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On the recent discovery of coronal [Fe x]λ6374 emission in the low-metallicity Dwarf Galaxy SDSS J0944-0038

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ABSTRACT

Coronal emission lines, especially the [Fe x]λ6374 line, are now being used as tracers for intermediate mass black holes (IMBHs) in low-mass galaxies. We show that the recent discovery of [Fe x]λ6374 emission in the metal-poor starburst SDSS J094401.87-003832.1 by Reefe et al. (2023b) is, in fact, a misidentified line. The line interpreted as [Fe x]λ6374 is Si iiλ6371. We caution that current and future campaigns hunting for IMBHs with the [Fe x]λ6374 line need to account for possible contamination by Si iiλ6371 emission.

INTRODUCTION

Collisionally excited emission lines from species with high ionization potentials, so called "coronal lines", are a potential observational tracer of accreting intermediate mass black holes (IMBH; $10^3\mathrm{M}_\odot \lesssim M_{\mathrm{BH}} \lesssim 10^5\mathrm{M}_\odot$) in low-mass galaxies (e.g., Molina et al. 2021). Recently, Reefe et al. (2023b), hereafter R23, reported that they were able to spatially pinpoint the location of an IMBH in the low-mass metal-poor starburst galaxy SDSS J094401.87-003832.1 (J0944 hereafter; common name: CGCG007-025). This result is based on a detection of the coronal [Fe x]λ6374 emission ($E_{\mathrm{ion}} = 262.1 \pm 0.1\,\mathrm{eV}$, $\lambda_{\mathrm{air}} = 6374.5\,\mathrm{Å}$)[1] from the brightest continuum region (dubbed "Nucleus 1") in this galaxy. The discovery was made in archival ESO VLT/MUSE integral-field spectroscopic data (ESO Program 0102.B-0325, PI: Privon).

From Figure 1 of R23 we notice that J0944 shows strong permitted emission of Si^+ ($E_{\mathrm{ion}} = 16.35\,\mathrm{eV}$), labeled as Si ii$\lambda$6347. This line arises from the $4\mathrm{p}\,^2\mathrm{P}^\mathrm{o} \rightarrow 4\mathrm{s}^2\mathrm{S}$ transition (e.g., Moore & Merrill 1968), with the upper $^2\mathrm{P}^\mathrm{o}$ state coupling to total angular momenta $J = 3/2$ and $J = 1/2$. The Si iiλ6347 line is thus part of a doublet, namely Si ii$\lambda\lambda$6347, 6371 with $\lambda_{\mathrm{air}} = \{6347.11, 6371.37\}$Å. The SiII$\lambda\lambda$6347, 6371 doublet originates in dense ($n_e \gtrsim 10^3\,\mathrm{cm}^{-1}$) and warm ($T_e > 10^4\,\mathrm{K}$) astrophysical plasmas. There the dominant excitation mechanism of the $^2\mathrm{P}^\circ$ state is fluorescence (Grandi 1976). The Si iiλ6371 line may act as a contaminant of potential [Fe x]λ6374 emission at the typical spectroscopic resolutions used for coronal line emission searches in low-mass galaxies.

METHODS AND RESULTS

We retrieved the reduced MUSE data cuboid of J0944 from the ESO Science Archive. The center of the "Nucleus 1" is unambiguously identifiable in a synthesized R-band image (see inset in our Figure 1 and compare with Figure 1 in R23). We extracted a spectrum and propagate the variances in an 1″ aperture centered on "Nucleus 1", as in R23. The extracted spectrum is shown in the top panel of Figure 1.

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[1] We use air wavelengths from NIST throughout (Kramida et al. 2022).

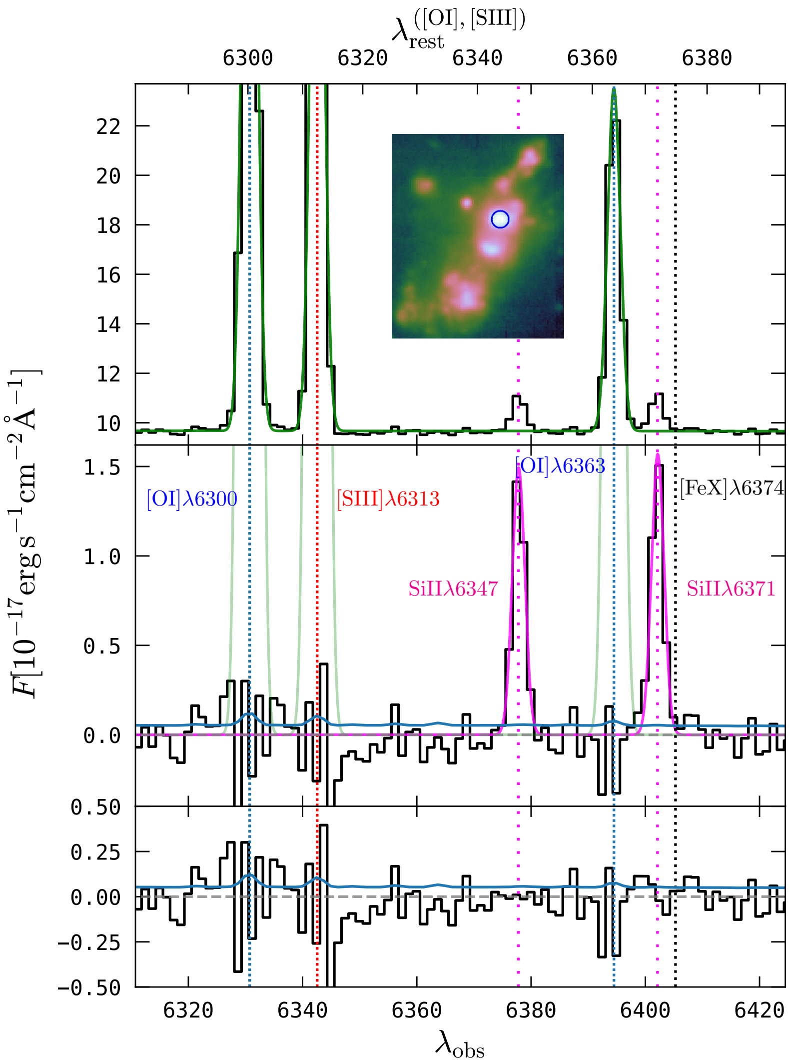

Figure 1. Spectral excerpt from "Nucleus 1" of J0944 from VLT/MUSE observations and the two modeling steps to subtract emission lines other than [Fe X]λ6374 and the continuum. The expected positions of the emission lines are marked and labeled by dotted lines that are colored according to species, with the rightmost black dotted line marking [Fe X]λ6374. The *top panel* shows the spectrum and the Gaussian models for the [O I]$\lambda\lambda$6300, 6363 and [S III]λ6313 lines. The inset shows a synthesized R-band from the MUSE datacube and the position of the circular 1″ extraction aperture. The *middle panel* shows the residual after subtracting this model. We modeled the Si IIλ6371 line based on the Gaussian fit to the Si IIλ6347 line (magenta line). The residual after subtraction of this model is shown in the *bottom panel*. The blue line indicates the noise.

We then followed Molina et al. (2021) to determine the redshift ($z = 0.00483$) of the spectrum and to model the [O I]λ6363 line ($\lambda_{\rm air} = 6363.776$ Å) based on a template from the [O I]λ6300 line. Different from Molina et al. (2021), we modeled the [S III]λ6313 line ($\lambda_{\rm air} = 6312.06$ Å) as well. Two emission line peaks are prominent in the residual spectrum (middle panel of Figure 1) and their peak positions are consistent with being Si IIλ6347, 6371. There is no apparent "bump" in the red wing of the Si IIλ6371 line that could indicate a [Fe X]λ6374 signal. We subtracted the Si IIλ6371 emission from this residual spectrum by deriving a template from the Si IIλ6347 line, with only the amplitude left as a free parameter. The result of this model and the final residual spectrum are shown in the center and bottom panel of Figure 1, respectively. In order to check for possible oversubtraction, we also manually decreased the amplitude of the Si IIλ6371 template, but the result is remains the same: We do not see a significant feature that could be associated with [Fe X]λ6347 emission in the residual spectrum.

DISCUSSION AND CONCLUSION

In the residual spectrum we derive a 3σ upper limit for [Fe X]λ6374 emission of $8.5 \times 10^{-18}\,\mathrm{erg\,s^{-1}cm^{-2}}$ using the expected response of a Gaussian matched filter (see Herenz 2023) whose half-width is matched to the half-width of the MUSE line spread function (i.e., assuming that the line is unresolved). We thus do not find new evidence arguing for an IMBH in J0944 based on the datasets analyzed by R23. Our result may cast doubt on the reported high incidence rate of [Fe X]λ6374 emission in SDSS spectra of low-mass galaxies reported by Reefe et al. (2022, 2023a). As illustrated, if Si IIλ6347 emission is present, Si IIλ6371 will be present as well and may contaminate potential signal from the [Fe X]λ6374 line.

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Software: astropy (Astropy Collaboration et al. 2022), mpdaf (Bacon et al. 2016)

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