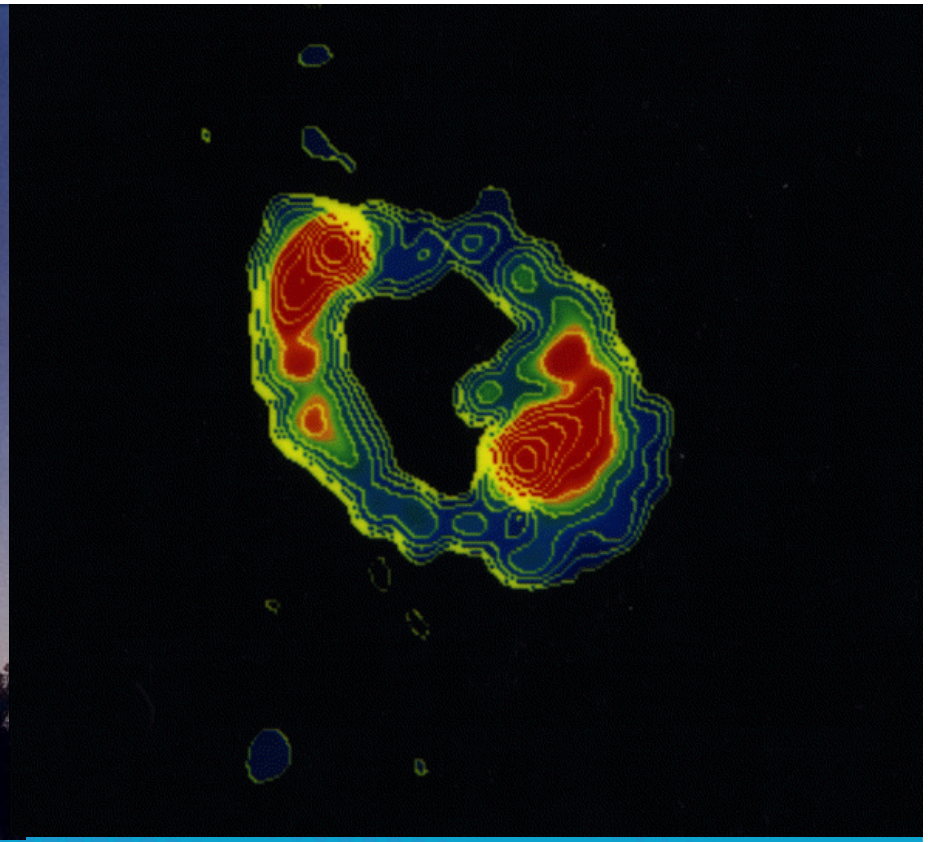

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The RAS protected bands and use by RA

Tasso Tzioumis *(Tasso.Tzioumis@csiro.au)*
Australia Telescope National Facility (ATNF)
CSIRO Astronomy and Space Science

SMS2014– Santiago **7-11 April 2014**

Scope

- Allocations Table
- RAS Allocations
  - Extent
- Footnote 5.340
- Footnote 5.149
- Telescope use
- Wide-band receivers
- SKA 70 MHz – 25 GHz !! - RQZ

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References

- Radio Regulations Volume 1 - ITU-R
- Radio Astronomy Handbook - ITU-R
  - Background and summaries
- CRAF Handbook for Frequency Management
  CRAF Handbook for Radio Astronomy (3rd edition)
  - Available free online at http://www.craf.eu/pub.htm
- CORF
- **Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses**
  - Available free online at
  - http://www.nap.edu/catalog.php?record_id=11719

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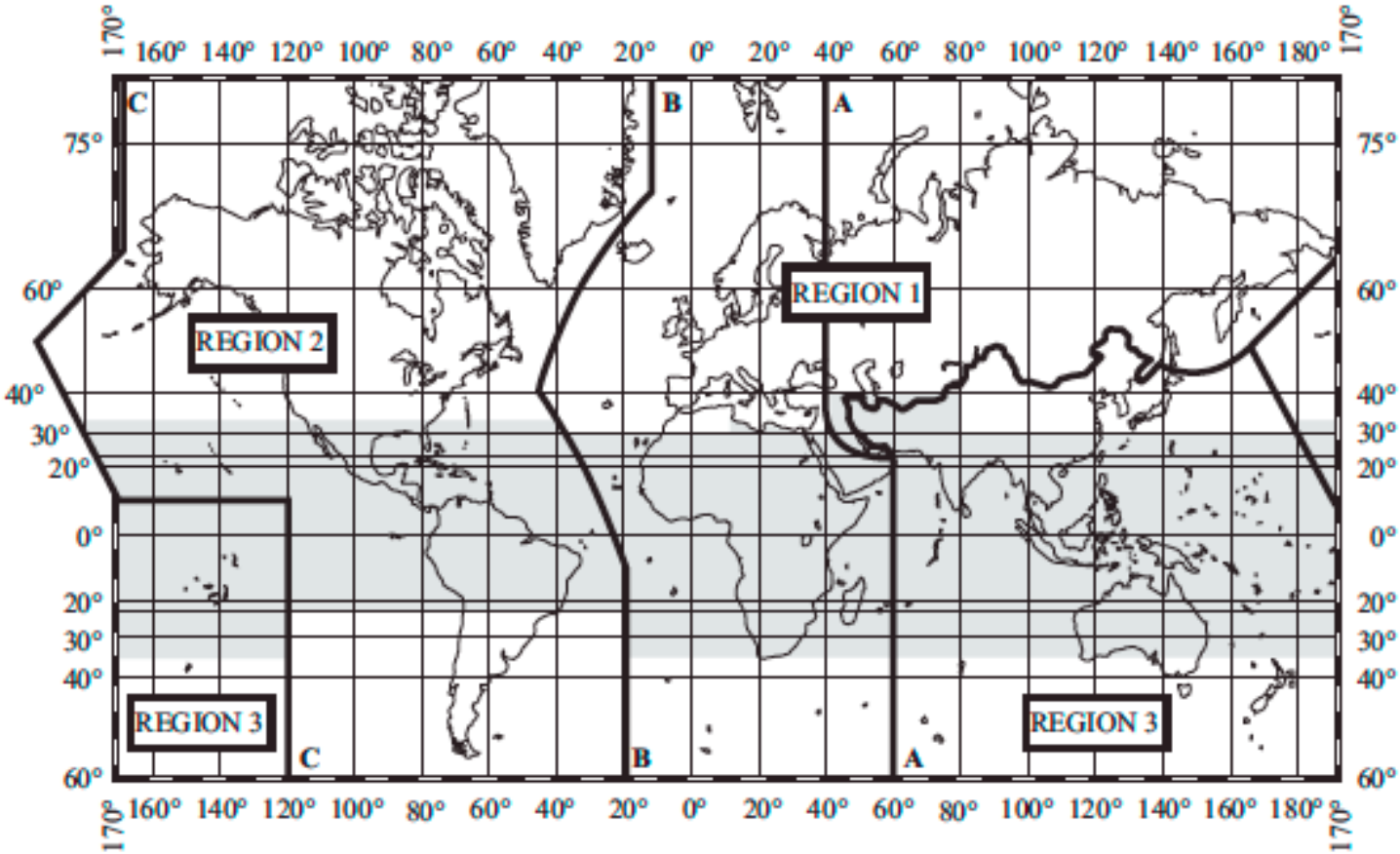
ITU regions


REGION 1
REGION 2
REGION 3
REGION 3
A
B
C
A
B
C
170° 160° 140° 120° 100° 80° 60° 40° 20° 0° 20° 40° 60° 80° 100° 120° 140° 160° 180° 170°
75° 60° 40° 30° 20° 0° 20° 30° 40° 60°

Allocations Table - Article 5 - Example

1 300-1 525 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
1 300-1 350	AERONAUTICAL RADIONAVIGATION 5.337 RADIOLOCATION RADIONAVIGATION-SATELLITE (Earth-to-space) 5.149 5.337A	
1 350-1 400 FIXED MOBILE RADIOLOCATION 5.149 5.338 5.338A 5.339	**1 350-1 400** RADIOLOCATION 5.338A RAS footnote ↓ 5.149 5.334 5.339	
1 400-1 427	EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY ←Primary RAS allocation SPACE RESEARCH (passive) 5.340 5.341 ← Footnotes relevant to RAS	
1 427-1 429	SPACE OPERATION (Earth-to-space) FIXED MOBILE except aeronautical mobile 5.338A 5.341	

- Co-primary allocations; Adjacent bands; OoB emissions

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Where are the RA bands ?

SUMMARY TABLE:

Frequency Bands(MHz)	Frequency Bands(GHz)
13.360 – 13.410	10.6 – 10.7
25.550 – 25.670	14.47 – 14.50 (H_2CO)
37.5 – 38.25	15.35 – 15.4
73 – 74.6	22.21– 22.50 (H_2O)
150.05 – 153	23.6 – 24.0 (NH_3)
322 – 328.6	31.3 – 31.8
406.1 – 410	42.5 – 43.5 (SiO)
608 – 614	76 – 116
1 400 – 1 427 (HI)	123 – 158.5
1 610.6 - 1 613.8 (OH)	164 – 167
1 660 – 1 670 (OH)	200 – 231.5
2 655 – 2 700	241 – 275
4 800 – 5 000 (H_2CO)	

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Details of RAS Allocations – from RAS Handbook

Frequency range (MHz) (1)	Status (2)	Comments (3)
13.36-13.41	P	
25.55-25.67	P (Pas)	
37.50-38.25	s	
73.00-74.60	P	Region 2
150.05-153.00	P	Region 1, Australia, India
225.00-235.00	s	China (RR No.5.250)
322.00-328.60	P	Deuterium line
406.10-410.00	P	
606.00-608.00	P	China and the African broadcasting area
608.00-614.00	P s	Region 2, China, India, and the African broadcasting area Regions 1 (except the African broadcasting area) and 3
1 400.00-1 427.00	P (Pas)	Hydrogen line
1 610.60-1 613.80	P	OH line
1 660.00-1 670.00	P	OH lines
1 718.80-1 722.20	s	OH line
2 655.00-2 690.00	s	
2 690.00-2 700.00	P (Pas)	
4 800.00-4 990.00	s	H_2CO line; 4 825-4 835 MHz and 4 950-4 990 MHz are primary in Argentina, Australia and Canada (RR No.5.443)
4 990.00-5 000.00	P	

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Frequency range (GHz) (1)	Status (2)	Comments (3)
10.60-10.68	P	
10.68-10.70	P (Pas)	
14.47-14.50	s	H_2CO lines
15.35-15.40	P (Pas)	
22.21-22.50	P	H_2O lines
23.60-24.00	P (Pas)	NH_3 lines
31.30-31.50	P (Pas)	
31.50-31.80	P	Passive (Pas) in Region 2
42.50-43.50	P	SiO lines
48.94-49.04	P	CS line
76.00-77.50	P	
77.50-79.00	s	
79.00-86.00	P	
86.00-92.00	P (Pas)	SiO lines
92.00-94.00	P	N_2H^+ line
94.00-94.10	s	
94.10-100.00	P	CS line
100.00-102.00	P (Pas)	
102.00-109.50	P	

109.50-111.80	P (Pas)	CO lines
111.80-114.25	P	CO line
114.25-116.00	P (Pas)	CO line
123.00-130.00	s P	Korea (128-130 GHz, SiO lines) RR No.5.562D
130.00-134.00	P	
134.00-136.00		
136.00-148.50	P	CS line
148.50-151.50	P (Pas)	
151.50-158.50	P	
164.00-167.00	P (Pas)	
171.00-171.60, 172.20-172.80 173.30-174.00	P	Korea RR No.5.562D
182.00-185.00	P (Pas)	H_2O line
200.00-209.00	P (Pas)	
209.00-226.00	P	CO lines
226.00-231.50	P (Pas)	CO line
241.00-248.00	P	CS lines
248.00-250.00	s	
250.00-252.00	P (Pas)	
252.00-275.00	P	HCN, HCO^+ lines

RAS Allocations notes

- Usual mixture of Primary (P) and Secondary (S) allocations
  - May vary between ITU-R regions
- Most adjacent bands are allocated to active services
  - No margin of protection
  - Out of band emissions from adjacent or even distant bands
- Other co-primary allocations
  - Sometimes with active services
- Passive primary bands P(passive)
  - Allocations only to passive services
  - All emissions are prohibited! Footnote 5.340
  - But difficult to protect in practice.. What level is “no emission”?

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Footnote 5.340 – No emissions – Passive bands

5.340 All emissions are prohibited in the following bands:

1 400-1 427 MHz,	
2 690-2 700 MHz,	except those provided for by No. **5.422**,
10.68-10.7 GHz,	except those provided for by No. **5.483**,
15.35-15.4 GHz,	except those provided for by No. **5.511**,
23.6-24 GHz,	
31.3-31.5 GHz,	
31.5-31.8 GHz,	in Region 2,
48.94-49.04 GHz,	from airborne stations
50.2-50.4 GHz[2],	
52.6-54.25 GHz,	
86-92 GHz,	
100-102 GHz,	
109.5-111.8 GHz,	
114.25-116 GHz,	
148.5-151.5 GHz,	
164-167 GHz,	
182-185 GHz,	
190-191.8 GHz,	
200-209 GHz,	
226-231.5 GHz,	
250-252 GHz. (WRC-03)	

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RAS Allocation Summary

- **< 30 GHz:**
  - 1.3% primary exclusive for passive frequency use
  - 1.2% primary shared allocations
  - 0.5% secondary allocations

- **30 - 275 GHz:**
  - 16.8% primary exclusive for passive frequency use
  - 38.3% primary shared allocations
  - 5.1% secondary allocations

- **All frequency bands <275 GHz:**
  - 15.1% primary exclusive for passive frequency use
  - 34.2% primary shared allocations
  - 4.6% secondary allocations

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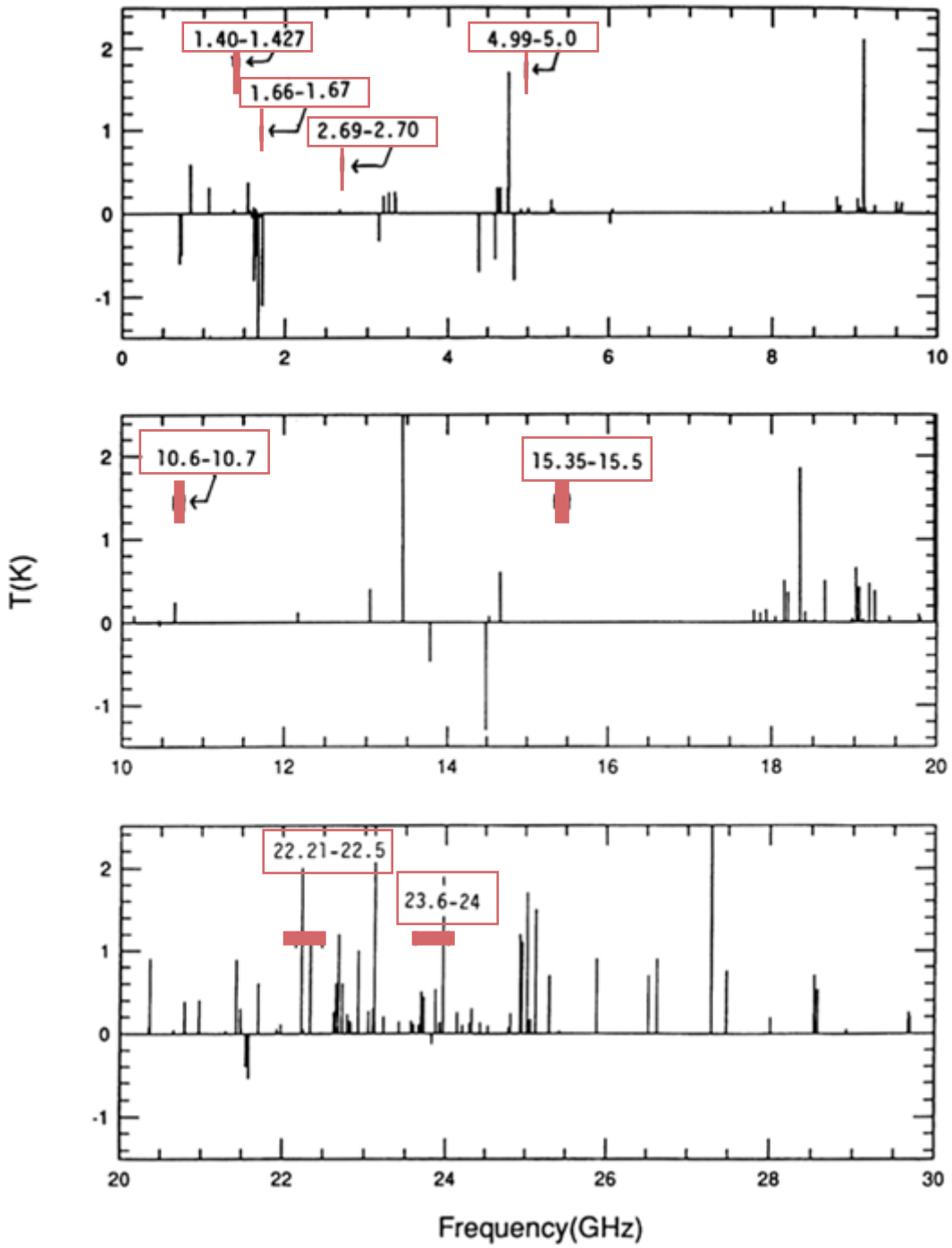
ITU RAS Spectrum - cm wavelengths



- In the metre and cm band <1% is allocated to radio astronomy!
- Need frequency coverage for redshifted lines
- Need bandwidth for continuum sensitivity

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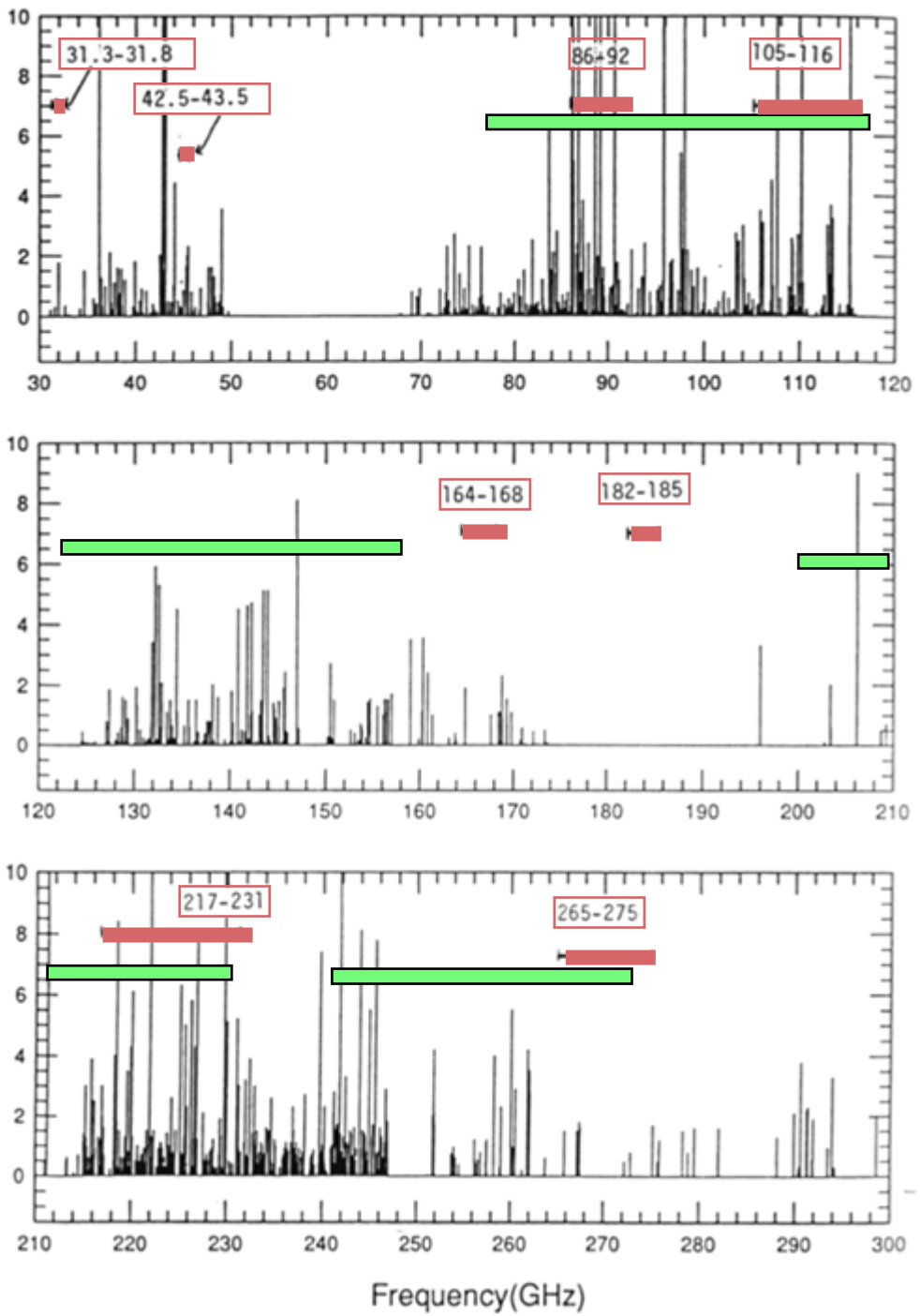
ITU RAS Spectrum - mm wavelengths



- In the mm band the situation is better
- But old allocations were not at best frequency
- WRC-2000 changes to allocations above 71GHz were a great improvement

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Recommendation RA.314 – Preferred bands

Radio-frequency lines of the greatest importance to radio astronomy at frequencies below 275 GHz

Substance	Rest frequency	Suggested minimum band	Notes[1]
Deuterium (DI)	327.384 MHz	327.0-327.7 MHz	
Hydrogen (HI)	1 420.406 MHz	1 370.0-1 427.0 MHz	(2), (3)
Hydroxyl radical (OH)	1 612.231 MHz	1 606.8-1 613.8 MHz	(4)
Hydroxyl radical (OH)	1 665.402 MHz	1 659.8-1 667.1 MHz	(4)
Hydroxyl radical (OH)	1 667.359 MHz	1 661.8-1 669.0 MHz	(4)
Hydroxyl radical (OH)	1 720.530 MHz	1 714.8-1 722.2 MHz	(3), (4)
Methyladyne (CH)	3 263.794 MHz	3 252.9-3 267.1 MHz	(3), (4)
Methyladyne (CH)	3 335.481 MHz	3 324.4-3 338.8 MHz	(3), (4)
Methyladyne (CH)	3 349.193 MHz	3 338.0-3 352.5 MHz	(3), (4)
Formaldehyde (H_2CO)	4 829.660 MHz	4 813.6-4 834.5 MHz	(3), (4)
→ Methanol (CH_3OH)	6 668.518 MHz	6 661.8-6 675.2 MHz	(3)
Helium ($^3He^+$)	8 665.650 MHz	8 657.0-8 674.3 MHz	(3), (6)
Methanol (CH_3OH)	12.178 GHz	12.17-12.19 GHz	(3), (6)
Formaldehyde (H_2CO)	14.488 GHz	14.44-14.50 GHz	(3), (4)
Cyclopropenylidene (C_3H_2)	18.343 GHz	18.28-18.36 GHz	(3), (4), (6)
Water vapour (H_2O)	22.235 GHz	22.16-22.26 GHz	(3), (4)
Ammonia (NH_3)	23.694 GHz	23.61-23.71 GHz	(4)
Ammonia (NH_3)	23.723 GHz	23.64-23.74 GHz	(4)
Ammonia (NH_3)	23.870 GHz	23.79-23.89 GHz	(4)
Sulphur monoxide (SO)	30.002 GHz	29.97-30.03 GHz	(6)
Methanol (CH_3OH)	36.169 GHz	36.13-36.21 GHz	(6)
Silicon monoxide (SiO)	42.519 GHz	42.47-42.57 GHz	(6), (8)
Silicon monoxide (SiO)	42.821 GHz	42.77-42.86 GHz	
Silicon monoxide (SiO)	43.122 GHz	43.07-43.17 GHz	
Silicon monoxide (SiO)	43.424 GHz	43.37-43.47 GHz	
Dicarbon monosulphide (CCS)	45.379 GHz	45.33-45.44 GHz	(6)

- Only a small part of list …
- List under review

- Many thousands of lines.
- Many have no allocation

- Redshifted lines also cover most of rest of spectrum…

- especially at mm

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Footnote 5.149 – Care but no commitment?

5.149 In making assignments to stations of other services to which the bands:

13 360-13 410 kHz,
25 550-25 670 kHz,
37.5-38.25 MHz,
73-74.6 MHz in Regions 1 and 3,
150.05-153 MHz in Region 1,
322-328.6 MHz,
406.1-410 MHz,
608-614 MHz in Regions 1 and 3,
1 330-1 400 MHz,
1 610.6-1 613.8 MHz,
1 660-1 670 MHz,
1 718.8-1 722.2 MHz,
2 655-2 690 MHz,
3 260-3 267 MHz,
3 332-3 339 MHz,
3 345.8-3 352.5 MHz,
4 825-4 835 MHz,
4 950-4 990 MHz,
4 990-5 000 MHz,
6 650-6 675.2 MHz,
10.6-10.68 GHz,
14.47-14.5 GHz,
22.01-22.21 GHz,
22.21-22.5 GHz,
22.81-22.86 GHz,
23.07-23.12 GHz,
31.2-31.3 GHz,
31.5-31.8 GHz in Regions 1 and 3,
36.43-36.5 GHz,
42.5-43.5 GHz,
48.94-49.04 GHz,
76-86 GHz,
92-94 GHz,
94.1-100 GHz,
102-109.5 GHz,
111.8-114.25 GHz,
128.33-128.59 GHz,
129.23-129.49 GHz,
130-134 GHz,
136-148.5 GHz,
151.5-158.5 GHz,
168.59-168.93 GHz,
171.11-171.45 GHz,
172.31-172.65 GHz,
173.52-173.85 GHz,
195.75-196.15 GHz,
209-226 GHz,
241-250 GHz,
252-275 GHz

are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-07)

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Footnote 5.511F – Controversial?

511F (WRC-2012)

In order to protect the radio astronomy service in the frequency band 15.35–15.4 GHz, radiolocation stations operating in the frequency band 15.4–15.7 GHz shall not exceed the power flux-density level of −156 dB(W/m^2) in a 50 MHz bandwidth in the frequency band 15.35–15.4 GHz, at any radio astronomy observatory site for more than 2 per cent of the time.

- Controversy about the 2%
  - Still being debated!

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Footnote 5.565 – above 275 GHz (WRC-12)

5.565 *The following frequency bands in the range 275-1 000 GHz are identified for use by administrations for passive service applications:*

– *radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453-510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;*

– *Earth exploration-satellite service (passive) and space research service (passive): 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz, 657-692 GHz, 713-718 GHz, 729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968-973 GHz and 985-990 GHz.*

The use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services. Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range.

All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services. (WRC-12)

- 1-3 THz – New Recommendation RA.1860
- Above 3 THz – New area for ITU – IR/Optical

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National Allocations

Column 1: ITU Radio Regulations Table of Allocations			Column 2:
Region 1	Region 2	Region 3	Australian Table of Allocations
4 400 – 4 500	FIXED MOBILE 440A		**4 400 – 4 500** FIXED MOBILE 440A AUS67 AUS87 AUS101
4 500 – 4 800	FIXED FIXED–SATELLITE (space-to-Earth) 441 MOBILE 440A		**4 500 – 4 800** FIXED FIXED–SATELLITE (space-to-Earth) 441 MOBILE 440A AUS67 AUS87 AUS101
4 800 – 4 990	FIXED MOBILE 440A 442 Radio astronomy 149 339 443		**4 800 – 4 940** FIXED AUS101A MOBILE 440A AUS101A Radio astronomy 149 443 AUS67 AUS87
			4 940 – 4 990 FIXED AUS97 MOBILE 442 AUS97 Radio astronomy 149 339 443 AUS67 AUS87
4 990 – 5 000	FIXED MOBILE except aeronautical mobile RADIO ASTRONOMY Space research (passive) 149		**4 990 – 5 000** FIXED AUS101A MOBILE except aeronautical mobile AUS101A RADIO ASTRONOMY Space research (passive) 149 AUS67 AUS87

Footnote AUS87

- **AUS87**

Radio astronomy facilities operated by the CSIRO at the Paul Wild Observatory Narrabri (latitude 30° 18' 46.40" S, longitude 149° 33' 0.43" E), the Parkes Observatory (latitude 32° 59' 54.25" S, longitude 148° 15' 48.65" E), and the Mopra Observatory Coonabarabran (latitude 31° 15' 58.81" S, longitude 149° 6' 2.91" E) and by the University of Tasmania at the Mount Pleasant Observatory Hobart (latitude 42° 48' 7.53" S, longitude 147° 26' 30.76" E) and the Ceduna Observatory (latitude 31° 52' 3.68" S, longitude 133° 48' 40.34" E), and at the Canberra Deep Space Communication Complex (latitude 35° 23' 48.4" S, longitude 148° 58' 44.4" E) conduct passive observations in the frequency bands 1.2–1 . 8 GHz, 2.2–2.7 GHz, 4.5–6.7 GHz, 8–10 GHz and 16–26 GHz using receivers that are highly sensitive to interference. The Paul Wild and Mopra observatories also operate in the bands 30–50 GHz and 75–115 GHz.

Allocations and Protection

- Allocations do not automatically mean protection!!
  - Indicate permitted usage but more is needed in practice
- National allocations and licensing very important!!
  - E.g. in Australia – have to take “Receive licenses”
  - Small fees but listed in national database → legal protection
  - AUS87 provisions of “notification zones”
    - Can work well in practice – co-operative efforts
    - Recent example for Methanol lat 6.7 GHz & Transgrid
- National sovereignty jealously guarded
  - Can go against international allocations!
    - Provided no impact on neighbouring nations
- Radio quiet zones easiest in National context

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ITU Registration of RAS telescopes

- Only via National administration
- Include in ITU Master Frequency Register (MFR)
- Only accepts registration in allocated bands
- Can register national allocations outside RA bands under Article 4.4 (no interference; no protection)

- Important for increased visibility of RAS

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Band usage by actual radio-telescopes

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eVLA Bands – 1.2-50 GHz continuous coverage!

Table 8: Tuning Ranges of EVLA Bands

Band	Range	Final EVLA Receivers Available	
		June 2009	December 2009
20 cm (L)	1.2 - 2.0 GHz	3	7
13 cm (S)	2.0 - 4.0 GHz	4	7
6 cm (C)	4.0 - 8.0 GHz	11	17
3 cm (X)	8.0 - 12.0 GHz	0	0
2 cm (U)	12.0 - 18.0 GHz	1	2
1.3 cm (K)	18.0 - 26.5 GHz	22	22
1 cm (Ka)	26.5 - 40.0 GHz	15	21
0.7 cm (Q)	40.0 - 50.0 GHz	22	22

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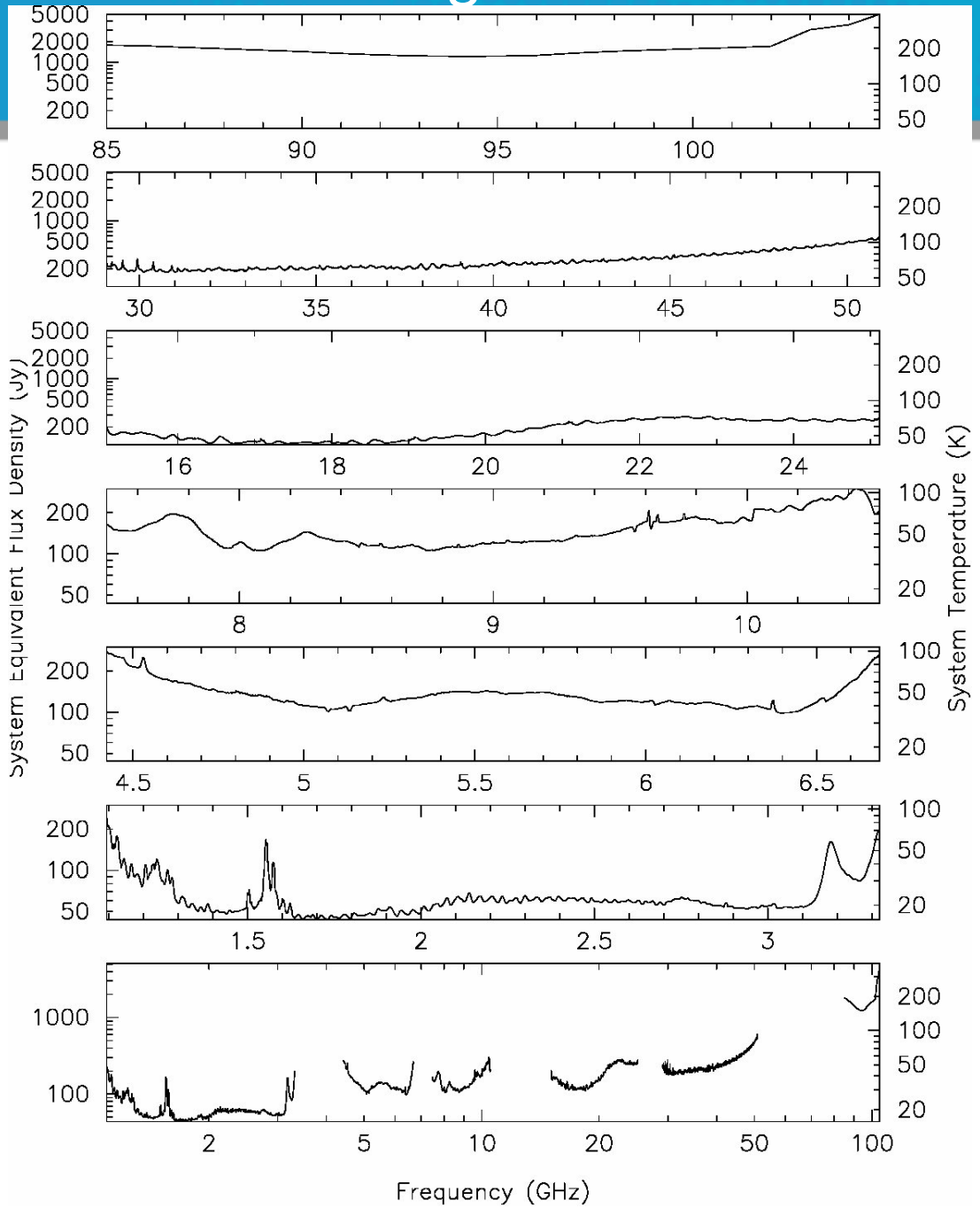
ATCA band usage – most of 1-100 GHz



Parkes Receivers

Receiver	Band (cm)	Range (GHz)	Diameter (m)	FWHP (')	Tsys (K)	Sen[a] (Jy/K)	Pols[b]	Bandw (MHz)
70cm	70	0.44	64	30	65	2	2xL	36
10/50cm	50	0.70-0.764	64	30	40	1.7?	2xL	64
concentric	10	2.60-3.600	64	7	30	1.5?	2xL	1000
20CM Multi	21	1.23-1.53	64	14	23.5	1.5	26xL	300
H-OH	21/18	1.2-1.8	64	14	28	1.5	2xL	500
		1.4	64	14	23	1.5	NBC	
		1.66	64	14	28	1.5	NBC	
Galileo	13	2.20-2.5	64	9.2	20	1.9	2xC	300
		2.15-2.27	64	9.2	20	1.9	2xC	120
		2.29-2.3	64	9.2	19	1.4	2xC	10
Multiband[c]	13	2.2-2.5	64	9.2	79	1.9	2xL	300
	6	4.5-5.1	64	4.2	50	2.2	C	500
	3	8.1.8.7	64	2.7	54	2.1	2xL|C	500
	3/13	8.1-8.7	64	2.4	60	2.1	2xL	500
		2.2-2.5	64	9.2	100	2.0	C	300
6GHz Multi	5	6.0-6.7	64	3.3	25	2.2	14xC	300
Methanol	5	5.9-6.3	64	3.3	50	2.2	2xC	300
		6.4-6.8	64	3.3	50	2.2	2xC	300
	2.5	12.0-12.4	64	2.0	50	3.5	2xC	250
Mars[d]	3	8.0-8.9	64	2.45	25	1.7	2xC	500
13MM[e]	1.3	16.0-26.0	55	1-1.4	60	4.5	2xL	1000
		21.0-22.3					2xC	1000
K/KU	2.2	12.0-15.0	64	1.5	105	3.5	2xL	500
	1.3	21.0-24.0	55	1.3	140	5.8	2xC	500

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GBT Bands

Table 2.1: Properties of the Prime Focus Receivers.

Name	Freq. Range (GHz)	Polarization	Beams	Polns/Beam	T_{rec}	T_{sys}
PF1	0.290-0.395	Lin/Circ	1	2	12	46
PF1	0.385-0.520	Lin/Circ	1	2	22	43
PF1	0.510-0.690	Lin/Circ	1	2	12	22
PF1	0.680-0.920	Lin/Circ	1	2	21	29
PF2	0.910-1.230	Lin/Circ	1	2	10	17

Table 2.2: Properties of the Gregorian Focus Receivers.

Name	Freq. Range (GHz)	Polarization	Beams	Polns/Beam	T_{rec}	T_{sys}
L–band	1.15-1.73	Lin/Circ	1	2	6	20
S–band	1.73-2.60	Lin/Circ	1	2	8-12	22
C–band	3.95-5.85	Lin/Circ	1	2	5	18
X–band	8.00-10.1	Circ	1	2	13	27
Ku–band	12.0-15.4	Circ	2	2	14	30
K–band (lower)	18.0-22.5	Circ	2	2	21	30-40
K–band (upper)	22.0-26.5	Circ	2	2	21	30-40
Ka–band (MM-F1)	26.0-31.0	Lin	2	1	20	35
Ka–band (MM-F1)	30.5-37.0	Circ	2	1	20	30
Ka–band (MM-F1)	36.0-39.5	Circ	2	1	20	45
Q–band	38.2-49.8	Circ	2	2	40-70	67-134
MUSTANG	80-100	-	64	-	-	-

Effelsberg Bands

Wavelength	Frequency range [GHz]	Technical information	Calibration information	Focus	Polarisation	Number of channels	Continuum / Spectral line	Comments
73 cm	0.395 - 0.440			primary	LCP / RCP	2	Both	Currently not available
49 cm	0.606 - 0.614			primary	LCP / RCP	2	Continuum	
30 cm	0.8 - 1.3			primary	LCP / RCP	2	Both	multi-box II (under construction)
21 cm (7 Beam)	1.29 - 1.43			primary	LCP / RCP / linear	14	Both	
18 - 21 cm	1.3 - 1.7			primary	LCP / RCP	2	Both	multi-box I
13 cm	2.2 -2.3			secondary	RCP	1	Continuum	
11 cm	2.60 - 2.68			secondary	LCP / RCP	9 x 4	Continuum	
9 cm	3.08 - 3.35			primary	linear	1	Spectral Line	
6.5 cm	4.3 - 4.9			primary	linear	1	Spectral Line	
6 cm	4.6 - 5.1			secondary	LCP / RCP	4	Continuum	
5 cm	5.75 - 6.75			primary	LCP /RCP	2	Both	multi-box II (under construction)
3.6 cm	7.8 - 8.9			secondary	LCP / RCP	2	Both	
2.8 cm	10.3 - 10.6			secondary	LCP / RCP	8	Continuum	
2.2cm	12.1 - 13.6			primary	LCP / RCP	2	Spectral Line	
2 cm	13.6 -15.6			secondary	LCP / RCP	2	Continuum	
1.9 cm	13.5 - 18.7			primary	linear	1	Spectral Line	multi-box I
1.3cm	18 - 26			primary	linear	2	Spectral Line	
1.3 cm	21.7 - 24.4			secondary	LCP / RCP	2	Continuum	
1 cm	27 - 36.7			primary	linear	1	Spectral Line	multi-box I
9 mm (7 Beam)	30 - 34			secondary	LCP / RCP / linear	10	Continuum	New system; currently being tested.
7 mm	41.6 - 44.4			secondary	LCP / RCP	2	Continuum	
6.5 mm	41.05 - 49.7			primary	linear	2	Spectral Line	
3mm	84.0 - 95.5			primary	LCP / RCP	3	Both	multi-box II (under construction)

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GMRT Bands

Table 3: Protected frequency bands.

GMRT band		Default band		Protected band		Protected by
130-170	MHz	150-156	MHz	150.05-153	MHz	ITU
215-255	MHz	237-243	MHz	230-235	MHz	Indian
305-345	MHz	309-341	MHz	322-328.6	MHz	ITU
580-640	MHz	594-626	MHz	608-614	MHz	ITU
1000-1450	MHz	-	-	1400-1427	MHz	ITU

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ALMA bands

ALMA Sensitivities, FOV, and Resolutions

Band	Frequency Range (GHz)	Wavelength Range (mm)	angular resolution (")	line sensitivity (mJy)	Continuum sensitivity (mJy)	Field of View (")	Largest scale (")
Band 1	31.3 - 45						
Band 2	67 - 90						
Band 3	84 - 116	3.6 - 2.6	3.18 - 0.038	8.9	0.05	56	37
Band 4	125 - 163	2.4 - 1.8	2.5 - 0.03	9.1	0.06	48	32
Band 5	163 - 211	1.8 - 1.4				35	23
Band 6	211 - 275	1.4 - 1.1	1.52 - 0.018	13	0.10	27	18
Band 7	275 - 373	1.1 - 0.8	1.01 - 0.012	21	0.20	18	12
Band 8	385 - 500	0.8 - 0.6	0.86 - 0.01	63	0.40	12	9
Band 9	602 - 720	0.5 - 0.4	0.52 - 0.006	80	0.69	9	6
Band 10	787 - 950	0.4 - 0.3	0.38 - 0.005		1.1	7	5

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Bands used for RA (VLBI)

Table 2: Frequency Bands Below 50 GHz Used for VLBI

Wavelength (cm)	R.A. Band (MHz) in ITU-R RR	MKIV Band (MHz)	EVN	VLBA	Other
90.0	322.00 - 328.60	315.0 - 335.0	-	-	R
		319.99 - 333.99	X	X	X
50.0	608.00 - 614.00	599.99 - 613.99	X	X	-
21.0	1400.00 - 1427.00	1374.99 - 1430.99	X	-	-
		1385.0 - 1435.0	-	-	R
18.0	1660.00 - 1670.00	1636.99 - 1692.99	X	X	X
		1645.0 - 1695.0	-	-	R
13.0	(2290.00 - 2300.00)	2075.0 - 2325.0	-	-	R
		2214.99 - 2270.99	-	-	DS
6.0	4990.00 - 5000.00	4805.0 - 4855.0	-	-	R
		4956.99 - 5012.99	X	X	*
		5000.0 - 5020.0	-	-	R
		7800.0 - 8700.0	-	-	R
3.6	(8400.00 - 8500.00)	8270.99 - 8326.99	X	X	DS
1.3	22210.00 - 22500.00	22195.0 - 22245.0	-	-	R
		22206.99 - 22262.99	X	X	*
0.7	42500.00 - 43500.00	43178.99 - 43234.99	X	X	+

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Summary of band usage by RA telescopes

- Increasing cover full spectrum !!!
  - eVLA: 1-50 GHz continuous; ATCA: most of 1-100 GHz
  - SKA: 70 MHz – 25 GHz !!
  - ALMA: 100-1000 GHz
- Allocated bands covered
  - But only a very small part of spectrum
  - Is it worth keeping them!!??
- YES – Reasons:
  - “Islands” for deep observations
  - Wider bands built around allocations
  - Critical RFI free bands for calibration
  - Keeps RAS visible in ITU-R and international for a

- Use of remote and radio-quiet zones – SKA; ALMA
- RFI mitigation

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Thank you!

Questions?

Tasso Tzioumis
Tasso.tzioumis@csiro.au

www.csiro.au

Contact Us

Phone: 1300 363 400 or +61 3 9545 2176

Email: enquiries@csiro.au Web: www.csiro.au

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