Semester Report 2017/2018 Spring

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Ph. D. Thesis Topic: Star formation and active galactic nuclei

Introduction

There is compelling evidence that the growth of supermassive black holes and the stellar populations of their host galaxies are intricately linked (Torres-Papaqui, J. P., et al. 2012). At the same time, the exact relationship between the buildup of stellar mass and the growth of supermassive black holes is still not well understood. The radio emission travels through the dusty media and allows a study of the active nucleus and its physical processes. Molecular line emission on the other hand indicates the physical properties of the interstellar medium. A statistical sample of galaxies should be investigated sampling all evolutionary phases and a range of galaxy masses. For that purpose, the current research will start to uncover parameters of the AGN galaxies in ELAIS N1 field.

The ELAIS (European Large Area ISO Survey) survey was the biggest open-time project of ISO (Infrared Space Observatory). Measurements were taken in four different bands (in a wavelength range of 6.7-175 μm), of multiple regions on the sky (12 square degrees in total). One of these regions was the ELAIS N1 field. Multiple follow up surveys were carried out in different wavelength ranges, from the optical to radio. This way the ELAIS N1 became one of the most known regions on the sky.

Description of my research work

In my second semester of doctoral school, the physical properties of all possible AGN galaxies were studied with different redshift in ELAIS N1 field. I have constructed a catalogue including 44 galaxies based on the new Herschel point source catalogue data combined with Sloan Digital Sky Survey (SDSS), 2MASS, Spitzer, WISE and other archival photometry data. Sources were taken from the HerMES CATALOG (R. S. Bussmann. et. al. 2015) and the WISE AGN CATALOG (R.J. Assef et. al. 2017). I have plotted spectral energy distributions (SEDs) that cover the rest-frame wavelength range from far-UV to far-IR (from 0.15 to 160 micrometre). The SED is a plot of energy versus frequency or wavelength of light and it is used to describe the emission which coming from the source along range of different wavelengths. The SEDs have been then modelled using the **CIGALE** software, deriving galaxy properties with a high reliability by fitting the attenuated stellar emission and the related dust emission at the same time. The 44 galaxies were sorted into 4 different types of AGNs: 7 Sy1, 5 Sy2, 31AGN and 1 BSG.

The CIGALE fitting resulted a large number of physical quantities for each galaxy. I focus on certain quantities in my research: the star formation rate (SFR),

stellar mass, AGN luminosity, stellar luminosity, star formation age and the metallicity. I made use of several modules in the CIGALE software: Star Forming History module, SSP module, Nebular emission module, Dust attenuation module, Dust emission module, AGN module, Radio and Redshift modules.

In our fitting you will see some symbols and lines indicate to some meanings. Where, the filled red circles indicate to the model fluxes, open squares to the observed fluxes, open red squares to the observed fluxes without errors, orange line to the stellar attenuated, blue dots line to the stellar unattenuated, light green lines to the nebular emission, red line to the dust emission, green line to the AGN emission, wine line to radio nonthermal emission, bold black line to model spectrum. During the current semester, 36 AGN galaxies out of 44 were fitted.

The quality of the SED fits was measured by a weighted Khi square value. I show a good fit as an example below in Fig. 1 A). The other figures demonstrate the importance of the Herschel photometry data, and the CIGALE AGN module. As it is clearly seen in Fig. 1B) the fitting has significantly different results without the Herschel fluxes. Fig 2 shows that without the fit quality gets worst without the use of the AGN module.

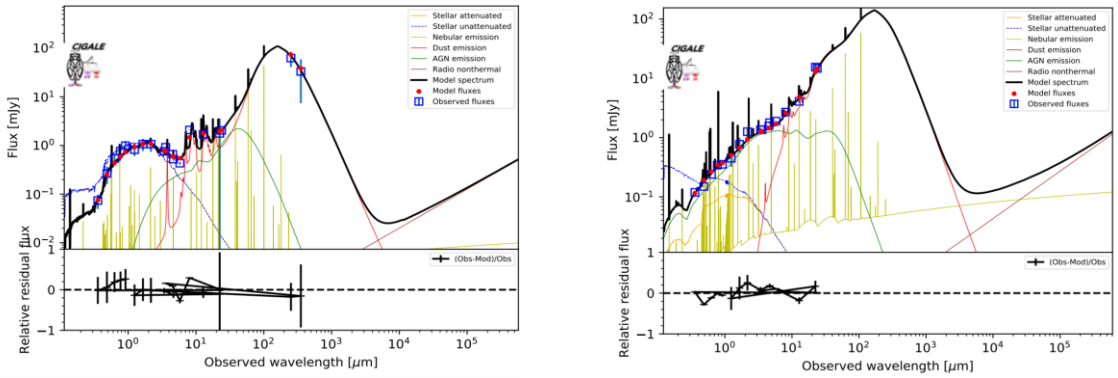

Fig. 1. The SED for object # 4. 1A) LEFT: with Herschel photometry data included; 1B) RIGHT: without Herschel data

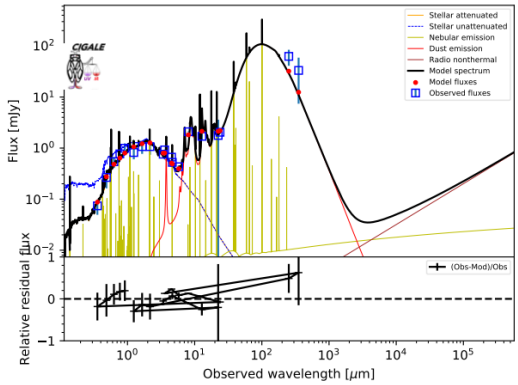

Fig. 2. The SED for # 4. The same as Fig. 1A without using the CIGALE AGN module

Main results

- Most of the available galaxies in the catalogue are in the Local Universe (i.e. with redshifts of z <0.2), except 3 objects: #22, #26, #42.
- According to the my SED fits the galaxies are divided in three categories depending on SFR:
    - 6 galaxies have an SFR of less than 1 solar mass/year
    - 12 galaxies have an SFR of a few solar masses/year (up to 10)
    - 3 galaxies have SFR >10 solar masses/year
- The 3 highest SFR galaxies are all beyond the Local Universe, also they have the greatest AGN and dust luminosity, while they do not show obvious differences in their stellar mass compared to the other galaxies.
- According to my SED fits there is a significant difference in most of parameters derived with or without using the AGN module.
- I note that there were a few objects for which I could not derive a good fit. For all of them there was a problem in optical data. The fluxes in the visible wavelengths were much higher than the prediction by the model spectrum.

Educational activities in the current semester

I have participated in three ELTE courses in weekly frequency:

Introduction to astronomy II: That was an introductory course by Dr. Kristóf Petrovay, based on the Fundamental Astronomy text book by Karttunen, where I learnt the basics and a lot of definitions. The topics were about the properties and the life of stars, binary stars, extragalaxies and the structure of the Universe.

Radio astronomy II.: Was given at the Konkoly observatory by Dr. Sandor Frey and Dr. Krisztina Gabanyi, based on the book "Tools of Radio Astronomy" by T. L. Wilson et al. This course was started with the radio Astronomy in the solar system and classification of radio galaxies. They also talked about the galactic radio Astronomy, giving examples for extragalactic and compact extragalactic radio sources. As well as, the Cosmic Microwave Radiation (CMB) and radio Astronomy of cosmology were discussed. Finally, the students made seminars about related topics with a certain published paper, and I had a chance to do a seminar about the water maser emission in the Saturnian system (S. V. Pogrebenko et al 2009). In that seminar I reviewed a brief history and the definition of MASER, and I discussed the feasibility of water maser detection in the Saturnian environment. In addition, their observations and data processing were explained. Moreover, I showed the final results and the main conclusion.

Infrared astronomy II: The course was given by Dr. L. Viktor Tóth, and it was based on the Infrared Astronomy text book by L. Viktor Tóth et al. 2013. In this course I learned about the extragalactic infrared astronomy as; nearby galaxies, luminous and ultraluminous galaxies, GRBs and the cosmic infrared background. Furthermore, the infrared confusion and the Herschel confusion as an example were dealt that text book. At the final, we prepare a project related to infrared topics. My

project was fitting the SED for AGN galaxies with new Herschel data and without to compare between that two fits for each one to know the changes of the physical parameters. That project improved my current research itself.

Grants and awards:

I have applied for and got a grant from the International Astronomers Union to attend the 30th IAU General Assembly in Vienna August 2018.

Conferences in current semester:

I am going to attend the 30th IAU General Assembly in Vienna August 2018 I will have two poster contributions there: one at the Focus Meeting 3 "Radio Galaxies: Resolving the AGN phenomenon" and another one at the Focus Meeting 15 "Astronomy for Development".

I note that have registered for two international doctorate schools which will be organized in the next (autumn) semester:

- VI Byurakan International Summer School (6BISS) will take place at Byurakan Astrophysical Observatory on September 10-15, 2018. it talks about Data Reduction and Analysis, Astrostatistics, Virtual Observatories, Astronomical Databases and Archives and Astrophysical Applications.
- The 10th IRAM millimeter interferometry school will be held October 1st - 05th 2018 at the IRAM headquarters (Grenoble, France). It is intended for students, post-docs and scientists who want to acquire a good knowledge of interferometry and data reduction techniques at millimeter wavelengths, with a special emphasis on the NOEMA interferometer and its new capabilities. The program will include lectures on: fundamentals of millimeter interferometry, atmospheric phase correction, data calibration and imaging techniques, NOEMA and ALMA. This school is very useful also for my next project.