The Interplay among Black Holes, Stars and ISM in Galactic Nuclei
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AGN black hole mass derived from the gravitational redshift in optical lines

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Abstract. We determined a central black hole mass of $M_{\text{virial}} = 1.8 \pm 0.4 \times 10^7 M_\odot$ in the Seyfert galaxy Mrk 110 with reverberation mapping methods - i.e. from integrated optical line profile variations as well as from velocity-delay maps. But this black hole mass depends on the unknown orientation of the central accretion disk. Here we report on the detection of gravitational redshifted emission in the variable fraction of all broad optical emission lines in Mrk 110. We derive a central black hole mass of $M_{\text{grav}} = 14.0 \pm 3.0 \times 10^7 M_\odot$ with this method. This value is independent on the orientation of the accretion disk. A comparison of both black hole mass estimates allows to determine the central accretion disk inclination angle i to 21 deg in Mrk 110, and therefore the orientation of the spin axis of the central black hole.

1. Introduction

The central black hole mass in active galaxies as well as the geometry and kinematics of their immediate surrounding Broad Line Region (BLR) are of fundamental interest. By monitoring the central ionizing continuum as well as variable broad emission lines we can get information about the BLR and derive the black hole mass.

2. Observations

We took 26 high quality optical spectra of Mrk 110 with the 9.2m HET telescope at McDonald Observatory over a period of 6 months. All observations were made under identical conditions with exactly the same instrumentation with a S/N ratio of better than 100.

3. Results and Discussion

Based on the delayed response of the emission line variations with respect to variations of the ionizing continuum we determined a central black hole mass of $M_{\text{virial}} = 1.8 \pm 0.4 \times 10^7 M_\odot$ (Kollatschny et al., 2001). This virial mass has been calculated from the radial distances of the line emitting regions as well as from the widths of the emission lines. We made the assumption that the gas dynamics is dominated by the central massive object. But the derived black hole mass is a lower limit because of the projection of the central accretion disk where the broad emission lines originate. 2-D velocity maps of the broad emission line profiles show that only Keplerian disk BLR models match our observed velocity-delay pattern (Kollatschny, 2002, 2003a).

Based on our spectra we could derive the black hole mass independently from the gravitational redshift in the optical emission lines (Kollatschny,2003b). We determined mean and rms emission line profiles of the most intense lines Hα, Hβ, HeIλ5876, and HeIIλ4686 from our variability campaign (Fig.1). The rms profiles are a measure of the variable component of the line profile. We detected a shift in all our rms emission line

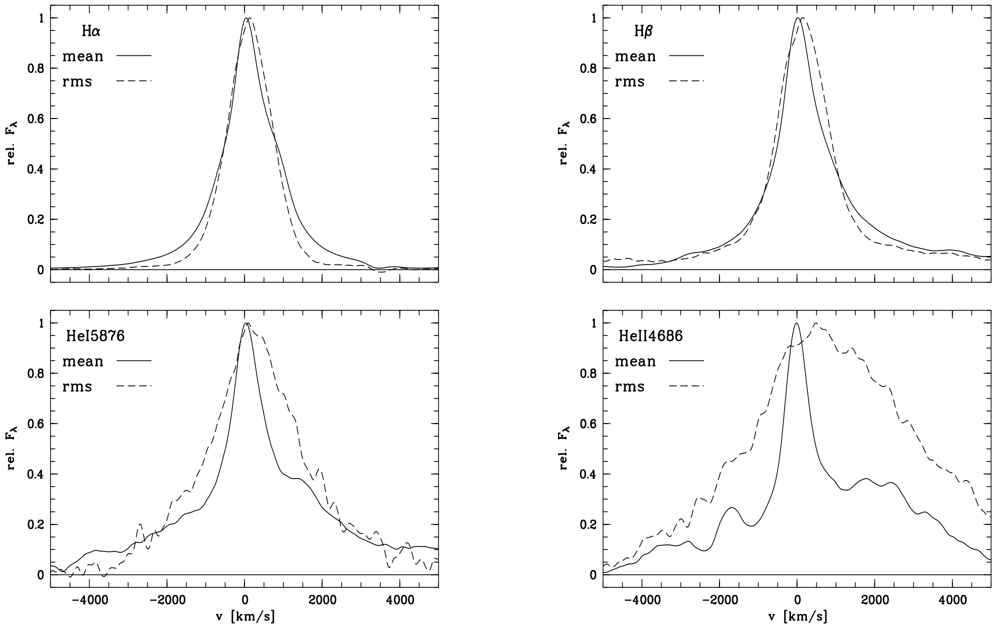

Figure 1. Normalized mean (dashed lines) and rms (solid lines) Balmer and Helium emission line profiles.

profiles with respect to their mean profiles. The variable rms line components originate more closely to the central black hole than the constant line components. We interpret the shifts $\Delta v = \Delta z\ c$ in the variable line components as gravitational redshift. Using the formula (e.g. Zheng & Sulentic, 1990)

$$M_{\mathrm{grav}} = c^2 G^{-1} R \Delta z$$

(with $R = c\tau$) we calculate a black hole mass $M_{\mathrm{grav}} = 14.0 \pm 3.0 \times 10^7 M_\odot$. The black hole masses we derive independently from all four line shifts are identical within the error limits.

The derived black hole mass M_{grav} is not affected by the orientation of the central accretion disk in contrast to the mass M_{orbital} derived from the emission line widths. The mutual comparison of both mass estimates gives us information on the orientation angle i of the accretion disk: $M_{\mathrm{orbital}}/M_{\mathrm{grav}} = \sin^2 i$. We derived an inclination angle of 21 deg in Mrk 110.

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