AUSTRALIA TELESCOPE OBSERVING APPLICATION

NAR

yr,term: 99MAYT

ATNF use
ident:
rcvd:

NARRABRI

AT COMPACT ARRAY

SEND TO: Director, ATNF, P.O. Box 76, Epping, NSW 2121, Australia

For ATNF information see: http://www.atnf.csiro.au

1. Title of proposal:

A Deep 1.4 GHz Radio Survey of WIRE Mid-Infrared Fields

2. Authors Principal investigator on line 1	**Institution/Country** (if not Australia)	**for Ph.D. thesis ?**	**Present at Narrabri ?**
Frank J. Masci	IPAC, Caltech/USA		YES
Carol J. Lonsdale	IPAC, Caltech/USA		
Thomas Barlow	IPAC, Caltech/USA		
Cong Xu	IPAC, Caltech/USA		
Perry Hacking/Glenn Morrison	Vanguard Research/USA		

3. Contact author and mailing address:

phone: +1 626-397-7218 FAX: +1 626-397-7354 e-mail: fmasci@ipac.caltech.edu

4. Continuation of previous proposal? No **Previous proposal no:**

Related ATNF proposal numbers (if any):

5. Scientific categories: ☐ Solar System ☐ Stellar ☐ Galactic ☐ Mag. Clouds ☒ Extragalactic

6. Type of observation: ☒ Imaging ☐ Snapshot ☐ Bandwidth synth. ☐ Mosaicing
☒ Point source ☐ Monitoring ☐ High time resol. ☐ Pulsar ☐ Phased array ☐ Survey
☒ Continuum ☐ Spectral line ☐ Lin pol ☐ Cir pol ☐ Solar ☐ 'Filler time'

7. Configuration: see 'Guide to Obs' Table 6	6A	+6D (?)		
8. Alternative configuration? if any				
9. Do you require the 6 km antenna?	Yes			
10. Receiver [20+13, 6+3, 20, 13, 6, 3 cm]	20cm			
11. Number of objects	2			
12. Number of observations per object	1			
13. Time per observation	40hrs			
14. Hours requested (this term)	80			

15. Estimated hours needed (incl. above) **to complete project:** ~ 80 **16. Hours already allocated** (if known):

17. Any publications to date from this proposal? No **(If YES, please list separately)**

18. Short summary of proposal (~150 words, minimum font size 8 point):

We propose a deep 1.4GHz survey of approximately 0.6 square degrees corresponding to two Wide-Field Infrared Explorer mid-infrared fields. WIRE consists of a 4-month survey at 12 and 25μm, with sensitivity levels 500-1000 times fainter than IRAS covering up to 1000 square degrees of sky. Based on local radio-to-mid-IR flux ratios, we expect to detect ~ 500 starburst galaxies and ~ 100 AGN with **both** WIRE and the ATCA. The relatively stronger and compact radio cores of AGN will enable us to pre-select candidates for further deep optical spectroscopy. We will in particular be sensitive to AGN 'type II' objects whose central cores are hidden by large columns of optically thick dust and are severely selected against in optical/UV surveys. This survey will also explore the nature of the 'micro-Jansky' excess in radio counts and whether there is any evolutionary link between their radio and mid-IR emission.

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19. Please indicate the amount of additional help required:

[ ] None [ ] Consultation [ ] Friend* [×] Staff collaborator

[ ] Absentee observing* [ ] Service Observing* * (see Guide Section 1)

20. Spectroscopy only:	Line 1	Line 2	Line 3
transitions to be observed			
velocity range (km s^{-1})			
channel bandwidth (kHz)			
approx observing frequency			
number of channels per baseline			
number of pol products (1,2 or 4)			
specific correlator configuration (see 'Guide to Observations', Table 5)			

21. Number of sources: 2

[If more than 8 sources, please attach list. If more than 30 give only selection criteria and LST range(s)]

22. Name [order of priority]	**Coordinates (J2000)**		**Band**	**Band width**	**Intensity (cont)**		**Angular size**	**Maximum baseline or specific configuration**	**Time requested (hr)**
	RA (h,m)	**DEC (±°,′)**	**(cm)**	**(MHz)**	**total (Jy)**	**peak (mJy)**			
WIRE0130-234	01h30m	-23d43m	20	128		$\lesssim$400	$< 12''$	6A (+6D?)	40
WIRE0103-184	01h03m	-18d40m	20	128		$\lesssim$400	$< 12''$	6A (+6 D?)	40

23. Have you consulted the ATCA archive (Y/N) ? Y see http://www.atnf.csiro.au/observers/data.html

24. Additional comments on configurations:

25. Special hardware, software or operating requirements:

26. Preferred range of dates for scheduling:

27. Unsuitable dates:

28. Please attach a description and scientific justification of proposal, in not more than 1500 words

Scientific Justification: A Deep 1.4 GHz Radio Survey of WIRE Mid-Infrared Fields

Background:

The Wide-Field Infrared Explorer (WIRE) is NASA's 5th Small Explorer Class mission, planned for launch in March 1999. WIRE will survey up to 1000 square degrees of sky in two broad mid-infrared bands (12 and 25μm) simultaneously to investigate the evolution of starburst galaxies and search for protogalaxies at high redshifts (Hacking et al. 1997). WIRE will have a sensitivity 500-1000 times greater than IRAS and an order of magnitude greater than ISO at 25μm. It will also have a sky coverage rate 200 times higher than ISO. We anticipate that WIRE will detect about 100,000 starburst galaxies at typical redshifts $0.5\lesssim z\lesssim 1$ and potentially hundreds of protogalaxies at much higher redshifts.

Figure 2 shows the correlation between radio and mid-IR flux for starburst galaxies (Xu et al. 1994). The sensitivity limit of WIRE, $f_{25\mu} \simeq 0.5$mJy, corresponds to a radio continuum flux density of $f_{20\mathrm{cm}} \simeq 30\mu$Jy. This is the flux level where the well established micro-Jansky excess in radio number counts appears (Condon 1984). There is weak evidence suggesting that this is due to a rapidly evolving starburst galaxy population (eg. Windhorst et al. 1995). Since most sources detected to WIRE's 3σ confusion limit of 0.5mJy are expected to be starburst galaxies, a mid-IR/radio comparison will allow us to firmly establish the origin of the micro-Jansky excess. High resolution optical spectroscopy will also be used to strongly contrain the nature of this population.

A comparison between the mid-IR and radio emission to our proposed flux levels will explore the mid-IR/radio correlation into the sub-mJy domain. This will enable us to investigate the connection between radiation mechanisms in the infrared and radio emission to flux levels two orders of magnitude fainter than currently available data. Furthermore, the data will reveal how this correlation and the radiation mechanisms evolve up to $z \sim 2$ in starburst galaxies and also AGN.

The mid-infrared is also an excellent region to search for AGN which have been missed in optical and UV surveys due to obscuration by dust (eg. Webster et al. 1995). This is particularly important for the far-infrared luminous 'type-II' (or narrow-line) AGN detected by IRAS (Low et al. 1988) whose central continuum source is believed to be obscured by optically-thick dusty molecular gas in a torus-like geometry (Pier & Krolik 1993). Emission from the torus is expected to peak in the mid-IR and is confirmed by the high detection rate of IRAS AGN using a 'blue' 60 to 25μm colour criterion. Due to limited sensitivity however, previous infrared surveys found a deficit of high luminosity 'type-II' AGN at high redshifts, with the majority being relatively low luminosity objects at $z\lesssim 0.5$. Only recently are studies at radio (eg. Becker et al. 1997) and hard X-ray (Iwasawa et al. 1997) wavelengths starting to reveal a potential new population of high z type-II AGN. The statistics however are too low from which to deduce any meaningful constraints on their evolution, the unified model, and their connection to luminous starburst galaxies.

WIRE's high sensitivity offers the possibility of detecting AGN to $z \sim 4$. In Figure 1, we show the number counts of starburst galaxies and AGNs at 25μm predicted for WIRE (Hacking et al. 1997; Lonsdale et al. 1997). These are based on an extrapolation of the measured local luminosity functions evolving as $L \propto (1+z)^3$. The predictions for AGN and QSOs are lower limits since no assumptions for hypothetical obscured populations are made.

Since radio wavelengths should have no bias against AGN obscured by huge columns of dust, we wish to combine the WIRE data with deep radio imaging as a diagnostic to pre-select high redshift AGN for further study. Studies have shown that local AGNs and QSOs have radio-to-**far-IR** flux ratios (eg. 20cm/100μm) somewhat different than normal galaxies and starbursts (eg. Norris et al. 1988; Condon, Anderson & Broderick 1995). Due to limited sensitivity and statistics, a similar result involving mid-IR wavelengths for AGN is not well established (cf. Marx et al. 1994). A combination of both WIRE and radio data with deep near-IR/optical imaging and spectroscopy will enable us to determine the radio-to-mid-IR relation for at least the 'optically brighter' and local AGN. Such a relation will then provide a diagnostic for selecting potential 'type II' candidates at $z\gtrsim 2$.

The recently completed 'Phoenix Deep Survey' and 'HDF-South Survey' at 20cm are complementary to this project (eg. Hopkins et al. 1998). These will also be followed up with WIRE. The 'Phoenix Deep Survey' however was imaged with a sensitivity $\simeq 100\mu$Jy (5σ), and will not be deep enough to match WIRE's expected sensitivity limit and source counts (see below). The HDF-South Survey on the other hand will go deeper and together with our proposed imaging of other WIRE fields, will provide an increased areal coverage with which to search for luminous protogalaxies, starbursts and AGN.

Detectability at 1.4GHz:

Based on the mid-IR/radio correlation for starburst galaxies from IRAS data (see Figure 2), we have the flux ratio $R = f_{20\mathrm{cm}}/f_{25\mu\mathrm{m}} \simeq 0.06$. Radio quiet AGN are observed to have similar values (eg. Marx et al. 1994), while the radio-intermediate to radio-loud AGN ($\lesssim$15% of the AGN population) have ratios larger by factors of 100-1000 (Sopp & Alexander 1991). For a given 25μm flux, this will ensure that a large fraction of sources to our This estimate for R together with WIRE's 3σ confusion limit of $\simeq 500\mu$Jy corresponds to a flux limit at 1.4GHz of $f_{20\mathrm{cm}} \simeq 30\mu$Jy. However, since the SEDs of starbursts and radio quiet AGN peak strongly in the mid/far-IR, it's likely that K-corrections will have the affect of increasing the observed ratio R to high redshift where $R \propto (1+z)^{0.5}$ for $\alpha_{20cm} \simeq 0.8$ and $\alpha_{MIR} \simeq 1.3$ ($f_\nu \propto \nu^{-\alpha}$) (Schmitt et al. 1997). This will ensure that most if not all sources to WIRE's sensitivity limit will be detected. To allow for modest integration times with the ATCA (see next section), we will aim for a sensitivity of $f_{20\mathrm{cm}} \simeq 40\mu$Jy at 3σ.

Over the 0.6 square degrees of sky we propose to image, this sensitivity will enable us to detect ~ 500 starburst galaxies and ~ 100 AGN (see Figure 1) with both WIRE and the ATCA. Source confusion down to 40μJy (3σ) is unlikely to be a problem since the expected cumulative source count predicts a 1σ confusion noise $\sigma_c \ll 10\mu$Jy for ATCA's 6A-configuration. (cf. with $\sigma_c \sim 10\mu$ for the VLA's C-configuration with $15''$ synthesised beam; Bridle 1988). Each of the WIRE 'deep' fields we propose to image are also part of a deep multiband study. We have already obtained deep optical images (to $R \sim 25$ mag) of all these fields and plan to do further imaging in the near-IR. We also plan to do deep optical spectrocopy of these same fields with $2dF$.

Observational Setup:

We plan to image ≈ 0.6 sq. degrees of sky, equivalent to two $33' \times 33'$ WIRE deep fields. This is an excellent match to ATCA's primary beamwidth of $33'$ FWHM. Furthermore, the 6A-configuration synthesised beamwidth of $6''$ FWHM provides a good match to the $20''$ FWHM resolution of WIRE. Starburst galaxies near our proposed detection limit ($\simeq 40\mu$Jy) however are still expected to be unresolved.

With the 6A configuration, we envisage a total 40 hours per WIRE field (allowing for calibration scans and additional noise sources) to enable detection down to $\simeq 40\mu$Jy (3σ). We envisage requiring 4 separate 10 hour synthesis pointings for each target field and we propose to observe two fields. These pointings will be fixed at the field center to ensure optimal sensitivity.

We propose to observe two WIRE target fields. These targets currently avoid 1.4GHz sources > 0.4Jy within two degrees of the field centers. However, a quick survey of some of these fields may be necessary to asses the impact of bright sources for the deep imaging. Ray Norris has given us technical advice on how to structure the observations and will eventually be offered to collaborate with us on this project. Please direct any correspondence to him.

References

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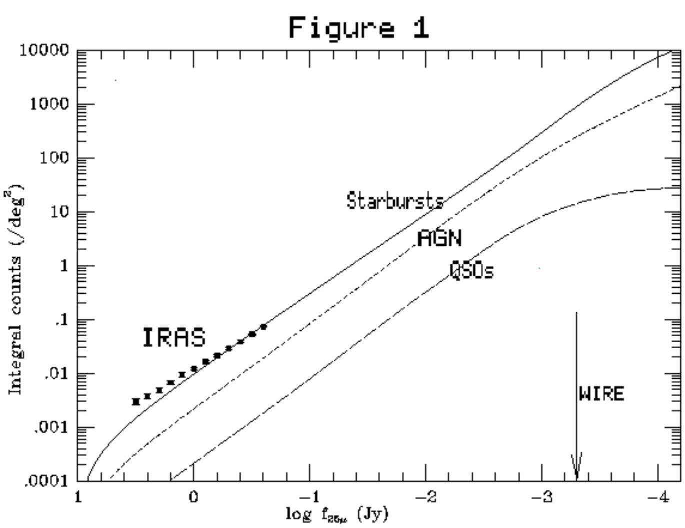

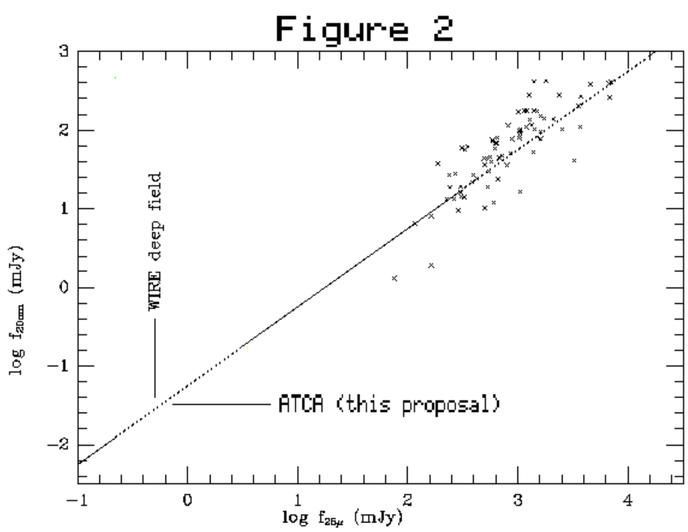

Figure 1: Predicted WIRE integral number counts at 25μm for Starbursts, AGN and a subset of AGN with QSO-like luminosity. These assume local luminosity functions derived from IRAS evolving as $L \propto (1+z)^3$ to $z = 4$ (Lonsdale et al. 1997).

Figure 2: IRAS mid-infrared vs. radio flux for starburst galaxies in the Revised Shapley-Ames catalogue (Xu et al. 1994). The predicted 3σ confusion limit for WIRE at 25μm is 500μJy. Our proposed ATCA 3σ limit is 40μJy.