Radio emission from auroras on planets around pulsars

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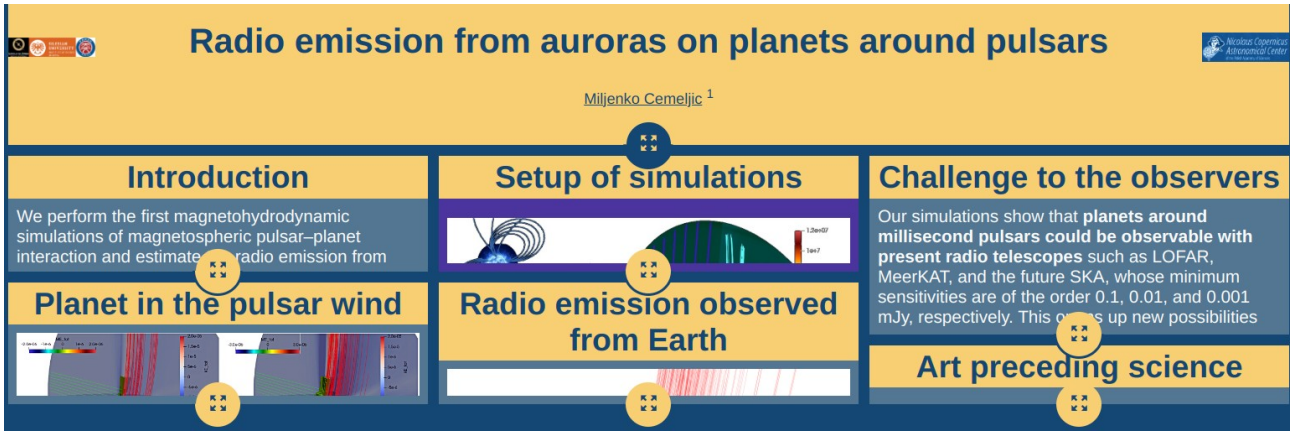
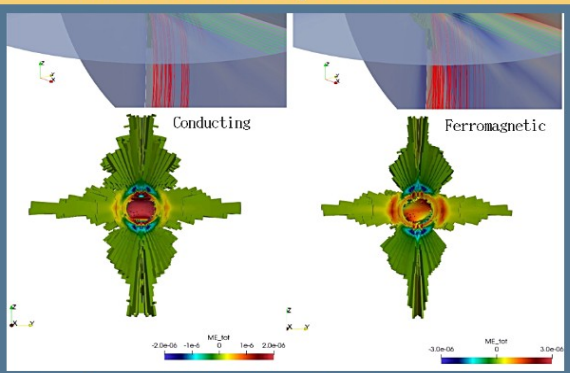
Abstract: Based on analogy with the solar system planets, we predict the existence of aurora on planets around millisecond pulsars. In the first special relativistic magnetohydrodynamic (RMHD) simulations of magnetospheric pulsar-planet interaction, we obtained the parameters of electromagnetic emission from such auroras. The first extrasolar planets were discovered around millisecond pulsars more than 30 years ago using the timing method: the slight variation in otherwise highly regular timing of the pulses, caused by the planets, would reveal their existence. Thanks to the extreme timekeeping precision of this method, bodies as small as asteroids or comets encircling pulsars could be detected. This gives an idea about the masses and orbits, but for more data we need a probe in the pulsar wind environment. Because of the large magnetic field of pulsars, pulsar wind carrying the magnetic field to the planet vicinity can induce an aurora even on planets without intrinsic magnetic field. We compute the emission from such planets in the cases of conducting and ferromagnetic obstacles moving through the pulsar wind. The obtained strength of the signal from our simulations shows that such auroras should be observable with the current instruments even at a distance to the first discovered planets around pulsar, at 2300 light years. With the position and expected properties of the signal known, we make a challenge for observers. Such an observation would be the first confirmed radio detection of an extrasolar planet and, even more important, it would be the first direct probe in a pulsar wind.



Introduction

We perform the first magnetohydrodynamic simulations of magnetospheric pulsar–planet interaction and estimate the radio emission from such systems. In analogy with the solar system planets, we predict the existence of aurora on planets around millisecond pulsars. Since the radio emission from an aurora is proportional to the strength of the magnetic field, planets around pulsars are the best candidates for the first confirmed detection of auroral radio emission from distant exoplanets. We find that the radio emission from aurora on pulsar planets could be observable with the current instruments, and provide parameters for such a detection. It would also be the first direct probe into the pulsar wind.

Planet in the pulsar wind

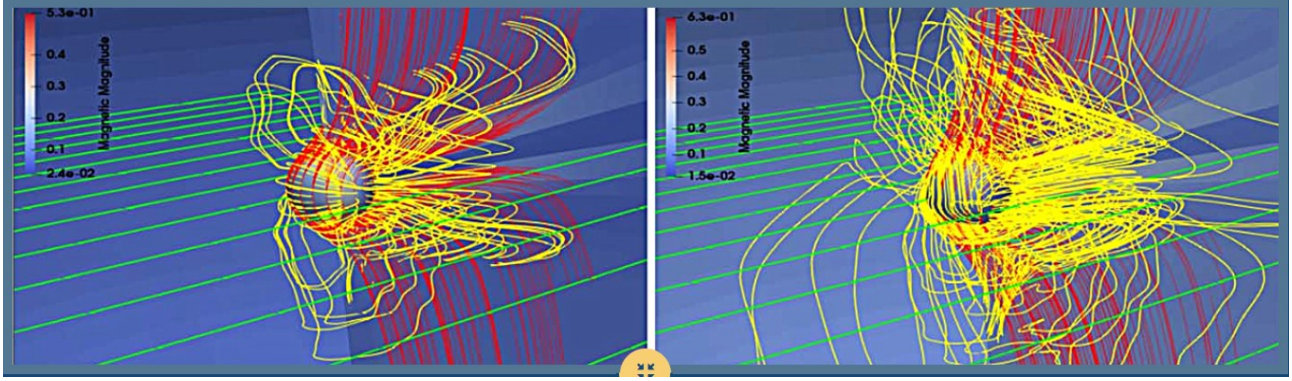


The divergence of the Poynting flux and the kinetic energy flux, quantifying the pulsar wind dynamic pressure in the cases with the nonmagnetic planet with a conducting and ferromagnetic surfaces, are shown with the color graded isocontours in the top panels. Color graded background shows the mass density ρ, red lines depict the magnetic field lines, and green lines show the velocity streamlines of pulsar wind. Bottom panels show zoomed-in images of the radiative patterns in the same cases. Locations with the maximum radiated power are in the middle of the plan
dayside and in the base of the Alfvén wings.

Challenge to the observers

Our simulations show that **planets around millisecond pulsars could be observable with present radio telescopes** such as LOFAR, MeerKAT, and the future SKA, whose minimum sensitivities are of the order 0.1, 0.01, and 0.001 mJy, respectively. This opens up new possibilities for studying and understanding the dynamics of pulsar systems and their planetary companions.

References: Mishra, R., Čemeljić, M., Varela, J., Falanga, M., 2023, ApJL, 959:L13 and references therein.



Art preceding science

Pulsar Planets I is a painting by Lynette Cook which was uploaded on November 25th, 2012.

There is an interesting artistic twist to the story of the pulsar planet auroras. In the EAS 2023 meeting in Cracow in July 2023, where Ruchi Mishra, who worked on the article, had a poster with our results, I met Prof. Alex Wolszczan, the dicoverer of first planets around pulsars (and extrasolar planets in general), and asked him what he thinks of our idea. He listened carefully and commented: "I did not come to such an idea. Give numbers!" Exactly this is what we did in the paper, making a challenge to the observers. After the paper was published, browsing "pulsar planets aurora" for a related content, I was stunned to find the picture above, dating to the year 2000! I contacted the artist, an accomplished science illustrator, Ms. Lynette Cook, asking if she just made it by analogy with Earth? She answered that no, she asked Prof. Alex Wolszczan, back in 1999 about the scientific plausibility of the painting, and he suggested her to add an aurora! So, it seems he did have an artistic idea of it, but it did not pass into the scientific work. Ours is the first where it is computed, almost a quarter of century after the painting!