The Vela and Geminga pulsars in the mid-infrared

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Outline

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  The Crab pulsar
  The AXPs
  Vela and Geminga

Results
  Identification of the pulsars in mid-IR
  Photometry

Discussion
  The dust disc
  An unresolved PWN structure

Conclusions
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The Crab pulsar and the nearby knot

Near-IR images and Optical/IR SED of the Crab (Sandberg & Sollerman (2009)). The pulsar and the knot are marked by the blue and red ticks consecutively. The Crab mid-IR fluxes are compatible with the spectral extrapolation from the optical range if we account for contribution from the knot which is not spatially resolved from the pulsar in the mid-IR.
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The AXPs

4U 0142+61

Wang, Chakrabarty & Kaplan (2006)

1E 2259+586

Kaplan et al. (2009)
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### Vela and Geminga

**Vela,**

- PSR B0833–45;
- age $\sim 10^4$ yr;
- distance to, 287$^{+19}_{-17}$ pc;
- associated with SNR G263.9–3.3;
- Crab-like PWN detected in X-rays only and some PWN features in $\gamma$-rays;

**Geminga,**

- PSR J0633+1746;
- age $\sim 10^5$ yr;
- distance to, 250$^{+120}_{-60}$ pc;
- not associated with any SNR;
- bow shock PWN detected in X-rays and $\gamma$-rays;
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Identification of the Vela pulsar

Figure: The near-IR images (Shibanov et al. (2003)) compared with the Spitzer data. The pulsar counterpart is marked by a tick line and the arrow shows the direction of its proper motion.
Identification of the Geminga pulsar

Figure: The Spitzer images vs the Subaru and HST ones (Shibanov et al. (2006)). The cross marks the pulsar position at the epoch the I-band image was obtained in. A tick line and the arrow marks the pulsar position and the direction of its proper motion.
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Unabsorbed spectra of the Crab, Vela and Geminga pulsars from the mid-IR to the optical-UV. Crab: optical and near-IR (Sandberg & Sollerman (2009)); mid-IR (Temim et al. (2009)); Vela: UV, optical, near-IR (Romani et al. (2005), Mignani et al. (2007), Shibanov et al. (2003)); Geminga: UV, optical/near-IR (Kargaltsev et al. (2005), Shibanov et al. (2006)); optical spectrum (Martin et al. (1998))
Multiwavelength spectrum: Vela

Figure: The mid-IR fluxes are marked by a red circles.
Multiwavelength spectrum: Geminga

Figure: The mid-IR fluxes are marked by a red circles.
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Possible contribution from the dust disc

**Figure:** The spectral fit of the Vela pulsar optical/IR SED by irradiated passive dust disc model (Vrtilek et al. (1990)). The solid line is the best-fitting result and the hatched region shows 1σ uncertainty of the fit. Here we assume that the mid-IR pulsar fluxes are described by power-law extrapolated from the optical-UV range.
Multiwavelength spectrum of Vela + disc

Figure: The same spectral fit as seen on the multiwavelength spectrum.
The Vela PWN at near-IR

**Figure:** The near-IR image of the Vela PWN (Shibanov et al. (2003)). The pulsar and the PWN features, o1 and counter-jet, are marked by the blue and red arrows consequently.
Whether the PWN structures can contribute significantly?

The fluxes of the PWN features, named o1 and counter-jet, are shown. If we extrapolate two point near-IR spectra of the features to mid-IR band, so we find that in mid-IR the fluxes of the features must be of same order as the pulsar fluxes. Bear in mind possible variability of the counter-jet we may conclude that this features can, at least partially, explain the observed excess.
Conclusions

- The detections of the Vela and Geminga pulsars as well as recent detections of several Crab-like PWNe (B0540, B1124, 3C 58 and G21.5) reveal strong emission excess in the mid-IR band, that was rather difficult to expect in advance.
- The question arise: What is the nature of the excess? Is it the sign of the hypothetical fall-back discs?
- Further studies of these and other pulsars in the mid-IR and especially submillimetre bands are necessary to get the answer.
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Thank you!
The Vela PWN

The mid-IR image in comparison with the Chandra one (Helfand et al. (2001)). There is no counterpart of the X-ray torus-like structure in the mid-IR.
Figure: The large scale structure of the Vela PWN at 8 $\mu$m and soft X-rays. East boundary of the X-ray plerion correlate with the west boundary of the a brigth extended emission visible in mid-IR.
Figure: Comparison of the mid-IR and HST/NICMOS near-IR (Shibanov et al. (2006)) images with the *Chandra* ones (Pavlov et al. (2010)).
The Geminga PWN

Figure: The transformation of the compact PWN from X-rays, through optical/near-IR, to the mid-IR.
Large-scale PWN structure

Figure: The extended tail at 5.8 $\mu$m and X-rays.