Galaxy Evolution and Feedback across Different Environments
Proceedings IAU Symposium No. 359, 2020
T. Storchi-Bergmann, W. Forman, R. Overzier & R. Riffel, eds.
doi:10.1017/S1743921320002082

The two-phase gas outflow in the Circinus Galaxy

M. A. Fonseca-Faria[1] and **A. Rodríguez-Ardila**[1,2]

[1]Instituto Nacional de Pesquisas Espaciais, Av. dos Astronautas, CEP 12227-010, São José dos Campos - SP, Brazil
email: marcosfonsecafaria@gmail.com

[2]Laboratório Nacional de Astrofísica, R. dos Estados Unidos, CEP 37504-364, Itajubá - MG, Brazil

Abstract. We employ Multi Unit Spectroscopic Explorer (MUSE) data to study the ionized and very ionized gas phase of the feedback in Circinus, the closest Seyfert 2 galaxy. The analysis of the nebular emission allowed us to detect a remarkable high-ionization gas outflow, out of the galaxy plane, traced by the coronal lines [Fe VIII] 6089Å and [Fe X] 6374Å, extending up to 700 parsecs north-west from the nucleus. The gas kinematics reveal expanding gas shells with velocities of a few hundred km s^{-1}, spatially coincident with prominent hard X-ray emission detected by *Chandra*. Density and temperature sensitive line ratios show that the extended high-ionization gas is characterized by a temperature of up to 18000 K and a gas density of $n_e > 10^2$ cm^{-3}. We propose two scenarios consistent with the observations to explain the high-ionization component of the outflow: an active galactic nuclei (AGN) ejection that took place $\sim 10^5$ yr ago or local gas excitation by shocks produced by the passage of a radio jet.

Keywords. active galaxy nuclei, Seyfert, emission lines, spectroscopic.

1. Introduction

Active Galactic nuclei (AGN) are extremely important objects for understanding the formation and evolution of galaxies. Results presenting a correlation between the mass of the black hole and the mass of the galaxy's bulge (Kormendy & Richstone 1995) as well as a correlation between the luminosity of the galaxy and the stellar velocity dispersion with the mass of the black hole (Kormendy & Ho 2013) were fundamental to suggest a co-evolution of the black hole and its host galaxy. In this context, the detection of outflows is key to understand the role of AGNs at controlling the growth of their host galaxy.

Traditionally, the identification of outflows in the warm ionized phase has been done by means of the [O III] 5007 Å line. In combination with integral field spectroscopy, critical insights about the the geometry, structure, extension, and physical conditions of the outflowing gas can be derived. However, because [O III] is also emitted in the galaxy disk and star-forming regions, isolating the contribution due to outflows is not straightforward. In this respect, Rodríguez-Ardila *et al.* (2006) showed that high-ionization lines are excellent tracers of the ionized component of the outflows. The energy required for their production rules out stellar or galactic origin.

Here, using data from the Multi Unit Spectroscopic Explorer (MUSE) spectrograph, we report optical observations of the Circinus Galaxy focusing of the detection of extended coronal gas, at scales of hundreds of parsecs from the AGN.

2. Observations

The data used here were obtained by the MUSE and retrieved from the European Southern Observatory (ESO) science portal. The integral field unit (IFU) cube is fully reduced, including calibration in flux (in absolute units) and wavelength. Details of the observation and data reduction is provided in Mingozzi *et al.* (2019).

The datacube was analyzed making use of a set of custom PYTHON scripts developed by us as well as software publicly available in the literature. First, we rebinned the cube, reducing the total number of spaxels to ∼10000. We then removed the stellar continuum across the whole spectral range of MUSE (4700−9100 Å) using STARLIGHT (Cid-Fernandes *et al.* 2005) and the Bruzual & Charlot (2003) stellar population models.

3. Results and Conclusions

We constructed maps of the flux distribution for the most important lines such as [O III] λ5007, Hβ, Hα and [Fe VIII] λ6087. That information revealed the largest outflow of high-ionization gas ever observed in Circinus. Because of its close proximity, we carried out a detailed analysis of the gas morphology and kinematics. The high-ionized outflow, detected by means of the [Fe VIII] λ6087 line, extends up to a distance of 700 pc from the AGN and runs along the radio jet axis. The gas emission appears clumpy, with several knots of emission within a region of $\sim 400 \times 300$ pc^2.

The kinematics of the high-ionization gas is complex, revealing split line profiles with full width at half maximum (FWHM) that implies gas velocities of 200–350 km s^{-1}. The simultaneous detection of approaching and receding components suggests expanding gas shells, produced either by nuclear ejections or inflated by the passage of the radio jet.

The gas emitting [Fe VII] has a density $n_e > 10^2$ cm^{-3}, a temperature $\sim 1.8 \times 10^4$ K and is little affected by dust extinction. Its spatial coincidence with extended, thermal X-ray emission, and its orientation along the radio jet axis, points out that it is likely the remnant of shells inflated by the passage of the radio-jet. The gas velocity dispersion of ∼300 km s^{-1} supports this hypothesis.

We found evidence of a scenario where the extended [Fe VII] emission cannot be driven by photoionization from the AGN. The gas velocity dispersion observed is consistent with the shock velocities needed to produce that line. Models of Contini & Viegas (2001) show that shock velocities of 300 km s^{-1} or larger produce [Fe VII]/Hα ratios $> 10^{-1}$, in agreement with the observations. The gas density measured along the region emitting [Fe VII], of a few hundred cm^{-3} is also consistent with the density required to power the coronal emission.

Our results highlight the relevance of the kinetic channel as a major way of releasing nuclear energy to the ISM in low-luminosity AGN (Wylezalek & Morganti 2018). Due to its proximity, Circinus is a showcase that demands further investigation of that scenario.

References

Bruzual, G. & Charlot, S. 2003, *MNRAS*, 344, 1000

Cid-Fernandes, R., Mateus, A., Sodré, L., *et al.* 2005, *MNRAS*, 358, 363

Contini, M. & Viegas, S. M. 2001, *Apj*, 132, 211

Kormendy, J. & Richstone, D. 1995, *ARAA*, 33, 581

Kormendy, J. & Ho, L. C. 2013, arXiv:1308.6483

Mingozzi, M., Cresci, G., Venturi, G., *et al.* 2019, *A&A*, 622, A146

Rodríguez-Ardila, A., Prieto, M. A., Viegas, S., *et al.* 2006, *Apj*, 6

Wylezalek, D. & Morganti, R. 2018, *Nature Astronomy*, 2, 181

https://doi.org/10.1017/S1743921320002082 Published online by Cambridge University Press