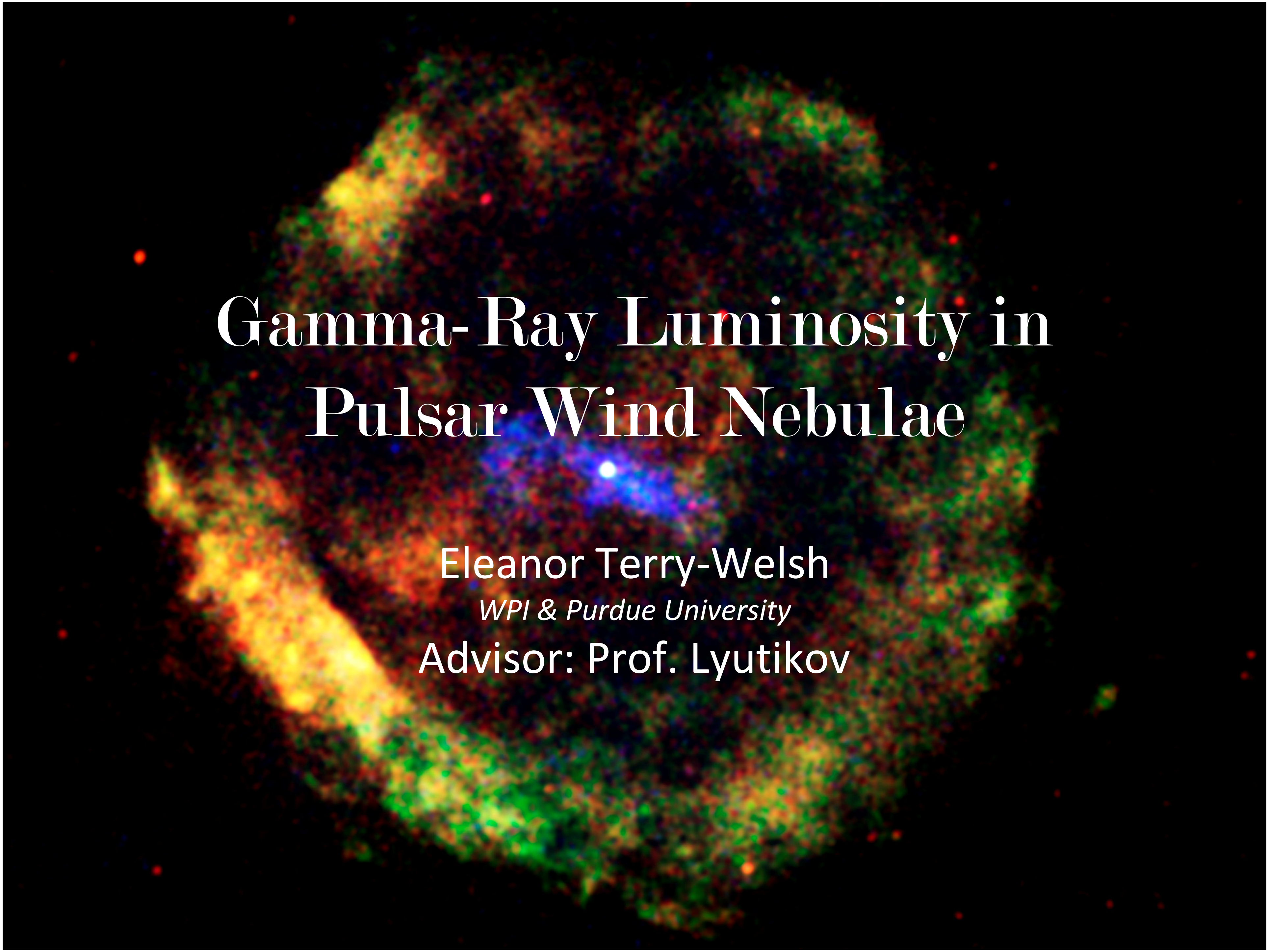

Gamma-Ray Luminosity in Pulsar Wind Nebulae

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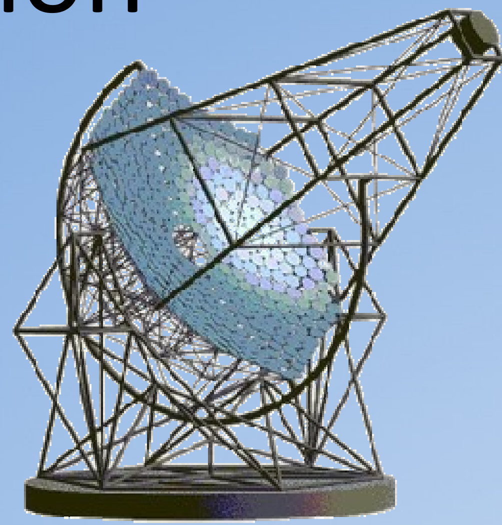
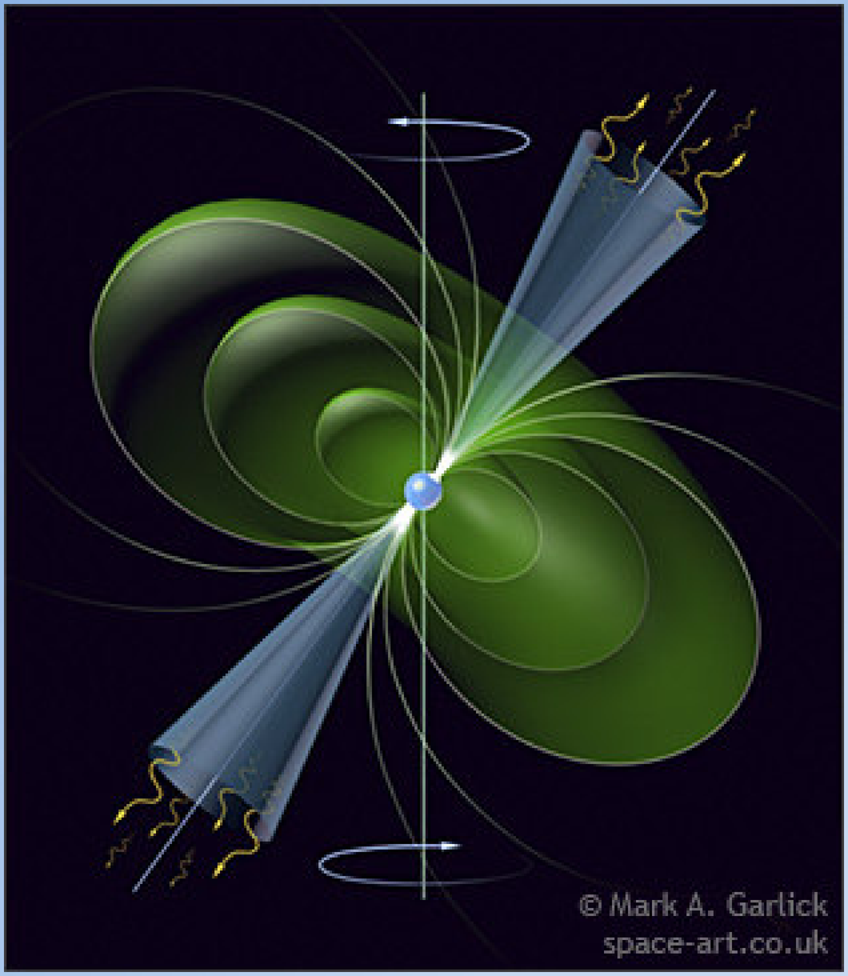
Introduction

- Telescopes:
  - H.E.S.S.
  - V.E.R.I.T.A.S.
  - FERMI satellite
- Understand how stars evolve
- Can be related to accelerator physics
- Create models to understand new data



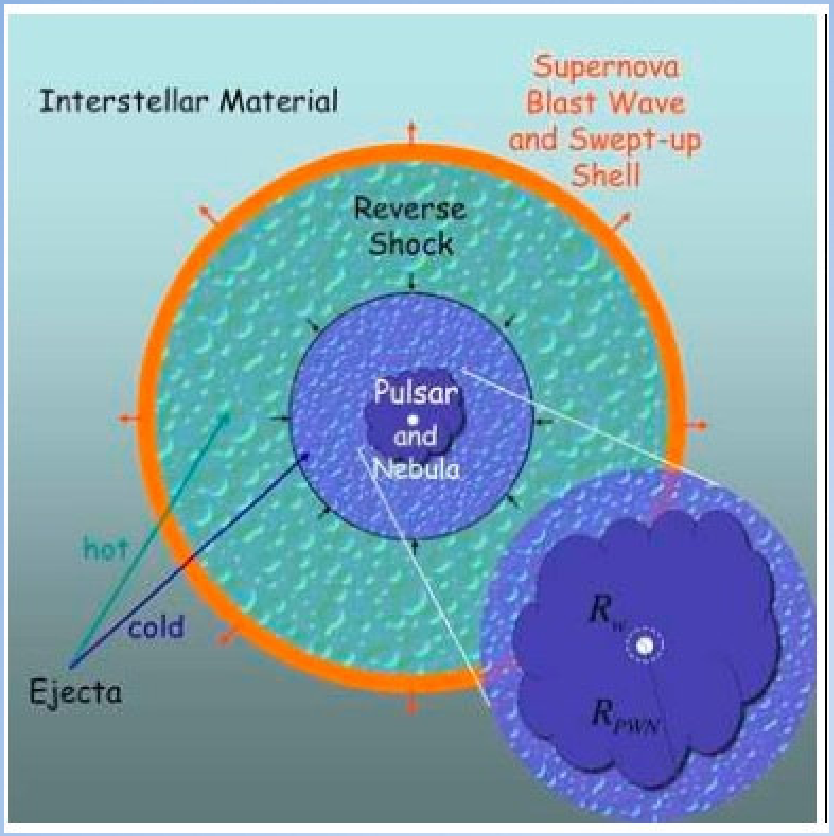
Pulsars

- Neutron stars
- Spinning very rapidly
- Large magnetic fields
    - ~10^{12} Gauss
- Rotation powered emissions
- Loosing rotational energy



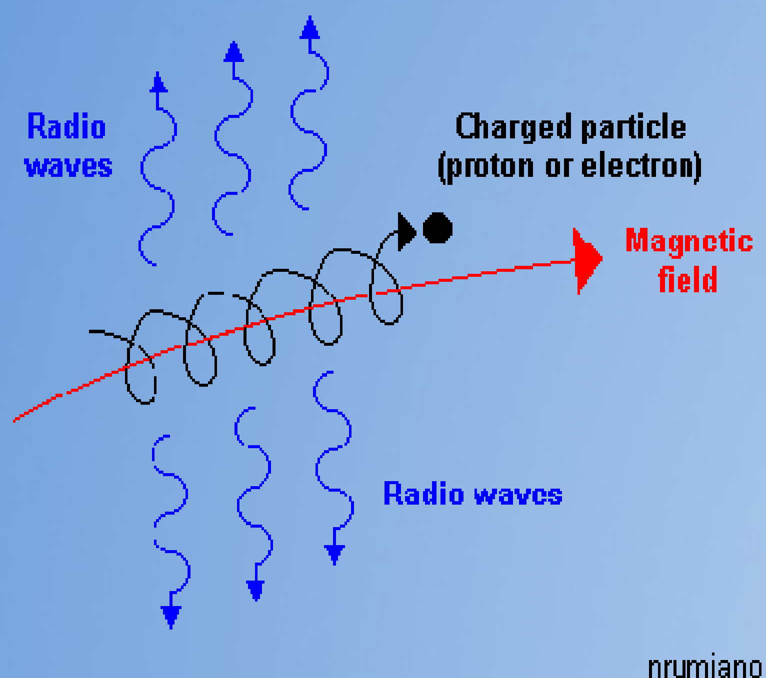
Pulsar Wind Nebulae

- Pulsar at the center
- Shell nebula from a Supernova
- Emits B-field and particles
- Interact with surrounding material

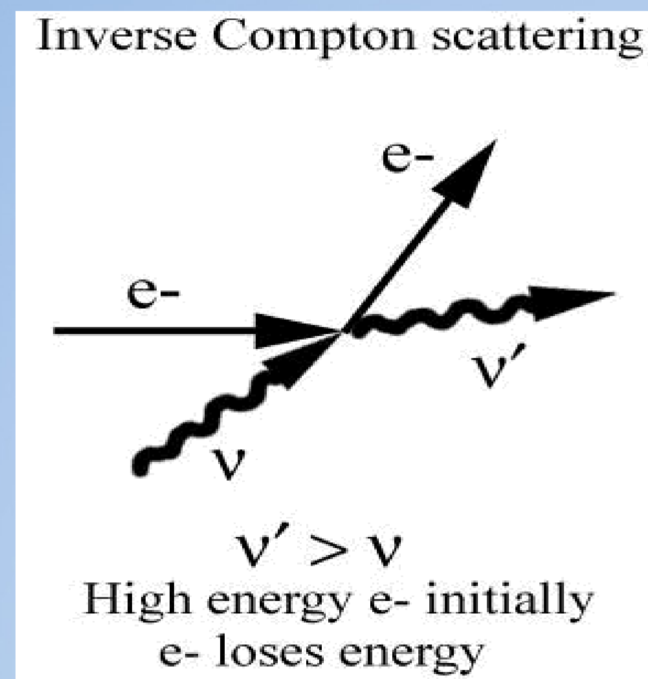


Pulsar Emissions

Synchrotron Emissions



Inverse Compton Scattering



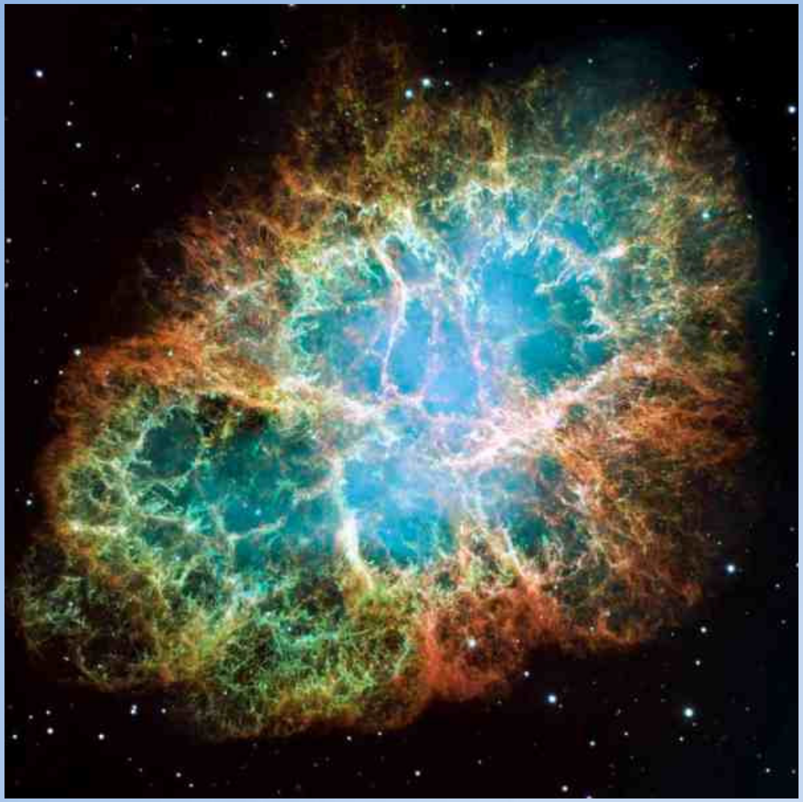
Characteristics of Interest

- Gamma-ray Luminosity
- Characteristic age

$$\tau = \frac{P}{(n-1)\dot{P}} - \frac{P_0}{(n-1)\dot{P}_0}$$

- Spin down luminosity

$$L_{SD} \propto \dot{P}$$



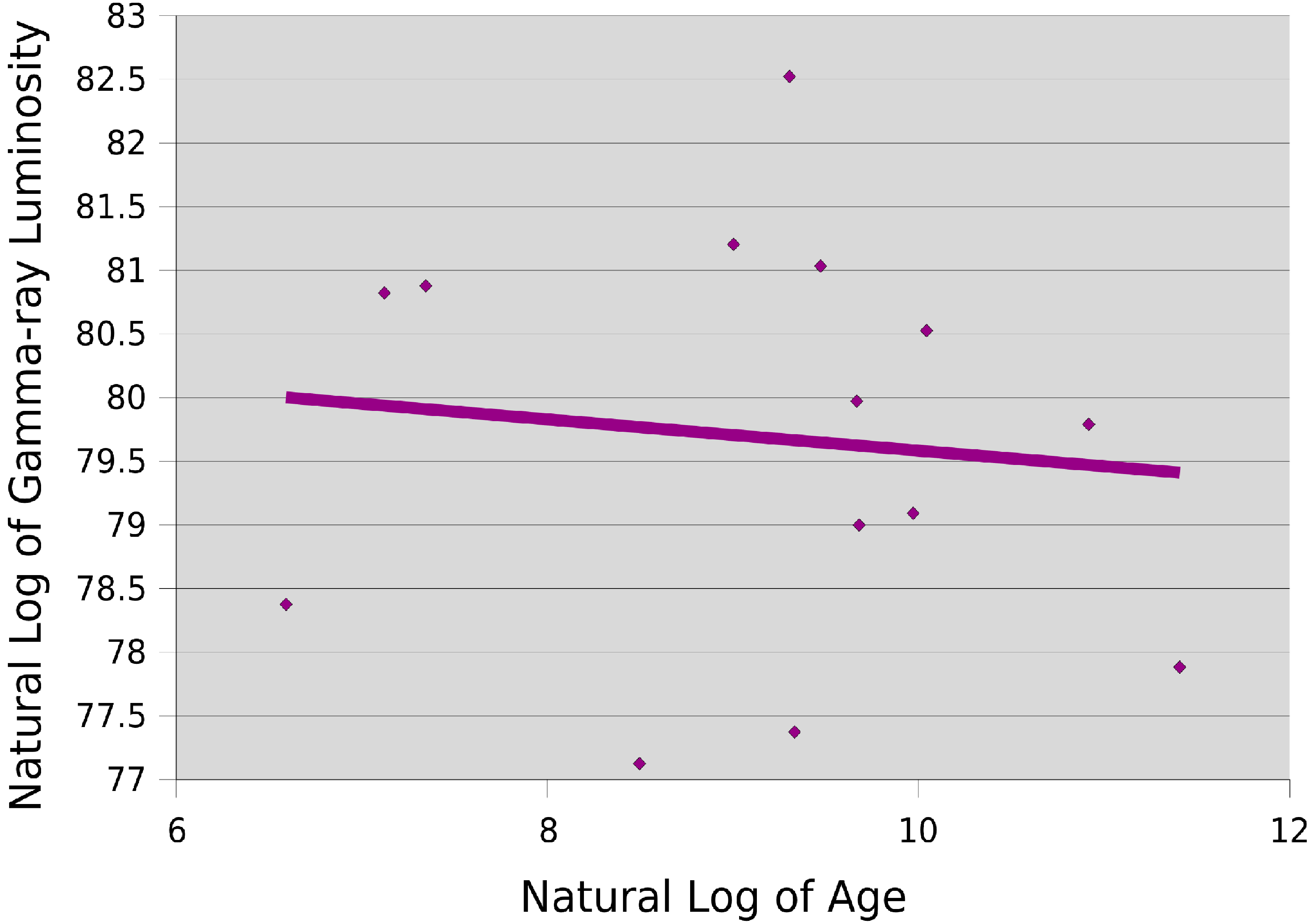
Correlating Luminosity, Spin Down, and Age

- Expect a relation in the form of

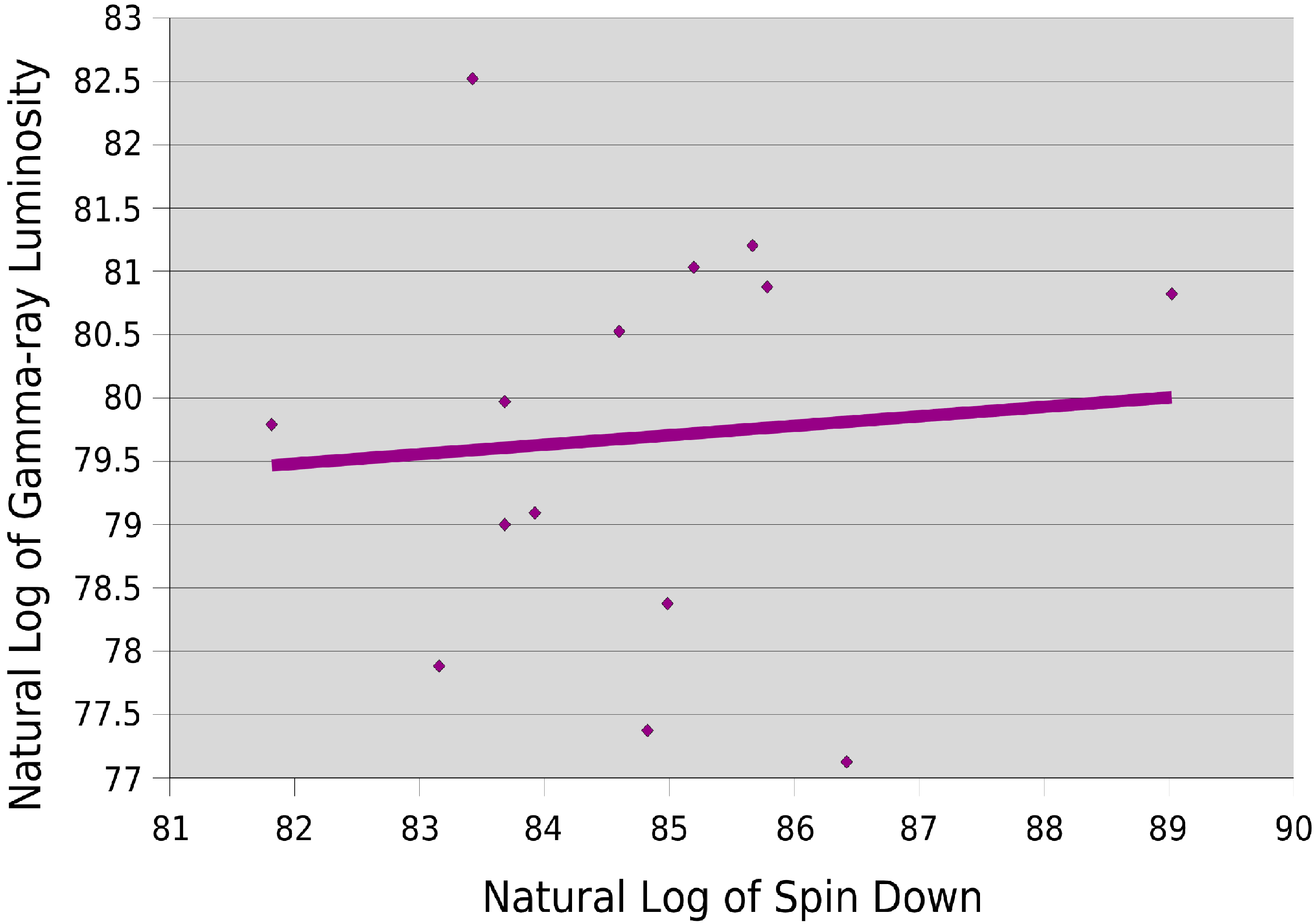
$$L_\gamma \propto \tau_{ch}^{\alpha} L_{sd}^{\beta}$$

- Existing pulsar data from the H.E.S.S. telescope (Gallant, Y. 2006, Mattana, F. et al. 2009)

Gamma-Ray Luminosity vs. Age



Gamma-Ray Luminosity vs. Spin Down Luminosity



Theoretical Model

Assume Luminosity is related to energy loss

$$L = \frac{dE_{rot}}{dt} = I\Omega\dot{\Omega}$$

Because of magnetic breaking

$$I\Omega\dot{\Omega} \propto \Omega^{n+1}$$

Differential Equation to be solved (D = all the constants)

$$\frac{d\Omega}{dt} = D\Omega^{n}$$

Theoretical Model

Solution to the differential equation

$$\Omega(t) = \frac{\Omega_0}{(1 - Dt\Omega_0{}^{n+1}(n-1))^{1/n-1}}$$

Luminosity becomes

$$L \propto \left(\frac{\Omega_0}{(1 - Dt\Omega_0{}^{n-1}(n-1))^{1/n-1}} \right)^{n+1}$$

Theoretical Model

Gamma ray emissions from IC scattering

$$L \propto \gamma m_e c^2 \dot{N}$$

Combine the two equations

$$\gamma m_e c^2 \dot{N} \propto \left(\frac{\Omega_0}{(1 - Dt\Omega_0{}^{n-1}(n-1))^{1/n-1}} \right)^{n+1}$$

Total particles emitted over time

$$N \propto \frac{\Omega_0{}^{n+1}}{\gamma m_e c^2} \int_{t_0}^{T} \frac{dt}{(1 - Dt\Omega_0{}^{n-1}(n-1))^{n+1/n-1}}$$

Conclusions

- Find number of particles injected by pulsar
- Use to find IC luminosity and SS luminosity for this electron population
- Luminosity is related to rotation and time by a power. But its complicated.

Future Work

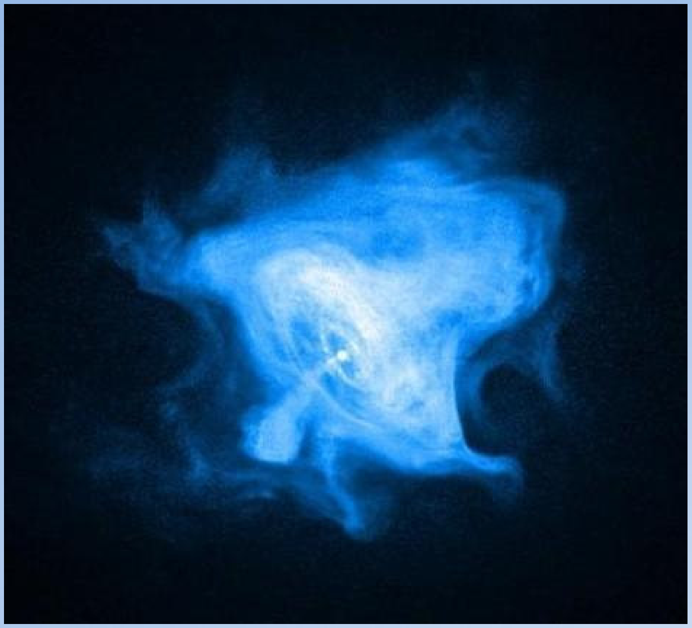
- Synchrotron emissions
  - Responsible for X-ray emissions

$$L \propto \frac{\dot{\phi}^2}{c}$$

  - Need to account for B-field

$$B(t) \propto \frac{1}{R(t)} \int \dot{\phi}\, dt$$

  - Need to account for expanding radius of PWN
  - Multiple electron populations



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