The usefulness of spectropolarimetry for NLSy1

Marzena Sniegowska[1,2], Swayamtrupta Panda[1,2], Bozena Czerny[2]

1 Nicolaus Copernicus Astronomical Center PAS
2 Center for Theoretical Physics PAS

CAMK PAN

We used FORS2/VLT observations

On the next slides you will see:

- ★ Our motivation for this project
- ★ What the spectropolarimetry is
- ★ Our estimation for viewing angle for 3 NLSy1 galaxies
- ★ Our preliminary results for modelling scattering regions

If you have questions:
msniegowska@camk.edu.pl

cft

40. Zjazd PTA – Szczecin 13-17.09.2021

NLSy1 galaxies

The most important features of NLSy1:

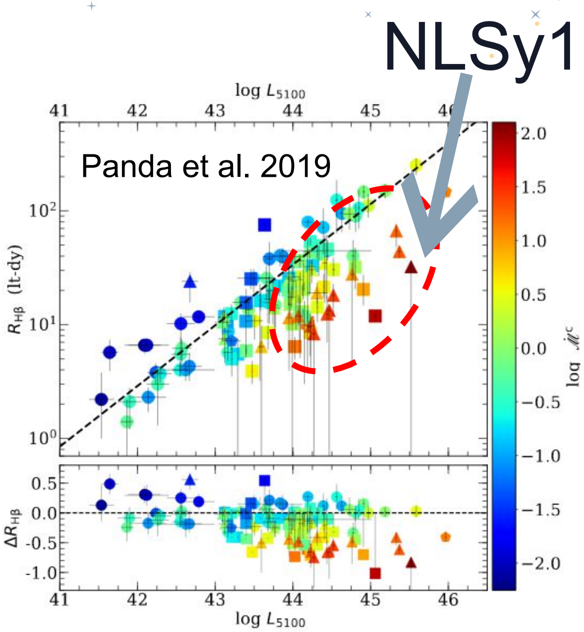
★ FWHM < 2000 km/s
★ Strong Fe II emission (optical/UV)
★ Stronger [OIII] line asymmetries
★ Lower-luminosity AGN
★ High Eddington ratio
★ Small black hole masses
★ NLSy 1 galaxies generally show stronger X–ray variability than BLSy 1s

★ Hβ lags much shorter than the well-known radius-luminosity relation compared with objects with same luminosity (Du et al. 2014, 2015, 2016; Wang et al. 2014)

Our motivation

★ Black hole mass measurement based on unexpectedly short time lags seen in the reverberation mapping (RM) campaigns are found to be smaller, although uncertain
★ NLSy1 are outliers in standard radius-luminosity relation, as the plot shows.

We may measure black hole mass with the independent method - using spectropolarimetry



Spectropolarimetry in the nutshell

‘Spectropolarimetry embraces the **most complete and detailed measurement and analysis of light**, as well as its interaction with matter’- Del Toro Iniesta, J. (2003). *Introduction to Spectropolarimetry*.
In this technique we measure the polarisation state of the light as a function of wavelength and it allows, for example, to explore the strength of a magnetic field present in a star’s atmosphere or linear polarisation by scattering some electromagnetic radiation - as we do in our project.

From spectropolarimetric measurements we obtain 4 spectra taken from different angles (the spectrometer has attached the special prism) 0, 22.5, 45 and 67.5 degrees. Then we use quite basic math to obtain Q and U, which are called the Stokes parameters (I show here just 2 out of 4 Stokes parameters).
As the next step we calculate the polarisation degree P, which multiplied by flux gives us the polarisation flux. This parameter you will see later in the presentation.

$$Q(\lambda) = \frac{1}{2}\left(F(\lambda)_{\theta=0^\circ} - F(\lambda)_{\theta=45^\circ}\right),$$

$$U(\lambda) = \frac{1}{2}\left(F(\lambda)_{\theta=22.5^\circ} - F(\lambda)_{\theta=67.5^\circ}\right),$$

→

$$P(\lambda) = \sqrt{Q(\lambda)^2 + U(\lambda)^2},$$

Afanasiev & Amirkhanyan (2012)

The viewing angle

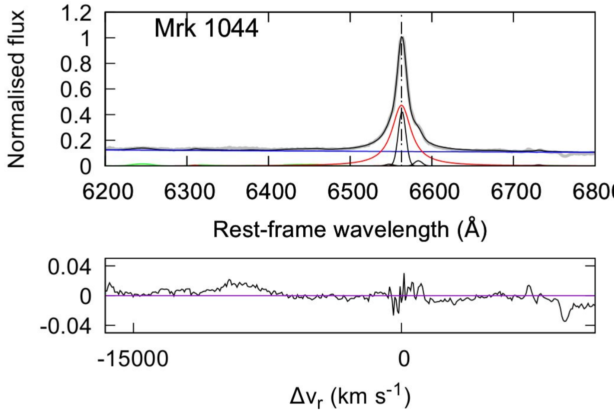
$$\Delta V_{\rm obs} \approx V_{\rm Kep}\left[(H/R)^2 + \sin^2 i\right]^{1/2},$$

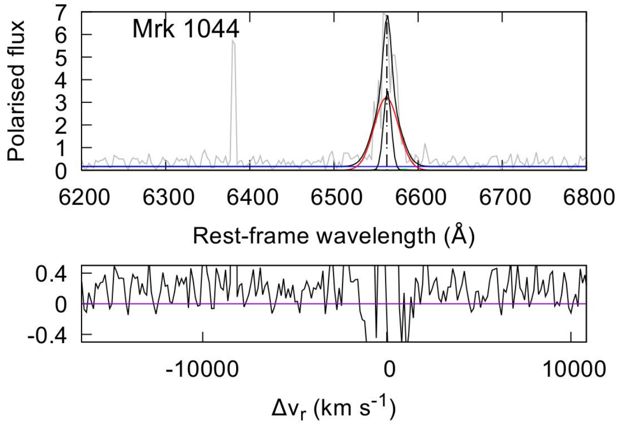
Collin et al. 2006

To estimate the viewing angle *i* we measured FWHM of the broad component of Halpha line in nonpolarised light (upper panel) and broad component of Halpha line in polarised light (bottom panel). We assume H/R as ⅓ and use formula from Collin et al. 2006
We estimate the viewing angle for 3 sources from our sample.

Using this the viewing angle we can correct the virial factor *f* in the black hole mass formula, which commonly is fixed as 1.

$$M_{\rm BH} = f\frac{r_{\rm BLR}{\rm FWHM}^2}{G} = \frac{r_{\rm BLR}{\rm FWHM}^2}{G(4\cdot(\kappa^2+\sin^2\theta))}$$





The viewing angle

$$\Delta V_{obs} \approx V_{Kep} \left[(H/R)^2 + \sin^2 i \right]^{1/2},$$

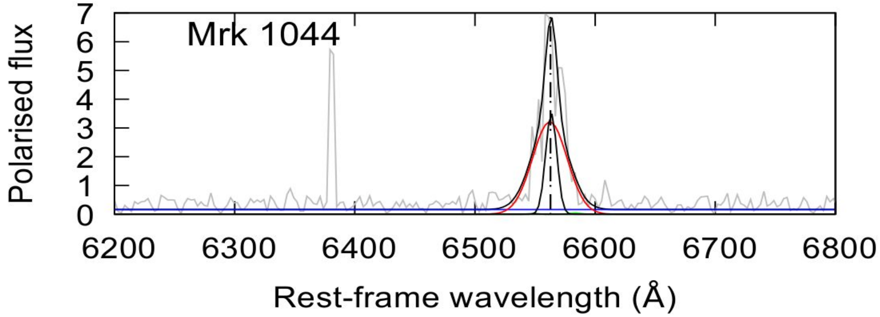
Formula from Collin et al. 2006, nonpolarised FWHM is V_{obs}, FWHM polarised is V_{Kep}

	FWHM nonpolarised [km/s]	FWHM polarised [km/s]	Viewing angle [degrees]
IRAS 04416+1215	1300	3810	4
SDSS J080101.41	1530	2500	31
Mrk 1044	1290	1480	54

The viewing angle for Mrk 1044 has been fitted as $46.4^{+1.9}_{-5.0}$deg (Mallick et al. 2018) from the shape of the relativistic reflection for data from XMM-Newton, which is an independent method. For other 2 sources we did not find measurements in the literature.

STOKES - preliminary results for Mrk 1044

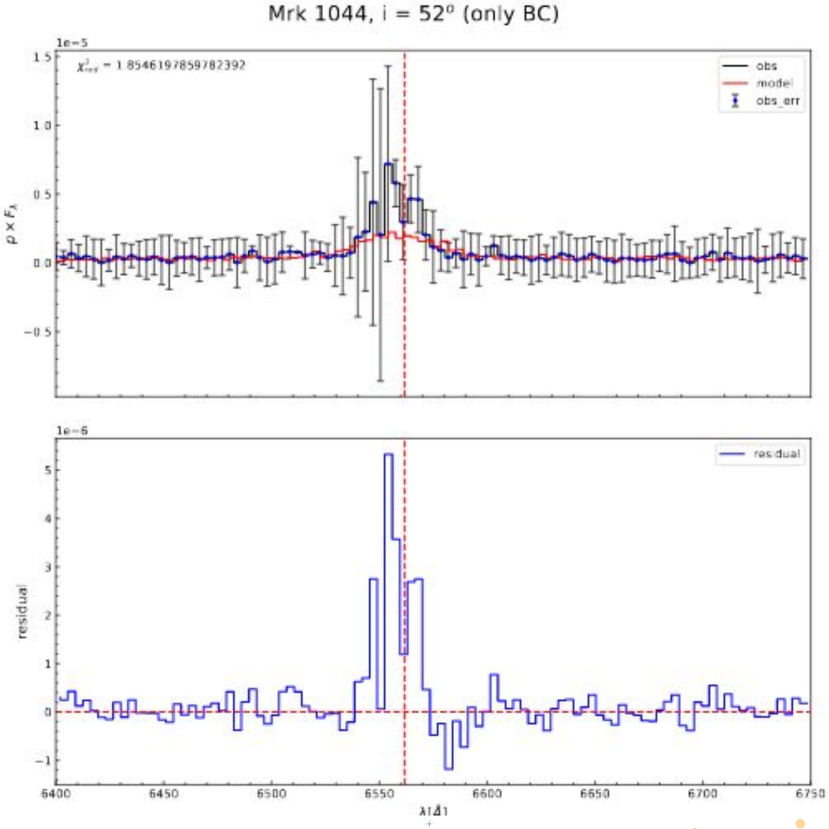
Observations



We use code STOKES to simulate radiative transfer in different geometries for emitting and scattering structures (uniform/clumpy), different dust compositions to compare with our observations.

To model polarised flux we use just equatorial placed scatterer. Residua on the bottom right plot suggest that we may have in this source different geometrical scattering structure. This part of the project is still in progress.

Binned observations and model



Take-home message

- ★ There is a problem with NLSy1 black hole mass measurements
- ★ Plan to achieve:

1) the sources' viewing angles ✓
2) independent determination of the black hole masses (in progress)
3) model of scattering region for each object (in progress)

Thank you!

If you have questions:
msniegowska@camk.edu.pl