The Age of the Local Interstellar Bubble

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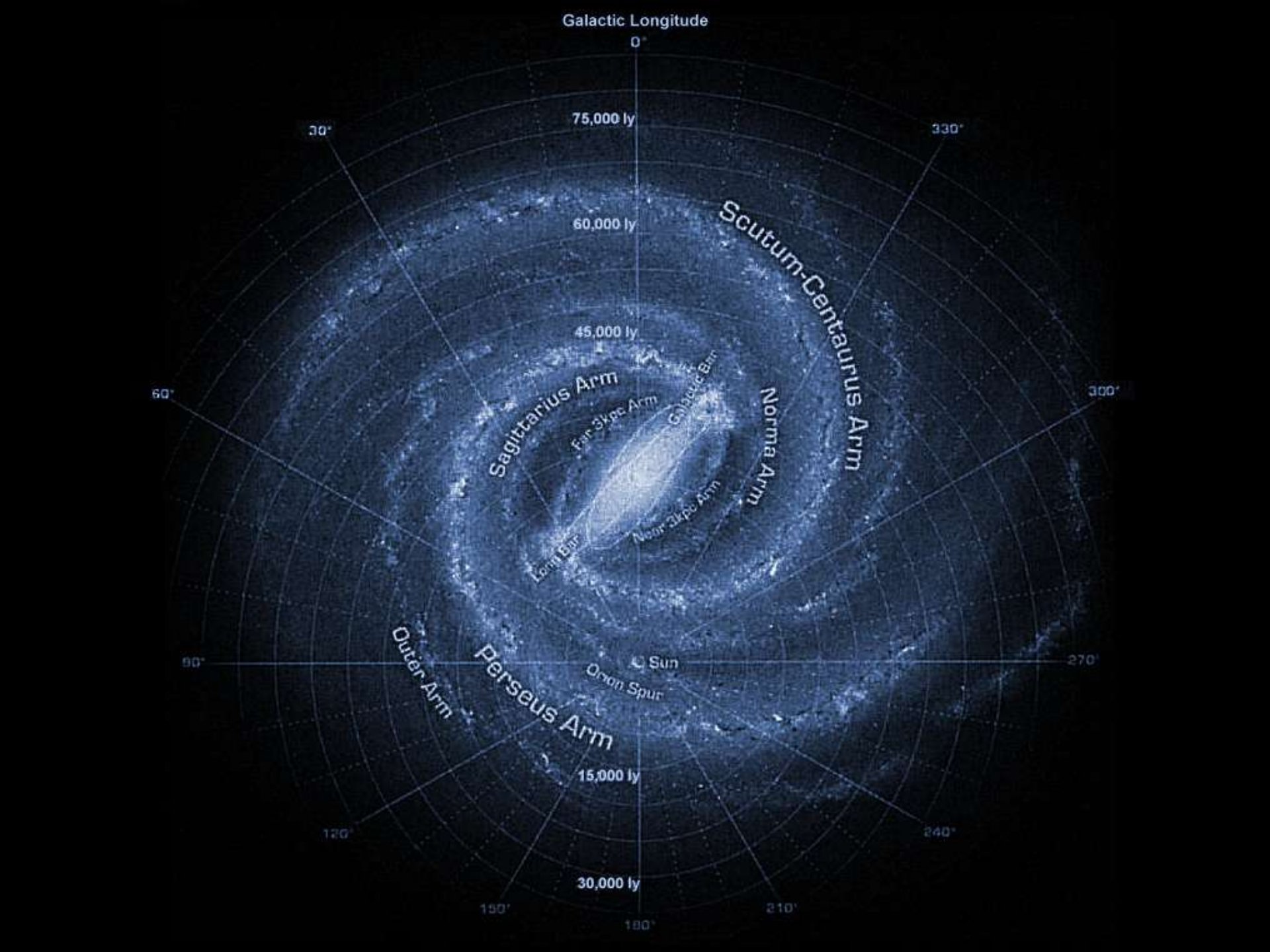
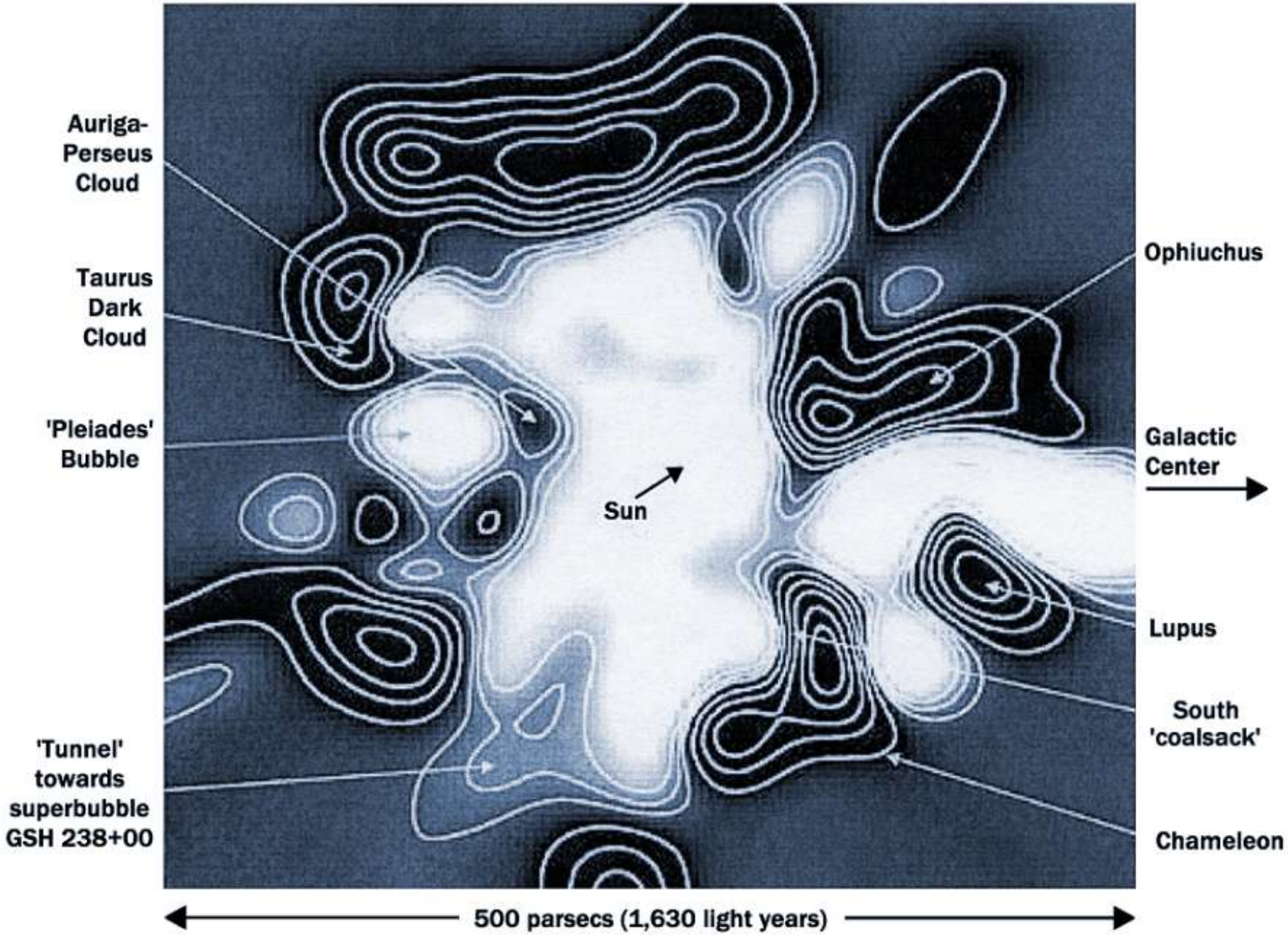
This is an example of how you can use the data currently available in the internet to answer an astrophysical question, namely when did the Local Interstellar Bubble occur?

It also tells about an astronomical feature unknown to most astronomers.


Galactic Longitude
0°
30°
330°
60°
300°
90°
270°
120°
240°
150°
210°
180°
75,000 ly
60,000 ly
45,000 ly
30,000 ly
15,000 ly
Scutum-Centaurus Arm
Norma Arm
Sagittarius Arm
Perseus Arm
Outer Arm
Far 3kpc Arm
Near 3kpc Arm
Galactic Bar
Long Bar
Sun
Orion Spur


Auriga-
Perseus
Cloud
Taurus
Dark
Cloud
'Pleiades'
Bubble
'Tunnel'
towards
superbubble
GSH 238+00
Ophiuchus
Galactic
Center
Sun
Lupus
South
'coalsack'
Chameleon
500 parsecs (1,630 light years)

Lallement et al. (A&A, 411, 447, 2003) measured Na I D-lines and found the interstellar density within the bubble is 200 times less than outside.

Smith et al. (PASJ, 59, 141, 2007) found the temperature within the bubble to be 2.1×10^6 °K.

So very little HI 21 cm radiation.

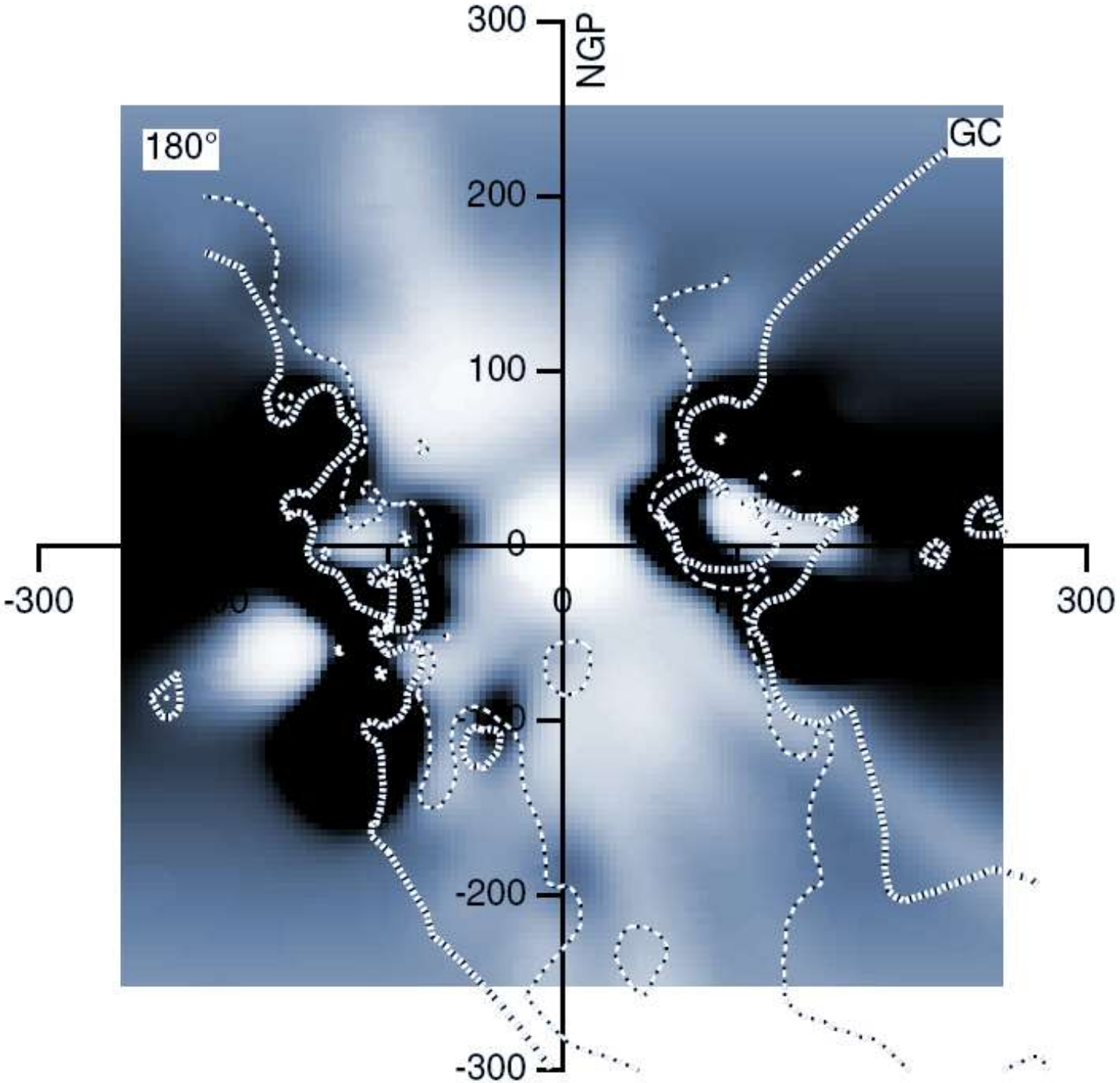
Therefore the pressure at the borders, density x temperature, is constant:

Outside		Inside
$1\ cm^{-3} \times 10{,}000°K$	~	$1/200\ cm^{-3} \times 2.1 \times 10^{6}\ °K$

So the bubble is stable.

It is a cylinder that passes completely through the galactic disk.

Probably caused by supernovae.


300
NGP
180°
GC
200
100
0
-300
0
300
0
-200
-300

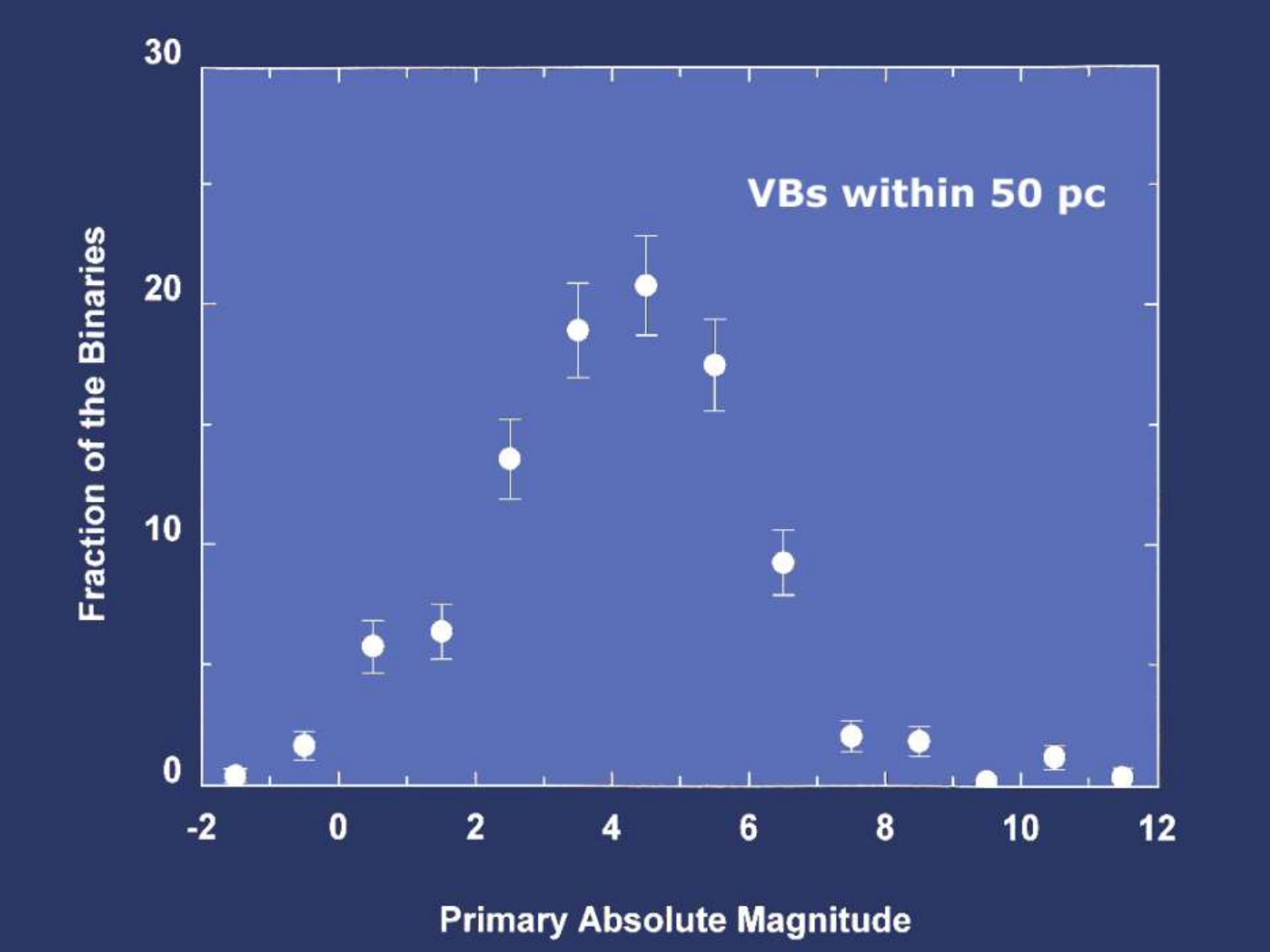
Three regions: center, Pleiades lobe, and lobe toward the galactic center.

Find the youngest stars in each region to find when the supernovae depleted the interstellar density so that stars could no longer be formed.

Eight samples of stars.

First visual binaries within 50 pc (from Hartkopf & Mason (http://www.astro.navy.mil/)

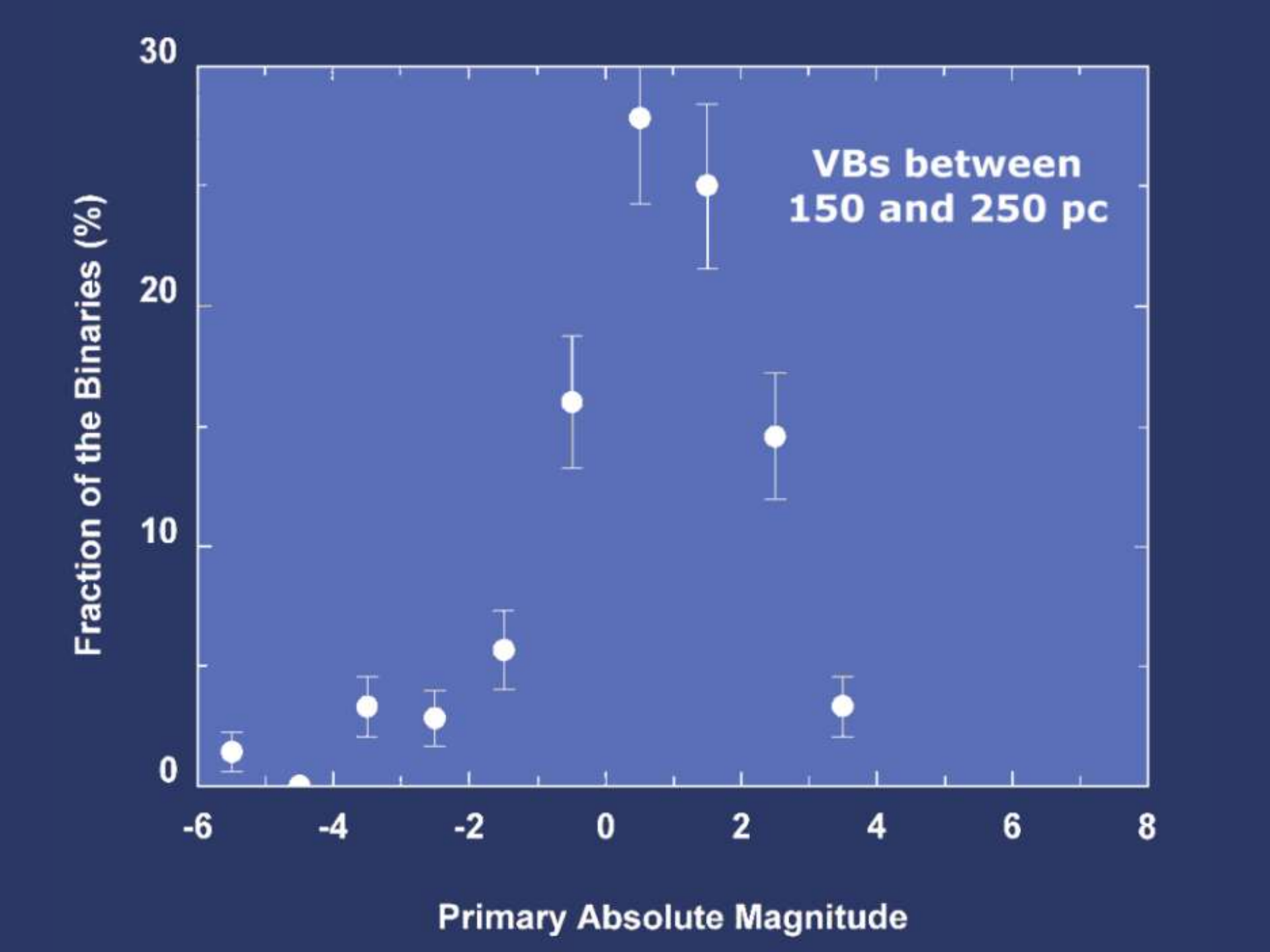
No stars earlier than M_V = -1 or B8 or 160 Myr.


VBs within 50 pc
Fraction of the Binaries
Primary Absolute Magnitude
30
20
10
0
-2
0
2
4
6
8
10
12

For the VBs outside the bubble, there are stars as early as M_V = -6 or O5 stars, so stars are currently being formed there.

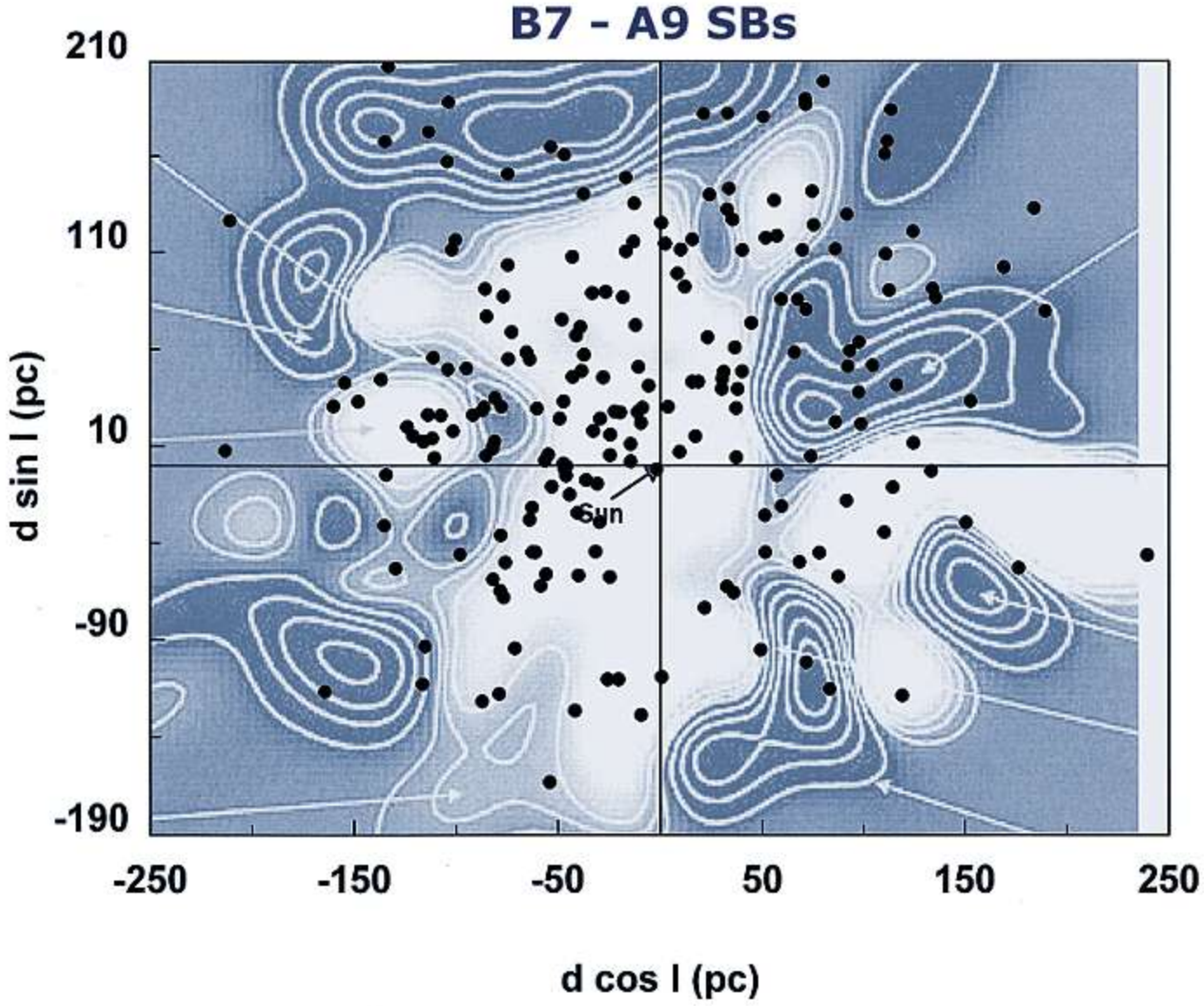
Second sample: spectroscopic binaries (Batten et al., Publ. DAO 17, 1, 1989).

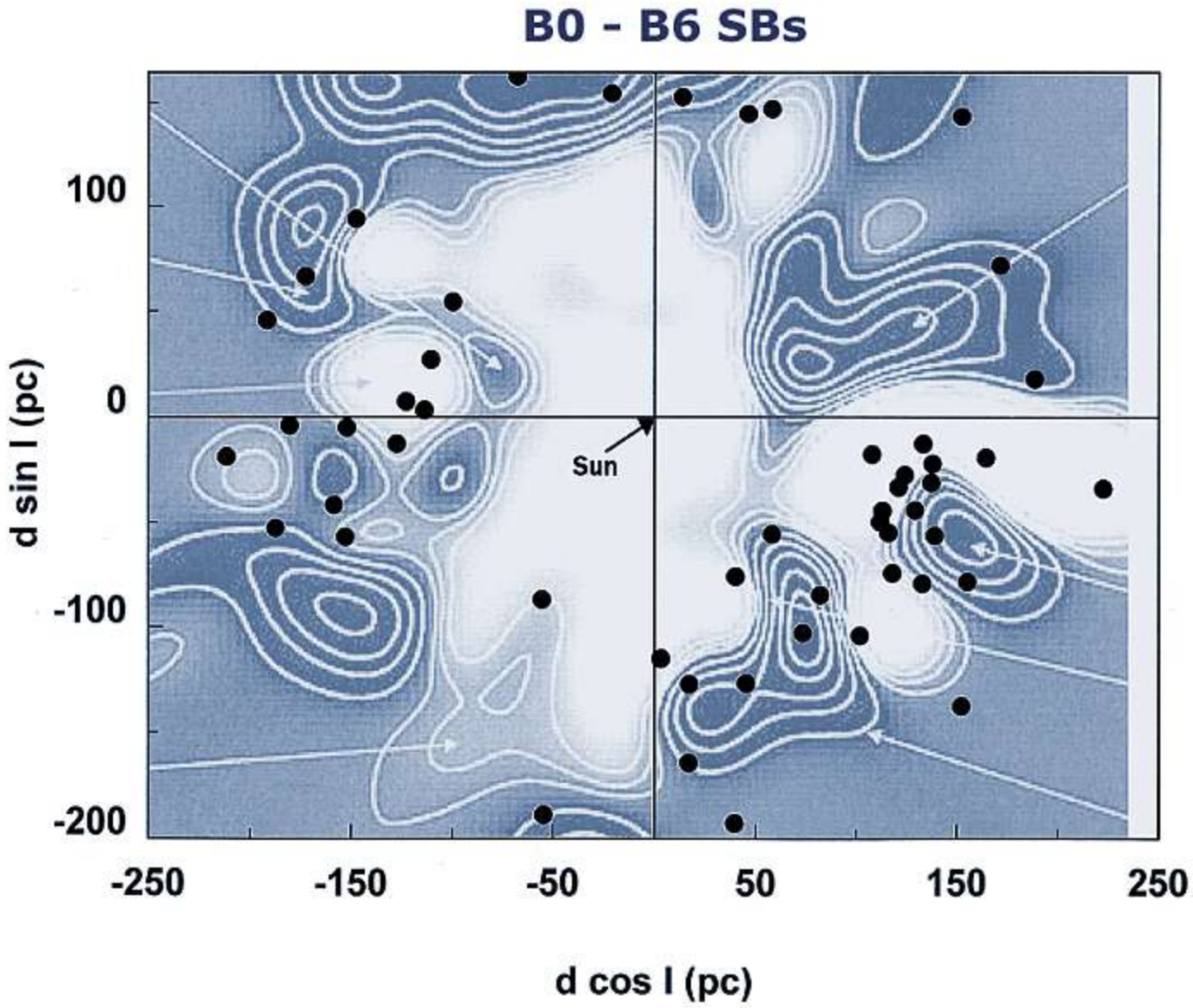
The B7-A9 SBs are found throughout the bubble.


VBs between
150 and 250 pc
Fraction of the Binaries (%)
Primary Absolute Magnitude
30
20
10
0
-6
-4
-2
0
2
4
6
8

C

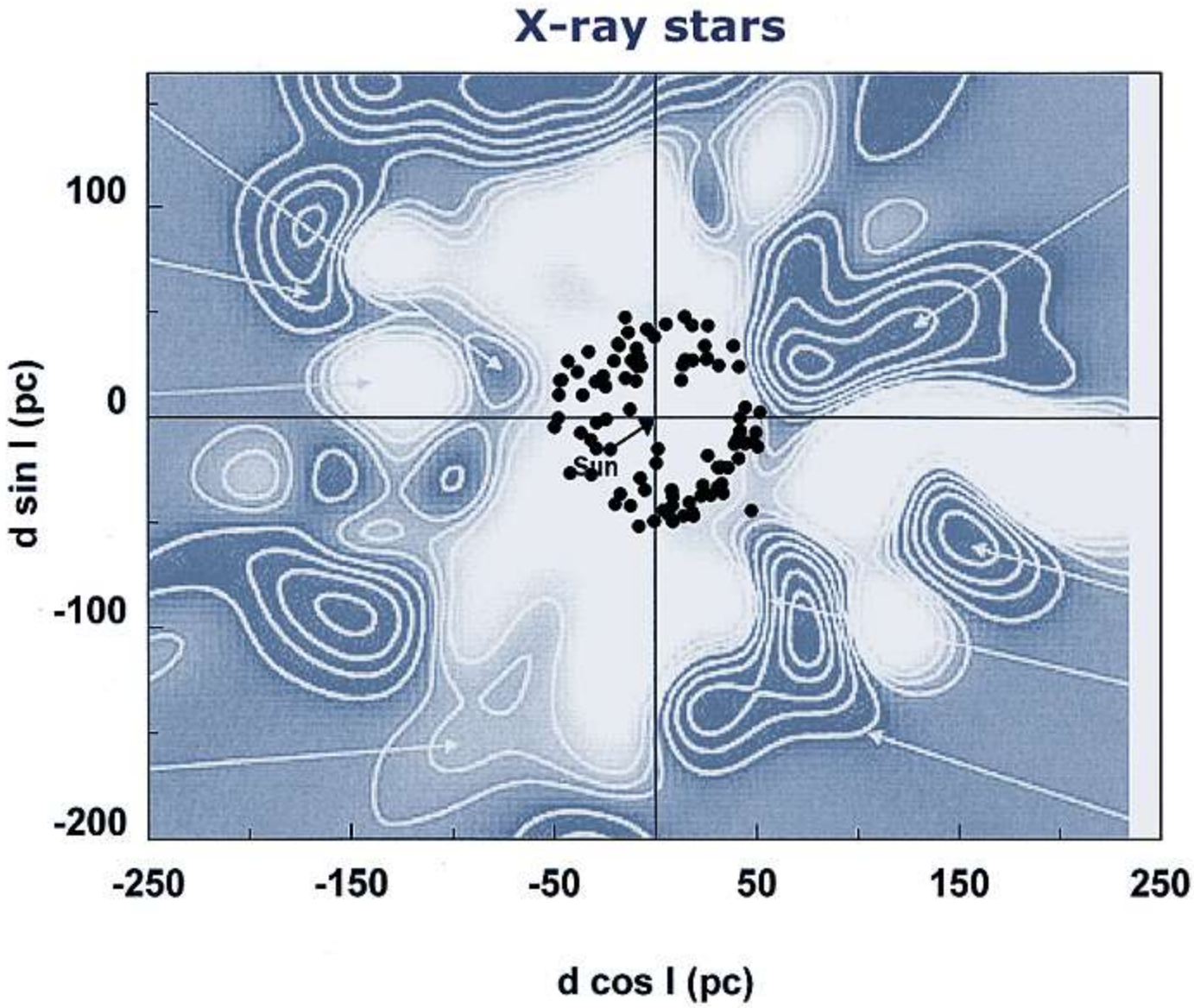
S


B7 - A9 SBs
210
110
10
-90
-190
-250
-150
-50
50
150
250
d sin l (pc)
d cos l (pc)
Sun


B0 - B6 SBs
100
0
-100
-200
d sin l (pc)
Sun
-250
-150
-50
50
150
250
d cos l (pc)

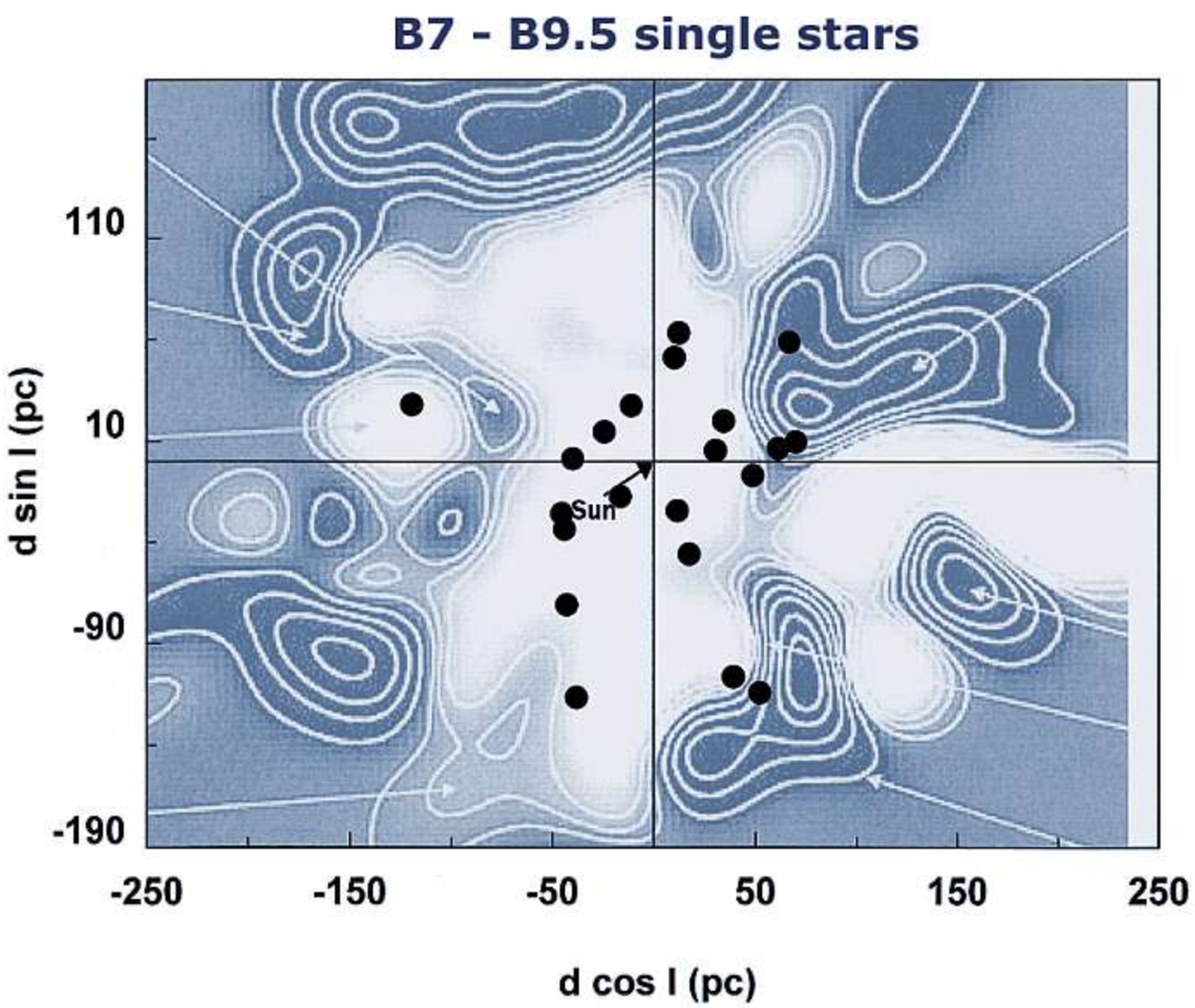
But for the B0-B6 SBs there are none within the central part of the bubble, although they occur in the Pleiades lobe and lobe toward the galactic center.

Third sample of stars: The 100 brightest X-ray stars within 50 pc of the Sun (Makarov, AJ, 126, 1996, 2003) are shown in the next figure.


X-ray stars
100
0
-100
-200
d sin l (pc)
-250
-150
-50
50
150
250
d cos l (pc)
Sun

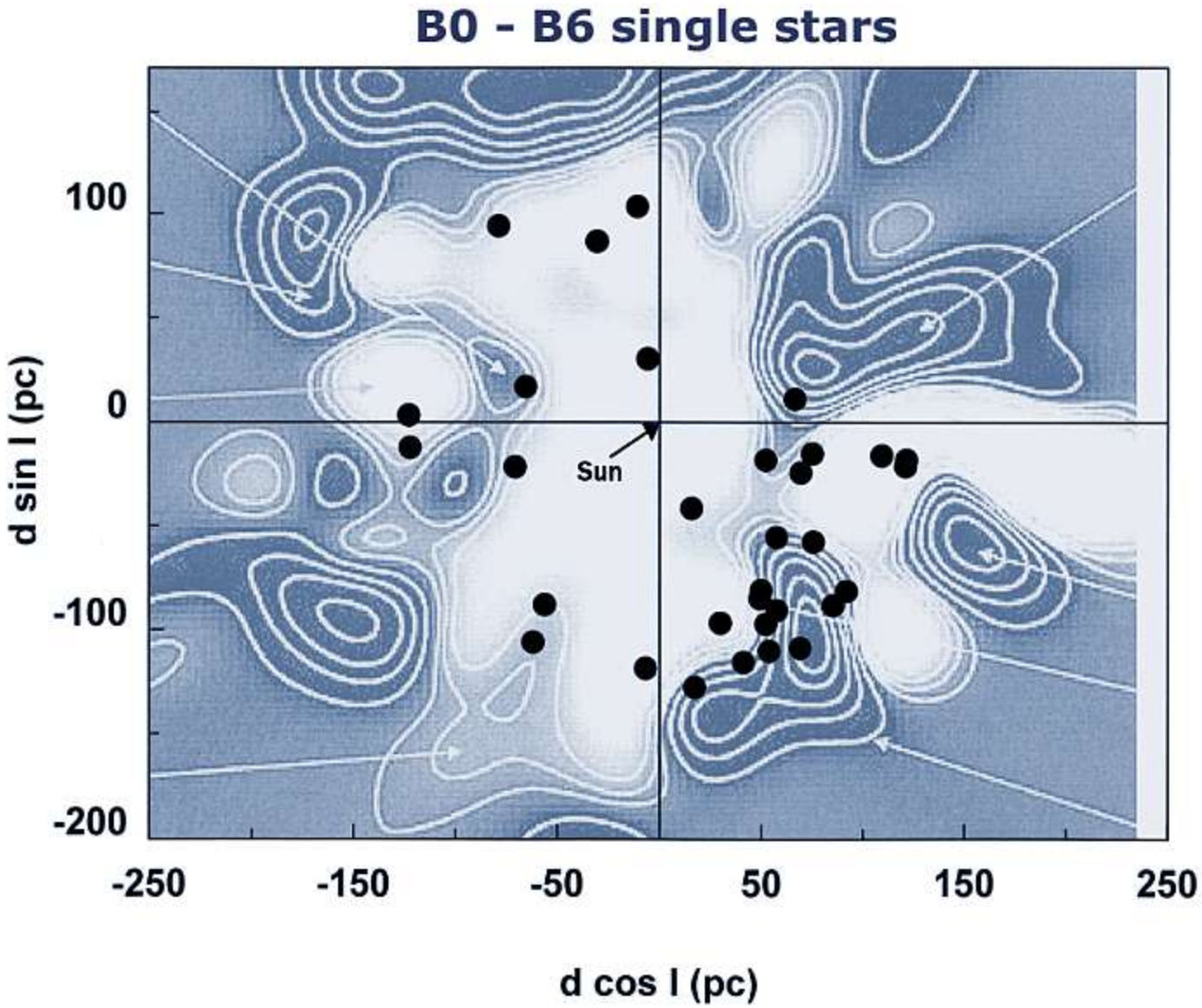
There are no surprises here because all the X-ray binaries are later than B7.

Fourth sample of stars: nearby stars (JRASC Observer's Handbook). The B7-B9.5 stars are shown in the next figure.


B7 - B9.5 single stars
110
10
-90
-190
d sin l (pc)
-250
-150
-50
50
150
250
d cos l (pc)
Sun

Many B7-B9.5 single stars occur in the bubble.

Now let’s look at the B0-B6 stars in the next figure.

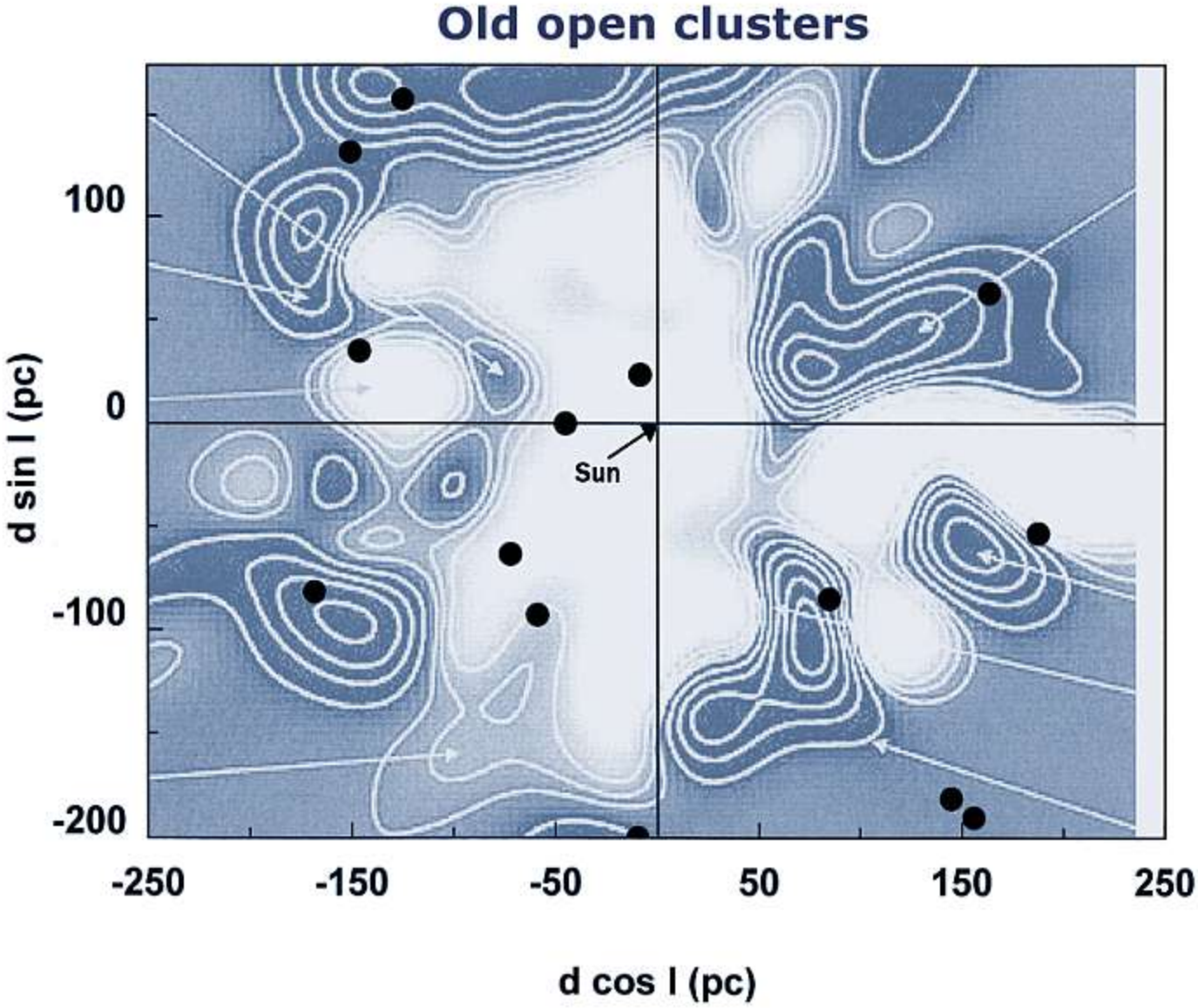

B0 - B6 single stars
100
0
-100
-200
d sin l (pc)
Sun
-250
-150
-50
50
150
250
d cos l (pc)

We see that there are B0-B6 stars in the Pleiades lobe and in the lobe toward the galactic center.

But there are four or five in the central region. They have a mean proper motion of 0.050” yr^{-1} and a mean distance of 86 pc. In 10 Myr they would have a motion of 200 pc. Therefore a few stars have wandered into the bubble in the millions of years since it was formed.

In particular, the Sun has a motion of 11.3 km s^{-1} toward galactic longitude 27° relative to the nearby stars so in 100 Myr it would move 1100 pc. Therefore it moved into the bubble long after the bubble was formed.

The fifth sample is the old open clusters (Paunzen & Mermilliod; http://obswww.unige.ch/webda). That is shown in the next figure.


Old open clusters
100
0
-100
-200
d sin l (pc)
Sun
-250
-150
-50
50
150
250
d cos l (pc)

The open cluster in the Pleiades lobe is, of course, the Pleiades with an age of 60 Myr, so that is the approximate age of the supernovae that produced the Pleiades lobe.

The three clusters in the central lobe (Coma, Hyades, Collinder 285), all have earliest types of B8.

I could give you the details about the remaining samples (emission regions, planetary nebulae, pulsars), but you can read them in Abt (AJ, 141, 165, 2011).

The results are that the central lobe was caused by a supernova about 160 Myr ago, and we cannot identify it because it may have moved away.

The Pleiades lobe was caused by the supernova 60 Myr ago, and we cannot identify it because it may have moved elsewhere during that time.
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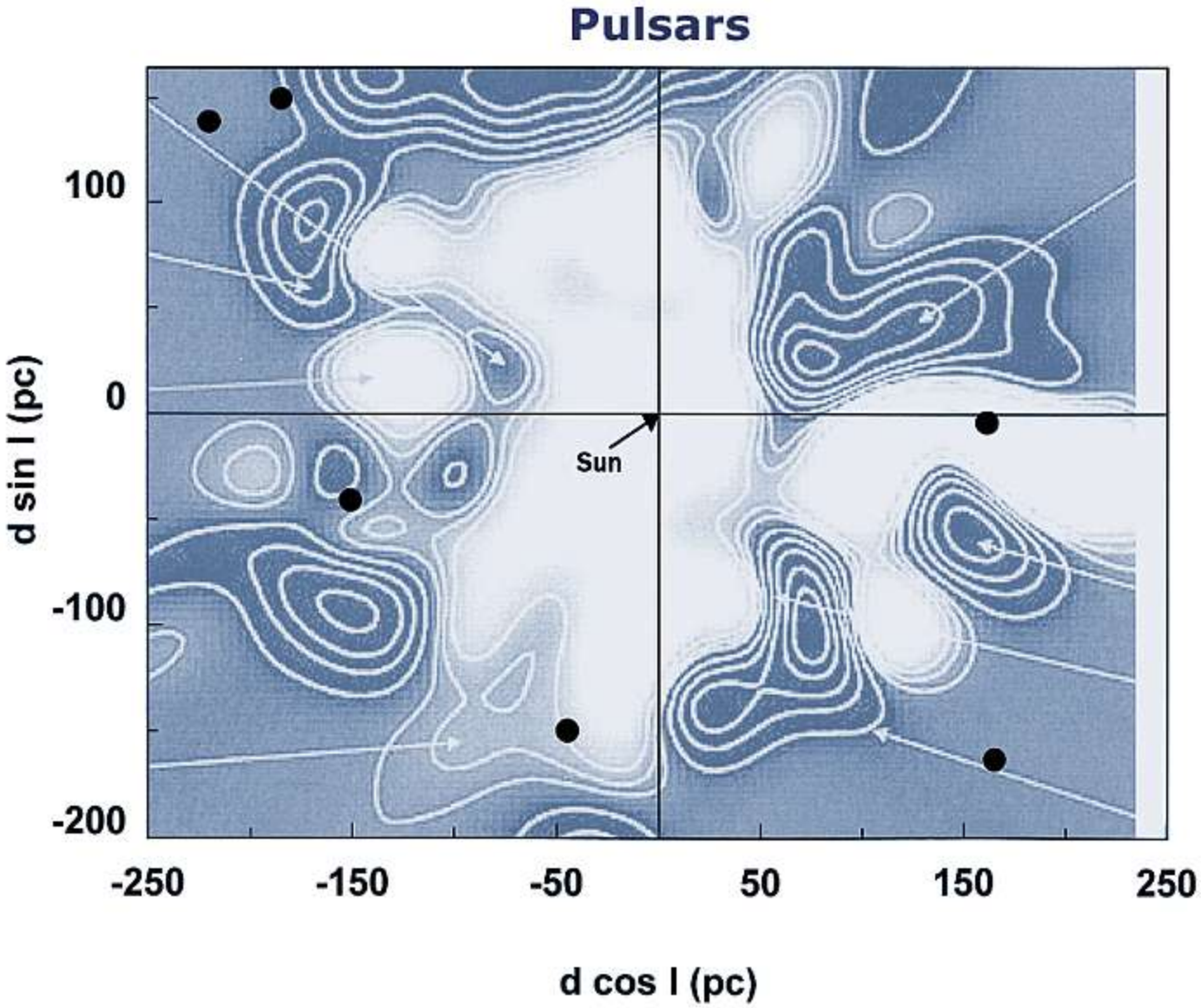
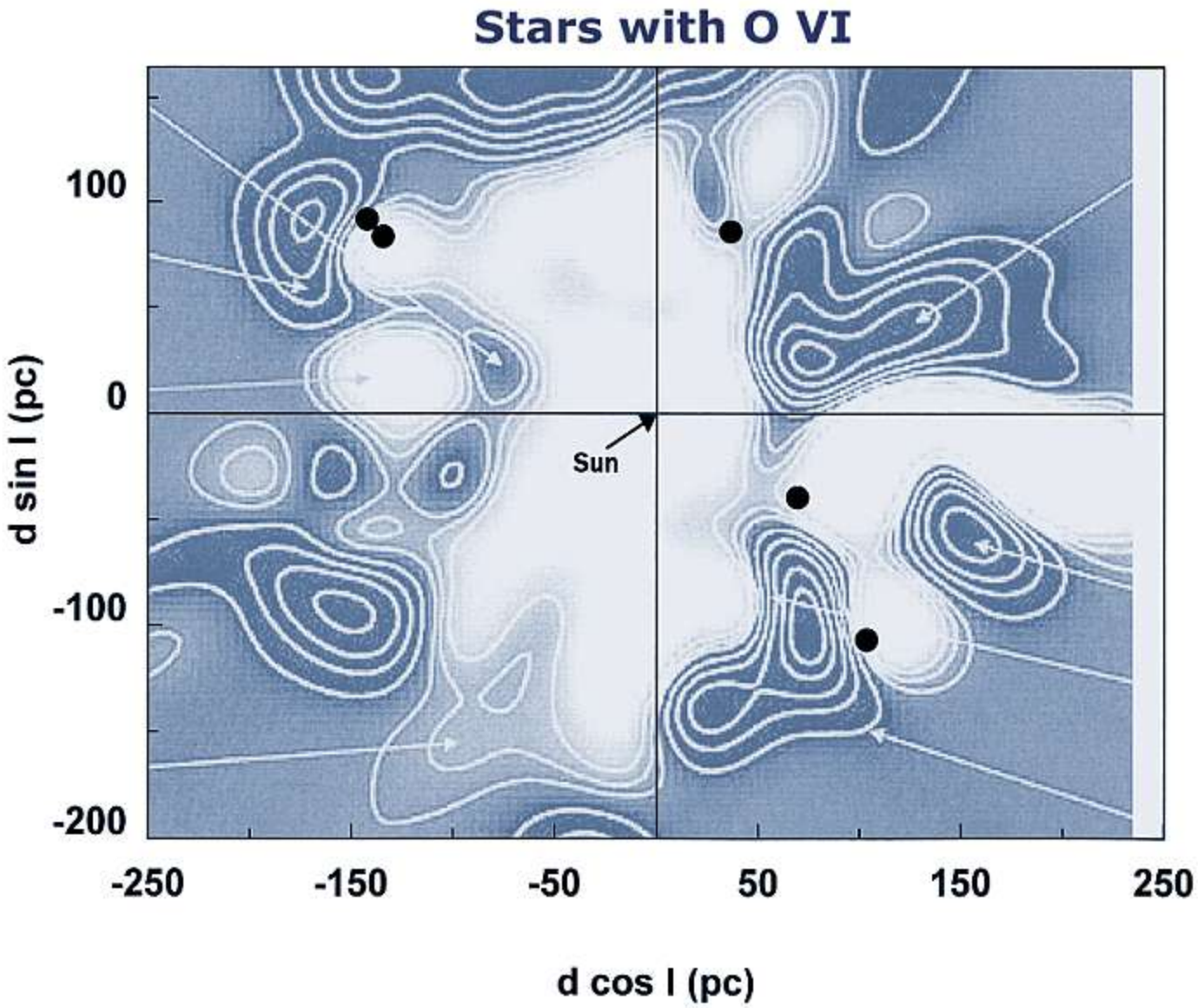
The lobe toward the galactic center has stars as early as O9.5, which have an age of 4 Myr year. But in that lobe there is a pulsar shown in the next figure.

In the list of known pulsars (Manchester et al. AJ, 129, 1993, 2005) it is No. 83 and has a spin-down time of 3.76 Myr. So it is likely the remnant of the supernova that caused that lobe.


Pulsars
100
0
-100
-200
d sin l (pc)
Sun
-250
-150
-50
50
150
250
d cos l (pc)

The temperature of the Local Interstellar Bubble is about 2.1 x 10^6 K, so one would expect to find highly-ionized atoms in it.

Welsh & Lallement (A&A, 490, 707, 2008) used the FUSE satellite, which detects O VI 1032 Å and C II 1036 Å. The last figure shows the five stars in this region whose lines-of-sight contain O VI or C II.


Stars with O VI
100
0
-100
-200
d sin l (pc)
Sun
-250
-150
-50
50
150
250
d cos l (pc)

We see that the five stars have lines of sight through the Local Interstellar Bubble, confirming its high temperature.

So we dated three high-temperature low-density bubbles and identified the pulsar that probably came from the supernova that caused one lobe.