  
Imaging Polarimetry Mission**

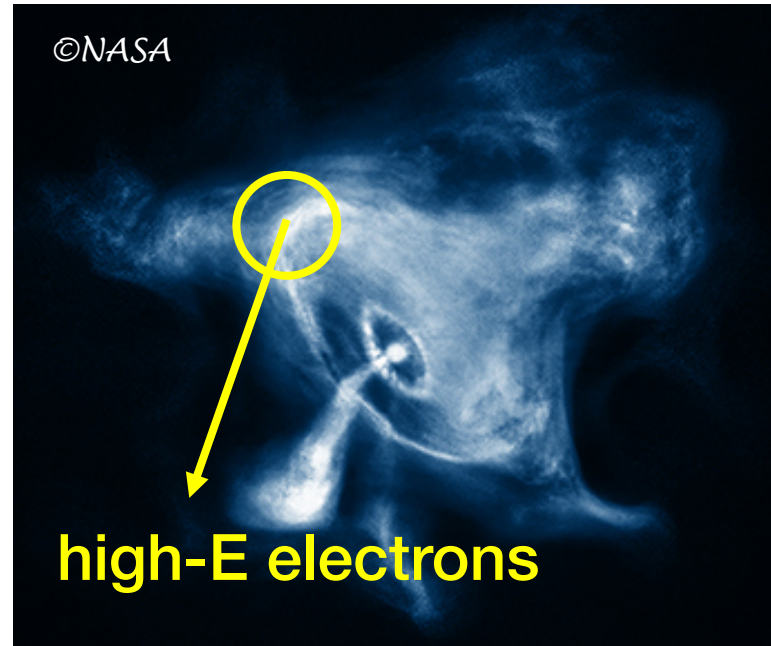


Tomoaki KASUGA (The University of Tokyo)  
[tomoaki.kasuga@phys.s.u-tokyo.ac.jp](mailto:tomoaki.kasuga@phys.s.u-tokyo.ac.jp)

Coauthors: H. Odaka, T. Tamba, K. Hatauchi,  
T. Watanabe, A. Tanimoto, S. Takashima, H. Suzuki,  
S. Nanmoku & A. Bamba (UT, Japan)

# X-ray Imaging Polarimetry

ex. Crab Nebula (X-ray)

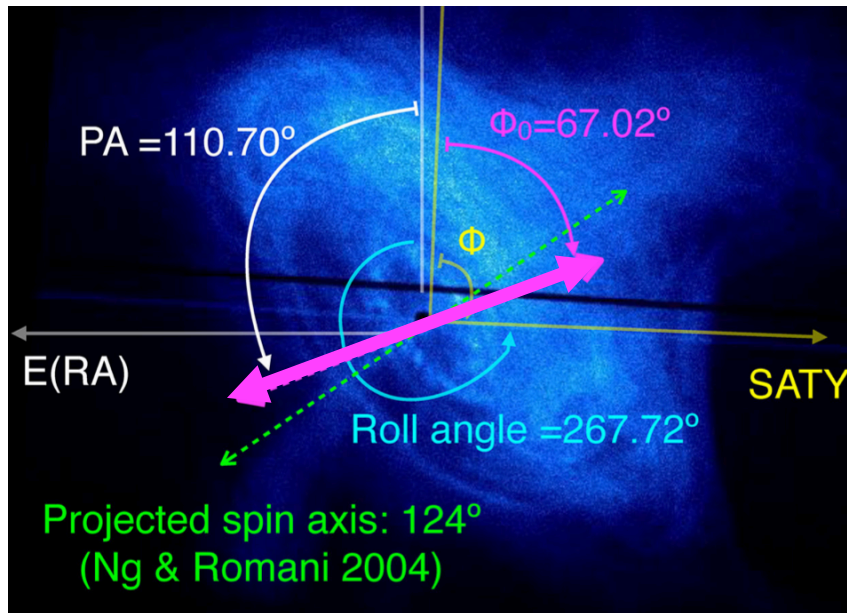


Polarization of synchrotron emission:  
angle  $\perp$  local magnetic field  
degree  $\rightarrow$  aligned? or turbulent?

**$\rightarrow$  Direct approach for the physics of acceleration!**

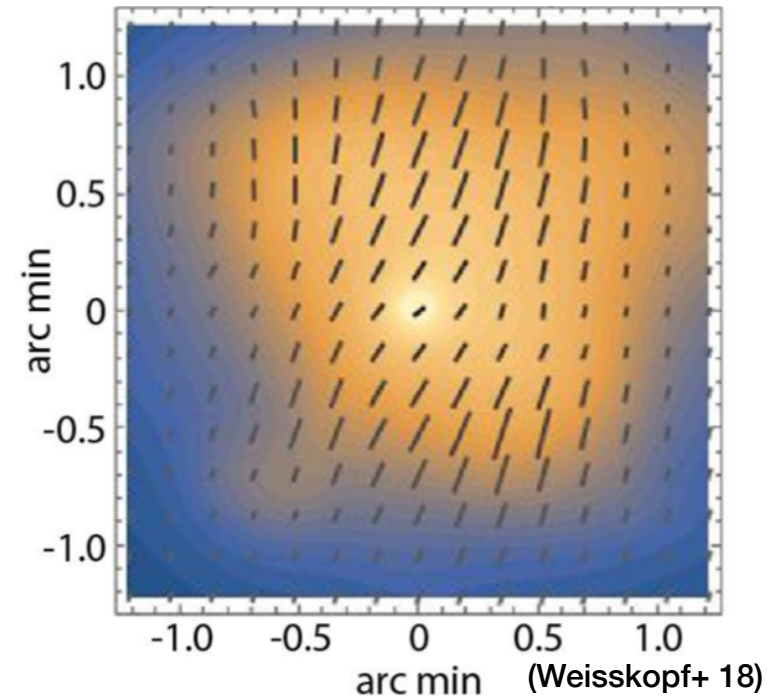
# X-ray Imaging Polarimetry

obs. by *Hitomi*  
w/o imaging



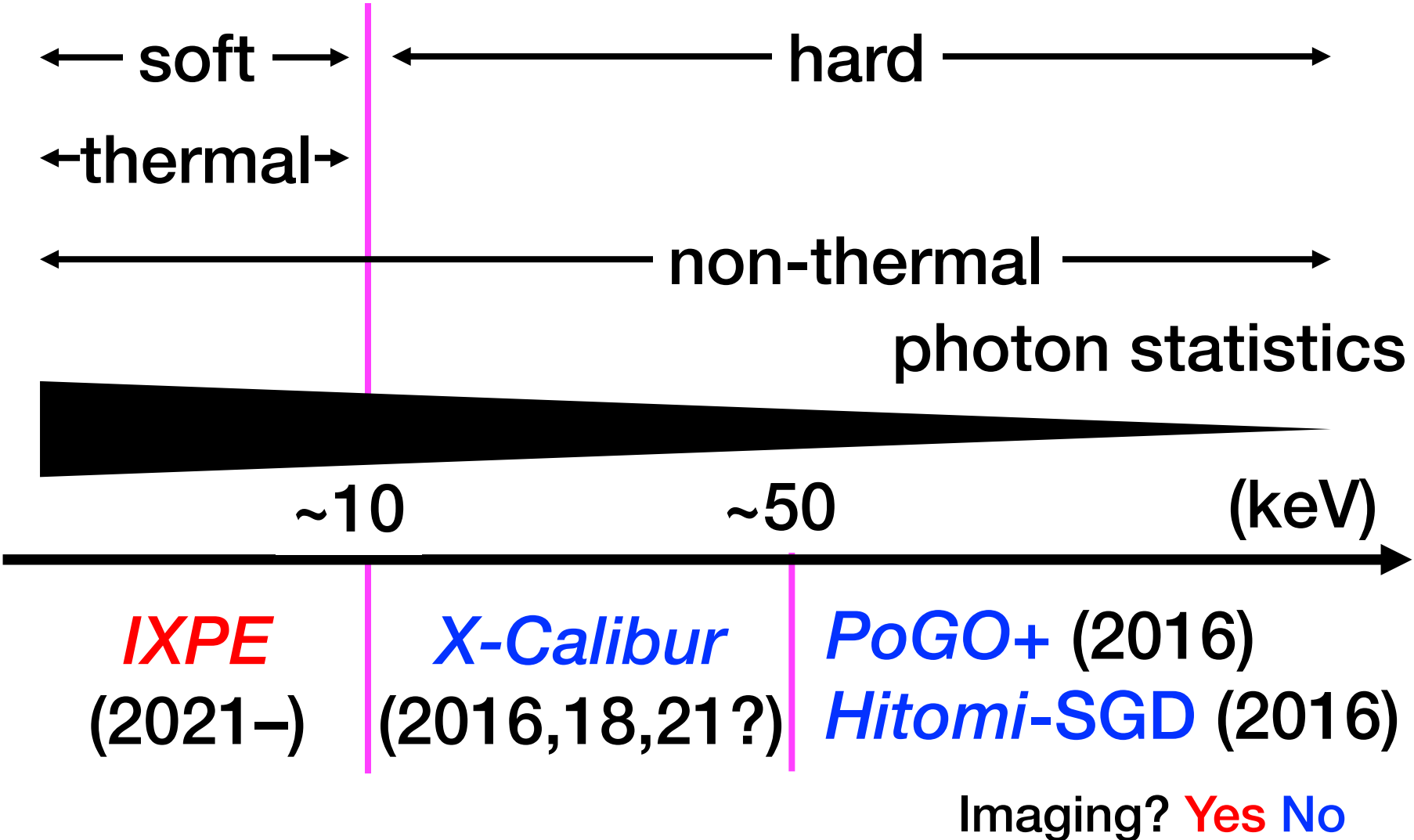
(Hitomi coll. 18)

sim. for *IXPE*  
w/ imaging!

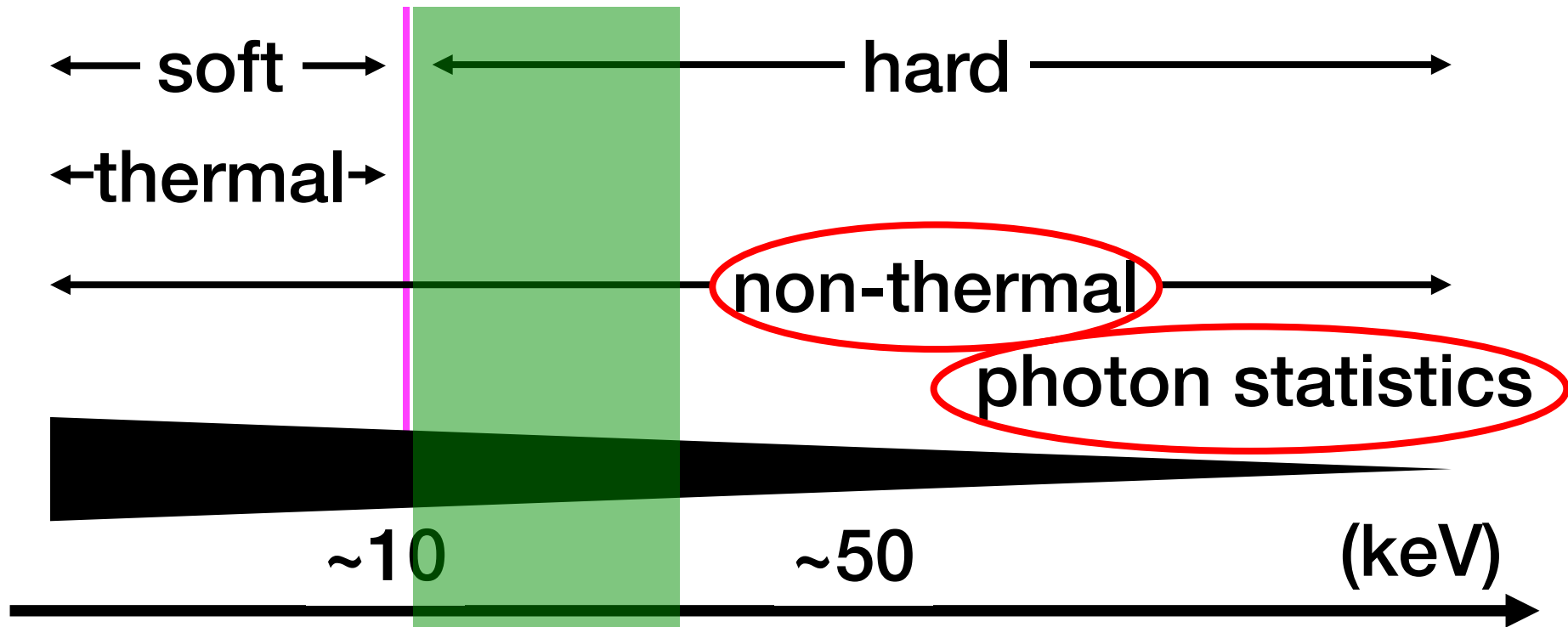


**We need “imaging polarimetry”!**

# Existing Polarimeters in X-ray



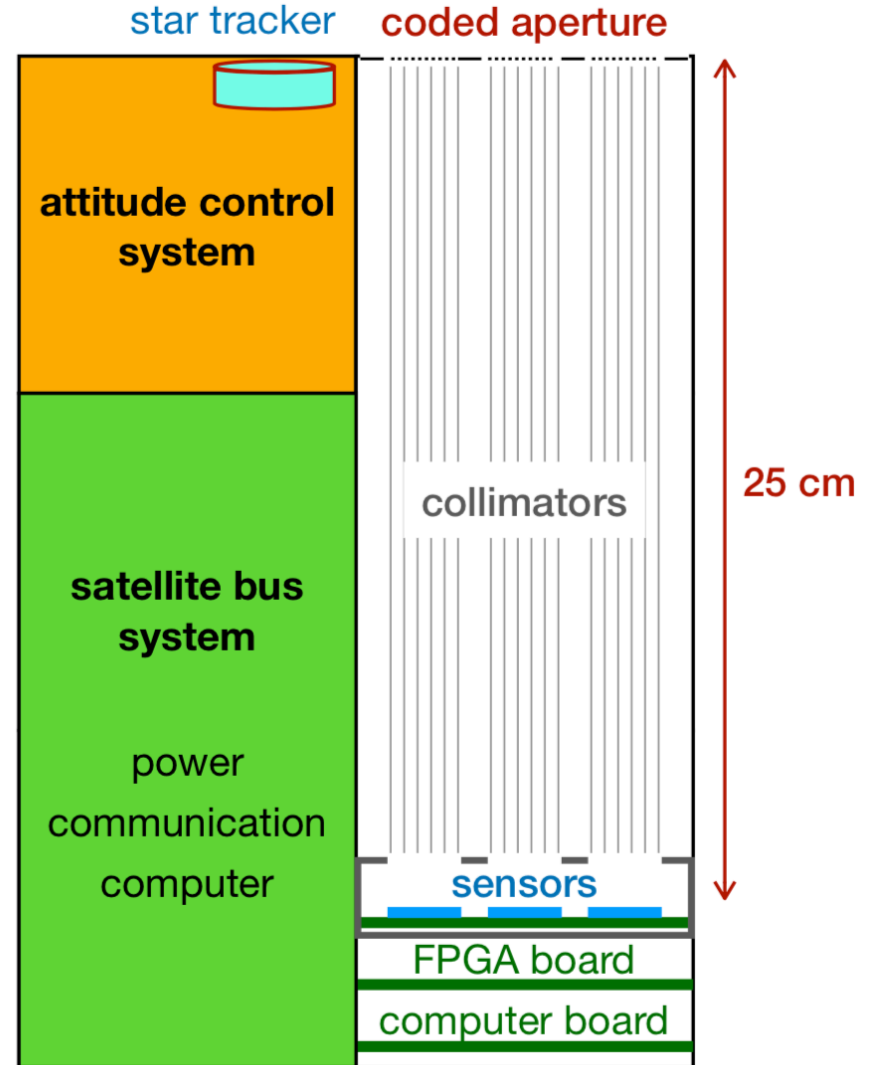
# Existing Polarimeters in X-ray



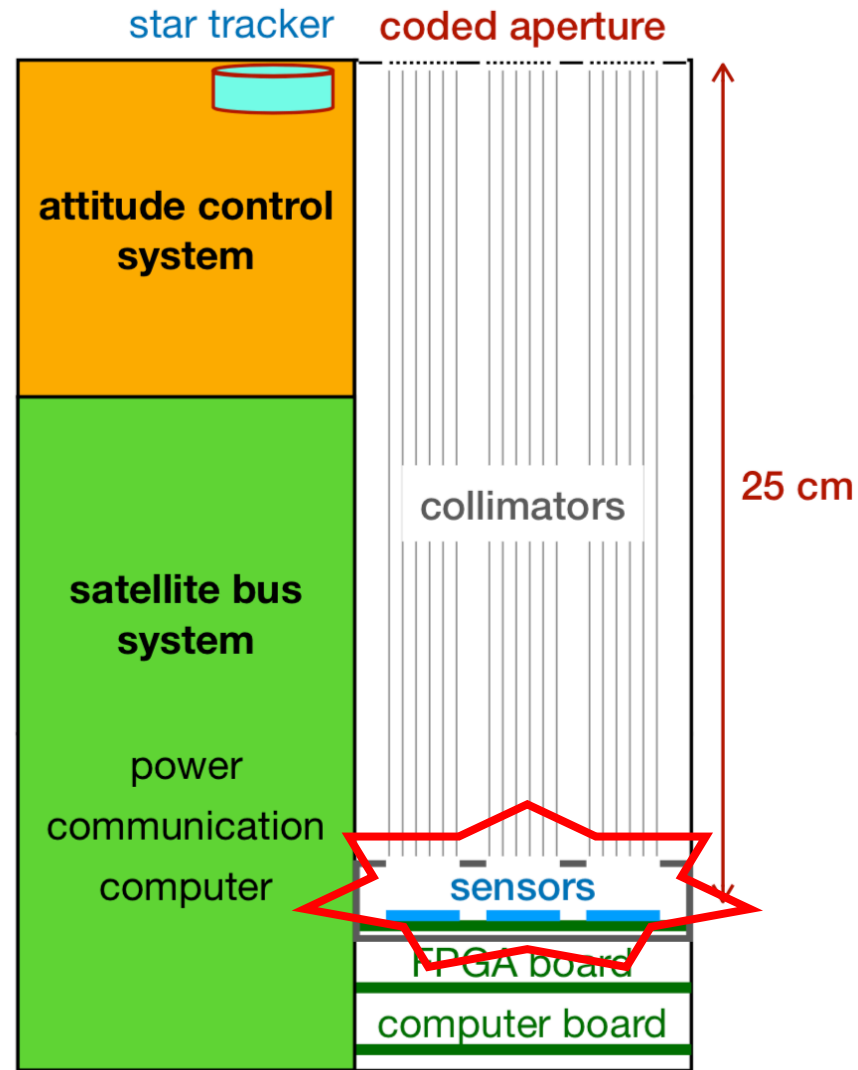
What we want for studying non-thermal emissions?:  
**Polarimeter with high angular resolution  
in a lower part of the hard X-ray band**

# Concept of *cipher*

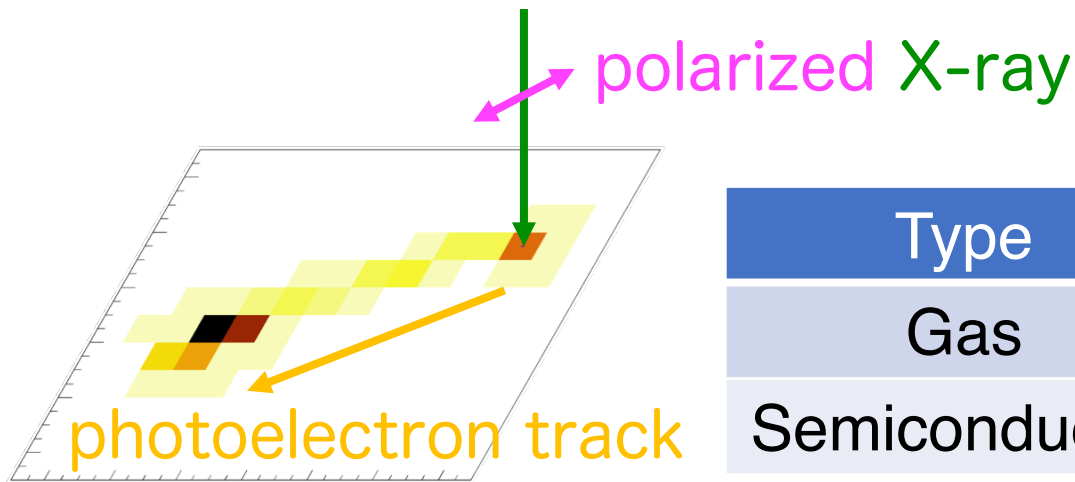
**Tiny Polarimeter  
+ Tiny Imager  
= CubeSat**  
speedy, low-cost  
easy to reproduce  
(still in design phase)



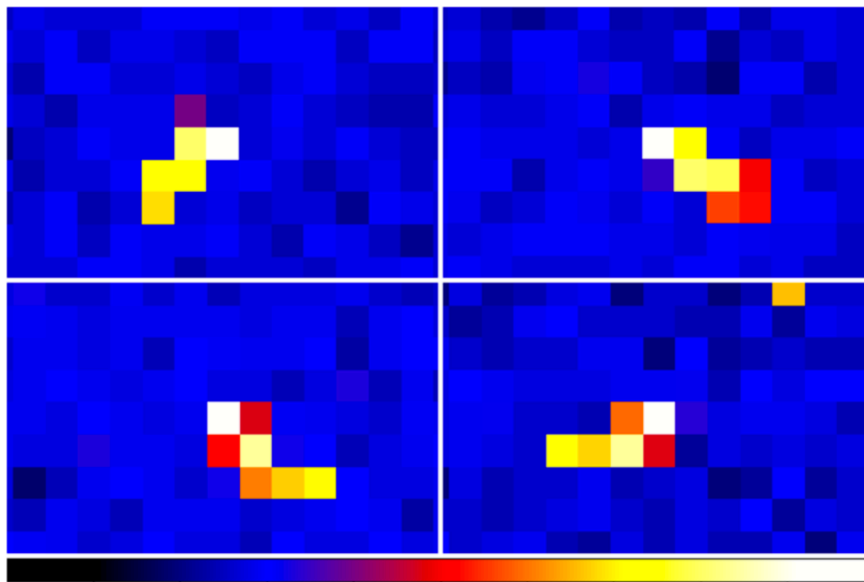
# Tiny Polarimeter



# Fine-pitch CMOS



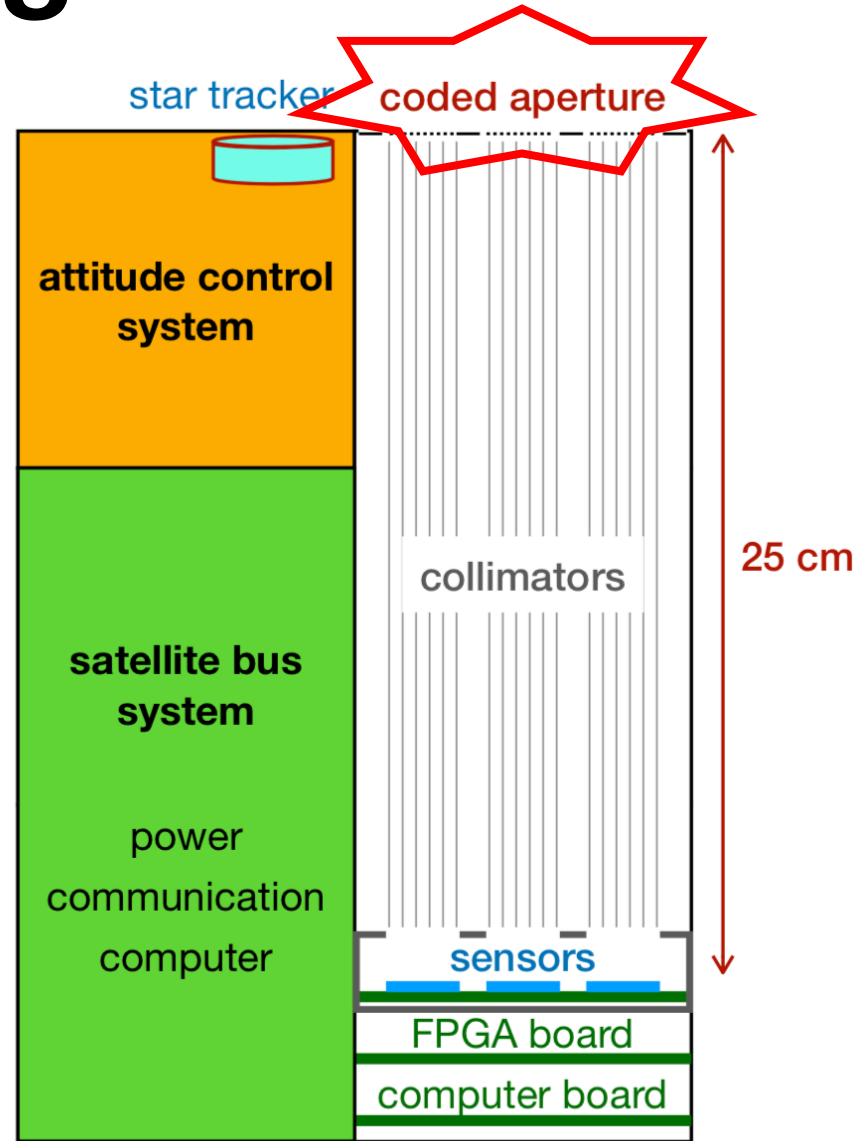
Type	Volume	Track
Gas	large	long
Semiconductor	<b>small</b>	short



24.8 keV @SPring-8 in 2018  
photoelectron tracks  
detected by 2.5  $\mu\text{m}$ -pitch CMOS  
(Asakura+ 19)

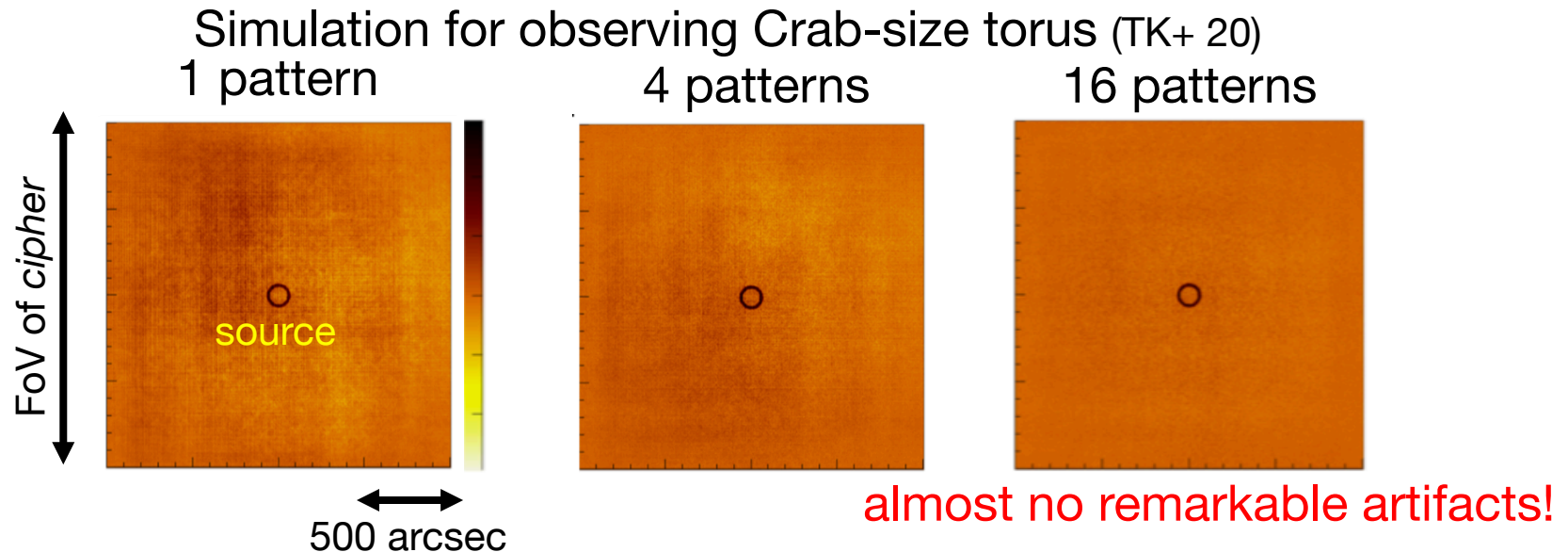


# Tiny Imager

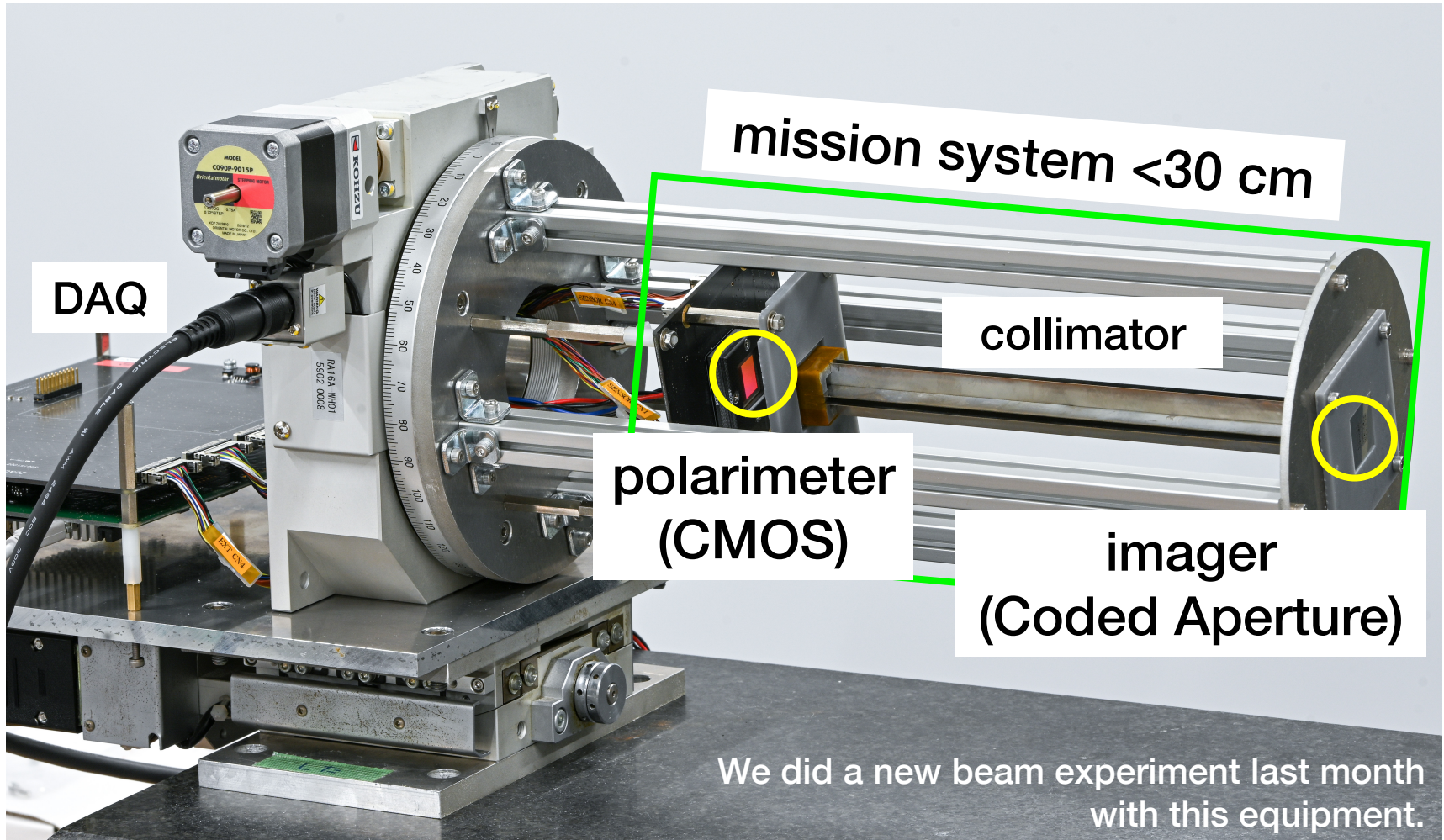


# Multiple different aperture patterns

- X-ray mirrors need  $>1$  m focal length.
- $\leftrightarrow$  Coded aperture system can work even in CubeSat.**
- fine pitch CMOS + fine pitch Coded Aperture  
= angular resolution  $\sim 30''$  (equivalent to *NuSTAR*, *IXPE*)
- Observing targets by multiple different aperture patterns at the same time (TK+20)
- $\rightarrow$  We can reduce the imaging noises (artifacts) !**



# Demonstration of *cipher*



# Key Takeaways

- The polarization of cosmic non-thermal X-rays tells us direct information on the acceleration of high energy cosmic rays.  
-> Imaging polarimetry in the hard X-ray band !
- Important techniques of *cipher*
  - Polarimeter: **Fine-pitch CMOS sensor**  
K. Asakura, K. Hayashida et al.,  
“X-ray imaging polarimetry with a 2.5 um pixel CMOS sensor for visible light at room temperature”,  
JATIS, 5, 035002 (2019) (doi: 10.1117/1.JATIS.5.3.035002)
  - Imager: **Coded Aperture with multiple different random patterns**  
T. Kasuga, H. Odaka et al.,  
“Artifact-less Coded Aperture Imaging in the X-ray Band with Multiple Different Random Patterns”,  
JATIS, 6, 035002 (2020) (doi: 10.1117/1.JATIS.6.3.035002)
- We will evaluate the science feasibility using the results of our beam experiment.