KONINKLIJKE
HOLLANDSCHE MAATSCHAPPIJ
DER WETENSCHAPPEN

Juryrapport
KHMW Jong Talent Afstudeerprijzen voor Sterrenkunde 2025

Sten Sipma MSc, Rijksuniversiteit Groningen
An Evolutionary Model for the Milky Way's Corona

This Master's thesis addresses a hot topic in astronomy, that of the physical state of the coronal gas surrounding spiral galaxies like our own Milky Way. The thesis stands out by its depth and breadth in addressing - through a newly developed semi-analytical model – this complex physical problem. The main result that the hot coronal gas is self-regulated and can be in a state of equilibrium by energy injection from a central super-massive black hole is unexpected. It provides a leap forward in our understanding of these systems.

The hot circumgalactic medium (CGM) associated with galaxy clusters has been an important topic for study for some time since it provides a solution to two key problems: it can account for the missing baryons in the universe, and it provides the fuel for star formation when it cools and supplies fresh cold gas to the galaxies' disks. Such cooling flows can be stopped, however, by heating by supermassive black holes (SMBHs) at their centers. To what extent this picture also applies to late-type spiral galaxies like the Milky Way has been an open question until Sten's thesis.

Sten has developed, completely independently, a new model by taking the ideas originally developed for galaxy clusters and applied them to a Milky-Way type galaxy. Moreover, he has added novel features such as the internal mechanical heating from a SMBH, which is known to exist at the center of our Milky Way, as well as heating from an extragalactic ultraviolet background. Constructing this model was far from simple since it requires deep insight into the (micro)physics of the heating and cooling processes of the gas in hydrostatic equilibrium. Such systems are also known to be computationally challenging in terms of numerical accuracy, stability, and efficiency, all of which Sten mastered during his thesis.

By changing the central energy input, Sten demonstrated that there is a power injection threshold above which the gas shifts from runaway cooling to runaway heating. He then demonstrated that the energy release from the SMBH at the Milky Way's center is around this threshold value, as estimated from observations of the two huge bubbles of hot gas observed above and below the Milky-Way disk with the Fermi and e-Rosita satellites. Thus, the Milky Way regulates its own flow and thereby its evolution.

Sten's Master thesis is exemplary in many ways. It is very well written, with the text going into considerable depth without becoming long and tedious to read. The methodology is exactly what is needed for a new code. Sten first tested it against known solutions and showed that without central heating, the gas indeed cools and that previous literature results are

recovered. By speeding up the code and thus being able to run hundreds of models, Sten has also demonstrated the robustness of his results. A journal paper is in advanced stages of preparation. Altogether, Sten has demonstrated that he already functions at the level of a PhD student and professional astronomer.

Sten is highly commended not just for his science but also for contributing to other aspects of an active astronomy institute like Kapteyn. He has been part of the local and national education committee as well as student representative on several others. Equally important, he is active in outreach by chairing the Astronomy on Tap monthly talks and volunteering for public events at, for example, the Blaauw Observatory. Sten's work and activities are thereby fully aligned with the KHMW mission, namely to provide a bridge between science and society.

Kaya Han Taş MSc,
Universiteit van Amsterdam en Vrije Universiteit Amsterdam
ExoMUSE and the Discovery of Ultra-Short Period Planet TOI-2431 b

This Master's thesis combines the development of original software with a frontline astronomical discovery.

The primary innovation of this thesis is the development of ExoMUSE, a new Python framework for jointly modelling transit, radial-velocity, and astrometric data. The software is shown to be robust and well-documented, with tutorials and validation against community tools, thereby turning a personal research engine into a resource the field can immediately reuse for teaching and research.

The thesis goes beyond just the development of a new code, it includes new observational data and the discovery and verification of a new exoplanet. The initial observations were obtained during a Master's observing experience on La Palma, after which additional telescope time was obtained to follow up the promising but insufficiently constraining initial observations.

The scientific payoff is impressive: the discovery and characterisation of TOI-2431b, an ultra-short-period planet with an orbit of only ~5.4-hour, making it the 6th shortest orbital period planet known to date. The thesis shows that TOI-2431b is unusually dense, lies perilously close to its Roche limit, and has the shortest tidal-disruption timescale among comparable ultra-short period planets. This makes it a unique laboratory for tidal physics, orbital decay, and atmospheric escape. Its predicted thermal brightness also marks it as an obvious candidate for JWST follow-up.

Methodologically, the work is exemplary. Mr. Taş implements state-of-the-art joint fits, including Floating-Chunk Offsets and quasi-periodic Gaussian Processes to separate planetary signals from stellar activity, and he stress-tests his solution with rigorous injection-recovery

experiments at the actual observing cadence. The result is not only a discovery, but a carefully quantified one. The thesis itself is clear, well-illustrated, and accessible to non-experts, reflecting mature research, programming, and scientific writing skills. Collaboration was excellent: Mr. Taş worked independently when needed and coordinated effectively across instruments and teams of specialists to obtain the additional data required to accurately characterise the discovery.

A peer-reviewed journal article based on this thesis was submitted during the project and has already received favourable referee feedback, with the discovery noted by several media outlets. In summary, this thesis stands out for: (i) a new, open, and impactful codebase; (ii) initiative that secured and exploited telescope time; (iii) modern, rigorous statistical modelling; and (iv) a discovery of immediate community interest. These qualities together make Mr. Kaya Han Taş a most deserving recipient of this prize.

Prof. dr. E. F. (Ewine) van Dishoeck, hoogleraar moleculaire astrofysica Universiteit Leiden
Prof. dr. E. (Eline) Tolstoy, hoogleraar sterrenkunde Rijksuniversiteit Groningen

De jury vergaderde op 11 november 2025 via Zoom onder leiding van KHMW-maatschappelijk lid dr. W. (Willem) Bijleveld. Tevens was ter vergadering aanwezig prof. dr. A.P. (Ad) IJzerman, bestuurslid en secretaris natuur- en medische wetenschappen KHMW.