
Durham
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The Slow Heartbeat of Supermassive Black Hole Fuelling
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Accretion Rates in BCGs

A back of envelope calculation returns ~20Msun/yr accretion is required to sustain Eddington luminosity for a 10^9Msun 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 $<10^{-3}L_{edd}$ accretion ($<10^{44}$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 Msun 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

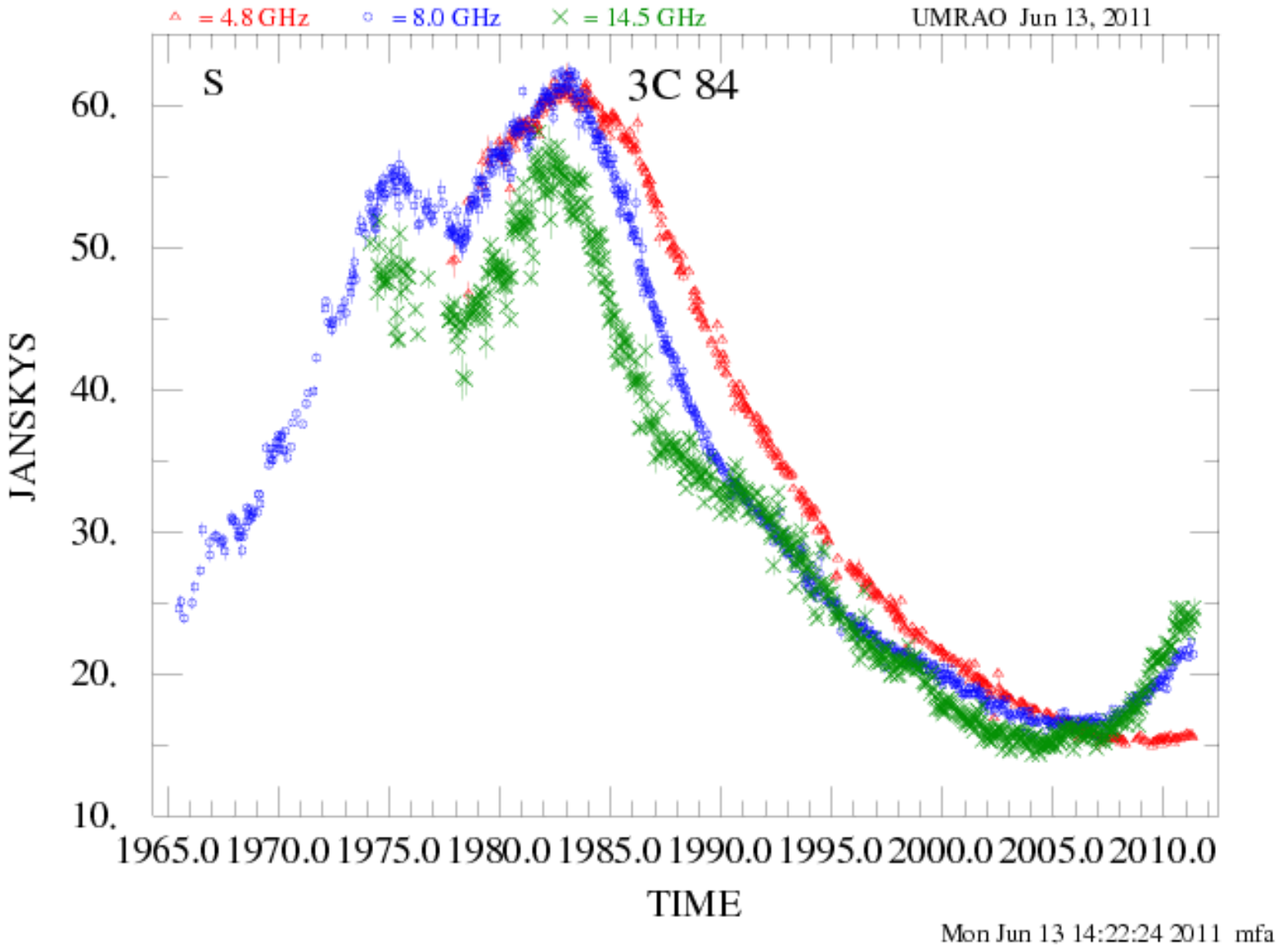
NGC1275 – lessons from history

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

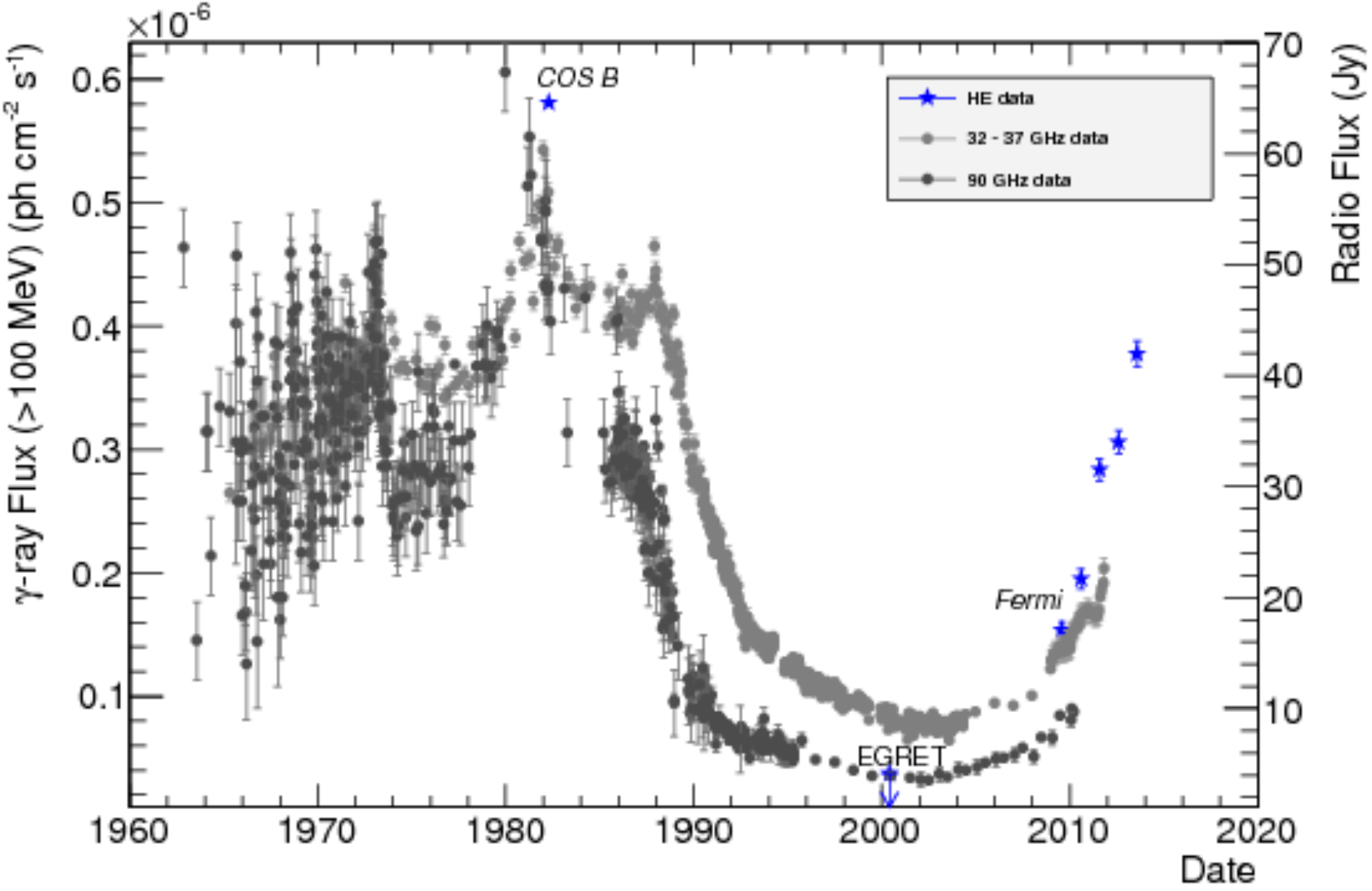
Any variation on this timescale relates to the accretion on to the central black hole and/or the impact on the jet on parsec scales.

Starting with the GHz radio regime…..

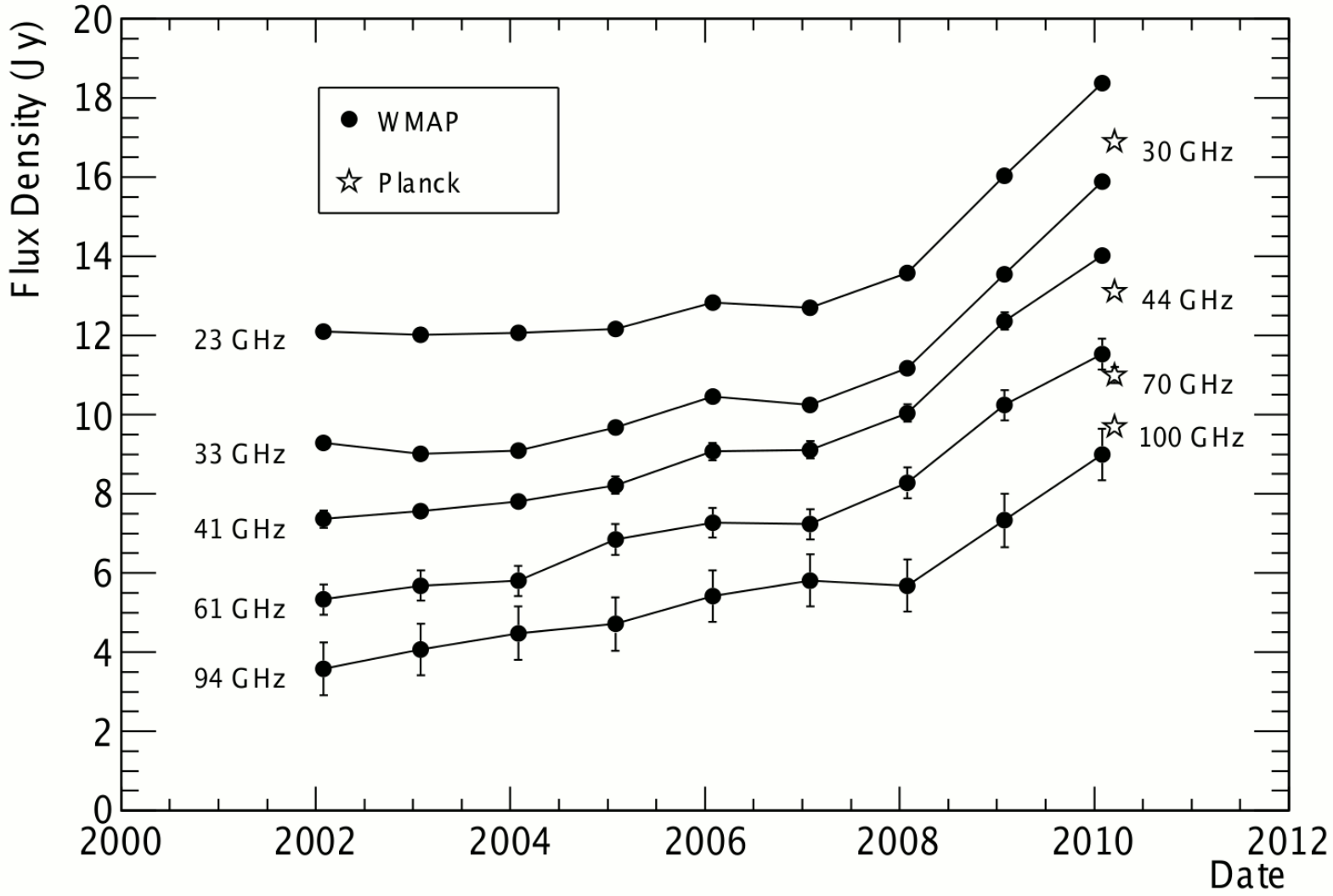
UMRAO Michigan radio monitoring (thanks to Margo and Hugh Aller)



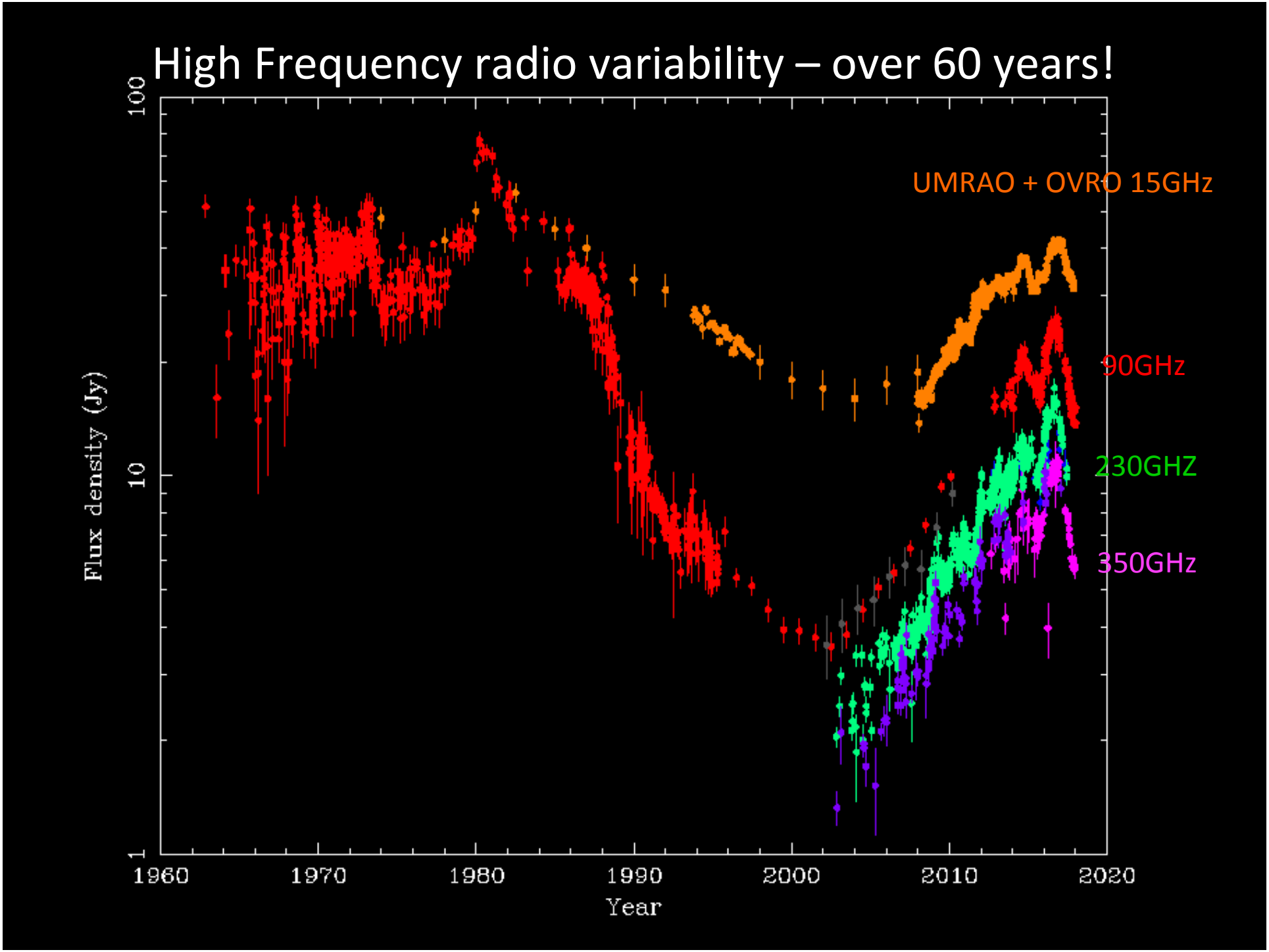
High Frequency radio variability Dutson et al 2014

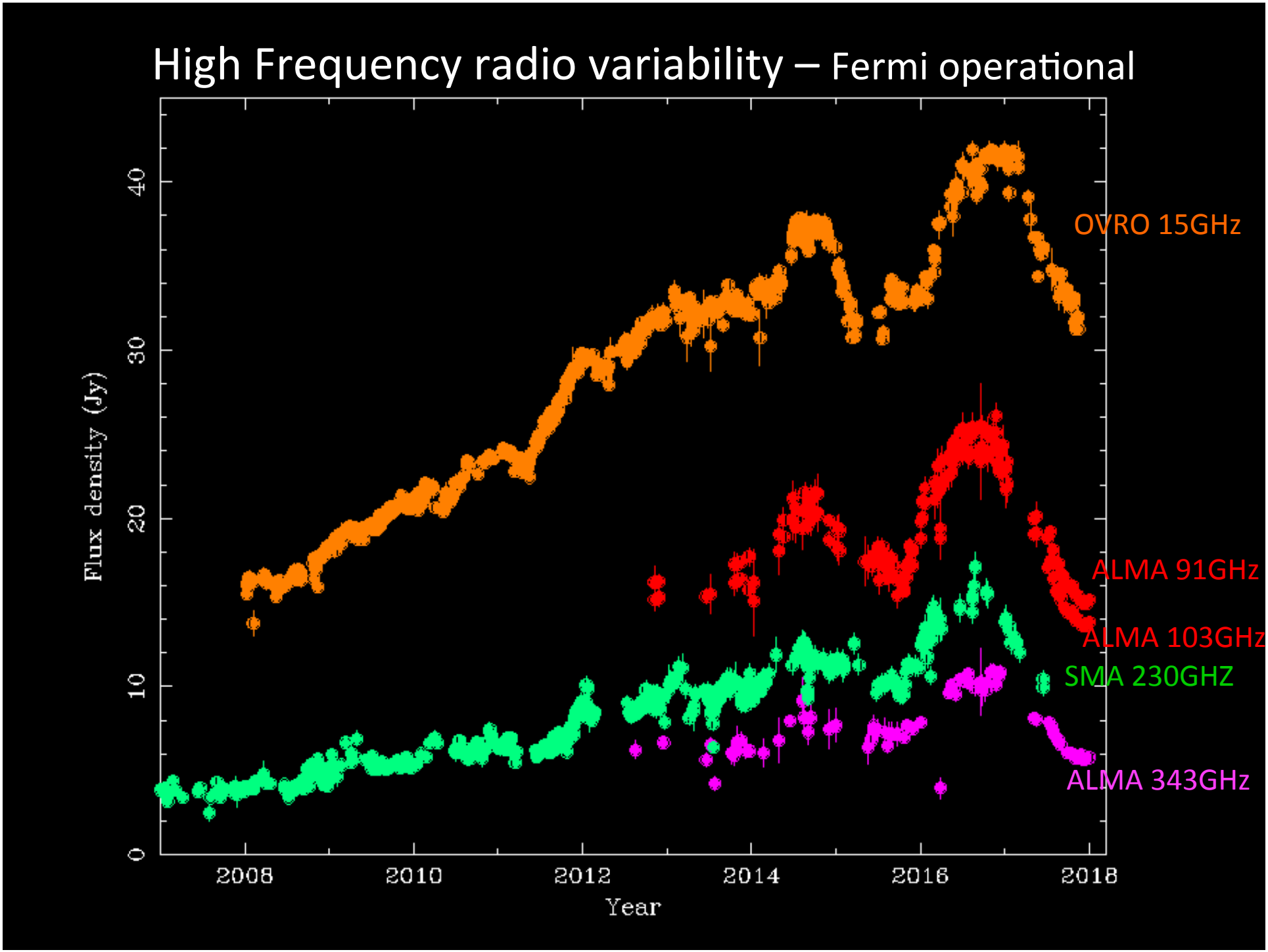


NGC1275 as seen by CMB satellites Dutson et al 2014

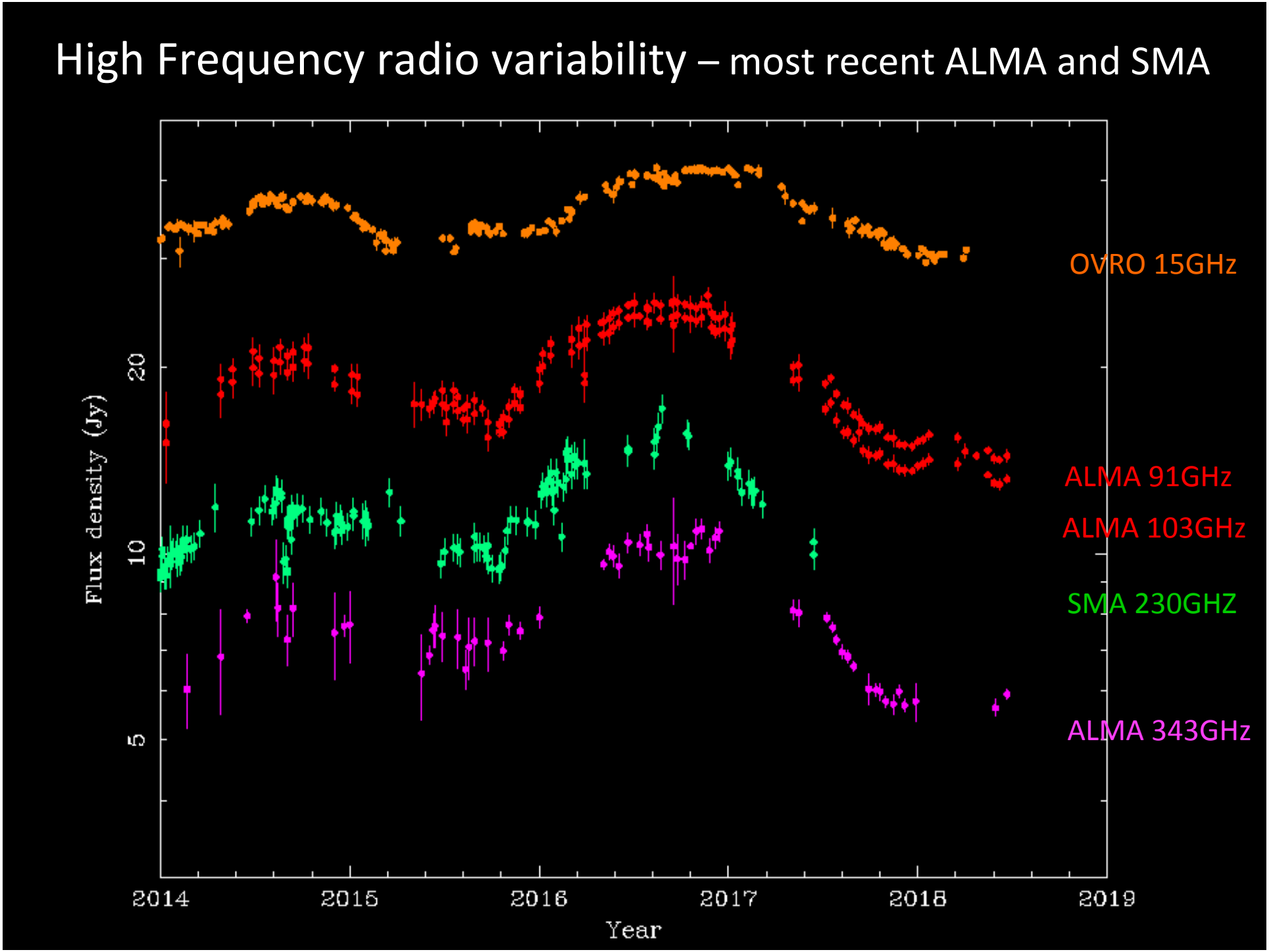


High Frequency radio variability – over 60 years!



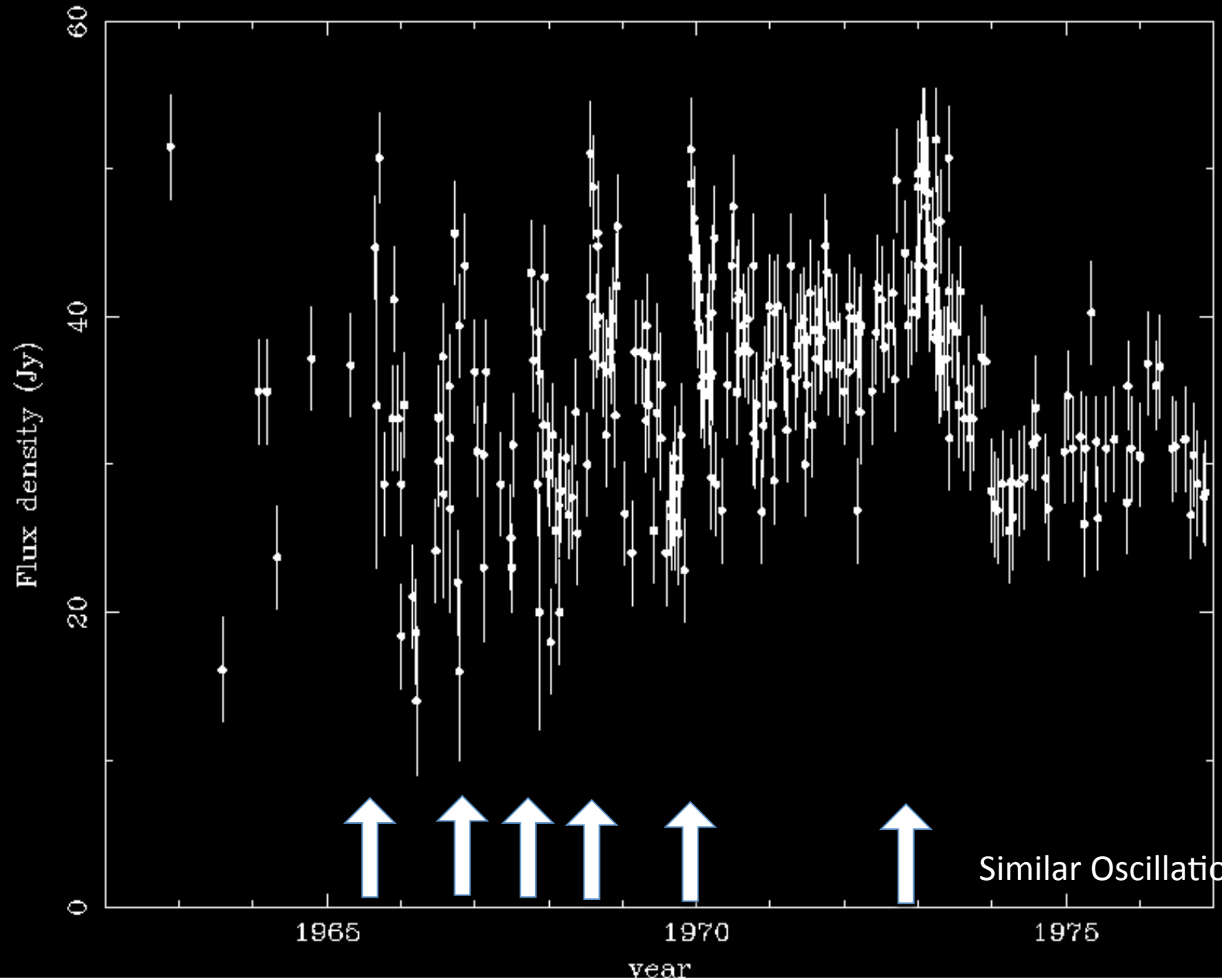

High Frequency radio variability – Fermi operational
Flux density (Jy)
0
10
20
30
40
2008
2010
2012
2014
2016
2018
Year
OVRO 15GHz
ALMA 91GHz
ALMA 103GHz
SMA 230GHZ
ALMA 343GHz

High Frequency radio variability – most recent ALMA and SMA

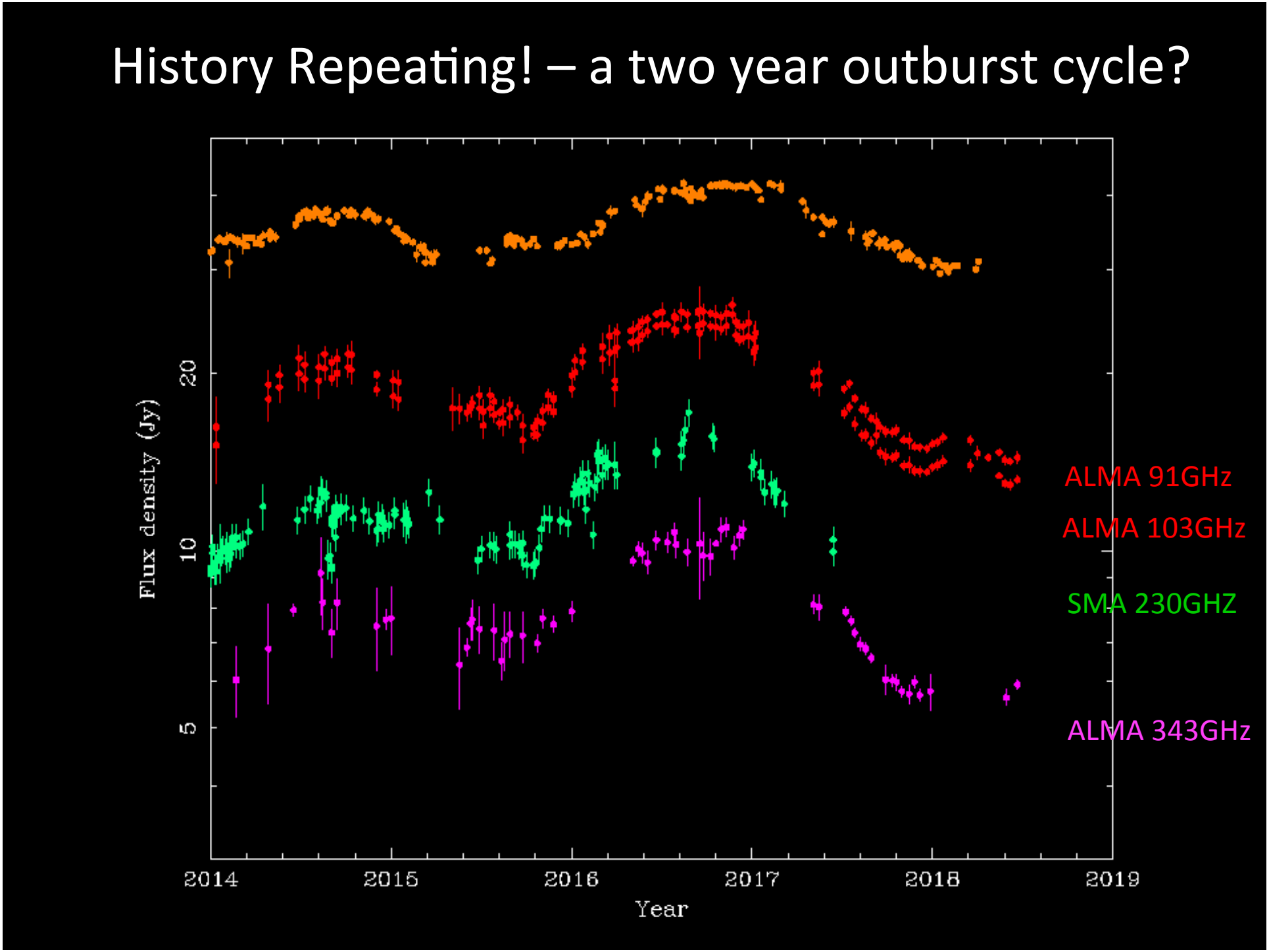


High Frequency radio variability - Early 3mm data

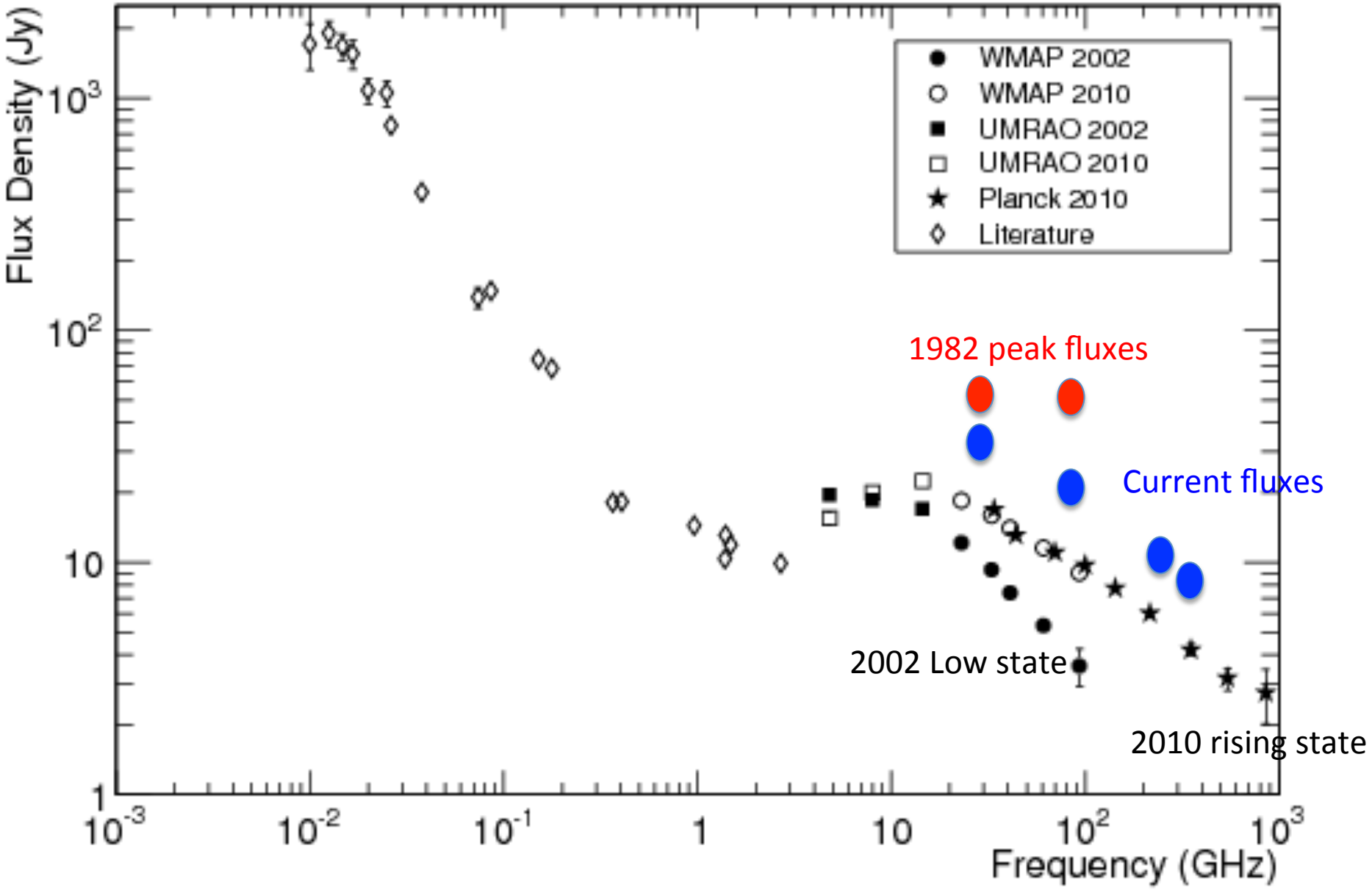
Dutson et al 2014

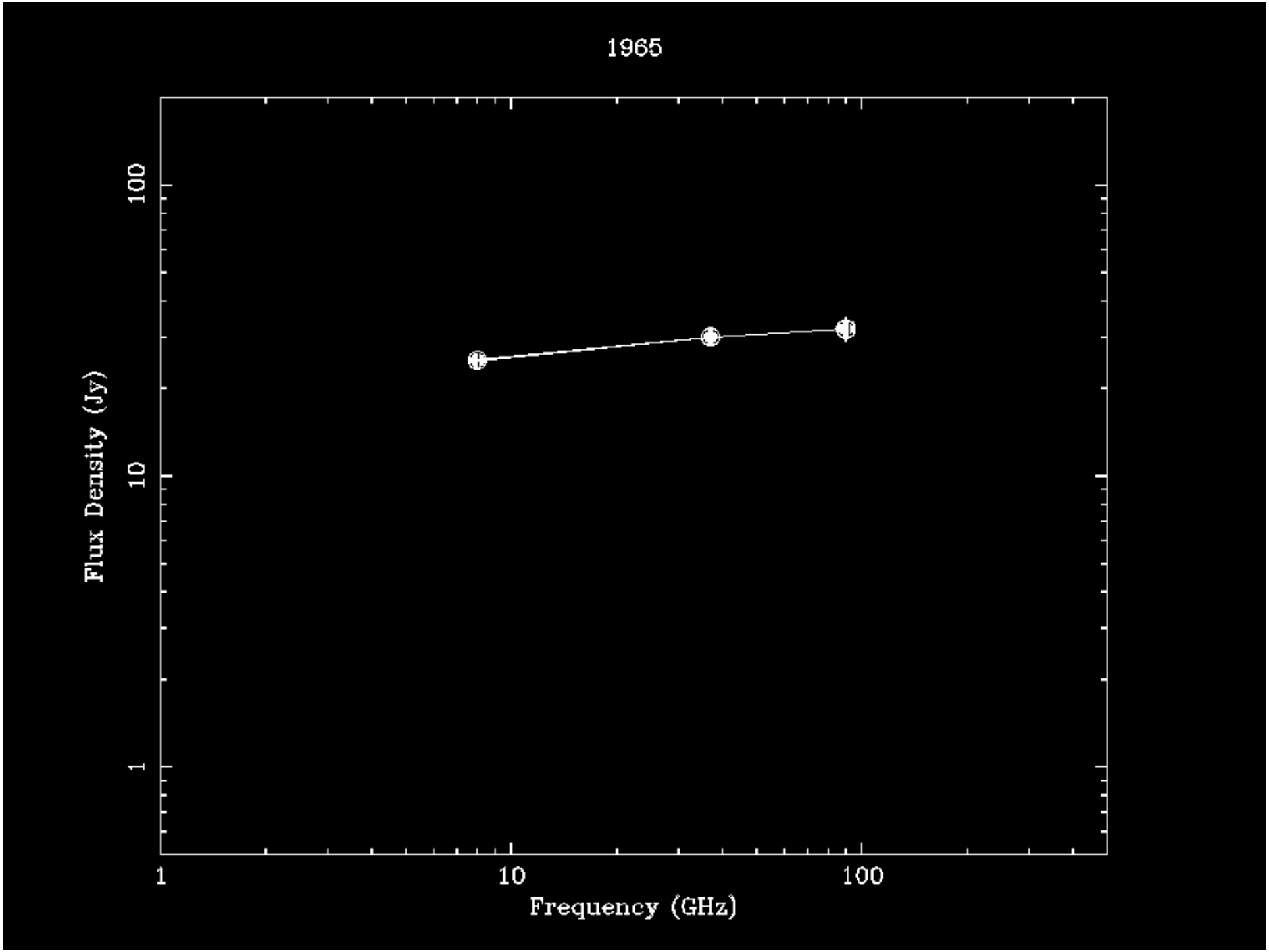


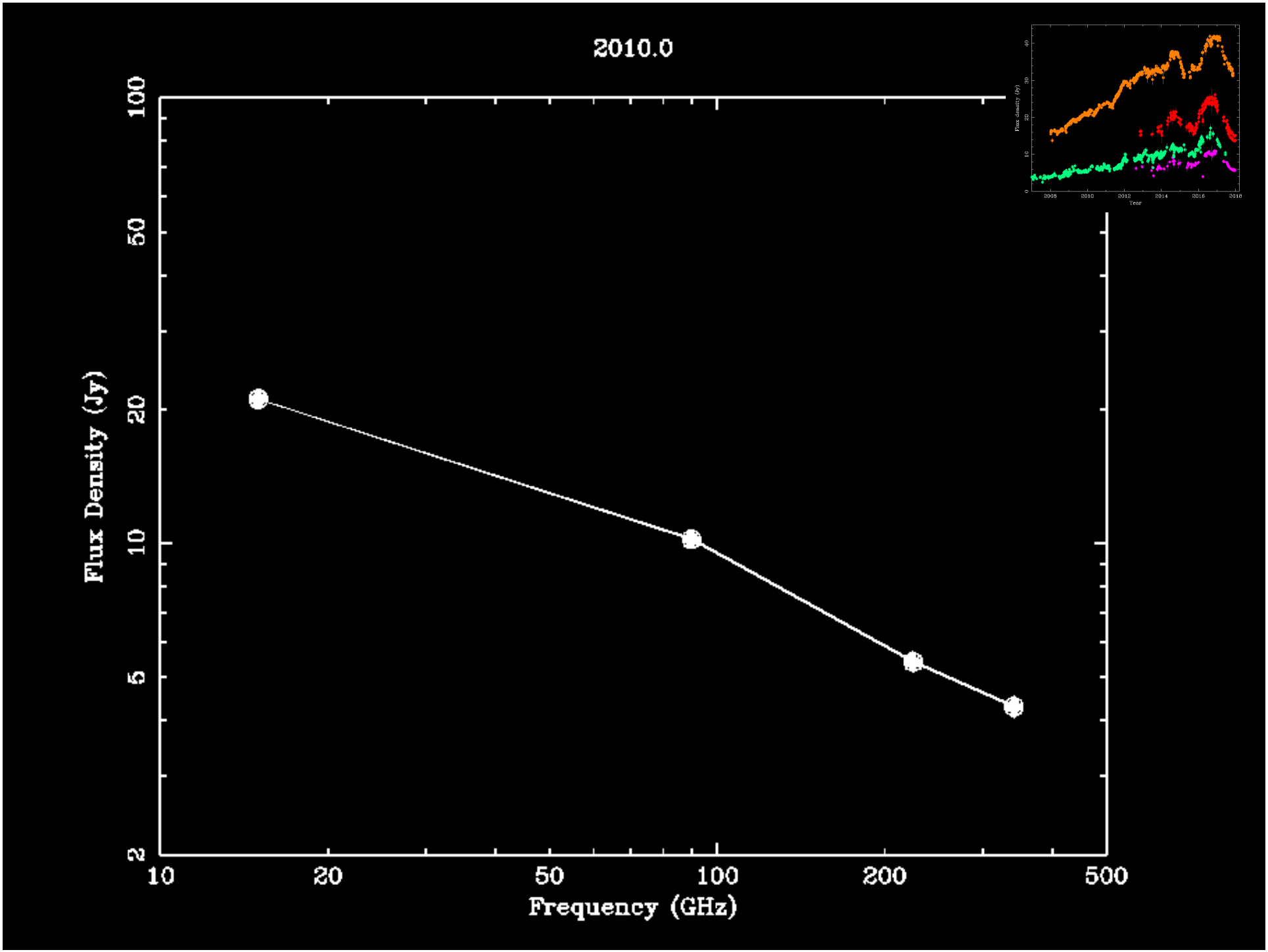
History Repeating! – a two year outburst cycle?



Full radio spectrum Dutson et al 2014




1965
Flux Density (Jy)
100
10
1
1
10
100
Frequency (GHz)


2010.0
Flux Density (Jy)
100
50
20
10
5
2
10
20
50
100
200
500
Frequency (GHz)
Flux density (Jy)
Year
2008
2010
2012
2014
2016
2018

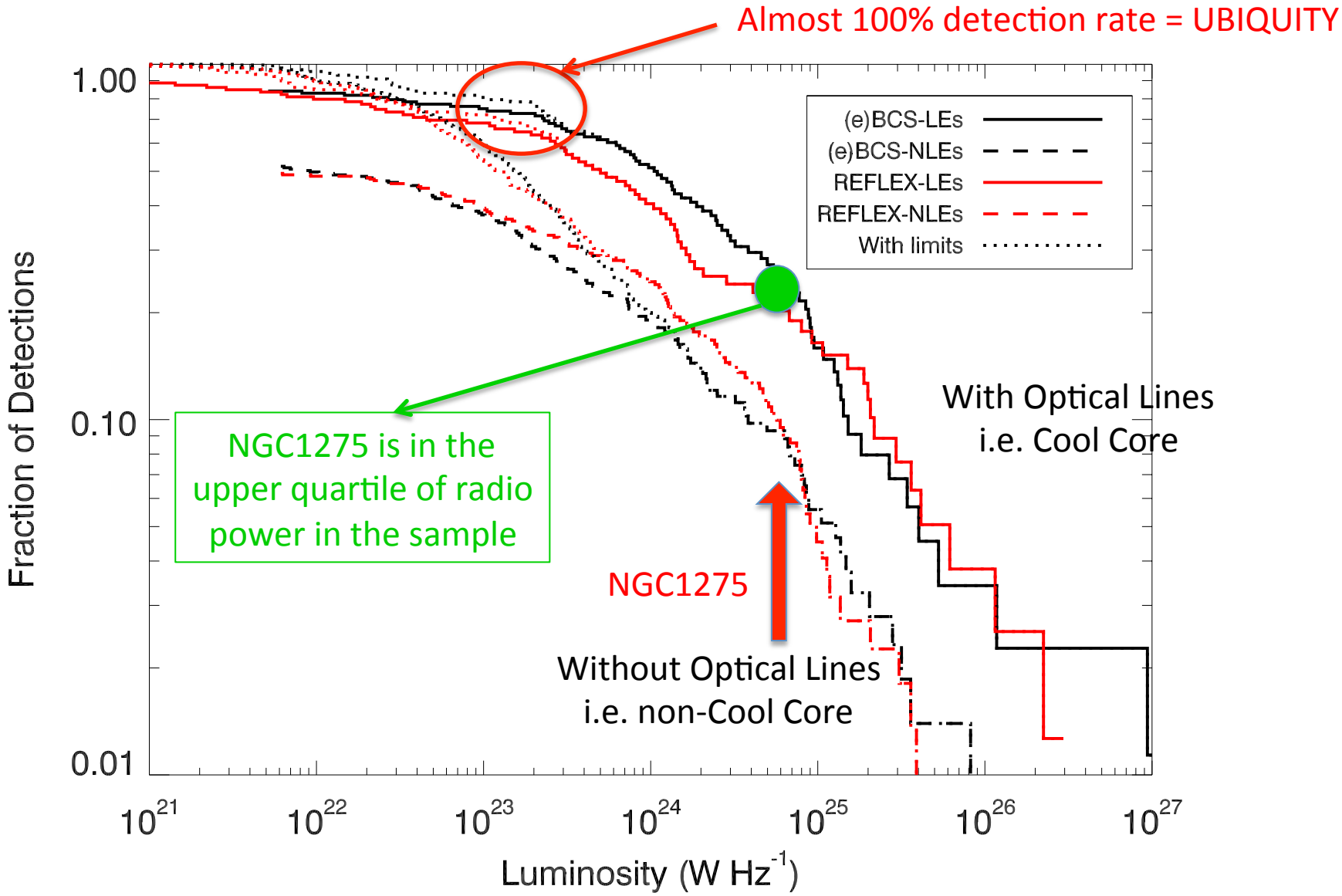
NGC1275 as a BCG archetype?

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?

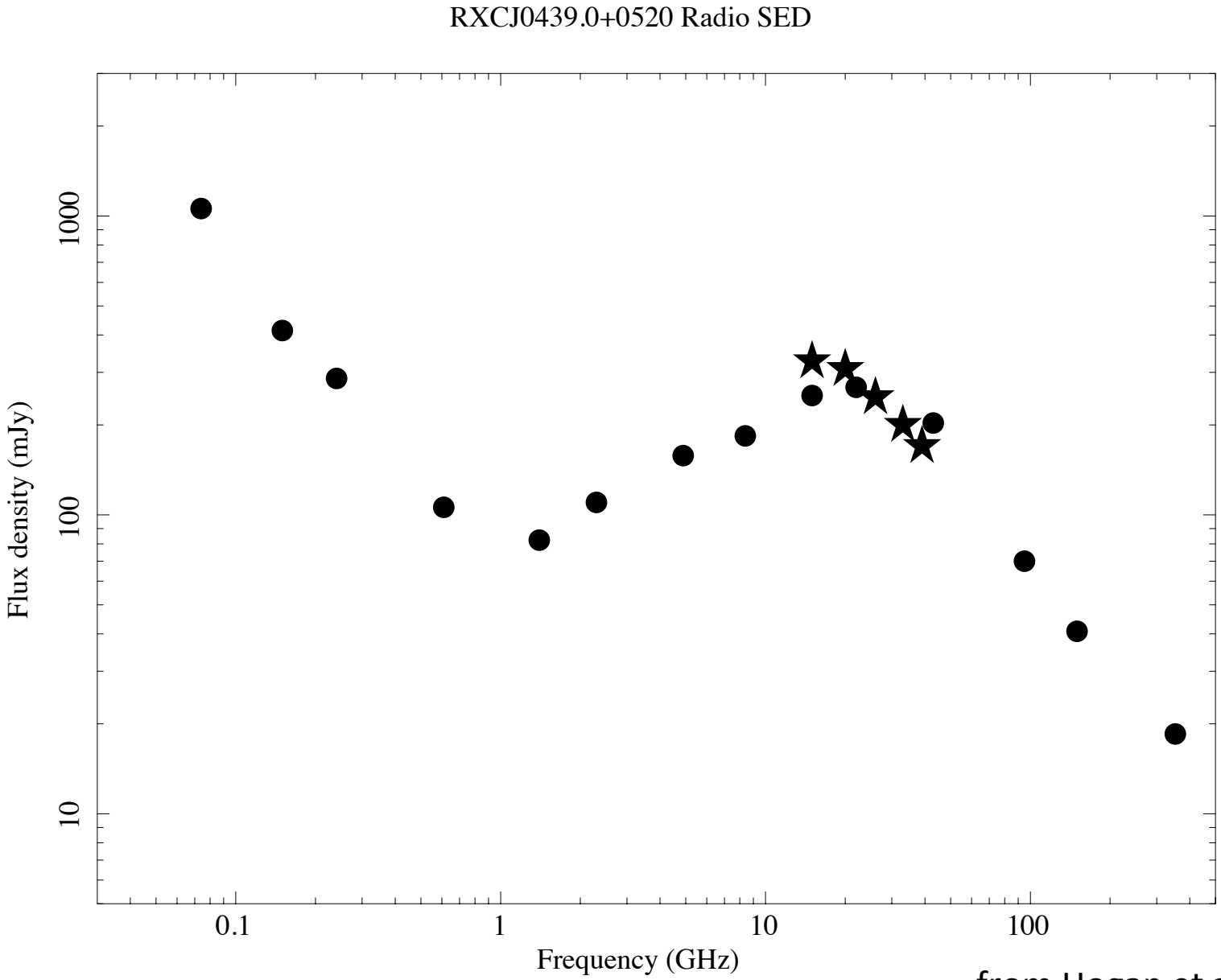
Let's first consider a single frequency radio power….

1.4GHz Radio luminosity function of BCGs with and without lines
from combined X-ray sample of >750clusters (BCS/eBCS/REFLEX)



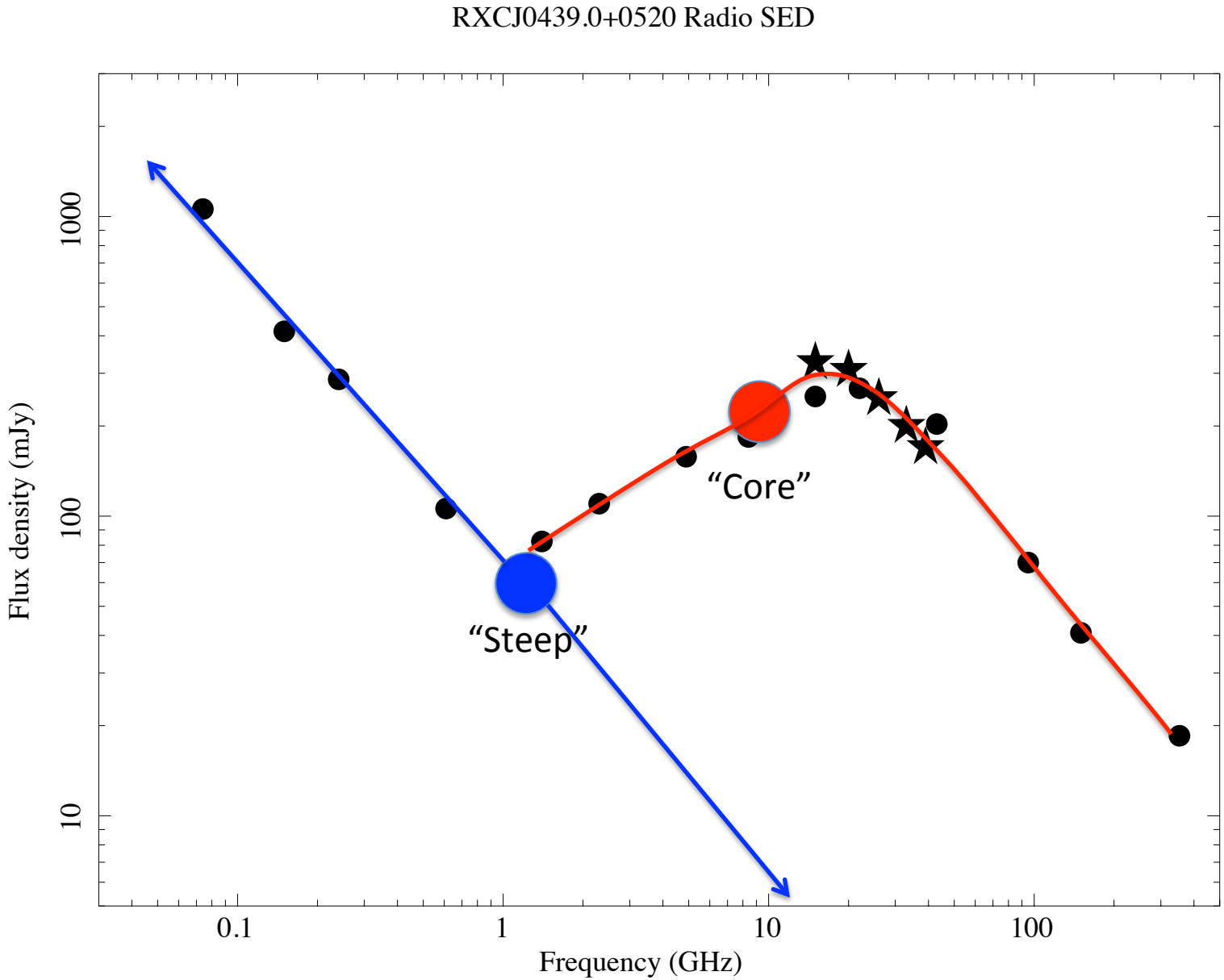
Hogan et al (2015a)

Is NGC1275 unusual in its radio SED?... NO!



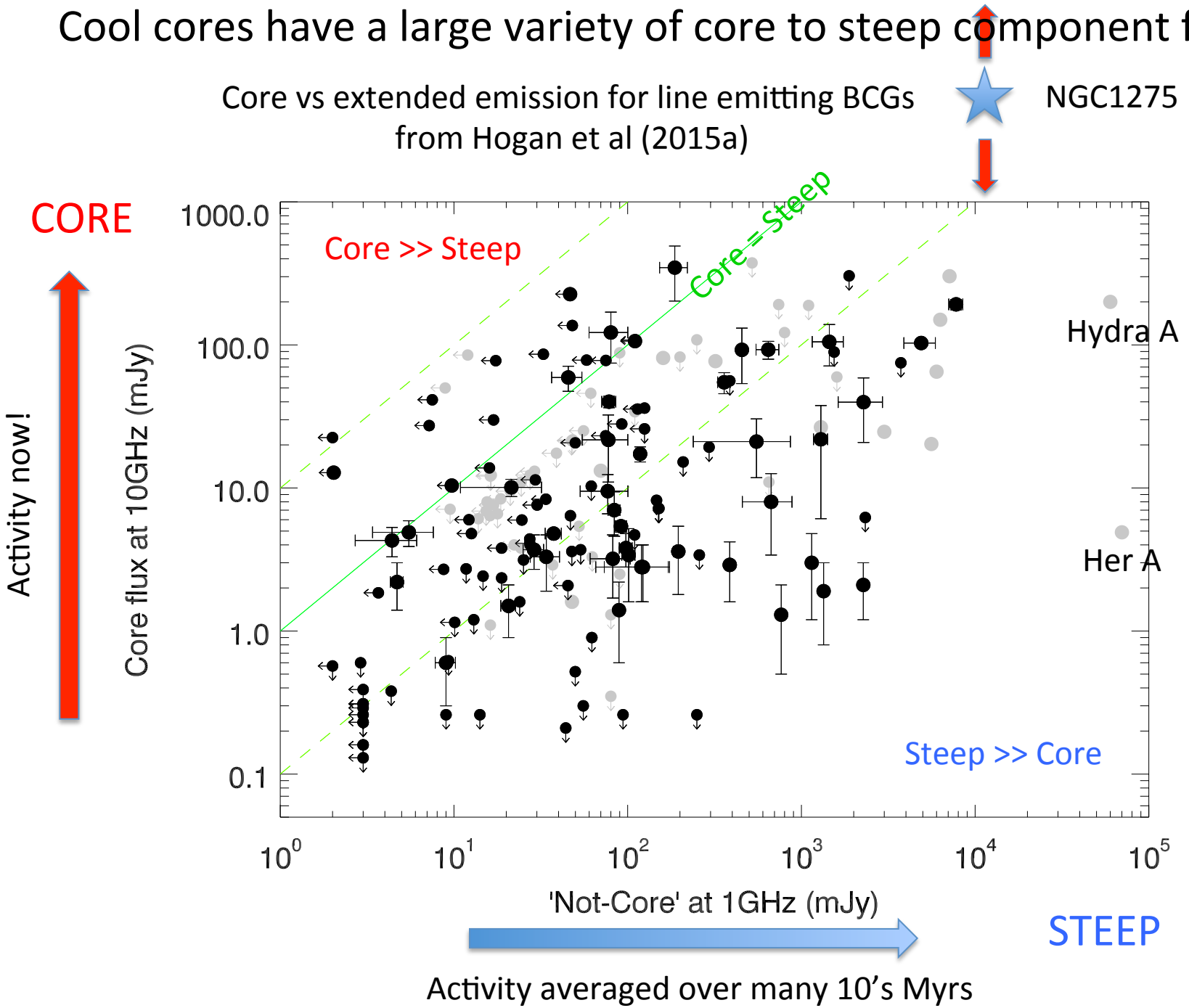
from Hogan et al (2015a)

How do you interpret such strange spectra?!



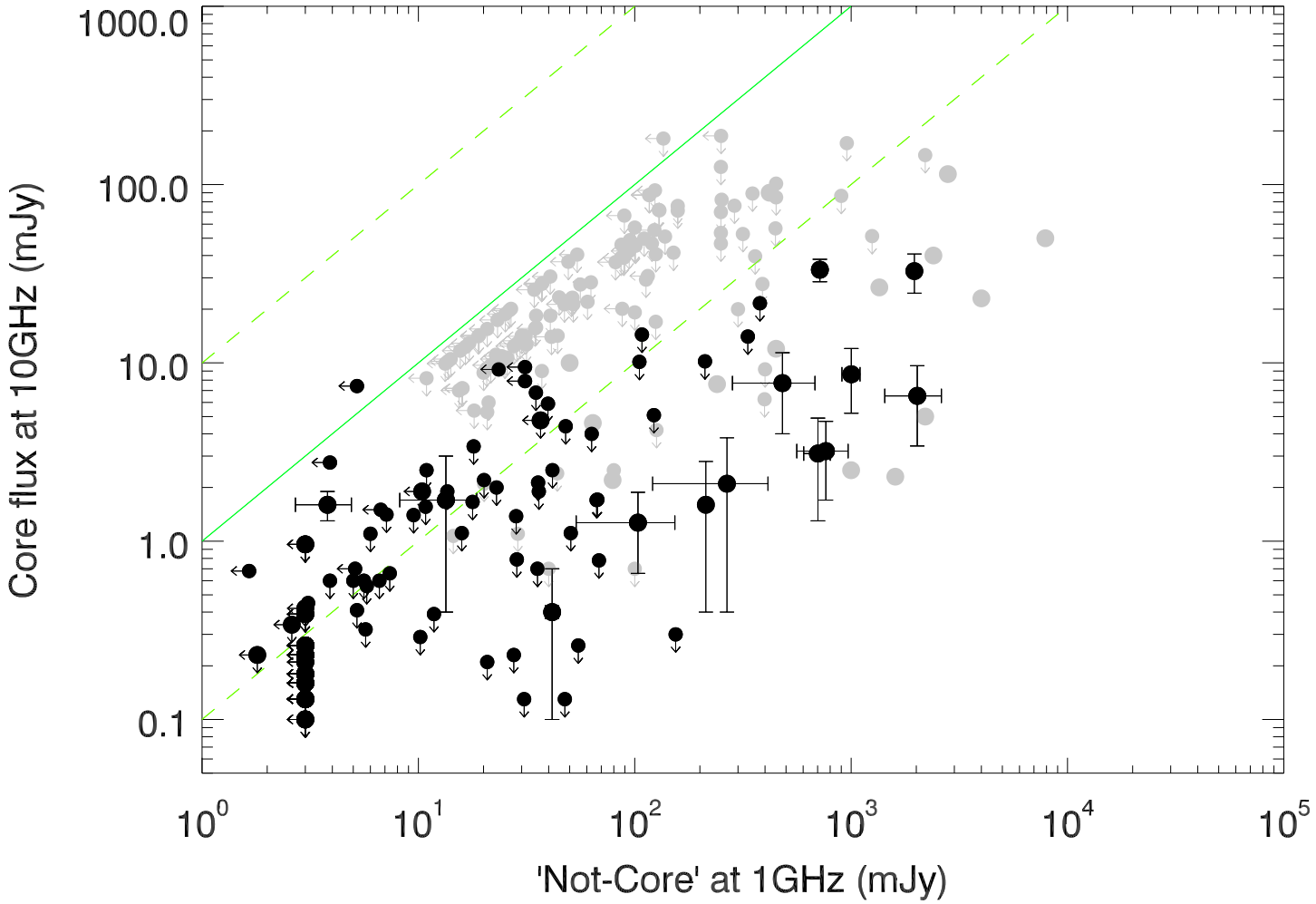
Cool cores have a large variety of core to steep component fluxes

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



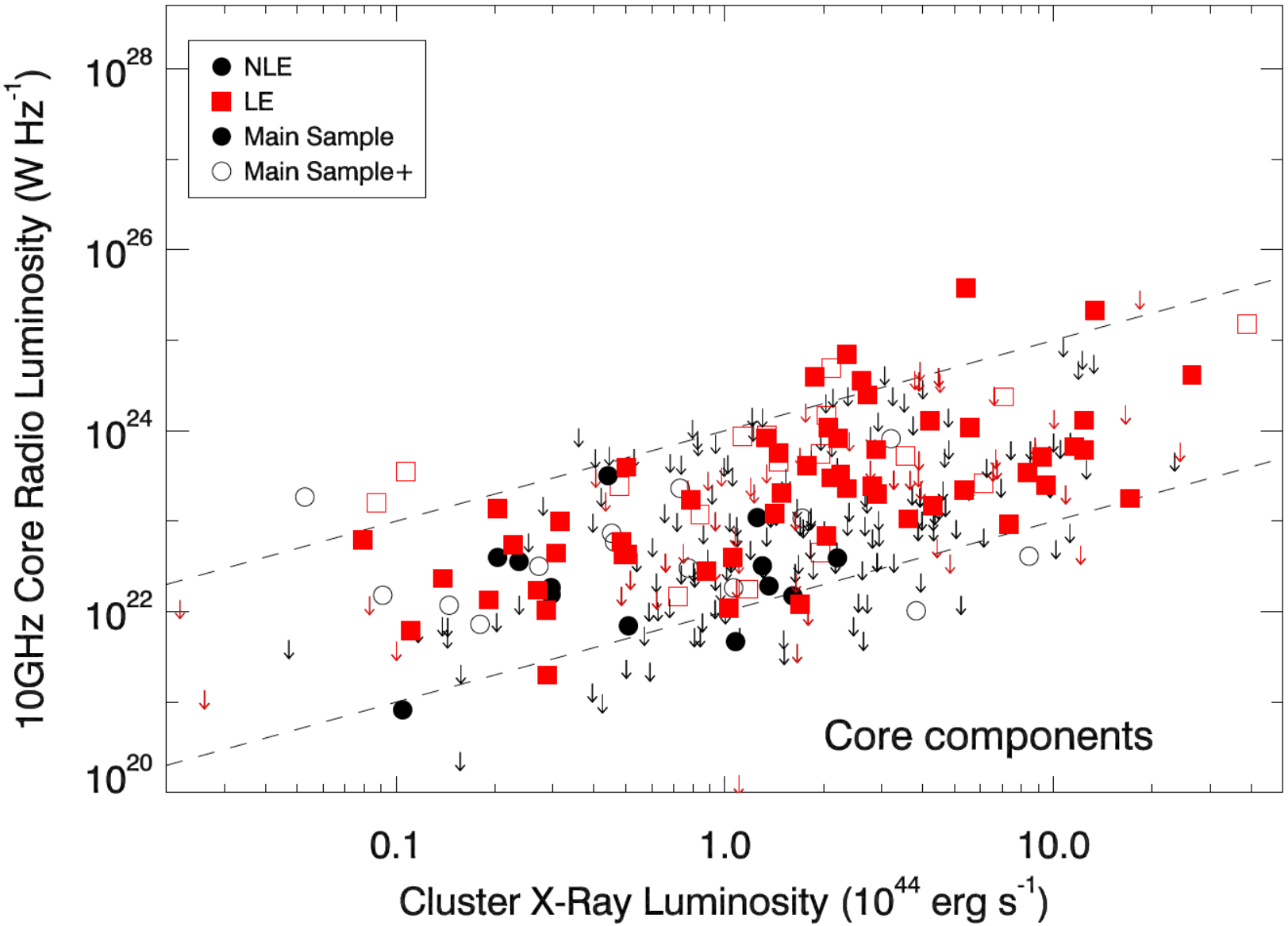
Whereas non-cool cores don't! Relatively few BCGs in these systems have a core

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



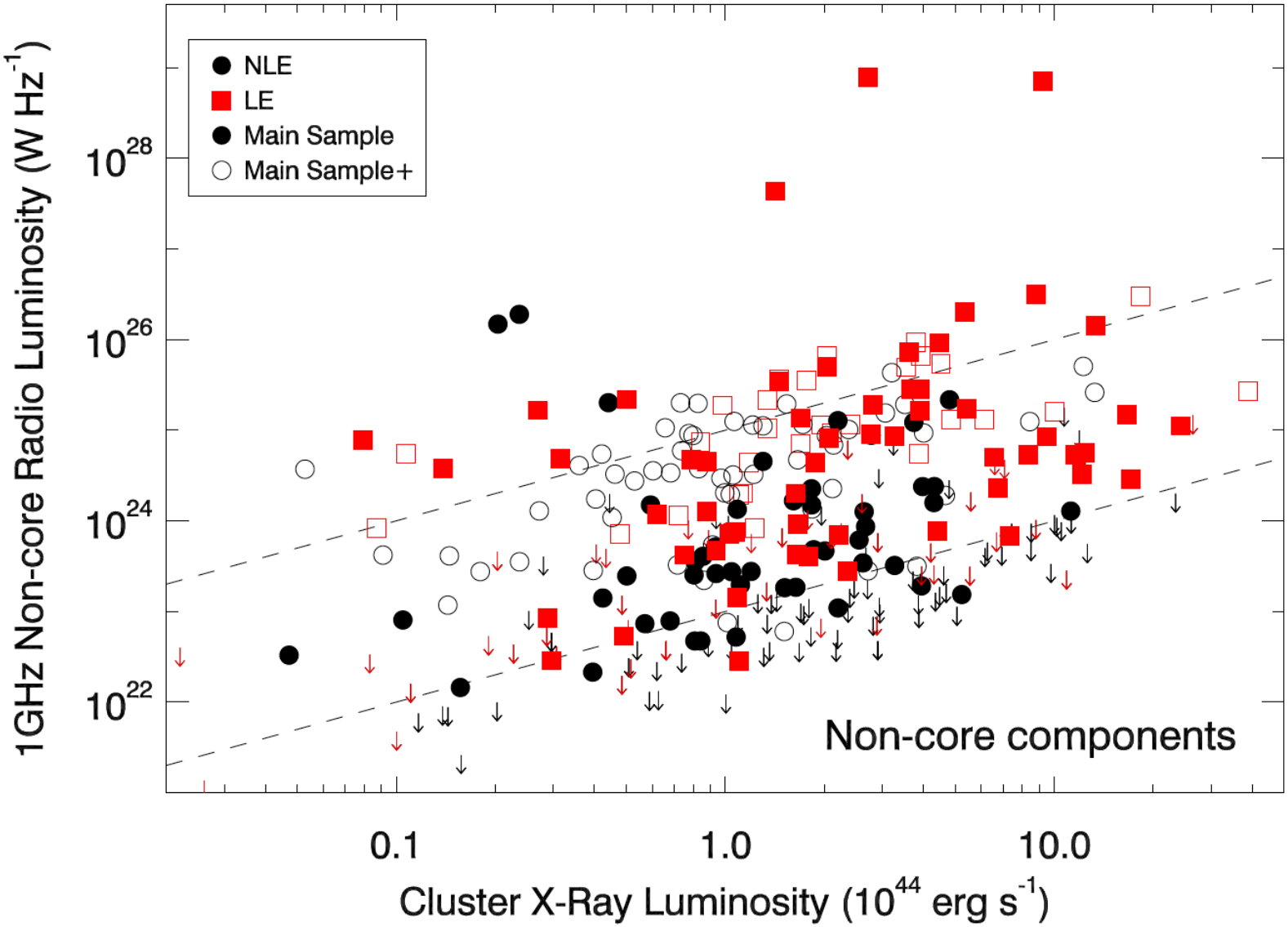
The maximum core radio power is linked to cluster X-ray luminosity

Core vs cluster X-ray luminosity for BCGs from Hogan et al (2015)



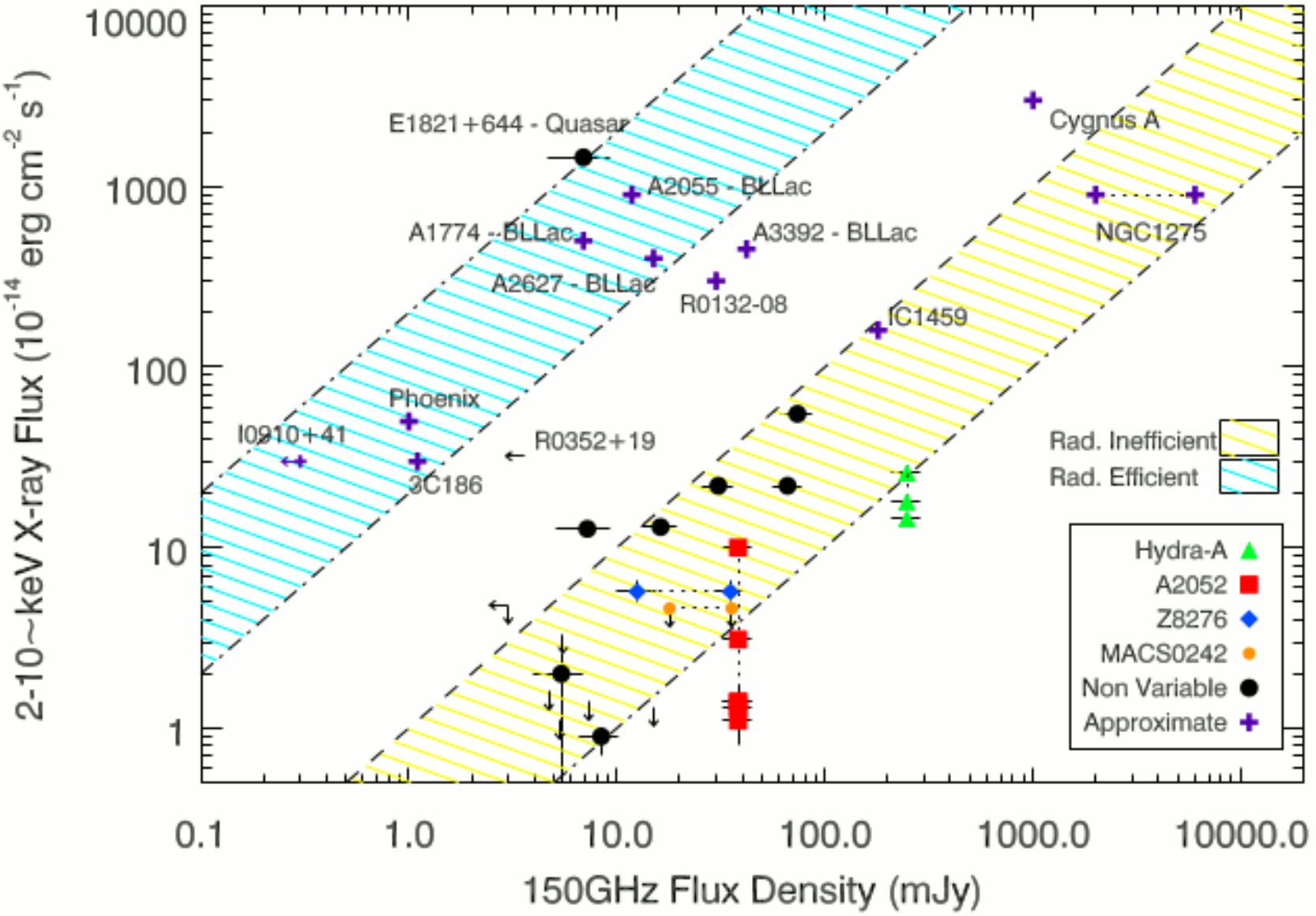
The maximum extended radio power is no so linked!

Extended vs cluster X-ray luminosity for BCGs from Hogan et al (2015)



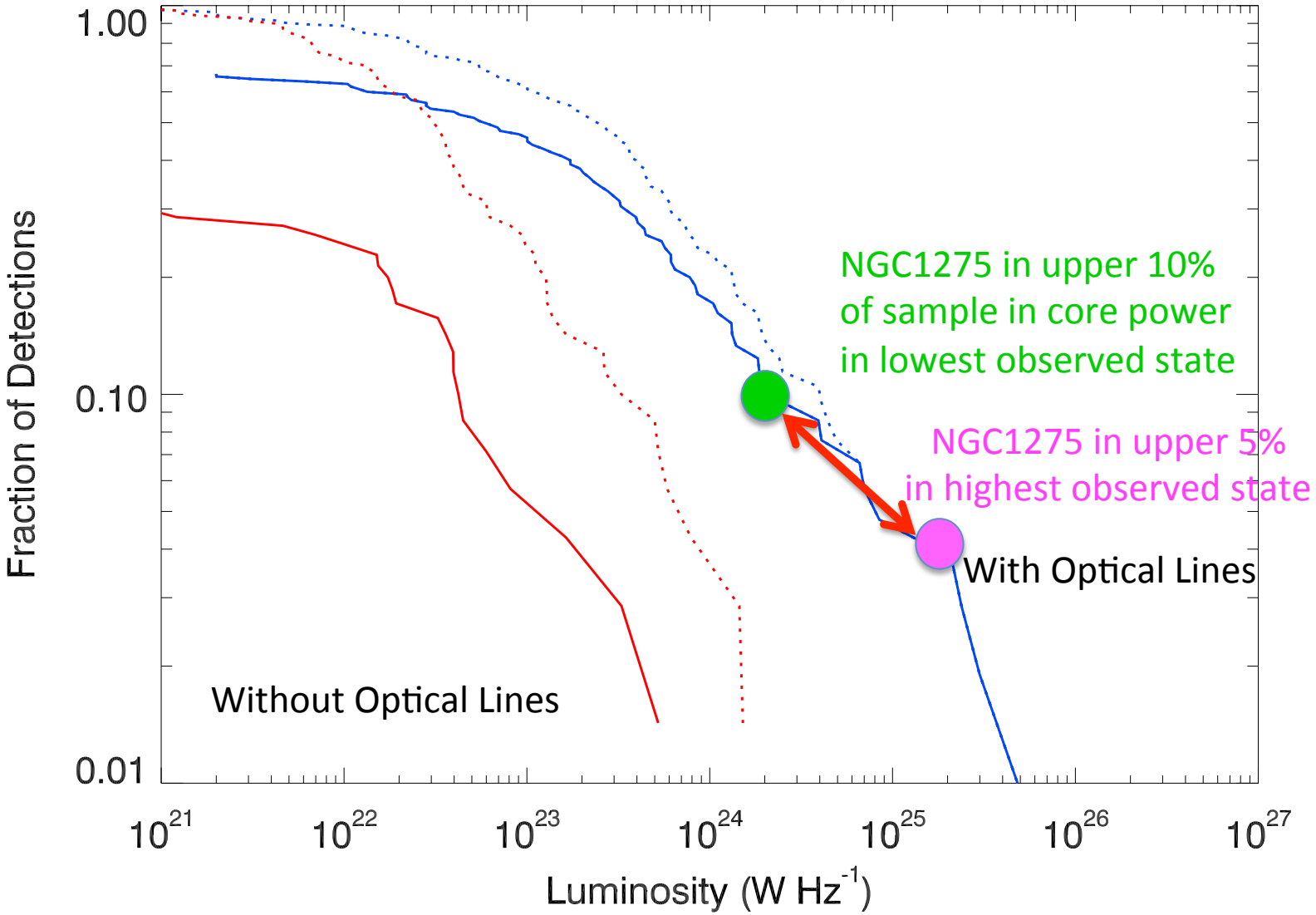
Highest Frequency flux correlates with X-ray point source flux

150GHz flux density vs X-ray point source for BCGs from Hoganl PhD (2014)



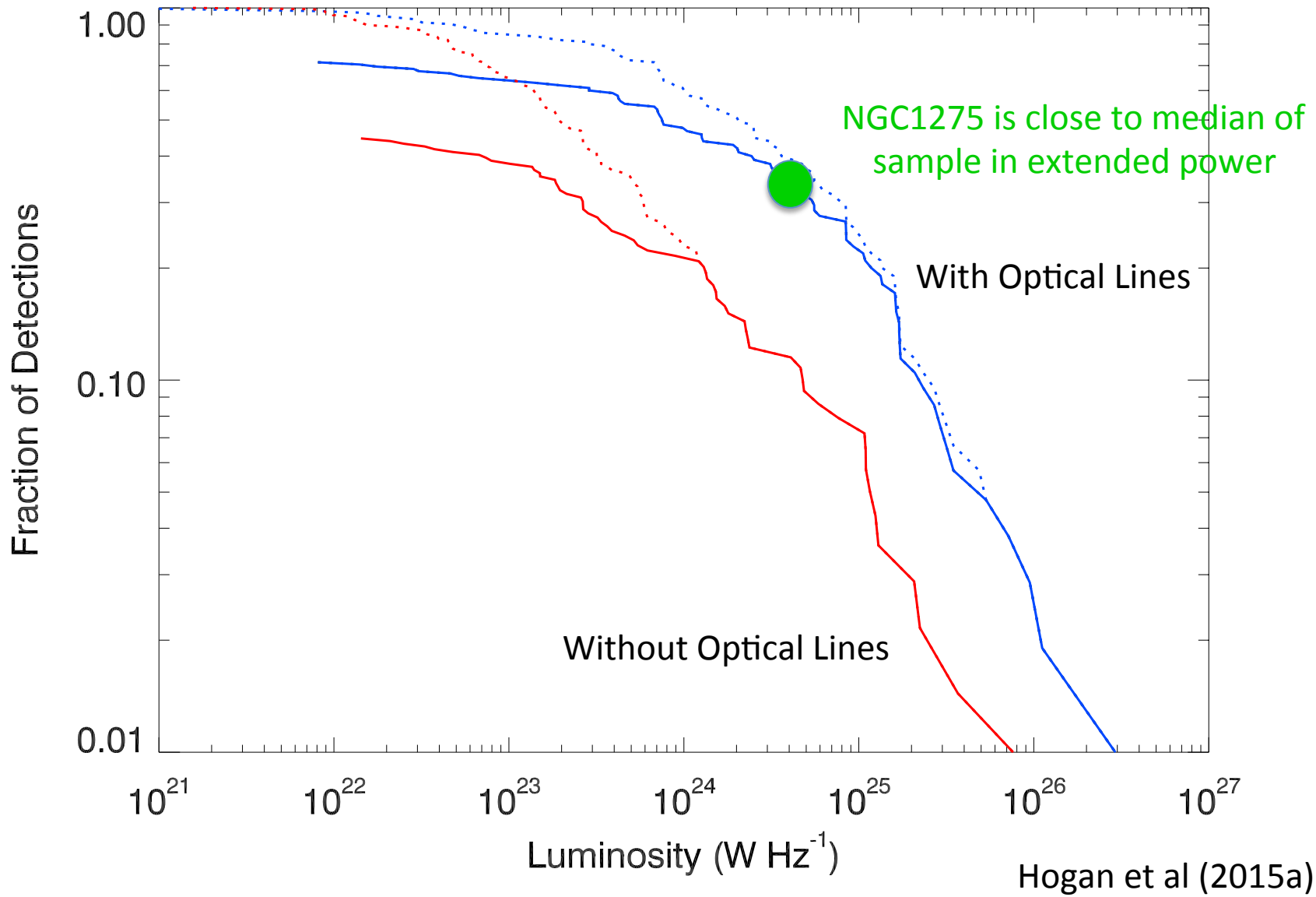
The radio cores in cool core clusters are >100 times more powerful

10GHz Radio luminosity function of cores with and without lines



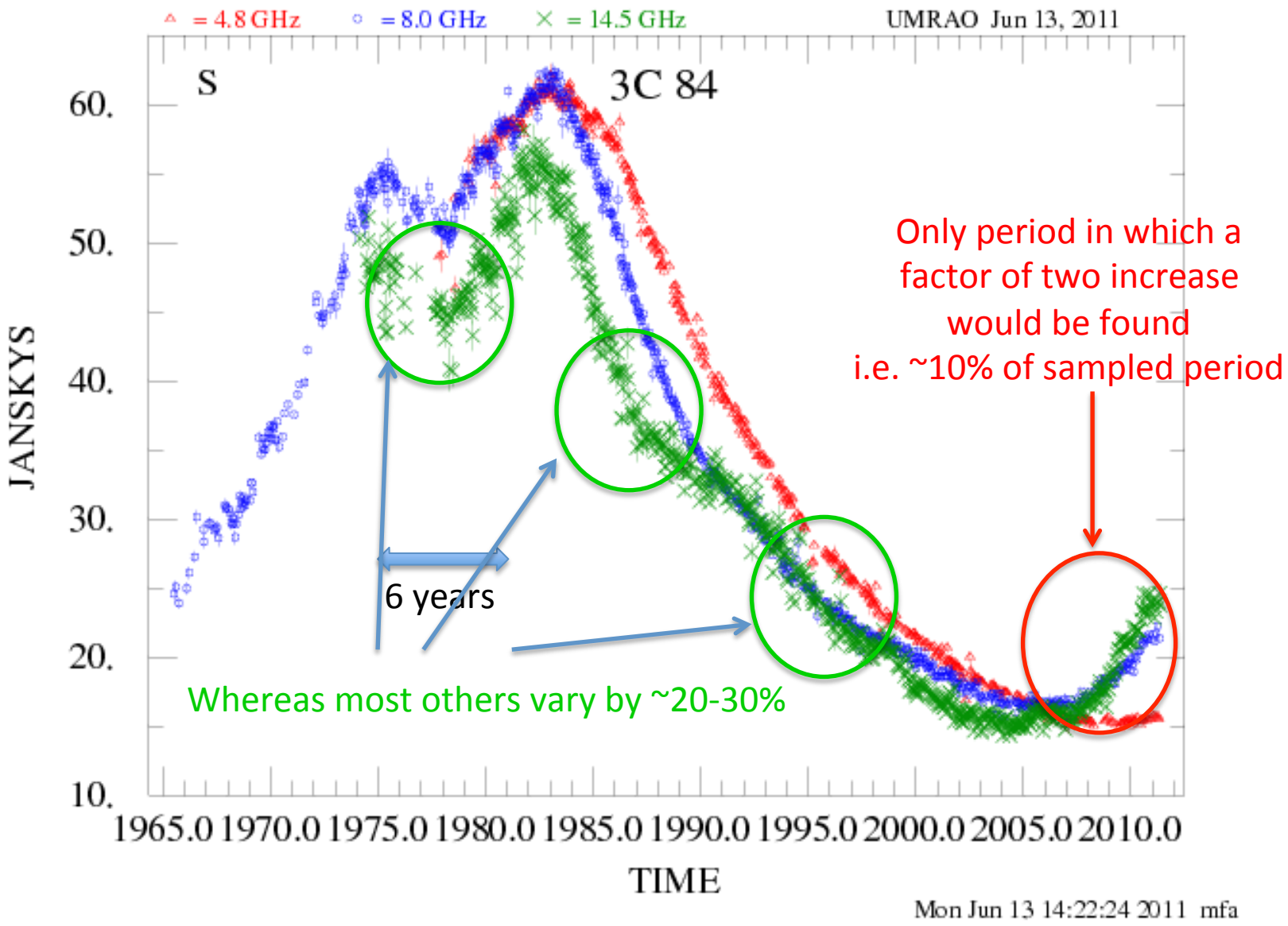
Hogan et al (2015a)

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



Hogan et al (2015a)

Compare them to NGC1275 UMRAO lightcurve!

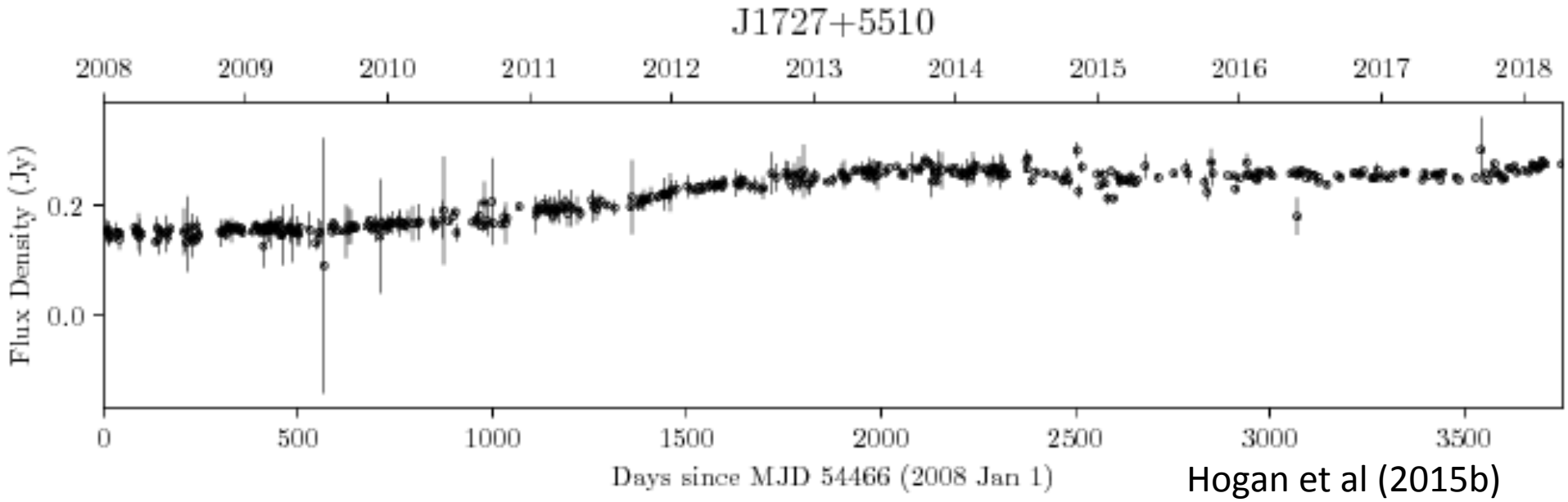


Also core components vary!

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).

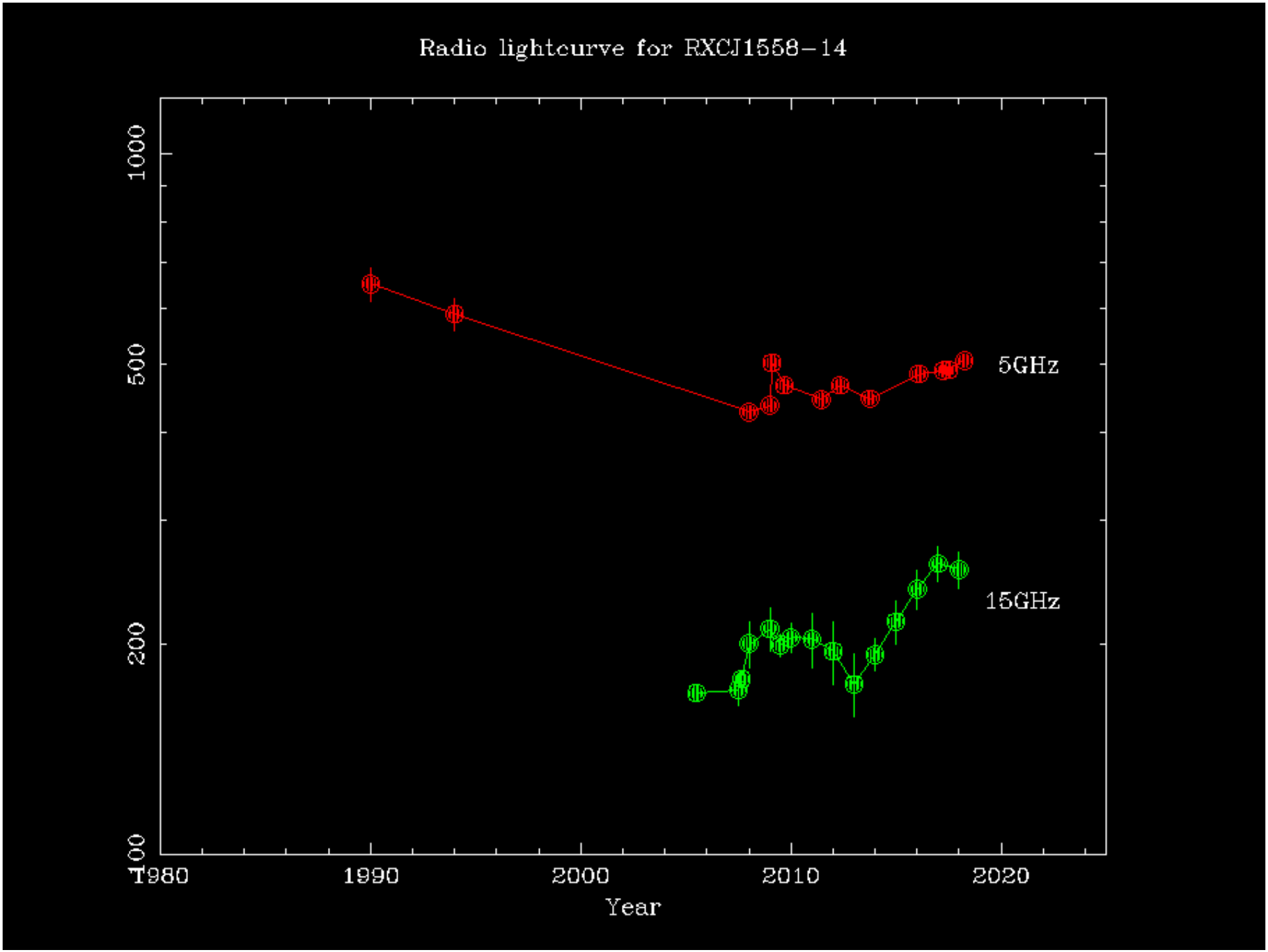
OVRO 40m 15GHz monitoring of the BCG in A2270 (J1727+5510)

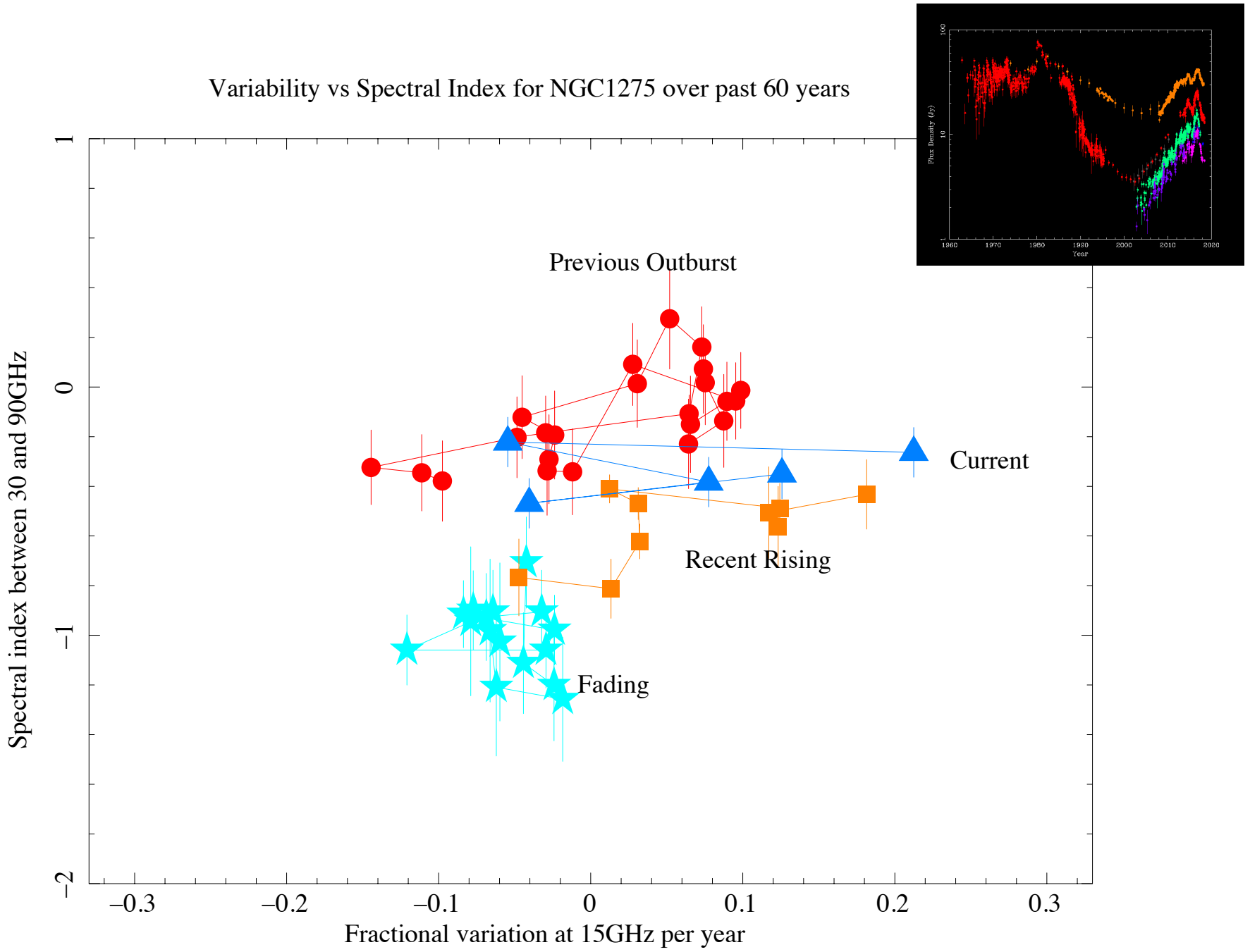


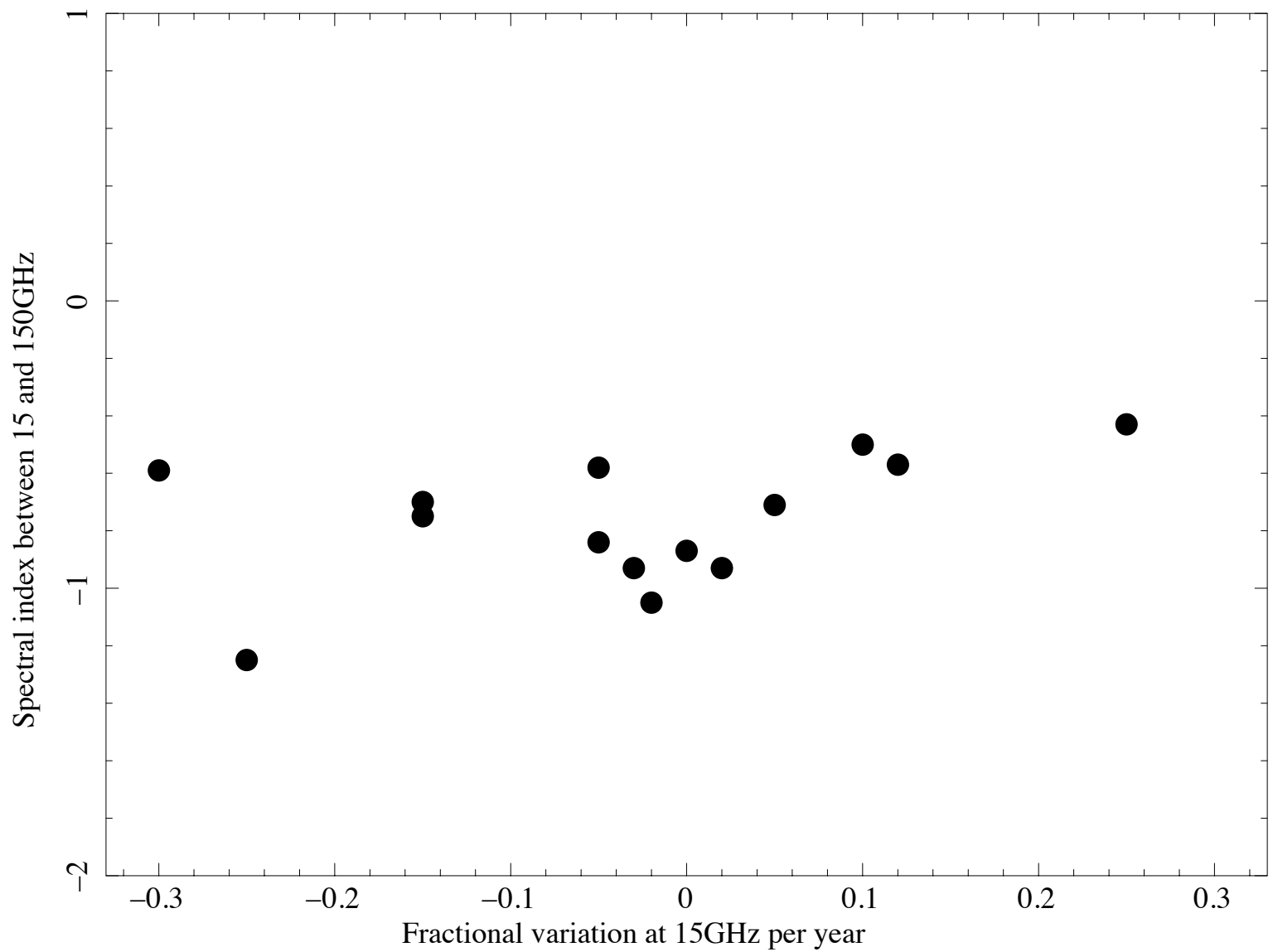
Hogan et al (2015b)

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
1000
500
200
100
1980
1990
2000
2010
2020
Year
5GHz
15GHz


Variability vs Spectral Index for NGC1275 over past 60 years
Previous Outburst
Current
Recent Rising
Fading
Spectral index between 30 and 90GHz
Fractional variation at 15GHz per year
1
0
−1
−2
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Flux Density (Jy)
Year
1960
1970
1980
1990
2000
2010
2020
10
100


Variability vs Spectral Index for OVRO sample
Spectral index between 15 and 150GHz
1
0
−1
−2
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
Fractional variation at 15GHz per year

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 varys 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…..!