Vassilios Mewes

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Computational physicist with 9 years of experience using HPC to numerically solve coupled multiphysics (gravity and magnetohydrodynamics) partial differential equations in the field of computational relativistic astrophysics and numerical relativity. I have developed algorithms and code and to numerically solve hyperbolic partial differential equations using high order finite difference and finite volume methods with high resolution shock capturing in the presence of coordinate singularities. My current work involves code development for hardware accelerated neutrino radiation hydrodynamics for supernova simulations in the ExaStar project within the ECP. I am also the lead developer of `SphericalNR`, the first framework that numerically solves a hyperbolic reformulation of the Einstein equations coupled to ideal general relativistic magnetohydrodynamics in spherical coordinates without symmetry assumptions. Experience in building, debugging, profiling and running MPI/OpenMP parallelized computational relativistic astrophysics codes on HPC systems as well as managing, analyzing, and visualizing the resulting large simulation datasets. I have assisted students and postdocs in various collaborations with the compilation and usage of the publicly available `Einstein Toolkit` on a variety of HPC systems, as well as providing them with help for code development for the `Einstein Toolkit`.

Research Experience

May 2021 – **Computational Scientist, Multi-Messenger Astrophysics**

Advanced Computing for Nuclear, Particle, and Astrophysics Group
National Center for Computational Sciences
Oak Ridge National Laboratory, USA

- Serving as a liaison between the National Center for Computational Sciences and the users of National Center for Computational Sciences computing resources and relevant National Center for Computational Sciences vendor partners.
- Code development for the `weaklib` and `thornado` codes as part of the ExaStar project in the Exascale Computing Project.

Sept. 2019 – May 2021 **Postdoctoral Research Associate in Computational Astrophysics**

Advanced Computing for Nuclear, Particle, and Astrophysics Group
National Center for Computational Sciences
Oak Ridge National Laboratory, USA
Mentor: Dr. O. E. Bronson Messer

- Developing hardware accelerated code to include nucleon-nucleon Bremsstrahlung opacities in the `thornado` code for neutrino radiation hydrodynamics using OpenMP/OpenACC offloading, as well as code development for the `weaklib` code as part of the ExaStar project in the Exascale Computing Project.
- Developing a double FFT-filter algorithm to alleviate the severe Courant–Friedrichs–Lewy restriction when solving hyperbolic PDEs in spherical coordinates in the `SphericalNR` framework. Performed first binary neutron star simulation with prompt collapse to a black hole in spherical coordinates using filtering.

Sept. 2016 – Aug. 2019 **Postdoctoral Research Associate**

Center for Computational Relativity and Gravitation
Rochester Institute of Technology, USA
Mentor: Prof. Manuela Campanelli

- Lead developer of `SphericalNR`, the first framework for numerically solving a hyperbolic formulation of the Einstein equations coupled to ideal general relativistic magnetohydrodynamics in spherical coordinates without symmetry assumptions, enabling the use of spherical coordinates in the publicly available `Einstein Toolkit`. Numerical method solves hyperbolic PDEs using finite difference and finite volume methods in the presence of coordinate singularities. Hybrid MPI/OpenMP parallelization making use of the infrastructure in the Einstein Toolkit. Developed algorithm using hyperslabbing to use internal parity boundary conditions with arbitrary domain decomposition.
- Part of collaboration performing first of its kind general relativistic magnetohydrodynamics simulations of circumbinary and mini-disk dynamics and predicting their electromagnetic signatures. Performed a significant part of the central simulation on the Bluewaters system at the National Center for Supercomputing Applications (approx. 3M node hours) and was involved in the analysis of the simulation data. Contributed to finding of key results by performing time series analysis of mini-disk mass evolution to establish quasi-periodic behavior in binary black hole mini-disks. The work of the collaboration was featured in a NASA press release.

Aug. 2011 – Jul. 2016 **PhD studies in Computational Relativistic Astrophysics**

Departamento de Astronomía y Astrofísica
Universitat de València, Spain
Advisors: Prof. J. A. Font and Dr. P. J. Montero

- Performed large parameter study of the first general relativistic hydrodynamics simulations of tilted accretion tori with a fully dynamical spacetime evolution using the `Einstein Toolkit`. Simulations were performed on the Hydra HPC system at the Max Planck Computing and Data Facility in Garching (Germany), the Loewe cluster at Goethe University Frankfurt (Germany) and the LluisVives cluster at the Universitat de València (Spain).
- Used tracer particles as a complementary analysis and visualization tool in this type of simulations.
- Code development to read black hole-torus initial data into the `Einstein Toolkit`, development of comprehensive disk analysis routines, both within the `Einstein Toolkit` and using Python to analyze tracer data in HDF5 format.

Oct. 2009 – Jun. 2010 **Natural Sciences Part III Research Project**

University of Cambridge, United Kingdom
Supervisor: Dr. S. Schirmer

- `Matlab` simulations of the control and the dynamics of quantum systems like lambda-systems and spin chains using reservoir assisted control schemes.

Education

Aug. 2011 – Jul. 2016 **PhD in Computational Relativistic Astrophysics**

Universitat de València, Spain
Dissertation: "Numerical relativity simulations of tilted black hole-torus systems"
Advisors: Prof. J. A. Font and Dr. P. J. Montero
Committee: José María Ibáñez (chair), Frédéric Daigne, and Ewald Müller

Oct. 2006 – Jun. 2010 **Master of Natural Sciences**

University of Cambridge, United Kingdom
Natural Sciences Tripos - Physical Sciences

Publications

[1] F. G. Lopez Armengol, L. Combi, M. Campanelli, S. C. Noble, J. H. Krolik, D. B. Bowen, M. J. Avara, **V. Mewes**, and H. Nakano, "Circumbinary Disk Accretion into Spinning Black Hole Binaries," Astrophys. J. **913**, 16 (2021), arXiv:2102.00243 [astro-ph.HE]

[2] **V. Mewes**, Y. Zlochower, M. Campanelli, T. W. Baumgarte, Z. B. Etienne, F. G. Lopez Armengol, and F. Cipolletta, "Numerical relativity in spherical coordinates: A new dynamical spacetime and general relativistic MHD evolution framework for the Einstein Toolkit," Phys. Rev. D **101**, 104007 (2020), arXiv:2002.06225 [gr-qc]

[3] A. del Rio, N. Sanchis-Gual, **V. Mewes**, I. Agullo, J. A. Font, and J. Navarro-Salas, "Spontaneous creation of circularly polarized photons in chiral astrophysical systems," Phys. Rev. Lett. **124**, 211301 (2020), arXiv:2002.01593

[4] D. B. Bowen, M. Avara, **V. Mewes**, Y. Zlochower, S. C. Noble, M. Campanelli, H. Shiokawa, R. M. Cheng, and J. H. Krolik, "PatchworkWave: A Multipatch Infrastructure for Multiphysics/Multiscale/Multiframe/Multimethod Simulations at Arbitrary Order," (2020), arXiv:2002.00088

[5] J. F. Mahlmann, M. A. Aloy, **V. Mewes**, and P. Cerdá-Durán, "Computational General Relativistic Force-Free Electrodynamics: I. Multi-Coordinate Implementation and Testing," Astron. Astrophys. **647**, A57 (2021), arXiv:2007.06580 [physics.comp-ph]

[6] J. F. Mahlmann, M. A. Aloy, **V. Mewes**, and P. Cerdá-Durán, "Computational General Relativistic Force-Free Electrodynamics: II. Characterization of Numerical Diffusivity," Astron. Astrophys. **647**, A58 (2021), arXiv:2007.06599 [physics.comp-ph]

[7] **V. Mewes**, Y. Zlochower, M. Campanelli, I. Ruchlin, Z. B. Etienne, and T. W. Baumgarte, "Numerical relativity in spherical coordinates with the Einstein Toolkit," Phys. Rev. D **97**, 084059 (2018), arXiv:1802.09625

[8] D. B. Bowen, **V. Mewes**, S. C. Noble, M. Avara, M. Campanelli, and J. H. Krolik, "Quasi-Periodicity of Supermassive Binary Black Hole Accretion Approaching Merger," Astrophys. J. **879**, 76 (2019), arXiv:1904.12048

[9] D. B. Bowen, **V. Mewes**, M. Campanelli, S. C. Noble, J. H. Krolik, and M. Zilhão, "Quasi-periodic Behavior of Mini-disks in Binary Black Holes Approaching Merger," Astrophys. J. Letters **853**, L17 (2018), arXiv:1712.05451

[10] D. B. Bowen, M. Campanelli, J. H. Krolik, **V. Mewes**, and S. C. Noble, "Relativistic Dynamics and Mass Exchange in Binary Black Hole Mini-disks," Astrophys. J. **838**, 42 (2017), arXiv:1612.02373

[11] S. d'Ascoli, S. C. Noble, D. B. Bowen, M. Campanelli, J. H. Krolik, and **V. Mewes**, "Electromagnetic emission from supermassive binary black holes approaching merger," Astrophys. J. **865**, 140 (2018), arXiv:1806.05697

[12] **V. Mewes**, J. A. Font, F. Galeazzi, P. J. Montero, and N. Stergioulas, "Numerical relativity simulations of thick accretion disks around tilted Kerr black holes," Phys. Rev. D **93**, 064055 (2016), arXiv:1506.04056

[13] **V. Mewes**, P. J. Montero, N. Stergioulas, F. Galeazzi, and J. A. Font, "General Relativistic Simulations of Accretion Disks Around Tilted Kerr Black Holes," Astrophys. Space Sci. Proc. **40**, 121–127 (2015), Springer International Publishing Cham

[14] **V. Mewes**, F. Galeazzi, J. A. Font, P. J. Montero, and N. Stergioulas, "On the dynamics of tilted black hole-torus systems," Mon. Not. R. Astron. Soc. **461**, 2480 (2016), arXiv:1605.02629

[15] **V. Mewes**, J. A. Font, and P. J. Montero, "Measuring the black hole spin direction in 3D Cartesian numerical relativity simulations," Phys. Rev. D **91**, 124043 (2015), arXiv:1505.07225

[16] N. Sanchis-Gual, J. C. Degollado, P. J. Montero, J. A. Font, and **V. Mewes**, "Quasistationary solutions of self-gravitating scalar fields around collapsing stars," Phys. Rev. D **92**, 083001 (2015), arXiv:1507.08437

[17] J. E. Adsuara, I. Cordero-Carrión, P. Cerdá-Durán, **V. Mewes**, and M. A. Aloy, "On the equivalence between the Scheduled Relaxation Jacobi method and Richardson's non-stationary method," J. Comput. Phys. **332**, 446 (2017), arXiv:1607.03712

Invited Talks/Presentations

1. *Towards realistic post-merger simulations of binary neutron stars with SphericalNR*
   TAPIR **Seminar**, California Institute of Technology, Pasadena, CA, USA, January 15, 2021

2. *Multi-messenger Astrophysics in the Upcoming Era of Exascale Computing*
   Seminar, Advanced Computing for Nuclear, Particles, & Astrophysics Group, Oak Ridge National Laboratory, TN, USA, January 14, 2021

3. *Developing and Using Code for HPC: Towards Efficient Binary Neutron Star Simulations in Spherical Coordinates with SphericalNR*
   Seminar, User Assistance – Pre-Production Systems Group, Oak Ridge National Laboratory, TN, USA, December 17, 2020

4. *Towards realistic BNS simulations in spherical coordinates with SphericalNR*
   Seminar, Strong Gravity Group, Perimeter Institute for Theoretical Physics, Waterloo, ON, Canada, December 16, 2020

5. *SphericalNR: A Dynamical Spacetime and GRMHD Evolution Framework in Spherical Coordinates with the Einstein Toolkit*
   High Energy Physics/Astrophysics **Seminar**, University of Tennessee, Knoxville, TN, USA, January 29, 2020

6. *SphericalNR: A Dynamical Spacetime and GRMHD Evolution Framework in Spherical Coordinates with the Einstein Toolkit*
Seminar, Computational and Applied Mathematics Group, Oak Ridge National Laboratory, TN, USA, January 16, 2020

7. *SphericalNR: numerical relativity in spherical coordinates with the Einstein Toolkit*
Seminar, Computational Relativistic Astrophysics group, Max Planck Institute for Gravitational Physics, Potsdam, Germany, April 09, 2019

8. *Addressing computational challenges in numerical relativity with SphericalNR: Black holes, accretion disks, and more in topologically spherical coordinates*
CTA **Seminar**, Center for Theoretical Astrophysics, Los Alamos National Laboratory, NM, USA, September 13, 2018

9. *SphericalNR: highly accurate numerical relativity in topologically spherical coordinates with the Einstein Toolkit*
CNLS **Seminar**, Center for Nonlinear Studies, Los Alamos National Laboratory, NM, USA, September 11, 2018

10. *Numerical relativity in the multi-messenger astronomy era*
Gravitational waves **Seminar** at Nikhef, Amsterdam, Netherlands, July 27, 2018

11. *Numerical relativity in the multi-messenger astronomy era*
Gravity and Field Theory **Seminar** at Institute for Nuclear Sciences, Autonomous University of Mexico, June 21, 2018

12. *Numerical relativity in spherical coordinates with the Einstein Toolkit*
Seminar at Universidad del Valle, Cali, Valle del Cauca, Colombia, April 04, 2018

13. *Numerical relativity simulations of BBH coalescence using the Einstein Toolkit*
Two day lecture series at Universitat de València, València, Spain, July 06, 2016

14. *Numerical relativity simulations of thick accretion disks around tilted Kerr black holes*
Seminar at Relativistic Astrophysics Group, Institute of Theoretical Physics, Goethe University, Frankfurt, Germany, April 15, 2015

Contributed Talks/Presentations

1. *SphericalNR: Numerical relativity in spherical coordinates with the Einstein Toolkit*
Conference talk, GR22 and Amaldi13, Valencia, Spain, July 10, 2019

2. *SphericalNR: Numerical relativity in spherical coordinates with the Einstein Toolkit*
Conference talk, North American Einstein Toolkit workshop 2019, RIT, Rochester, NY, USA, June 14, 2019

3. *Binary neutron star merger models*
Panel discussion, PAX III meeting, Penn State, PA, USA, February 05, 2018

4. *Relativistic dynamics of binary black hole mini-disks*
Conference talk, CoCoNut Meeting, València, Spain, December 14, 2016

5. *Numerical relativity simulations of tilted black hole-torus systems*
Conference talk, Midwest Relativity Meeting, Perimeter Institute, Waterloo, ON, Canada, October 14, 2016

6. *Measuring spin magnitude and direction in 3D GRHD simulations on Cartesian grids*
Conference talk, CoCoNut Meeting, València, Spain, November 26, 2014

7. *General relativistic simulations of tilted self-gravitating accretion disks around Kerr black holes*
Conference talk, ERE, València, Spain, September 01, 2014

8. *General relativistic simulations of tilted self-gravitating accretion disks around Kerr black holes*
Conference talk, Sant Cugat Forum on Astrophysics, Sant Cugat, Spain, April 24, 2014

9. *General relativistic simulations of tilted self-gravitating accretion disks around Kerr black holes*
Conference talk, Iberian Gravitational Wave Meeting, Granada, Spain, February 28, 2014

10. *General relativistic simulations of thick self-gravitating accretion disks around black holes*
Conference talk, ERE, Benasque, Spain, September 10, 2013

Teaching

2014/2015 — **Universitat de València**, Spain
- Teaching assistant for Mathematics II in Engineering Studies, an undergraduate course averaging 60 students per semester.
- Taught part of the course (in Spanish), designed and graded part of the exams.
- Responsible for practical `Mathematica` labs and their grading.
- 6 ECTS credits.

2013/2014 — **Universitat de València**, Spain
- Teaching assistant for Mathematics II in Engineering Studies, an undergraduate course averaging 60 students per semester.
- Responsible for practical `Mathematica` labs and their grading.
- 4 ECTS credits.

Mentoring

2018-2020 — Jens Mahlmann, PhD student at the Universitat de València, Spain
- Providing user assistance for the `Einstein Toolkit` in his development of a general relativistic force-free electrodynamics code.
- First external user of `SphericalNR`, provided pre-release code and support using the framework for the project.

2020 - — Federico Cipolletta, Postdoc at Rochester Institute of Technology, USA
- Using `SphericalNR` in large science project.
- Providing support and help for the use of and development for the `SphericalNR` framework.

Professional Development

June 17-19 2018 — **North American Einstein Toolkit Workshop**
Rochester Institute of Technology, Rochester, USA

June 18-20 2017 — **North American Einstein Toolkit Workshop**
Georgia Tech, Atlanta, USA

August 11-14 2015 — **Einstein Toolkit Workshop**
NORDITA, Stockholm, Sweden

Synergistic Activities

- **Scientific Organizing Committee**, 2017 North American Einstein Toolkit School and Workshop at NCSA.
- **Peer-reviewed articles** for: Astrophysical Journal Letters, Monthly Notices of the Royal Astronomical Society Letters, Classical and Quantum Gravity, General Relativity and Gravitation, and ORNL internal manuscript review.
- **Peer-reviewed proposals** for: DOE Office of Science 2020 ASCR Leadership Computing Challenge Postal Review, OLCF Director's Discretion Project Applications, and 2021 INCITE Computational Readiness Review.
- **Junior mentor** at the 2020 OLCF GPU Hackathon, working with the Nimrod team.

Technical Skills

Programming Languages	C/C++, Python, Fortran, Shell Scripting.
Computational Physics	Numerically solving hyperbolic and elliptic partial differential equations, computational fluid dynamics in the presence of coordinate singularities, finite volume/difference methods, high resolution shock-capturing methods, root finding, interpolation, nonlinear data fitting, time series analysis.
Scientific Code Development	Main developer of `SphericalNR`, a dynamical spacetime and general relativistic magnetohydrodynamics evolution framework in spherical coordinates for the `Einstein Toolkit`, featuring MPI-parallelized internal boundary conditions for spherical coordinates. Developed double FFT-filtering technique to alleviate severe CFL-restriction when solving hyperbolic partial differential equations via finite difference or finite volume methods in spherical coordinates. Analysis modules for general relativistic hydrodynamics simulations with the `Einstein Toolkit`.
High Performance Computing	OpenMP and MPI parallelization. Compiling, debugging, and running scientific codes on HPC systems. Analyzing and post-processing terabyte scale data sets from simulations on HPC systems, using grid based data as well as tracer particles.
Visualization	Visualization of simulation data with `VisIt`, featured in Phys. Rev. D Kaleidoscopes, Matplotlib, Gnuplot.
Tools	OpenMP, MPI, HDF5, Make, gdb, Linux/Unix, Windows, Mac OS X, git, mercurial, `Mathematica`, `Matlab`.

Honors and Awards

July 2016	**PhD thesis** Awarded cum laude honors.
2011 - 2015	**Spanish Ministry of Science and Innovation predoctoral fellowship** FPI-MICINN grant awarded by the Spanish government for 4 years to pursue my PhD studies at the Universitat de València, Spain.

Outreach

2017	**Imagine RIT**, Rochester, USA Annual public event at Rochester Institute of Technology, participated as exhibitor for Center of Computational Relativity and Gravitation, engaging the public in gravitational wave science. Showcased visualization from our simulations.

Languages

German	native proficiency
English	full professional proficiency
Spanish	professional working proficiency