"Asymmetric Expansion of the Fe ejecta
in Kepler's Supernova Remnant"
TK et al. 2018
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Doppler velocity measurement of Fe ejecta in Kepler's SNR

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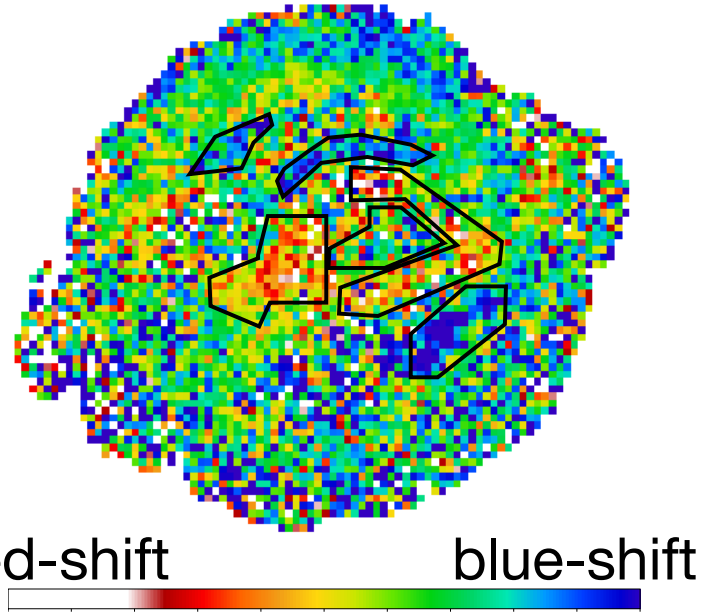
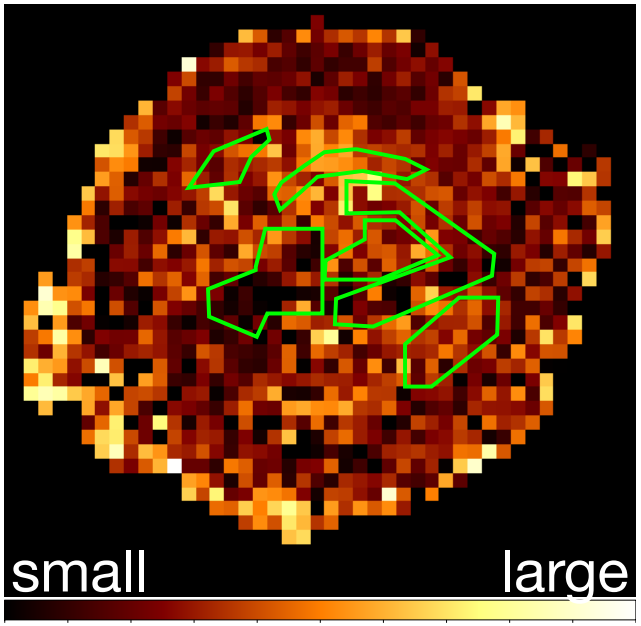
Today's Goal

1. Doppler Maps of Fe Ejecta in Kepler's SNR

Doppler Velocity



Doppler Broadening

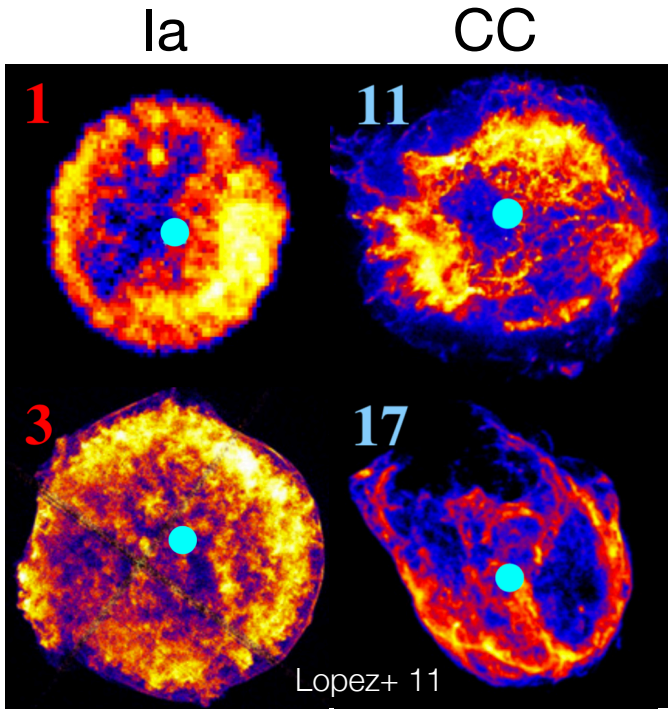


(TK et al. 2018)

2. Comparison to Tycho's SNR

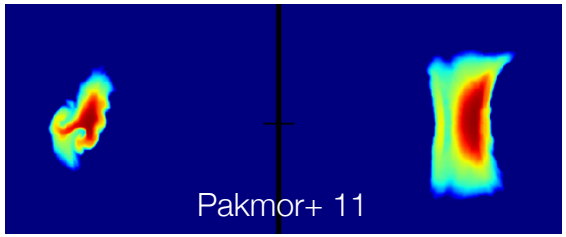
Introduction

Type Ia is more symmetric than CC (Lopez+ 11).
⇔ No diversity in Ia SNRs?
ex.) SD or DD
detonation or deflagration



- One of the crucial clues: **the symmetry of ejecta kinematics**
  ⇒ Studying the expansion structure of heated ejecta in SNRs directly by K-shell emission lines in the **X-ray** band (cf. Williams' talk)
- **Fe** ejecta is the best probe ! (not mixed with ISM)

ex.) Fe ejecta asymmetry in violent merger model →



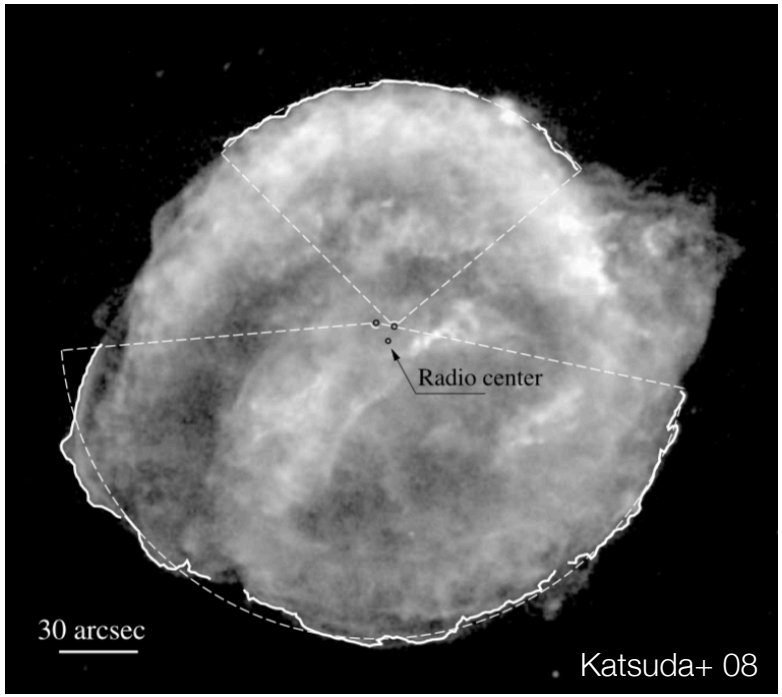
Kepler's SNR (SN1604)

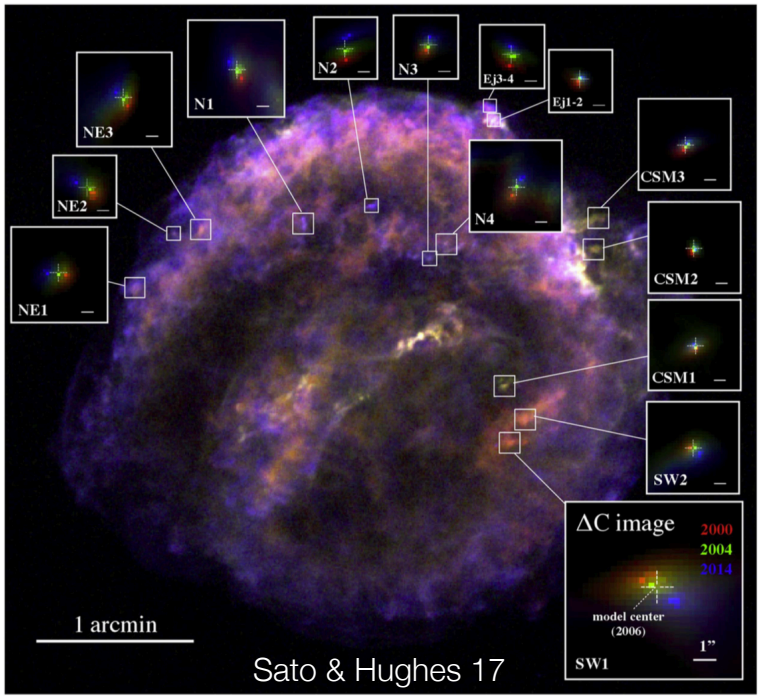
- **Young Ia SNR with Bright & Strong Fe emission lines**

(Park+ 13; Katsuda+15)

⇒ Suitable for probing the ejecta motion

Proper motion of forward shock Si kinematics of several knots

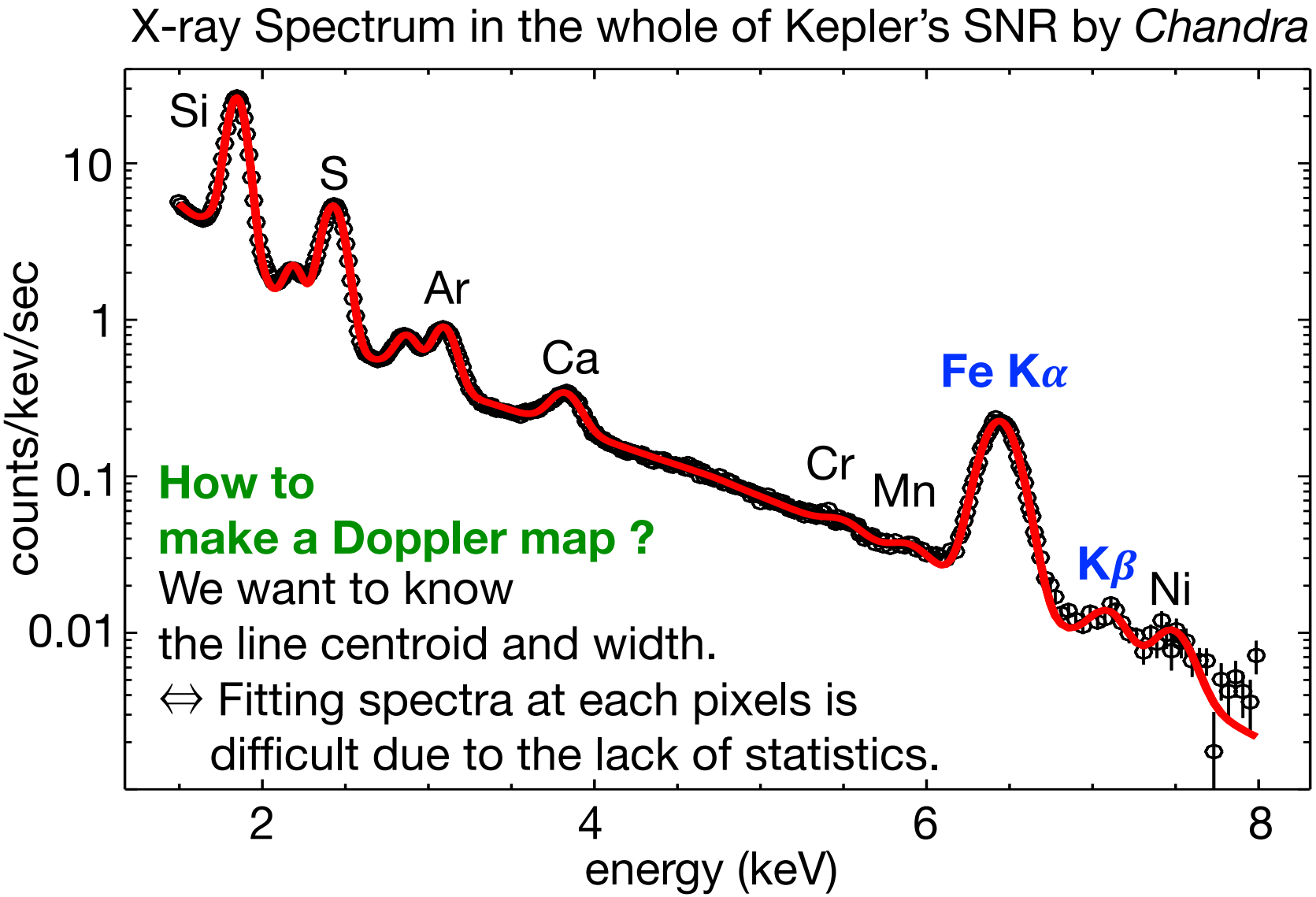




- Our goal: the whole expansion structure

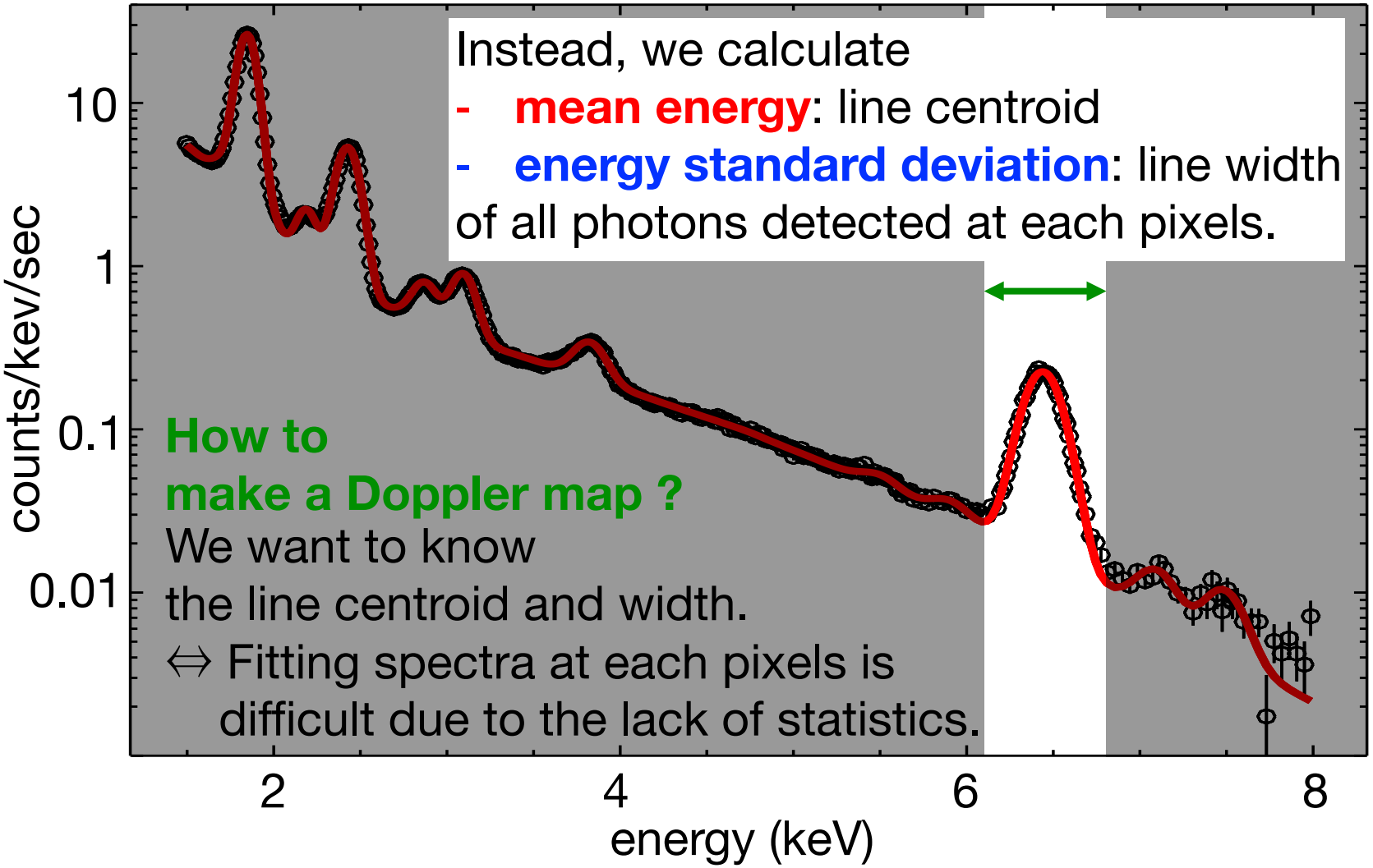
⇒ Measuring **Doppler (line-of-sight) velocity** is important.

Doppler Measurement



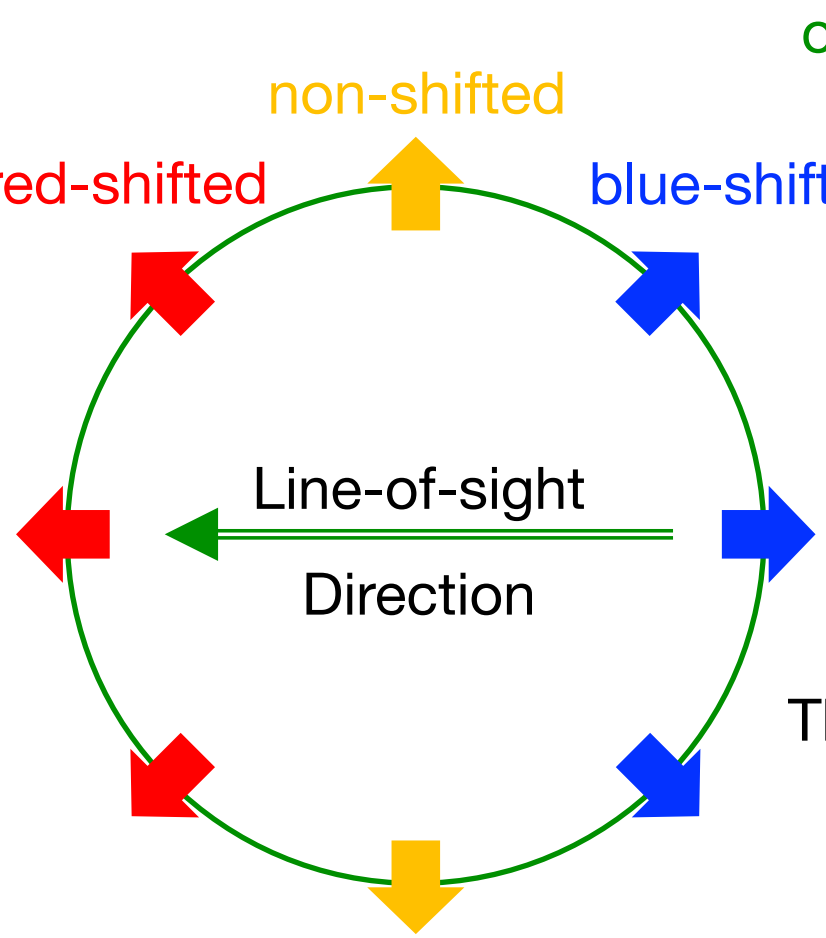
Doppler Measurement

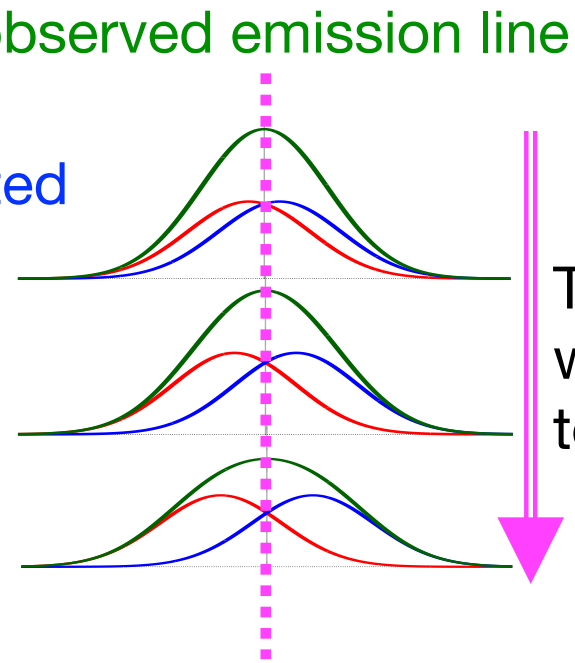
X-ray Spectrum in the whole of Kepler's SNR by *Chandra*



Doppler Broadening

If the SNR expands spherically ...





The line width would **get wider** to the center.

The line centroid would **keep uniform**.

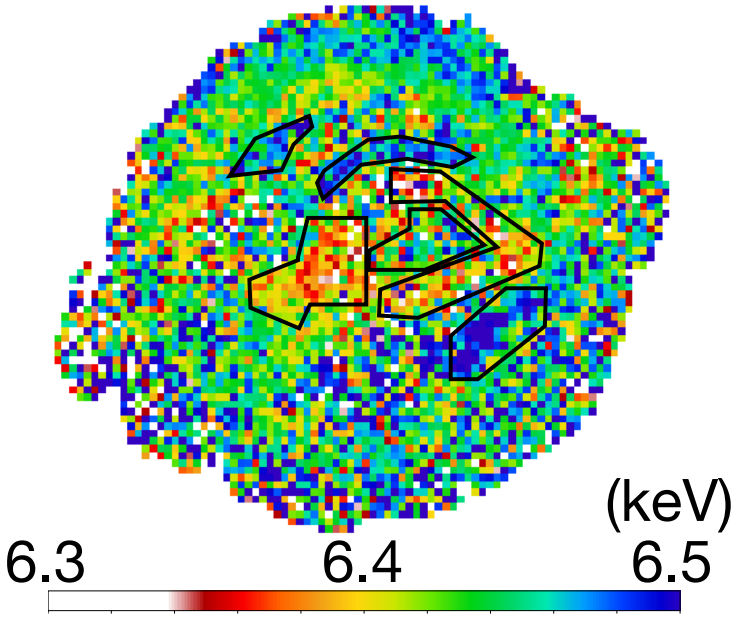
How about Kepler ...?

Results of Kepler

Fe Kα Doppler Mapping

Mean Energy

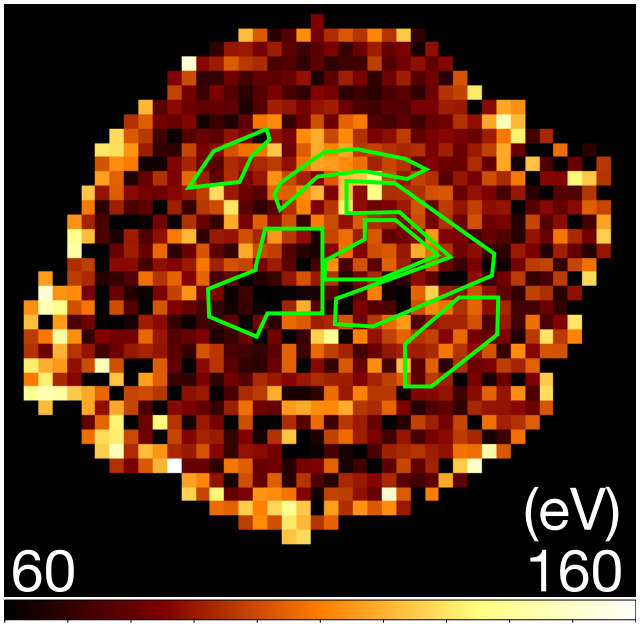
Probe of line centroid



not uniform ...

Energy Standard Deviation

Probe of line width

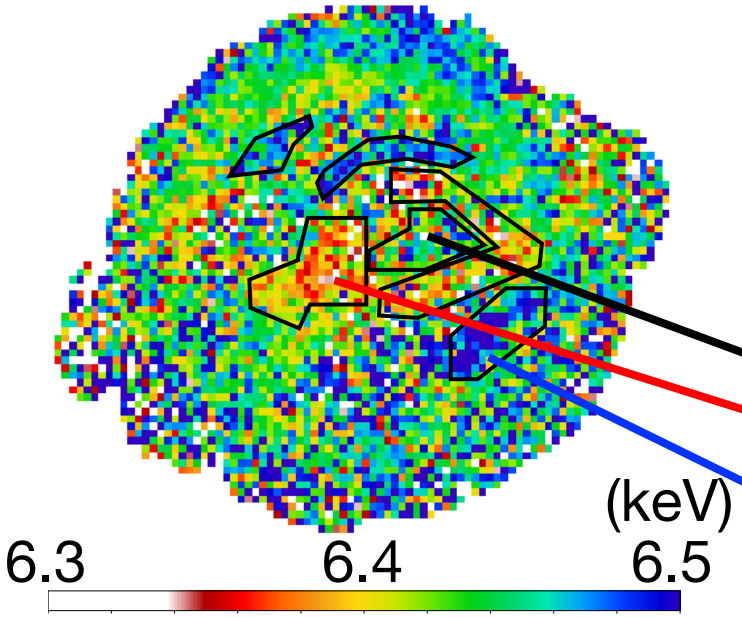


(TK et al. 2018)

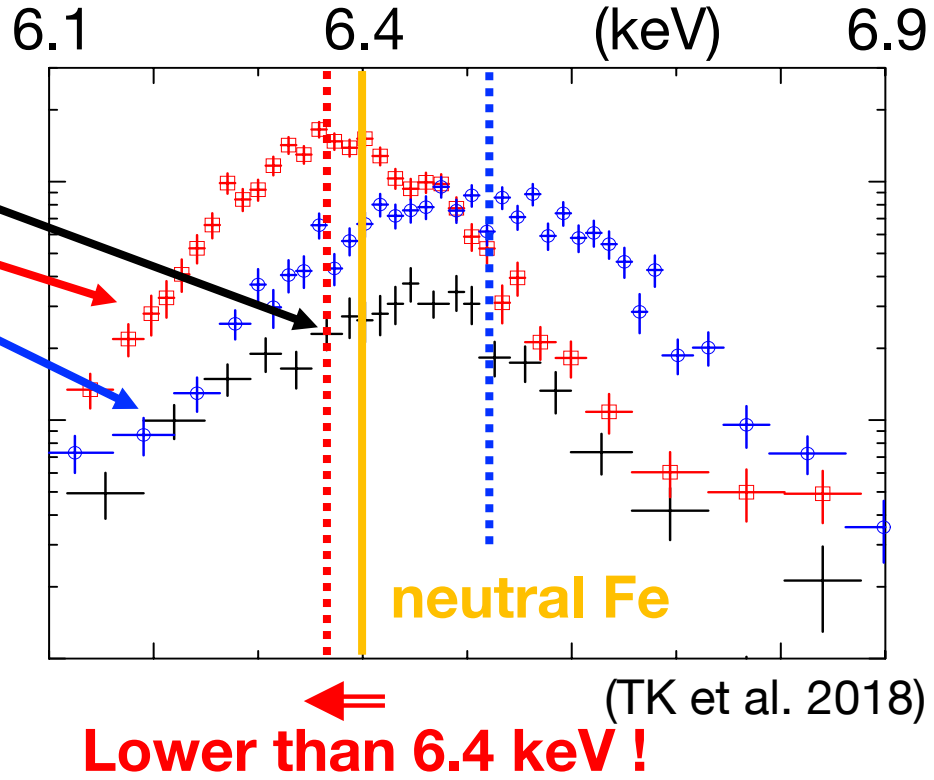
Fe Kα Doppler Mapping

Mean Energy

Probe of line centroid



Mean Energy trend is real !

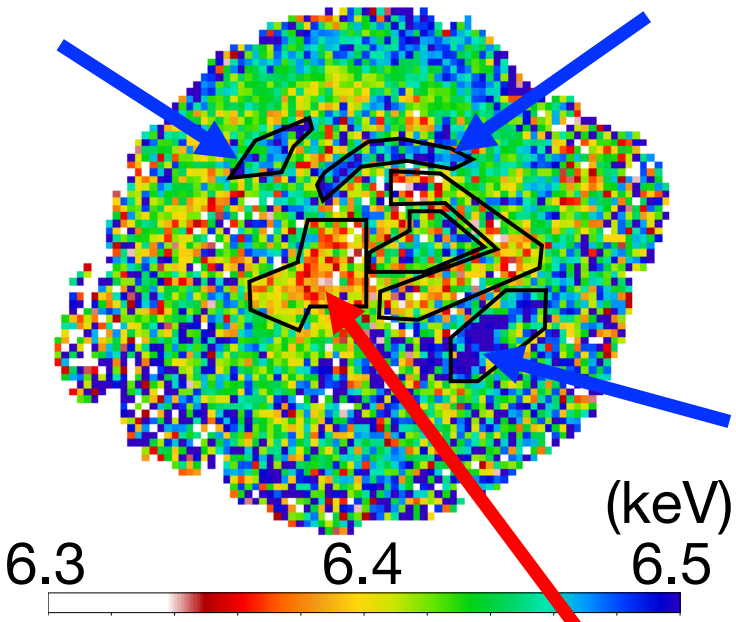


Lower than 6.4 keV !

Fe Kα Doppler Mapping

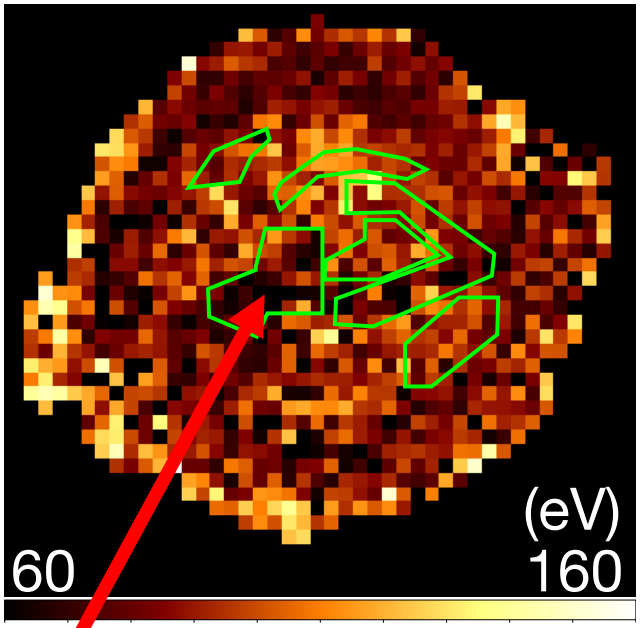
Mean Energy

Probe of line centroid



Energy Standard Deviation

Probe of line width



(TK et al. 2018)

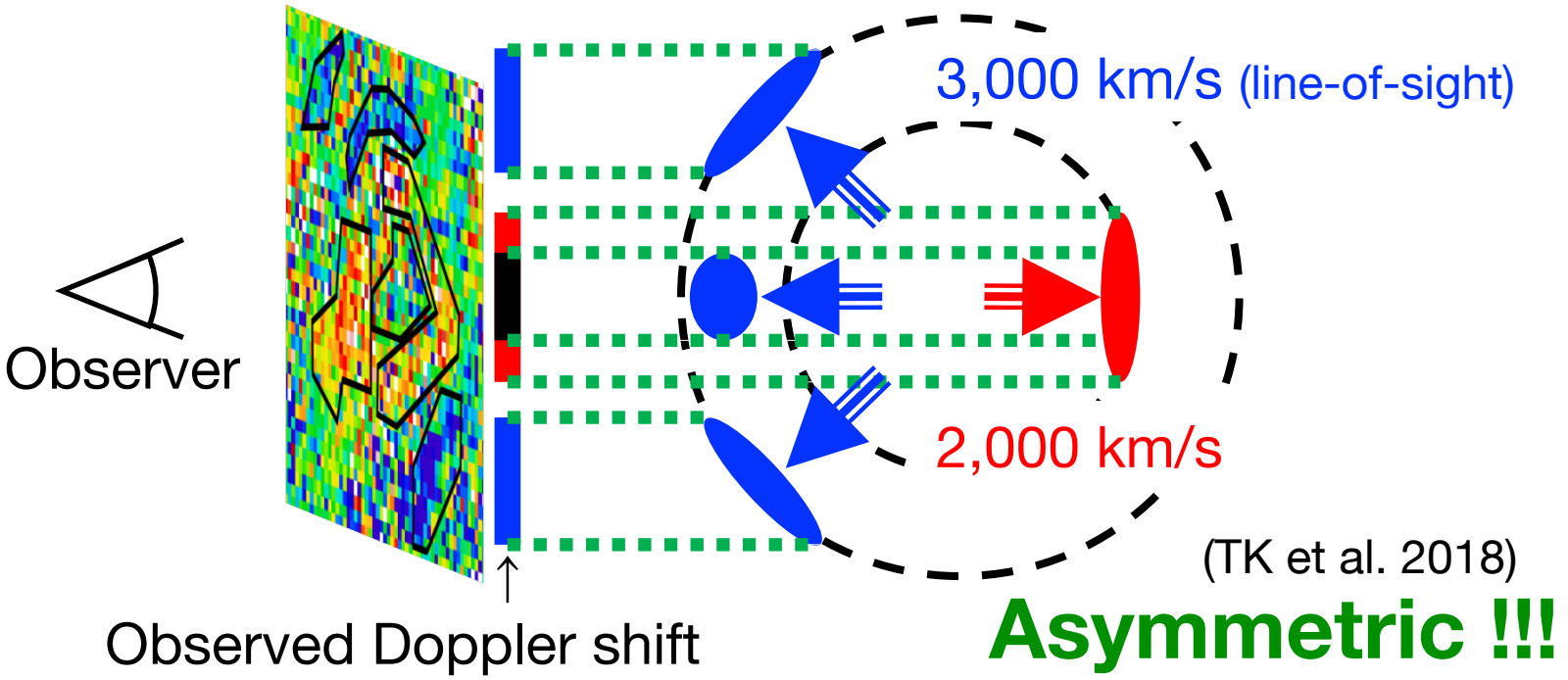
Low line centroid & **Narrow** line width
⇒ Ejecta are only moving away from us.

First Detection of the Red-Shifted Component !!!

Also find some Blue-Shifted Components !

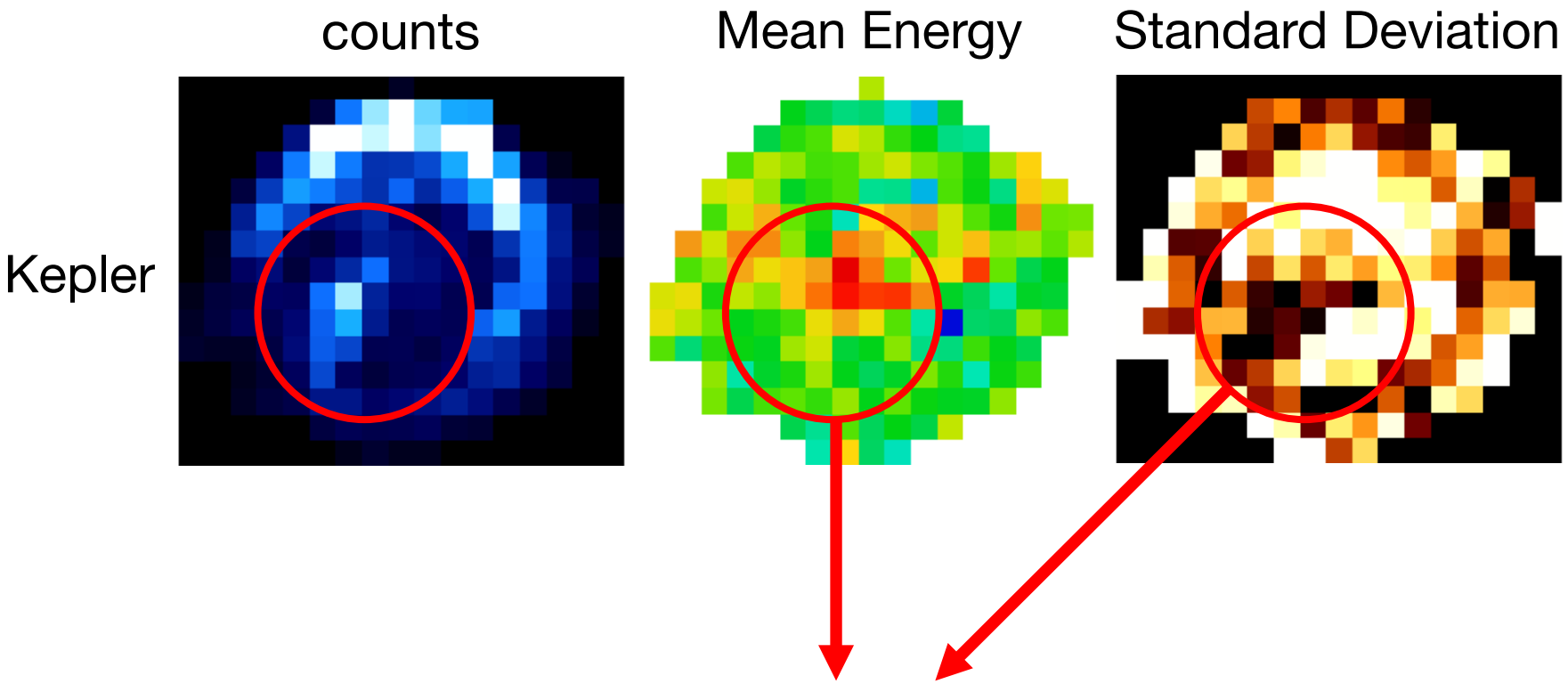
Fe Expansion Structure

We estimate the ionization state by using Fe Kβ line,
and calculate Kα centroid at the static system.
⇒ The energy shift tells us the line-of-sight velocity.



Comparison to Tycho

Fe Maps



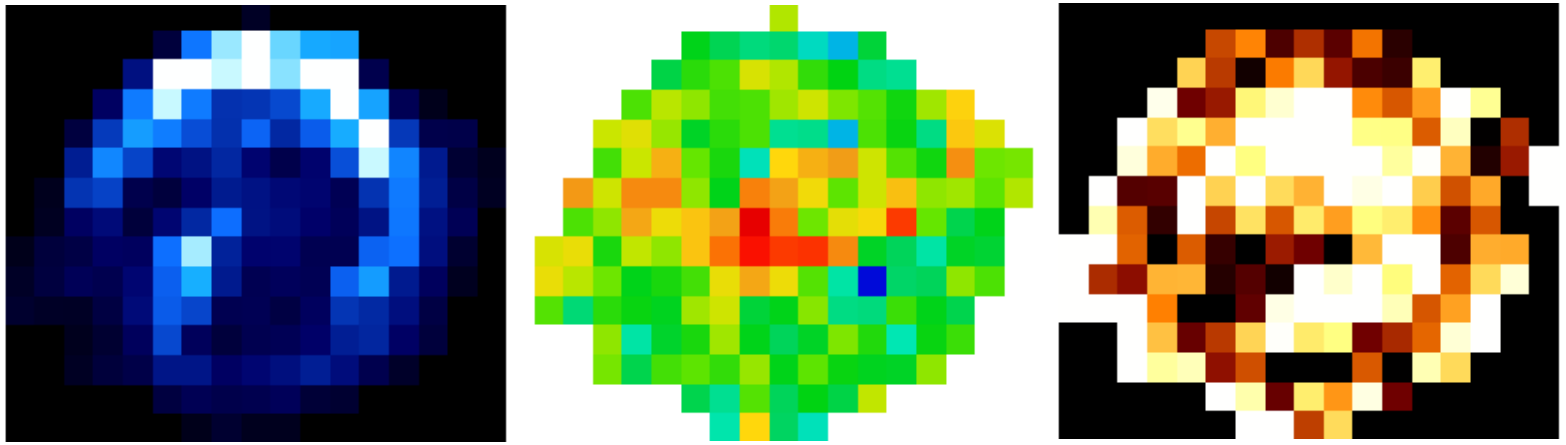
low Mean Energy & narrow Standard Deviation

⇒ **red-shifted !**

Fe Maps

counts | Mean Energy | Standard Deviation

Kepler



Tycho

Preliminary

CCD gap

Fe Maps

Symmetric Expansion !

(c.f., Williams+ 17)

Different explosion mechanism from Kepler ?

symmetric emission (e.g., Lopez+ 11)

uniform (c.f., Si: Sato & Hughes 17)

spherical broadening (e.g., Hayato+ 10; Williams+ 17)

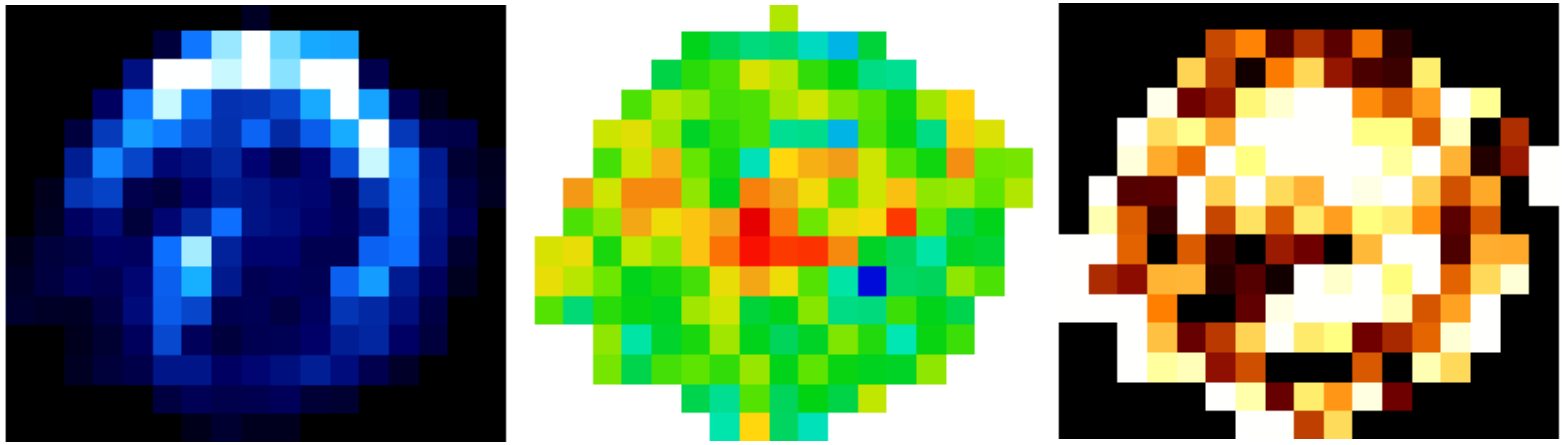
Tycho

counts | Mean Energy | Standard Deviation

Fe Maps

counts | Mean Energy | Standard Deviation

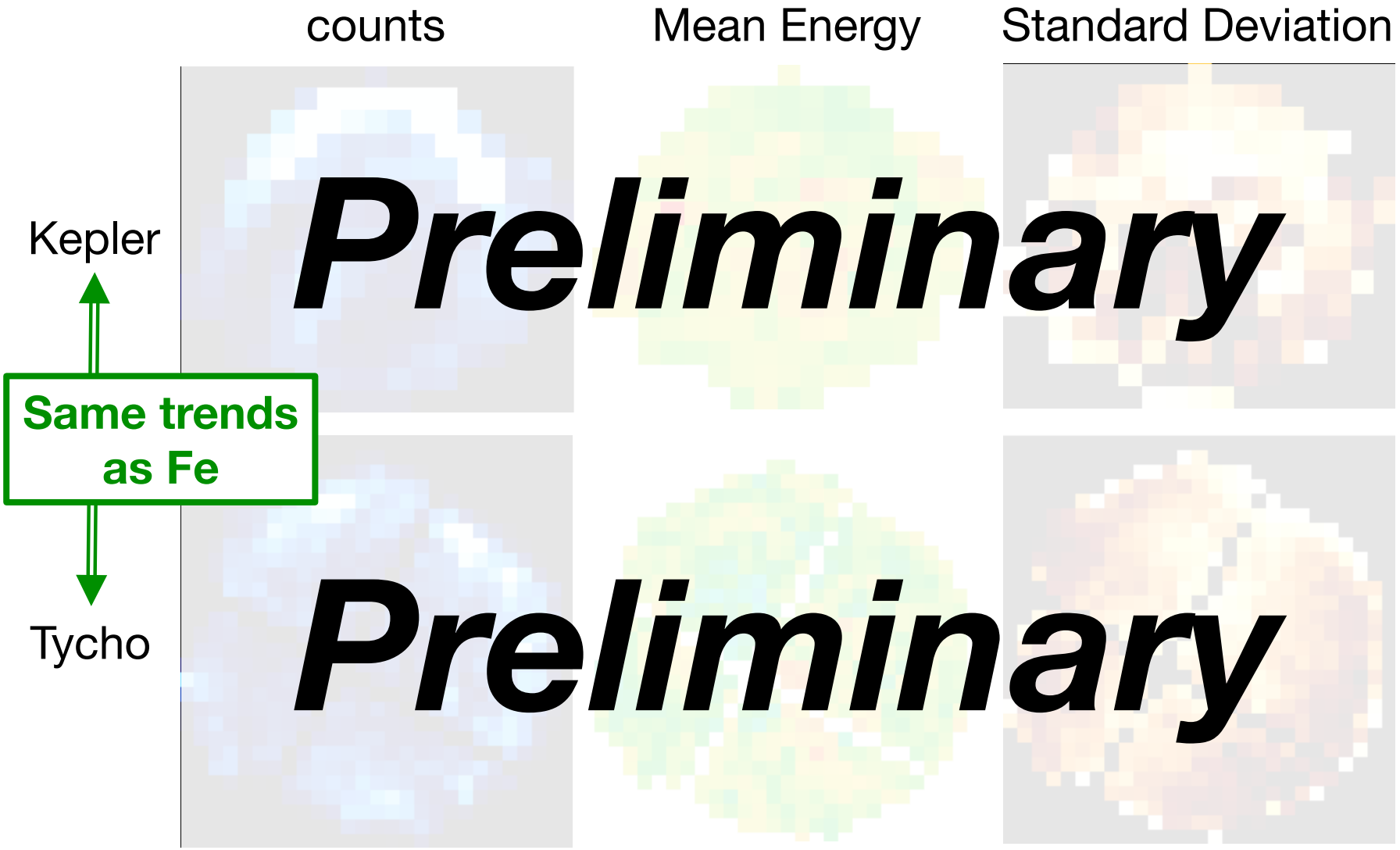
Kepler



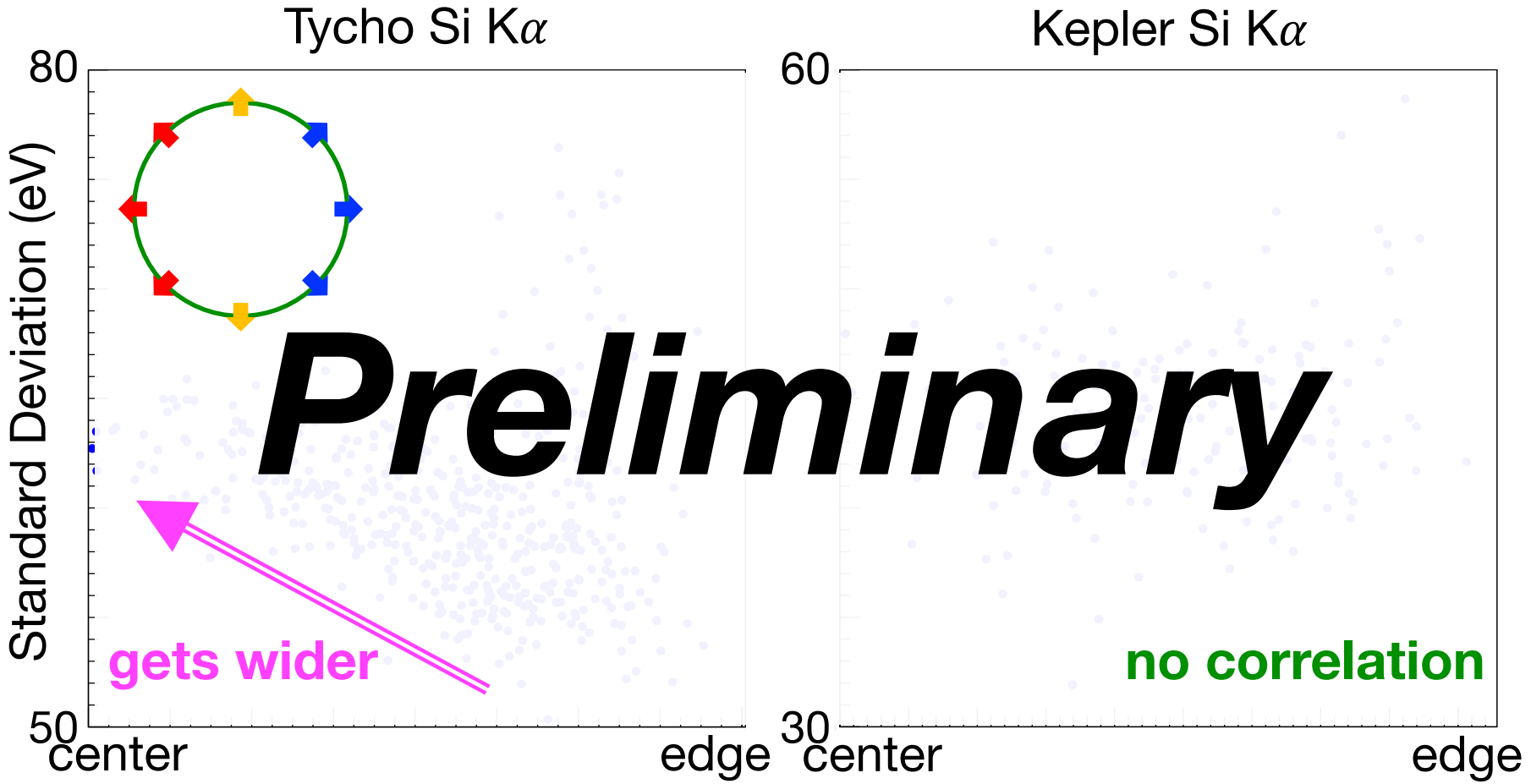
Tycho

Preliminary

Si Maps for better statistics



Si expansion structure

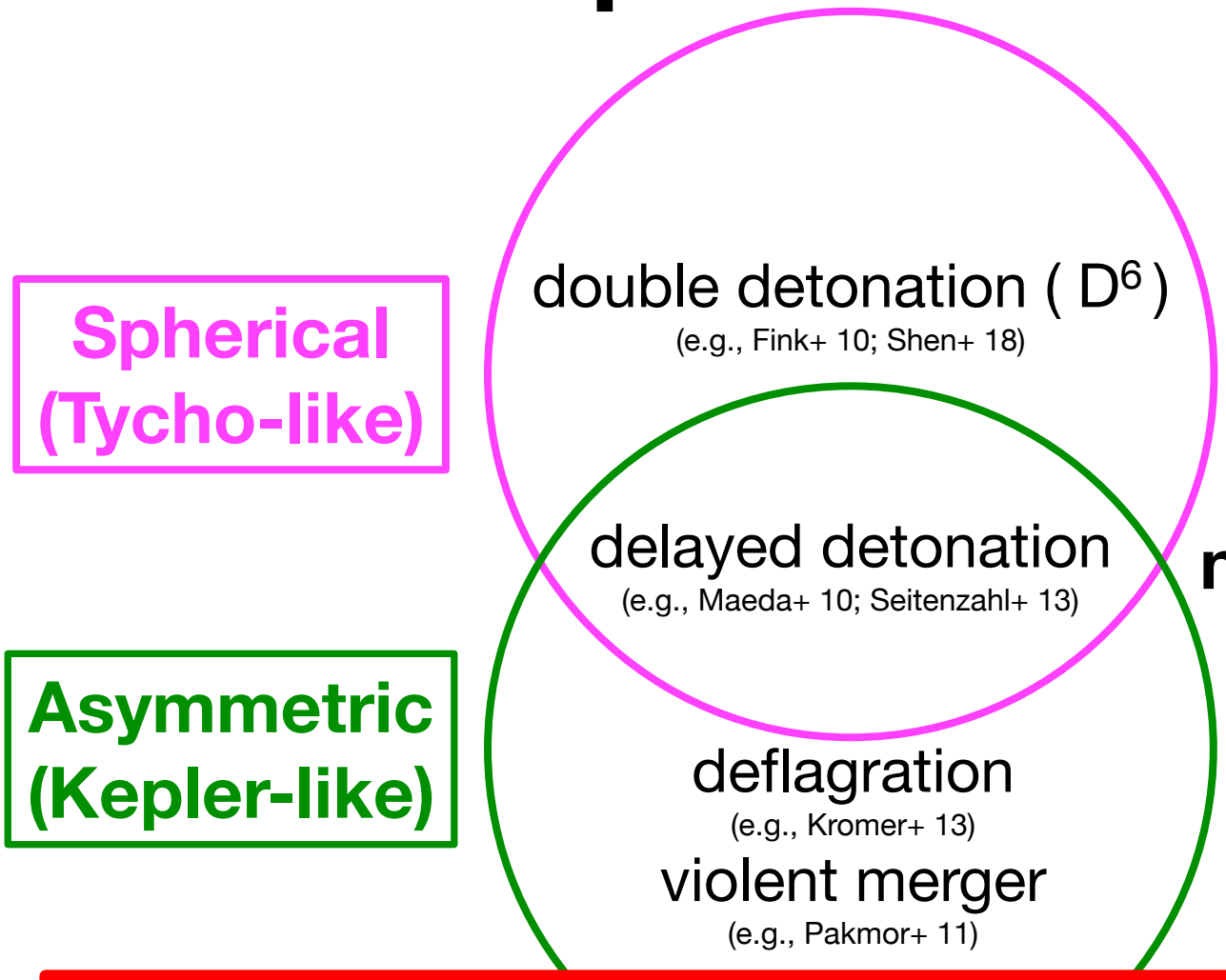


Spherical Doppler Broadening

Asymmetric Expansion

See also S9.2 Millard's Poster with HETG analysis

Different Explosion Mechanism ?



not confirmed ...

Collaborate with us !

We need helps from SN researchers for further understandings.

Conclusion

In this talk

- The ejecta kinematics of SNR is one of the crucial clues to understand the explosion mechanism of SN.
- We measured Doppler velocity of Fe ejecta using the mean value and standard deviation of photon energy.
- We found **the asymmetric expansion structure of Fe ejecta in the line-of-sight direction** in Kepler's SNR.
- On the other hand, Tycho's SNR is **very symmetric unlike Kepler.**
- Their explosion mechanism might be different.

↑(TK et al. 2018)

Future Works

- Systematic analysis with other SNRs.
- Similar analysis with Si, S, Ar etc... lines.

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