



Universiteit
Leiden
The Netherlands

Unveiling the nature of giant radio galaxies

Dabhade, P.

Citation

Dabhade, P. (2021, May 25). *Unveiling the nature of giant radio galaxies*. Retrieved from <https://hdl.handle.net/1887/3179453>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3179453>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <https://hdl.handle.net/1887/3179453> holds various files of this Leiden University dissertation.

Author: Dabhade, P.

Title: Unveiling the nature of giant radio galaxies

Issue Date: 2021-05-25

Unveiling the nature of giant radio galaxies

Pratik Dabhade

Unveiling the nature of giant radio galaxies

Proefschrift

ter verkrijging van

de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir H. Bijl,
volgens besluit van het college voor promoties

te verdedigen op dinsdag 25 mei 2021

klokke 10:00 uur

door

Pratik Dabhade

Born in Jalna, India

June 1989

| | |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Promotores: | Prof. dr. H. J. A. Röttgering Prof. dr. Joydeep Bagchi (IUCAA & CHRIST University, India) |
| Promotiecommissie: | |
| Secretaris: | Prof.dr. Paul van der Werf |
| Overige leden: | Prof.dr. Frank Israel Prof.dr. Peter Barthel (Groningen University) Prof.dr. Raffaella Morganti (Groningen University) Prof.dr. Somak Raychaudhury (IUCAA, India) Prof.dr. Dhruba Jyoti Saikia (IUCAA, India) Dr. Reinout van Weeren |

© 2021 Pratik Dabhade

Dit proefschrift werd ondersteund door de Universiteit Leiden en IUCAA (India).

Cover: The front side shows the radio sky with giant radio galaxies with LOFAR on the ground. The back side shows GMRT and IRAM telescope investigating a special giant radio galaxy.

Dedicated to
my parents

“If you want to shine like the sun, first burn like the sun”
- Dr. A. P. J. Abdul Kalam

Contents

| | | |
|--------|--------------------------------------------------------------------------|----|
| 1 | Introduction | 1 |
| 1.1 | Active Galactic Nuclei | 3 |
| 1.2 | Radio-loud Galaxies and Quasars | 5 |
| 1.3 | Giant radio galaxies | 11 |
| 1.4 | Work in this thesis | 15 |
| 1.5 | Future scope | 19 |
| 2 | Discovery of Giant Radio Galaxies from NVSS: Radio & Infrared Properties | 25 |
| 2.1 | Introduction | 26 |
| 2.2 | Multi-frequency Properties of GRG Sample | 30 |
| 2.2.1 | Identification of New GRGs and Radio Analysis | 30 |
| 2.2.2 | Optical Analysis | 32 |
| 2.2.3 | Infrared Analysis | 33 |
| 2.2.4 | Black Hole Mass Estimation | 34 |
| 2.3 | Results | 35 |
| 2.3.1 | GRG1 (J001604+042024) | 35 |
| 2.3.2 | GRG2 (J002224.96-081845) | 35 |
| 2.3.3 | GRG3 (J031536-074338) | 35 |
| 2.3.4 | GRG4 (J042925+003304): A Giant Radio Quasar? | 35 |
| 2.3.5 | GRG5 (J044932-302638): A Giant Radio Quasar | 36 |
| 2.3.6 | GRG6 (J080248+492723) | 45 |
| 2.3.7 | GRG7 (J085701.76+013130.9) | 45 |
| 2.3.8 | GRG8 (J105838.66+244535) | 45 |
| 2.3.9 | GRG9 (J105920-170920) | 46 |
| 2.3.10 | GRG10 (J132741+574943) | 46 |
| 2.3.11 | GRG11 (J132743.50+174837) | 46 |

| | | |
|--------|--------------------------------------------------------------------------------------------------------|----|
| 2.3.12 | GRG12 (J200843+004918): An Extremely Large Radio Source? | 46 |
| 2.3.13 | GRG13 (J203449-263036) | 49 |
| 2.3.14 | GRG14 (J205939+243423) | 49 |
| 2.3.15 | GRG15 (J223301+131502): A GRG hosted by a BCG | 49 |
| 2.3.16 | GRG16 (J225039.15+284445.5) | 52 |
| 2.3.17 | GRG17 (J225615.1-361759) | 52 |
| 2.3.18 | GRG18 (J230444-105048) | 53 |
| 2.3.19 | GRG19 (J231201.27+135655.9) | 53 |
| 2.3.20 | GRG20 (J231620-010207) | 53 |
| 2.3.21 | GRG21 (J232623+245840) | 53 |
| 2.3.22 | GRG22 (J232849.99-082512.7) | 54 |
| 2.3.23 | GRG23 (J233552.1+521539) | 54 |
| 2.3.24 | GRG24 (J234929-000305) | 54 |
| 2.3.25 | GRG25 (J235531+025607) | 55 |
| 2.4 | Discussion | 55 |
| 2.4.1 | Black Hole Mass of GRG | 55 |
| 2.4.2 | Demographics of GRGs | 57 |
| 2.4.3 | WISE mid-IR studies of GRGs | 58 |
| 2.4.4 | P-D Diagram | 61 |
| 2.5 | Conclusions and Summary | 63 |
| 2.6 | Supplementary material | 66 |
| 3 | Giant radio galaxies in the LOFAR Two-metre Sky Survey-I: Radio and environmental properties | 69 |
| 3.1 | Introduction | 70 |
| 3.2 | Identifying new GRGs in LoTSS | 73 |
| 3.2.1 | The LoTSS first data release | 73 |
| 3.2.2 | Semi-automated search for GRGs | 75 |
| 3.2.3 | Manual Visual Search from LoTSS DR1 | 76 |
| 3.2.4 | Final catalogue: VAC+MVS | 78 |
| 3.3 | Results : The LoTSS catalogue of GRGs | 78 |
| 3.3.1 | Optical host properties | 78 |
| 3.3.2 | Spectral Index (α_{144}^{1400}) | 79 |
| 3.3.3 | Notes on individual objects | 82 |
| 3.3.4 | Giant radio quasars | 84 |
| 3.3.5 | Environment analysis of GRGs | 87 |
| 3.4 | Discussion | 88 |
| 3.4.1 | GRGs with sizes > 2 Mpc | 88 |

| | | |
|-------|-------------------------------------------------------------------------|-----|
| 3.4.2 | Morphology of GRGs | 88 |
| 3.4.3 | GRGs in dense environments | 91 |
| 3.5 | Summary | 93 |
| 3.6 | Supplementary material | 107 |
| 4 | Chapter 4 : SAGAN. I. New sample and multi-wavelength studies | 117 |
| 4.1 | Introduction | 118 |
| 4.2 | Project SAGAN | 122 |
| 4.2.1 | New sample of GRGs from NVSS | 123 |
| 4.2.2 | The GRG catalogue | 128 |
| 4.3 | Analysis | 128 |
| 4.3.1 | Size | 128 |
| 4.3.2 | Flux density and radio power | 129 |
| 4.3.3 | Jet kinetic power | 129 |
| 4.3.4 | Spectral index | 130 |
| 4.3.5 | Absolute r-band magnitude | 131 |
| 4.3.6 | Black hole mass | 131 |
| 4.3.7 | Eddington ratio | 131 |
| 4.3.8 | Black hole spin | 132 |
| 4.3.9 | WISE mid-IR properties | 133 |
| 4.4 | SAGAN GRG sample: Results | 135 |
| 4.4.1 | Spectral index distribution of the SGS | 135 |
| 4.4.2 | PD $\zeta\alpha$ parameters of GRGs | 137 |
| 4.4.3 | Morphology of GRGs | 141 |
| 4.4.4 | Environmental analysis of the SGS | 142 |
| 4.5 | GRG catalogue: Properties and correlations | 142 |
| 4.5.1 | Comparison of the properties of GRGs and GRQs . | 143 |
| 4.5.2 | Comparison of the properties of HEGRGs and LEGRGs | 150 |
| 4.5.3 | How similar are GRGs and RGs ? | 155 |
| 4.5.4 | Astrophysical processes near accreting black holes in GRGs | 158 |
| 4.5.5 | Environment analysis | 165 |
| 4.6 | Discussion | 166 |
| 4.7 | Summary | 169 |
| 4.8 | Tables | 170 |
| 4.9 | Notes on individual sources from SGS | 181 |
| 4.10 | Radio maps of all GRGs from the SGS. | 183 |

| | | |
|--------|------------------------------------------------------------------------------------------------------------|-----|
| 5 | SAGAN. II : Molecular gas content of giant radio galaxies- Based on observations carried out with IRAM-30m | 191 |
| 5.1 | Introduction | 192 |
| 5.2 | The sample | 193 |
| 5.2.1 | R1-1: 2MASX J23453268–0449256 | 196 |
| 5.2.2 | R1-2: CGCG 245–031 | 196 |
| 5.2.3 | R1-3: B2 1029+28 | 196 |
| 5.2.4 | R2-1: WNB0313+683 | 197 |
| 5.2.5 | R2-2: LCRS B132559.3–025215 | 197 |
| 5.2.6 | R2-3: 2MASX J14504940+1006497 | 197 |
| 5.2.7 | R2-4: NGC 6251 | 197 |
| 5.2.8 | R2-8: Speca | 198 |
| 5.2.9 | Other GRGs | 198 |
| 5.2.10 | Non-GRGs | 198 |
| 5.3 | Observations | 198 |
| 5.4 | Results | 202 |
| 5.4.1 | Molecular masses | 205 |
| 5.4.2 | Deconvolving the two-horn spectra | 205 |
| 5.5 | Discussion | 207 |
| 5.5.1 | Star formation and gas mass | 208 |
| 5.5.2 | Radio power and fueling | 211 |
| 5.6 | Summary | 214 |
| 6 | Chapter 6 : Barbell shaped giant radio galaxy with \sim 100 kpc kink in jet | 217 |
| 6.1 | Introduction | 218 |
| 6.2 | Observations and data analysis | 219 |
| 6.2.1 | Optical | 219 |
| 6.2.2 | Radio Observations and data analysis | 224 |
| 6.3 | Results & Discussion | 228 |
| 6.3.1 | Redshift | 228 |
| 6.3.2 | Size, radio power and jet kinetic power | 228 |
| 6.3.3 | Radio morphology | 228 |
| 6.3.4 | Spectral index (α) | 233 |
| 6.3.5 | Spectral ageing and magnetic field | 233 |
| 6.3.6 | Jet and the kink | 237 |
| 6.3.7 | Environment Studies | 240 |
| 6.4 | Summary | 242 |
| | Bibliography | 243 |

| | |
|----------|----|
| CONTENTS | xi |
|----------|----|

| | |
|------------------------------------------|-----|
| Summary | 261 |
| Samenvatting in het Nederlands | 267 |
| List of publications | 273 |
| Curriculum Vitae | 277 |
| Acknowledgements | 279 |

