Spatially Resolved Kinematics and Morphology of Mrk 3

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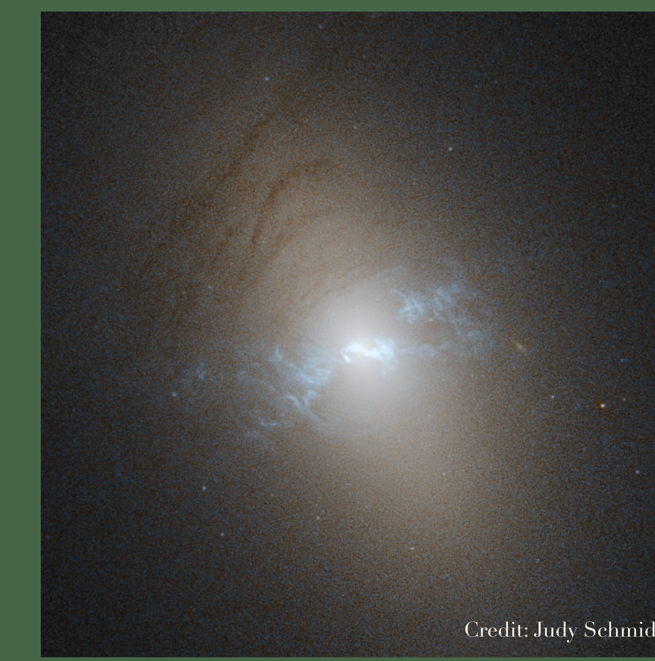
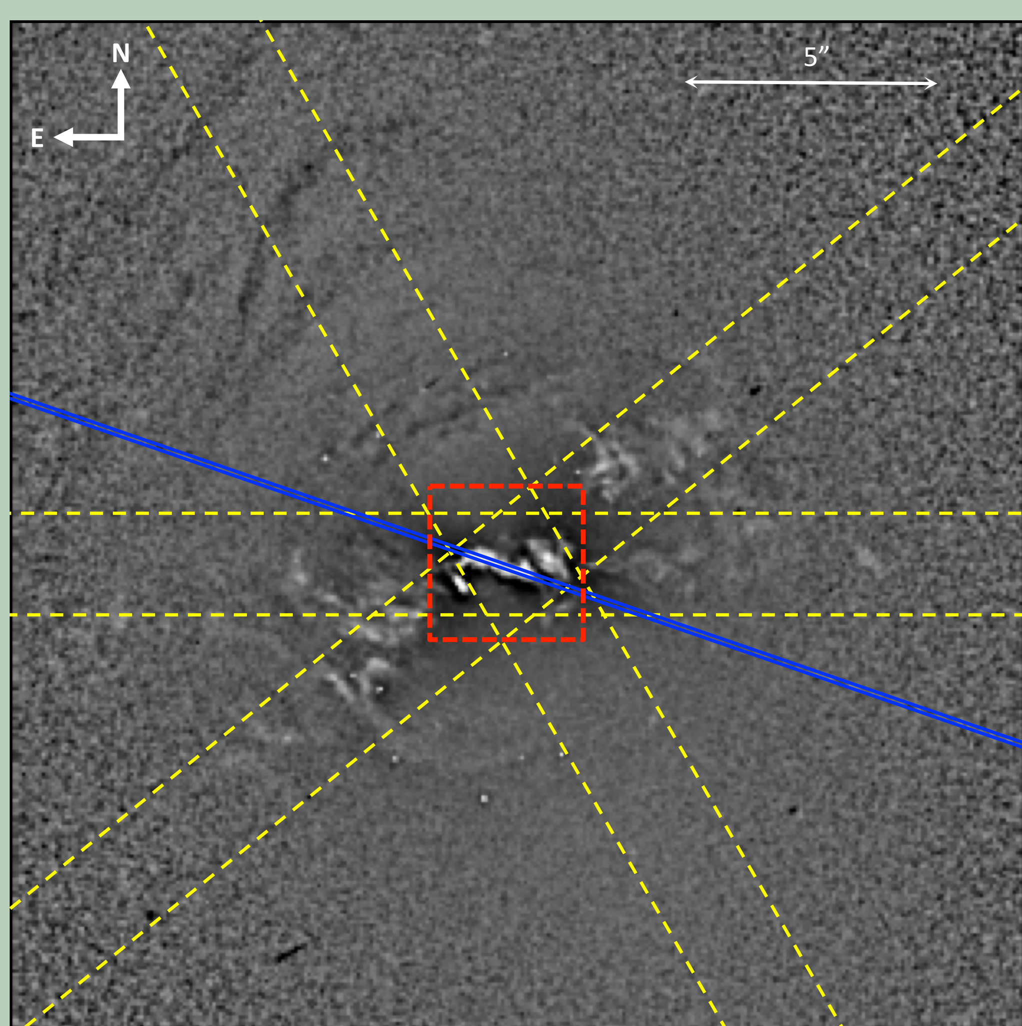
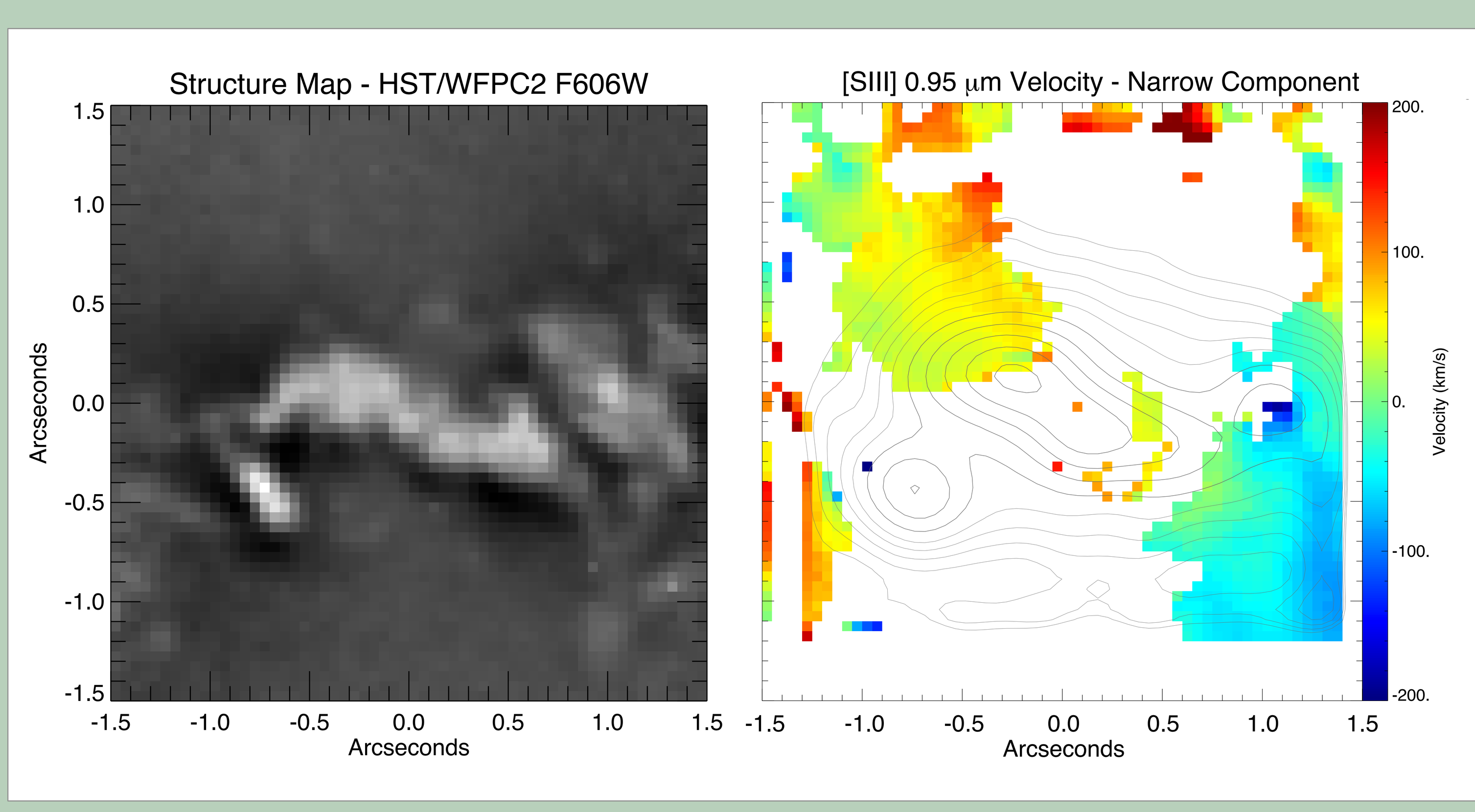




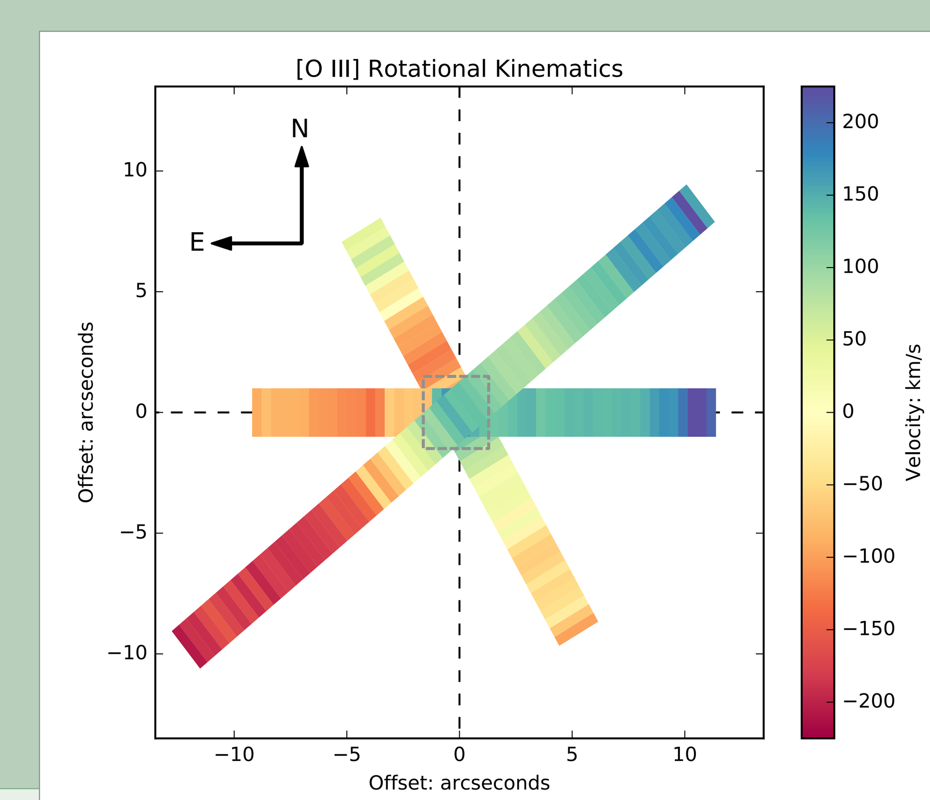
Abstract: We present an analysis of the kinematics and structure of the narrow-line region (NLR) and the lenticular host galaxy of the nearby Seyfert 2 Mrk 3. The NLR of Mrk 3 is composed of several overlapping and spatially-defined emission-line knots that together form a characteristic backwards "S" shape. We map the kinematics of these knots, tracing active galactic nuclei (AGN) outflows and fueling flows, with observations from *Gemini* North's Near-infrared Integral Field Spectrometer (NIFS). We compare these kinematics and those from the host disk, observed with *Apache Point Observatory*'s (APO) 3.5m Dual-Imaging Spectrometer (DIS). We find a misaligned gas disk arising from a tidal stream due to an encounter with a nearby gas-rich spiral, UGC 3422. We explore the impact of this encounter on the AGN NLR and circumnuclear inflows and outflows.

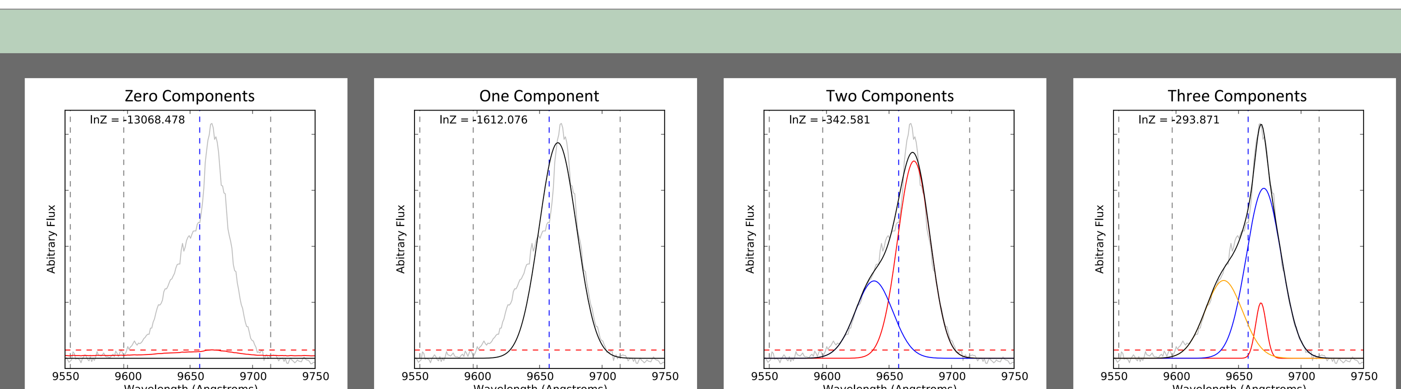
Left: Structure map of Mrk 3 produced with HST WFPC2 and the F606W filter where dark areas correspond to line emission and light areas correspond to dust absorption. The dashed red box encompasses the backwards S-shaped NLR and corresponds to the 3" x 3" FOV for *Gemini*-NIFS. The thin blue rectangle corresponds to previous observations from the *Hubble Space Telescope*'s Space Telescope Imaging Spectrograph (STIS). And the dashed yellow rectangles correspond to the five position angles of our *APO*-DIS observations, the widths proportional to the 2" width of the slit used.
Right: Picture of *Gemini*-North, featuring the laser guide used in the adaptive optics



Small-Scale Ionized Gas Kinematics

Left: Close up of the the *HST* structure map, aligned with the position of the NIFS 3" x 3" FOV.
Right: Kinematics of the highly ionized [S III] λ0.95μm emission line (comparable to [O III] λ5007Å). Velocities shown are from a single component fitted to the emission line (*details below*) which has a narrow FWHM and is likely rotating gas in a circumnuclear disk. Contours shown trace the high velocity outflows within the NLR.



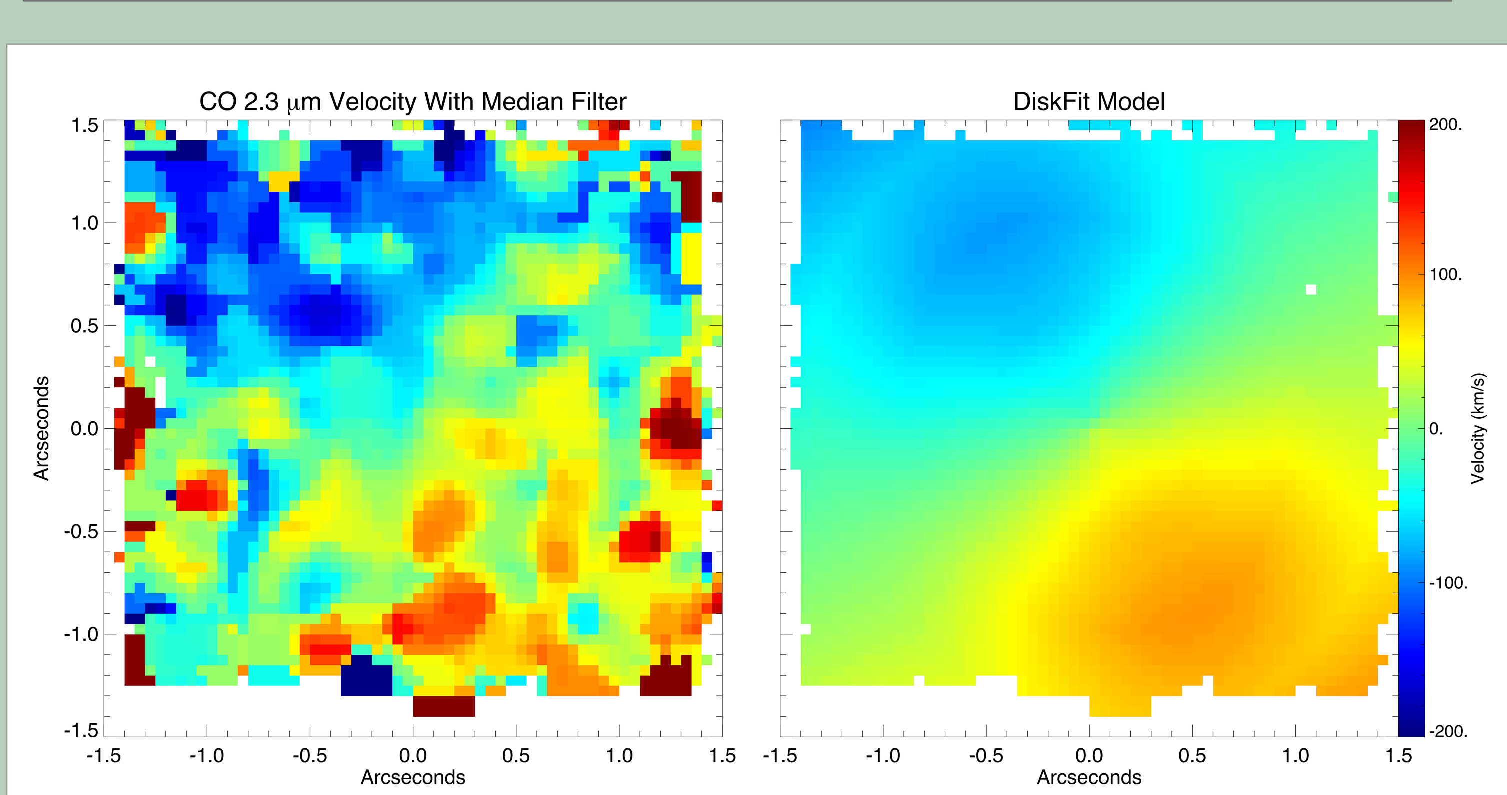


Example outputs from the Bayesian Multi-Component Gaussian Fitting Routine (Fischer+2017). The best model is chosen by the difference in evidence values (lnZ) between two models. Shown here is an example fit to [S III] 0.95μm from a single spaxel within the NIFS datacube. In this case, a model using three components provides the best fit.

Apache Point Observatory with the Sloan Digital Sky Survey (SDSS) 2.5m telescope, the Astrophysical Research Consortium Small Aperture Telescope (ARCSAT) 0.9m telescope, and the ARC 3.5m which houses the DIS instrument featured here.

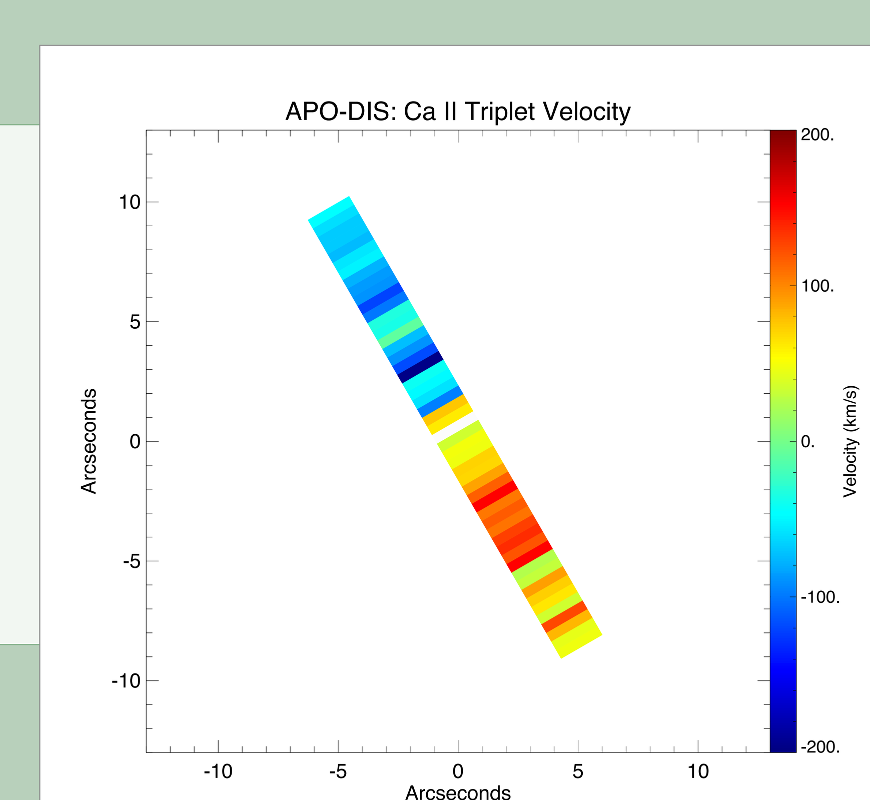
Large-Scale Ionized Gas Kinematics

Left: Kinematics along PA=30°,90°,129° of [O III] λ5007Å, observed with *APO*-DIS and measured through multi-component gaussian emission line fitting. Velocities shown are from a single component, characteristic of rotating gas. Note that the major axis of the large-scale gas disk is misaligned from the small-scale gas disk as well as the stellar kinematics.



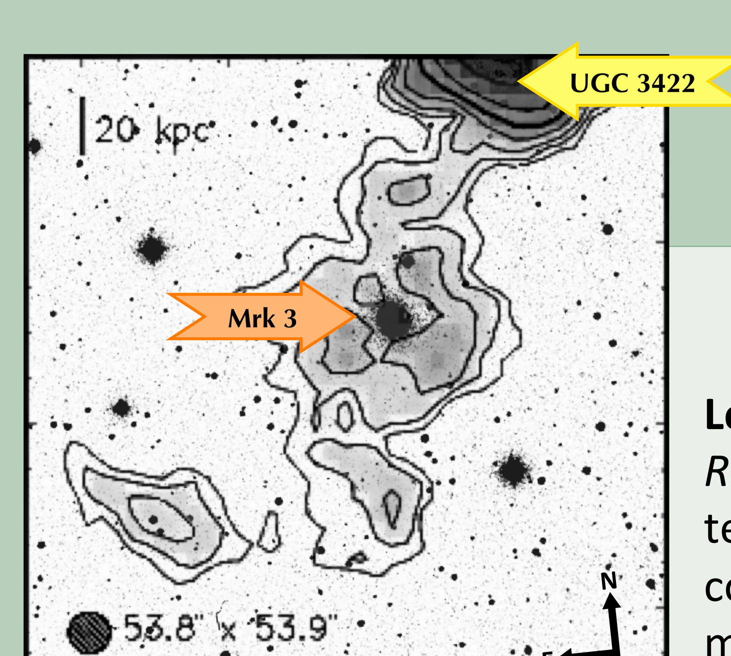
Large-Scale Stellar Kinematics

Left: Stellar kinematics along PA=30°, measured by fitting the Ca II Triplet ~λ0.85μm with the Penalized PiXel Fitting (*pPXF*) routine [Cappellari & Emsellem 2004]. Velocities range within ±200 km/s. These values are consistent with the small-scale stellar kinematics in orientation and velocity.



Small-Scale Stellar Kinematics

Left: Stellar kinematics within the NLR, measured by fitting the CO 2.3μm bandheads with the Penalized PiXel Fitting (*pPXF*) routine [Cappellari & Emsellem 2004]. Velocities range within ±200 km/s
Right: We model the stellar disk within the NLR by using DiskFIT [Sellwood & Spekkens 2015, Reese+ 2007] and constraining our pPXF results with host disk parameters, determined from isophotal analysis of broad I-Band imaging: *PA = 28°; e = 0.159* [Schmitt+ 2000].



Galactic Tidal Interactions

Left: Image of H I 21cm line emission from the *Westerbork Synthesis Radio Telescope* (WSRT) overlaid on an image from the *Palomar* 48in telescope at λ=6450Å [Noordermeer+ 2005]. Mrk 3 appears to be connected to its neighbor UGC 3422 by a tidal stream of gas, with a maximum surface density of only ~0.3$M_\odot$/pc^2. This tidal stream could explain the disturbed ionized gas disks throughout Mrk 3.

Conclusions

- **Small-scale**: Disagreement between ionized gas and stellar kinematics
- **Large-scale:** Ionized gas kinematics are misaligned ~90° from the measured stellar kinematics & isophotal parameters
- The circumnuclear region of Mrk 3 has a surprising amount of dust and gas for an S0 galaxy. The presence of this dust/gas and its misalignment can be explained by tidal interactions with the companion galaxy, UGC 3422.