Quasar Ionization Echoes -- 100,000 Year Baseline AGN Light Curves

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Quasar ionization echos – 100,000 year baseline AGN light curves

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Bill Keel (U of Alabama; low-z echos)
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Hai Fu (UC Irvine; EELRs, PI models)
Nancy Levenson (Gemini; X-ray)
James Turner (Gemini; IFU)
Ruben Diaz (Gemini; Star burst)
1. Quasar ionization echos
2. The cosmic soup: Green Bean galaxies (Schirmer et al. 2013)
3. How to extract an AGN light curve from an ionization echo (i.e. a GB galaxy)
1. Quasar ionization echos

Hanny’s Voorwerp (z=0.05, near IC 2497)

Credit: 3.5m WIYN, W. Keel
1. Quasar ionization echos

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Hanny’s Voorwerp (z=0.05, near IC 2497)

\[ \sim 70,000 \text{ years ago, output drops by } \sim \times 10^4 \]
Other Voorwerpjes (from SDSS)

BLUE = [OIII] in gri poststamps

Keel, W. et al. 2012:

- $\sim 200$ found by Galaxy Zoo
- 19 AGN ionized
- 7 good ionization echoes
- Median redshift $z = 0.06$
- [OIII] luminosity: 
  $(0.5 - 5) \times 10^{41}$ erg cm$^{-2}$ s$^{-1}$

AGN undergo luminous 
$(0.2 - 2) \times 10^5$ year episodes.
Lifelong restlessness ...

Credit: McHardy, I. et al. 2007

Martini, 2004; Bourneaud et al., 2011
Lifelong restlessness ...

See Gabriele Ponti’s talk on Monday
NGC 5972 \((z = 0.029, \text{ SDSS})\)

- Size: \(20 \times 35 \text{ kpc}\)
- \(L_{[\text{OIII}]} = 1.5 \times 10^{41} \text{ erg cm}^{-2} \text{ s}^{-1}\)
2. Green Bean galaxies

NGC 5972 (z = 0.029, SDSS)

- $20 \times 35$ kpc
- $L_{\text{[OIII]}} = 1.5 \times 10^{41}$ erg cm$^{-2}$ s$^{-1}$

4''x7'' (26x44 kpc) $z=0.326$
2. Green Bean galaxies

8"x17" (36x77 kpc) $z=0.306$

4"x7" (26x44 kpc) $z=0.326$
Green beans – rare but luminous

Color selection in SDSS-DR9 yields: 17 GBs in 14500 sq.deg.

<table>
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<tr>
<th>#</th>
<th>Name</th>
<th>SDSS objID</th>
<th>$r$ [mag]</th>
<th>$R_r$ [&quot;]</th>
<th>$z$</th>
<th>$\log \left( \frac{[O_{III}]}{H\beta} \right)$</th>
<th>$F_R$ [mJy]</th>
<th>$F_{24\mu m}$ [mJy]</th>
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</tbody>
</table>

- Volume density ($0.19 < z < 0.34$): $4.4 \text{ Gpc}^{-3}$, 1 in $z < 0.1$
- $L_{[O_{III}]} = (0.6 − 5.7) \times 10^{43} \text{ erg s}^{-1}$
- Most [OIII] luminous type-2 AGN known
Proving ionization echos: Assess SMBH activity

- Directly, in X-rays (not yet)
- Indirectly, in the mid-IR (reprocessed X-rays in dusty torus)
- 5 – 50 times brighter in [OIII] at given $L_{22}$ than comparison sample

![Graph showing the relationship between log $L_{[OIII]}$ and log $L_{24\mu m}$](image)
Proving ionization echos: Assess SMBH activity

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![Graph showing data points and labels](image)

- Torus emits disprop. less IR at given $L_{BOL}$?
- [OIII] is not a faithful probe of $L_{BOL}$?

Not explicable by our broad-band selection. Violates mid-IR-X-ray and [OIII]-X-ray relations.

BUT: GBs are ionization echos nonetheless! Imprint of past AGN luminosity.
GBs: Where do they come from, what do they tell us?

- At least 2/3 show merger signatures
- Very gas rich
- Live in the field or very small groups, not in clusters
- Exclusively radio-quiet

Some Questions (out of many):

- Formed from gas from rich, instable disks (feeders of AGN; Bournaud et al., 2011; 2012); fires up the BH, massive blowout, AGN feedback (Somerville et al., 2008; Schawinski 2012) shuts it down?

- Rare only because extremely short-lived?

*Is this how most luminous quasars die?*
Quasars, soon to be extinct

Quasar luminosity function (Paris et al., 2012):

\[ z = 2 \rightarrow z = 0.5: \text{Number of bright quasars reduced 100 times} \]
3. Reconstructing 10e5 year AGN light curves

In principle straightforward:
run photoionization models, and infer X-ray luminosity

Expect about 10-20 statistically independent measurements
per galaxy and light curve.
Some pre-requisites

1. 10 GBs
2. Optical integrated field spectroscopy for gas properties (T, n, U, extinction, shocks, velocity); 10h per GB with 8m telescopes
3. HST narrow-band imaging in [OII], [OIII]: clear view, ID bad regions; 2-3 orbits per target
4. Chandra, internal obscuration, slope of ionising spectrum, current activity; 30 ks with ACIS-S per target

Obstacles (only some of them!):
- Deprojection, for correct distances and time delays: Doppler mapping with IFU+HST (Keel et al., 2012)
- Missing control sample! Internal control: independent PI models using CLOUDY and MAPPINGS
- Variable long-term (10^4 years) AGN absorption?
Quasar ionization echos probe a previously uncharted regime in AGN variability, on scales quasars are expected to shut-down.

Green Bean galaxies are very rare ionization echos, but (optically) luminous and offer unique laboratory.

Formation process of GBs is still largely unknown, but will be answered with the data proposed for.

Reconstructing $10^{4−5}$ AGN light curves is hard, yet feasible.