合体中性子星の磁気圏の効果

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概要

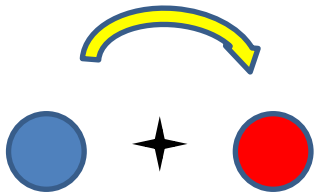
磁気圏の効果でEM放射の可能性があるという論文の紹介をした。？な内容で、信じがたいが、今後の研究が必要

計画研究A05 合宿
2013年1月7日-9日　　熱海

Magnetized NS

連星軌道への影響

- Ioka & Taniguchi (2000) APJ 537, 327
- Vasuth et al (2003) PRD 68, 124006
- . . . . .



→2PN for B=10^16G

$$E = Gm_1m_2 / r$$

$$\rightarrow \ldots + \vec{d}_1(3\vec{n}\vec{n} - I)\vec{d}_2 / r^3$$

磁気圏の影響
（本主題）
合体前のEM 放射

Precursor ?

温故知新

THE ASTROPHYSICAL JOURNAL, Vol. 156, April 1969

NS(Pulsar)

BH(QSO)

IO, A JOVIAN UNIPOLAR INDUCTOR

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Received April 15, 1968; revised October 7, 1968

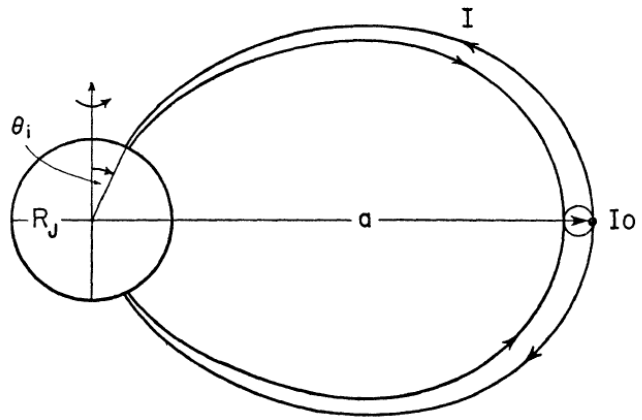


FIG. 2.—Current circuit in the meridian plane (not to scale)

ABSTRACT

We show that Io may be considered to be a unipolar generator which develops an emf of 7×10^5 volts across its radial diameter (as seen from a coordinate frame fixed to Jupiter). This voltage difference is transmitted along the magnetic flux tube which passes through Io. The induced charge separation on the surface of the flux tube causes the plasma within it to rotate with Io's orbital angular velocity. A current of about 10^6 amp is driven across each foot of the flux tube in the Jovian ionosphere. The current flows up along the half-surface of the flux tube which faces Jupiter, crosses the magnetic field in Io, and then flows down along the opposite half of the flux tube's surface. Because the number density of charge carriers in the magnetosphere is low (we use $n = 0.5$ cm^{-3} in our calculations) the current must be carried by keV electrons which are electrostatically accelerated at Io and at the top of Jupiter's ionosphere. We argue that beam instabilities in the current sheets are responsible for the Io-induced decametric bursts. The geometry of the beaming of the bursts strongly suggests coherent cyclotron radiation as the emission mechanism. In addition, we are led to predict that Europa should modulate decametric bursts whose maximum frequencies are below 8 Mc/s.

Bigg was the first to demonstrate that the position of Io in its orbit was strongly correlated with the reception of Jovian decametric bursts. Previously it had been established that the detection of the bursts was influenced by the position of Jupiter's magnetic dipole. Our aim is to explain the origin of Io's great influence.

-> Binary of NS+BH(NS)

Goldreich & Linden-Bell(1969)

- EMF $E \approx 10^6[V](10^3\,?)$
- Current $I = V/R \approx 10^6[A]$
- Power $P = IV \approx 10^{19}[erg/s]$

n->

Velocity $v/c \approx 0.1$

- Two stream inst.

->Decameter Burst

Coherent Cyclotron Rad. @ w_B=10MHz

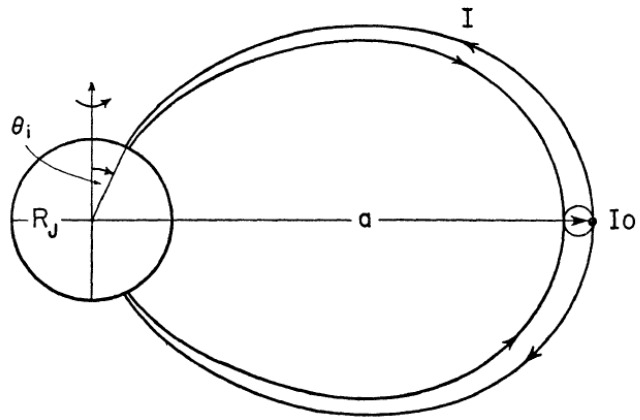


FIG. 2.—Current circuit in the meridian plane (not to scale)

Unkown for compact binaries

Magnetosphere of NS

- Merge of Mag. NS + Schwarzschild BH
  Lyutikov (2011) PRD83, 064001, 124035
  McWilliam & Levin(2011) APJ, 742, 90

- Merge of Mag. NS + (Mag.) NS
  Piro(2012) APJ, 755, 80
  Lai (2012) APJL, 757, L3

Order of Magnitude

(Mag.)X (Vel.) X (Size) = EM Power

- Two Steps
- Ep
- Bt
- Poynting Flux

  Bt x Ep

$$E_p = -v_t \times B_p$$

Ideal MHD

$$B_t \approx v \times B_p$$

$$P = \int dA_r (E_\theta B_\phi - E_\phi B_\theta) / 4\pi$$

=0

Stat. & Axisym.

Current circuit (I,V,R)

E x L = V

Bt/L = I/L^2

$$P \approx v^2 B^2 L^2 \approx IV \approx V^2 / R$$

Resistance? V=I x R

$$R_V = 4\pi / c = 377 Ohms$$

Vacuum impedance

Order of Magnitude -2-

$$P \approx v^2 B^2 L^2 \approx IV \approx V^2 / R$$

- Pulsar
  dipole B, Rotation, Light cylinder

$$P \approx \mu^2 \Omega^4 \approx 10^{36} erg/s \mu_{31}{}^2 \Omega_1{}^4$$

- Kerr BH (BZ)
  B in disk, Spin, Horizon
  + negative ingoing flux

$$P \approx B^2 (a/M)^2 M^2$$

$$\approx 10^{45} erg/s (M_9)^2 (B_4)^2$$

0 or finite?

How realized?

Resistance?

Big Problem

→ Merge of NS

Problem^2 ?

Merging Ns+(Ns, BH)

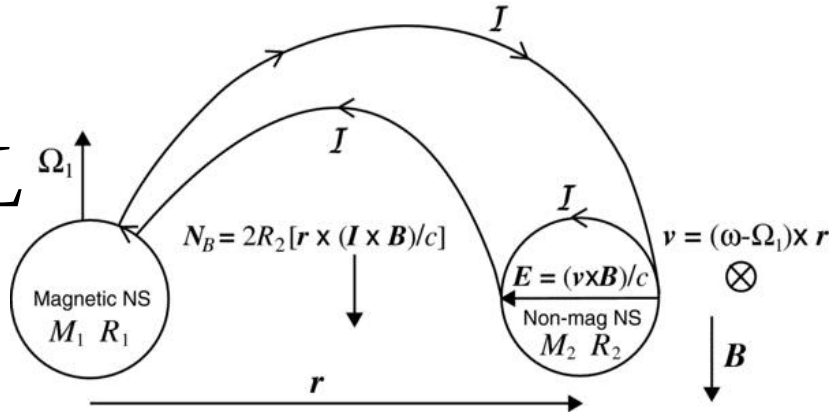
Current circuit (I,V,R)

EMF $V \approx (\mu / r^3) \times r\Delta\Omega \times L$

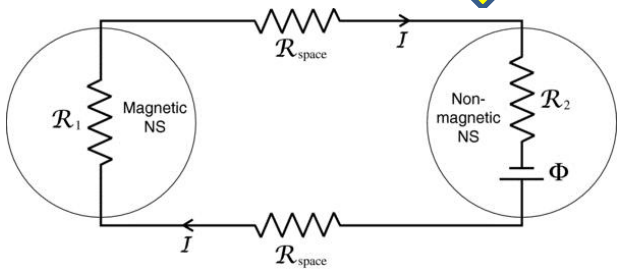
Current $I = V / R$

Power $P \approx IV \approx V^2 / R$

Potential E $\approx 10^{13} eV$



Piro(2012)

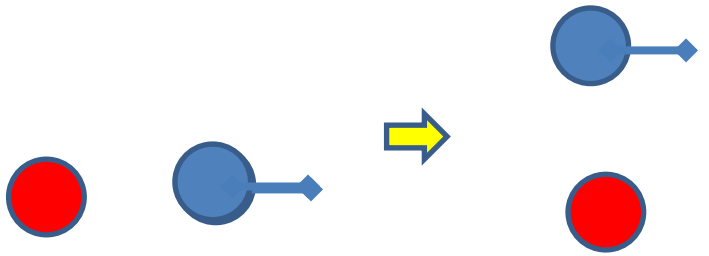


Two different points

✓ r(t) $r \leftrightarrow \Omega$

✓Not synchronized

$$\Delta\Omega = \Omega_1 - \Omega_2$$



Luminosity before Merge

$$R = \sigma^{-1} = 4\pi / c = 377 Ohms$$

- Piro(2012)

$$P \approx 10^{46} erg/s \mu_{31}^{\ 2} \Omega_2^{\ 17/3} (\Delta\Omega/\Omega)$$

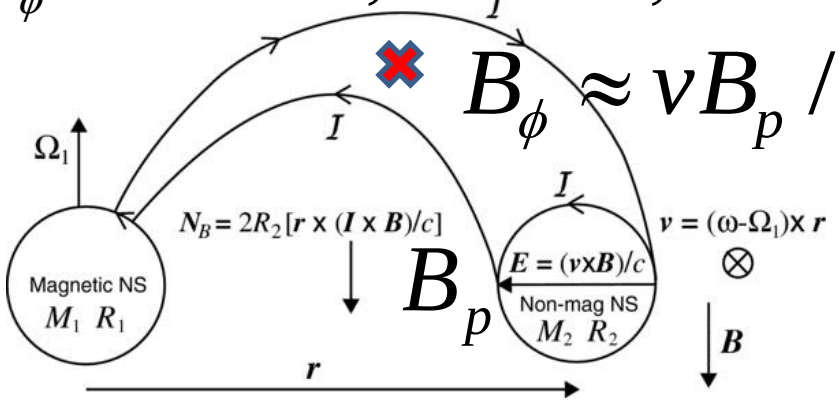
$$B_\phi / L \approx I / L^2, I = V/R, V/L = vB_p$$

- Limit (Lai (2012))

Circuit broken for large twist

$$\varsigma = B_\phi / B_p \leq 1$$

$$P \approx 10^{42} \varsigma [erg/s]$$



Resistance

Vacuum impedance(Resistance)

$$R_V = 4\pi / c = 377 Ohms$$

$$c^{-1}E_{,t} = -4\pi j / c + \nabla \times B$$

$$j = \sigma E$$

- Displacement current is important when $\sigma^{-1} > R_V / 2\pi\lambda$

- Rv is large
- Rv in stationary problem?

  BH -> ingoing flux

  NS -> ?

まとめ（感想）

- 磁気圏の研究の必要性
  プラズマ分布の不定性

More Constraint(study), Less Power?

2D(no?)
->3D+Time-dependent=4D (yes?)