Important scales in Astrophysics used in slides :

Solar Radius ($R_\odot$) ~ 6.96 x 10^8 m
Speed of light (c) ~ 3 x 10^8 m/sec
Light Year (ly) ~ 9.46 x 10^{15} m
1 parsec (pc) ~ 3.086 x 10^{16} m
Solar mass ($M_\odot$) ~ 1.989 x 10^{30} kg
Solar Luminosity (L) ~ 3.826 x 10^{26} W or 3.826 x 10^{33} erg/s
1 Jansky (Jy) ~ 10^{26} W /m^2Hz
1 Year (y) ~ 3.15 x 10^7 sec
Mass of a galaxy: 10^{12} $M_\odot$
Size of a galaxy: a few kiloparsecs (kpc);
Size of galaxy clusters: a few megaparsecs (Mpc);
Size of the observable Universe: gigaparsecs (Gpc)

Abbreviations used
RG - Radio Galaxy
GRG - Giant Radio Galaxy
GRQ - Giant Radio Quasar
GRS - Giant Radio Sources (GRG + GRQ)

A sample study of radio galaxy properties using TOPCAT

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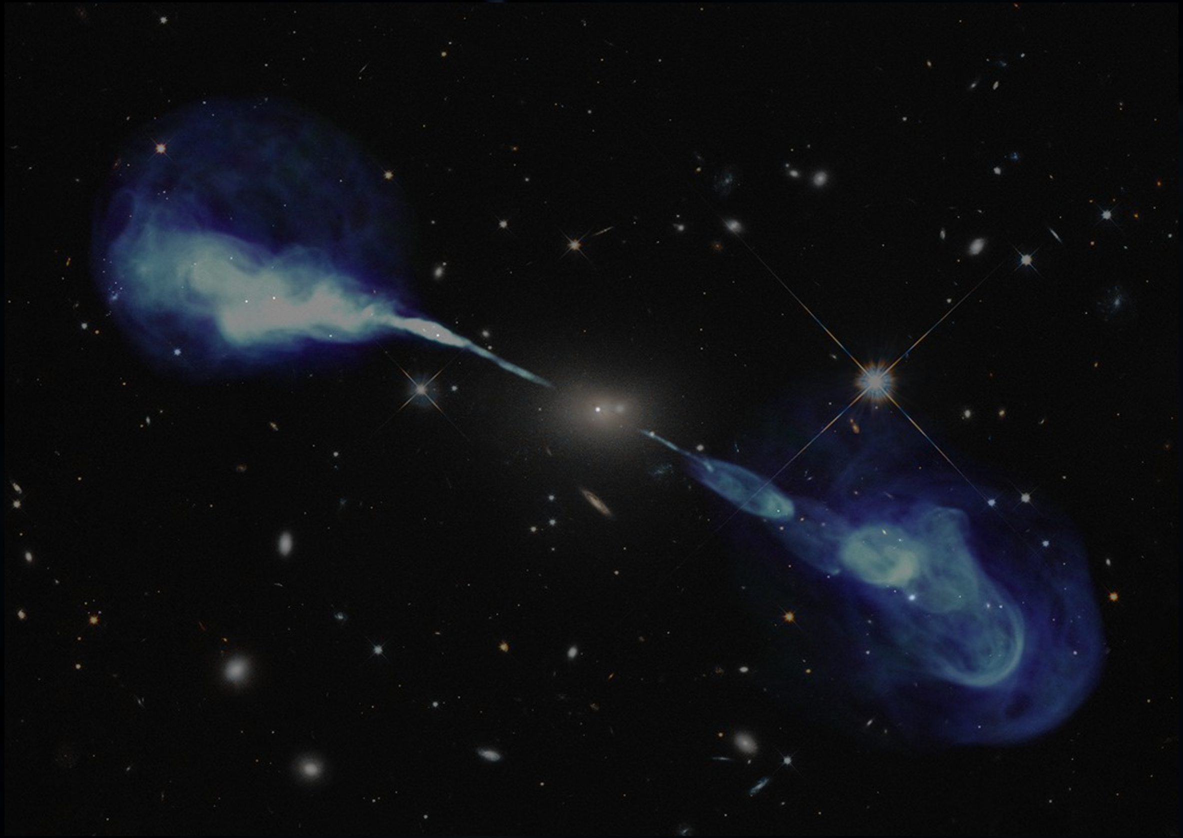
Radio galaxy

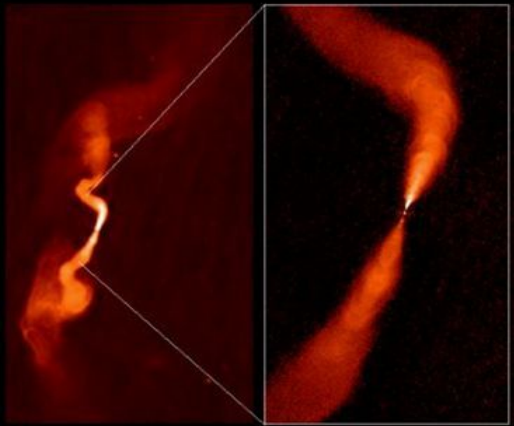
1. Radio galaxies (RGs) are one of the interesting type of active galactic nuclei (AGNs) which has maximum emission in the radio domain.
2. Radio luminosity (10^{39} W) between 10 MHz and 100 GHz.
3. The radio emission is due to the synchrotron process.
4. Elliptical host/ spiral host in some cases.
5. You can see bipolar jet coming out of central region.
6. If a RG has a radio jet with size greater than 0.7 Mpc is considered as a giant radio galaxy (GRG).
7. GRGs are excellent natural laboratories to study the evolution of RGs in cosmic time. RGs have first discovered about seven decades ago and since then millions of RGs have been found. In contrast to that only ~ 1000 GRSs

Hercules A optical vs radio wavelength, credit - VLA and HST



Radio galaxies – FR I/FR II dichotomy

- Fanaroff & Riley (1974): Connection between radio galaxy luminosity and morphological type
- FR I: Prominent two-sided jets, brighter towards center, often distorted with bends => 1.4 GHz luminosities below 10^{25} W/Hz
- FR II: Double-lobed, edge-brightened, prominent hot-spots; relatively weak, straight, one sided jets => 1.4 GHz luminosities over 10^{25} W/Hz



FR Class I source: radio galaxy 3C31

FR Class II source: quasar 3C175

To analyse physical parameters of radio galaxies and giant radio galaxies.
I have chosen sample all (~) giant radio sources discovered till date ~ 1000

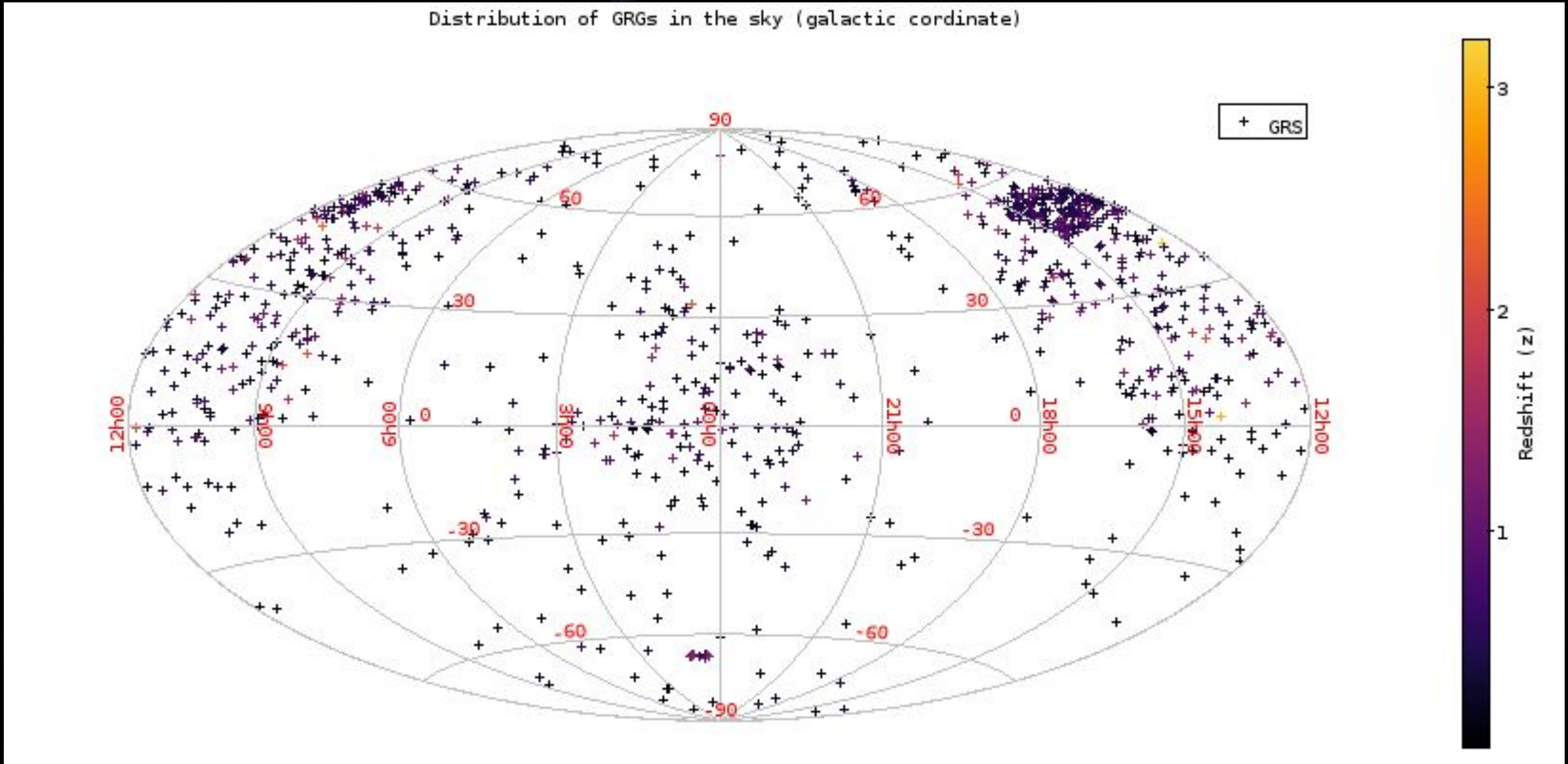
I have chosen a sample of FR 2 radio galaxies ~ 400

I find all VO tools are interesting, time saver, easy to learn, and handle large catalogs easily.

I used TOPCAT to get a quick overview and preliminary analysis.

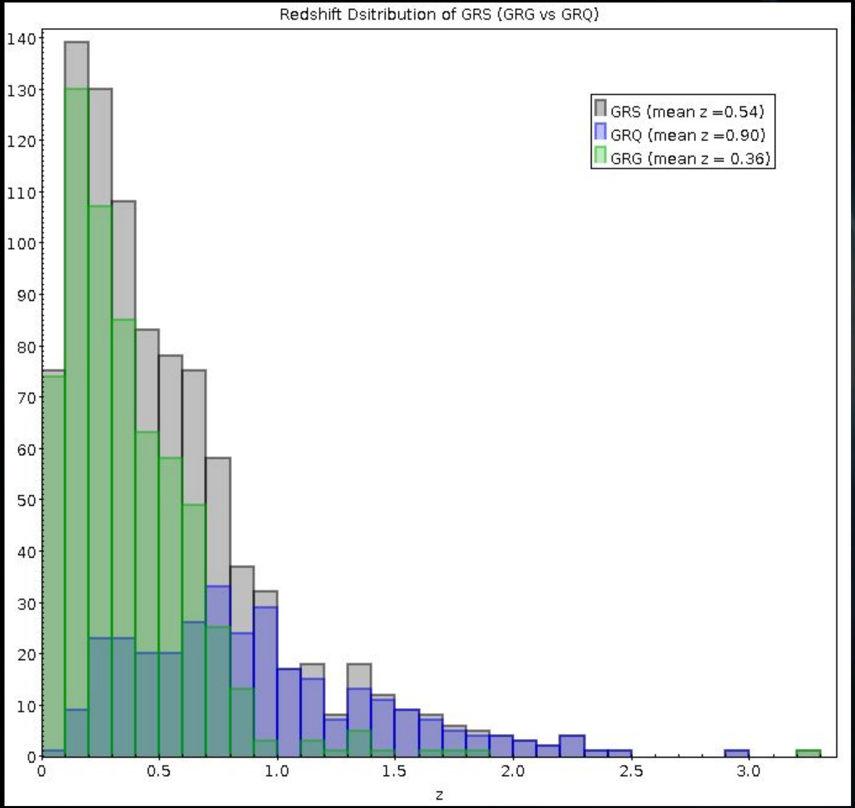
Brief Content

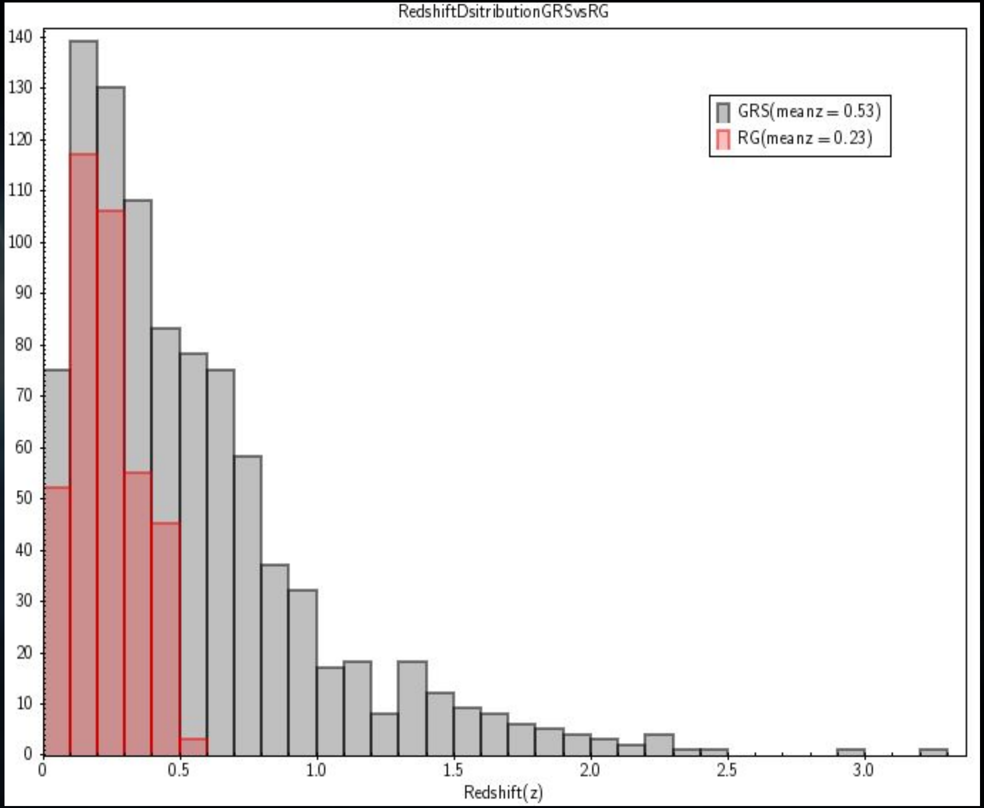
1. Distribution of GRSs in the sky.
2. Distribution of redshift (GRS vs normal RG)
3. Distribution of Power (GRS vs normal RG)
4. Distribution of Size (GRS vs normal RG)
5. Power vs redshift Diagram
6. PD- diagram
7. Conclusion



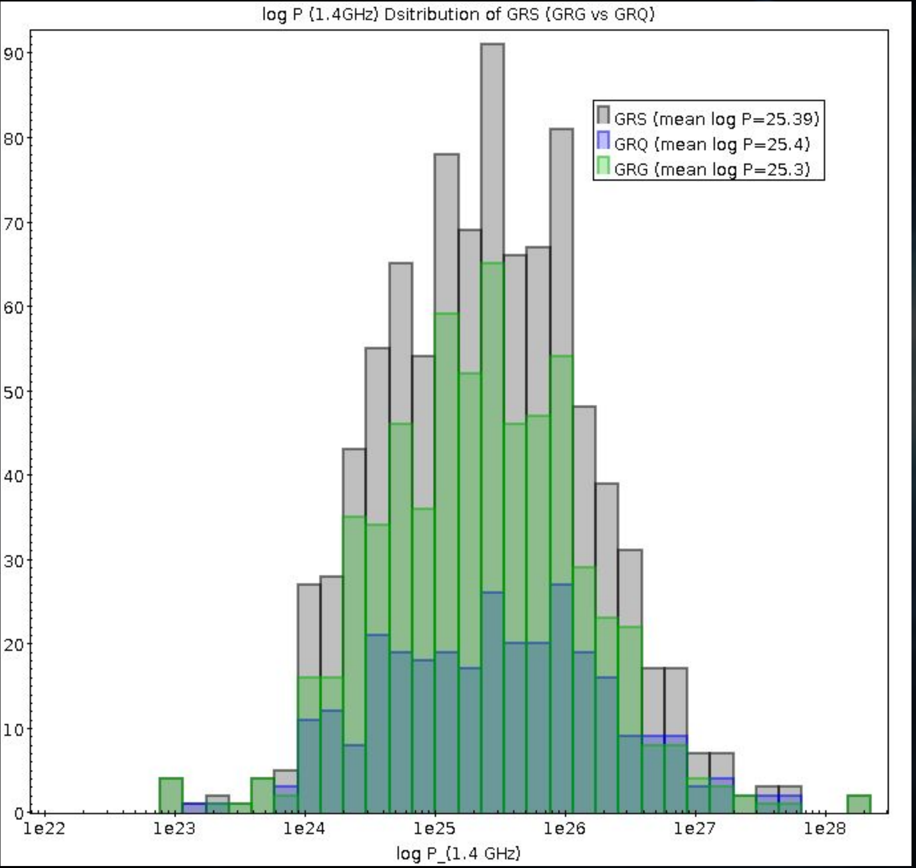
Dabhade et al. (2020a) discovered 182 GRGs over a 424 deg2 sky area in the local universe (z ~ 0.6) which gives a GRG density ~ 0.4 GRGs per deg2 sky area. This is the most robust sky density estimate of GRGs presently available.

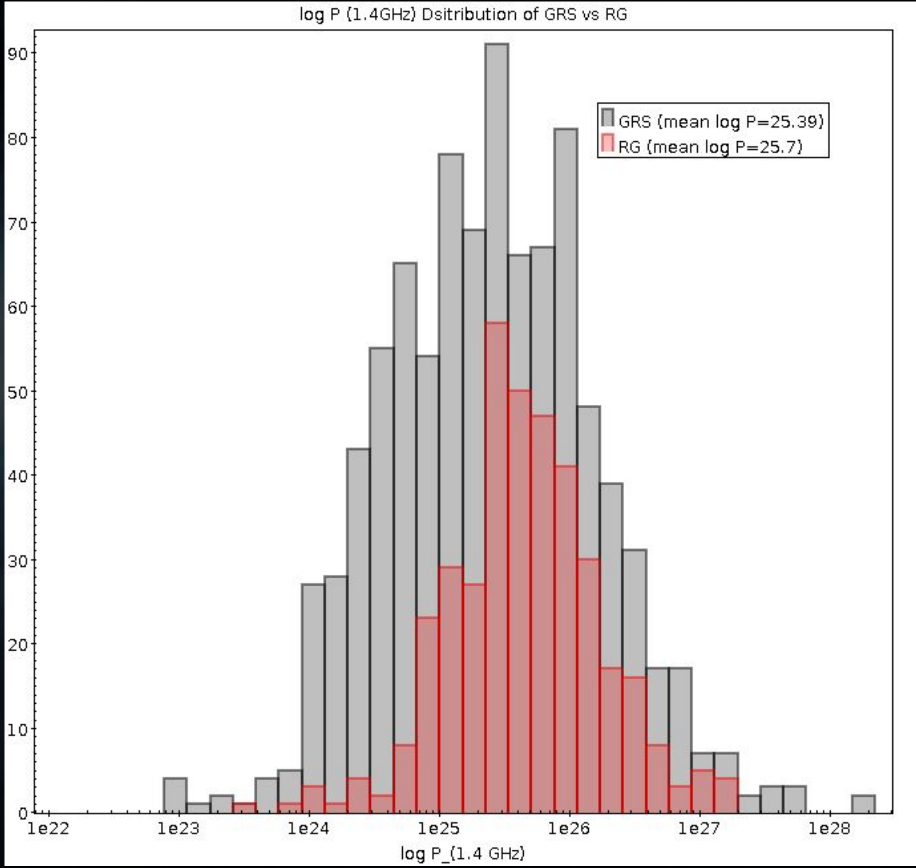
Distribution of redshift (GRS vs normal RG)



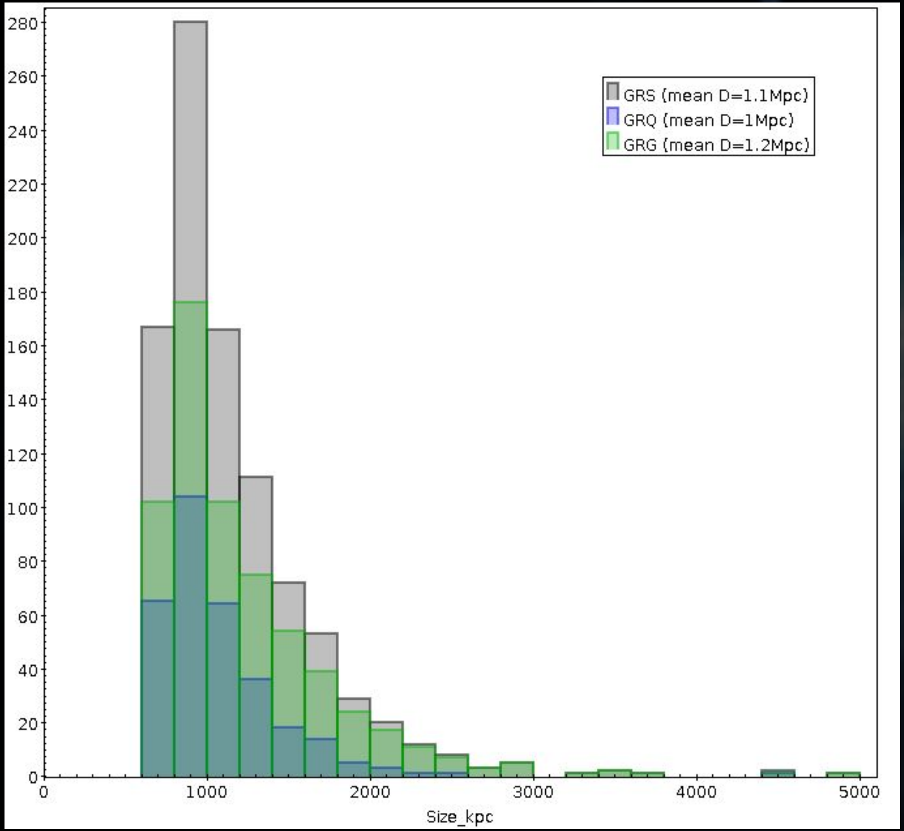


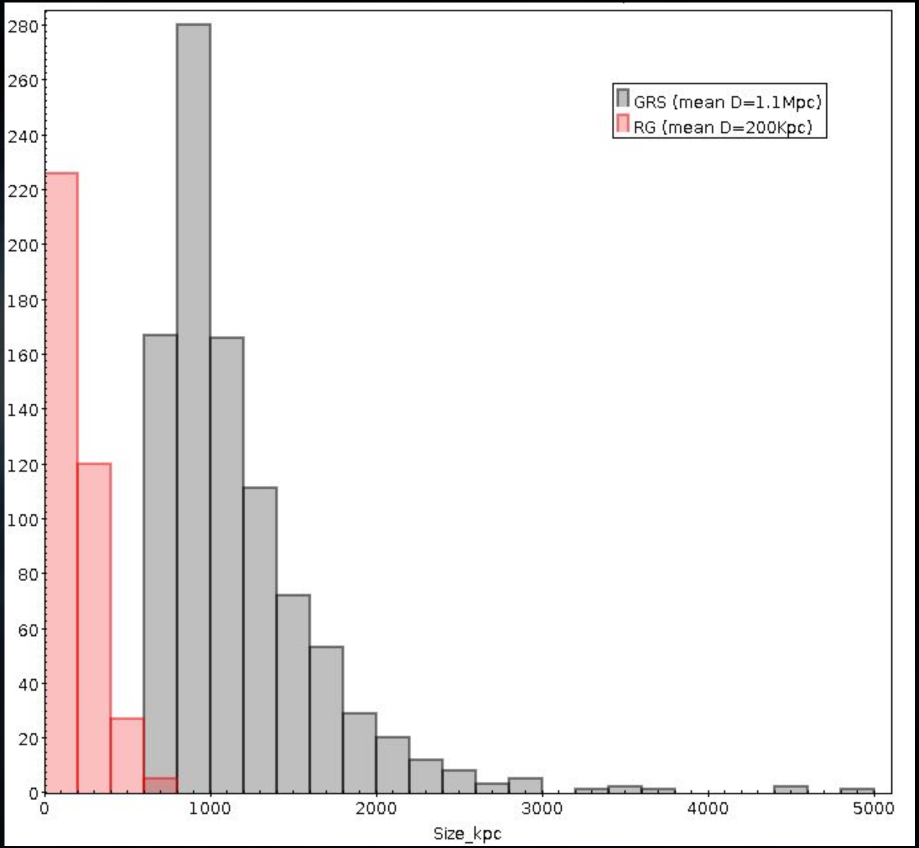
Distribution of Power (GRS vs normal RG)



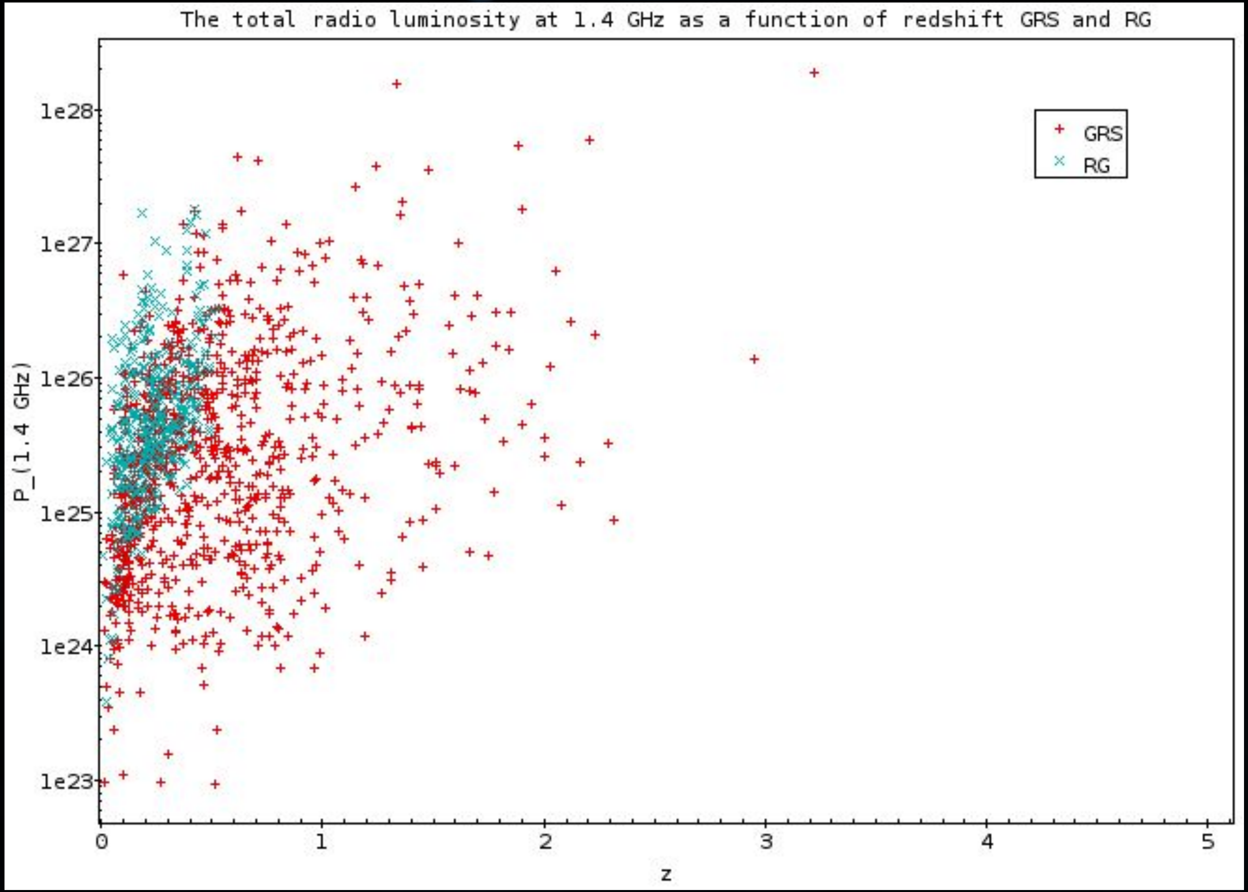


Size Distribution



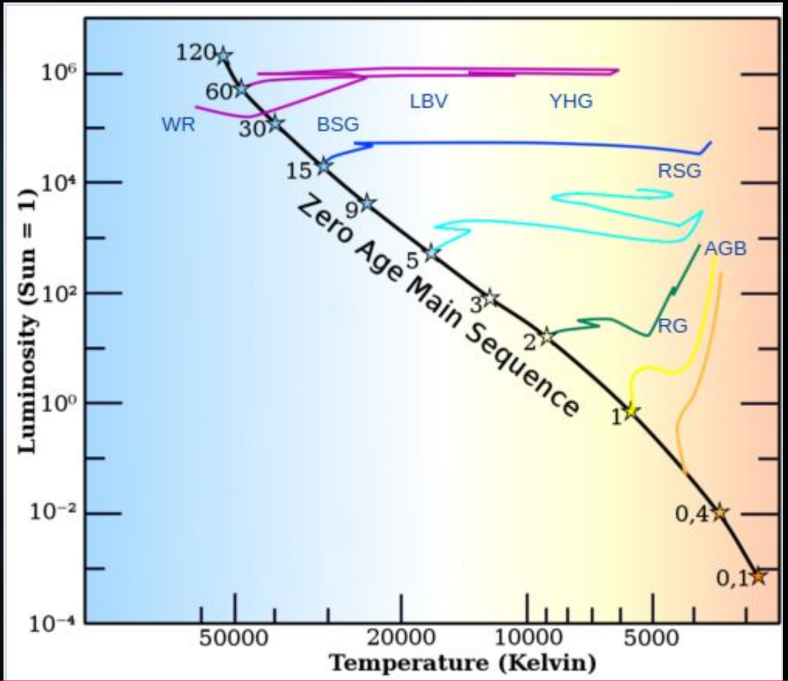


The total radio luminosity at 1.4 GHz as a function of redshift for a sample of GRSs vs RGs



Here we extend our discussion the **luminosity evolution** of the sources. And the tracks it follows through the power-linear size (P-D) diagram (Shklovskii 1963).

- The P-D diagram is a powerful tool for investigating the temporal evolution of FRI and FRII radio sources.
- By plotting the radio luminosity at a specific frequency, as a function of the linear size of a source, D, a diagram analogous to the **Hertzsprung - Russell** diagram is obtained.



The evolutionary tracks of stars with different initial masses on the Hertzsprung–Russell diagram

For FRI,

Weaker jets (Jet K E = $Q_O < 10^{37}$ W)

- In general, the jets in these sources widen rapidly. After destruction of laminar structure by surrounding, the jet becomes completely turbulent. They decelerate from relativistic to sub-relativistic speeds on scales of 1-10 kpc .
- The deceleration and the turbulence in the flow result in strong entrainment of external thermal medium. This helps balancing the pressure between the jet and the external medium, preventing the jet to be underpressured.

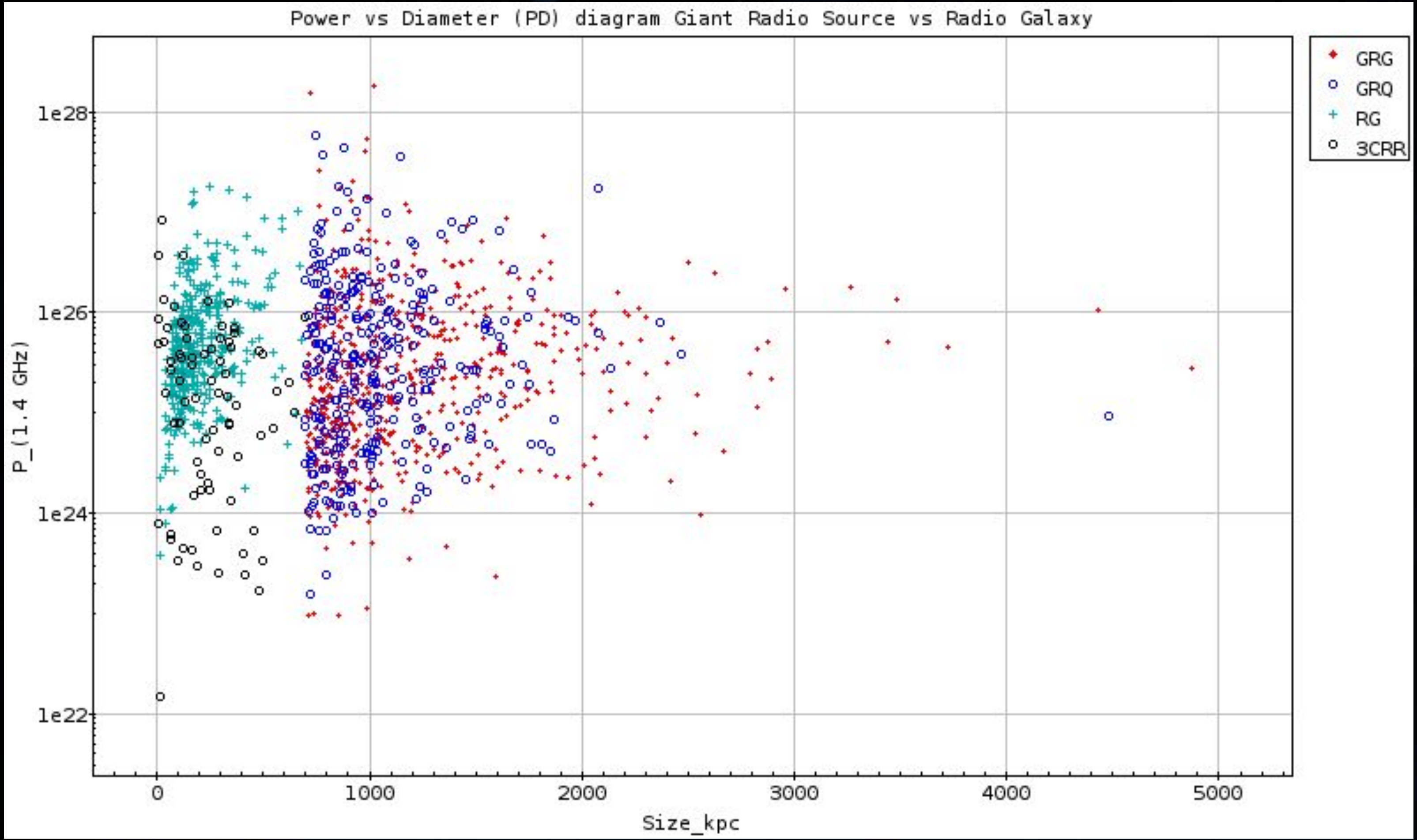
Bridle (2012, 2014); Laing (2015) (Laing, & Bridle 2012), (KA1997)

For FRII,

Weaker jets (Jet K E= $Q_O > 10^{37}$ W)

- The situation is different in FRII. The laminar structure will remain for entire journey. and finally ends in a shock.

- Hot spots are observed at the end of the jets indicating high Mach number jets and overpressure with respect to the medium.

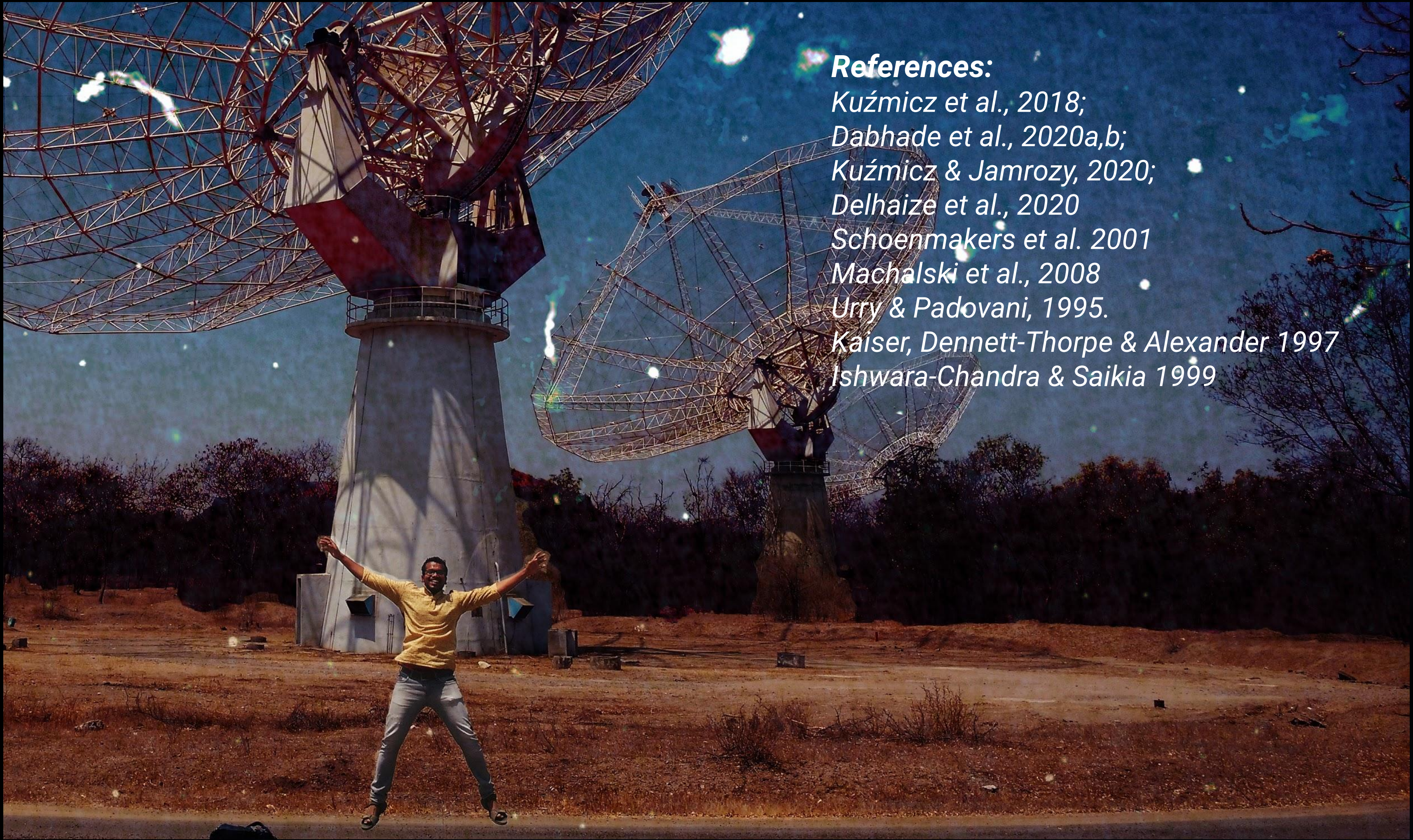

Power vs Diameter (PD) diagram Giant Radio Source vs Radio Galaxy
GRG
GRQ
RG
3CRR
1e28
1e26
1e24
1e22
P_(1.4 GHz)
0
1000
2000
3000
4000
5000
Size_kpc

Conclusion :

Despite numerous studies on GRGs, no unified model emerged that can explain how RGs are evolving to such large sizes, which remains an unsolved problem in astrophysics. Determining physical parameters (e.g. the ages) of the largest RGs is crucial for understanding the evolution of RGs in general.

1. Distribution of GRSs in the sky. (Mostly in northern hemisphere due to more radio surveys done in northern part)
2. Distribution of redshift (GRS present in higher redshift than normal RG).
3. Distribution of Power (Power seems similar for both GRS and normal RG).
4. Distribution of Size
5. Power vs redshift Diagram (shows the instrumentation limitation for power).
6. PD- diagram (shows the evolutionary tracks of GRSs)

Thank you for this wonderful workshop on VO tools.



References:

Kuźmicz et al., 2018;
Dabhade et al., 2020a,b;
Kuźmicz & Jamrozy, 2020;
Delhaize et al., 2020
Schoenmakers et al. 2001
Machalski et al., 2008
Urry & Padovani, 1995.
Kaiser, Dennett-Thorpe & Alexander 1997
Ishwara-Chandra & Saikia 1999