IRAS 16511+2354: A type II quasar

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IRAS 16511+2354: A Type II Quasar*

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Abstract. Both the (ultra) luminous infrared galaxies and quasars are associated with mergers. IRAS 16511+2354 is a luminous infrared galaxy hosting a type II quasar. Based on deep optical images, we find weak asymmetrical features that are most probably of tidal origin. The spectral energy distribution of the object was fitted with models accounting for the host galaxy and the nucleus. We derive the star formation rate related to the emission of the starburst component in the far-infrared: $\mathrm{SFR_{IR}} = 36.7^{+2.9}_{-3.8}\ M_\odot\ \mathrm{yr}^{-1}$.

INTRODUCTION

Luminous infrared galaxies (LIRGs) and ultra LIRGs (ULIRGs) are defined as having total IR luminosity $10^{11} L_\odot \leq L_{\mathrm{IR}} \equiv L(8-1000\ \mu\mathrm{m}) < 10^{12} L_\odot$ and in excess of $10^{12} L_\odot$ up to $10^{13} L_\odot$, respectively. Both are rich in dust, as well as neutral and molecular gas. The IR excess results from dust reprocessing due to star formation (SF) and active galactic nuclei (AGNs). Generally, the SF in local LIRGs is centrally localized and is considered related to interactions and mergers [1].

The high accretion rates of luminous AGNs are typically associated with mergers. ULIRGs host dust-enshrouded quasars in their centres [2]. Besides, type II quasars may be observed at an earlier evolutionary stage compared to type I ones.

There are various SF rate (SFR) indicators throughout the electromagnetic spectrum based on emission line (e.g., Hα and [O II]) and continuum, like ultraviolet and far-infrared (FIR), luminosity (see the review of Ref. [3]). Hα luminosity, among the most often used indicators, seriously underestimates the SFR due to extinction. Furthermore, the AGN emission must be taken into account. The other SFR estimators share the same disadvantages. It is the FIR-based SFR that is assumed to be free of extinction effects to the utmost extent [4].

We initiated a study on objects, transition in phase between ULIRGs and "classical" quasars. IRAS 16511+2354 (z=0.103415) is a part of this sample. It hosts a type II nucleus with [O III] $\lambda 5007$ luminosity $L_{[\mathrm{O\,III}]} = 10^9 L_\odot$ [5]. This makes IRAS 16511+2354 a type II quasar hosted by an LIRG. It is located in the AGN region of the Baldwin-Phillips-Terlevich (BPT) diagnostic diagrams [6] and shows no Wolf-Rayet features in its spectrum [7].

DATA PROCESSING

Data from the Hubble Space Telescope (HST; Proposal ID 13728, PI: S. Kraemer), Canada-France-Hawaii Telescope (CFHT), and Sloan Digital Sky Survey (SDSS) were used. Regarding the HST data, we constructed a structure map of the continuum (FR647M) image and an unsharp-divided residual (with median filter size of 9 px) of the [O III] (FR551N) image. The stacked deep (total exposure time of 720 sec) r-band CFHT image was adaptive filtered.

We built the spectral energy distribution (SED) of the object using data from IRAS, WISE, 2MASS, SDSS, Swift/UVOT, and GALEX surveys. Two deviant data points – IRAS (12 μm) and Swift/UVOT (M2 filter) – were removed. The SED was fitted with the AGNfitter code of Ref. [8].

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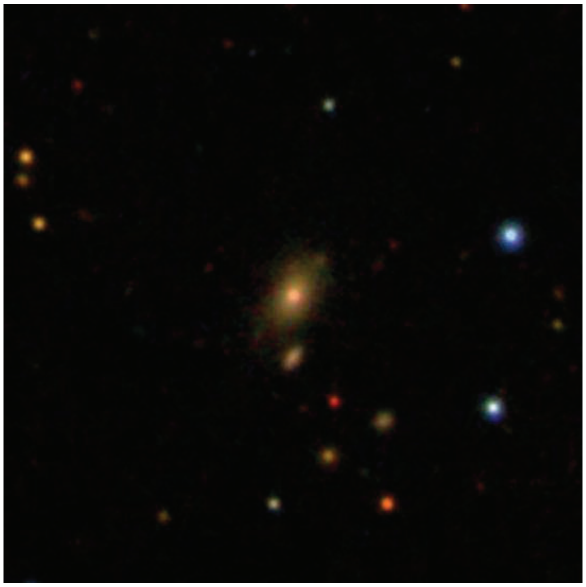

FIGURE 1. RGB SDSS image of IRAS 16511+2354. The image size is as in Figure 2. In all figures north is up and east to the left.

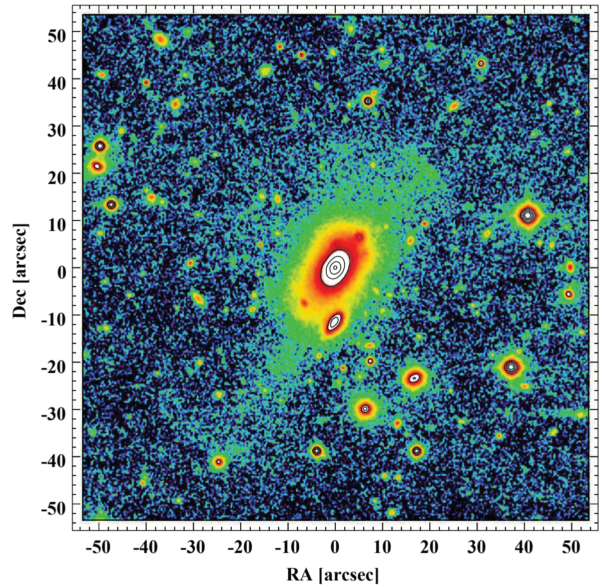

FIGURE 2. Adaptive filtered r-band CFHT image of IRAS 16511+2354.

RESULTS AND DISCUSSION

The host galaxy has smooth early type (E or S0) appearance on the SDSS images (Figure 1). The deep CFHT images (Figure 2), however, reveal a northern arc/shell, brightest 29″ to the northwest and a fainter one 47″ in the opposite direction. There is diffuse emission up to the northern arc. The brightest parts of both arcs seem connected to the central galaxy region by elongated features. These structures (which may also be affected by inclination effects in case of a disk galaxy) are most probably relics from a past merger. There are no confirmed companions. The largest among the projected objects of non-stellar appearance is just 12″ to the south.

The HST continuum structure map (Figure 3) unveils a protrusion to the northwest, as well as dust patches to the south and west, in the innermost arcsecond. Regarding the [O III] unsharp-divided residual (Figure 4), a conical structure up to 2.4″ east-northeast and 1.3″ in the opposite direction, the latter more irregular, are outstanding. Rotational pattern in the innermost ≈ 0.6″ was reported in Ref. [9].

To assess the SFR, we used the FIR continuum luminosity as least affected by extinction. The SFR was derived following Ref. [10]:

$$\left(\frac{\mathrm{SFR_{IR}}}{M_\odot\,\mathrm{yr}^{-1}}\right) = 3.88 \times 10^{-44} \left(\frac{L_{\mathrm{IR}}}{\mathrm{erg\,s}^{-1}}\right).$$

We estimated the IR luminosity after Ref. [11]. The IRAS 12 μm flux value is an outlier on the SED, so, we used the WISE W3 flux value instead. Given the adopted cosmological parameters ($H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}, \Omega_\mathrm{M} = 0.3, \Omega_\Lambda = 0.7$), the object has $L_{\mathrm{IR}} = (3.6 \pm 0.5) \times 10^{11} L_\odot$ (it would be by one third larger if using the original 12 μm flux value).

In order to account for the torus emission, the SED was fitted with models involving the emission of both the host galaxy (stellar population and starburst cold dust), and the AGN (accretion disk and torus). The output luminosity related to the starburst component is $L_{\mathrm{IR,SB}} = 2.47^{+0.20}_{-0.26} \times 10^{11} L_\odot$. The corresponding SFR is $36.7^{+2.9}_{-3.8}\,M_\odot\,\mathrm{yr}^{-1}$. Reported are the median values (the 50$^{\mathrm{th}}$ percentile) with the 16$^{\mathrm{th}}$ and 84$^{\mathrm{th}}$ percentiles serving as uncertainty estimates.

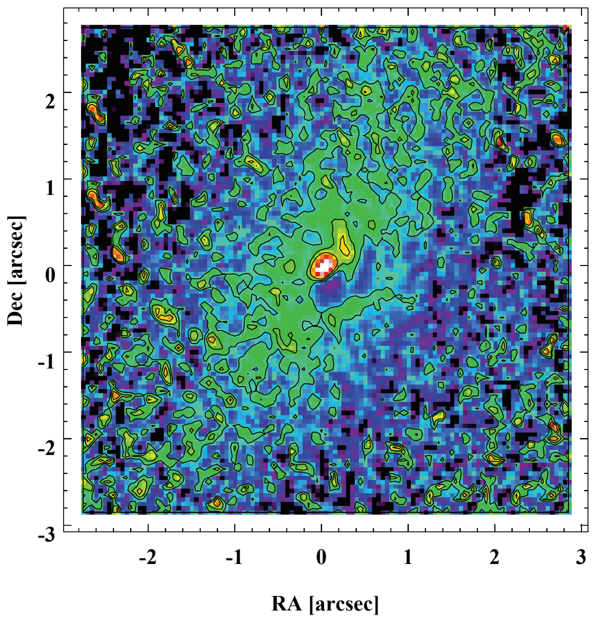

FIGURE 3. Structure map of the continuum (FR647M) HST image of IRAS 16511+2354.

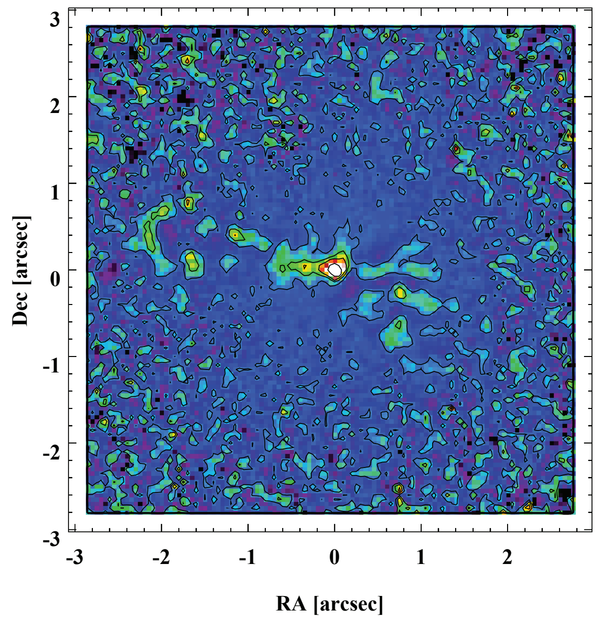

FIGURE 4. Unsharp-divided residual of the [O III] FR551N HST image of IRAS 16511+2354.

SUMMARY

We presented a study on the morphology and SF of IRAS 16511+2354, a type II quasar hosted by an LIRG. The deep ground-based images revealed disturbed features, indicative of past interaction. The HST images bore evidence of dust presence in the circumnuclear regions. The IR luminosity estimate is $L_{\rm IR} = (3.6 \pm 0.5) \times 10^{11} L_\odot$. The luminosity related to the starburst component after fitting the SED with models of both the host galaxy and AGN is $L_{\rm IR,SB} = 2.47^{+0.20}_{-0.26} \times 10^{11} L_\odot$. The respective SFR is $36.7^{+2.9}_{-3.8}\ M_\odot\ {\rm yr}^{-1}$.

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