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CAC and Marina Romanova, Min Long, and Richard Lovelace

The Life of a Young Magnetized Star: Astrophysical Flows and Hot Spots

What is the nature of young magnetized stars?

Finding the Answer

Marina Romanova, Senior Research Associate in the Department of Astronomy; Min Long, a former graduate student at Cornell; and, Richard Lovelace, Professor of Applied and Engineering Physics used the parallel computing systems at CAC to execute numerical simulations of the disk accretion to rotating magnetized stars.

The Life of a Young Magnetized Star

A young star is formed when a cloud of gas collapses in on itself due to its gravity. After the collapse, the star is usually surrounded by a disk of gaseous matter–the accretion disk–that slowly falls into the star. As the ionized matter in the disk approaches the star, the star's magnetic field modifies the motion of the charged matter, and the matter is drawn toward the magnetic poles during the descent. The oldest stars, white dwarfs and neutron stars, also have dipole type or more complex magnetic fields and accretion disks. However, their disks are created from the matter lost from a companion star.

Romanova, Lovelace, and the US-Russia Plasma Astrophysics Collaboration were the first research team to calculate the complicated flows of ionized matter drawn into rotating magnetized stars in full 3D simulations. Their modeling was done on CAC HPC systems. Most recently, the team ran full 3D simulations to gain new insights and a better understanding of the life of young stars.

Improved Research

Research Metrics

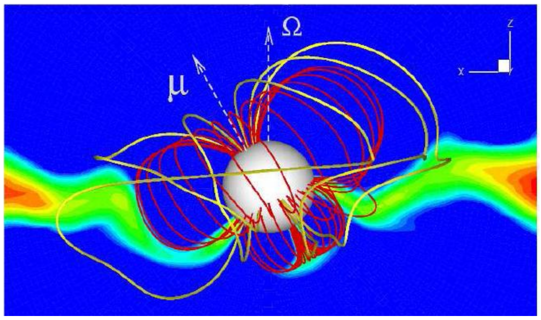
- Speed: Complete more complex simulations in less time using CAC systems

Research Challenge

Astrophysical phenomena that cannot be resolved by today's best telescopes need to be modeled, "observed," and studied through numerical experiments using high-performance computing simulations. The magnetic field of real stars may be more complex than a dipole and simulations require a high resolution grid and a large number of processors.

Solution

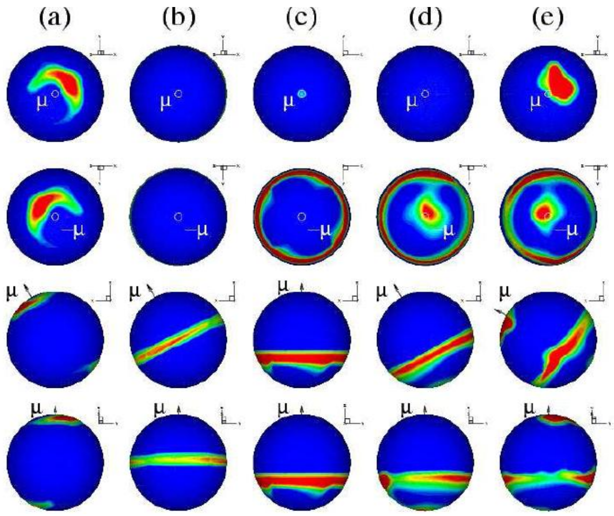
Min Long, Marina Romanova, and Richard Lovelace investigated for the first time disc accretion to a rotating star with a complex dipole plus quadruple fields in full 3D magneto -hydrodynamic (MHD) simulations using Cornell CAC and NASA high-performance computing systems.



Detailed structure of disk accretion to a star with a dipole plus quadrupole field (from Long, Romanova, and Lovelace MNRAS)

The simulations show that for relatively small misalignment angles, matter flows in a thin wide sheet to the quadruple's belt. This flow forms a ring-like hot spot at the surface of the star. The position of the ring coincides with the magnetic equator in the case of the pure quadrupole field, and is displaced into the southern hemisphere in the case of the dipole plus quadrupole fields. At large angles, most of the matter may accrete to one or both magnetic poles. The simulations also show that the torque on the star is larger in the case of the dipole field.

The angular momentum flow between the star and disc is more efficient in the case of the dipole field. The hot spots are hotter and brighter in the case of the dipole field because the matter accelerates over a longer distance compared with the flow in a quadrupole case.



Inflowing matter of the funnel streams falls onto the star and forms hot spots on the stellar surface (from Long, Romanova, Lovelace, MNRAS)

The Clients

- Marina Romanova, Senior Research Associate, Department of Astronomy, Cornell University
    - Investigated for the first time disk accretion to a star with a misaligned dipole magnetic field in full 3D MHD simulations
    - Investigated in 3D simulations accretion to a magnetized star with complex fields and accretion through instabilities
- Richard V.E. Lovelace, Professor of Applied and Engineering Physics, Cornell University
    - Research focus on astrophysical flows and plasma
    - Discovered the period and location of the Crab Nebula Pulsar while at Arecibo
- Min Long, former Cornell Graduate Student
    - Investigated disc accretion to a magnetized star in the rotational equilibrium state in 2.5D simulations
    - Investigated in 3D simulations accretion to a star with a complex magnetic field

The Collaborative Relationship

"The Cornell University Center for Advanced Computing provided excellent consulting and support for our parallel runs on their high-performance computing clusters."

Marina Romanova
Senior Research Associate
Department of Astronomy, Cornell University