

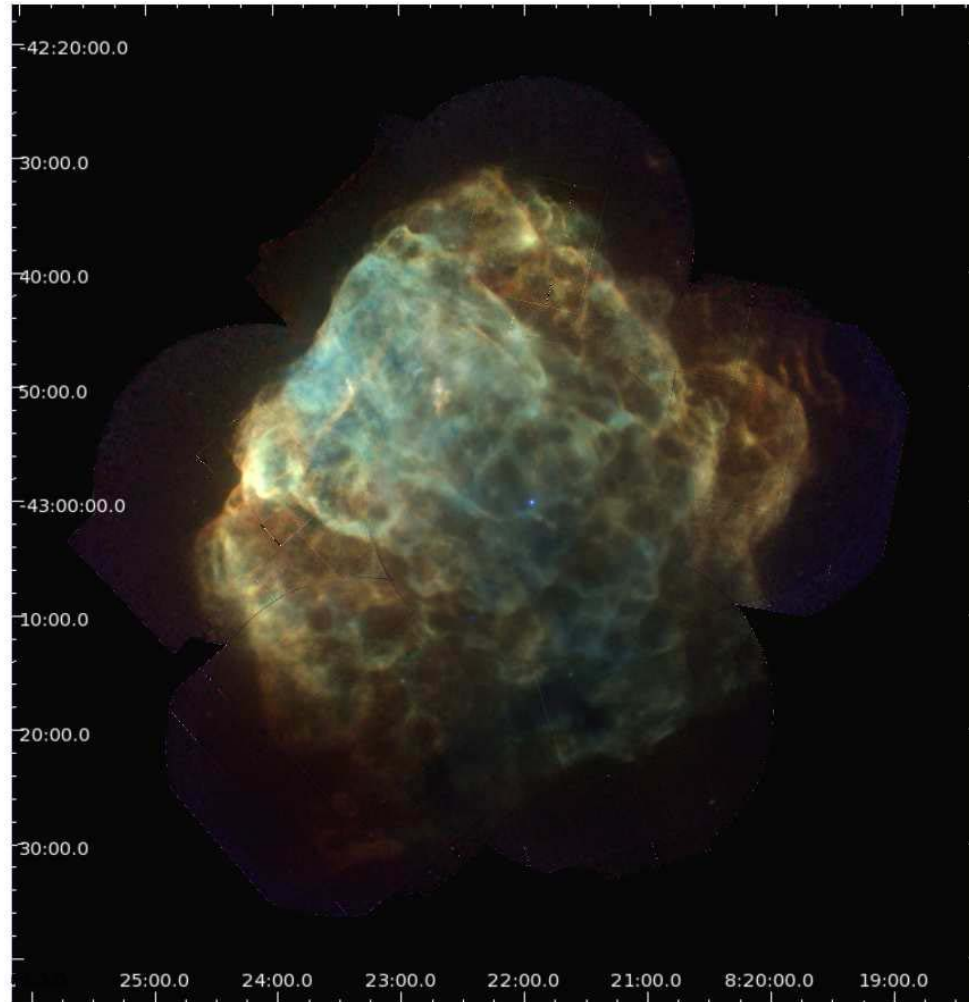
Age and Distance of Puppis A Revised

- The Supernova Remnant of the 'Star of Bethlehem' -

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Puppis A in X-Rays

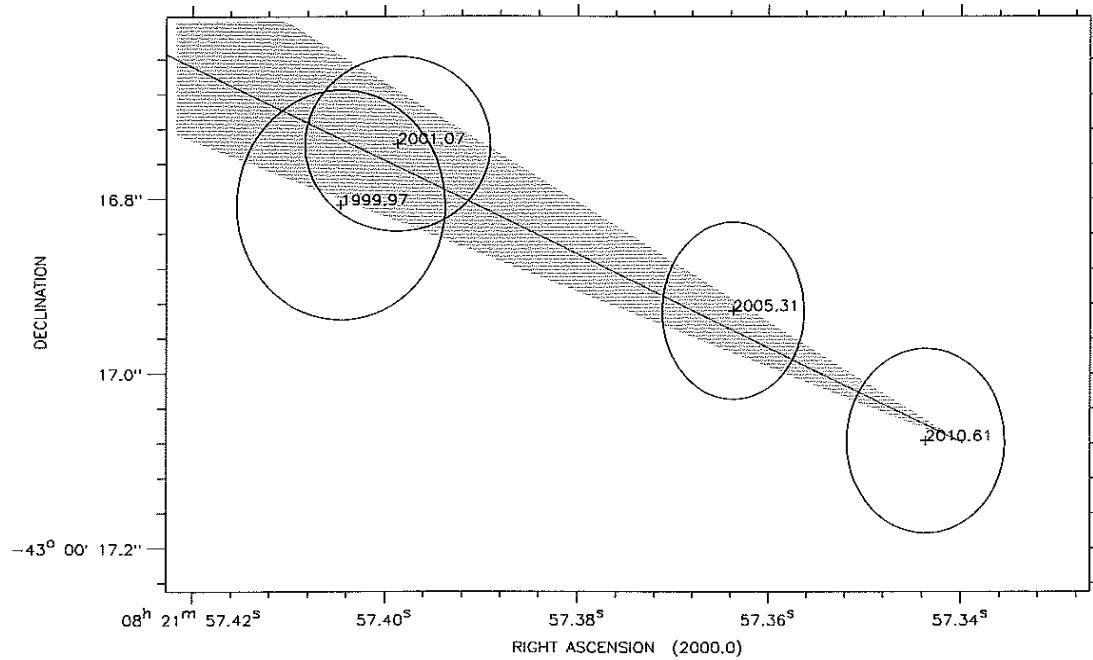


$d = 2.2$ kpc

age: 4500 yrs

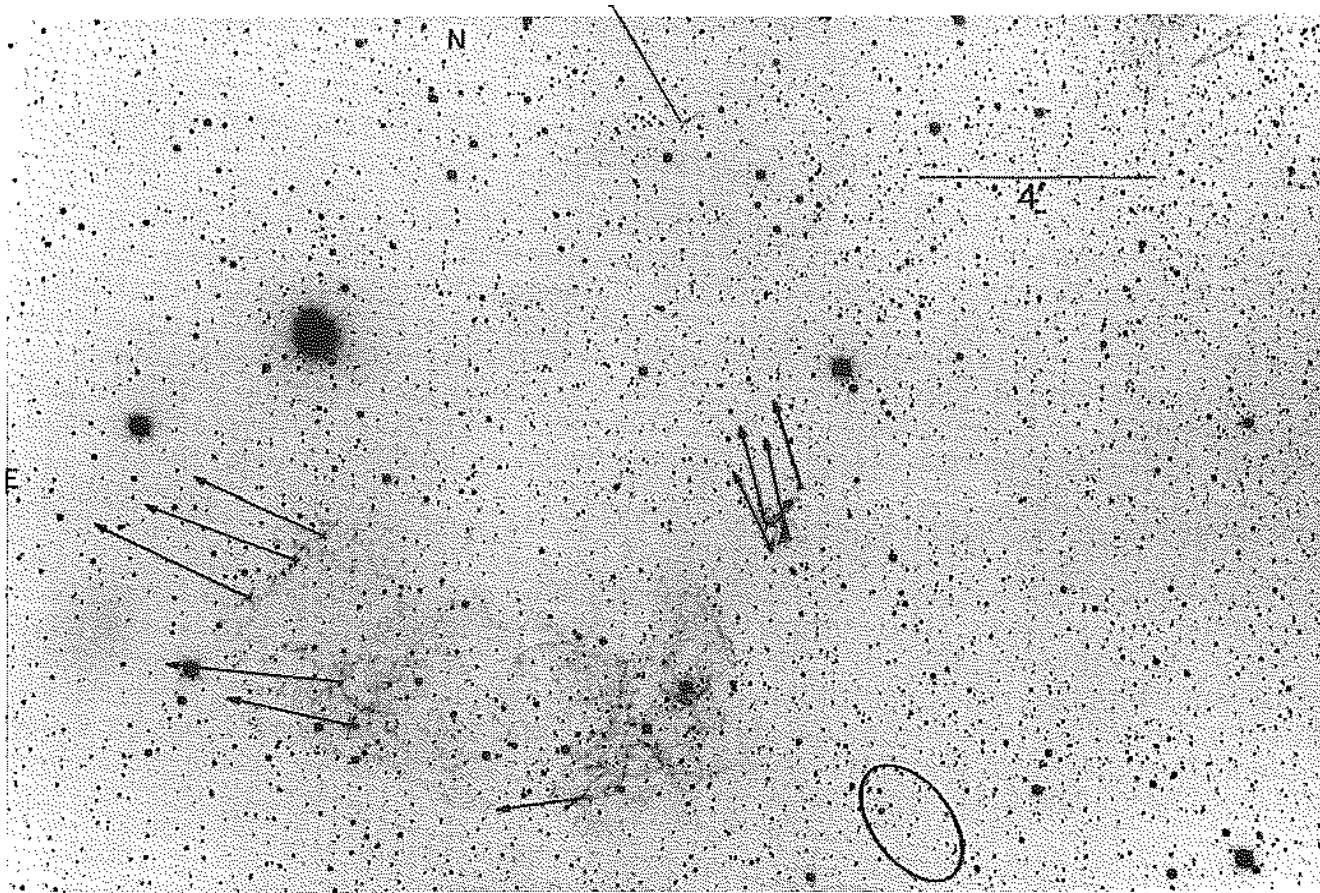
the currently best traded values

Proper Motion of the Puppis A Neutron Star



Becker et al., 2012

Location and Proper Motion of Oxygen Rich Filaments (ORF)



$$t_0 = 3700 \pm 300 \text{ yrs}$$

(RA, Dec) of
expansion center =

Explosion Site

Figure 1. Section of CTIO green plate shows primarily [O III] and H β emission. The arrows indicate proper-motion vectors for approximately 1000 yrs. The 90-percent-confidence contour for the expansion center is shown by the ellipse.

Winkler et al., 1988

Results

ORF: $(RA, Dec)_O$ of explosion site; age: $t_0 = 3700 \pm 300$ yrs

NS: $(RA, Dec)_{NS}$ of present location
proper motion: $\mu = 71 \pm 12$ mas/yr

p.a.: $244 \pm 11^\circ$

separation (s) between ORF and NS: $s = 371''$



age: $t = 5200 \pm 1000$ yrs

FIRST CONFLICT

SECOND CONFLICT

for $d = 2.2$ kpc , $\mu = 71 \pm 12$ mas/yr correspond to a space velocity of

765 ± 130 km/s !!! (max. kick velocities of pulsars < 500 km/s)

Suggestion for a Solution

N.B. data for age and explosion center position derived from the ORFs assumes

NO DECELERATION OF THE ORFs

Alternative: **DECELERATION OF ORFs**

self similarity: $r \sim t^m$ and $v = m \langle v \rangle$

no radial symmetry: $r_x \sim t^{m_x}$ and $v_x = m_x \langle v_x \rangle$

$r_y \sim t^{m_y}$ and $v_y = m_y \langle v_y \rangle$

The Configuration

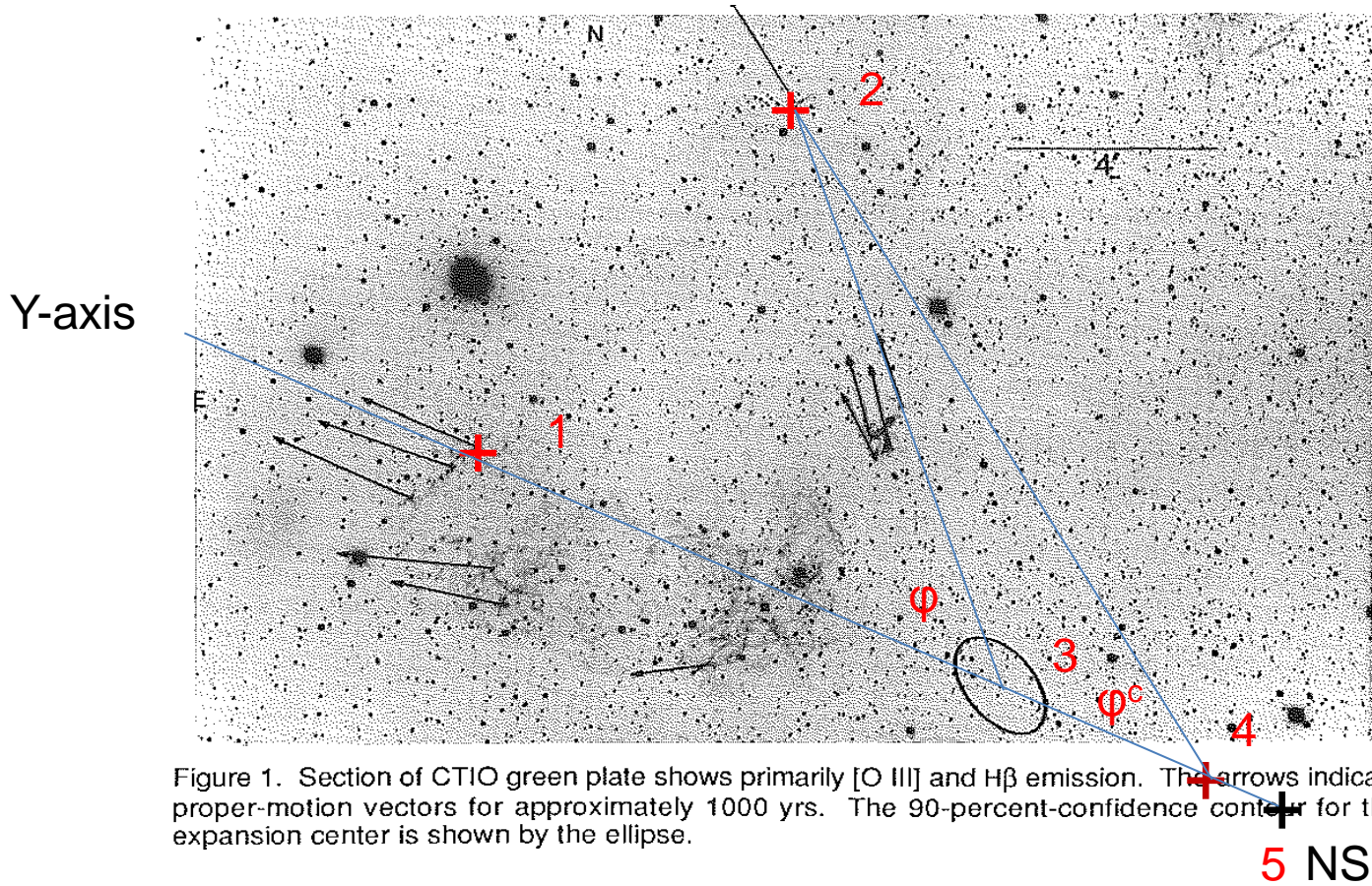


Figure 1. Section of CTIO green plate shows primarily [O III] and H β emission. The \times arrows indicate proper-motion vectors for approximately 1000 yrs. The 90-percent-confidence center for the expansion center is shown by the ellipse.

5 NS

1: ORF 'on-axis', 2: ORF 'off-axis', 3: ORF 'apparent explosion center', 4: 'true explosion center', 5: present NS position

The Relations

1: on-axis;

$$(\mu_y/m_y t - \mu_y t_0) + \mu_{NS} t = s_{35}$$

$$\mu_y/m_y t + \mu_{NS} t = s_{15}$$

2: off-axis;

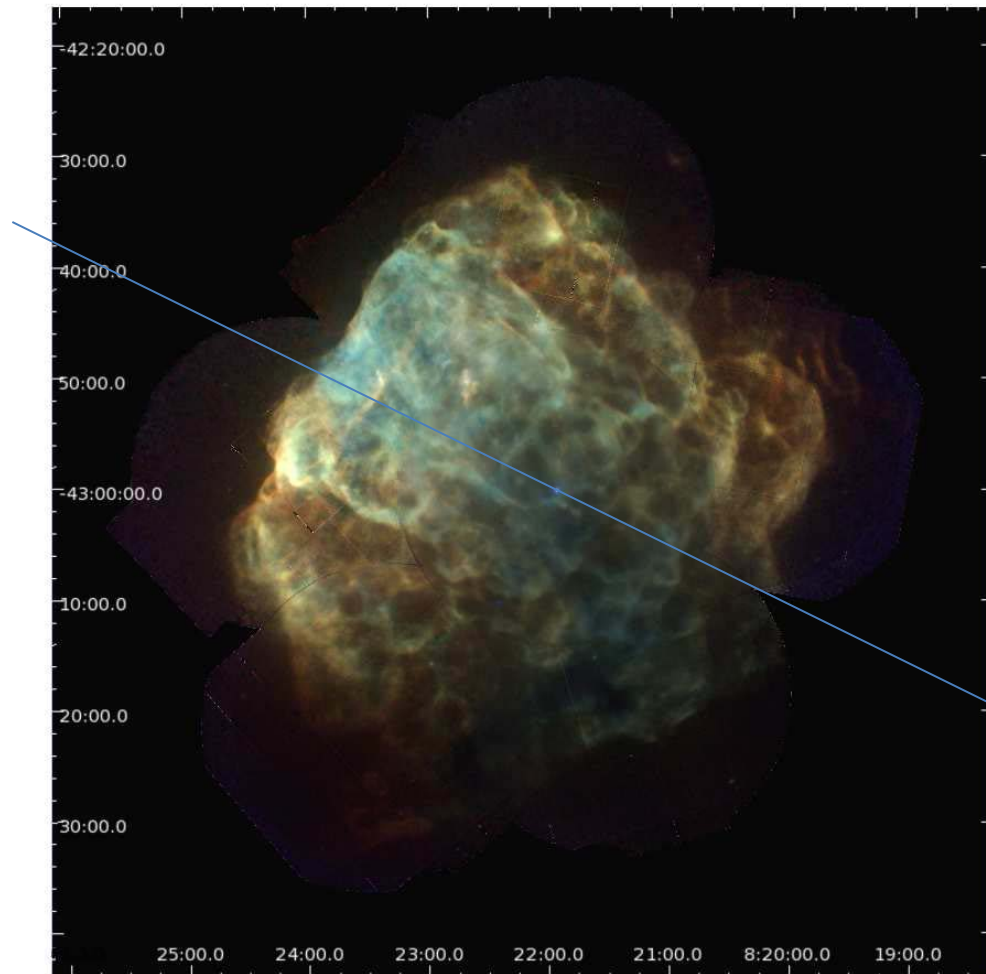
$$m_y \tan(\varphi) = m_x \tan(\varphi^c)$$

with $m_x = 2/3$ (expansion into the wind of the progenitor)

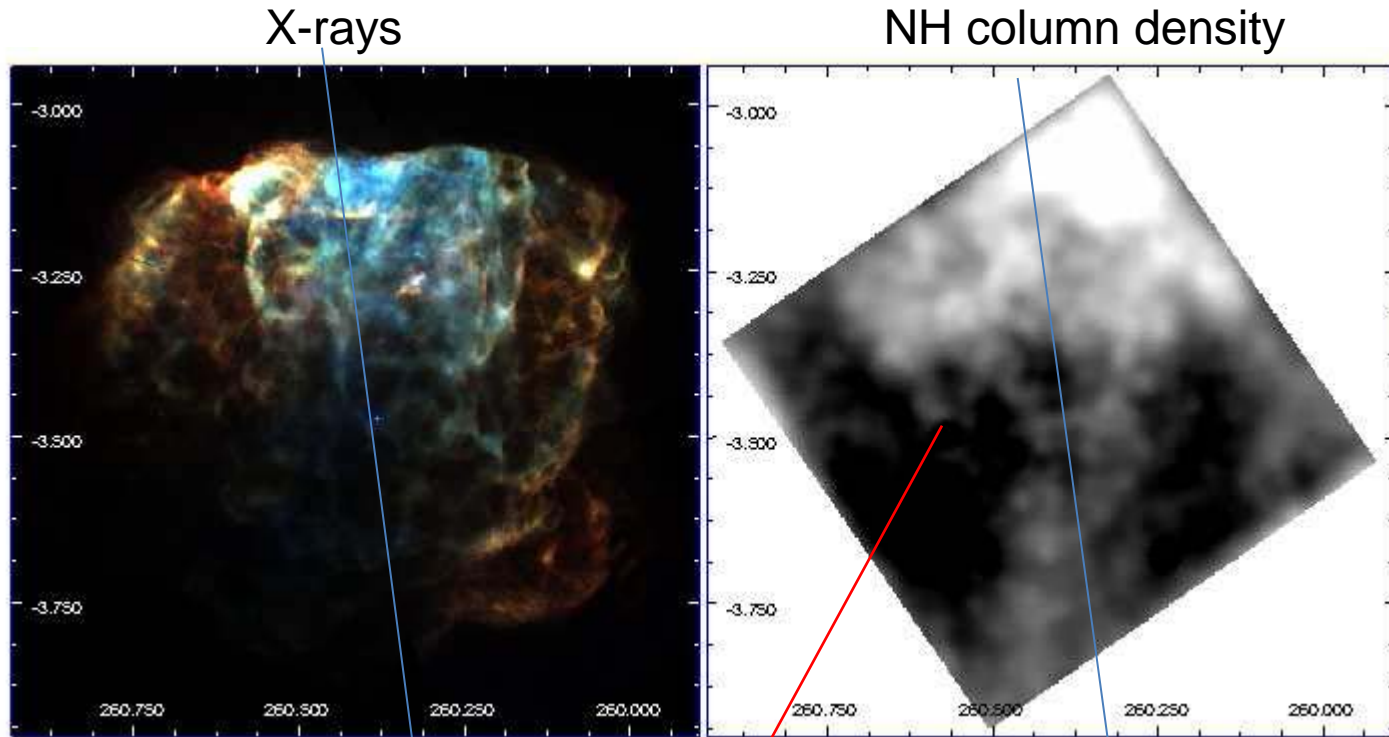


- 1.) $m_y = 0.45$ (adiabatic or Sedov-like expansion m_y would be $2/5$)
- 2.) 'true' position of the explosion site: just $50''$ off-set from the radio remnant center
- 3.) age: $t = 2015 \pm 150$ years

The Explosion Axis in (RA, Dec)



The Explosion Axis in Galactic Coordinates

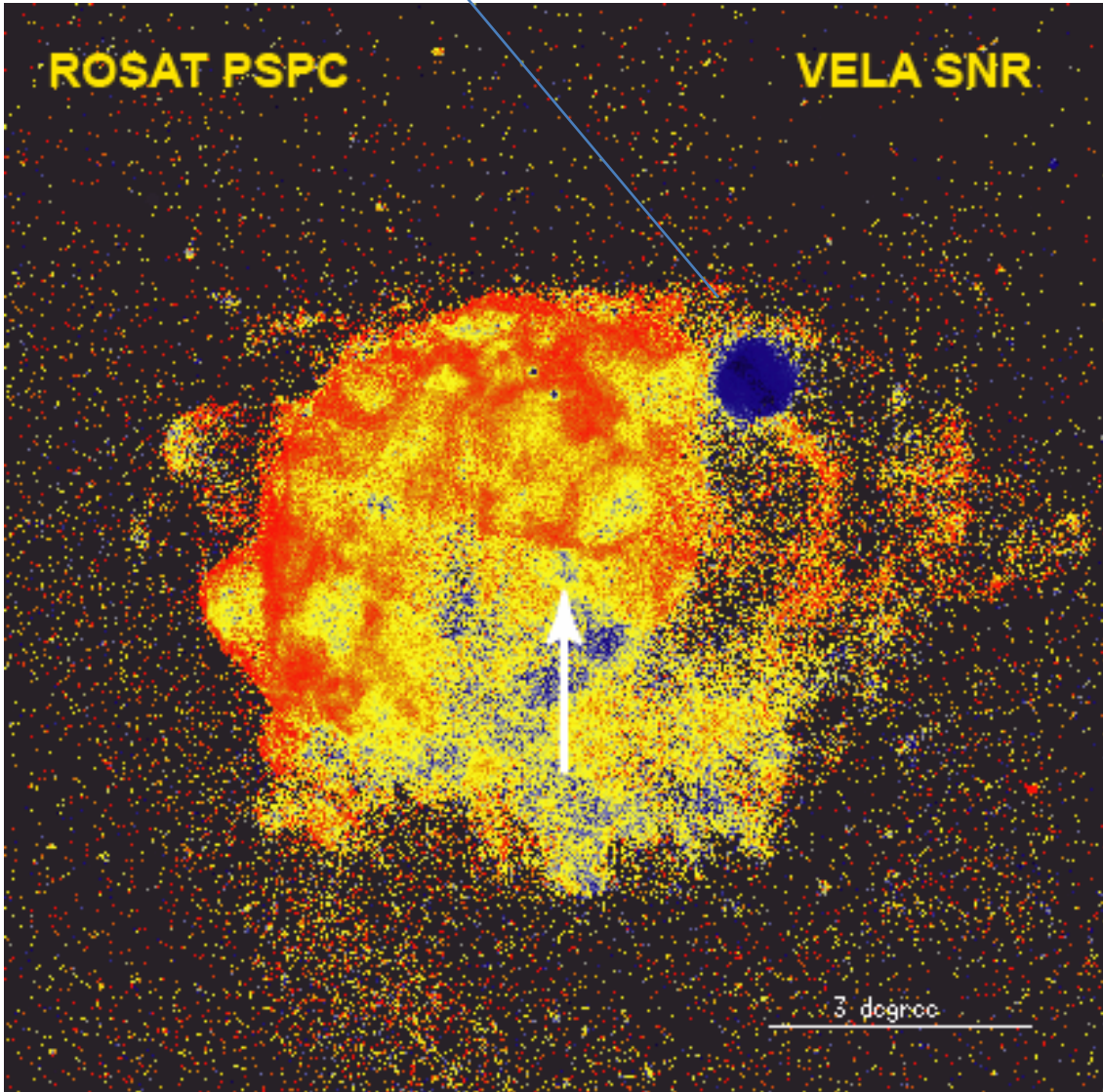


Dubner et al., 2013

note the low NH values

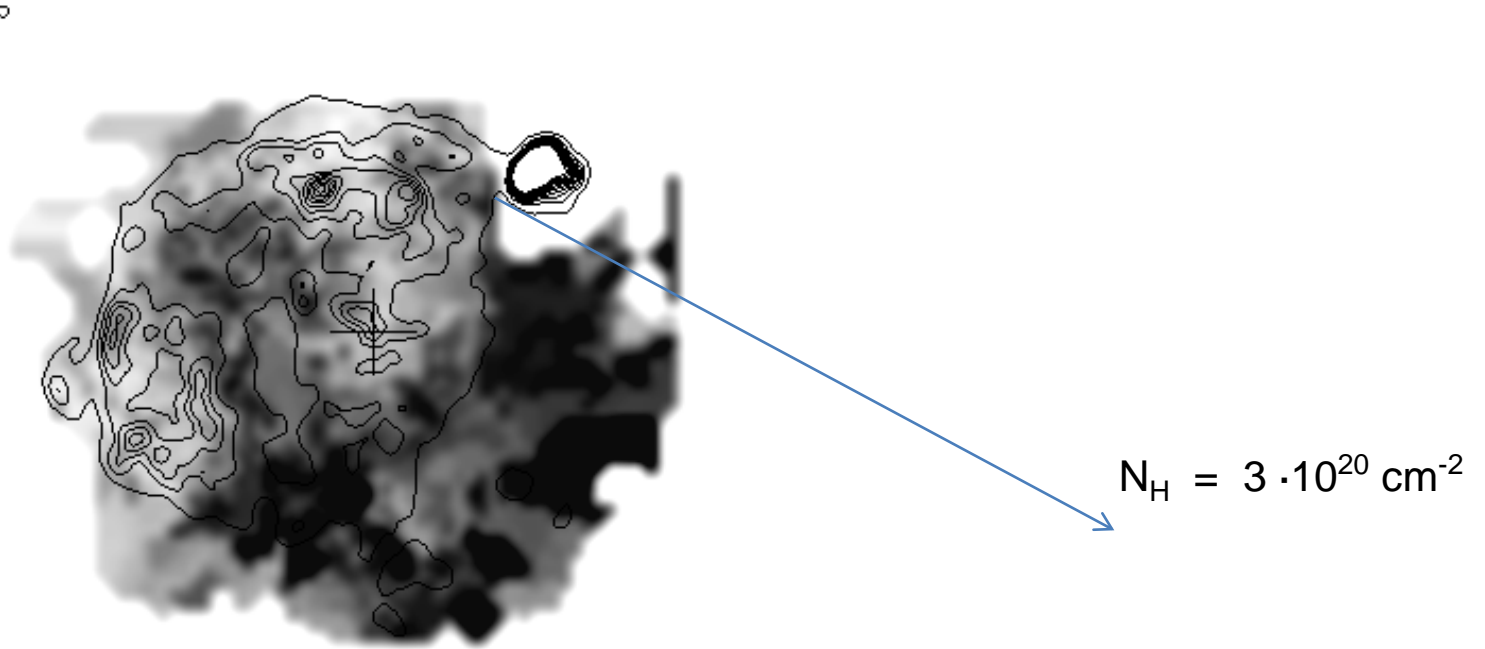
Location of Puppis A w.r.t. the Vela SNR

Lu & Aschenbach, 2000



Total X-ray Absorbing Column Density N_H towards the Vela SNR

Lu & Aschenbach, 2000



0,04

0,22

0,40

The Distance to Puppis A

$d = 2.2$ kpc derived from studies of HI and CO (Reynoso et al., 2003); radio meas.

$d = 1.3$ kpc derived from studies of OH (Woermann et al., 2000) ; radio meas.

X-ray absorption of the eastern and western parts,
omitting the central bright lane !

$$N_{\text{H}} = 16 \cdot 10^{20} \text{ cm}^{-2} \text{ (Aschenbach, 1993);}$$

$$N_{\text{H}} = 15 \cdot 10^{20} \text{ cm}^{-2} \text{ (Hwang et al., 2008)}$$

scaling with the Vela SNR northwest data:

$$d_{\text{puppis}} = d_{\text{Vela}} \times N_{\text{HPuppis}} / N_{\text{HVela}} \quad ; \quad d_{\text{Vela}} = 250 \text{ pc (Cha et al., 1999)}$$

$$d = 1.3 \text{ kpc}$$

with $d = 1.3$ kpc the space velocity of the Neutron Star is reduced to 440 ± 75 km/s

The Supernova Observed ?

records:

China, 5 BC (position estimated by Clark & Stephenson, 1981, doesn't match Puppis A)

China, 105 AD (position within 20° radius of Puppis A, but very vague)

The New Testament, Gospel of Matthew 2, 1–9; {4-7} BC:

‘The Star of Bethlehem’

The Supernova Lightcurve estimated from SN1993J in M81 (type IIb)

peak magnitude $m_v = -7.2$ (progenitor $m_v = 2.8$)

day 5, minimum $m_v = -4.9$

day 17, sec.max. $m_v = -6.6$

after 4 months $m_v = -4.6$

after 1 year $m_v = -2.2$

after 2.3 years $m_v = 2.8$ (the level of the progenitor star)

after 3 years $m_v = 5$

Some ancient Astronomy

Use of Decan Stars in Ancient Egyptian Dynasties – the Ramses Periods

Part of Egyptian coffin lid showing two Egyptian astronomer's assistants
and hieroglyphic list of decan stars and the star's positions
~ 1500 BC

