

Course: The Physics and Evolution of Active Galactic Nuclei

Reading report: # 4

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Date: 2017/12/3

Paper name: PHYSICAL CONDITIONS IN ULTRA FAST OUTFLOWS IN AGN

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Paper download link: <https://arxiv.org/abs/1711.07965>

Paper abstract:

XMM-Newton and Suzaku spectra of AGN have revealed highly ionized gas, in the form of absorption lines from H-like and He-like Fe. Some of these absorbers, Ultra Fast Outflows (UFOs), have radial velocities of up to $0.25c$. We have undertaken a detailed photo-ionization study of high-ionization Fe absorbers, both UFOs and non-UFOs, in a sample of AGN observed by XMM-Newton. We find that the heating and cooling processes in UFOs are Compton-dominated, unlike the non-UFOs. Both types are characterized by Force Multipliers on the order of unity, which suggests that they cannot be radiatively accelerated in sub-Eddington AGN, unless they were much less ionized at their point of origin. However, such highly ionized gas can be accelerated via a Magneto-Hydrodynamic (MHD) wind. We explore this possibility by applying a cold MHD flow model to the UFO in the well-studied Seyfert galaxy, NGC 4151. We find that the UFO can be accelerated along magnetic streamlines anchored in the accretion disk. In the process, we have been able to constrain the magnetic field strength and the magnetic pressure in the UFO and have determined that the system is not in magnetic/gravitational equipartition. Open questions include the variability of the UFOs and the apparent lack of non-UFOs in UFO sources.

Q1. What is this work all about? What is your overall impression on the quality of this work (poor, average, good, or great)? Explain briefly your assessment. [≥ 100 words required]

In this study, using photoionization models, the authors investigated the physical conditions in both Ultra Fast Outflows (UFOs) and non-UFOs in a sample of AGN observed by XMM-Newton and showed that the physical processes in UFOs and non-UFOs are different. They also argued that a magneto-hydrodynamic (MHD) wind can be considered as an acceleration mechanism of UFOs. However, because of some great simplifications we cannot consider this article as very precise hypothesis, it is a development in this field and has a midpoint validity. In fact, to clarify the picture of UFOs structure shown in this article, providing more detail on physical parameters of model is required.

Q2. Why do the authors carry out this work (including, e.g., current research status, issues, scientific motivations)? [≥ 150 words required]

Recent detection of blue shifted Fe XXV/XXVI absorption lines in the X-ray spectra of some AGNs, indicates the presence of highly ionized outflows in these systems. Although, these UFOs are slower than particle jets, they reach much higher speeds in comparison with other types of galactic outflows. Therefore, it is expected that UFOs are powerful enough to transmit feedback effects from a black hole into the host galaxy, however, the origin and acceleration mechanism of UFOs is unknown yet. Some studies suggest an origin close to the AGN (Tombesi et al. 2010). In respect of acceleration mechanism, Gofford et al. (2013) used the Suzaku Data Archives and Transmission System (DARTS) for 51 Type 1.0-1.9 AGN and concluded the UFOs being radiatively accelerated by electron scattering processes. Also, using the 2001 XMM-Newton observation of PG1211+143, King & Pounds (2015) suggested the possibility of radiative acceleration of UFOs via electron scattering. Since most AGNs with UFO are sub-Eddington

AGN, it is not likely unless there are multiple scatterings, which are not practicable because the column densities of the UFOs are $< 10^{24} \text{cm}^{-2}$. Therefore, it is reasonable to explore for non-radiative means of acceleration. With this motivation, in this study, the authors used photoionization models and considered the model of MHD wind to explore location and acceleration mean of UFOs.

Q3. How do the authors manage to finish this work (including, e.g., using new data, new techniques, new models)? [≥ 250 words required]

In the first step, the authors generated photoionization models using Cloudy for a sample of UFOs and non-UFOs. The input parameters of the model are: the spectral shape of the incident radiation or spectral energy distribution (SED), the radial distances of the emission-line gas with respect to the central source, and column density of the gas, and its chemical composition. They set the upper limits for the radial distance by requiring that the physical depth, Δr , not exceed r , or $\Delta r/r < 1$ and assumed the values of other parameters from some previous studies. They optimized models to match the predicted Fe XXV and Fe XXVI column densities determined from the line Equivalent Width values using the curve of growth analysis. Then, they compared predicted values with the measured values and obtained constraints on quantities such as density, electron temperature, and heating and cooling processes. As a case study, using derived constraints on the properties of the UFOs and the inclination of the accretion disk, the authors applied a solution of the cold MHD flow model proposed by Blandford & Payne (1982, BP82) to the UFO in NGC 415 to characterize the flow. They calculated the footprint radius (radius that flow lines originate in the Keplerian disk) as a function of launch angle (Θ_0) and the flow scaling parameters and obtained values of parameters characterizing the flows for different launch angles. Also, they constrained the magnetic field strength and magnetic pressure in the flow for NGC 4151 to analysis the conditions of equipartition in this system.

Q4. What are the main results and conclusions of this work? What are the differences/improvements of this work compared to previous relevant works? [≥ 250 words required]

Using a thermal stability plot, the authors showed that the non-UFOs have the negative slope and it means that they are thermally unstable, in contrast, UFOs occupy the region with the Compton-dominated range. Therefore, they concluded that the heating and cooling processes among UFOs and non-UFOs are different. According to constraints which authors imposed on the model, UFOs lie at smaller radial distances than the non-UFOs. Therefore, the ionization state of the absorbers decreases with distance resulting in the associated change in the heating and cooling processes. Also, by calculating the Force Multiplier ($FM \sim 1$), the authors confirmed that UFOs and non-UFOs in sub-Eddington sources cannot be radiatively accelerated, because they are too ionized at their launch points. So, it requires an alternative mechanism of acceleration such as a MHD wind. By applying the cold MHD model to case of NGC 4151, the authors concluded that for a range of launch angles the observed velocity is consistent with MHD acceleration along a streamline and traced the origin of the UFO back to its footprint radius. They found that for $\Theta_0 = 20^\circ$ the flow stays close to equipartition and at greater Θ_0 the ratio of the magnetic pressure and the gravitational energy density rapidly exceeds equipartition which it means that the magnetic field is significantly greater than as pressure predicted by the Cloudy models which it is in agreement with the definition of a cold flow. Finally, they concluded that the UFO in NGC 4151 can be characterized as part of a cold MHD flow, with an origin in the accretion disk.

Q5. What are the main contributions (i.e., scientific significances) of this work? [≥ 100 words required]

Despite extensive studies of UFOs, their origin and means of outward acceleration are still not well understood. According to the results of this article, the origin of UFOs accelerated through a magnetohydrodynamic wind is in the inner accretion disk. If, these results be confirmed, we can achieve more comprehensive knowledge of physics of accretion disks in AGN through understanding variability and the different origins of UFOs and non-UFOs, in particular, if a connection between UFO properties and the radio emission of these sources is confirmed. Also, in regard to this idea that UFOs are critical components in the structure and evolution of AGN, particularly in sub-Eddington AGN, it would be possible to find the effects of magnetic properties of the disk on the host galaxy.

Q6. Why can the authors make such contributions (e.g., using new idea, new data, new techniques, new theories)? [≥ 100 words required]

In this article, the authors came up the idea that the MHD wind accelerates UFOs. Although, this idea has been studied before (Fukumura, et al. 2014), a number of physical processes such as radiation pressure and thermal instability have been ignored. Here, for the first time, the authors by performing a photoionization modeling analysis and considering a MHD wind enabled to obtained constrains on some critical parameters in UFOs such as density, location, electron temperature, and the heating and cooling processes. Additionally, new observational data from highly ionized gas reported by XMM-Newton provided the authors with intrinsic Fe XXV and Fe XXVI absorption to explore the possibility of this idea more precisely.

Q7. Can you think of some way to improve this work or to verify it? [≥ 100 words required]

The most critical issue about this study is simplicities used in the model, specifically the assumptions of rigid field lines and parabolic geometry which limited analysis to one class of solutions possible from BP82. Another negative point about this study is that based on this model, the non-UFOs are at larger distances and this model unable to explain why UFOs and non-UFOs cannot be present in the same objects. In addition, since the Cloudy model do not consider the relativistic limit, the model predictions are not very valuable. Therefore, to achieve more reliable results, more sophisticated models including important physical parameters of wind allowed by spectrum analysis are required to enable researchers to impose more precise limitations on physical conditions.