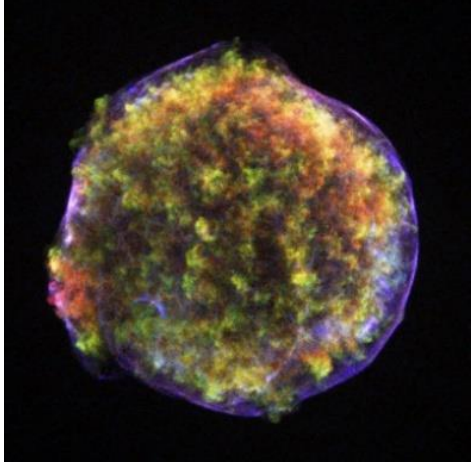
Tycho Brahe´s SN 1572

History and color evolution

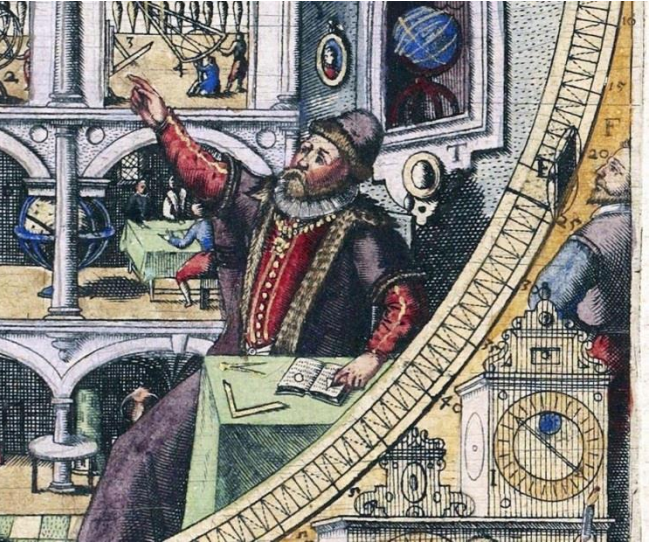
Ralph Neuhäuser

Astrophysikalisches Institut
www.astro.uni-jena.de
Friedrich-Schiller-Universität Jena, Germany



in collaboration with:
Latin: Dagmar L. Neuhäuser, Daniela Luge (Jena), Matteo Cosci (Venice)
Chinese: Jesse Chapman (Berkeley)
Arabic: Paul Kunitzsch (Munich), Wafiq Rada (Iraq), both passed away
Modern SNe: Stefano Benetti, Enrico Cappellaro (Padua), Sascha Hellmund (Jena)
Color vision: Salva Bara (Compostela) and Larry Thibos (U Bloomington)

Topics:- Historical observations 1572-1574
- Modern research: light curve, SNR, light echo, etc.
- Color evolution: conversion of texts to B-V color indices (and contradiction between Brahe and others ?)



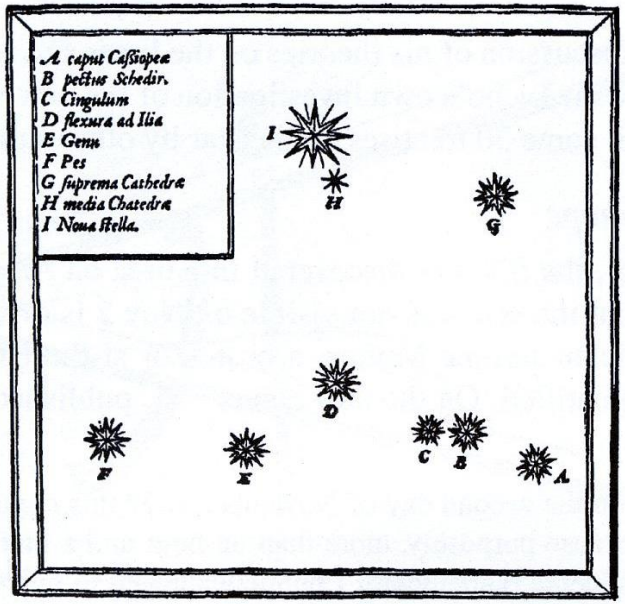
Tycho Brahe (1546-1601, Denmark):

Transient phenomena like **SN 1572 and comet 1577** are outside the Earth atmosphere and beyond moon,

i.e. not sub-lunar, but supra-lunar –

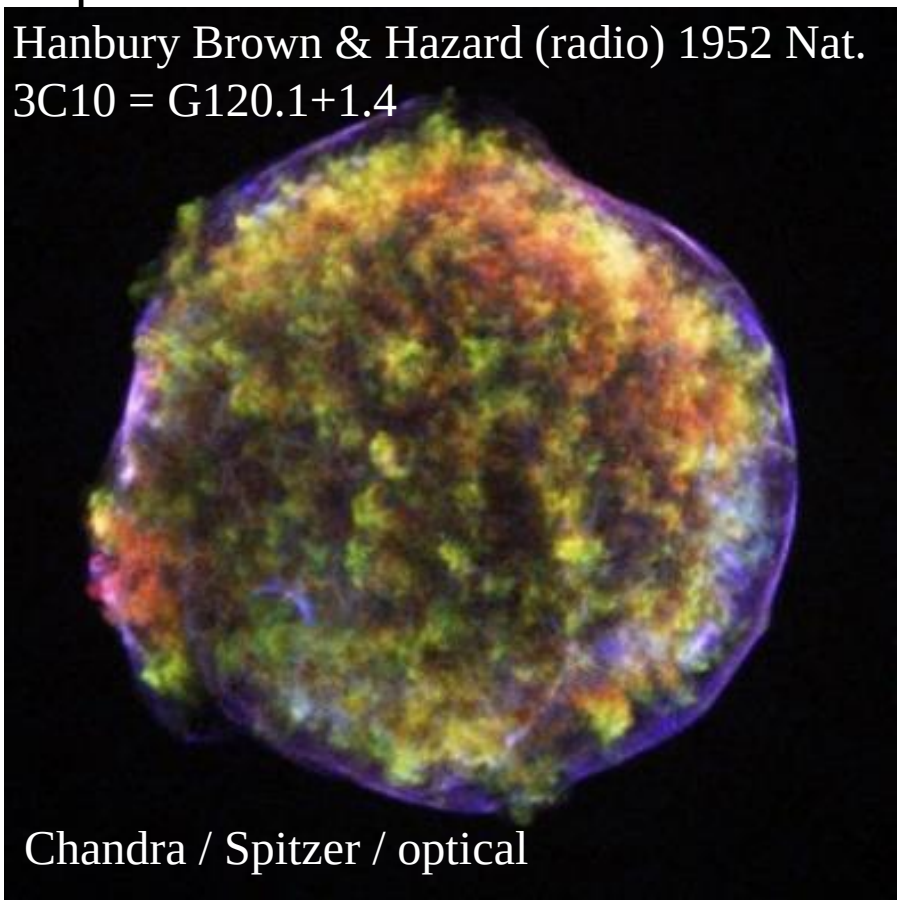
both with very precise position, no parallax

Precise positional measurement relative to Cassiopeia stars ±1′



Baade (1945), Green (2004)

Supernova remnant identified:



Ejecta ~1.4 solar mass, i.e. SN type Ia

Brahe on SN 1572 in Astronomiae Instauratae Progymnasmata (1602):

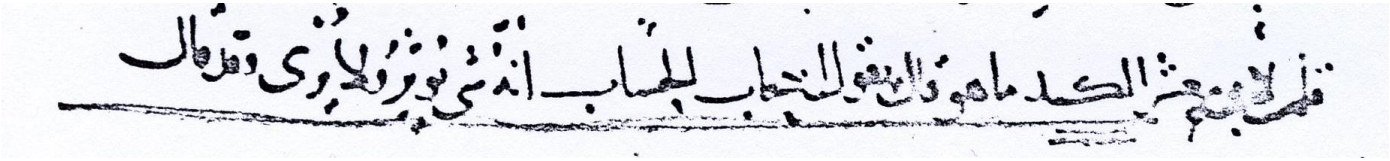
Id solummodo, quod in fine sui Scripti ex Aphorismo quodam Cardani (qui sic habet) citat:
Dixit Albumasar, Cometa supra Venerem visus fuit;
non igitur in Elementari Regione est, contra Philosophum (p. 783).

"Just this, that he [Adam Ursinus], at the end of his work, quotes from a certain sentence of Cardanus:
Albumasar said: A comet was seen above Venus; it is therefore ***not*** in the sphere of the [four] elements [i.e. not sub-lunar], contrary to the philosopher (Aristotle).“

Adam Ursinus = Adam Bär (1524-1590, Thuringia, Germany), work on SN 1572 in 1574
„Beyneben einer kurtzen Beschreibunge des erschienenen Cometens im 1572. und 1573. Jhare“
citing

Jerome Cardanus: *Aphorismorum Astronomicum Segmenta* VII, Opusculum incomparabile
citing

Albumasar = Abū Maᶜshar: Persian astrologer/astronomer (AD 787-886): “What is al-Kaid? …
I have seen the western comet years ago … I could conclude that it stood above [i.e. behind] Venus, because the light of Venus was unimpaired for the eye.” **(Neuhäuser et al. 2016, JHA)**



Workshop on SN 1572

and early-modern cosmology

yesterday in Venice

Ca' Foscari University of Venice
Department of Philosophy and Cultural Heritage

IASH
50 YEARS 1970 - 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 892528

Susan Manning Workshop,
IASH, University of Edinburgh/
Ca'Foscari University of Venice

Supernovae, Comets, and Aristotelian Cosmology: a collapse of philosophical paradigms and the birth of the new sciences in the 16th and 17th centuries?

Monday 27th June, 2022
9.00am – 4.45pm CET

Aula Biral
Palazzo Malcanton Marcorà,
Ca'Foscari University of Venice

A zoom link is available for this event. Please contact organisers Xiaona Wang (xiaona.wang@warwick.ac.uk) or David McOmish (davidmalcom.mcomish@unive.it) to register and for further details.

9.00 CET
Welcome and introduction to workshop
(David McOmish/Xiaona Wang)

9.30 CET
Morning 1: Aristotle and Celestial Influence
Pietro Daniel Omodeo (Venice), *Aristotelian Metaphysics and Cosmology in Philoponus.*
Darrel Rutkin (Venice), *Giovanni Pico della Mirandola's Attack on Astrology and its Role in Ultimately Undermining Aristotelian Cosmology in the 16th and 17th Centuries: A Speculative Reconstruction.*
Monica Azzolini (Bologna), *Kircher's Cosmology: Celestial Influence, Comets and the New Astronomy.*

11.00 CET Pausa caffè

11.15 CET
Morning 2: Aristotle and Innovation: the supernova and comets.
Matteo Cosci (Venice), *The* Dialexis *on the new star by Tadeáš Hájek.*
Jonathan Regier (Venice), *From Cardano to Kepler: Comets, stellae novae, and syncretism among the innovators.*

12.15 CET Lunch

2.00 CET
Afternoon 1: The impact of the supernova and comets in the academic and public imagination
Richard Oosterhoff (Edinburgh), *The Astronomical Teaching of Henri de Monantheuil.*
David McOmish (Venice), *'Our author does not seem to have observed that about which he speaks.' From Philosophy to observation and imagination at Edinburgh, 1600-1660.*
Anna Jerratsch (Berlin), *The Superlunarity of Comets.*

3.30 CET Pausa caffè

3.45 CET
Afternoon 2: A long tale? The lingering light of the supernova and comets.
Sergio Orozco-Echeverri (Antioquia), *The 'unknown heaven': comets, celestial novelties, and the structure of the cosmos in early modern Iberian-American repertorios de los tiempos.*
Xiaona Wang (Warwick), *Upon closer inspection: The comets of 1664 and 1665.*

Further observations of the new star:

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

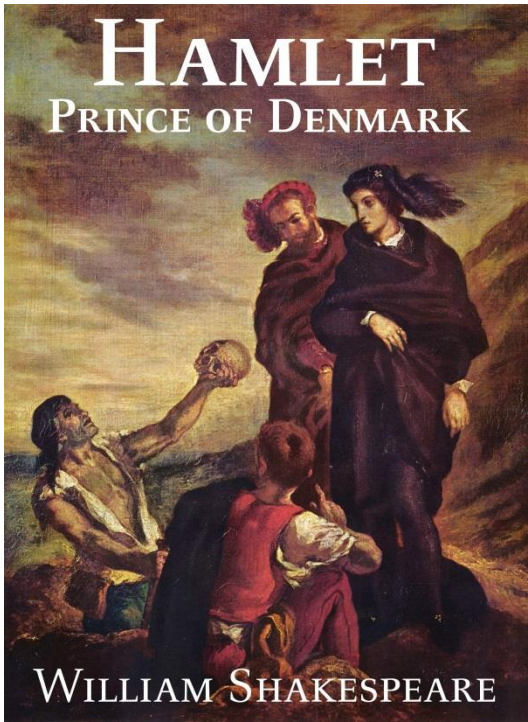
Act 1, scene 1 in the middle of a very cold winter night:

„When yond same stars that‘s westward of the pole

had made his course to illume that part of the heaven.

Where it now burns, Marcellus and myself,

The Bell then beating one …“



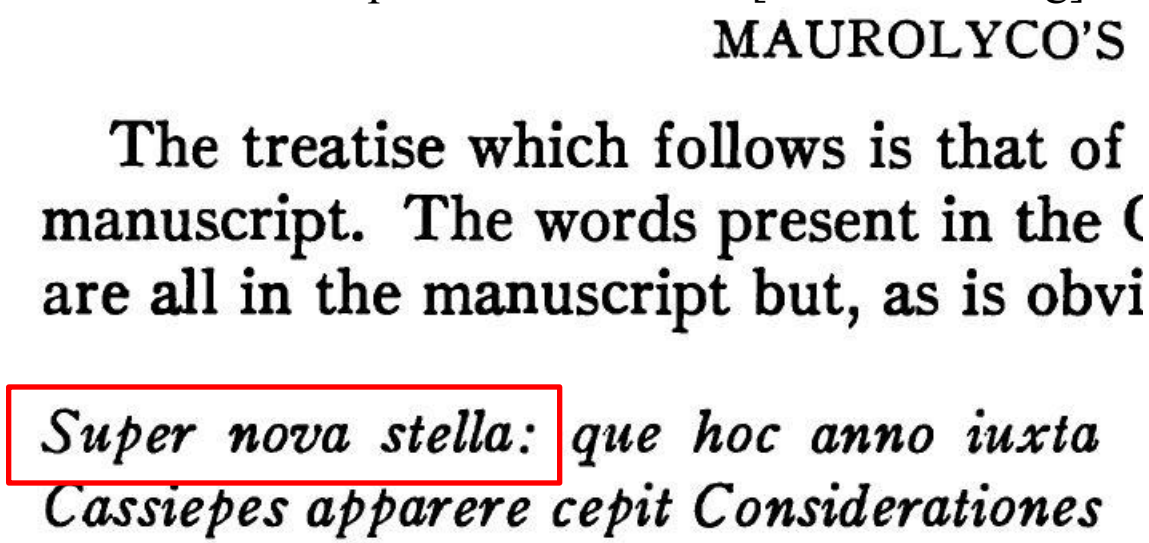
SN 1572 in Nov around midnight indeed west of pole

(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"

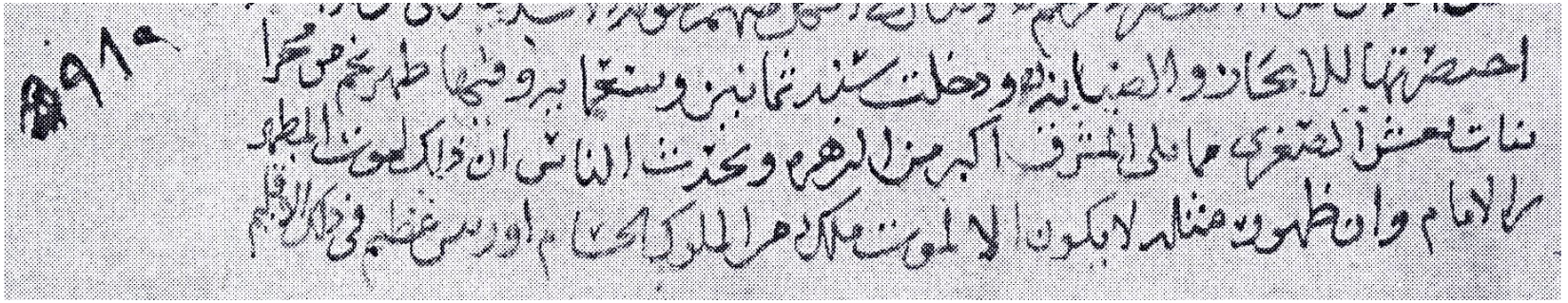
Schuler (Wittenberg) since Nov 6, Mästlin (Tübingen) since Nov 7,

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



ᶜĪsā b. Luṭf Allāh b. al-Muṭahhar:

„Then began the year [AH] 980
(= 14 May 1572 to 2 May 1573 A.D. ± 2 days).

In it there appeared a star [*najm*] in the path [*majrā*] of Ursa Minor [*Banāt Naᶜsh 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 ± 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 ~0 mag late Jan

Feb / Mar 1573: Brahe „equal to brighter stars of first mag” (0.19 ± 0.15 mag)

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

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

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

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

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

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

Baade (1945 ApJ):

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

Reconstruction from historical observations:

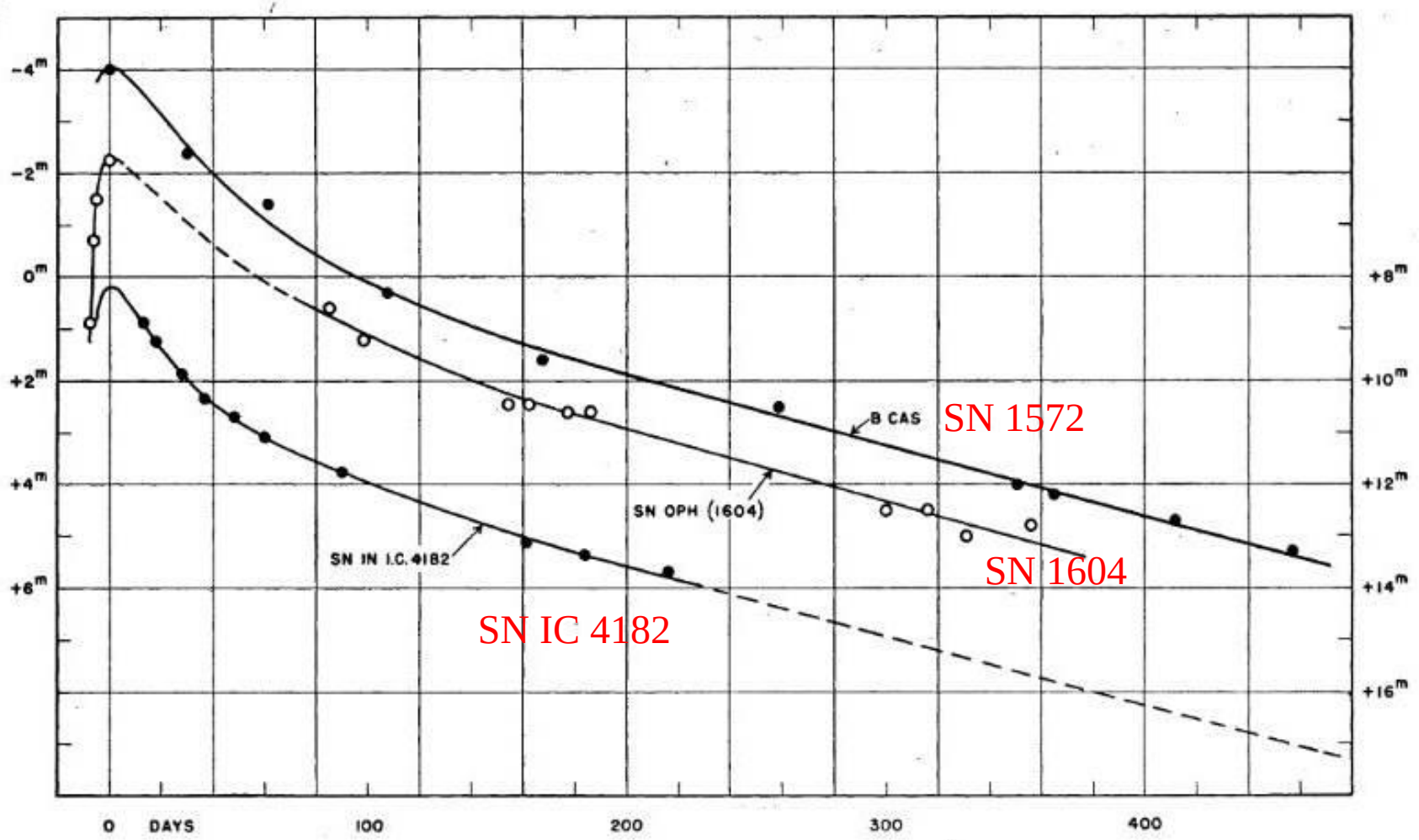
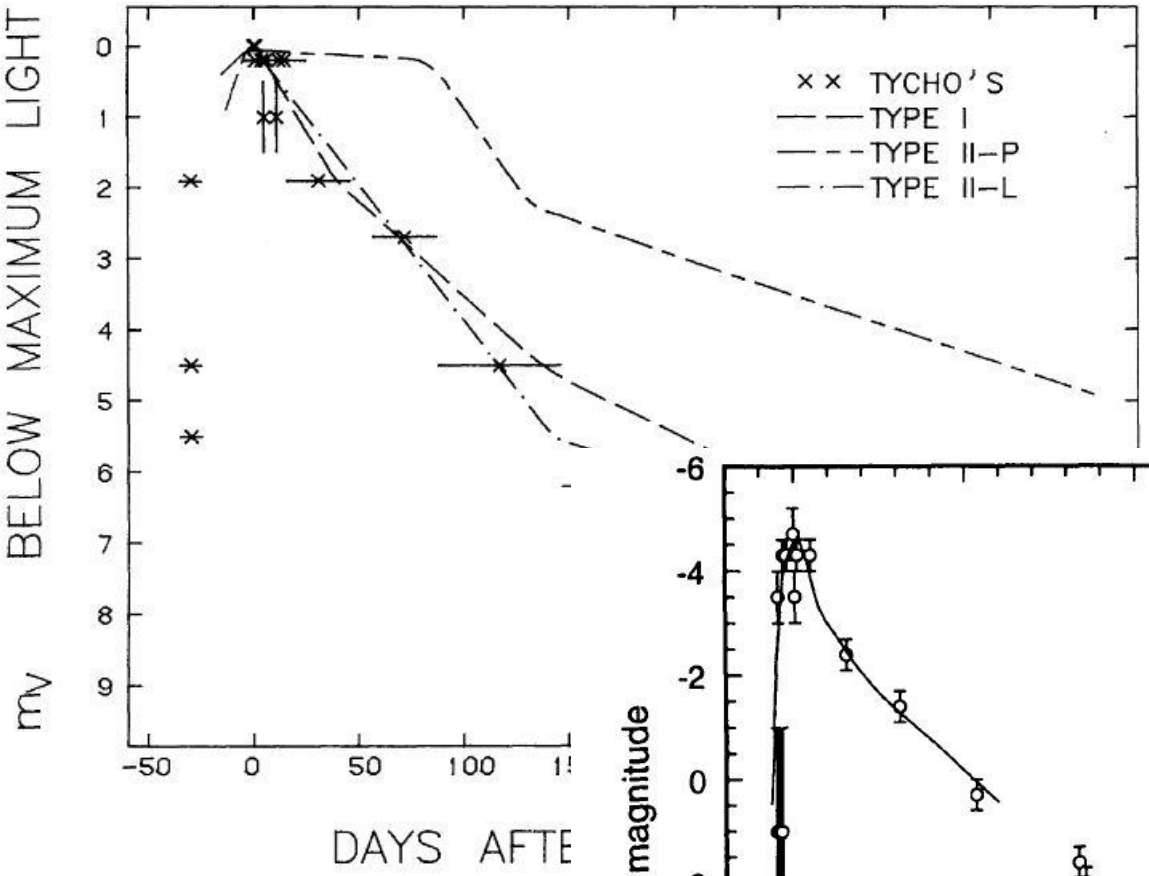


FIG. 1.—Visual light-curves of B Cas, SN Oph (1604), and SN in I.C. 4182. Magnitudes on the left refer to B Cas and SN Oph (1604); on the right, to SN in I.C. 4182. The extrapolated (*dotted*) part of the light-curve of SN in I.C. 4182 has been taken from the photographic light-curve, after an adjustment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

Doggett & Branch (1985 AJ): SN II-L would also fit …



Schaefer (1996): SN Ia or Ib

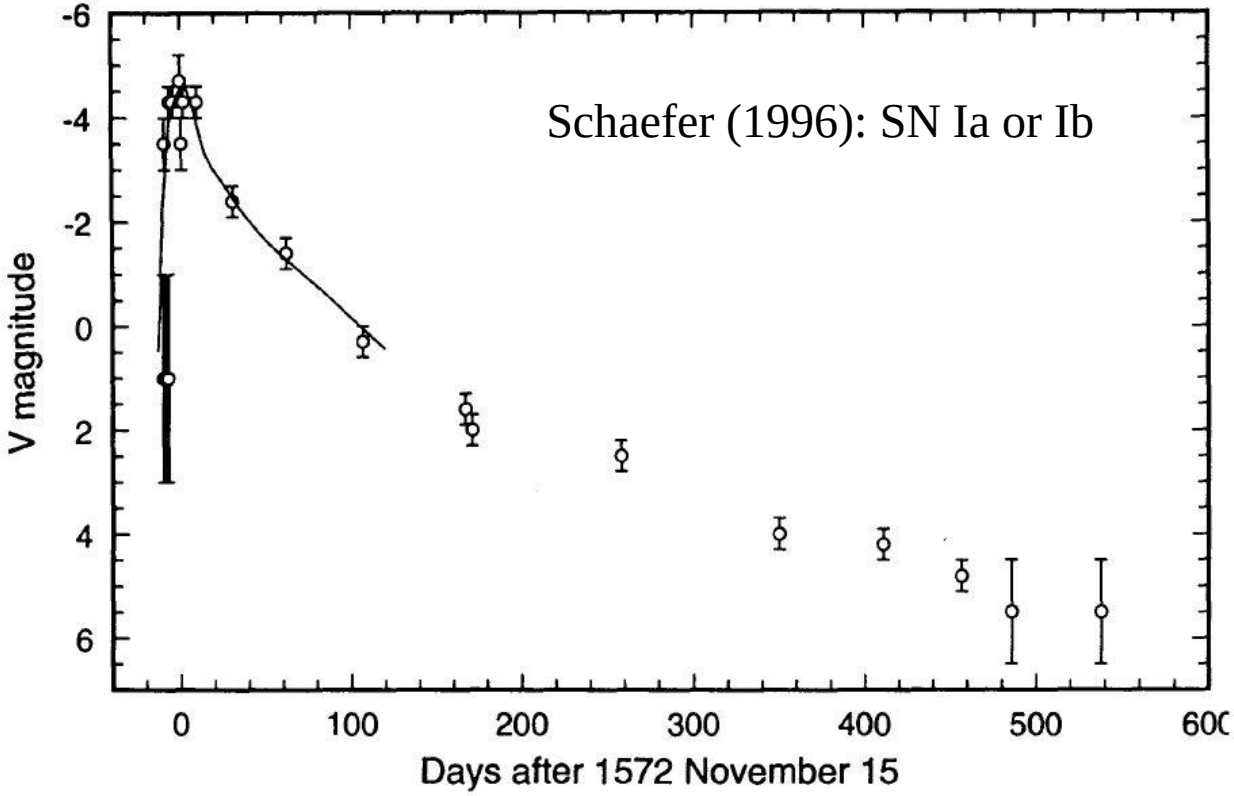
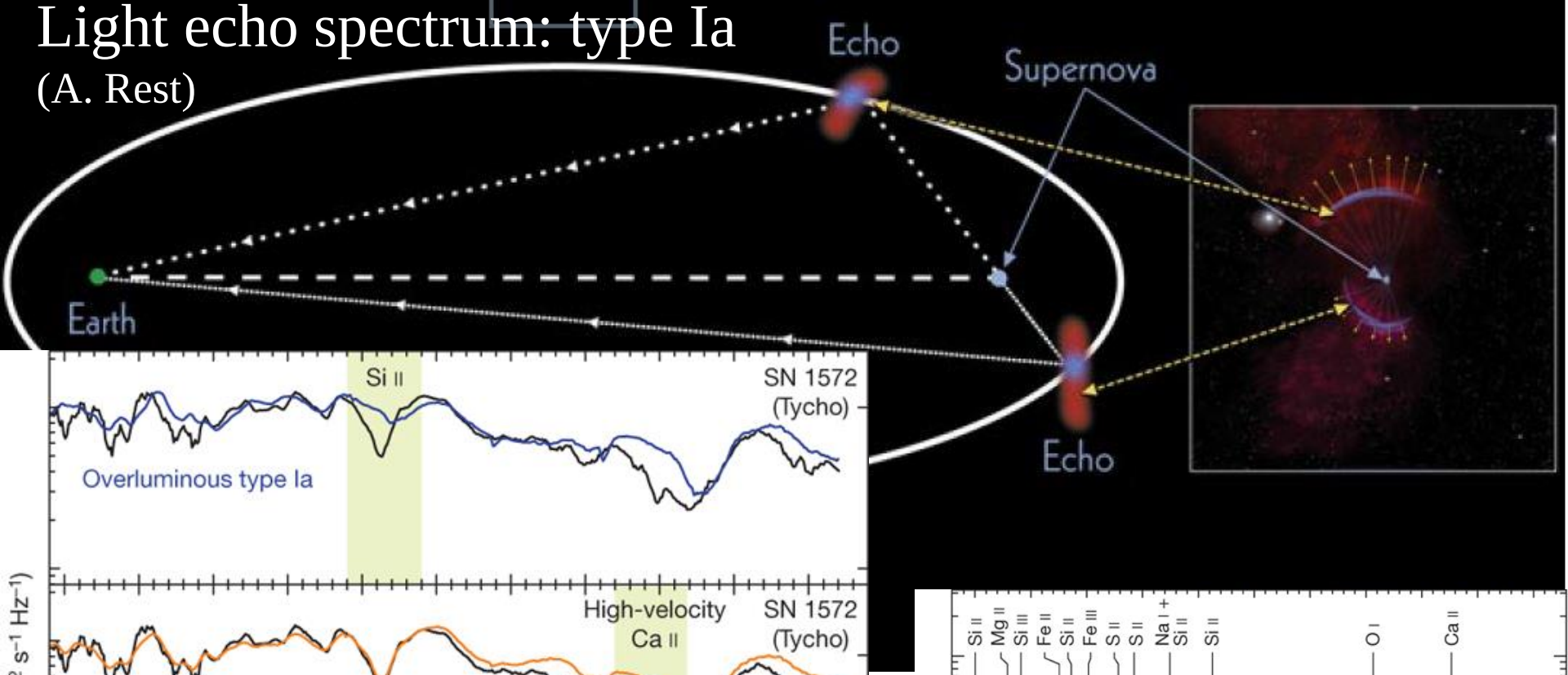
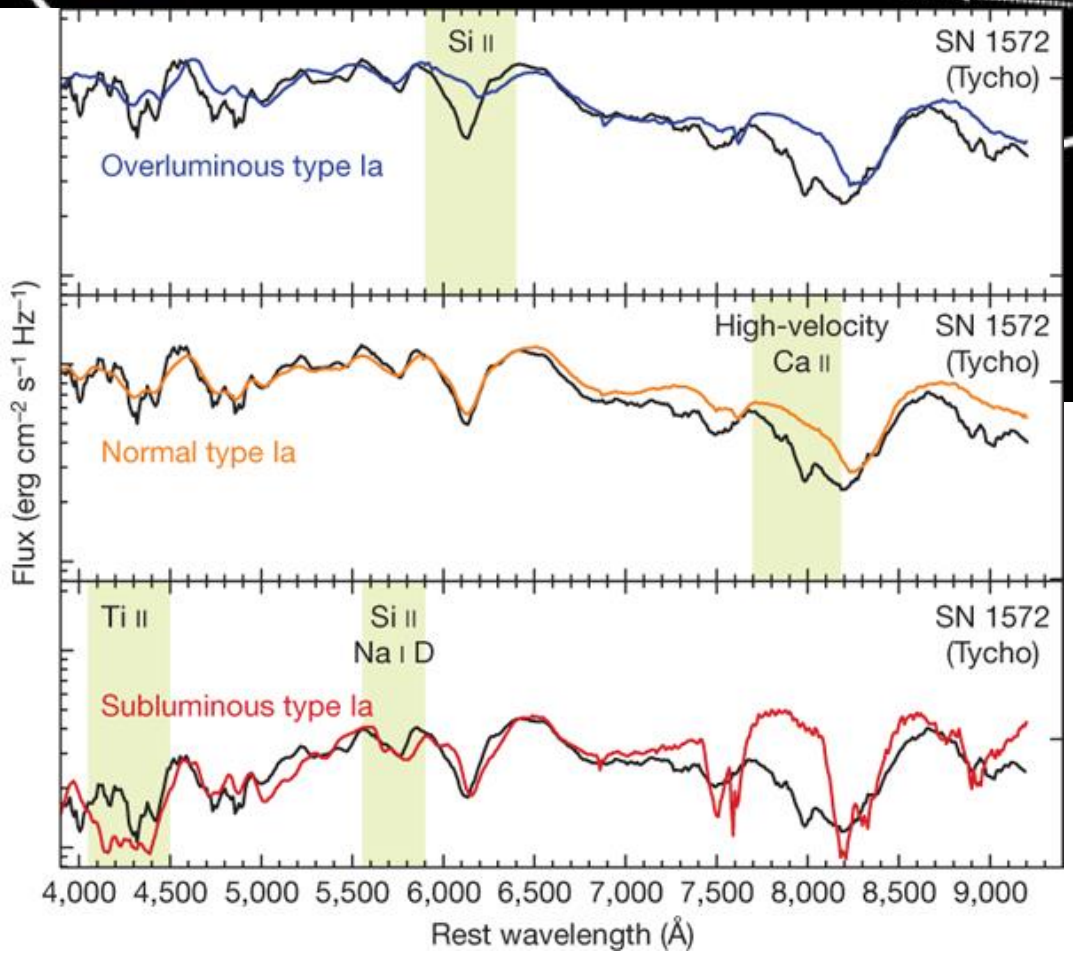
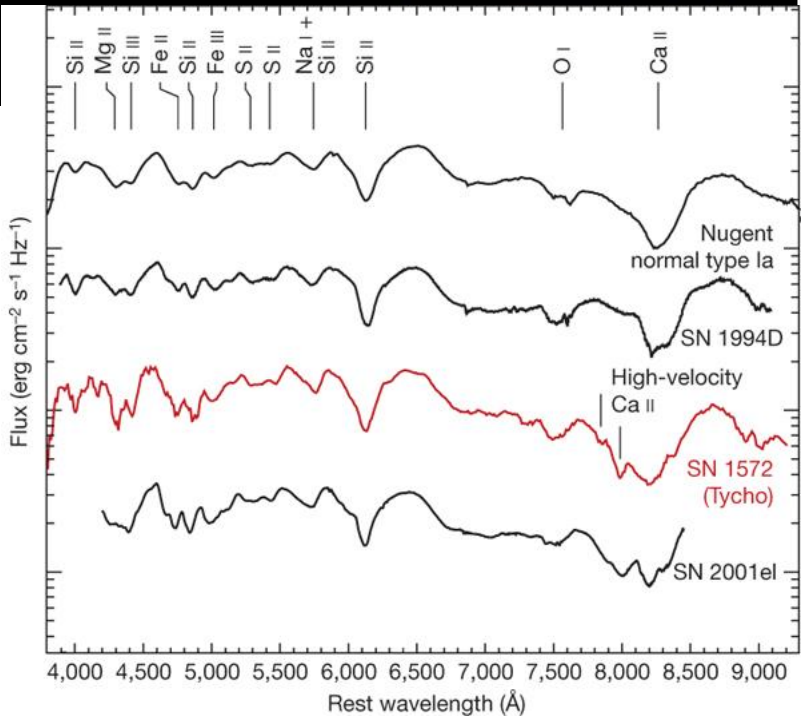


FIG. 3.—Light curve of Tycho's supernova. SN 1572 is less well observed than SN 1604, yet the light curve is still well defined for roughly

Light echo spectrum: type Ia
(A. Rest)





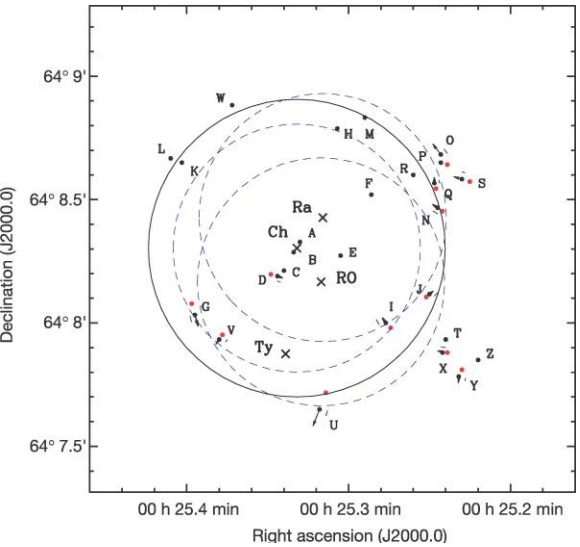


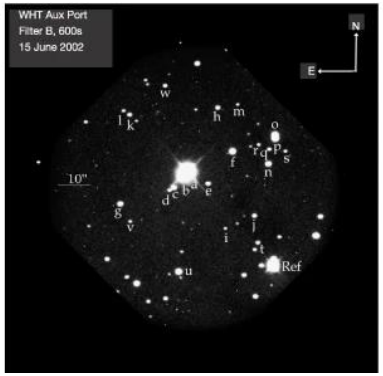
Krause et al. (2008) & Rest et al. (2008)

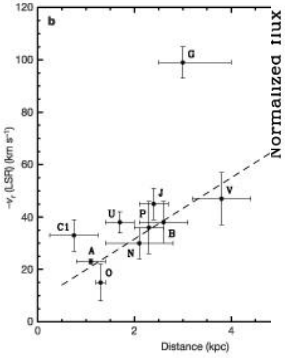
Type Ia ➔ distance $3.8^{+1.5}_{-0.9}$ kpc

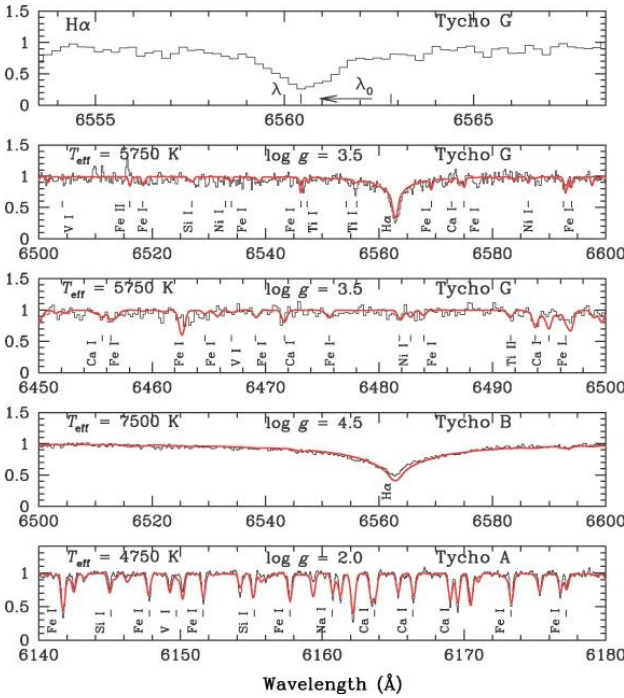
Tycho G star as former companion / donor ?

(Ruiz-Lapunte et al. 2004 Nature)









Some mass stripped ? Atmo shock-heated by SN ? Fast 3D space motion ? (136 km/s)

However, Gaia distance is $2.0^{+0.6}_{-0.4}$ kpc,

hence, 3D vel 56 km/s and maybe too far from SNR center …

(see Kerzendorf et al. 2013)

TYCHO BRAHE'S SUPERNOVA: LIGHT FROM CENTURIES PAST

PILAR RUIZ-LAPUENTE[1,2]

Received 2003 August 30; accepted 2004 May 5

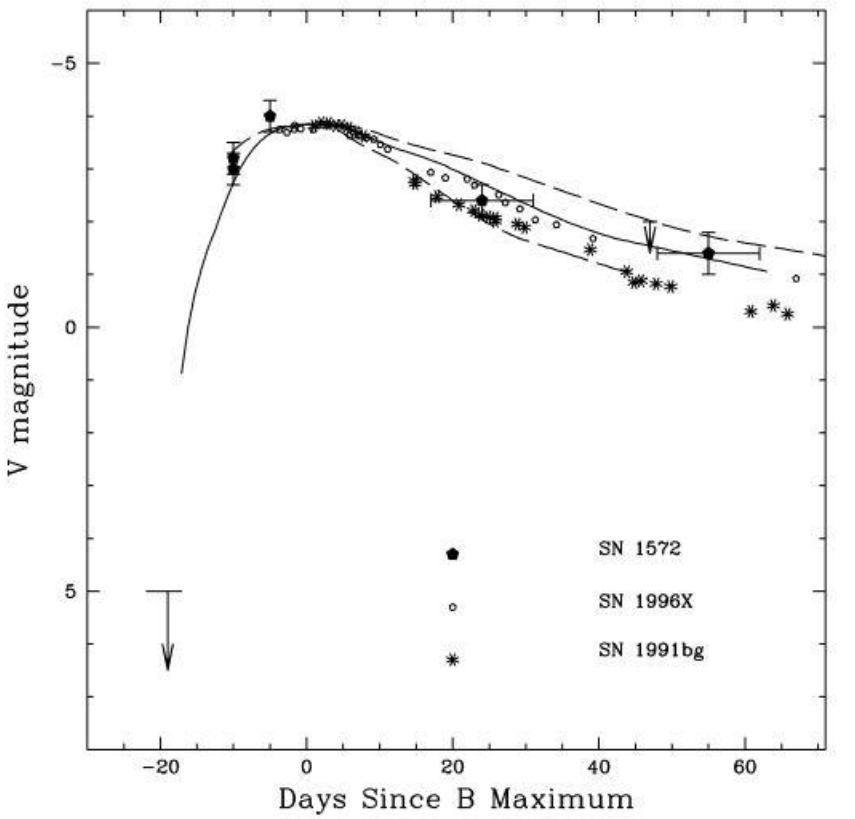


FIG. 1.—Visual light curve of SN 1572 until 60 days. The solid curve shows the V light curve of an $s = 0.9$ SN Ia, which gives the best account for the decline. Such a stretch factor is typical of normal SNe Ia. We show for comparison the V light curve of the normal SN Ia 1996X, whose stretch factor is $s = 0.889$, and of the fast-declining SN 1991bg. SN 1572 was significantly slower than SN 1991bg. The light curves plotted in dashed lines are the templates of SN 1991bg–type events and SN 1991T–like events, which depart significantly from the data.

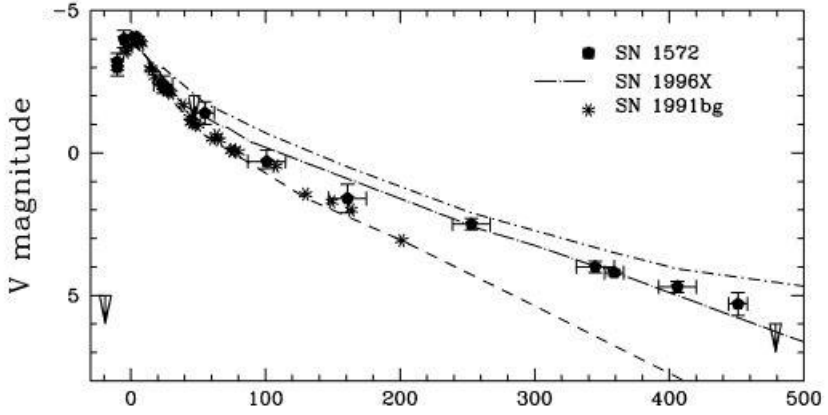


FIG. 2.—Visual light curve of SN 1572 until 500 days. Its late rate of decline is one of a normal SN Ia. It is very similar to the decline of the $s = 0.889$ SN 1996X. The visual data of SN 1991bg and the template light curves of this SN Ia and SN 1991T are shown for comparison.

Light curve like normal Ia
(e.g. SN 1996X)
slower than fast SN 1991bg
(Ruiz-Lapuente 2004 ApJ)

Schaefer (1996 ApJ):
Fast Ia gives best fit –
like SN 1991 bg ?

Let us check the color evolution B-V

Ok,
but a few problems ?

TYCHO BRAHE'S SUPERNOVA: LIGHT FROM CENTURIES PAST

PILAR RUIZ-LAPUENTE[1,2]

TABLE 2

COLORS OF TYCHO'S SUPERNOVA

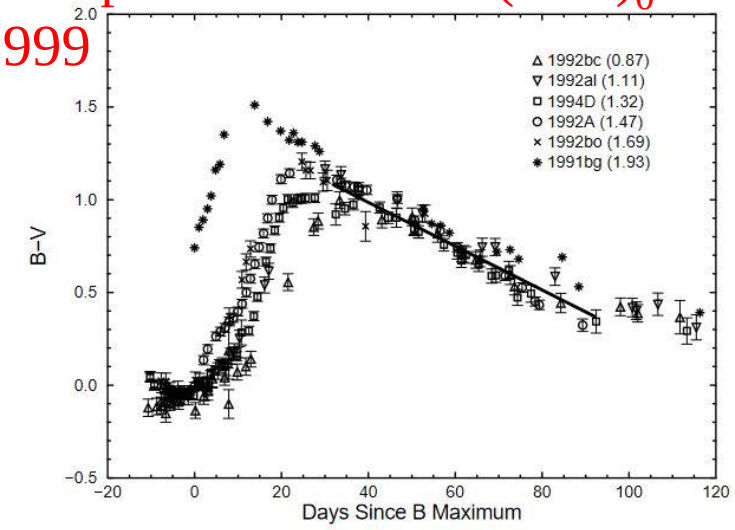
Date	Day	Phase Adopted	Description	$B-V$ Adopted	Notes
1572 Nov	Nov 21 ± 7	−6 ± 7	Like Venus ($B-V=0.83$) and Jupiter ($B-V=0.82$)	0.82 ± 0.25	1
1572 Dec	Dec 1 ± 5	10 ± 5	Yellowish	1.0 ± 0.25	2
1572 Nov–Dec	Dec 2^{+7}_{-22}	11^{+7}_{-22}	Between Saturn ($B-V=1.04$) and Mars ($B-V=1.36$), closer to Mars	1.2 ± 0.25	3
1572 Jan	Jan 1 ± 7	41 ± 7	Like Aldebaran ($B-V=1.52$)	1.52 ± 0.25	4
1573 Jan	Jan 15 ± 7	55 ± 7	Similar to Mars ($B-V=1.36$)	1.36 ± 0.2	5
1573 Feb	Feb 28 ± 7	99 ± 7	Return to original	0.82 ± 0.25	6
1573 May	May 15 ± 7	175 ± 7	Like the original ($B-V=0.83$)	0.82 ± 0.25	7

intrinsic $B-V$ color evolution

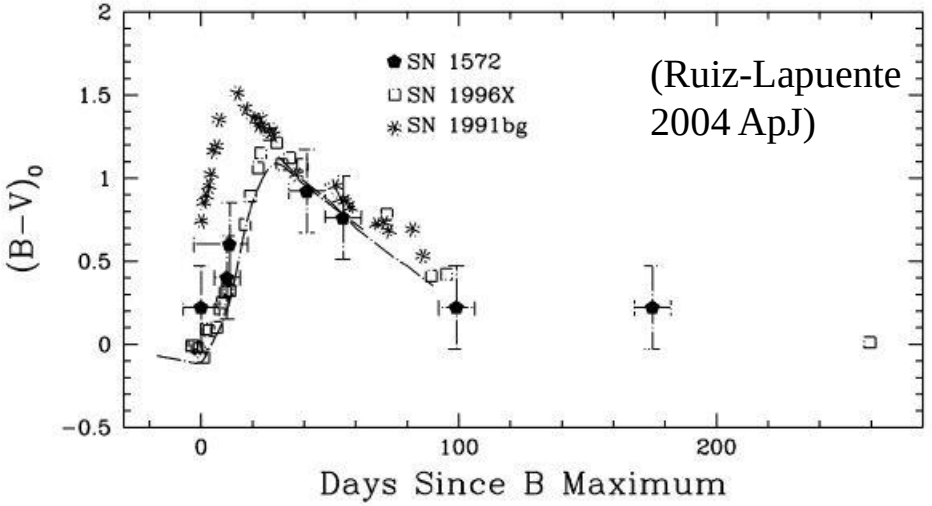
$$(B-V)_0 = 0.725 - 0.0118(t_V - 60)\,, \qquad (1)$$

where t_V is the phase measured in days since V maximum. This fit, which is plotted in Figure 1, is valid over the phase interval $30 \le t_V \le 90$ and can be applied to any SN Ia with

Phillips-Lira relation: $(B-V)_0$ for Ia 1999



Color evolution seems like normal Ia



(Ruiz-Lapuente 2004 ApJ)

FIG. 3.—Color evolution of SN 1572 corrected from extinction as compared with normal SNe Ia and SN 1991bg. SN 1572 is consistent with the color evolution of an $s = 0.9$ SN Ia (the template for this stretch is plotted as the dot-dashed curve). SN 1996X has been corrected for its very small reddening $E(B-V) = 0.01 \pm 0.02$, as well as SN 1991bg [$E(B-V) = 0.03 \pm 0.05$] (Ph99).

Color evolution seems like Ia

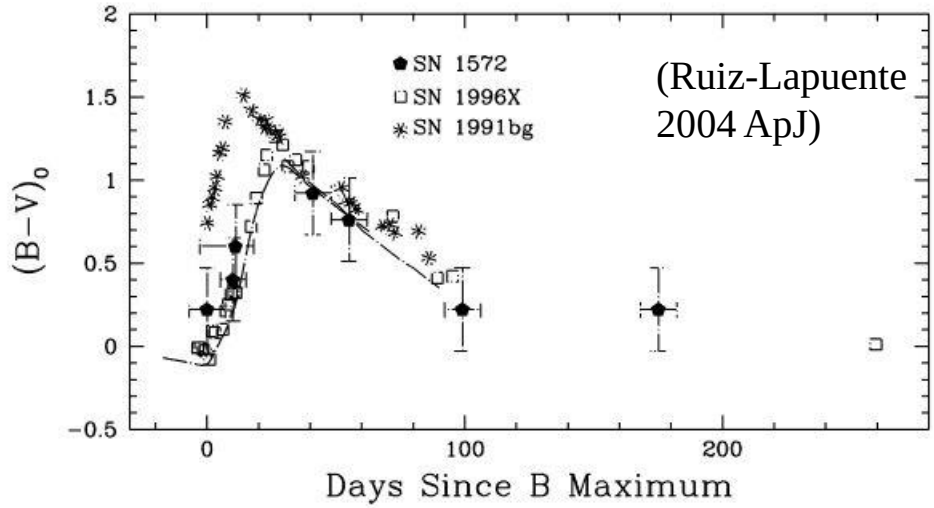


FIG. 3.—Color evolution of SN 1572 corrected from extinction as compared with normal SNe Ia and SN 1991bg. SN 1572 is consistent with the color evolution of an $s = 0.9$ SN Ia (the template for this stretch is plotted as the dot-dashed curve). SN 1996X has been corrected for its very small reddening $E(B - V) = 0.01 \pm 0.02$, as well as SN 1991bg [$E(B - V) = 0.03 \pm 0.05$] (Ph99).

Ok, but some possible problems:

(1) Strong admixture of white at excessive brightness –4 mag

(2) Discrepancies between Brahe and others (?)

(3) Conversion of textual color statements to B-V color indices can be tricky

(4) Early reddening in China on Nov 24 (?) … like SN 1991bg ?

+ a few more historical sources (not considered before)

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)

(1) First few color detections („whitish“ or „like Venus“) could be affected by too much admixture of white at excessive brightness -4 mag (like Venus and Jupiter)

Planet	modern values (1)			as seen in antiquity:			Ptolemy (7)	India
	V [mag]	B–V [mag]	color	China (2)	Plato (5)	Pliny (6)	Tetrabiblos	(8)
Mercury	-1.5 to 3.0	0.97 ± 0.03	orange	dark (3)	yellow	sparkling	variegated	green
Venus (4)	-4.9 to -3.9	0.81 ± 0.11	yel.-or.	white	white	bright white	yellow	white
Mars	-2.9 to 1.8	1.43 ± 0.13	red	red	ruddy	fiery	red	red
Jupiter (4)	-2.9 to -1.7	0.87 ± 0.01	orange	[green-]blue	white	brilliant	white	yellow
Saturn	-0.5 to 1.3	1.09 ± 0.16	orange	yellow	yellow	white	dark/livid	black

SN 1572 at peak around mid Nov 1572:

Peucer: „it seemed to mimic the color of Venus and (then) Jupiter, respec.” (Nov 16)

Brahe: “color ... at the beginning whitish, and it came closer to a Jupiter-like color”

Mästlin: “it was of a **white and silver color** at one time, changing to …”

New texts:
Leowitz: “until end of November the color appeared to be **golden-yellow whitish”**

Ursinus: “color was whitish, clear and bright (Nov 22), then mixed with weak-yellow color, end Nov”

Busch (Erfurt, Germany): “it colors **yellow mixed with silver**”

Too much admixture of white above –4 mag (Venus), but ok for good eyes if fainter than Venus

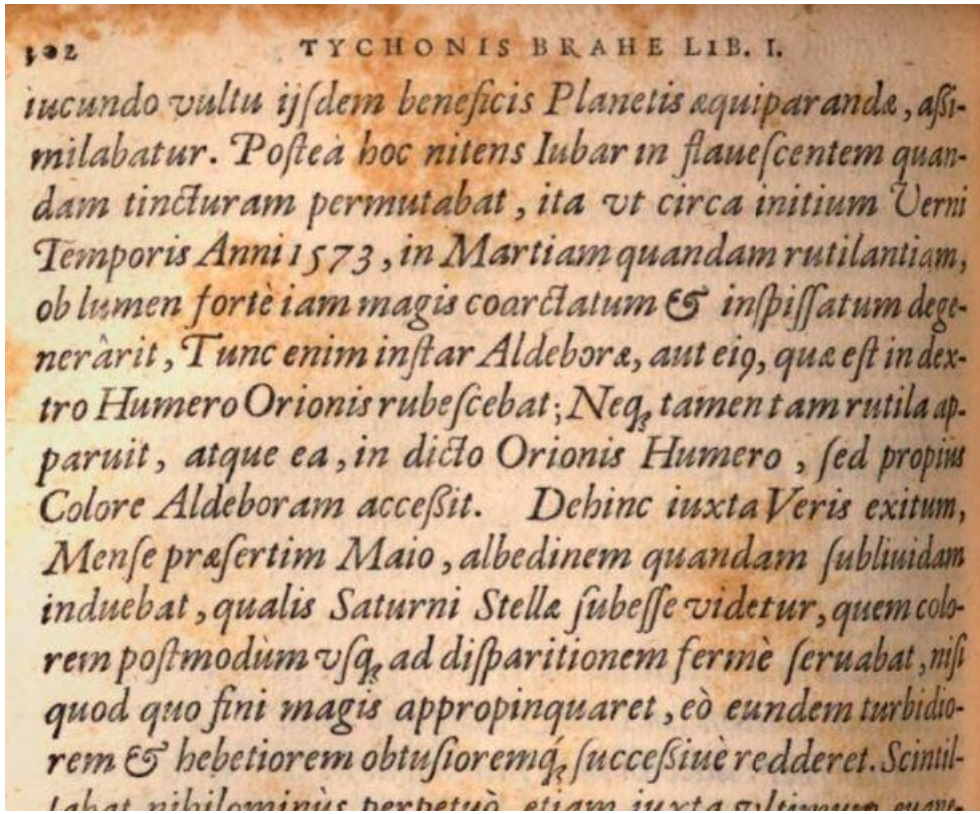
Brahe, Munoz, Peucer, etc.: brighter than Jupiter (–2.6 mag), fainter than Venus (–4 mag)

(2) Discrepancies for the time it got red between Brahe (March 1573) and others (mid Dec 1572)

Brahe (1602): „After the shining light had changed to a golden-yellow color, as at ca. the beginning of spring in the year 1573, it changed into some Mars-like color.

Then, it became red like Aldebaran, or like the one in the red shoulder of Orion. And still it did not appear as red as the one that is in the named shoulder of Orion, but it was more like the color of Aldebaran.

In the month of May [1573], it had some kind of white color, which seemed to lie below that of Saturn …"


102 TYCHONIS BRAHE LIB. I.
iucundo vultu ijſdem beneficis Planetis æquiparandæ, aſſi-
milabatur. Poſteà hoc nitens lubar in flaueſcentem quan-
dam tincturam permutabat, ita vt circa initium Verni
Temporis Anni 1573, in Martiam quandam rutilantiam,
ob lumen fortè iam magis coarctatum & inſpiſſatum dege-
nerârit, Tunc enim inſtar Aldeboræ, aut eiꝰ, quæ eſt in dex-
tro Humero Orionis rubeſcebat; Neqꝫ tamen tam rutila ap-
paruit, atque ea, in dicto Orionis Humero, ſed propius
Colore Aldeboram acceßit. Dehinc iuxta Veris exitum,
Menſe præſertim Maio, albedinem quandam ſubluuidam
induebat, qualis Saturni Stella ſubeſſe videtur, quem colo-
rem poſtmodùm vſqꝫ ad diſparitionem fermè ſeruabat, niſi
quod quo fini magis appropinquaret, eò eundem turbidio-
rem & hebetiorem obtuſioremq́ ſucceſſiuè redderet. Scintil-

Peucer: „It started from Dec 14 on to change the color to a flaming red, equal to that of Mars"

Leowitz: "since the beginning of December it had a reddish color"

Ursinus: "… color assign[ed] to Mars … which it had on Dec 12, but not since long."

Busch: „On the 12th day of the Christ month [Dec.], I have seen this comet in its strongest burning and so wonderful in its rays ... rays, which have shown bloody reddish color"

(2) Discrepancies for the time it got red between Brahe and others ?

Brahe (1602): „After the shining light had changed to a golden-yellow color,

as at ca. the beginning of spring in the year 1573, it changed into some Mars-like color.

Then, it became red like Aldebaran, or like the one in the red shoulder of Orion. And still it did not appear as red as the one that is in the named shoulder of Orion, but it was more like the color of Aldebaran.

In the month of May [1573], it had some kind of white color,
which seemed to lie below that of Saturn …"

Brahe (1573): „Regarding the color of this star, it did not always keep the same, but at the beginning it was seen whitish, and it came closer to a Jupiter-like gleam:

as time went by, its light degenerated by contracting and inspiring, into the fire of Mars:

it was like Aldebaran, or the one, which is red in the right shoulder of Orion. But it was not as red like the one in the shoulder, but more like the color of Aldebaran.

Now, however, after it had layed down the redness of Mars, it got a bluish white,

so that, in this month of May, it is seen similar to Saturn and Venus."

Brahe died in 1601,
the large work on nova of 1572 appeared in 1602, edited by Kepler.

no real discrepancy left !

(3) Conversion of textual color statements to B-V color indices can be tricky:

TABLE 1 Relations between true color, wavelength at peak intensity, effective temperature, color index, and spectral type/luminosity class (Allen 1973, Schmidt-Kaler 1982, Steffey 1992, Schaefer 1993, Drilling & Landolt 2000):

Color	wavelength [Å]	effective temp. [K]	color index B−V [mag]	spectral type dwarfs	giants	supergiants	examples and notes
red	≥ 5900	≤ 4000	≥ 1.40	M0-9	K4-M9	K3-M9	α Ori, α Tau, α Sco
orange	5800-5900	4000-5000	0.80 to 1.40	K0-7	G4-K3	G1-K2	α Boo, β Gem
yellow	5700-5800	5000-6000	0.60 to 0.80	G1-9	G0-3	F8-G0	Sun (1), α Aur
greenish-white	4800-5700	6000-7300	0.30 to 0.60	F	F	F4-7	α CMi (2)
white		7300-10000	0.00 to 0.30	A	A0-9	A0-F3	α Lyr (3)
bluish-white	4400-4800	≥ 10000	−0.33 to 0.00	OB	OB	OB	α Vir

Notes: (1) Our Sun has B−V=0.65 mag (Livingston 2000). (2) Technically, we cannot percieve any stars as truly 'green', not even in the given temperature or spectral type range, but whitish; fainter white stars can *appear* greenish (Steffey 1992). (3) The well-known photometric standard star Vega (spectral type A0) by definition has brightness and color index 0.0 mag (white).

Simple color statements, e.g. „white“ or „red“, are not sufficient, unclear how used or defined.

Objective statements, e.g., by comparison with other stars or planets are fine, e.g.
Brahe: „It changed into some Mars-like color [B-V=1.43 ± 0.13 mag].
Then, it became red like Aldebaran [B-V=1.48 mag],
or like the one in the red shoulder of Orion [B-V=1.8 mag?].
And still it did not appear as red as the one that is in the named shoulder of Orion,
but it was more like the color of Aldebaran.”

Betelgeuse at the end of the Hertzsprung gap – changed in color:

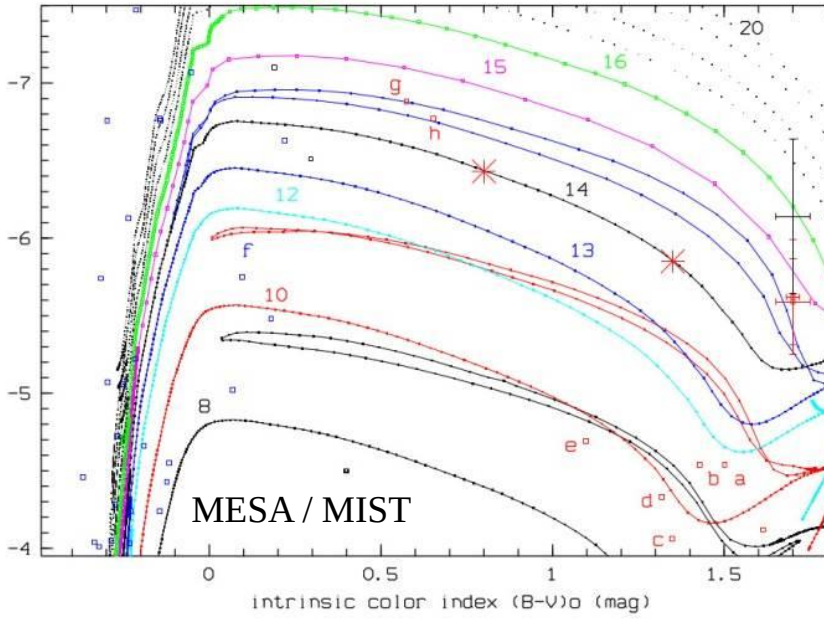
Sima Qian (ca. BC 100, China): „... white like Sirius, red like Antares, yellow like Betelgeuse, blue like Bellatrix, dark like Mirach …“ B-V = 0.95 ± 0.35 mag

Hyginus (BC/AD turn, Rome): „Saturn … in color similar to that star which is in the right shoulder of Orion” B-V = 1.09 ± 0.16 mag

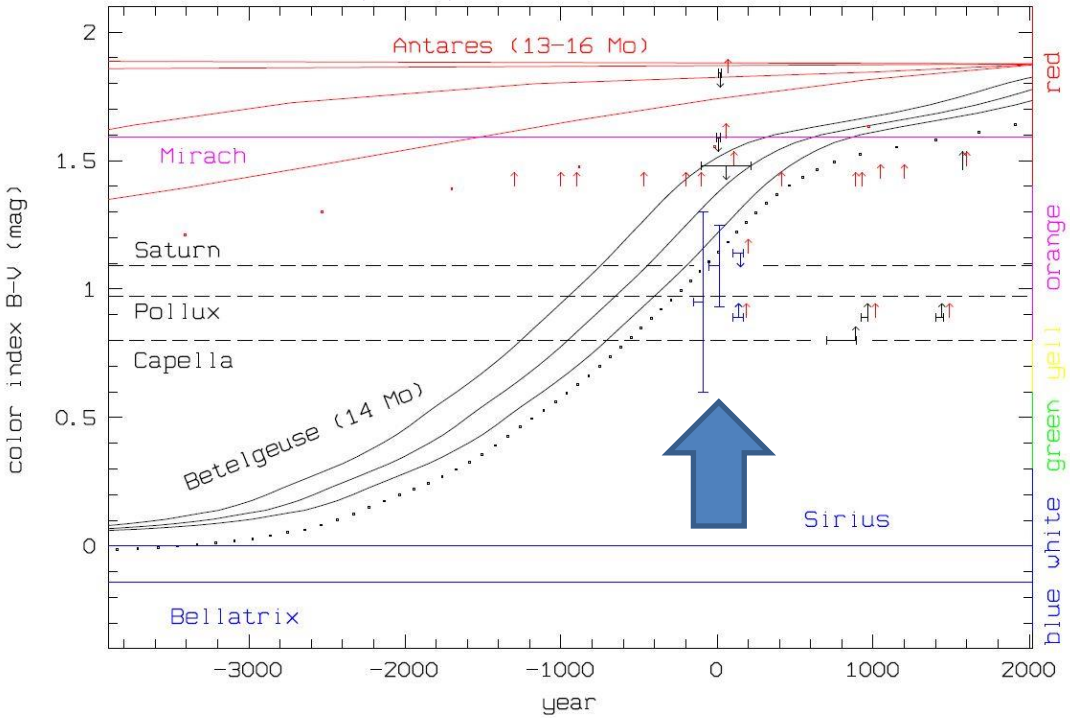
Ptolemy (ca. AD 150): Bet. in color between Capella and Arcturus B-V=0.8-1.14 mag

Betelgeuse now: B-V = 1.78 ± 0.05 mag, i.e. 5σ different

CMD: abs. mag. vs. color $(B-V)_0$



Color (B-V) vs. time from MIST



Historical records consistent with MESA/MIST tracks (Neuhäuser et al. 2022 MNRAS in press)

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 ± 8	like Jupiter	Brahe, Denmark	(c)	0.87 ± 0.1	-3 to -4
1572 late Nov (20-30)	4 ± 5	golden-yellow white	Leowitz, Czech Rep.	(e)	0.7 ± 0.1:	-4 ± 0.3
1572 Nov 22-Dec 11	11 ± 10	white, pale yellow	Ursinus, Germany	(e)	0.7 ± 0.1:	-4 to -3
after 1572 Nov 24	?	red-yellow	Shenzong Shilu, Ch.	(d)	1.1 ± 0.2	?
1572 Dec 1-20:	29 ± 10	golden-yellow	Brahe, Denmark	(c)	0.9 ± 0.2	-2.4 ± 0.2
1572 Dec 2	21 ± 5	closer	Munoz, Spain	(f)	1.3 ± 0.2	-2.4 ± 0.2
1572 begin Dec (1-10)	16 ± 5		Leowitz, Czech Rep.	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 12 (-31?)	33		Busch, Germany	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 12 (-31?)	33 ±	mars-like	Ursinus, Germany	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 14 (-31?)	35 ±	Mars than Jup	Peucer, Germany	(c)	1.2 ± 0.2	-2.4 ± 0.2
1572/3 Dec 21-Jan 10	42 ± 1	Mars	Brahe, Denmark	(g)	1.43 ± 0.13	-2.2 ± 0.2
ca. 1572 Jan 16	58 ± 7	like Mars	Praetorius, Germany	(c)	1.43 ± 0.13	-2.0 ± 0.2
1573 Jan 21-Feb 10	73 ± 10	closer to α Tau than α Ori	Brahe, Demnark	(g)	1.55 ± 0.05	-2.0 ± 0.2
1573 end Feb (20-28)	95 ± 4	white like first	Mästlin, Germany	(c)	0.87 ± 0.1	0.19 ± 0.15
1573 May	175 ± 15	lead-white below Saturn	Brahe, Denmark	(c)	0.80 ± 0.2	1.55 ± 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 ± 0.12 mag (Ruiz-Lapuente2004)

i.e. subtract color excess

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

to get $(B-V)_0$

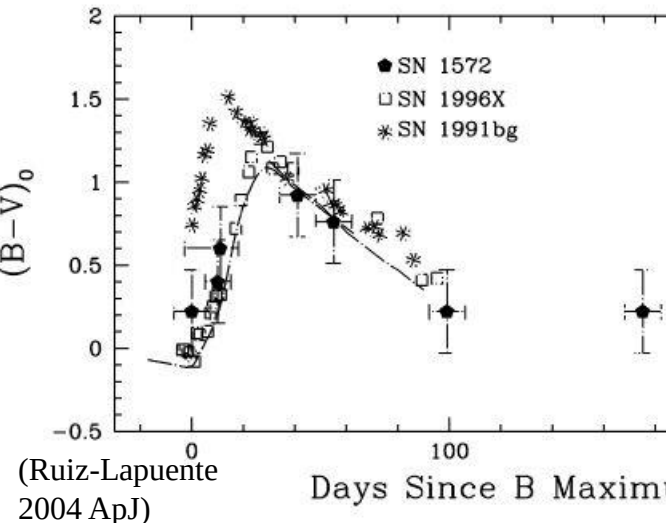
Final color evolution:

(Neuhäuser et al. in prep.)

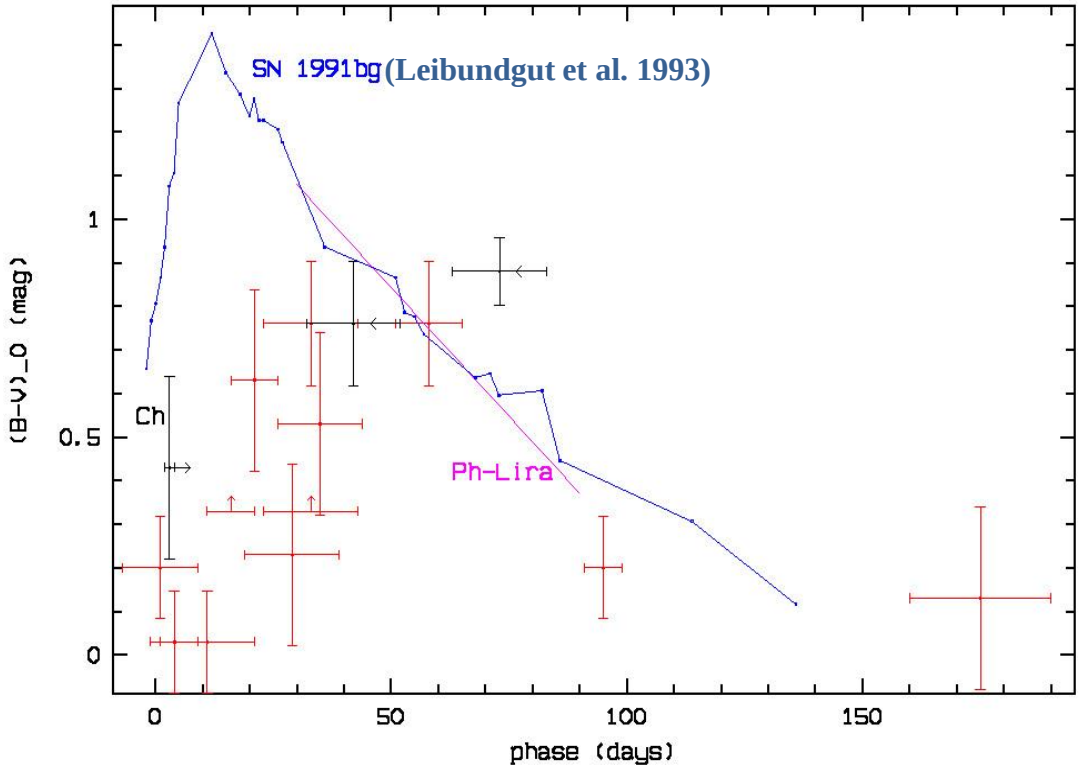
Date	phase	color report	source/observer	Ref	B−V (a)	mag (c)
1572 Nov 14-30	1 ± 8	like Jupiter	Brahe, Denmark	(c)	0.87 ± 0.1	-3 to -4
1572 late Nov (20-30)	4 ± 5	golden-yellow white	Leowitz, Czech Rep.	(e)	0.7 ± 0.1:	-4 ± 0.3
1572 Nov 22-Dec 11	11 ± 10	white, pale yellow	Ursinus, Germany	(e)	0.7 ± 0.1:	-4 to -3
after 1572 Nov 24	?	red-yellow	Shenzong Shilu, Ch.	(d)	1.1 ± 0.2	?
1572 Dec 1-20:	29 ± 10	golden-yello	Brahe, Denmark	(c)	0.9 ± 0.2	-2.4 ± 0.2
1572 Dec 2	21 ± 5	closer	Munoz, Spain	(f)	1.3 ± 0.2	-2.4 ± 0.2
1572 begin Dec (1-10)	16 ± 5		Leowitz, Czech Rep.	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 12 (-31?)	33		Busch, Germany	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 12 (-31?)	33 ±	ars-like	Ursinus, Germany	(e)	≥ 1:	-2.4 ± 0.2
1572 Dec 14 (-31?)	35 ±					
1572/3 Dec 21-Jan 10	42 ± 1	M				
ca. 1572 Jan 16	58 ± 7	like M				
1573 Jan 21-Feb 10	73 ± 10	closer				
1573 end Feb (20-28)	95 ± 4	white				
1573 May	175 ± 15	lead-v				

numbers preliminary

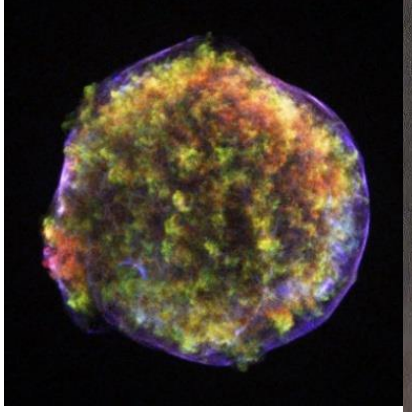
(after May, not too faint for color detection,

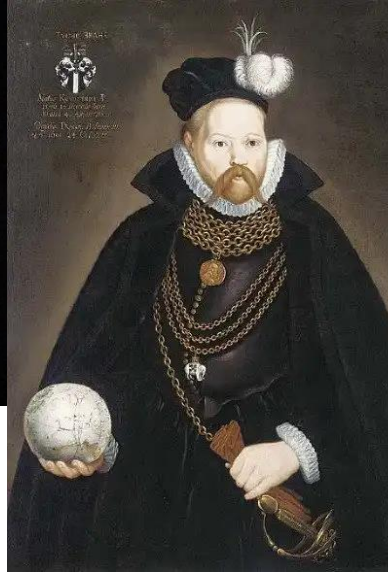


(Ruiz-Lapuente 2004 ApJ)



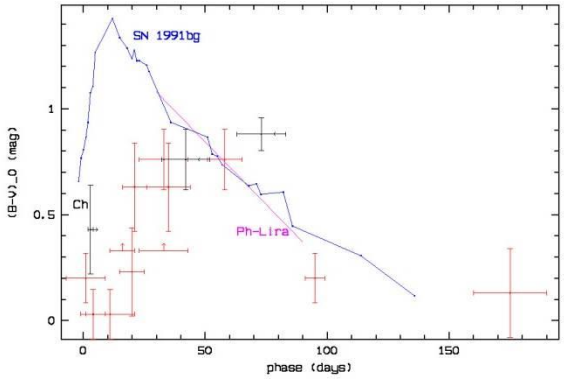
Summary:





- Brahe‘s SN 1572 well observed
- Light-echo spectrum: SN type Ia
- Brightness and color points every 1-2 months

- Conversion of text statements to color index tricky:



- too much admixture of white ?
- apparent discrepancies due to late edition
- objective comparison with stars and planets (Betelgeuse moved thru Hertzsprung gap)

- Light curve and color evolution consistent with *normal* Ia

(SNe type II redden to $(B\text{-}V)_0$ =1.5 mag after ~100 days)