Unveiling the nucleus of NGC 7172

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Abstract. We present the results of near-infrared (NIR) H+K ESO-SINFONI integral field spectroscopy (IFS) of the Seyfert 2 galaxy NGC 7172. The aim is to investigate the central 800pc, concentrating on excitation conditions, morphology and stellar content. The NIR is less influenced by dust extinction than optical light and therefore yields a close undisturbed look at the central region.

In this proceedings we concentrate on emission line measurements in the central 800pc of NGC 7172. The detection of [SiVI] and broad Pa\textsubscript{α} and Br\textsubscript{γ} components are clear signs of an accreting super-massive black hole (SMBH) which hides behind the prominent dustlane. Temperatures of about 1400K show evidence of hot dust in the nuclear region. Narrow components of Pa\textsubscript{α} and Br\textsubscript{γ} allow for an extinction measurement. The molecular hydrogen lines, hydrogen recombination lines and [FeII] point out that the excitation of these lines is caused by an AGN. The findings show evidence for nuclear activity located behind the prominent dustlane crossing the central region of the galaxy. The nucleus of NGC 7172 is a Seyfert 1 nucleus either surrounded or hidden by a molecular dust torus. Our observation aids the unified model scheme in its basic proposition, however, we can not conclude the shape of the torus due to our spatial resolution.

1. Introduction

For more than 20 years we try to figure out the mechanisms that lead to the formation of supermassive black holes (SMBH) and how these are fed successfully. The composition and design of the inner kpc around the active galactic nucleus (AGN) is a very important fact since it is in direct 'contact' with the central source. Antonucci [1] proposed the Unified Model (UM) which describes all AGN as being intrinsically the same, but show different characteristics due to the positioning of the central region with respect to the observer. The narrow line region (NLR) extends to several hundred pc and can be seen in both Seyfert types. It harbors high ionization emission lines (e.g., HI recombination lines, [OIII]) which are used to classify a galaxy as active. These lines are supposed to be ionized by high energy photons from the central source. Therefore the higher the ionization potential of the detected line the closer it is situated to the central source (i.e. coronal lines [SiVI]) [2; 3]. The shape of the dusty torus is not exactly known. It can have scales of up to several pc going down to the radius which is dictated by the sublimation temperature of the dust. The most simple model is a donut surrounding the central region, however, a more realistic approach is to assume the donut to be patchy consisting of several separated and coinciding clouds. The composition of the torus is another remark. What makes up the inner parts of this torus and what does it consist of in its outer parts. Is it molecular
dust or does atomic gas also play a role, especially in the transition phases (inner and outer part of the torus). The broad line region (BLR) are clouds of mainly hydrogen and helium which are close to the central source and show high velocities which can be seen in broad line profiles. This part and the accretion disk of the central black hole cannot be seen directly in Seyfert 2 but can be detected in polarized light due to light refraction and reflection on dust grains. The torus hides the BLR and the rest of the inner part from our view in Seyfert 2’s. Therefore the classification of Seyfert galaxies is done in first instance by the emission line ratio [OIII]/Hβ > 3 [4] to decide if the ionization of the central source is strong enough and then to divide into Seyfert 1 and 2 galaxies the detectability of a broad Hα component is needed. For Seyfert 1 galaxies a broad Hα line is detected whereas for a Seyfert 2 no broad lines are detected. This conventions have their roots in the historically preferred optical wavelength regime, however, in the recent years with new detector generations and new telescopes using adaptive optics (AO) systems the near-infrared (NIR) can be investigated even better than the optical. In these years in a few Seyfert 2 galaxies (e.g. NGC 1386, NGC 7582, IRAS 05189-2524) that show no optical broad lines broad NIR emission lines were detected (i.e. Paschen and Bracket series) [5–7].

1.1. NGC 7172

NGC 7172 is a peculiar spiral galaxy S0/a and it is a member of the Hicks Compact Group (HCG) 90. The inclination of the galaxy is almost 90 degrees (edge-on) with a prominent dust lane crossing the nuclear region. The dust lane is visible in the optical as seen in figure 1. NGC 7172 is at a distance of about 36Mpc. It is classified as a Seyfert 2 galaxy [9] with no signs of polarized broad lines [10]. Other observations show a decrease in the flux level in the X-ray since the 80’s [11; 12] and a flux short term variability of 30% [11]. A column density of about 10^{23} cm^{-2} was calculated by several authors [11–15]. In the optical only narrow emission lines were detected with deep internal absorption visible in the NaI D absorption [9]. In the NIR with respect to optical observations a spatial offset for the nuclear emission of about 2” was detected [16]. PAH emission at 3.3μm was not detected in the nuclear region but in the disk

![Figure 1. HST F606W image [8]. The dark box shows the FOV of the observation. The brightness scale is linear in the detail image. To be able to show the edges of the galaxy we chose a higher contrast in the big image.](image)
which hints at a starburst within the disk but not in the nuclear region [17–19]. In the radio extended emission in the disk was detected [20] and an outflow from the nuclear region to the south-western region can be recognized [21].

1.2. Observation
The galaxy was observed within a sample of Seyfert 2 galaxies. These were chosen to test the UM that got challenged in the last years (e.g., [22], [23]). We used SINFONI, the AO assisted NIR integral field unit (IFU) at the very large telescope (VLT) on mount Paranal in Chile. The nucleus of NGC 7172 was used as a natural guide star (NGS) for the AO. We used the H+K grating with the 3” × 3” field of view (FOV). Therefore we got spectra from 1.45 to 2.4 microns with a resolution of about 1500. We used a dithering method to decrease the chance of stacking of dead pixel. This dithering increased the nominal FOV to 4” × 4”, however, by dithering the FOV by 0.5 arcsec in eight directions separated by 45 degrees we lose integration time on the edges of the FOV. The central region of 2” × 2” benefits from the full integration time on the source of 1300 seconds. Another 650 seconds integration time was spent on sky.

Although we had good weather conditions and the AO loop closed we got a spatial resolution of about 0.5 arcsec. The reason for this is that SINFONI uses a wavefront sensor that works in the optical wavelength regime. This is usually not a problem since the NIR and optical point source of a galaxy is the same, the nucleus. As can be seen in figure 2 the brightest point in the optical does not overlap with the brightest point in the NIR. Additionally the brightest source in the optical is not the active galactic nucleus (AGN) but an extended region to the south-west. Hence, the AO correction, which corrects the PSF for a point source, tried to correct something that is not a point source into a point source. Therefore, we did not benefit from the AO in fully which would have given us a near diffraction limited spatial resolution of about 200 marcsec.

2. Emission Line Regions
2.1. Continuum
We compare 2MASS J, H and K images of NGC 7172 [24] with the HST image [8] (see Fig. 1) and our observation. Figure 2 shows the HST image of our FOV overlayed with K-band contours from our observation and showing the centers of J (five pointed star), H (four pointed star) and K (triangle) flux peaks from the 2MASS images. It becomes clear from the 2MASS flux peaks that the flux peak moves from south to north for about 2” as already noted by Sharples [16]. We note that the pixel scale of the 2MASS images have a pixel scale of 1” and a spatial resolution of 2”-3”. The pointing accuracy of the 2MASS observation and of our SINFONI observation is about 0.1 arcsec. We use the world coordinate system (WCS) to overplot the data. Furthermore, we overlayed the HST image and the 2MASS images and checked for the locations of two foreground stars. It is also clear that our K-band flux peak (white contours) and the 2MASS K-band flux peak are both behind the dust lane. The dust lane is so opaque that it is still recognizable in J-
and H-band and dissolves for the most part eventually in the K-band. Therefore, we conclude that observations in the optical did not point at the actual nucleus since the nucleus is hidden behind the opaque dust lane. Hence, the AO system was not able to actually see the nucleus and therefore was closed on an extended region in the south-west.

2.2. Emission Lines
As already mentioned NGC 7172 was classified as a Seyfert 2 nucleus from optical observations. We detect for the first time broad emission lines in NGC 7172 with broad Pa\(\alpha\) and Br\(\gamma\) detections (see Fig. 5(a),(b)). Using the flux of Pa\(\alpha\) we are able to determine the black hole mass \[25\].

\[ M_{BH} = 10^{7.16} \left( \frac{L_{Pa\alpha}}{10^{42} \text{ ergs}^{-1}} \right)^{0.49} \left( \frac{P_{Pa\alpha}}{10^3 \text{ km s}^{-1}} \right)^2 \]

We determine a black hole mass of \(M_{BH} = (4.5 \pm 1.0) \times 10^8 M_\odot\). The literature value of \(M_{BH} = 2.04 \times 10^8 M_\odot\) [26] affirms our black hole mass.

We detect a strong narrow Pa\(\alpha\) and a Br\(\gamma\) component (see Fig. 5). Both are detected in the central region with lower luminosity wings in the east-west direction (galactic disk) and both show a flux peak offset to the south-west from the nuclear flux peak. Using the flux of the narrow components of Pa\(\alpha\) and Br\(\gamma\) we can determine the extinction \(A_V\) using the line ratios of the case B recombination [4]. With the formula for \(A_V\) [27]

\[ A_V = -2.5 \times \log \left( \frac{f_{Br\gamma}/f_{Pa\alpha}}{f_{Br\gamma}/f_{Pa\alpha}} \right) \]

we determine an average extinction for the central region of \(A_V = 7\) with a Pa\(\alpha\)/Br\(\gamma\) line ratio of about 10.

We also detect the coronal line [SiVI] \(\lambda 1.963\mu m\) (see Fig. 4(a)). Coronal lines have a high ionization potential and therefore are considered as AGN tracer. [SiVI] has an ionization potential of about 150eV, which cannot be produced by mere starbursts. In our observation [SiVI] extends from the nuclear region to the south-west. The flux peak is offset to the south-west with respect to the nucleus, similar to the HI recombination lines Pa\(\alpha\) and Br\(\gamma\). Although offset, the flux peaks are situated behind the dust lane. Hence, we can affirm that the nucleus is situated behind the dust lane and the same is true for the NLR.

Two molecular lines were detected. The \(H_2 \lambda\lambda 1.957\mu m, 2.122\mu m\) lines (see Fig. 4(a),(b),(c),5(b)). Both peak in the central, nuclear region. No other molecular lines were detected. The forbidden line transition of [FeII] \(\lambda 1.644\mu m\) is detected, however, the CO(7-4) absorption feature is strong and [FeII] is blended by this absorption feature (see Fig. 4(d)).

The line ratio diagram \(\log([\text{FeII}]\lambda 1.257\mu m/\text{Pa}\alpha)\) over \(\log(H_2/\text{Br}\gamma)\) shows that our data point lies in the AGN regime, which shows combined ionization of shock and photoionization.
data is taken from a circular aperture in the central region with a radius of 5 pixel. The rhombs represent starburst galaxies [28], circles represent LINERs and asterisks supernovae [29], left hand triangles represent Seyfert 1 galaxies [30] and head-long triangles represent Seyfert 2s [31]. The data points are not corrected for extinction. Our data point is slightly lower than other points in that log(H_2/Brγ) regime. But note that [FeII] is heavily biased by the CO absorption feature. Additionally, [FeII] λ1.257μm and Paβ were calculated from [FeII] λ1.644μm and Paα [4; 32] which are not close by and therefore, extinction plays an important role. Extinction correction and correction for the absorption feature would push our data point further up where the other data points are situated.

3. Conclusion
For the first time broad emission lines are detected in the active galaxy NGC 7172. The HI recombination lines Paα and Brγ are detected with a FWHM of 5700km⁻¹ which is typical for Seyfert 1 galaxies. From these lines we determine a black hole mass of 4.5×10⁸M⊙. The coronal line [SiVI], which is an AGN tracer is detected, too. This confirms our detection of the nucleus behind the dust lane. The molecular hydrogen lines at 1.96μm and 2.12μm are also detected. The [FeII] line at 1.64μm is heavily blended by the stellar absorption feature CO(7-4) and marginally detected in the same region as [SiVI].

Further investigation of stellar composition and gaseous and stellar kinematics is in process. This will help us to determine the recent history of the nuclear region in NGC 7172 and the feeding process of the black hole.

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(a) Linemap of [SiVI] with spectrum.

(b) H$_2$ λ1.96μm linemap.

(c) H$_2$ λ2.12μm linemap.

(d) Linemap of [FeII] with spectrum.

**Figure 4.**
(a) Pa$\alpha$ broad component linemap with nuclear spectrum.

(b) Br$\gamma$ broad component linemap with nuclear spectrum.

(c) Pa$\alpha$ narrow component linemap.

(d) Br$\gamma$ narrow component linemap.

Figure 5.