Why Didn't G2 Disrupt?

— Magnetic Support, Orbital Twisting, and the Invisible Galactic Center —

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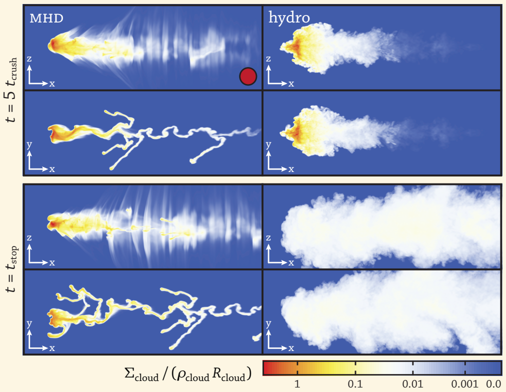
Introduction

A gas cloud known as *G2* passed close to the black hole at the center of our galaxy in 2014. Conventional simulations predicted it would be torn apart by *shear instabilities*—but observations show the cloud largely *survived*.

This tension suggested that something important was missing from the models. We show that *magnetic fields* fundamentally change the fate of gas clouds like G2, and that their orbits can be used to probe the structure and dynamics of the galactic center.

Magnetic Fields Stabilize Gas Clouds



Early simulations of G2 modeled the cloud as a simple, non-magnetic fluid. In these simulations, the cloud disrupts rapidly due to *Kelvin-Helmholtz instabilities*.

We performed magnetohydrodynamic (MHD) simulations and found a striking result: even *weak magnetic fields* can stabilize the cloud, suppressing its disruption and extending its lifetime. This helps explain why G2 remained intact longer than expected—and reduces the need to revise estimates of gas density in the galactic center.

Using G2 to Probe the Galactic Center

While much attention focused on G2's potential for fueling the black hole, it also acts as a *test particle:* its trajectory encodes information about the *rotation, density, and magnetic field* of the background gas.

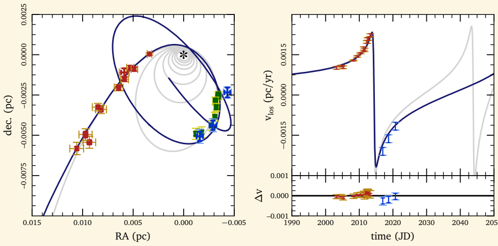
We developed a dynamical model that accounts for:

- *Magnetically enhanced drag,* acting between the cloud and the rotating medium
- *Orbital precession,* as the plane of G2's orbit twists to align with the accretion flow
- The cloud's evolution across *multiple pericenter passages*

Our model explains not only G2's orbit, but also that of a similar cloud, *G1*, which shares its trajectory but shows more orbital decay—consistent with earlier infall and drag.

Observational Constraints and Predictions

We used the G1/G2 system to *fit a dynamical model* of cloud evolution in a rotating, magnetized background. We used numerical orbital simulations, with Markov-Chain Monte Carlo to constrain our model parameters.



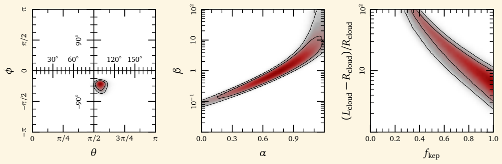
Though it looks slightly crazy, this orbit is in fact entirely consistent with the observations, both in the plane of the sky, and along the line of sight. ***This model does just as well as fitting G1 and G2 with two unrelated Keplerian orbits***.

Constraining Galactic Center Parameters

By comparing with to astrometry and spectroscopy, we inferred *probability distributions* for six key parameters:

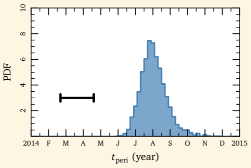
- *Rotation axis* of the galactic center accretion flow
- *Magnetic field strength* and *density profile* (degenerate with each other)
- *Shape of the cloud*
- *Rotation profile* of the background gas

Our model matches the full 3D orbit and velocity evolution of both G1 and G2—including the *twisting of the orbital plane* and the observed *orbital energy difference* between the clouds.



We find that the ***rotation axis is tightly constrained***—a prediction that can be tested by *upcoming EHT observations*. Other parameters remain degenerate, but could be constrained with independent measurements (e. g., magnetic field strength via polarization).

What's Next?



Our model predicts a delay in G2's closest approach to the black hole, after most of the observing campaigns monitoring G2 ended, but *consistent with flaring activity observed in late 2014*. This work provides a framework for using future infalling clouds to *map the hidden structure* of the galactic center and to test theories of black hole accretion.

References

McCourt et al. (2015), McCourt & Madigan (2016), Madigan, McCourt, & O'Leary (2017)