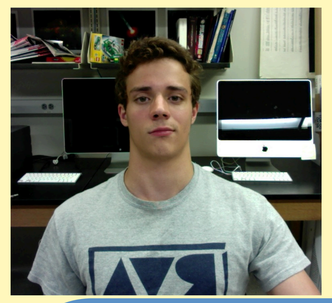

Searching for Accreting Supermassive Black Holes in Bulgeless Galaxies

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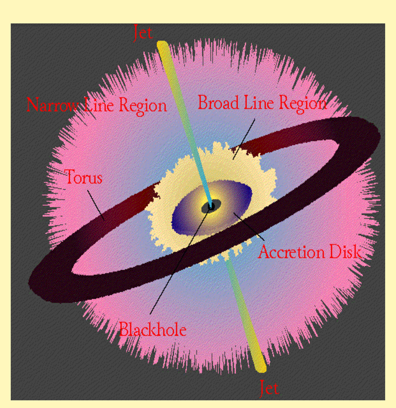
Bulgeless Galaxies and their Black Holes: A Summary

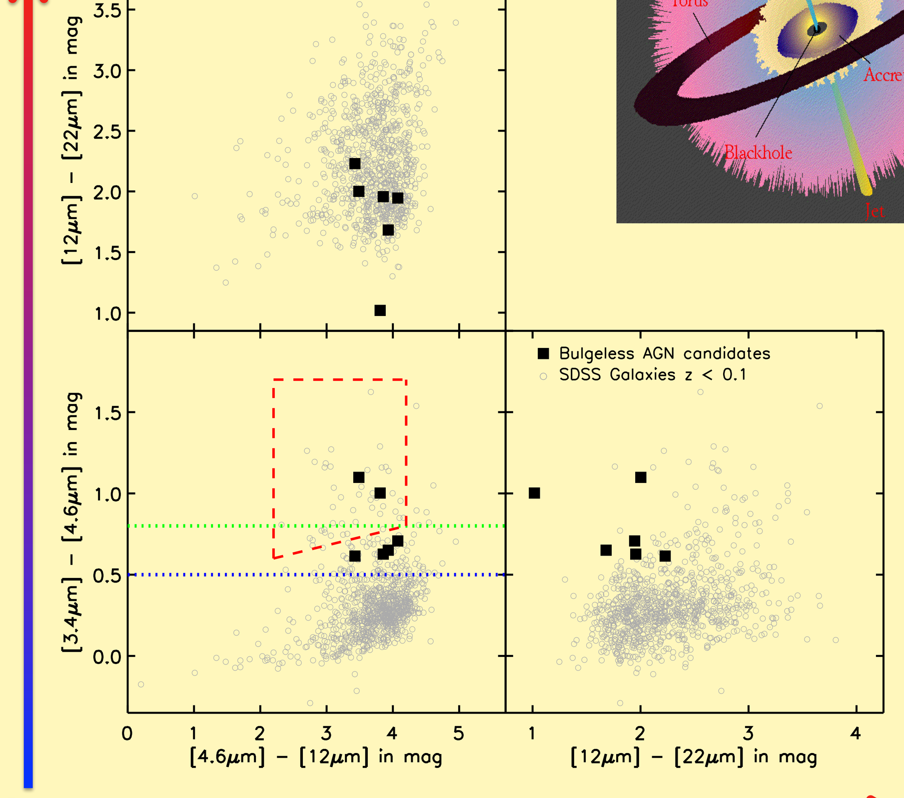
There is increasing evidence that supermassive black holes are created and evolve in bulgeless galaxies, revealing pathways for merger free, secular growth. Given the positive correlation between the masses of bulges and the masses of the black holes residing in their centers we expect to find in low-mass, bulgeless galaxies only the so called intermediate mass black holes. Constraints on the fraction of bulgeless galaxies that host an Active Galactic Nucleus (AGN) remain, however, extremely limited. Following the recent discovery of a large population of bulgeless galaxies with red mid-infrared colors, that are highly suggestive of heated dust by powerful accreting massive black holes, we have employed the *Large Binocular Telescope* (LBT) to investigate the near-IR spectra of six of these systems. We present here the data and measurements of near-infrared hydrogen molecular and recombination lines. We find no evidence for broad components of the Paschen Alpha emission lines, suggesting the AGNs are either too weak or too absorbed to be detected. The data allow for new estimates of extinction which, via comparisons with optical measurements, offer important constraints on the likelihood of these systems being heavily obscured AGN or galactic nuclei with vigorous, yet dust embedded star formation.

The Sample Selection & the LBT Observations

- Satyapal et al (2014) reported the discovery of over 300 local (z<0.3) bulgeless, disk galaxies with extremely red mid-infrared colors that are highly suggestive of accretion activity, i.e., an active galactic nuclei (AGN).
- **The red mid-IR colors** have been observed with the *Wide-Field Infrared Survey Explorer* (WISE; Wright et al. 2010) that surveyed the entire sky in four wavelength bands: W1 (3.4μm), W2 (4.6μm), W3 (12μm), W4 (22μm). Red colors of W1-W2 > 0.5 are best explained by dust that is heated to high temperatures by an AGN, although there could be alternative heating mechanisms (e.g. extreme star formation, low metallicity).



Cartoon representation of an AGN* showing how a dusty torus can obscure the line emission activity from fast rotating clouds of gas (Broad Line Region). The high energy photons from the accretion disk (in yellow) heat up the dusty torus (in black) which will emit mid-IR radiation that is measured by WISE.
*http://imagine.gsfc.nasa.gov/Images/basic/xray/agn.gif



WISE color-color diagrams are used to identify red, AGN-like, galaxies. The dashed red demarcation is from Jarrett et al. (2011) AGN study, and is shown together with W1-W2 > 0.8 (the green dotted line) and W1-W2 > 0.5 (the dotted blue line) color cuts, corresponding to a 95% and 50% chance to host an AGN, respectively.

- **Our sample** presents LBT spectroscopy for the six bulgeless AGN candidates with the brightest radio emission and availability of Very Large Array (VLA) observations. Radio observations are crucial for determining the amount of obscuration in these nuclei which consequently will offer quantitative constraints on the strength and morphology of star formation activity.
- **LBT spectra** of these six galaxy nuclei were obtained with LUCIFER (LBT NIR Spectrograph Utility with Camera and Integral-Field Unit for Extragalactic Research) on Nov. 2013, Dec. 2013, Nov. 2014, and March 2015. We used a 0.50" wide slit, that obtained spectra covering 1.4μm-2.2μm at ~2000 resolution, with a 0.25"/pixel spatial scale. The total integration time for each object was ~20 minutes. The LBT is an 8-10m telescope that has two 8.4m mirrors on a single mount.

SDSS Optical Spectra

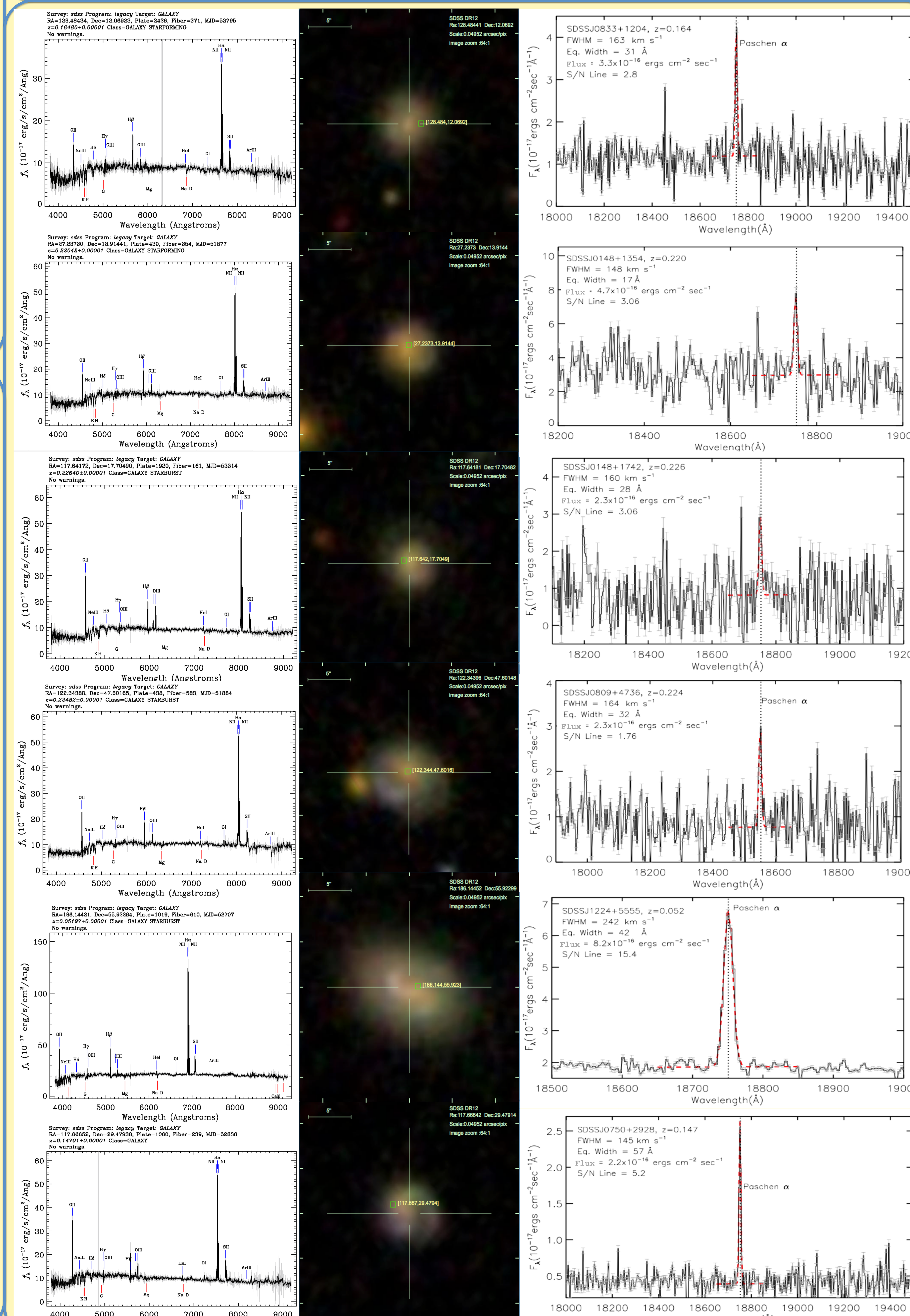
No AGN-like line flux ratios or broad Hα emission

SDSS Images

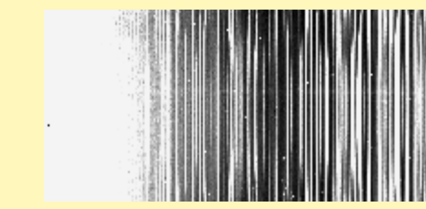
No obvious galactic nucleus

LBTO Near-Infrared Spectra

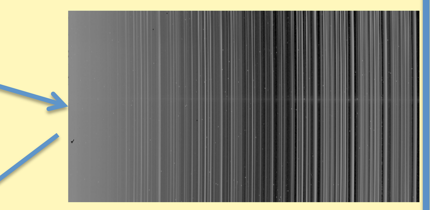
No broad Paschen Alpha Emission Line detected



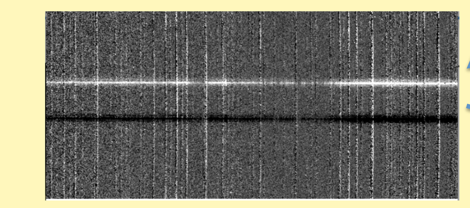
LBT Data Reduction Process



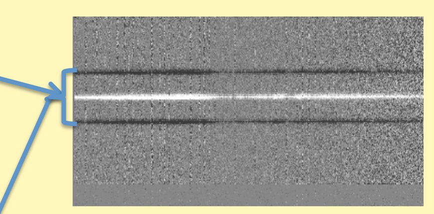
1) Raw data set= object spectrum + detector response + sky emission



2) Raw frame divided by flatfield to correct for intrinsic detector response function.



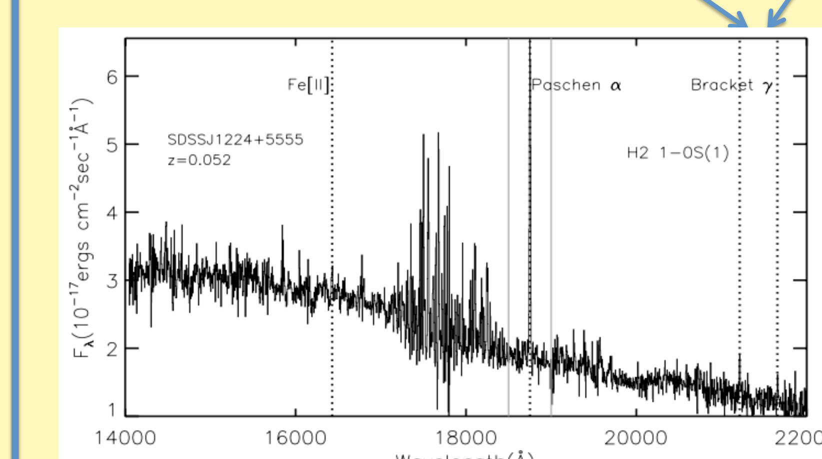
3) Use known wavelength of sky emissions to assign proper wavelength to each pixel on the x-axis. Skylines are removed by subtracting individual scaled frames.



4) Combine skyline subtracted frames into one 2d spectrum

5) Extract the 1-D spectrum by adding the central 10 pixels (2.5")

6) Flux calibrate and correct for telluric absorption using the IRAF XTELLCOR package Vacca et al. (2003)



This is the final calibrated and Doppler corrected LBT spectrum of SDSSJ1224+5555 over the entire wavelength range measured by LBT.

A strong (but narrow) Paschen Alpha emission line is detected at rest wavelength 18751 Å in all six galaxies.

Conclusions and Future Directions

- We found **no significant evidence for broad Paschen α** emission lines in these six bulgeless galaxies. Higher signal-to-noise observations are needed to clarify the presence or absence of these features.
- **If an AGN is responsible for the red mid-IR colors in these sources, it is either too absorbed or too weak to be detected in these spectra.**
- Preliminary comparisons of the Paschen α fluxes with those of the Balmer Hα emission measured in their SDSS spectra reveal only moderate A_V values, suggesting that the extinction toward the nuclear star forming regions is not excessively high; the observed red WISE colors argue thus more likely for a highly obscured AGN than for extreme star formation.
- We are **pursuing follow-up observations in X-ray (XMM) and radio (VLA)** wavelengths in order to constrain further the bolometric luminosities of these sources, and thus the true origin of the red mid-IR colors, as well as the mass of the putative black hole and its accretion rate.

References:

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