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ABSTRACT

Aims. This paper investigates the electromagnetic interaction of a relativistic stellar wind with a planet or a smaller body in orbit around the neutron star. The interaction is based on the theory of Alfvén wings adapted to the context of relativistic winds.The 2011 paper comprises a short section with numerical applications. This requires an estimate of the magnetic field in the pulsar wind, that depend on the magnetic flux Ψ in the wind asymptotic regime. This flux is badly approximated.

Methods. The present erratum corrects the consequences of this wrong estimate of Ψ in three papers where it has consequences: about the magnetic drag acting on pulsar companions, and a model of fast radio bursts (FRB).

Results. In those three papers, the physics is unchanged, but the numerical results must be re-scaled. The theory of FRB published in 2014 is briefly discussed.

Key words. pulsars - exoplanets - magnetospheres -

1. Magnetic coupling of planets and small bodies with a pulsar wind

In Mottez & Heyvaerts (2011b), the magnetic field in the pulsar wind is expressed as a function of the magnetic flux in the asymptotic regime of the wind $\Psi = B_0^r r^2$, where B_0^r is the local magnetic field, and r is the distance to the neutron star. This is an integral of motion along stream lines. In the end of section 2, in view of numerical applications, it is evaluated as $\Psi = B_*^r R_*^2$ where quantities with a star refer to the neutron star (NS) surface. This approximation corresponds to the monopole solution, which overestimates the wind magnetic field by orders of magnitude. Because this is an asymptotic approximation, its value must be evaluated in the domain where the field lines are wind-like, not on the NS surface. The most admitted approximation is its value at the light cylinder Goldreich & Julian (1969), where between the NS surface and the light cylinder (LC), the magnetic field is supposed dipolar. Then, $\Psi = B_{LC}^r r_{LC}^2 = B_* R_*^3 \Omega_*/c$ where Ω is the NS angular velocity, and c is the speed of light. Then the toroidal component of the pulsar wind magnetic field is approximated by $B_0^\phi = B_* R_*^3 \Omega_*^2 / rc^2$ where $r >> r_{LC}$. The numerical estimates of the potential drop U associated with PSR 1257+21 and PSR 1620-26 in the end of section 2 are not correct. Their right values as well as the corrected values of Table 3 in Mottez & Heyvaerts (2011b) are given in four first columns of the present Table 1.

* Deceased.

2. A magnetic thrust action on small bodies orbiting a pulsar

In Mottez & Heyvaerts (2011a), the same wrong evaluation of Ψ leads to an overestimate of the magnetic thrust acting on bodies orbiting a pulsar described in the joint paper .

Table 1 in Mottez & Heyvaerts (2011a) must be replaced by Table 1 of the present erratum. The conclusion is that even for small bodies orbiting the pulsars given in example, the influence of this effect on the orbit is totally negligible. The figures 2, 3, and 4 must be replaced by flat functions showing no significant evolution of the eccentricity and of the semi-major axis.

Table 1. Electric potential drop, total electric current associated to the Alfvén wing. Electrical energy $\dot{E}_{Jmax}$ dissipated in the Alfvén wing. Variation per (terrestrial) year of the semi-major axis, variation of the eccentricity, per year, $\Delta e/year$), and the coefficient $D/\sqrt{GM}$ that scales these computations.

Name	U	I	$\dot{E}_{Jmax}$	$\Delta a/year$	$\Delta e/year$	$D/\sqrt{GM}$
Unit	(V)	(A)	(W)	(m.yr^{-1})	(yr^{-1})	(m$^{5/2}$·s $^{-1}$)
PSR 1257+12 a	$4.0\,10^{10}$	$1.1\,10^{8}$	$3.4\,10^{18}$	$1.5\,10^{-7}$	0	$2.1\,10^{3}$
PSR 1257+12 b	$1.3\,10^{11}$	$3.4\,10^{8}$	$3.4\,10^{19}$	$1.3\,10^{-8}$	$3.3\,10^{-21}$	$3.4\,10^{2}$
PSR 1257+12 c	$9.7\,10^{10}$	$2.6\,10^{8}$	$1.9\,10^{19}$	$1.0\,10^{-8}$	$2.8\,10^{-21}$	$3.5\,10^{2}$
PSR 1620-26 a	$1.9\,10^{10}$	$3.0\,10^{7}$	$2.8\,10^{17}$	$6.7\,10^{-11}$	0	$1.1\,10^{2}$
PSR 1s b 10,000 km	$8.4\,10^{9}$	$2.2\,10^{7}$	$1.5\,10^{17}$	$6.3\,10^{-9}$	0	$9.9\,10^{1}$
PSR 10ms 100 km	$1.6\,10^{8}$	$4.2\,10^{5}$	$5.1\,10^{13}$	$2.6\,10^{-8}$	$3.1\,10^{-19}$	$1.7\,10^{2}$
PSR 10ms 1 km	$1.6\,10^{6}$	$4.2\,10^{3}$	$5.1\,10^{9}$	$2.6\,10^{-6}$	$3.1\,10^{-17}$	$1.7\,10^{4}$
PSR 1s b 100 km	$1.6\,10^{8}$	$4.2\,10^{5}$	$5.1\,10^{13}$	$2.6\,10^{-6}$	$3.1\,10^{-17}$	$1.7\,10^{4}$
PSR 1s b 1 km	$1.6\,10^{6}$	$4.2\,10^{3}$	$5.1\,10^{9}$	$2.6\,10^{-4}$	$3.1\,10^{-15}$	$1.7\,10^{6}$

3. Radio emissions from pulsar companions: a refutable explanation for galactic transients and fast radio bursts

In (Mottez & Zarka 2014), because of the new evaluation of Ψ, equation (1) must be replaced by

$$B_0^\phi = B_0^r \frac{v_0^\phi - \Omega_* r}{v_0^r} \sim -\frac{B_0^r \Omega_* r}{c} = -\frac{B_*^r \Omega_*^2 R_*^3}{rc^2}, \quad (1)$$

and in the same section, the current in the Alfvén wing for an Earth-like orbiting body at 0.2 AU for a 1s standard pulsar is not 10^{11} A but $I_A = 0.23\,10^8$ A. For the same body orbiting a recycled pulsar, $I_A = 10^9$ A must be replaced by $I_A = 0.23\,10^8$ A. In section 4.3 (frequencies), the correct value of Ψ is $\Psi = B_* R_*^3 \Omega_*/c$, and Eq. (15) becomes

$$f_{c,s} = \frac{qB_*\Omega_*}{2\pi mc}\frac{R_*^3}{r^2}\sqrt{1+\left(\frac{r}{\gamma r_{LC}}\right)^2}, \quad (2)$$

where γ is the wind Lorentz factor, and R_{LC} is the light cylinder radius. Equation (16) becomes

$$f_{c,o} = 0.52\ \gamma \left(\frac{B_*}{10^5\mathrm{T}}\right)\left(\frac{1\mathrm{AU}}{r}\right)^2\left(\frac{R_*}{10^4\mathrm{m}}\right)^3\left(\frac{10\mathrm{ms}}{T_*}\right)\times \left\{1+\left[\frac{\pi\ 10^5}{\gamma}\left(\frac{10\mathrm{ms}}{T_*}\right)\left(\frac{r}{1\mathrm{AU}}\right)\right]^2\right\}^{1/2}. \quad (3)$$

In section 4.4 (brightness), Eq. (18) becomes

$$\dot{E}_J = \frac{\pi}{\mu_0 c^3} {R_b}^2 r^{-2} R_*^6 B_*^2 \Omega_*^4, \quad (4)$$

where R_b is the radius of the body orbiting the NS. Equation (19) becomes

$$P_{radio} = \epsilon \dot{E}_J = \epsilon \frac{\pi}{\mu_0 c^3} {R_b}^2 r^{-2} R_*^6 B_*^2 \Omega_*^4, \quad (5)$$

and Eq. (20) becomes

$$\left(\frac{< S >}{\mathrm{Jy}}\right) = 2.7\,10^{-3}\left(\frac{\gamma}{10^5}\right)^2\left(\frac{\epsilon}{10^{-3}}\right)\left(\frac{R_b}{10^7\mathrm{m}}\right)^2\times \left(\frac{1\mathrm{AU}}{r}\right)^2\left(\frac{R_*}{10^4\mathrm{m}}\right)^6\left(\frac{B_*}{10^5\mathrm{T}}\right)^2\times \left(\frac{10\mathrm{ms}}{T_*}\right)^4\left(\frac{\mathrm{Mpc}}{D}\right)^2\left(\frac{1\ \mathrm{GHz}}{\Delta f}\right). \quad (6)$$

On fig. 6, the frequencies (vertical axis) must be reduced by a factor $2.1\,10^{-2}$. In fig. 7, they must be rescaled by a factor $2.1\,10^{-4}$. In fig. 8, the distances from where a 1 Jy signal can be observed must be rescaled by a factor $2.1\,10^{-2}$.

In the second paragraph of section 5.1, it is said that a recycled millisecond pulsar and a planet corresponding to the reference values of Eq. (20) except $\gamma = 10^6$ could provide a FRB signal seen from a distance of 1 Gpc. This is wrong. Actually, a young millisecond pulsar, characterized by the reference values of Eq. (20), except $\gamma = 10^6$ and $B_* = 10^7$ T could provide the required FRB characteristics.

In section 5.2, third paragraph, it is said erroneously that a kilometer-sized asteroid orbiting a standard pulsar ($P = 1$ s, $B_* = 10^8$ T) could explain the PSR J1928+15 event. Actually, the same asteroid orbiting a highly magnetized pulsar ($P = 1$ ms, $B_* = 10^9$ T) could explain it.

References

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