The Slow Heartbeat of Supermassive Black Hole Fuelling

Alastair Edge
Durham University
Accretion Rates in BCGs

A back of envelope calculation returns $\sim 20 M_{\text{sun}} / \text{yr}$ accretion is required to sustain Eddington luminosity for a $10^9 M_{\text{sun}}$ Black Hole.

Therefore the duty cycle of the activity in such a system can’t be much more than 1% over $10^{10}$ yrs and, given rarity of QSOs, that matches observations.

However, constant $<10^{-3} L_{\text{edd}}$ accretion ($<10^{44} \text{erg/s}$) is possible without having to worry about Black Hole growth.
Accretion Rates in BCGs

Interestingly this level of activity is consistent with all BCGs in cool core clusters (see later!) as almost every one contains radio source brighter than $10^{22}$W/Hz.

So radiatively inefficient accretion at the $10^{-5}$-$10^{-3}$ Msun/yr level is present.

This is what you’d expect for Bondi accretion but is this constant and does it scale with cluster mass?
Accretion Rates in BCGs

Well let’s consider the most nearby system and see if it has the properties you’d expect for a Bondi fed ~$10^9$ M$_{\odot}$ Black Hole?

That local example is NGC1275 in the Perseus cluster.....
NGC1275 – lessons from history

NGC1275 holds an important position as being an archetypal object in a number of different astronomical “special interest groups”!
- Brightest Cluster Galaxy in a cool core cluster
- Gamma-ray detected radio galaxy
- BLLac/AGN hybrid
- Target to search for Dark Matter annihilation in
NGC1275 – lessons from history

As such it is worth reviewing the full span of our observations of it to understand its evolution since 1960.

Any variation on this timescale relates to the accretion on to the central black hole and/or the impact on the jet on parsec scales.

Starting with the GHz radio regime.....
UMRAO Michigan radio monitoring (thanks to Margo and Hugh Aller)
High Frequency radio variability Dutson et al 2014

The diagram shows the gamma-ray flux (greater than 100 MeV) in units of photons per cm$^2$ s$^{-1}$ plotted against date. The graph includes data from different frequency bands: HE data, 32-37 GHz data, and 90 GHz data. The data points are marked with markers indicating 'COS B', 'EGRET', and 'Fermi'. The y-axis represents the flux in units of $10^{-6}$ Jy.
NGC1275 as seen by CMB satellites Dutson et al 2014
High Frequency radio variability – over 60 years!

UMRAO + OVRO 15GHz
350GHz
230GHz
90GHz

Flux density (Jy)

Year
High Frequency radio variability – Fermi operational

- OVRO 15GHz
- ALMA 91GHz
- ALMA 103GHz
- SMA 230GHz
- ALMA 343GHz
High Frequency radio variability – most recent ALMA and SMA

Flux density (Jy)

Year


OVRO 15GHz
ALMA 91GHz
ALMA 103GHz
SMA 230GHz
ALMA 343GHz
High Frequency radio variability - Early 3mm data

Dutson et al 2014

Similar Oscillations!
History Repeating! – a two year outburst cycle?
Full radio spectrum Dutson et al 2014

- 1982 peak fluxes
- Current fluxes
- 2002 Low state
- 2010 rising state
NGC1275 as a BCG archetype?

The Brightest Cluster Galaxies (BCGs) in cool core clusters are similar to NGC1275 in that they also exhibit extended optical emission line nebulae, cold molecular gas reservoirs, recent star formation and a powerful radio source. How similar are the radio properties? Let’s first consider a single frequency radio power....
1.4GHz Radio luminosity function of BCGs with and without lines from combined X-ray sample of >750 clusters (BCS/eBCS/REFLEX)

Almost 100% detection rate = UBIQUITY

NGC1275 is in the upper quartile of radio power in the sample

Hogan et al (2015a)
Is NGC1275 unusual in its radio SED?... NO!

from Hogan et al (2015a)
How do you interpret such strange spectra?!
Cool cores have a large variety of core to steep component fluxes

Core vs extended emission for line emitting BCGs
from Hogan et al (2015a)

Activity now!

Core flux at 10GHz (mJy)

Core >= Steep

Core >> Steep

Steep >> Core

Activity averaged over many 10’s Myrs
Whereas non-cool cores don’t! Relatively few BCGs in these systems have a core.
The maximum core radio power is linked to cluster X-ray luminosity

![Core vs cluster X-ray luminosity for BCGs from Hogan et al (2015)](image)
The maximum extended radio power is no so linked!

Extended vs cluster X-ray luminosity for BCGs from Hogan et al (2015)
Highest Frequency flux correlates with X-ray point source flux

150GHz flux density vs X-ray point source for BCGs from Hoganl PhD (2014)
The radio cores in cool core clusters are $>100$ times more powerful

10GHz Radio luminosity function of cores with and without lines

With Optical Lines

Without Optical Lines

Hogan et al (2015a)
With Optical Lines

Without Optical Lines

1GHz Radio luminosity function of steeper spectrum emission with and without lines

Hogan et al (2015a)

NGC1275 is close to median of sample in extended power

Fraction of Detections

Luminosity (W Hz⁻¹)

Hogan et al (2015a)
Compare them to NGC1275 UMRAO lightcurve!

Only period in which a factor of two increase would be found i.e. ~10% of sampled period

Whereas most others vary by ~20-30%
Also core components vary!

Few BCG sources other than NGC1275 have been monitored to allow us to search for longer term variability consistent with the >30 year cycle of NGC1275. However, the OVRO 40m has been monitoring a sample of 20 BCGs with a core brighter than 100mJy (as well as NGC1275) for the past 2-10 years (Hogan et al 2015b).
OVRO 40m 15GHz monitoring of the BCG in A2270 (J1727+5510)

Hogan et al. (2015b)

16 other sources monitored: two varied by factor 2, three more by >+/-30%, five between 20% and 30%, seven <20%, i.e.~half sample vary more than 20%

Decade long monitoring at >10GHz is vital to study this issue!
A role for ALMA, KVA, NOEMA and ngVLA in the SKA era!
Radio lightcurve for RXCJ1558−14

- 5GHz
- 15GHz

Year

Variability vs Spectral Index for NGC1275 over past 60 years

Spectral index between 30 and 90GHz Fractional variation at 15GHz per year

Previous Outburst
Recent Rising
Fading

Current
Variability vs Spectral Index for OVRO sample

Fractional variation at 15GHz per year vs
Spectral index between 15 and 150GHz
NGC1275 in its wider context

So from a large parent sample of >750 X-ray selected clusters we can identify many sources with the same characteristics as NGC1275 in terms of radio activity on month to Myr timescales from their core variation to their radio lobe properties!

The MIR, optical, X-ray and gamma-ray properties of their AGN are similar too.
What is in store in the near future?

The radio/sub-mm emission we see appears to lag the optical and gamma-ray variability we observe by at least a year in NGC1275.

With our current JCMT project combined with KVN, OVRO 40m and IRAM 30m NIKA2 data we will have a sample of sufficient size to determine if NGC1275 is representative of all active BCGs.

Watch this space!
Conclusions

BCGs in cool cores ALL contain an AGN that varies on year to decade timescales. NGC1275 started brightening when I was born. It reached maximum brightness as I started my (paid) astronomical career. I hope it will reach maximum brightness again before I retire.....!