Refining emission line fitting in NGC 4552 for black hole mass determination

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Abstract

The elliptical galaxy NGC 4552 is about 15.6 Mpc away and show signs of nuclear activity. A supermassive black hole (BH) is surely present, but a secure BH mass is not yet published for this galaxy. A dataset from Space Telescope Imaging Spectrograph (STIS) shows promise for providing a BH mass using the gas kinematics method. Here we report on the emision line fitting which is a prerequisite for the gas kinematical modelling. We fit gaussians to the lines using chi-squared minimization. For some of the spectral extractions the fitting is problematic because of either noise, non-gaussian line profiles, or a strong blending of narrow lines with broad lines from the active nucleus. We present our final rotation curves which look consistent with a disk of excited gas rotating about a central dark mass.

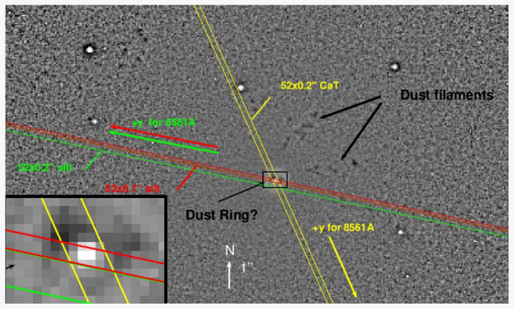
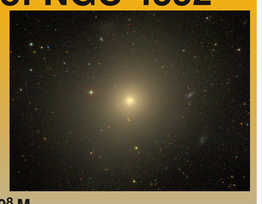


Figure 1. Slit Overlay: the STIS 0.1" slit is represented by the red lines, and the 0.2" slit is represented by the green lines. The greyscale image is an unsharp - masked, V-band (F555W), HST image of the inner ~10" of NGC 4552. The inset shows the somewhat irregular dust ring at the center. The pixels are 0.046".

Properties of NGC 4552



- Distance = 15.6 Mpc
- Scale = 75.6 pc/arcsec
- σ_e = 250±5 km/s
- AGN Sp. Type = Sy2
- M_V = -21.36
- b/a = 0.95
- Galaxy Type = E0/1
- R_e = 27"
- M_{BH} (from M_{BH} - σ_e)‡ = 3.4x10^8 M_{sol}

‡Using Gultekin et al. (2009)

Fig. 2: Line Fitting for s0.1" slit, R=0.05"

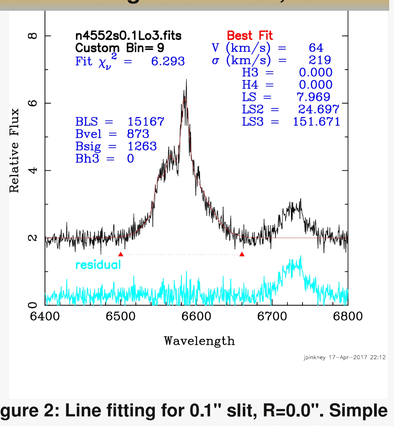


Figure 2: Line fitting for 0.1" slit, R=0.0". Simple four-gaussian fits to the complex line. Smooth residual line are shown (light blue).

Fig. 3-a: 2-D Spectrum for 0.1" slit

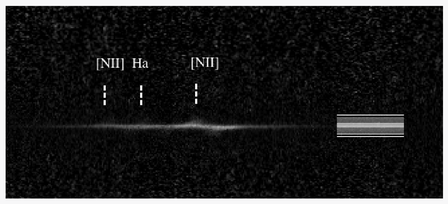


Fig. 3-b: 2-D Spectrum for 0.2" slit

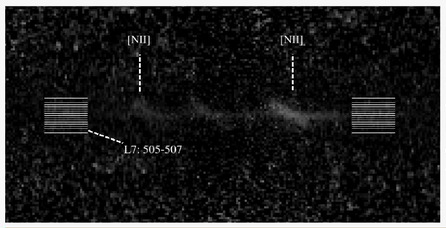


Figure 2-a,b: 2D STIS Hα and [NII] spectra for NGC 4552. White lines represent the extraction bin width.

Fig. 4-a. Spectral Extractions for 0.1" slit

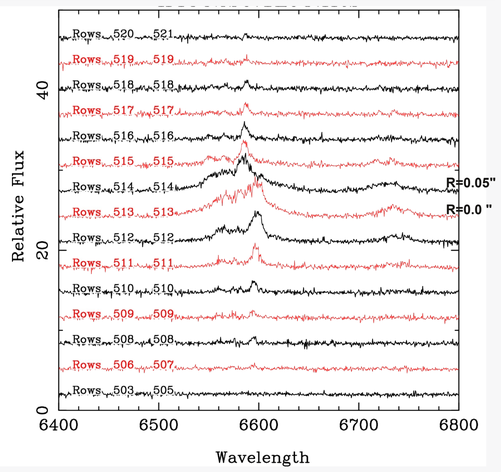


Fig. 4-b: Spectral Extractions for 0.2" slit

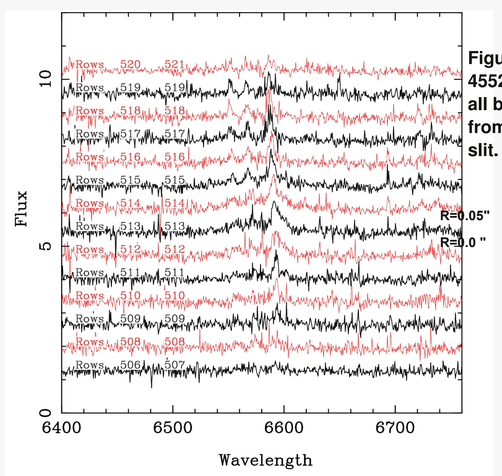


Figure 3-a,b: NGC 4552 spectra from all bins extracted from 0.1" and 0.2" slit.

Fig. 5-a: Line Fitting for 0.1" slit

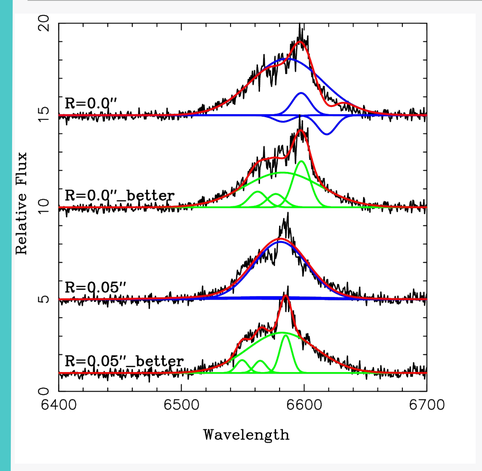


Fig. 5-b: Line Fitting for 0.2" slit

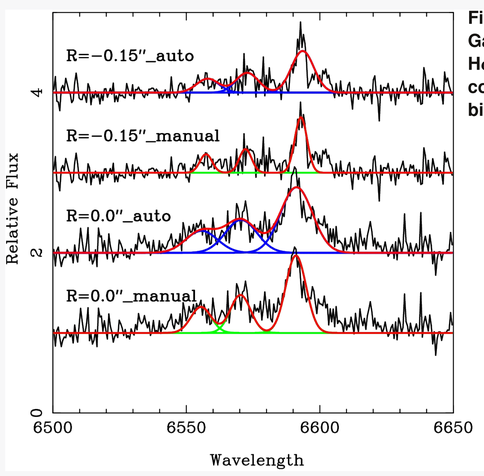


Figure 5-a,b: Gaussian fits to the Hα and [NII] line complex in two bins.

Fig. 6-a: Kinematics Profiles for 0.1" slit

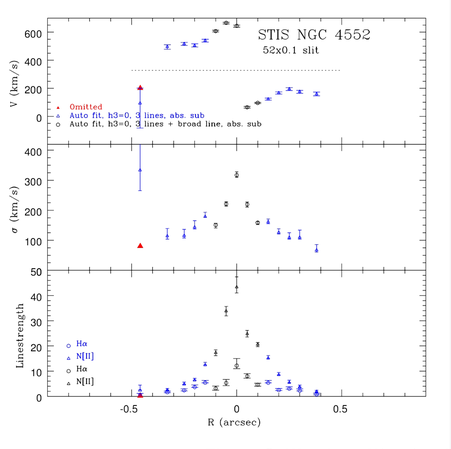


Fig. 6-b: Kinematics Profiles for 0.2" slit

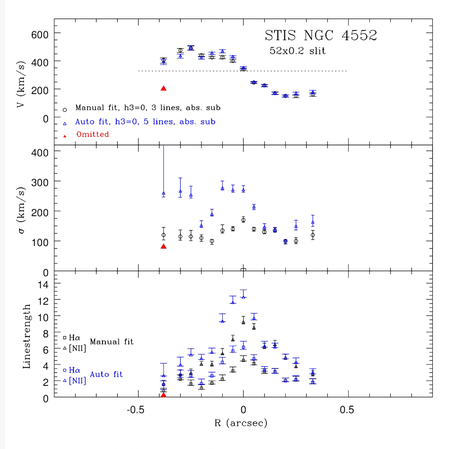


Figure 6: We show V(top), σ (middle) and Linestrength (bottom) for Ha and [NII]. Absorption line subtraction was done. "Auto" means that we used the amoeba filter to find the best fit. "Manual" means that we found the best fit by eye.

Results

* We have run over 30 automated fits to each extracted spectrum by varying wavelength ranges, number of lines fit (sometimes [SII] included), fitting h3 (asymmetric deviations from a Gaussian), first guesses for parameters, the fractional tolerance and parameter "deltas" for the *amoeba* algorithm. We also tried "manual" fitting of parameters.

*The central bins of the 0.1" slit show a strong, broad-line component (BLR). Our 4-line fits of the Hα+[NII] emission lines shows that the broad-line is fairly well fit by a Gaussian as well as the 3 narrow lines.

* Our chi-squared minimization algorithm (*amoeba* from Numerical Recipes) requires careful guidance to provide good fits, especially to the 0.1" slit. This means finding sensible parameters manually (i.e., trial and error) and using these as the starting point in the parameter search.

* Many fits to Hα+[NII] lines for the 0.2" slit give widths (σ) which appear too large (see Fig. 5-b). These were robust to different fitting approaches. We produced a file of "manual" fits by eye as an alternative.

* Despite the irregular morphology of the dust disk in NGC 4552, the velocity profiles are consistent with a rotating gas disk (see preliminary model in Fig. 8). This has been seen in other galaxies like M87 (NGC 4486), M84 (NGC 4374), and M105 (NGC 3379).

* **Future work:** So far our best fit M_{BH} = 3.2x10^8 M_{sol}, however more work needs to be done searching parameter space. Our preliminary models demonstrate that the data are consistent with a rotating gas disk which is rotated about 15˚ relative to slit.

Fig. 7: Model Kinematics Profiles

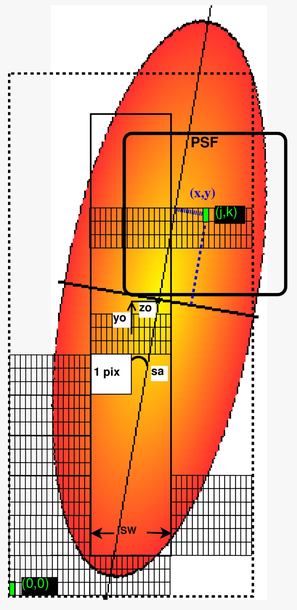


Figure 7: Geometry of a model gas disk (orange) and 0.1" STIS slit (inner rectangle). This is a general case in which the disk is rotated and translated relative to the slit. (Optimum sa, yo, and zo have not yet been determined for N4552.)

Fig. 8: Model Kinematics Profiles

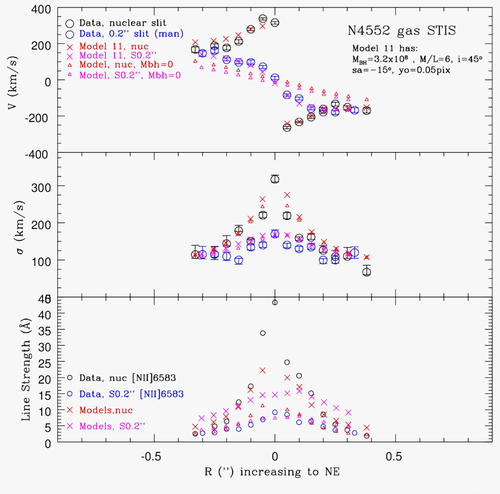


Figure 8: Model kinematics (x's) compared to the data (circles) for 0.1" and 0.2" slits. This model used M_{BH} = 3.2x10^8 M_{sol} , slit angle = -15˚ and inclination=45˚.

References

Gultekin et al. 2009, ApJ 698, 198. "The M-sigma and M-L Relations in Galactic Bulges, and Determinations of Their Intrinsic Scatter"

Press et al. 1999, "Numerical Recipes in Fortran 77" 2nd Ed.

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