

ACTIVITIES of AST ASTROPHYSICAL SUB-COMMITTEE

1. INTRODUCTION

1.1 At its meeting in November 1980 the AST Steering Committee decided to set up an Astrophysical Sub-Committee to advise on scientific programs for the AST. It was felt that although the engineering side of the AST proposal had been dealt with effectively by a representative Design Study Group, there was no direct channel for input from the astronomical community on the scientific programs for the AST.

1.2 The aims of the AST Astrophysical Sub-Committee, defined in a communication from B.J. Robinson, Deputy Chairman of the Steering Committee, to representative Australian institutions on January 2, 1981, is to provide guidelines on astrophysical projects and priorities that may have some bearing on the basic AST design. Parameters of relevance are operating frequencies, field of view, angular resolution, velocity resolution, mapping speed, scope for partial sampling of UV plane.

1.3 The Astrophysical Sub-Committee is composed of 9 members viz.

K.C. Freeman (MSSSO)
P.D. Godfrey (Monash U)
J.G. Greenhill (UniTas)
J.G. Robertson (AAO)
J. Ross (Uni Qld)
L.F. Smith (Wollongong U)
K.N.R. Taylor (Uni NSW)
A.J. Turtle (Uni Syd)
J.B. Whiteoak (CSIRO) - Convenor

1.4 In communications of January 27 and February 18, 1981 the Convenor requested information on possible astrophysical projects for the AST, and related matters. To date, 19 documents (see listing in Appendix I) are available as background material for discussions by the Sub-Committee.

1.5 On April 8, 1981 a meeting (with all Sub-Committee members present) was held at Division of Radiophysics, CSIRO, Epping. The discussions were based on the AST configurations proposed by R.H. Frater in ASTDOC53, 57.

2. REPORT OF MEETING OF SUB-COMMITTEE

2.1 General matters

2.1.1 Overlap with VLA. The VLA has significant capability at southern declinations (ASTASC8) - for $\delta = -40°$ there is an hour angle coverage of ± 2 hours with maximum projected baselines of 36 km EW and 8 km NS. Because the AST will have a poor projected NS baseline for δ near 0°, it will be much less useful than the VLA for observations of the Sun and planets (ASTASC18). The Sub-Committee concluded that although it would like to see the AST doing unique research, some overlap could be tolerated because there was so much work to be done.

2.1.2 Primary beamwidths. For 64 m - 22 m antenna pairs, the primary beamwidths range from about 19 arcmin at 1.4 GHz to 1.4 arcmin at 43 GHz (ASTASC8). Some may be too small for solar observations. For observations of extended objects, to have adequate primary beamwidths it may be necessary to (a) use 22 m - 22 m pairs only (the range of primary beamwidths is then 44 - 1.4 arcmin or (b) observe at the lowest frequencies (ASTASC12).

2.1.3 The AST as an element of a long baseline array (ASTASC11). There is support from some groups in Australia for the AST as part of a long-baseline interferometer network. In addition to its large collecting area, it could be useful for achieving a lower system temperature for sources where the compact component is surrounded by an extended bright background component - the latter is resolved out by the AST. Unfortunately, with existing large telescopes in Australia as array elements, a good UV coverage would require an AST location away from Parkes. However, it was generally felt that for some types of observation (e.g. HI in external galaxies), the AST must include the 64 m Parkes telescope to provide adequate sensitivity, and that no other location should be considered. At the same time, the Sub-Committee recommended that in current design studies the possible future use of the AST in a long baseline array should be borne in mind.

2.1.4 AST calibration etc. The Sub-Committee recommended that -
(a) a person or group be designated to work on calibration problems so that the AST is calibrated and reliable as soon as it is available for general operation,
(b) complete sets of software and hardware, already tested on artificial or real data, should be available when the AST is put into general operation.

2.2. General matters relevant to observations

2.2.1 Period of observations (ASTDOC53, 57). The Sub-Committee recommended that one or two-day mapping, if possible, should be supported. At the same time it realized that for some observations (e.g. HI observations of external galaxies) longer runs would be required to (a) obtain adequate sensitivity, (b) remove grating rings from the primary beam.

2.2.2 Short-period observations (ASTASC1, 7). The sensitivity of the AST will be sufficient to enable short-period (e.g. 10 minute or less) observations of objects such as compact sources, masers, where only positions are needed. However, it was felt that the use of a pair of antennas in this mode, while at the same time using the other elements in an independent program, may be too difficult to program. There would be some virtue in having a single N-S antenna pair for observations of sources at low declination, except that such objects are well covered by the VLA.

2.2.3 Multi-frequency operation (ASTASC13). Simultaneous observations at more than one frequency are desirable for projects concerning solar flares and fast-period variables such as X-ray sources. Since the antenna design does not allow this configuration, then if such projects are to be carried out on the AST, a means of quickly changing from one frequency to another should be available.

For observations of two spectral lines with a small frequency separation, it would be of some advantage if two IF bands separated in frequency could be used.

2.2.4 Internationally-protected bands. The Sub-Committee recommended that the selected AST frequency ranges should include the relevant bands protected internationally in the Radio Regulations. If these bands are not utilized, the case for having them protected in the future will be weakened. In addition there are several bands important to radioastronomers (e.g. 1390 - 1420 MHz, 4.8 - 5.0 GHz) which are currently free from interference in Australia, in contrast to the situation elsewhere.

2.3 Observation parameters

2.3.1 Types of objects to be observed. (Ref.: all ASTASC docs.)

2.3.1.1 Position and intensity information only: source surveying; compact radio sources (QSO's, BL Lac's); optical, IR or X-ray identifications; radio stars (mass-loss, flare, X-ray binary, symbiotic); astrometry; spectral-line masers.

2.3.1.2. Intensity distributions: extra-galactic radio sources; galaxies (line and continuum); SNR's; planetary nebulae; HII regions and associated molecul clouds (line and continuum); late-type stars (line); planets (line and continuum); Sun.

2.3.2 Recommended continuum frequencies

2.3.2.1 Priorities. The Sub-Committee concluded that AST frequencies selected for continuum observations are as follows (in order of priority): 10, 5, 1.4, 22, 43 GHz. The overall best band is 10 GHz - it is the highest band not unduly affected by the atmosphere, the highest for which the full surface of the 64 m telescope can be used, is optimum for the observation of both steep-spectra and flat-spectra objects, provides a maximum angular resolution (1 arcsec) similar to that obtaine optical photography under good observing conditions, and is not present on the VLA. With future long-baseline interferometry in mind, the 10 GHz receiving system should be tunable down to the NASA frequency of 8.4 GHz (used at Tidbinbilla). For extended steep-spectra objects, the 5 GHz or even 1.4 GHz bands may be more useful. All bands should be tunable to the appropriate frequency ranges protected in the Radio Regulations viz: 10.6 - 10.7, 4.95 - 5.0, 1.4 - 1.427, 22.21 - 22.5 and 23.6 - 24.0 (the latter is less affected by the atmosphere), 42.5 - 43.5 GHz.

2.3.2.2 Bandwidth. The Sub-Committee concluded that the bandwidths should be as large as possible, and at least 50 MHz. Techniques such as band-splitting would be necessary to prevent band-width smearing of images (apparently this problem occurs with the VLA). The splitting provides other advantages, such as the possibility of eliminating frequency-dependent interference. It should be at intervals sufficiently small to avoid degradation of the images within the primary beam.

2.3.2.3. Additional band near 3 GHz. There was no great support for a band near 3 GHz, which would complete an approximate octal spacing of frequency bands. However, if it were decided to provide such a frequency a setting at 3.3 GHz, although remote from the protected band 2.69-2.7 GHz, would also permit limited observations of GH lines (3.26, 3.33, 3.35 GHz).

2.3.3. Recommended line frequencies.

2.3.3.1 Priorities (based on statistics in ASTASC16). The bands for the observation of spectral lines, in order of priority, are as follows: 1.35 - 1.72, (4.6) 4.8 - 6.1, 22 - 24 (25), 42.5-(45), (49 GHz). The main lines to be observed are (a) HI in external galaxies (1.35 - 1.42 GHz), (b) Galaxy absorption and 'thermal' emission lines: HI (1.42 GHz), OH (1.61, 1.66, 1.67, 1.72 GHz), H_2CO (4.83 GHz), NH_3 (23.6 GHz), [CS (48.9 GHz)], (c) maser emission lines: OH (1.61, 1.66, 1.67, 1.72 GHz), OH (6.1 GHz), H_2O (22.2 GHz), SiO (42.8, 43.1 GHz), (d) recombination lines (mainly hydrogen) at 5, 10 and perhaps 22 GHz. With regard to the 5 GHz band, the Sub-Committee felt that if it is not possible to observe both H_2CO and OH lines, it would support H_2CO observations at the expense of the OH observations. Extra tuning capability down to 4.6 GHz would permit limited observations at $H_2{}^{13}CO$. For the 24 GHz band, an extension to 25 GHz would permit limited observations of CH_3OH (ASTASC15). If the 43 GHz could be extended to 45 GHz, limited HC_3N observations might be possible. By way of comparison, the VLA operating frequencies are (ASTASC8): 1.3 - 1.7, 4.5 - 5.0, 14.4 - 15.4, 22.0 - 24.0 GHz.

2.3.3.2 General characteristics of line profiles. These are listed in Appendix II.

2.3.3.3 Protection of lines. The protection afforded the spectral lines in the Radio Regulations is as follows: (a) primary frequency allocation: HI (1.400 - 1.427 GHz), OH (1.660 - 1.670 MHz), H_2CO (4.825 - 4.835 GHz), H_2O (22.21 - 22.5 GHz), NH_3 (23.6 - 24 GHz), SiO (42.5 - 43.5 GHz); (b) s dary frequency allocation: OH (1.6101 - 1.6138, 1.7188 - 1.7222 GHz).

2.3.3.4 Atmospheric problems at high frequency (ASTASC11). Observations at frequencies above 20 GHz are affected by atmospheric phase irregularities, and measures such as closure phase, 'phaseless synthesis', short observations may have to be employed. Much of the phase variation is believed due to water vapour content, and would greatly affect observations at 22 GHz. On the other hand, the bands at higher frequencies are on the edge of an oxygen absorption band that peaks at 62 GHz, and because the distribution of oxygen has a large scale-height, small-scale atmospheric phase irregularities may be considerably smaller than at 22 GHz.

2.3.3.5 Observations of CS at 49 GHz. Although 49 GHz is higher than the frequencies normally considered for the AST, the CS emission line is sufficiently strong and abundant to be considered for observation. The angular resolution at the smallest spacing (720 m) is more than adequate (2 arc sec) and a CS program could be more effectively carried out with a smaller spacing (480 m for example); in addition the atmospheric effects could be lessened. (This argument could also apply to 24 GHz NH_3 observations). However, the Sub-Committee felt that any provision for operation at 49 GHz should be postponed until the atmospheric effects at 43 GHz have been evaluated. The small primary beamwidth (1½ arcmin) at 49 GHz should be no handicap because it is believed that CS is concentrated towards the nuclei of HII regions.

2.3.4 Sensitivity of the AST (ASTASC8, ASTASC19).

2.3.4.1 Sensitivity tables. Appendix III shows a set of sensitivity tables for operation of the AST with different velocity resolutions. The numbers are based on calculations by P.A.G. Scheuer in ASTASC8. However, his numbers were scaled up by a factor of 2.8 to correct for (a) a factor of 2 in collecting area that was omitted from the original calculations, and (b) a factor of 1.4 that is present when the 64 m telescope is also used. Although not specified by Scheuer, an additional factor for dual-polarization operation is cancelled out by an omitted factor of $\sqrt{2}$ in system noise temperature of the paired antennas. The second table in the Appendix shows the conversion of bandwidth into radial velocity scale.

2.3.4.2 Scheuer points out that for observations where UV coverage is not important (e.g. compact sources, masers), higher sensitivity is obtained if only 64 m - 22 m antenna pairs are used.

2.3.5 Recommended line profile parameters:

Line type	Minimum Velocity Resolution	Minimum angular Resolution
Maser lines	0.1 km/s	highest possible*
Absn/'thermal' emission	1 km/s	10 arcsec
HI (galaxies)	20 km/s	25 arcsec
Recombination lines	3-5 km/s	10 arcsec

* For the low-frequency maser lines, even the 6 km spacing is barely adequate.

2.3.6 Possible backend spectrometer configurations. Appendix III lists possible configurations for the various line observations.

21 August 1981 J.B. Whiteoak

APPENDIX I

BACKGROUND DOCUMENTATION FOR SUB-COMMITTEE

ASTASC1	(D.L. Jauncey)	Compact Sources and the AST
ASTASC2	(J.B. Whiteoak)	Some Thoughts on Possible AST Line Projects
ASTASC3	(J.L. Caswell)	Memorandum to Design Study Group, AST
ASTASC4	(M.M. Komesaroff)	Use of the Proposed Australian Synthesis Telescope for Planetary Studies
ASTASC5	(J.G. Robertson)	Reply to letter of 27 January from Convenor of Sub-Committee
ASTASC6	(R.X. McGee)	High Resolution Investigation of HII Regions
ASTASC7	(A.E. Wright)	Use of AST, Thoughts on AST Frequencies etc.
ASTASC8	(J.B. Whiteoak)	Memo of 18 February to members of Radiophysics
ASTASC9	(W.H. McCutcheon)	Astrophysical Projects for AST
ASTASC10	(R.N. Manchester)	AST Parameters
ASTASC11	(P.A.G. Scheuer)	The AST and High Angular Resolution
ASTASC12	(O.B. Slee)	Response to memo of 18 February from Convenor of Sub-Committee
ASTASC13	(K.V. Sheridan)	Solar Use of AST
ASTASC14	(D.K. Milne)	SNR Observations with the AST
ASTASC15	(P.D. Godfrey)	Possible Astrophysical Projects for the AST
ASTASC16	(J.B. Whiteoak)	Summary of Parkes Observations
ASTASC17	(B.J. Robinson)	Tables 1 and 2 from ASTDOC55.
ASTASC18	(R.T. Stewart)	Response to memo of 18 February from Convenor of Sub-Committee
ASTASC19	(J.G. Robertson)	Noise Estimates for the AST

APPENDIX II

GENERAL CHARACTERISTICS OF LINE PROFILES (ASTASC16)

1.42 GHz HI (gals.): The brightness temperatures are typically a few K. Line profiles can be up to 300 - 400 km/s wide.

1.42 GHz HI (absorption): The brightness temperatures of galactic absorption against galactic and extragalactic continuum emission can be several hundred K. A total bandwidth of 1 MHz would be needed to cover all absorption components along some lines of sight. The typical velocity half-widths of individual clouds is 5 km/s.

1.6 GHz OH (masers): The typical flux densities are several Jy. Individual features are polarized and have typical velocity half-widths of about 0.5 km/s. At 1612 MHz there are generally two lines about 30 km/s apart (the separation can be as great as 50 km/s). At the other frequencies, the main profile width is normally less than 25 km/s.

1.6 GHz OH (em/abs): The absorption brightness temperatures can reach tens of K, and the velocity half-widths are typically 5 km/s. There is also emission from dark clouds, but this is faint (about 1 K) and has narrow velocity half-widths (1 km/s or less).

5 GHz H_2CO (absorption): The absorption lines associated with HII regions can attain brightness temperatures typically of a few K. As for other absorption lines, the velocity half-widths average 5 km/s.

6 GHz OH (masers): Typical flux densities are several Jy. Individual features have widths of about 1 km/s; total widths are less than 7 km/s.

10 GHz Recomb.: Hydrogen recombination lines have brightness temperatures of 1 - 2 K, half-intensity widths of 33 km/s. Helium lines are an order of magnitude fainter and have half-widths of 19 km/s.

22 GHz H_2O (masers): The peak flux densities of observed southern objects are typically 100 Jy. The main features in profiles have half-widths down to 1 km/s; profile widths are typically 20 km/s, but may extend to several hundred km/s.

23.7 GHz NH_3 (emission/absorption): Only very limited observations have been made in the southern hemisphere. The brightness temperatures are low, typically 1 K; the velocity half-widths are about 5 km/s.

43 GHz SiO (masers): There are two transitions, giving typical peak flux densitiies of about 100 Jy. The spectra usually consist of two main lines separated by up to 40 km/s.

APPENDIX II (Cont'd)

49 GHz CS (emission): Brightness temperatures of at least a few K are observed towards many HII regions. The typical velocity half-width is 5 km/s.

Note: The brightness temperatures quoted are based on a uniform molecular cloud distribution over a continuum source of extent 3½ arcmin. In the event of small scale structure, higher peak temperatures would be expected.

APPENDIX III

THE SENSITIVITY OF THE AST

1. Table 1 shows the r.m.s. noise in beam-brightness temperature scale as a function of spacing and bandwidth ($\Delta\nu$). The calculations are based on the discussions by P.A.G. Scheuer in ASTASC8, and assume the following parameters:

(a) 15 spacings of 22 m - 22 m pairs + 6 spacings of 64 m - 22 m pairs.
(b) observation period of 12 hours.
(c) system noise temperature of 45K.
(d) surface efficiency of 60%.
(e) 1-bit correlation.
(f) truncated Gaussian taper to 0.25 at longest spacing
(g) dual polarization

Table 1

$\Delta\nu$ / Spacing (m) (MHz)	6000	3120	1680	960	720
50	1.1 K T_B	0.31	0.091	0.030	0.017
10	2.4	0.69	0.20	0.067	0.038
2	5.5	1.6	0.45	0.15	0.090
1	7.8	2.2	0.64	0.21	0.12
0.5	11	3.1	0.91	0.30	0.17
0.2	17	4.9	1.4	0.47	0.27
0.1	24	6.9	2.0	0.67	0.38
0.05	34	9.8	2.8	0.95	0.54
0.02	55	16	4.5	1.5	0.85
0.01	78	22	6.4	2.1	1.2
0.005	110	31	9.1	3.0	1.7
0.002	174	54	16	5.2	3.0
0.001	246	76	22	7.4	4.2

By way of comparison, the signal to noise ratio for a 1 Jy point source and a 50 MHz bandwidth is 21000, (i.e. the rms noise is 48 μJy).

APPENDIX III (Cont'd)

2. Table 2 gives a conversion of radial velocity into bandwidth ($\Delta\nu$).

Table 2

$\Delta\nu$ (MHz)/ Frequency (GHz)	1.4	5	10	22	43
50	km/s			680	350
10		600	300	136	70
2	428	120	60	27	14
1	214	60	30	14	7.0
0.5	107	30	15	6.8	3.5
0.2	42	12	6.0	2.7	1.4
0.1	21	6.0	3.0	1.4	0.70
0.05	11	3.0	1.5	0.68	0.35
0.02	4.2	1.2	0.60	0.27	0.14
0.01	2.1	0.60	0.30	0.14	0.07
0.005	1.1	0.30	0.15	0.07	
0.002	0.4	0.12	0.06		
0.001	0.2	0.06			

APPENDIX IV

POSSIBLE BACKEND SPECTROMETER CONFIGURATIONS

1. General

The listed configurations are based on the line profile parameters tabled in #2.3.4, with some scaling to maintain the total bandwidth in the 1, 2, 5 sequence that has been satisfactorily used at Parkes in the digital correlator. A 'basic' 128-channel quantum is adopted for the correlator; since processing such as Hanning Smoothing will be needed to remove the Sin x/x modulation, the basic resolution is assumed to be equivalent to two channels. The angular resolution/baseline conversion is taken from ASTDOC53.

2. Configuration

Spectral Line	Velocity Resolution	Bandwidth	Velocity Coverage	Baseline	Notes
1.42 GHz HI (gals.)	16 km/s	5 MHz	1050 km/s	1.68 km	
1.42 GHz HI (absn.)	0.7	0.2	42	6	
1.6 GHz OH (masers)	0.14	0.05	9	6	1
1.6 GHz OH (em/abs)	0.6	0.2	36	3.1, 6	
5 GHz H_2CO (abs)	1.0	1	62	0.96,1.68	
6 GHz OH (masers)	0.08	0.1	5	6	2
10 GHz Recomb.	2.6	5	168	0.72	3
22 GHz H_2O (masers)	0.21	1	14	6	4
43 GHz SiO (masers)	0.11	1	7	6	5
(49 GHz CS (em)	0.5	5	31	0.72	)

Notes:

1. Full line coverage requires 0.2 MHz (0.5 MHz at 1.612 GHz), so number of channels would have to be increased in a trade-off against number of spacings, polarizations, etc.

2. Maser lines may exceed 0.2 MHz in width, and trade-off is needed. In addition, a resolution twice the quoted value may sometimes be preferred.

3. Scaling of numbers would give parameters for recombination lines at other frequencies.

4. Lines can vary in size from 20 km/s upwards, and trade-off may be needed to gain more bandwidth.

5. Some compromise is needed because typical line widths (not features within lines) are 20 km/s. The maser spectrum has two spaced narrow lines and it would be useful if two IF's, spaced in frequency, were available to cover both lines simultaneously.

- Phase stable operation on long baselines would result in dramatic improvements in sensitivity and precision over existing arrays.

- High sensitivity on limited baselines is vital for HI synthesis on external galaxies.

- In limited areas the AT will be useful for solar and planetary studies.

- The high sensitivity and resolution make the AT ideal for studies of radio stars.

CONTENTS

SYMPOSIUM

THE AUSTRALIA TELESCOPE - ASTROPHYSICAL OBJECTIVES

Tuesday 2 February 1982

Lecture Theatre · Division of Radiophysics
EPPING

PROGRAM

1100	R.H. Frater	The Australia Telescope Project - Current Status
1130	B.J. Robinson	Complementary Instruments
1150	J.B. Whiteoak	Galactic spectral-line observations
1220	B.Y. Mills	Supernova remnants
1240	O.B. Slee	Low Frequency Observations
	1300 - 1400	*LUNCH*
1400	D.L. Jauncey	VLBI and Extragalactic Continuum Observations
1430	K.C. Freeman	Extragalactic spectral-line observations
1450	D.J. McLean	Solar Observations
1510	D.A. Allen	Radio Stars
1530	Other contributions and discussion	
1600	R.H. Frater	Concluding remarks

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