Central UV Spikes in two Galactic Spheroids†

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FOS spectra and FOC photometry of two centrally located, UV-bright spikes in the elliptical galaxy NGC 4552 and the bulge-dominated early spiral NGC 2681, are presented. These spectra reveal that such point-like UV sources detected by means of HST within a relatively large fraction (≈ 15%) of bulges can be related to radically different phenomena. While the UV unresolved emission in NGC 4552 represents a transient event likely induced by an accretion event onto a supermassive black hole, the spike seen at the center of NGC 2681 is not variable and it is stellar in nature.

1. Introduction

HST UV images of nearby galaxies presented by Maoz et al. (1996) and Barth et al. (1998), as well as analogous space-borne optical images of early-type galaxies discussed by Lauer et al. (1995) and Carollo et al. (1997) have shown that about 15% of imaged galaxies show evidence of unresolved central spikes.

In the following we discuss two ‘prototype’ galactic spheroids—NGC 2681 and NGC 4552 we properly monitored with HST—which host UV-bright, unresolved spikes at their center. While the early-spiral (Sa) galaxy NGC 2681 shows a nonvariable unresolved cusp, the UV spike which became visible at the center of the Virgo Elliptical NGC 4552 is a UV flare caught in mid-action, presumably related to a transient accretion event onto a central supermassive black hole (Renzini et al. 1995; Cappellari et al. 1998).

Although radically different phenomenologies are involved, the appearance of either nuclei—recently imaged in the UV (FOC/96 F342W) by means of the refurbished HST—is quite similar. Nevertheless, basic pieces of information can still be extracted from photometric profiles alone which represent a potential diagnostics to disentangle the above scenarios. For instance, the UV-bright unresolved spike observed at the center of NGC 2681 does not vary and matches a pure nuker law profile of the power law type (Cappellari et al. 1999). On the contrary, in order to model the flaring UV spike at the center of NGC 4552 one has to add to the observed galaxy profile the contribution of an unresolved central point source, whose intensity is allowed to vary (see Fig. 1).

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Figure 1. The inner surface brightness profiles (arbitrary magnitudes) of NGC 2681 (Left panel) and NGC 4552 (Right panel) vs. log $r$ in the FOC/96 F342W waveband. Diamonds represent the observed profiles, the dashed lines represent models of the true galaxy profiles and finally the solid line shows the above models after convolving with the proper PSF. NGC 2681 is a typical power-law bulge, while NGC 4552 is a classic giant elliptical with core, but one need to add a central point-like source to the Nuker-law in order to reproduce the observed profile.

2. Observations and Reductions

FOC UV observations of NGC 4552 obtained in 1991, 1993 and 1996 are described in detail by Cappellari et al. (1998). These data include a single FOC/96 F342W frame obtained on July 19, 1991 and subsequent images obtained on November 27-28, 1993 in four consecutive UV passbands (FOC/96 F175W, F220W, F275W, F342W). We observed NGC 4552 for a third time on May 24, 1996 with COSTAR-Corrected HST making use of a comparable set of UV filters as in 1993 (FOC/96 F175W, F275W and F342W). Initial FOC images of NGC 2681 were obtained by our group on November 4-5, 1993 in the FOC F175W, F220W, F275W, and F342W filters, pre-COSTAR. As with NGC 4552, we also obtained a set of post-COSTAR UV images on February 1, 1997 of NGC 2681 with the same FOC filter set (apart from F220W) as used in 1993. All FOC images have been re-calibrated in a self-consistent manner, including all required correction factors for PSF and sensitivity differences (zoom/non-zoomed modes and COSTAR) as well as nonlinearity effects. In addition to the FOC images obtained in 1996, we were also able to obtain FOS spectra of both galaxies. The FOS peak-up procedure was used to locate the $0''/2$ square aperture on the nucleus of each galaxy (as confirmed via the multiple peak-up output). FOS gratings G270H, G650L and G780H were used for each galaxy. The nuclear spectra of NGC 4552 and NGC 2681 were obtained on May 24, 1996 and on February 2, 1997, respectively.

3. Results

The ultraviolet-bright source in NGC 4552 was first detected in 1991, it increased in luminosity by a factor of $\sim 4.5$ by 1993, and then declined a factor of $\sim 2.0$ by 1996. On the contrary 1993 and 1997 UV FOC observations of NGC 2681 are consistent with no variation at all.

The overall nuclear FOS spectra of NGC 2681 and NGC 4552, together with the IUE and optical underlying spectra normalized to the visual region, are shown in Fig. 2. As is evident, in the case of NGC 2681 the match of the two spectra is quite striking, thus implying that the UV continuum flux of NGC 2681 is simply dominated by its stellar population, essentially identical in its innermost regions and in the whole $10''\times 20''$ IUE aperture. On the other hand, FOS spectroscopy of NGC 4552 reveals a strong UV
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Figure 2. Upper panel: The overall 1997 FOS spectrum of NGC 2681 within the 0\arcsec.2 × 0\arcsec.2 aperture centered on the spike (thin line), is superimposed to the IUE spectrum of the same galaxy within a 10\arcsec.×20\arcsec. aperture (Burstein et al. 1988), properly normalized to the visual region. Lower panel: The 1996 FOS spectrum of NGC 4552 centered on the spike (thin line), is superimposed to a scaled combination of the IUE spectrum of the same galaxy matched to ground-based optical spectrum of NGC 4649, a giant elliptical whose SED is virtually the same as that of NGC 4552 (thick line). The spectra have been normalized to the visual region. The NGC 4552 spectrum appears quite different owing to a continuum UV excess shortward of \(\lambda \sim 3000\ \text{Å}\). This UV excess is absent in NGC 2681.

Figure 3. The FOS G780H spectrum of NGC 2681 (left panel) and NGC 4552 (right panel), showing the region of the [O i], [N ii], H\(\alpha\), and [S ii] emission lines. In both panels a starlight template (obtained as in Ho et al. 1997) has been subtracted from the upper plot spectrum to obtain the continuum-free spectrum of the lower plot.

The FOS G780H spectra of NGC 2681 and NGC 4552 including the [O i], [N ii], H\(\alpha\), and [S ii] emission lines. In both panels a starlight template (obtained as in Ho et al. 1997) has been subtracted from the upper plot spectrum to obtain the continuum-free spectrum of the lower plot.

continuum over the spectrum of the underlying galaxy, along with several emission lines in both the UV and the optical ranges. The SED of the spike alone—obtained by subtracting the V-mag normalized IUE spectrum of the galaxy from the FOS spectrum—indicates a temperature of \(T \sim 15000\ \text{K}\) for the spike in 1996, if a thermal origin for the UV flux is assumed.
Figure 4. The location of the NGC 2681 (large gray square) and NGC 4552 (large open square) nucleus (as derived from the narrow line emission components measured on the FOS spectra) on the diagnostic diagrams used by Ho et al. (1997). The corresponding errors are of the size of the smaller symbols. The other symbols represent the nuclei included in the Ho et al. sample (crosses = H II nuclei, filled squares = Seyfert nuclei, filled circles = LINERS, open circles = transition objects). The vertical and horizontal lines delineate the boundary adopted by Ho et al. between (a) H II nuclei, (b) Seyfert galaxies, (c) LINERS and (d) Transition objects.

and [S II] emission lines are presented in Fig. 3. In NGC 2681 all lines are well fitted by a single gaussian component with FWHM of $\sim 470$ km s$^{-1}$. In the case of NGC 4552 however both permitted and forbidden lines are best modelled with a combination of broad and narrow components, with FWHM of $\sim 3000$ km s$^{-1}$ and $\sim 700$ km s$^{-1}$, respectively. The 1996 broad Hα luminosity of this mini-AGN is $\sim 5.6 \times 10^{37}$ erg s$^{-1}$, about a factor of two less than that of the nucleus of NGC 4395, heretofore considered to be the faintest known AGN (Filippenko et al. 1993).

The FOS spectroscopy indicates also a significant similarity between the two nuclei, namely their emission line ratios and related gas diagnostics and UV-source classification. A comparison of the emission line ratios of the narrow components for both the NGC 4552 and NGC 2681 spikes with the distribution of Seyfert galaxies, LINERS and H II regions in the diagnostic emission line diagrams of Ho et al. (1997) is given in Fig. 4. As is evident, the line ratios definitively place both spikes among extreme AGNs. The ratios for NGC 4552 fall just on the borderline between Seyferts and LINERS, while those measured for NGC 2681 indicate that this nucleus can be classified as a LINER.

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