Joonas Nättilä

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Born: June 25th, 1989, Finland
Nationality: Finnish citizen
Languages: Finnish (native), English, Swedish

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Research interests

High-energy astrophysics: Energization of accretion flows around black holes; fluid dynamics of thermonuclear X-ray bursts; radiative plasma physics of magnetar giant bursts and FRBs; electromagnetic precursors of neutron star mergers; pulsar magnetospheres and radio emission.
Plasma physics: Turbulence in magnetically-dominated plasmas; collisionless shocks; magnetic reconnection.
Fluid dynamics: Storm dynamics of exoplanet atmospheres.
Nuclear physics: Constraining equation of state of ultra-dense matter inside neutron stars.
Computer sciences: High-performance computing; parallelization techniques; machine learning; Monte Carlo methods.
Mathematics: Cellular automata models

Education & Employment

2019–2023	**Joint Columbia/Flatiron Research Fellow**, Columbia University & Flatiron Institute, USA. Mentors (Columbia; 2019-2021): Andrei Beloborodov, Lorenzo Sironi Mentors (CCA; 2021-2023): James Cho, Yuri, Levin, Sasha Philippov
2018–2019	**Nordita Fellow**, Nordita (Nordic Institute for Theoretical Physics), Sweden. Mentor: Axel Brandenburg
2014–2017	**Ph.D. in Astrophysics (with honours)**, University of Turku, Finland. Supervisors: Juri Poutanen, Jari Kajava
2012–2013	**M.Sc. in Astronomy**, University of Oulu, Finland.
2008–2012	**B.Sc. in Physics**, University of Oulu, Finland.

Awards & Recognitions

2022	Cover of *Phys. Rev. Letter* (vol. 128, issue 7), *Editor's Suggestion*, and *Viewpoint* article in APS.
2021	Mikael Björnberg Memorial Fund Prize for Young Theoretical Physicist; 10 000 Eur
2019	Joint Princeton/Flatiron Postdoctoral Research Fellowship, Princeton University (*Declined*)
2018	Turku Finnish University Society Prize for best doctoral dissertation
2018	Väisälä Prize 2018: Prize for outstanding thesis in Astronomy
2018	PCS Best Doctoral Thesis of 2017 Prize
2016	Nordita Visiting Ph.D. Fellow

Presentations & Talks

In total 2 colloquium, 19 invited, 27 contributed talks. Most recent ones include:

2022	***Colloquium:***, Brandeis University, USA.
2022	***Invited***: ECT Workshop on "*Neutron stars as multimessenger laboratories*", Trento, Italy.
2022	***Invited***: Nordita Program on "*Magnetic field evolution*", Stockholm, Sweden.
2022	Purdue Plasma 2022 meeting, Purdue, USA.
2022	***Invited***: Nordita Astrophysics Seminar, Nordita, Stockholm, Sweden.
2022	Stars & Compact Object meeting, Flatiron Institute, USA.
2022	CCA Lunch talk, Flatiron Institute, New York, USA.
2021	Frontiers in Relativistic Astrophysics, Flatiron Institute, New York, USA.
2021	***Invited:*** MIAPP Program on "*High Energy Plasma Phenomena*", Munich, Germany.

Teaching

2021	**Lecturer, Nordita Winter School, Waves in Astrophysics**, Nordita, Sweden. lecturer on "Numerical methods for collisionless plasmas".
2019	**Visiting Lecturer, Computational fluid dynamics course**, Columbia University, USA. Visiting lecturer on "Collisionless plasma simulations".
2015—2019 (5 times)	**Lecturer, High Performance Computing Summer School**, CSC, Finland. Lecturer & tutor for Finnish IT Center for Science HPC Summer School.
2018, 2019 (2 times)	**Lecturer, Introduction to Julia**, CSC, Finland. Lecturer for an introductory course on the Julia programming language.
2015—2017 (3 times)	**Lecturer, Software tools in Physics**, University of Turku, Finland. Lecturer of the "Introduction to Unix" section of the course (3 ECTS).

In addition, teaching assistant in **Optics** (2016; 6 ECTS) in Univ. Turku, and **Thermophysics** (3 times, 2011—2013; 6 ECTS), **Electricity and Magnetism** (2012; 4 ECTS), **Laboratory Exercises in Physics 1** (2 times, 2011—2012; 3 ECTS), **Mathematics of Physics** (2011; 6 ECTS), and **Waveforms and Optics** (2 times, 2011; 6 ECTS) in Univ. Oulu.

Mentoring & Supervision

2017–2020	**Tuomo Salmi**, PhD. student, University of Turku, Finland. PhD. co-supervisor: Neutron star mass and radius constraints from pulse profile modeling.
2019	**John Hope**, M.Sc. student, University of Bath, United Kingdom. M.Sc. thesis supervisor: PIC simulations of collisionless shocks across different magnetizations.
2015–2017	**Jere Kuuttila**, co-supervisor for M.Sc. thesis, University of Turku, Finland.
2015–2016	**Tuomo Salmi**, co-supervisor for M.Sc. thesis, University of Turku, Finland.
2014–2015	**Jere Kuuttila**, co-supervisor for B.Sc. thesis, University of Turku, Finland.

In addition, Nordita host for visiting PhD. students: **M. Bussov**, Dec. 2019; **K. Smedt**, Nov. 2019; **T. Salmi**, May 2019.

Funding

Research

2020	$\sim$ **60 000 Eur Wenner-Gren grant, Co-I**: "Reconnection, Radio observations, and switchbacks" (PI: D. Mitra)
2020	$\sim$ **300 000 USD NASA ATP Grant, Co-I**: "Thermal and non-thermal emission in galaxy clusters: a first-principles approach" (PI: L. Sironi)
2016	$\sim$ **2 000 Eur Magnus Ehrnrooth Foundation** (travel grant)
2015–2017	$\sim$ **82 000 Eur UTUGS Physical and Chemical Sciences Ph.D. scholarship** "Constraining neutron star mass and radius"
2015–2016	**23 000 Eur Väisälä Foundation grant, PI** (1 yr PhD scholarship) "Magnetar atmosphere models" (*Declined*)
2014–2015	**23 000 Eur Väisälä Foundation grant, PI** (1 yr PhD scholarship) "Magnetar atmosphere models: breaking the barrier between observations and theory"

+ Some smaller travel grants (in total $\sim$ 10k Eur).

Supercomputer time

2021	$\sim$ **22M CPUh SNIC/Beskow**, **Co-PI**: Astrophysical turbulence and dynamo action
2020	$\sim$ **22M CPUh SNIC/Beskow/Kebnekaise**, **Co-PI**: Astrophysical turbulence and dynamo action
2019	$\sim$ **22M CPUh SNIC/Beskow/Kebnekaise**, **Co-PI**: Astrophysical turbulence and dynamo action
2018	$\sim$ **60k CPUh SNIC/Kebnekaise**, **PI**: Relativistic plasma in silico (testing of Runko).

September 30, 2022

Professional Societies and Services

Memberships:

2021–	Member of "Open Science" Working Group (under Young Academy Global)
2019–	Member of Young Academy Finland (under Finnish Academy of Sciences and Letters)
2018–	IAU Junior member
2016–	eXTP Dense Matter science working group
2015–2018	ESA XIPE satellite Science Team (SWG2.2 Accreting Millisecond Pulsars)
2013–2019	Member of JuliaLang organization (Open source community for Julia programming language)
2012–	Member of Finnish Astronomical Society

Organizer/convenor/active participant:

2021–	Convenor for CCA lecture series on "Observational High-energy Astrophysics"
2021	Panelist for discussion session on "Open Science" (organized by YAF)
2017	Organizer & Convener for CompCoffee meetings (weekly gatherings to discuss computational problems)
2014–	Member of organizing committee for CSC HPC Summer Schools

In addition, referee for PRL, ApJL, ApJS, ApJ, A&A, MNRAS, PRD, PRE, EPJA, and Universe.

Conference organization

2022	**Dynamics of Coherent Structures in Astro-Geo-Turbulence**, Flatiron Institute, New York, USA. Main organizer & convenor of a 4-day, $\sim$ 20 ppl conference
2022	**Flatiron Exoplanet Symposium**, Flatiron Institute, New York, USA. Main organizer & convenor of a 5-day symposium, $\sim$ 50 ppl symposium
2022	**Physics of Exoplanet Atmospheres**, Flatiron Institute, New York, USA. Main organizer & convenor of a 4-day symposium, $\sim$ 10 ppl symposium
2022	**PCTS Workshop**: "Weather and Climate on Neutron Stars", Princeton University, USA. Organizer of a 4-day symposium, $\sim$ 40 ppl symposium
2021	**Frontiers in Relativistic Turbulence**, Flatiron Institute, New York, USA. Main organizer & convenor of a 2-day, $\sim$ 20 ppl conference
2017	**Nordita Workshop: Exascale thinking of particle energization problems**, Stockholm, Sweden. Member of the scientific and local organizing committee for a 5-day, $\sim$ 25ppl conference.
2015	**Workshop on Relativistic Astrophysics**, Kavalto, Finland. Member of the local organizing committee for a 5-day, $\sim$ 15 ppl conference.
2015	**Physical/Chemical Sciences Annual Seminar day**, University of Turku, Finland. Chairman & member of the organizing committee for a 1-day, $\sim$ 100 ppl seminar.

Public outreach

2020—	**Responses/commentaries on newspapers and popular science magazine Q&A sections**, "How is it possible that neutron stars have magnetic field?" Tähdet & Avaruus Sep. 2020 issue. "What happens to neutron star matter outside the star?" Tähdet & Avaruus Oct. 2020 issue. "Do neutron stars reflect light?" Lasten tiedepalsta (Children's science column), HS, 6th of Jan, 2021.
2020	**Appearance on "Meet the scientist"**: Educational science video on "Gravitation". Popular science video targeted for high school students, youtube.com/watch?v=Ch38VpF341I
2019	**Academy Club for Young Scientist**: Public science talk. Astrophysical turbulence: from stirring coffee to mixing galaxies; youtube.com/watch?v=W7ljVlSEAX4
2019—2020	**On the possibility of quark matter cores in neutron star**, Annala et al. (2020), Nature Astronomy Incl.: Astrobites, Universe Today, Physics World, Wikipedia on QCD matter, Tähdet & Avaruus 4/2019
2019	**Twitter AMA on scientists abroad** In part of TimeoutDialogue/Erätauko society.
2018	**Personal profile** on Tähdet & Avaruus Finnish science magazine. Tähdet & Avaruus Feb 2018 issue.
2017	**Groundbreaking new neutron star radius measurement** (Nättilä et al. 2017) Incl.: Cosmos 27.11.2017, Phys.org. Tähdet & Avaruus (25.11.2017), Turkulainen (10.11.2017), Turun Sanomat (10.11.2017), Aamuset (8.12.2017), Tekniikka & Talous (8.12.2017), Verkkouutiset (8.12.2017)

Publications — Joonas Nättilä

31 refereed publications; incl. *Nature Physics* (1), *PRL/PRX* (4).
In total 1073 citations since 2014; h-index 17, g-index 32, i10-index 29, i100-index 3 (ADS).

Peer-reviewed scientific articles

[31] **J. Nättilä** and A. M. Beloborodov. Heating of Magnetically Dominated Plasma by Alfvén-Wave Turbulence. *Phys. Rev. Lett.*, 128(7):075101, February 2022, [arXiv:2111.15578].

[30] K. Smedt, D. Ruprecht, J. Niesen, S. Tobias, and **J. Nättilä**. New applications for the Boris Spectral Deferred Correction algorithm for plasma simulations. *BIT (Submitted)*, page arXiv:2110.08024, October 2021, [arXiv:2110.08024].

[29] M. Bussov and **J. Nättilä**. Segmentation of turbulent computational fluid dynamics simulations with unsupervised ensemble learning. *Signal Processing: Image Communication*, 99:116450, September 2021, [arXiv:2109.01381].

[28] L. Sironi, I. Plotnikov, **J. Nättilä**, and A. M. Beloborodov. Coherent Electromagnetic Emission from Relativistic Magnetized Shocks. *Phys. Rev. Lett.*, 127(3):035101, July 2021, [arXiv:2107.01211].

[27] E. Annala, T. Gorda, E. Katerini, A. Kurkela, **J. Nättilä**, V. Paschalidis, and A. Vuorinen. Multimessenger constraints for ultra-dense matter. *PRX*, May 2021, [arXiv:2105.05132].

[26] E. Sobacchi, **J. Nättilä**, and L. Sironi. A fully kinetic model for orphan gamma-ray flares in blazars. *MNRAS*, 503(1):688–693, May 2021, [arXiv:2102.11770].

[25] **J. Nättilä** and A. M. Beloborodov. Radiative Turbulent Flares in Magnetically Dominated Plasmas. *ApJ*, 921(1):87, November 2021, [arXiv:2012.03043].

[24] M. Al-Mamun, A. W. Steiner, **J. Nättilä**, J. Lange, R. O'Shaughnessy, I. Tews, S. Gandolfi, C. Heinke, and S. Han. Combining Electromagnetic and Gravitational-Wave Constraints on Neutron-Star Masses and Radii. *Phys. Rev. Lett.*, August 2020, [arXiv:2008.12817].

[23] V. Loktev, T. Salmi, **J. Nättilä**, and J. Poutanen. Oblate Schwarzschild approximation for polarized radiation from rapidly rotating neutron stars. *A&A*, 643:A84, November 2020, [arXiv:2009.08852].

[22] T. Salmi, V. F. Suleimanov, **J. Nättilä**, and J. Poutanen. Magnetospheric return-current-heated atmospheres of rotation-powered millisecond pulsars. *A&A*, 641:A15, September 2020, [arXiv:2002.11427].

[21] E. Annala, T. Gorda, A. Kurkela, **J. Nättilä**, and A. Vuorinen. Evidence for quark-matter cores in massive neutron stars. *Nature Physics*, 16(9):907–910, June 2020, [arXiv:1903.09121].

[20] P. Abolmasov, **J. Nättilä**, and J Poutanen. Kilohertz quasi-periodic oscillations from neutron star spreading layers. *A&A*, 638:A142, June 2020, [arXiv:1910.09906].

[19] A. Veledina, **J. Nättilä**, and A. M. Beloborodov. Pulsar Wind-heated Accretion Disk and the Origin of Modes in Transitional Millisecond Pulsar PSR J1023+0038. *ApJ*, 884(2):144, October 2019, [arXiv:1906.02519].

[18] F. Nauman and **J. Nättilä**. Exploring helical dynamos with machine learning: Regularized linear regression outperforms ensemble methods. *A&A*, 629:A89, September 2019, [1905.08193].

[17] **J. Nättilä**. Runko: Modern multiphysics toolbox for plasma simulations. *A&A*, 664:A68, August 2022, [1906.06306].

[16] J. J. M. in't Zand, E. Bozzo, J. Qu, X.-D. Li, L. Amati, Y. Chen, I. Donnarumma, V. Doroshenko, S. A. Drake, and et al. (incl. **J. Nättilä**). Observatory science with eXTP. *Science China Physics, Mechanics, and Astronomy*, 62:29506, February 2019.

[15] A. L. Watts, W. Yu, J. Poutanen, S. Zhang, S. Bhattacharyya, S. Bogdanov, L. Ji, A. Patruno, T. E. Riley, and et al. (incl. **J. Nättilä**). Dense matter with eXTP. *Science China Physics, Mechanics, and Astronomy*, 62:29503, February 2019.

[14] Z. Li, V. F. Suleimanov, J. Poutanen, T. Salmi, M. Falanga, **J. Nättilä**, and R. Xu. Evidence for the Photoionization Absorption Edge in a Photospheric Radius Expansion X-Ray Burst from GRS 1747−312 in Terzan 6. *ApJ*, 866:53, October 2018, [arXiv:1809.00098].

[13] T. Salmi, **J. Nättilä**, and J. Poutanen. Bayesian parameter constraints for neutron star masses and radii using X-ray timing observations of accretion-powered millisecond pulsars. *A&A*, 618:A161, October 2018, [arXiv:1805.01149].

[12] P. Pihajoki, M. Mannerkoski, **J. Nättilä**, and P. H. Johansson. General purpose ray-tracing and polarized radiative transfer in General Relativity. *ApJ*, 863:8, August 2018, [arXiv:1804.04670].

[11] **J. Nättilä** and P. Pihajoki. Radiation from rapidly rotating oblate neutron stars. *A&A*, 615:A50, July 2018, [arXiv:1709.07292].

[10] **J. Nättilä**, M. C. Miller, A. W. Steiner, J. J. E. Kajava, V. F. Suleimanov, and J. Poutanen. Neutron star mass and radius measurements from atmospheric model fits to X-ray burst cooling tail spectra. *A&A*, 608:A31, December 2017, [arXiv:1709.09120].

[9] V. F. Suleimanov, J. J. E. Kajava, S. V. Molkov, **J. Nättilä**, A. A. Lutovinov, K. Werner, and J. Poutanen. Basic parameters of the helium-accreting X-ray bursting neutron star in 4U 1820-30. *MNRAS*, 472:3905–3913, December 2017, [arXiv:1708.09168].

[8] J. J. E. Kajava, K. I. I. Koljonen, **J. Nättilä**, V. Suleimanov, and J. Poutanen. Variable spreading layer in 4U 1608-52 during thermonuclear X-ray bursts in the soft state. *MNRAS*, 472:78–89, November 2017, [arXiv:1707.09479].

[7] J. Kuuttila, J. J. E. Kajava, **J. Nättilä**, S. E. Motta, C. Sánchez-Fernández, E. Kuulkers, A. Cumming, and J. Poutanen. Flux decay during thermonuclear X-ray bursts analysed with the dynamic power-law index method. *A&A*, 604:A77, August 2017, [arXiv:1705.05653].

[6] V. F. Suleimanov, J. Poutanen, **J. Nättilä**, J. J. E. Kajava, M. G. Revnivtsev, and K. Werner. The direct cooling tail method for X-ray burst analysis to constrain neutron star masses and radii. *MNRAS*, 466:906–913, April 2017, [arXiv:1611.09885].

[5] J. J. E. Kajava, **J. Nättilä**, J. Poutanen, A. Cumming, V. Suleimanov, and E. Kuulkers. Detection of burning ashes from thermonuclear X-ray bursts. *MNRAS*, 464:L6–L10, January 2017, [arXiv:1608.06801].

[4] **J. Nättilä**, A. W. Steiner, J. J. E. Kajava, V. F. Suleimanov, and J. Poutanen. Equation of state constraints for the cold dense matter inside neutron stars using the cooling tail method. *A&A*, 591:A25, June 2016, [arXiv:1509.06561].

[3] **J. Nättilä**, V. F. Suleimanov, J. J. E. Kajava, and J. Poutanen. Models of neutron star atmospheres enriched with nuclear burning ashes. *A&A*, 581:A83, September 2015, [arXiv:1507.01525].

[2] J. J. E. Kajava, **J. Nättilä**, O.-M. Latvala, M. Pursiainen, J. Poutanen, V. F. Suleimanov, M. G. Revnivtsev, E. Kuulkers, and D. K. Galloway. The influence of accretion geometry on the spectral evolution during thermonuclear (type I) X-ray bursts. *MNRAS*, 445:4218–4234, December 2014, [arXiv:1406.0322].

[1] J. Poutanen, **J. Nättilä**, J. J. E. Kajava, O.-M. Latvala, D. K. Galloway, E. Kuulkers, and V. F. Suleimanov. The effect of accretion on the measurement of neutron star mass and radius in the low-mass X-ray binary 4U 1608-52. *MNRAS*, 442:3777–3790, August 2014, [arXiv:1405.2663].

Proceedings

[3] S. Bogdanov, et. al (including **J. Nättilä**). Snowmass 2021 Cosmic Frontier White Paper: The Dense Matter Equation of State and QCD Phase Transitions. September, 2022. [arXiv:2209.07412].

[2] E. Annala, T. Gorda, A. Kurkela, **J. Nättilä**, and A. Vuorinen. Constraining the properties of neutron-star matter with observations. In *12th INTEGRAL Conference*, Geneva, Switzerland, 11-15 February 2019 [arXiv:1904.01354].

[1] P. Soffitta, R. Bellazzini, E. Bozzo, V. Burwitz, A. Castro-Tirado, E. Costa, T. Courvoisier, H. Feng, S. Gburek, R. Goosmann, and et al. (incl. **J. Nättilä**) XIPE: the x-ray imaging polarimetry explorer. In *Space Telescopes and Instrumentation 2016: Ultraviolet to Gamma Ray*, volume 9905 of *Proc. SPIE*, page 990515, July 2016. doi.org/10.1117/12.2233046.

Theses

[3] **J. Nättilä**. X-ray bursts as a tool to constrain the equation of state of the ultra-dense matter inside neutron stars. PhD thesis, University of Turku, Finland, 2017. ISBN:978-951-29-7057-5.

[2] **J. Nättilä**. Mass and radius constraints for neutron stars using the cooling tail method. Master's thesis, University of Oulu, Finland, 2013. oulu-201312041966.

[1] **J. Nättilä**. Spectral analysis of X-ray bursts from neutron stars: IGR J1747–2721 (*Neutronitähtien röntgenpurkaukset ja niiden spektrianalyysi: IGR J1747–2721*). Bachelor's thesis, University of Oulu, Finland, 2012.

Open source software

[6] **Runko**, Modern C++14/PYTHON3 toolbox for kinetic plasma simulations. https://github.com/natj/runko

[5] **CORGI**, C++14 grid infrastructure for massively parallel multi-physics simulations. https://github.com/natj/corgi

[4] **mpi4cpp**, User-friendly C++14 MPI headers with template metaprogramming. https://github.com/natj/mpi4cpp

[3] **Bender, ray tracing code**, General relativistic ray tracing code for computing radiation from rapidly rotating oblate neutron stars in JULIA/PYTHON3. https://github.com/natj/bender

[2] **Hydro, modular 2D hydrodynamical code** with unsplitted HLLC Rieman solver, second order Runge-Kutta time-stepping, and linear piecewise reconstruction written in pure JULIA. https://github.com/natj/hydro

[1] **CellularAutomata.jl**, JULIA library for 1/2D elementary and totalistic Cellular automata modeling. https://github.com/natj/CellularAutomata.jl

+ Smaller libraries and software available at https://github.com/natj.