Stellar Populations in the Nucleus of NGC 6764

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Abstract. We present first results of near-infrared integral field spectroscopy of the central 8″×8″ of the Wolf-Rayet nucleus of the barred spiral galaxy NGC 6764. In addition to stellar CO and Na I absorption lines as well as recombination lines of H and He I the K-band spectrum shows strong emission from molecular hydrogen. Analysis of the stellar nuclear light using population synthesis in conjunction with NIR spectral synthesis suggests either the presence of two starbursts with ages of \(\sim 5\) Myrs and \(\sim 20\) Myrs or continuous star formation with a star formation rate of \(\sim 0.4\) \(M_\odot\) yr\(^{-1}\) over the past 1 Gyr.

1. INTRODUCTION

NGC 6764 is a nearby (32 Mpc for \(H_0=75\) km s\(^{-1}\); 1″=160 pc) S-shaped barred spiral galaxy (SBB), classified as a LINER galaxy on the basis of optical spectroscopy. The galaxy contains a nuclear stellar optical continuum source with a “width” of \(\sim 1.6″\) or about 200 pc (Rubin, Thonnard, & Ford 1975). NGC 6764 is unusual in that it displays a prominent 466 nm Wolf-Rayet emission feature at the nucleus. Wolf-Rayet emission features are rarely observed in galaxies, and their presence is indicative of very recent massive star formation (Armus, Heckman & Miley 1988; Conti 1991). The study of such objects is essential for understanding the starburst phenomenon in galaxies.

A first analysis of the starburst activity in NGC 6764 was presented in Eckart et al. (1991) and Eckart et al. (1996) and revealed a dense concentration of molecular gas and a very recent (at most a few times \(10^7\) years) starburst at the nucleus of NGC 6764. Here we present first K-band integral field spectroscopy of the NGC 6764 nucleus (see Fig.1). Observational details as well as a more thorough description of the analysis will be presented in a forthcoming paper.
2. THE NUCLEAR STAR FORMATION HISTORY

To investigate the nuclear star formation history further, we use the population synthesis code STARS which was successfully applied to a number of galaxies (e.g. Krabbe, Sternberg & Genzel 1994, NGC 1808) in conjunction with the NIR spectral synthesis code SPECSYN (Schinnerer et al. 1997 and references therein). STARS has as output observable parameters such as the bolometric luminosity \( L_{\text{bol}} \), the \( K \) band luminosity \( L_K \), the Lyman continuum luminosity \( L_{\text{LyC}} \) and the supernova rate \( \nu_{\text{SN}} \), as well as the diagnostic ratios between these quantities: \( L_{\text{bol}}/L_{\text{LyC}} \), \( L_K/L_{\text{LyC}} \) and \( 10^9 \nu_{\text{SN}}/L_{\text{LyC}} \). All three ratios are measures of the time evolution and the shape of the IMF, with slightly different dependencies on its slope \( \alpha \) and upper mass cutoff \( m_u \). H-R diagrams representing the distribution of these luminosities are calculated. SPECSYN uses the distribution of K band luminosity \( L_K \) within the H-R diagram to weight standard star spectra of different spectral type and luminosity (Schinnerer et al. 1997, Schinnerer et al. in prep).

2.1. The Parameters for the Population Synthesis

NIR integral field spectroscopy revealed that the star formation is concentrated on the nuclear region. To estimate \( L_{\text{bol}} \) for the central 3” (~ 500 pc) of NGC 6764 we followed the approach of Eckart et al. (1991). \( L_K \) and \( L_{\text{LyC}} \) were estimated via the equations given in Genzel et al. (1995) (using a \( \delta \lambda = 0.6 \mu \text{m} \) as the \( K \) band width) and taking the values measured with 3D in a 3” aperture. From our analysis we infer an extinction towards the nuclear stellar cluster of about \( (2 - 3)^{\text{mag}} \) in agreement with the observed Br\( \delta / \text{Br\( \gamma \)} \) ratio and earlier findings by Eckart et al. (1996). In addition we see evidence for a 5% non-stellar contribution to the \( K \) band continuum either from warm dust or a power law contribution from the AGN itself. For \( \nu_{\text{SN}} \) we used the relation given by Condon (1992) and the nuclear 5 GHz flux of 3.4 mJy from Baum et al. (1993).

2.2. Results of the Modeling

Given the presence of the WR stars two scenarios have been considered: (1) Two starburst events and (2) continuous star formation. Both possibilities are
Figure 2. Maps of the 2.29\(\mu\)m \(^{12}\)CO 2-0 absorption (left) and 2.06\(\mu\)m He I emission line towards the nucleus of NGC 6764. The black solid contour line is the 50/continuum emission and the white solid line is the 3\(\sigma\) contour line of the line absorption and emission. The beam in the lower left corner of the maps has a FWHM of 1.2".

explored in the following.

**Two Young Starbursts:** The Wolf-Rayet features indicate a very recent star formation event only about 5 Myrs ago. This immediately implies a second starburst event to account for the presence of the cool evolved stars indicated by the stellar absorption features (see fit in Fig.1). The current appearance of the NGC 6764 nucleus may therefore be dominated by two major starburst events:

**Starburst about 5 Myrs ago (SB#1):** Assuming a starburst event with a decay time of 3 Myrs seems reasonable given the fact that SN explosions might disturb the ISM medium and prevent further star formation. For a starburst of that age STARS gives a mean hot star of type O5 with a mean effective temperature of \(T_{\text{eff}}=45000\text{K}\). Boer & Schulz (1989) find an electron density of of \(n_e \approx 6 \times 10^2\text{cm}^{-3}\) (with \(T_e=10^4\text{K}\)). Neglecting dilution effects this gives an HeI/Br\(\gamma\) ratio of 0.7 (Laçcon & Rocca-Volmerage 1996). Comparison of \(K\) band spectra from active galaxies with an AGN and starburst galaxies (Vanzi et al. 1998) suggests that strong HeI line emission is only present in starburst galaxies. This may indicate that most of the HeI line flux observed towards the nucleus of NGC 6764 is due to young, hot stars and not due to an AGN component. This allows us to correct the observed HeI/Br\(\gamma\) ratio and obtain the Br\(\gamma\) line flux that is associated with this starburst event. We derive that about 65\% of the Br\(\gamma\) line flux is due to an 5 Myrs old starburst.

**Starburst about 16 Myrs ago (SB#2):** This second starburst has to account for about 94\% of the total \(L_K\) and the total amount of \(\nu_{SN}\). If the age is about 20 Myrs all Br\(\gamma\) line flux not accounted by SB#1 could be associated with the LINER nucleus. For starbursts with ages of \(\sim 1\) Gyr AGB stars have a prominent contribution to the \(K\) band continuum (Laçcon & Rocca-Volmerage 1994, Laçcon & Rocca-Volmerage 1996). However, in the case of the NGC 6764
nucleus a starburst of this age cannot account for the observed extended nonthermal radio emission which is very likely due to star formation, e.g. SN explosions. A starburst age of \( \sim 1 \) Gyr therefore does not appear to be very plausible for SB#2. This scenario is similar to the one found in IC 342 where a 70 pc diameter starburst ring with an age of about 5 Myrs surrounds a nuclear starburst of about 15 Myrs (Böker, Förster-Schreiber & Genzel 1997).

**Continuous Star Formation:** Assuming continuous star formation in the nuclear region the stellar cluster must have an age of \( \leq 1 \) Gyr, since enough cool evolved stars are produced to obtain the observed ratio of \( L_K \) to \( L_{LyC} \) ratio. It is necessary to reach the AGB phase to obtain a reasonable fit, since only then the cool luminous stars are numerous. This analysis is, however, hampered by the fact, that the currently available evolutionary tracks of the high mass stars in general do not produce very cold red super-giants (e.g. of type M) and that SPECSYN does not use spectra of AGB stars. We use evolutionary tracks extended for the AGB phase (N.M. Schreiber 1998, PhD thesis, LMU Munich) and approximate the spectra of AGB stars by those of a red M type super-giant (RSG). In this scenario, it is expected that the WR emission and the stellar absorption bands would have similar distribution even at highest spatial resolution. The corresponding fit to the data is of similar quality as the fit for two bursts shown in Fig.1.

**In summary:** The hot stars (HeI/Br\( \gamma \) ratio of \( 0.46 \pm 0.06 \) indicating \( T_{\text{eff}} \sim 35000 \) K), the Wolf-Rayet stars (466 nm Wolf-Rayet emission feature) and the evolved cool stars (see CO absorption band heads at \( \lambda \geq 2.29 \mu \text{m} \) and NaI absorption at 2.21 \( \mu \text{m} \) could be either co-spatial or might form a young starburst ring around the older nuclear stellar cluster as observed in IC 342 (Böker, Förster-Schreiber & Genzel 1997). Our analysis indicates two possible nuclear star formation histories: (1) Two starbursts with ages of about 5 Myrs and about 16 Myrs producing the WR stars and red super-giants that contribute to a large amount of the \( K \) band continuum. (2) Continuous star formation with a SFR of \( \sim 0.4 \, M_\odot/\text{yr} \) for at least 1 Gyr.