The DM contribution of Galactic pulsar wind nebulae

Samayra Straal and Joeri van Leeuwen
Outline

• Pulsar Wind Nebula recap
• DM contribution of the nebula
  • Theoretical predictions
  • Galactic PWNe contribution
• LOFAR search for pulsars in PWNe and SNRs
  • PWN G141.2+5.0 with an X-ray point source
  • High DM candidate
• Summary
Figure 2

(a) A deep Chandra X-ray image of the composite SNR G21.5–0.9 (Matheson & Safi-Harb 2005). A circular supernova remnant (SNR) of diameter \( \approx 5\ \text{arcmin} \) surrounds a symmetric pulsar wind nebula (PWN) of diameter \( \approx 1.5\ \text{arcmin} \), with the young pulsar J1833-1034 at the center (Gutpa et al., 2005; Camilo et al., 2006). The central location of the pulsar and PWN and the symmetric appearance of the PWN and SNR both argue for a relatively unevolved system in which the PWN expands freely and symmetrically into the unshocked interior of the SNR.

(b) A schematic diagram of a composite SNR showing the swept-up interstellar medium shell, hot and cold ejecta separated by the reverse shock, and the central pulsar and its nebula. The expanded PWN view shows the wind termination shock. Note that this diagram does not correspond directly to G21.5–0.9, in that a significant reverse shock has probably yet to form in this young SNR.

The outline of this review is as follows: in Section 2 we explain the basic observational properties of pulsars and their nebulae; in Section 3 we review current understanding of the evolutionary sequence spanned by the observed population of PWNe; in Section 4 we discuss observations of PWNe around young pulsars, which represent the most luminous and most intensively studied component of the population; in Section 5 we consider the properties of the bow shocks produced by high velocity pulsars; and in Section 6 we briefly describe other recent and interesting results in this field.
Theoretical Predictions

- \( M_{\text{nb}} \sim 10^{-7} \, \text{M}_\odot \)
- \( M_{\text{NS}} \sim 1.4 \, \text{M}_\odot \)
- Age expectation for magnetar or RNS: 10-100 yrs

(Murase et al. 2016)

\[ \log(DM [\text{pc cm}^{-3}]) \]

\[ \log(T [\text{yr}]) \]

Murase et al. 2016
Measured vs. NE2001 DM

Measured DM vs NE2001 model DM based on independent distance measurements

- Observed DM == Modeled DM
- Fit with $y = x + b$, $b = 26.8$
- Fit with $y = x + b$, $b = 19.5$
- Maximum error on DM
- DM error based on distance error

Underestimated by model

Overestimated by model

Expected DM NE2001 (pc/cc)

Observed DM (pc/cc)
Theoretical Predictions

- Measurable DM contribution from Galactic PWNe

From Murase et al. 2016
LOFAR search

- Search for pulsars in 8 known and new SNRs and PWNe
- Low-frequency beam might pass Earth
- Some pulsars are brighter at low frequencies
## Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Object</th>
<th>Diameter</th>
<th>Previous searched</th>
<th>Sensitivity 400-1420MHz</th>
<th>Sensitivity LOFAR 150 MHz</th>
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<td>G049.2-0.7</td>
<td>SNR + PWN</td>
<td>25’</td>
<td>2%-15%</td>
<td>0.5-0.6 mJy</td>
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<td>-</td>
<td>-</td>
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<td>full</td>
<td>0.4 mJy</td>
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<td>7</td>
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G141.2+5.0

- PWN in Cygnus arm discovered by Kothes et al. 2014
- In a small HI bubble. Shell contains ~35M_⊙
- Reynolds & Burkowski 2016 discovered a central X-ray point source (NS)
- Lorimer searched for pulsar with GBT at 800 MHz, no detection
Promising candidate

2 Pulses of Best Profile
Candidate: [Diagram]
Telescope: LOFAR

Search Information
RA$_{2000}$ = 03:37:12.0000
DEC$_{2000}$ = 61:53:05.0000

Best Fit Parameters
DOF$_{eff}$ = 43.52
χ$^2$$_{red}$ = 2.473
P(Noise) < 7.95e−10 (6.0σ)
Dispersion Measure (DM; pc/cm$^3$) = 226.000

Samayra Straal
13 February 2017, Aspen
Measured vs. NE2001 DM

Measured DM vs NE2001 model DM based on independent distance measurements

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Underestimated by model

Overestimated by model

G141.2+5.0

1.47e+05 yrs

1.58e+04 yrs

5.37e+03 yrs

2.03e+04 yrs

5.64e+05 yrs

Samayra Straal

13 February 2017, Aspen
Summary

• Theoretical predictions predict no measurable local-DM contribution to the FRB after ~ 100 yrs.

• But: the Galactic PWN DM contribution is ~ 27 pc/cc (age independent)

• Pulsar candidate in new PWN G141.2+5.0, confirmation observations are ongoing