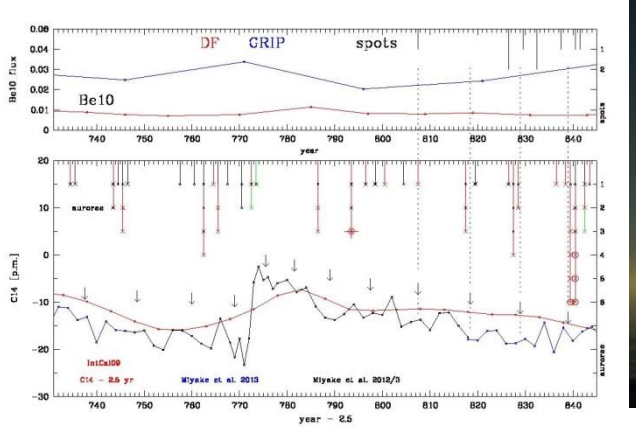
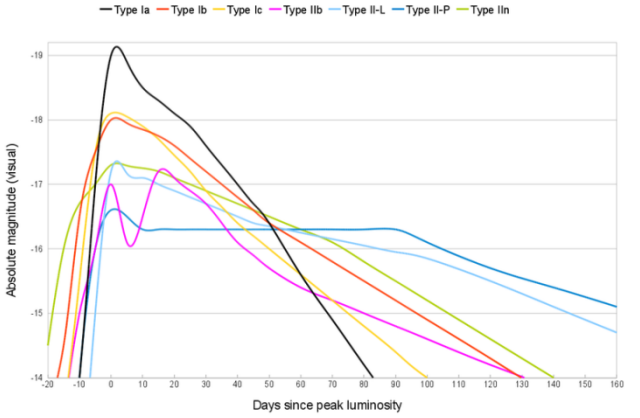
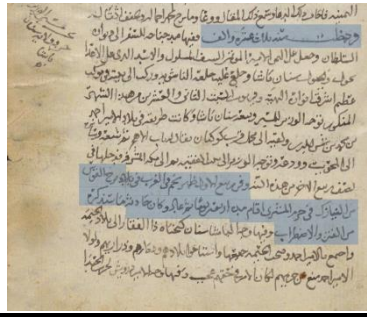
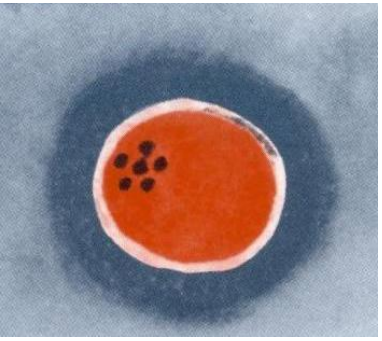






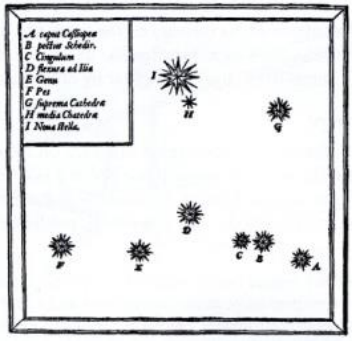
Solar activity and supernovae –

astrophysical relevance of historical celestial observations



Ralph Neuhäuser

Universität Jena, Germany



www.astro.uni-jena.de → Terra-Astronomy

What is Terra-Astronomy? An Introduction

Terra-Astronomy is the study of transient celestial phenomena (nearby supernovae, solar variability, comets, conjunctions, etc.) with possible impact on Earth (*Terra*):

Earth rotation, climate, biosphere, space weather, culture, etc. – studied with astronomical methods and *terrestrial* archives: radio-nucleids (^{14}C, ^{10}Be, ^{60}Fe, etc.) and human reports, but also astronomical follow-up observations (and old plates).

Understanding historical observing reports is also important
for studying the past climate (weather records),
for geophysics (e.g. Earth quakes, volcanic eruptions), etc.

International Astronomical Union (triannual) General Assembly 2018 Vienna:
„Understanding historical observations to study transient phenomena“,
3-day Focus Meetings with ~350 attendees …

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I. Historical time: at least ~ 3000 years
e.g. reconstruction of solar activity,
historical Supernovae, etc.

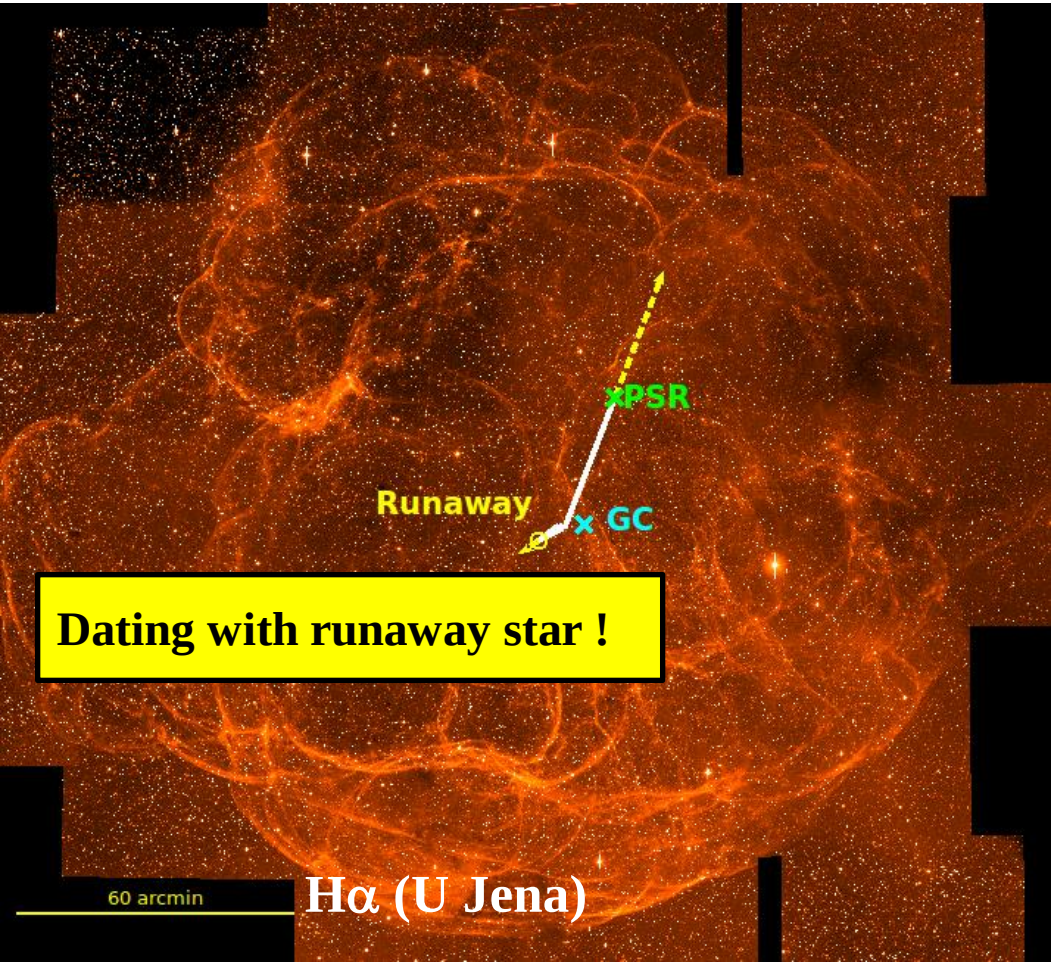
II. Astronomical time scale: ~ Myr
Supernovae, neutron stars, runaway stars

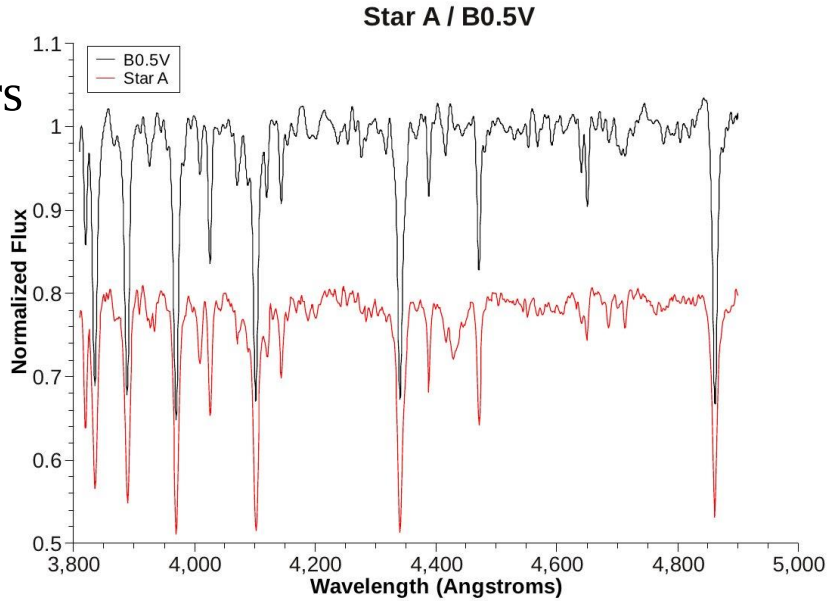
www.astro.uni-jena.de → Terra-Astronomy

Pair of runaway star and pulsar in a supernova remnant (S 147):

Pulsar and B0.5-type star both near the geometrical center
of SN remnant S147 about 30,000 years ago (pre-historical SN)

➔ confirms SN scenario as origin of runaway stars

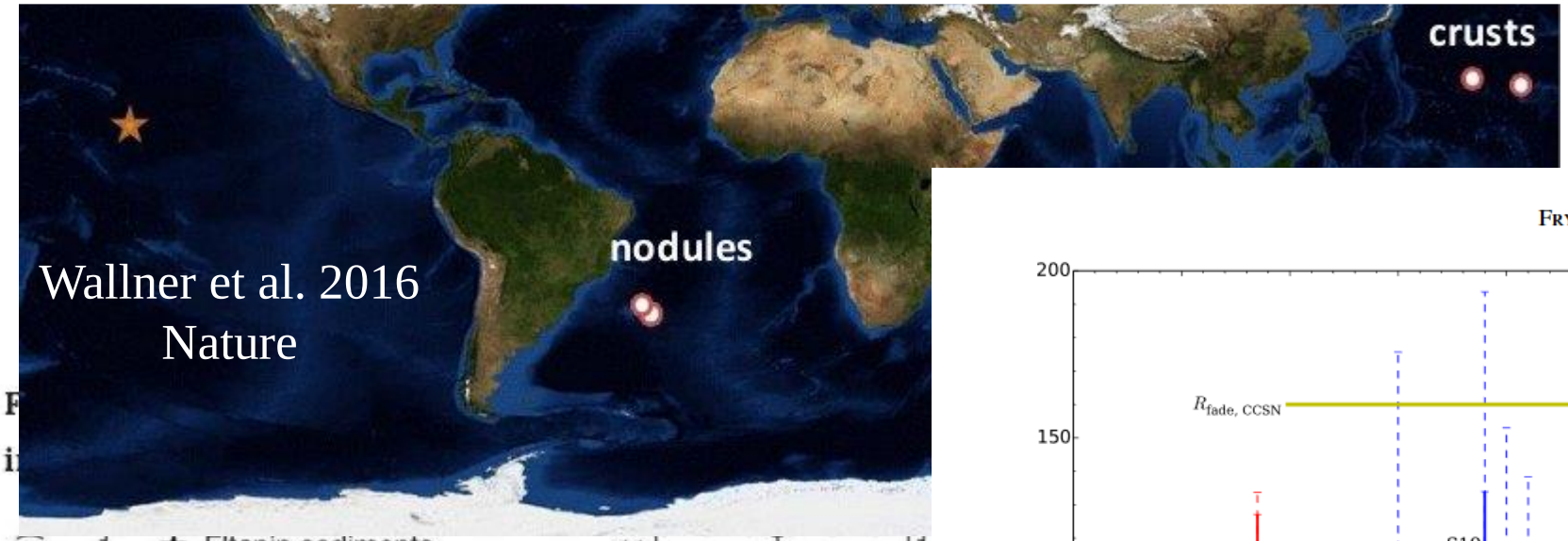




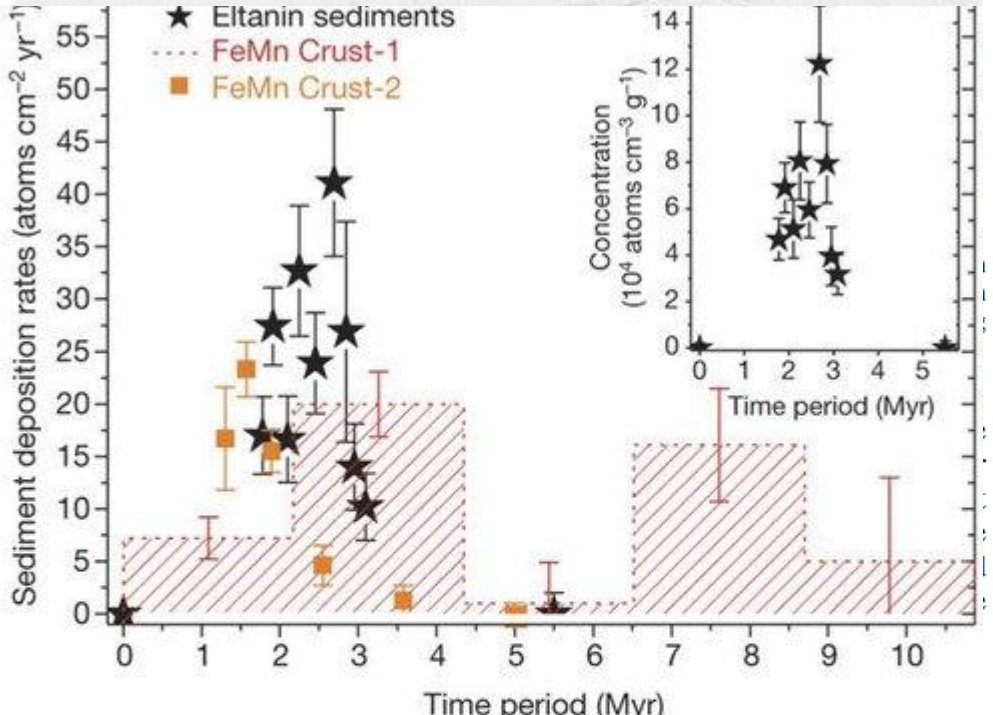
Dincel, Neuhäuser et al. 2015, MNRAS:
Runaway star at 1333 ± 112 pc

(confirmed by Gaia DR2: 1520 ± 140 pc)

^{60}Fe detected in the Earth ocean crust – due to nearby recent supernovae



Wallner et al. 2016
Nature



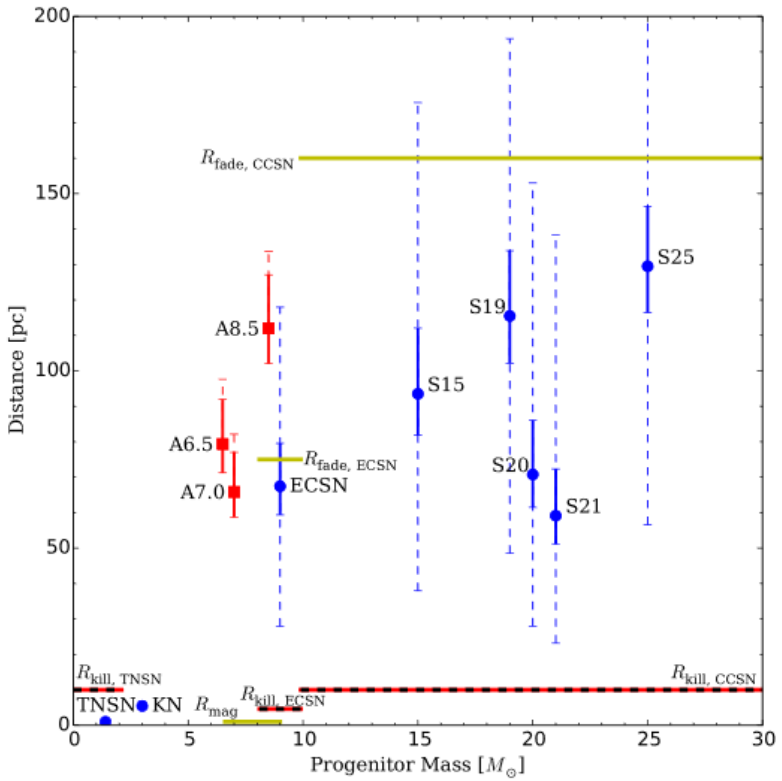
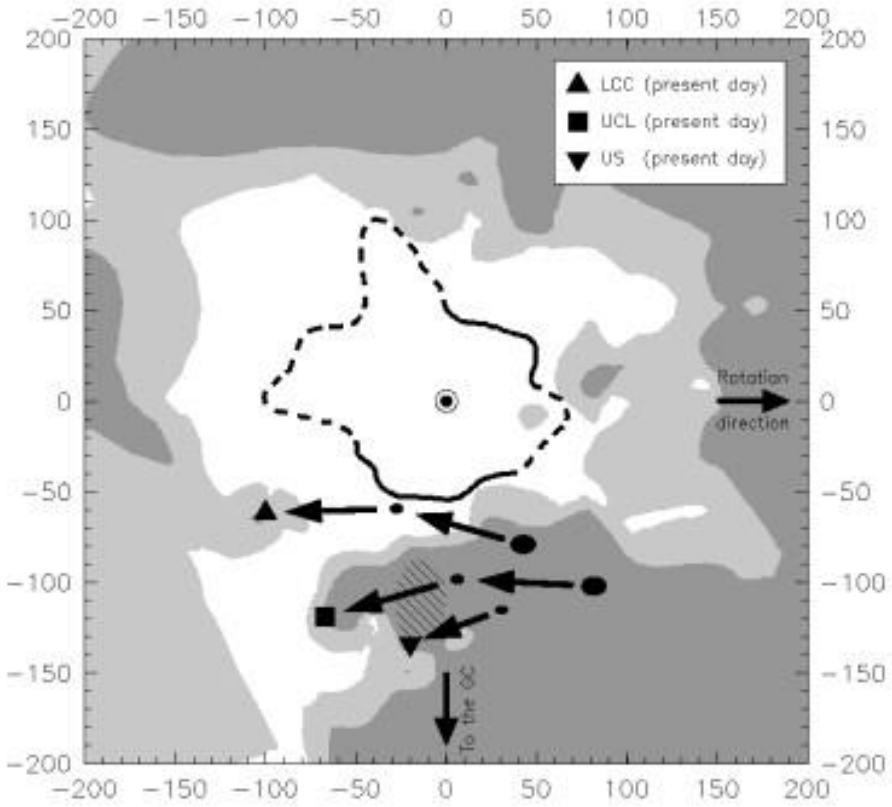
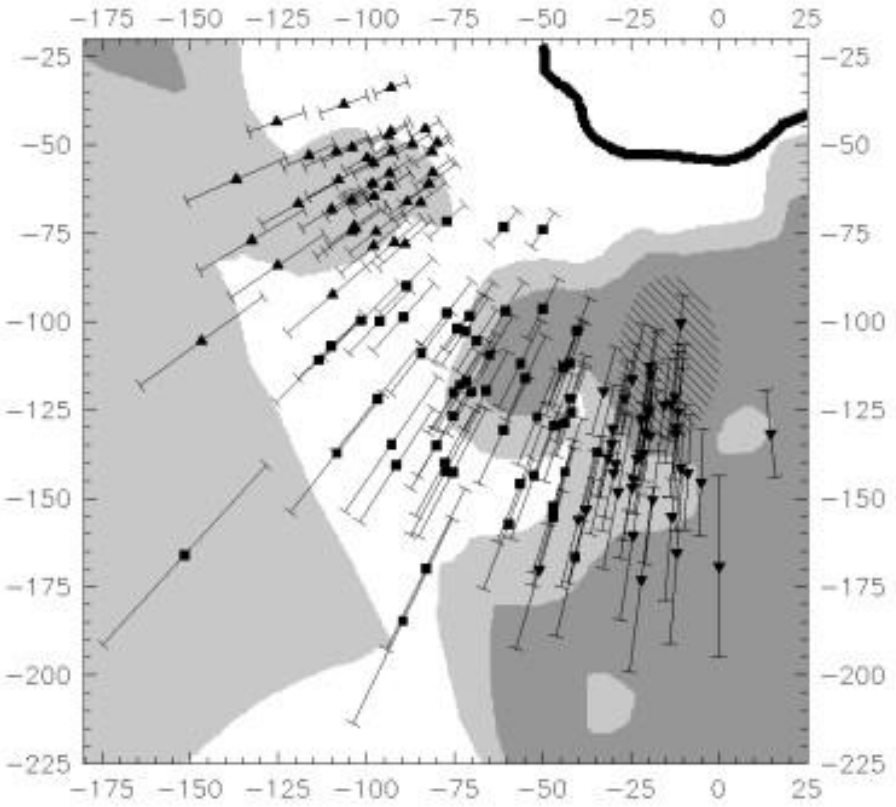


Figure 3. Estimated distances for possible progenitors, for $U_{\rm Fe} = 0.5$. SN candidates are circles and SAGB candidates are squares. The solid error bars represent uncertainty in the fluence measurement (Knie et al. 2004). The dashed error bars represent additional uncertainty in ^{60}Fe yields due to nuclear reaction rates in SNe (Tur et al. 2010) and a delayed super-wind phase in SAGBs (Doherty et al. 2013). Of particular note are the TNSN/Type Ia SN and the KN/NS–NS merger models, which are too close to have produced the detected ^{60}Fe signal.

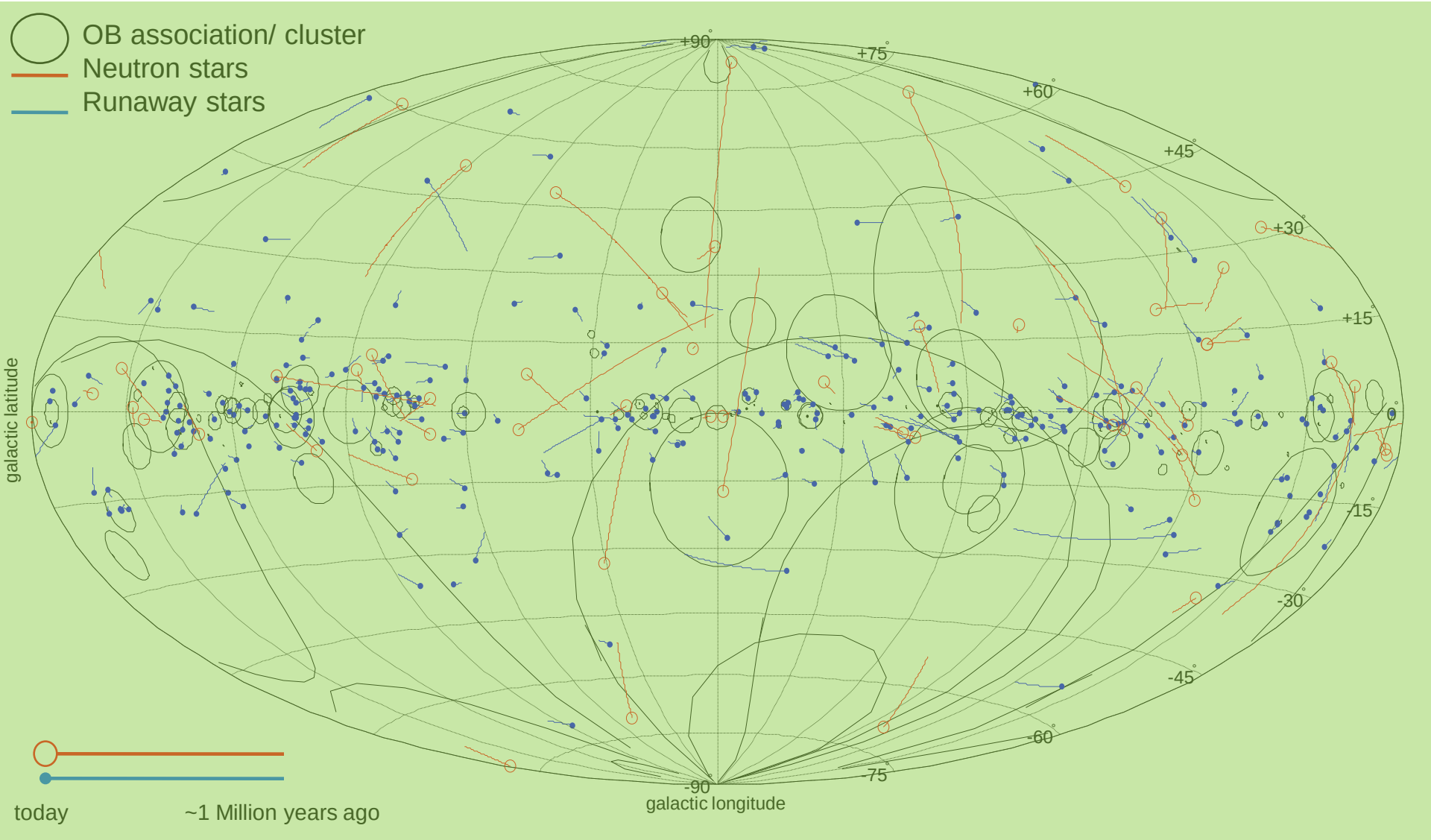




Upper Scorpius (US),
Upper Centaurus Lupus (UCL),
And Lower Centaurus Cruz (LCC):

~ 16 Myr young OB associations near Earth (~130 pc)

Neutron stars, runaway stars, OB associations …



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Astrophysical and cultural relevance of historical celestial observations

- Conjunctions to study Earth rotation changes
- Comets, meteors, etc.
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- Solar activity: A large solar super-flare around AD 775 ?

Secular variations in Earth rotation
[from Newton 1972 and Schove 1984 to Stephenson, Morrison, Hohenkerk 2017]
(*rebounce* after ice age)

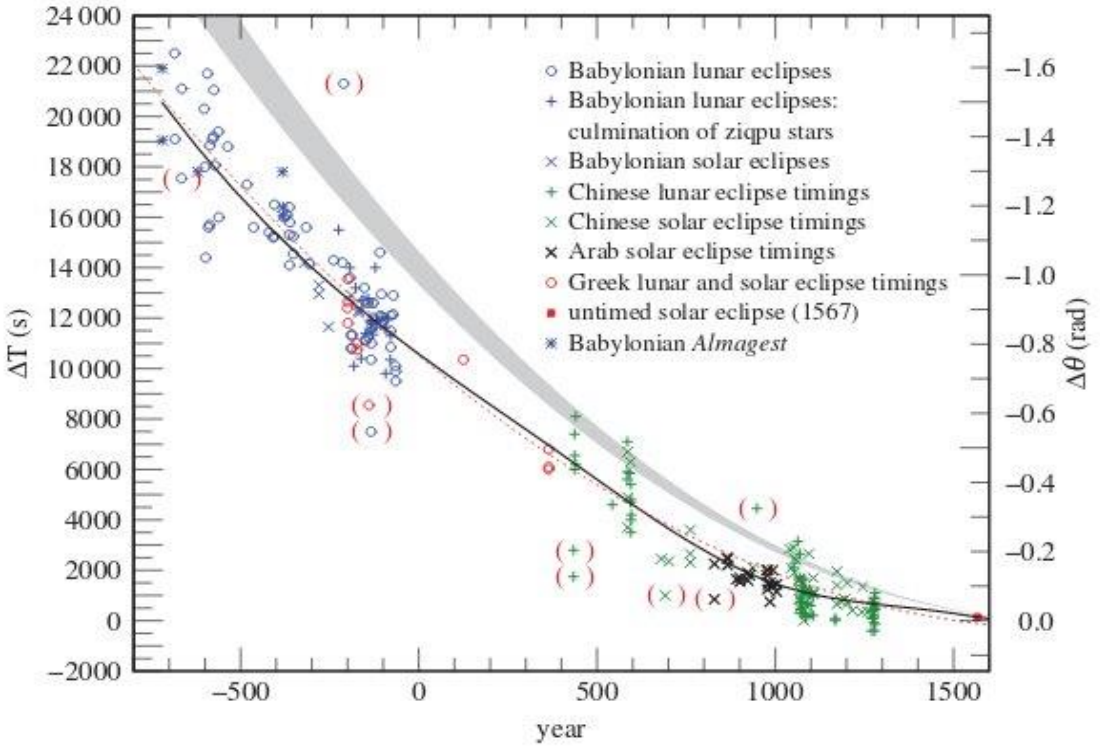


Figure 9. Results for ΔT for collected timed observations —720 to 1280 and the untimed total solar eclipse of 1567. The dotted red curve is the parabola given by equation (4.1). The black curve is the spline curve described in §4b. The grey curve is the parabola (equation (1.5)), predicted on the basis of tidal friction. The observations in brackets were treated as outliers, apart from a Babylonian observation in —666 which is intrinsically doubtful.

(figures from Stephenson, Morrison, Hohenkerk 2017)

ΔT:

Offset of Earth rotational phase to be measured by exact timing of some conjunction or occultation:

Solar eclipse, Lunar eclipse, other conjunctions

For constraining Earth‘ rotation, one would need an historical report with precise location and timing !

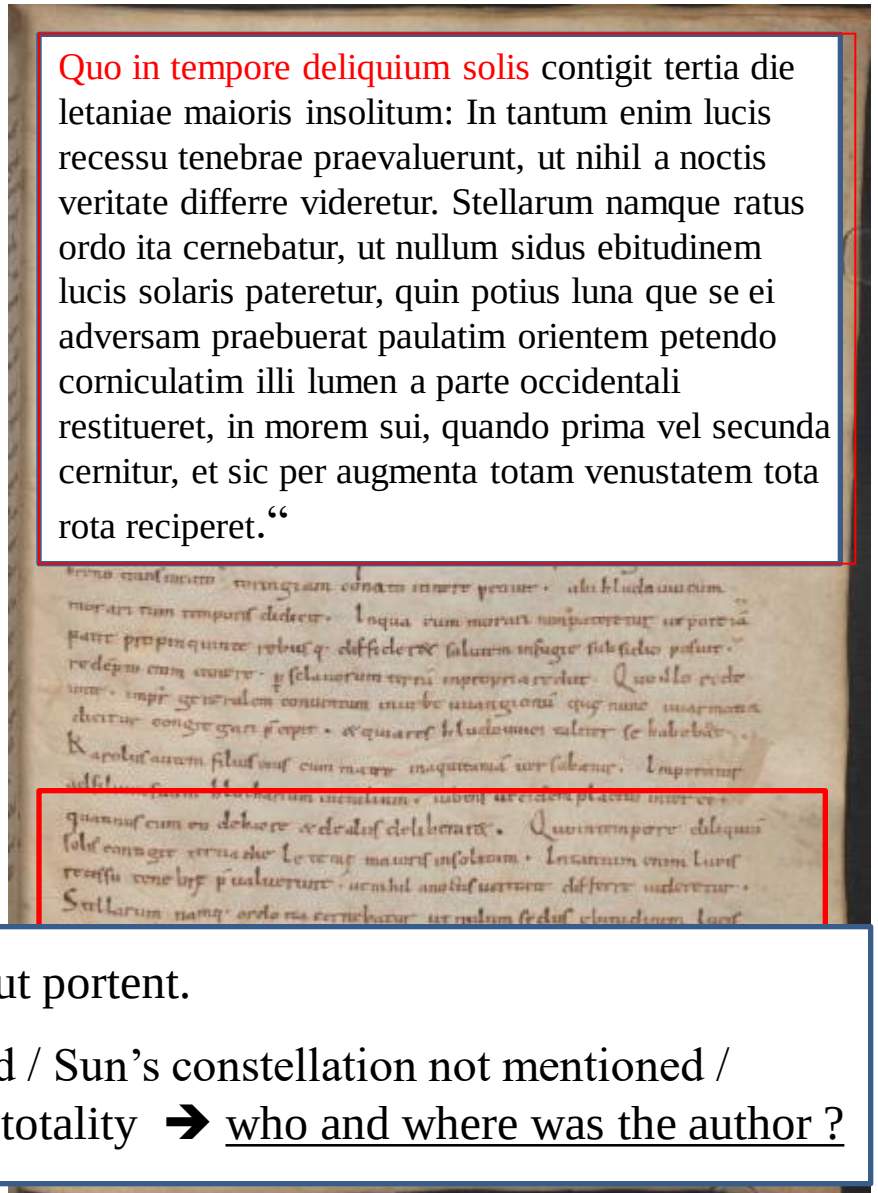
Secular variations in Earth rotation, e.g. total solar eclipse AD 840 May 5

Vita on Emperor Louis the Pious by an Anonymous „Astronomer“, for 840 May 5, here manuscript Vienna 529, 10th century, Austrian National Library, Vienna, f42r:

“At that time there was a most unusual disappearance of the sun on the third day of the Greater Litany [May 5]; darkness so prevailed with the receding of the light that, in truth, it seemed to differ not at all from night. The determined order of the stars was preceived such that no star seemed to suffer from the extinguishing of the sun's light except perhaps the moon, which lay opposite the sun.

But as the moon moved gradually to the east, a little horn of light was restored to the sun's western parts, as in the case when it is seen at first or second light. Thus, little by little the whole circle (disk) got back its total beauty.

Although this prodigy is rightly ascribed to nature, nevertheless it was completed with an awful result. For it portended that the great light of mortals, which shone before all like a candelabrum placed in God's house – I am referring to the Emperor of most pious memory – would very soon be withdrawn from human affairs, leaving the



Quo in tempore deliquium solis contigit tertia die letaniae maioris insolitum: In tantum enim lucis recessu tenebrae praevaluerunt, ut nihil a noctis veritate differre videretur. Stellarum namque ratus ordo ita cernebatur, ut nullum sidus ebitudinem lucis solaris pateretur, quin potius luna que se ei adversam praebuerat paulatim orientem petendo corniculatim illi lumen a parte occidentali restitueret, in morem sui, quando prima vel secunda cernitur, et sic per augmenta totam venustatem tota rota reciperet.“

A very good eyewitness report !!! Natural event, but portent.

BUT: Venus, Mars, Jupiter visible, but not mentioned / Sun’s constellation not mentioned / exact hour not given / location (of Emperor) outside totality ➔ who and where was the author ?

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Natural event, but portent. (F. Espenak, NASA, eclipse.gsfc.nasa.gov)

BUT: Venus, Mars, Jupiter visible, but not mentioned / Sun’s constellation not mentioned / exact hour not given / location (of Emperor) outside totality ➔ who and where was the author ?

Secular variations in Earth rotation, e.g. total solar eclipse AD 840 May 5

Annals of St. Bertin (Troyes, France):
"Eclipsis solis iii nonas maii ante nonam diei horam multis in locis a plurimis visa est."

"On May 5, **before the ninth hour of the day**, an eclipse of the sun was seen by a lot of people in many different places."

("before 9th hour": 2-3 sun-dial hours after noon / eclipse at Troyes: ~11:30-14:00h, 97% max.)

Annals of Fulda (central Germany):
"On the eve of Ascension [May 5] … there was so great an eclipse of the sun **around the seventh and eighth hour of the day** that **even the stars could be seen** because of the veiling of the sun, and terrestrial objects changed color."

("7th & 8th hour": 1-3 sun-dial hours after noon / eclipse at Fulda: ~11:30-14:00h, 90% max.)

Annals of Xanten (The Netherlands):
"on … the third Rogation Day [May 5], there was an eclipse of the sun **in the ninth hour**, and the **stars were as clearly visible** in the sky as at night."

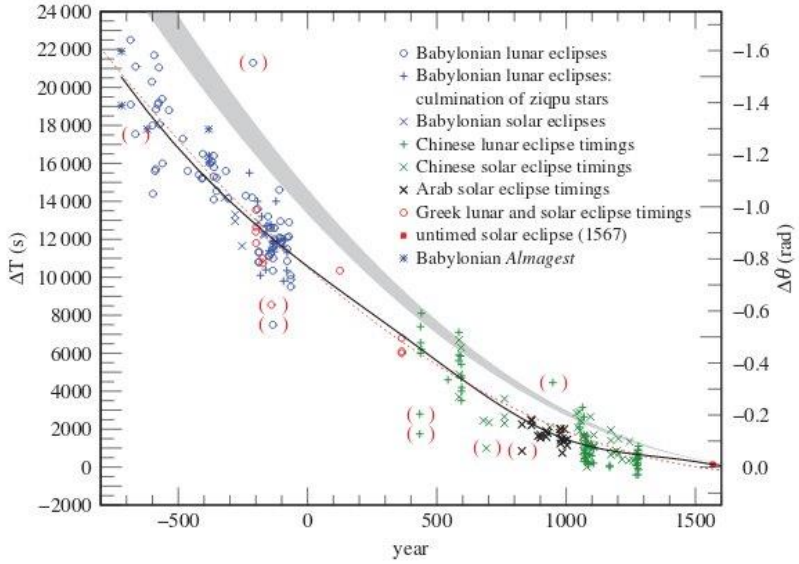
("in the 9th hour" on sun-dial is 2-3h after noon / eclipse at Fulda: ~11:30-14:00h, 85% max.)

Secular variations in Earth rotation
[from Newton 1972 and Schove 1984 to Stephenson, Morrison, Hohenkerk 2017]

ASTRONOMICAL
DIARIES AND RELATED TEXTS
FROM BABYLONIA

7′ 12 DIR AN ZA GE_6 13 13 DIR AN ZA GE[$_6$ ....]
8′ *ki* TAB-*ú ina* 21 GE_6 *gab-bi-šú* ŠÚ 20 GE_6 [....]
9′ RÍN *šá* ULÙ *a-dir ina* AN-KU_{10}-*šú* GÍR GÙ U AN [....]
10′ MAŠ-MAŠ IGI 1 KÙŠ *in* EN 18 MÚL-BABBAR *ana* NIM *k*[*i* UŠ-*ú* ...
11′ *ina* ZALÁG *sin ina* IGI GÌR *ár šá* UR 2/3 KÙŠ *ina* IGI [....]

Offset from expectation due to either ice age rebound or different Earth core-mantle coupling



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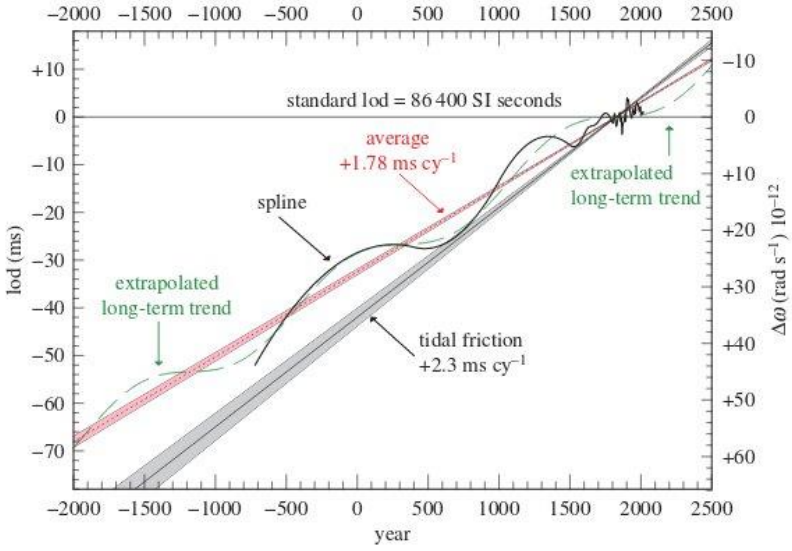


Figure 18. lod −2000 to 2500. The dotted red line is the average measured rate of change in the lod, +1.78 ± 0.03 ms cy^{-1}, which is equivalent to an acceleration of $-4.7 \pm 0.1 \times 10^{-22}$ rad s^{-2}. The shaded grey area shows the change expected on the basis of tidal friction, +2.3 ± 0.1 ms cy^{-1}, equivalent to $-6.2 \pm 0.4 \times 10^{-22}$ rad s^{-2}. The black curve is the slope on the spline fit shown in figures 9 and 10. The green-dashed curve is the extrapolation of the oscillation (equation (5.1)).

(figures from Stephenson, Morrison, Hohenkerk 2017)

„Guest stars“:

→ Comets

→ Novae

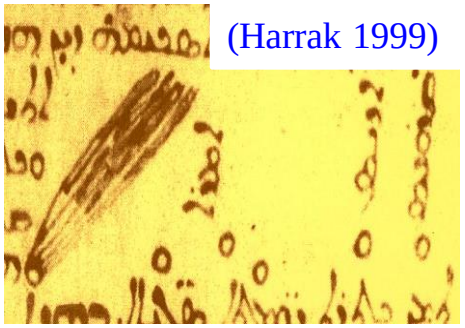
→ Supernovae

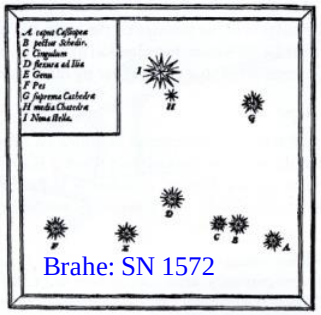
→ Kilo-Novae / Macro-Novae (GRBs)

→ (other) variable stars (e.g. Mira)

→ Meteors and bolides

→ other atmospheric phenomena (e.g. mock moons)


(Harrak 1999)


Brahe: SN 1572


DLN+RN 2015 Astron. Notes

Historically: all transient phenomena were atmospheric („meteorology“)

Old written records „pheno-typical“

We need good criteria to classify and to distinguish

Astrophysical and cultural relevance of historical celestial observations

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- **Comets, meteors, etc.**
- Historical Supernovae
- Solar activity: A large solar super-flare around AD 775 ?

Orbit of comet Halley AD 760:

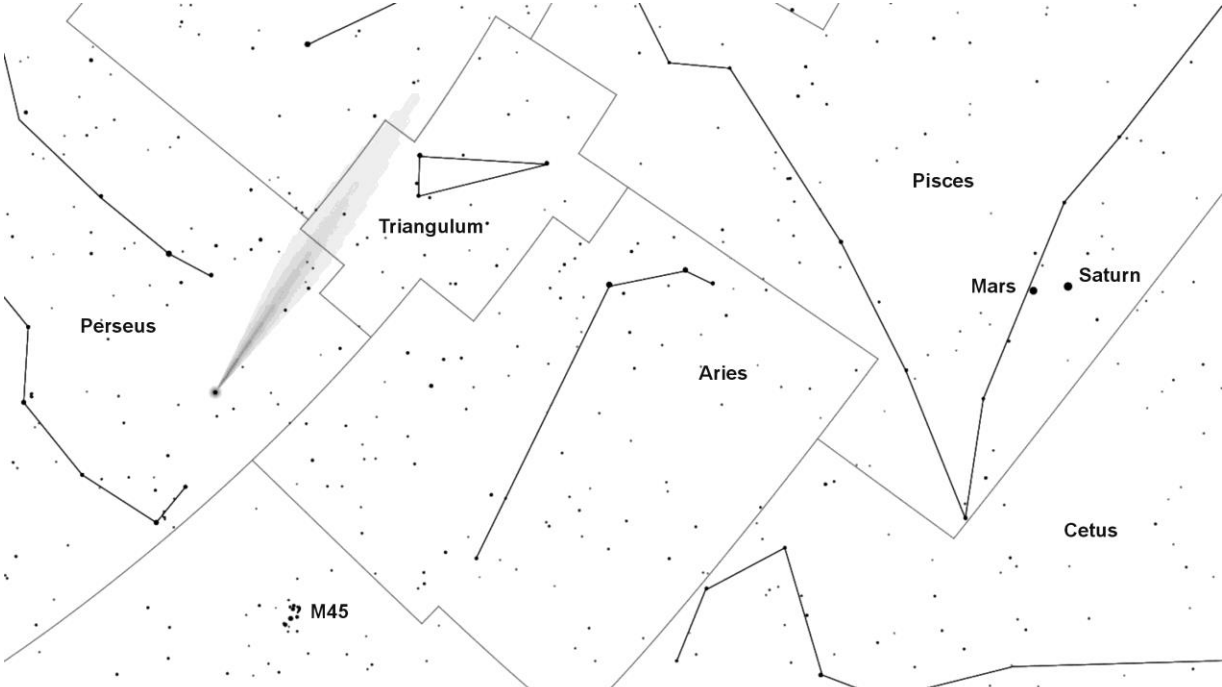
8th century Syriac Chronicle of Zuqnīn (Amida, Turkey) for 760 May and June

comet Halley

Aries

Ares = Mars

Kronos = Saturn

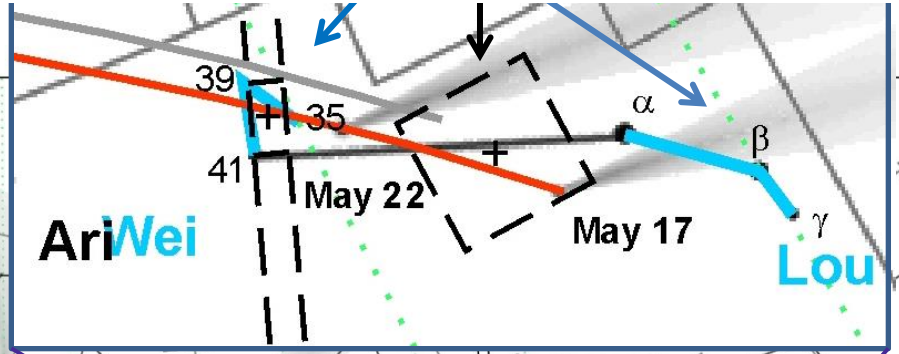


D.L. Neuhäuser. R. Neuhäuser,
A. Harrak, J. Chapman,
M. Mugrauer, to be submitted

The path of comet 1P/Halley in AD 760 May / June:

Table 2: Historical observations of comet 1P/Halley in AD 760 (position for 760.5)

Date 760	Text	Right Ascension	Declination	Obs. time (UT)	Location
May 16/17	between Lou and Wei	01h 14 ± 8m	18.5 ± 2°	May 16.9 ± 1h	China
May 16/17	at the 3 most shining stars of Ram	01h 14 ± 8m	18.5 ± 2°	May 17.1 ± 2h	Zuqnīn
[illegible]	[illegible]	λ = 30 − 31°	41 to 39 Ari	May 22.1 ± 2h	Zuqnīn
[illegible]	[illegible]	8h 39m 10s ±2.7°	32.0 ± 2.7°	June 9.55 ± 1h	China
[illegible]	[illegible]	0h 43m 12s ±1°	8°38′ ± 1°	July 5.55 ± 1h	China



4) China, Jul 5: „7 cun off Youzhifa“ (β Vir)

Yeomans & Kiang orbit grey
Our rew orbit red (prelim.) fits better at the end !

[Carte du Ciel]

D.L. Neuhäuser. R. Neuhäuser, A. Harrak, J. Chapman, M. Mugrauer, to be submitted

Astrophysical and cultural relevance of historical celestial observations

- Conjunctions to study Earth rotation changes
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- **Historical Supernovae**
- Solar activity: A large solar super-flare around AD 775 ?

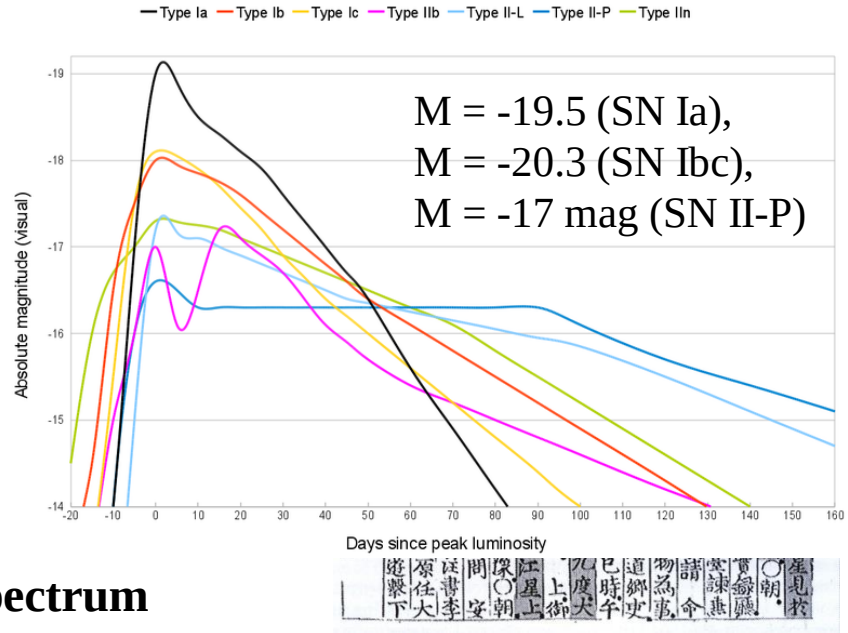
Historical Supernovae (see Stephenson & Green 2003 book)

Table 1 **Historic supernovae in the last 2000 yr.** There are several Galactic historic SN sightings since 185 (sorted here by time), but no SN sighting within 200 yr around AD 774/5. This listing shows that SNe were observed before and after the AD 774/5 event. Also, the SNRs Vela Jr and Cas A are listed, because they were considered in M12 to be possibly related to the AD 774/5 event; at the end of the table, we list six more SNRs, which should be related to recent SNe given the ages of the pulsars and/or SNRs; however, all those eight SNRs are all too distant for the AD 774/5 event (if that were a normal SN at ~ 1.24 pc); Vela Jr is too young given its expansion velocity.

SN	Location	Ext. Av	Peak magnitude		Supernova remnant				Neutron star				SN type
Year	δ [°]	[mag]	hist.	Equ. (3)	G name	d [kpc]	age [kyr]	Ref	name	d [kpc]	age [kyr]	Ref	& Ref.
185?	Cen −59	6.3(3.2)[1]	−8(2)[2]	−3 to 8	320.4-1.2	5.0(1.6)	1.7-20	1,3	1513-5908	3.3-8.4	≤ 1.56	3-5	cc(?),2,(a)
369?	(b) ~ 65		≤ 2[6]										?,6
386	Sgr −19	8.7(3.4)[7,8]	~ 2[9]	0 to 10	11.2-0.3	5.0(6)	0.4-3.4	10-15	1811-1925		≤ 23.3	16,17	II,16-18
393	Sco −39	3.9(2.4)[19]	−1(1)[20,21]	−8 to 2	347.3-0.5	1.4(5)	1.6-9.0	19-23	CCO (c)			(c)	cc(?),(c)
1006	Lup −42	0.32(3)[2]	−7.5[24]	−8 to −7	327.6+14.6	2.18(8)		24-26	none				Ia,(d),27
1054	Tau +22	~ 1.1[28]	−4.8[28]	−7 to −3	184.6-5.8	2.0(5)	0.953 (21)	29-31	0534+2200	2.0-2.5	≤ 1.24	32,33,115	II,Crab,32
1181	Cas +64	1.3(0.2)[34]	~ 0.7[2]	−6 to −2	130.7+3.1	2.9(3)	0.8-7.0	34-37	0205+6449	3.2-7.5	≤ 5.37	33-39	II,2,40,41
1572	Cas +65	2.25(16)[2]	−4.5[2]	−6 to −5	120.1+1.4	2.25(16)	~ 441	2,42	none	(Tycho's SN)			Ia,43
1604	Oph −20	3.27(14)[2]	−3.0[2,9,44]	−3 to −4	4.5+6.8	3.4(3)	~ 409	2,45	none	(Kepler's SN)			Ia,(e)
Other young SNRs considered in Miyake et al. 2012													
~ 1300	Vel −46	1.63(98)[46]		−12 to −3	266.2-1.2	0.20 - 1	0.4-4.3	47-50	CCO	(Vela Jr)		(f)	cc(?),47,48
~ 1680	Cas +58	11.6(2.6)[49]	(g)	3 to 11	111.7-2.1	$3.5^{+0.3}_{-0.1}$	~ 333	51,52	CCO	(Cas A)		53	IIb,54

~9 SNe observed: AD 185, 369, 386, 393 1006, 1054, 1181 1572, 1604

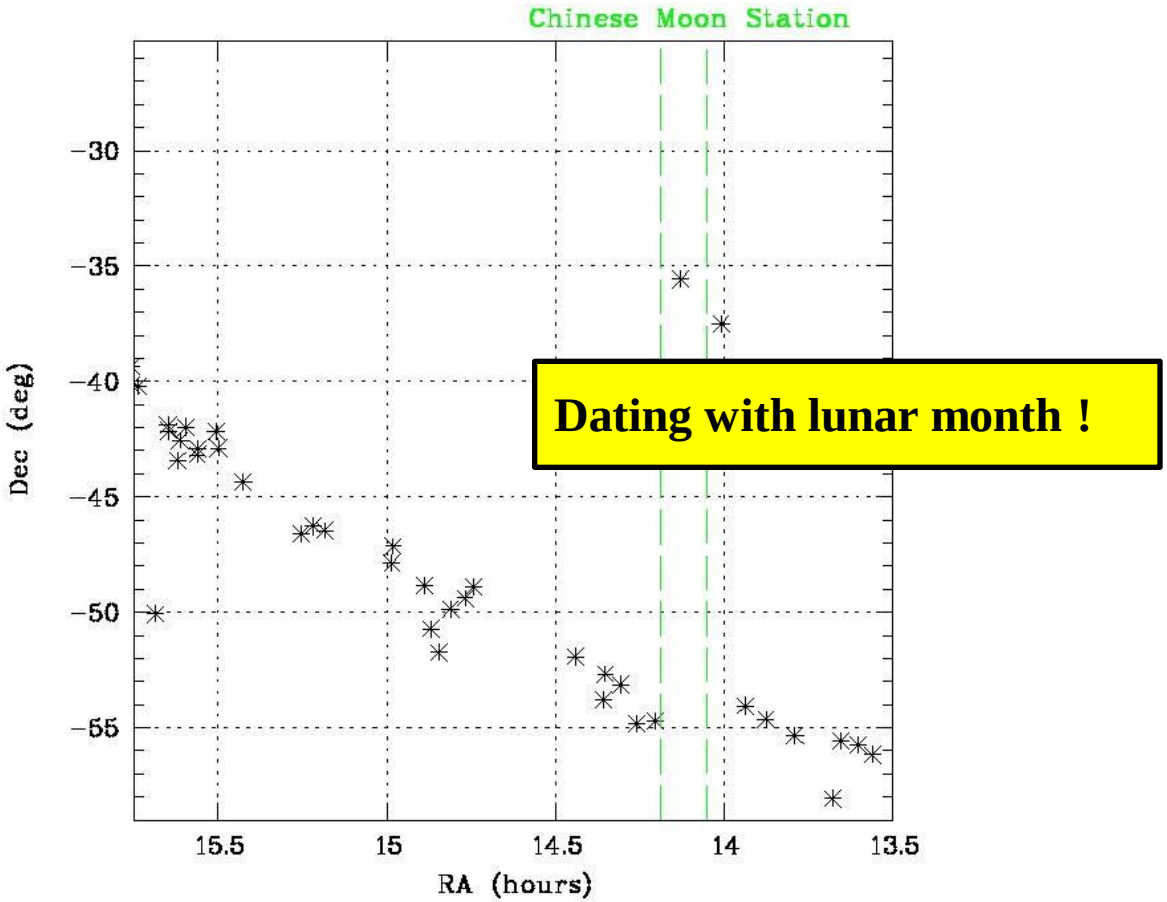
9 in China (some also in Korea und Japan)
3 in Europe (SNe 1006, 1572, 1604)
4 in Arabia (SNe 1006, 1054, 1572, 1604)
+ 2 probably not noticed: Vel Jr. and Cas A (?)
~ 9 + 2 historical supernovae in ~2000 years



➔ **All nearby (our Galaxy, within ~5 kpc), exact age of remnant (and neutron star), sometimes parallax of runaway star, supernova type from light curve or light echo spectrum**

SN 1006:

China: On the 2nd day of the 4th lunar month (i.e. May 1) in the first double hour of the night,a large star was seen. Its color was yellow … its brightness had increased slowly. Its position was in the 3rd degree of the lunar mansion Di … ➔ right ascension ! (**Zhoubo star**, -7.5 mag)



Dating with lunar month !

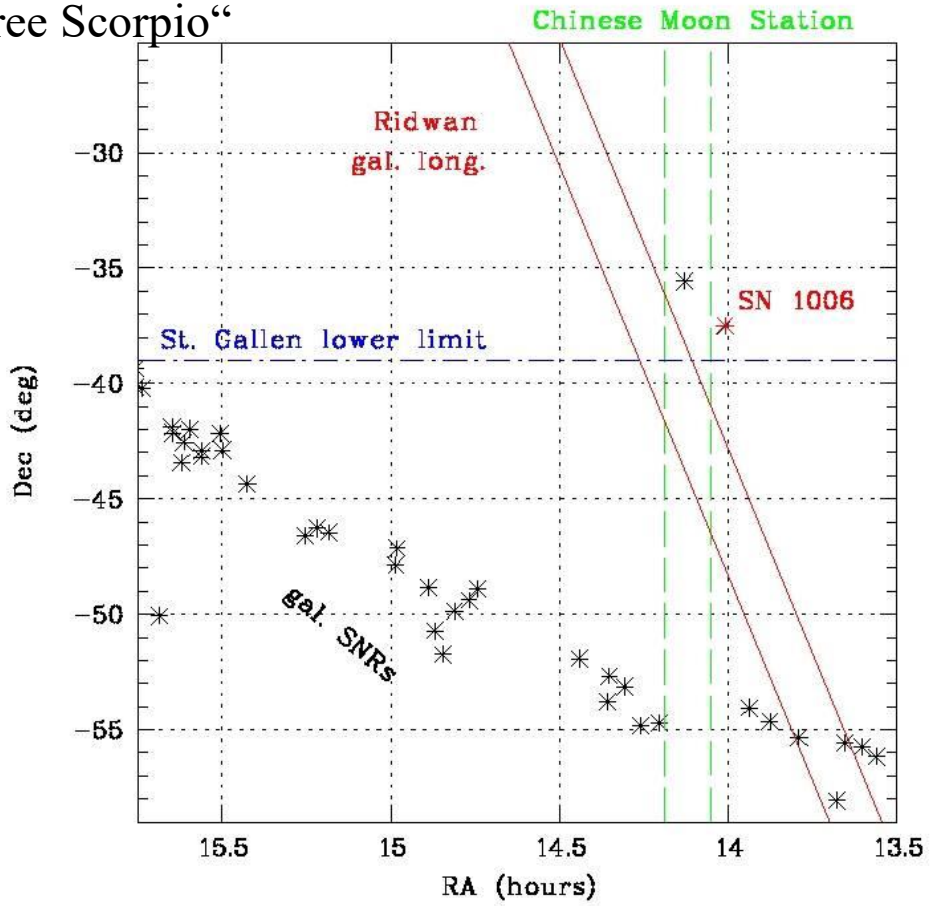
景德三年四月戊寅周伯星見出氐南騎官西一度狀如半月有芒角煌煌然可以鑒物歷庫樓東八月隨天輪入濁十一月復見在氐自是常以十一月辰見東方八月西南入濁

Goldstein & Ho 1965/66 and Stephenson et al.

SN 1006:

ᶜAlī ibn Riḍwān, Cairo: I describe to you now a star, which I saw myself at the beginning of my education … in the 15th degree of Scorpio … 2.5 to 3 times as large as Venus … brightness like the quarter moon … it moved with the stars … it disappeared after 3 months … The position of the planets was as follows: (Sun, moon, Saturn, Jupiter, Mars, Venus, Mercury positions ➔ observing date1006 Apr 30 = new moon

„15th degree Scorpio“ i.e. an ecliptic longitude (range)



Dating w/ Sun/planet positions !

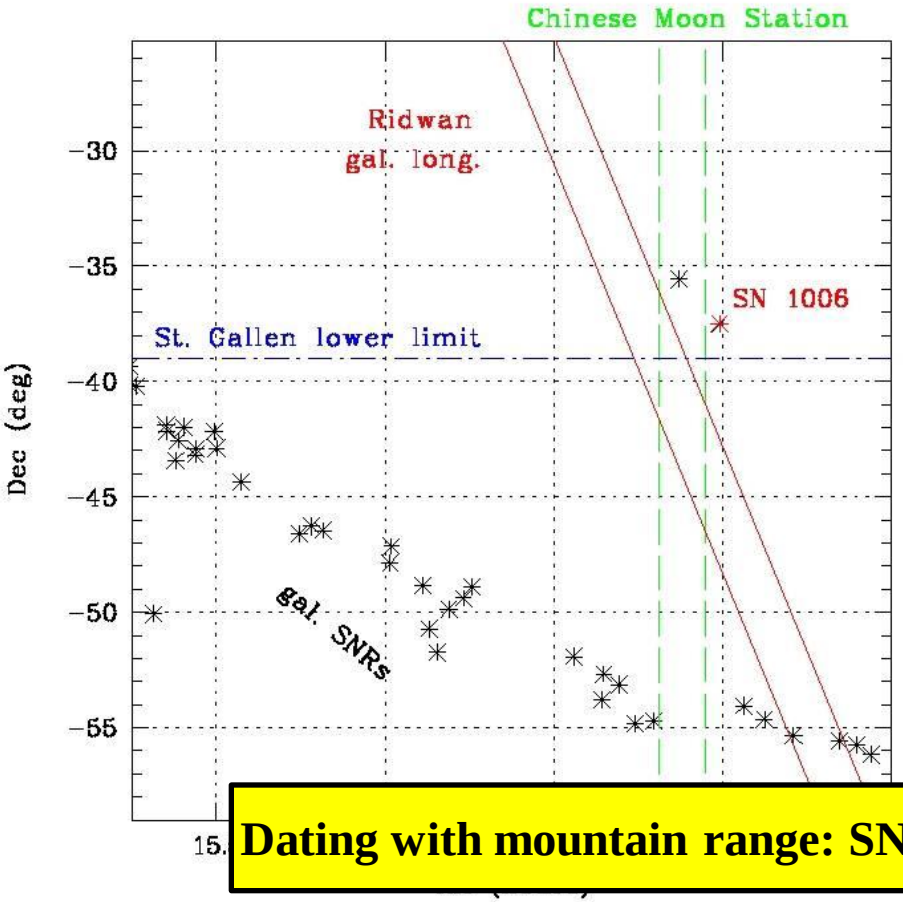
ᶜAlī ibn Riḍwān:

Goldstein 1965 and Stephenson et al. 1970s

Right ascension range from China + ecliptic longitude range from Arabia
(all since 30 April or May 1)

St. Gallen: A new star of large size twinckled much … and was sometimes not seen at all (behind mountain tops). It was seen **for three month** in the far south below all other constellations ➔ southern declination limit -39 degree

➔ Identification of SNR for SN 1006 (Goldstein, Stephenson)

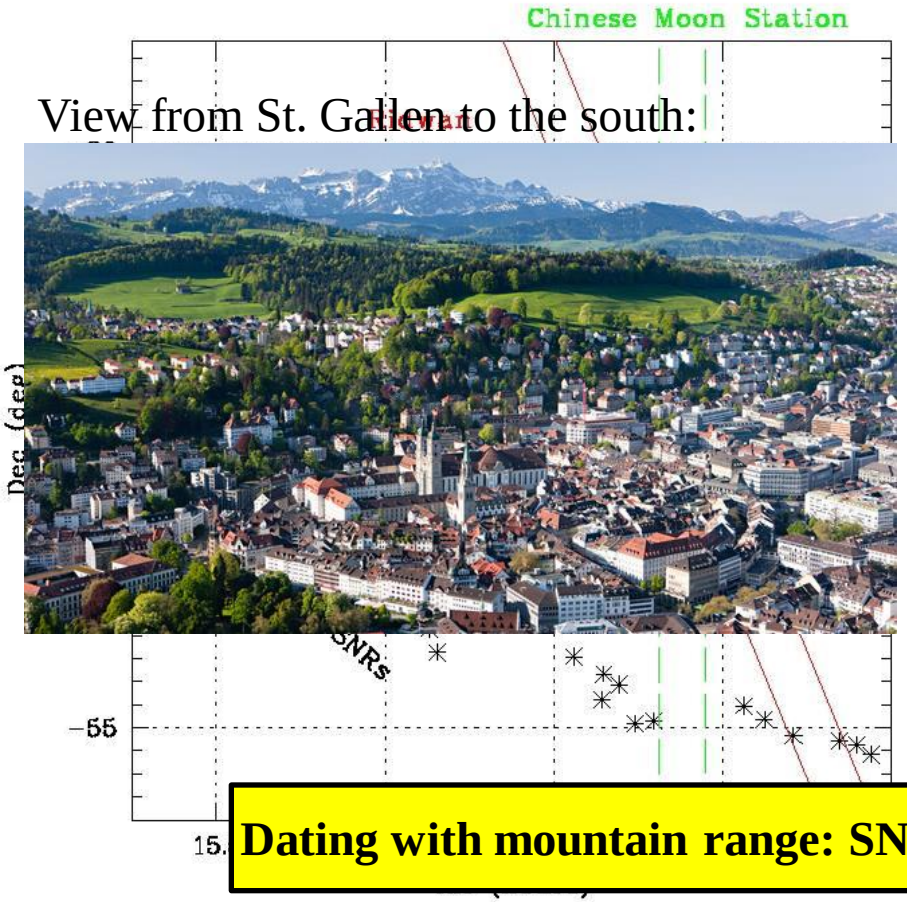


Dating with mountain range: SN started already mid to late April

Right ascension range from China + ecliptic longitude range from Arabia
(all since 30 April or May 1)

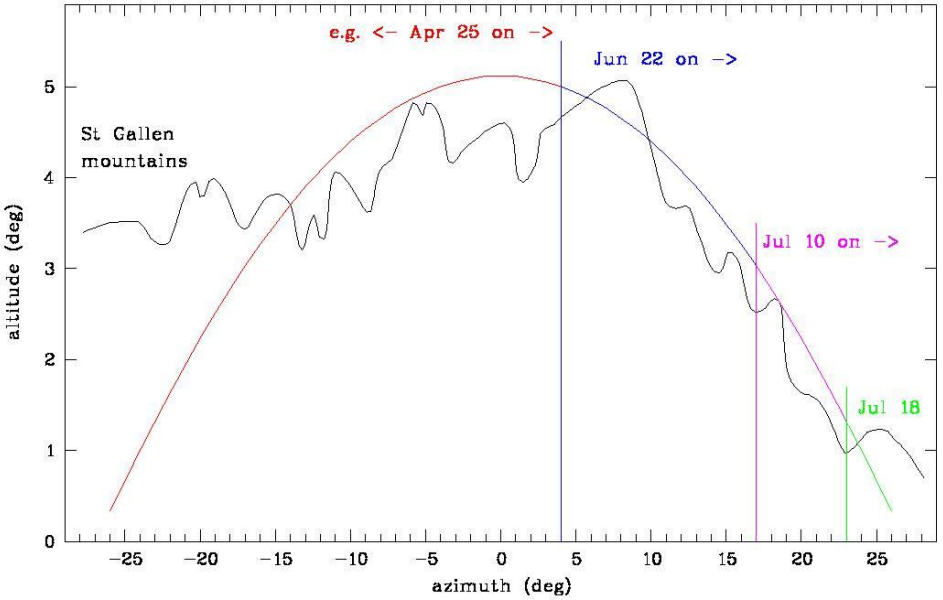
St. Gallen: A new star of large size twinckled much … and was sometimes not seen at all (behind mountain tops). It was seen **for three month** in the far south below all other constellations ➔ southern declination limit -39 degree

➔ Identification of SNR for SN 1006 (Goldstein, Stephenson)



View from St. Gallen to the south:

St. Gallen mountain range after Stephenson:



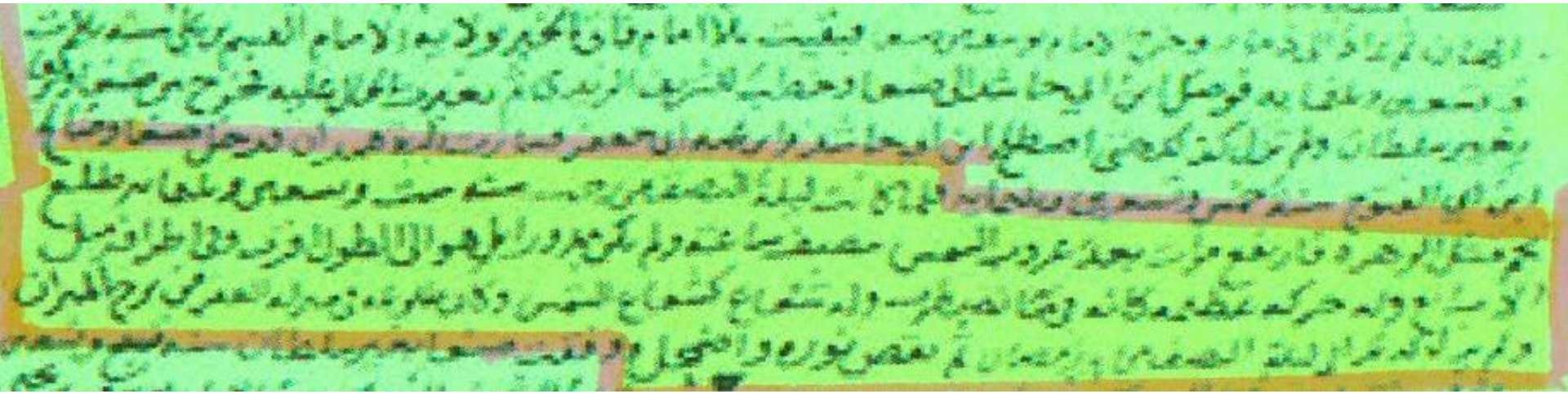
Early detection before Apr 25 not considered before (Neuhäuser & Rada 2014, RN+ 2015)

Dating with mountain range: SN started already mid to late April

Newly found old reports from Yemen: Supernova 1006

found by Wafiq Rada (indep. scholar, Iraq)

Al-Yamānī (died AD 1342), Yemen:



(additional text from Ibn al-Dayba^{c} (AD 1461 - 1537), Yemen, depends on al-Yamānī)

Al-Yamānī:

On the night of mid-Rajab [15th of Rajab], in the year 396h [AD 1006 Apr 17 ± 2],

a star (najm) appeared from the east at half an hour after sunset.

It was four times as large [= as bright] as Venus.

It appeared in the zodiacal sign of Libra in Scorpio and remained unchanged like that.

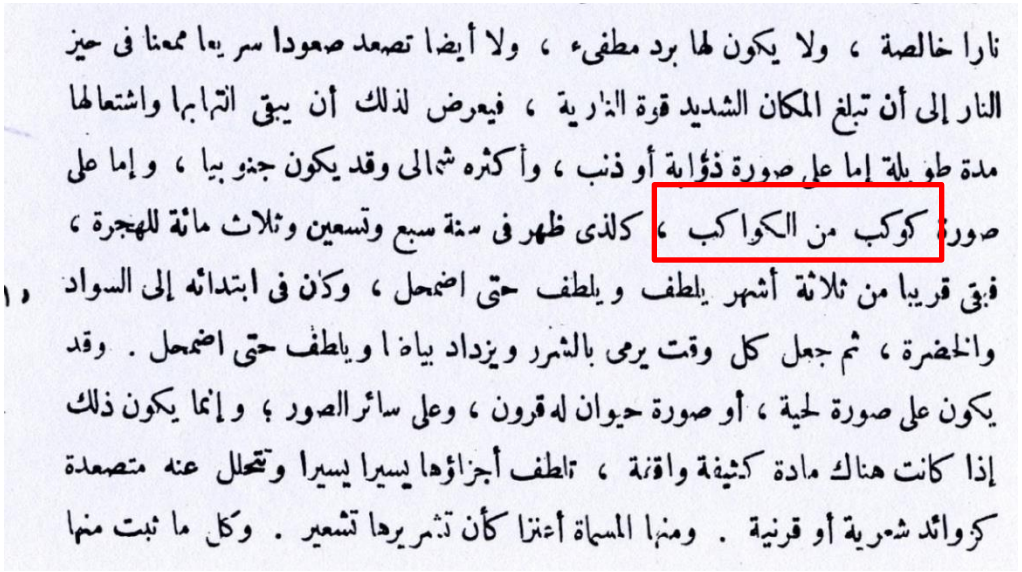
In the night of mid-Ramaḍān [3 months later]

its light started to decrease and gradually faded away.

(Rada & Neuhäuser, 2014, AN 336, 249, arXiv:1508.06126)

Additional (newly found) observation of SN 1006 by Ibn Sīnā (Avicenna) AD 980-1037

(in his commentary on Aristotle's Meteorology)



نارا خالصة ، ولا يكون لها برد مطفىء ، ولا أيضا تصعد صعودا سريعا ممعنا فى حيز
النار إلى أن تبلغ المكان الشديد قوة النارية ، فيعرض لذلك أن يبقى التهابها واشتعالها
مدة طويلة إما على صورة ذؤابة أو ذنب ، وأكثره شمالى وقد يكون جنوبيا ، وإما على
صورة كوكب من الكواكب ، كالذى ظهر فى سنة سبع وتسعين وثلاث مائة للهجرة ،
فبقى قريبا من ثلاثة أشهر يلطف ويلطف حتى اضمحل ، وكان فى ابتدائه إلى السواد
والخضرة ، ثم جعل كل وقت يرمى بالشرر ويزداد بياضا ويلطف حتى اضمحل . وقد
يكون على صورة لحية ، أو صورة حيوان له قرون ، وعلى سائر الصور ؛ وإنما يكون ذلك
إذا كانت هناك مادة كثيفة واقدة ، تلطف أجزاؤها يسيرا يسيرا وتنحلل عنه متصعدة
كزوائد شعرية أو قرنية . ومنها المسماة أعنزا كأن تشريها تشعير . وكل ما ثبت منها

It therefore happens that the burning and flaming stays for a (long) while, either in form of a lock of hair or with a tail (i.e. in form of a comet), mostly in the north,

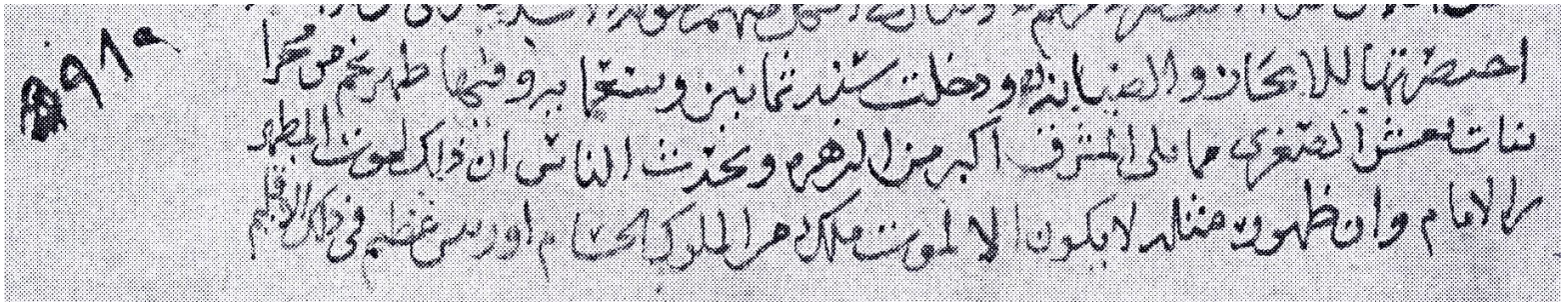
but sometimes also in the south, or in form of a star among the stars [kawkab min al-kawākib] – like the one which appeared in the year 397(h). It remained for close to three months getting fainter and fainter until it disappeared; at the beginning it was towards a darkness and greenness, then it began to throw out sparks all the time, and then it became more and more whitish and then became fainter and disappeared.

It can also have the form of a beard or of an animal with horns or of other figures …

(Neuhäuser, Kunitzsch, Ehrig-Eggert, Astron. Notes 2017)

Newly found Arabic reports on SN 1572:

Tycho's SN 1572 Nov 6

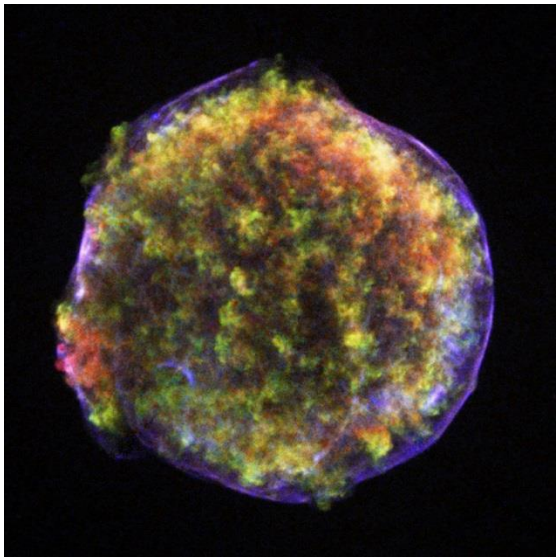


Ibn al-Muṭahhar, died 1639, History of Yemen AD 1494-1620 (MS Berlin 9743):

Dating with a portent !

„Then began the year 980h
[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.“

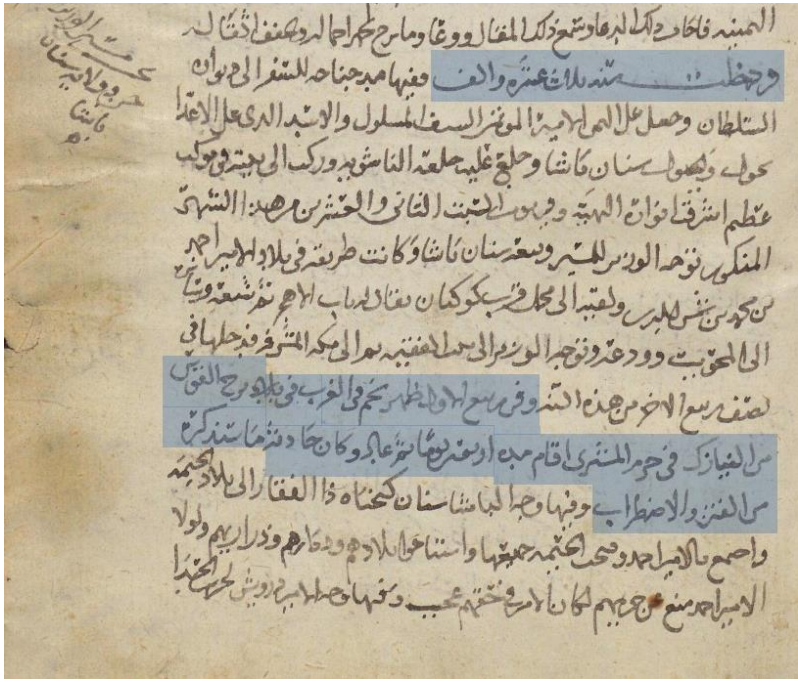


NASA/CXC/Rutgers/J.Warren & J.Hughes et al.

(R. Neuhäuser, Rada, Kunitzsch, D.L. Neuhäuser, JHA, Nov. 2016)

New Arabic reports on SN 1604:

MS Berlin 9743:



Kepler's Supernova (SN 1604):

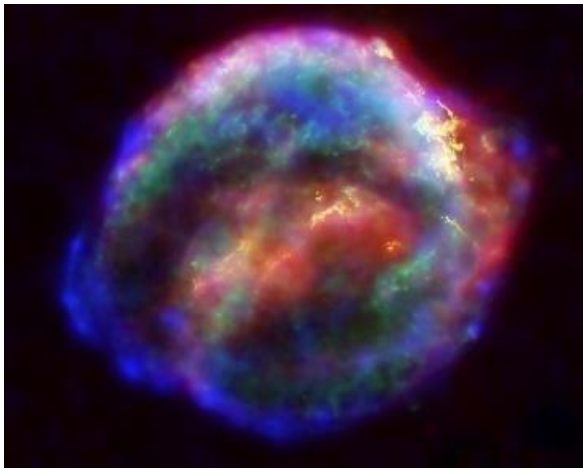
Ibn al-Muṭahhar, died 1639, History of Yemen AD 1494-1620 (MS Berlin 9743):

"And in the month of Rabīᶜ I [1604]
a star [*najm*] of the *nayāzik* appeared
in the West in (the beginning of)
the zodiacal sign [*burj*] Sagittarius
as large as Jupiter [lit.: *in the body of Jupiter*].
It remained for 40 days and then faded away.

And what it caused was what we shall mention
of conflicts and tumult ..."

(Kepler since Oct 17, others in Italy since Oct 9)

"nayāzik" = transient celestial object



CXO/HST/Spitzer (Sankrit & Blair)

(R. Neuhäuser, Rada, Kunitzsch, D.L. Neuhäuser, JHA, Nov. 2016)

Historical observations of supernovae

are important and relevant for:

- location of supernova
- identification of SN remnant and (possibly) neutron star
- rough distance

- Time of explosion / peak: Age of SN remnant (and neutron star), (otherwise only very roughly known)

- peak brightness (at known distance) ➔ Type of SN

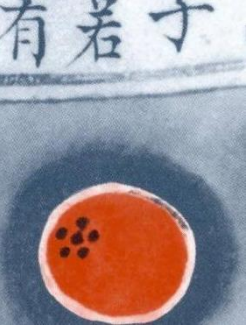
- Light curve ➔ Type of SN

- possibly identification of a run-away star for SN II in binary
➔ precise distance

- Possibly light echo spectroscopy ➔ Type of SN, asymmetry etc.

Astrophysical and cultural relevance of historical celestial observations

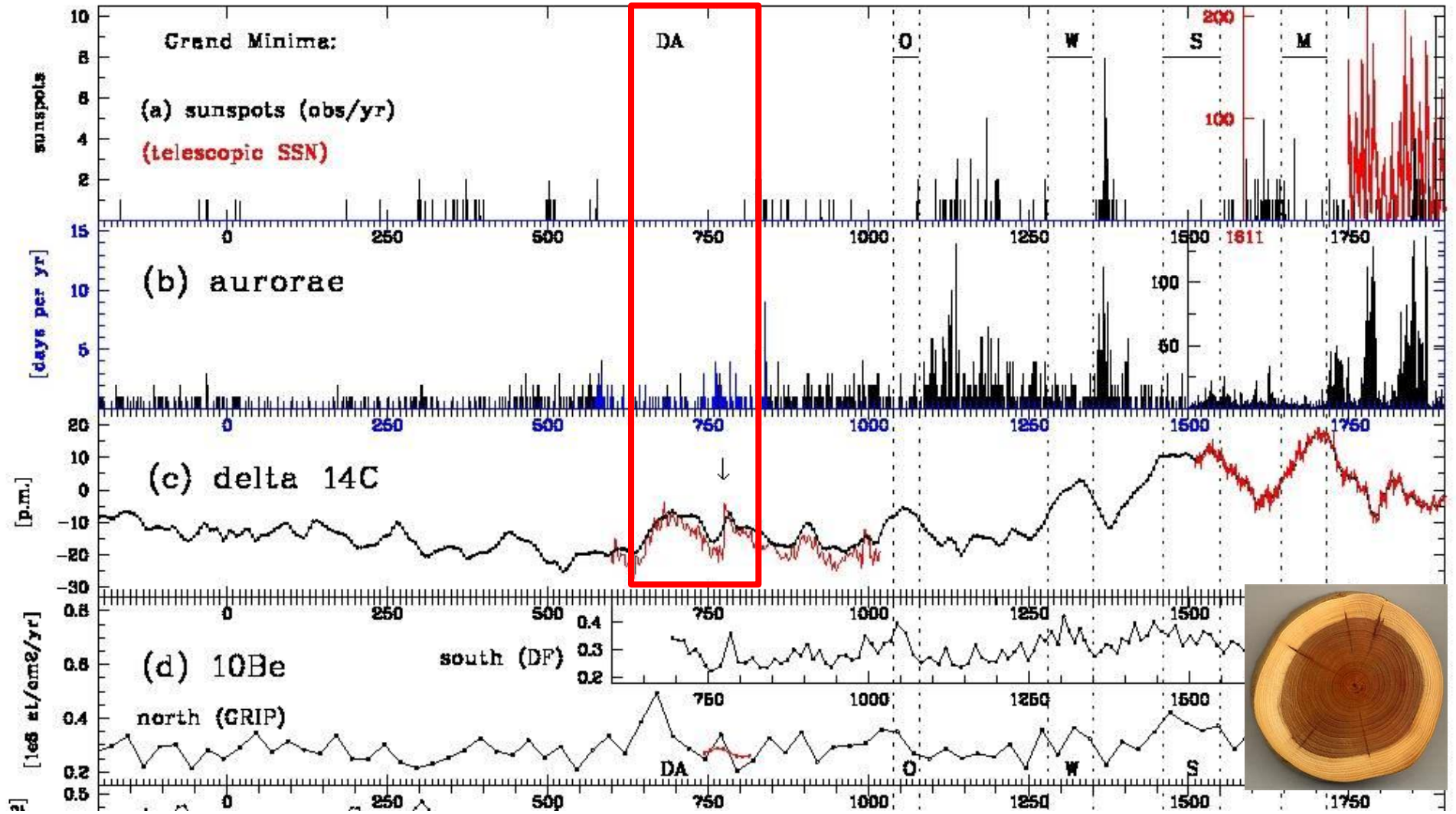
- Conjunctions to study Earth rotation changes
- Comets, meteors, etc.
- Historical Supernovae
- **Solar activity: A large solar super-flare around AD 775 ?**



Reconstruction of solar activity over millennia:

Less solar activity ➔ less solar wind
➔ more cosmic rays ➔ more ^{14}C and ^{10}Be

Grand Minima: **Dark Age** **O**ort **W**olf **S**pörer **M**aunder



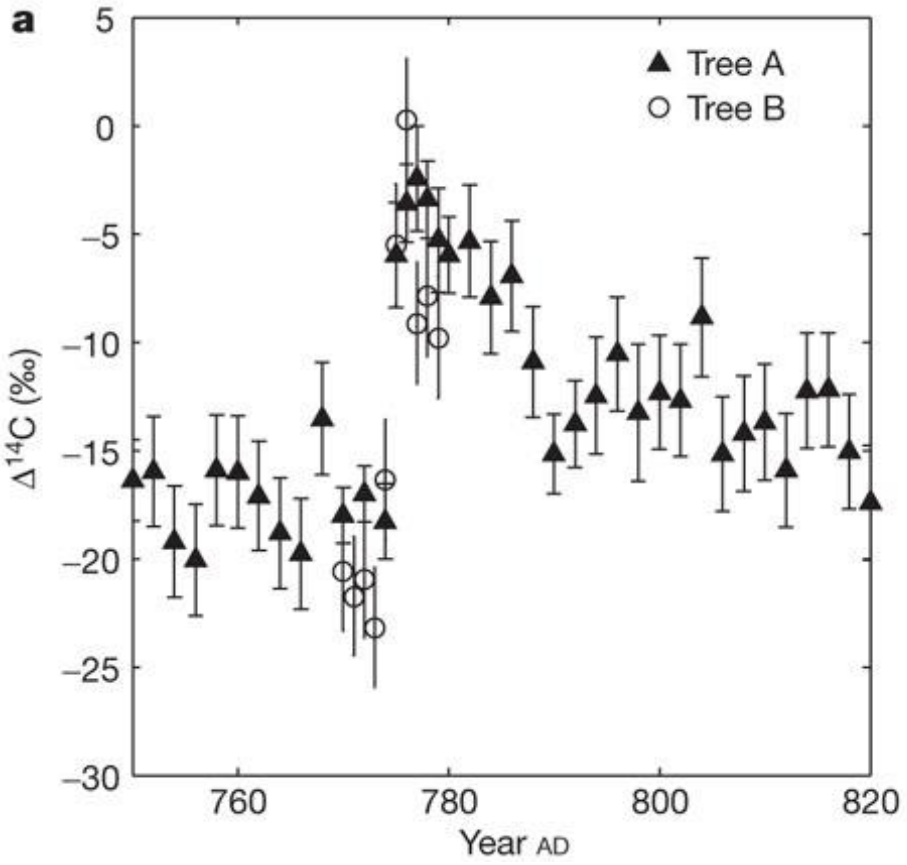
Strong ^{14}C variation around AD 775 –

What is the cause ?

Nearby supernova ?

Galactic gamma-ray burst ?

Solar super-flare ?



Miyake et al. 2012

^{10}Be and ^{14}C (radioactive isotopes)
form by cosmic rays modulated by solar wind
(and solar protons or γ-rays)

Cosmic rays (protons)
➔ spallation
➔ thermal neutrons

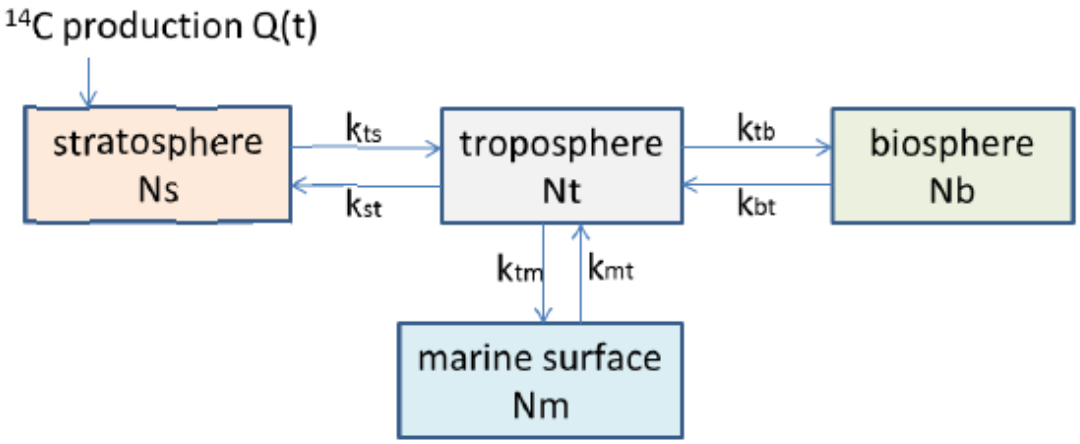
➔ $^{14}N(n,p)^{14}C$

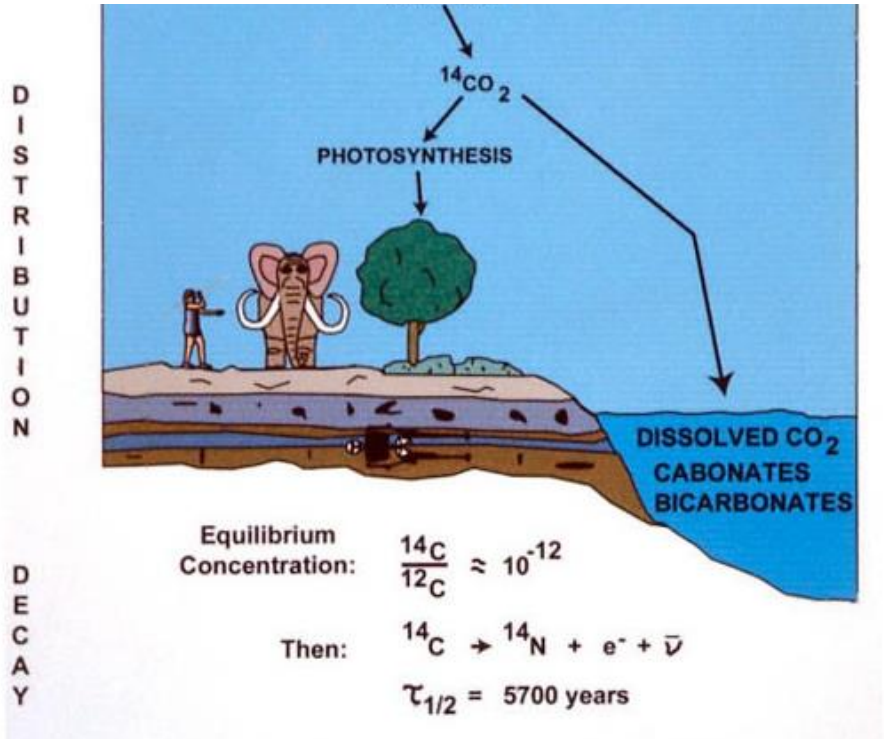
($^{14}N+n = p+^{14}C$)

(then ^{14}C ➔ ^{14}N
with half life 5730 yr)

$^{14}N(n,p+\alpha)^{10}Be$

(half life 1.36 Myr)





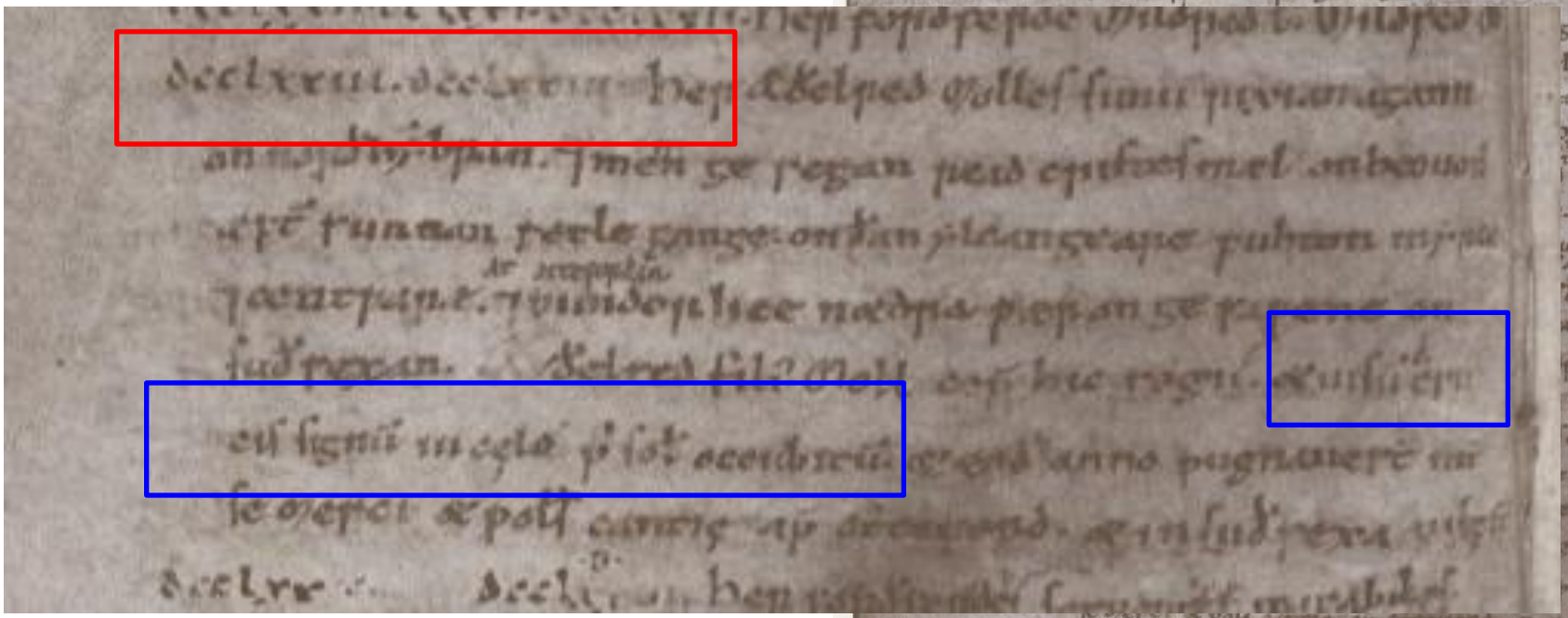
A red crucifix after sunset ?

Anglo-Saxon Chronicle:

„This year also appeared

in the heavens a red crucifix,

after sunset.“



Original in British Museum

773. 774 …

… & … cru-

cis signum in coelo p(ost) sol occidirum …

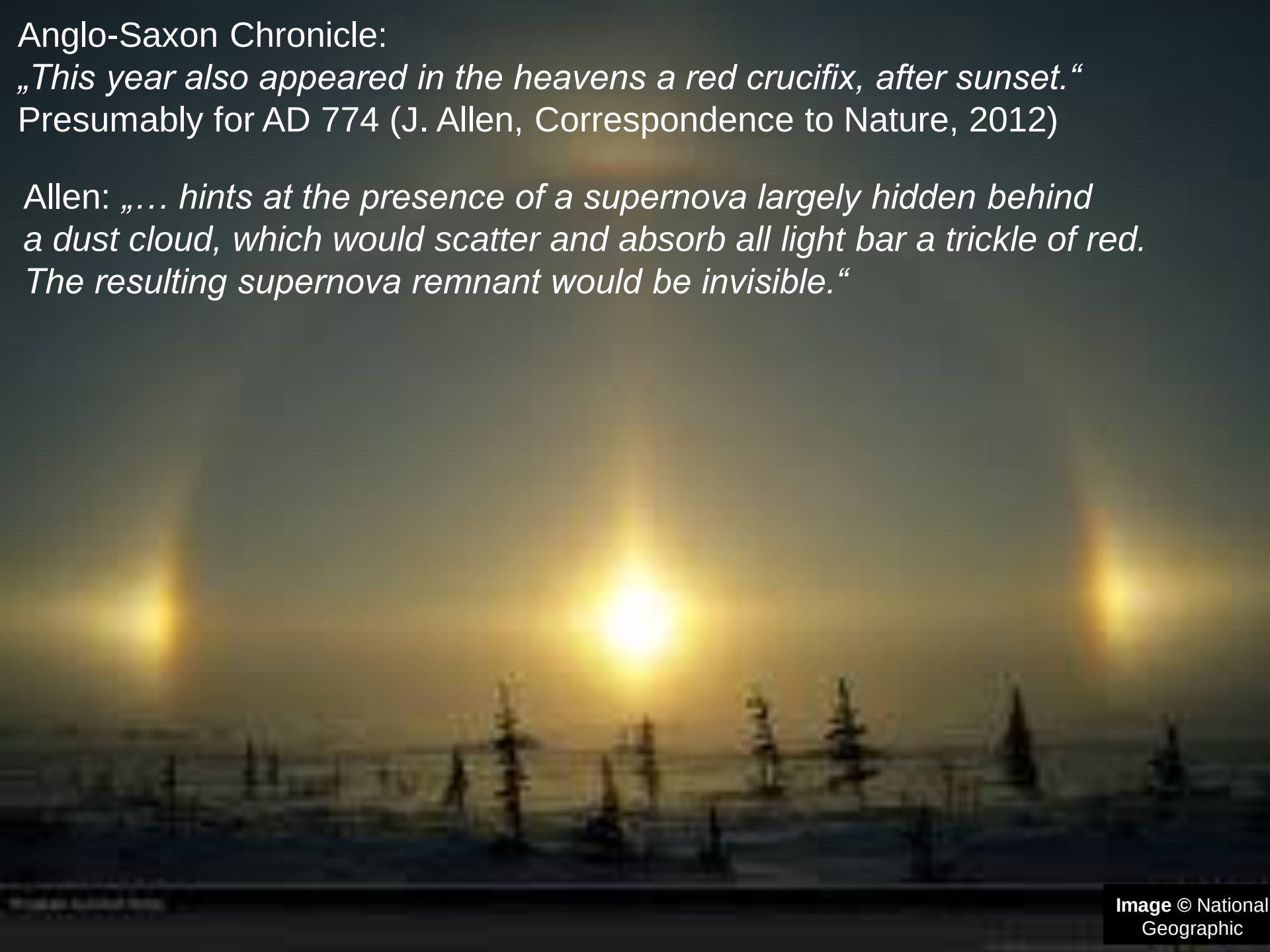
Manuscript F in Latin

old english: „Her ooeowde read Cristes mael on heofonum aefter sunnansetlgange“

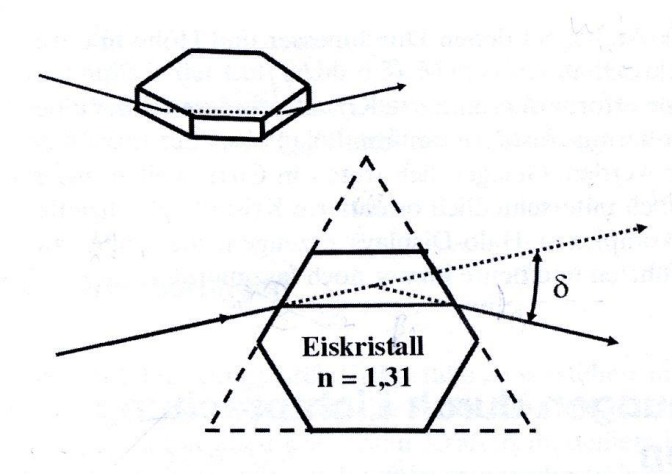
new english: „And also a red cross/crucifix on sky after sunset“

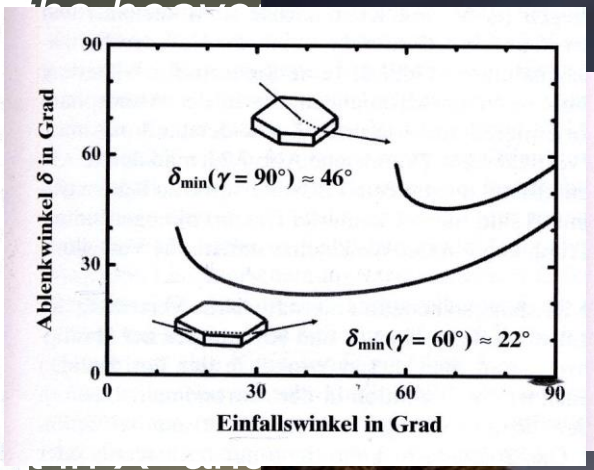
Anglo-Saxon Chronicle:
„This year also appeared in the heavens a red crucifix, after sunset.“
Presumably for AD 774 (J. Allen, Correspondence to Nature, 2012)

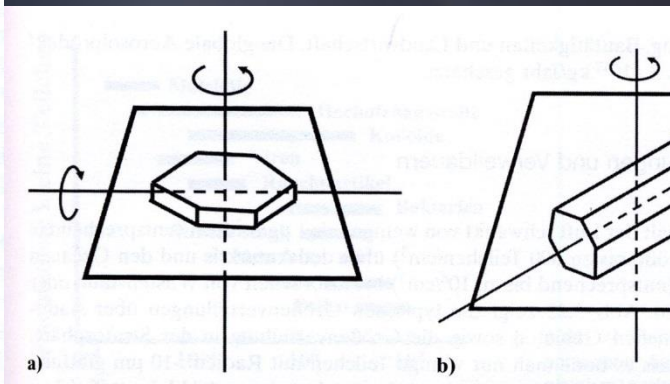
Allen: *„… hints at the presence of a supernova largely hidden behind a dust cloud, which would scatter and absorb all light bar a trickle of red. The resulting supernova remnant would be invisible.“*



Anglo-Saxon Chronicle:





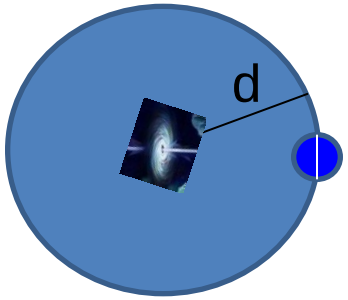


Red Cross: Parhelion with horizontal arc, sun-dogs, and vertical pillar (or paraselene if really *after sunset*)

A short GRB ?

Energetics

$$\frac{E_{\mathrm{event}} \cdot g}{E_{\mathrm{obs}}} = \frac{4 \cdot \pi \cdot d^2}{\pi \cdot R^2}$$



For E(obs) = 7e24 erg as in AD 775,

and for E(event) = 1e49…52 with g = 0.1 to 1 (short GRB),

it would have to happen at d = 0.1 to 4 kpc

i.e. within our Galaxy.

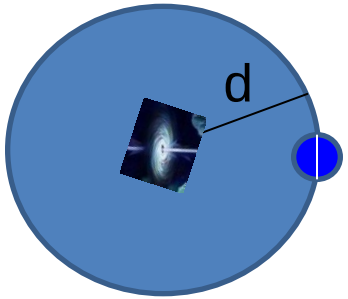
Events at that distance range are well possible !

➔ Energetics ok !

Hambaryan & RN 2013 MNRAS

short GRB

$$\frac{E_{\rm event} \cdot g}{E_{\rm obs}} = \frac{4 \cdot \pi \cdot d^2}{\pi \cdot R^2}$$



Energetics:

E(event) = 1e49…52 erg (short GRB)

➔ 0.1 to 4 kpc (ok, in our Galaxy)

Time-scale:

Up to 2 sec is consistent with ^{14}C increase (maybe < 1 yr)

Neither SN-like light curve, nor afterglow, nor SN remnant: ok

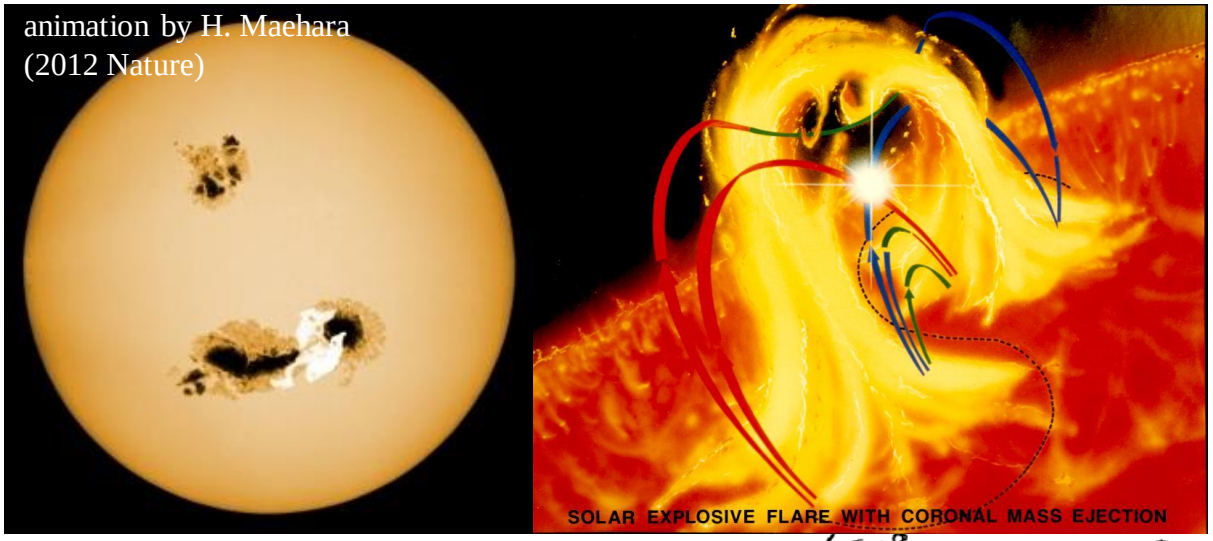
No mass extinction on Earth around AD 775 –
Ok if more distant than 1 kpc

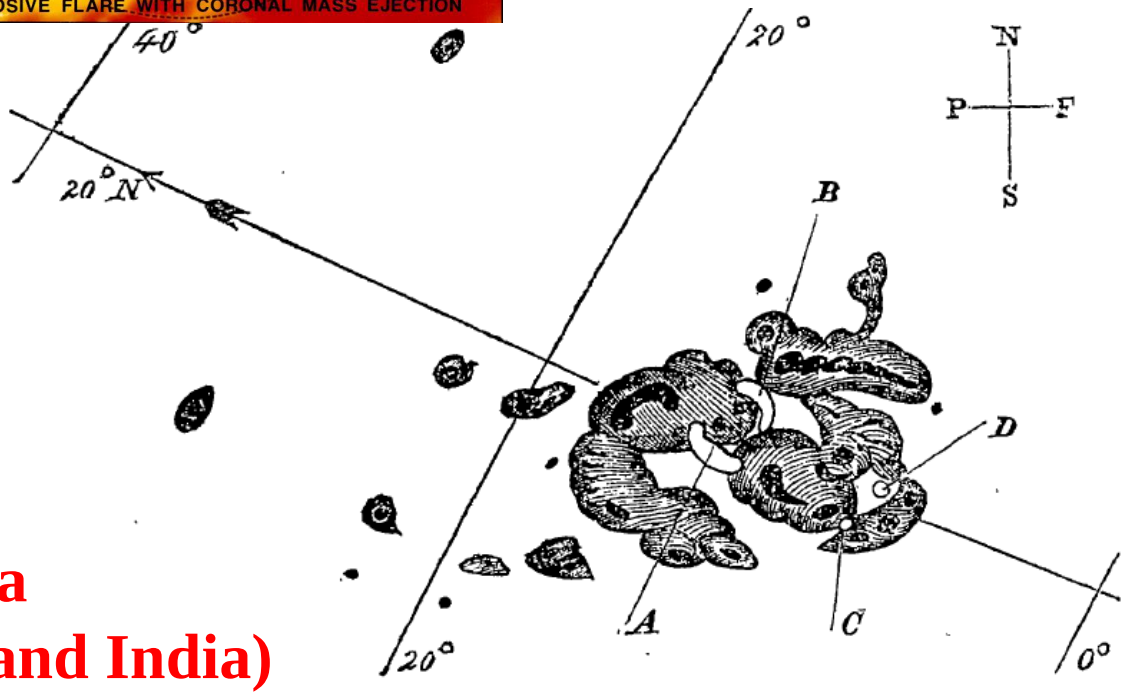
Spectrum:
Typical spectra of short GRBs are consistent
with production rates of ^{14}C and ^{10}Be !

Short GRB consistent with all observables !
(but very rare)

Hambaryan & RN 2013 MNRAS

A solar super-flare
(stronger than Carrington flare in AD 1859):





Almost world-wide aurora
in AD 1859 (incl. Hawaii and India)

Previous aurora suggestions for the 770s:

770 Jun 20, Xi'an, China: "In the **NW**, a white vapour [qi] extended across the sky." (Keimatsu) N=1, moon's last quarter Jun 20/21, possible aurora (?)

770 Jul 20, Xi'an, China: "A white vapour [qi] appeared in the **NW** direction. It extended accross the sky." (Keimatsu) N=1, moon's last quarter Jul 2, possible aurora (?)

772 Sep 29, Ireland: "The assembly of the hand-clapping at which occurred lightning and thunder like the day of judgment. The hand-clapping on St Michael's Day 29 Sep which called **fire from heaven**." (Usoskin)
N=2, new moon Oct 1, very possible aurora or thunderstrom (?)

772 summer, Amida, Turkey: "Another sign appeared in the northern side … a red sceptre, a green one, a black one, and a yellow one … it would change into 70 shapes." (Dall'Olmo)
N=3, probable aurora, summer 772

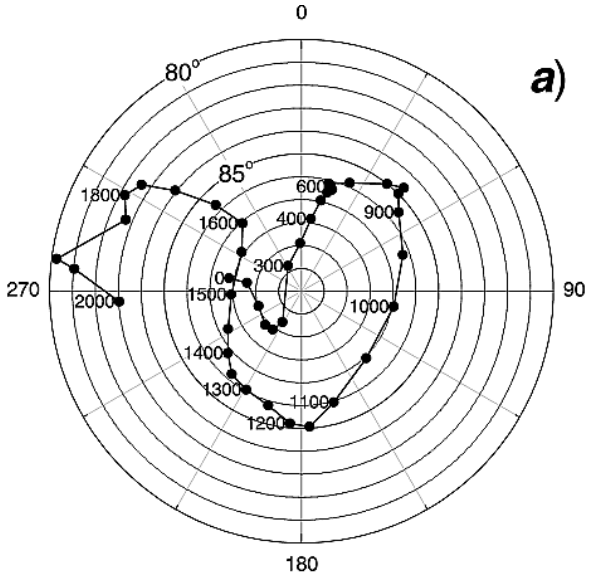
773 June, Amida,Turkey: "The sign that was seen a year ago in the northern region was seen again in this year … a red ray, a green one …" (Dall'Olmo)
N=3, probable aurora, 773 June

(next 786)

(Neuhäuser & Neuhäuser 2015 AN 336, 225)

Chronicle of Zuqnīn

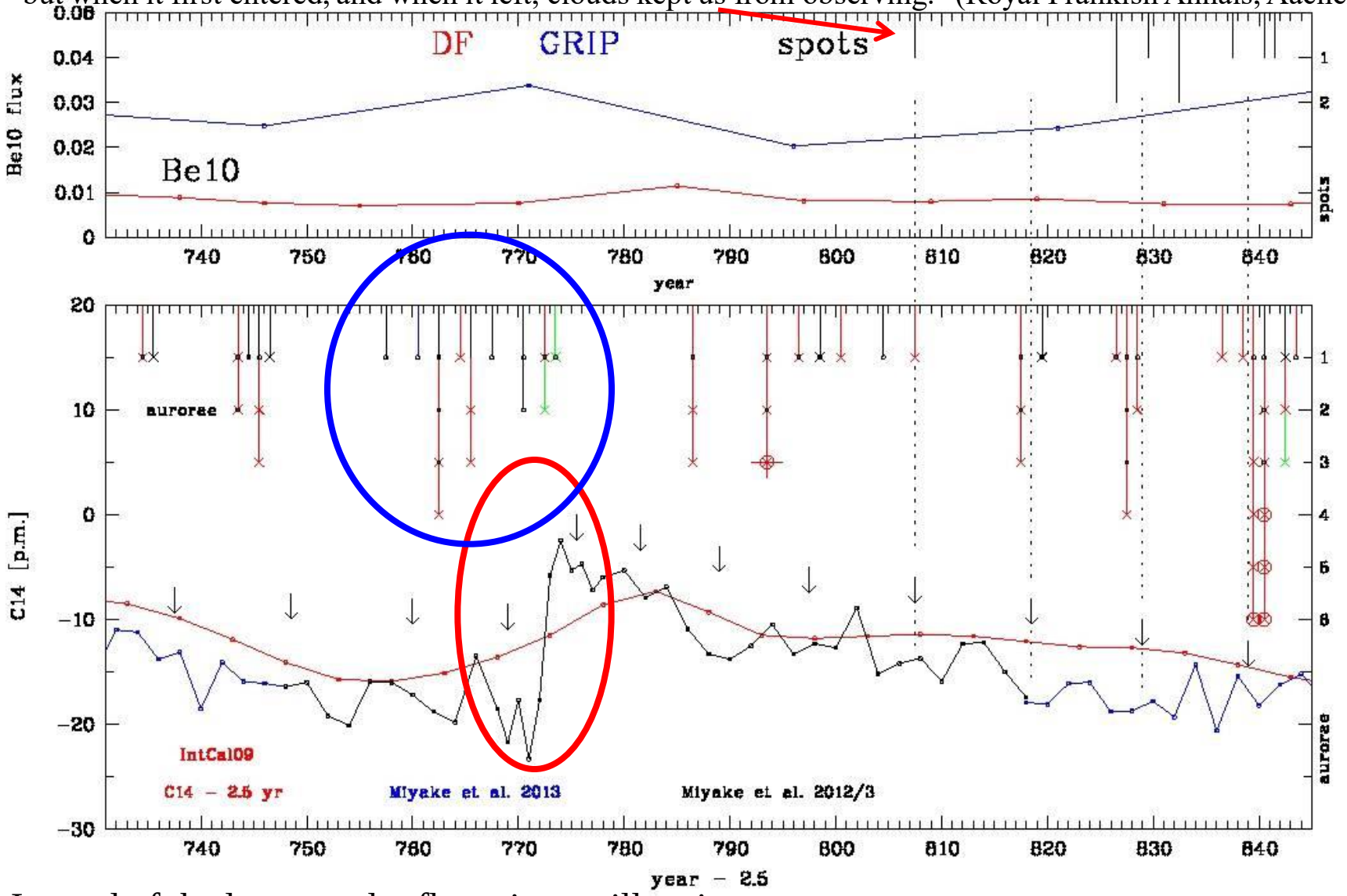
f),
f
l



772: Another sign … seen at harvest time … occupying the entire **northern** side … as follows: **a red sceptre**, a green one, a black one, and a yellow one. It was moving up from the ground, while one sceptre was vanishing and another appearing. … it would change into 70 shapes …

also on a Friday
in June AD 773

807 March: “the star Mercury on the 16th calends April [Mar 17] was seen in the Sun like a small black spot [in sole quasi parva macula, nigra tamen], a little above the center of that very body, and it was seen by us for 8 days, but when it first entered, and when it left, clouds kept us from observing.” (Royal Frankish Annals, Aachen)



Instead of the largest solar flare since millennia,

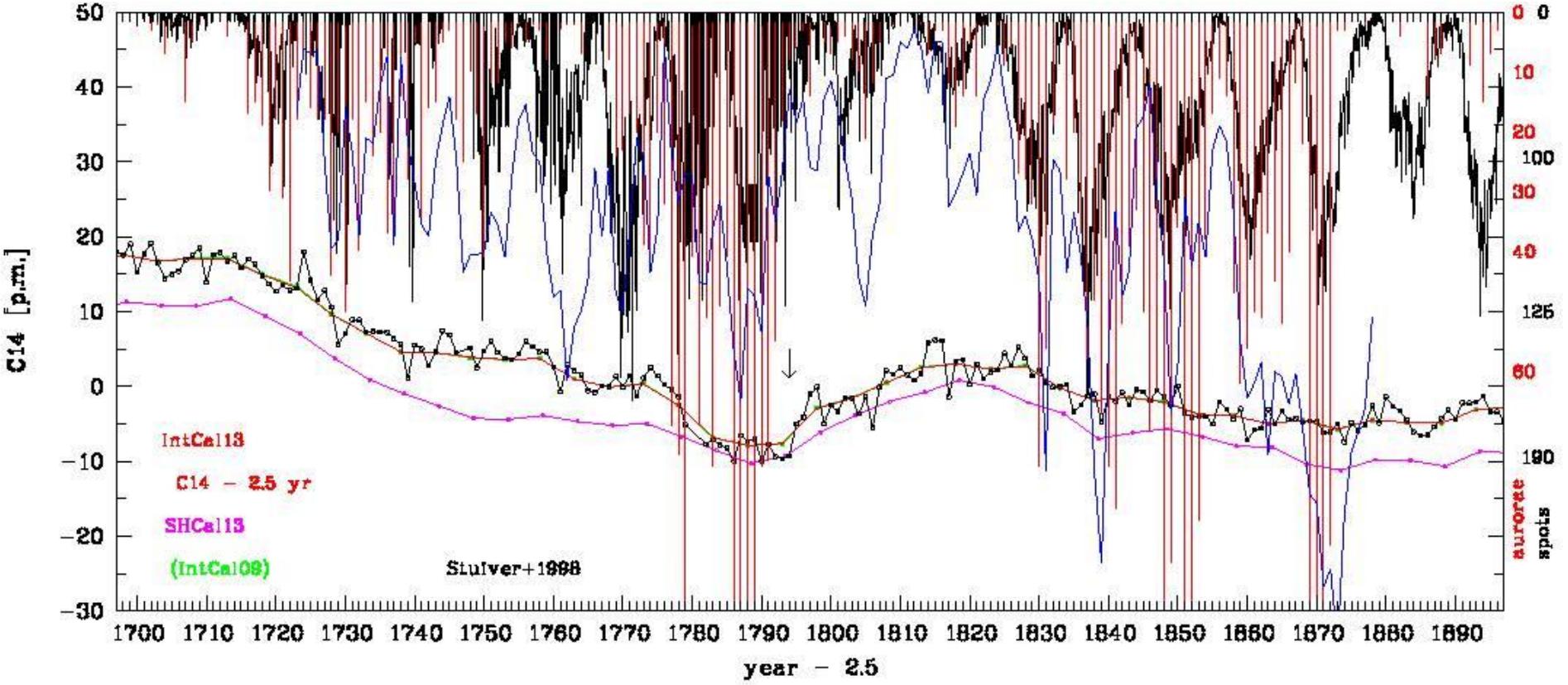
a fast strong drop in solar activity ➔ less solar wind ➔ more cosmic rays and ^{14}C

(Neuhäuser & Neuhäuser 2015 AN 336, 225)

Maunder Minimum ended AD 1712/15.

Aurora level increases from cycle minimum to minimum.

sunspots, aurorae (Tromholt, Fritz), ^{14}C

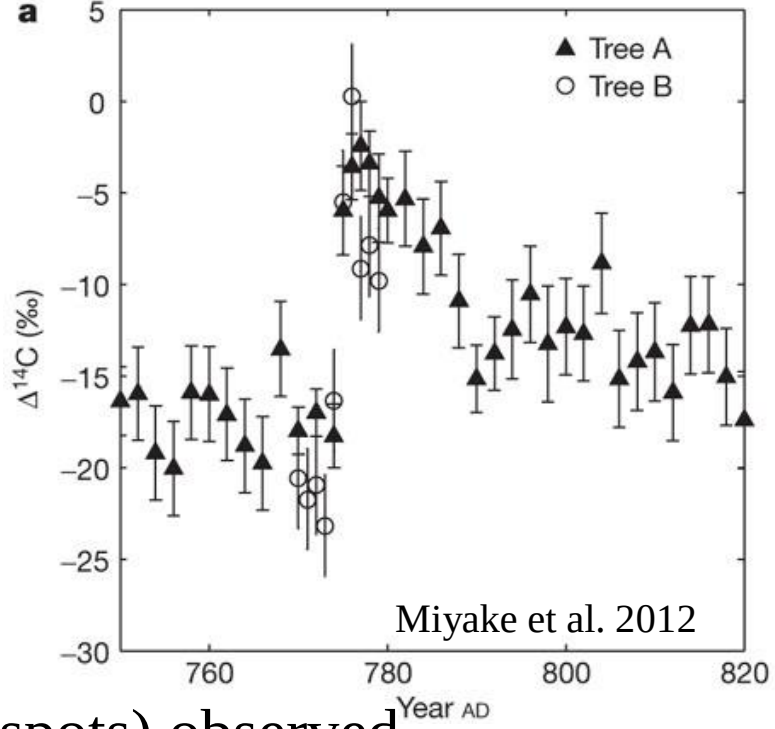


(1) At the end of the Grand Maximum (~1790) ➔ low ^{14}C level
(2) Decline of strong Schwabe cycle no. 4 (~ 1793) ➔ ^{14}C rises
(3) Weak activity in Dalton (~1800-1830) ➔ ^{14}C level high

Neuh & Neuh 2015

Strong ^{14}C variation around AD 775 –

What is the cause ?



Nearby supernova ? Not observed
(neither histor. nor SNR)

Gamma-ray burst ? Too rare

Solar flare ? Neither aurorae (nor super-spots) observed

What else ? We suggest a solar activity drop:

Less activity ➔ less solar wind

➔ more cosmic rays to solar system ➔ more ^{14}C on Earth

(around AD 775, weaker also around 994, 1795, and BC 671)

(Neuhäuser & Neuhäuser, 2015, Astron. Notes 336, 225 and 336, 930)

Problems with categorisation of „celestial signs“:

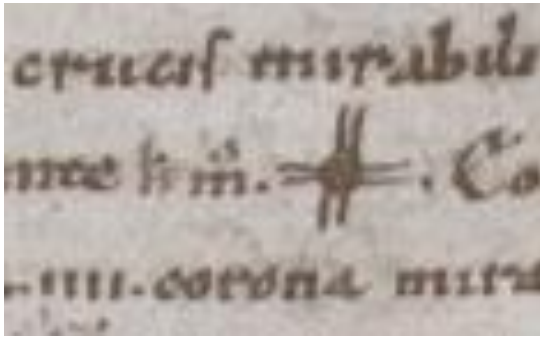
So far, seldom a historical-critical exegesis, but „quarry“

(e.g. Allen: „quick google research“ to red cross in AD 774/5)

- Critical text editions not consulted (variants, drawings, etc.)

- Dating ! Which calendar ? (also offsets in MSS)

- Translation problems (cross/crucifix, sky/heaven, etc.)



- consider the context and interpretation
  for categorisation of dubious phenomena

- Meaning of words change with time,

  e.g. lat. *cometes* or arab. *nayzak:*

  previously „transient celestial phenomenon“

  including comets, novae, supernovae, etc.

Uncritical categorisation

(e.g. *red cross* as supernova, aurora, airglow, meteor, etc.)

I. Historical time: at least ~ 3000 years
e.g. reconstruction of solar activity, historical Supernovae, etc.

II. Astronomical time scale: ~ Myr
Supernovae, neutron stars, runaway stars

Astrophysical and cultural relevance of historical celestial observations

- Conjunctions to study Earth rotation changes
- Comets, meteors, etc.
- Historical Supernovae
- Solar activity: A large solar super-flare around AD 775 ?