New Black Hole Results

From STIS

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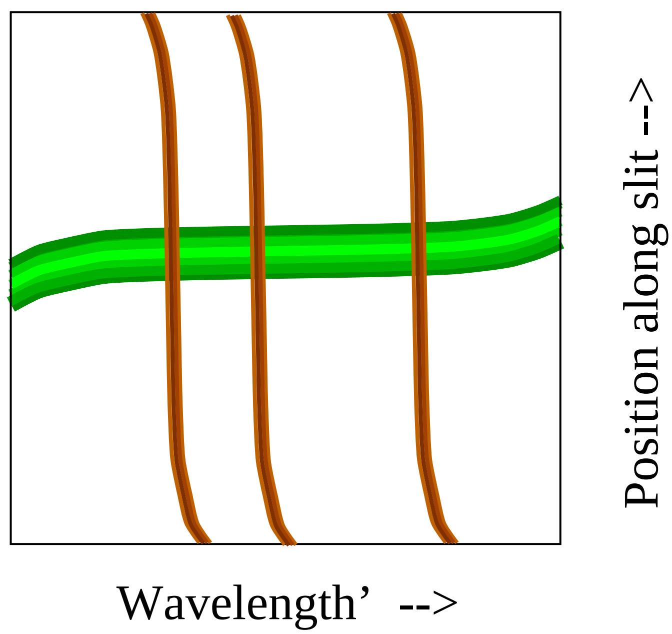
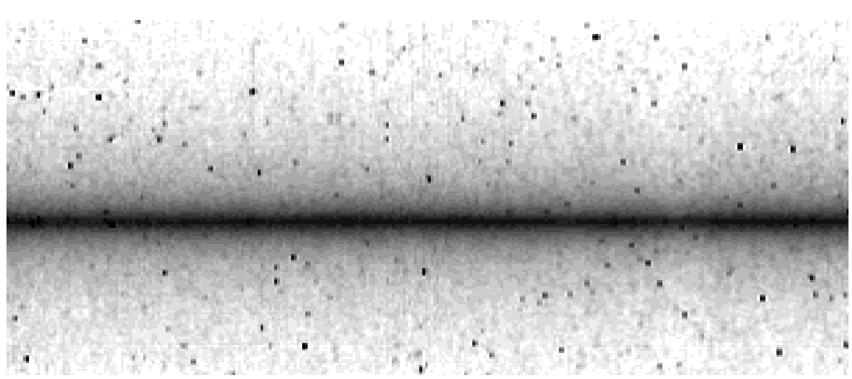
Layout of Spectrum on CCD

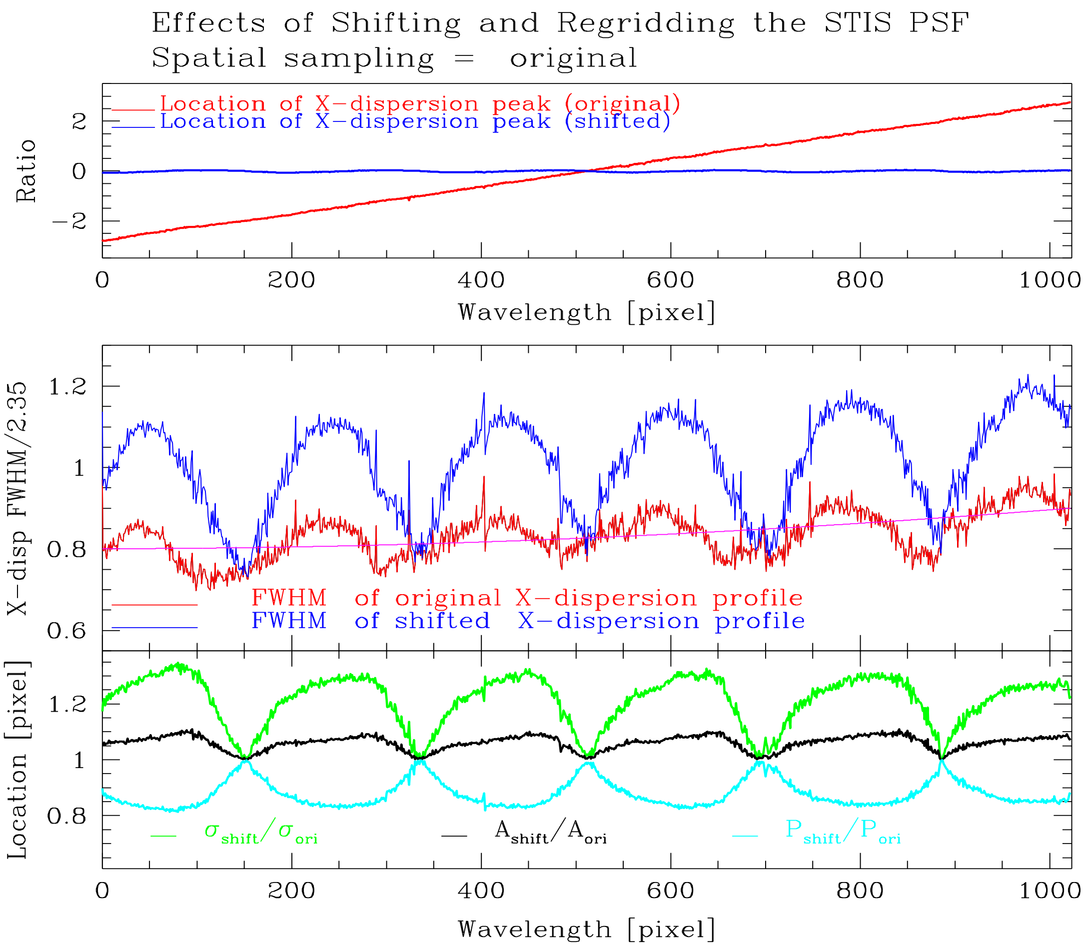


Real Data (NGC 2841)



Spectral Variation of Cross Dispersion Properties

- Rectification (straightening) of spectrum $\Longrightarrow$ regridding.
- Before regridding, location of Cross Dispersion Maximum (CDM) varies with "wavelength".
- STIS' spatial PSF is UNDER-SAMPLED ($\sigma_S \approx 0.73$ pixels) at 8300 $\AA$.
- $\Longrightarrow$ Apparent Width, Area and Peak vary along slit
- Linear regridding makes matters worse
- $\rightarrow$ Undulation with $\lambda \sim 175$ pixels $\sim 95\ \AA \sim 3300$ km s^{-1}
- Bad for point-like sources (M87, standard star)
- Higher order regridding helps a lot



Position dependency of cross dispersion properties of the raw data for a point source. At each "wavelength," we fit a gaussian to the cross dispersion profiles (CDPs) and tabulate the location, width and peak. In the top panel we plot the relative location of the peak as measured from the raw data, the blue line is the location of the peak after a linear 1D regridding step. As a result of regridding, the amplitudes, widths and integrated area change in a way which depends on the exact CDP location (fig. 1). The measured widths of the CDP (middle panel) show a strong undulations before (red) and after (blue) regridding. As the location of the peak of the CDP w.r.t. the pixel center changes gradually (top panel), the CCD pixels sample different parts of the PSF. The apparent undulation only results if the PSF is significantly undersampled, as STIS is in the Ca-triplet region. In the lower panel we present the effects of regridding on the CDPs in the form of after/before ratios of the width (green), area (black) and peak (cyan). Linear interpolation was used to shift the cross dispersion profiles (CDPs). Higher order regridding works better (fig. 2) for extended sources, but much worse for cosmic-ray hits.

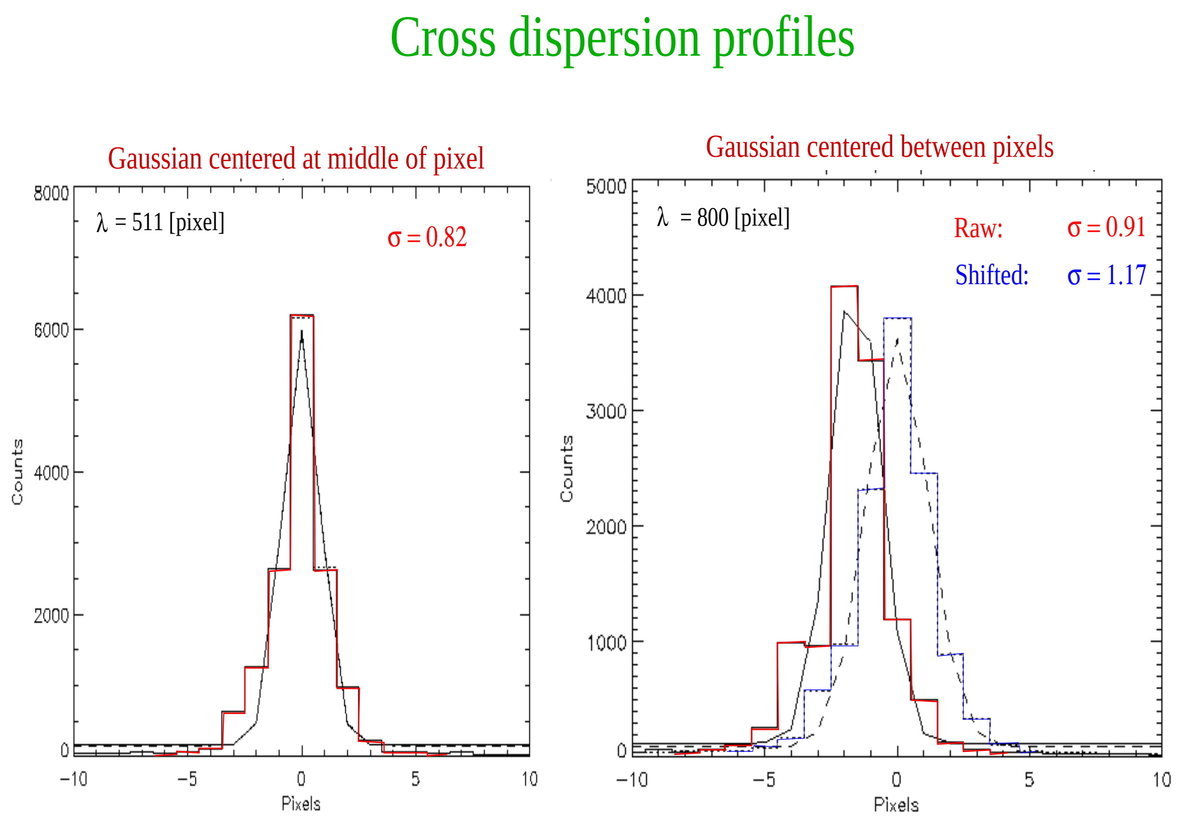


Figure 1: Cross dispersion profiles at two wavelengths (full line histograms in red). The asymmetry of the PSF is clearly visible at $\lambda = 800$. Centering the $\lambda = 800$ profile on 0.0, yields the dotted histogram (blue), which is significantly wider than the unshifted profile. The CDPs are extracted from the raw data (as returned by *stis_read*). The profiles are not exactly *cross* dispersion as the CDPs are really columns form the images returned by *stis_read*.

Effects of regridding on the width of the PSF

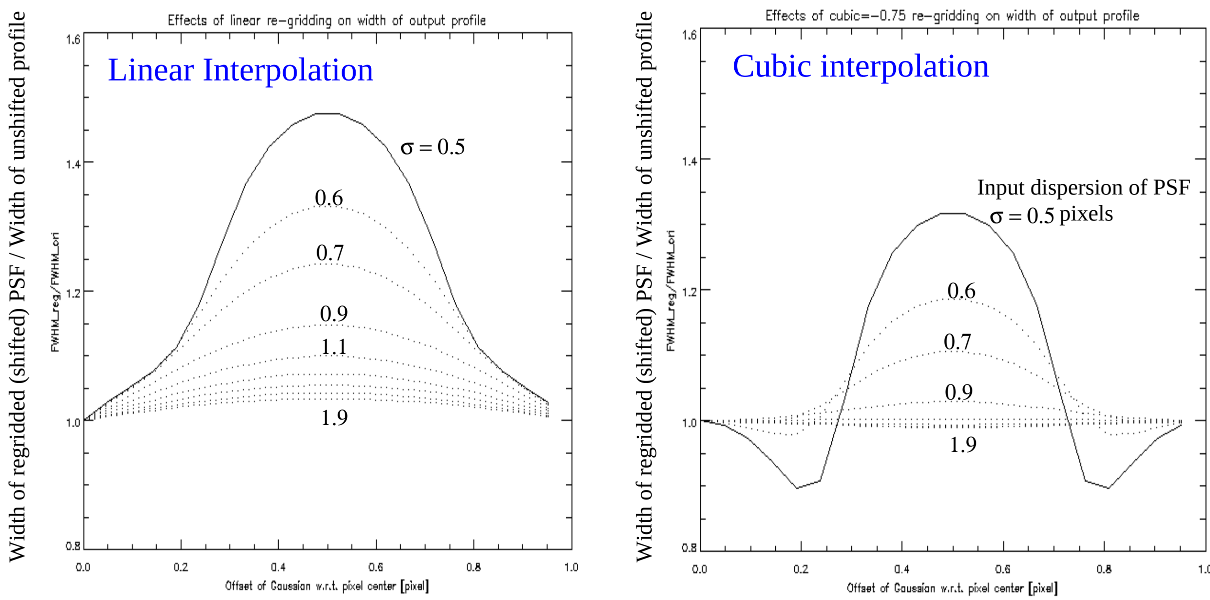


Figure 2: Plotted here is ratio of the widths of the cross dispersion profiles ("after-shifting" / "raw"). For Gaussians centered at various positions within a pixel. Linear regridding (left panel) can be worse than cubic interpolation. The effects are strongest if the data is under-sampled. We present curves for the case where the dispersion of the Gaussian equal 0.5, 0.6, 0.7, 0.9, ... 1.9 pixels.

The Problem of Cosmic Rays (CRs)

- $\sim$5% of pixels are strong CR hits, per orbit
- $\sim$5% of pixels are weak CR hits, per orbit
- on-board re-binning $\Longrightarrow$ $\times 2$ (20% = CR-pixel)
- 1D regridding $\Longrightarrow$ $\times 2$ (40% = CR-pixel)
- 2D regridding $\Longrightarrow$ $\times 4$ (80% = CR-pixel)
- Strong CRs contain $\sim$90% of the total flux
- BUT: $\sim$50% of flux in Galaxy region

Cure:

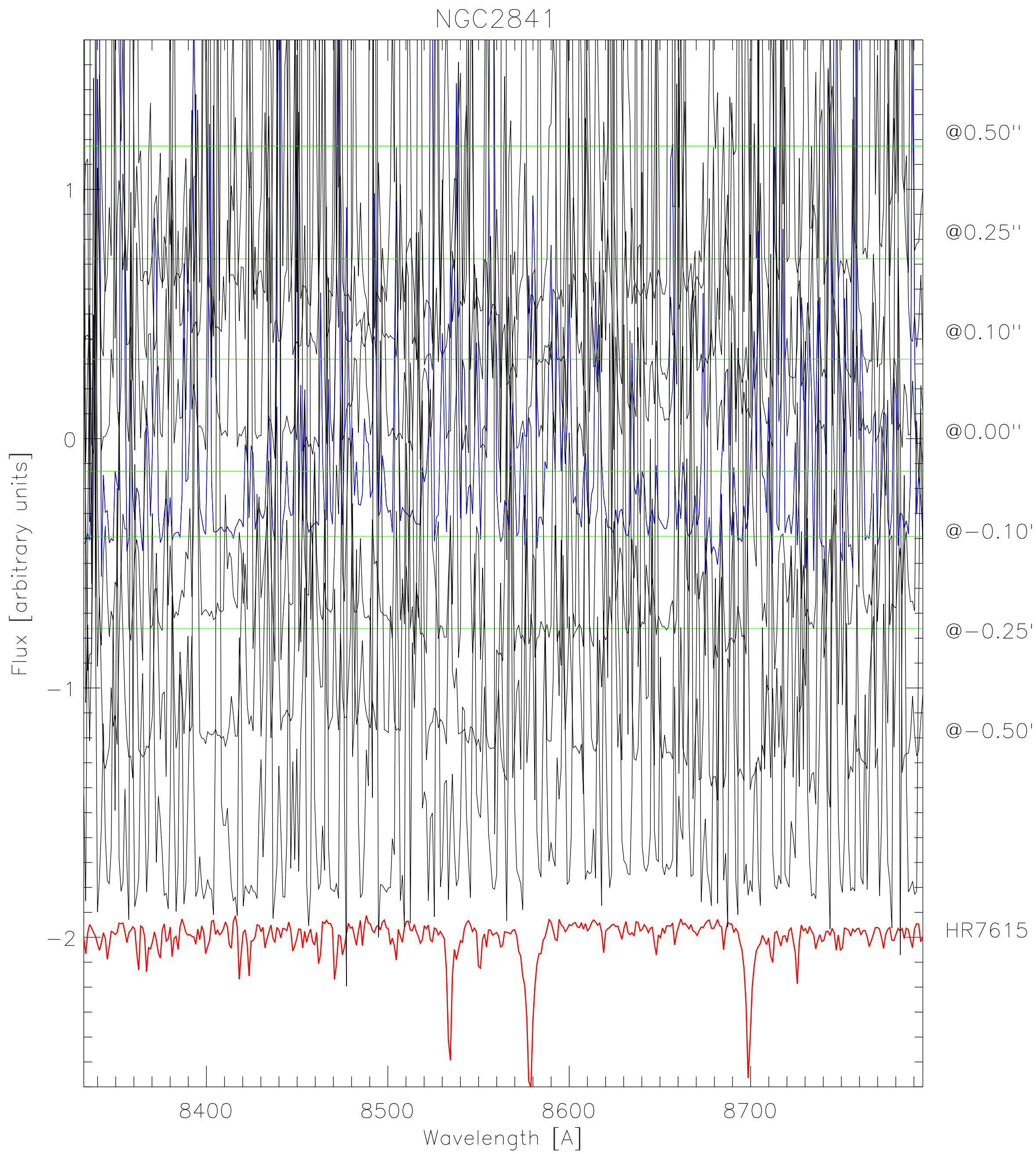
- save factor 2: $\frac{1}{2}$ orbit integration
- save factor 2: 1D LINEAR regridding
- $\Longrightarrow$ 20% CRs pixels

Implications:

1D regridding only $\Longrightarrow$ observe at same λ_0 setting

Some Data: NGC 2841

Unsophisticated data processing: Registering & Averaging.

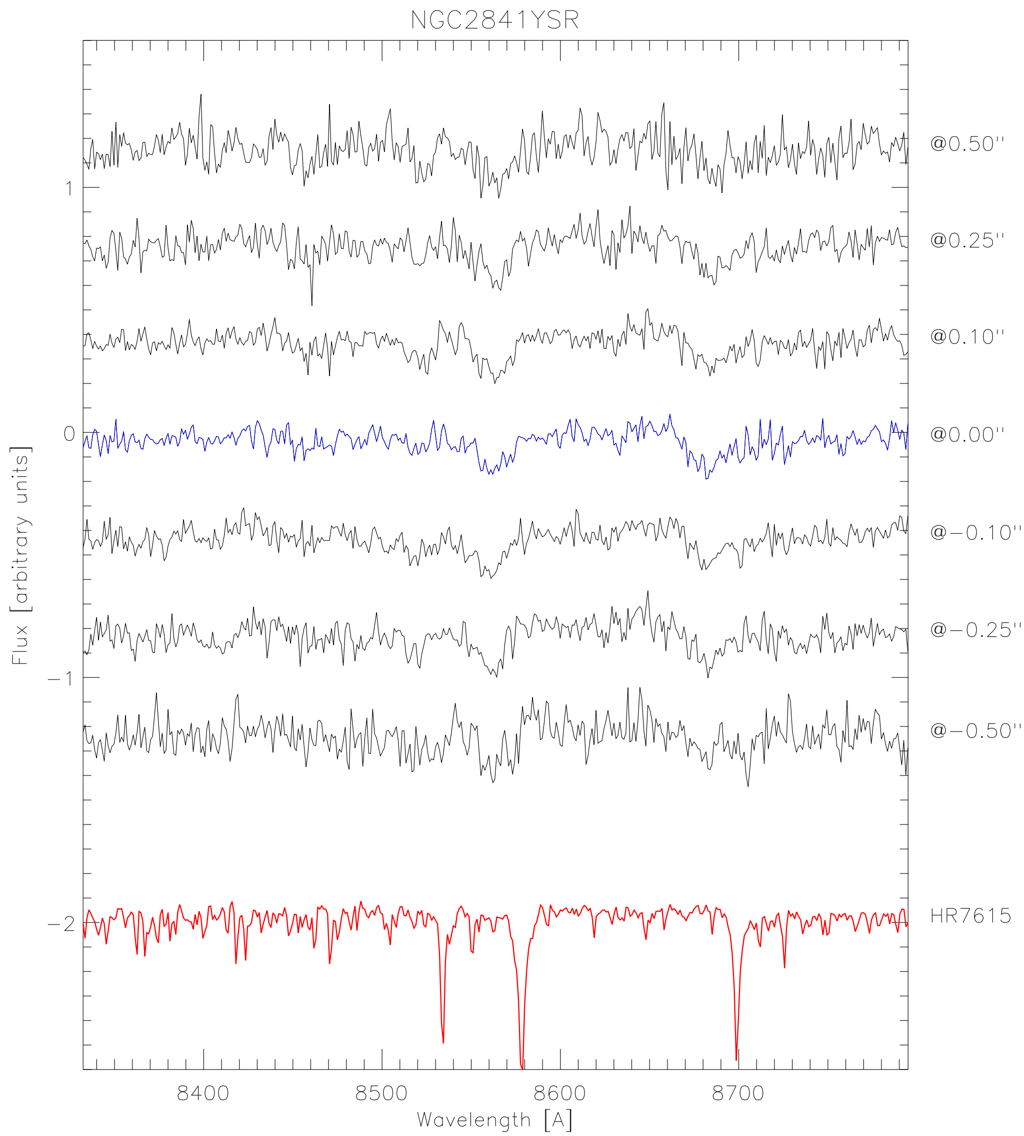


Our Approach

- Flux calibrate images
- Line up spectra with 1D interpolation/shifts
- create CR mask (never perfect)
- – weighted average of un-masked pixels
  – 2D re-mapping to space-wavelength coords
- – 1D-shift CR masks back
  – Interpolate over CR pixels
  – Increase errors around CR pixels
  – (Optional spatial smoothing)
  – 2D re-mapping: images, errors, CR masks
  – weighted average
- Comparison of the two approaches
  $\longrightarrow$ estimate of systematic errors

State of the Art processing:

Registering, Cosmic Ray removal,
Error Propagation & Weighted Averaging.



NGC 2841: Properties

- Nearby Sb Spiral with power-law core
- Declining large-scale rotation curve [Begeman 1987]
- Distance uncertain: Hubble flow [9 Mpc], TF [18] [Begeman *et al.* 1991]
- Chemically decoupled nucleus [Sil'chenko *et al.* 1997]
- Tri-axial bulge [Varela *et al.* 1996]

Our Preliminary Results:

- Central velocity dispersion: 350 - 400 km s^{-1}
- Rotation to $\sim$90 km s^{-1} within 20 pc
- $\sigma^2 \propto 1/R$
- Very Simple Model $\Longrightarrow M_{BH?}$ several $10^7 M_\odot$
- Analyzed data with Bender's FCQ algorithm

  Problems with low S/N (30/Å, central)

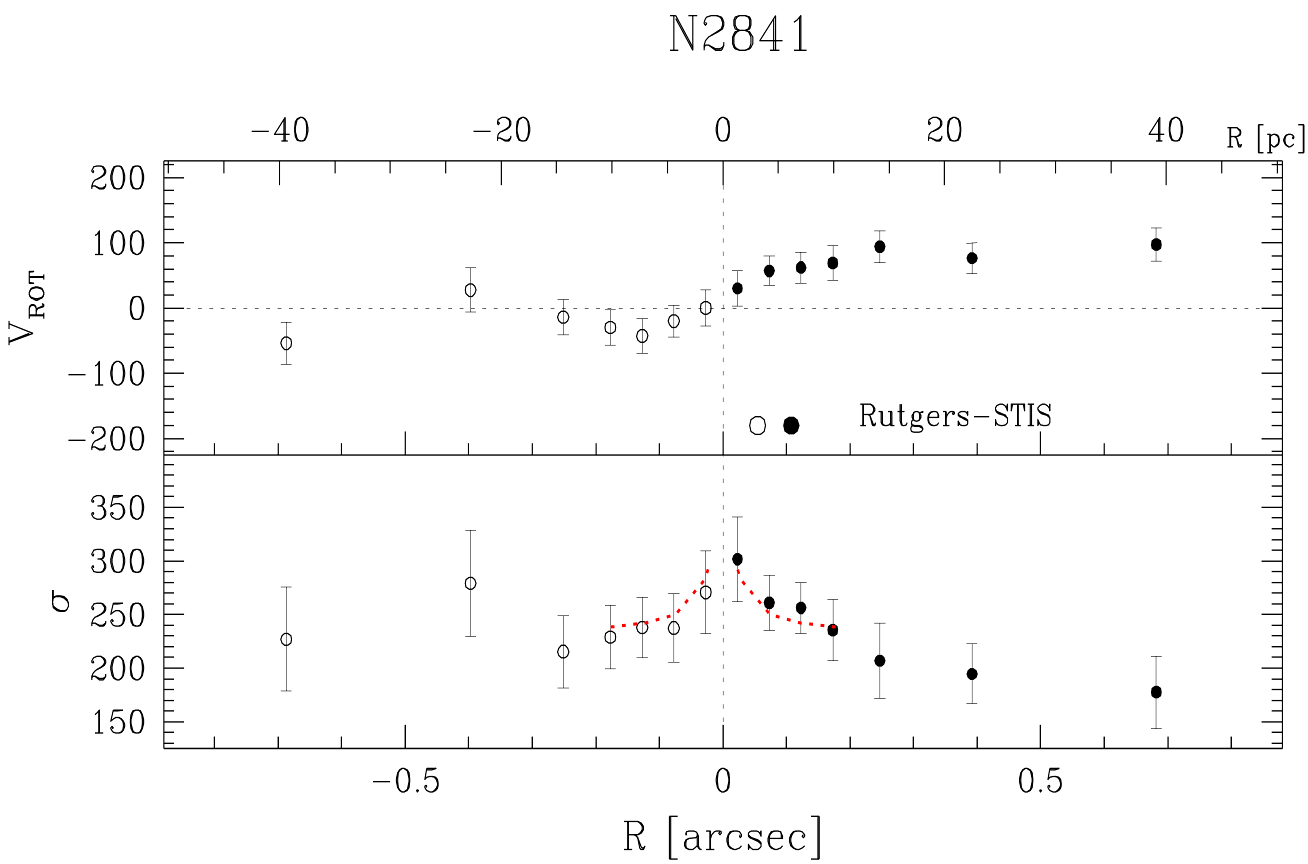
  Limits to $\sigma = 300 - 400$ km s^{-1}

  [$\gtrsim$ 50% of EW is in closey separated lines]

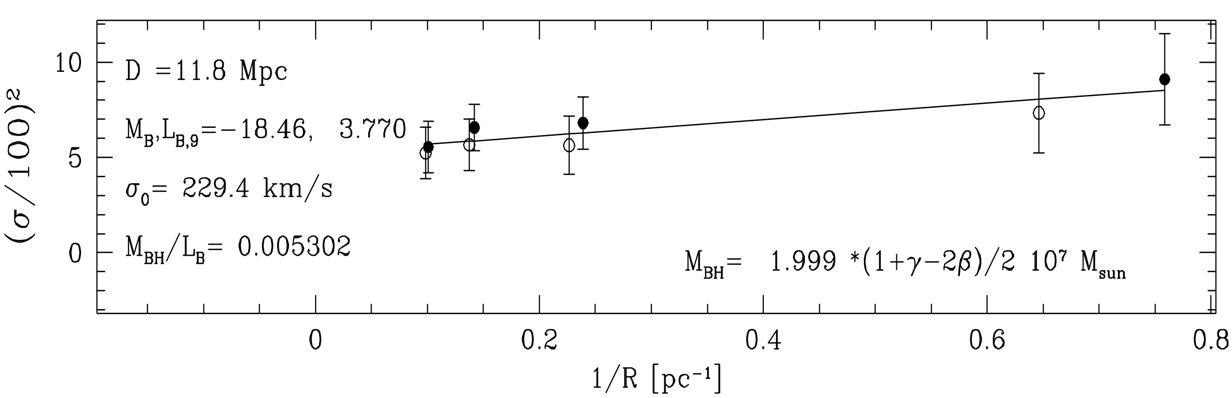
  Problems with extended wings?

  Problems with choice of continuum level
- Will use Merritt's MPL code, better for low S/N

Kinematics



N2841
R [pc]
V_{ROT}
Rutgers–STIS
σ
R [arcsec]



D =11.8 Mpc
M_B,$L_{B,9}$=−18.46, 3.770
σ_0= 229.4 km/s
M_{BH}/L_B= 0.005302
M_{BH}= 1.999 *(1+γ−2β)/2 10^7 M_{sun}
$(\sigma/100)^2$
1/R [pc^{-1}]

High Signal to Noise: M32