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Selected lessons in radio source counts and a lot more…

Carole Jackson
5 December 2018

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COLOURS

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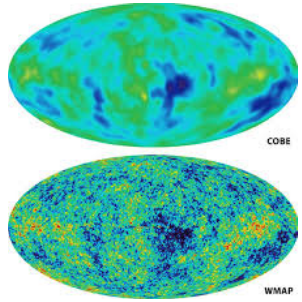
H2R 1S3 CONFIRM

adio Astronomy

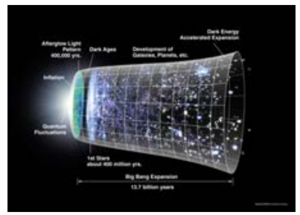
Radio source counts as cosmological probes



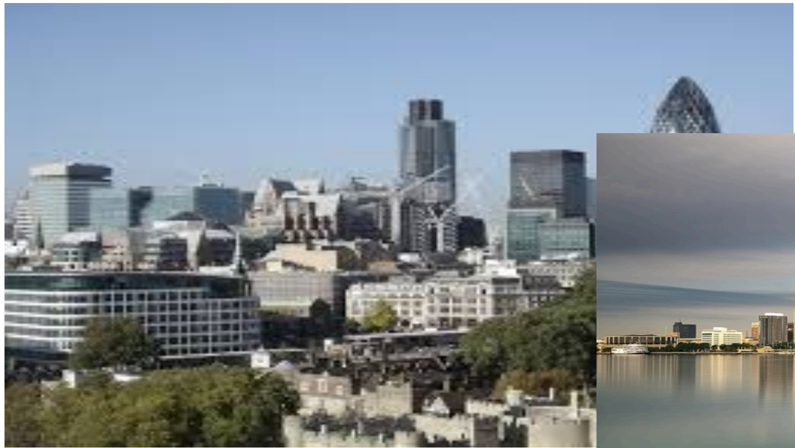
a 2019 student thesis aim

- **Derive precision sky models for SKA-era galaxy surveys,**
- **Permit exquisite foreground extraction for EOR detection**

- **Gain direct insights into AGN lifetimes, growth of large scale structure, etc.**



… this is a story of old data (circ 1994) & new developments….



1982

1987

1991-1994 BA
1994 – 1997 PhD

Lessons from Jasper

- **Radio emission is unattenuated by the ISM or IGM: radio galaxies and quasars allow us to sample the whole observable Universe**

- **Radio spectra are relatively smooth; radio sources at z=1 in 3CR are so luminous they could be detected at z=10 *if they exist***

- **Modern radio surveys are statistically complete**

- **There are discrete radio source populations with differing(?) evolution histories**

- **The imprint of large-scale structure is clearly seen in radio surveys**

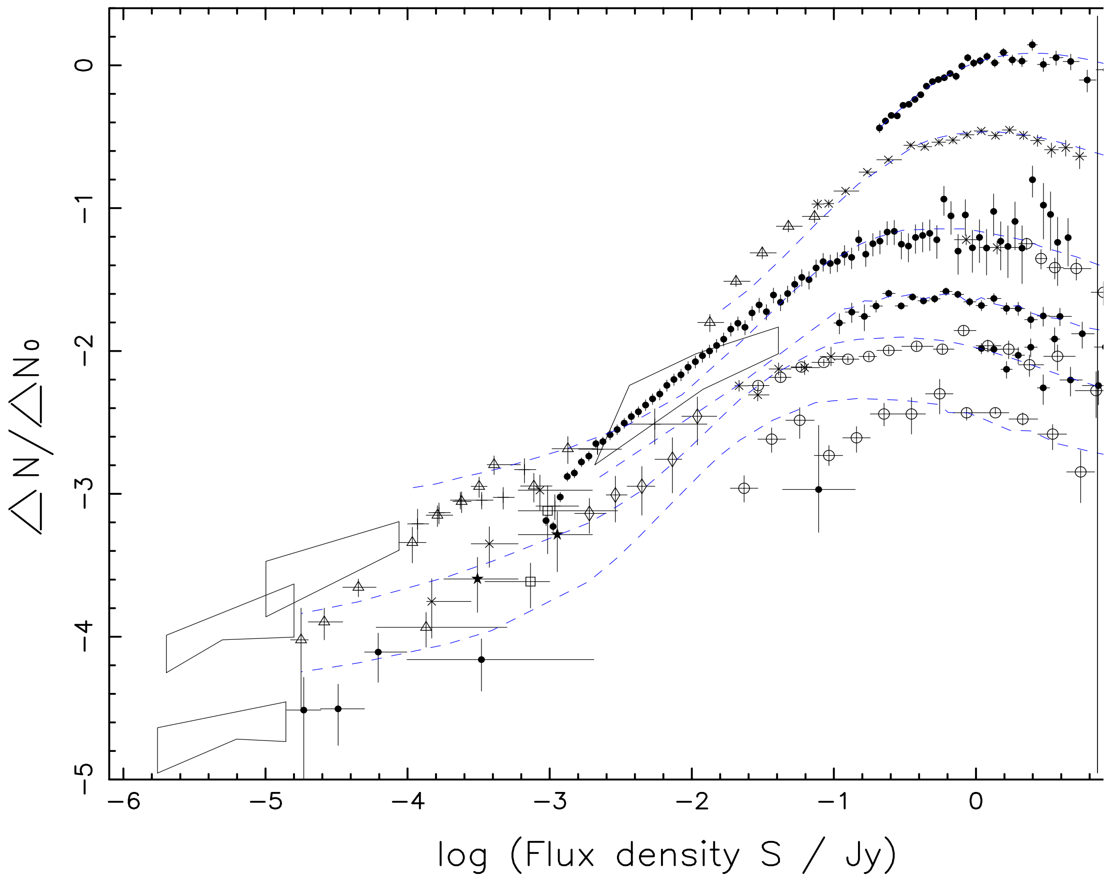
(advanced?) Radio lessons from Jasper ….

- The evolution of powerful radio sources mirrors (and probably influences) cosmic star formation history
- Modern radio surveys are statistically complete: mJy-sensitivity surveys sample the whole of the (powerful) radio source population

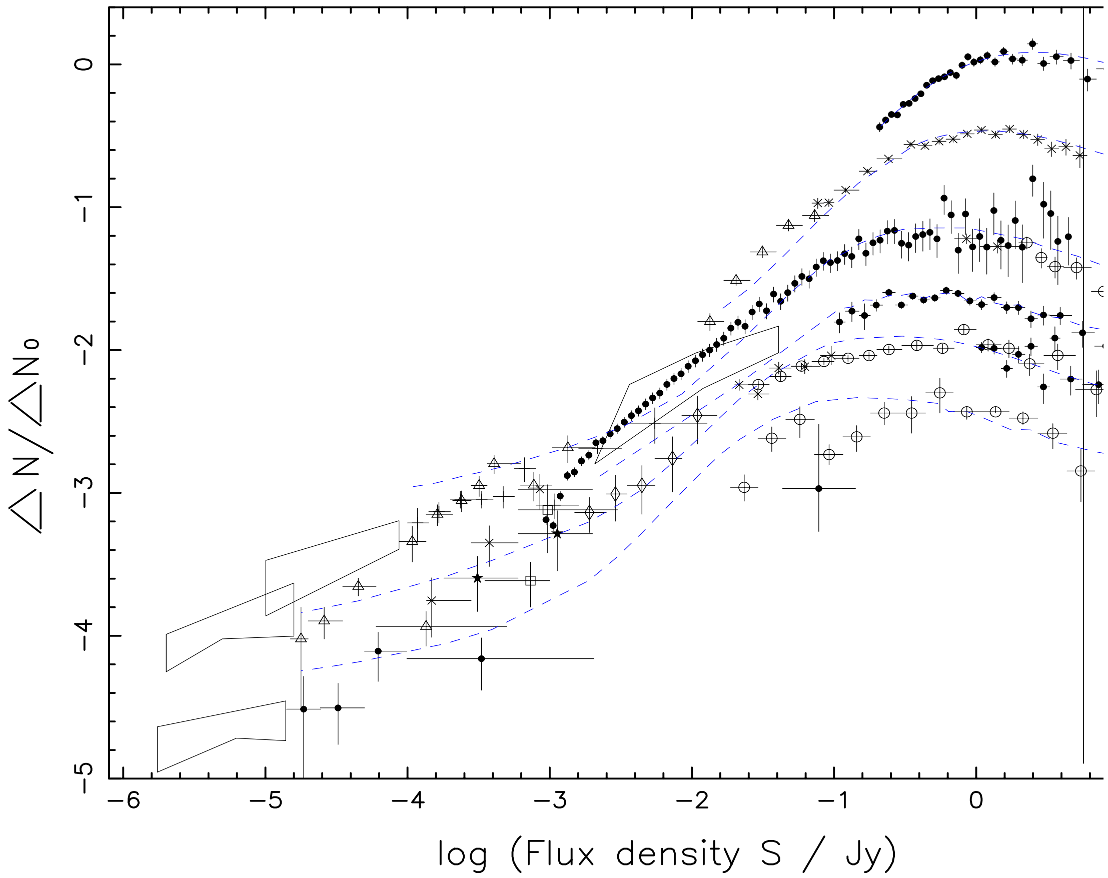
However ….

- At low frequencies(<200 MHz) surveys & data are limited by large beams (confusion) and lack of a sizable complete sample to define source evolution

The extragalactic radio frequency sky



The extragalactic radio frequency sky

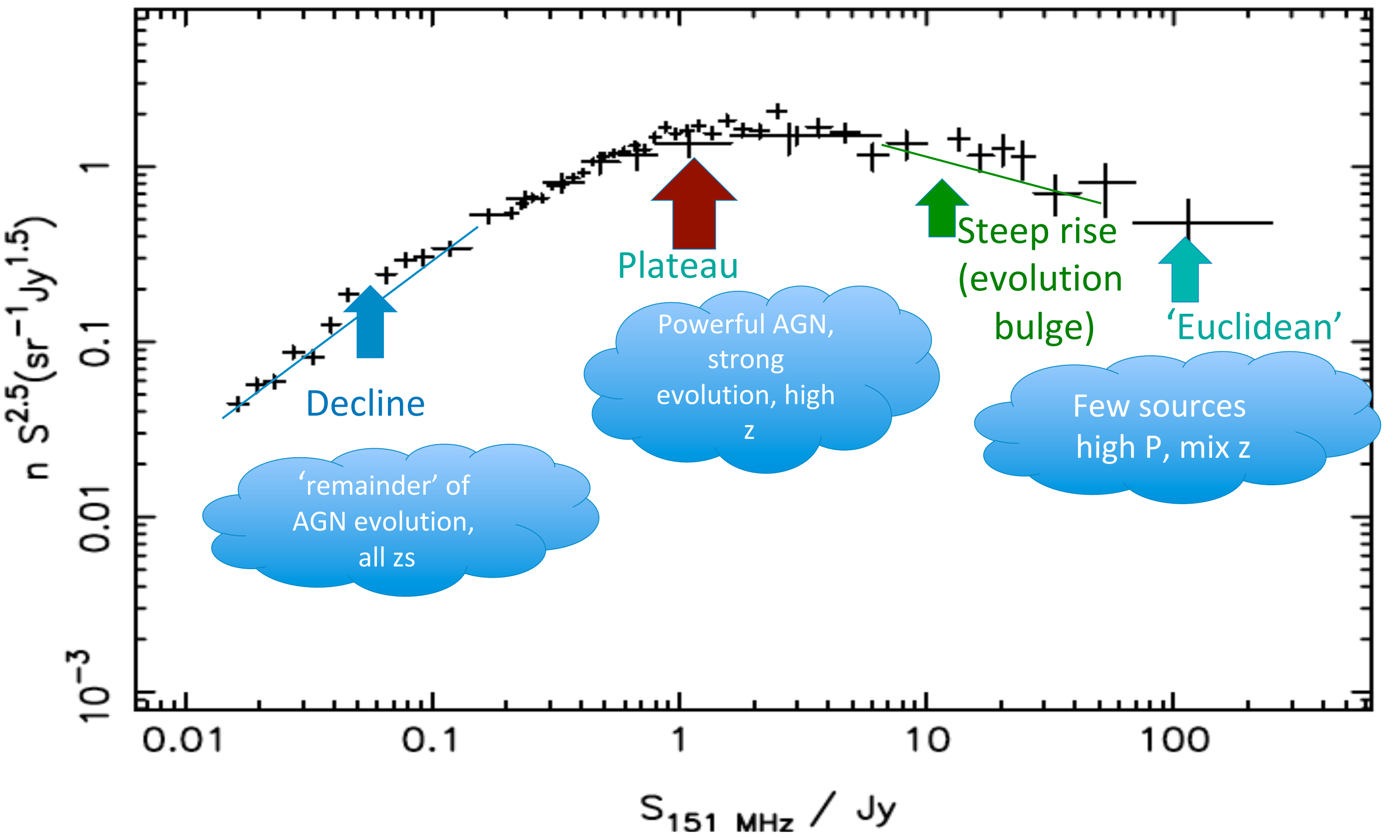


Radio source counts are Cosmological Probes

(but) 1990's analyses rely on significant extrapolation from higher frequency data

Complete, identified samples are tiny & remain highly degenerate to any model fit

Radio source counts embody information about the source populations & their evolution (space density) over cosmic time



Radio lessons from Jasper

- The evolution of powerful radio sources mirrors (and probably influences) star Formation history

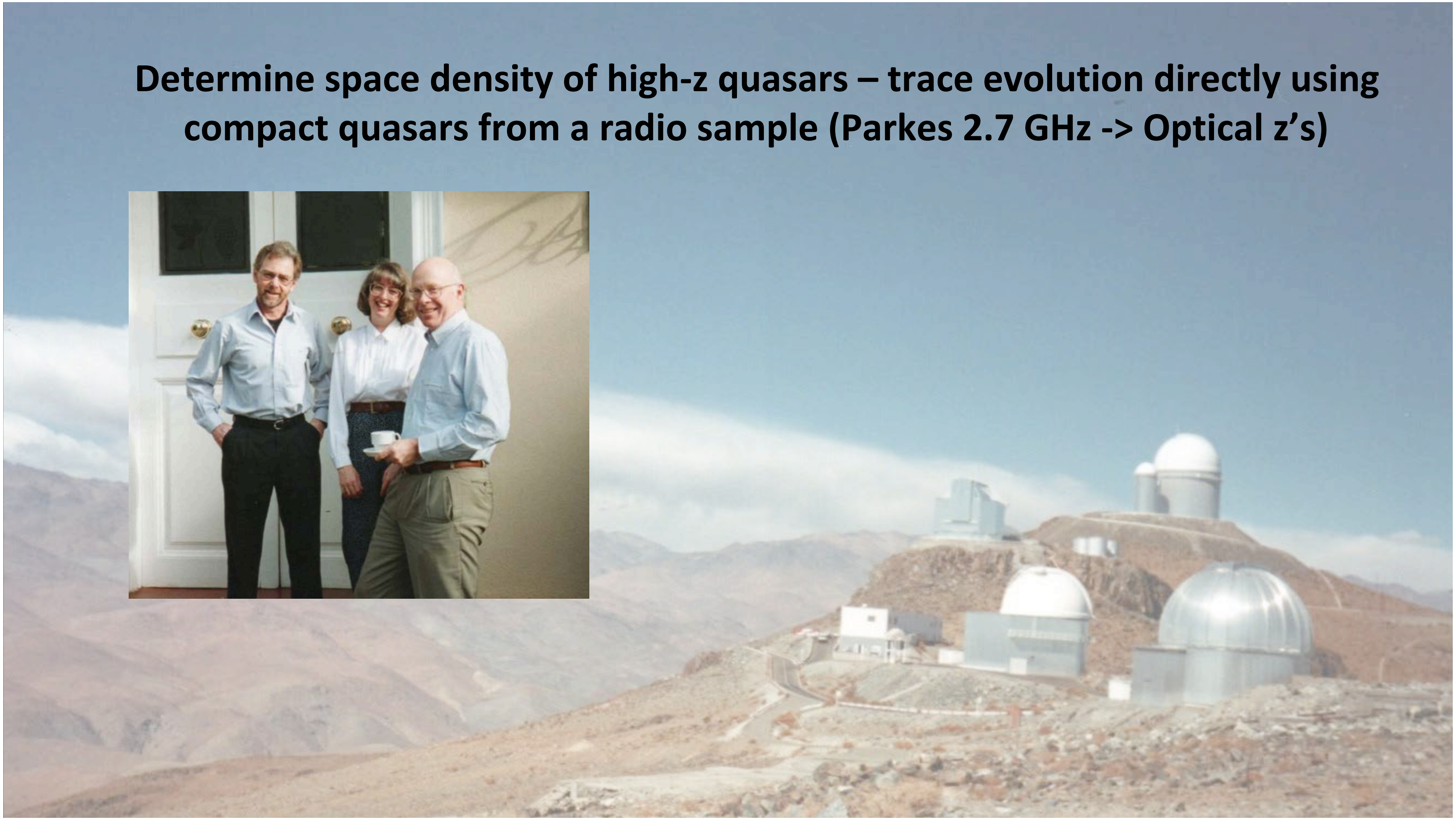
- Modern radio surveys are statistically complete: mJy level surveys sample the whole of the (powerful) radio source population(s)

However ….

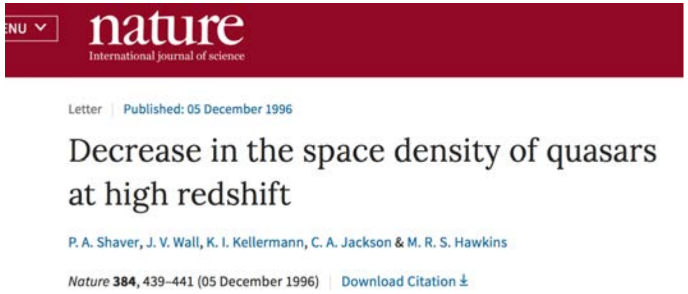
- **At low frequencies(<200 MHz) surveys & data are limited by large beams (confusion) and lack of a sizable complete sample to define source evolution**

So ….

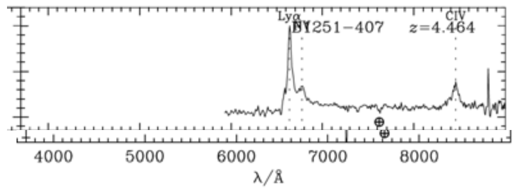
- **(1994 – 1997) use low frequency + deeper high frequency data together, and**
- **Directly attempt to probe the space density of the highest-z quasars**


Determine space density of high-z quasars – trace evolution directly using
compact quasars from a radio sample (Parkes 2.7 GHz -> Optical z’s)

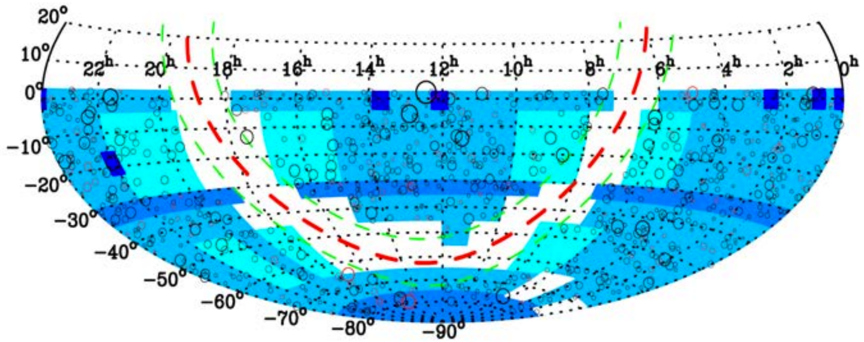
Determine space density of high-z quasars – trace evolution directly using compact quasars from a radio sample (Parkes 2.7 GHz -> Optical z’s)



nature
International journal of science
Letter | Published: 05 December 1996
Decrease in the space density of quasars at high redshift
P. A. Shaver, J. V. Wall, K. I. Kellermann, C. A. Jackson & M. R. S. Hawkins
Nature 384, 439–441 (05 December 1996) | Download Citation

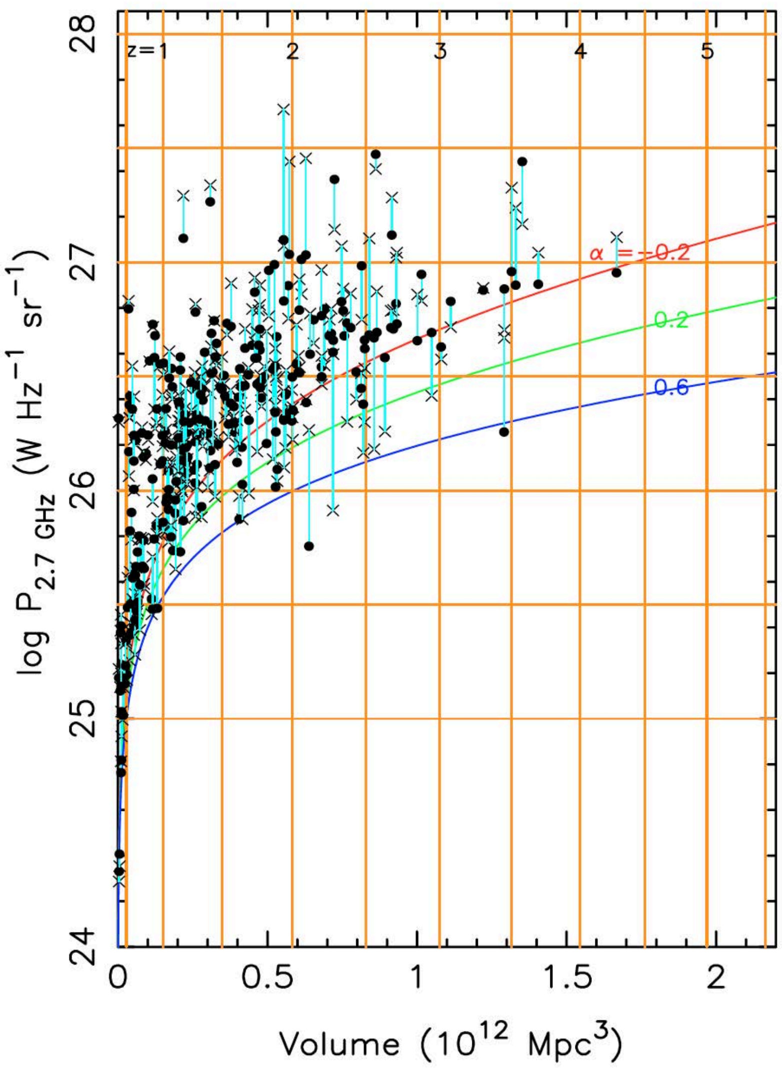


Lyα
BR1251−407
z=4.464
CIV
4000
5000
6000
7000
8000
λ/Å



20°
10°
0°
−10°
−20°
−30°
−40°
−50°
−60°
−70°
−80°
−90°
22h
20h
18h
16h
14h
12h
10h
8h
6h
4h
2h
0h

IAU GA 2003 (Sydney): Jasper returns to Parkes…



The Parkes quarter-Jansky flat-spectrum sample

III. Space density and evolution of QSOs

J. V. Wall[1,⋆], C. A. Jackson[2,⋆⋆], P. A. Shaver[3], I. M. Hook[1], and K. I. Kellermann[4]

2005

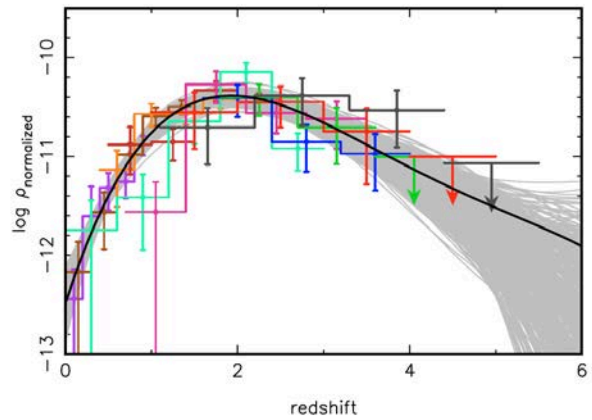
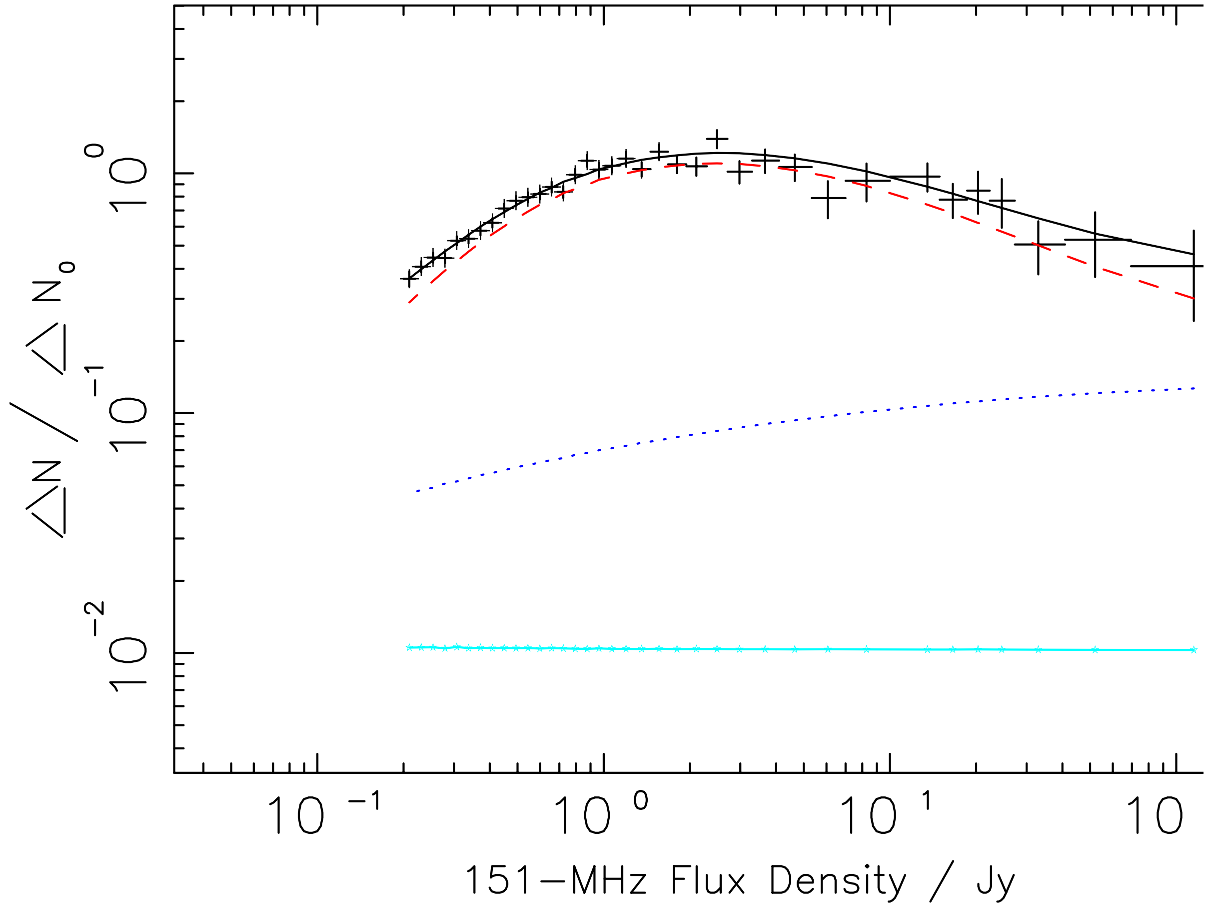
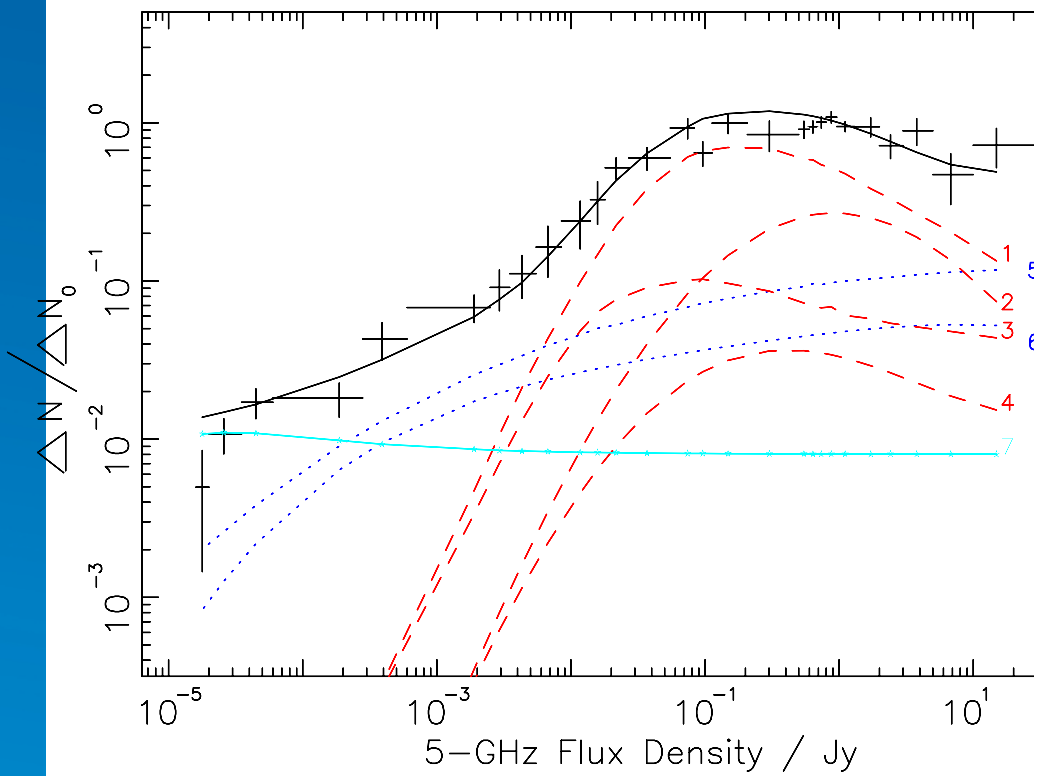


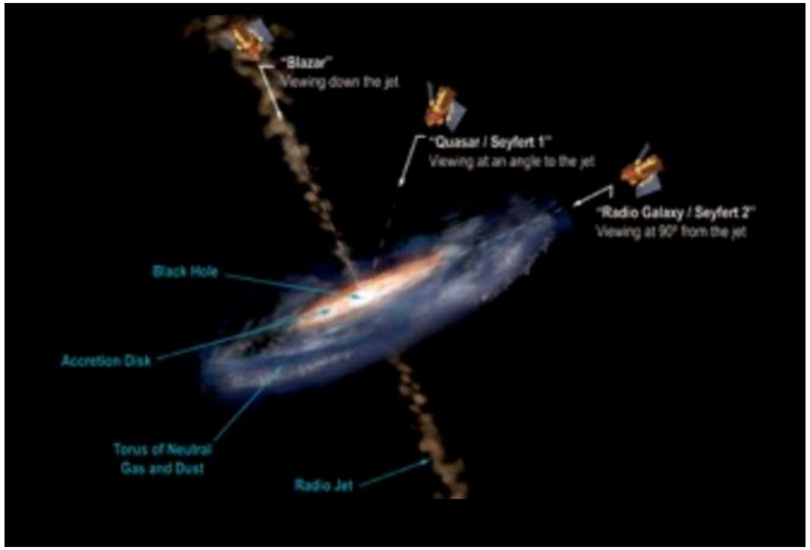
Fig. 10. Above: space density ρ vs redshift. The individual RLFs are each complete from $z = 1.0$ to $z = 5.5$ in steps of $\Delta z = 0.5$, in the order purple, brown, orange, dark red, light blue, turquoise, blue, green, red, grey. Below: these RLFs normalized to agree over the range at $1.0 < z < 2.5$. The bold black line is a least-squares fit with a polynomial of fifth order, given in the text. The grey lines represent 1000 bootstrap trials. In this process, fits which resulted in lines of positive slope beyond $z = 5$ were rejected.

The extragalactic radio frequency sky – 151 MHz

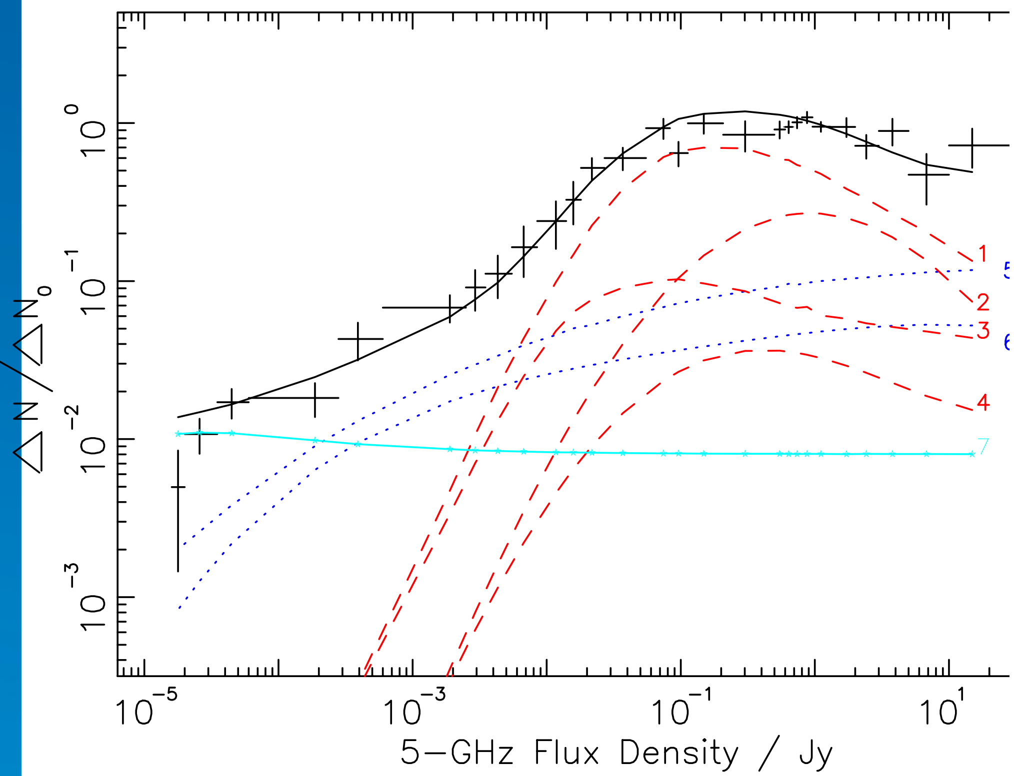


The extragalactic radio frequency sky – 5 GHz





The extragalactic radio frequency sky – 5 GHz

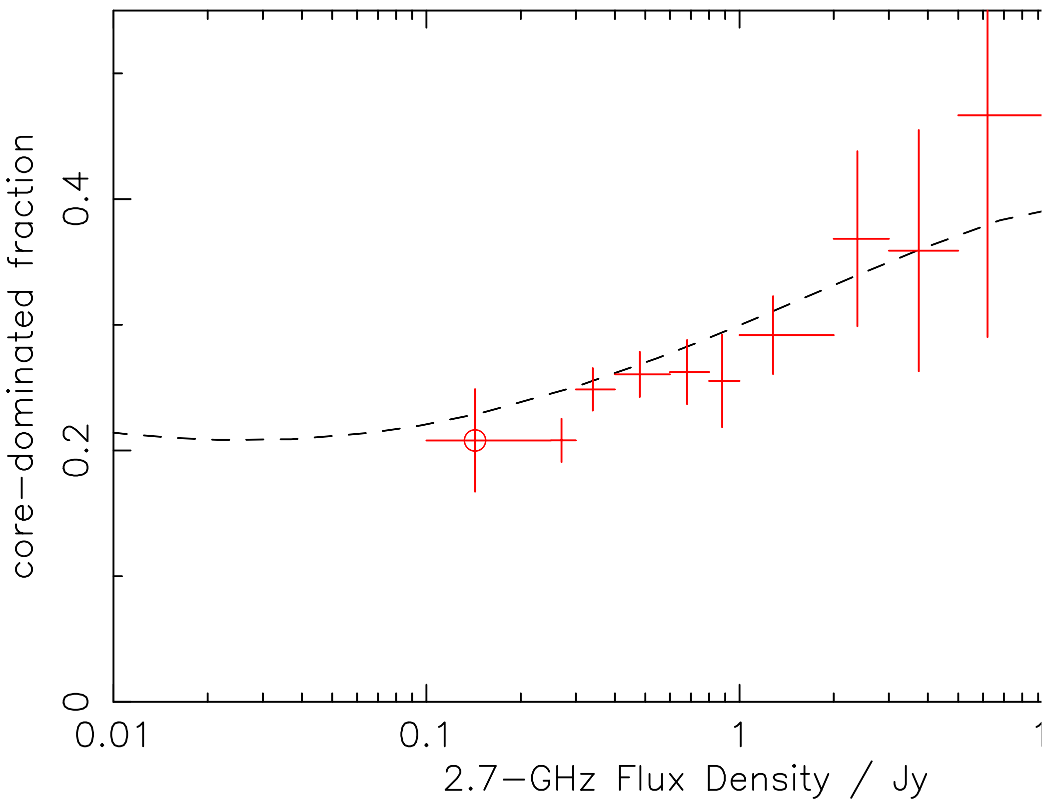


A "dual-population" unified scheme

- Can describe the radio source counts
- Can produce 'testable predictions'
- Predicts *population-specific N(z)'s*

Wall & Jackson (1997)
Jackson & Wall (1999)

2.7 GHz: *increasing* Quasar fractions



... as "surprising" evidence for a (our) unified scheme!

(Jackson & Wall 1996)

THE UNIVERSITY OF
SYDNEY

1997 - 1999

Australian
National
University

1999 - 2003

CSIRO

PAF, ASKAP

SKA
SQUARE KILOMETRE ARRAY
DISH

2003 - 2013

CSIRO PUBLISHING

Publications of the Astronomical Society of Australia, 2007, **24**, 174–188 www.publish.csiro.au/journals/pasa

Science with the Australian Square Kilometre Array Pathfinder

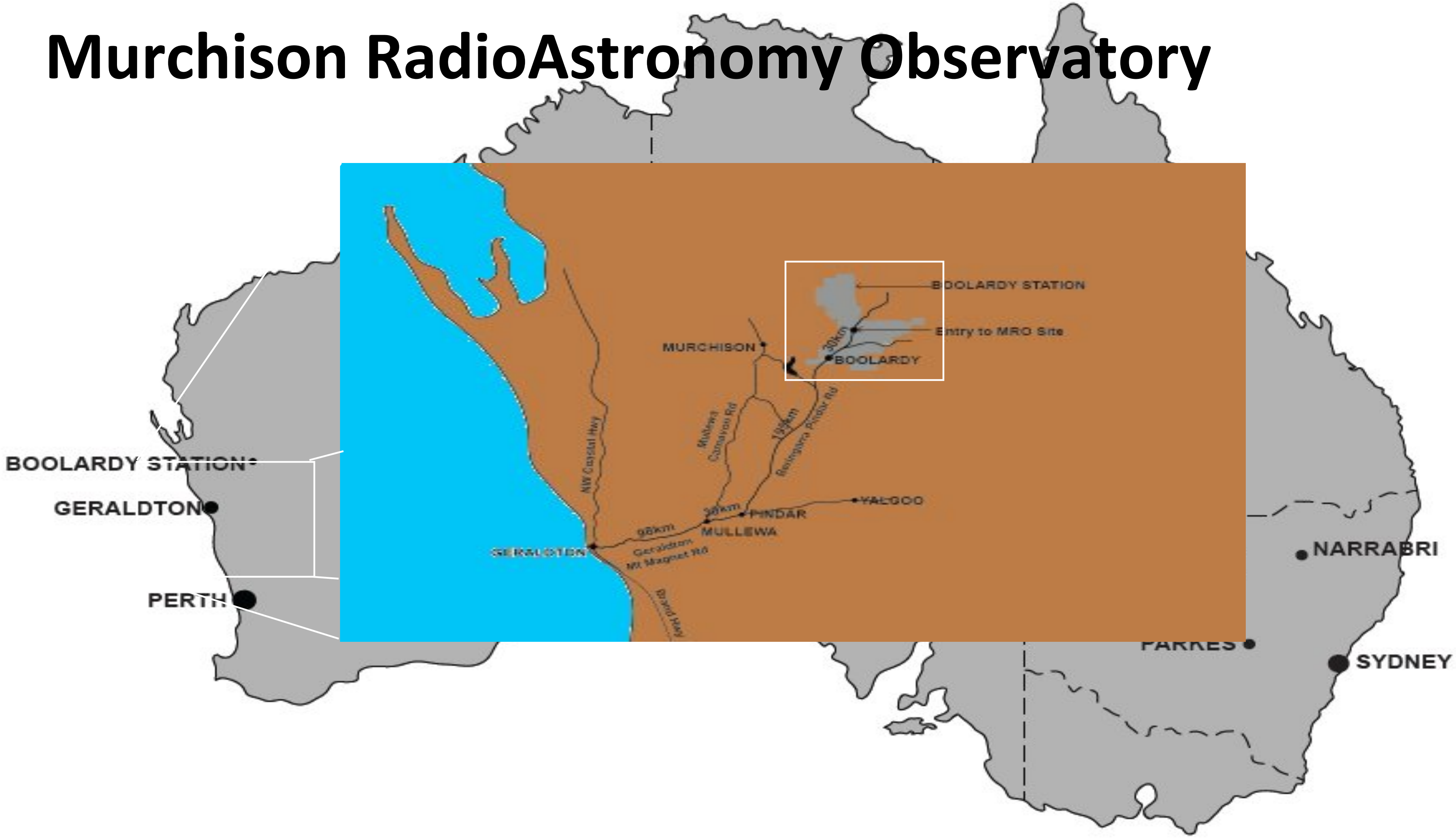
S. Johnston[A,X], *M. Bailes*[B], *N. Bartel*[C], *C. Baugh*[D], *M. Bietenholz*[C,W], *C. Blake*[B], *R. Braun*[A], *J. Brown*[E], *S. Chatterjee*[F], *J. Darling*[G], *A. Deller*[B], *R. Dodson*[H], *P. G. Edwards*[A], *R. Ekers*[A], *S. Ellingsen*[I], *I. Feain*[A], *B. M. Gaensler*[F], *M. Haverkorn*[J], *G. Hobbs*[A], *A. Hopkins*[F], *C. Jackson*[A], *C. James*[K], *G. Joncas*[L], *V. Kaspi*[M], *V. Kilborn*[B], *B. Koribalski*[A], *R. Kothes*[E], *T. L. Landecker*[N], *E. Lenc*[B], *J. Lovell*[I], *J.-P. Macquart*[O], *R. Manchester*[A], *D. Matthews*[P], *N. M. McClure-Griffiths*[A], *R. Norris*[A], *U.-L. Pen*[Q], *C. Phillips*[A], *C. Power*[B], *R. Protheroe*[K], *E. Sadler*[F], *B. Schmidt*[R], *I. Stairs*[S], *L. Staveley-Smith*[T], *J. Stil*[E], *R. Taylor*[E], *S. Tingay*[U], *A. Tzioumis*[A], *M. Walker*[V], *J. Wall*[S], *and M. Wolleben*[N]

EMU: Evolutionary Map of the Universe

Ray P. Norris[1], *A. M. Hopkins*[2,36], *J. Afonso*[3], *S. Brown*[1], *J. J. Condon*[4], *L. Dunne*[5], *I. Feain*[1], *R. Hollow*[1], *M. Jarvis*[6,38], *M. Johnston-Hollitt*[7], *E. Lenc*[1], *E. Middelberg*[8], *P. Padovani*[9], *I. Prandoni*[10], *L. Rudnick*[11], *N. Seymour*[12], *G. Umana*[13], *H. Andernach*[14], *D. M. Alexander*[21], *P. N. Appleton*[15], *D.Bacon*[16], *J. Banfield*[1], *W. Becker*[17], *M. J. I. Brown*[18], *P. Ciliegi*[19], *C. Jackson*[1], *S. Eales*[20], *A. C. Edge*[21], *B.M. Gaensler*[22,36], *G. Giovannini*[10], *C. A. Hales*[1,22], *P. Hancock*[22,36], *M.Y.Huynh*[23], *E. Ibar*[24], *R. J. Ivison*[24,25], *R. Kennicutt*[26], *Amy E. Kimball*[4], *A. M. Koekemoer*[27], *B. S. Koribalski*[1], *Á. R. López-Sánchez*[2,37], *M. Y. Mao*[1,2,28], *T. Murphy*[22,36], *H. Messias*[29], *K. A. Pimbblet*[18], *A. Raccanelli*[16], *K. E. Randall*[1,22], *T. H. Reiprich*[30], *I. G. Roseboom*[31] *H. Röttgering*[32], *D.J. Saikia*[33], *R.G.Sharp*[34], *O.B.Slee*[1], *Ian Smail*[21], *M. A. Thompson*[6], *J. S. Urquhart*[1], *J. V. Wall*[35], *G.-B. Zhao*[16]


Murchison Radio-Astronomy Observatory (MRO)
S26° 42′ 15″, E116° 39′ 32″
Perth

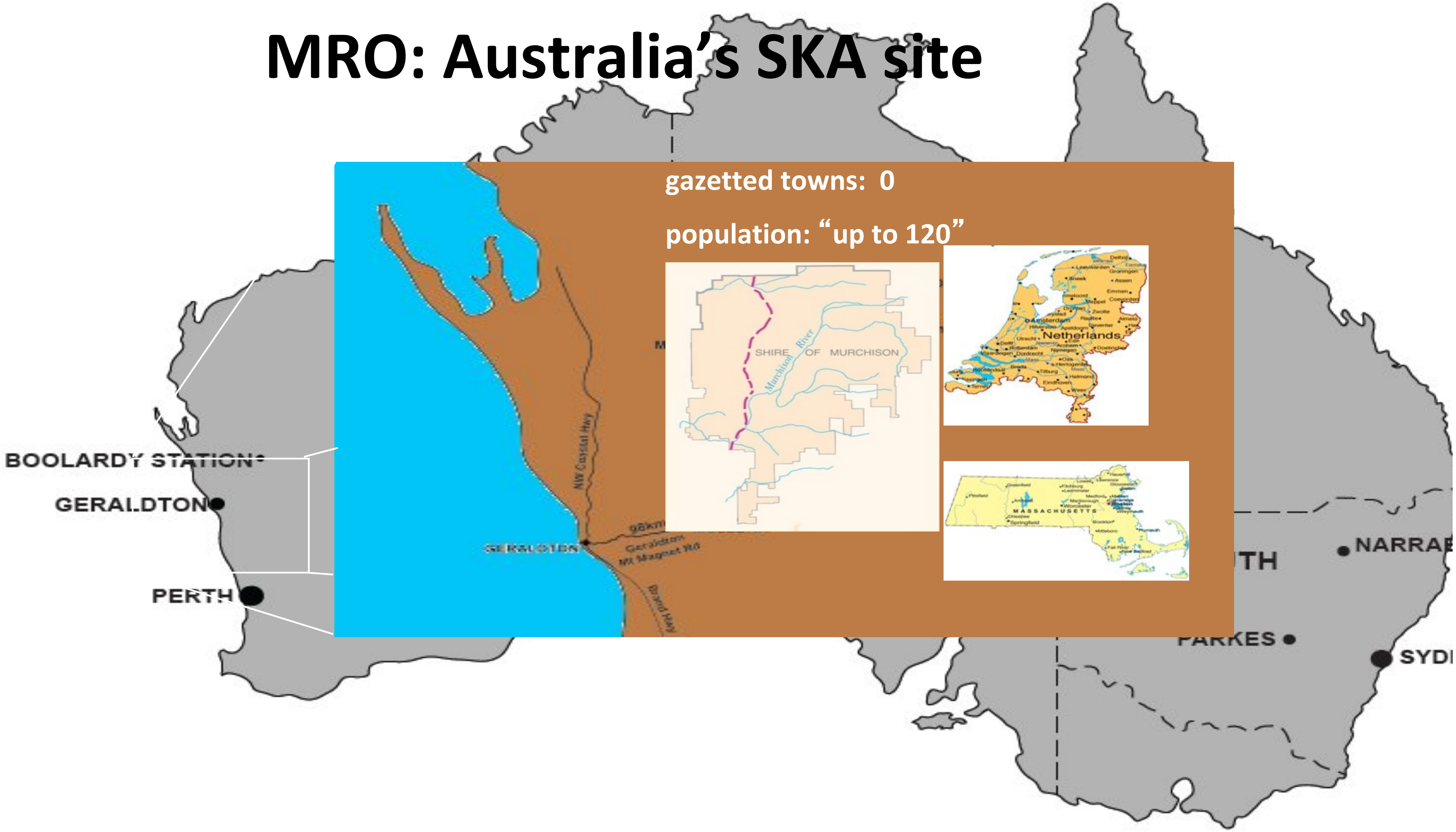
Murchison RadioAstronomy Observatory



MRO: Australia’s SKA site

gazetted towns: 0

population: “up to 120”



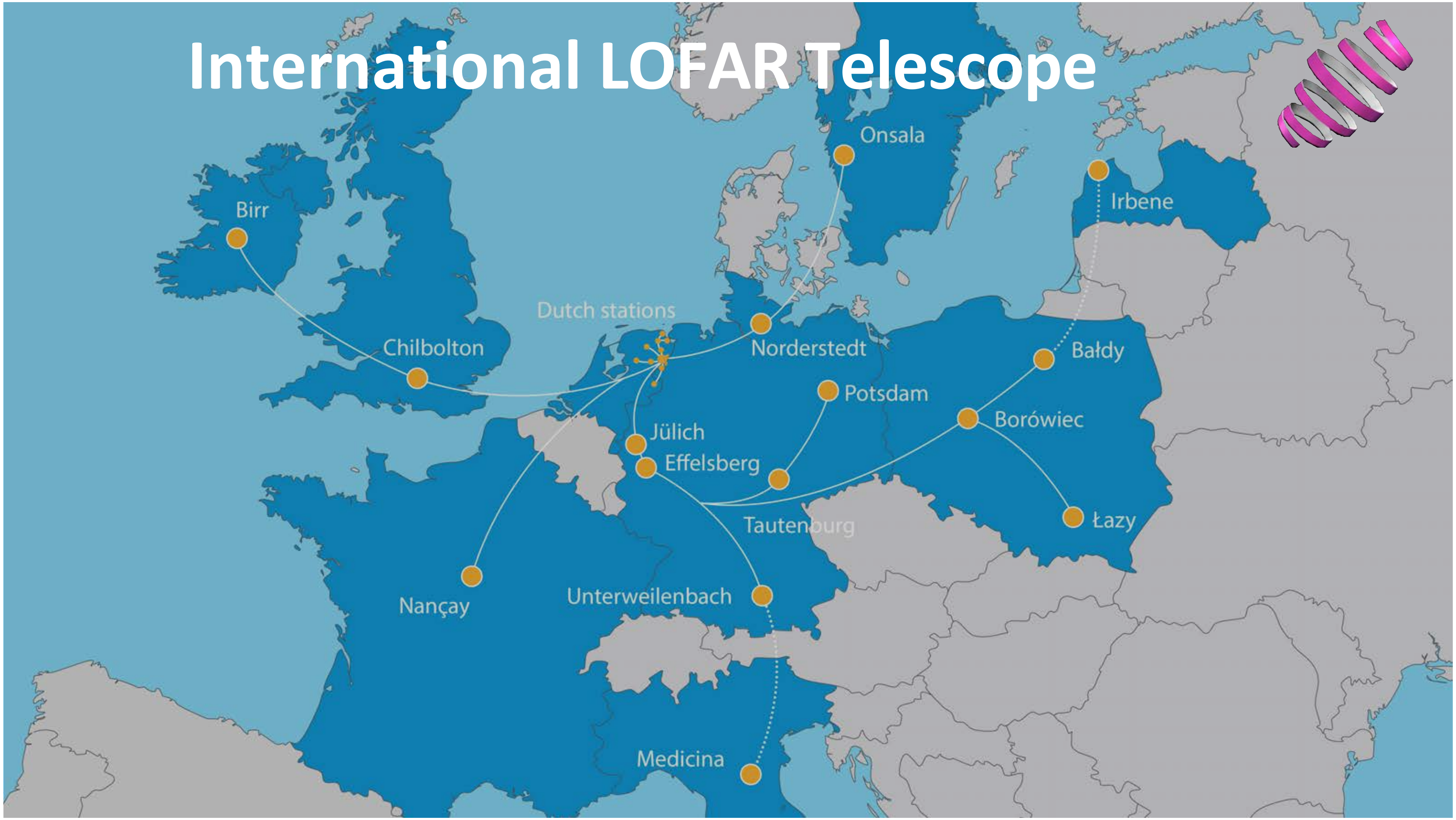
Murchison Widefield Array (MWA)

- World's first **operational** **SKA precursor** (August 2013)
- Managed & operated by Curtin University
- 128 tiles*2 (Area~2750 m^2 at 150 MHz) – 16 dipoles per tile
- Frequency range 72 MHz - 300 MHz (30 MHz BW)
- Maximum baseline 3 km -> 5km
- MWA System description

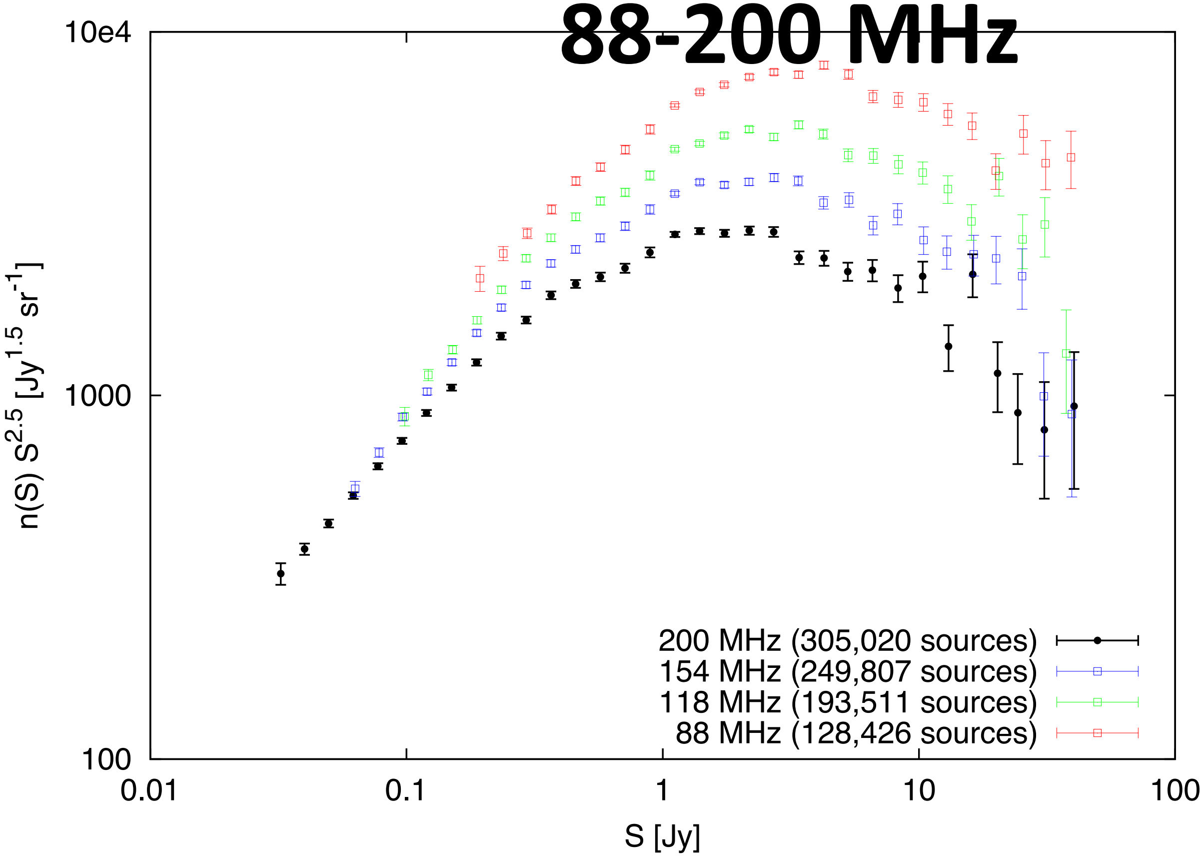
  Tingay et al. PASA, 2013

LOFAR 1.0, core @ Exloo

International LOFAR Telescope



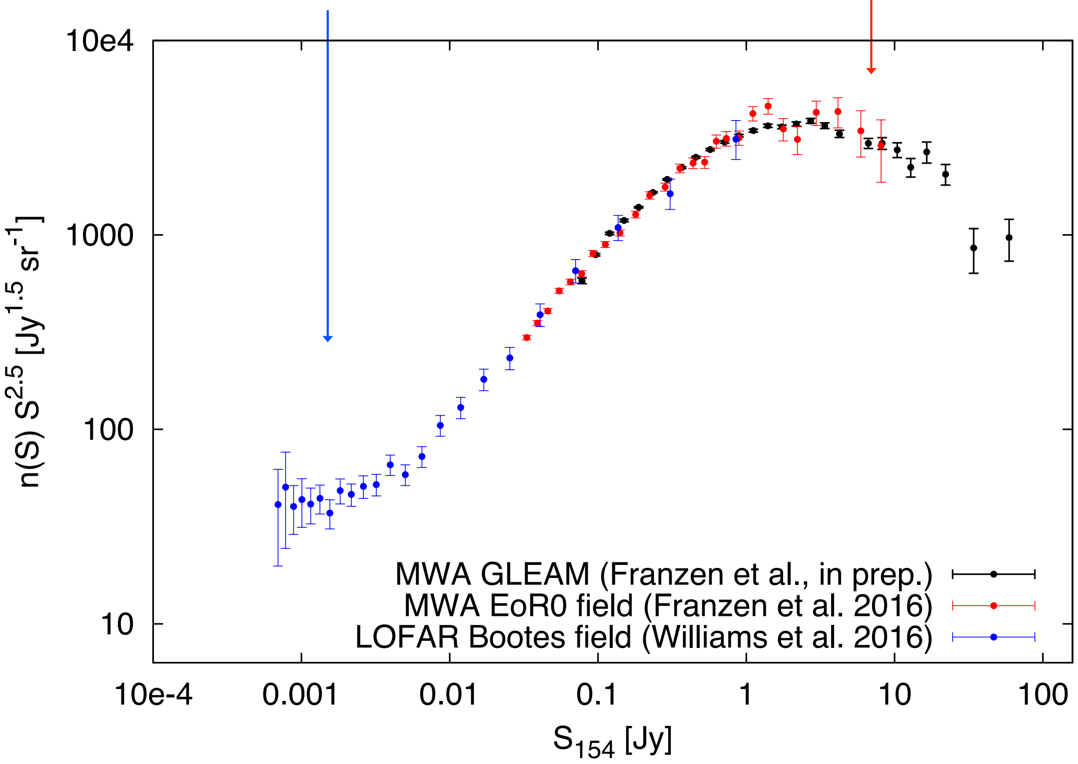
MWA GLEAM multi-frequency counts 88-200 MHz



The deep 154 MHz radio source sky

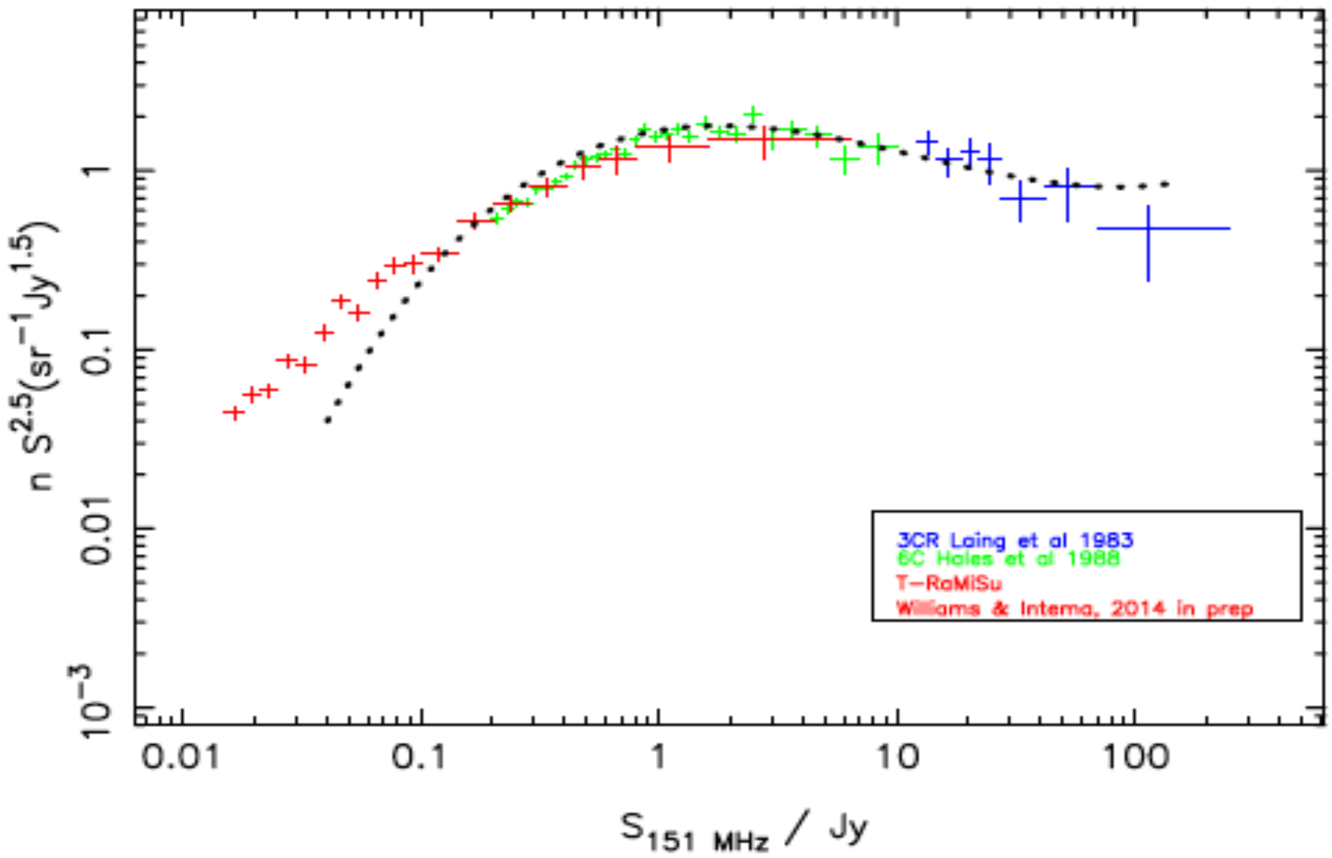
LOFAR counts

MWA counts



and far deeper to come…
LOFAR EOR fields
(1000 hr+, 120-168 MHz
10 μJy/beam
)

Radio source counts @ low radio-frequencies !



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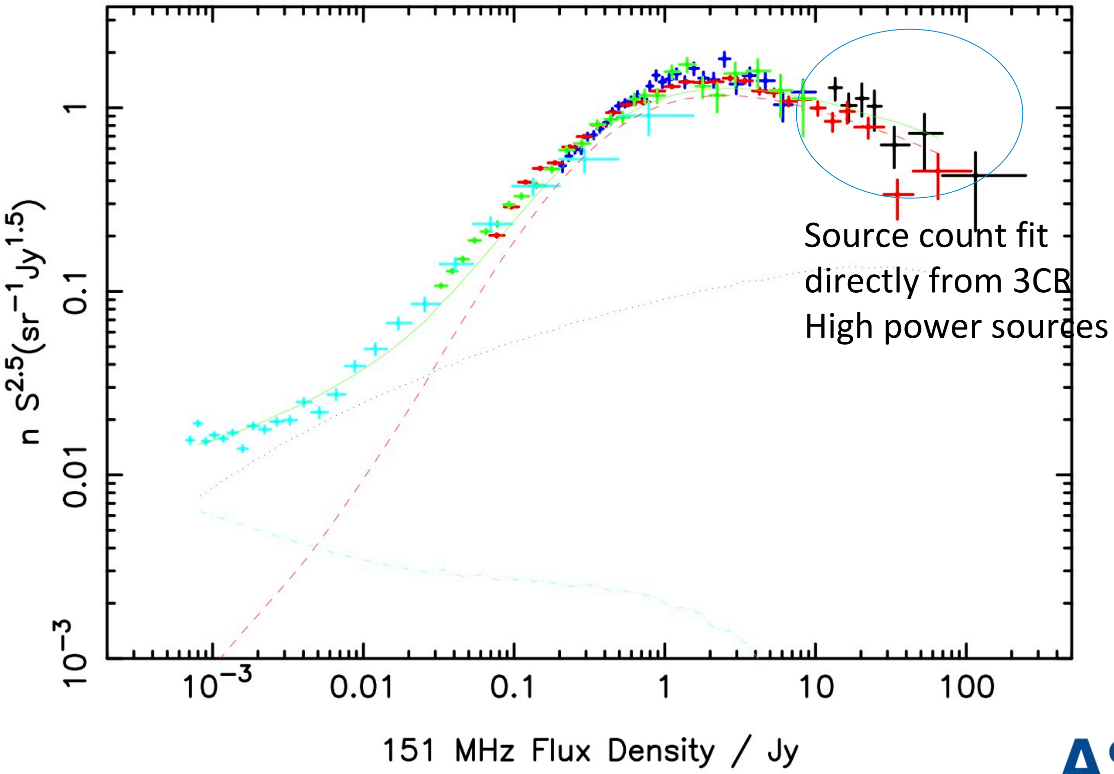
Radio source counts @ low radio-frequencies



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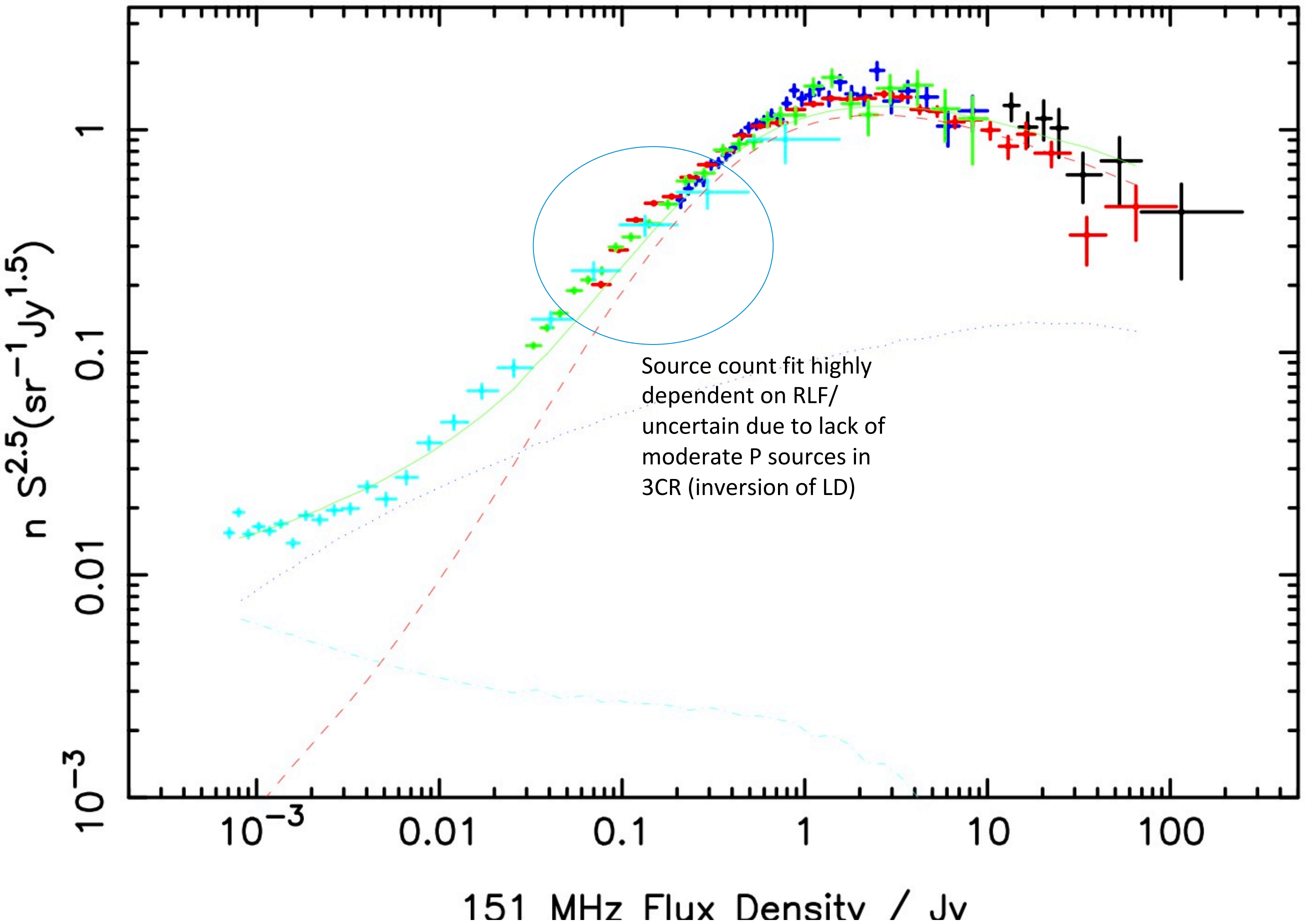
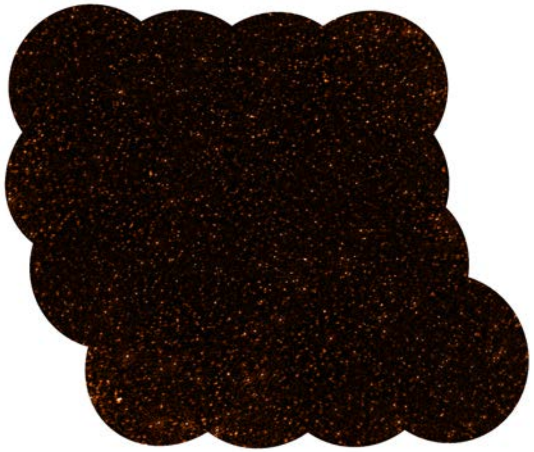
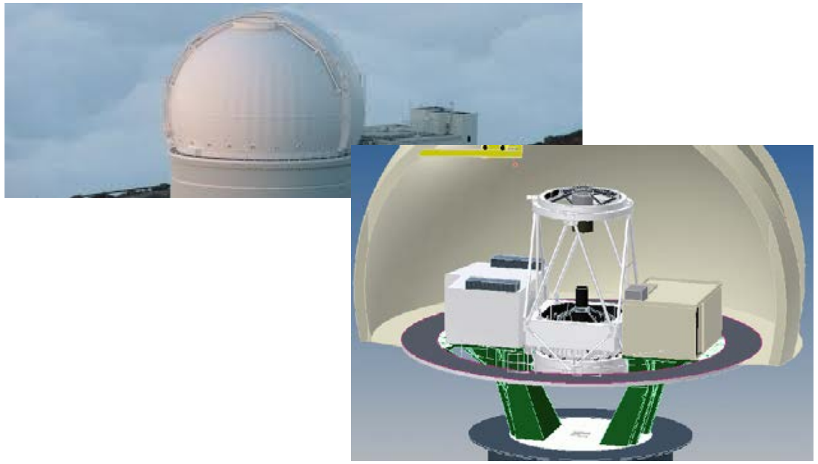
Radio source counts @ low radio-frequencies



LOFAR + deep optical redshift surveys





- LOFAR target sources for 4.2m WHT WEAVE MOS

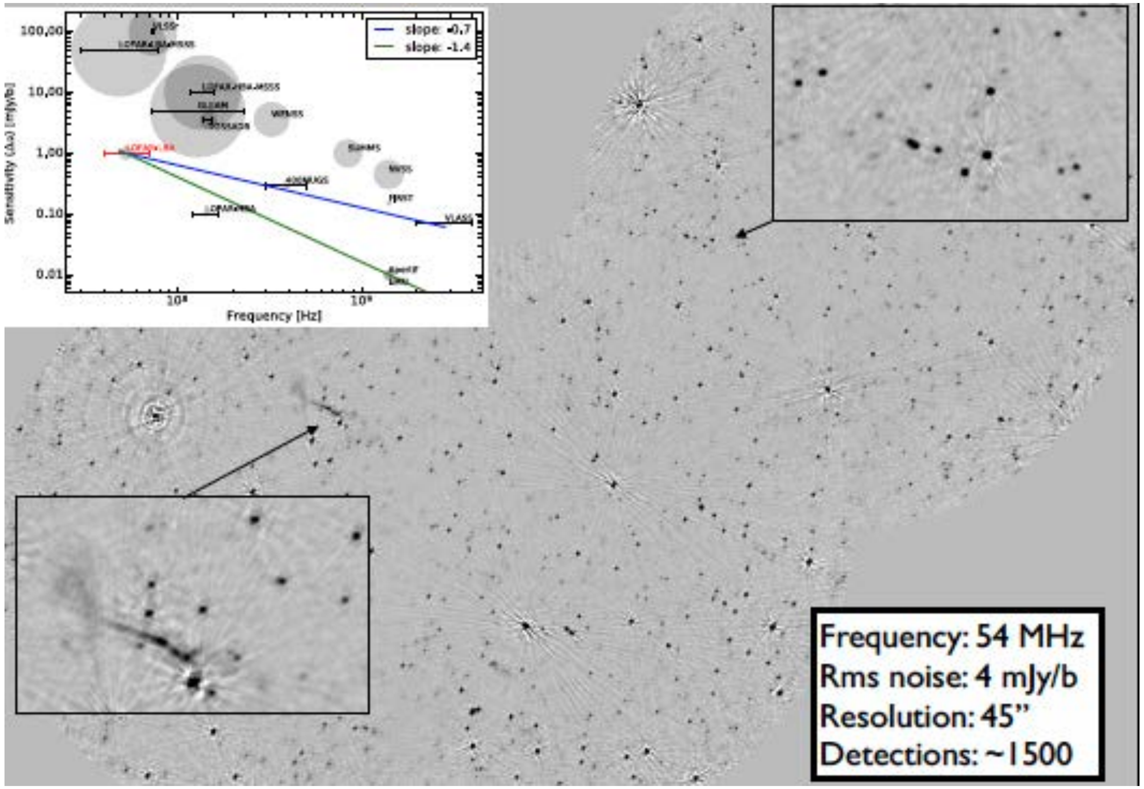
- Expect > 1 million spectra of radio sources during 5 years of WEAVE observations

- No magnitude or colour selection -> fully representative view of the SFG and AGN populations
(“approaching 100% complete for z<1”)

LOFAR, deep surveys and the future

LOFAR LBA upgrade

LBA pilot survey
Mosaic 54 MHz



de Gasperin et al

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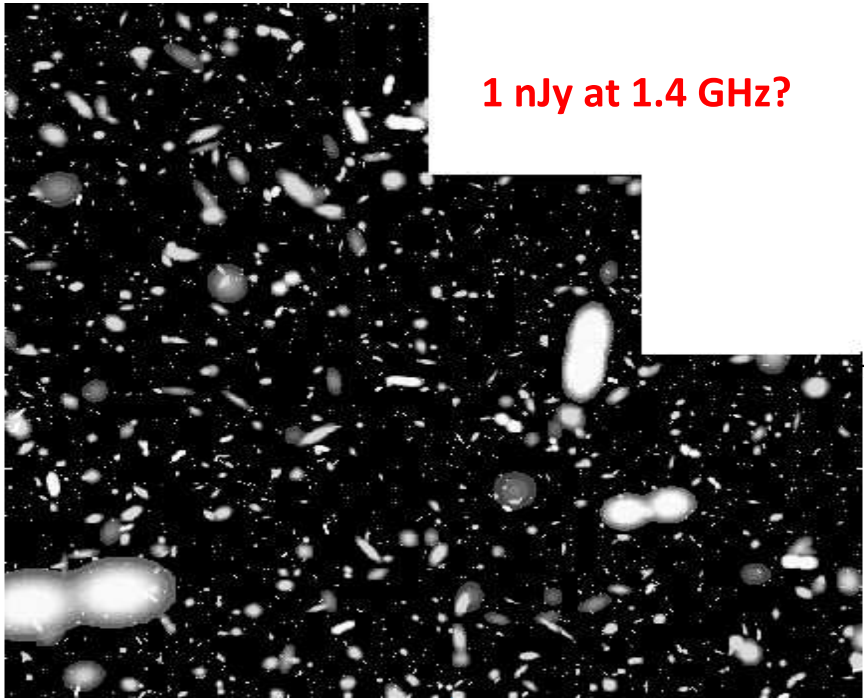
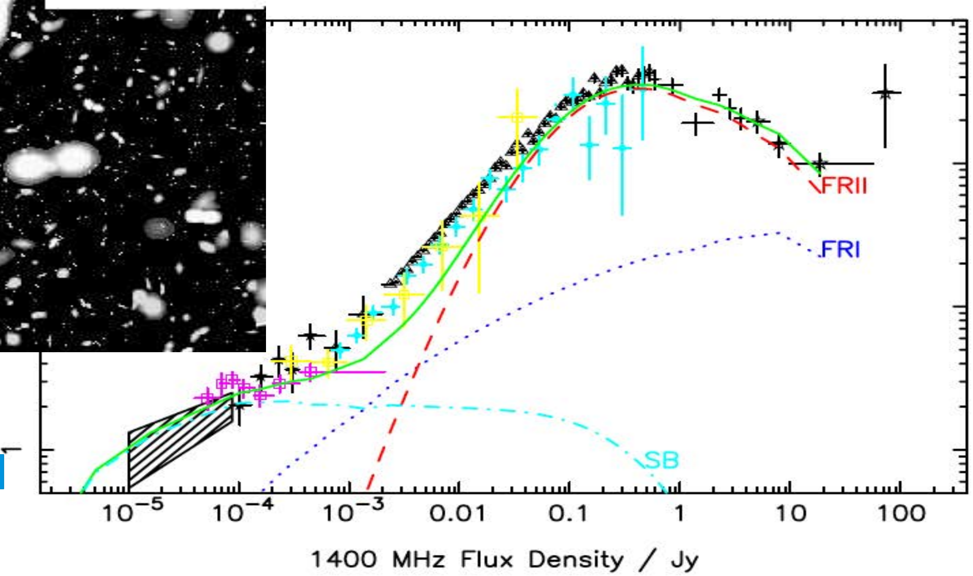
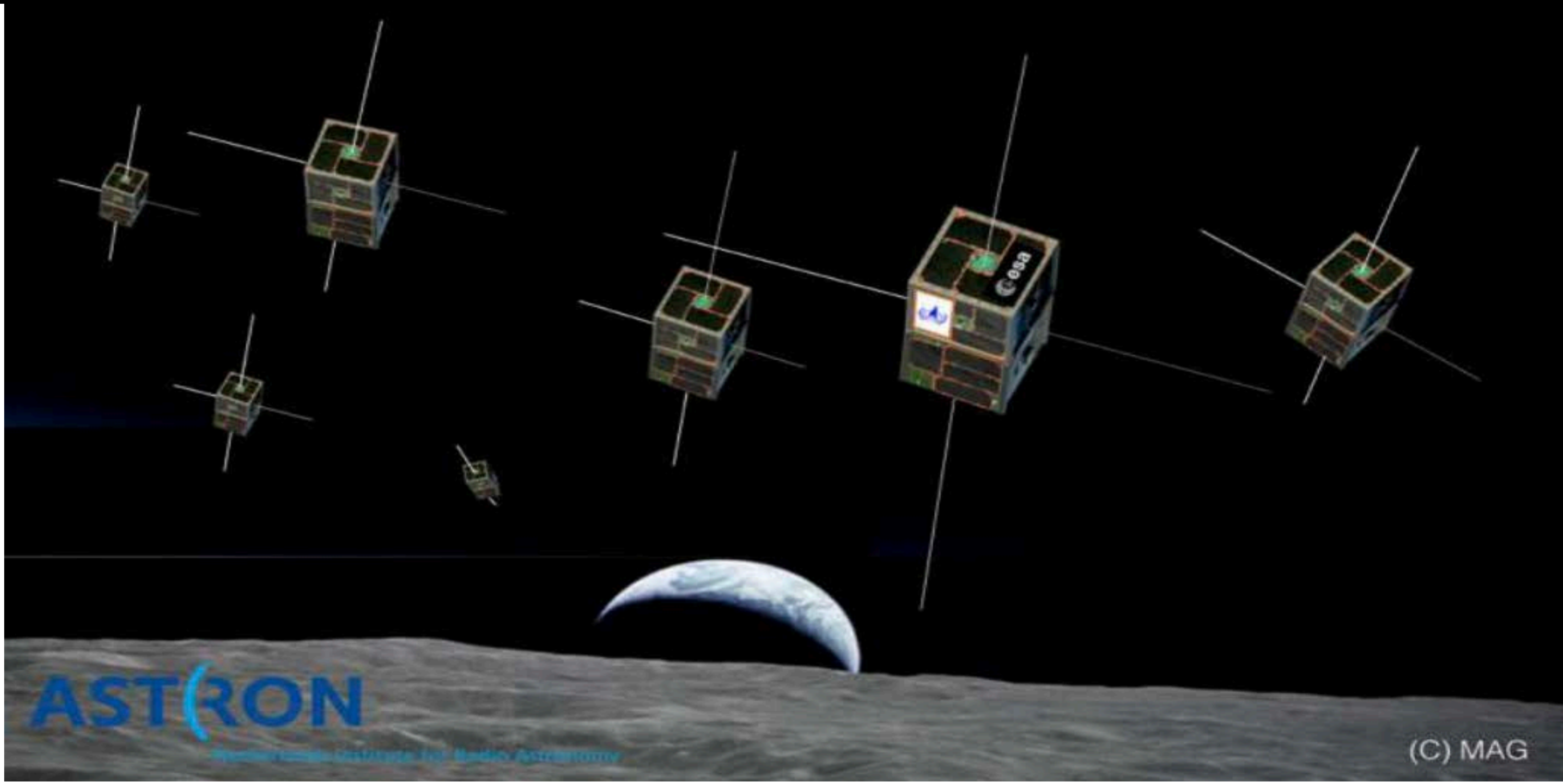
The SKA extragalactic sky at 1 GHz

1 nJy at 1.4 GHz?





Low Frequency Radio Space Missions



CHANG'E4, NCLE

ESA Netherlands-China low frequency Explorer

Pathfinder for Dark Age/Cosmic Dawn HI – 1 – 80 MHz

ASTRON – antenna + receiver system (with Radboud + ISIS)

Launch 22 May 2018 - first low frequency radio telescope in space (L2)