

# IllinoisGRMHD: A Compact, Dynamic-Spacetime General Relativistic Magnetohydrodynamics Code for Easy User Adoption

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## Abstract

**IllinoisGRMHD** solves the equations of General Relativistic MagnetoHydroDynamics (GRMHD) using a high-resolution shock capturing scheme. It is a rewrite of the Illinois Numerical Relativity (ILNR) group's GRMHD code, and generates results that agree to roundoff error with that original code. Its feature set coincides with the features of the ILNR group's recent code (ca. 2009–2014), which was used in their modeling of the following systems:

1. Magnetized circumbinary disk accretion onto binary black holes
2. Magnetized black hole–neutron star mergers
3. Magnetized Bondi flow, Bondi-Hoyle-Littleton accretion
4. White dwarf–neutron star mergers

**IllinoisGRMHD** is particularly good at modeling GRMHD flows into black holes without the need for excision. Its HARM-based conservative-to-primitive solver has also been modified to check the physicality of conservative variables prior to primitive inversion, and move them into the physical range if they become unphysical.

## 1 Introduction

Currently **IllinoisGRMHD** consists of

1. the Piecewise Parabolic Method (PPM) for reconstruction,
2. the Harten, Lax, van Leer (HLL/HLLE) approximate Riemann solver, and
3. a modified HARM Conservative-to-Primitive solver (see REQUIRED CITATION #2 below).

**IllinoisGRMHD** evolves the vector potential  $A_\mu$  (on staggered grids) instead of the magnetic fields ( $B^i$ ) directly, to guarantee that the magnetic fields will remain divergenceless even at AMR boundaries. On uniform resolution grids, this vector potential formulation produces results equivalent to those generated using the standard, staggered flux-CT scheme. This scheme is based on that of Del Zanna (2003, see below OPTIONAL CITATION #1).

For further information about motivations, basic equations, how **IllinoisGRMHD** works, as well as basic code test results, please see the **IllinoisGRMHD** code announcement paper, at

<http://arxiv.org/abs/1501.07276>. If you use IllinoisGRMHD for your research, you are asked to include the REQUIRED CITATIONS listed below in your citations.

For a quick “Guide to Getting Started”, please visit the IllinoisGRMHD web page:  
<http://math.wvu.edu/~zeticienne/ILGRMHD/>

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REQUIRED CITATIONS:

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1. IllinoisGRMHD code announcement paper: Class. Quantum Grav. 32 (2015) 175009,  
(<http://arxiv.org/abs/1501.07276>)
2. Noble, S. C., Gammie, C. F., McKinney, J. C., & Del Zanna, L. 2006, Astrophysical Journal, 641, 626.

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OPTIONAL CITATIONS:

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1. Del Zanna, Bucciantini & Londrillo A&A 400, 397 (2003)

## 2 Acknowledgements

Note that IllinoisGRMHD is based on the GRMHD code of the Illinois Numerical Relativity group (ca. 2014), written by Matt Duez, Yuk Tung Liu, and Branson Stephens (original version), and then developed primarily by Zachariah Etienne, Yuk Tung Liu, and Vasileios Paschalidis.