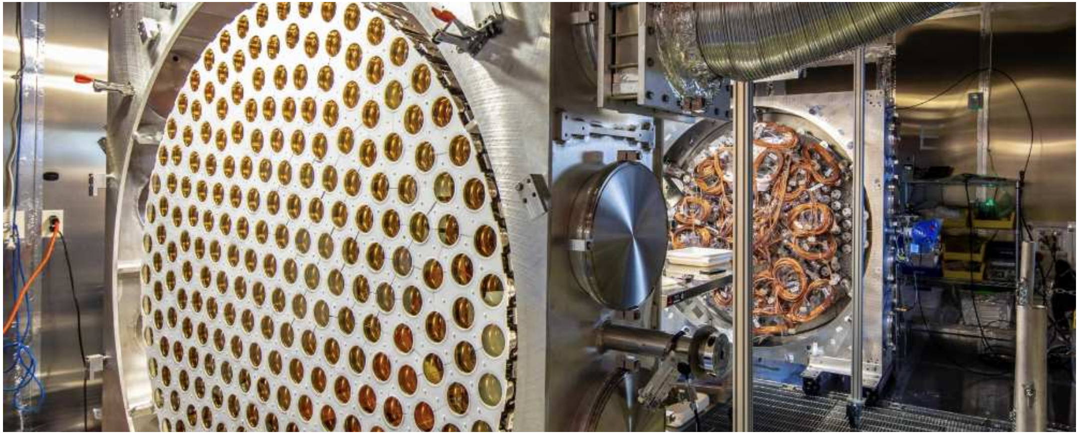
Cosmology, Astro- and Astroparticle Physics



Photosensors of the LZ experiment. (Credit: LZ collaboration)

Astrophysics and General Relativity

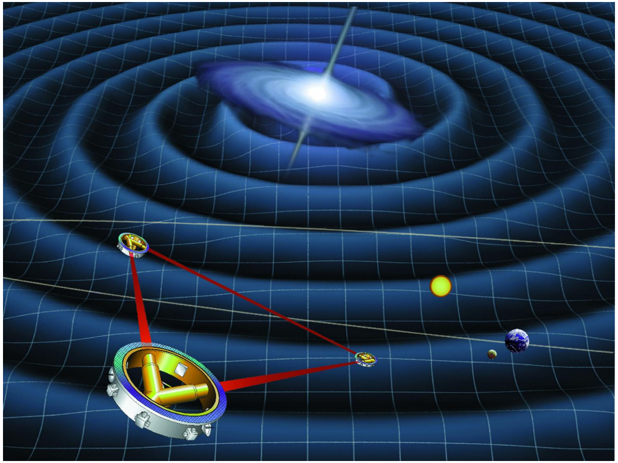
Prof. Philippe Jetzer

LIGO (Laser Interferometer Gravitational-Wave Observatory) together with Virgo aimed to detect gravitational waves in the frequency range from about 10 to 1000 Hz. In 2015 the first gravitational wave signal has been detected. Since then more than 100 events have been found. Our group has made important contributions to the analysis of LIGO/Virgo data and in the modelling of more accurate gravitational waveforms. The latter results are used in LIGO/Virgo data analysis and in future for the Einstein Telescope project and the LISA mission, which was adopted in January 2024 by ESA.

https://www.physik.uzh.ch/groups/jetzer

P. Jetzer as a member of the LISA Science Working Team of ESA was involved in the writing of the Definition Study Report for LISA, which appeared in February 2024. This report was an important contribution towards the so-called Mission Adoption of LISA, and marks the end of the study phases and the beginning of the construction of the satellites. S. Tiwari and C. García Quirós are both member of the LISA Distributed Data Processing Center (DDPC), and responsible for waveform modelling.

Y. Xu et al. investigated the role of the non-linear memory effect in gravitational wave (GW) parameter estimation, particularly by exploring its capability to break the degeneracy between luminosity distance and inclination angle in binary coalescence events. Motivated by the rapid growth in GW detections and the increasing sensitivity of GW observatories enhancing the precision of cosmological and astrophysical measurements is crucial. They proposed leveraging the non-linear memory effect — a subtle, persistent feature in the GW signal resulting from the cumulative impact of emitted gravitational waves — as a novel approach to enhance parameter estimation accuracy. Through a comprehensive series of injection studies, encompassing both reduced and full parameter spaces, the effectiveness of non-linear memory in various scenarios for aligned-spin systems was evaluated. The results demonstrate the significant potential of non-linear memory in resolving the inclination-distance degeneracy, particularly for events with high signal-to-noise ratios (SNR > 90) for the



Artist's illustration of LISA.

current generation of detectors or closer than 1 Gpc in the context of future detector sensitivities such as the planned LIGO upgrade. The results also suggest that excluding non-linear memory from parameter estimation could introduce significant systematics in future LIGO detections. This will hold even greater weight for next-generation detectors.

GW observations provide unique information about compact objects. As detectors sensitivity increases, new astrophysical sources of GW could emerge. Close hyperbolic encounters are such a source class: scattering of stellar mass compact objects is expected to manifest as GW burst signals in the frequency band of current detectors. In a paper with S. Tiwari, Y. Xu and P. Jetzer as co-authors, the search for GW from hyperbolic encounters in the second half of the third Advanced LIGO-Virgo observing run was presented. To this aim a model-informed search with machine-learning enhanced Coherent WaveBurst algorithm was performed. No significant event has been identified in addition to known detections of compact binary coalescences. For the first time it was possible to report an upper limit to the sensitivity volume achieved for such sources, which reaches up to $3.9 \pm 1.4 \times 105$ Mpc^3 year for compact objects with masses between 20 to 40 solar masses, corresponding to a rate density upper limit of $0.589 \pm 0.094 \times 10^{-5}$ Mpc^{-3} year^{-1}.

- Enhancing Gravitational Wave Parameter Estimation with Non-Linear Memory: Breaking the Distance-Inclination Degeneracy,
  Phys. Rev. D107 (2023), 103049, arXiv:2403.00441
- Search for hyperbolic encounters of compact objects in the third LIGO-Virgo-KAGRA observing run,
  Phys. Rev. D107 (2023), 104035, arXiv:2311.06630

Theoretical Astrophysics

Prof. Prasenjit Saha

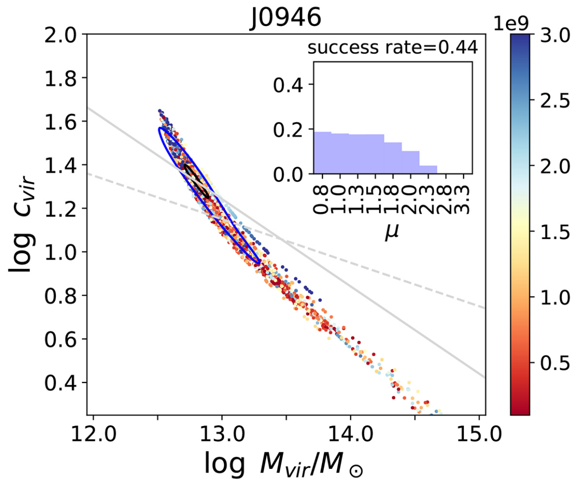
Our research has been on diverse astrophysical phenomena involving light and gravity, especially gravitational lenses, but also novel applications of spacecraft ranging.

https://www.physik.uzh.ch/g/saha

Galaxies and clusters that create multiple mirages of background galaxies through gravitational lensing have long been understood as a probe of dark matter and indeed the process of galaxy formation. We have continued our long-running research program in this area.

In other work we have continued our study of ranging to deep-space missions as detectors of long-period gravitational waves, in the gap between the LISA and PTA ranges.

Reconciling concentration to virial mass relations,
D. Leier *et al.*, Astronomy & Astrophysics, vol **691**, id. A362, 9 pp (2024)



Inferred properties (total mass, concentration, IMF slope) for a lensing galaxy.

Cherenkov Telescope Array Observatory

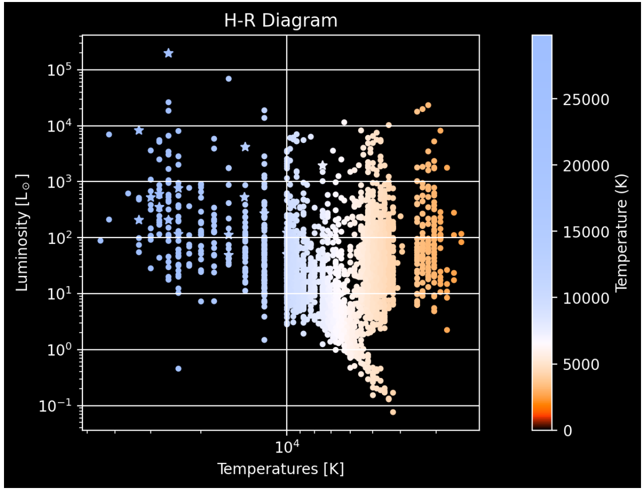
Prof. Prasenjit Saha

The CTAO is a next-generation facility to observe high-energy sources in the Milky Way and beyond. It is designed especially for gamma-ray photons from 10 GeV to above 100 GeV, which it will detect indirectly, through optical Cherenkov showers in the atmosphere. Fortuitously, the facility will also have the capacity to operate in a completely different mode, as an optical intensity interferometer, which can image stellar-scale phenomena.

https://www.physik.uzh.ch/r/cta

We have continued our developmental simulation work on the CTAO as an intensity interferometer, as well as contributing to the precursor telescopes of MAGIC in intensity interferometry mode to resolve stars below the milli-arcsecond range.

Performance and first measurements of the MAGIC Stellar Intensity Interferometer,
MAGIC Collaboration, MNRAS, 529, 4387–4404 (2024)



An HR diagram of stars potentially resolvable using the intensity interferometry mode of the CTAO.
https://target-stars-sii.streamlit.app/

Astroparticle Physics Experiments

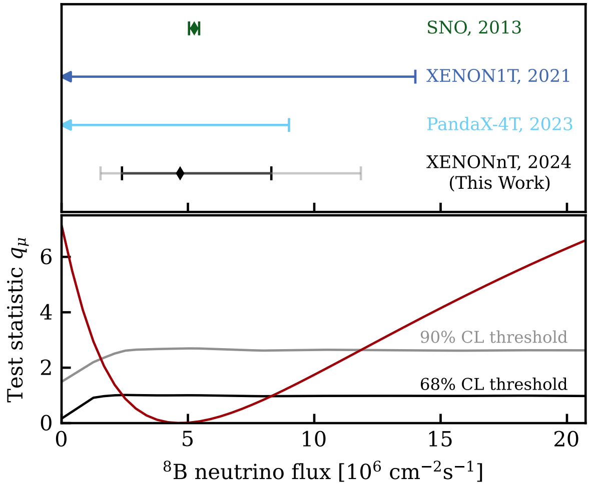
Prof. Laura Baudis

We study the composition of **dark matter** in the Universe and the **fundamental nature of neutrinos**. We build and operate ultra low-background experiments to detect dark matter particles, to search for the neutrinoless double beta decay, a rare nuclear process which only occurs if neutrinos are Majorana particles.
We are members of the **XENON collaboration**, which operates **xenon time projection chambers** to search for rare interactions such as from dark matter, and participate in the **DARWIN** and **XLZD collaborations**, with the goal of building a 80 t liquid xenon observatory to address fundamental questions in astroparticle physics.
We participate in the **LEGEND-200 experiment**, which looks for the **neutrinoless double beta decay of ^{76}Ge** in high-purity Ge crystals immersed in liquid argon, with an unprecedented sensitivity. We also conduct R&D for the future, ton-scale experiment LEGEND-1000.

https://www.physik.uzh.ch/g/baudis

First Measurement of Solar Neutrino-Induced Nuclear Recoils in XENONnT

The XENONnT experiment was designed to detect rare interactions, such as expected from weakly interacting massive particles (WIMPs) as dark matter candidates. WIMPs are predicted to elastically scatter off nuclei with interaction rates well below one event per year and tonne of target material. With stringent requirements on exposure and background suppression, XENONnT operates with a 5.9-tonne xenon target in a dual-phase (liquid and gas) time projection chamber. The detector achieves a low energy threshold due to the detection of light in both liquid and gaseous xenon with high efficiency. The UZH group played a key role in characterizing the VUV-sensitive, low-radioactivity photosensors and in the assembly and operation of the detection arrays in charge of light readout. Active background reduction due to the water Cherenkov muon and neutron vetoes, alongside continuous radon removal via cryogenic distillation, further enhance the detector's sensitivity to interactions from rare events.



Constraints on solar ^{8}B neutrino flux. The 68 % (90 %) confidence level measurement from XENONnT is shown in black (gray). Results from SNO and upper limits from XENON1T and PandaX-4T are also included. Bottom: the red curve represents the likelihood test statistic q_μ as a function of the ^{8}B neutrino flux, with constraints at 68 % (90 %) CL marked by the black (gray) lines.

XENONnT has recently achieved a major milestone by detecting nuclear recoils induced by ^{8}B solar neutrinos via coherent elastic neutrino-nucleus scattering (CEνNS). This process was never before observed on xenon nuclei, nor with solar neutrinos. A blind analysis with an exposure of 3.51 t×yr revealed 37 observed events above 0.5 keV, with a background expectation of $(26.4^{+1.4}_{-1.3})$ events. The background-only hypothesis was rejected with a statistical significance of 2.73σ, confirming the presence of solar neutrino-induced nuclear recoils. The measured ^{8}B solar neutrino flux of $(4.7^{+3.6}_{-2.3}) \times 10^6\,\mathrm{cm^{-2}s^{-1}}$ aligns well with results from the Sudbury Neutrino Observatory. Additionally, the neutrino flux-weighted CEνNS cross section on Xe, measured at $(1.1^{+0.8}_{-0.5}) \times 10^{-39}\,\mathrm{cm}^2$, is consistent with Standard Model predictions. This marks the first direct measurement of nuclear recoils from solar neutrinos using a dark matter detector, expected to yield new insights into both solar neutrino properties and detector capabilities.

Highlighted Publications:

1 First Indication of Solar ^{8}B Neutrinos via Coherent Elastic Neutrino-Nucleus Scattering with XENONnT, XENON Collab. (E. Aprile et al.), Phys. Rev. Lett. **133** (2024) 191002

2 Searches for new physics below twice the electron mass with GERDA, GERDA Collab. (M. Agostini et al.), Eur. Phys. J. C **84** (2024) 9, 940

3 Search for Pauli Exclusion Principle violations with Gator at LNGS, L. Baudis et al., Eur. Phys. J. C **84** (2024) 11, 1137

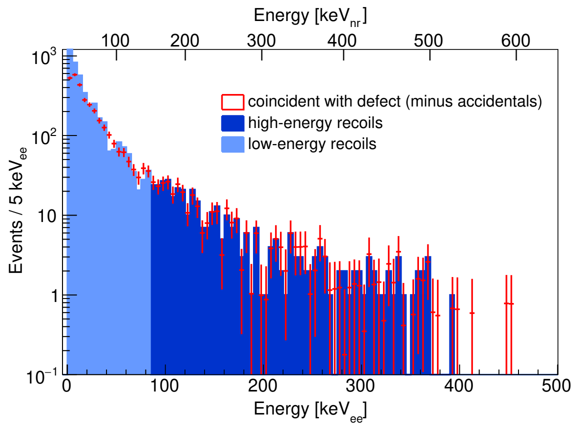
DAMIC Experiment

Prof. Ben Kilminster

DAMIC-M (Dark Matter in CCDs at Modane Underground Lab) is an experiment that searches for the dark matter (DM) gravitationally bound in our Milky Way through electrical signals produced from its collisions with silicon CCD detectors. This experiment represents a factor of 10 increase in mass, a factor of 10 decrease in the energy threshold, and a factor of 50 decrease in background rates, as compared to the current DAMIC experiment operating in SNOLAB.

https://www.physik.uzh.ch/r/damic

Our group helped found the DAMIC experiment in 2008. We are contributing readout electronics, mechanical components, and detector control and safety systems for the next phase, DAMIC-M. DAMIC-M has been taking data since 2022 with a prototype, the Low Background Chamber (LBC), and a manuscript describing its operation was produced in 2024. New, world-leading results on hidden-sector DM with the LBC have been achieved and are soon to be published, and which probe theoretically favored production rates for low-mass DM. The construction of the complete DAMIC-M experiment is expected to conclude in 2025. The UZH group has pioneered a new approach to DM searches using CCDs, in which nuclear recoils from potential DM signals can be identified through the electronic characteristics of defects that are produced in the silicon. The research was first demonstrated in a 2023 UZH PhD thesis. In 2024, we published the first demonstration of such nuclear recoil identification in a CCD. This breakthrough may lead to improved sensitivity for DM searches, as well new experiments optimized to this new method of detection.



This plot shows the ionization spectra of nuclear recoils caused by a neutron source. For each recoil observed using standard techniques of measuring ionization energy (blue), the events in which a spatially correlated silicon-lattice defect was detected is also shown (red). The agreement demonstrates that the new technique of identifying nuclear recoils through lattice defects is fully efficient for ionization deposits above 85 keV electron-equivalent (keV$_{ee}$).

Highlighted Publications:

1. The DAMIC-M Low Background Chamber, DAMIC-M collaboration, arXiv: 2407.17872, JINST **19** (2024) 11, T11010.
2. Nuclear Recoil Identification in a Scientific Charge-Coupled Device, K. J. McGuire, A.Chavarria, N.Castello-Mor, S. Lee, B. Kilminster, et al., arXiv: 2309.07869, Phys.Rev.D **110** (2024) 4, 043008.

Dark Matter Searches

Prof. Björn Penning

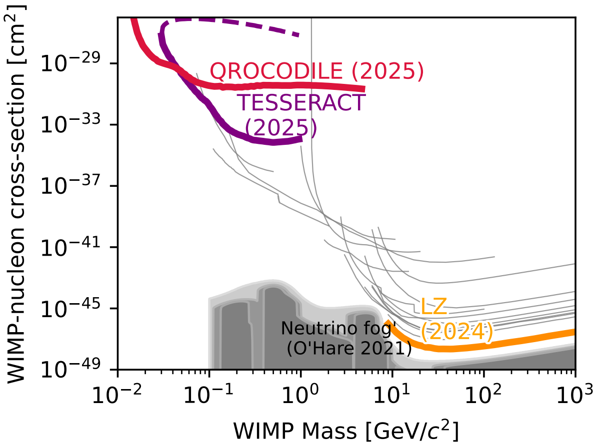
The research group is interested in a wide range of **dark matter (DM) searches**. The group performs direct DM searches at the **LUX-Zeplin (LZ) experiment** located in South Dakota, providing leading sensitivity to WIMP-type dark matter using a 7 tonne liquid xenon target. The group is deeply involved in dark matter analysis, calibration of the central detector, the time projection chamber, rare decays, and the outer veto detector. The group is also a member of the **DARWIN and XLZD collaborations**, contributing to R&D for building the ultimate (60-80 tonne) liquid xenon observatory.
Prof. Penning is a founding member of a novel low-mass dark matter experiment, **TESSERACT** to be installed in the Modane underground laboratory. The group is also involved in development and characterisation of new quantum sensing technologies for dark matter searches through the **QROCODILE experiment**.

https://www.physik.uzh.ch/g/penning

Status of Dark Matter (DM) Searches

Astrophysical observations provide strong evidence for the existence of DM, which dominates the matter density of the Universe while interacting only very weakly or not at all with ordinary matter. Well-motivated as a thermal relic, the weakly interacting massive particle (WIMP) is a leading hypothesis for DM, arising in a number of beyond-the-standard-model theories. Direct detection experiments, searching for interactions between DM particles and a detector target are placing ever more stringent constraints in the parameter space of WIMP mass and WIMP-matter interaction strength.

For DM with weak-scale masses, the group participates in the LZ collaboration to provide the worlds strongest constraints on DM using around 7 tonnes of liquid xenon as a target. With a 4.2 tonne-year exposure from 280 live days, LZ was able to place the most stringent constraints on WIMP models above $\sim$10 GeV/c^2. The Darwin/XLZD collaboration is developing and demonstrating the detector technologies required for an even more sensitive liquid xenon detector at



Collection of direct detection constraints on the coupling between dark matter and nuclei - models above the lines are excluded at 90% confidence level. Highlighted lines represent results that this group had direct involvement in.

the 60 – 80-tonne scale. The sensitivity target for this ultimate detector will be to lower all other backgrounds to the point where even the faint background of neutrinos from supernovae and atmospheric cosmic rays will become important.

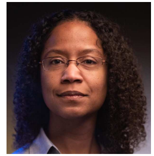
At lower mass, cryogenic quantum sensors with ultra-low detection thresholds expand the DM search landscape. The QROCODILE and TESSERACT collaborations were each able to set world-leading constraints while demonstrating the potential of low-threshold superconducting sensors for exploring new DM parameter space. TESSERACT aims to substantially improve upon this surface DM search, as well as search for other DM interactions, with a plan to deploy a novel multi-target system using gallium arsenide, superfluid helium and sapphire in the Modane underground laboratory before the end of the decade.

Highlighted Publications:

1. Dark Matter Search Results from 4.2 Tonne-Years of Exposure of the LUX-ZEPLIN (LZ) Experiment,
J. Aalbers *et al.* (2024), arXiv:2410.17036 [hep-ex]
2. A New Bite Into Dark Matter with the SNSPD-Based QROCODILE Experiment,
L. Baudis *et al.* (2024), arXiv:2412.16279 [hep-ex]
3. First Limits on Light Dark Matter Interactions in a Low Threshold Two Channel Athermal Phonon Detector from the TESSERACT Collaboration,
C. L. Chang *et al.* (2025), arXiv:2503.03683[hep-ex]

Astrophysics and Cosmology Experiments

Prof. Marcelle Soares-Santos



Our group focuses on uncovering the physics of the accelerated expansion of the universe. We combine data from optical/near-infrared **cosmic surveys** with data from **gravitational-wave observatories** to realize powerful **multi-messenger analyses**. We advance the state-of-the-art in the field through our **instrument science** research.

We are members of the collaborations **DES** and **LSST**, which have built the most powerful telescope cameras world-wide. We are members of **LIGO**, the most sensitive gravitational-wave observatory ever built.

Together, observations from these experiments blaze a trail for a major leap in our understanding of the universe.

https://www.physik.uzh.ch/g/soares

LSST Camera commissioning

Comprised of a 3.2 gigapixel focal plane that covers a 10 square degrees FOV of the southern sky, the LSST Camera will create a time-lapse record of the universe. The camera has been optimized for observations every 30 seconds with a deep dynamic range of 8 magnitudes to create this time-lapse of the southern sky. For such high-frequency observations to be possible, the camera shutter actuates in 0.9 seconds and the electronic readout of the sensors completes in 2.4 seconds. Optical filters across six different chromatic bands enable a census of astrophysical color, allowing for precise measurement of the age and composition of astrophysical objects. The camera was constructed at the SLAC National Accelerator Laboratory in California, USA. In May 2024, it was transported from Menlo Park, California, to Cerro Pachón, Chile, where the Vera C. Rubin Observatory is being constructed. The camera was first installed in the clean room on Level 3 in the Rubin Observatory. After connecting power and cooling lines and veri-

The Rubin Observatory commissioning team after the successful lift of the LSST Camera into the Simonyi Survey Telescope dome in Cerro Pachón, Chile, on March 5, 2025. The UZH group has had a permanent presence on-site since July 2024.

fying the vacuum performance, the LSST Camera underwent the seventh and final series of electro-optical (EO) testing from September 2024 to December 2024, collecting 358 TB of data over 56,000 exposures. The UZH group was strongly involved in the EO characterization tests. Improvements to the LSST Camera have been tested and implemented in preparation for the start of the LSST survey. The operational changes have been made to maximize science-quality observations while maintaining efficiency once the survey has begun. The LSST Camera was installed on the telescope in March 2025. The camera is going through final engineering activities until April 2025. Afterward, the LSST Camera and Rubin Observatory will go through an on-sky commissioning phase to verify observatory performance. The LSST survey is scheduled to begin in late 2025.

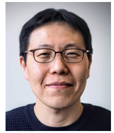
Highlighted Publications:

1. The Dark Energy Survey: Cosmology Results with ∼1500 New High-redshift Type Ia Supernovae Using the Full 5 yr Data Set, DES Collaboration, Astrophys. J. Lett. **973** (2024) L14.
2. Small pitch tilting spine optical fiber positioners for massively parallel spectroscopy, R. A. Sebok *et al.*, SPIE Conf. Proc. **13100** (2024) 131006A.
3. Designing an Optimal Kilonova Search Using DECam for Gravitational-wave Events. C. R. Bom *et al.*, Astrophys. J. **960** (2024) 122.

Theoretical Astrophysics

Department for Astrophysics



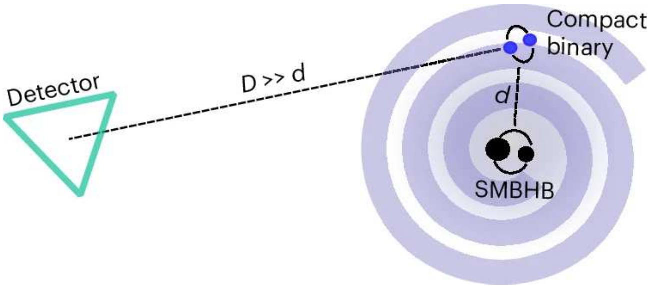





The research groups of the Department for Astrophysics work on theoretical and computational astrophysics and cosmology.
In what follows scientific highlights from these different groups over the course of 2024 are reported.
https://www.astro.uzh.ch/

Yoo's group has identified for the first time the monopole fluctuations in galaxy clustering. They found that large-scale fluctuations on our sky (or monopole) change the mean number density in galaxy clustering, and the observed galaxy is hence correlated with the monopole fluctuation. The initial investigation shows that the impact of the monopole fluctuations is as large as 7% at the baryonic acoustic oscillation scale and it is highly an-isotropic. Given the level of precision in the baryon acoustic oscillations surveys is 0.1%, this new effect in galaxy clustering would be highly influential. Further investigations are already on the way.

Mayer's group discovered a new way to detect supermassive black hole binaries by measuring their perturbation onto the gravitational wave signal from stellar mass binaries [1]. Using cosmological hydrodynamical simulations at very high redshift they showed how the largest black holes in the Universe can be formed by direct relativistic collapse of gas in a supermassive gas disk without prior formation of a supermassive star [2]. Finally, using a Bayesian data analysis framework they published the first forecast for the concur-



The presence of an super massive black hole emitting gravitational waves (GW) causes frequency modulations in the GW emission of a compact binary source at a distance d. The modulations can be observed over a long observation time with proposed decihertz GW detectors, at a distance D.

rent detection of eccentricity and environmental perturbations from the gravitational wave in-spiral signal of massive black hole binaries in the LISA band, showing how to infer properties of the accretion disk in which the binary is embedded [3].

Schneider's group has focused on weak lensing studies, using both existing observations and preparing for future Euclid data. They have published new constraints on dark matter models based on data from the Kilo Degree Survey (KiDS) and the Dark Energy Survey (DES). Additionally, the group has made significant contributions to modeling baryonic feedback, a crucial systematic effect in weak lensing cosmology. Beyond this, Schneider's group has also concentrated on modelling the high-redshift universe during the epoch of reionization. Using their new code, BEoRN, they have critically examined commonly used approximations in the literature, demonstrating that these methods are not applicable in general cases.

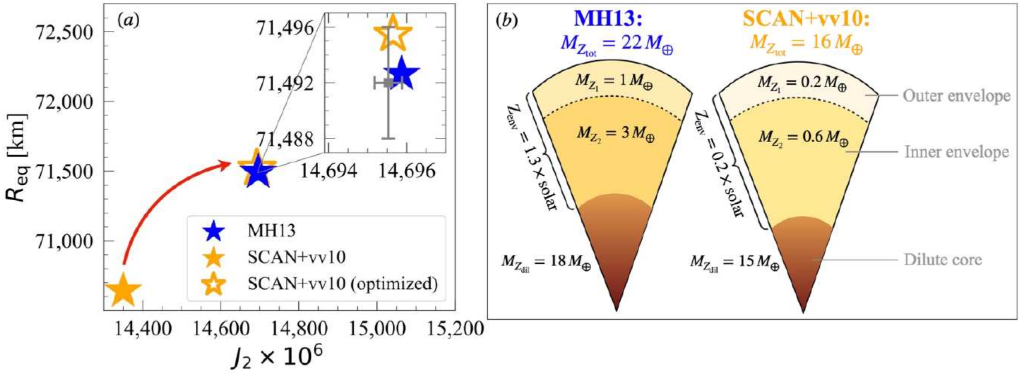
The group of Helled continued to explore planets in the Solar System and planets around other stars with the focus of interior models, and planet formation and evolution simulations. They introduced a new Jupiter model which has a deep radiative layer and suggested that Jupiter's enriched atmosphere is caused by late accretion. This model suggests a solution for the tension between the measurements of the Juno and Galileo missions [4]. They also explored the role of convective mixing in connecting the atmospheric and bulk composition of giant exoplanets [5]. These results emphasize the complexity in the interpretation of atmospheric abundance measurements and show that the planetary formation process plays a key role in determining the planetary evolution and final structure.

Feldmann's group explored the unexpectedly high star formation activity in the early Universe, revealed by recent JWST observations. Using a state-of-the-art cosmological simulation it was found that this elevated activity arises from a greater-than-expected contribution of lower-mass halos, offering a new interpretation of these observations and informing future studies of high-redshift galaxies [6]. Further publications addressed metal enrichment, atomic hydrogen content, and the role of gas compaction in driving star bursts. The group also completed the development of a deep learning emulator designed to predict multiple baryonic properties, including the atomic hydrogen distribution, from the dark matter density field across cosmic history. The new emulator is both more computationally efficient and more capable, enabling a broader range of applications. In addition to developing its capabilities further, future plans include using an advanced emulator for various inference-based studies to advance our understanding of galaxy formation and cosmic structure. They also published studies analyzing the structure of galaxies with the help of data science methods.

The group of Stadel continued their contribution to the Euclid mission. The Euclid – Flagship 2.0 Mock Galaxy Catalog was completed and delivered to the science teams of the Euclid Consortium. This Mock Galaxy Catalog was critical for the data release in 19. Mar. 2025. The N-body simulation that was used to produce was the World's largest at 4 trillion particles. This simulation was performed using the pkdgrav3 N-body code written by Stadel and Potter. They also performed N-body simulation for the deep part of the Euclid survey mock catalog.This simulation will be used to create the "Deep Mock" which will be needed for Euclid's data releases. The Smoothed Particle Hydronynamics (SPH) simulations now include state-of-the-art equations of state and ultra-high resolution and can model giant impacts in the solar system and beyond. In planetary collisions, a material strength implementation was added which allows for more realistic simulations of smaller rocky bodies, such as asteroids in our solar system. This development will allow to increase the scope of planetary collision simulations. The second paper in a series on the formation of the Moon including initial spins for the target and impactor [7].

Ita's group has made contributions to particle-physics phenomenology by providing precision computations for the production of three light final-state objects in proton collisions. They also developed new methods in Feynman-integral calculus to provide efficient computer programs for massive five particle processes. They published precise theory predictions for gravitational wave signals of black-hole scattering [8].

Adamek and his group members led the first of a series of key project papers by the Euclid Collaboration on numerical methods and simulations for nonlinear cosmic structure formation beyond the standard CDM model, aimed at supporting Euclid's dark energy research objectives. With a small team of collaborators, Adamek participated in a hackathon event organised by the Swiss National Supercomputing Centre (CSCS) in Lugano. Experts from CSCS



The effect of the new hydrogen equation of state (EOS) on Jupiter's internal structure. Panel (a) shows the equatorial radius R_{eq} and J_2 for Jupiter interior models using the new EOS (SCAN+vv, orange) and one that is commonly used (MH13, blue). The orange empty star shows a model which was optimized to match the observed R_{eq} and J_2. Panel (b) shows schematics of Jupiter's internal structure using the old (left) and new (right) EoSs. The new EOS affects the inferred internal structure and total heavy-element mass in Jupiter.

and Nvidia helped to take the first steps towards porting their cosmological N-body code 'gevolution' to GPUs, which will allow to significantly improve simulations' performance.

The group of Mazzola inferred an accurate equation of state for hydrogen, which has critical applications for planetary science [9]. First, the longstanding technical problem of calculating entropy from first-principle atomistic simulations was solved, an issue that had affected equations of state for about a decade. Highly accurate quantum mechanical methods were used to compute an updated equation of state for dense hydrogen. The results indicate that hydrogen is denser under planetary conditions compared to the state-of-the-art equations of state used today. This result imply that Jupiter's interior is inhomogeneous and also has consequences for the interior modeling of giant exoplanets.

Moore's group plays a major role in the ARRAKIHS mission - a planned astronomical satellite mission by European Space Agency (ESA) where Moore is the Swiss Principle Investigator. The mission focuses studying dark matter haloes of galaxies. Moore and Kehl co-lead the instrument team while Rebekka Bieri is the deputy science coordinator. The mission is currently in phase B and has secured significant funding.

The Department of Astrophysics introduced a new Bachelor program in Astronomy and Astrophysics, which is unique in Switzerland. The new bachelor program has the primary goal of providing students with a solid foundation in the fields of astrophysics, astronomy, physics, mathematics, and computational science. This includes a thorough understanding of the laws of physics, celestial mechanics, and the mathematical and numerical tools essential for astrophysical calculations.

Selected publications:

1. Imprints of massive black-hole binaries on neighbouring decihertz gravitational-wave sources,
   Stegmann *et al.*, 2024, Nature Astronomy, 8, 132
2. Direct Formation of Massive Black Holes via Dynamical Collapse in Metal-enriched Merging Galaxies at z ~ 10: Fully Cosmological Simulations,
   L. Mayer *et al.*, ApJ **961** 76
3. Measuring eccentricity and gas-induced perturbation from gravitational waves of LISA massive black hole binaries, M. Garg *et al.*, 2024, MNRAS 532, 4060
4. Can Jupiter's Atmospheric Metallicity Be Different from the Deep Interior?
   S. Müller, R. Helled, ApJ **967** 7
5. Convective Mixing in Gas Giant Planets with Primordial Composition Gradients,
   H. Knierim, R. Helled, ApJ **977** 227
6. Elevated UV luminosity density at Cosmic Dawn explained by non-evolving, weakly mass-dependent star formation efficiency,
   R. Feldmann *et al.*, Monthly Notices of the Royal Astronomical Society 536, 988–1016

Galaxy M33, taken by Joachim Stadel in August 2024 from Esslingen. The photo was taken with the equipment used for our Astronomy courses and was chosen to decorate the UZH Christmas Card in 2024.

7. A Systematic Survey of Moon-forming Giant Impacts. II. Rotating Bodies,
   T. Meier *et al.*, ApJ, **978**, Issue 1, id.11, 24 pp.
8. Gravitational Bremsstrahlung in black-hole scattering at $\mathcal{O}(G^3)$: linear-in-spin effects,
   L. Bohnenblust *et al.*, JHEP **11** (2024) 109
9. A Denser Hydrogen Inferred from First-Principles Simulations Challenges Jupiter's Interior Models,
   C. Cozza *et al.*, eprint arXiv:2501.12925