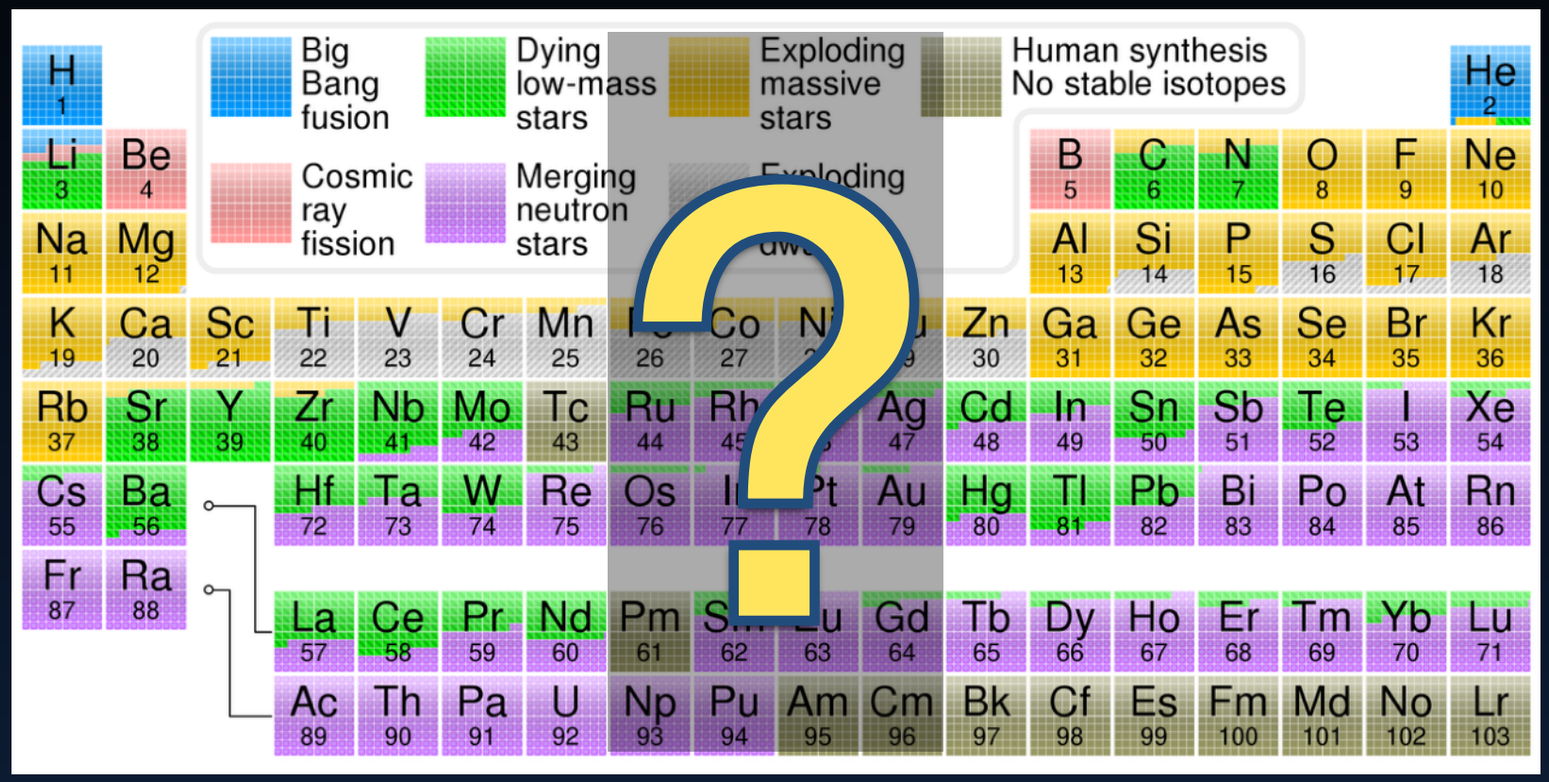
第２回
MeVガンマ線天文学研究会
Discussion

小高裕和 (東大)

Origin of matter



Wikipedia

supernova

neutron star merger

Detection of nuclear lines

Nature

LETTER

doi:10.1038/nature13672

Cobalt-56 γ-ray emission lines from the type Ia supernova 2014J

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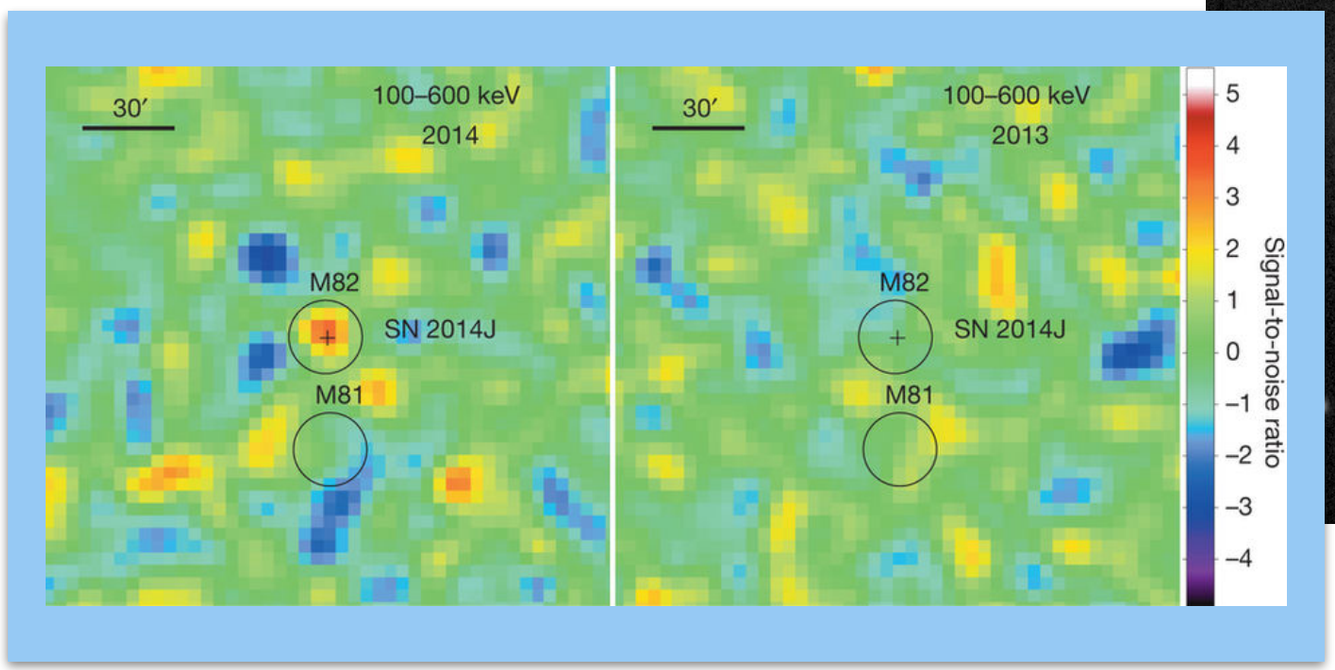
A type Ia supernova is thought to be a thermonuclear explosion of either a single carbon–oxygen white dwarf or a pair of merging white dwarfs. The explosion fuses a large amount of radioactive ^{56}Ni (refs 1–3). After the explosion, the decay chain from ^{56}Ni to ^{56}Co to ^{56}Fe generates γ-ray photons, which are reprocessed in the expanding ejecta and give rise to powerful optical emission. Here we report the detection of ^{56}Co lines at energies of 847 and 1,238 kiloelectronvolts and a γ-ray continuum in the 200–400 kiloelectronvolt band from the type Ia supernova 2014J in the nearby galaxy M82. The line fluxes suggest that about 0.6 ± 0.1 solar masses of radioactive ^{56}Ni were synthesized during the explosion. The line broadening gives a characteristic mass-weighted ejecta expansion velocity of 10,000 ± 3,000 kilometres per second. The observed γ-ray properties are in broad agreement with the canonical model of an explosion of a white dwarf just massive enough to be unstable to gravitational collapse, but do not exclude merger scenarios that fuse comparable amounts of ^{56}Ni.

The model spectrum is binned similarly to the observed supernova spectrum. The signatures of the 847 and 1,238 keV lines are clearly seen in the spectrum (along with tracers of weaker lines of ^{56}Co at 511 and 1,038 keV). The low-energy (<400 keV) part of the SPI spectrum is not shown because of possible contamination due to off-diagonal response of the instrument to higher-energy lines. At these energies, we use ISGRI/IBIS data instead (Methods).

By varying the assumed position of the source and repeating the flux-fitting procedure using SPI data (Methods) we construct a 40° × 40° image of the signal-to-noise ratio in the 800–880 and 1,200–1,300 keV energy bands (Fig. 2). SN 2014J is detected at 3.9 s.d. and 4.3 s.d. in these two bands, respectively. These are the highest peaks in both images.

The images obtained by ISGRI at lower energies (100–600 keV) during the observations of SN 2014J and in October–December 2013, that is, a few months before the SN 2014J explosion (see Methods for the details of the earlier observation), are shown in Fig. 3. An inspection of images in the 25–50 keV band shows that the fluxes observed in 2013



Science

SUPERNOVAE

Early ^{56}Ni decay gamma rays from SN2014J suggest an unusual explosion

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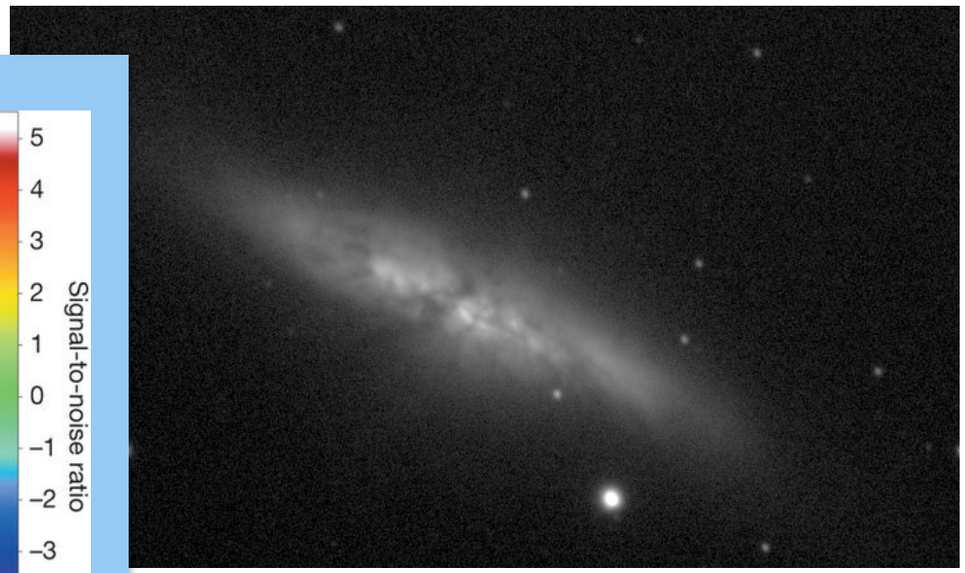
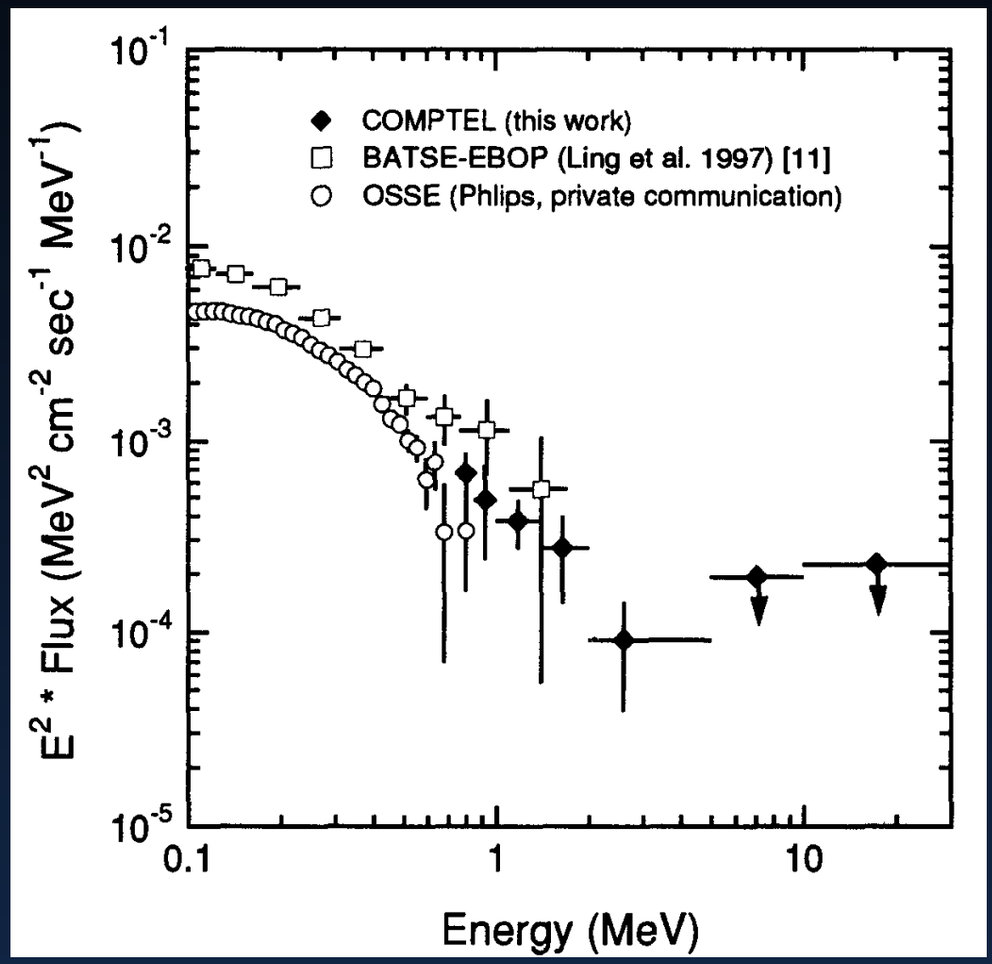
Type Ia supernovae result from binary systems that include a carbon-oxygen white dwarf, and these thermonuclear explosions typically produce 0.5 solar mass of radioactive ^{56}Ni. The ^{56}Ni is commonly believed to be buried deeply in the expanding supernova cloud. In SN2014J, we detected the lines at 158 and 812 kiloelectron volts from ^{56}Ni decay (time ~8.8 days) earlier than the expected several-week time scale, only ~20 days after the explosion and with flux levels corresponding to roughly 10% of the total expected amount of ^{56}Ni. Some mechanism must break the spherical symmetry of the supernova and at the same time create a major amount of ^{56}Ni at the outskirts. A plausible explanation is that a belt of helium from the companion star is accreted by the white dwarf, where this material explodes and then triggers the supernova event.



Transition to non-thermal

- Everything eventually goes to thermal equilibrium. ***How?***
- Plasmas closest to black holes have temperatures of a few hundred keV, which seems like the highest observable temperature in the universe.
- Could see what happens to the boundary between thermal and non-thermal.

Cygnus X-1

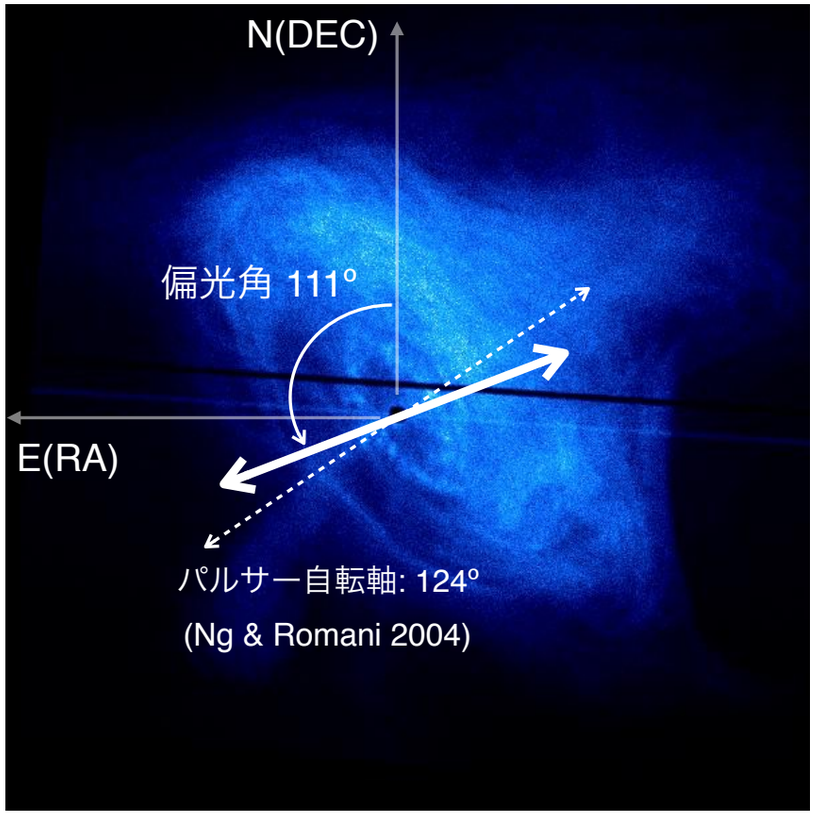


McConnell et al. 1997

Polarimetry

表1　かに星雲の軟ガンマ線偏光の主要な観測結果.

実験名	エネルギー（keV）	偏光角（度）	偏光度（%）	露光時間（ks）	文献
Hitomi/SGD	60–160	111±13	22±11	5	本研究（6）
PoGO＋	20–160	131.3±6.8	20.9±5.0	92	Chauvin et al. 2017（7）
AstroSAT/CZTI	100–380	143.5±2.8	32.7±5.8	800	Vadawale et al. 2018（8）
INTEGRAL/SPI	130–440	117±9	28±6	600	Chauvin et al. 2013（5）
INTEGRAL/IBIS	200–800	110±11	47（＋19/－13）	1200	Forot et al 2008（4）



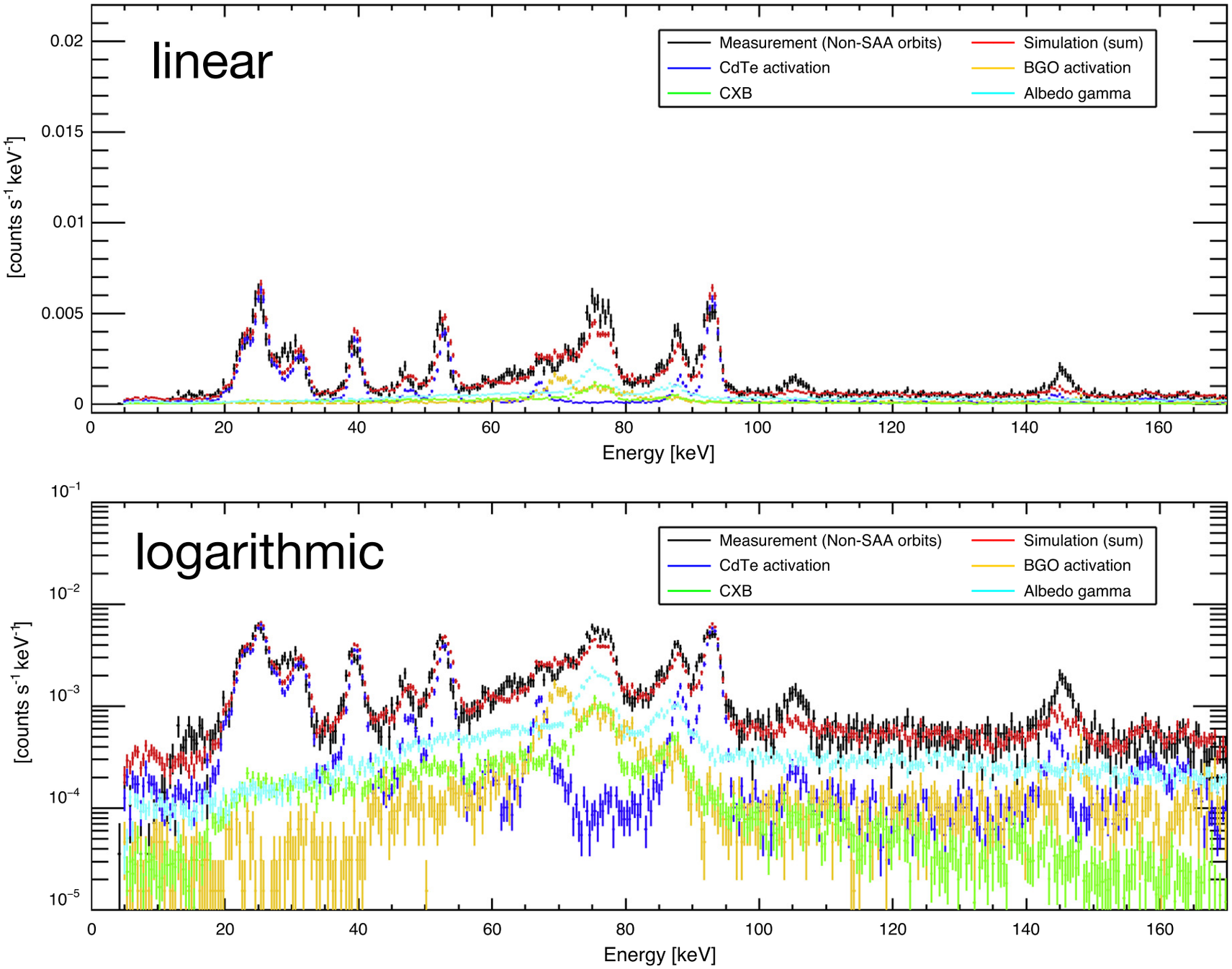
- a pure toroidal B-field からの
  シンクロトロン放射なら約50%の偏光度
  (inclinationに依存)
- 乱流磁場などがdepolarizeするので、
  約20%の偏光度は自然と言えそう。
- パルサー成分と星雲成分
- エネルギー依存性、場所依存性などが今後の課題

まとめ

- MeV検出器の技術は進んできた
- 重要かつ多様なサイエンス
- 具体的な観測の計画と期待されるサイエンスの精度の良い議論がまだなされていない
  →高精度の観測シミュレーション
- 「難しい、難しい、、、」と言っている時代は終わった。

HXIバックグラウンドシミュレーション

CdTe放射化に加えて、BGO放射化、X線背景放射、大気ガンマ線を追加



Odaka et al. 2018

主要なラインを再現

連続成分も実測と非常によく一致

マニアックな分野から主要な領域へ

大勢の皆さんのご参加に感謝します

第３回は？