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The galaxy NGC 1222 seen from the Near-Infrared

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Abstract. The Galaxy NGC 1222 is a starburst with a compact nucleus, producing a spectrum with intense emission, which is estimated to be photoionized by approximately 10^5 OB type stars. There are studies suggesting that this galaxy may have formed much more massive stars than any other similar galaxy with the same morphology and metallicity. However, these studies are based on low spatial resolution spectra, which mix the emission from the compact source with the more extended emission. In this work we propose to study the ionizing sources of NGC 1222 using long slit spectra in the near infrared. The slit used is narrow, so the likelihood of contamination of the nuclear source from external sources is unlikely. With these data we hope to obtain more robust conclusions about the ionizing stellar population of this galaxy.

Resumo. A Galáxia NGC 1222 é uma starburst com núcleo compacto, produzindo um espectro com intensa emissão, que se estima ser fotoionizada por aproximadamente 10^5 do tipo OB. Há estudos que sugerem que esta galáxia pode ter formado estrelas muito mais massivas do que qualquer outra galáxia semelhante com a mesma morfologia e metalicidade. No entanto, esses estudos são baseados em espectros de baixa resolução espacial, que mesclam a emissão da fonte compacta com a emissão mais extensa. Neste trabalho propomos estudar as fontes ionizantes de NGC 1222 usando espectros de fenda longa no infravermelho próximo. A fenda usada é estreita, portanto, a probabilidade de contaminação da fonte nuclear por fontes externas é improvável. Com esses dados esperamos obter conclusões mais robustas sobre a população estelar ionizante desta galáxia.

Keywords. Infrared: galaxy – Galaxies: starburst – Galaxies: evolution

1. Introduction

Starburst galaxies are galaxies that are forming stars at a significantly higher rate than could be sustained by Hubble time. These galaxies are natural laboratories for the detailed study of stellar formation and evolution, as well as the interstellar medium.

Star formation in starburst galaxies is often concentrated in heavily obscured compact regions. For this reason, it is often quite difficult to study the stellar content of these sources. It is not possible to study these stars directly, but only through the nebulae they excite. However, results obtained using nebular diagnoses have shown controversial results. In a study of all infrared spectrum galaxies available in the literature at the time, Rigby & Rieke (2004) concluded that young stellar populations in solar metallic galaxies have a relatively low effective temperature, and that, considering the Initial Mass Function (IMF) from Salpeter Salpeter (1955), their masses should not exceed $100M_{\odot}$. They suggest that the stellar mass upper limit for these galaxies is $\approx 40M_{\odot}$. This apparent absence of extremely massive stars in starburst galaxies is a major puzzle for studies of star formation. Understanding whether this effect is real or just apparent due to observational biases is one of the biggest questions to be answered in this area of astrophysics.

In light of this scenario, we look into the galaxy NGC 1222 (or Mrk 603), which is a large spheroidal galaxy (morphological type S0) with a starburst core that is a compact source in both radio and in infrared. Located 34 Mpc away, NGC 1222 is notable for being only slightly richer in metals than our Galaxy (if that), and yet having the spectral signatures in the mid-infrared of the hottest and most massive stars (Beck et al. 2007). Beck et al. (2007) present a study of the mid-infrared spectrum of this galaxy obtained with the Infrared IRS spectrograph aboard the Spitzer Space Telescope. They modeled the infrared emission from this galaxy by superimposing a bright, compact nebula that contains the youngest stars and produces high excitation emission lines, and a "cooler" spectrum of a wider region ($\approx$ 500pc). However, the results obtained by the authors are based on the Spitzer spectra, which have a very wide slit, in such a way that it mixes the emission of compact and extended sources. For this reason the authors had to separate the spatial distribution of observed line ratios using assumptions and models. As the authors themselves argue, the models they present are based on many assumptions and the results presented are just lower limits. Still, it is possible to say that galaxy NGC 1222 has one of the highest upper limits of mass for a galaxy other than a metal-poor dwarf. For this reason, a more detailed study, with narrower slits and larger spatial resolution could help unravel the nature of star formation in this galaxy. We then obtained long-slit spectra of galaxy NGC 1222 using the Spex spectrograph of NASA's 3m IRTF (Infrared Telescope Facility) telescope. The 0.8" width of this slit, compared to the $\approx$3.5" width of the observations by Beck et al. (2007) will be crucial to isolate the compact fonts.

2. Data

For the development of this project, data collected with the NASA 3m infrared telescope (IRTF) in November 2007 was used (P.I. L.P. Martins), using the Spex spectrograph (Rayner et al. 2003). The instrument was used in cross-dispersion mode (0.8-2.4μ). The detector consists of an ALLADIN 3 InSb array of 1024 x 1024 pixels, with a spatial scale of 0.15 arcseconds per pixel. A 0.8" x 15" slit oriented in the north-south direction was used, providing an average spectral resolution of 320 km/s. A telluric star was observed after observing the galaxy, close in air mass, to remove the telluric signatures. Flux calibration, spectrum extraction and wavelength calibration was performed using SPEXTOOL software (Cushing et al. 2004). In the end, the spectrum was corrected by galactic extinction using the extinction law of Cardelli (1989) and the extinction maps by Schlafly & Finkbeiner (2011). We were able to extract 8 apertures along the north-south axis of the galaxy NGC 1222.

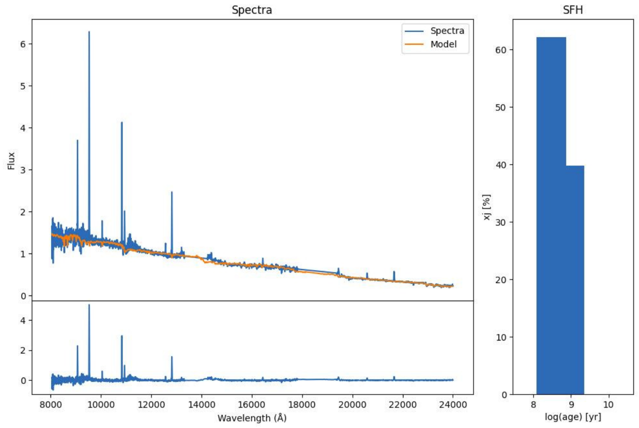

Figure 1. Top left: Stellar population fit of the nuclear aperture of the galaxy NGC 1222. Bottom left: residual spectrum, after the stellar population subtraction. Right: star formation history of the aperture obtained through the stellar population fit.

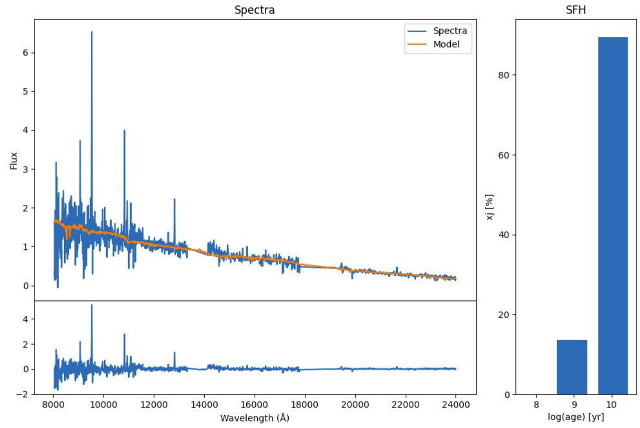

Figure 2. Top left: Stellar population fit of the most distant off-nuclear aperture of the galaxy NGC 1222. Bottom left: residual spectrum, after the stellar population subtraction. Right: star formation history of the aperture obtained through the stellar population fit.

We are interested in measuring the emission lines in the spectra, and because of that we have to subtract from them the stellar population contribution. To fit the stellar population, we used the code STARLIGHT (Cid Fernandes et al. 2004, 2005; Mateus et al. 2006; Asari et al. 2007). As a base of single stellar population models we used the E-MILES library (Vazdekis et al. 2015), as it covers the entire spectral region of our observations.

For the base, 3 different metallicity values were used. They are: [M/H] = -0.66 (Z = 0.004); +0.06 (Z = 0.0198); +0.40 (Z = 0.040); and 11 ages ranging from 0.03 Gyr to 13 Gyr, totaling 33 models. We chose the models with isochrones from BaSTI ((Bag of Stellar Tracks and Isochrones, Hidalgo et al. 2018) and Kroupa Universal IMF (Kroupa 2001), which is similar to the Salpeter IMF for stars with masses greater than 0.5 $M_{\odot}$, but with decreasing contribution from smaller masses.

3. Preliminary Results

The results of the stellar population fitting of two apertures are shown as example in Figures 1 (central aperture) and 2 (most distant off nuclear aperture).

From these figures it is possible to identify the presence of many emission lines, much stronger in the central apertures, which will be used to test the scenario of ionization by high mass stars. From the stellar population fit it is possible to note a clear gradient of stellar population age, with the nuclear region presenting a very young stellar population, the region near the nucleus with an intermediate age population, and the far region with an older stellar population. In the lower panel of the figures is the final spectrum of the galaxy without the stellar population.

The next step of this work will be to measure the emission lines and use photoionization models to carry out the analysis of the gas excitation source. In addition to this information, we can raise other information that will help to better understand the morphology of this galaxy, such as the extinction by dust and its effects, which are crucial for understanding the physics of the star formation.

4. Conclusions

We are using long-slit NIR spectra of the galaxy NGC 1222 to try to understand if this galaxy harbors the very massive ionizing starts missed in most galaxies with similar morphology and metallicity. The preliminary study of the stellar population in this galaxy shows that the young population is mostly concentrated in the very center, where most of the strong emission lines are observed (although some extended emission is present). After the subtraction of the stellar population from the spectra, we will measure its emission lines and use photoionization models to test the hypothesis of the presence of these very massive stars. With that we hope to shed some light into the relationship between the metallicity of the interstellar medium and the star formation process.

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