MNXAS **4**, 87–88 (2017) Preprint 31 March 2017 Marvel Notices of the Xavier Astronomical Society

Detection of vibranium in the Seyfert galaxy NGC 1365 through X-ray spectroscopy

F. Ursini,[1⋆] A. Tortosa[1,2], and F. Ricci[1,2]
[1] *Xavier Institute for Higher Learning, 1407 Graymalkin Lane, Salem Center, Westchester County, New York, U.S.A.*
[2] *Dipartimento di Matematica e Fisica, Università degli Studi Roma Tre, via della Vasca Navale 84, 00146 Roma, Italy.*

Released 2017, April 1

ABSTRACT
We present results from a joint *NuSTAR*/*VLT* monitoring of the Seyfert 2 galaxy NGC 1365. We find conclusive evidences for an emission K α line from atomic vibranium in the X-ray spectrum, in combination with molecular vibranium absorption features in the mid-infrared spectrum. This is the first direct observation of vibranium in an astronomical environment. We also derive a measurement for its abundance of 2×10^{-6} with respect to hydrogen.

Key words: galaxies: active — galaxies: nuclei — galaxies: emission lines — X-rays: galaxies — X-rays: individuals (NGC 1365)

1 INTRODUCTION

Vibranium (Vb) is an element never observed outside of the Earth's crust. Indeed, the very presence of Vb in astronomical environments is a long-standing issue in our understanding of the elemental abundances in the Universe. The most striking property of molecular vibranium is the capability of absorbing an indefinite amount of energy from sound and electromagnetic waves. This makes it difficult to perform spectroscopy, since molecular Vb is expected to show only absorption features in the mid-IR, with no emission. The spectrum of atomic Vb, on the other hand, has a number of emission lines in the hard X-ray band.

Active galactic nuclei (AGNs) are generally considered the most promising objects to constrain the cosmic abundance of Vb, due to their morphology. According to the unified model (e.g. Antonucci & Miller 1985), the accretion disc of AGNs is surrounded by a torus of dust and gas at pc scales, obscuring the optical broad-line region (BLR) emission and much of the soft X-ray nuclear emission. The optical/UV radiation from the accretion disc heats up the dust in the torus, which then re-emits thermal radiation in the infrared at temperatures around 100 K up to the dust sublimation temperatures around 1500 K. This thermal radiation dominates the mid-IR emission of the AGN (IR bump). Generally, broad spectral features are seen at around 10 and 18 μm, due to hot silicate dust. Such features appear in absorption in most type 2 AGNs, where the torus is seen edge-on (e.g. Hönig et al. 2010). The torus can also contribute to the X-ray emission. The primary emission of AGNs is thought to be due to thermal Comptonization of soft disc photons in a hot region, the so-called corona (e.g. Haardt & Maraschi 1991). On top of this primary, power law-like emission, a reflection component is commonly observed, giving rise to a bump at around 20-30 keV (Compton bump) and a number of fluorescence emission lines. Usually, the strongest of such lines is the neutral Fe K α at 6.4 keV, but other lines are often seen from ionized species such as Fe XXV or Fe XXVI. If vibranium is present in the torus of an AGN, we expect to observe significant absorption features in the IR simultaneously with atomic emission features in hard X-rays.

In this Letter, we discuss a joint monitoring with *NuSTAR* and *VLT* of the Seyfert 2 NGC 1365, with the goal of investigating the presence of Vb features in the mid-IR and hard X-ray spectra. In Section 2, we briefly describe the campaign and present the main results. In Section 3, we summarize our conclusions and discuss future extensions of this work.

2 SEARCHING FOR VIBRANIUM IN NGC 1365

2.1 Observations

Our group recently undertook a program specifically designed to find spectral signatures of vibranium in AGNs. We have begun with NGC 1365, for which we obtained 70 ks of observing time with both *NuSTAR* (PI: Tortosa) and *VLT*/VISIR (PI: Ricci). The two instruments operated simultaneously. All the data have been extracted following standard procedures; the technical details concerning the observations and the data reduction will be presented in

⋆ e-mail: fu@xavier.astro.edu

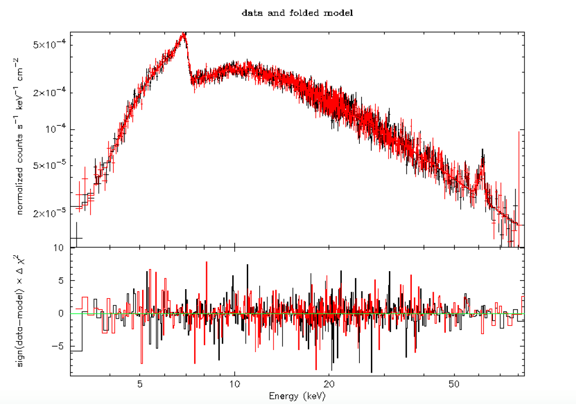

Figure 1. The 3–79 keV *NuSTAR* spectrum of NGC 1365. The Vb line at 60 keV is the main feature.

an accompanying paper (Ricci, Tortosa et al., accepted for publication in MNXAS).

2.2 Main results

In Fig. 1, we show the *NuSTAR* spectrum, which is well described by a power law with a photon index of 1.9 absorbed by a column density of 1×10^{24} cm^{-2} (for more details, see the accompanying paper) plus a Gaussian line with an energy of 60 ± 1 keV and a probability of chance improvement less than 10^{-5} (calculated with an F-test). We point out that the strongest Vb line is the K α at a theoretical energy of 60 keV rest-frame. In fact, the lack of good-quality X-ray spectra at such energies has always been a major problem in assessing the presence of Vb features. It is the first time that a Vb line is detected with such a high significance.
This emission line is accompanied by a forest of absorption lines from molecular vibranium at ~ 10 μm (see the accompanying paper).
The equivalent width (EW) of the vibranium K α line is found to be of 150 ± 5 eV. Theoretically, the EW depends on the photon index Γ of the incident power law, the inclination i of the illuminated material, and the abundance of Vb relative to the other elements. If the geometry and input spectrum are known, then the equivalent width gives a direct measure of the abundance A_{Vb} relative to hydrogen. For example, in the case of iron, assuming a face-on slab, photon index 1.9 and abundance relative to hydrogen of 3.31×10^{-5} (Anders & Ebihara 1982), the predicted equivalent width for the K α line is $\mathrm{EW}_0 = 144$ eV (George & Fabian 1991). In the case of vibranium, the following general formula holds:

$$\log \mathrm{EW} = \log \mathrm{EW}_0 \left[m \log A_{\mathrm{Vb}} - n (\log A_{\mathrm{Vb}})^2 \right] \tag{1}$$

where m and n are functions of Γ and i (for a detailed discussion, and the numerical values of m and n, see Tortosa 2016). In the end, we have $A_{\mathrm{Vb}} = 2 \times 10^{-6}$, assuming $i = 60$ deg (Risaliti et al. 2013). Interestingly, this abundance is similar to that of aluminium or calcium (Lodders 2003). This result is clearly crucial for any theoretical model aimed at explaining the nucleosynthesis of vibranium.

3 CONCLUSIONS

Vibranium is one of the rarest metals on Earth. We have reported on the first robust, direct detection of a Vb feature in an astronomical source, i.e. the Seyfert galaxy NGC 1365. This observation opens up a new window of opportunity in the search for signatures of elusive, yet important, chemical elements in the Universe. Probing the presence of adamantium will be our next step.

ACKNOWLEDGEMENTS

We thank the referee, S. Rogers, for helpful comments that improved the paper.
We acknowledge support from the Xavier Astronomical Society and from the S.H.I.E.L.D. Center for Astrophysics.

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