

## Contents

References:

### Structure of the magnetar

Because magnetic flux converges in the lower hemisphere and diverges in the upper one in the split-monopole solution, a current sheet must lie in the equatorial plane (see Figures 7, 8). This sheet closes the longitudinal electric currents elsewhere in the magnetosphere. This structure of the magnetic field and current sheet has been confirmed numerically (Contopoulos et al. 1999; Ogura & Kojima 2003; Gruzinov 2005; Física de plasmas bajo campos ultra fuertes ( $>44$  terragauss), incluyendo magnetosferas de magnetar, reconexión magnética ultrasónica, procesos MHD y cinética relativista/QED

### References;

Komissarov 2006; McKinney 2006; Timokhin 2006). Using Eqn. (14), one easily finds that the Poynting vector  $S = (c^4/E)B$  is:  $S(\theta) = B_0^2 c^4 R^2 \sin^2 \theta$  (15)

This implies that the energy flux is concentrated near the equatorial plane. This-dependence of the energy flux. On the other hand, at large distances  $r \gg RL$ , Ingraham (1973) and Michel (1974) found another asymptotically radial solution, with  $E(\theta) = B(\theta)$ , resulting in a radial Poynting vector with arbitrary-dependence.

Example: In all of these solutions, the relation  $S(\theta) \propto B^2 r \sin^2 \theta$  (16) is valid. Bogovalov (1999) generalized the split-monopole model, showing that in the force-free approximation the “inclined split monopole field” is a solution of the problem as well. In this solution,  $B = E = B_0 R \sin \theta$  and  $B_p = B_0(Rr)^{1/2} \sin \theta$ , where  $\theta = \sin^{-1} \sin \theta \sin(\Omega r \sin \theta \sin t + \Omega c) + \cos \theta \cos(\Omega r \sin \theta \sin t + \Omega c)$ . In this case, within the cones  $\theta < \pi/2$ , (17)  $\theta < \pi/2$  around the rotation axes, the electromagnetic field is not time dependent; whereas in the equatorial region, the electromagnetic fields change the sign at the instant  $t = 0$ . In other words, the condition  $\theta = 0$  defines the location of the current sheet. We stress that the expression (18) for the shape of the current sheet remains true for the other radial asymptotic solutions, with  $E(\theta) = B(\theta)$  but arbitrary-dependence.

### Artículo científico como base centrado en magnetar y en campos magnéticos extremos

Magnetars: the physics behind observations de Roberto Turolla, Silvia Zane & Anna Watts

Este es un artículo extenso tipo revisión (más que un libro),

Estructura de magnetar, campos magnéticos  $\sim 10^{13}$ – $10^{15}$  G, evolución magnética, emisiones X/gamma, oscilaciones, etc. Explica modelos teóricos y procesos físicos que combinan gravedad cuántica, QED y dinámica del interior de la estrella. Procesos: Evolución magnética y conexión con pulsars.

### Introduction to Black Hole Physics de Valeri P. Frolov & Andrei Zelnikov

Se trata del texto que ya mencionas: cubre geometría de Riemann, soluciones de Schwarzschild y Kerr, curvaturas, ecuaciones de Einstein y métricas de la curvatura de las piezas del puzzle de los agujeros negros.

## Puntos de Propulsor híbrido

1. La estructura y composición, incluyendo la posible aparición de materia exótica (quarks, hiperones) en estrellas de neutrones altamente densas.
2. En un posible () confinado de la magnetosfera dentro del cilindro de luz, sin líneas abiertas, basada en una ecuación pulsar
3. Tubos o circuitos con un dipolo rotativo, incluye distribución de líneas de campo abierto/cerrado, geometría de corriente, hojas de corriente (current sheets) y cierre del circuito magnético esférico:
4. Tubo principal de confinamiento de plasma (como un VASIMR, pero alimentado por energía de fusión).
5. Sólo la estructura: Circuitos cuánticos superpuestos como líneas de control alrededor del motor, indicando que son controladores de campos magnéticos cuánticos.
6. Estructura de soporte con materiales avanzados (grafeno, cerámicos).
7. freno electromagnético y el acoplamiento magnético interno

Magnetosfera: Los electrones y positrones se aceleran en ellas hasta factores Lorentz de  $\sim 10^3$ , lo que permite emisiones tipo Cherenkov coherentes con geometría cónica estrecha con algunos ángulos reducidos respecto al eje magnético con efectos de relatividad general y estructura de gravedad local.

Secciones:

Sección sobre campos magnéticos y geometría: incluye la descripción del dipolo rotante oblicuo y cómo evoluciona el ángulo inclinado entre ejes.

Sub-sección de hojas de corriente y emisión: extrae las ecuaciones para espesor del sheet, perfil de densidad y ángulo de emisión desde la geometría de los current sheets.

Integración con modelos métricos y de curvatura: vincula estas geometrías magnetosferas con las métricas de espacio-tiempo cercanas, como las que exploran Frolov y MTW, para comparar cómo cambia la curvatura junto al campo magnético. El cómo construir un circuito cuántico por definición ultra resistente y meter dentro o fusionar esto: Sección sobre campos magnéticos y geometría: incluye la descripción del dipolo rotante oblicuo y cómo evoluciona el ángulo inclinado entre ejes. Sub-sección de hojas de corriente y emisión: extrae las ecuaciones para espesor del sheet, perfil de densidad y ángulo de emisión desde la geometría de los current sheets. Integración con modelos métricos y de curvatura: vincula estas geometrías magnetosferas con las métricas de espacio-tiempo cercanas, como las que exploran Frolov y MTW, para comparar cómo cambia la curvatura junto al campo magnético.

El proceso de construcción de cómo los campos magnéticos de una estrella o posible planeta puedan servir de base para crear o diseñar un objeto que se propulse pero con los materiales de la tierra no se si es posible que lo pueda diseñar por componentes.



Geometría de campos magnéticos de pulsares, magnetares y métricas gravitatorias de los agujeros negros para crear o construir un modelo de circuito cuántico ultra resistente como una estructura de ingeniería con bases teóricas y de software.

Magnetohydrodynamic Models: (Def) As was already stressed, recently numerical simulations have become possible that can simulate the structure of plasma-filled magnetospheres from first principles.

dipolo oblicuo rotante con hojas de corriente ecuatoriales y polares o modelo para un "motor cuántico magnético" que guía las partículas ya cargadas.

Contopoulos et al. (1999) found an iterative way to do this and obtained the first solution for an aligned force free pulsar magnetosphere that extended out to infinity (see Figure 8). Their results were subsequently verified by other groups within force-free and magnetohydrodynamic (MHD) approximations (e.g., Gruzinov 2005; Timokhin 2006; McKinney 2006; Komissarov 2006;

Parfrey et al. 2012; Ruiz et al. 2014) as well as using particle-in-cell (PIC) approach (Philippov & Spitkovsky 2014; Chen & Beloborodov 2014; Cerutti et al. 2014; Belyaev 2014). Spitkovsky (2006) carried out the first 3D, oblique pulsar magnetosphere simulations.

Using the force-free approximation, he found that pulsar spindown luminosity increases with increasing obliquity angle,  $\theta$ , which is the angle between the rotational and magnetic axes. The spindown obtained in such force-free and MHD models is well-described by

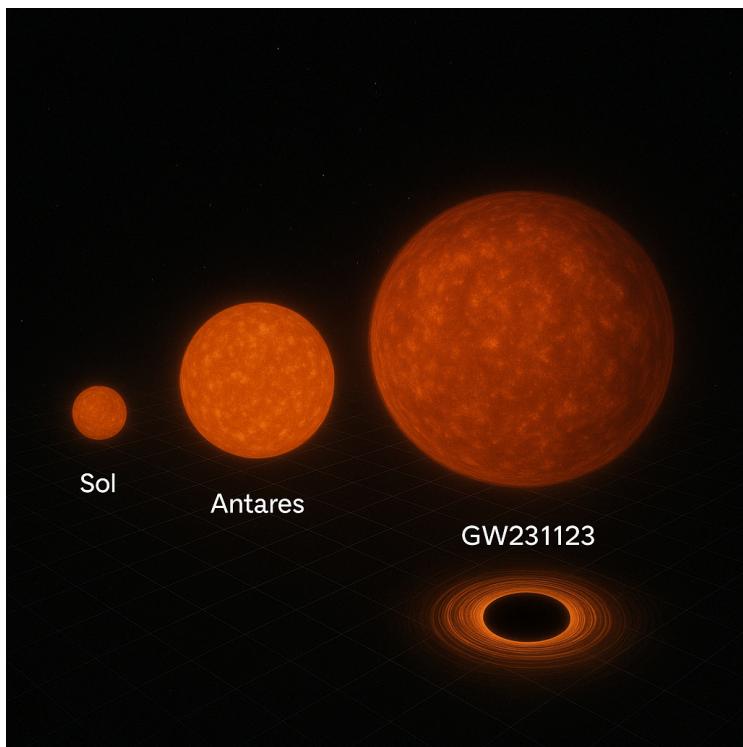
$$W_{tot} = W_{aligned}(1 + \sin^2 \theta)$$
 (19) where  $W_{aligned} = m^2 / 4 c_3$  is the spindown luminosity of an aligned plasma-filled pulsar magnetosphere, and  $m = B_0 R^3 / 2$  is the magnetic dipole moment of the pulsar and time-dependent 3D force-free.

$\omega_p / \omega_p$  es la frecuencia de plasma y métricas del libro de Valeri Frolov que tienen métricas de tipo Kerr o Schwarzschild modificadas para estudiar cómo la curvatura afecta al confinamiento de campos. En física de estructura y material tenemos que se establece:

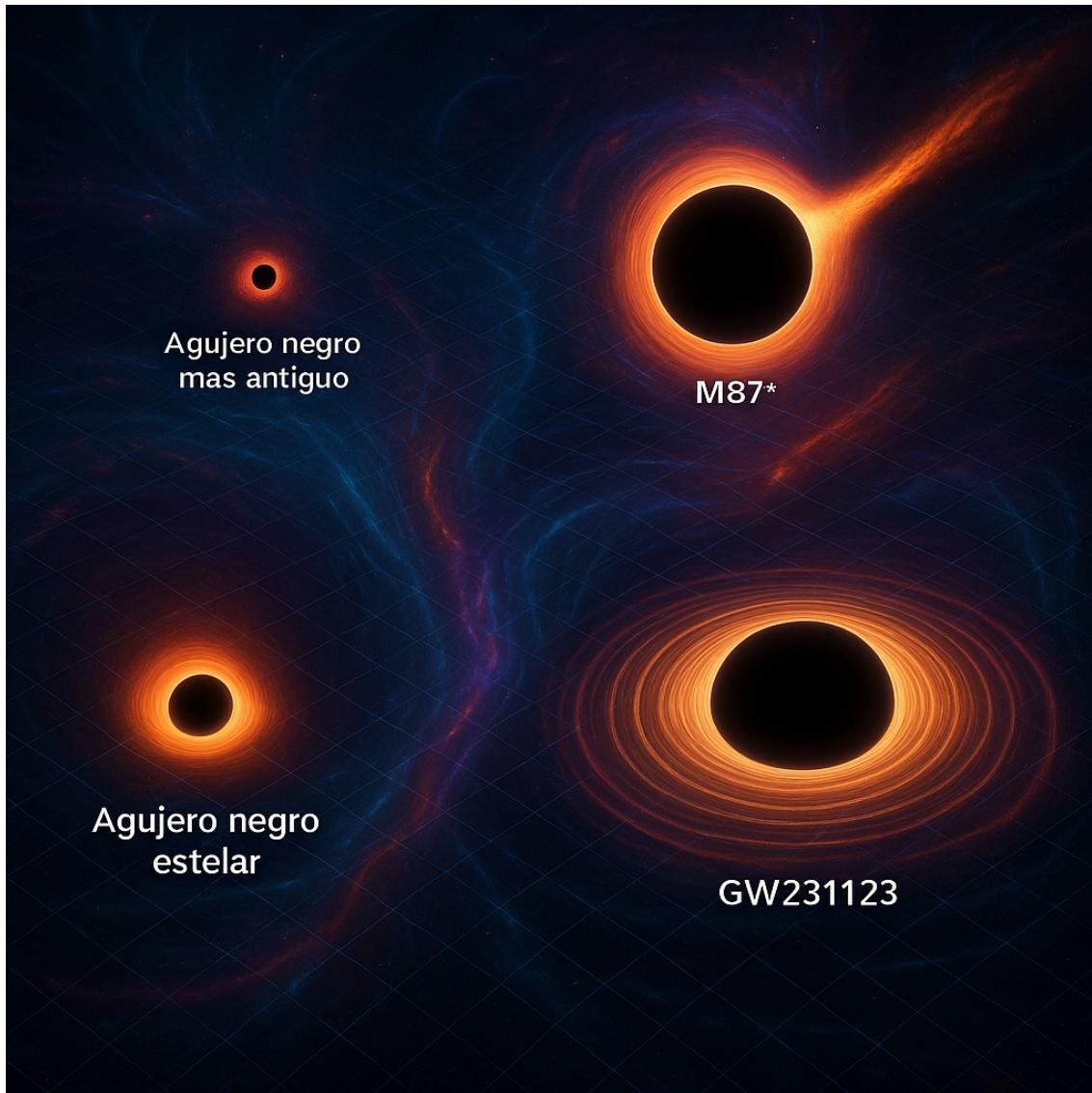
1. Núcleo magnético
2. Campo dipolar pulsar
3. Bobinas superconductoras ( $NbTi$ ,  $Nb_3Sn$ , YBCO)

## *Circuitos superconductores planos (Josephson junctions) simulando distribución de corriente*

1. Geometría  
a curva
2. Métrica de  
agujeros negros
3. Guías de onda curvas o cavidades resonantes  
cuánticas
4. Cámaras de confinamiento tipo stellarator a escala  
pequeña



- Ejemplo: campos magnéticos para confinar y acelerar plasma de hidrógeno.
- La región de ionización (RF)
- magnética (espiral forzada tipo dipolo)
- escape del plasma por tobera magnética(Motor o similar)
- Estrella fría (enana marrón)
- Campo magnético fuerte sin calor excesivo



Modelos de Ionización y calentamiento con el Sistema de control  
Y ecuación dipolar rotante para campo  $B(r, \theta)$

- Diseño de bobinas superconductoras coaxiales y planas
- Configuración de hojas de corriente

Aplicar ecuaciones MHD para dinámica y estabilidad

- Simular zona de ionización por RF/helicón
- Modelar escape de plasma y colimación del chorro

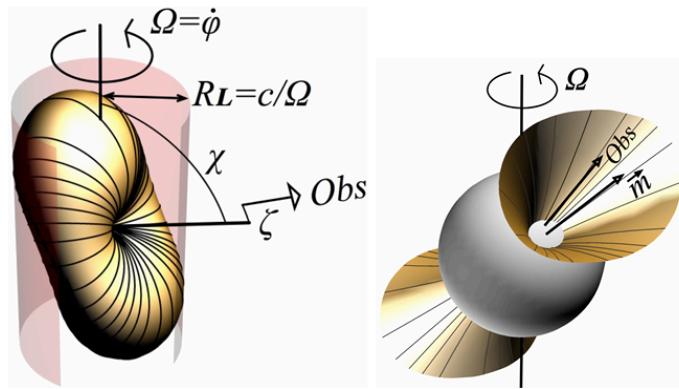
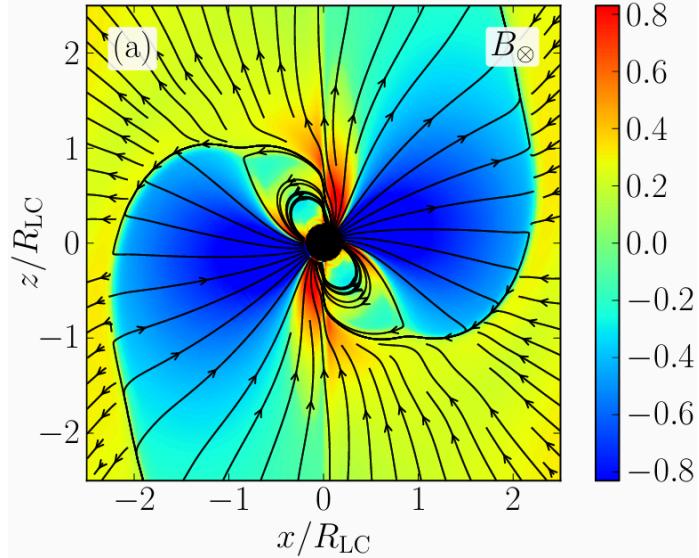
Selección de superconductores y blindajes térmicos

Motor o nave propulsada tipo Magnetar



Las hojas de corriente modelan zonas de aceleración de plasma (análogas a zonas de empuje o boosters magnéticos).

1. bobinas superconductoras (YBCO, Nb<sub>3</sub>Sn) para reproducir esta geometría en la cámara del motor.
2. Plasma generado con ionización RF o helicón (hidrógeno, deuterio).
3. Aceleración del plasma a lo largo de líneas de campo tipo magnetar , flujo altamente colimado.
4. Escape controlado mediante toberas magnéticas que permiten variar impulso específico (VASIMR)
  - Campo magnético fuerte con bobinas superconductoras de alta Tc (10–20 T).
  - Energía suministrada por un reactor compacto de fusión o fuente nuclear confiable.
  - Blíndaje térmico y radiativo para mantener la superconductividad y proteger el sistema.

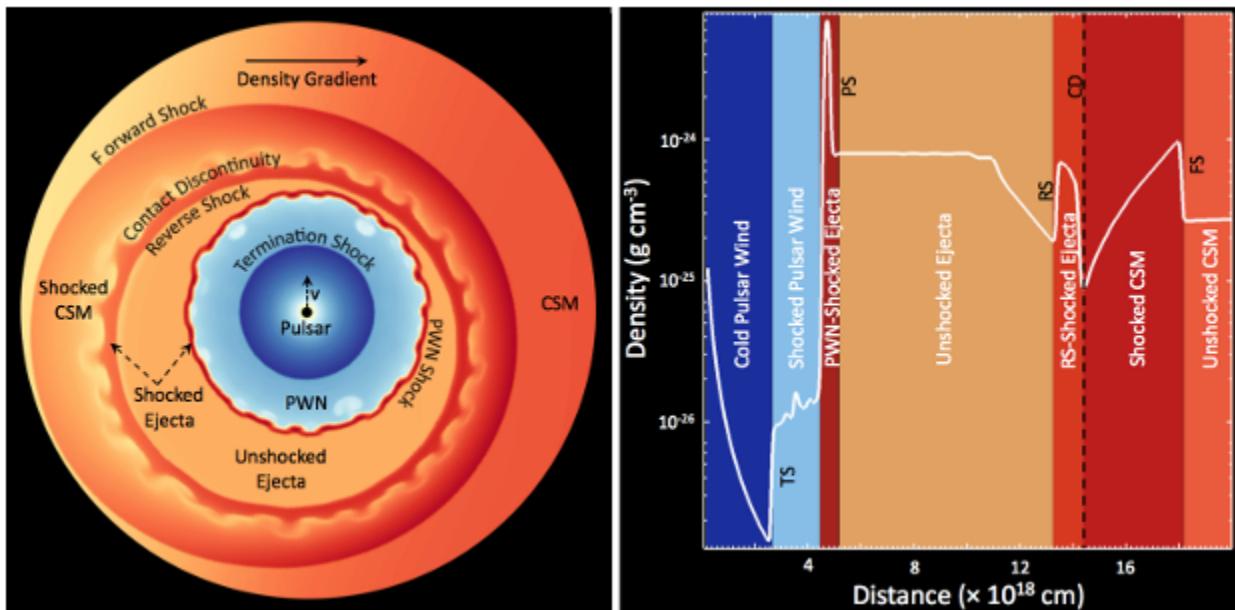


**Fig. 1** Vacuum dipole model of a pulsar, showing the region of closed magnetic field lines and the light cylinder. The angle between the rotation and magnetic poles is  $\chi$ ; often called the “inclination angle”; and the minimum angle between the line of sight and the magnetic axis is  $\zeta$ , sometimes called the “impact angle”. Sometimes  $\chi$  is denoted by  $\alpha$ , and  $\zeta$  by  $\beta$ . See Lyne & Manchester (1988).

**Fig. 2** Intersection of the cone of the last open field lines with the surface of the neutron star, showing the polar cap. The vector  $\mathbf{m}$  is the axis of the magnetic dipole field, and Obs points toward the observer.

Bloque	Función	Tecnología
Bobinas superconductoras	Crear campo magnético dipolar	YBCO en espiras coaxiales
Cámara de plasma	Contener y acelerar plasma	Materiales refractarios, guías magnéticas
Generador RF/helicón	Ionizar y calentar el plasma	Fuentes RF ajustables

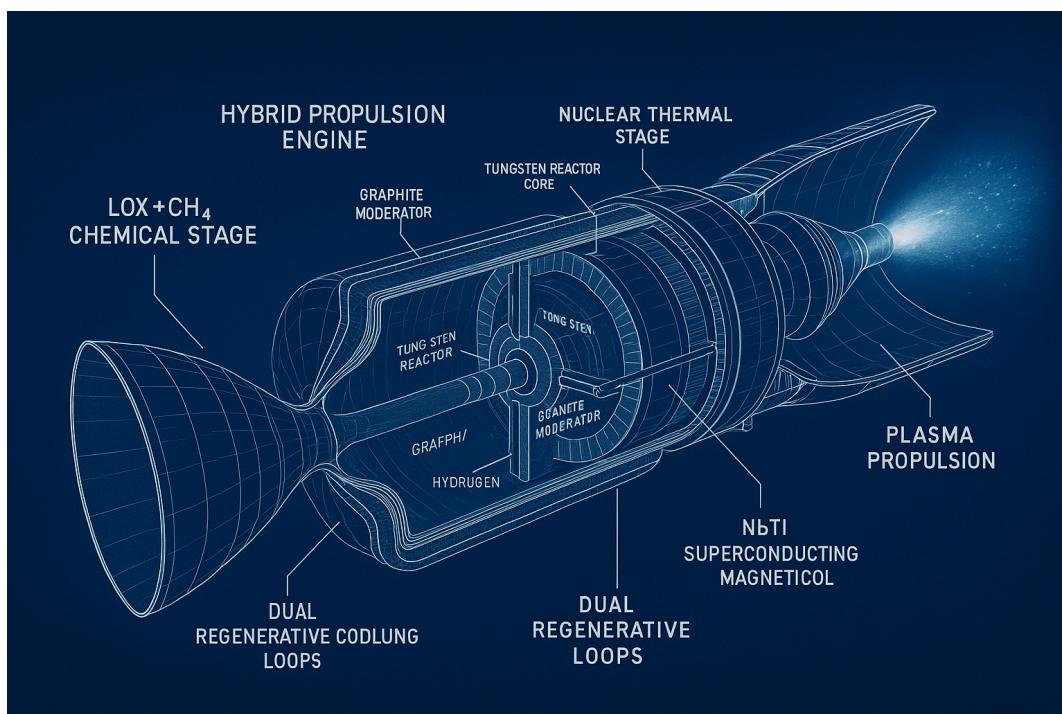
Toberas magnéticas	Expulsar plasma con control de impulso	Diseño optimizado por MHD
Sistema de control	Gestionar campo y flujo de plasma	Electrónica de potencia y sensores



As the PWN expands into the surrounding supernova ejecta, as described below, it heats the ejecta. The resulting emission, often confined to filaments, is a combination of radiation from shocked gas and continuum emission from dust condensed from the cold ejecta in the early adiabatic expansion of the SNR. The thermal emission depends on the velocity of the PWN shock driven into the ejecta which, in turn, depends on the spin-down power of the central pulsar and the density and velocity profile of the ejecta. For slow shocks, line emission may be observed in the IR and optical bands, such as that observed from the Crab Nebula (see Chapter “Super nova of 1054 and its remnant, the Crab Nebula.

- [1] Definir geometría del campo magnético
  - Implementar ecuación dipolar rotante  $B(r, \theta)$
  - Diseñar bobinas superconductoras coaxiales y planas
  - Configurar hojas de corriente como zonas de aceleración
- [2] Física de plasma (según Chen)
  - Aplicar ecuaciones MHD para flujo y estabilidad
  - Simular ionización por RF/helicón
  - Modelar escape de plasma y colimación del chorro
- [3] Integrar propulsión
  - Configurar toberas magnéticas para control del impulso

- Ajustar parámetros según misión y necesidades
- [4] Fuente de energía y materiales
- Definir reactor compacto o nuclear
  - Seleccionar superconductores y blindajes térmicos
- [5] Validación y simulación
- Ejecutar simulaciones COMSOL/MATLAB para campo y plasma
  - Optimizar geometría para máxima eficiencia y estabilidad



relativistic MHD simulation of an oblique pulsar magnetosphere (obliquity angle = 60°) taken after 3 rotations. Solid lines show field lines as traced in the image plane. Into-the-plane magnetic field component,  $B_z$ , is shown with color (red—into plane, blue—out of plane).

Establecer relaciones entre las estructuras de los magnetares e imaginar esto de manera fría y plasmática dentro de una nave o motor. Las civilizaciones siguientes podrían tener materiales resistentes en sus cuerpos o robots o máquinas que soportan índices de radiación y temperatura elevados.

Examples and images of the Exploded view of hybrid rocket engine safety systems with cooling loops, isolation valves, reactor control rods, and deployable carbon-carbon radiators, blueprint engineering drawing, white lines, dark blue background:

References: Pulsars Spindown: Period derivative is easily associated with the loss of rotational kinetic energy via electromagnetic radiation and particle wind. The Larmor formula for magnetic dipole radiation then

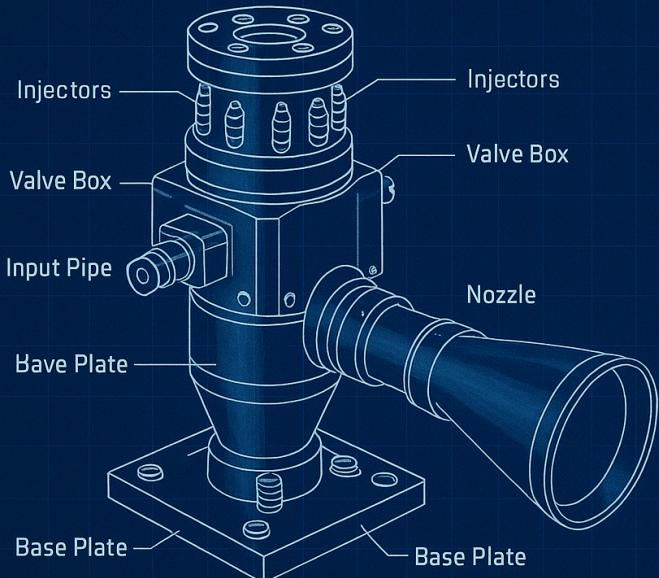
directly associates energy loss with the magnetic moment of the neutron star. This provides a characteristic scale. Pulsars with periods longer than a fraction of a second show timing noise: random variations of pulse arrival time that change slowly with time (Helfand et al. 1980). These variations are most extreme for the young Crab and Vela pulsars (Boynton et al. 1972; Lyne & Graham-Smith 1998; Scott et al. 2003; Dodson et al. 2007). Among millisecond pulsars, B1937+214 shows timing noise, but other millisecond pulsars may not (Kaspi et al. 1994; Cognard et al. 1995). Several pulsars show clear variations in spindown rate associated with changes in pulse properties.

The radio pulsars B1931+24, J1832+0029, and J1841-0500 intermittently switch between an “on” radio-loud state in which they appear as ordinary radio pulsars, and an “off” state in which no radio emission is detected. The spin-down rate is higher in the “on” state than the “off” state, by a factor of  $f_{\text{on}}/f_{\text{off}} = 1.5$  for B1931+24 (Kramer et al. 2006) and J1832+0029 (Lyne 2009), and  $f_{\text{on}}/f_{\text{off}} = 2.5$  for J1841-0500 (Camilo et al. 2012). The gamma-ray pulsar J2021+4026 (Allafort et al. 2013) displays two states with intensities different by 20% and with distinct pulse profiles, each associated with a different spindown rate:  $f_{\text{on}}/f_{\text{off}} = 104$ . Pulsar B0919+06 shows quasiperiodic variations between two states with different spindown rates and different pulse profiles (Perera et al. 2015). Lyne et al. (2010) propose that the phenomenon of intermittency is quite general: they find that timing noise for six pulsars can be expressed as the superposition of two states, characterized by distinct pulse profiles and spindown rates, with rather rapid changes between states. From these discussions it is clear that magnetospheric structure affects spindown.

Rocket engine example:



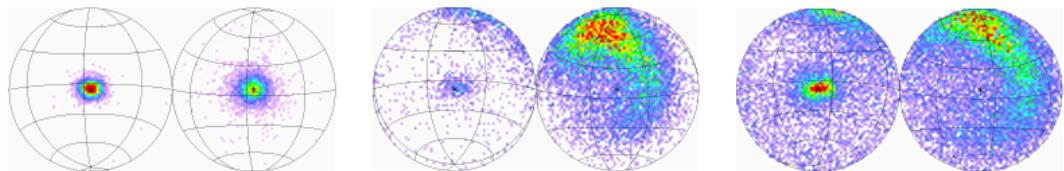
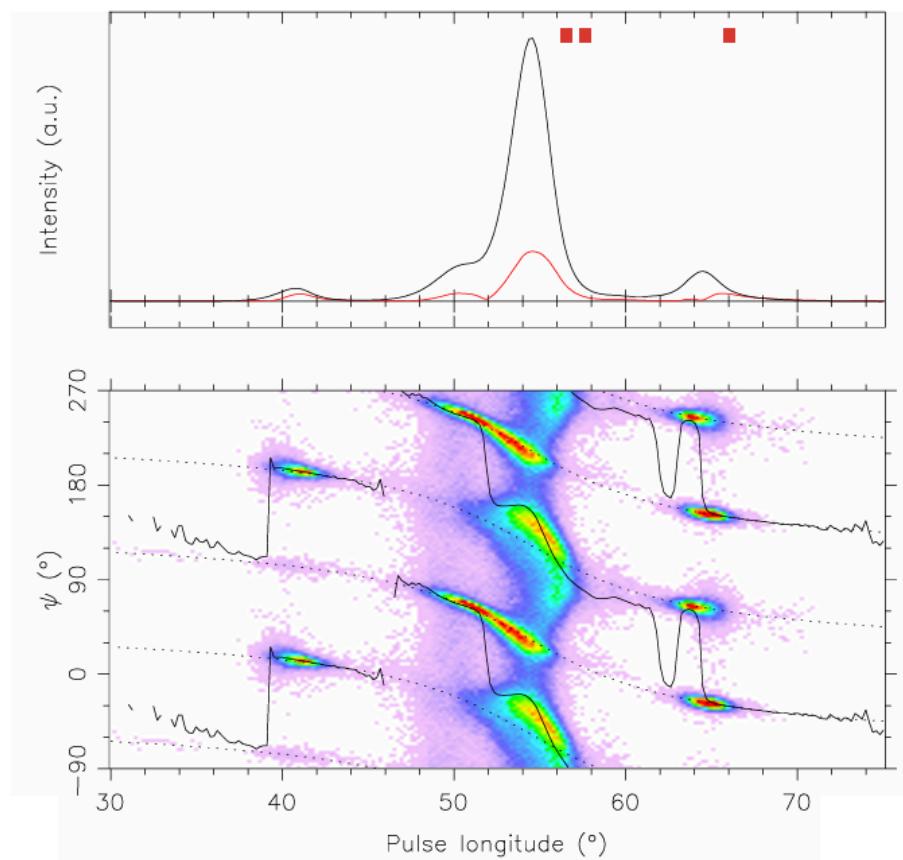
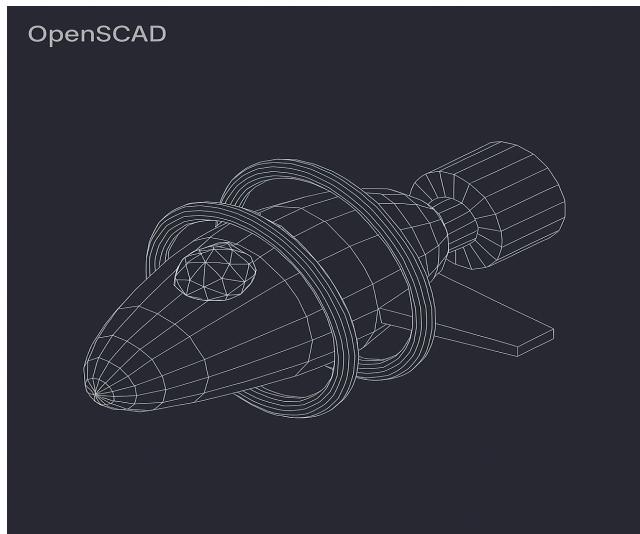
## 400N MONO-PROPELLANT KEY TECHNICAL CHARACTERISTICS

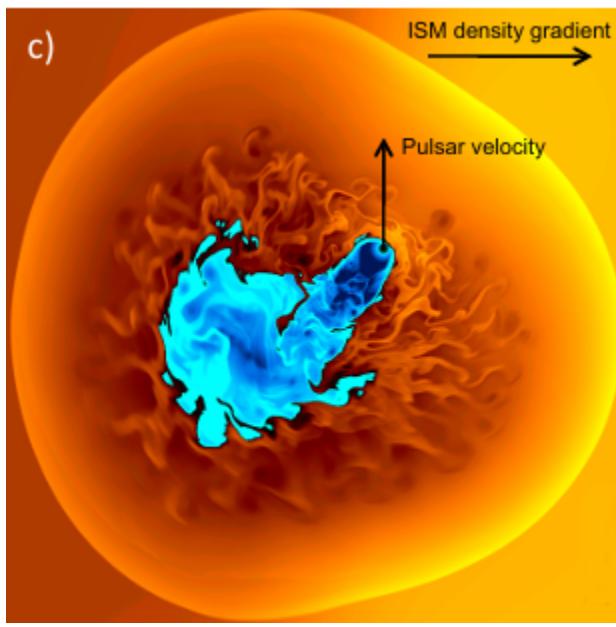


Thrust Range	120-420 N
Supply Pressure	5.5-25 bar
Nominal Mass Flow Range	58-190 g/s
Nominal Specific Impulse Range	2080-2155 Ns/kg
Minimum Impulse Bit Range	< 9 Ns
Shortest On-time	16 ms
Nozzle Area Ratio	30
Propellant	PI-design
Qualification	< 188 kNs
Total number of pulses	> 3900
Total hydrazine throughput	> 850 s
Total operating time	> 850 s
Longest steady start	450 s

1) A magnetosphere depleted of charge, and the “on” state with magnetospheric currents sufficient to produce the observed change in spindown. Li et al. (2012) observe that the simplest model for the “on” state is the force-free magnetosphere (Spitkovsky 2006), which exhibits spindown rates at least three times that of a vacuum dipole. They suggest a modified picture where the “on” state is the force-free magnetosphere, and the “off” state has no charge on open field lines, but carries the Goldreich-Julian charge on closed field lines. This leads to ratios of  $\alpha = 12$  to  $29$  for inclination angles of  $> 30^\circ$ . Smaller inclinations lead to larger  $\alpha$ .

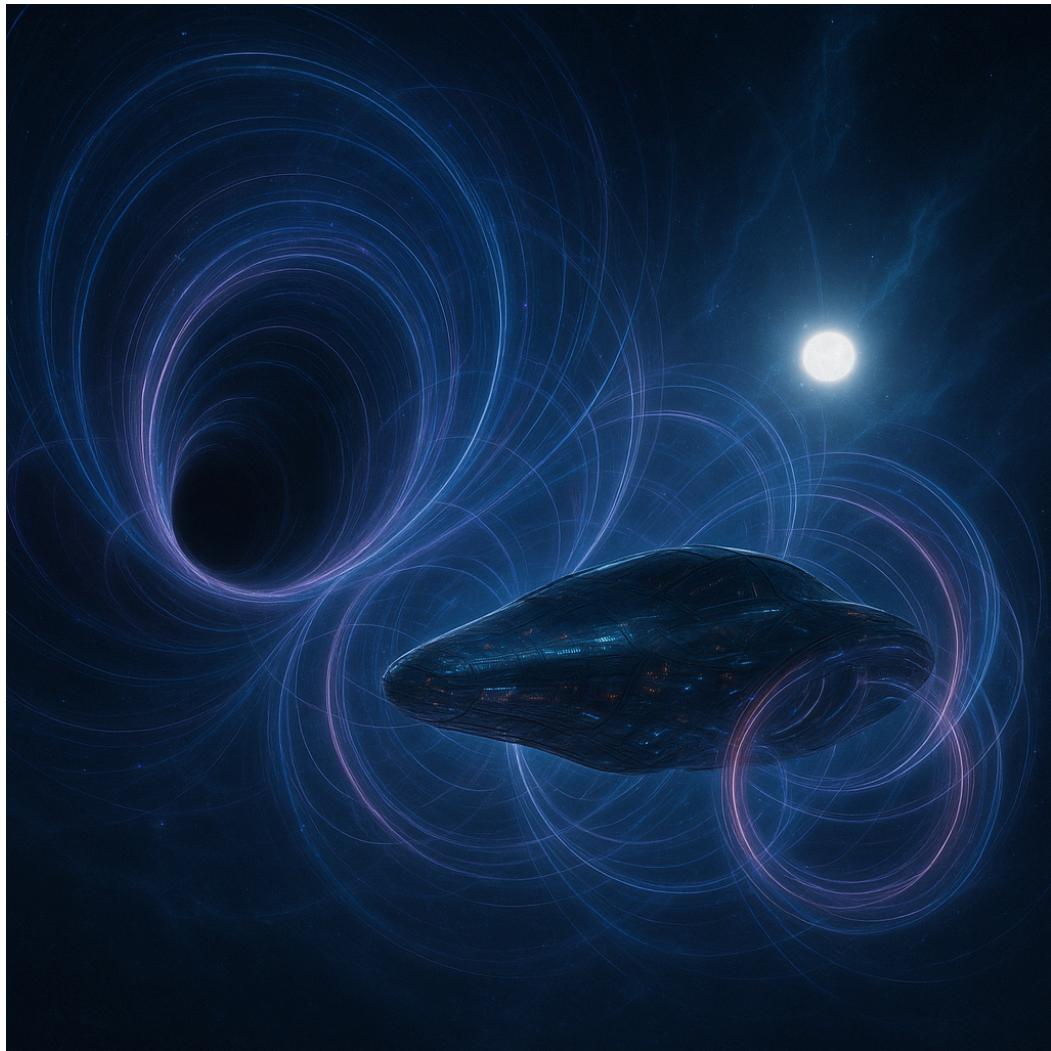
Reverse-shock Interaction As the SNR blast waves sweep up increasing amounts of material, the RS propagates back toward the SNR center. In the absence of a central PWN, it reaches the center at a time  $t_c \approx 7(M_{ej}/10^{56} E_{51})^{1/3} n_0^{1/3}$  kyr, where  $E_{51}$  is the explosion energy,  $M_{ej}$  is the ejecta mass, and  $n_0$  is the number density of ambient gas (Reynolds & Chevalier 1984). When a PWN is present, however, the RS interacts with the nebula before it can reach the center (Figure 3). The shock compresses the PWN, increasing the magnetic field strength and resulting in enhanced synchrotron radiation that burns off the highest energy particles. In the simplified case of SNR expansion into a uniform medium, with a spherically-symmetric PWN, the system evolves approximately as illustrated in Figure 2 (from Gelfand et al. 2009), where the Sedov solution has been assumed for the SNR evolution,  $R_{SNR} \propto t^{2/5}$ ,  $E_{SNR} \propto t^{1/2}$ , and the PWN evolves approximately as  $R_{PWN} \propto t^{1/5}$ .





a) Radio emission from G327.1 1.1 (SIFA/MOST, CSIRO/ATNF/ATCA) showing SNR shell surrounding central PWN. b) Chandra image showing faint X-ray SNR shell and PWN. c) Hydrodynamical simulation of evolved composite SNR with properties similar to G327.1 1.1. (See text for details.) d) Expanded Chandra view of central region of G327.1 1.1. A compact nebula surrounding the neutron star is embedded in a

cometary structure with an extended tail, formed by a combination of northward pulsar motion and an interaction with the SNR reverse shock approaching from the west. Prong-like structures of unknown origin extend from several regions around the nebula. [After Temim et al. 2015. All images have north at top and west at the right.] from electrons with energies of 100 TeV (see Eqns. 9, 12). The higher energy X-ray producing electrons fall beyond the cooling break, while those producing the-rays are predominantly uncooled. The result is a bright TeV nebula accompanied by a fainter X-ray nebula.





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### Composite Hgbri Fushice

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