



History and Obscuration of Galaxy-Scale Clouds of Ionized Gas Around AGN



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Overview

We present the results of a spectroscopic hunt for remnants of recently deceased quasars in the $z < 0.1$ universe. The ghostly green object in the image to the right is the progenitor of our search – Hanny’s Voorwerp, an 11x16 kpc cloud of glowing gas whose level of excitation suggests that it saw a quasar in IC 2497 less than 100k yrs. If that quasar still existed, it would be a whopping 500 Mpc nearer to us than current record holder, 3c273. Along with Galaxy Zoo (GZ) participants worldwide, we wondered, is this a unique situation? In other words, can we find additional examples in SDSS data?

Sample Selection

Answers to our early questions came quickly thanks to efforts of an elite group of GZ ‘citizen-scientists,’ who rapidly perused some 16000 images of local AGN in search of Voorwerp analogues. Their final list included over 100 galaxies featuring unusual patches of fluorescent color, and we proceeded to test the reality of each object by subtracting the associated, scaled-down SDSS r -band image from the g -band image. With some finagling of the scaling factor so as to account for object distance, this ‘[OIII]-filter’ effectively eliminates starlight and exposes reservoirs of gas emitting strongly at [OIII] λ 5007 (as is the case in Hanny’s Voorwerp. Our final list included 50 objects we saw as viable targets for long-slit spectroscopy.

Spectroscopic Data

We used the GoldCam CCD spectrograph on the KPNO 2.1-m to perform the initial survey, taking 45-min exposures for 30 objects, with each spectrum covering 3300-5700 Å. These data allowed us to (a) estimate extent of and level of ionization in extended emission-line regions, and (b) map the kinematic structure of ionized gas clouds. Building on the KPNO results, deeper exposures covering 3300 -8400 Å were obtained for 7 of the more interesting KPNO objects and 1 new object via the Kast double spectrograph on the Lick 3-m. Using a similar setup, an additional 14 objects were observed in another recent Lick run.

Discussion

Extended emission was observed in 18 total objects. The most exciting of these were cases of high-ionization lines such as H β extending > 10 kpc from galaxy cores. Emission line ratios measured at such distances often match or nearly match those from around the host galaxy’s core, validating their ‘AGN cloud’ classification.

To test the ‘obscured AGN’ hypothesis for such activity in the absence of a sufficiently powerful AGN, we compared ionizing luminosities implied at the outer edges of the AGN clouds to FIR survey data for the system. While these values often matched, FIR output was insufficient to account for the ionizing luminosity ‘seen’ by gas at large distances from the cores of 10 objects, most notably SDSS 1430+13 where the mismatch was a factor of 12.

Future Studies

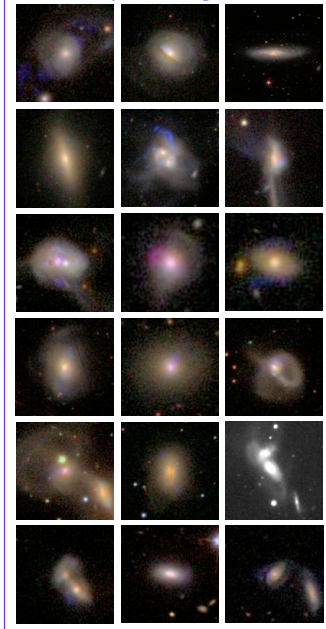
These results suggest several lines of work which we are pursuing, as to how common such large-scale ionized clouds are, and whether there is a significant population of faded AGN.

- ➔ An [OIII] imaging survey from SARA of several galaxy samples – known AGN, luminous non-AGN galaxies from the SDSS, and HI-selected samples which are more likely to have extraplanar gas tails to be ionized by AGN.
- ➔ X-ray observations of candidate faded AGN too search for deeply obscured (Compton-thick) extant AGN.
- ➔ HI mapping of the vicinities of ionized clouds, to show where these features are matter- or ionization-bounded and thus estimate cone angles of the illumination pattern.

Results

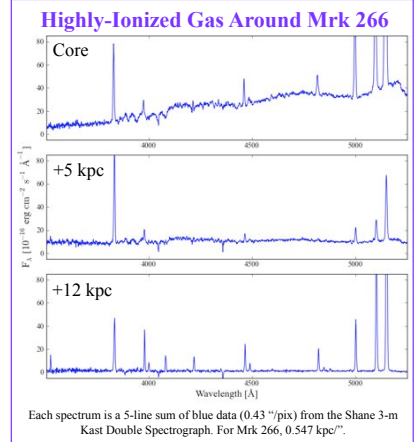
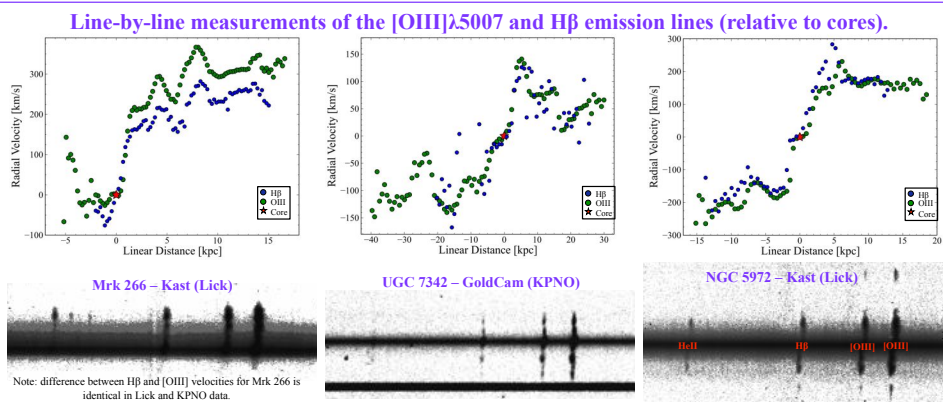
- ➔ We have confirmed the existence of galaxy-scale clouds of AGN-ionized gas around 18 out of 45 total objects surveyed.
- ➔ Most of the AGN clouds are associated with narrow-line Seyfert 2 nuclei (13/18).
- ➔ Providing a plausible means by which to put gas into tidal tails where it can be exposed to hard radiation from the core, 12/18 AGN cloud hosts are involved in merger and/or interaction activity.
- ➔ For 8 of the AGN cloud systems, ionizing luminosity at cloud edges exceeds nuclear FIR output by multiple factors. This could imply either variability in or impending demise of the ionizing source.

Confirmed extended AGN clouds from Galaxy Zoo sample (50-kpc boxes)



Acknowledgments

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Cloud Sizes and UV/FIR Mismatches

OBJECT	SPECTRAL TYPE	CLOUD SIZE	UV/FIR RATIO
SDSS 1430+13	Sy 2	20	> 12.00
NGC 5252	1.5	21	> 8.00
SDSS 1510+07	Sy 2	12	> 3.40
CGCG 428-014	LINER/HII	18	> 3.40
UGC 7342	Sy 2	37	> 3.00
NGC 5972	Sy 2	35	1.80
UGC 11185	Sy 2	11	> 1.70
SDSS 1005+28	LINER	12	> 1.40
Mrk 78	Sy 2	16	> 1.20
Mrk 1498	Sy 1.9	26	> 0.60
Mrk 266	Sy 2	31	0.40
Mrk 463	Sy 2	18	0.30
Mrk 883	Sy 1.8	46	0.26
SDSS 0955+39	LINER	10	> 0.15
IC 2637	Sy 1.5	17	0.10
NGC 7212	Sy 2	7	0.05
Mrk 273	Sy 2	36	0.03
NGC 4388	Sy 2	11	0.02

Note: Cloud sizes given in kpc.

Images of [OIII] Structure in CGCG 428-014

