An overview of PWNe

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PULSAR WIND NEBULAE

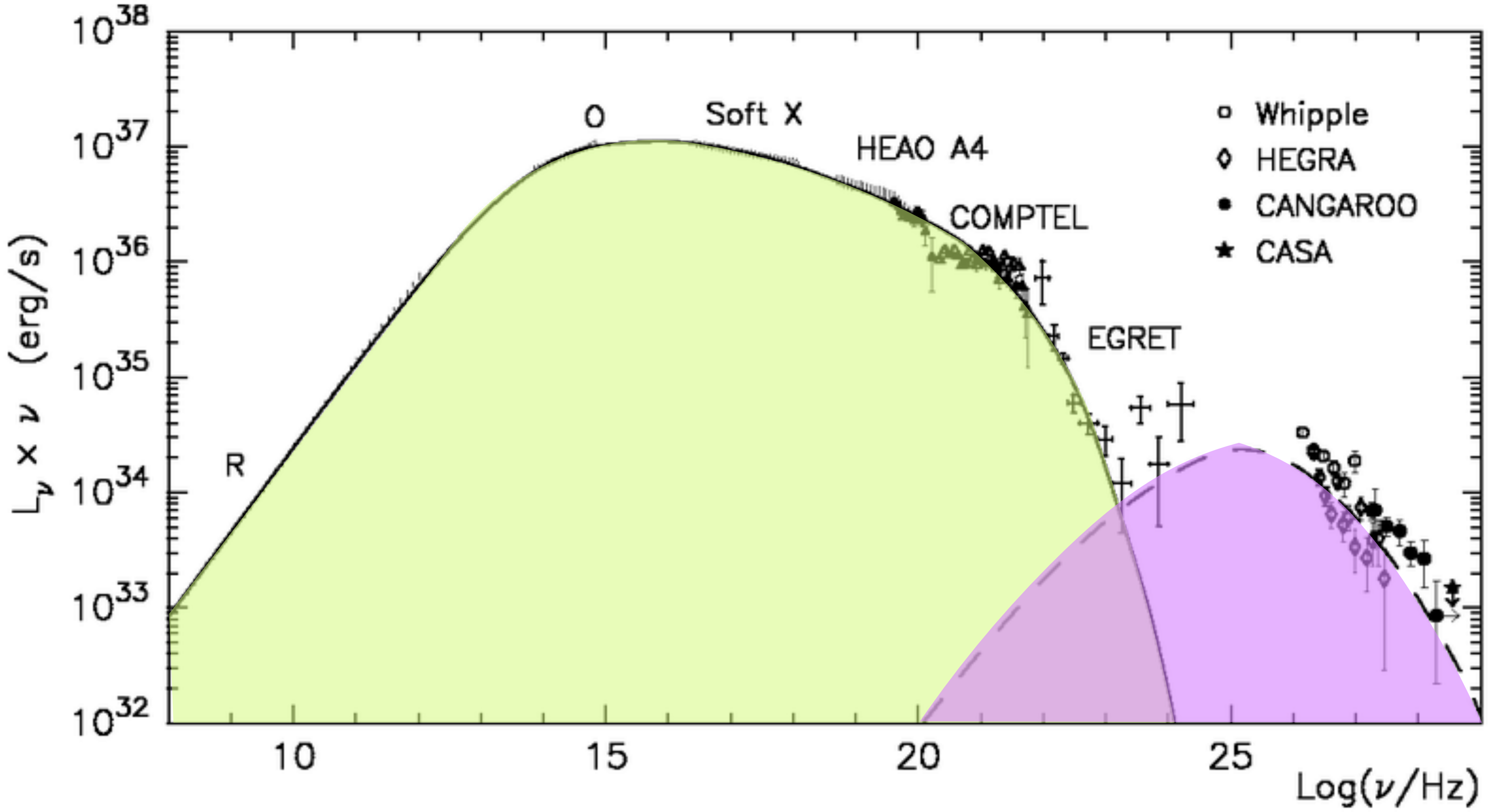
SNRs WITH

- CENTER FILLED MORPHOLOGY
- FLAT RADIO SPECTRUM

$$F_\nu \propto \nu^{-\alpha}, \quad \alpha < 0.5$$

BROAD BAND NON-THERMAL SPECTRUM

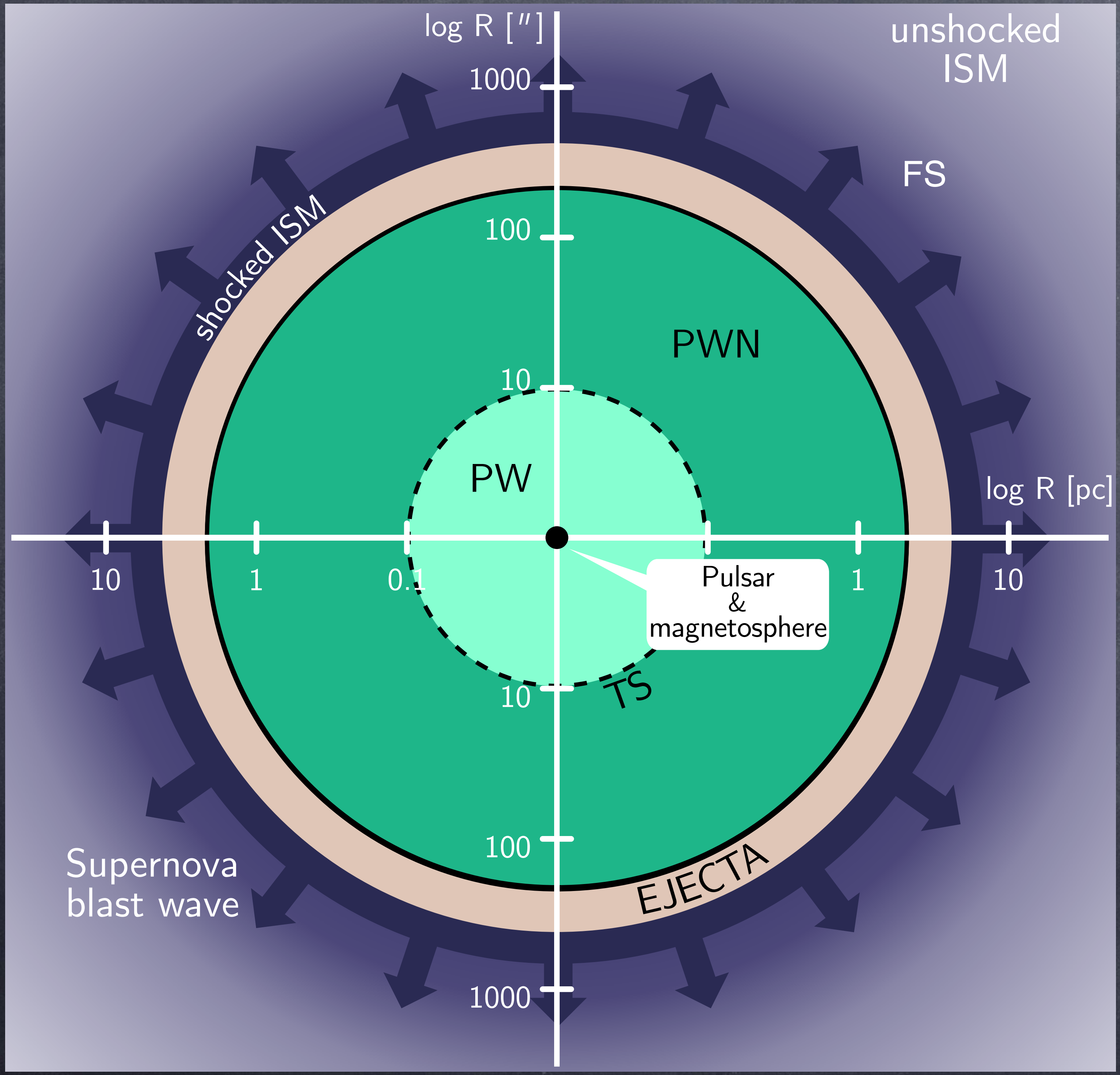
CRAB NEBULA spectrum [adapted from Atoyan & Aharonian 1996]



synchrotron radiation by relativistic particles in the nebular B field

Inverse Compton scattering with local photon field

BASIC PICTURE FOR YOUNG SYSTEMS



Adapted from Kennel & Coroniti 1984
[Del Zanna & Olmi 2017]

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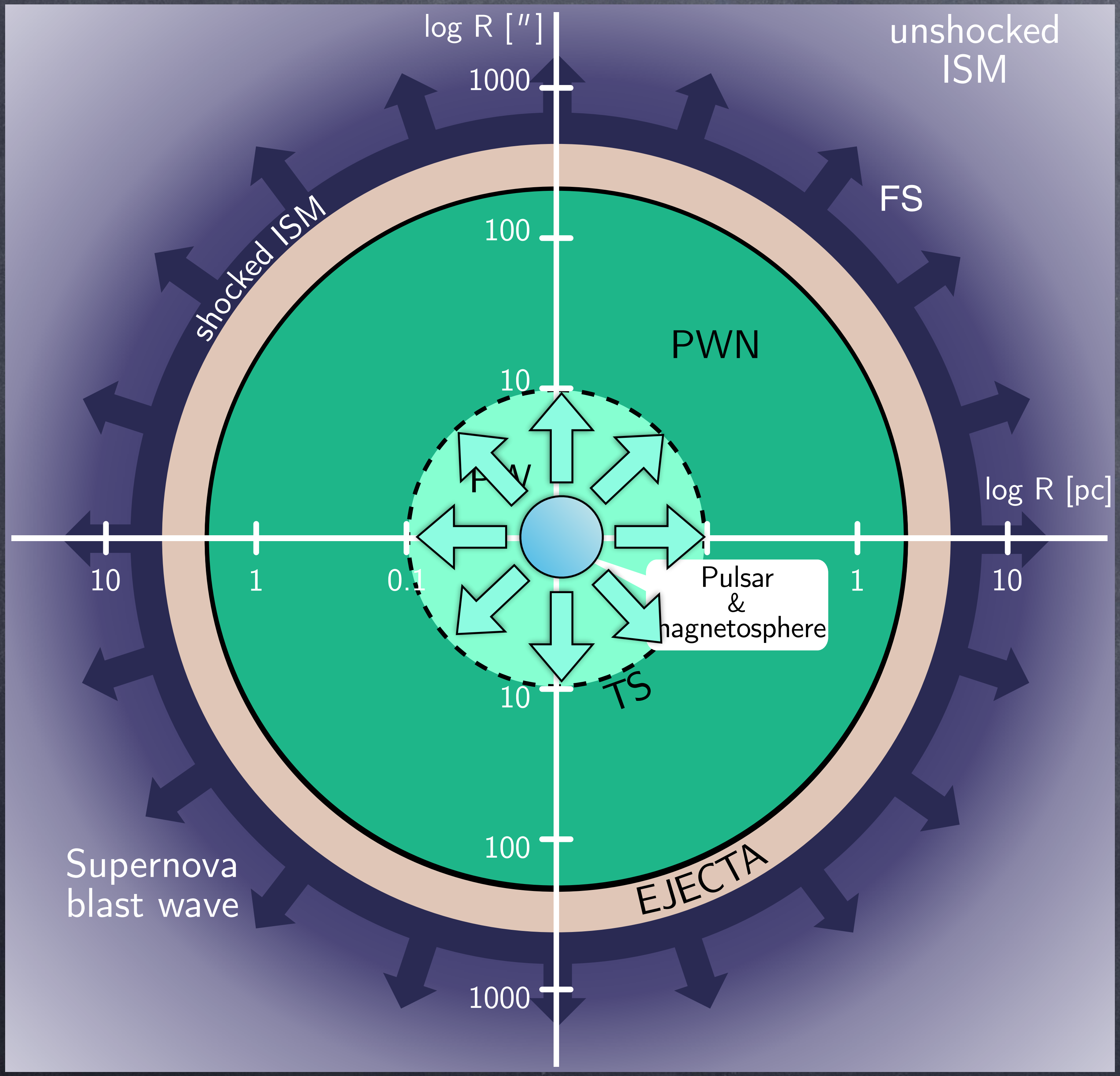


Adapted from Kennel & Coroniti 1984
[Del Zanna & Olmi 2017]

CENTRAL PULSAR

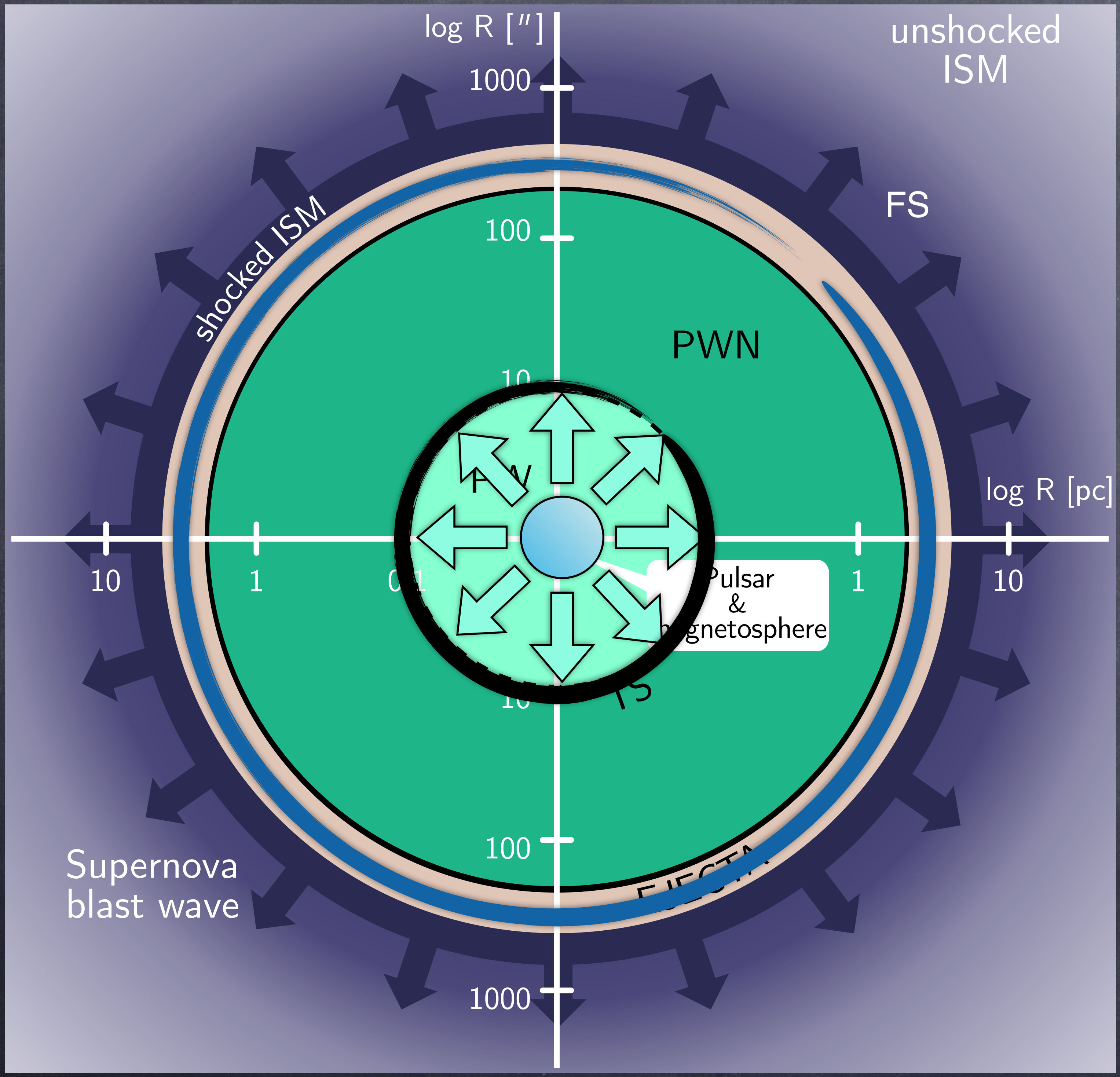
↓

RELATIVISTIC MAGNETIZED WIND

manly made of e^+-e^- pairs

(maybe a minority of ions)

BASIC PICTURE FOR YOUNG SYSTEMS



Adapted from Kennel & Coroniti 1984
[Del Zanna & Olmi 2017]

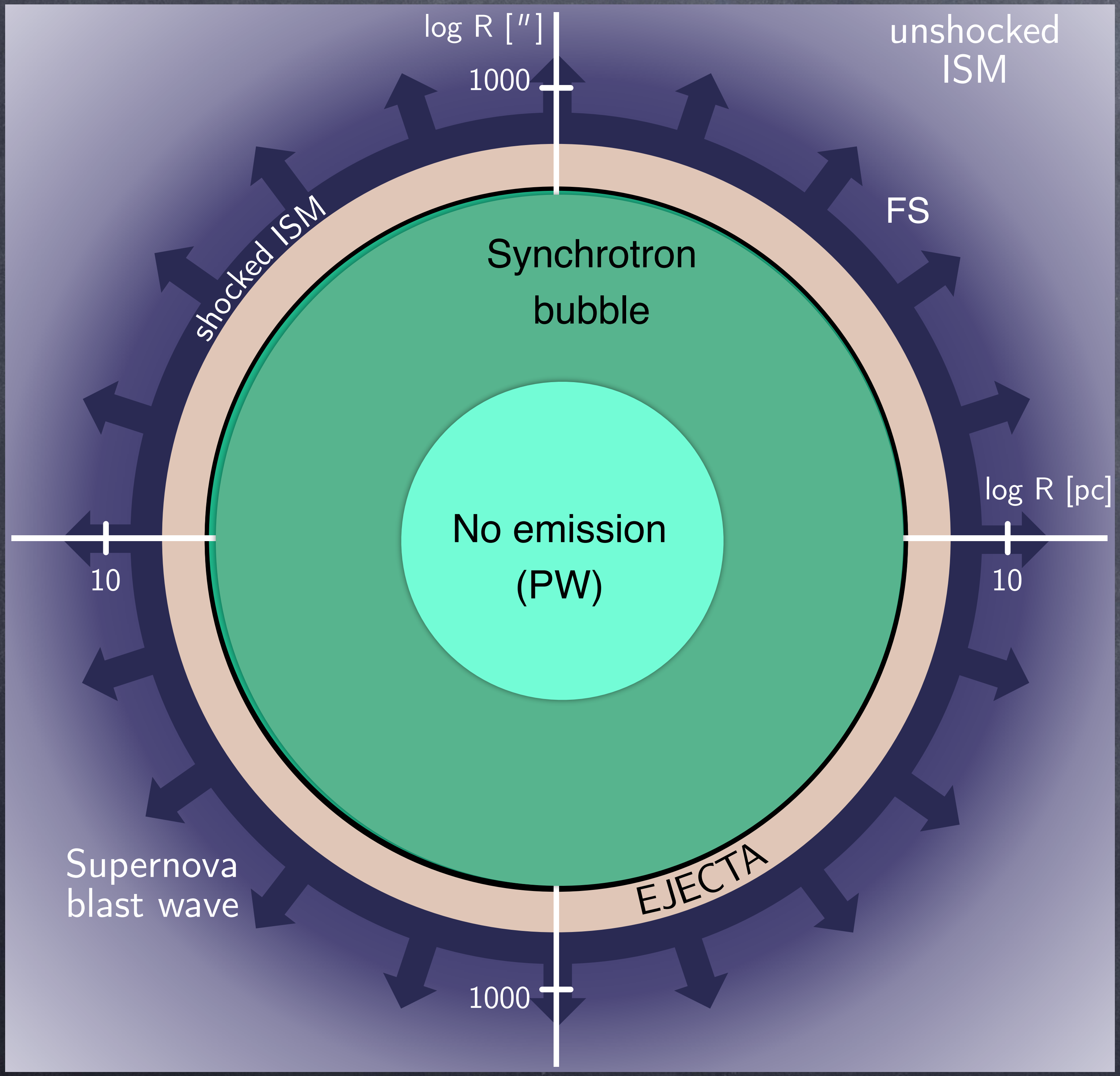
INTERACTION WITH EJECTA CAUSES A SHOCK AND A **REVERSE SHOCK**

TERMINATION SHOCK POSITION FROM PRESSURE EQUILIBRIUM

$$\frac{\dot{E}}{4\pi c R_{TS}^2} = P_{PWN} = \frac{\dot{E}\ t}{4\pi R_N^3}$$

$$R_{TS} = \left(\frac{v_N}{c}\right)^{1/2} R_N$$

BASIC PICTURE FOR YOUNG SYSTEMS

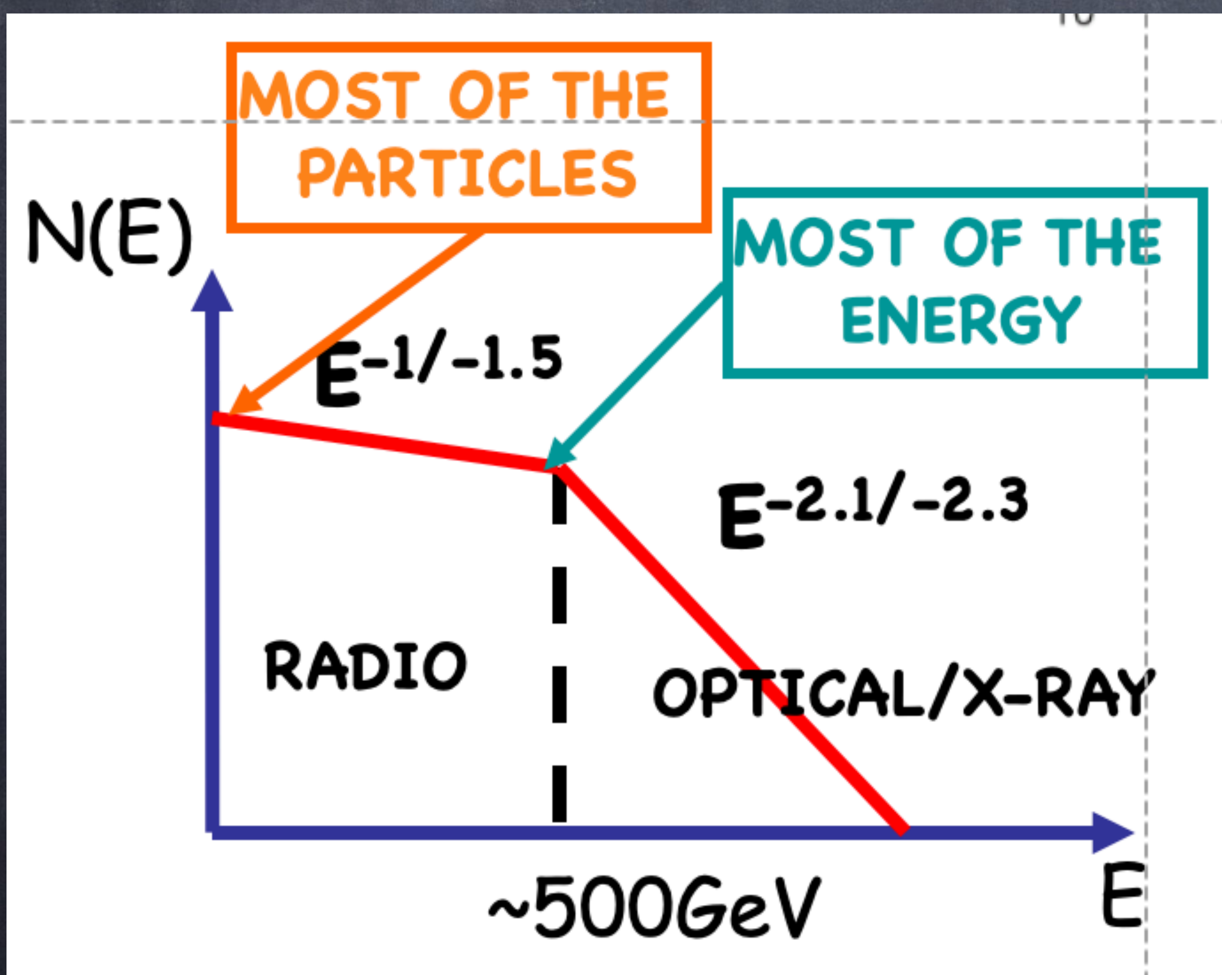


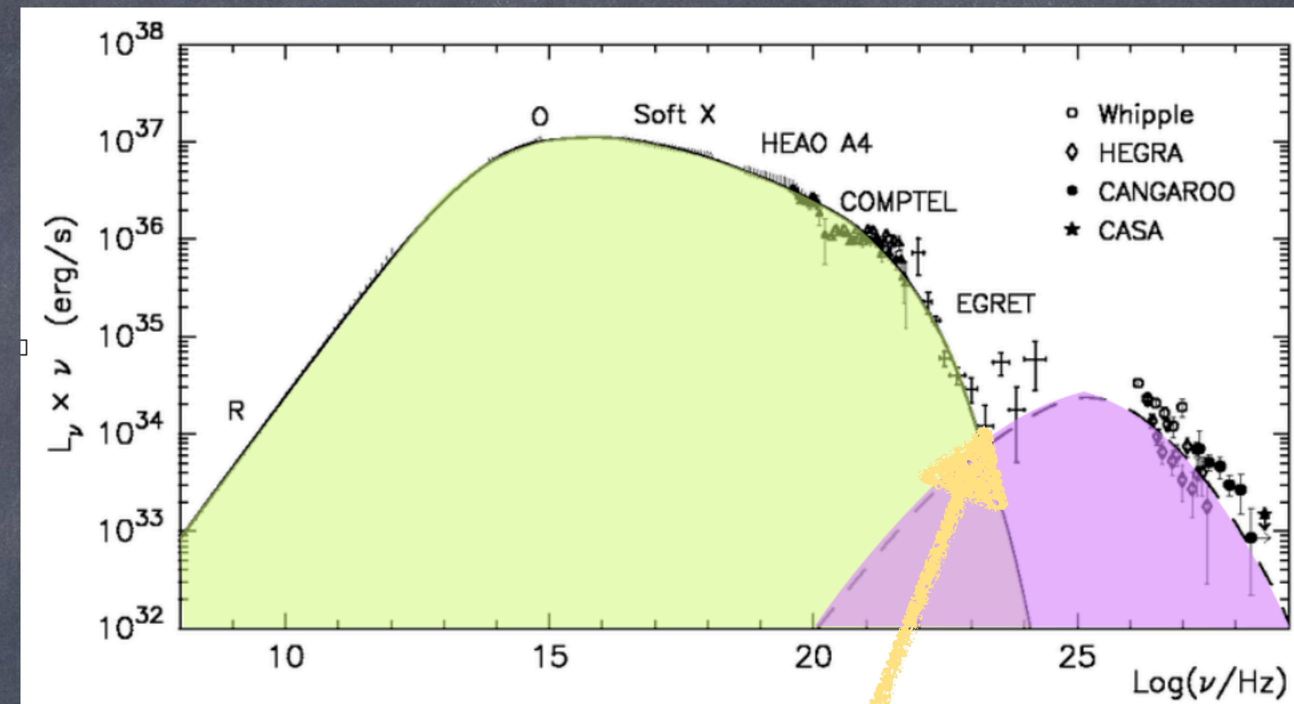
Adapted from Kennel & Coroniti 1984
[Del Zanna & Olmi 2017]

$$R_{TS} = \left(\frac{v_N}{c}\right)^{1/2} R_N$$

DISSIPATION AND PARTICLE ACCELERATION AT TS

EMITTING PARTICLES





PeV ELECTRONs

$B_{NEB} \approx 100\ \mu G$

$L_{NEB} \approx 30\,\%\,\dot{E}$

GREAT ACCELERATOR!

ONE ZONE MODELS
(Pacini & Salvati 1973, EA+ 2000, Bucciantini+ 2011….)

MAIN OPEN QUESTIONS

WHAT WE KNOW:

- MOST EFFICIENT ACCELERATORS IN NATURE
- ACCELERATION IN THE MOST HOSTILE ENVIRONMENT
- MAIN ANTIMATTER REPOSITORIES IN THE GALAXY
- ENERGY FLUX THAT LEAVES THE PSR

$$\dot{E} = \kappa \dot{N}_{GJ} m_e \Gamma c^2 \left(1 + \frac{m_i}{\kappa m_e}\right)(1+\sigma)$$

WE DO NOT KNOW:

- WHAT THE ACCELERATION MECHANISM(S) IS (ARE)

POSSIBILITIES DEPEND ON

WIND COMPOSITION (IONS? κ?)

WIND MAGNETIZATION (σ?)

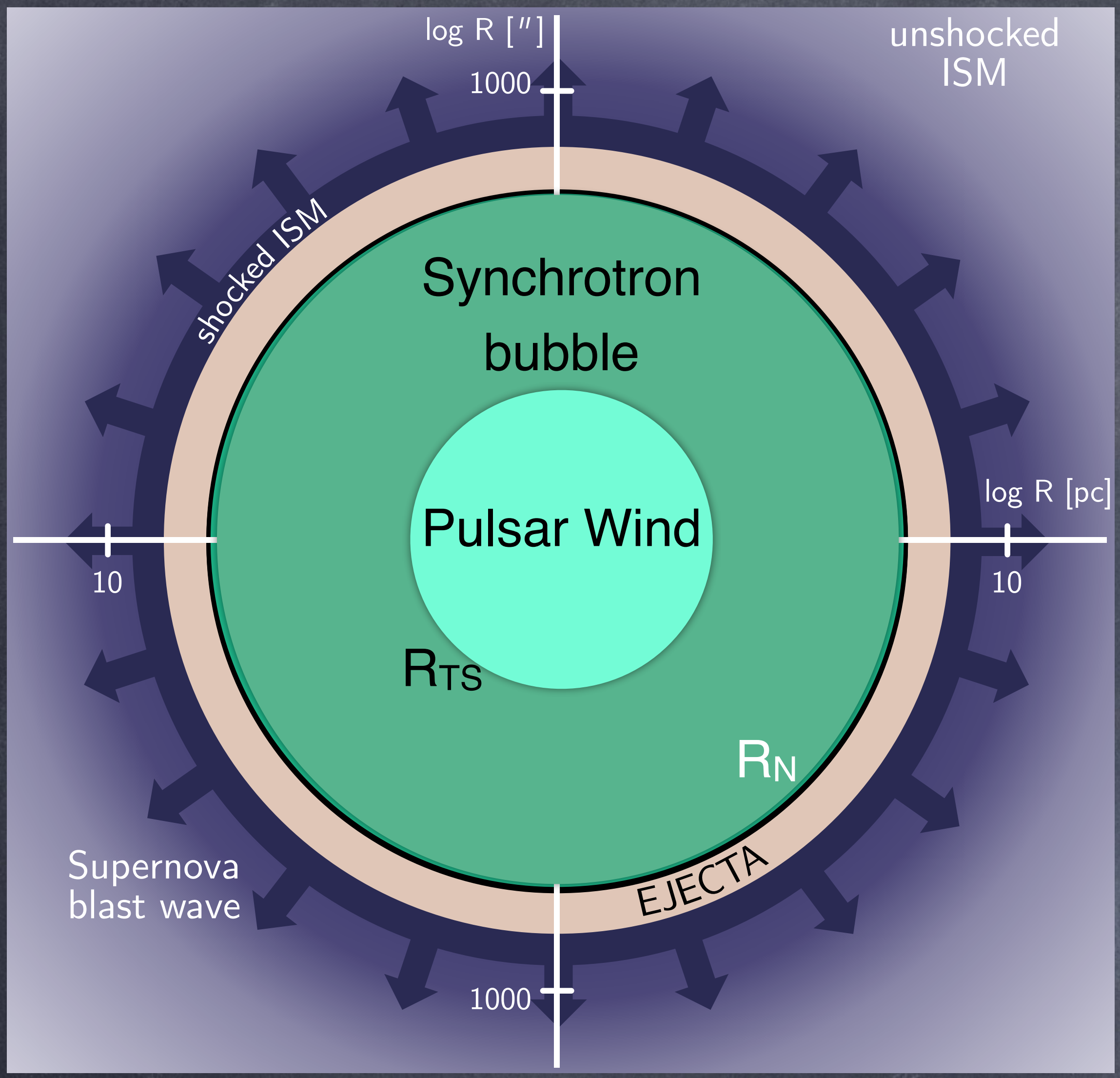
← IN PRINCIPLE BOTH DEPEND ON LOCATION

- HOW PARTICLES ESCAPE

CONSTRAINING THE WIND MAGNETIZATION

1D/2D STEADY STATE MODELS

[Rees & Gunn 1974, Kennel & Coroniti 1984, Emmering & Chevalier 1987, Begelman & Li 1992]



Assumptions:

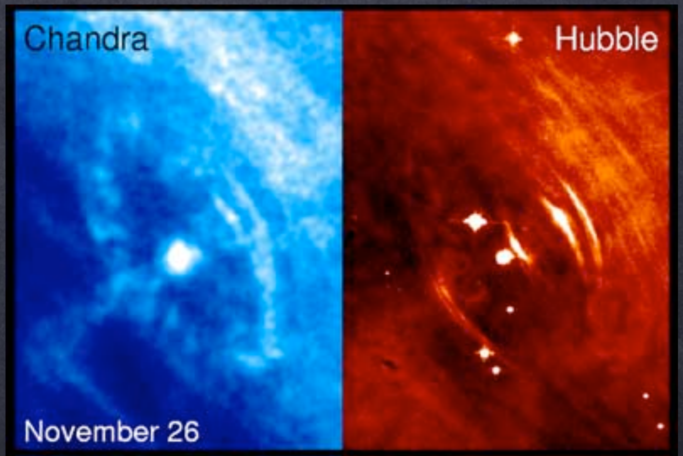
- strong perpendicular shock
- subsonic flow in the nebula
- particle acceleration at the shock
- synchrotron losses beyond the shock

Main Free parameters:

- particle spectral index(es) $\rightarrow \gamma$
- wind Lorentz factor $\rightarrow \Gamma$
- wind magnetization $\rightarrow \rightarrow \sigma = \dfrac{B^2}{4\pi\ n_\pm\ m_e\ c^2\ \Gamma^2}$

Predictions:

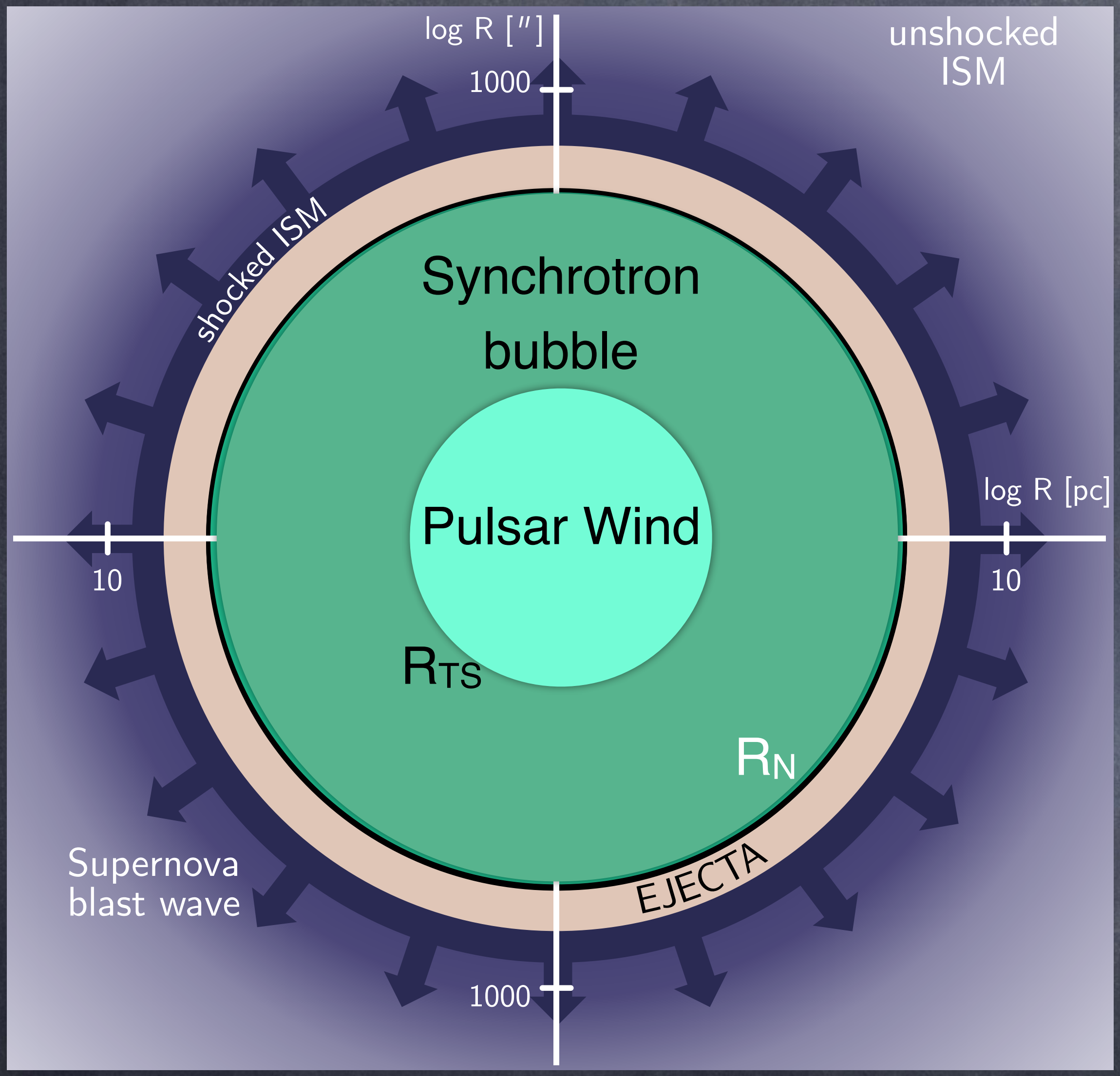
- position of TS $\rightarrow R_{TS} \sim R_N (V_N/c)^{1/2} \sim 0.1$ pc



- Optical / X-ray spectrum [de Jager & Harding 1992, Atoyan & Aharonian 1996]
- size shrinkage with increasing energy

1D/2D STATIC MODELS OF PWNE

[Rees & Gunn 1974, Kennel & Coroniti 1984, Emmering & Chevalier 1987, Begelman & Li 1992]



Main Free parameters:

- particle spectral index(es) → $\gamma = 2.3$
- wind Lorentz factor → $\Gamma = 3 \times 10^6$
- wind magnetization → $\sigma = v_N/c \approx 3 \times 10^{-3}$

FROM DYNAMICS AND RADIATION MODELING OF OPTICAL /X-RAY EMISSION

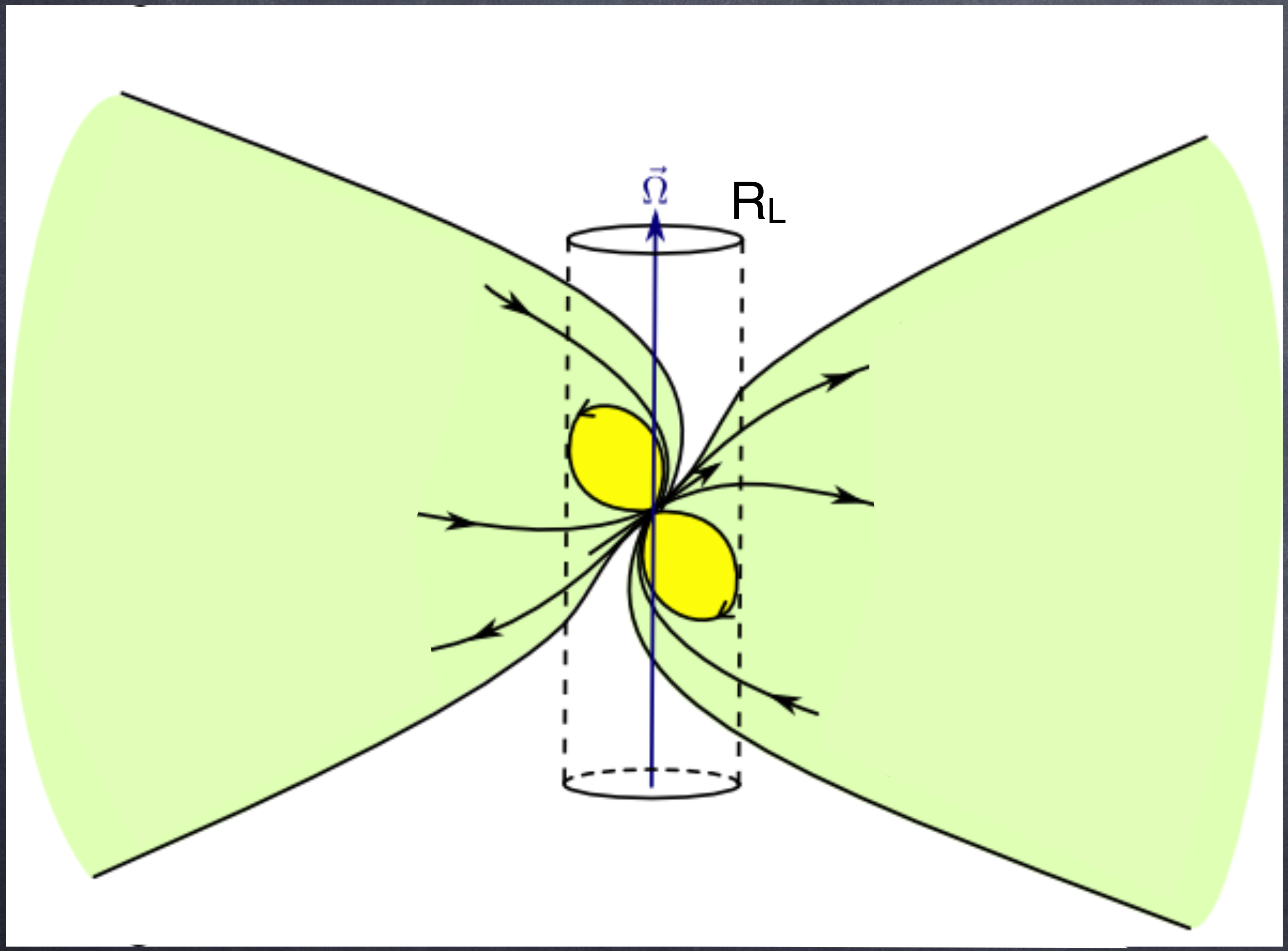
THE σ PROBLEM

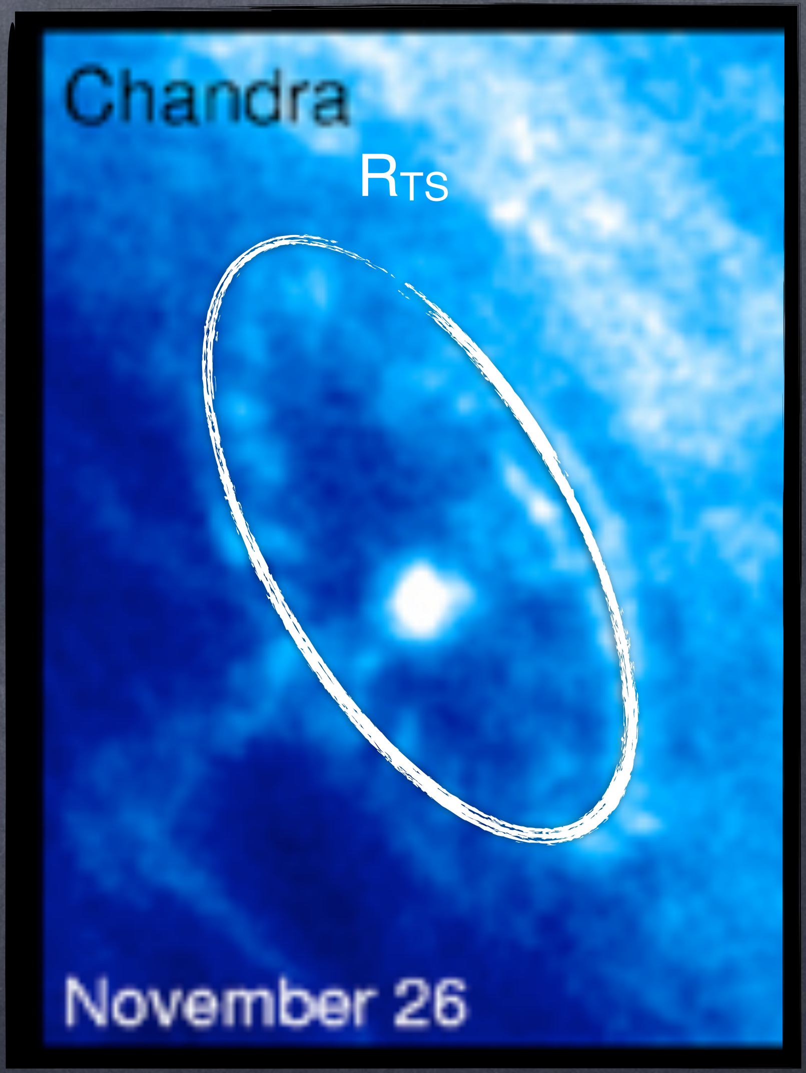
FROM PULSAR THEORIES:

$$\sigma \sim 10^4 @ R_L$$

FROM 1D PWN MODELS:

$$\sigma \sim 10^{-3} @ R_{TS}$$

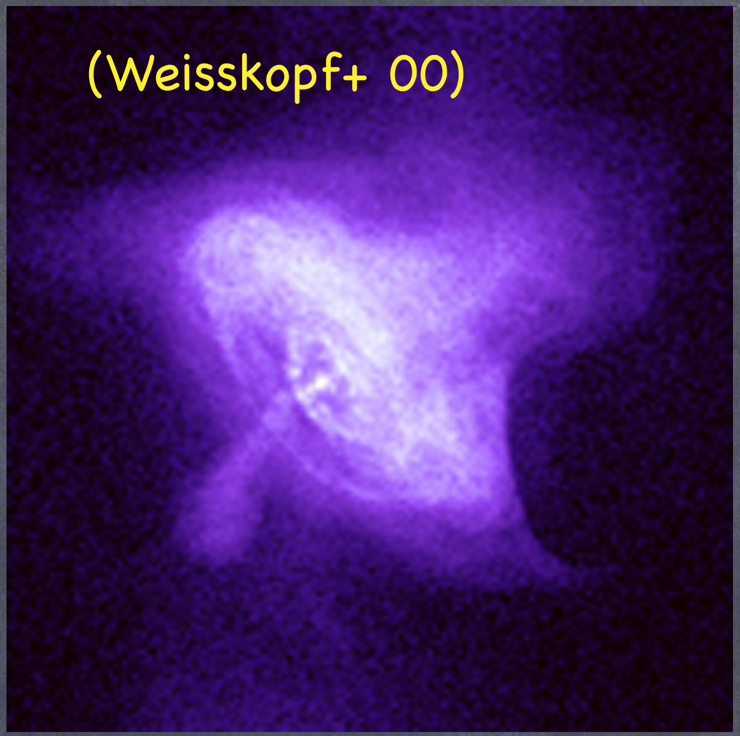




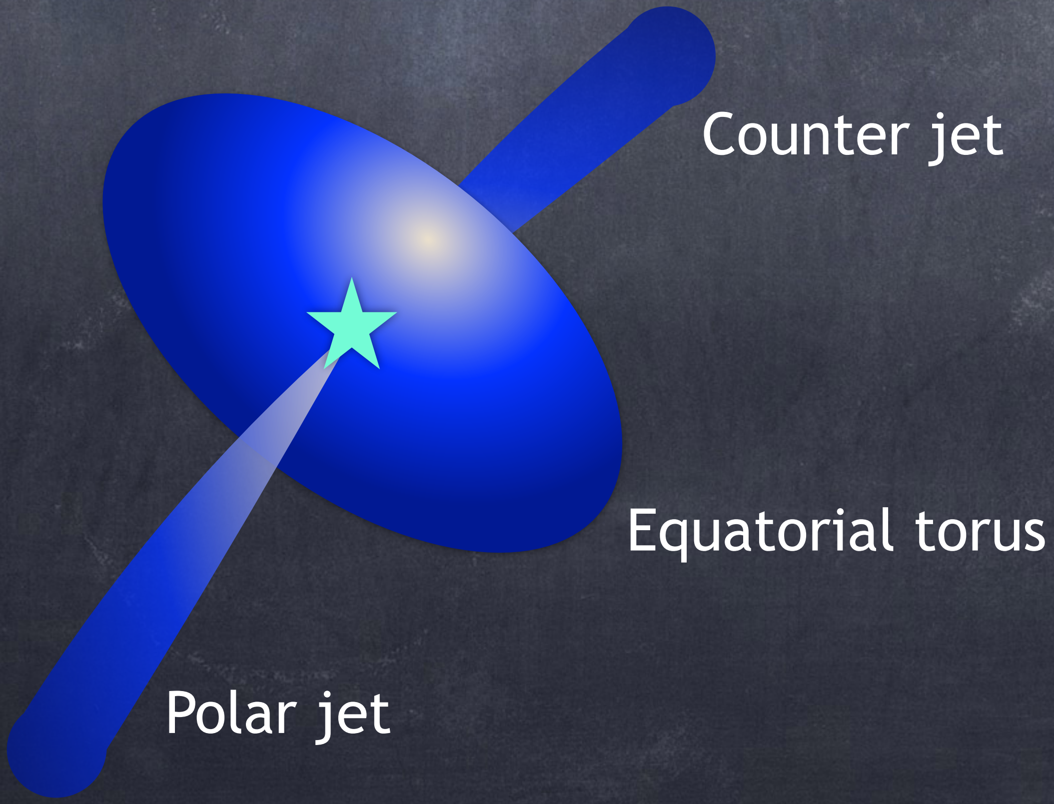
$$R_{TS} \sim 10^9 R_L$$

BUT ENERGY CONVERSION DIFFICULT TO EXPLAIN

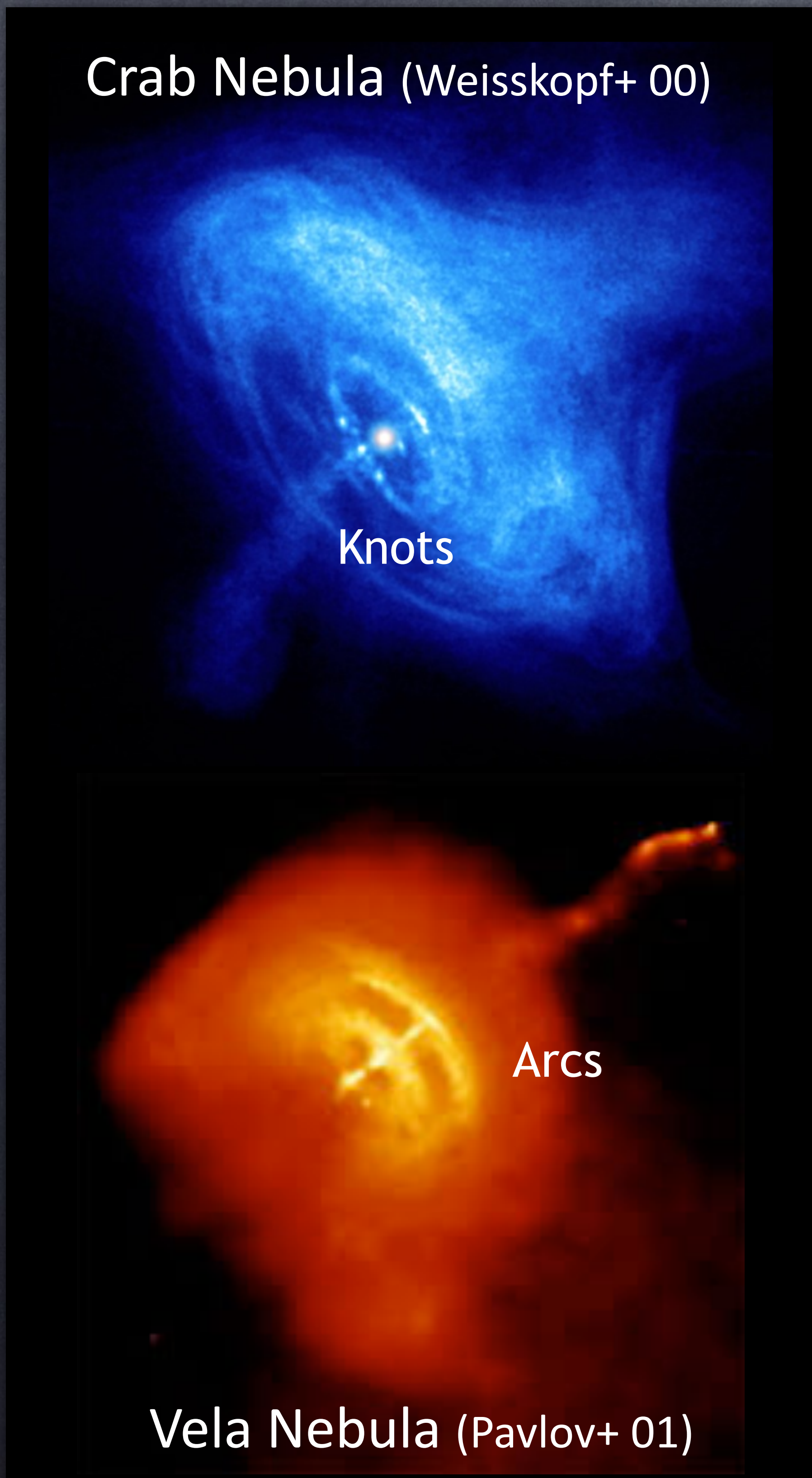
CHANDRA'S VIEW OF PWNE



Jet-torus morphology of inner nebula



THE JET PUZZLE



JET FROM
$R < R_{TS}$

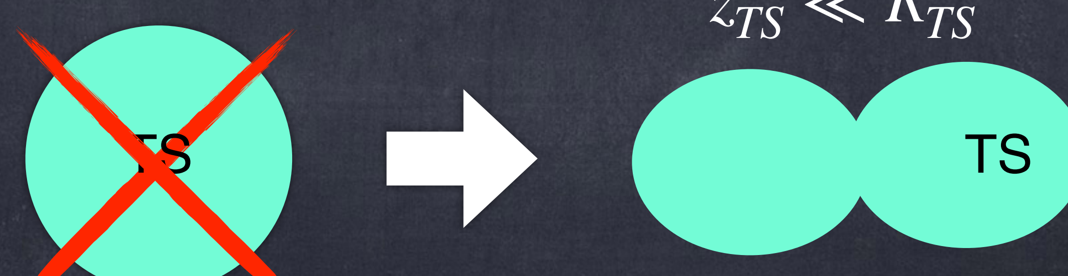
BUT NO MAGNETIC COLLIMATION IN RELATIVISTIC FLOWS
(Lyubarsky & Eichler 01)

$$\Gamma \gg 1 \;\rightarrow\; \rho\vec{E} + \vec{J} \times \vec{B} \sim 0$$

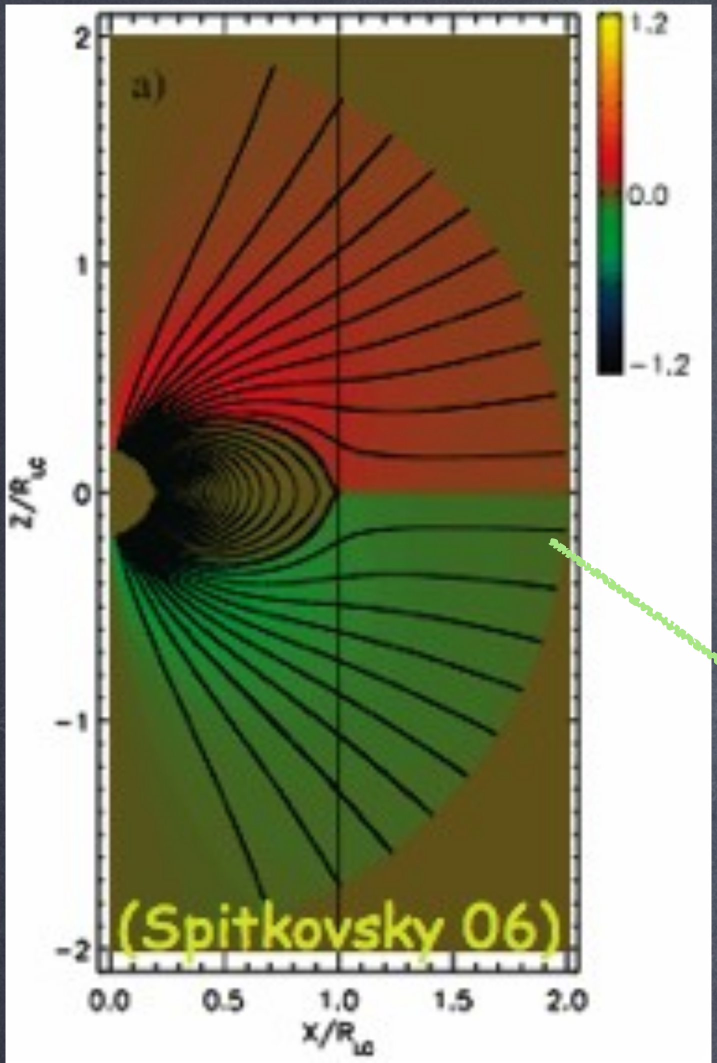
$$F \propto \sin^2(\theta)$$

[Bogovalov & Khangoulian 02, Lyubarsky 02]

$$z_{TS} \ll R_{TS}$$



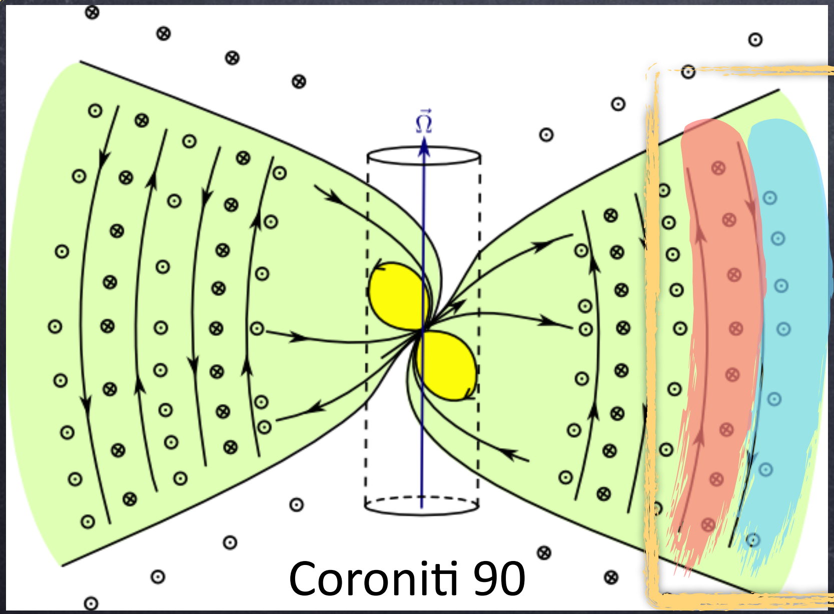
2D MHD NUMERICAL MODELING: INGREDIENTS



Komissarov & Lyubarsky 03, 04; Del Zanna+ 04, 06; Bogovalov+ 05
Camus+ 09; Volpi+ 08; Olmi+ 14, 15

$$F(\theta) \propto \sin^2(\theta)$$

$$B(\theta) \propto \sqrt{\sigma}\ \sin\theta\ G(\theta)$$

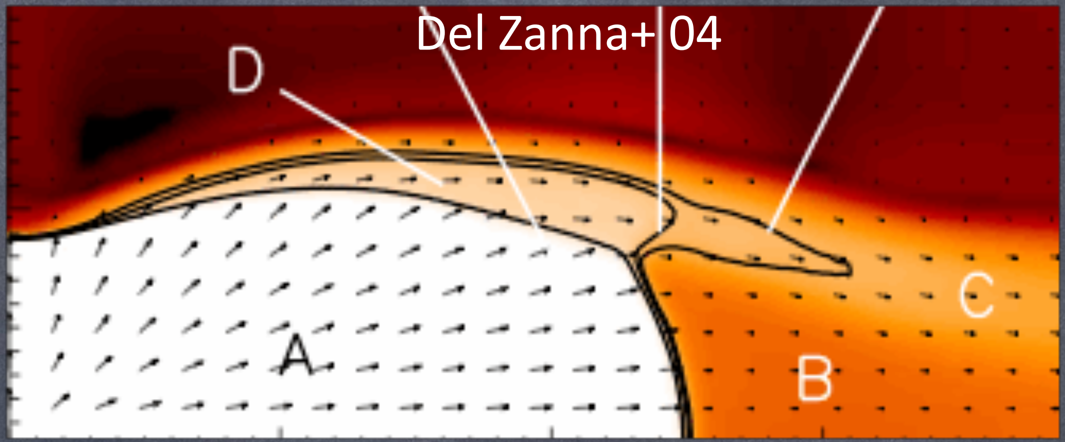


alternating stripes of opposite B polarities

dissipation in current sheet

2D MHD NUMERICAL MODELING: RINGS AND TORII

A: ULTRARELATIVISTIC WIND
B: SUBSONIC OUTFLOW
C: SUPERSONIC FUNNEL



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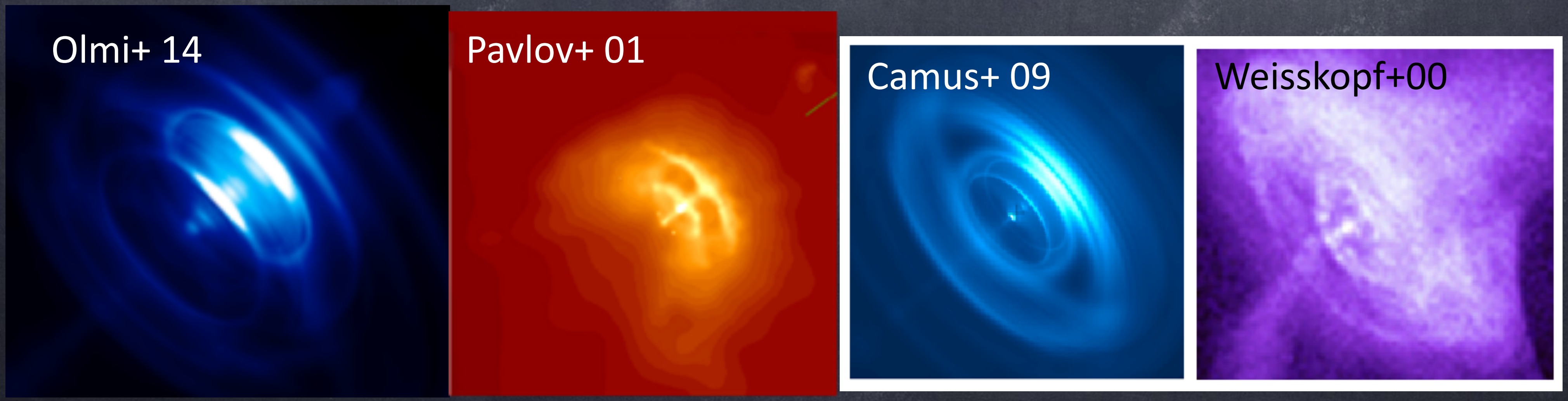
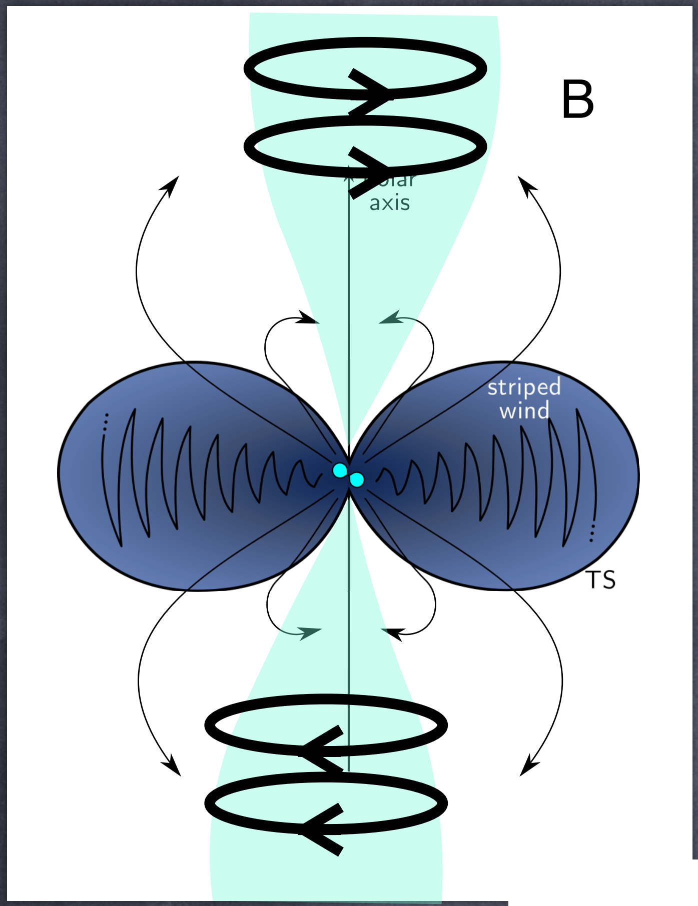
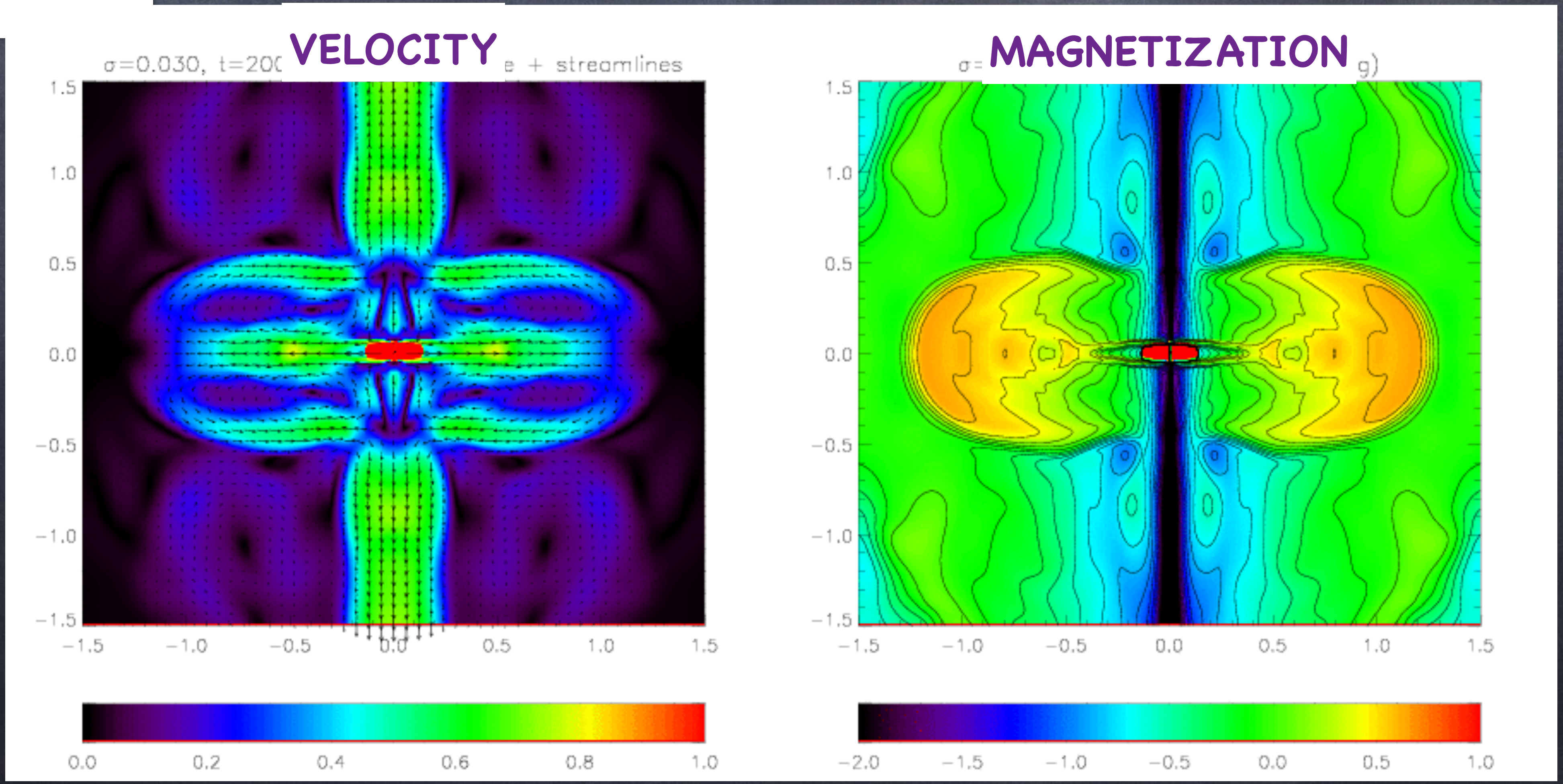


2D MHD NUMERICAL MODELING: JETS

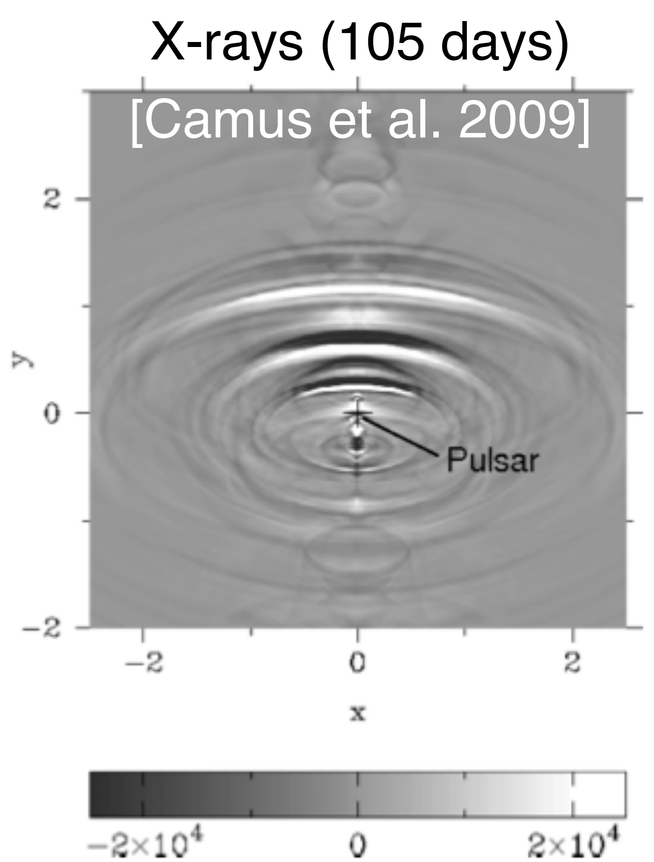


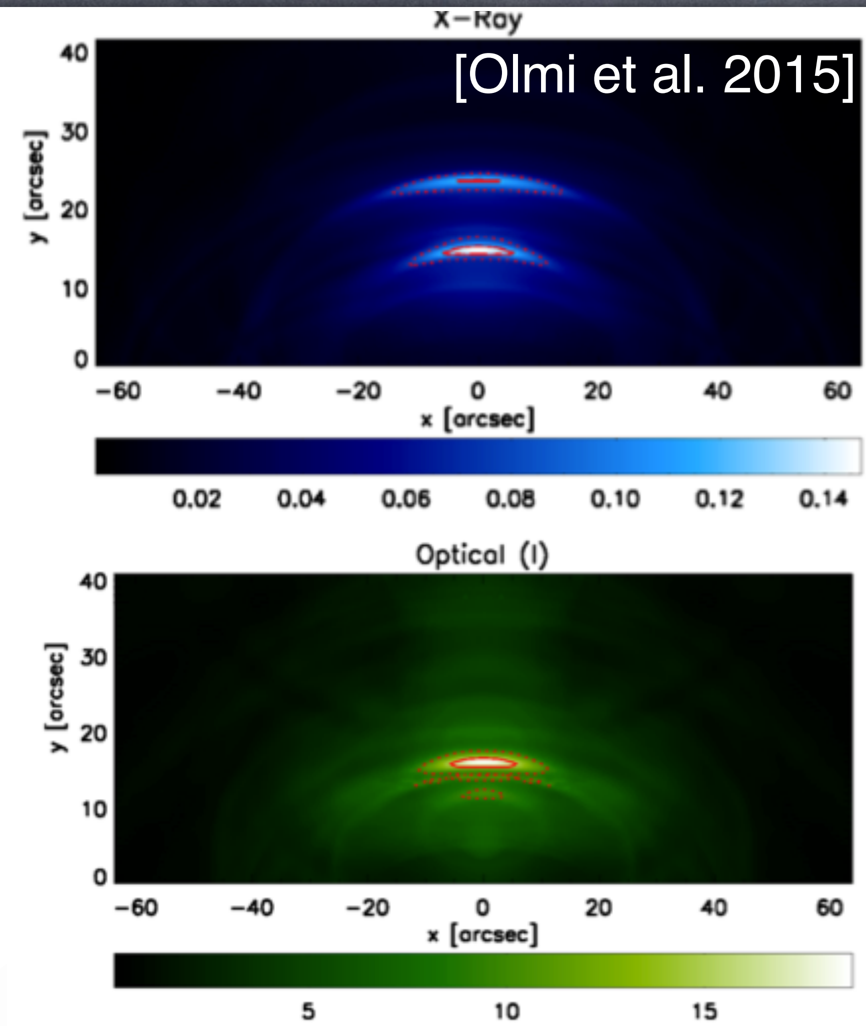
EQUIPARTITION NEEDED FOR JET FORMATION

IN 2D JETS REQUIRE σ>0.03

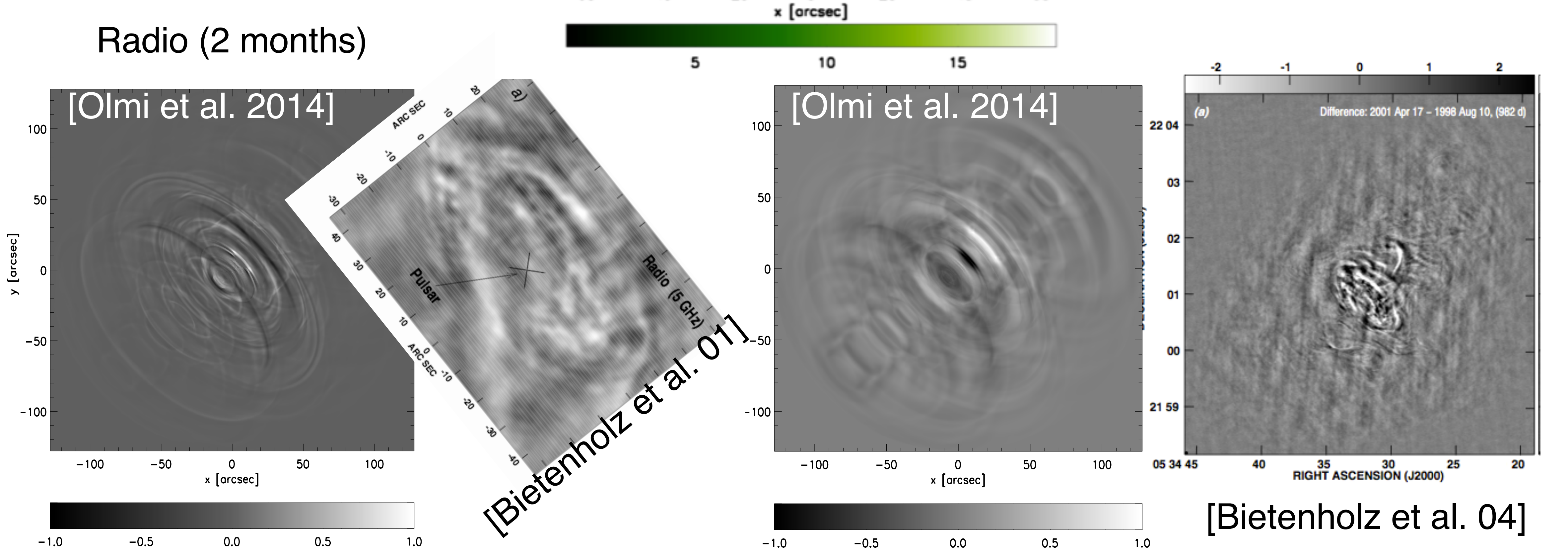


THE MANY SUCCESSES OF 2D MODELING



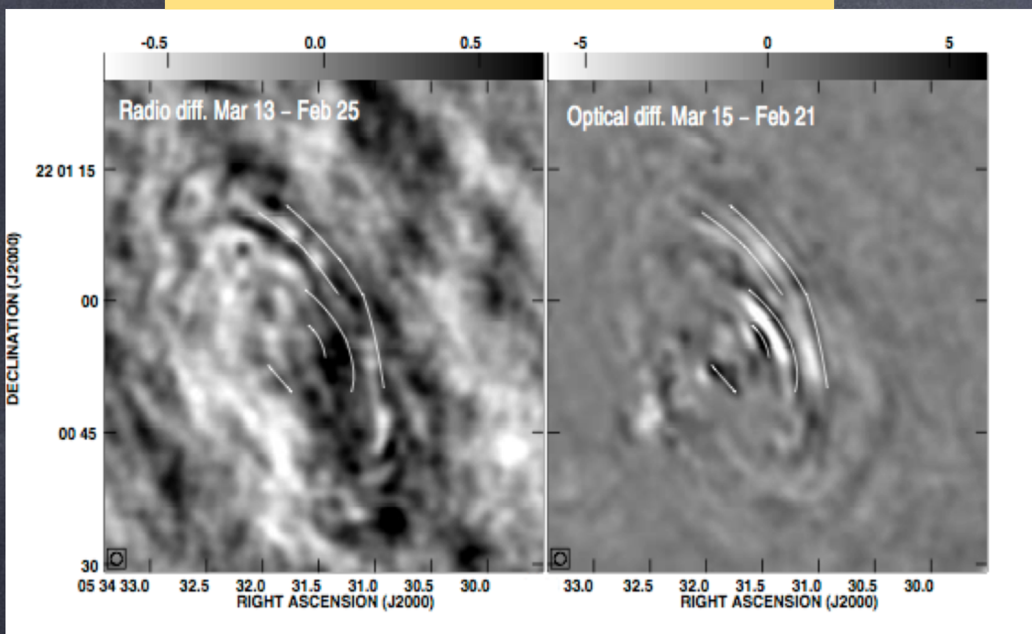


WISPS VARIABILITY
REPRODUCED AT
MULTI-WAVELENGTHS



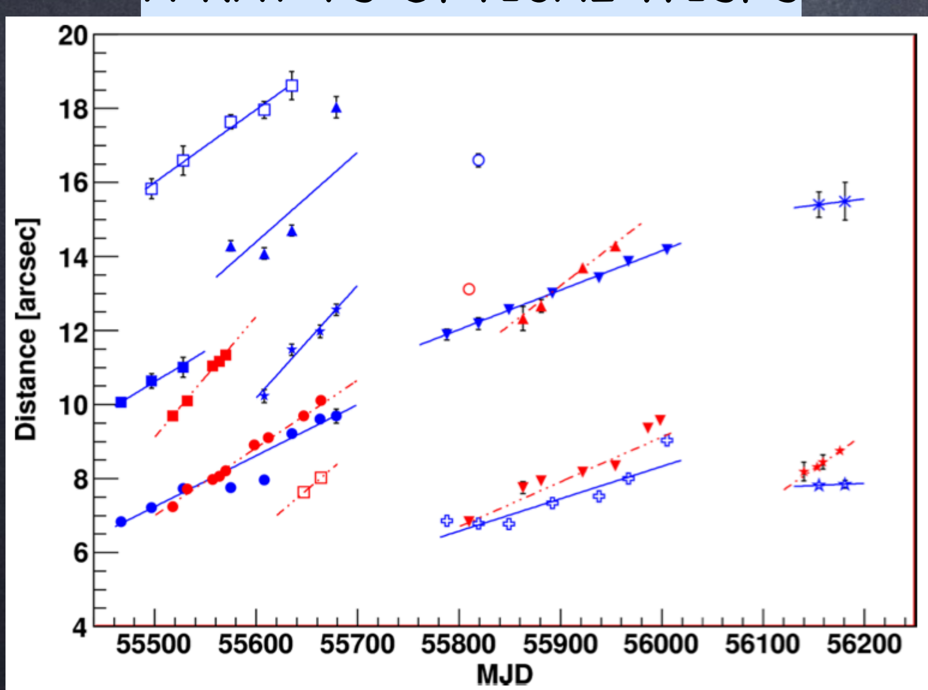
HINTS ON LOCATIONS OF PARTICLE ACCELERATION

RADIO VS OPTICAL WISPS



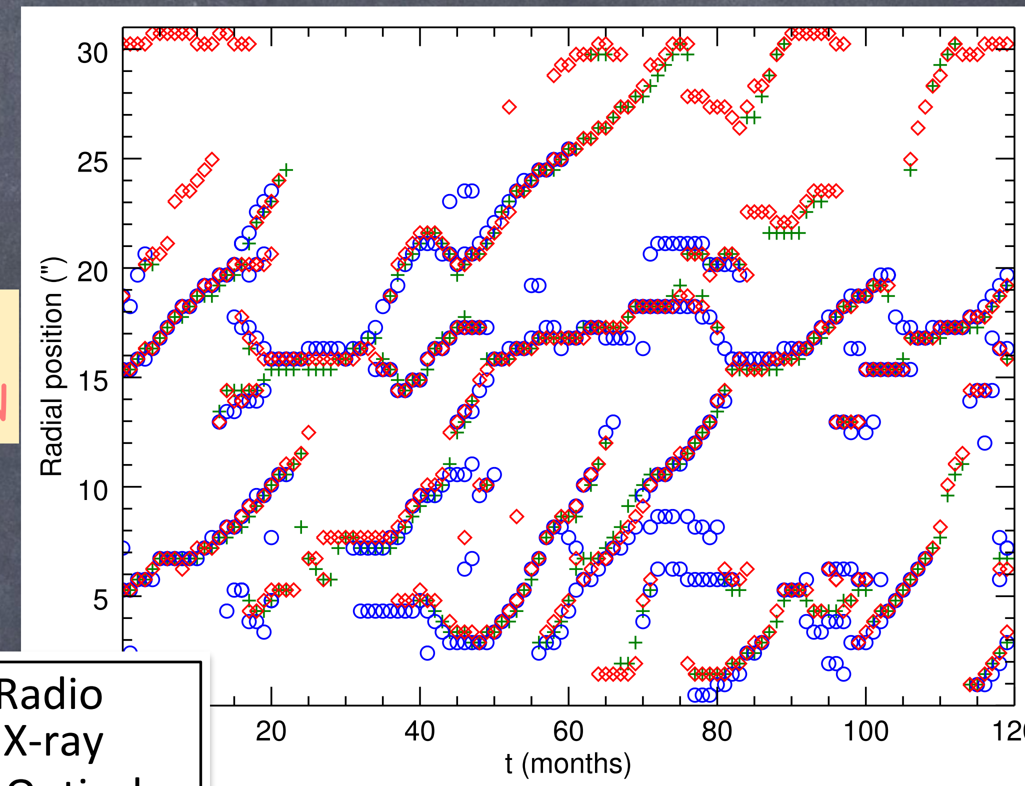
[Bietenholtz et al. 2004]

X-RAY VS OPTICAL WISPS

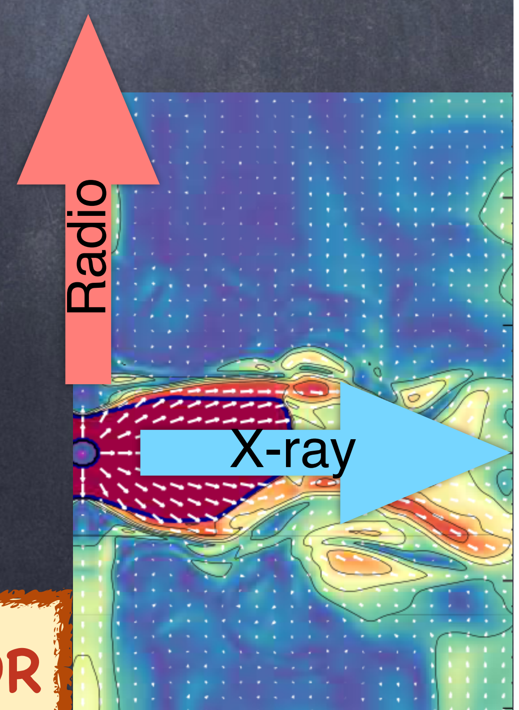


[Schweizer et al. 2013]

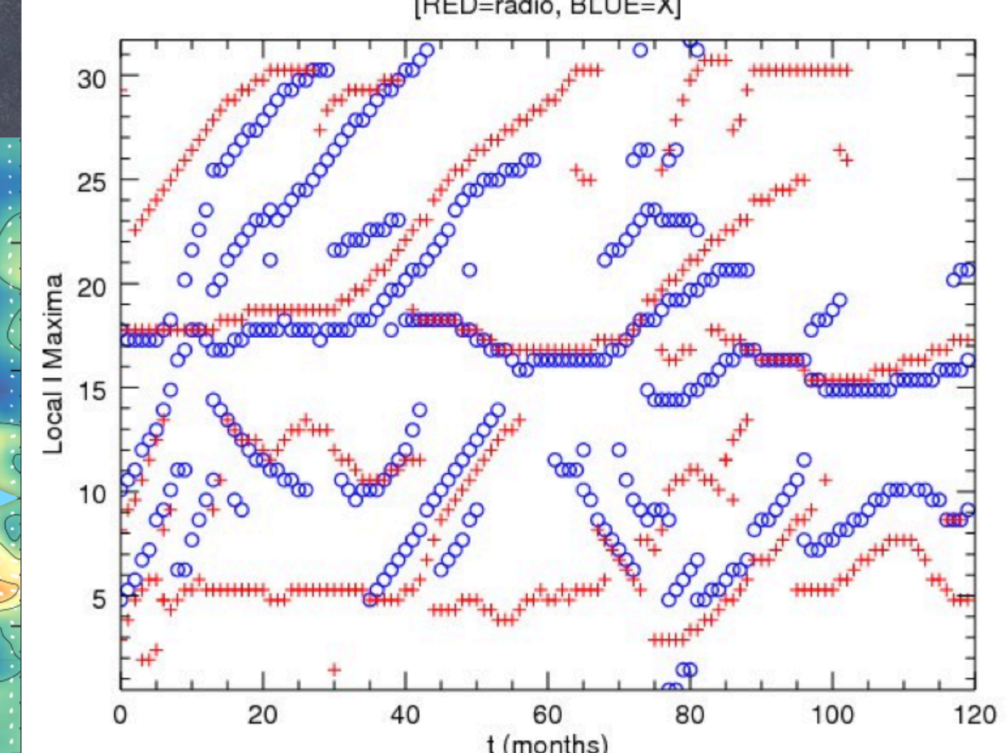
ISOTROPIC ACCELERATION



[Olmi et al. 2015]

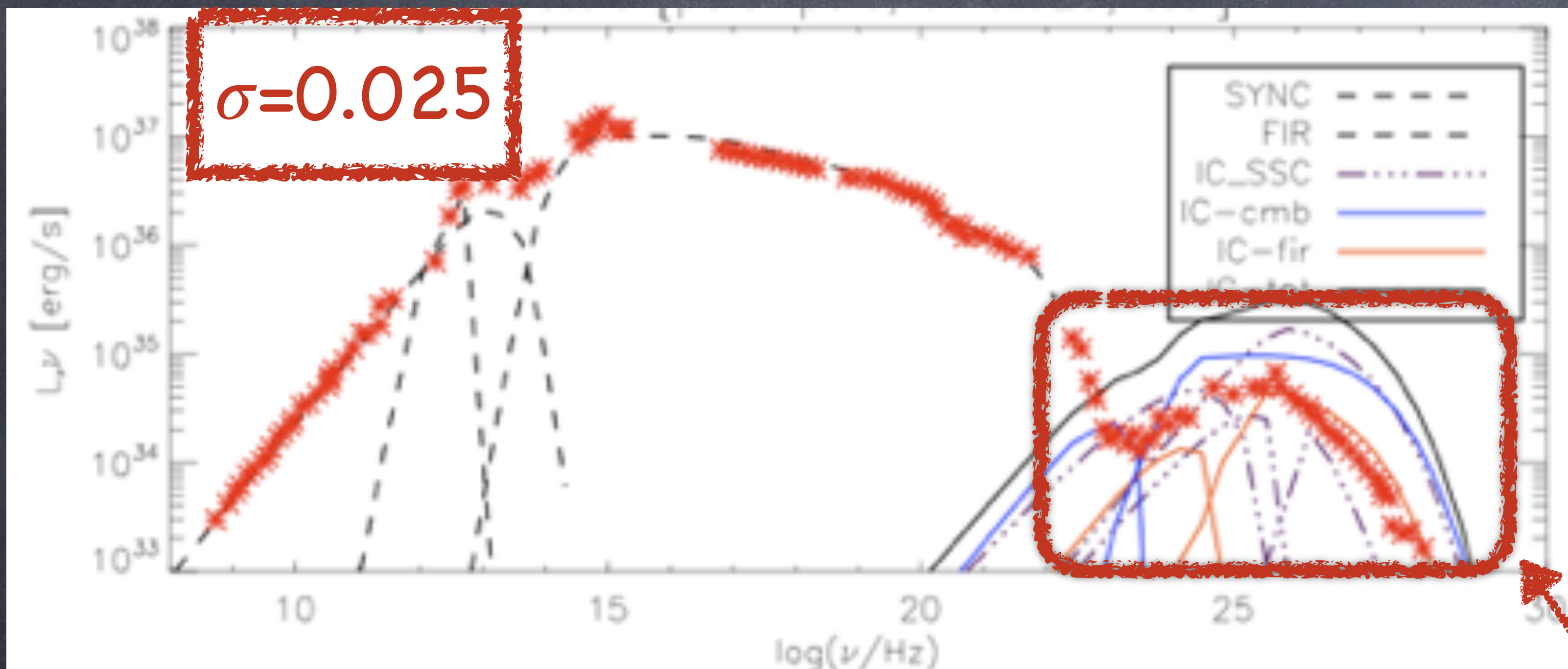


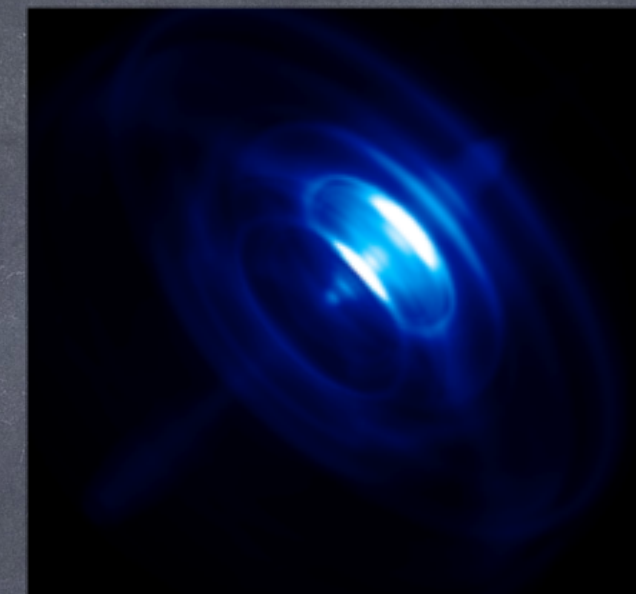
[RED=radio, BLUE=X]



X-RAY EMITTERS FROM EQUATOR
LOWER ENERGY ANYWHERE

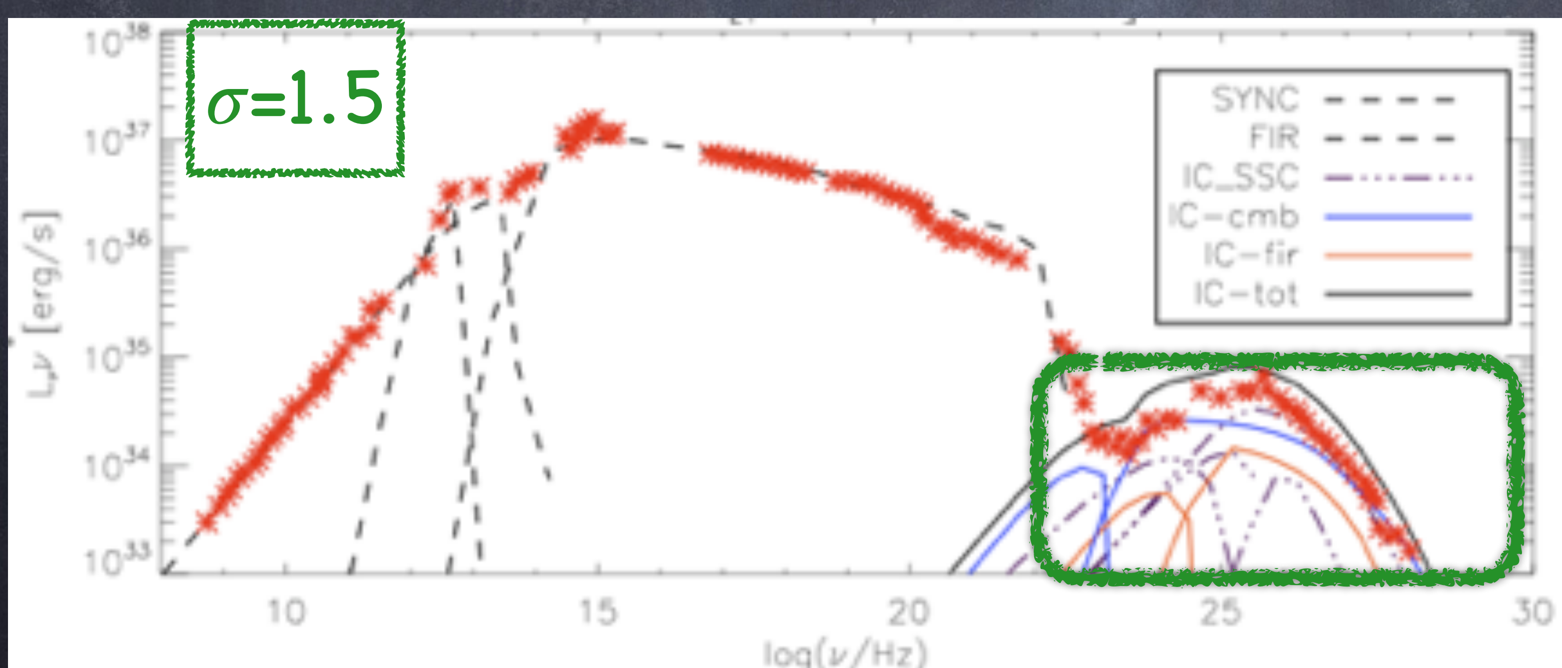
BEHIND PRETTY PICTURES

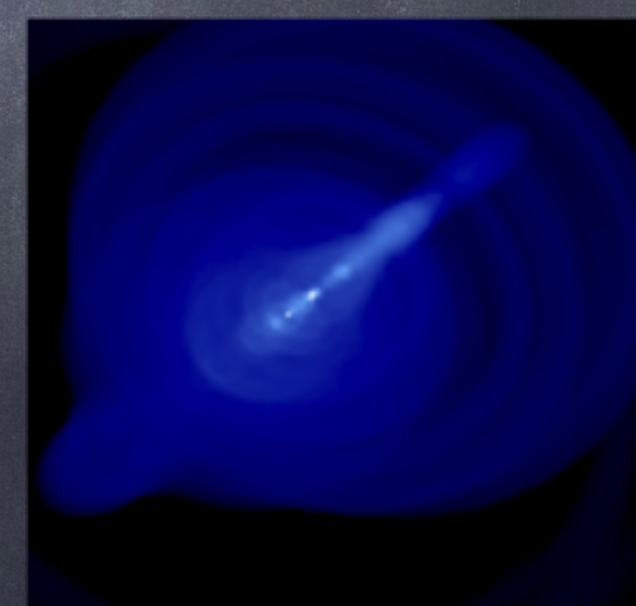




$B_{sim} \approx 10^{-5}\ G$

Olmi+14



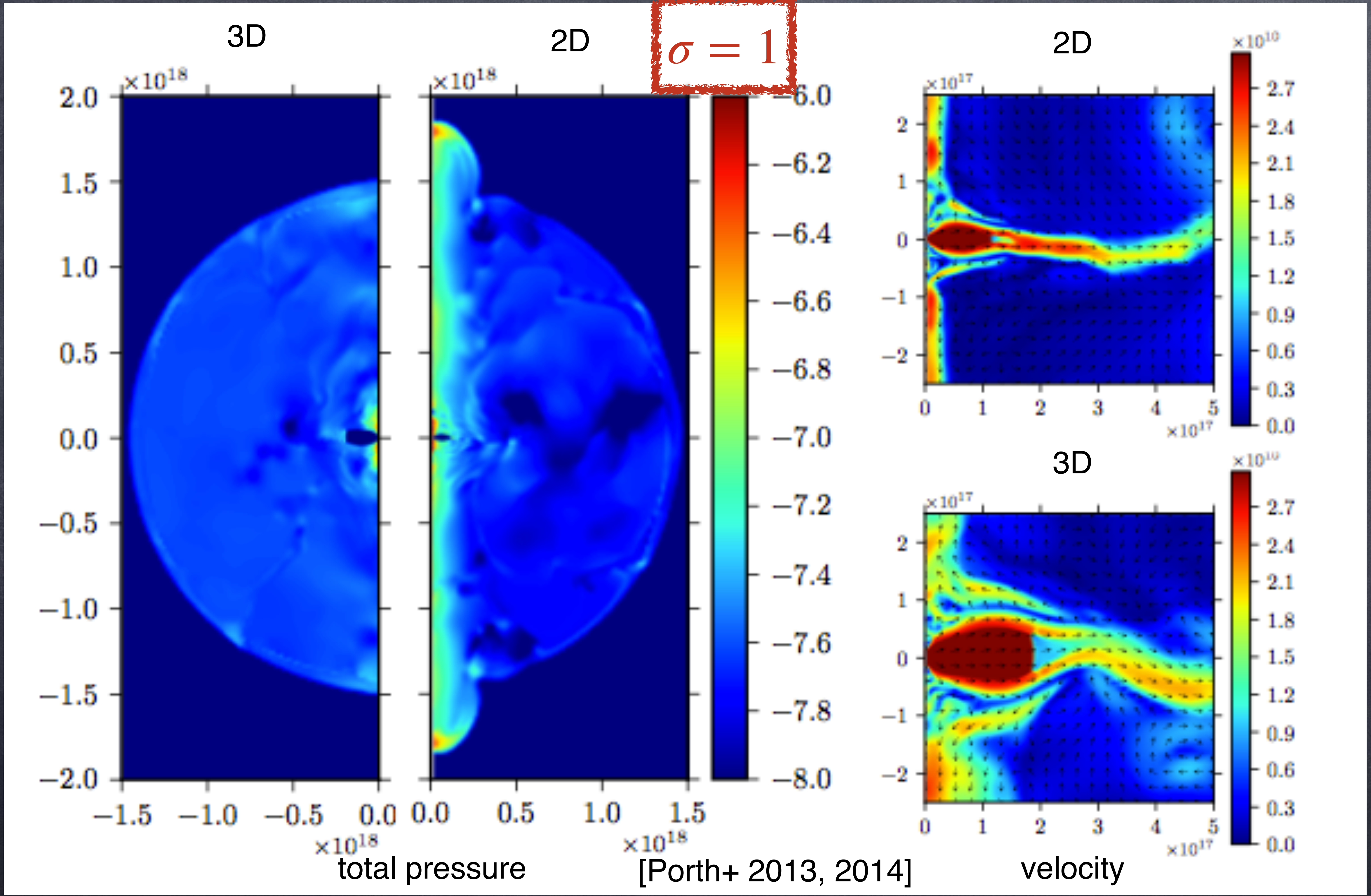


$B_{obs} \approx 10^{-4}\ G$

3D RMHD SIMULATIONS

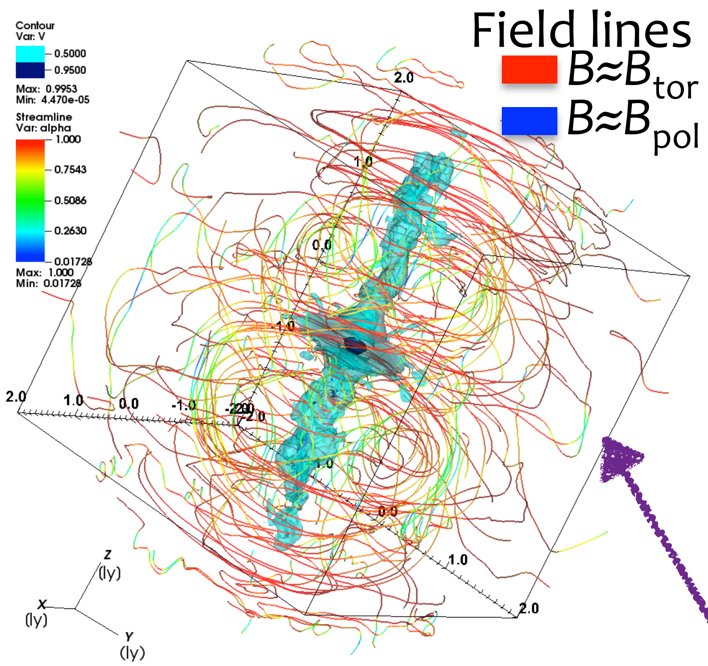
GLOBAL DYNAMICS DIFFERENT

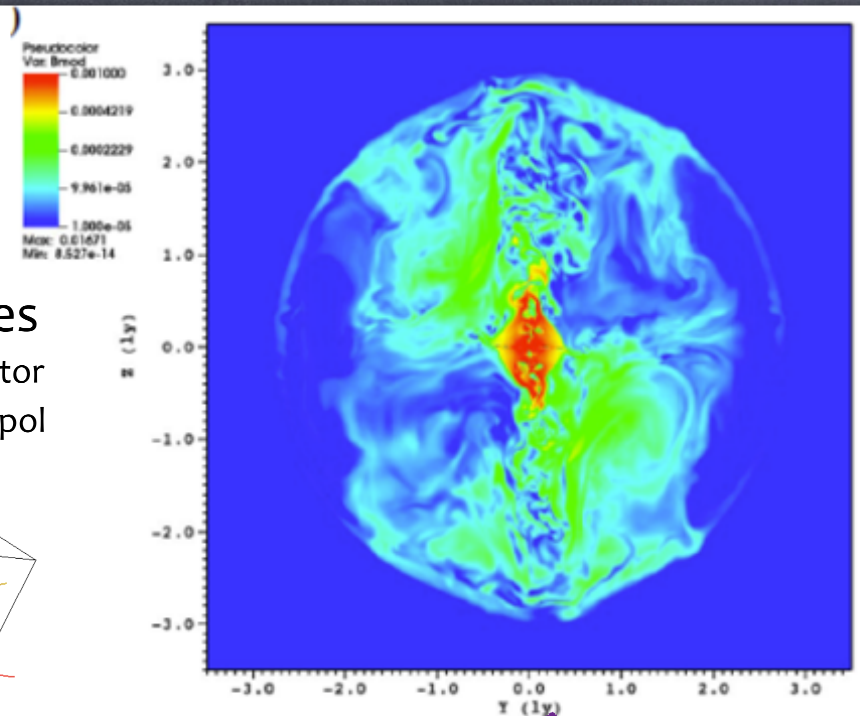
INNER DYNAMICS SIMILAR

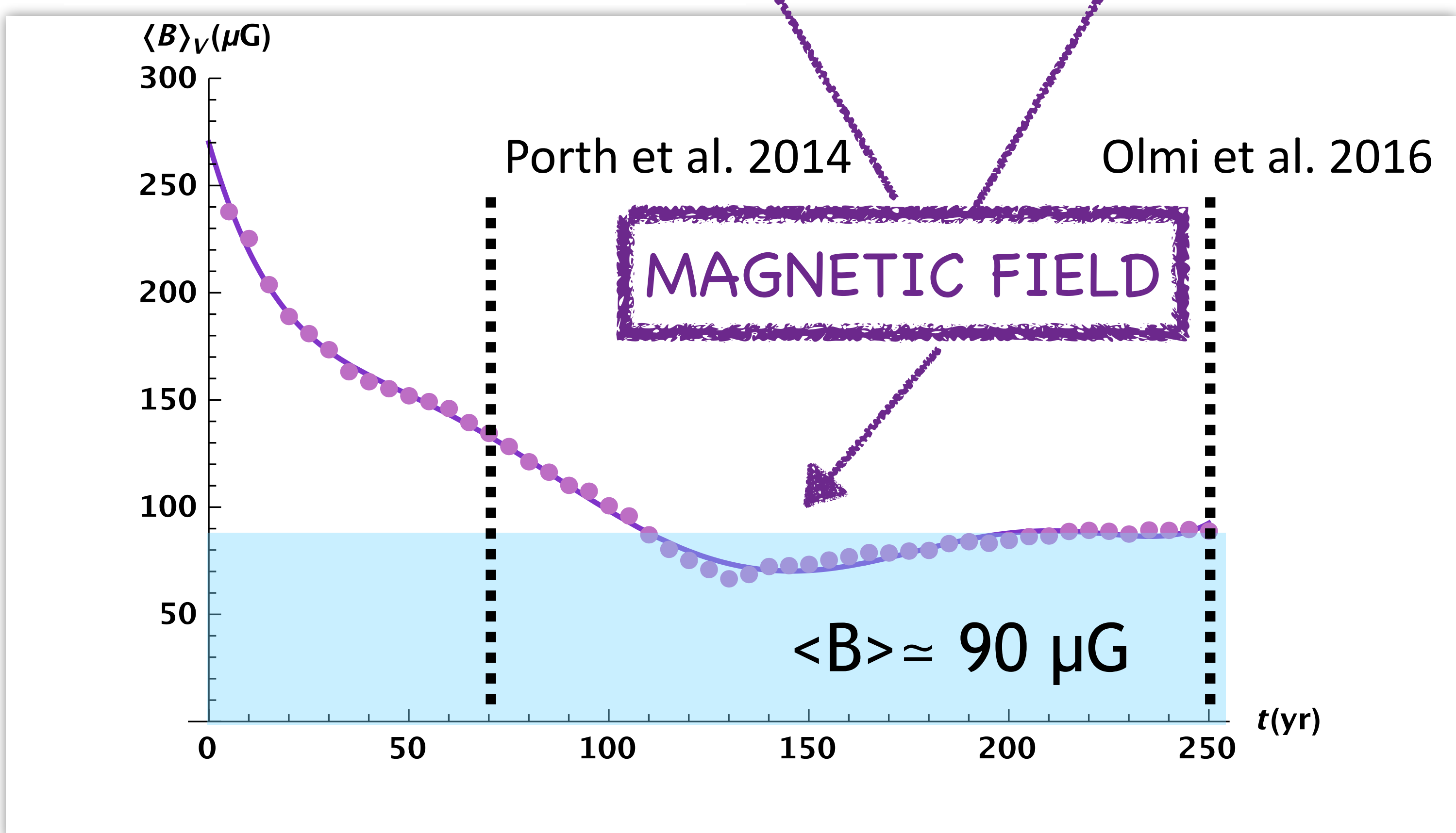


EARLY SUGGESTION (Begelman 98): KINKS REDUCE HOOP STRESS WITH LITTLE DISSIPATION

LONGER 3D RMHD SIMULATIONS

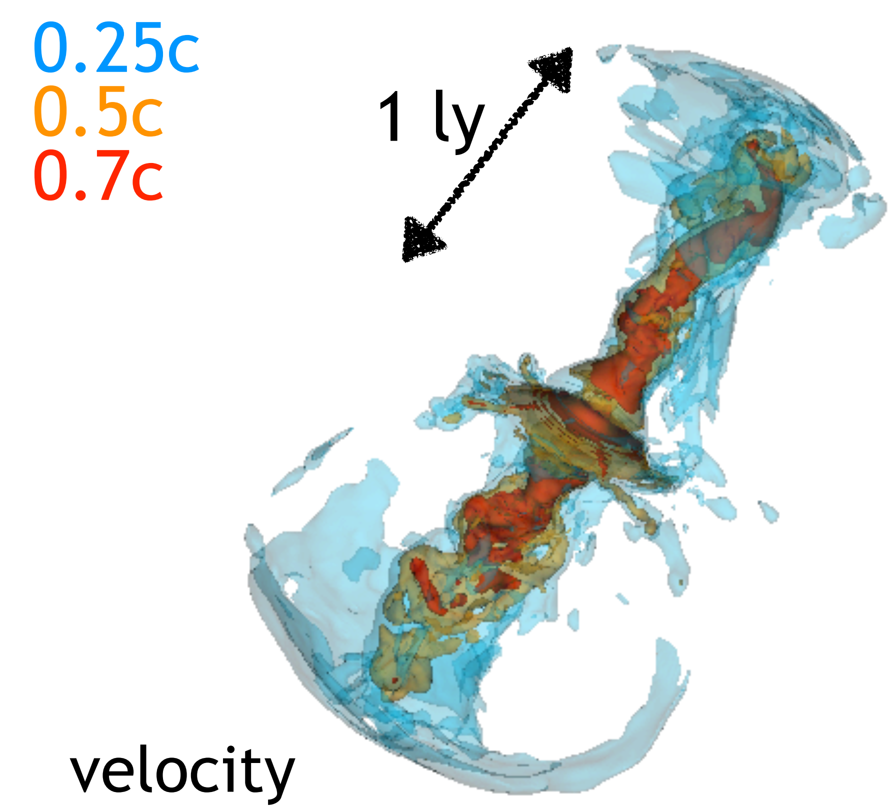






MAGNETIC FIELD

SELF SIMILAR PHASE FULLY REACHED



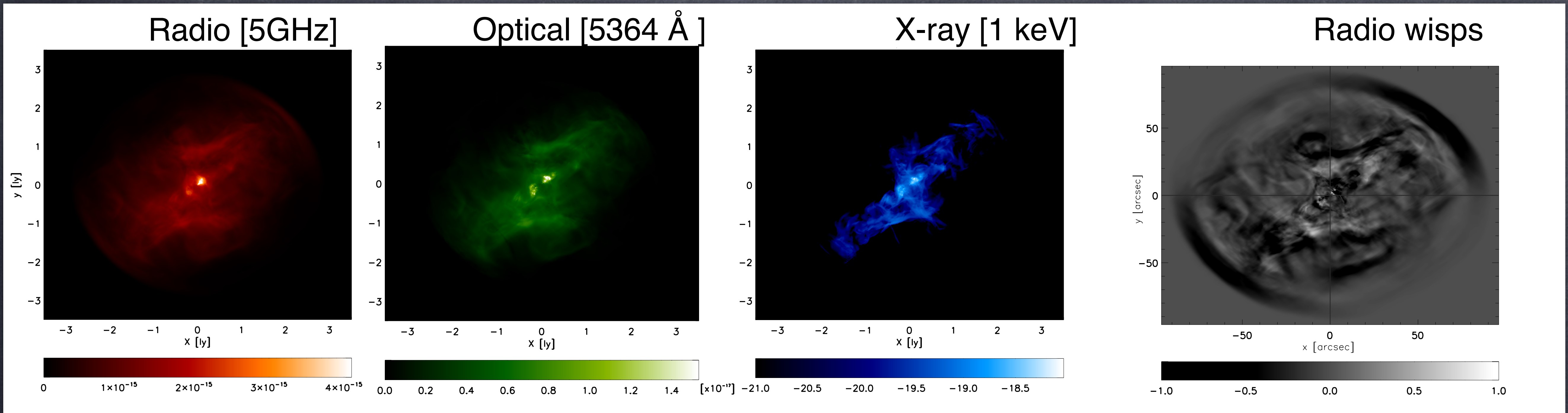
σ=1.5

ALL IS SOLVED?

✓ SHRINKAGE AND WISPS VARIABILITY OK

- NO BRIGHT X-RAY TORUS

Olmi+ 16



...NOT YET...

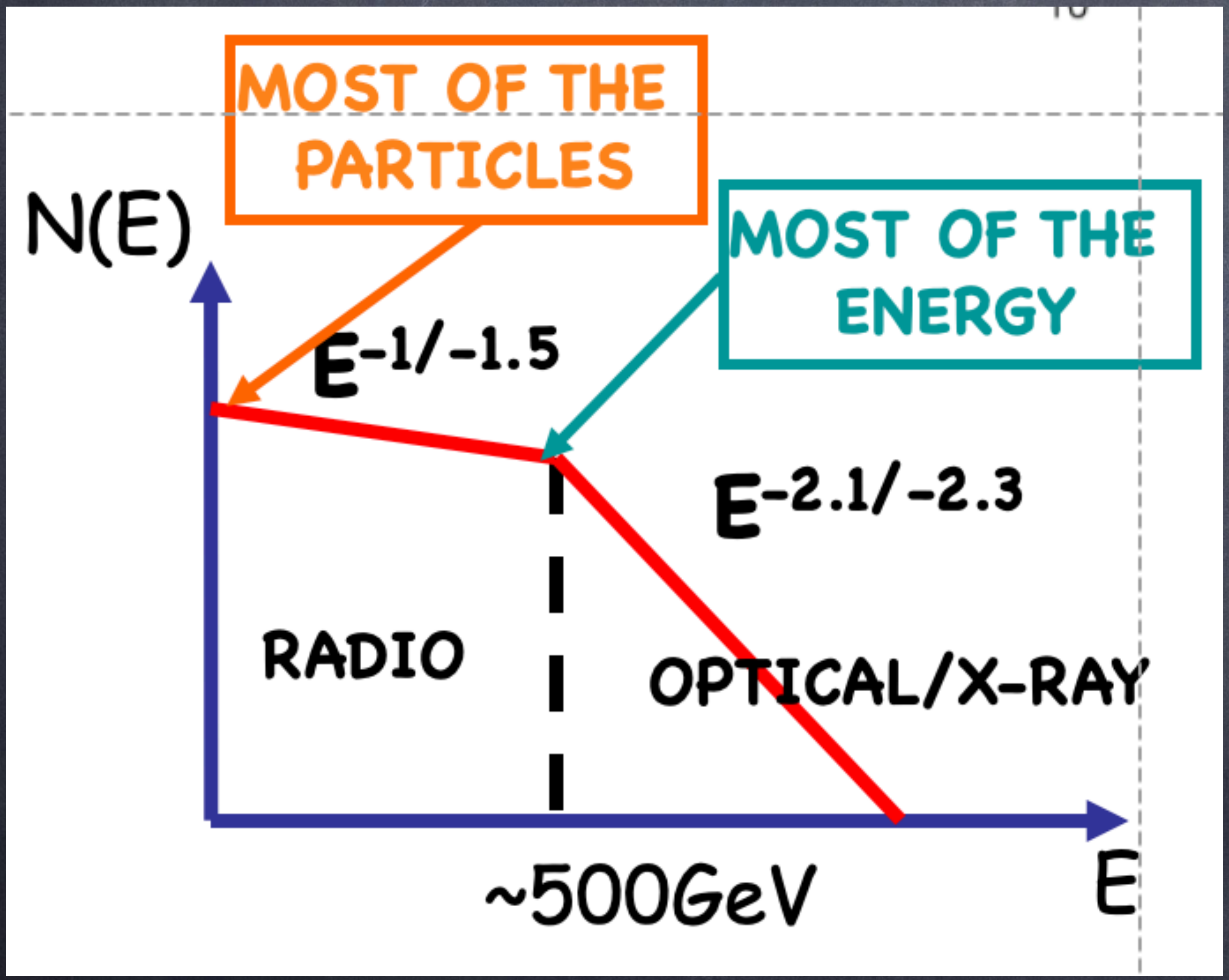
AVERAGE FIELD STILL TOO LOW

- ARTIFICIAL STEEPENING OF X-RAY PARTICLE SPECTRUM STILL NEEDED
- IC SPECTRUM STILL OVERESTIMATED

EVEN HIGHER σ NEEDED?

CONSTRAINING THE PULSAR MULTIPLICITY

κ IS CONSTRAINED BY RADIO EMITTING PARTICLES



RADIO EMITTING PARTICLES HAVE LONG LIFETIMES: DO NOT NEED TO BE PART OF THE FLOW

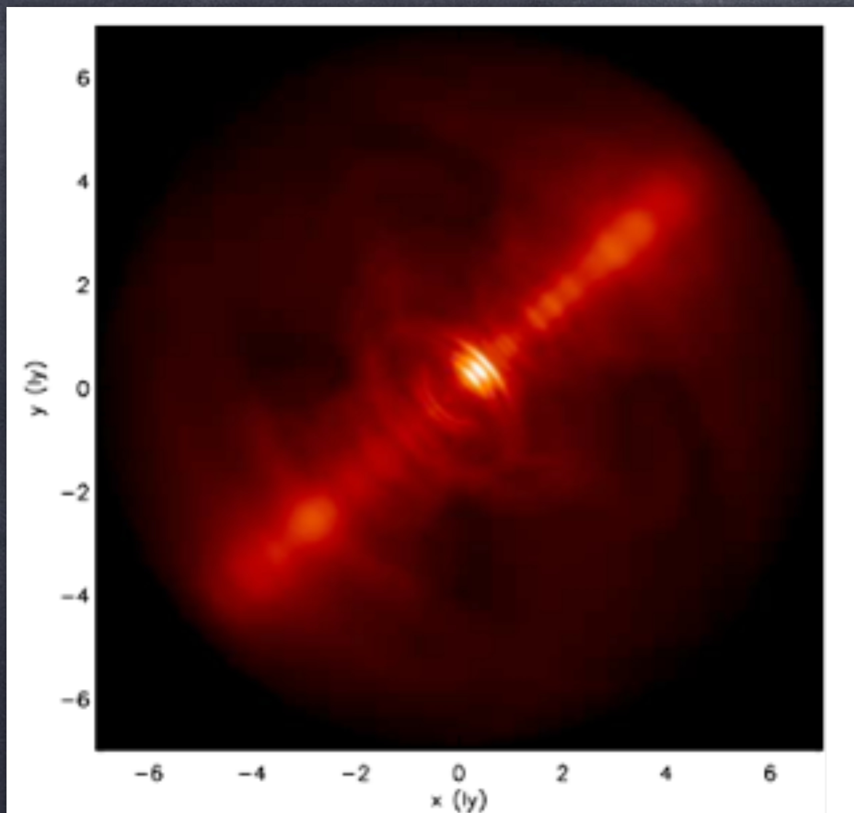
IF PART OF THE FLOW

$\kappa \approx 10^6$ $\Gamma \approx 10^4$

OTHERWISE

$\kappa \approx 10^3 - 10^4$ $\Gamma \approx 10^6 - 10^7$

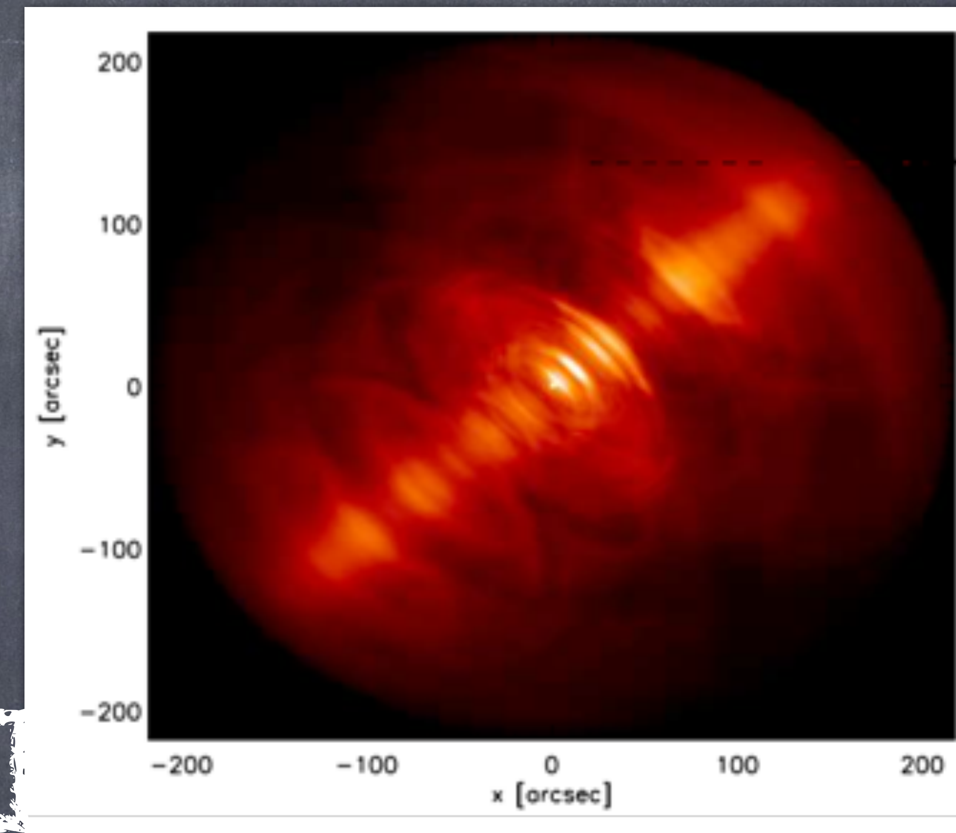
RADIO EMISSION

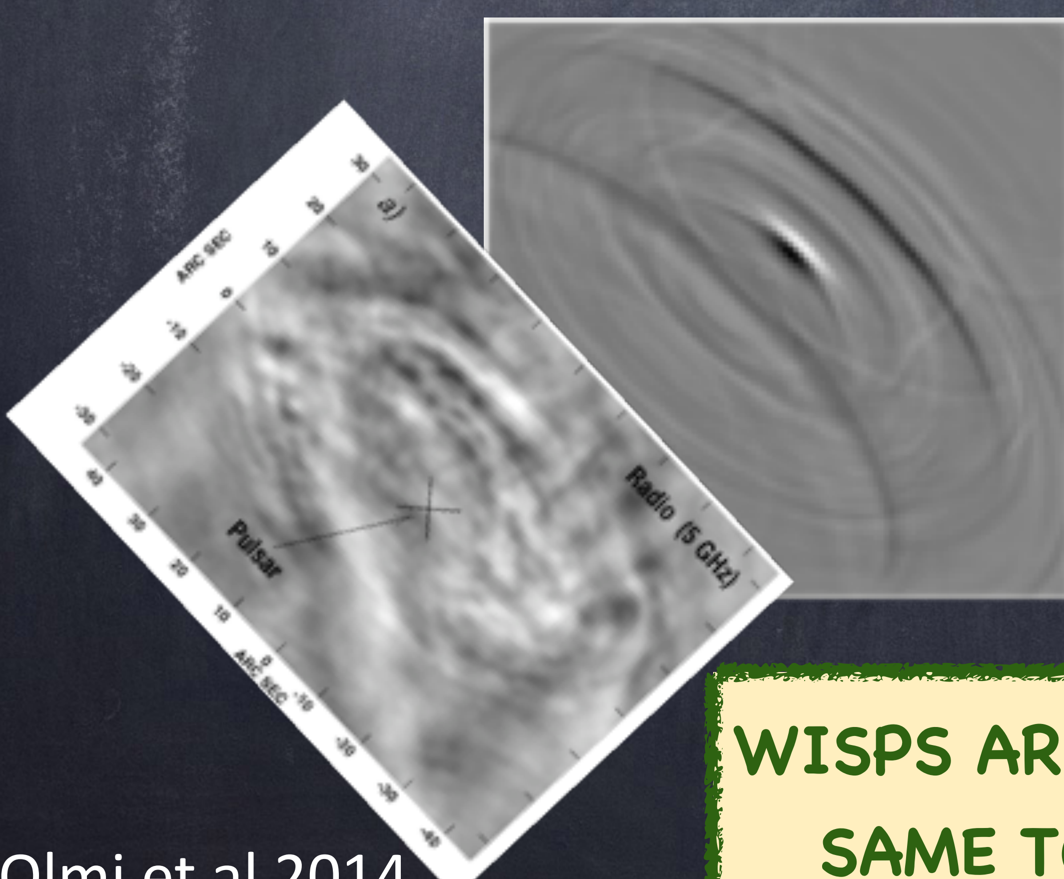


SHOCK ACCELERATION & ADVECTION

EMISSION MAPS CANNOT DISTINGUISH

UNIFORM INJECTION





Olmi et al 2014

WISPS ARE THE SAME TOO

RADIO PARTICLES DO NOT NEED TO BE CURRENTLY ACCELERATED AT THE SHOCK

$\kappa \sim 10^3 - 10^4$ IS VIABLE

PARTICLE ACCELERATION IN PWNe

PARTICLE ACCELERATION MECHANISMS (BEST STUDIED)

FERMI MECHANISM → MAGNETIZATION: REQUIRES LOW ← HOWEVER SEE VARIANTS

DRIVEN MAGNETIC RECONNECTION → MAGNETIZATION: REQUIRES HIGH

DRIVEN MAGNETIC RECONNECTION → PLASMA MULTIPLICITY: REQUIRES HIGH

ION CYCLOTRON ABSORPTION IN ION DOPED PLASMA → PLASMA MULTIPLICITY: REQUIRES LOW

PARTICLE ACCELERATION MECHANISMS (BEST STUDIED)

FERMI MECHANISM

- EFFICIENT AT UNMAGNETIZED e^+-e^- RELATIVISTIC SHOCKS [Spitkovsky 08]
- RIGHT SPECTRUM FOR X-RAYS
- NO ACCELERATION AT σ>0.001 SUPERLUMINAL SHOCKS [Sironi & Spitkovsky 09, 11]
- TOO SLOW TO GUARANTEE MAXIMUM ENERGY OBSERVED IN CRAB [Pelletier+ 17]

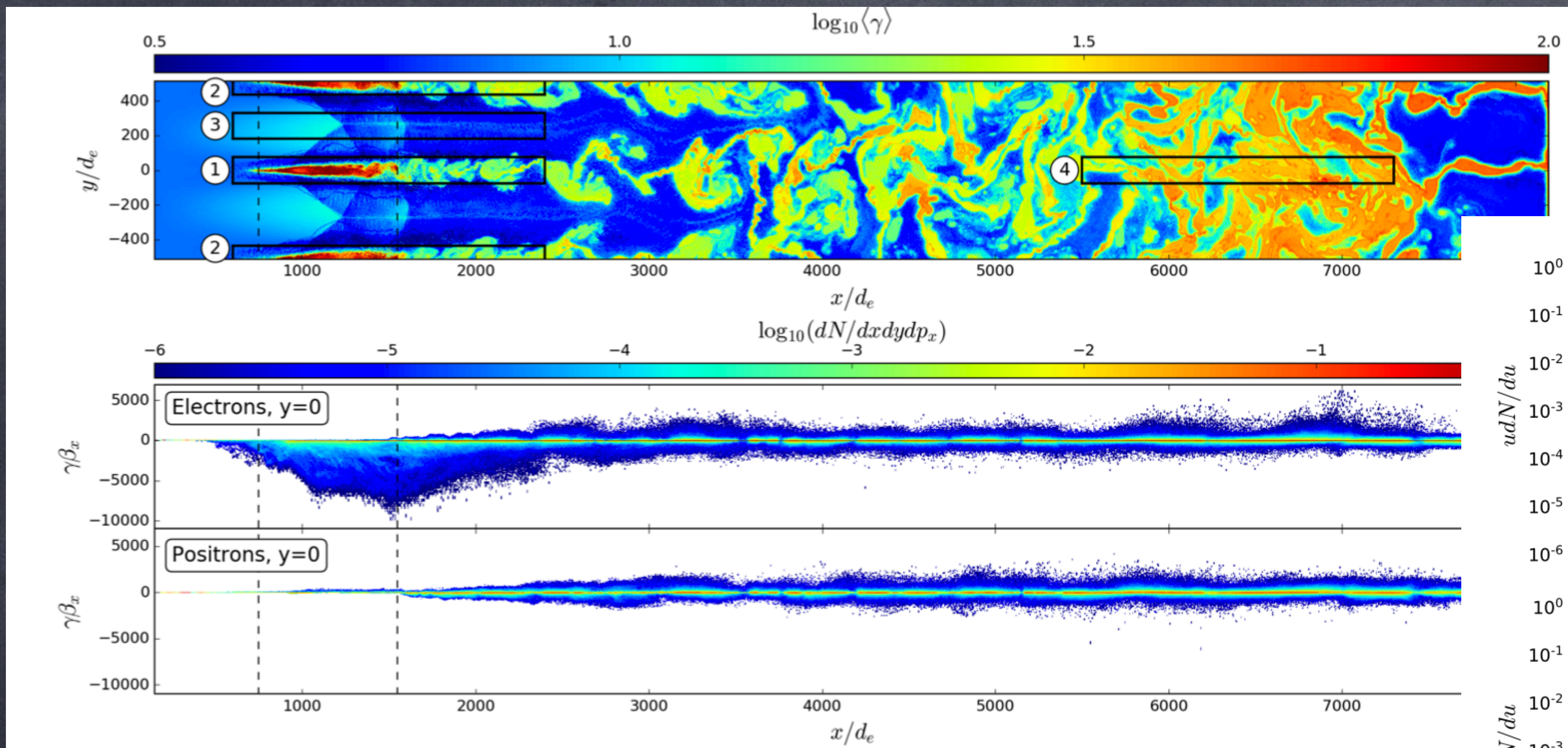
DRIVEN MAGNETIC RECONNECTION:

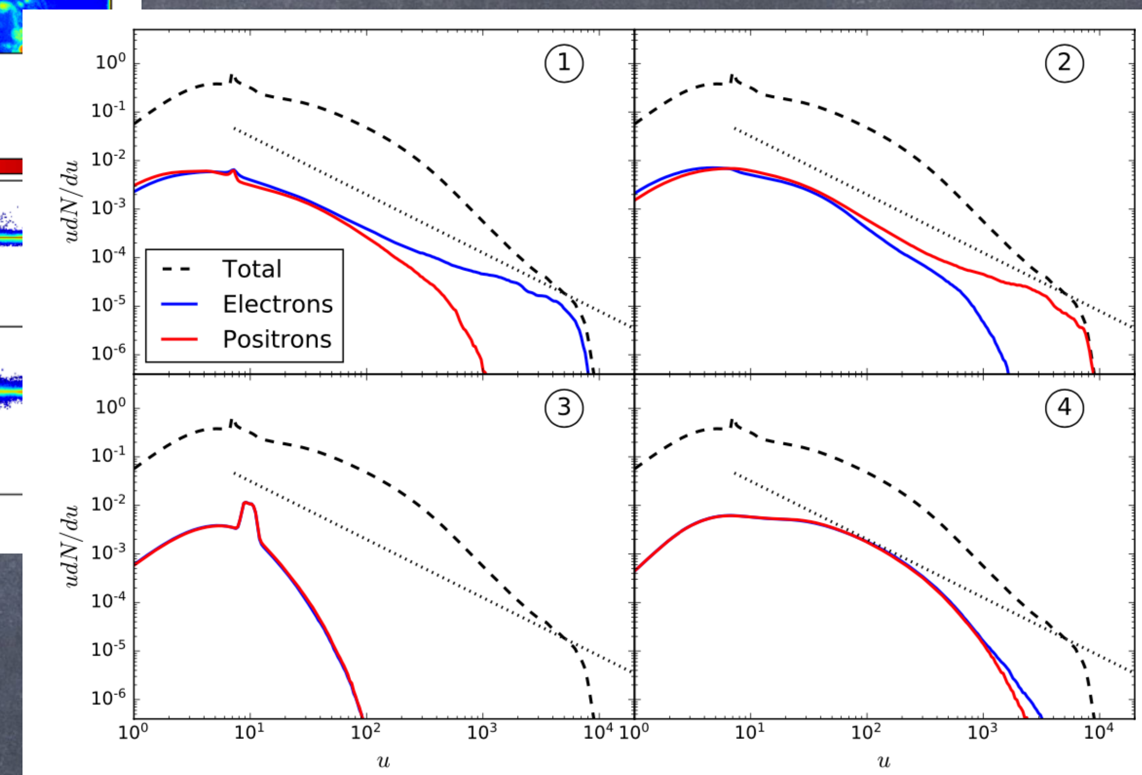
- BROAD AND HARD PARTICLE SPECTRA IF $\sigma \geq 30$ AND $\kappa > 10^8$ [Sironi & Spitkovsky 11b]
- FOR THIS LARGE κ WIND LIKELY TO DISSIPATE BEFORE SHOCK [Kirk & Skjeraasen 03]

RESONANT CYCLOTRON ABSORPTION:

- SPECTRA AND ACCELERATION EFFICIENCY DEPEND ON ENERGY FRACTION IN IONS: U_i/U_{TOT}=0.8-0.6, γ=1.5-3, ε_{ACC}=0.3-0.03 [EA & Arons 06; Stockem et al 12]
- HIGHER σ IMPLIES FASTER ACCELERATION
- NO ACCELERATION IF $\kappa > m_i/m_e$

SHOCK ACCELERATION VARIANTS





Cerutti & Giacinti 20

TURBULENT SHOCK FRONT

- CORRUGATED SHOCK [Lemoine 17]
- DIFFERENT TURBULENCE LEVELS AT DIFFERENT LATITUDES [Giacinti & Kirk 18]
- POSSIBLY PROVIDED BY ANISOTROPIC B- FIELD [Cerutti & Giacinti 20]
- PRODUCES HARD (STEEP) SPECTRA FOR LOW (HIGH) TURBULENCE LEVEL
- SPECTRUM HARDENS WITH INCREASING MAGNETIZATION
- INTERESTING LATITUDE DEPENDENCE OF SPECTRAL INDEX (SEE LATER)
- ACCELERATES ONE SIGN OF CHARGES PREFERENTIALLY

PWNe AS PEVATRONS

MAXIMUM ENERGY IN A PWN

IN YOUNG ENERGETIC SYSTEMS ACCELERATION IS LOSS LIMITED

$$t_{acc} = \frac{E}{e\eta Bc} < t_{loss} = \frac{6\pi(mc^2)^2}{\sigma_T c B^2 E} \quad \Rightarrow \quad E_{max} \approx 6\ PeV\ \eta^{1/2}\ B_{-4}^{1/2}$$

STRICT LIMIT FROM THE PSR POTENTIAL DROP $\Phi_{PSR} = \sqrt{\dot{E}/c}$

$$E_{max,abs} = eB_{TS}\ R_{TS}$$

$$\frac{B_{TS}^2}{4\pi} = \xi_B \frac{\dot{E}}{4\pi R_{TS}^2 c}$$

$$\Rightarrow \quad E_{max,abs} = e\xi_B^{1/2}\sqrt{\dot{E}/c} \approx 1.8\ PeV\ \xi_B^{1/2}\ \dot{E}_{36}^{1/2}$$

LEPTONIC OR HADRONIC PEVATRONS?

12 SOURCES DETECTED BY LHAASO ABOVE 100 TeV

Table 1 | UHE γ-ray sources

Source name	RA (°)	dec. (°)	Significance above 100 TeV (×σ)	E_{max} (PeV)	Flux at 100 TeV (CU)
LHAASO J0534+2202	83.55	22.05	17.8	0.88 ± 0.11	1.00(0.14)
LHAASO J1825-1326	276.45	−13.45	16.4	0.42 ± 0.16	3.57(0.52)
LHAASO J1839-0545	279.95	−5.75	7.7	0.21 ± 0.05	0.70(0.18)
LHAASO J1843-0338	280.75	−3.65	8.5	$0.26\,{-0.10}^{+0.16}$	0.73(0.17)
LHAASO J1849-0003	282.35	−0.05	10.4	0.35 ± 0.07	0.74(0.15)
LHAASO J1908+0621	287.05	6.35	17.2	0.44 ± 0.05	1.36(0.18)
LHAASO J1929+1745	292.25	17.75	7.4	$0.71\,{-0.07}^{+0.16}$	0.38(0.09)
LHAASO J1956+2845	299.05	28.75	7.4	0.42 ± 0.03	0.41(0.09)
LHAASO J2018+3651	304.75	36.85	10.4	0.27 ± 0.02	0.50(0.10)
LHAASO J2032+4102	308.05	41.05	10.5	1.42 ± 0.13	0.54(0.10)
LHAASO J2108+5157	317.15	51.95	8.3	0.43 ± 0.05	0.38(0.09)
LHAASO J2226+6057	336.75	60.95	13.6	0.57 ± 0.19	1.05(0.16)

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LHAASO SOURCE ASSOCIATIONS

ALL SOURCES EXCEPT FOR 2 HAVE A PSR IN THE FIELD

LHAASO Source	Possible Origin	Type	Distance (kpc)	Age (kyr)[a]	L_s (erg/s)[b]	Potential TeV Counterpart[c]
LHAASO J0534+2202	PSR J0534+2200	PSR	2.0	1.26	4.5×10^{38}	Crab, Crab Nebula
LHAASO J1825-1326	PSR J1826-1334	PSR	3.1 ± 0.2^d	21.4	2.8×10^{36}	HESS J1825-137, HESS J1826-130,
	PSR J1826-1256	PSR	1.6	14.4	3.6×10^{36}	2HWC J1825-134
LHAASO J1839-0545	PSR J1837-0604	PSR	4.8	33.8	2.0×10^{36}	2HWC J1837-065, HESS J1837-069,
	PSR J1838-0537	PSR	1.3^e	4.9	6.0×10^{36}	HESS J1841-055
LHAASO J1843-0338	SNR G28.6-0.1	SNR	9.6 ± 0.3^f	$< 2^f$	—	HESS J1843-033, HESS J1844-030,
						2HWC J1844-032
LHAASO J1849-0003	PSR J1849-0001	PSR	7^g	43.1	9.8×10^{36}	HESS J1849-000, 2HWC J1849+001
	W43	YMC	5.5^h	—	—	
LHAASO J1908+0621	SNR G40.5-0.5	SNR	3.4^i	$\sim 10 - 20^j$	—	MGRO J1908+06, HESS J1908+063,
	PSR 1907+0602	PSR	2.4	19.5	2.8×10^{36}	ARGO J1907+0627, VER J1907+062,
	PSR 1907+0631	PSR	3.4	11.3	5.3×10^{35}	2HWC 1908+063
LHAASO J1929+1745	PSR J1928+1746	PSR	4.6	82.6	1.6×10^{36}	2HWC J1928+177, 2HWC J1930+188,
	PSR J1930+1852	PSR	6.2	2.9	1.2×10^{37}	HESS J1930+188, VER J1930+188
	SNR G54.1+0.3	SNR	$6.3^{+0.8\ d}_{-0.7}$	$1.8 - 3.3^k$	—	
LHAASO J1956+2845	PSR J1958+2846	PSR	2.0	21.7	3.4×10^{35}	2HWC J1955+285
	SNR G66.0-0.0	SNR	2.3 ± 0.2^d	—	—	
LHAASO J2018+3651	PSR J2021+3651	PSR	$1.8^{+1.7\ l}_{-1.4}$	17.2	3.4×10^{36}	MGRO J2019+37, VER J2019+368,
	Sh 2-104	H II/YMC	$3.3 \pm 0.3^m/4.0 \pm 0.5^n$	—	—	VER J2016+371
LHAASO J2032+4102	Cygnus OB2	YMC	1.40 ± 0.08^o	—	—	TeV J2032+4130, ARGO J2031+4157,
	PSR 2032+4127	PSR	1.40 ± 0.08^o	201	1.5×10^{35}	MGRO J2031+41, 2HWC J2031+415,
	SNR G79.8+1.2	SNR candidate	—	—	—	VER J2032+414
LHAASO J2108+5157	—	—	—	—	—	—
LHAASO J2226+6057	SNR G106.3+2.7	SNR	0.8^p	$\sim 10^p$	—	VER J2227+608, Boomerang Nebula
	PSR J2229+6114	PSR	0.8^p	$\sim 10^p$	2.2×10^{37}	

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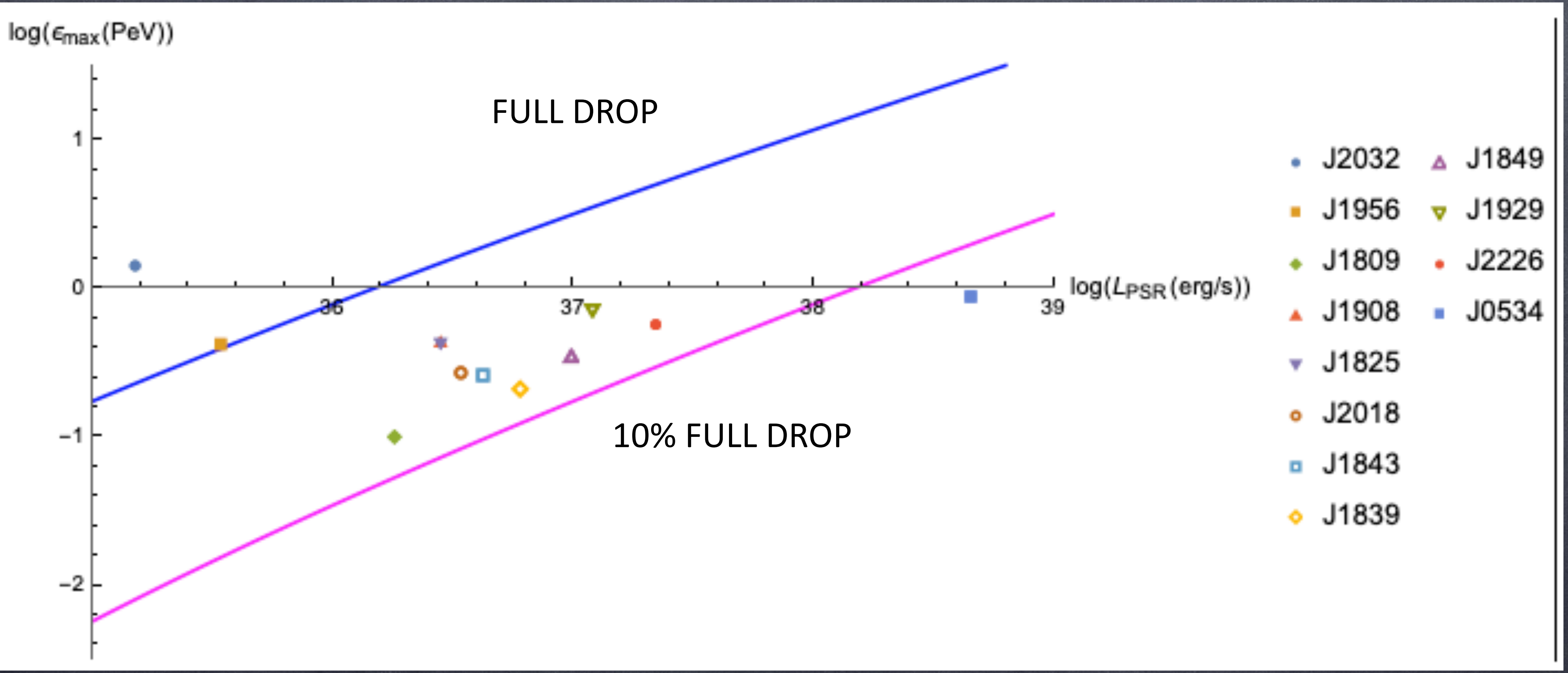
LEPTONIC OR HADRONIC PEVATRONS?

SOURCE	PSR	L_{PSR} [10^{36} erg/s]	E_{max} [PeV]	ε_{max} th. [PeV]	ε_{max} obs [PeV]	
J0534+2202	PSR J0534+2200	450	36,7	26,4	0,88	
J1809-193	PSR J1809-1917	1,8	2,3	1,12	0,1	HAWC only
J1825-1326	PSR J1826-1334	2,8	2,9	1,48	0,42	
J1839-0545	PSR J1838-0537	6	4,23	2,34	0,21	
J1843-0338	PSR J1844-0346	4,2	3,55	1,9	0,26	no PSR fo LHAASO
J1849-0003	PSR J1849-0001	9,8	5,4	3,12	0,35	
J1908+0621	PSR J1907+0602	2,8	2,9	1,48	0,44	
J1929+1745	PSR J1930+1852	12	6	3,52	0,71	LHAASO only
J1956+2845	PSR J1958+2846	0,34	1,01	0,39	0,42	LHAASO only
J2018+3651	PSR J2021+3651	3,4	3,2	1,66	0,27	
J2032+4102	PSR J2032+4127	0,15	0,67	0,23	1,42	
J2108+5157					0,43	LHAASO only/no PSR
J2226+6057	PSR J2229+6114	22	8,12	4,98	0,57	LHAASO only

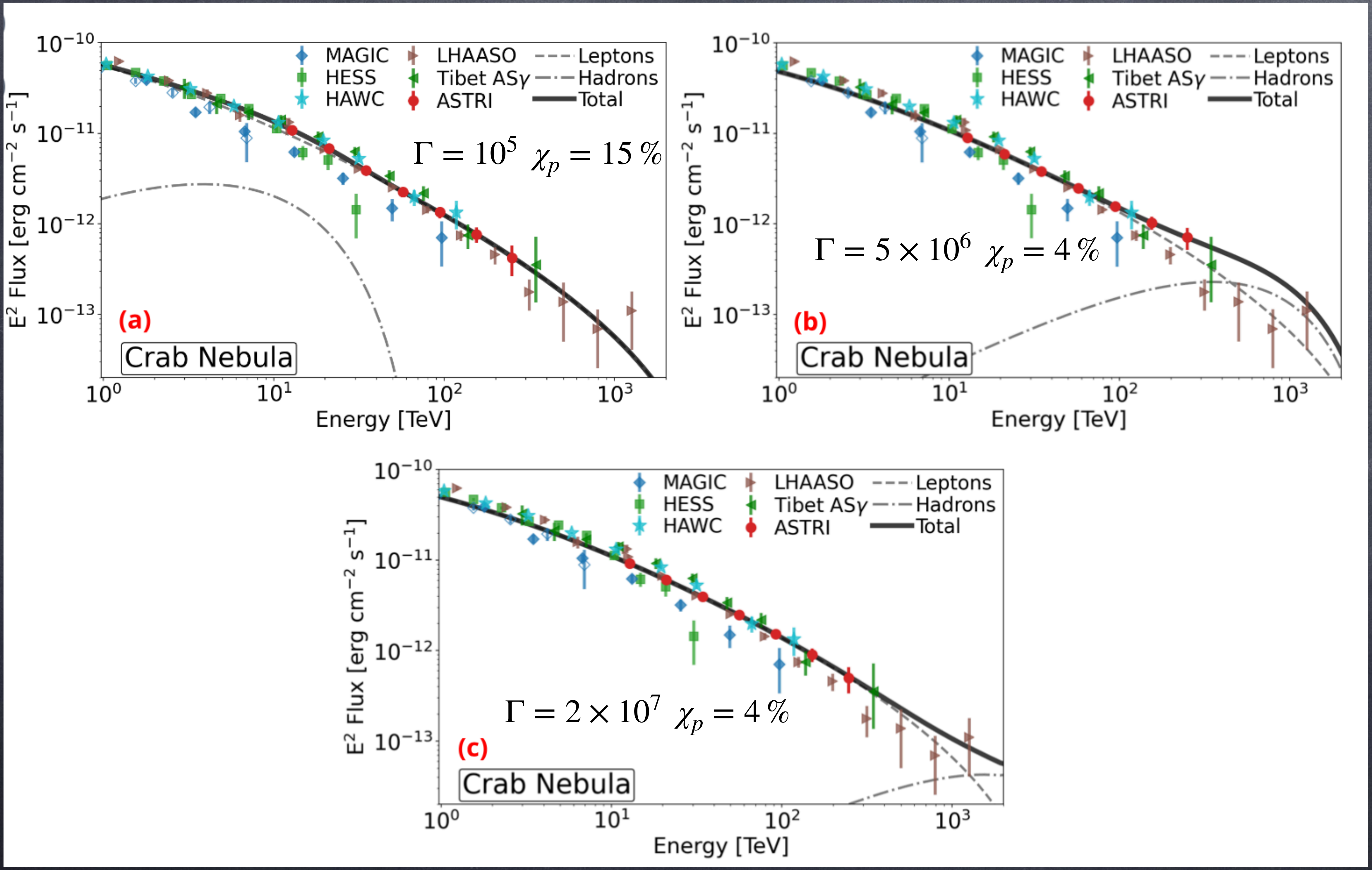
IC KN WITH CMB

LHAASO PeVatrons and PWNe

MAXIMUM ELECTRON ENERGY AS A FUNCTION OF PSR POTENTIAL DROP
AND LHAASO SOURCES



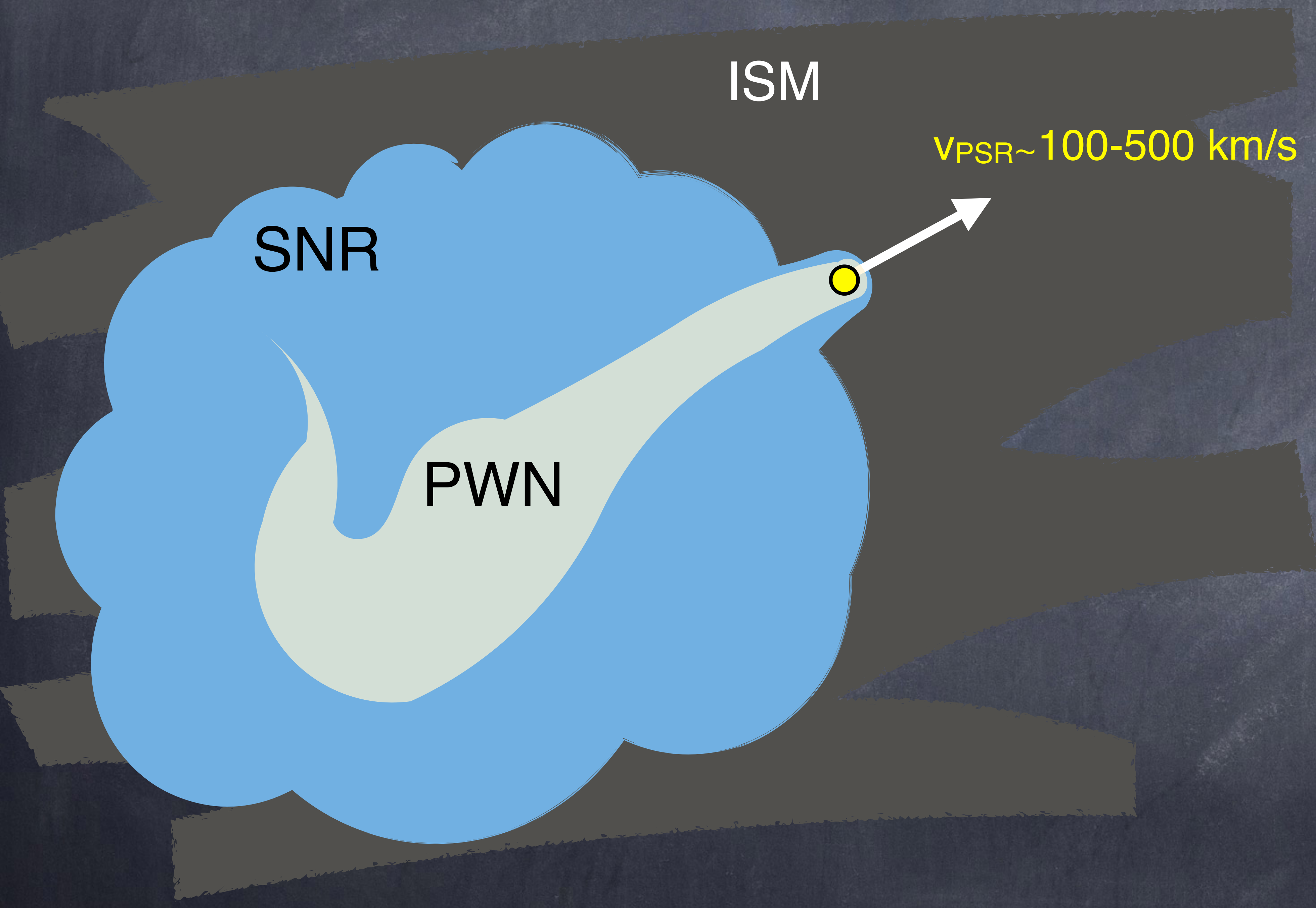
HADRONS IN CRAB?



Vercellone + in prep.

EVOLVED SYSTEMS AND PARTICLE ESCAPE

EVOLVED PWNe

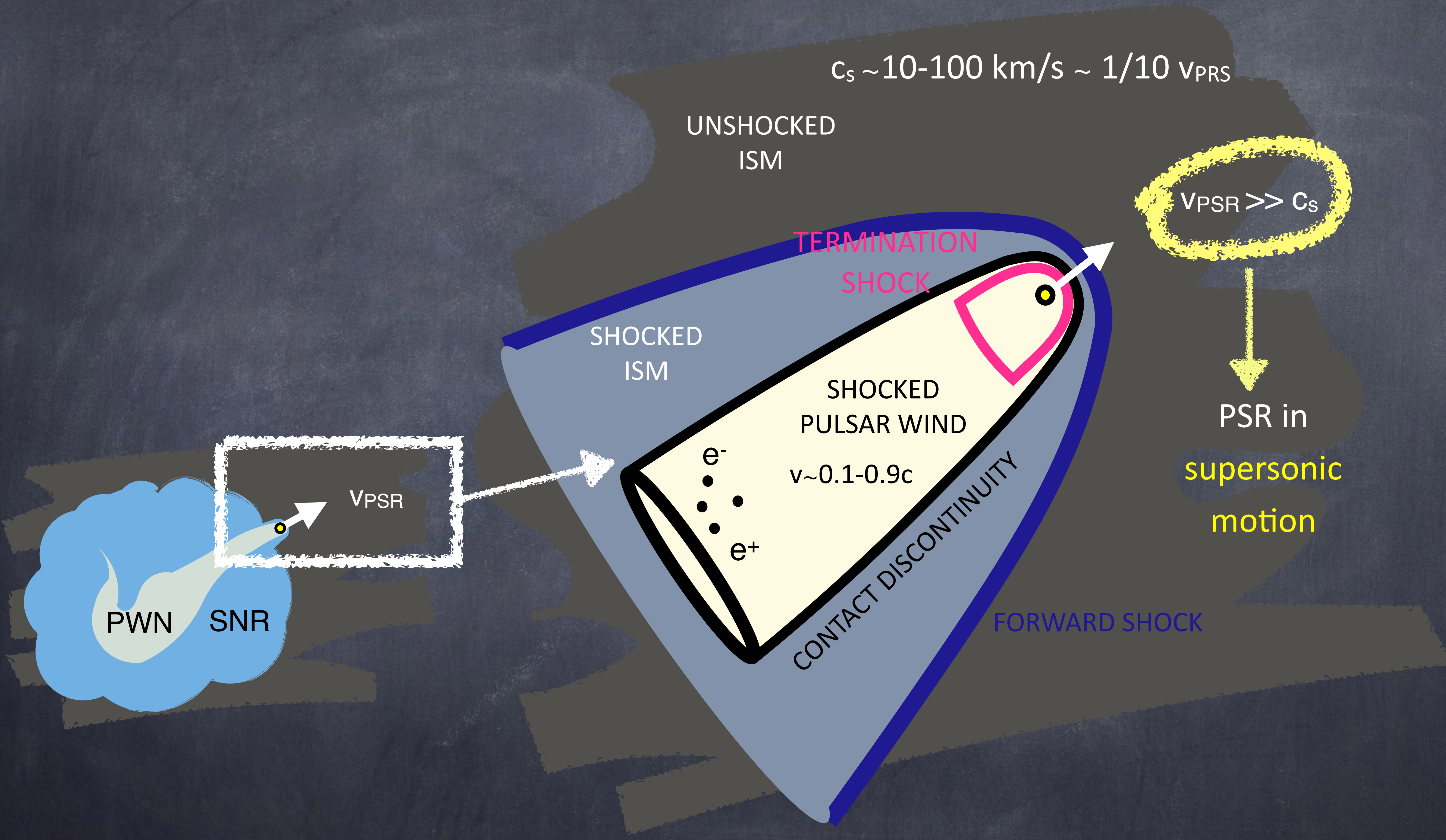


LARGE FRACTION OF ALL THE PULSARS BORN WITH HIGH KICK VELOCITY

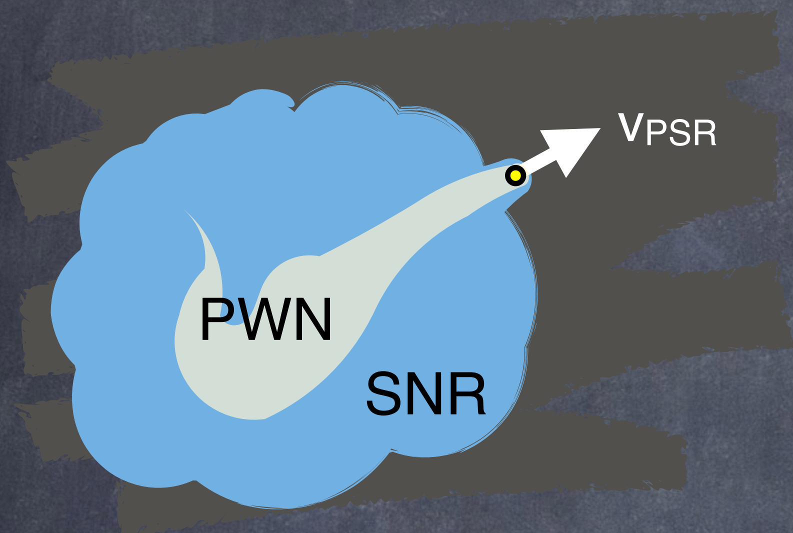
↓

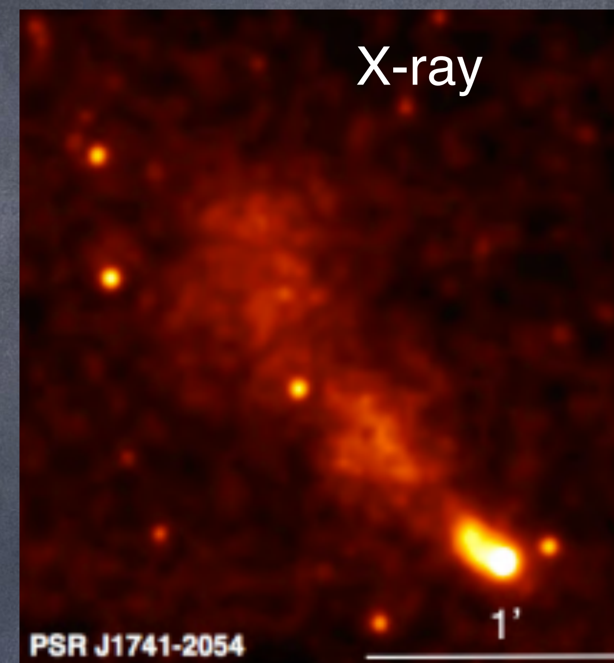
THEY WILL LEAVE THE SNR ON TIMESCALES FEW X 10^4 – 10^5 YR

BOW SHOCK NEBULAE

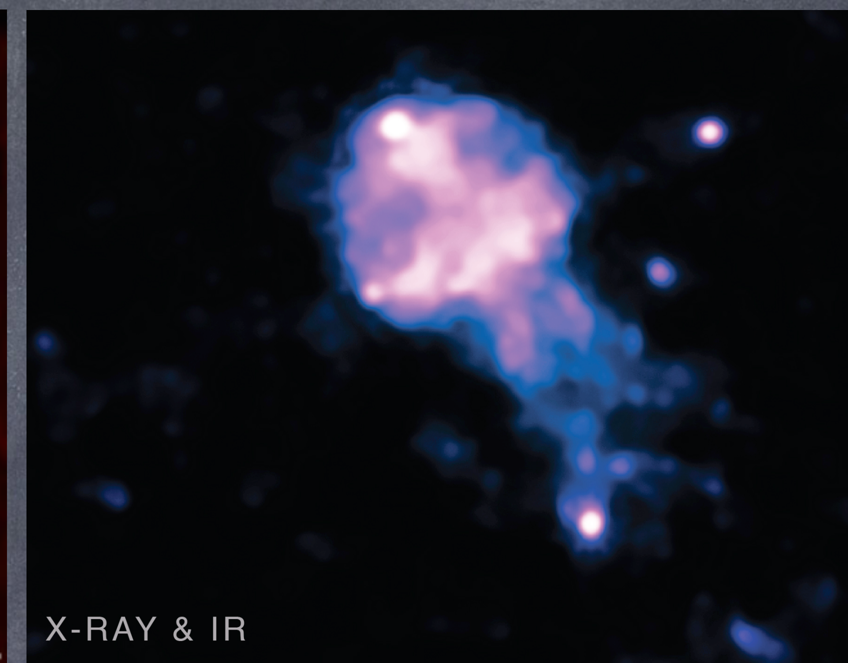


OBSERVATIONS: COMETARY NEBULAE

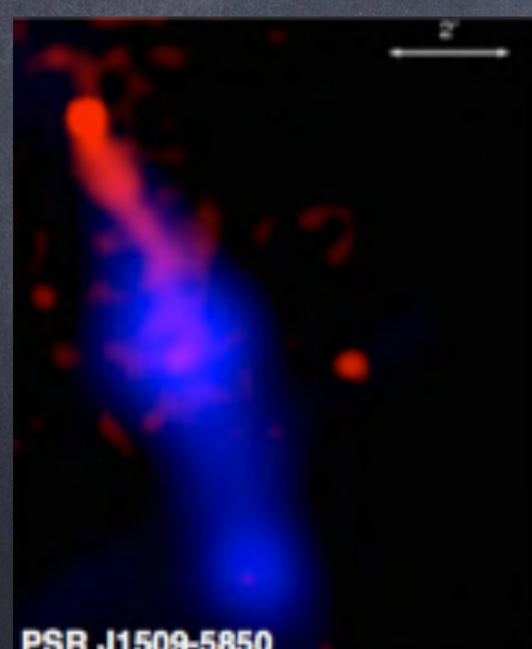




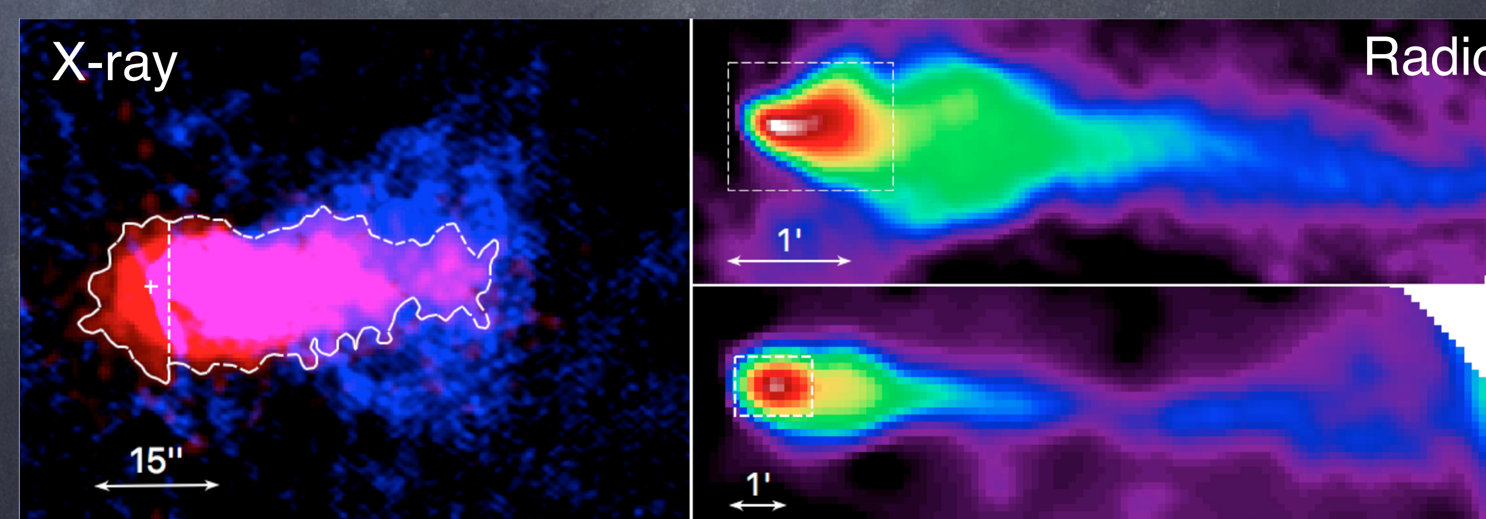
PSR J1741-2054
[Kargaltsev et al. 2016]



B0355+54
[Emre et al. 2005]

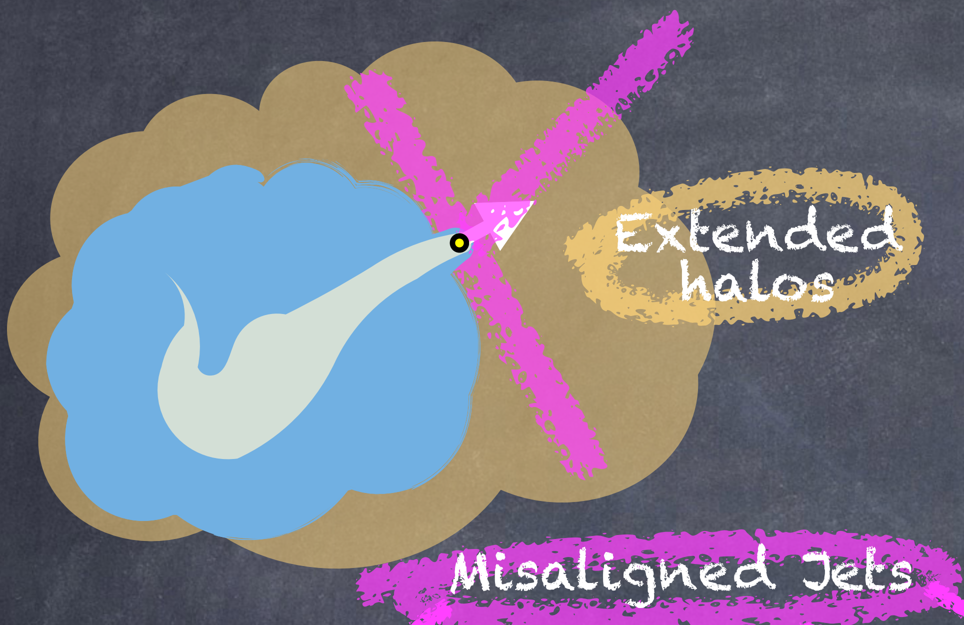


PSR J1509-5850
[Hui & Becker 2007, Klinger et al. 2016]

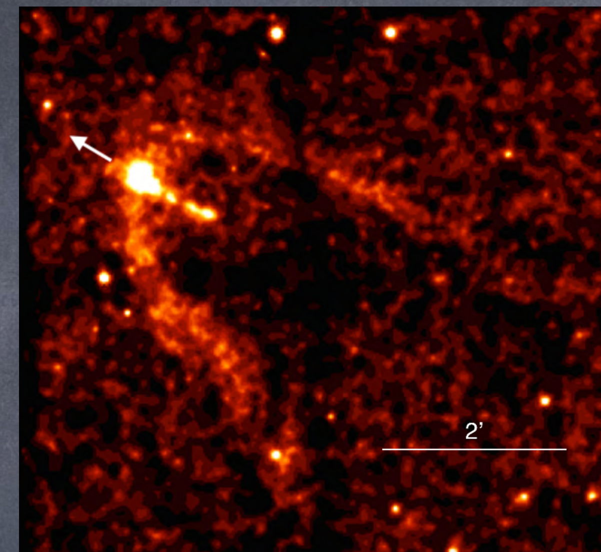


Mouse PWN
[Yusef-Zadeh & Bally 1987, Yusef-Zadeh & Gaensler 2005, Klinger et al. 2018]

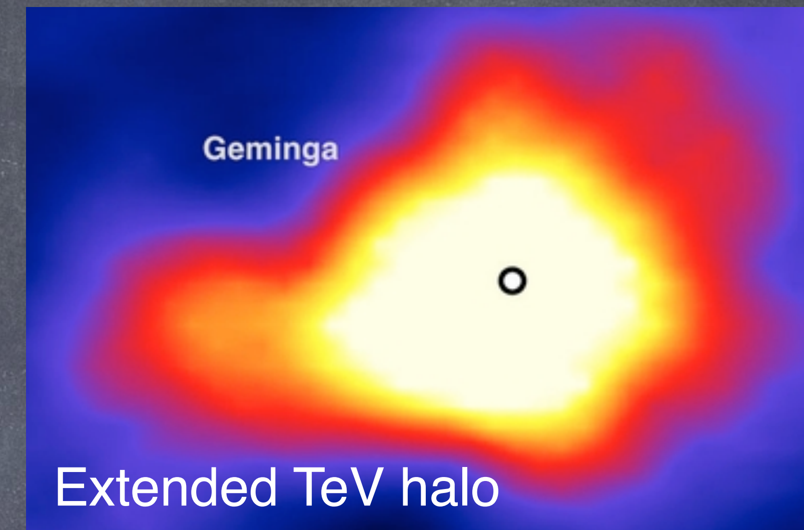
OBSERVATIONS: JETS AND HALOES



X-ray

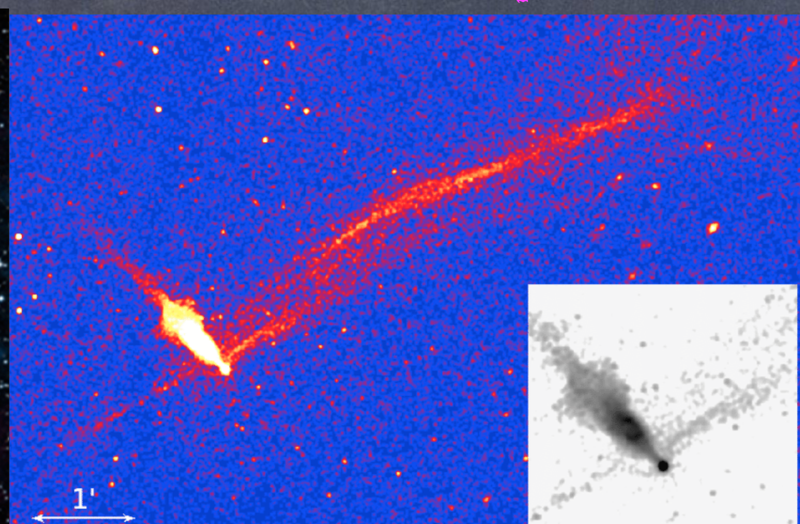


Geminga
[Posselt et al. 2017]

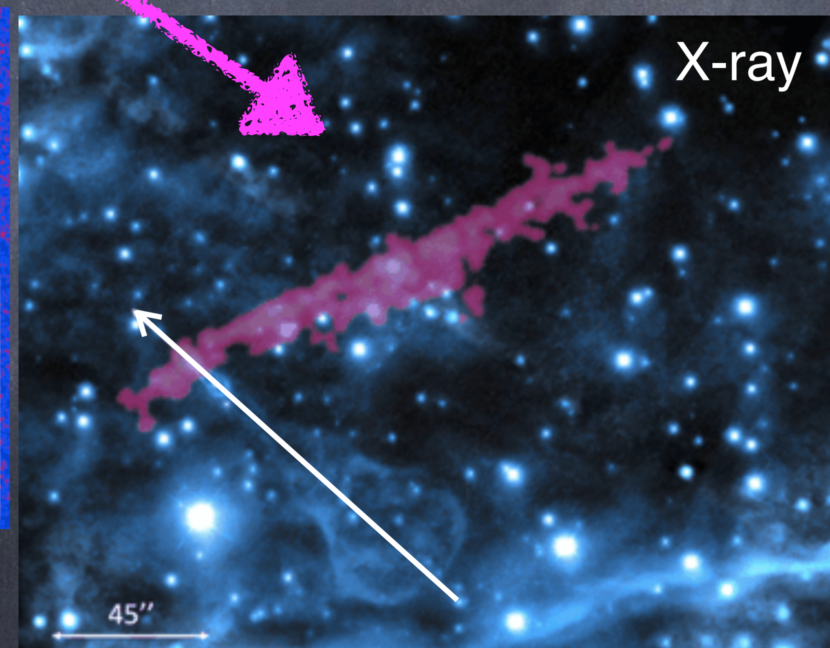


[Abeysekara et al. 2017]

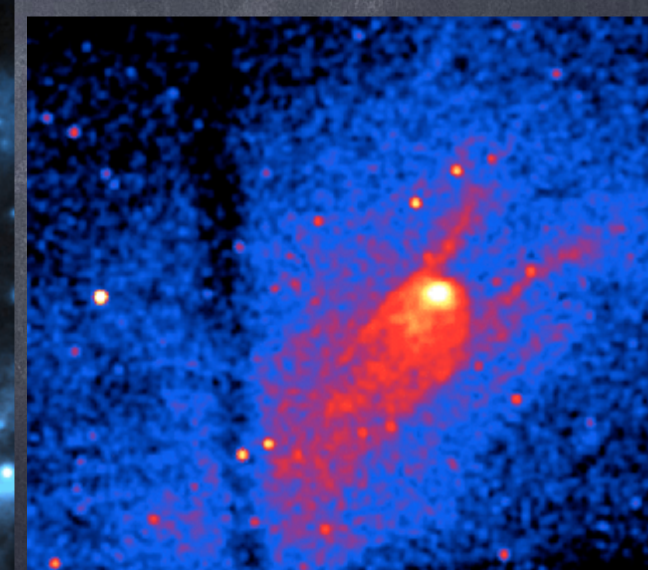
PSR J1509-5850
[Klinger et al. 2016]



Lighthouse nebula
[Pavan et al. 2016]

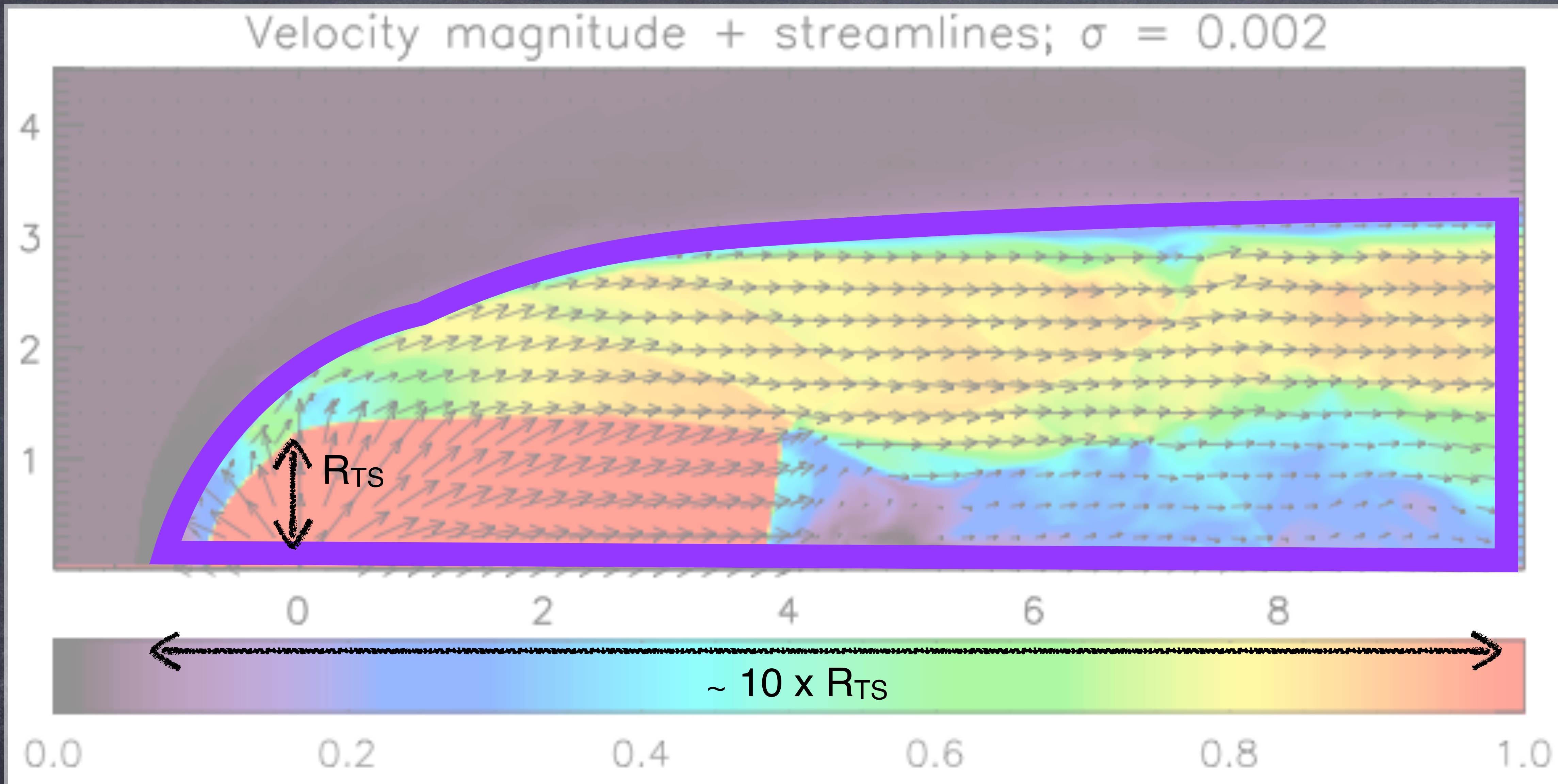


Guitar nebula
[Cordes et al. 1993, Wong et al. 2003]



G327
[Temim et al. 2009]

2D RMHD MODELS OF BS PWNE



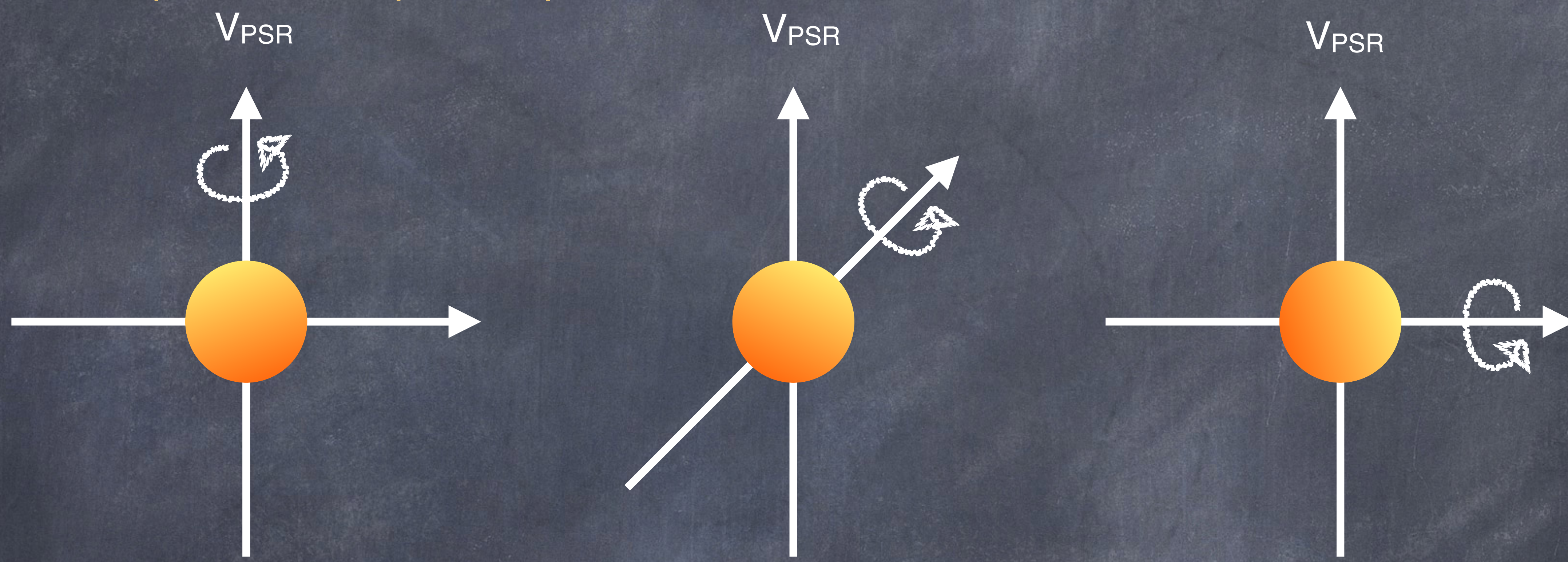
Bucciantini et al 2005

FORMATION OF BOW SHOCK, TS DEFORMATION, CYLINDRICAL TAIL WITH MILDLY RELATIVISTIC OUTFLOW IN THE TAIL

3D MHD MODELS OF BSPWNe

PARAMETERS OF THE PULSAR WIND

Inclination of the spin-axis and pulsar speed:



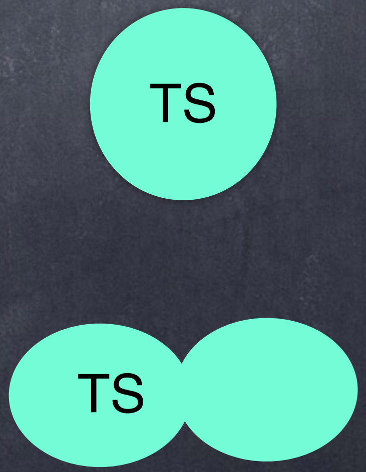
Spin-axis aligned with pulsar motion $\Phi_M=0°$

$\Phi_M=45°$

$\Phi_M=90°$

Anisotropy in the energy flux: $F(\psi) \propto 1 + \alpha \sin^2 \psi$

ψ colatitude from the spin-axis



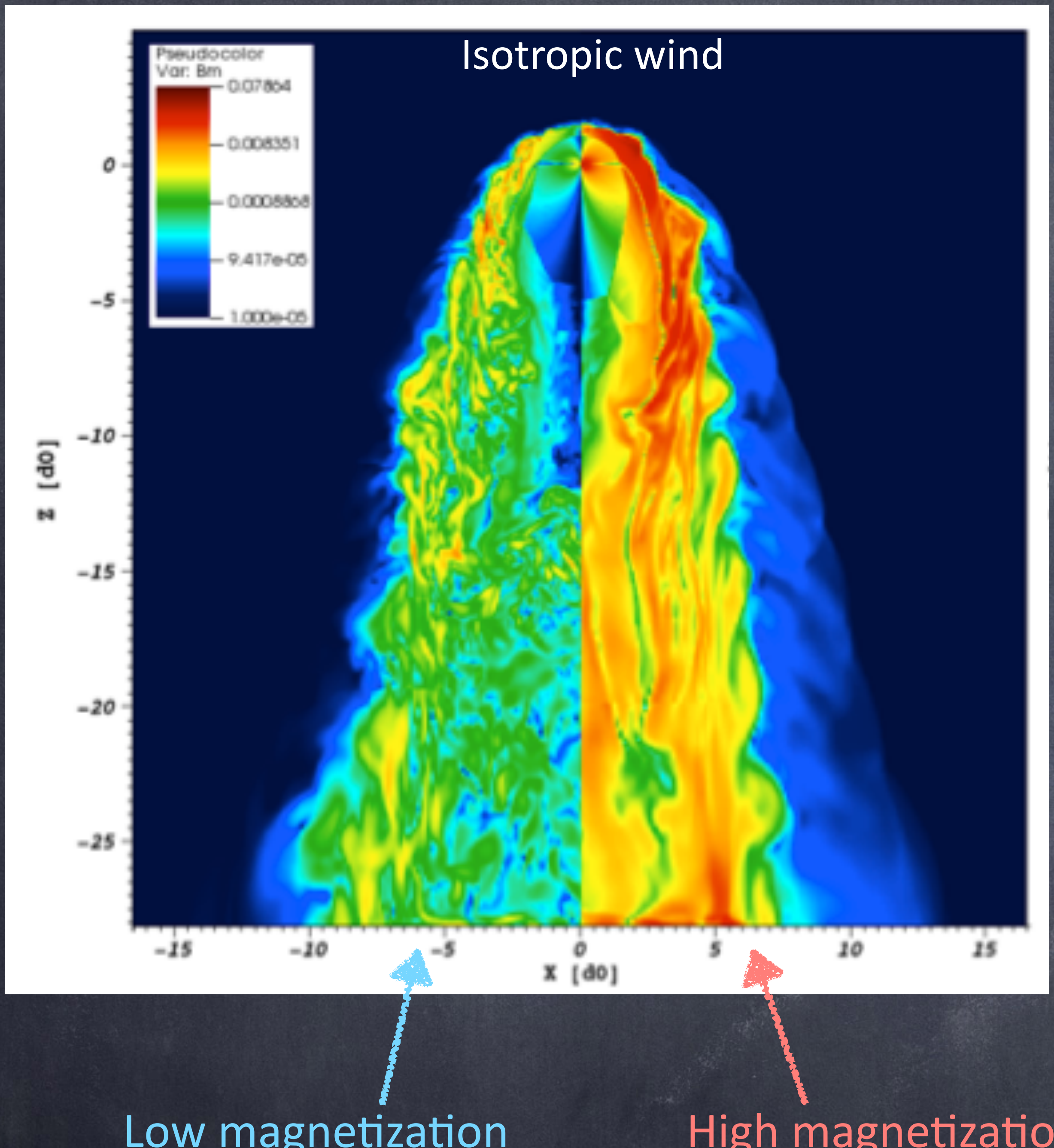
ISOTROPIC case ($\alpha=0$)

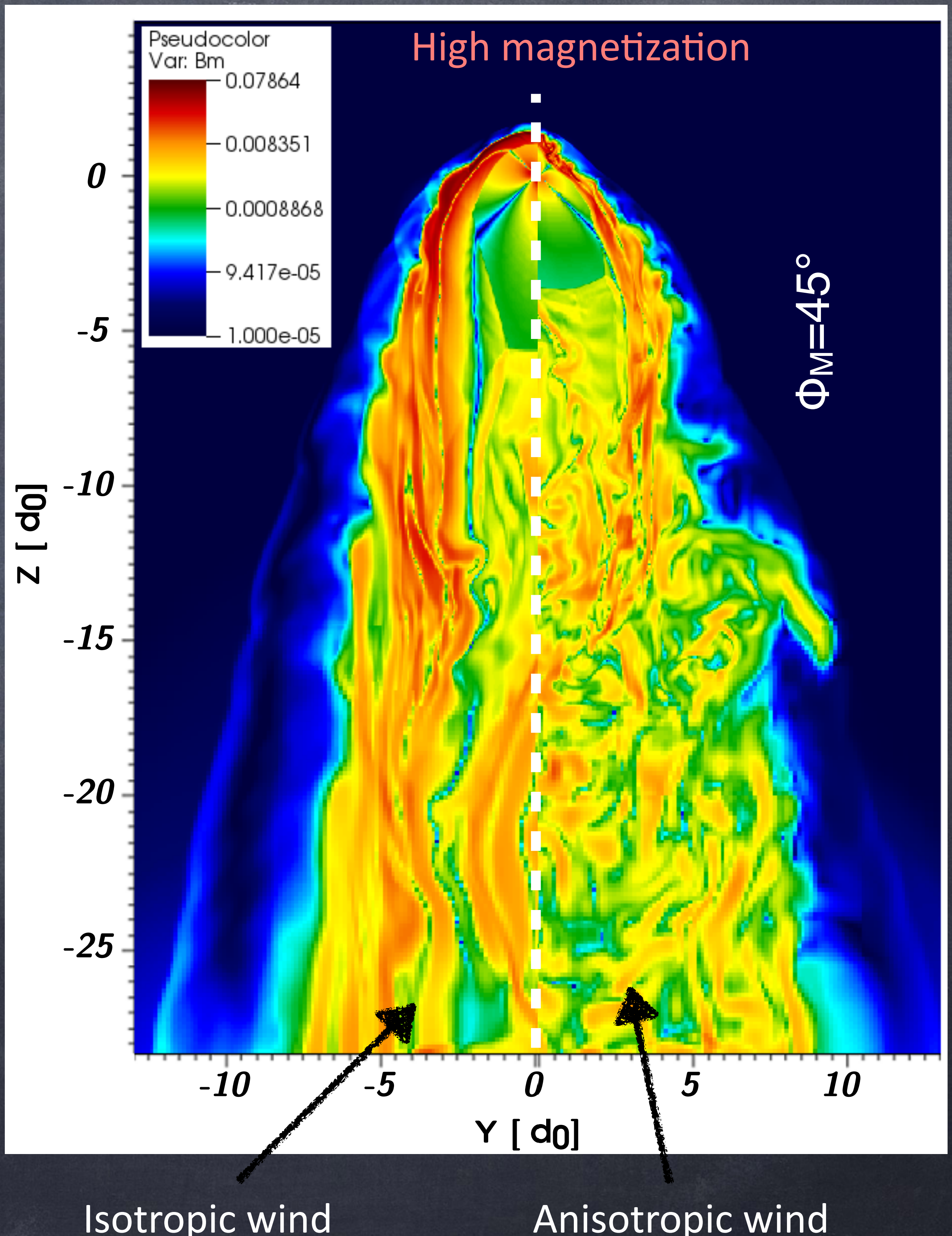
ANISOTROPIC case ($\alpha\neq0$)

Wind magnetization: $0.01 \lesssim \sigma \lesssim 1$

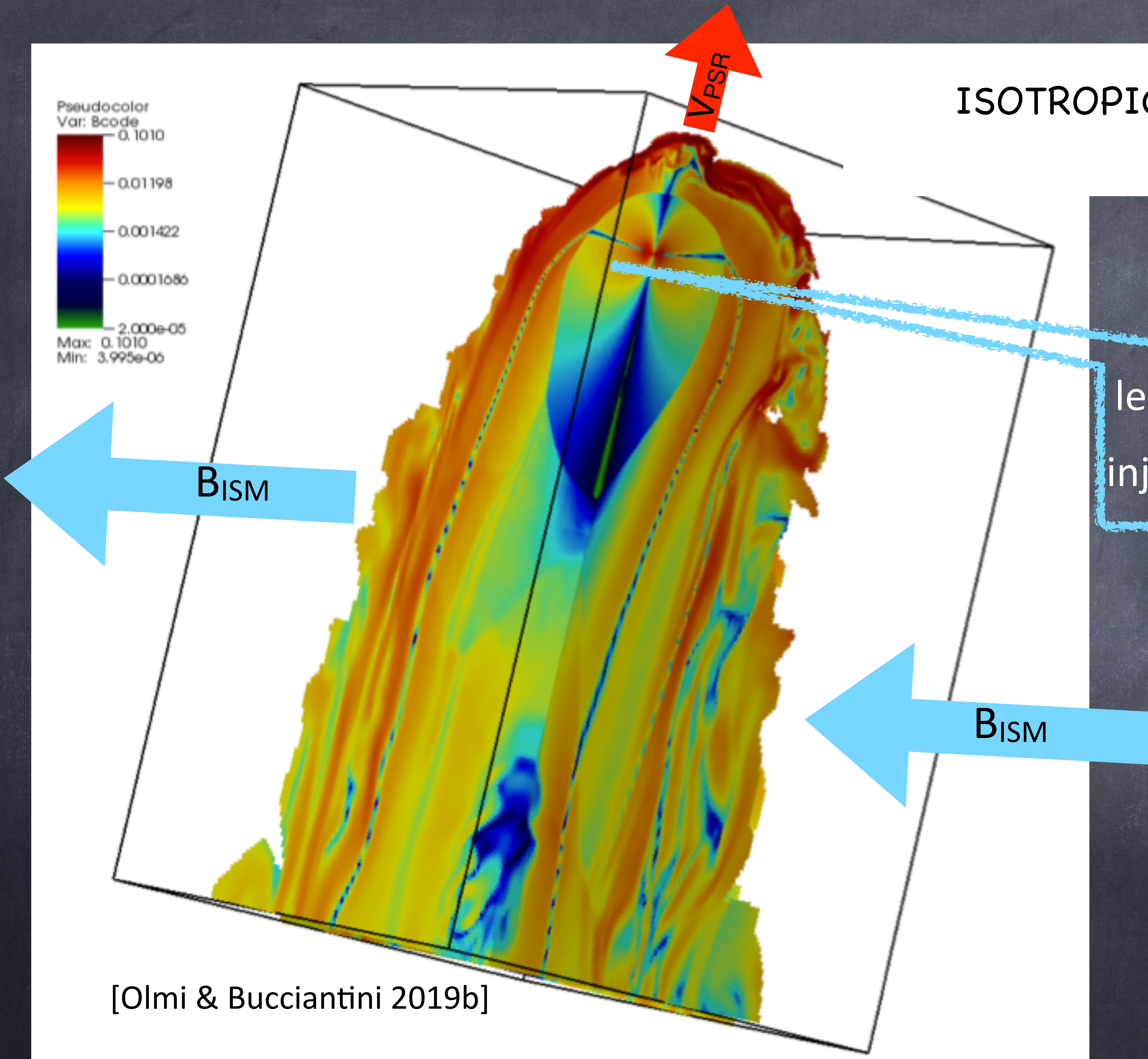
3D RMHD SIMULATIONS OF BSPWNe

[Olmi & Bucciantini 2019]





PARTICLE ESCAPE FROM BSPWN



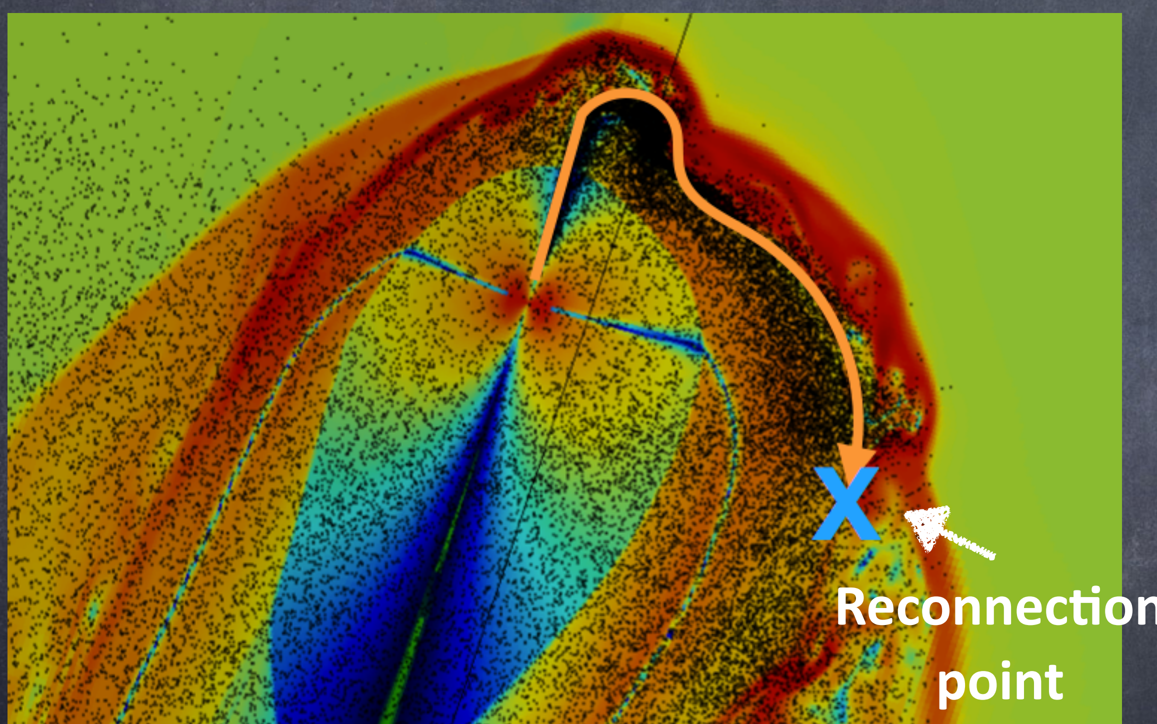
ISOTROPIC WIND MODEL
σ=1

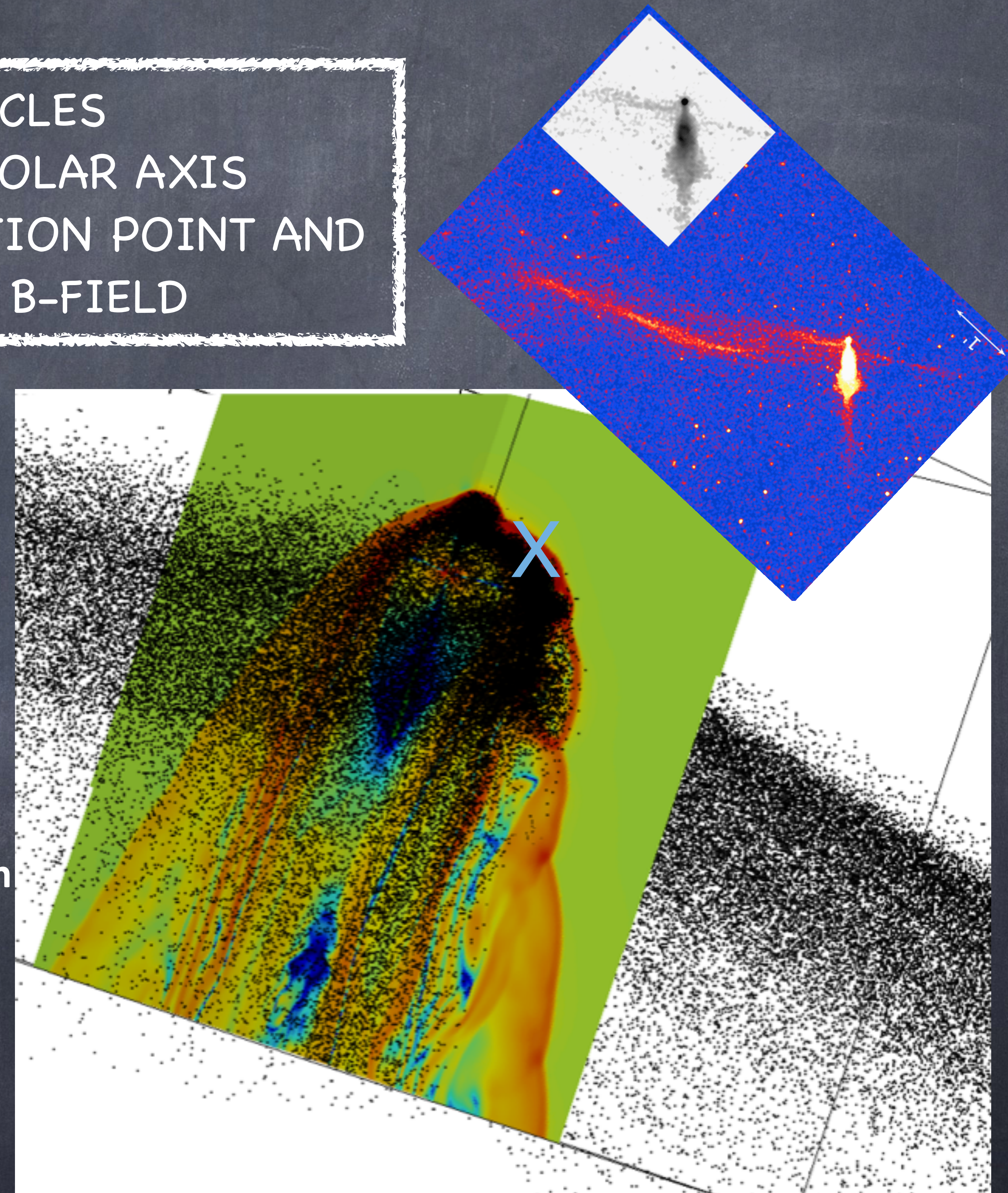
leptons with $\gamma=3\times10^7$ injected into the wind

[Olmi & Bucciantini 2019b]

PARTICLE ESCAPE FROM BOW SHOCK PWNe

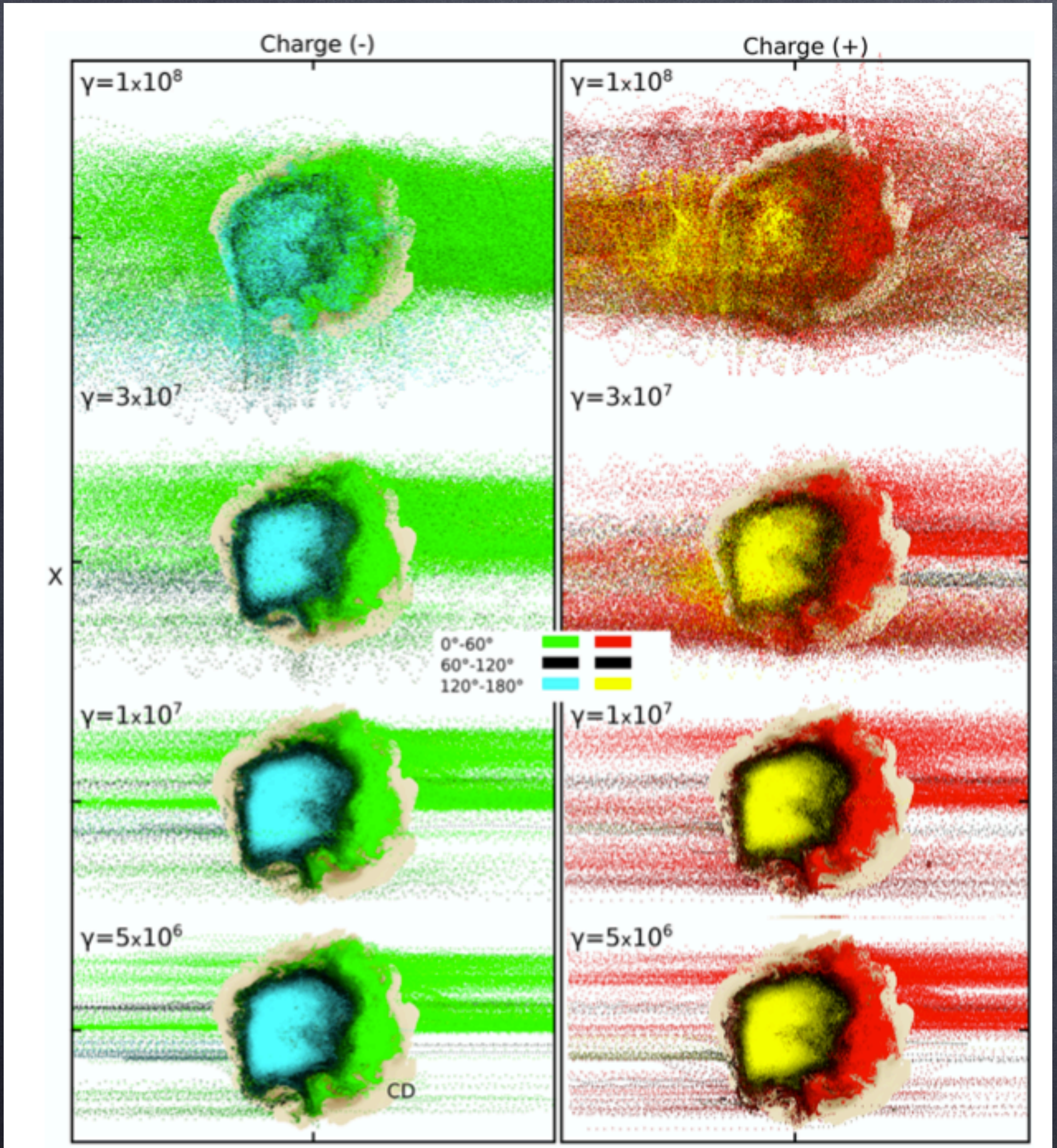
HIGH ENERGY PARTICLES
INJECTED CLOSE TO THE POLAR AXIS
STREAM OUT FROM RECONNECTION POINT AND
FORM JETS IN THE ISM B-FIELD





Olmi & Bucciantini 2019b

ENERGY DEPENDENCE OF THE ESCAPE



[Olmi & Bucciantini 2019b]

WITH INCREASING ENERGY:
- LARGER FRACTION OF PARTICLES
- MORE ISOTROPIC RELEASE

AT GeV ENERGIES:
- ESCAPE EXPECTED ONLY FROM THE TAIL
- NO GeV HALO EXPECTED!

NOTICE THAT:
- ENERGY DEPENDENT ESCAPE PROBABILITY MAKES HALO SPECTRUM NON TRIVIAL
- ESCAPE IS CHARGE SEPARATED!

SUMMARY AND CONCLUSIONS

- 3D MHD SIMULATIONS SEEM TO REQUIRE σ> A FEW IN ORDER TO REPRODUCE SPETRUM AND MORPHOLOGY
- FERMI MECHANISM PROBLEMATIC, THOUGH SHOCK CORRUGATION MIGHT HELP
- DRIVEN MAGNETIC RECONNECTION DIFFICULT TO MAKE SELF-CONSISTENT, BUT MAGNETIC RECONNECTION IN HIGH TURBULENT PLASMA…
- RADIO PARTICLES DO NOT NEED TO BE PART OF THE FLOW AND SPECTRUM CAN RESULT FROM ACCELERATION IN HIGH σ TURBULENCE [Comisso+ 2020]
- MULTIPLICITY CAN BE SMALL ENOUGH FOR ION CYCLOTRON… BUT ARE THERE SUFFICIENT IONS?
- CRAB IS A LEPTONIC PEVATRON, BUT IS IT ALSO A HADRONIC PEVATRON?
- EVOLVED SYSTEMS MAY ACCELERATE PARTICLES TO FULL POTENTIAL DROP AND THEY SEEM TO DO IT
- MOST LHAASO SOURCES COULD INDEED BE PWNe
- ISOTROPIC PARTICLE ESCAPE EFFICIENT ONLY AT THE HIGHEST ENERGIES
- ESCAPING PARTICLES CARRY ELECTRIC CURRENT…