

太元十一年三月客星在南斗至六月乃没占  
曰有兵一曰有赦是後司雍充督其而有兵殺十

# G7.7-3.7: a young supernova remnant probably associated with the guest star in 386 CE

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(Veni Fellow)



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Collaboration

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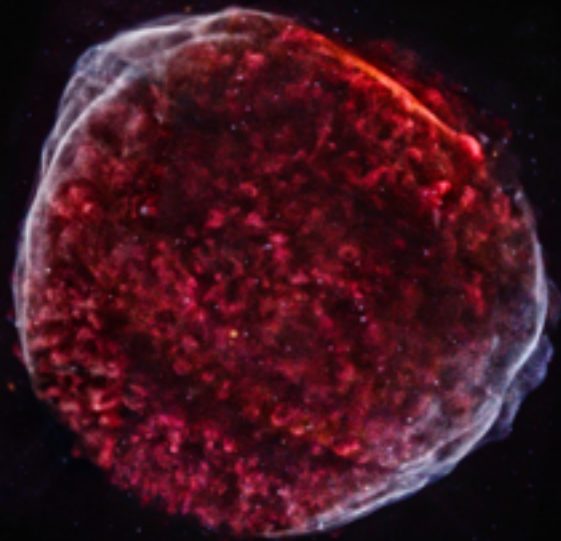
(historians of astronomy) G. Li, S. Zhao



# Historical supernovae in the 2nd millennium

SNR—SN connections using historical records

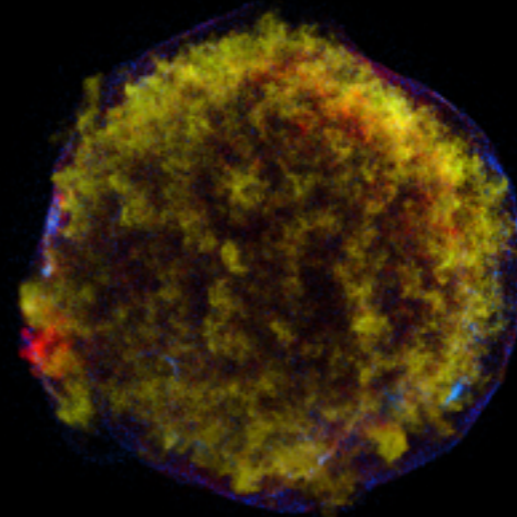
SN 1006



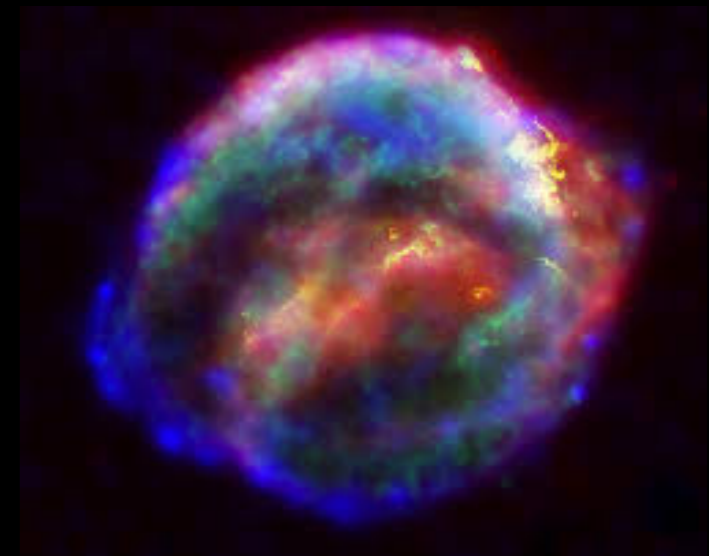
Crab



Tycho's SNR



Kepler's SNR



chandra/HST

CE

**1006**

1181 (3C58?)

**1054**

**1572**

**1604**

records  
from

China  
Japan  
Arab  
Europe

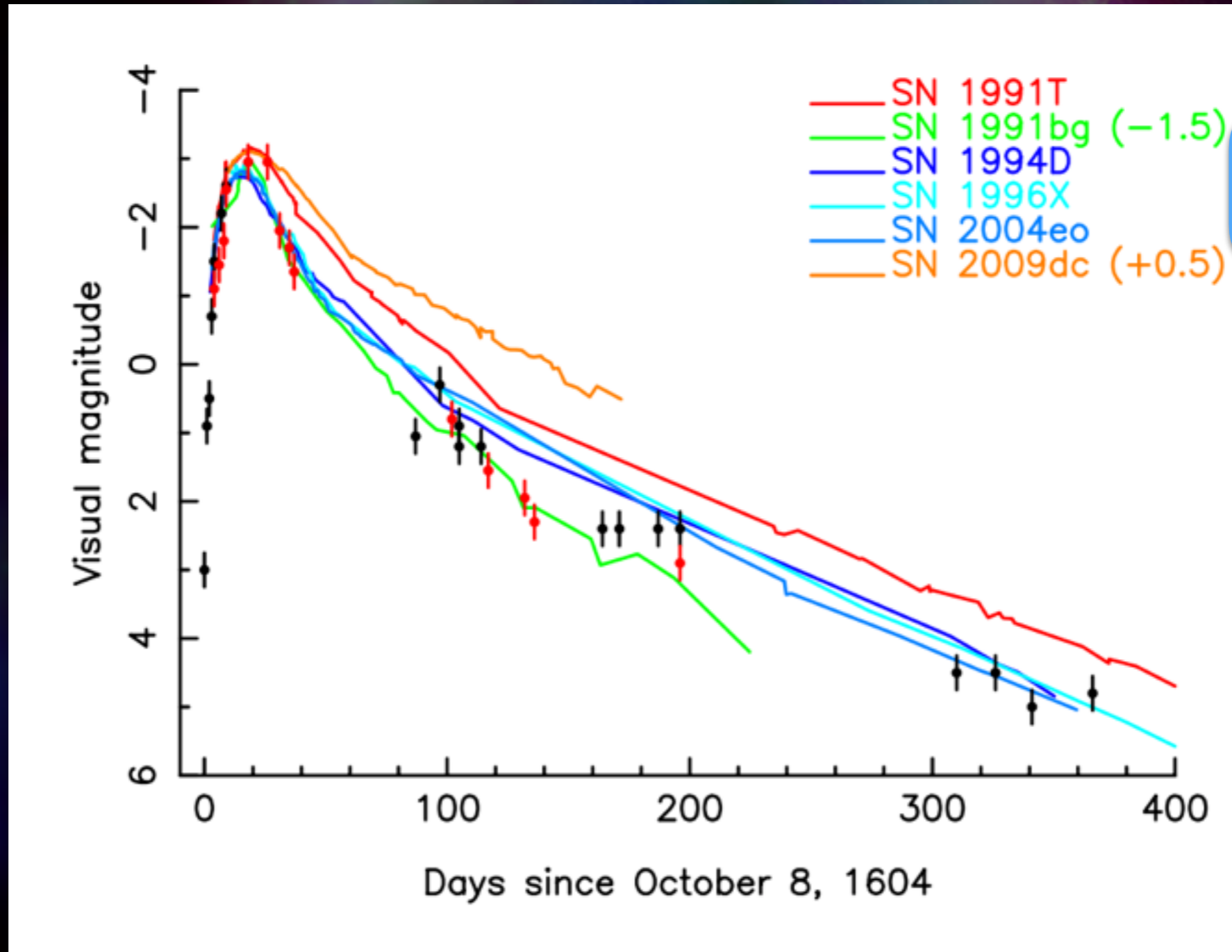
China  
Japan  
Arab

Europe  
China  
Korea

Europe  
Korea  
China

Green & Stephenson 2003

# Light curve of Kepler's SN using ancient observations



-19.44	Bright Type Ia
-17.77	Sub-Chandrasekhar
-19.00	Normal Type Ia
-18.16	Normal Type Ia
-19.11	Sub-Chandrasekhar?
-19.89	Super-Chandrasekhar

black dots — European observations  
 red dots — Korean observations

Vink 2017



# Historical supernovae in the 1st millennium?

RCW86



NASA/JPL-Caltech/UCLA - WISE

Vink et al. 2006

RXJ1713.7-3946



Wang, Qu, Chen 1997

Acero + 2017

? ?

CE

185

369?

386?

393

China

Europe?

后汉 中平二年

8 or 20 months

China

晋太和四年

5 months

China

晋太元十一年

3 months

China

晋太元十八年

8 months

Xi 1955, Xi & Bo 1965

records  
from  
length of  
visibility

# Types/Diversity of historical supernova remnants (SNRs)

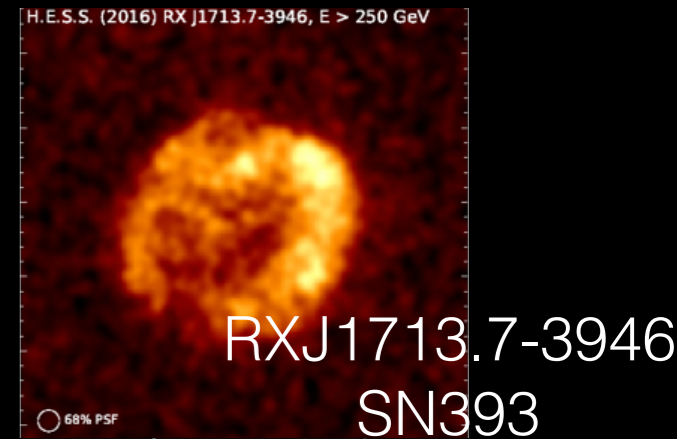
Type Ia  
(from white dwarfs)

RCW 86  
SN185

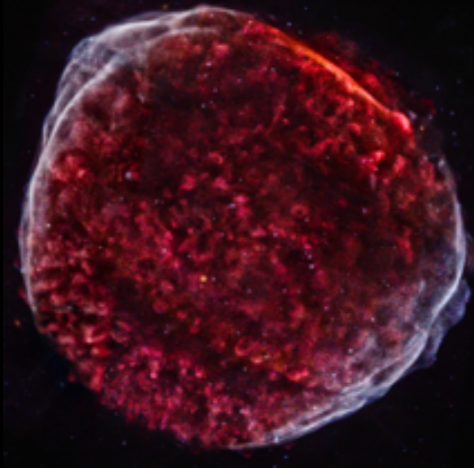


SNR with a central compact object,  
progenitor mass  $\sim 15 M_{\text{sun}}$  (Chen,  
Zhou & Chu 2013)

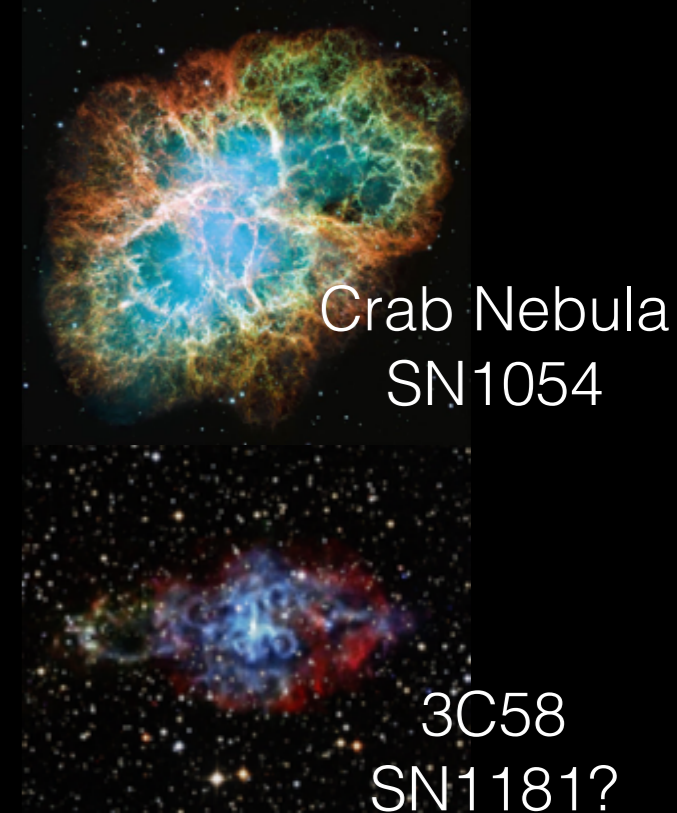
core-collapse or non-Type-Ia  
(from massive stars)



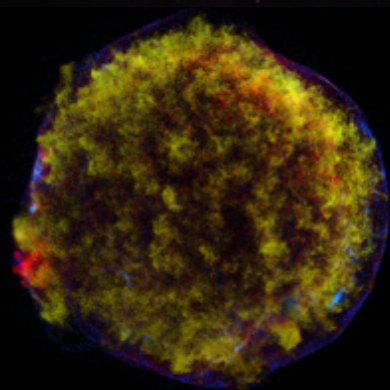
SN1006



A pulsar wind nebula likely from a  
Type II-P SN,  
progenitor mass  $\sim 8\text{--}10 M_{\text{sun}}$   
(Smith 2013)

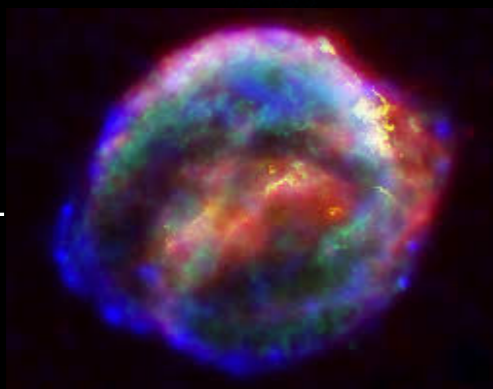


Tycho  
SN1572



The number of historical core-collapse SNRs < sub-types of core-collapse SNe (Type II-P, II-L, II-b, Ib, Ic, ...)

Kepler  
SN1604



We need to find more  
historical core-collapse SNRs.  
Guest stars **386** and 369



# Guest star in 386 CE

Songshu by Shen Yue

宋书 沈约

太元十一年三月客星在南斗至六月乃没占  
曰有兵一曰有赦是後司雍充冀冀而有兵後十

二年正月大赦八月又赦

太元十一年二月戊寅熒惑八月占曰有亂皇死  
相持有戰者一曰親為敗天下亂是時琅玕主  
輔佐主如從口國寶以姻昵受寵又陳郡人素沈  
昧私苟進交連主相扇揚朋黨二年帝親視  
於吳主相有明圖借興矣

太元十二年十一月庚午太白書見在斗十三

閏月戊辰天狗東北下南聲十二月戊子辰星

八月在斗占曰賊臣欲殺主不出三年必有内亂

是年熒惑在斗六月形色熒盛占曰熒惑其常

吏出棄其法詔侯亂其政自是後慕容容平建述

姚萇苻苌黃蓋谷永並明兵爭疆十四年正月彭

城叛城又稱號於丘則牢之破滅之三月張道

破合鄉圍大山向欽之殺走之是年司隸遼又

沒陽陽路陳項等事多矣治道陵遲

太元十四年十二月熒惑入羽林乙未月犯

During the third month of the eleventh year of the Tai-Yuan reign-period of the Jin dynasty, there was a guest star at Nan-Dou (南斗) until the sixth month, when it was extinguished

- time: 386 CE
- position: Nan-Dou  $l \sim 6.9^\circ - 10^\circ, b \sim -1.6^\circ - 15.4^\circ$
- duration of the visibility: 2—4 months



# Previous searches for the remnant of Guest star 386

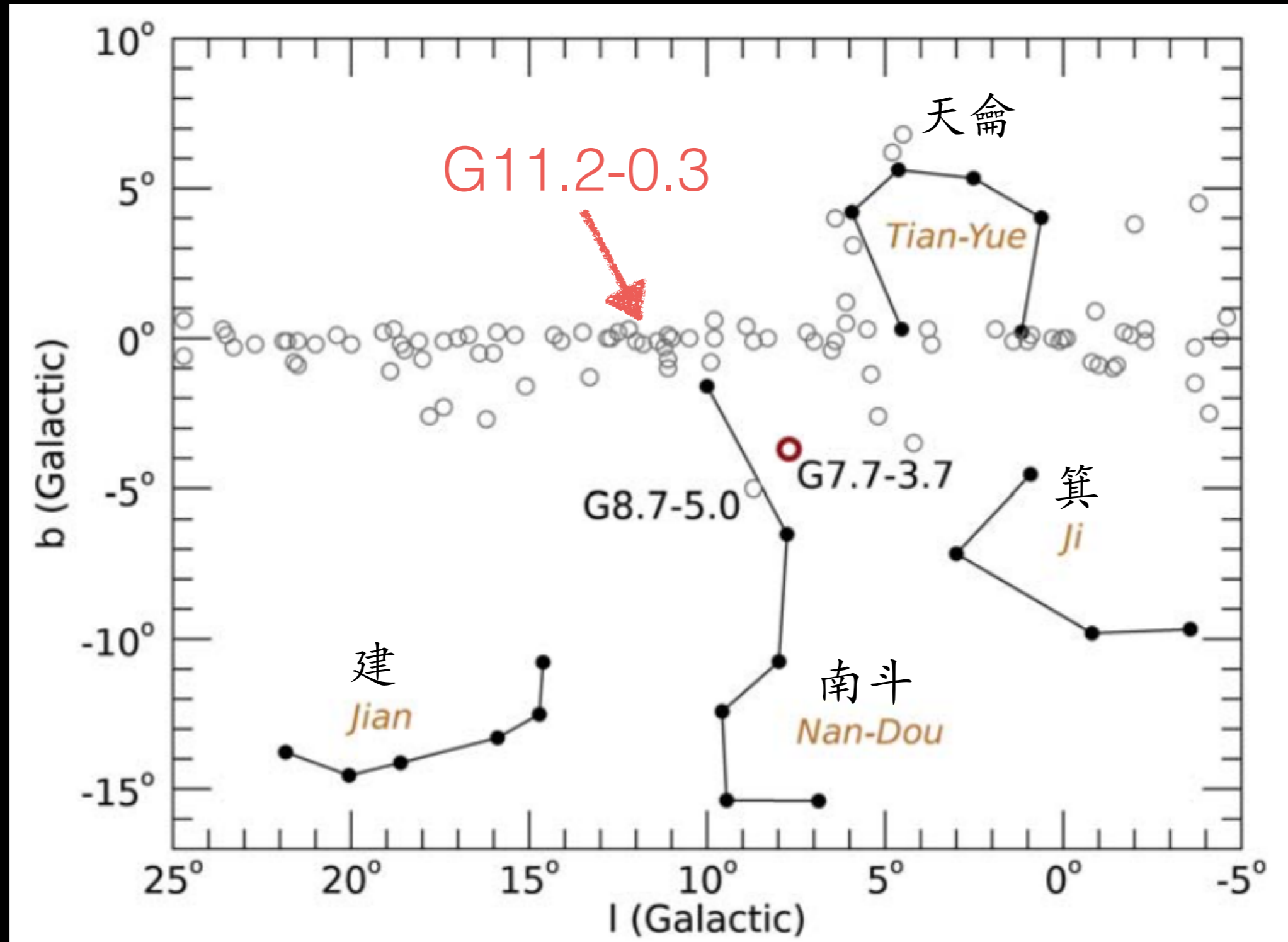


G11.2-0.3

- position: a few degrees away
- distance: 5 kpc
- age: 1.4—2.4 kyr
- **absorption: too large ( $A_V \sim 16m \pm 2m$ )**

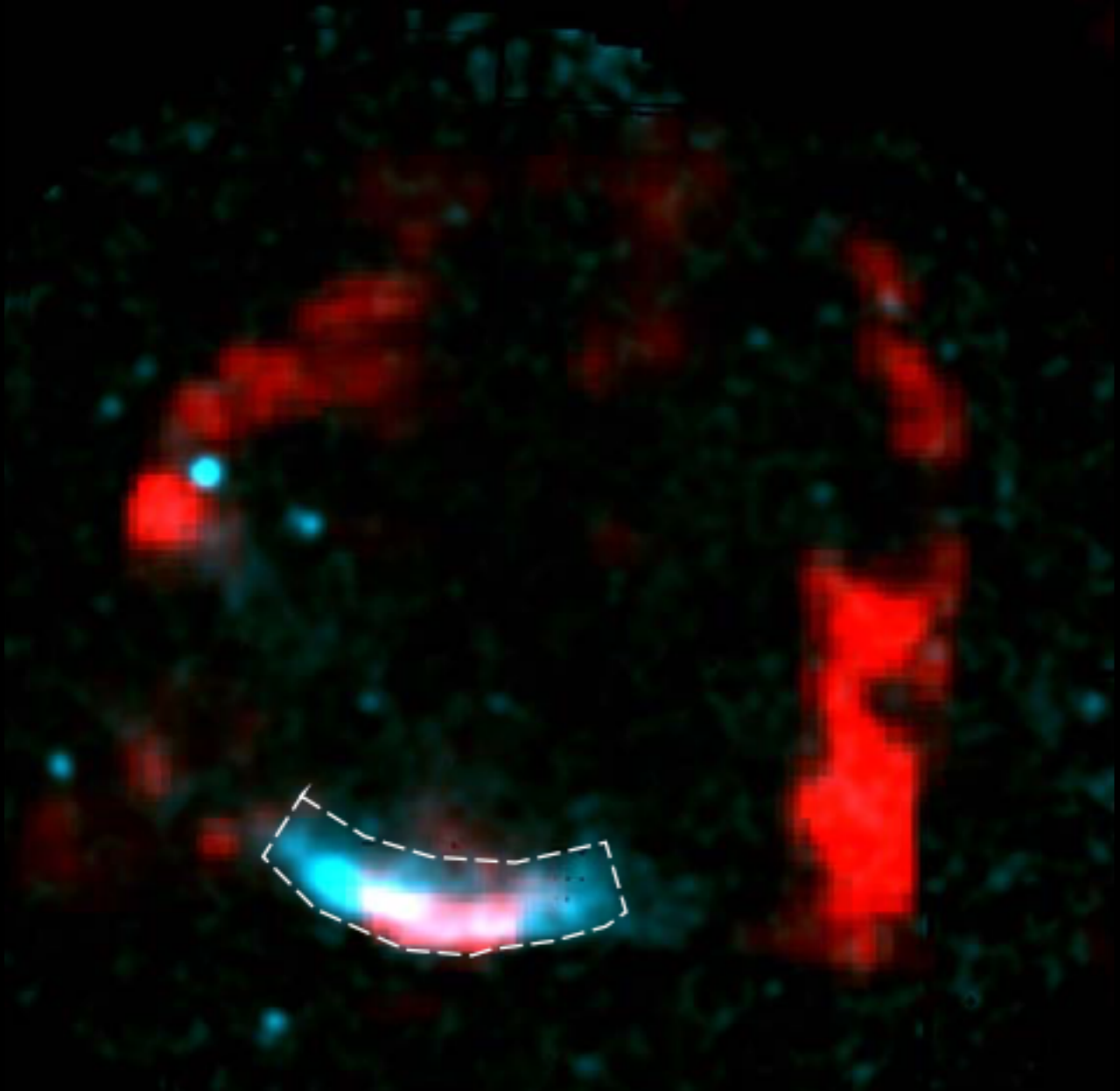
Borkowski+2016

# Position of Nan-dou and SNRs





# G7.7-3.7



red: VLA (radio)  
cyan: XMM-Newton (X-ray)

Distance: 3–6 kpc ( $\Sigma$ -D, Milne + 1996, Pavlovic+2014)

Archival XMM data:

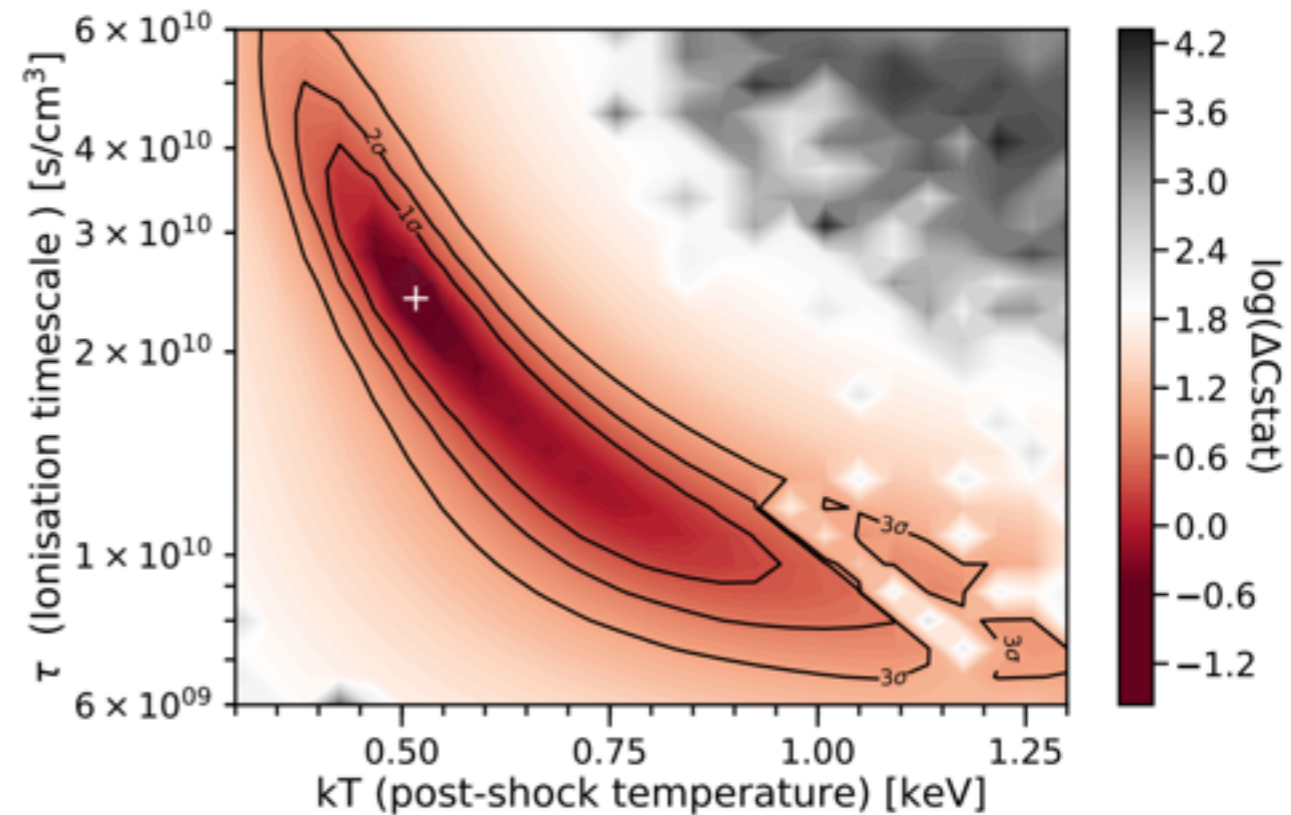
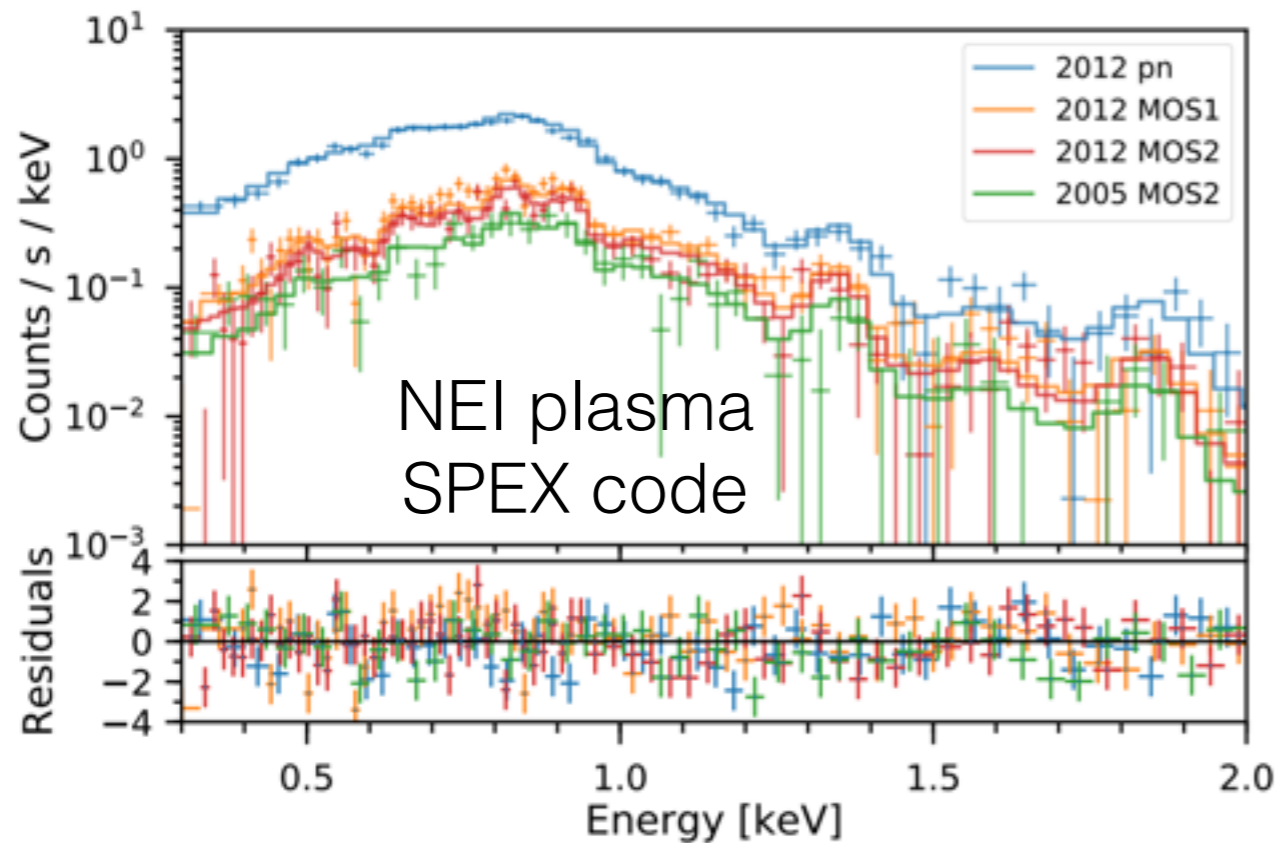
2005 (ObsID: 0304220401,  
PI: E. Gotthelf, only MOS2)

2012 (ObsID: 0671170101,  
PI: M. Smith)

only 10 ks in total

We need the SNR age and extinction

# Spectral analysis of the 10 ks X-ray data



- $N_H = 3\text{--}4 \text{ E}21 \text{ cm}^{-2} \rightarrow$  **low extinction  $A_V \sim 1.2$**
- Ionization timescale:  $1\text{--}4 \text{ E}10 \text{ s cm}^{-3} \rightarrow$  **SNR age  $t \sim 0.6\text{--}1.8 (d/4 \text{ kpc})^{0.5} \text{ kyr}$**
- Temperature  $kT = 0.4\text{--}0.8 \text{ keV}$
- Abundance  $<$  solar (ISM dominated)
- Density:  $n_H \sim 0.5 \text{ cm}^{-3}$

ionization timescale  $\tau = \int_{t_s}^{t_0} n_e dt$

10



# Info about G7.7

Probably SN 386:

Age: 600 – 1800 yr ( $1-\sigma$ )

Position: very close to Nan-Dou (part of Sgr)

Distance: 3–6 kpc ( $\Sigma$ -D, Milne + 1996, Pavlovic+2014)

$A_v$ : 1.2

Peak Brightness: brighter than -2 mag for normal SN with peak  $m_v = -17$

Explosion energy:  $2e51 (d/4 \text{ kpc})^{4.5}$  erg

Intriguing properties:

- faintest historical SNR in X-ray
  - no evidence of SN ejecta
  - no X-ray synchrotron emission
- Low density medium ( $0.1 \text{ cm}^{-3}$  + special SN?)

# A special SN according the historical record in 386 CE?

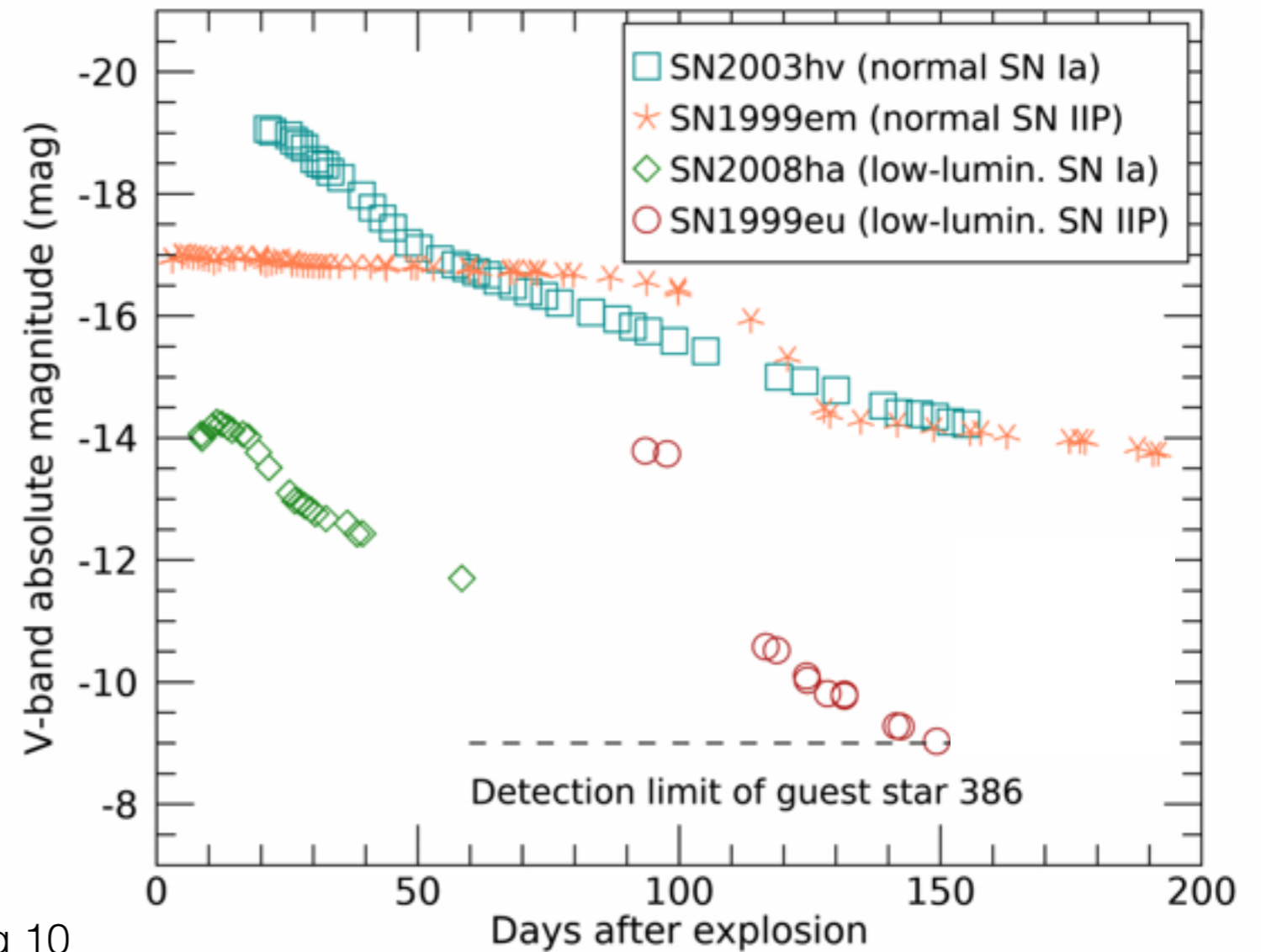
The guest star was only visible on the Earth within 2—4 months

$$m_V = M_V + 5 \log(d/10 \text{ pc}) + A_V$$

Record of SN 386: Apr 15/May 14 — Jul 13/Aug 10

Visibility of Nan-Dou asterism in 386 CE: Jan — Oct

low-luminosity SN explosion?



V-band light curve



# Summary and outlook

- G7.7-3.7 is a probable remnant of the Guest star 386, which is likely a rare low-luminosity SN.
- To date, we have known ~8 historical SNRs. Our study increases the diversity of this small sample.
- The properties and SN (transient?) type of G7.7-3.7 are intriguing. We are conducting a multi-wavelength campaign to pin down the association between G7.7-3.7 and Guest star 386 and to unveil its SN properties.

*Workshop at Lorentz Center  
Leiden, the Netherlands*

# Historical Supernovae, Novae and Other Transient Events

from 14 Oct 2019 through 18 Oct 2019

Topics:

- historical supernovae
- historical novae
- properly understanding historical records and exploring (new) records from different cultures
- prehistorical transient phenomena (e.g. nearby supernovae measured with  $^{60}\text{Fe}$ , proton events measured with  $^{14}\text{C}$ , etc.)



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