School of Physics and Astronomy
The Raymond and Beverly Sackler
Faculty of Exact Sciences
Tel Aviv University

בית הספר לפיזיקה ולאסטרונומיה
הפקולטה למדעים מדויקים
ע״ש ריימונד ובברלי סאקלר
אוניברסיטת תל אביב

Prof. Benny Trakhtenbrot
School of Physics & Astronomy
Tel Aviv University
Tel Aviv 69978, Israel
bennyt@tauex.tau.ac.il
www.astro.tau.ac.il/~bennyt
Phone: +972-3-640-6108
Mobile: +972-52-586-7121

May 5, 2025

Dr. Michal Zajaček - Review of Habilitation Thesis

To whomever it may concern,

I hereby provide my evaluation of the Habilitation Thesis by Dr. Michal Zajaček, which was submitted to the The Faculty of Science at Masaryk University.

The Thesis essentially comprises 7 (seven) papers where Dr. Zajaček is obviously the leading author, and which were all published in leading peer-reviewed journals (all in the top quartile of journals in astronomy and astrophysics, according to Web of Science). As of the end of April 2025, the Thesis papers have been cited over 160 times by other works.

The research work presented in the Thesis focuses on various physical processes occurring in the vicinity of so-called supermassive black holes (SMBHs), which we know exist in the centers of the vast majority of (massive) galaxies. The work that Dr. Zajaček led is definitely versatile, as it involves a wide range of such processes - from stellar populations in the center of our own Milky Way galaxy (Chapters 4 & 6/Papers 3 & 5), through detailed "echo-mapping" analyses of the surroundings of accreting, distant SMBHs (Chapters 3, 5, & 8/Papers 2, 4, & 7), to the potential of using such accepting SMBHs as cosmological probes (Chapter 7/Paper 6). As a testimony of his breadth and natural curiosity, that is not bound to a specific technical/spectral regime, Dr. Zajaček also presents a study of the relativistic jets launched from SMBH vicinities (Chapter 2/Paper 1).

Given the scope of work presented in this Habilitation Thesis, and the fact that all papers have been already published in leading, peer-reviewed journals, it would be unreasonable to evaluate all seven papers here. Instead, I chose to focus on the subset of paper related to reverberation mapping (Chapters 3, 5, & 8/Papers 2, 4, & 7) - a topic that is the most relevant to my expertise and which requires immense observational efforts, and thus naturally forms the backbone of the Thesis.

In Chapter 3 (Paper 2), Dr. Zajaček presents an ambitious reverberation mapping campaign of the broad MgII λ2800 emission line in a luminous quasar at cosmological redshift $z = 1.38$, based on six years (!) of spectroscopic monitoring with the SALT 10m telescope. Such heroic campaigns and careful analyses are crucial for our ability to estimate SMBH masses throughout the (distant) Universe, for which it is impossible to use neither reverberation mapping nor any other "direct" method. The particular quasar chosen for this campaign is important, since its high luminosity and accretion rate make it particularly useful for determining the high-luminosity end of the size-luminosity scaling relation and thus for studies of other higher redshift, highly accreting systems. Using a variety of techniques, the line emitting region in this particular quasar was found to be located closer to the SMBH than expected from simplistic scaling relations, in a way that is reminiscent of some earlier findings for lower-redshift systems studied with other emission lines. Indeed, the analysis led by Dr. Zajaček provides a way to account for such discrepancies given the observed accretion rate of the source, showing that the residual scatter on the size-luminosity relations is actually rather small, at ~0.1 dex. This study is impressive in the attention given to various details that are, at times, neglected in other works. One of them is the detailed spectral decomposition of the spectral region surrounding the MgII line, which is known to be challenging for various reasons. It has been a standard reference in many other works that try to determine MgII lags in quasar reverberation mapping campaigns, often with much larger samples but shorter baselines. As such, it remains a key result for the high-luminosity end of all these scaling relations.

In Chapter 5 (Paper 4) Dr. Zajaček presents another, similar reverberation mapping campaign, of another luminous quasar, this time at z~1.2. Here, the SALT data enabled to determine a more precise MgII lag measurement. Adding this new measurement to a literature sample of similar results (from the large SDSS-RM project), the analysis by Dr. Zajaček and collaborators reveals a rather flat size-luminosity relation, again with considerable scatter. Based on their prior experience, they then focus on the highly-accreting sources and show that for those the scatter is actually more limited. The analysis then demonstrates how a tight size-luminosity relation could be used to harness quasars as standard(ized) candles for cosmological measurements. This latter utility has been the focus of several studies for decades, with the great promise of having a direct distance measurement tool out to very early epochs (z>>2), however it is clear the path to this goal is long and is full of hurdles. The work of Dr. Zajaček offers some hope, as it shows us that perhaps a certain subset of quasars could be more useful than others, thus raising a pragmatic way forward.

Chapters 7 & 8 (Papers 6 & 7) present two detailed analyses of two outstanding "technical" issues that may affect our ability to measure lags and luminosities in quasars, and thus limit their usability as cosmological distance indicators. Chapter 8 (Paper 7) re-examines the subtle art of accounting for iron emission when measuring the MgII line. While the refined redshift determination and refined accounting for iron does not significantly affect the MgII lag determination, it does demonstrate the great attention to detail, technical skills, and scientific integrity of Dr. Zajaček. Essentially, the entire analysis presented in Chapter 3 (Paper 2) is critically revisited. The resulting MgII size-luminosity relation is again found to be flat, and indeed flatter than the one related to iron (which is generally thought to be produced in the same region as MgII). In Chapter 7 (Paper 6), Dr. Zajaček asks to test how one of the key prescriptions used in quasar-based cosmological distance measurements (the so called UV--X-ray luminosity relation) is affected by dust attenuation. The latter is generally unknown in any given (distant) source, but this study nicely demonstrates that a simple dust extinction law can explain some of the discrepancies obtained when using this prescription. Both these Chapters (Papers) are the most detailed and novel of their kind I've seen. Dr. Zajaček should be commended for insisting to better understand those seemingly minor, but potentially important issues.

As I noted above, this Habilitation Thesis clearly shows the breadth of interests and skills of Dr. Zajaček, and his ability to lead numerous studies on diverse topics and using various techniques. The reverberation mapping projects alone require meticulous data collection and calibration efforts, precise measurements, the usage of various dedicated and non-trivial statistical tools to retrieve the time lags, an eye for how to construct a relevant literature sample, and finally a physically-sound interpretation of the results. Other projects involve additional, complementary approaches & skills. The overall impression is that Dr. Zajaček can successfully lead teams of researchers in various kinds of studies.

Looking beyond the Thesis content and towards its purpose, I note that Dr. Zajaček is indeed a prolific researcher. Over the same timespan covered by the Thesis papers, he was a 2nd author (co-lead; typically mentoring younger researchers) on 23 *additional* peer-reviewed papers (with over 400 citations), and has contributed to 27 other papers (510+ citations).

All these considerations would definitely place Dr. Zajaček in a position of being promoted to Associate Professor in the institutions I'm familiar with, and indeed in other leading departments. I hereby convey my strong recommendation that Dr. Zajaček should be seriously considered for such a position.

With kind regards,

Benny Trakhtenbrot