

# Tycho

## De Nova Stella

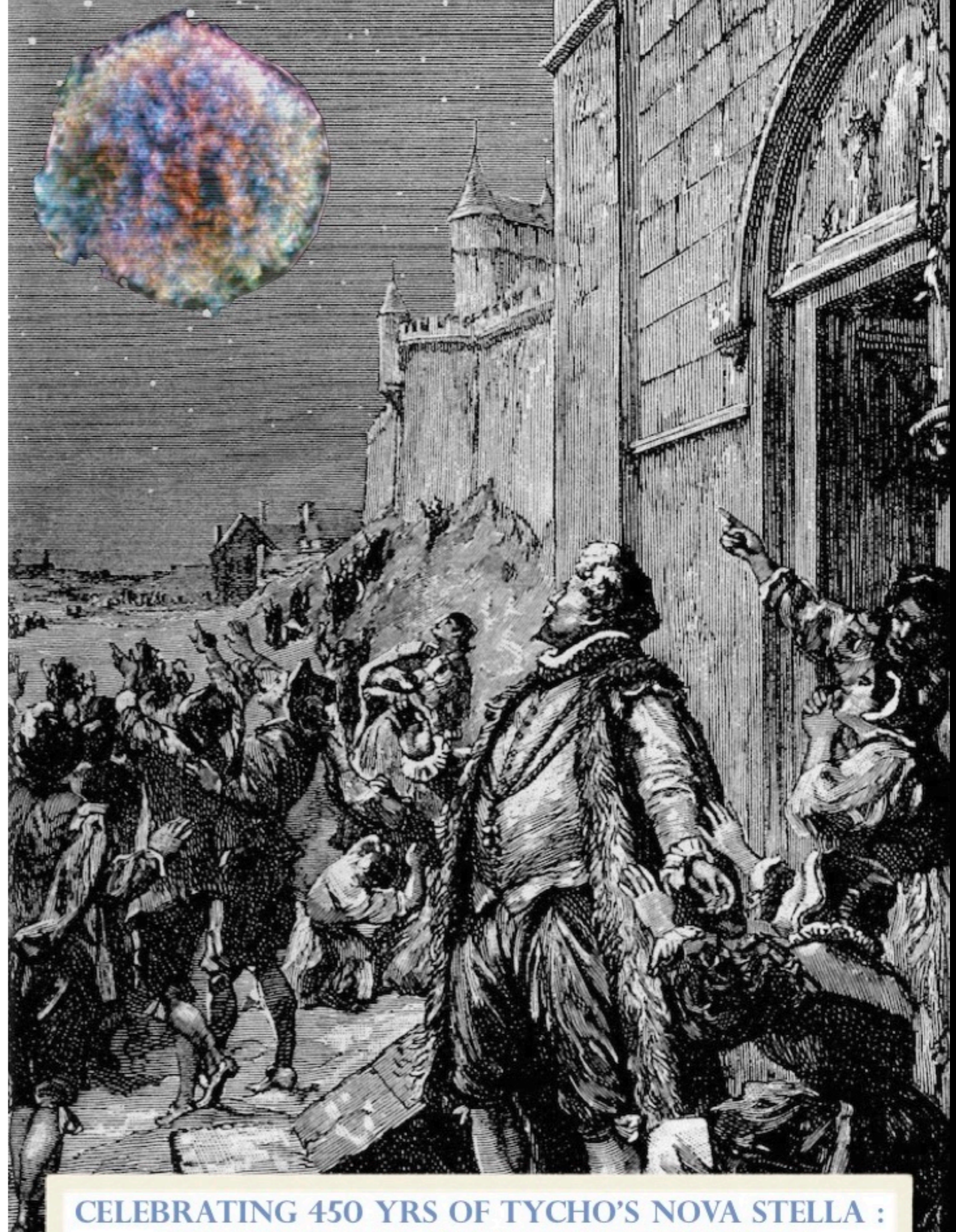
SN 1572 - 2022

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Many slides from R. Neuhäuser @ EAS22

Astronomy department, CEA/Saclay

 @fabacero



CELEBRATING 450 YRS OF TYCHO'S NOVA STELLA :

# Nova stella in Cassiopeia constellation in Nov 1572



**Brighter than Jupiter in November 1572**

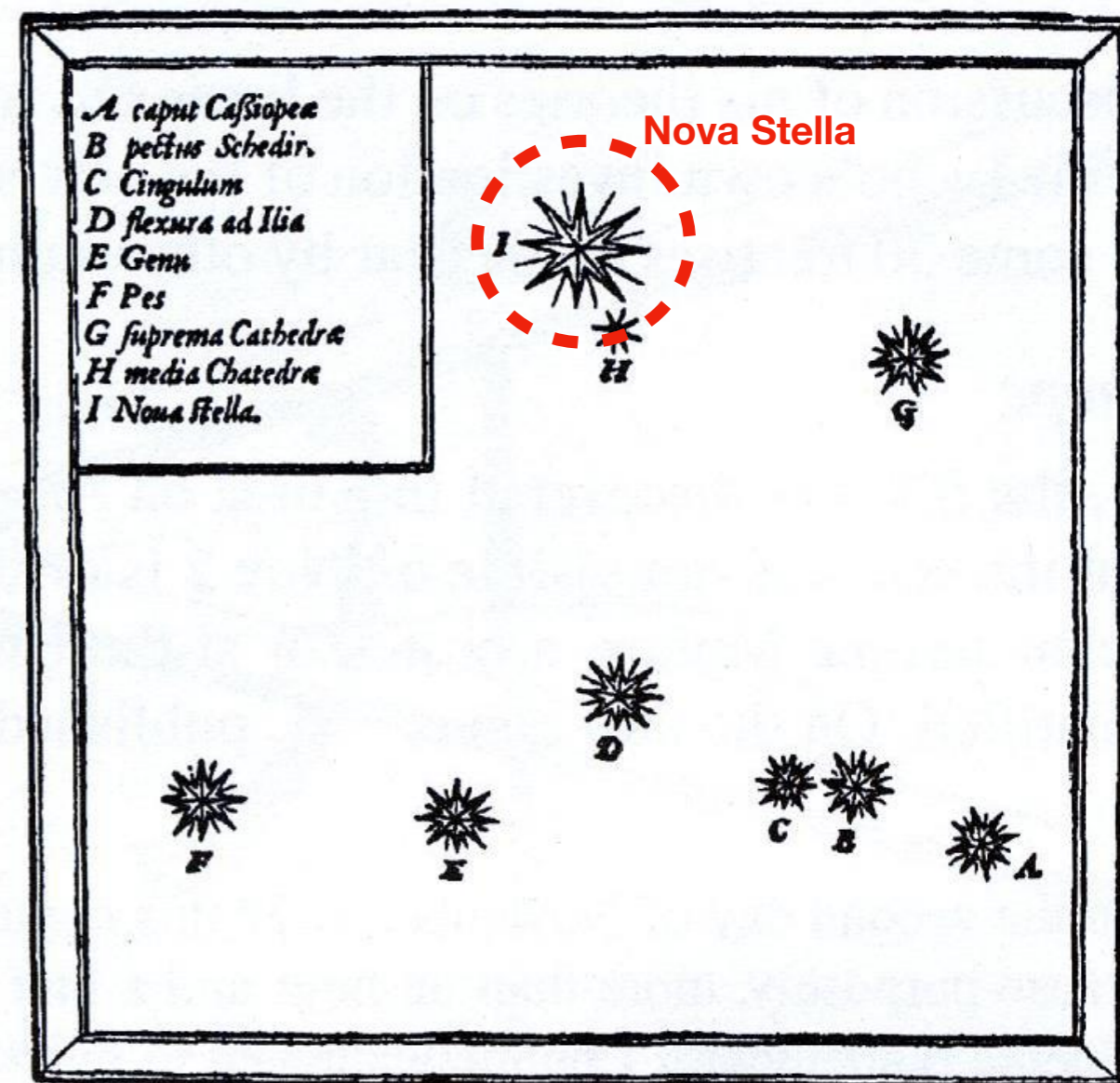
Tycho Brahe in his Caste of Uraniborg

## Note that:

Brahe died in 1601

The large work on nova of 1572 appeared in 1602 edited by Kepler.

Kepler published two books on Galactic supernovae !  
Quite a nice publication record



## Further observations of the new star:

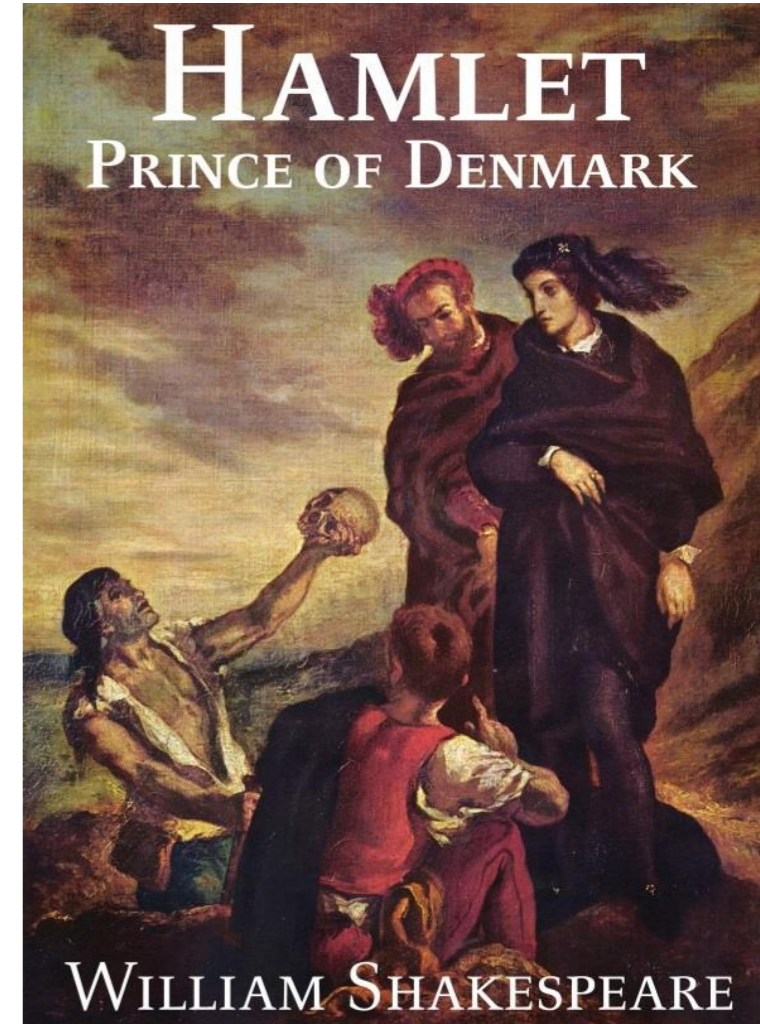
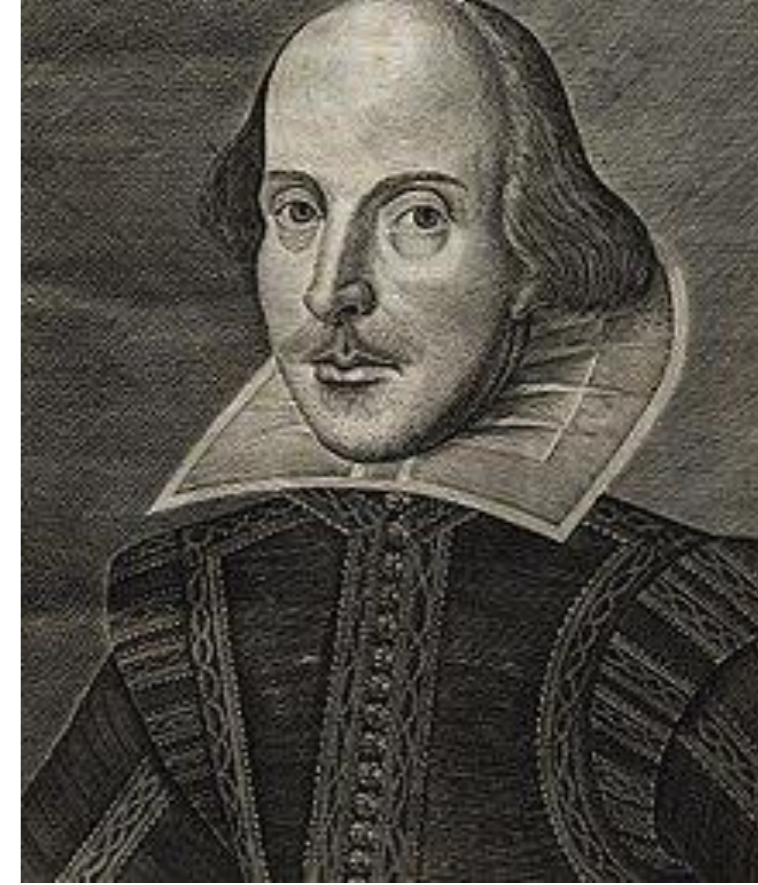
Shakespeare (born 1564), Hamlet (written ~1600):

Act 1, scene 1 in the middle of a very cold winter night:

**„When yond same stars that’s westward of the pole  
had made his course to illumine that part of the heaven.  
Where it now burns, Marcellus and myself,  
The Bell then beating one ...“**

SN 1572 in Nov around midnight indeed west of pole

(Olson, Doescher, Olson, S&T)



## First observations of the new star of 1572:

Munoz (professor of Hebrew and mathematics at U Valencia, Spain, 1563-1578):  
“I am certain that on the second day of November 1572 there was not this comet in the sky.  
... Nov 11 greater than that of Jupiter ... and almost equal to that of Venus ...”

Francesco Maurolyco (mathematician, astronomer, professor at U Messina, d. 1575)  
wrote „hastly“ on Nov 6 (Hellman 1960):

“This new star surpasses these fifteen [stars of 1st mag] in brilliance ...”

### MAUROLYCO'S

The treatise which follows is that of  
manuscript. The words present in the (  
are all in the manuscript but, as is obvi

*Super nova stella: que hoc anno iuxta  
Cassiepes apparere cepit Considerationes*

Latin „super nova stella“  
= „about the new star“

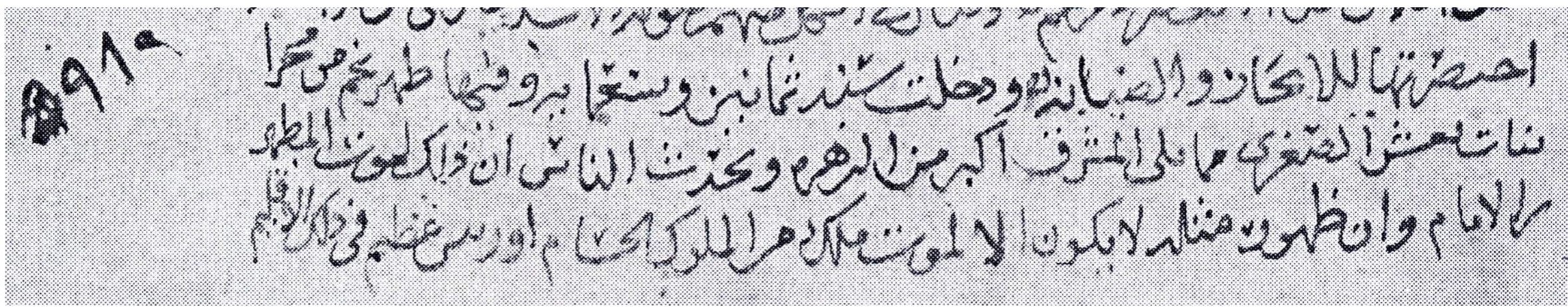
Schuler (Wittenberg) since Nov 6, Mästlin (Tübingen) since Nov 7,

Brahe in Denmark / Sweden since Nov 11

Korean and Chinese court astronomers since Nov 6 and 8, respec.

All: comet ? ... but without tail and stationary

Tycho's  
SN 1572  
Nov 6



°Isā b. Luṭf Allāh b. al-Muṭahhar:

„Then began the year [AH] 980

(= 14 May 1572 to 2 May 1573 A.D.  $\pm$  2 days).

In it there appeared a star [*najm*] in the path [*majrā*] of Ursa Minor [*Banāt Na<sup>c</sup>sh al-Ṣughrā*] towards the East. It was larger than Venus. People said that this would indicate the death of al-Muṭahhar [AD 1572 Nov 9  $\pm$  2], the son of the Imam, and that the appearance of such [objects] only happens in order to indicate the death of some mighty king or a great leader in that region.“

Same author also reported SN 1604

(Neuhäuser et al. 2016, JHA)

## Further observations of the new star of 1572 to 1574:

Nov 1572: brighter than Jupiter (-2.6 mag), fainter than Venus (-4 mag)

Dec 1572: Brahe „like Jupiter“ (-2.4 mag)

Jan 1573: Brahe „little fainter than Jupiter“ (-2.2 mag)

and „somewhat brighter than the brighter stars of first mag” ( $\leq 0.19 \pm 0.15$  mag),  
i.e. about -2 mag early Jan to  $\sim 0$  mag late Jan

**Feb / Mar 1573: Brahe „equal to brighter stars of first mag” ( $0.19 \pm 0.15$  mag)**

**Apr / May 1573: Brahe “equal to stars of 2nd magnitude” ( $1.55 \pm 0.42$  mag)**

**July / Aug 1573: Brahe “equal to the brighter stars of Cas” ( $2.33 \pm 0.24$  mag)**

Oct 1573: Brahe “compared to stars of 4th magnitude” ( $4.1 \pm 0.57$  mag)

Nov 1573: Brahe “very similar to the nearby 11th star of Cas” ( $\kappa$  Cas: 4.17 mag)

Dec 73 - Jan 74: Brahe “hardly exceeded the stars of 5th magnitude” ( $4.5 \pm 0.3$  mag)

Feb 1574: Brahe “compared with the 6th mag stars” ( $5.0 \pm 0.3$  mag)

Baade (1945 ApJ):

Light curve of B Cas = SN 1572 typical for SN type I

Reconstruction from historical observations:

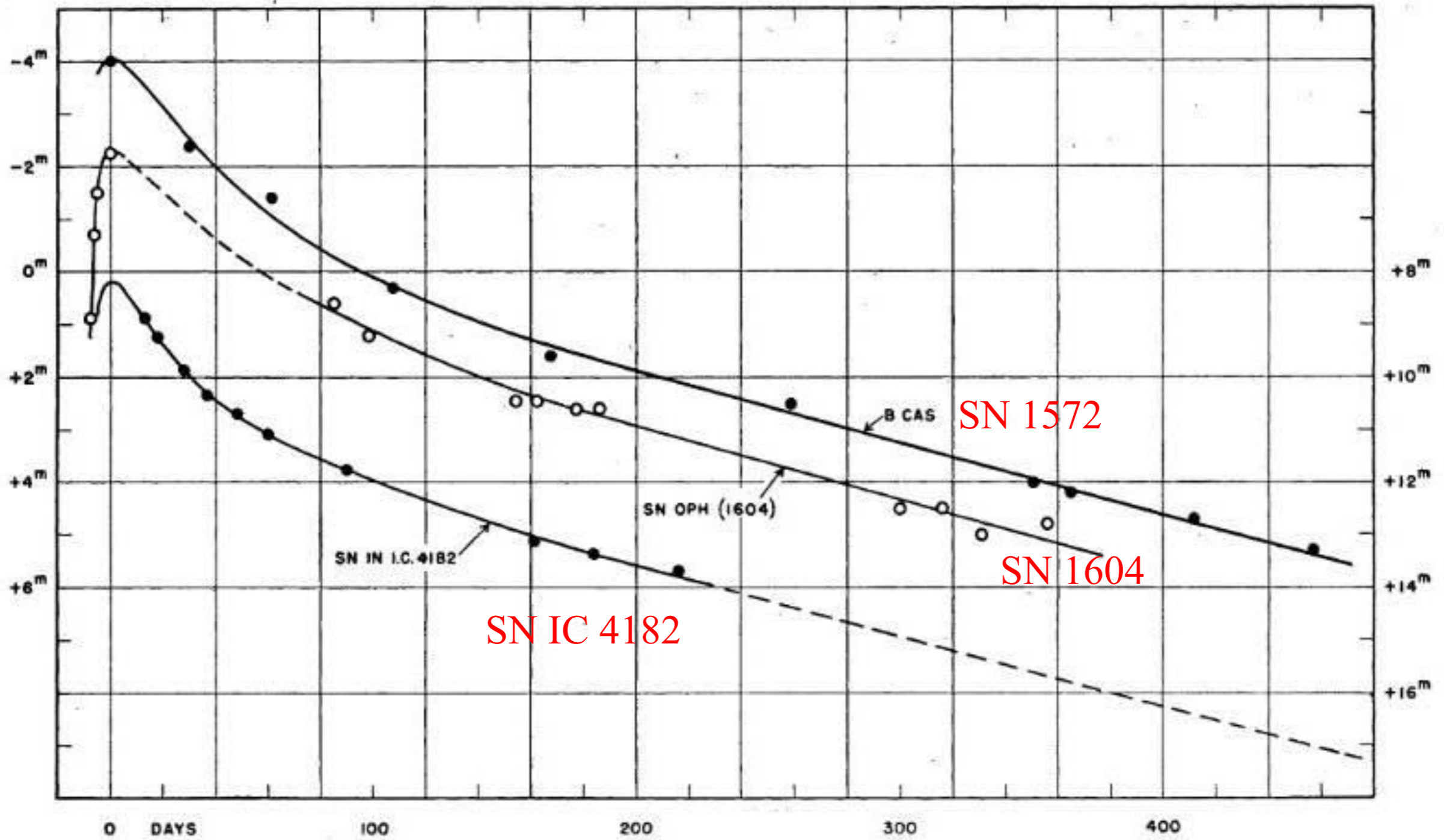
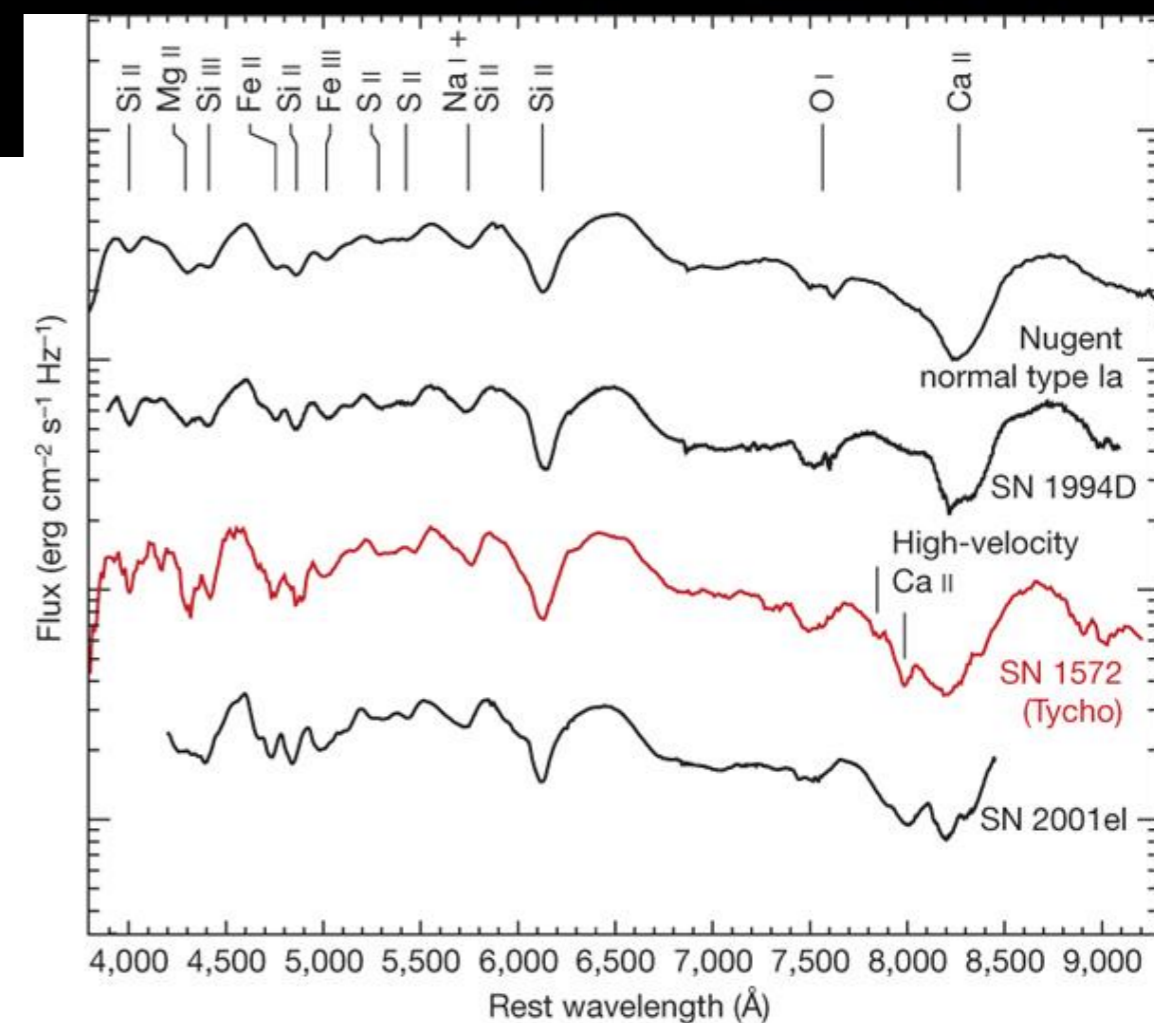
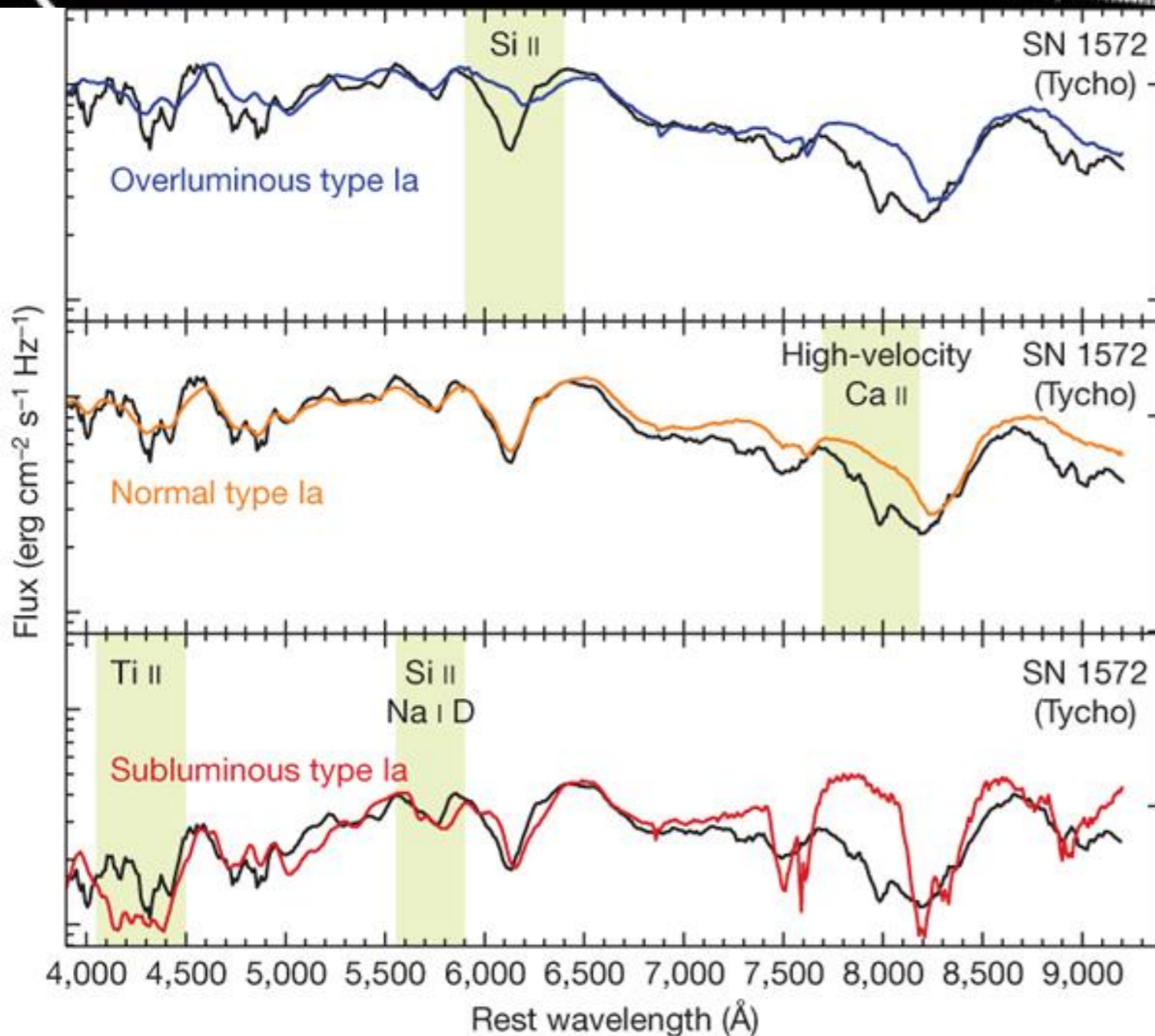
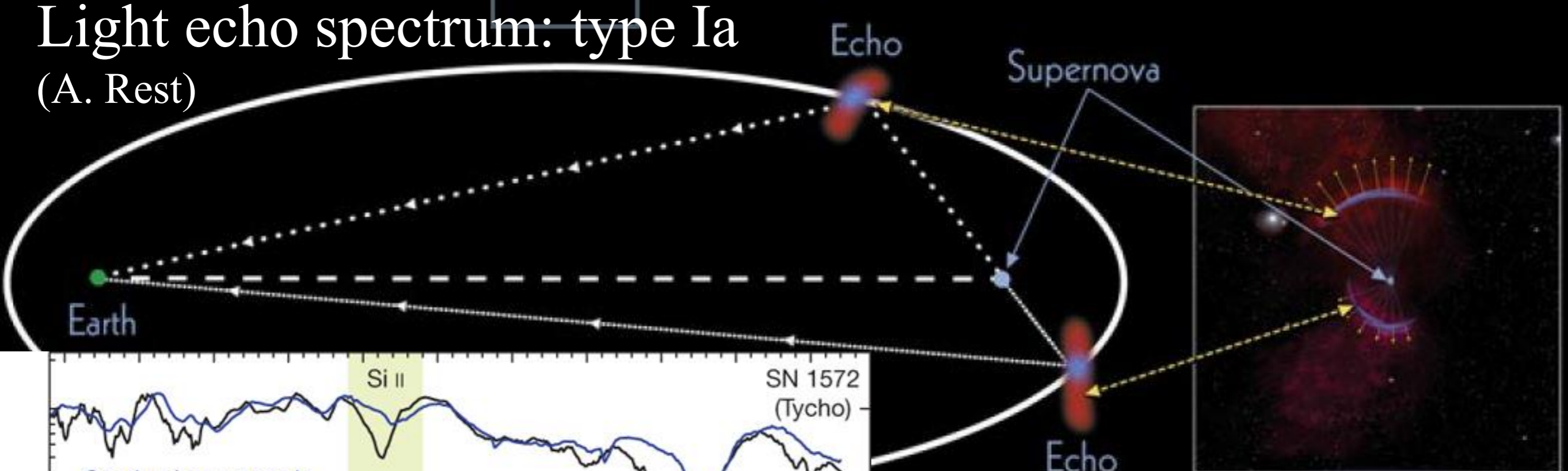


FIG. 1.—Visual light-curves of B Cas, SN Oph (1604), and SN in I.C. 4182. Magnitudes on the left refer to B Cas and SN Oph (1604); on the right, to SN in I.C. 4182. The extrapolated (*dotted*) part of the light-curve of SN in I.C. 4182 has been taken from the photographic light-curve, after an adjustment in zero point.

# Light echo spectrum: type Ia

(A. Rest)



Krause et al. (2008) & Rest et al. (2008)



## Color evolution, e.g. by Adam Ursinus (1524-1590):

“Its color was whitish, clear and bright, but mostly mixed with weak-yellow color, except for several days around Dec 12 and afterwards, when it was seen in dark red brownish color,

finally it had again the earlier clear color,

and it was substantially brighter than all stars of the 1st magnitude including the four planets, except just the single Venus

That is a real gold comet ... Assign[ed] to Mars because of its dark brown-red color, which it had in December, but not since long.”

(Beyneben einer kurtzen Beschreibunge des erschienenen Cometens im 1572. und 1573. Jhare)

## Final color evolution:

(Neuhäuser et al. in prep.)

Date	phase	color report	source/observer	Ref	B-V (a)	mag (c)
1572 Nov 14-30	$1 \pm 8$	like Jupiter	Brahe, Denmark	(c)	$0.87 \pm 0.1$	-3 to -4
1572 late Nov (20-30)	$4 \pm 5$	golden-yellow white	Leowitz, Czech Rep.	(e)	$0.7 \pm 0.1$ :	$-4 \pm 0.3$
1572 Nov 22-Dec 11	$11 \pm 10$	white, pale yellow	Ursinus, Germany	(e)	$0.7 \pm 0.1$ :	-4 to -3
after 1572 Nov 24	?	red-yellow	Shenzong Shilu, Ch.	(d)	$1.1 \pm 0.2$	?
1572 Dec 1-20:	$29 \pm 10$	golden-yellow	Brahe, Denmark	(c)	$0.9 \pm 0.2$	$-2.4 \pm 0.2$
1572 Dec 2	$21 \pm 5$	closer to Mars	Munoz, Spain	(f)	$1.3 \pm 0.2$	$-2.4 \pm 0.2$
1572 begin Dec (1-10)	$16 \pm 5$		Leowitz, Czech Rep.	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 12 (-31?)	33		Busch, Germany	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 12 (-31?)	33	like Mars	Ursinus, Germany	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 14 (-31?)	$35 \pm 5$	more Mars than Jup	Peucer, Germany	(c)	$1.2 \pm 0.2$	$-2.4 \pm 0.2$
1572/3 Dec 21-Jan 10	$42 \pm 10$	like Mars	Brahe, Denmark	(g)	$1.43 \pm 0.13$	$-2.2 \pm 0.2$
ca. 1572 Jan 16	$58 \pm 7$	like Mars	Praetorius, Germany	(c)	$1.43 \pm 0.13$	$-2.0 \pm 0.2$
1573 Jan 21-Feb 10	$73 \pm 10$	closer to $\alpha$ Tau than $\alpha$ Ori	Brahe, Denmark	(g)	$1.55 \pm 0.05$	$-2.0 \pm 0.2$
1573 end Feb (20-28)	$95 \pm 4$	white like first	Mästlin, Germany	(c)	$0.87 \pm 0.1$	$0.19 \pm 0.15$
1573 May	$175 \pm 15$	lead-white below Saturn	Brahe, Denmark	(c)	$0.80 \pm 0.2$	$1.55 \pm 0.42$

numbers preliminary

(after May, not too faint for color detection,  
but not sufficiently colorful anymore.)

## Extinction

$A_V = 2.25 \pm 0.16$  mag (Schaefer 1996)

to  $1.86 \pm 0.12$  mag (Ruiz-Lapuente 2004)

i.e. subtract color excess

$E(B-V) = 0.66 \pm 0.06$  mag (R=3.1)

to get  $(B-V)_0$

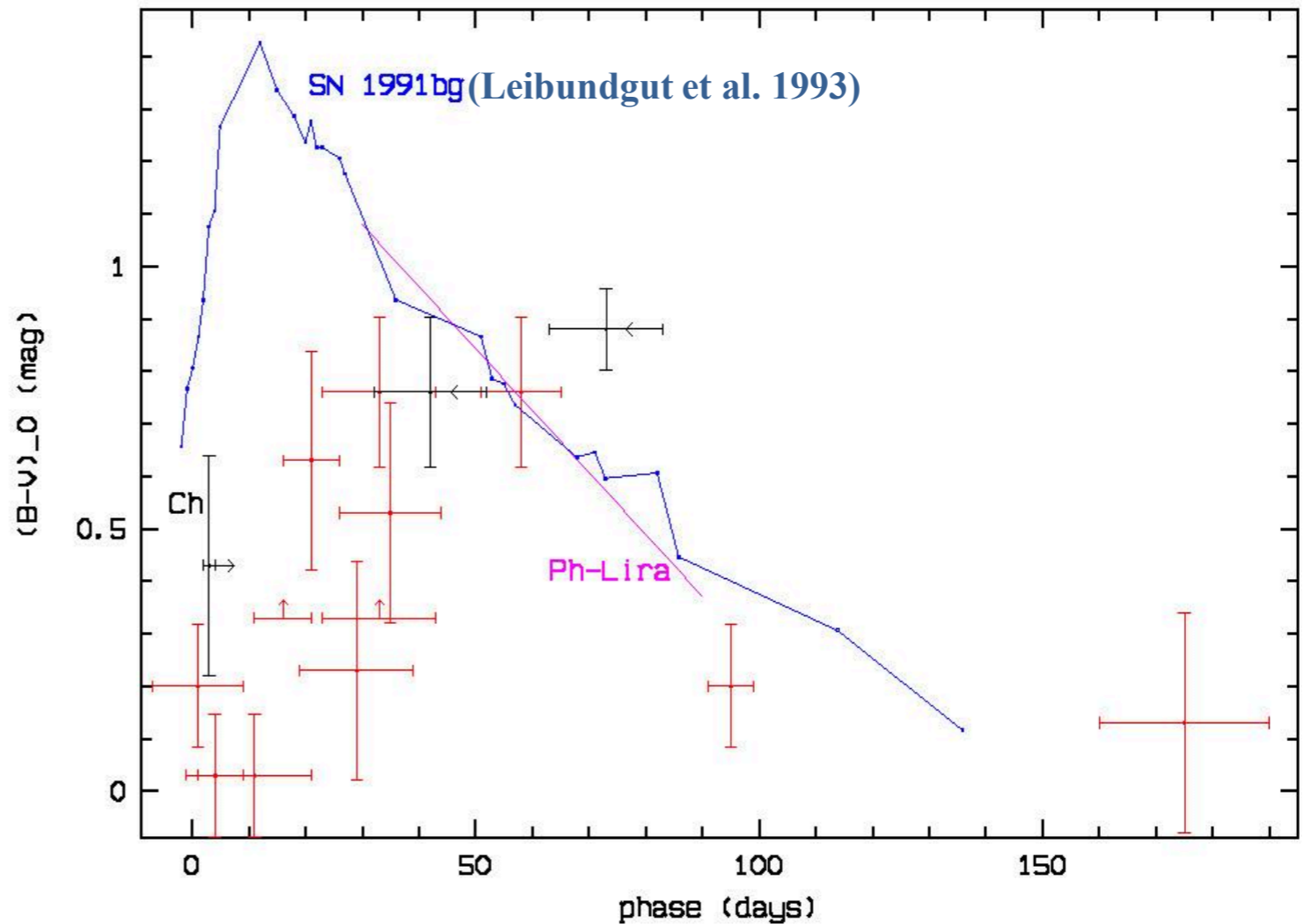
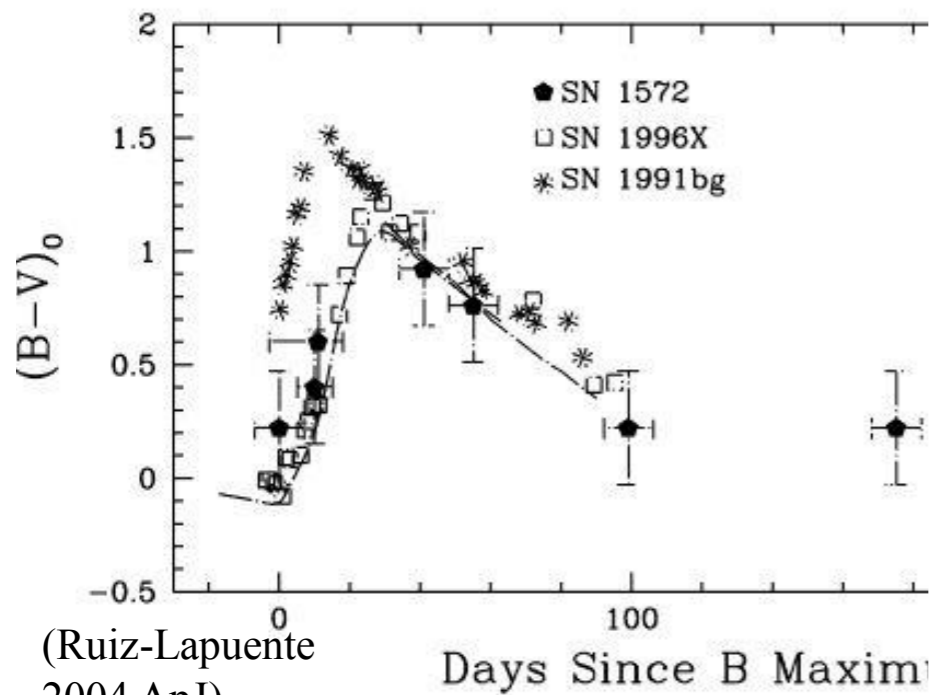
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1572 Dec 2	$21 \pm 5$	closer	Munoz, Spain	(f)	$1.3 \pm 0.2$	$-2.4 \pm 0.2$
1572 begin Dec (1-10)	$16 \pm 5$		Leowitz, Czech Rep.	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 12 (-31?)	33		Busch, Germany	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 12 (-31?)	$33 \pm 5$	Mars-like	Ursinus, Germany	(e)	$\geq 1$ :	$-2.4 \pm 0.2$
1572 Dec 14 (-31?)	$35 \pm 5$					
1572/3 Dec 21-Jan 10	$42 \pm 10$	like M				
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1573 end Feb (20-28)	$95 \pm 4$	white				
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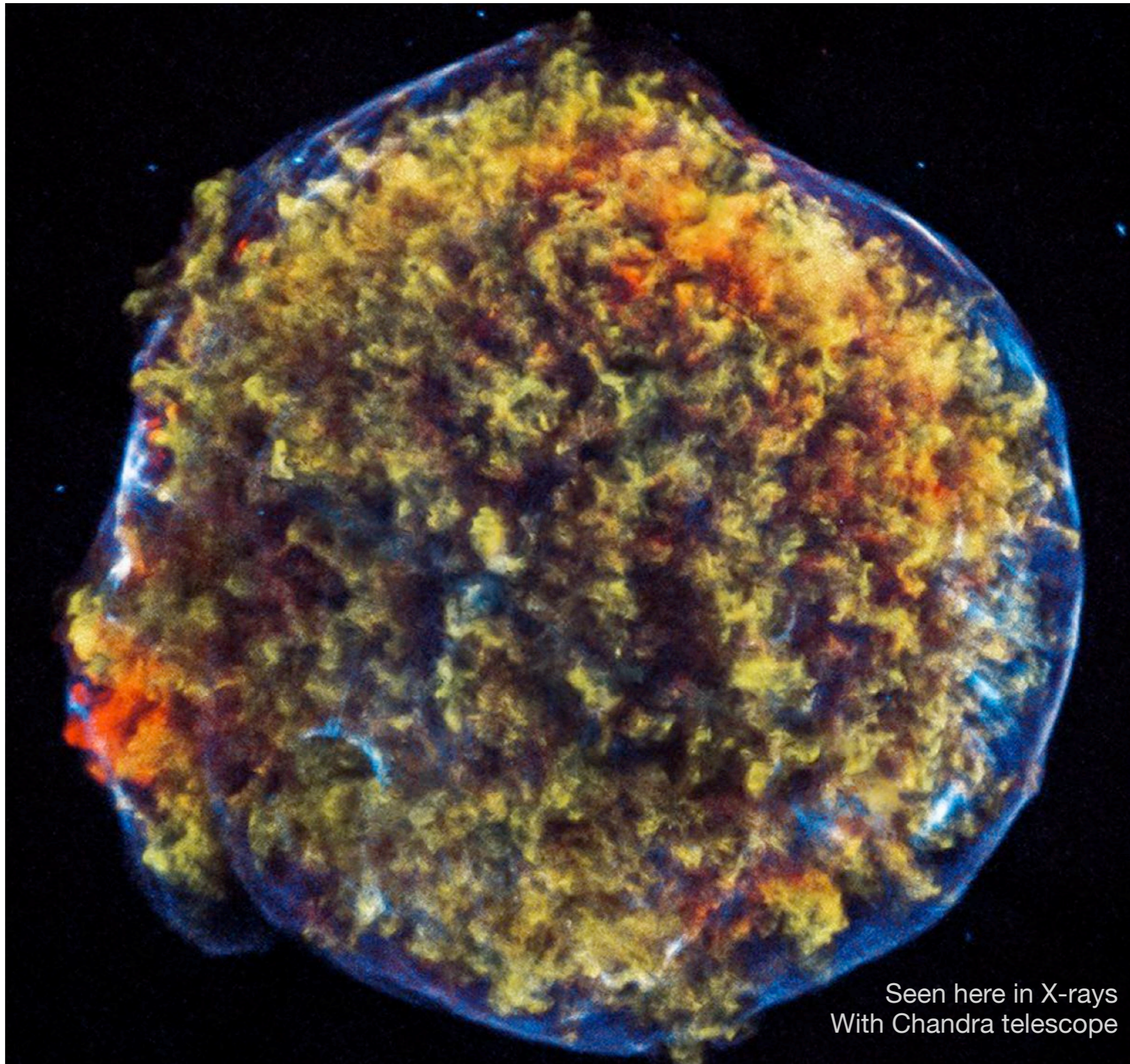
numbers preliminary

(after May, not too faint for color detection,



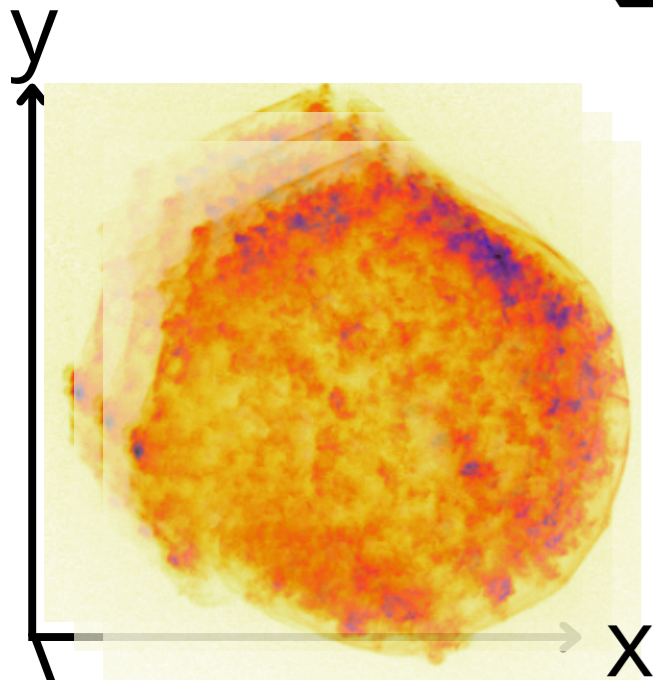
**And 450 years later :**

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Seen here in X-rays  
With Chandra telescope

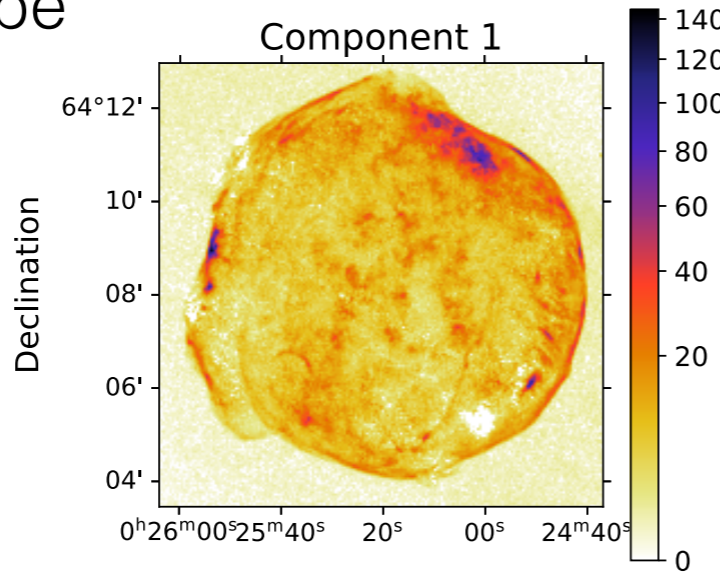
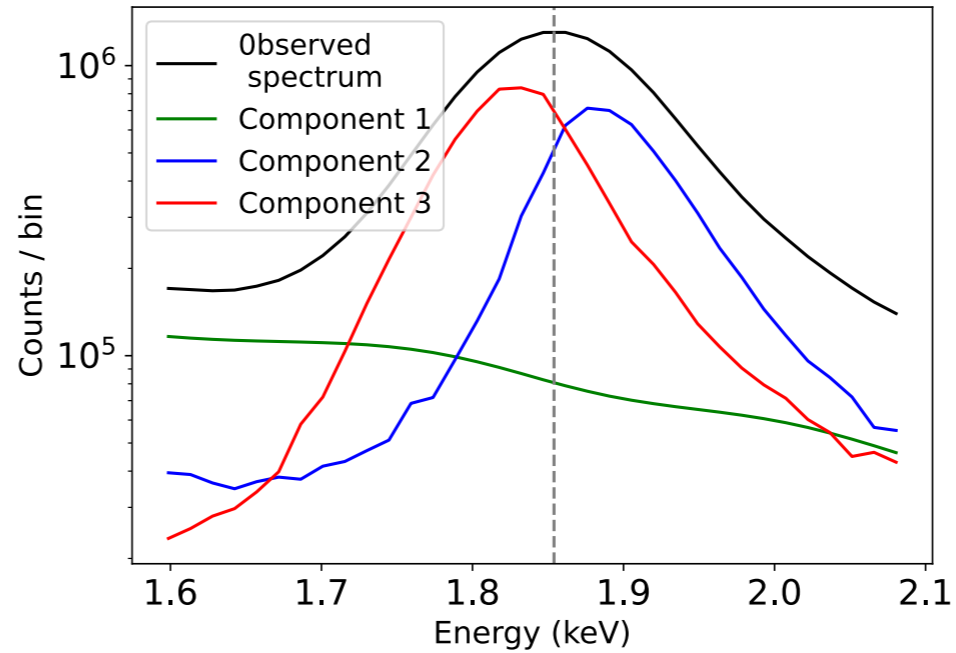
# Tycho SNR: asymmetries with 3D vector fields



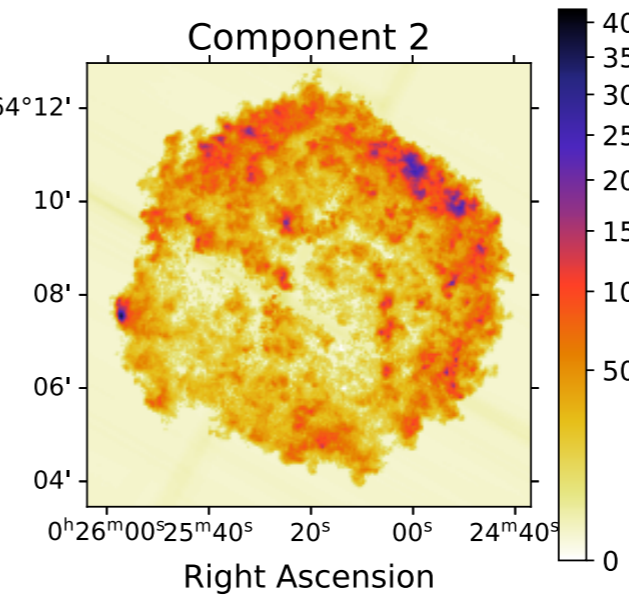
Chandra 750 ks  
1.6-2.1 keV cube

GMCA

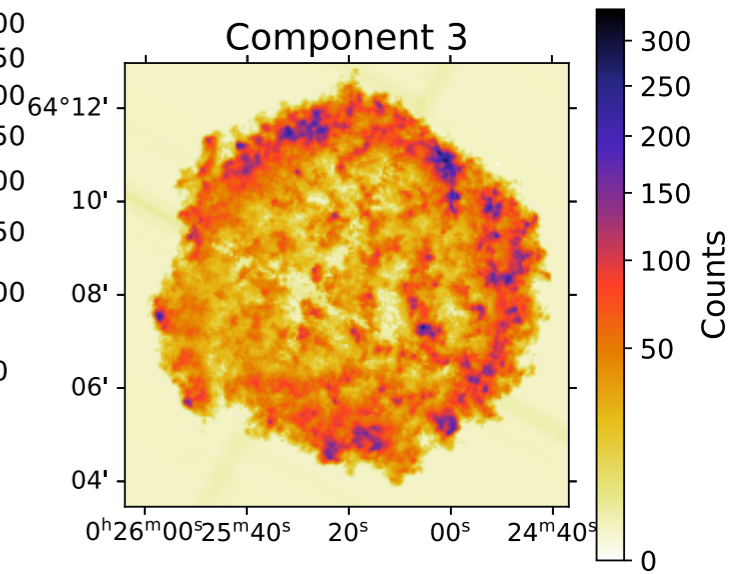
Godinaud, Acero, in prep



**Synchrotron**



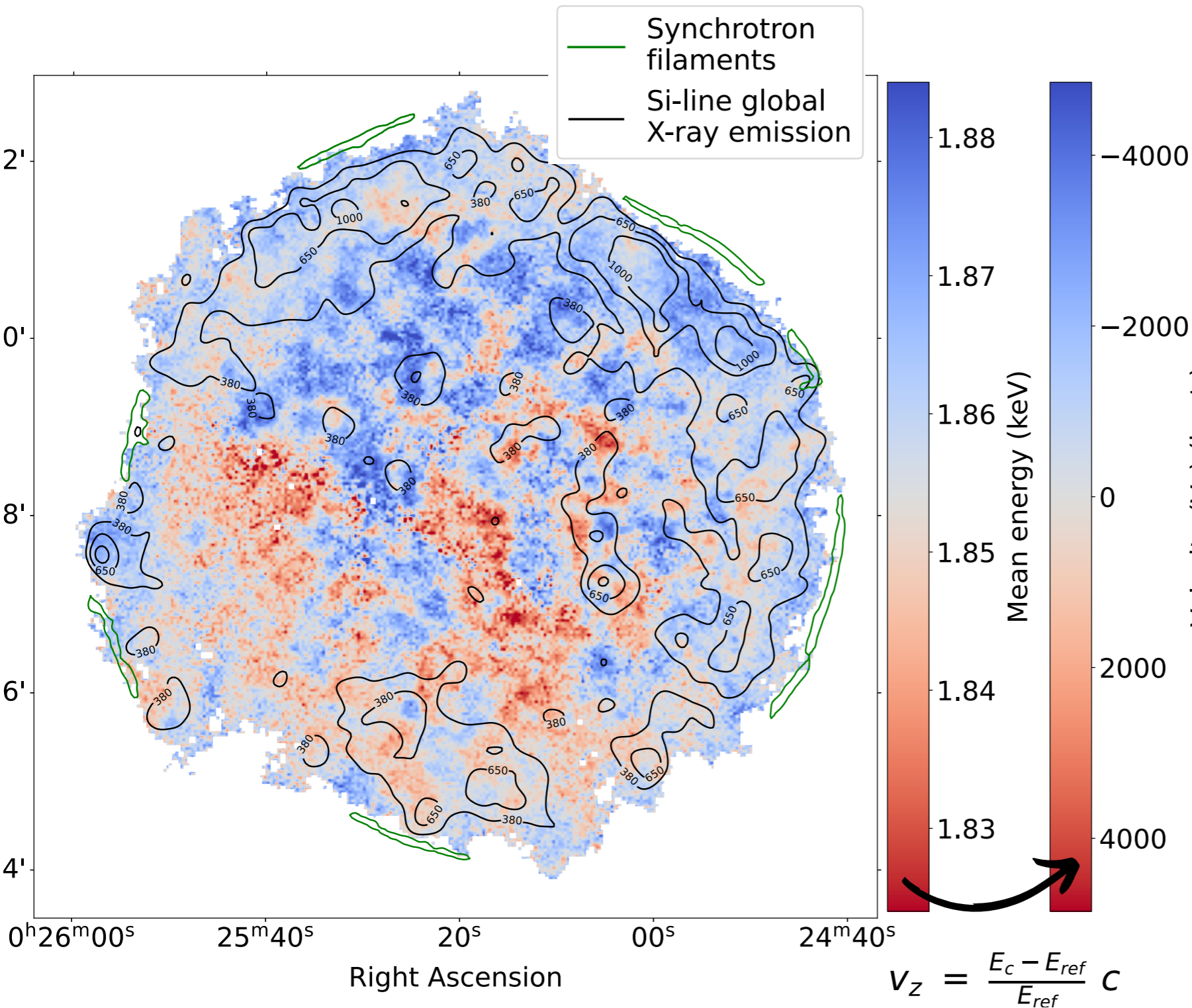
**Blue-shifted  
ejecta**



**Red-shifted  
ejecta**

Components that  
we interpret as:

# Tycho SNR: ejecta velocity along the line of sight ( $V_z$ )

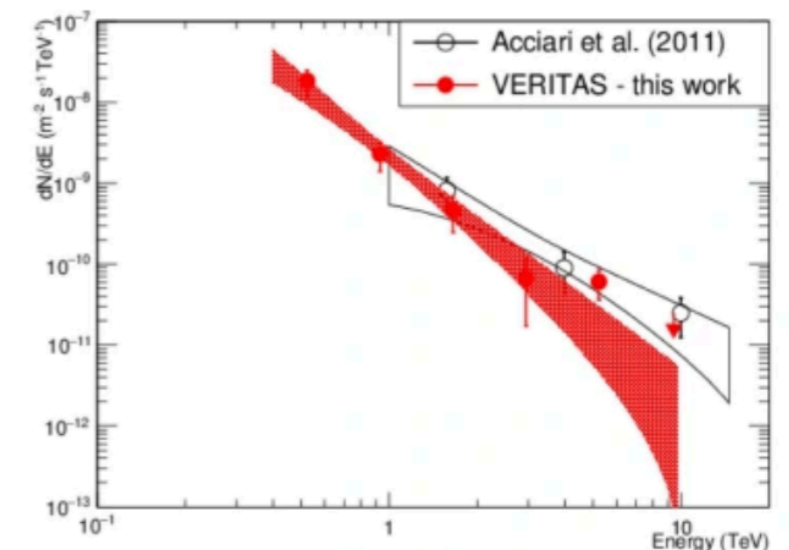
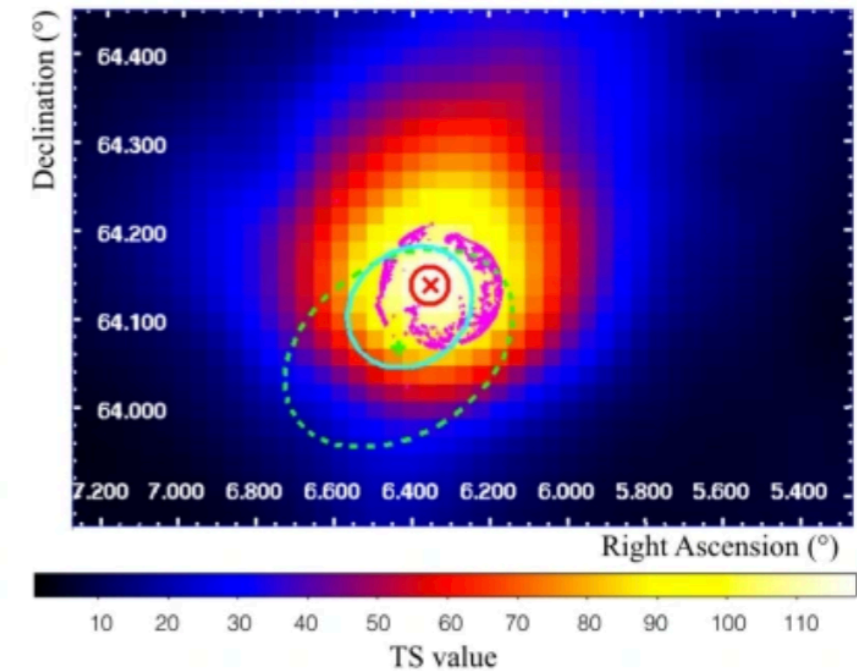
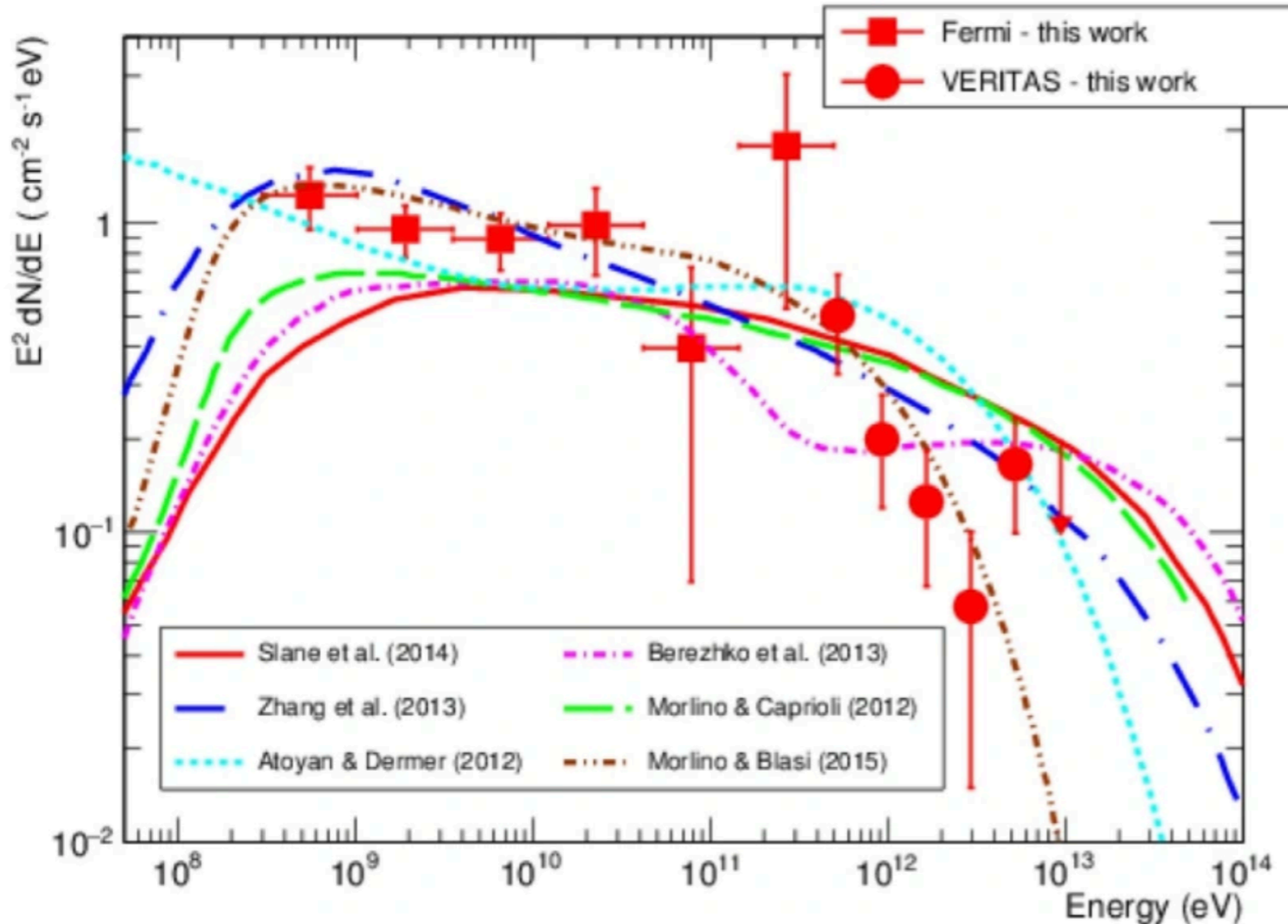


Godinaud, Acero, in prep

- **Idea: Use GMCA components (red/blue) as a basis to reconstruct the energy centroid in each pixel**
- **Complete coverage + pixel level**
- **Clear asymmetry of ejecta North/South**

# Tycho SNR: a particle accelerator ?

- Observed in GeV & TeV gammas with Fermi-LAT & VERITAS
- Compatible with accelerated proton emission via  $\text{Pi}^0$
- but  $E_{\text{cut\_ph}} \sim 10$  TeV well below  $E_{\text{proton}} < 1$  PeV



# SN 1572 - 2022

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- One of the brightest transient in recent history (SN 1006 has the record)
- A historical astronomical object which transformed our way of understanding our Universe, breaking the immutability of heavens
- Historical records provide brightness and color points every 1-2 months
- But studying color evolution is more tricky
  - Colors names are subjectives
  - Comparison with other stars is more reliable
  - Too much admixture of white when very bright

- Centuries after still a major subject of scientific interest

