MERLIN Proposal

RadioNet

No code

Beswick

This is the title of the proposal. It is less than 100 characters long.

Abstract

This is the abstract of the proposal. It is less than 200 words long.

Total requested time this semester (including calibration)

16 hours

Beswick

This is the title of the proposal. It is less than 100 char...

No code

Applicants

Name	Affiliation	Email	Country		Potential observer
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		Country	UK

Summary of observations

Field	RA	Dec	Equinox	Exposure (hrs.)	Receiver
NGC4194	12:14:09.66	+54:31:35.2	J2000	16.00	C-band (4500-5200 MHz)
NGC4194	12:14:09.66	+54:31:35.2	J2000	16.00	L-band (1330-1430 MHz)

Science Category	Telescope Requirements	Observation Modes	Data Reduction Location	Help Required
Extragalactic	Subset of telescopes	Continuum Wide-field Spectral line Phase referencing	JBO	Consultation

Linked proposals: No

Related proposals approved or submitted for other facilities

10 hrs of VLA A-configuration time to observe the H1 absorption in this galaxy. It is planed that these VLA data will be combined with the MERLIN H1 absorption data proposed for here.

List allocations on this telescope in the previous 3 years

(program id; number or hours/days;status of observations and data analysis;and publications.)

"H1 absorption in nearby starburst galaxies" PI Beswick MN/XXB/XXX

6 runs observed.

Currently 2 papers have been published:

Beswick et al 2002, MNRAS, XXX, XXX

Student, Beswick et al 2003, MNRAS, XXX XXX

PhD Students involved

Student	Applicant	Supervisor	Applicant	Expected completion date	Data required
A student	No	DR Rob Beswick	Yes	2008/10	Yes

Related publications

Beswick et al, 2004, MNRAS 352, 49

Beswick et al 2005 A&A, 444, 791

Discussion of data analysis plan

The data reduction and analysis will be done by A. Student. It is planned she will visit JBO following these observations

No additional remarks

High resolution 5GHz observations of the heart of the Medusa:– *Characterising the radio emission from a highly efficient starforming galaxy*

1 Introduction

The high resolution study of the radio continuum emission from starburst and AGN system still remains of great scientific importance. Studies using the matched resolution of MERLIN at lower frequencies (L & C-band), in conjunction with matched resolution, higher frequency VLA observations have proved an invaluable tool to study the structure and spectral index (and hence nature) of compact radio emission in the densely obscured central regions of starburst (e.g. McDonald et al 2002; Neff et al 2004). Similarly high resolution MERLIN radio studies of nearby starburst galaxies can be used to disentangle the contributions of both starformation and weak AGN activity to the radio emission of starforming galaxies, such as found in NGC6240 (Beswick et al 2001; Gallimore & Beswick 2004).

As part of an ongoing and extensive multi-wavelength study of the nearby starforming galaxy NGC4194 *'the Medusa merger'* we propose to observe the radio continuum of this source at 5GHz with MERLIN in order to image the most compact radio components. These data in-conjunction with our exiting MERLIN 1.4GHz, VLA 5, 8.4 & 15GHz data will be used to characterise the spectral indices, sizes and, as a consequence, the nature of the compact radio continuum components and further trace the star-formation of this dust enshrouded galaxy.

The Medusa merger

The Medusa starburst merger (NGC 4194, IZw33, Mrk 201) belongs to a class of moderate luminosity mergers ($L_{\rm IR} = 8.5 \times 10^{10}$ L$_\odot$ at D=39 Mpc), an order of magnitude fainter than the well known Ultra Luminous Infrared Galaxies (ULIRGs) such as Arp 220, but with an equally spectacular morphology. The "hair" or "tentacles" are a broad, patchy tidal tail stretching out 60″ (11 kpc) north of the twisted main body. Faint loops and shells surround the central body along the minor axis and a sharp, curved feature can be found 15 arcsec south of the center. The central 2 kpc starburst (e.g. Prestwich et al 1994; Armus et al 1990) is extended compared to the often compact (100 – 300 pc) bursts in ULIRG nuclei. High resolution OVRO aperture synthesis maps of the CO 1–0 emission (Aalto and Hüttemeister 2000) reveal that also the molecular gas distribution is extended compared to that of ULIRGs. It is distributed on a scale greater than 5 kpc even if more than 60% is associated with the central burst of star formation (Figure 2). The CO emission occupies mainly the center and the north-eastern part of the main optical body where it follows two prominent dust lanes. One extends into the beginning of the tidal tail and single dish observations reveal that *the molecular emission continues along the whole tail* (Aalto, Hüttemeister and Polatidis 2001). The molecular mass in the tail is estimated to be at least 8.5×10^7 M$_\odot$ which is about 4% of the total molecular mass measured so far in this system.

The current starburst is rapidly consuming the gas in the inner few kpc of the galaxy and when it has subsided the Medusa will likely develop into an elliptical galaxy with an evolved starburst population — likely with a remnant dust lane. Thus the Medusa is an example of a precursor to the so called "E+A galaxies, i.e. elliptical galaxies with A-type stellar populations and faint shells surrounding their main bodies. The connection between E+A galaxies and minor mergers is well known, but the Medusa is a rare example of such an object caught in its early stages of formation when the starburst is still active. Through studying the properties of the Medusa and establishing the evolutionary links to other shell galaxies, we will find important clues to the formation of E+A galaxies in general. The Medusa as the missing link between minor mergers and E+A galaxies leaves many questions in its wake and it is important to try and find more objects in a similar stage of their evolution. We have found three more galaxies which have the same'cometary' morphology and appear to be in their early shell-forming stages. Morphologically, they are Medusa look-alikes, but they appear neither to be starbursts nor to have as much molecular gas as the Medusa. This could be because they are slightly more evolved, but also because there was not enough gas, or the gas became too scattered by the collision. These objects will also be studied and compared to the Medusa as well as more evolved shell-galaxies.

2 Scientific Justification

The starformation in the Medusa is fuelled by the copious volumes of neutral and molecular gas within this merging system. Our previously detailed studies of the molecular gas content of this galaxy using OVRO (Aalto & Huttemeister 2000; Aalto et al 2001) have revealed the extent of the molecular gas distribution. Plus more recently our MERLIN HI absorption and 1.4GHz radio continuum observations (Beswick et al. 2005) have shown that large volumes of HI gas are also situated close to the nuclear region of the Medusa. In these MERLIN observations the HI, observed via absorption, is shown to be spatially coincident with the molecular gas and dust obscuration (see Fig. 1). Both of these observations have revealed that the cold neutral and molecular gas is distribution differently to the 1.4GHz radio continuum as observed by MERLIN. The cold gas, the fuel for the starformation, is primarily situated along the dust lane of this galaxy, whereas the brightest areas of 1.4GHz radio continuum is distributed to the north of this region (see Fig 1). It is thought that these areas of high (neutral hydrogen and molecular) gas surface density are acting as a

reservoir for the ongoing starformation whilst the 1.4GHz radio emission is tracing the recently occurred starformation regions.

Complementary high resolution VLA imaging at 5, 8.4 & 15GHz of the centre of the Medusa (see Fig 2) trace the distribution of the higher frequency radio continuum at comparable resolutions to our previous 1.4GHz and these proposed 5GHz MERLIN observations. As can be seen in Fig. 2 ∼45 compact sources are detected to limiting luminosity of $\sim 5 \times 10^{18} \mathrm{W\,Hz^{-1}}$ (∼5 times the luminosity of Cas A). Of these sources approximately 50% have nominally flat spectral indices indicative of non-thermal sources, such as HII regions. Many of these non-thermal sources are clearly visible in the higher frequency VLA images (see fig. 2). Consequently it is crucial that we obtain high resolution 5GHz observations in order to begin to resolve the structure of these compact components on scales of ∼50mas (∼10pc) as well as allowing the calculation of the spectral indices these compact radio components.

Possible AGN components?

Without doubt at the *heart* of the Medusa merger there is considerable starformation. However the presence of a weak AGN cannot yet completely be ruled out.

The Medusa merger is currently at an intermediate evolutionary stage prior or during the turning-on of it's central AGN. Hence, we are observing the Medusa's AGN before it is fed enough to "turn-on" and/or while it's still a LLAGN, making it a particularly important nearby example of a galaxy at this stage in its evolution.

At 1.4GHz with MERLIN the radio continuum structure of the core of region of NGC4194 is shown in Fig. 1 (left). The brightness and radio structure of these two components shows some similarities with nearby weak Seyfert galaxies. However it is equally plausible that these components may be composed of a compact group of radio supernovae. Our previous observations alone cannot categorically confirm the nature of these components. The 5GHz observations proposed here with a beam size of 50mas will provide a linear resolution of ∼10pc, at the distance of NGC4194. At this linear resolution it will be possible to place much more stringent constraints on the nature of these components – plus, possibly, provide a important opportunity to observe the switching on of an AGN.

3 Technical Considerations

We require 1 full-track observation at 5GHz of the Medusa Merger (NGC4194). Due to the extended nature of this source, we request that these observations be made in wide field mode. From our previous VLA A-configuration 5 & 8.4GHz observations we expect the 5GHz radio continuum of the Medusa to be composed of many compact components with fluxes of ∼1 to a few mJy. Hence we require a sensitivity of ∼0.05mJy/bm.

4 Summary of objectives

1. To image the radio continuum of the Medusa at 5GHz
2. To disentangle the contributions to the radio continuum of starformation and AGN emission
3. To use these MERLIN data along with VLA 8.4 & 15 GHz plus our existing 1.4GHz MERLIN data to characterise the spectral indices of the compact radio components
   - To separate the thermal and non-thermal radio emission
     (a) To identify the distribution of non-thermal and thermal sources; tracers for recent and ongoing star-formation.
     (b) To compare the distribution of these sources with distribution of neutral and molecular gas species
4. To investigate the radio continuum emission LLAGN during its 'turn-on' phase

5 References

Aalto & Hüttemeister 2000, A&A 362, 42
Aalto, Hüttemeister & Polatadis 2001, A&A letters 372, 29
Armus et al. 1990, ApJ, 364, 471
Beswick et al 2001 MNRAS 325, 620
Beswick et al 2005 A&A in press (astro-ph/0508637)
Gallimore & Beswick 2004 AJ 127, 239
McDonald et al 2002, MNRAS, 334, 912
Neff et al 2004, ApJ, 611, 186
Prestwich et al 1994, ApJ, 442, 73

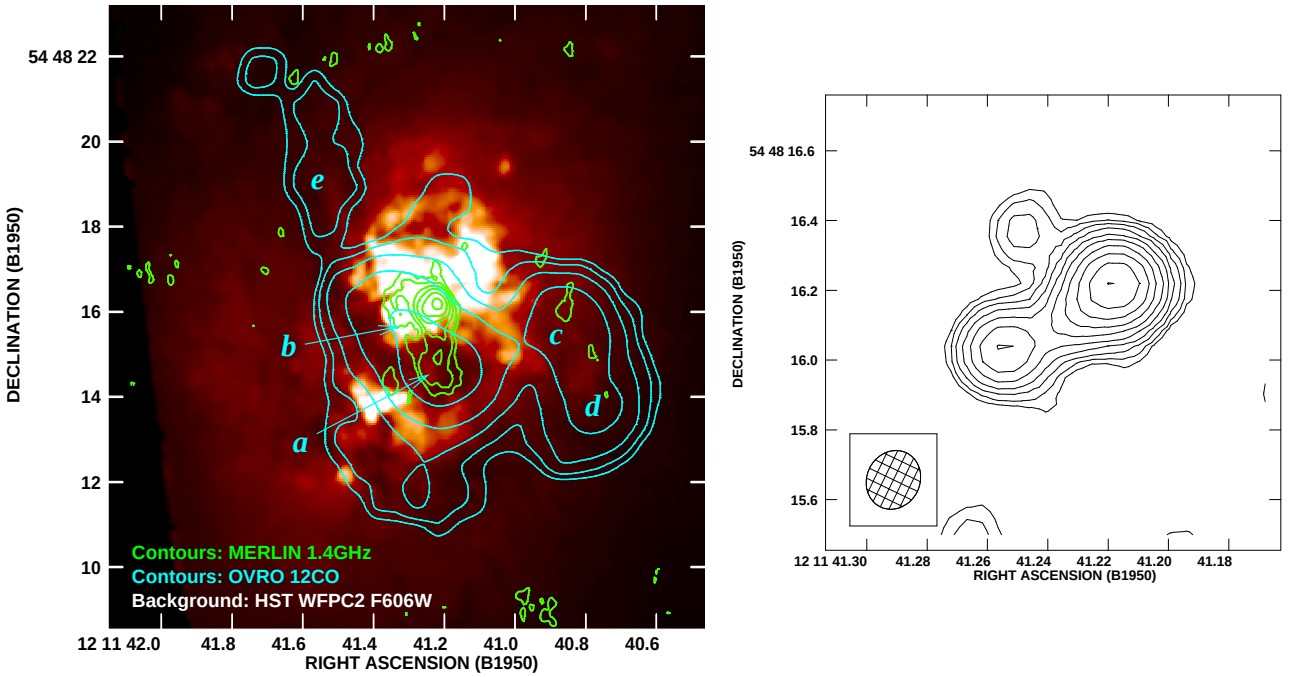

Figure 1: **Left-hand**:1.4 GHz MERLIN radio continuum emission in green contours and OVRO 12CO (Aalto & Hüttemeister 2000) in pale blue contours over a F606W WFPC2 HST image. The contour levels on the radio continuum image are -1, 1, 2, 4 ,8, 16 & 32 times 0.3mJy/beam (from Beswick et al 2005). **Right-hand**: 1.4GHz MERLIN uniform weighted image of the core components in Medusa merger (from Beswick et al 2005).

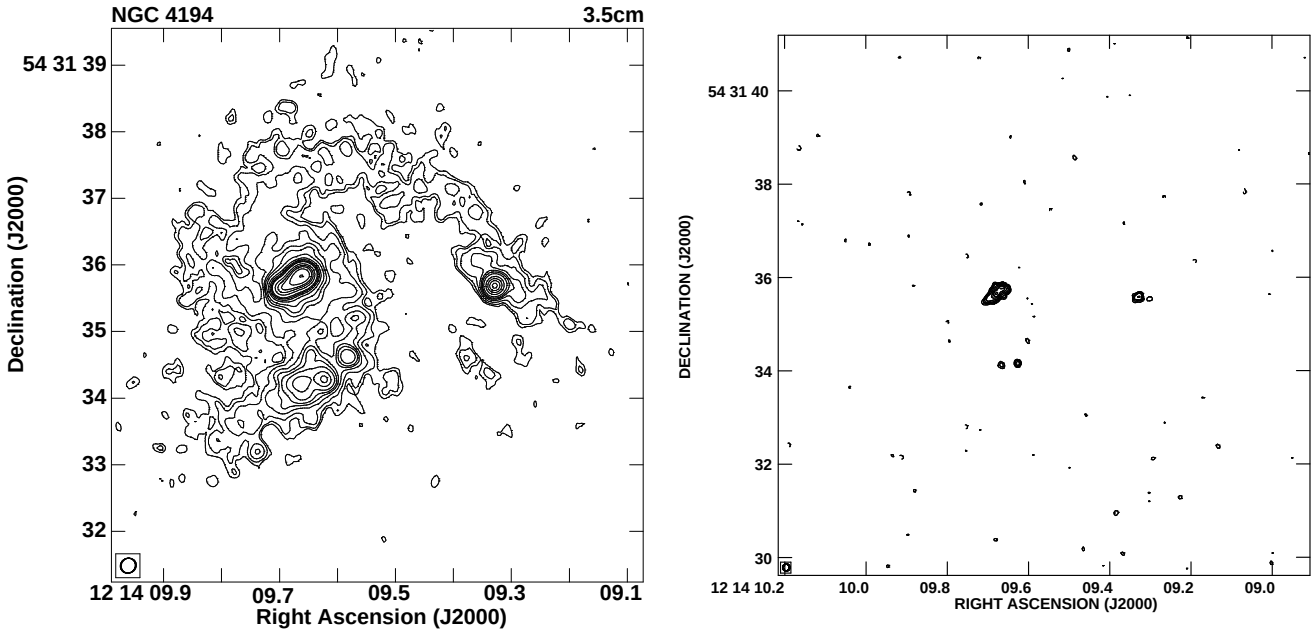

Figure 2: **Left-hand**:8.4GHz VLA A-configuration contour image of the Medusa merger. **Right-hand**: 15GHz VLA A-configuration contour image of the Medusa merger.

Observation details

Field	RA	Dec	Equinox	Exposure (hrs.)	Receiver
NGC4194	12:14:09.66	+54:31:35.2	J2000	16.00	C-band (4500-5200 MHz)

No required scheduling constraints

No preferred scheduling constraints

Peak Flux :	5.0 mJy/bm	***Total field to be imaged :***	5.0 arcsec
Total Flux:	10.0 mJy/bm	***Three sigma noise level :***	1.0 mJy/bm
Largest angular size :	2.0 arcsec		

Calibration sources defined by Merlin staff

Wide Field Continuum Correlator details

Central Frequency	*Polarisation Products*	*Bandwidth*	*Channels*
Default	LL + RR	16.0 MHz	32 x 500.00 kHz channels

Field	RA	Dec	Equinox	Exposure (hrs.)	Receiver
NGC4194	12:14:09.66	+54:31:35.2	J2000	16.00	L-band (1330-1430 MHz)

No required scheduling constraints

No preferred scheduling constraints

Peak Flux :	10.0 mJy/bm	***Total field to be imaged :***	30.0 arcsec
Total Flux:	40.0 mJy/bm	***Three sigma noise level :***	0.05 mJy/bm
Largest angular size :	5.0 arcsec		

Calibration sources defined by Merlin staff

Spectral Line Correlator details

Polarisation Products	*Bandwidth*	*#Spec Channels per Pol*	*Reference Frequency*	*Doppler Calculation*
LL + RR	8.0 MHz	64 x 125.00 kHz channels	1420.405752 MHz	v(rad,lsr) = 2560.0 km/s