PULSAR WIND NEBULAE: THE PRESENT STATUS AND FUTURE PROSPECTS

NICCOLO' BUCCIANTINI INAF ARCETRI - UNIV. FIRENZE - INFN

PWNE ARE HOT BUBBLES OF RELATIVISTIC PARTICLES AND MAGNETIC FIELD EMITTING NON-THERMAL RADIATION.

ORIGINATED BY THE INTERACTION OF THE ULTRA-RELATIVISTIC MAGNETISED PULSAR WIND WITH THE EXPANDING SNR (OR WITH THE ISM)

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

DEATH OF A MASSIVE STAR - THE BIRTH OF PULSAR

STAR MORE MASSIVE THAN 8 MSUN END THEIR LIFE IN SUPERNOVA EXPLOSION

STAR LESS MASSIVE THAN 25-30 MSUN LEAVE BEHIND A COMPACT STELLAR REMNANT IN THE FORM OF A NEUTRON STAR

THE COMBINATION OF STRONG MAGNETIC FIELD (1012G) AND RAPID ROTATION (P=0.001-1S) CRATE STRONG ELECTRIC FIELD AT THE SURFACE, EXTRACTION PAIRS AND PRODUCING PAIR CASCADES. OBSERVED AS PULSARS

CRAB SYNCHROTRON SPECTRUM broadband non-thermal spectrum, extending from radio to X-ray and TeV energies, and a high degree of linear and polarization. The Radio spectrum is well fitted by a power-law, and the same holds for the same holds for the s

The meet officient nebula peaks each nebula peaks in the Crab Nebula peaks in the range between 1014–1014–1014– **Example 20 and 20 an**

very close to the canonical value assuming equipartition and B ∼ 300 µG (Trimble 1968).

Figure 5.1: Left panel: images of the Crab Nebula in different bands. In optical the green filaments are a thermal

 $A \rightarrow 300$ $A \rightarrow 300$

Bucciantini - 11th Fermi Symposium - 2024 **4** from the Crab above frequencies of [∼]10²³ Hz is thought to be due to inverse Compton radiation These characteristics are common to the class of PWNe: a flat spectral index in the radio band, ⇠ 0 0*.*3 which

IC GAMMA SPECTRUM

IC GAMMA SPECTRUM

FINE STRUCTURES - A LAB FOR RELTIVISTICN FLUID DYNAMICS

REPRODUCING OBSERVATIONS

MAIN TORUS INNER RING (WISPS STRUCTURE) KNOT BACK SIDE OF THE INNER RING

EACH FEATURE TRACES AN EMITTING REGION

REPRODUCING OBSERVATIONS

REPRODUCING OBSERVATIONS

THE COMPLEXITY OF GOING 3D - STATE OF THE ART COMPUTATIONS

Bucciantini - 11th Fermi Symposium - 2024 **999** in Cartesian Gartesian geometry. We employ a cubic domain with edge length \sim

THE COMPLEXITY OF GOING 3D - STATE OF THE ART COMPUTATIONS

FERMI VS RECONNECTION

Maxwellian at low energies Evidence for non-thermal tail only for subluminal shock **FERMI DSA HIGHLY INEFFICIENT IN PSR WIND SHOCK - VERY LOW MAGNETISATION**

Bucciantini - 11th Fermi Symposium - 2024 **10** Since the positive feedback required for the onset of efficient $\mathbf{v} \cdot \mathbf{c}$ is the picture described above repermi Symposium - ZUZ4 $\sum_{i=1}^{n}$ particular, the fast and the fast and the fast and the $\sum_{i=1}^{n}$

POTENTIAL LIMITED ACCELERATION

$$
mc^2 \gamma_{max} = e \sqrt{\frac{L}{c}} = e \Phi_{psr}
$$

POTENTIAL LIMITED ACCELERATION

$$
mc^2 \gamma_{max} = e \sqrt{\frac{L}{c}} = e \Phi_{psr}
$$

ACCELERATION LIMIT AT THE TS

MAGNETISATION IN THE CRAB IS JUST BELOW EQUIPARTITION B ~ 150-120 UG

$$
\frac{L}{4\pi c R_{ts}^2} = \frac{1}{2} \frac{3Lt}{4\pi R_n^3}
$$

$$
\frac{L}{4\pi c R_{ts}^2} = P_{neb} = \frac{1}{\sigma} \frac{B_{ts}^2}{8\pi}
$$

$$
R_{ts} = \frac{1}{B_{ts}} \sqrt{\frac{\sigma L}{c}}
$$

$$
eB_{ts}
$$

 eB_{ts} *mc*2*γmax* $=R_L = R_{ts}$

$$
\frac{mc^2\gamma_{max}}{eB_{ts}} = R_L = R_{ts}
$$

$$
\frac{E_{max}}{eB_{ts}} = e\sqrt{\frac{\sigma L}{c}} = e\Phi_{psr}\sqrt{\sigma}
$$

LOSS LIMITED ACCELERATION

COMPARING GYRO-PERIOD WRT SYNCH COOLING TIME

$$
\tau_{gyr} = \frac{mc\gamma}{eB} \qquad \tau_{syn} = \frac{3m^3c^5}{2e^4B^2\gamma} \qquad \gamma_{max} \simeq 10^8 \frac{1}{\sqrt{B}}
$$

LOSS LIMITED ACCELERATION

COMPARING GYRO-PERIOD WRT SYNCH COOLING TIME

$$
\tau_{gyr} = \frac{mc\gamma}{eB} \qquad \tau_{syn} = \frac{3m^3c^5}{2e^4B^2\gamma} \qquad \gamma_{max} \simeq 10^8 \frac{1}{\sqrt{B}}
$$

MAXIMUM FREQUENCY IS FIXED

 $\nu_{syn,max} \simeq 150 MeV$

LOSS LIMITED ACCELERATION

COMPARING GYRO-PERIOD WRT SYNCH COOLING TIME

$$
\tau_{gyr} = \frac{mc\gamma}{eB} \qquad \tau_{syn} = \frac{3m^3c^5}{2e^4B^2\gamma} \qquad \gamma_{max} \simeq 10^8 \frac{1}{\sqrt{B}}
$$

MAXIMUM FREQUENCY IS FIXED

 $\nu_{syn,max} \simeq 150 MeV$

IN CRAB THE LIMITS ALL COINCIDE

OTHERS ALL POTENTIAL LIMITED

achievable by galactic accelerators, based on measurements of the cosmic ray spectrum at the Earth (see e.g., [53] for a recent review). Before discussing the most impressive surprises that came from gamma-rays and how they have impacted our understanding of the Crab nebula, we briefly review the physical picture of the nebular dynamics and emission properties that has been built through time, thanks to constant improvements in

Bucciantini - 11th Fermi Symposium - 2024 **12** shown with diverse symbols/colors—namely, green rectangles for HEGRA data $\mathcal{F}_{\mathcal{A}}$

B

PWNE AND LHAASO SOURCES

12 (NOW MORE) SOURCES DETECTED BY LHAASO ABOVE 100 TEV

Table 1 | UHE y-ray sources

PEV PROTONS OR ELECTRONS?

ALL SOURCES HAVE A PSR IN THE FIELD EXCEPT ONE

PWNE AND LHAASO SOURCES

12 (NOW MORE) SOURCES DETECTED BY LHAASO ABOVE 100 TEV

PSR WINDS ARE STRIPED AND THIS IMPLIES ALTERNATING FIELD POLARITIES IN THE PWN

PSR WINDS ARE STRIPED AND THIS IMPLIES ALTERNATING FIELD POLARITIES IN THE PWN

PSR WINDS ARE STRIPED AND THIS IMPLIES ALTERNATING FIELD THE ASTROPHYSICAL JOURNAL, 782:104 (15pp), 2014 POLARITIES IN THE PWN

TEARING INSTAB

PSR WINDS ARE STRIPED AND THIS IMPLIES ALTERNATING FIELD THE ASTROPHYSICAL JOURNAL, 782:104 (15pp), 2014 POLARITIES IN THE PWN

TEARING INSTAB

Bucciantini - 11th Fermi Symposium - 2024 **14 Figure 2.** Snapshots of the plasma density at *t*ω⁰ = 0 (top left)*,* 132 (top right)*,* 265 (bottom left), and 353 (bottom right) of the 2D simulation 2DXY0 in the *xy*-plane (with no guide) and a simulation, a simulation, this simulation, the development of the tearing instability for
Simulation, the development of the tearing instability forms multiplees multiplees instability forms multiple (γ 2(1*/*N)*d*N*/d*γ , top) and synchrotron radiation spectral energy distribution normalized by the total (frequency-integrated) photon flux ((1*/F*)ν*F*^ν , bottom)

~4 TIME OVER QUIESCENT

Fig. S2 – Top panel: The AGILE gamma-ray light curve (1-day binning) of the Crab Pulsar/nebula a during the period $2007-08-28 - 2007-10-27$ with the satellite in pointing mode. Bottom panel: same a light curve but for the nearby Geminga pulsar. Dashed lines and shadowed bands indicate the Crab avera 3σ uncertainty range.

~4 TIME OVER QUIESCENT

Fig. S2 – Top panel: The AGILE gamma-ray light curve (1-day binning) of the Crab Pulsar/nebula a during the period $2007-08-28 - 2007-10-27$ with the satellite in pointing mode. Bottom panel: same a light curve but for the nearby Geminga pulsar. Dashed lines and shadowed bands indicate the Crab avera 3σ uncertainty range.

~4 TIME OVER QUIESCENT

Fig. S2 – Top panel: The AGILE gamma-ray light curve (1-day binning) of the Crab Pulsar/nebula a during the period 2007-08-28 – 2007-10-27 with the satellite in pointing mode. Bottom panel: same a
⁸ light cuⁿve but for the nearby Geminga pulsar. Dashed lines and shadowed bands indicate the Crab avera light curve bands are neare-the near-bandsing pulsar. Dashed lines and shadowed bands indicate the Crab avera 3σ uncertainty range

~4 TIME OVER QUIESCENT

NO CHANGE IN PSR

Bucciantini - 11th Fermi Symposium - 2024 **111 accumulated in the energy value 0.5-10 kev**. Nev. Nev. 1 **Fig. 35** Fig. State (WT) accumulated in the energy band 0.5-10 keV. Red $\sqrt{2.027}$ (10-15 23:59 UT, exposure: 4485 s). Green line: reference 5 light curve accumulated in September 2009 (T_{start} 2009-09-17 13:26 UT, exposure: 6284 s). Blue line: light curve

accumulated during α and α and α 2010-09-22 16:40 UT to 2010-09-22 07:40 UT (10:40)

25 TIMES ABOVE QUIESCENT

FLARE IS STRUCTURED

FLARE DURATION DAYS-WEEK

25 TIMES ABOVE QUIESCENT

FLARE IS STRUCTURED

FLARE DURATION DAYS-WEEK

ranges, algorithm to determine the algorithm to determine the douoptimal partition is described by Jackson et al.

original light curve *C>d/ndj* 257/232}. This implies that flux variations with the each BB cannot be each be cannot be each cannot be each control of uneven distinguished with confidence from a locally con-**LOCATION - KNOT?**

stant flux. The shortest BBs are detected at the

Bucciantini - 11th Fermi Symposium - 2024 **16** \ldots red, obtained for a one-day integration (MJD \ldots); \ldots

SPECTRAL EVOLUTION Compton component of the nebula. It can be clearly seen that a new spectral component emerges from the synchrotron nebula during the flare, moving into the *Fermi* energy range as the flare evolves. Its flux reaches a maximum between MJD 55666.997

and 55667.366 (frame 7); during this period the peak in the SED

best-fit spectral indices are given in the text. Dotted black lines indicate the ±1σ, +2σ, and +3σ confidence intervals derived from white noise simulations

(A color version of this figure is available in the online journal.)

SPECTRAL EVOLUTION Compton component of the nebula. It can be clearly seen that a new spectral component emerges from the synchrotron nebula during the flare, moving into the *Fermi* energy range as the flare evolves a maximum between M

and 55667.366 (frame 7); during this period the peak in the SED

during the first 33 months of observation. The spectral index of

$t_{\rm{max}}$ of the flux of the average synchrotron nebula summed to the latter. The solid black lines show the best fit of a model consisting of a model consisting of a model consisting of a model consisting of a model cons constant plus an exponential function at the rise of both sub-flares (see the text). The blue vertical lines indicate the intervals of each Bayesian Block during which the flux remains constant windows are enumerated at the top of the panel. The corresponding flux is shown by the panel. The panel of the panel. The corresponding flux is shown by the blue marker marker marker marker marker mar below each number. The SED for each of the time windows is shown in Figure 6. 2 part of the *Fermi* Science Tools. Λ is the background synchrotron nebula synchrotron nebula synchrotron nebula synchrotron nebula synchrotron nebula during the flare period are *FS* ⁼ (5.4 [±] 5.2) 10−⁷ cm−² ^s−¹ **CUTOFF ENERGY IS HIGHER AT PEAK**and γ*^S* = 3.9 ± 1.3, consistent with the average value measured

best-fit spectral indices are given in the text. Dotted black lines indicate the ±1σ, +2σ, and +3σ confidence intervals derived from white noise simulations

(A color version of this figure is available in the online journal.)

SPECTRAL EVOLUTION Compton component of the nebula. It can be clearly seen that a new spectral component emerges from the synchrotron nebula during the flare, moving into the *Fermi* energy range as the flare evolves. Its flux reaches a maximum between MJD 55666.997 MJD 55666.997 MJD 55666.997 MJD 55666.997 MJD 55666

best-fit spectral indices are given in the text. Dotted black lines indicate the ±1σ, +2σ, and +3σ confidence intervals derived from white noise simulations

(A color version of this figure is available in the online journal.)

Bucciantini - 11th Fermi Symposium - 2024 **17** It is thus of interest to check the status of the knot during the is scaled from flux assuming isotropic emission at 2 kpc. The *Fermi*-LAT data for the 2011 April flare component appear in dark blue (Buehler et al. 2012).

GAMMA-RAY VARIABILITY

VARIABILITY PRESENT ALSO FOR QUIESCENT EMISSION IN THE FORM OF MONTH-LONG MODULATION

LIKELY ORIGINATING IN THE VARIABILITY OF THE WISPS KNOT REGION

Bucciantini - 11th Fermi Symposium - 2024 **18** above 100 l\leV from the Crab as a function of for the first 35 months of *Fermi*

TWINKING

IMPOSSIBLE TO GET ACCELERATION AND EMISSION FROM THE SAME REGION IN A NAIVE DSA APPROACH

DECOUPLE EMISSION FROM ACCELERATION

INTRODUCE REGIONS OF VERY HIGH MAGNETIC FIELD THAT ARE RESPONSIBLE FOR RADIATION Figure 1. Light curves of synchrotron emission at 5 keV (dotdash line), 500 MeV (dotted line), 1 GeV (dotted line), 1 GeV (dotted line), 1 GeV (dotted line) and 2 GeV (d GeV (short-dash line) as a response to an imposed fluctuation light curves are normalized to maximal intensity. The background magnetic field in the emission \mathbf{R} region \mathbf{S} region \mathbf{R} as a stochastic as a stochastic as a stochastic model as a st gaussian field of the imposed fluctuation field fluctuation in the imposed fluctuation of the imposed fluctuation

FLARE PROPERTIES DEPENDS ON THE MAGNETIC FIELD IN THESE REGIONS $\overline{}$ $\overline{\$ provides the photon variability times in the photon $\mathbf n$ in the photon value of about 105 s in the set of about 10

 \blacksquare \sim rf \sim 1 mg is at comparation of B(t) $=$ 1 mg is at ct/ \sim

In this work we consider the case when the formation

TWINKING

IMPOSSIBLE TO GET ACCELERATION AND EMISSION FROM THE SAME REGION IN A NAIVE DSA APPROACH

DECOUPLE EMISSION FROM ACCELERATION

INTRODUCE REGIONS OF VERY HIGH MAGNETIC FIELD THAT ARE RESPONSIBLE FOR RADIATION Figure 1. Light curves of synchrotron emission at 5 keV (dot-GeV (short-dash line) as a response to an imposed fluctuation light curves are normalized to maximal intensity. The background magnetic field in the emission \mathbf{R} region \mathbf{S} region \mathbf{R} as a stochastic as a stochastic as a stochastic model as a st gaussian field of the imposed fluctuation field fluctuation in the imposed fluctuation of the imposed fluctuation

FLARE PROPERTIES DEPENDS ON THE MAGNETIC FIELD IN THESE REGIONS $\overline{}$ $\overline{\$ provides the photon variability times in the photon $\mathbf n$ in the photon value of about 105 s in the set of about 10

 \blacksquare \sim rf \sim 1 mg is at comparation of B(t) $=$ 1 mg is at ct/ \sim

In this work we consider the case when the formation

Figure 2. Normalized specifically regions different time moments controlled the moments controlled the original line of \sim **line), which model the quiescent and flags and flags and flags spectra, respectively. The contract of the con** (see Fig. 1). The dotted curve shows the contribution of the vari-**FIELD UP TO MILLI-G** able magnetic field. The power emitted in the power emitted in the GeV flare is about the GeV flare is about t

REQUIRE EMISSION TO COME TO \overline{a} the stochastic magnetic magnetic field, the source of the **This regions very close to the TS**

tions rather than the electron acceleration/losses timescales.

Fast temporal variations will appear even for a quasi-steady

JETLETS ^ρ(δ) d^δ ⁼ ¹ β%δ² ^dδ*,* (14)

effectively mono-energetic and (ii) significant emission beyond this **limit implies that the emitting region is moving along the line of the line o** sight at relativistic speeds. Observations of the 2011 April flare suggests of the 2011 April flare suggests o **Example 12 ARISING FROM RECONNECTION LED** $\overline{}$ for $\overline{}$ for $\overline{}$ suggests a pile-up observed SED suggests a pile-up of $\overline{}$ distribution that is not yet effectively monomental monomental \blacksquare **TO BEAMED PARTICLES THAT GIVES** \blacksquare \blacksquare as Buehler et al. (2012) point of an are not an out and we confirm, the notation of \blacksquare **FLARE DUE TO DOPPLER BOOSTING**

range of the SED goes as *^F*" [∝] "¹*/*3. Such a power law could extend

down to γ min ∠ min ∠ 10−5γ rad before the flare was comparable to the flare was comparable to the flare wa Crab nebula flux in one *Chandra* resolution element. Hence, with a

^γ min as low as [∼]104, it is possible to explain the non-detection of

can lead to the formation of a pile-up electron distribution that is

produce **produce and all 2000**). Instead, we suggest that the instead, we suggest that the instead, we suggest observations are consistent with harder distributions (*p* " 1) found in many magnetic reconnection models³ (Romanova & Lovelace

JETLETS ^ρ(δ) d^δ ⁼ ¹ type flares' represent flares' represent flares with increases of ∠ 30 over the nebula average of ∠ 30 over th as found in Buehler et al. (2012). '2010 September' flares representation of the september of the september of

range of the SED goes as *^F*" [∝] "¹*/*3. Such a power law could extend

down to γ min ∠ min ∠ 10−5γ rad before the flare was comparable to the flare was comparable to the flare wa Crab nebula flux in one *Chandra* resolution element. Hence, with a

INTERMITTENCY

IN TURBULENCE INTERMITTENCY MANIFESTS AS HIGHER TAILS AT SMALL SCALE ON THE PDE

Bucciantini - 11th Fermi Symposium - 2024 **21**

INTERMITTENCY (nello stesso verso del campo magnetico principale).

IN TURBULENCE INTERMITTENCY MANIFESTS AS HIGHER TAILS AT SMALL SCALE ON THE PDE

INTERMITTENCY (nello stesso verso del campo magnetico principale).

IN TURBULENCE INTERMITTENCY MANIFESTS AS HIGHER TAILS AT SMALL SCALE ON THE PDE

INTERMITTENCY (nello stesso verso del campo magnetico principale).

IN TURBULENCE INTERMITTENCY MANIFESTS AS HIGHER TAILS AT SMALL SCALE ON THE PDE

Figura 7.17: *[|]V*[~] *[|]*, *^t* = 12*.*5. La velocità è lievemente più alta nel *run* B. **NOT CLEAR IF STATISTICS OF INTERMITTENCY COMPATIBLE WITH MILL-G FIELD**

OLDER SYSTEMS SHOW A DISPLACEMENT OF THE TEV GAMMA EMISSION FROM THE PULSAR: REVERBERATION, BOW-SHOCK

BOW SHOCK PWNE

MOST PULSARS KICK VELOCITY IS SUPERSONIC IN ISM

FORWARD SHOCK VISIBLE IN HΑ PWN VISIBLE AS A RADIO AND X-RAYS TAIL

PAIR ESCAPE

rather deep into the V_{max} factor into the bound of the bound of the bound of the bound of the bow shock in the bound of the bow shock in the bow sho The are BS PWNe where the X-ray **"tail" is** $\,$ These so-called "misaligned outflows" are sometimes inwhere it should not helo cannot be jets. However, they can where it should not be! **where it should not be!**

2 *Barkov et al.*

 $t \rightarrow 0$ and $t \rightarrow 1$ and B p ues in unese teatures are \sim r5R $^{-1}$ The particles in these features are \sim PSR $\,$ To stress this dividend we will refer to the second will refer to the second will refer to the second will ref missaligned outflows as "kinetic jets". As we demonstrate in the "kinetic jets". As we demonstrate in the "kine 4 *Barkov et al.*

Guitar Nebula^{*} Guitar (Wong et al 2003)

B0355-54, Chattering et al. 2004) up to vertice et al. 2004, currence et al. 2004, currence TeV halo suggest strong inferred from the measurements of (or an upper limits on) *r^s* for PSR J1101–6101 (see Eq. 1), and inferred from proper motion measurements in ferred from proper motion measurements in \sim 0.11111510 **diffusion**

PAIR ESCAPE IN MHD MODELS

Exercis 11th Fermi Symposium - 2024 25 20% right of the international features in the text are in the text are in the text are in

2 *B. Olmi* & *N. Bucciantini*

IXPE - X-RAY POLARIMETRY - CRAB

Bucciantini et al 2023

IXPE - X-RAY POLARIMETRY - VELA

independent.

Fei et al 2023

Polarization degree and polarization angle measured using *ixpeobssim*. Uncertainties on the polarization degree and angle are calculated for a 68.3% confidence level, assuming that they are

The row number where \mathbf{V} **The column very high PF suggest no turbulence in** The polarization degree (%) with 68.3% confidence level error. The polarization angel (°) with 68.3% confidence level error. the PWNe

Unlikely reconnection to play a major role in accelerating particles and old sytems should be more turbulent.

IXPE - X-RAY POLARIMETRY - CRAB PSR

15% PF in the core of **P1**

Bucciantini et al 2023

Only models with emission coming from the current sheet in the wind survive

IXPE - X-RAY POLARIMETRY - CRAB PSR

5- sigma detection in the core of P1

15% PF in the core of **P1**

Bucciantini et al 2023

Only models with emission coming from the current sheet in the wind survive

CURRENT CANONICAL PICTURE WELL ESTABLISHED

CURRENT CANONICAL PICTURE WELL ESTABLISHED

PWNE WILL BE MAIN SOURCE OF GAMMA RAY SKY

LIKELY TO DOMINATE THE PEVATRONS

PSR/PWN PROBABLY THE MAIN ANTIMATTER FACTORIES

CURRENT CANONICAL PICTURE WELL ESTABLISHED

PWNE WILL BE MAIN SOURCE OF GAMMA RAY SKY

LIKELY TO DOMINATE THE PEVATRONS

PSR/PWN PROBABLY THE MAIN ANTIMATTER FACTORIES

NO CLEAR IDENTIFICATION FOR THE ACCELERATION MECHANISM

NO CLEAR INDICATION FOR THE ORIGIN OF THE OBSERVED DIVERSITY

CURRENT CANONICAL PICTURE WELL ESTABLISHED

PWNE WILL BE MAIN SOURCE OF GAMMA RAY SKY

LIKELY TO DOMINATE THE PEVATRONS

PSR/PWN PROBABLY THE MAIN ANTIMATTER FACTORIES

NO CLEAR IDENTIFICATION FOR THE ACCELERATION MECHANISM

NO CLEAR INDICATION FOR THE ORIGIN OF THE OBSERVED DIVERSITY

NONE OF EXISTING MODEL FOR FLARING FULLY SATISFACTORY

RECONNECTION LIKELY TO BE OPERATIVE BUT NOT CLEAR IF M-G FIELD IS THERE

CURRENT CANONICAL PICTURE WELL ESTABLISHED

PWNE WILL BE MAIN SOURCE OF GAMMA RAY SKY

LIKELY TO DOMINATE THE PEVATRONS

PSR/PWN PROBABLY THE MAIN ANTIMATTER FACTORIES

NO CLEAR IDENTIFICATION FOR THE ACCELERATION MECHANISM

NO CLEAR INDICATION FOR THE ORIGIN OF THE OBSERVED DIVERSITY

NONE OF EXISTING MODEL FOR FLARING FULLY SATISFACTORY

RECONNECTION LIKELY TO BE OPERATIVE BUT NOT CLEAR IF M-G FIELD IS THERE

POLARISATION IN GENERAL IN LINE WITH EXPECTATION

HIGH PD SUGGEST MINOR TURBULENCE IN THE PWNE

NONE OF CURRENT PSR MODEL SEEMS TO WORK