Dr. Dinko Milaković
Osservatorio astronomico di Trieste, Via Tiepolo 11, 34131 Trieste (TS), IT | +39 344 4019 347 | milakovic.net | dinko@milakovic.net

Scientific interests

Fundamental physics & cosmology	*Fundamental constants, redshift drift, gas at high redshift.*
Astronomical observations	*High resolution optical / near infra-red spectroscopy (HARPS & ESPRESSO).*
Improving spectroscopic performance	*Laser frequency combs, data reduction, instrument calibration.*
Artificial Intelligence	*Machine learning, computer vision, deep learning.*

Employment history

Postdoctoral researcher	Astronomical Observatory of Trieste	*since Oct 2024*
Postdoctoral researcher	Institute for Fundamental Physics of the Universe (IFPU)	*Oct 2021 – Sep 2024*
Postdoctoral researcher	Astronomical Observatory of Trieste	*Dec 2020 – Sep 2021*
Associate	European Southern Observatory (ESO)	*Apr 2020 – Sep 2020*
Doctoral researcher	European Southern Observatory	*Sep 2016 – Mar 2020*

Education

Ludwig-Maximillian University	PhD in Astronomy | Magna cum laude	*Sep 2016 – Nov 2020*
University of Zagreb	MSc in Physics	*Sep 2009 – Mar 2015*
University of New South Wales	Exchange student (MSc thesis work)	*Jul 2014 – Jan 2015*

Experience

HARPS as a testbed for new technology (PI D. Milaković, 3 peer-reviewed publications)

- Developed new methods for wavelength calibration based on astronomical Laser Frequency Comb (LFC) technology and successfully applied them to archival LFC observations taken using the ESO 3.6m/HARPS spectrograph.
- Independently built a data analysis pipeline and investigated the practical limits of using LFCs.
- By comparing two LFCs operated simultaneously, I established that long-term radial velocity stability with LFCs is 45 cms^{-1} at best, significantly above the photon noise limit (3 cms^{-1}). This result motivated an experiment that compared the LFC calibration to a calibration from an iodine cell on ESPRESSO (see below).
- By reconstructing the line-spread function (LSF) of HARPS, I demonstrated that using accurate LSF models results in spectroscopic accuracy close to the photon noise limit.
- I am developing deep learning methods to reconstruct the point-spread function (PSF) from LFC spectra. These methods will be used to develop a new data reduction pipeline for HARPS based on "spectral perfectionism" (PI G. Cupani) and inform whether the future ELT/ANDES pipeline should be based on the same principles.

Artificial Intelligence and Fundamental Physics (PI J. K. Webb, 8 peer-reviewed publications)

- Co-developed AI-VPFIT, a new data analysis tool combining non-linear least squares with an information criterion, Monte Carlo methods, genetic and artificial intelligence algorithms to automatically produce unbiased, reproducible, and robust models of complex spectroscopic datasets. AI-VPFIT presents a major leap in the field, speeding up the modelling process by a factor of $>$100 when used on a supercomputer, freeing up human resources for other tasks.
- Applied AI-VPFIT to the first ever LFC-calibrated spectrum (produced by me) and obtained 40 new measurements of the fine structure constant (α) at $z = 1.15$ towards quasar HE0515$-$4414. The measurements present the first ever constraint on fundamental constant variations on kpc scales.
- Tested the performance of a new information criterion (SpIC) specifically designed for spectroscopy and to guide the AI-VPFIT modelling process. Using SpIC results in 99% accuracy when retrieving simulated parameter values and results in no bias. For comparison, accuracy is 70% when other information criteria (e.g. AICc) are used.
- Published several other α measurements at high redshift and on white dwarf surfaces.

ESPRESSO Large Programme for Fundamental Physics (PI P. Molaro, 7 peer-reviewed publications)

- Measured the relative carbon isotopic abundance at $z = 1.776$ towards quasar B1331$+$170 to be $^{12}\mathrm{C}/^{13}\mathrm{C} = 28.5^{+51.5}_{-10.4}$. For the first time ever, the quoted errors include uncertainties arising from model non-uniqueness. This robust result suggests an additional production of ^{13}C at low metallicity, in tension with many chemical evolution models.
- Investigated the origin of unexpected flux artefacts in ESPRESSO observations of faint objects. My work helped to identify them as weak warm pixels, allowing for the development of mitigation methods and improve instrument performance.
- Collaborated on improving ESPRESSO data reduction procedures.
- Published in the field of fundamental constants, inter-galactic medium, and isotopic abundances in metal-poor gas and stars.

ESO ELT Working Group for Line Calibrations (Coordinator C. Martins)

- Co-author of the ESO technical note "Recommendations and considerations stability of wavelength calibration for HIRES" (ESO-388314). A large part of recommendations were drawn from conclusions of my PhD research.

- Co-I of the approved ESO calibration proposal “An ESPRESSO iodine cell to prepare for ELT–HIRES science”. I contributed to all aspects, and majorly to writing the science case, defining instrument requirements and the observation strategy of the commissioning run.
- At the joint meeting of ESO ELT working groups in 03/2020, I presented the status of the field and discussed paths to overcome challenges required to reach ELT/ANDES goals.
- Invited to join the Working Group still as a PhD student (by M. Cirasuolo).

Charting the way forward (2 peer-reviewed publications)

- Invited to write the section on redshift drift (IX.B.2) of the Snowmass 2021 contribution paper “Cosmology intertwined: A review of the particle physics, astrophysics, and cosmology associated with the cosmological tensions and anomalies”.
- Co-author of the ESA Voyage 2050 contribution paper “Unveiling the faint ultraviolet Universe”.
- Member of Cosmoverse, a working group addressing observational tensions in cosmology with systematics and fundamental physics.

Additional technical experience

- In-person participation in the commissioning of HARPS’s LFC in 09/2016.
- Co-authored reports of ESPRESSO Science Team to ESO on ESPRESSO / LFC performance.
- Invited to assess ESPRESSO LFC performance after a major intervention in 10/2022 (by A. Manescau).
- Developed a method to correct improper flux calibration of quasar spectra in the Sloan Digital Sky Survey Data Release 12.
- Developed software to simulate realistic high-resolution quasar spectra with provisions for input of instrument characteristics. It will be used to further refine methods and observing strategies for high precision measurements.

Management & responsibility roles

Leadership	ESO student representative	*2017 – 2019*
Reviewing	Invited to review for *Astrophysical Journal*, *Scientific Reports*, *Advances in Space Research*, *Galaxies*	
Hiring committee	“Phi in the Sky” PhD grant allocation (Porto University).	*2023 and 2024*
	“Phi in the Sky” MSc grant allocation (Porto University).	*2024*
Administrative support	Organising Committee for the Munich Joint Astronomical Colloquium	*2019 – 2020*
	Assistant to the ESO Observing Programmes Committee	*2017 and 2018*
Teaching	“Astrocamp” lecturer, Vascões, PT. I developed and delivered 15h of lectures.	*2021*
Supervision	Julien Poyatos (undergraduate thesis) together with C. Martins.	*2022*
Organisation	Meetings of the ESPRESSO Working Group for Fundamental Physics	*since 2020*
	IFPU workshop on fundamental constants, 10 participants, Trieste, IT	*2023*
	IFPU Journal Club, Trieste, IT	*2022 – 2023*
	ESO Friday social event, Garching, DE	*2017 – 2019*
	ESO Science Day 2018, 100+ participants, Garching, DE	*2018*
	ESO Journal Club, Garching, DE	*2016 – 2018*
	LOC chair for 3rd IMPRS Student Symposium, Garching, DE	*2018*
	LOC member “Multiwavelength-surveys: Galaxy Formation and Evolution from the early Universe to today”, Dubrovnik, HR	*2015*
Liaison & negotiation	Main liaison & coordinator between six partners in a private enterprise	*since 2022*

Research support

INAF technology grant (as Co-I, PI G. Cupani, project start Oct 2024)	*200k EUR*
ESO Early-Career Scientific Visitor Programme Garching, 6 weeks	*3.5k EUR*
ESO Director General’s Discretionary Fund, 4 weeks visit to IoA, Cambridge University, UK	*2k EUR*
International Max Planck Research School on Astrophysics, supported by ESO (Sep 2016 - Mar 2020)	*≈80k EUR*
CoSMass funds to travel to Sydney in 2014 (awarded by project PI, V. Smolčić)	*2k EUR*
OzSTAR Supercomputer (Swinburne University of Technology, Melbourne, AU)	*1.1M CPU-core hours*
VLT/ESPRESSO (as Co-I on GTO and normal observing programmes)	*>120h*
ESO 3.6m/HARPS (as PI on a normal proposal)	*8 nights*
Featured as a talented young researcher in the ESO Annual Report 2017	

Collaborations & memberships

Collaboration	ESPRESSO Large Programme on Fundamental Physics (PI P. Molaro)	*since 2020*
	Quasar spectroscopy research group (PI J. K. Webb)	*since 2014*
Membership	Cosmoverse (Chairs J. Levi Said and E. Di Valentino)	*since 2023*
	ESPRESSO Science Team (Chair A. Sozzetti)	*since 2020*
	ESO ELT working group on Line Calibrations (Coordinator C. Martins)	*since 2019*

Talks & seminars

Contributed talk	1st meeting of INAF Computing Unit, Battaglia Terme, IT	*Oct 2024*
Contributed talk	17th Marcel Grossmann meeting, Pescara, IT	*Jul 2024*
Contributed talk	Universum V, Rome, IT	*Mar 2024*
Invited talk	Spectral fidelity, Florence, IT	*Sep 2023*
Contributed talk	Cosmology at Miramare 2023, Trieste, IT	*Aug 2023*
Invited seminar	Weizmann Institute for Science, Tel Aviv, IL	*May 2023*
Invited review talk	Rencontres de Moriond, La Thuile, IT	*Mar 2023*
Seminar	ESO Lunch Talk, Garching, DE	*Feb 2023*
Contributed talk	ESPRESSO Science Team meeting, Lanzarote, ES	*Feb 2023*
Seminar	ESO Informal Discussion, Garching, DE	*Jan 2023*
Contributed talk	Tensions in Cosmology, Corfu, GR	*Sep 2022*
Invited talk	Hack 100, Trieste, IT	*Jun 2022*
Invited talk	The stubborn inconstancy of constants, Cambridge, UK	*Nov 2021*
Contributed talk	4th Azores School of Cosmology, Angra do Heroismo, PT	*Aug 2021*
Invited seminar	OPINAS group, MPE, Garching, DE (online)	*Apr 2020*
Seminar	ESO Informal Discussion, Garching, DE	*Mar 2020*
Invited seminar	Trieste Observatory Colloquium, Trieste, IT	*Jan 2020*
Invited seminar	ESO Thirty minute talk, Santiago de Chile, CL	*Dec 2018*
Contributed talk	Shedding Light on the Dark Universe with ELTs, Trieste, IT	*Jul 2018*
Seminar	Department of Physics, Zagreb University, HR	*Mar 2018*
Contributed talk	4th IMPRS Student Symposium, Garching, DE	*Oct 2017*
Contributed talk	3rd Azores School of Cosmology, Angra do Heroismo, PT	*Aug 2017*

Public outreach & engagement

Public talks	*Skeptics in the Pub*, Zagreb, HR (video has >300 views)	*2024*
	Petar Preradović Gymnasium, Virovitica, HR	*2022*
	Astronomy on Tap, London, UK (online, video has >100 views)	*2021*
	Višnjan Summer School, Višnjan, HR	*2019*
	Skeptics in the Pub, Zagreb, HR (video has >3600 views)	*2018*
Volunteering	Ambassador of Astronomy, IAU 100 funded project (proposer C. Harrison, link)	*2019*
	Ask an Astronomer, ESO Open Door day, Garching, DE	*2017*
	Open Door of the Ruđer Bošković Institute, Zagreb, HR	*2015*
Organisation	*Skeptics in the Pub*, >40 events with 50+ participants, Zagreb, HR	*2011-2016*
Interview	Internet news portal ICV.hr (link)	*2022*
	ESO blog (link)	*2020*

Skills

Language	Croatian	*Native*
	English	*Proficient, C2*
	Italian	*Proficient, C1*
	German	*Basic, A2*
Programming	Python (numpy, scipy, jax, jaxopt, numpyro)	*Proficient*
	Fortran	*Intermediate*
	git	*Basic*
Training	Public speaking & presentation	
	Courtesy, respect, and fair treatment	
	Mentoring & supervision	