The TeV gamma-ray luminosity of the Milky-Way

the contribution of H.E.S.S. unresolved sources to VHE diffuse emission

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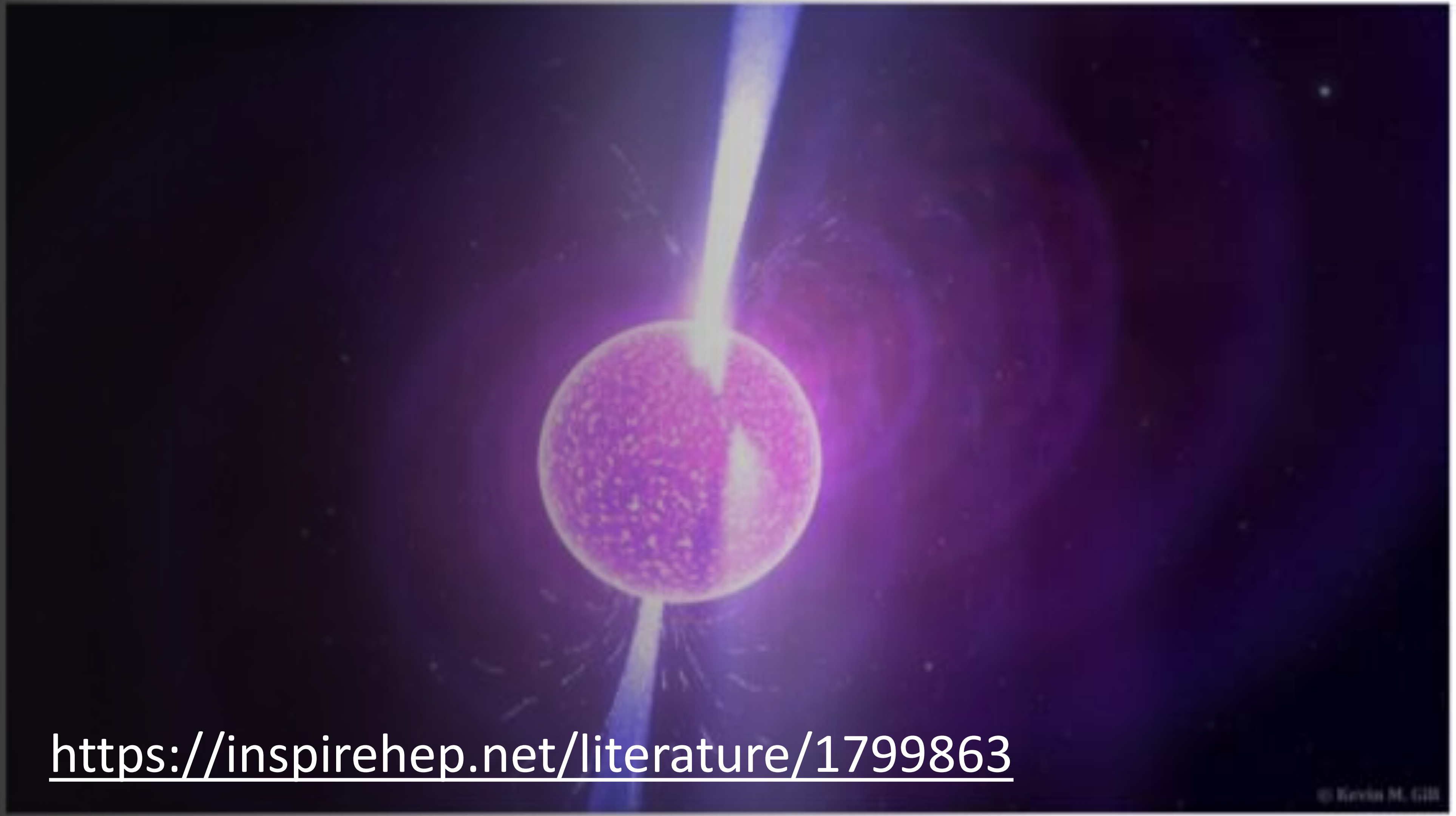
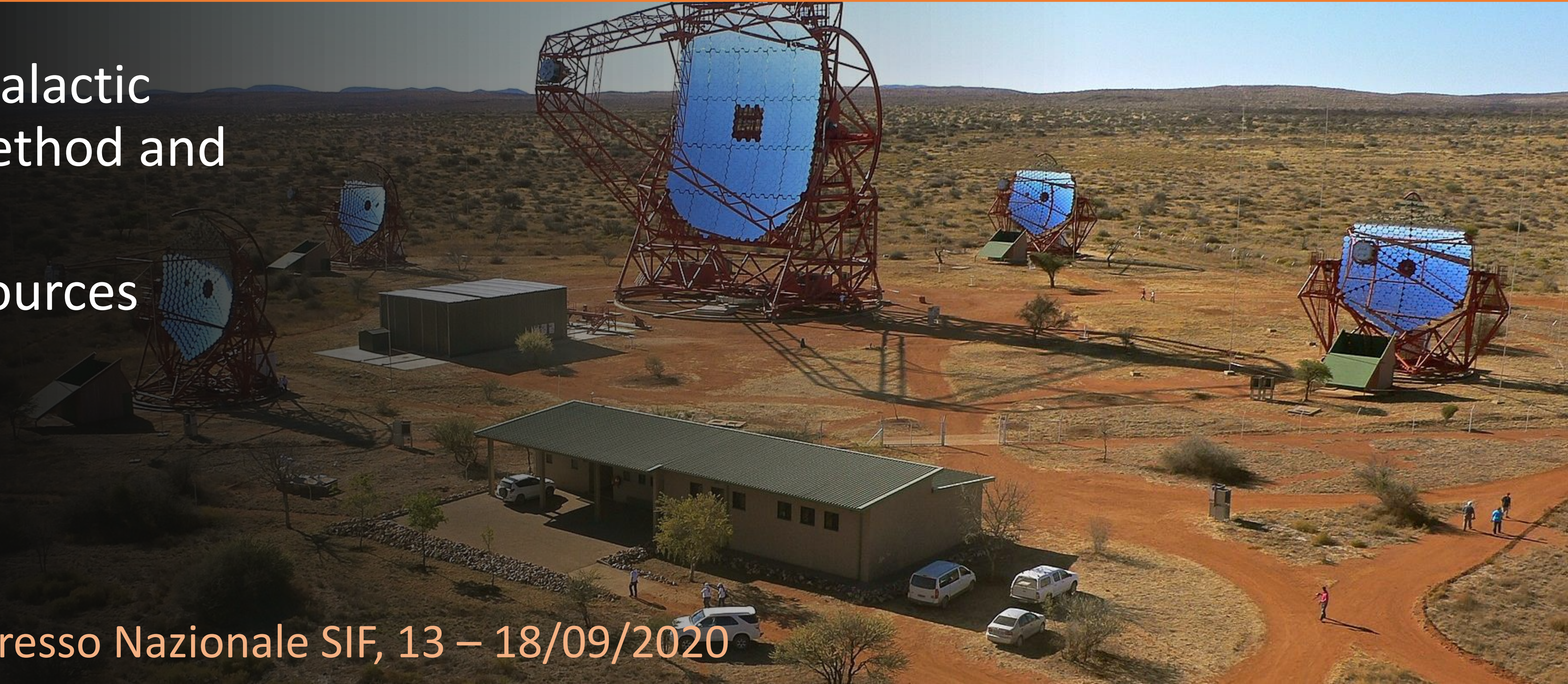
Overview:



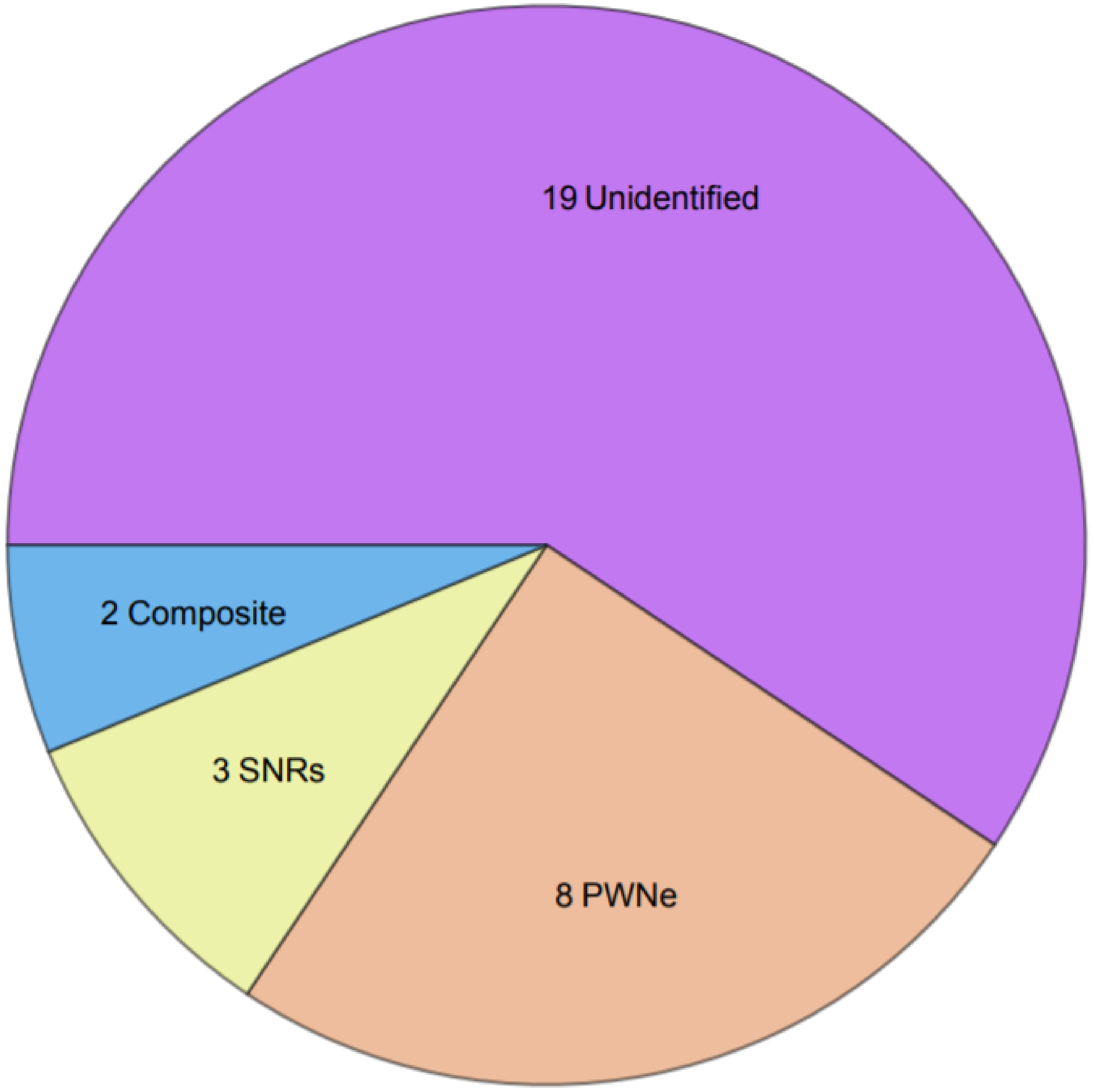
https://inspirehep.net/literature/1799863

- Population study of the H.E.S.S. Galactic Plane Survey (H.G.P.S) catalog (method and results);
- Interpretation in term of fading sources (method and results);
- Conclusions.



H.G.P.S catalog:

- It includes **78 VHE** sources in the H.E.S.S. observational window: $\mathbf{-110^{\circ} < \mathit{l} < 60^{\circ}}$ **and** $\mathbf{|\mathit{b}| < 3^{\circ}}$;
- It provides the integrated flux above 1 TeV of each sources ϕ.



We focus on the brightest sources with flux:

$$\phi > 0.1\phi_{Crab} = 0.1\ (2.26 \times 10^{-11} cm^{-2} s^{-1})$$

The catalog above this threshold is considered complete: **32 sources**.

We considered all sources with an energy dependence following a **power-law** spectra with index $\boldsymbol{\beta = 2.3}$ that is the average index of the catalog;

Model: We postulate the spatial and intrinsic luminosity distribution of the TeV sources:

$$\frac{dN}{dr^3 dL} = \rho(r) \boxed{Y(L)}$$

- The spatial distribution of sources in the Galaxy is assumed to be proportional to the pulsar distribution as in Lormier et Al.;
- The luminosity distribution of sources in the Galaxy is assumed to be a power law:

$$Y(L) = \frac{\boxed{N}}{L_{max}} \left(\frac{L}{L_{max}} \right)^{-\alpha}$$

We have two free parameters:

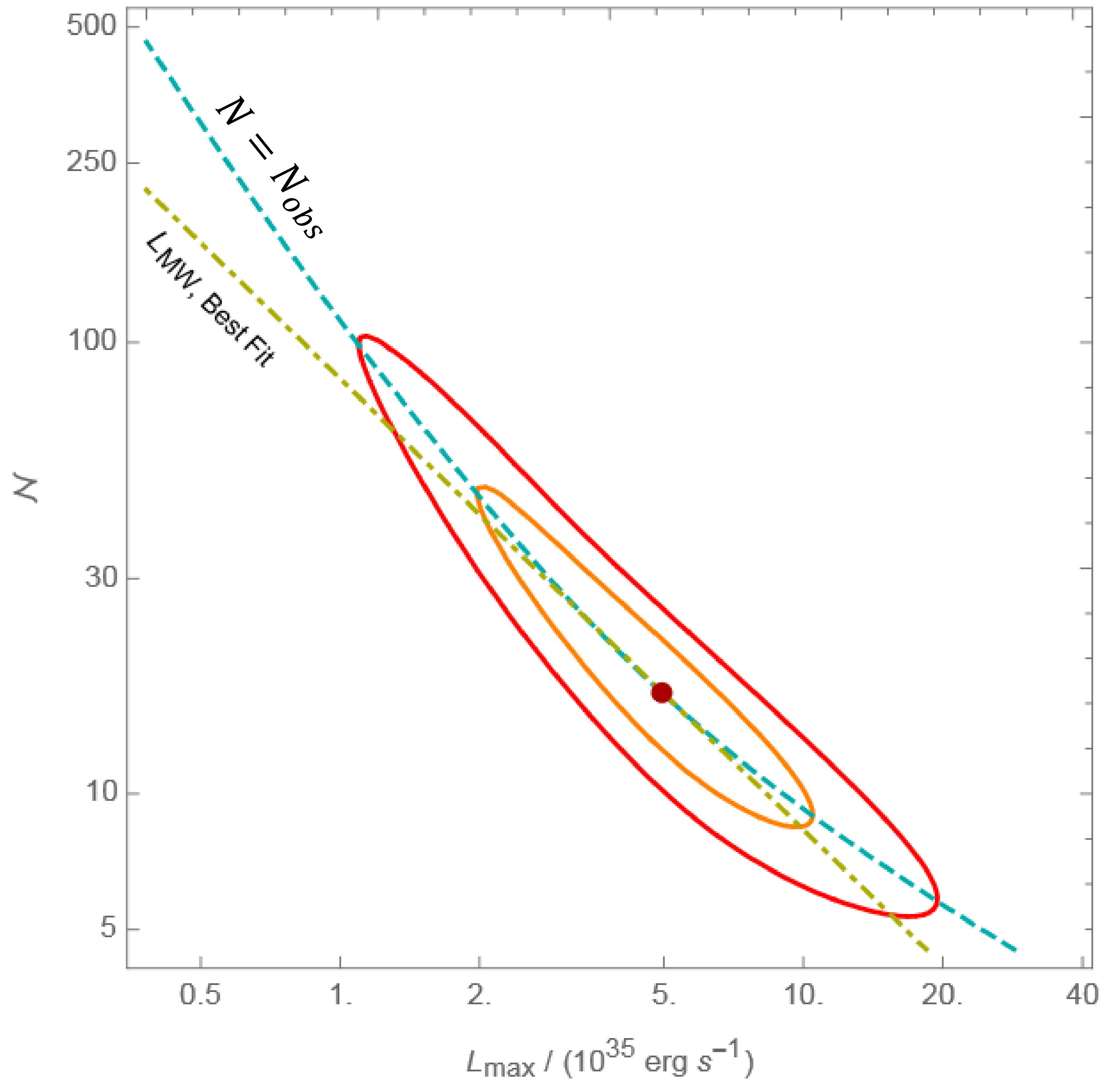
- the normalization $\boldsymbol{N}$ number of high-luminosity sources
- the maximum luminosity of the population $\boldsymbol{L_{max}}$

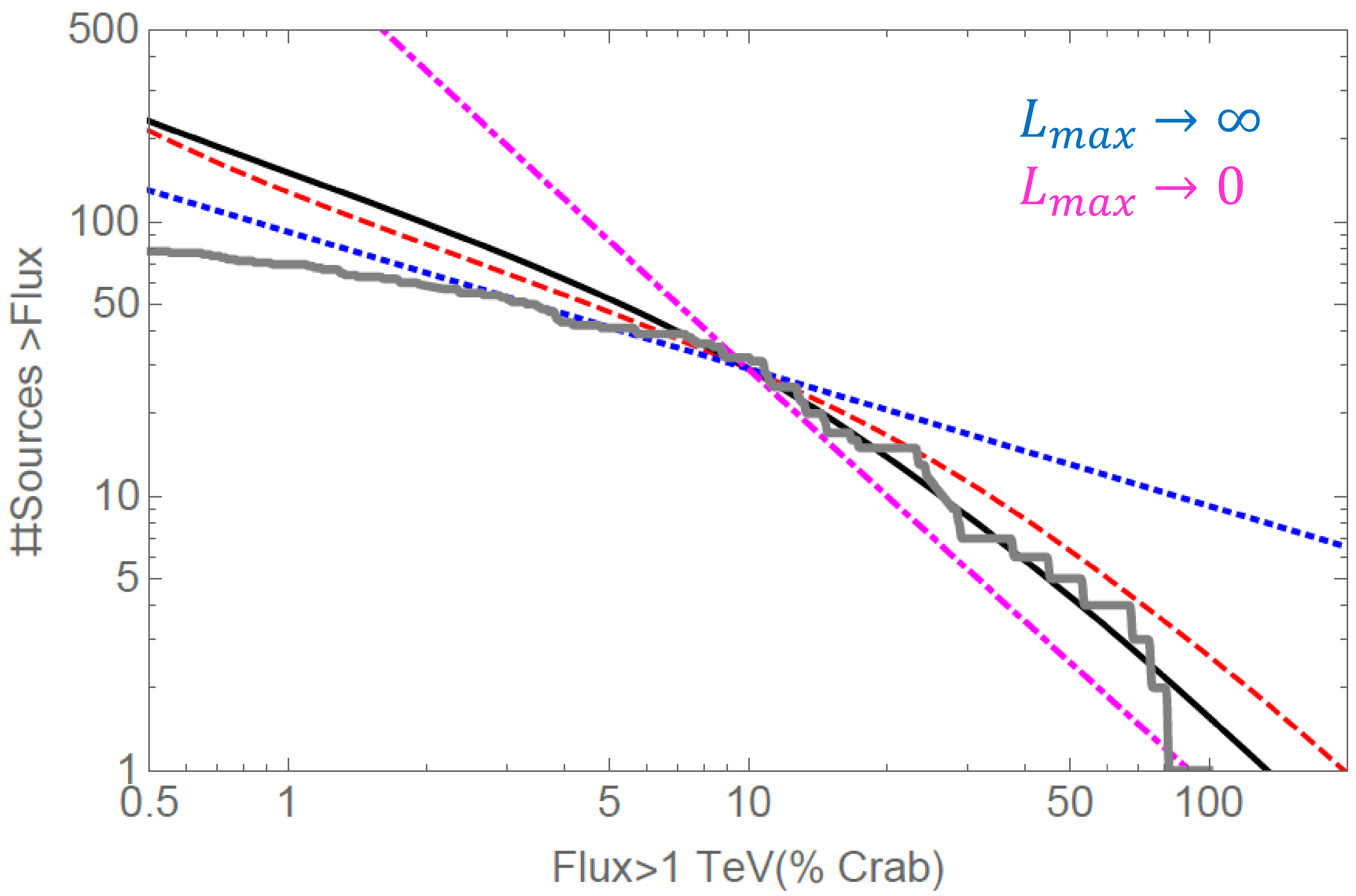
Goal: Estimation of the free parameters of our model by fitting H.E.S.S. observational results with an unbinned likelihood

Results:

$$L_{\max} = 4.9^{+3.0}_{-2.1} \times 10^{35} \mathrm{ergs/s}$$

$$\mathcal{N} = 17^{+14}_{-6}$$





Results:

- The total TeV luminosity (1-100 TeV) of the Galaxy:

$$L_{MW} = \frac{N\, L_{max}}{(2-\alpha)}\left[1 - \left(\frac{L_{min}}{L_{max}}\right)^{\alpha-2}\right] = 1.7^{+0.5}_{-0.4} \times 10^{37}\ erg\ \sec^{-1}$$

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- The flux at Earth produced by all sources (1-100 TeV) (resolved and unresolved) in the H.E.S.S. OW:

$$\phi_{tot} = \frac{L_{MW}}{4\Pi\langle E\rangle}\int_{OW} d^3r\,\rho(r)r^{-2} = 3.8^{+1.0}_{-1.0} \times 10^{-10} cm^{-2} \sec^{-1}$$

3.25 TeV

- By subtraction we can obtain the contribution of unresolved sources in the H.E.S.S. observational window knowing that: $\phi_{S,res} = 2.3 \times 10^{-10} cm^{-2} s^{-1}$

$$\boxed{\phi_{S,unres} = \phi_{tot} - \phi_{S,res} = 1.4^{+1.0}_{-0.8} \times 10^{-10}\ cm^{-2} s^{-1}} \sim 60\%\ \phi_{S,res}$$

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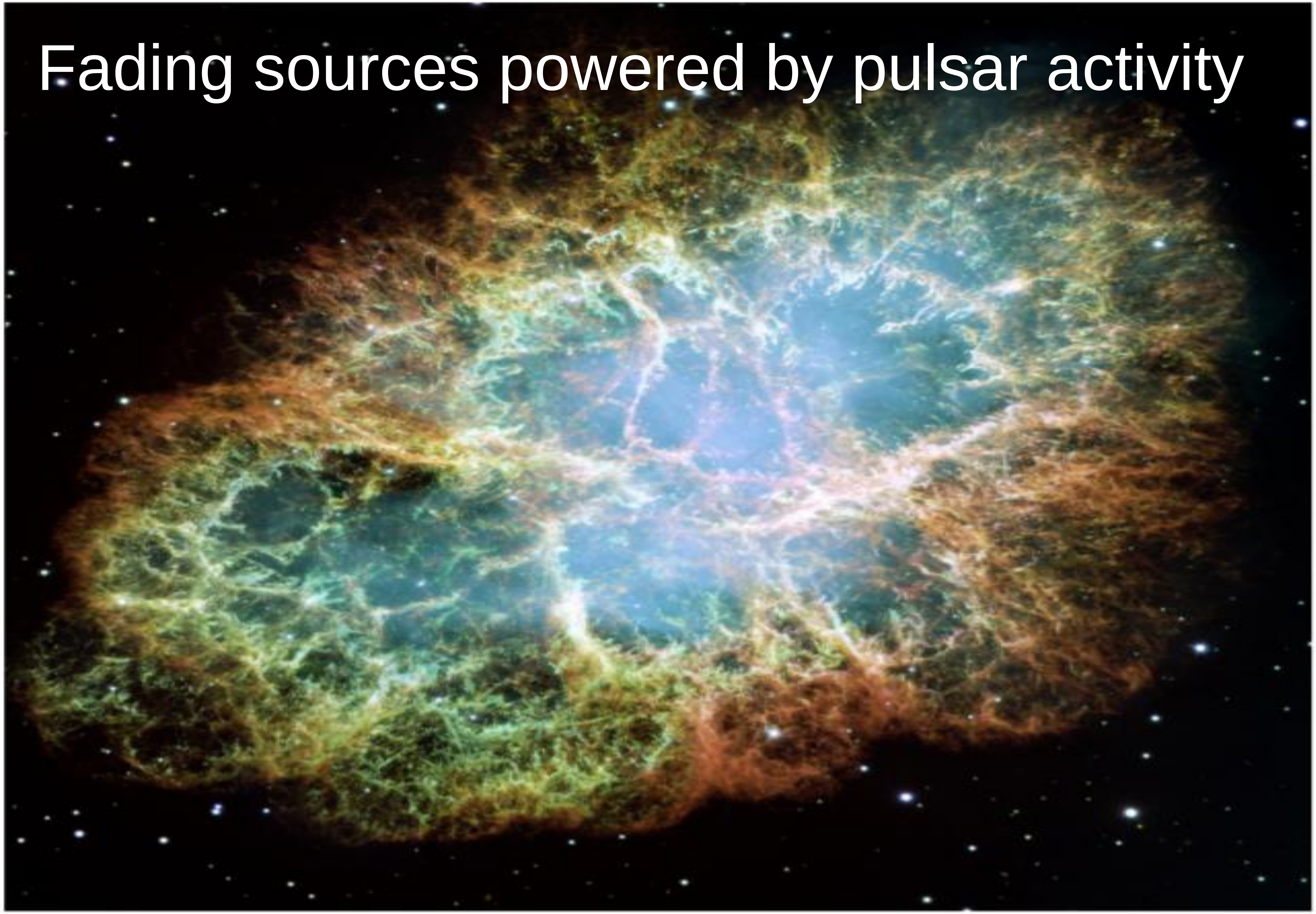
Fading sources powered by pulsar activity



Model:

$$\frac{dN}{d^3r\,dL} = \rho(\mathbf{r})\boxed{Y(L)}$$

We automatically obtain a power law for the luminosity distribution:

$$Y(L) = \frac{R\,\tau\,(\alpha - 1)}{L_{\max}}\left(\frac{L}{L_{\max}}\right)^{-\alpha}$$

Where $R = 0.019\,yr^{-1}$ is the SN's rate and $\alpha = 1.5$ that comes from pulsar theory.

In conclusion the new free parameters are:

- the spin-down timescate τ
- the maximum luminosity of the population L_{max}

Model:

The best fit parameters $\boldsymbol{L_{max}}$ and $\boldsymbol{\tau_{sd}}$ are linked to the magnetic field $\boldsymbol{B_0}$ and the initial spin-down period $\boldsymbol{P_0}$ of the pulsar through this relations:

$$L_{max} = \lambda \dot{E}_0 = \lambda \frac{8\pi^4 B_0^2 R^6}{3c^3 P_0^4}$$

$$\tau_{sd} = \frac{3Ic^3 P_0^2}{4\pi^2 B_0^2 R^6}$$

$$\frac{P_0}{1\,\mathrm{ms}} = 94 \left(\frac{\lambda}{10^{-3}}\right)^{1/2} \left(\frac{\tau}{10^4\mathrm{y}}\right)^{-1/2} \left(\frac{L_{\max}}{10^{34}\mathrm{erg\,s^{-1}}}\right)^{-1/2}$$

$$\frac{B_0}{10^{12}\mathrm{G}} = 5.2 \left(\frac{\lambda}{10^{-3}}\right)^{1/2} \left(\frac{\tau}{10^4\mathrm{y}}\right)^{-1} \left(\frac{L_{\max}}{10^{34}\mathrm{erg\,s^{-1}}}\right)^{-1/2}$$

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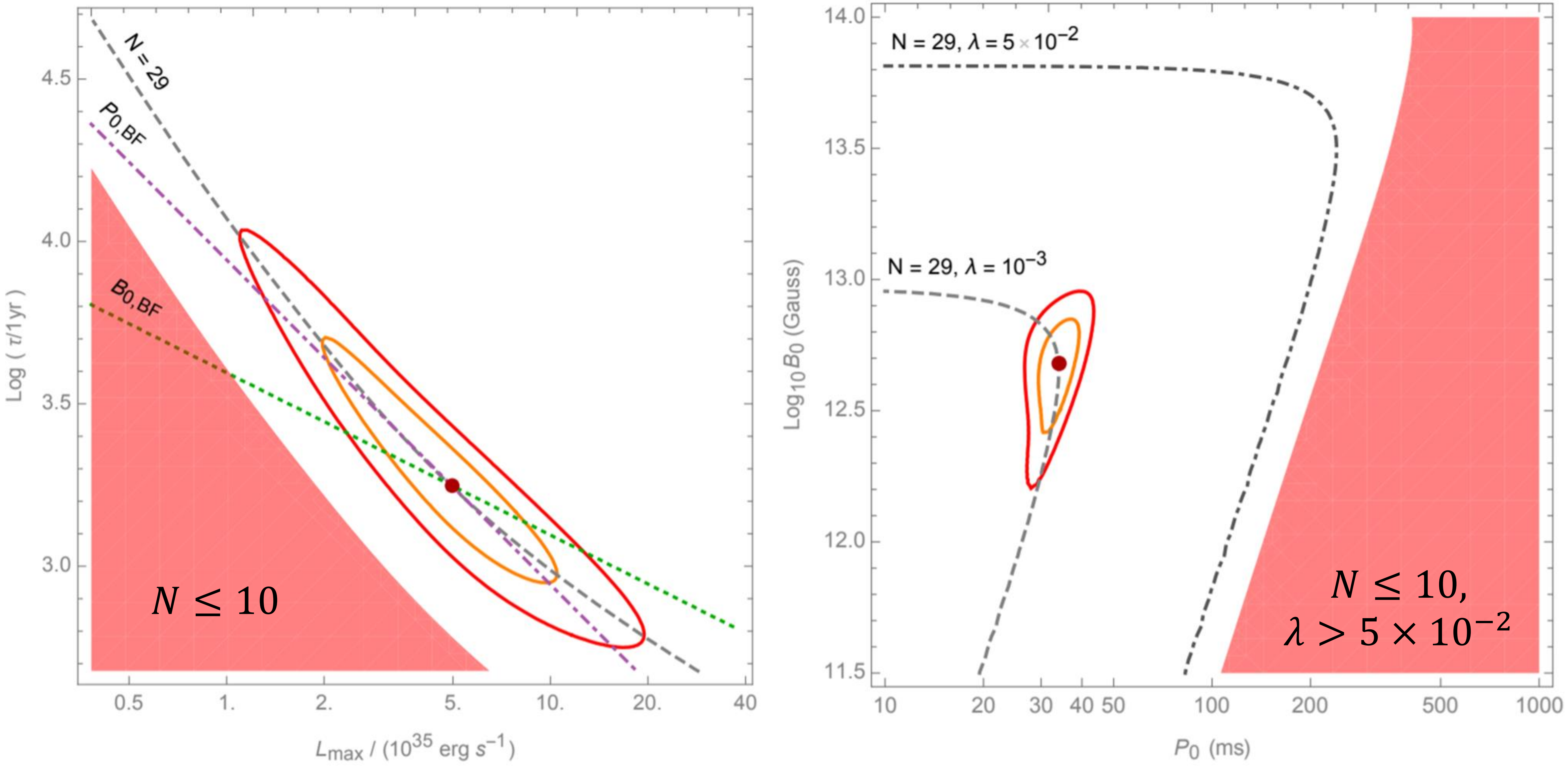
Results:



$$\tau_{sd} = 1.8^{+1.5}_{-0.6} \times 10^3 yr$$
$$\mathrm{L}_{max} = 4.9^{+3.0}_{-2.1} \times 10^{35} ergs\ s^{-1}$$

$$P_0 = 33^{+5.4}_{-4.3}\ ms \times \left(\frac{\lambda}{10^{-3}}\right)^{\frac{1}{2}}$$

$$B_0 = 4.32(1 \pm 0.45)10^{12} G \times \left(\frac{\lambda}{10^{-3}}\right)^{\frac{1}{2}}$$

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Conclusions:

- Using the H.G.P.S. we are able to calculate the total Milky Way luminosity in the energy range 1 -100 TeV and the total flux in the H.E.S.S. observational window in the energy range 1 -100 TeV;

- The contribution of unresolved source is not negligible being $\sim 60\ \%$ of the resolved signal mesured by H.E.S.S.;

- In the hypothesis of a fading-source population powered by pulsar activity we are able to predict the general parameters of the pulsar P_0 and B_0. Our predictions are in agreement with values obtained from TeV pulsars but is 1 order of magnitude lower than the value observed for radio pulsars .

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