# The unusual Seyfert Markarian 926 – a link to the LINERs?

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**Abstract.** Markarian 926 (= MCG-2-58-22) is one of the earliest Seyfert galaxies identified. At discovery it was one of the most luminous nearby active galactic nuclei (AGN), with strong, wide broad lines. In the late 1980's it started fading, eventually settling at barely ~10% of its recorded peak luminosity. The luminosity decrease was accompanied by significant spectral changes, with the broad-line component now much weaker and highly asymmetrical. Low ionisation narrow lines, however, are now unusually strong, more typical of the AGN class referred to as LINERs rather than a Seyfert. This peculiar low-luminosity phase spectrum has remained relatively constant over the last decade. The paper discusses the spectral and other characteristics of Markarian 926 and compares these to standard Seyfert models. It furthermore investigates Markarian 926's relationship to the LINERs, and whether SALT observations of this object could shed light on the interrelationship between Seyferts and LINERs.

## 1. Introduction

Quasars, the most luminous objects in the universe, are widely believed to be powered by matter sucked onto an accretion disk surrounding a large black hole. The range in luminosity of these black hole-accretion disk systems is however yet to be accurately determined. In this regard, a class of active galactic nuclei referred to as the LINERs (Low Ionisation Nuclear Emission-line Regions) has yet to be fully understood [1]. LINERs are defined by the comparative weakness of their high-excitation spectral lines. Initially believed to be unrelated to the generally more luminous Seyfert galaxies and quasars, there is now a lot of evidence suggesting that LINER spectra can also be produced by photoionization from an accretion disk.

Markarian 926 (Mkn 926) was identified as a broad line Seyfert galaxy by Ward et al [2] during an investigation of bright x-ray sources. That work remarked about the asymmetric Balmer lines with broad line widths of over 20000 km.s$^{-1}$ (FWZI), and the absence of Fe II bands. At that time only few Seyferts were known, and it was therefore not noticed that low-ionisation spectral features such as the [O I] 6300 Å line were rather strong compared to other members of that class.

## 2. Spectral and luminosity variations

### 2.1. Spectral variations

Numerous spectra have been recorded of Mkn 926 since its discovery spectrum, in 1978 [3], 1984 [4], 1987-1988 [5], 1990-1997 [6] and 2004-2005 [7]. Mkn 926 was also observed spectroscopically during the Sloane Digital Sky Survey (SDSS) in 2004 [8]. While already bright at discovery, Mkn 926´s luminosity was to increase by the mid-1980´s. It appears to have achieved its greatest nuclear brightness around 1984, when the upper spectrum in figure 1 was recorded by Morris and Ward [4], before generally declining in the late 1980´s. A weaker maximum was reached in August 1991 before the nuclear luminosity faded to a minimum in August 1994 [6]. Thereafter the spectrum maintained an appearance similar to the SDSS spectrum in figure 1, although small changes in the broad line profile have seemingly been ongoing [7].

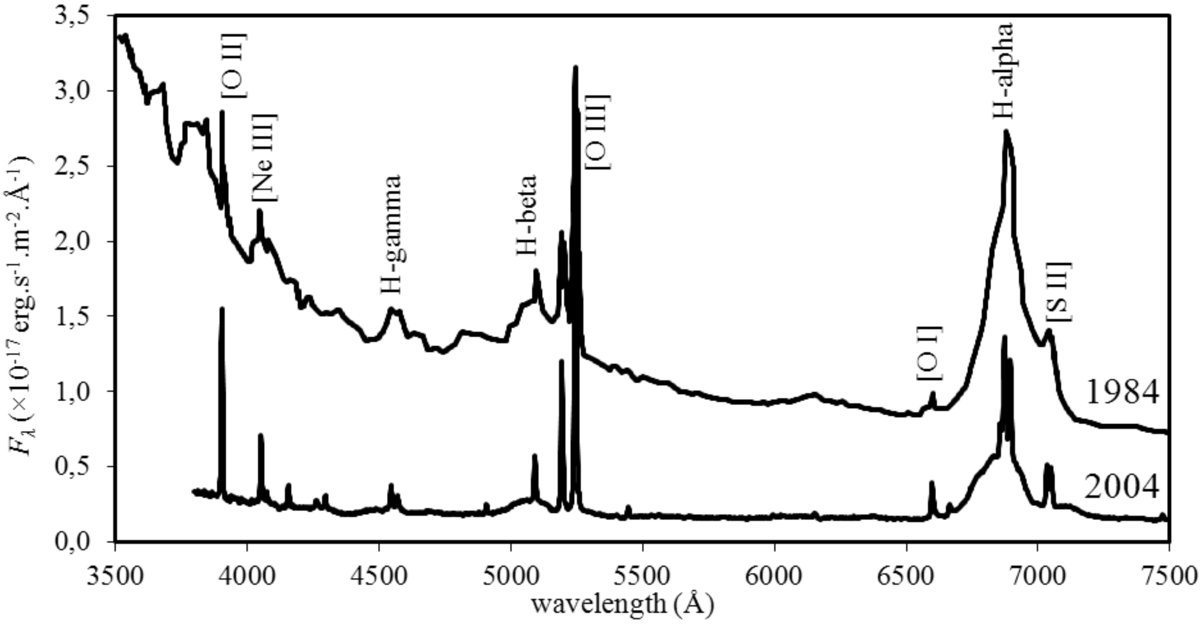


**Figure 1.** Optical spectra of Mkn 926 in 1984 (from Morris and Ward [4]) and in 2004 (from SDSS [8])

2.2. Photometric variations

Early *V*-band measurements suggest that the magnitude of Mkn 926 was approximately *V* = 14 mag (adjusted to 20″ aperture diameter) in the early 1980´s [9], and then brightened to a peak of *V* ~ 13.7 mag [10]. A large set of visual photometric data recorded at SAAO [11, 12, 13] trace the fading of Mkn 926 from 1986. These data are complemented by SAAO infrared data [14] spanning the period 1980-1998, with one early measurement in December 1980 followed by reasonably regular points after July 1984. Light curves for the optical *V*-band and infrared *J*-band are displayed in figure 2. Note how these light curves replicate the spectroscopic maxima around 1984 and 1991, as well as the long-term minimum that started in 1994.

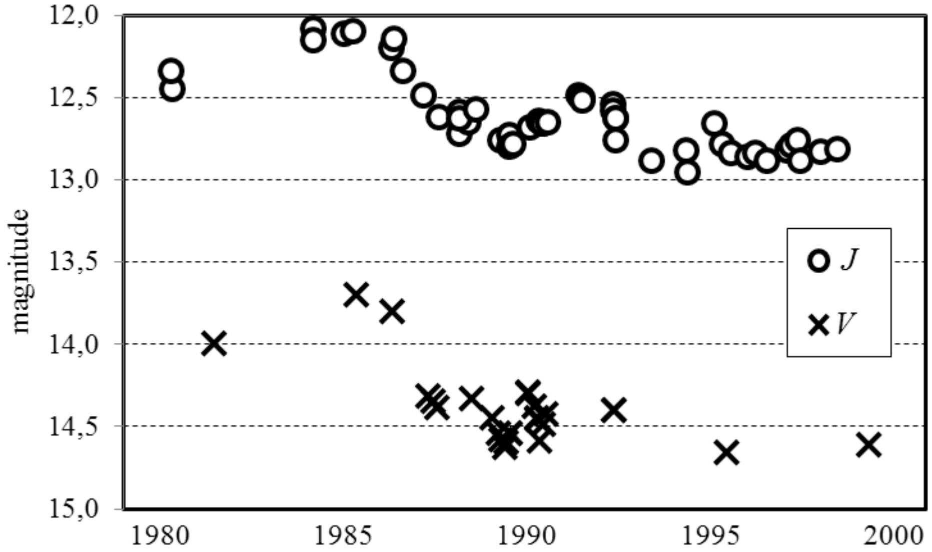


**Figure 2.** Infrared (*J*) and optical (*V*) light curves of Mkn 926 for the period 1980-2000. Data sources [9, 10, 11, 12, 13, 14]

## 3. Spectral characteristics

Spectral line strengths were measured in the 2004 SDSS spectrum that is characteristic of the low-luminosity epoch. The broad lines are difficult to measure accurately due to their comparative weakness, extreme width and asymmetry. The total (broad plus narrow components) H-beta line at 4861.33 Å corresponds to 0.70 times the line strength of the narrow [O III] 5006.84 Å line. This ratio had been 2.07 in 1984 [4]. The ratio of the total 6562.80 Å H-alpha line to H-beta was measured to be 5.08. The relative strengths of the narrow lines are in turn listed in Table 1.

**Table 1.** Narrow line strengths relative to the [O III] 5006.84 Å emission line

| Ion | $\lambda_0$ (Å) | *I*/*I*(5007) |
|---|---|---|
| [O II] | 3727[a] | 0.372 |
| [Ne III] | 3868.74 | 0.109 |
| [S II] | 4072[a] | 0.021 |
| H I | 4340.46 | 0.042 |
| [O III] | 4363.21 | 0.028 |
| He II | 4685.68 | 0.020 |
| H I | 4861.33 | 0.097 |
| [O III] | 4958.91 | 0.318 |
| [N I] | 5199[a] | 0.020 |
| He I | 5875.62 | 0.011 |
| [Fe VII] | 6086.92 | 0.021 |
| [O I] | 6300.30 | 0.096 |
| H I | 6562.80 | 0.358 |
| [N II] | 6583.45 | 0.290 |

| | | |
|---|---|---|
| [S II] | 6716.44 | 0.120 |
| [S II] | 6730.82 | 0.120 |

[a]representative wavelength for blended lines.

### 3.1. Broad line profiles

The H-alpha and H-beta line profiles are compared in figure 3. The blue-shifted peak at –2000 km.s$^{-1}$ and the bump near +10000 km.s$^{-1}$ are similarly represented in both profiles. A weaker bump is also visible at –5000 km.s$^{-1}$.

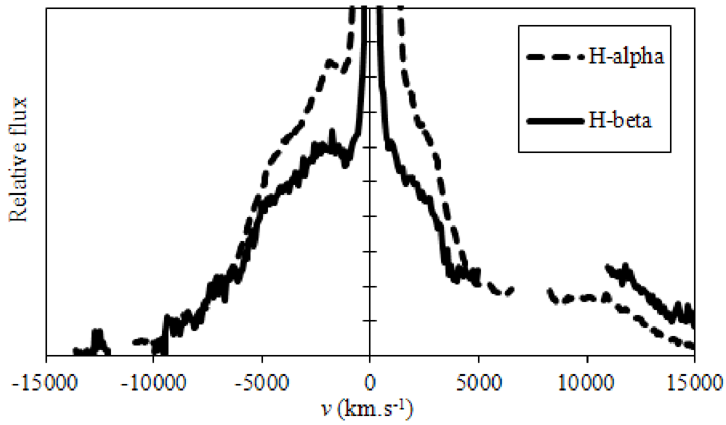


**Figure 3.** Comparison of H-alpha and H-beta broad line profiles. The H-beta line vertical scale was increased to ease the comparison between the two profiles

### 3.2. Narrow line profiles

Whittle [15] and Busko and Steiner [16] noticed [O III] asymmetry towards the red, virtually the only such object in their samples. This asymmetry is still noticeable in the SDSS spectrum, indicating that the basic structure of the narrow line region remains thus far largely unaffected by the nuclear variability.

### 3.3. Reddening

The ratio of H-alpha to H-beta is known to be of the order of 3, the exact value being dependent on the applicable excitation and recombination model. Using standard reddening formulas (e.g. Osterbrock and Ferland, 2006 [17]) leads to extinction estimates of $A_V = 0.62$ for the narrow line region and $A_V \sim 1.6$ for the broad lines. It is further highlighted that the red bump is comparatively more pronounced in H-beta, indicating that the part of the emission line region responsible for this emission is less reddened.

### 3.4. Gas conditions

The measured emission line ratio $I$([S II] 6717)/$I$([S II] 6731) of 1 corresponds to free electron density of $N_e \sim 10^{2.5}$ cm$^{-3}$ ~ 300 cm$^{-3}$ in the narrow line region (Osterbrock and Ferland [17]). The line ratio ($I$([O III] 4959)+$I$([O III] 5007))/$I$([O III] 4363) in turn determines the electron temperature of the region where the [O III] lines form. Applying the formula given in [17] implies that $T_e \sim$ 19,000 K in the $O^{++}$ region. These values are typical of Seyfert galaxies.

## 4. Discussion

4.1. Double-peaked emission line AGN
The strikingly wide, asymmetric Balmer-line profiles and associated bumps are characteristic of a group of AGN extensively studied by Eracleous, Halpern and co-workers [18, 19]. This type of AGN includes bright quasars as well as fainter objects with a more hidden nuclear core. The list of objects even includes LINERs and radio galaxies, such as Pictor A. These studies were able to explain the profile changes through warped elliptical accretion disk models as well as through disks with spiral arm-like irregularities. The detailed study of spectral variations in Mkn 926 by Kollatschny and Zetzl [7] does not refer to these works, but highlights a very similar broad-line behaviour. Thus Mkn 926 is a new member of this class of AGN. It is a particularly important example of the class due to its comparative proximity, and because of its documented history of extreme luminosity changes.

4.2. Seyfert or LINER?
The high-ionisation [O III] and [Ne III] lines have been comparatively strong throughout the spectral evolution, and thus Mkn 926 is technically not a LINER (which would require *I*([O II] 3727)/*I*([O III] 5007) > 1 and *I*([O I] 6300)/*I*([O III] 5007) > 1/3 [1]). The [O I] and [S II] lines are however more prominent than in most Seyferts and quasars, especially when compared to the H-alpha-[N II] complex during the faint stage. As mentioned, the broad line profile and variations also resemble some LINERs. It is plausible that the light echo from the bright phase in the mid-1980´s is still crossing much of the narrow-line region, and that therefore the [O III] lines still appear bright. If the broad line region stays faint then it should be possible to monitor the eventual fading and profile changes of these lines, which in turn will offer a unique opportunity to map the narrow line region of a Seyfert galaxy.

4.3. Potential future work
The light collecting potential and high resolution spectroscopic capacity of SALT could be used to characterize the narrow line shapes at different ionisations, and thus unravel the density and temperature gradients in the outer parts of the nucleus. Such data would also highlight the latest changes in the broad line profiles. Imaging by MeerKAT would show whether Mkn 926 displays a radio structure that differs from other Seyferts, and perhaps has similarities with LINERS such as Pictor A. In conclusion, regular monitoring of the optical luminosity would indicate whether the luminosity decline is permanent or whether bright phases are a common occurrence.

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