Pulsar Wind Nebulae @ INAF

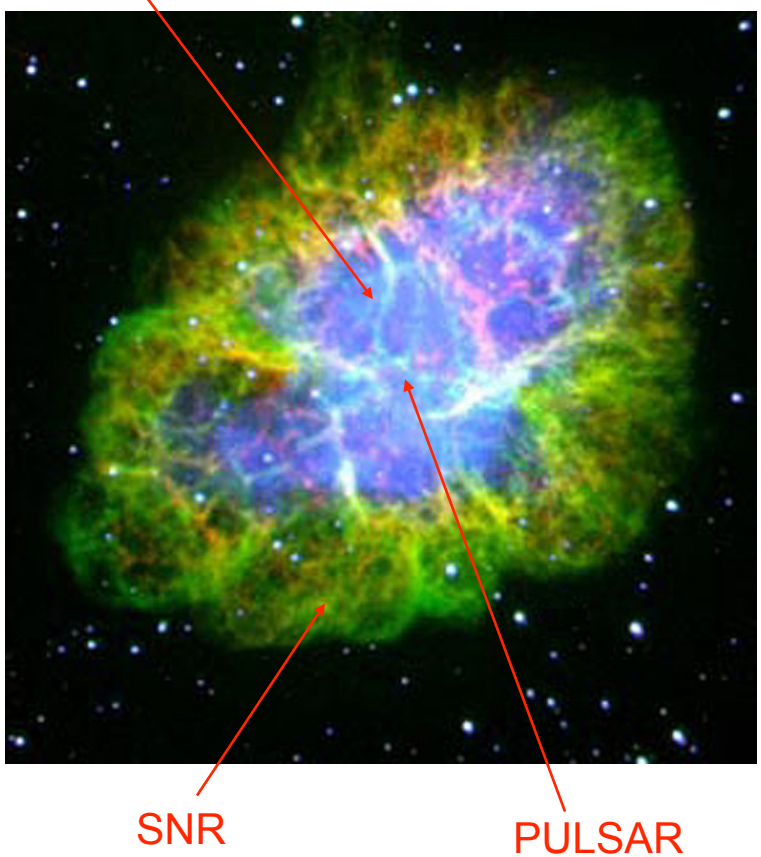
Niccolo' Bucciantini

INAF - Osservatorio di Arcetri

INFN - Sezione di Firenze

UniFi - Dipartimento di Fisica & Astronomia

Pulsar Wind Nebulae



- **PWNe are hot bubbles of relativistic particles and magnetic field emitting non-thermal radiation.**
- **Galactic accelerators. The only place where we can study the properties of relativistic shocks (as in GRBs and AGNs)**
- **Allow us to investigate the dynamics of relativistic outflows**

Arcetri: Bucciantini, Bandiera, Amato.
UniFi: Del Zanna, Olmi.

PWNe beyond PWNe

PWNe are prototypical example of the interaction of a relativistic outflow with the confining environment:

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- Dynamics of Interaction (instabilities, role of magnetic field, efficiency of confinement, etc...).
- Acceleration processes: amplification of magnetic field at shocks, origin of non-thermal particles, efficiency of acceleration hard vs soft distributions.
- Engine signatures: energy outflow and collimation, signature of leptons and hadrons, pair creation processes in the magnetospheres of compact objects

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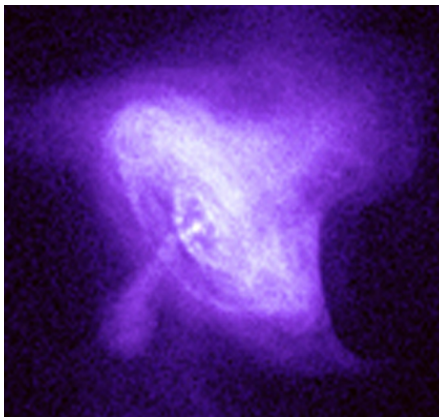
Magnetar Wind Nebulae in the millisecond magnetar model for L/S GRBS

PWNe shock as typical relativistic shock accelerators (GRBS /AGNs)

PWNe as antimatter reservoirs/factories int he galaxy (PAMELA positron excess)

Going Beyond 2D

- **In the past 10 years the main focus on PWNe modeling has been the attempt to reproduce the jet-torus morphology observed in X-rays**



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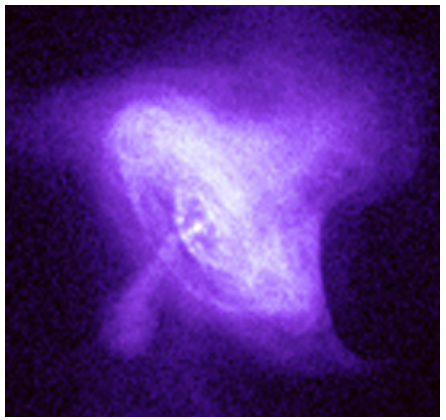
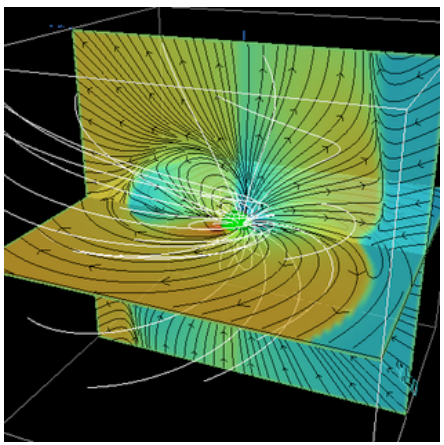
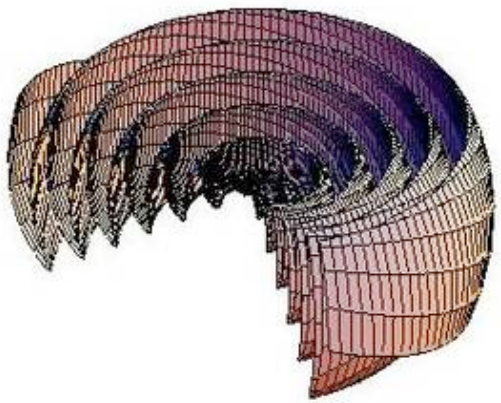


- **Ability to model the outflow properties of oblique rotators in accord with FE simulations**





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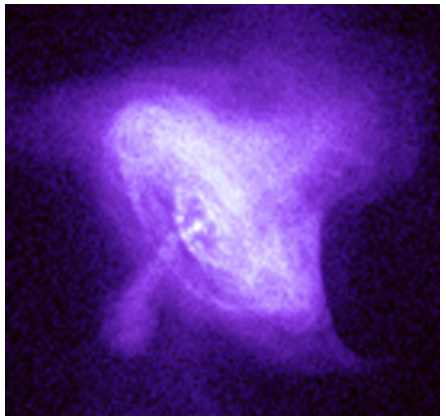

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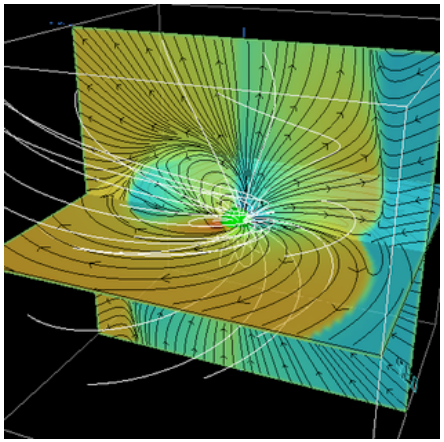
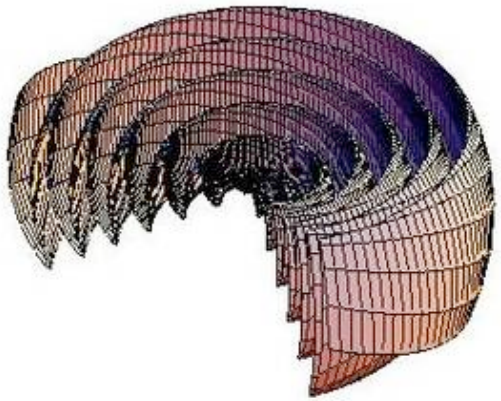
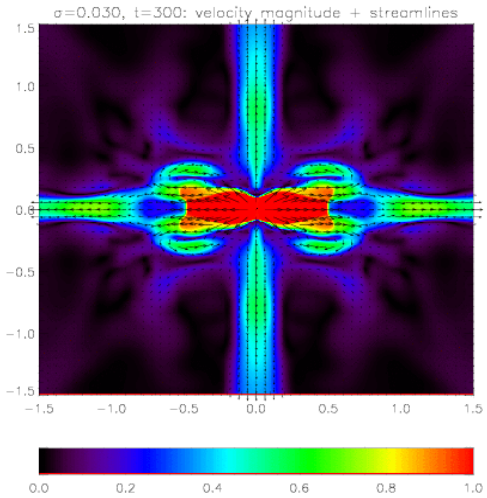


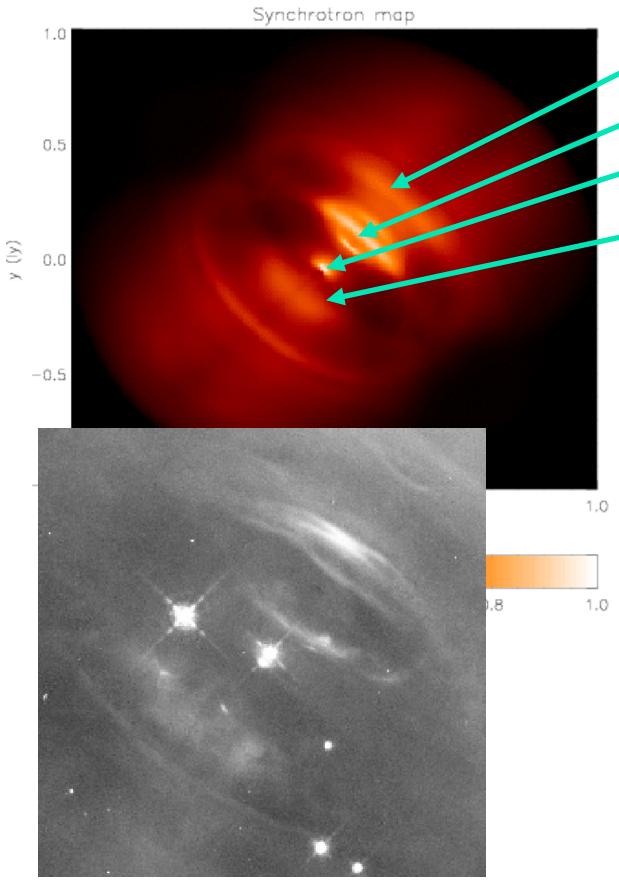




Del Zanna et al. 2004

Comparison with Observations

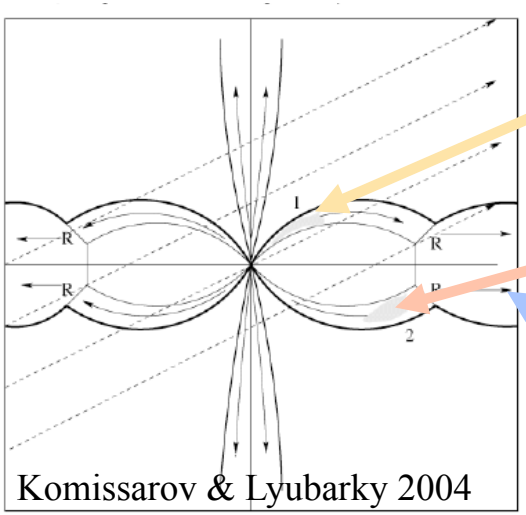
Del Zanna et al.



Hester et al. 1995

Main torus
Inner ring (wisps structure)
Knot
Back side of the inner ring

Each feature traces an emitting region



Knot

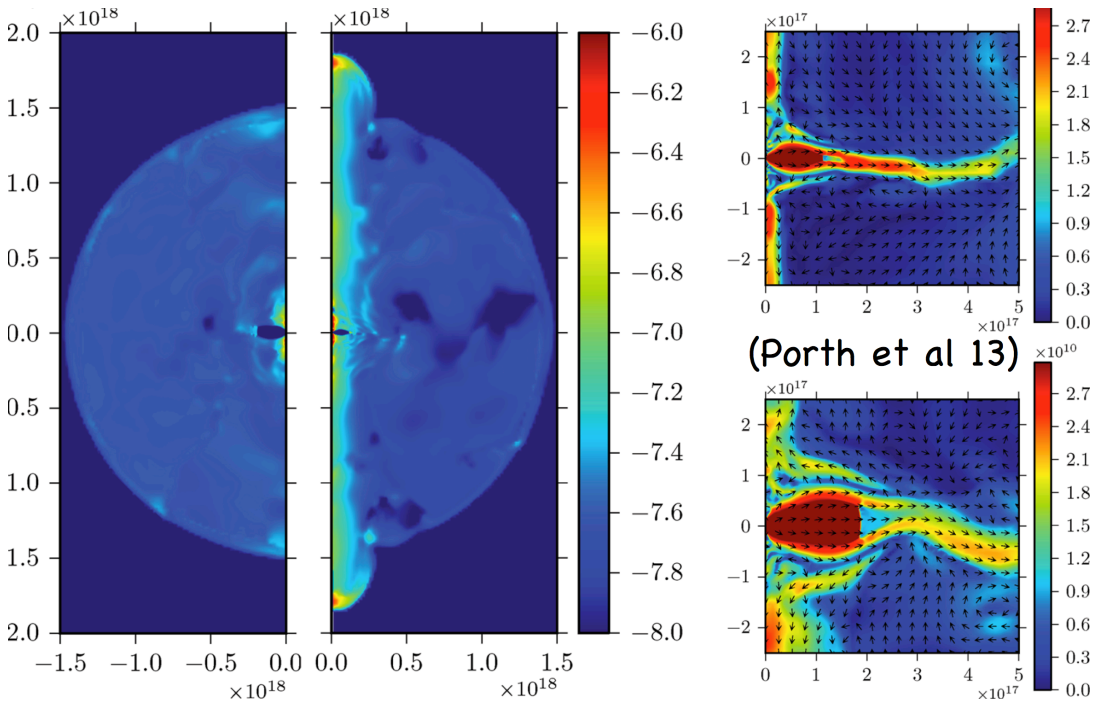
Ring

Torus

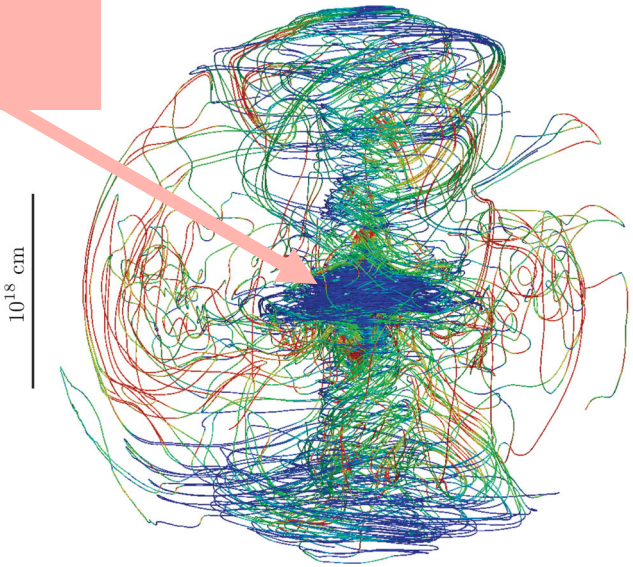
3D vs 2D

3D allows for higher magnetizations

Inner region still axisymmetric Torus-Jet



(Porth et al 13)



Weaker jet and polarization

3D Simulations

Olmi et al. (in prep)

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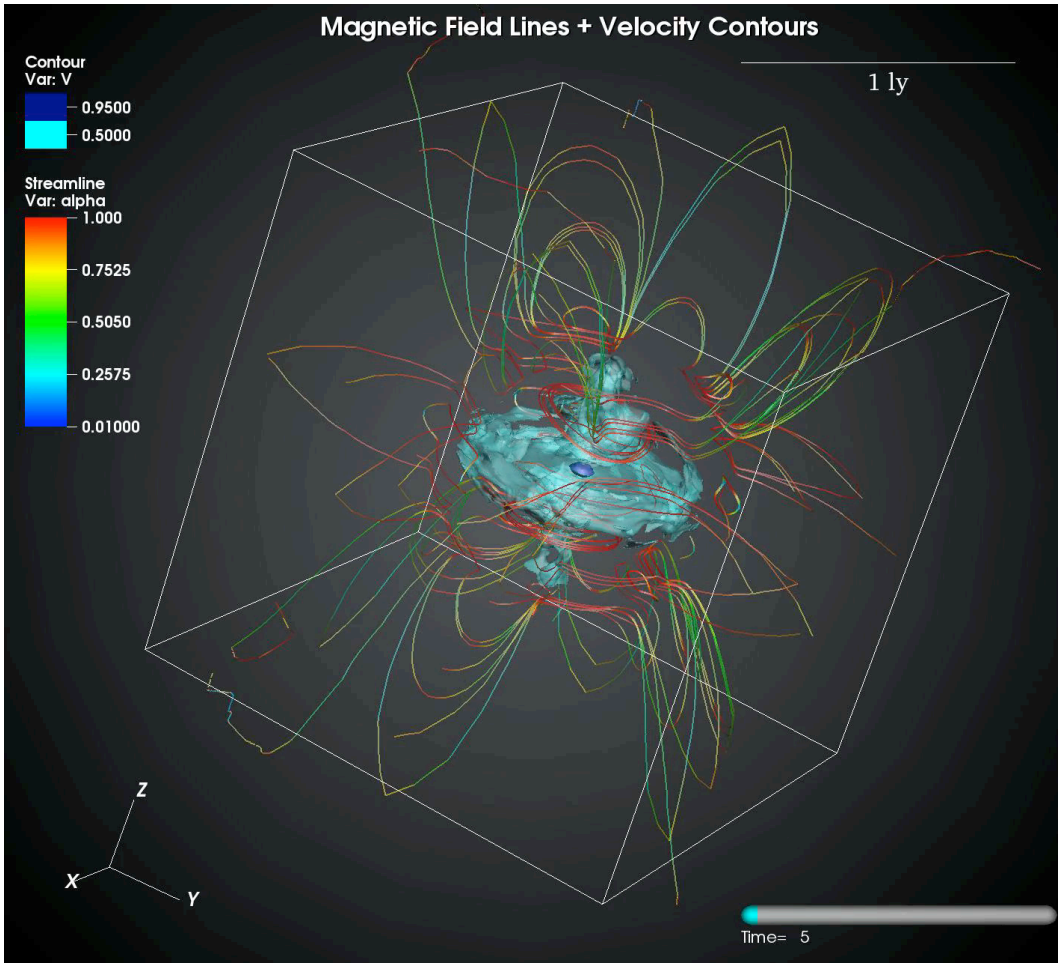

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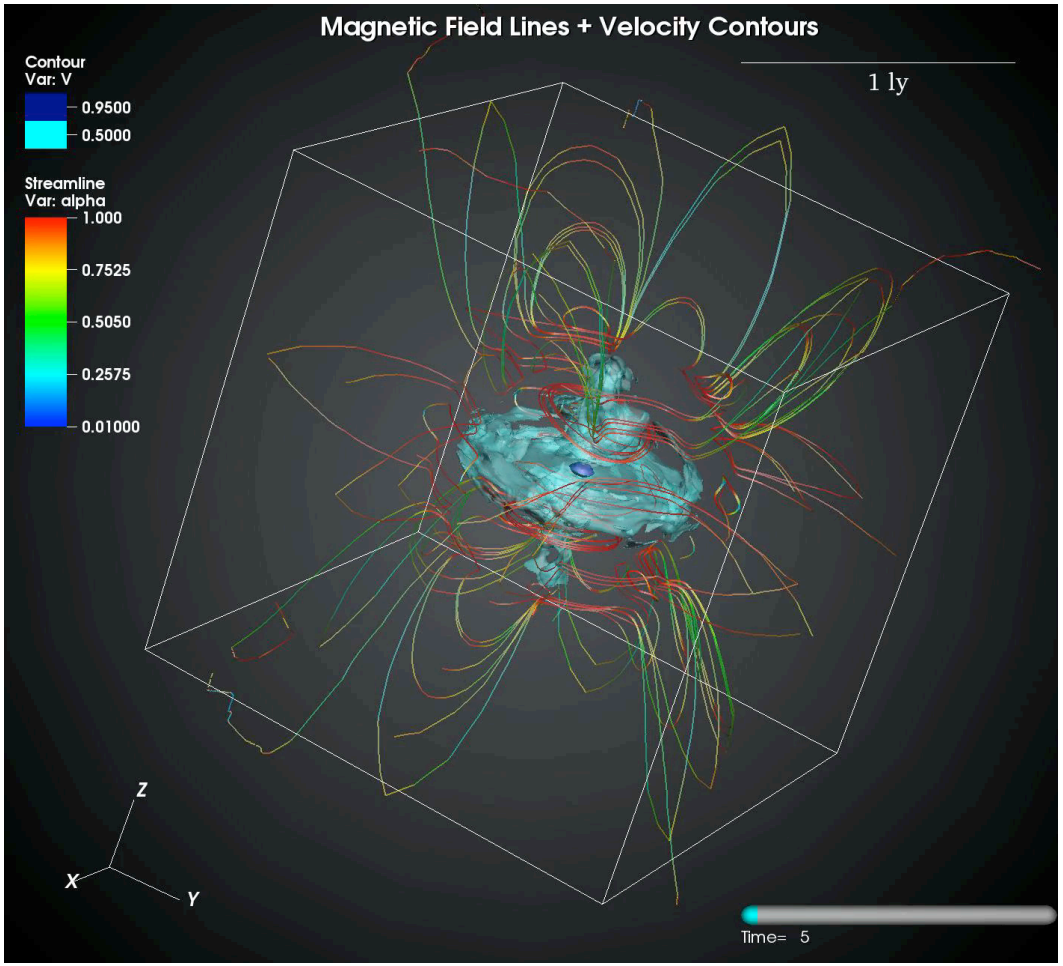

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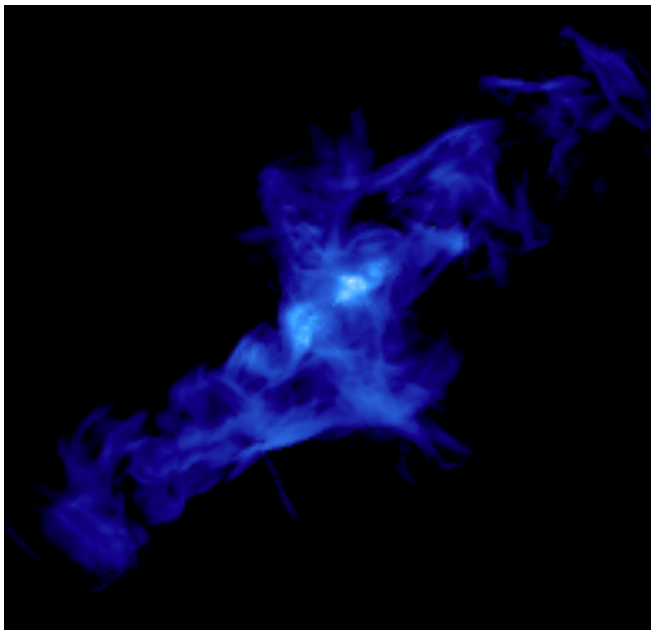
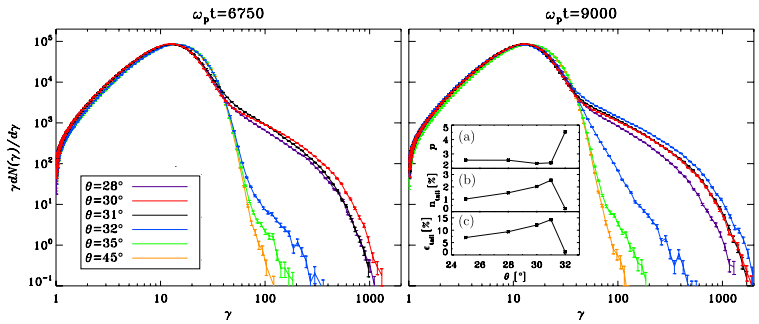


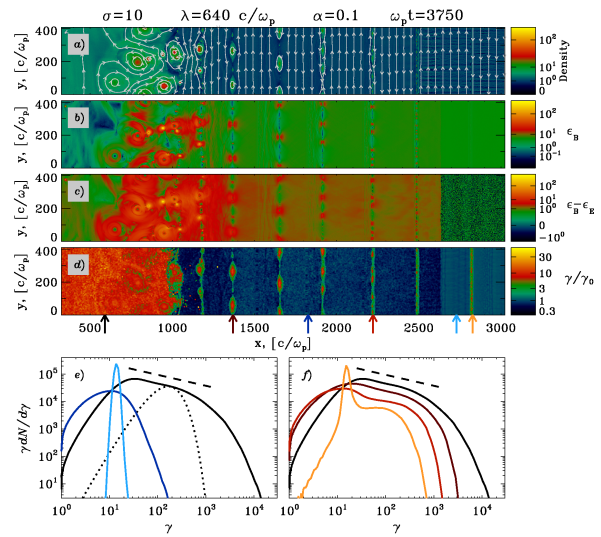
Jet dominated systems?

Acceleration at the TS



Spitkovsky 2006

Diffusive Fermi Process shown to work only for small magnetization - soft spectrum

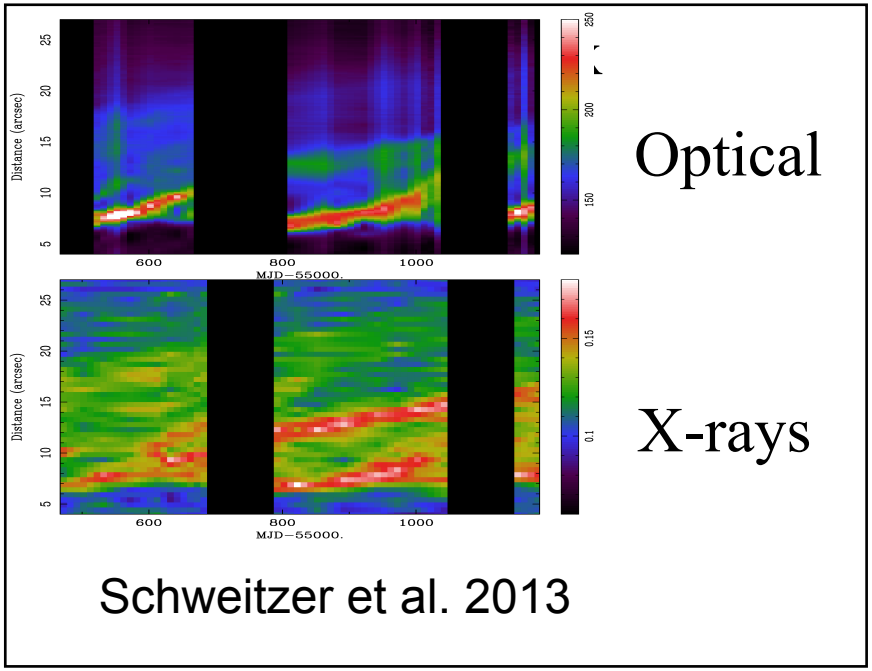


Sironi & Spitkovsky 2008

Reconnection likely to work of higher magnetization (but constraints on multiplicity - Hard spectrum can be obtained

PWNe are the only place where we can with “some confidence” connect a position at the shock to an given regime in the outflow

Imaging the Wind



Schweitzer et al. 2013

Wisp properties are wavelength dependent

Do wisps trace different injection condition at the shock?

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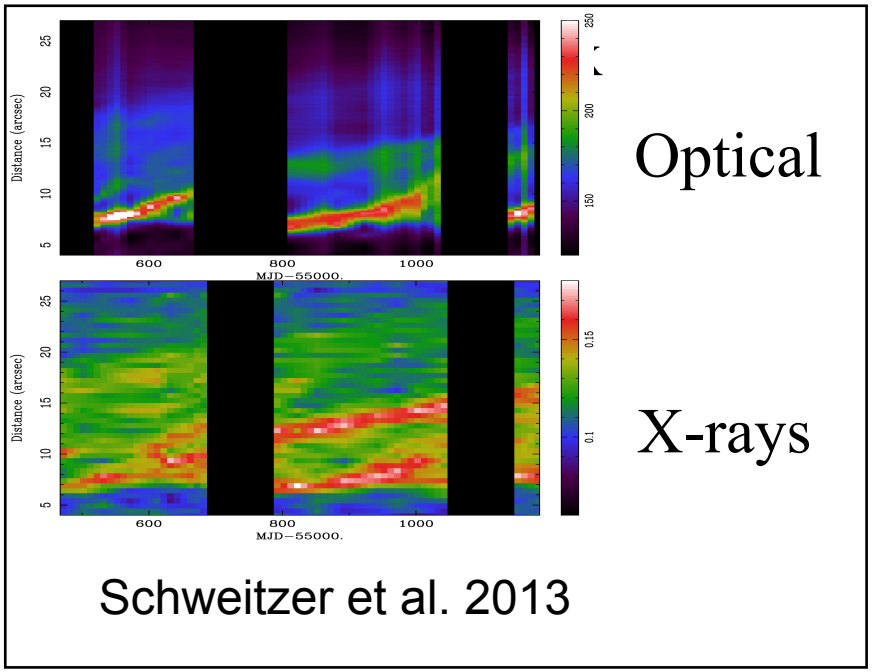

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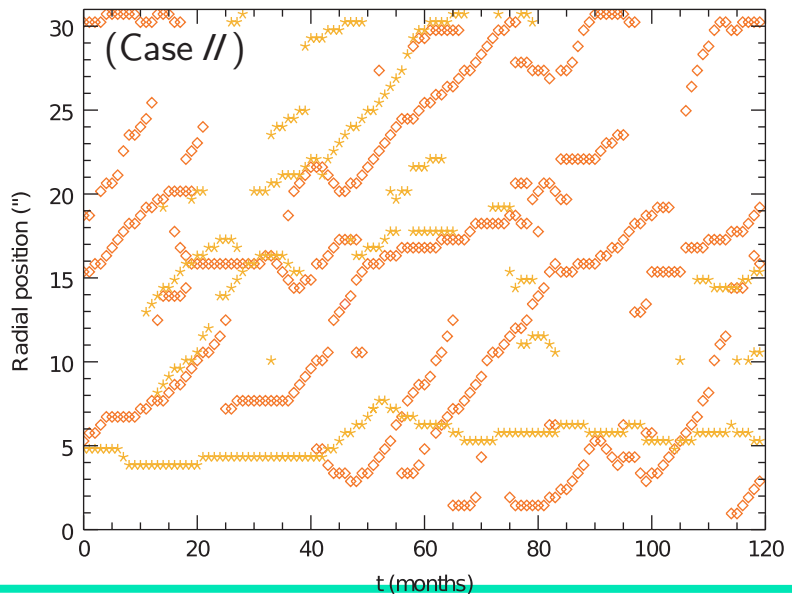

Different wisps structure for different injection (**Polar** vs **Equatorial**)

Ahead....

- How do PWNe evolve? What is the role and confinement of the SNR? How do they interact with clumpy environment? Can we developed a unified model for old systems?
- What is the role of turbulence in PWNe? How does it relates with their emission properties? Is there distributed re-acceleration?
- What is the origin of the radio emitting particles? Are the relic? Are they captured from evaporating filaments? Do they come from the PSR?
- How good are PWNe at accelerating pairs? How good are they at confining them?
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