Six of the 36 ASKAP dishes (photo by Maxim Voronkov, CASS)

An update on ASKAP and WALLABY

Bärbel Koribalski

CSIRO Astronomy and Space Science
www.csiro.au

The Australian SKA Pathfinder

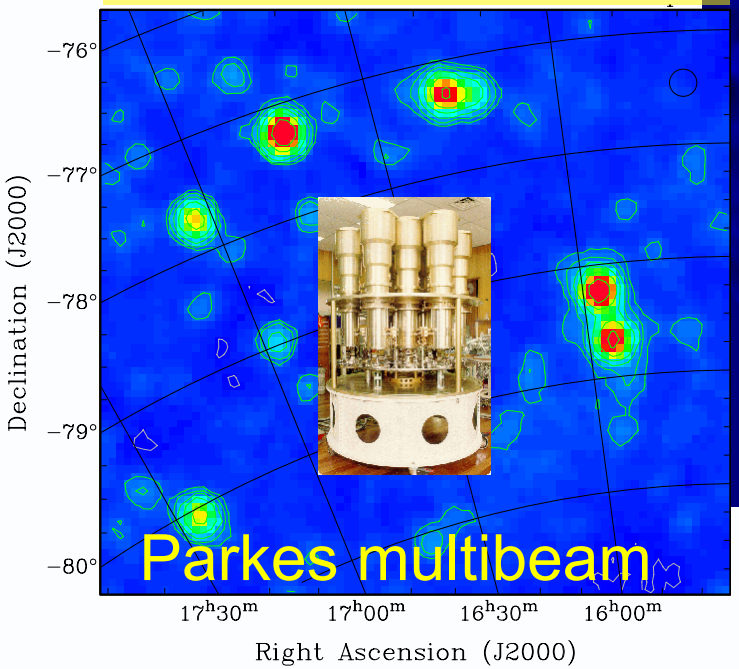
- **ASKAP**: 36 ×12-m dishes (freq. 0.7 – 1.8 GHz, baselines up to 6 km; eg., mapping the 21-cm line of neutral atomic hydrogen gas)
- 2014: started commissioning work with 6 PAF-equipped antennas
- ASKAP's **data rate** is expected to be **72 Tbit/s** (once fully operational), data output **~500 PB /yr** ; raw data will be stored only temporarily; archive data outputs (images/cubes) long term
- **ASKAP correlator** (delivering **340 Tflop/s**)

ASKAP Commissioning

BETA = Boolardy Engineering Test Array

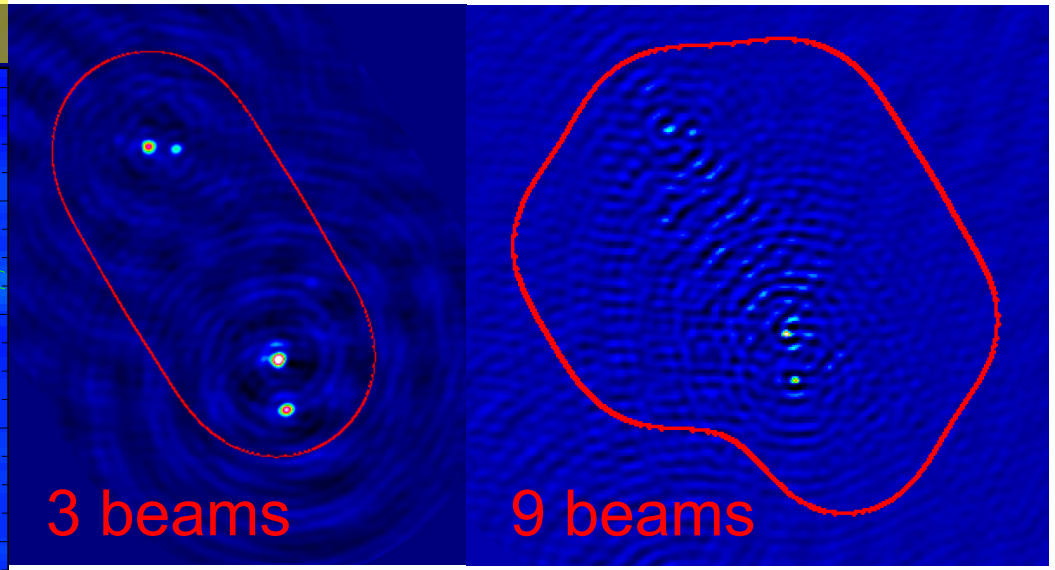
BETA Mk1 PAFs – an engineering testbed

HIPASS 20-cm radio continuum map



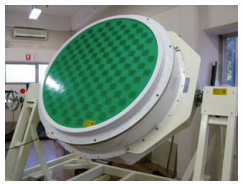
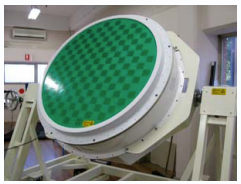
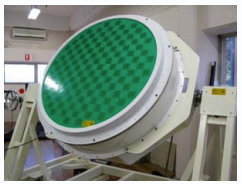
BW = 64 MHz (1024 ch)
8 min/pointing, 2 pols
15.5 arcmin resolution

3 & 9 beam continuum images achieved with 3 PAFs

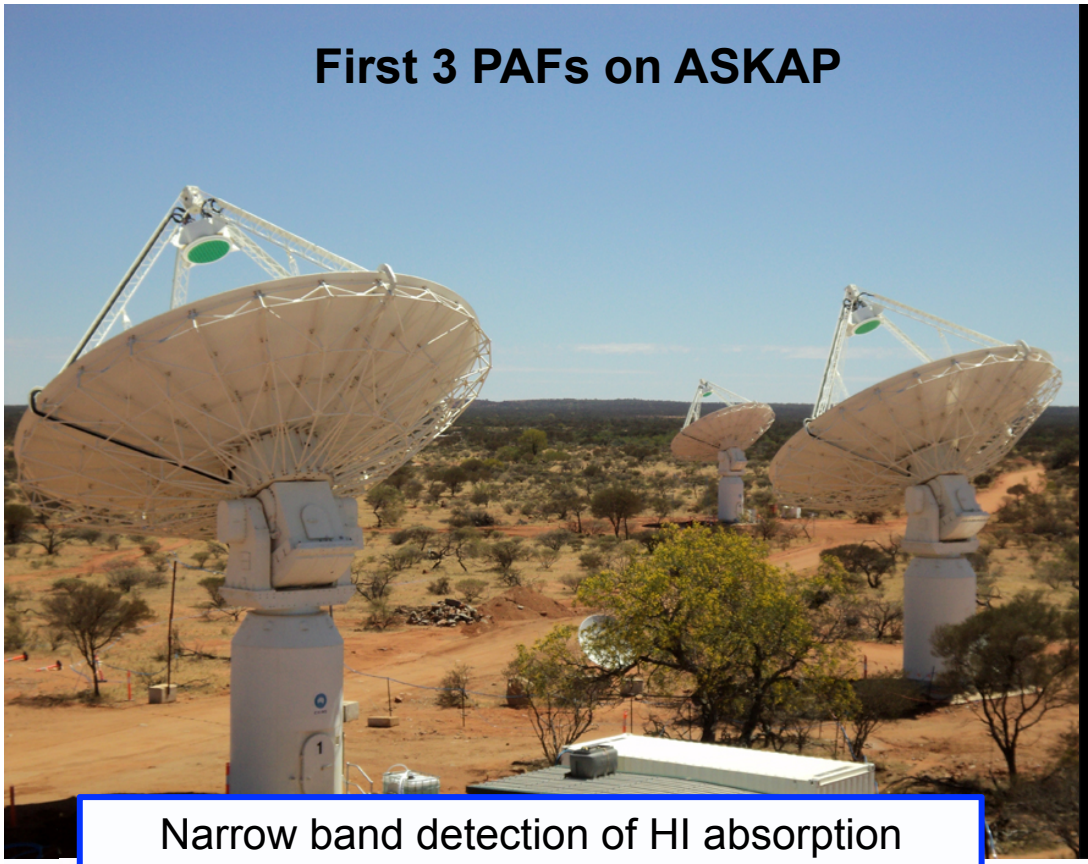


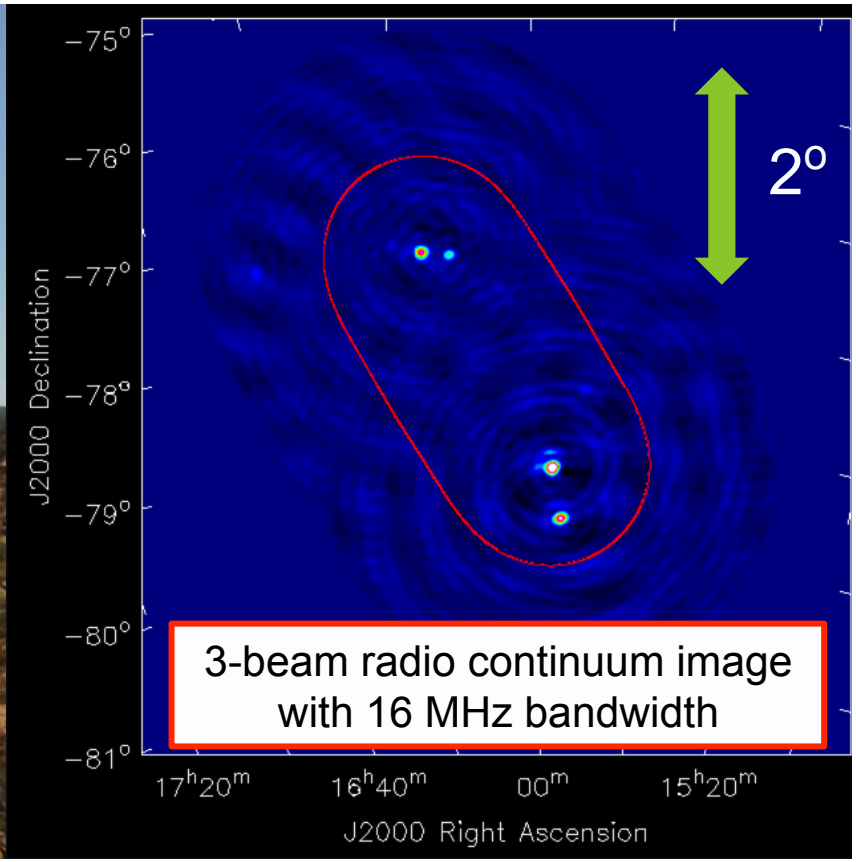
BW = 16 x 1 MHz
12h, 1p, 928 MHz

BW = 32 x 1 MHz
12h, 1p, hardware corr.

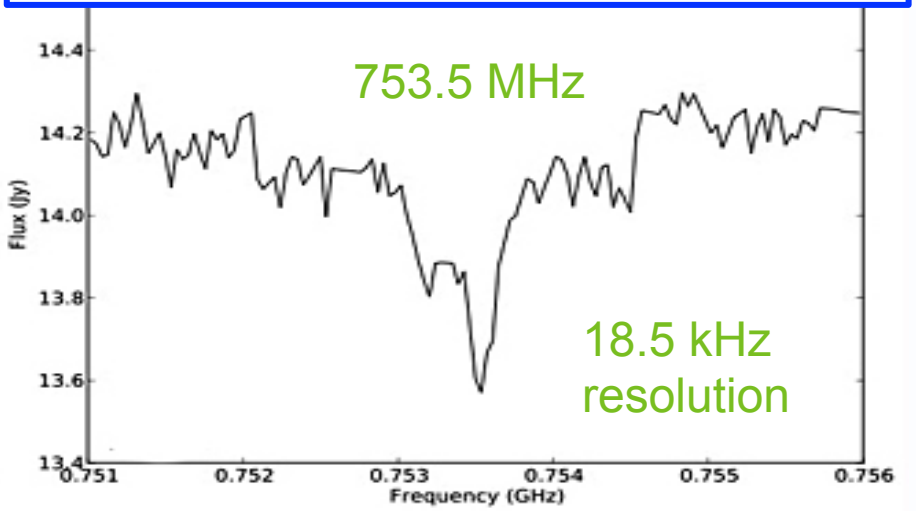
First 3 PAFs on ASKAP



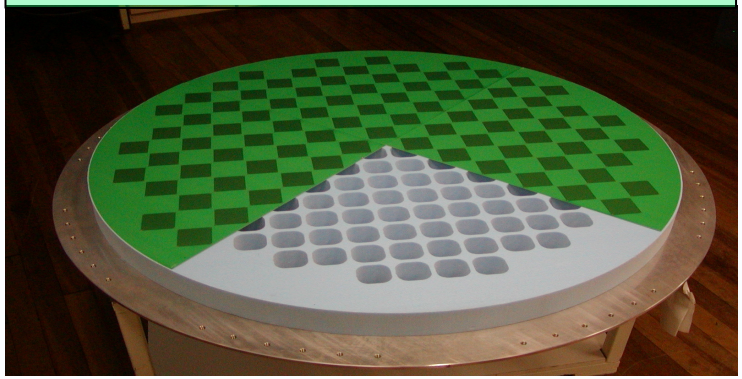


3-beam radio continuum image with 16 MHz bandwidth

Narrow band detection of HI absorption towards the gravitational lens PKS 1830-221



Phased Array Feed Mk I

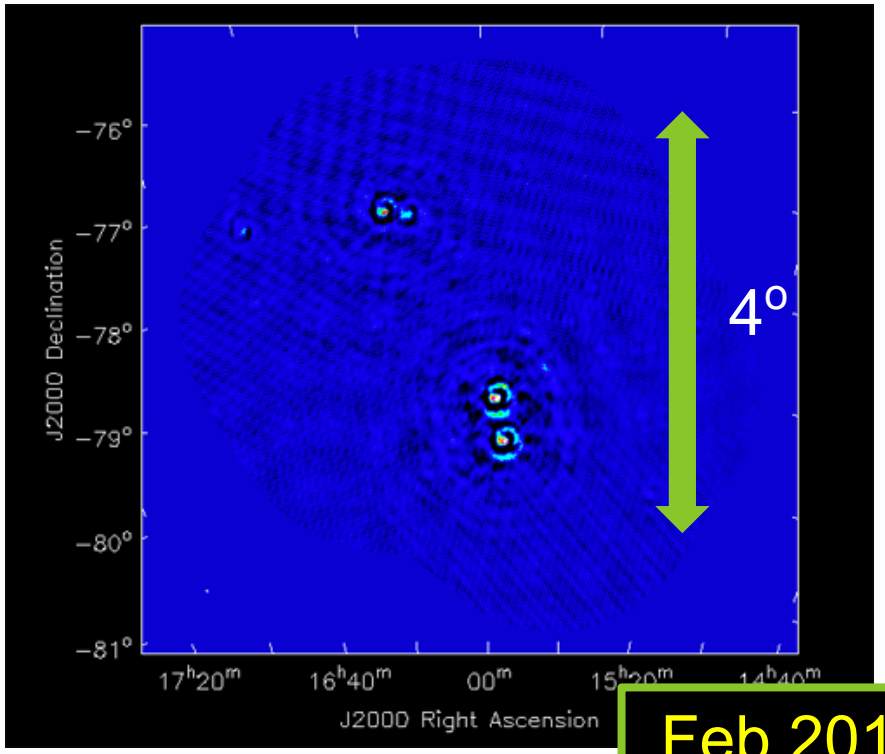


Now 6 PAFs on ASKAP

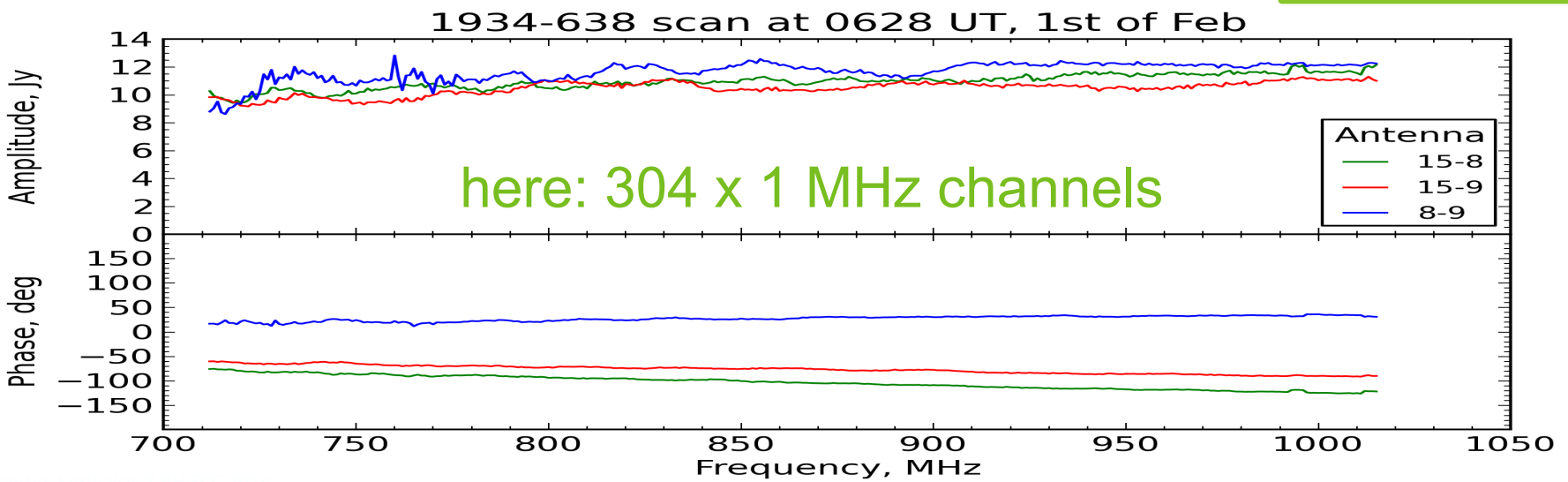
until Feb 2014: testing
two groups of 3 PAFs

First 9-beam image with six PAFs on ASKAP antennas

- 6 antennas (36)
- 2 x 3 baselines (630)
- **9 beams** (36)
- 304 MHz bandwidth ✓

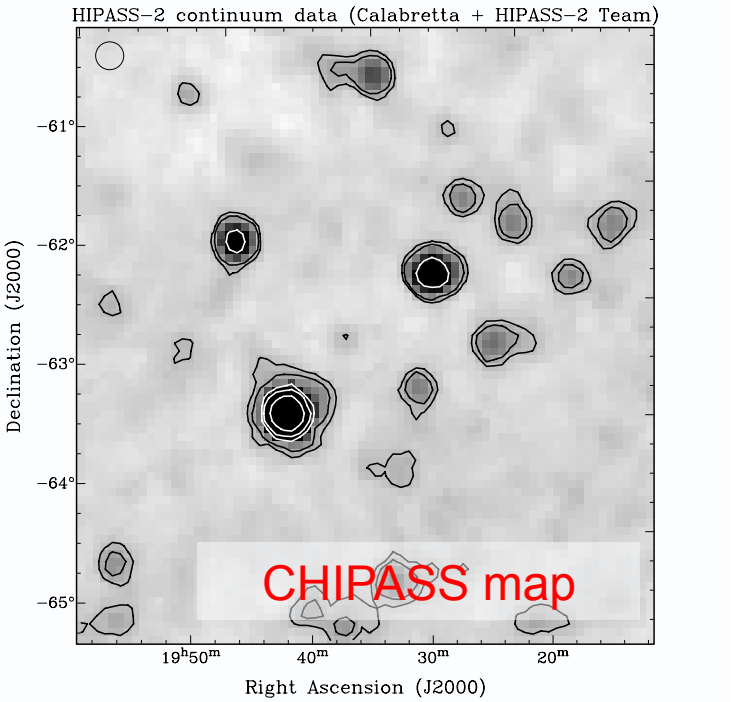


Feb 2014

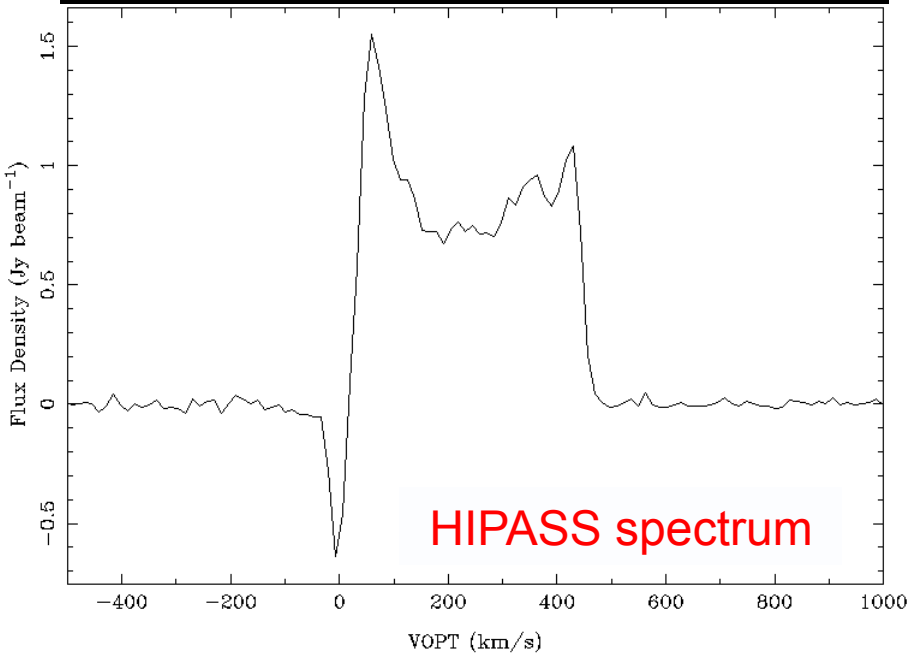


BETA = 6 Mk1 PAFs working together

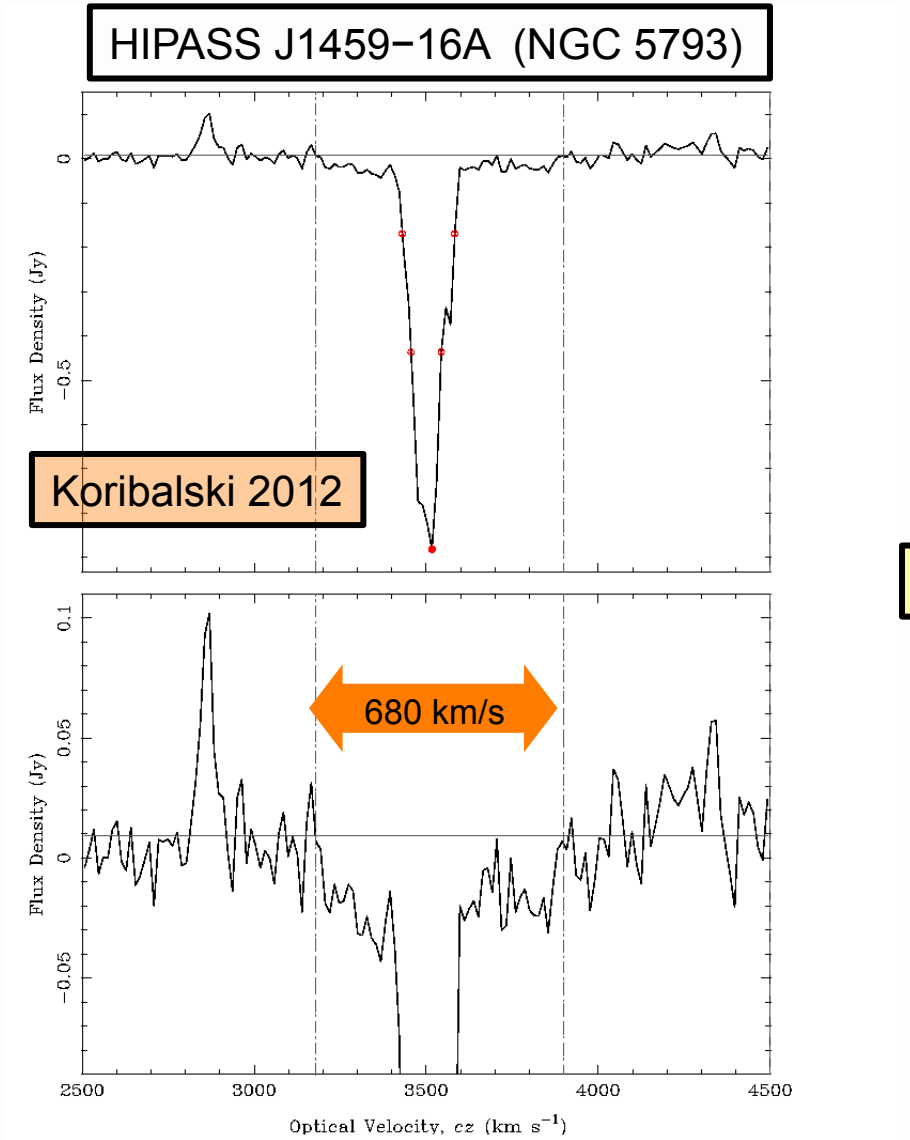
producing 9-beam continuum maps + HI images/spectra for science verification

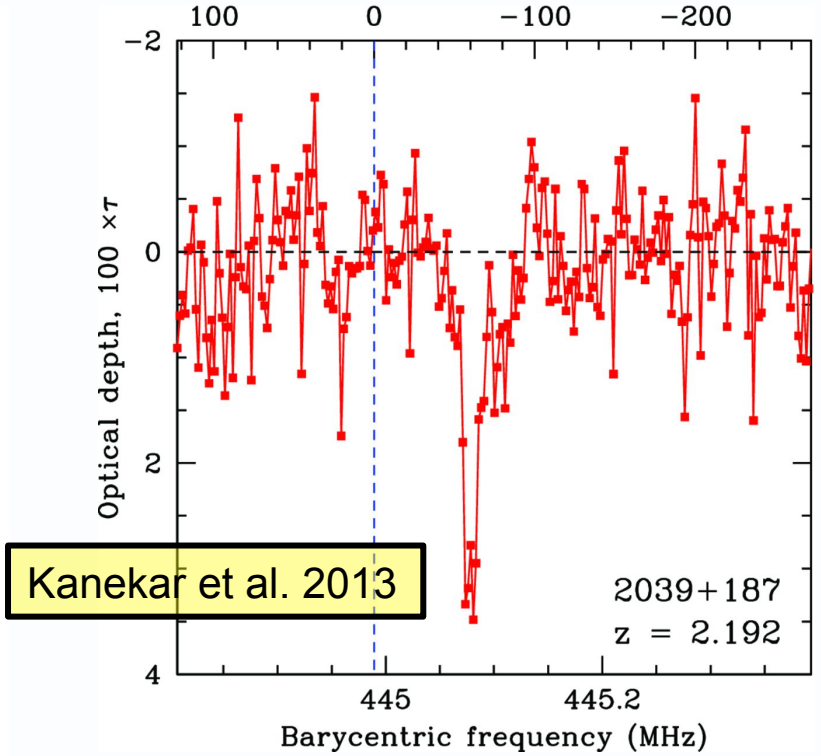


Example Target: NGC 253



The starburst galaxy **NGC 253** is a member of the Sculptor Group.
It has **~6 Jy** radio continuum flux at 20-cm; very **bright HI emission** (and absorption) over 400 km/s, approx. from 1418 - 1420 MHz.





↑ A new detection of HI 21 absorption, at **z = 2.192** towards **TXS 2039+187** (high-redshift analogue of gas-rich galaxy in the Local Universe)

← HIPASS hints at wide HI absorption towards **NGC 5793** (tbc).

ASKAP Commissioning – Part 2

with Mk II PAFs or ADE PAFs

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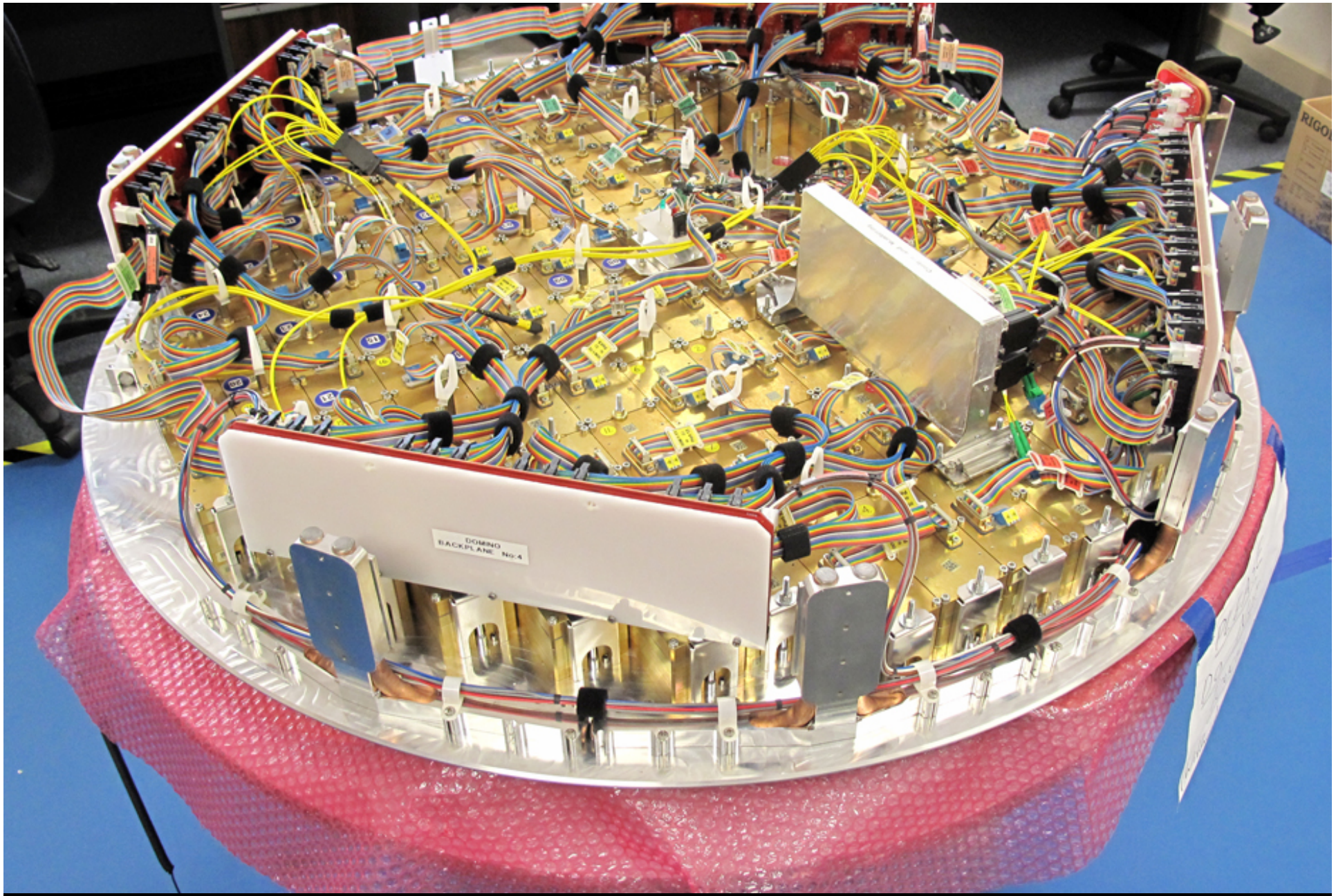
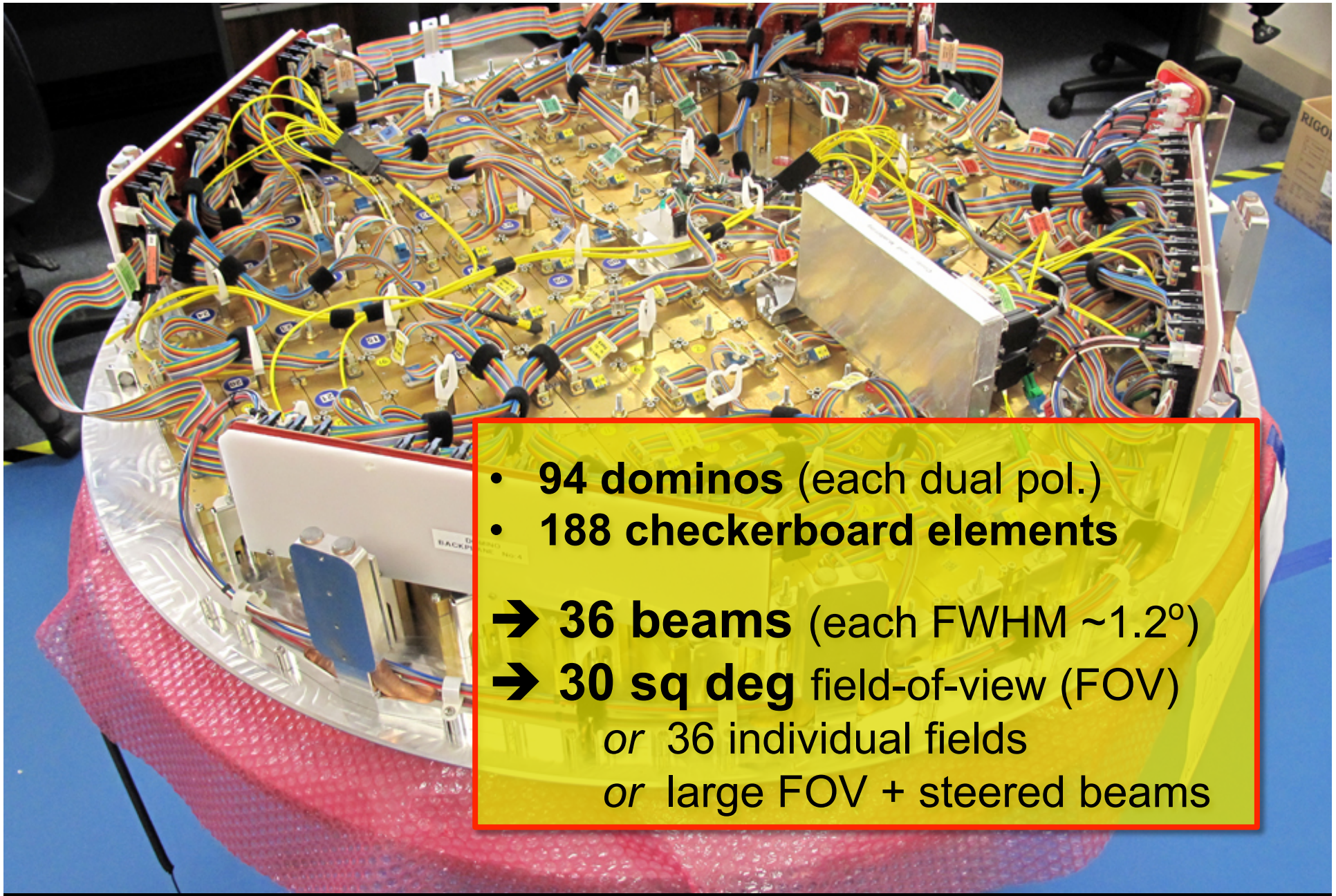
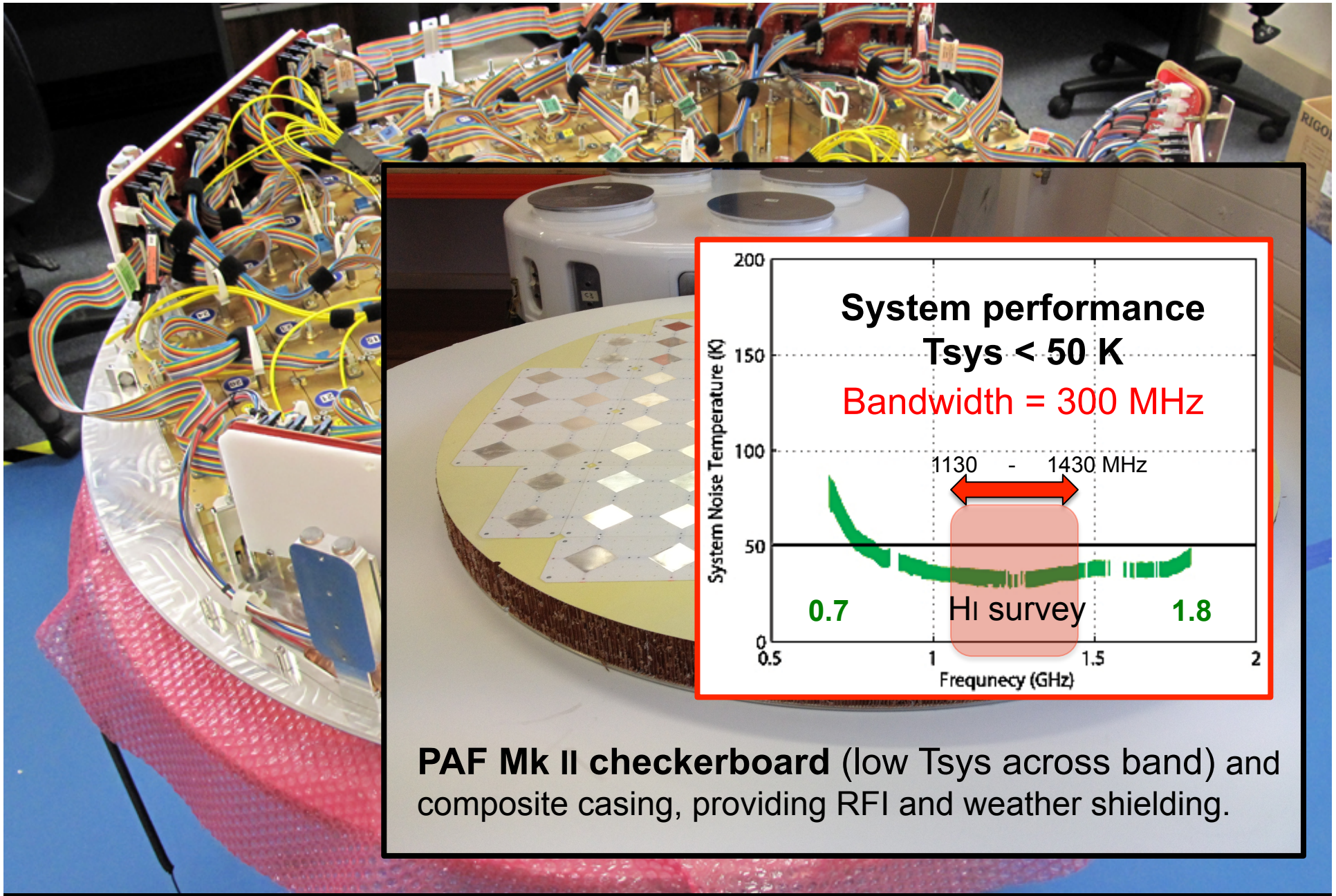


ASKAP Mk II Phased Array Feed (PAF) assembly

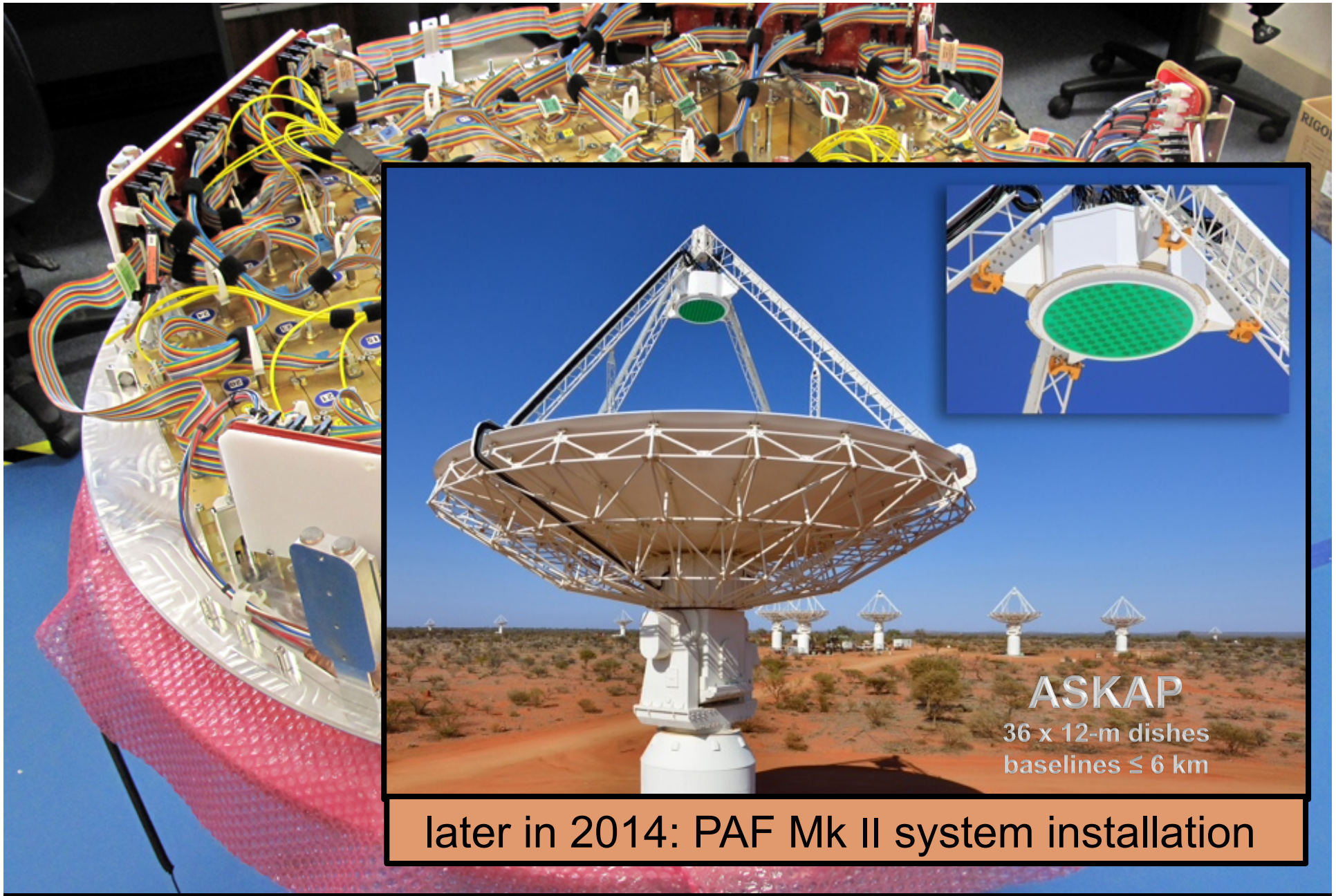


ASKAP Mk II Phased Array Feed (PAF) assembly

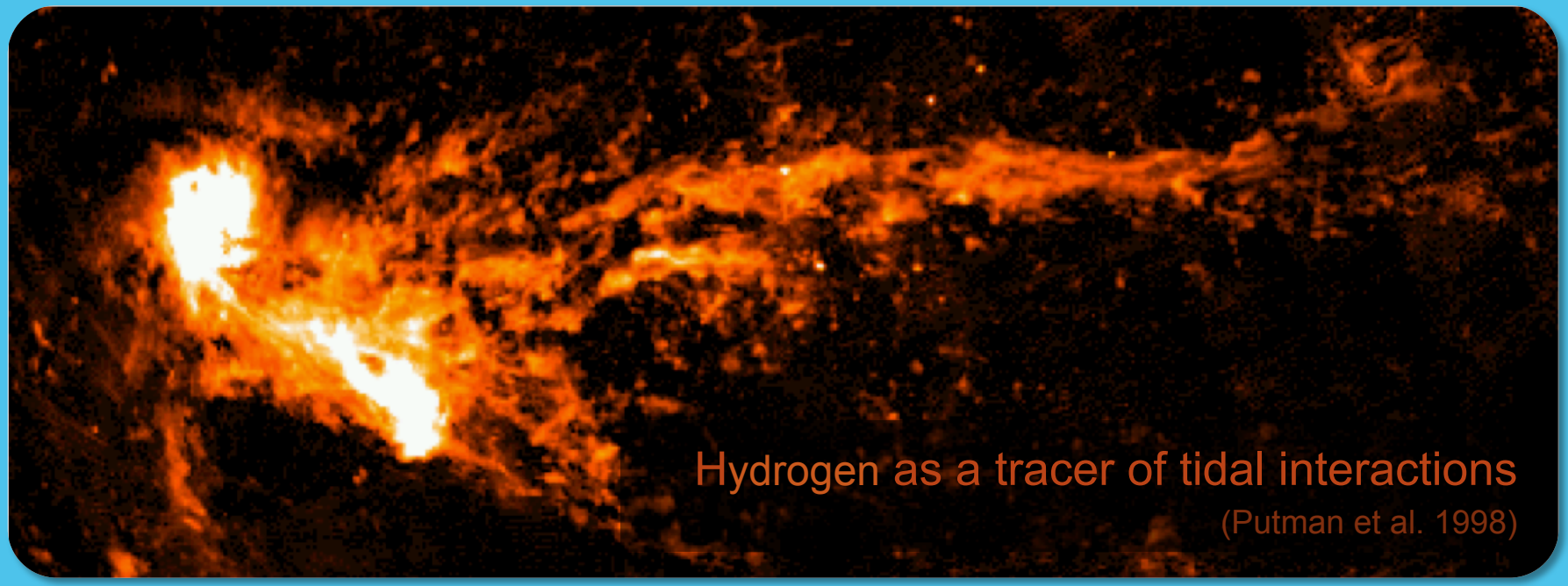


PAF Mk II checkerboard (low Tsys across band) and composite casing, providing RFI and weather shielding.

ASKAP Mk II Phased Array Feed (PAF) assembly



ASKAP Mk II Phased Array Feed (PAF) assembly



HI Early Science with ASKAP-12

Bärbel Koribalski

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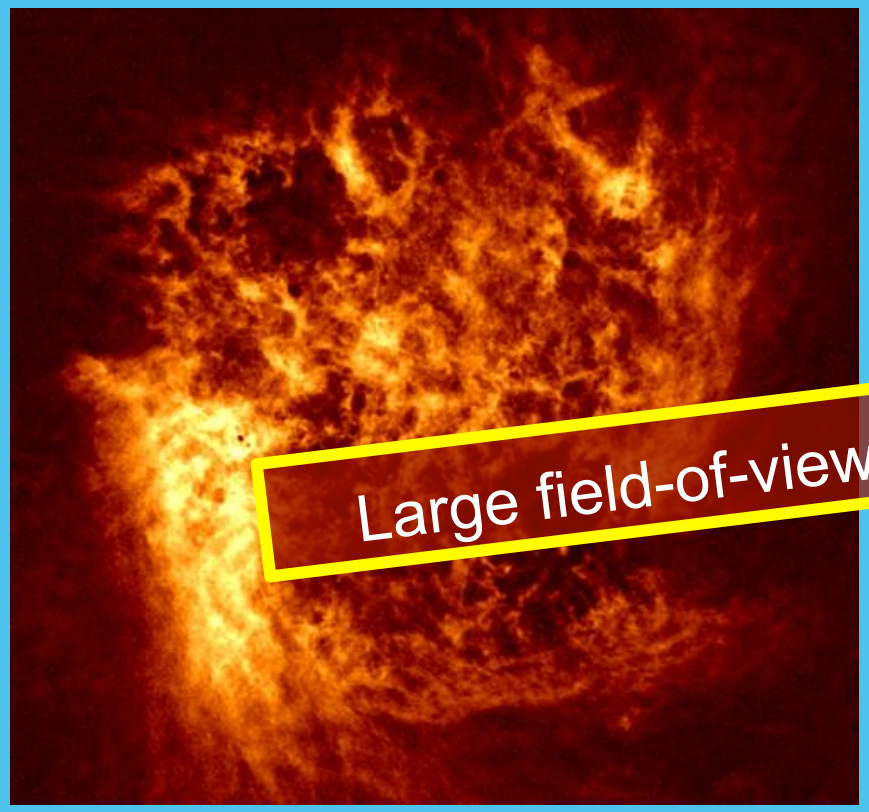
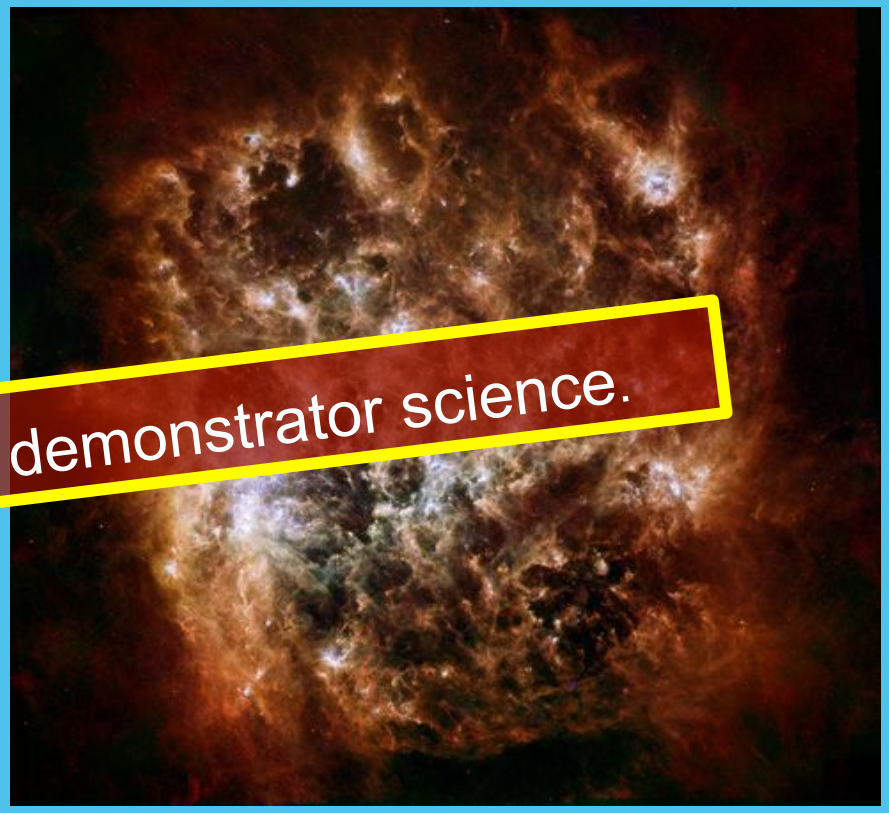
Six ADE PAFs working together could produce this:



Atomic Hydrogen in the LMC
(Kim et al. 1998)



Infrared Portrait of the LMC
(Spitzer + Herschel)

Large field-of-view demonstrator science.


Our science goal
for ASKAP-ADE12
Study the evolution of galaxies, their transformation and star formation as a function of environment.
HI in the NGC 3263 galaxy group – English, BK et al. (2010)

Our science goal for ASKAP-ADE12

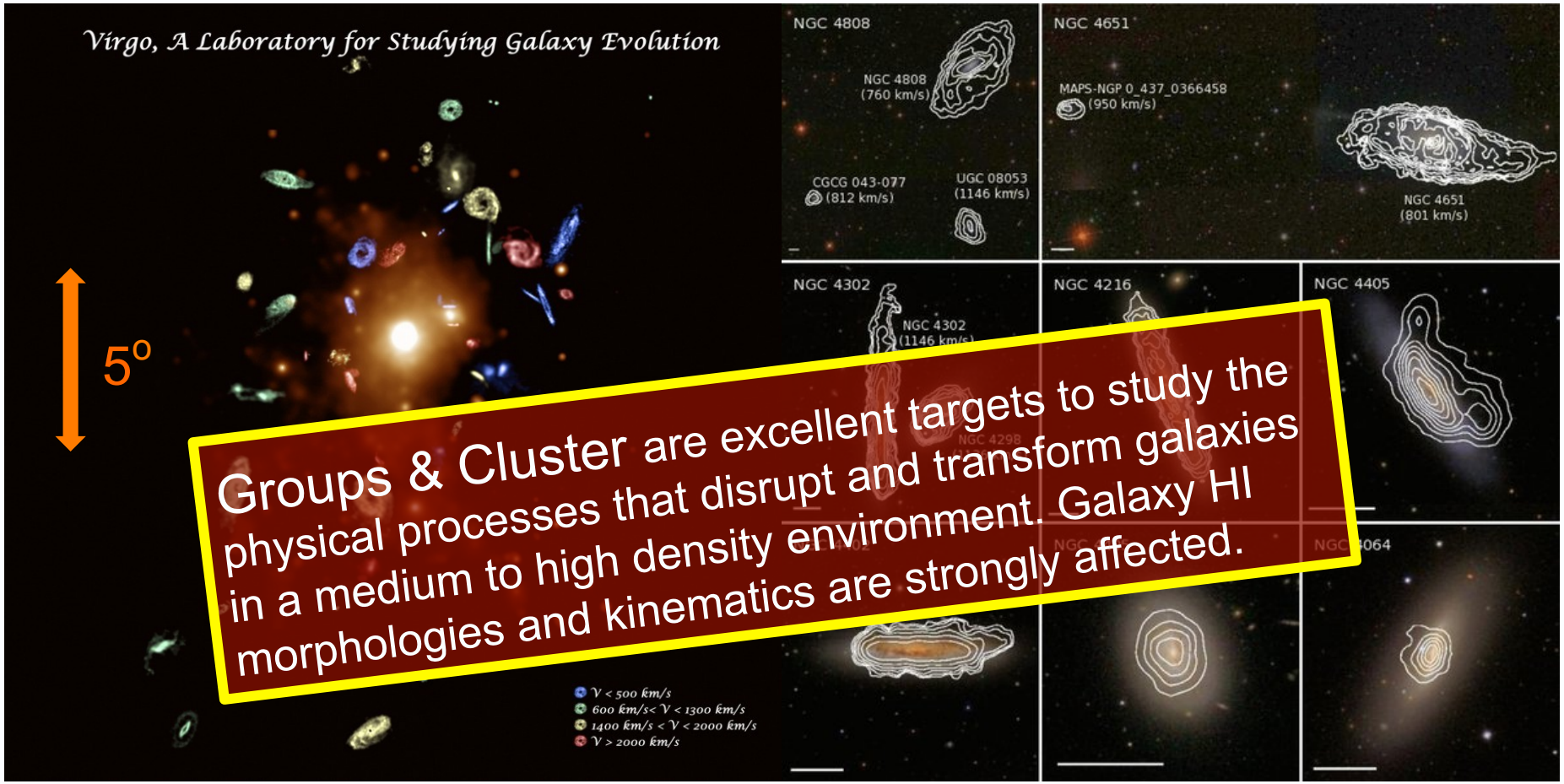
Study the HI morphology, kinematics and star formation of galaxies in:

- voids
- loose groups
- compact groups
- and clusters

Discover HI clouds / filaments between galaxies, tracing their interaction history.

HI in the NGC 3263 galaxy group – English, BK et al. (2010)

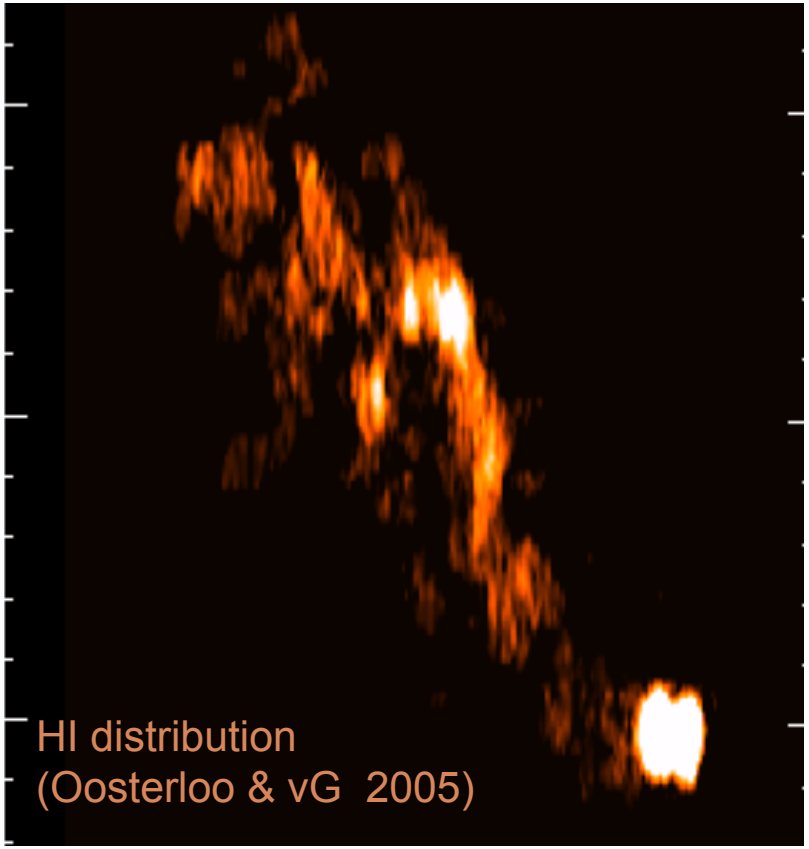

Our science goal
for ASKAP-ADE12
Our strategy:
• in-depth study of **10 fields** (z = 0 – 0.2)
• targeting galaxies in different environments
• approx. **60 hours (6 − 10 nights) per field**
• need to **resolve** galaxies and detect faint gas in and outside galaxy disks
• focus on **nearby** groups and clusters
HI in the NGC 3263 galaxy group – English, BK et al. (2010)



VLA HI Study of the Virgo Cluster.

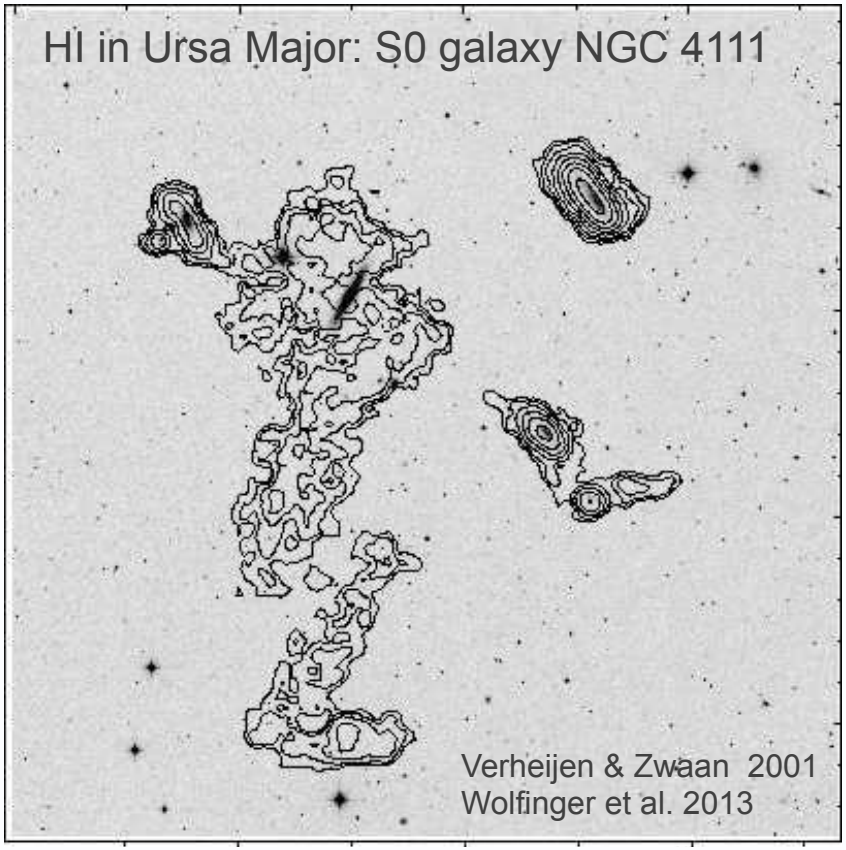
About **400h** to obtain single pointings of 53 late-type Virgo cluster galaxies.

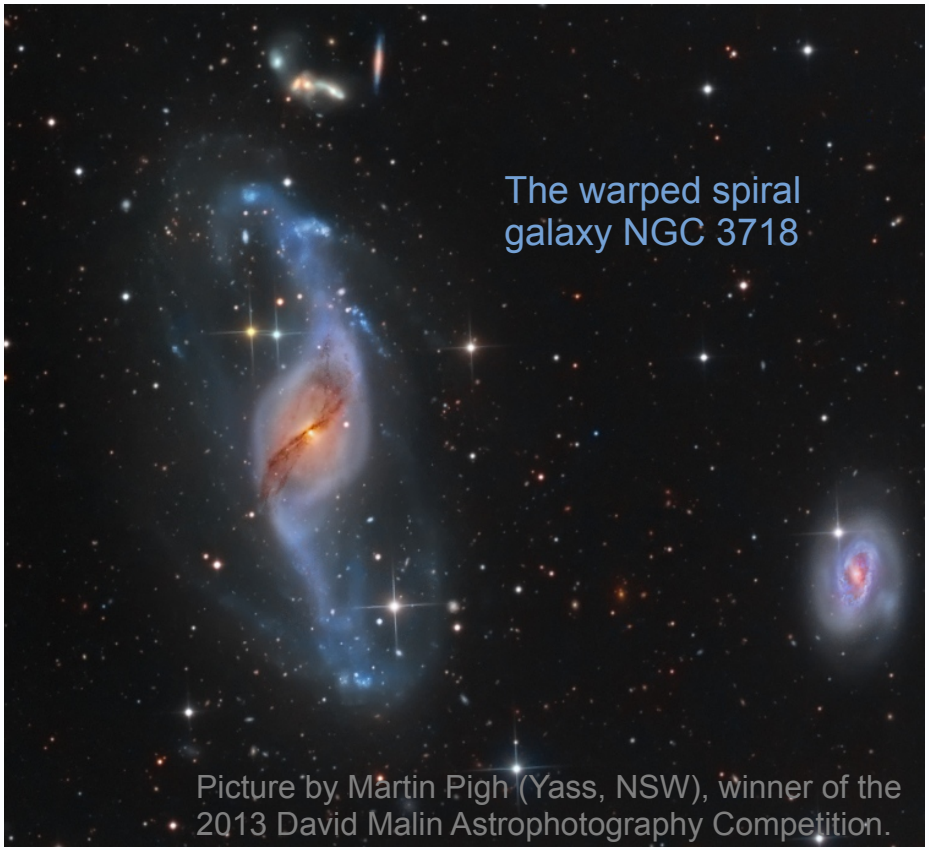
SDSS + HI contours (Chung et al. 2009).



The 21-cm spectral line allows us to study

- the physical processes affecting galaxy disks
- star-formation locations in the outer disk
- gaseous filaments/bridges between galaxies
- intra-group/cluster gas





The 21-cm spectral line allows us to study

- the physical processes affecting galaxy disks
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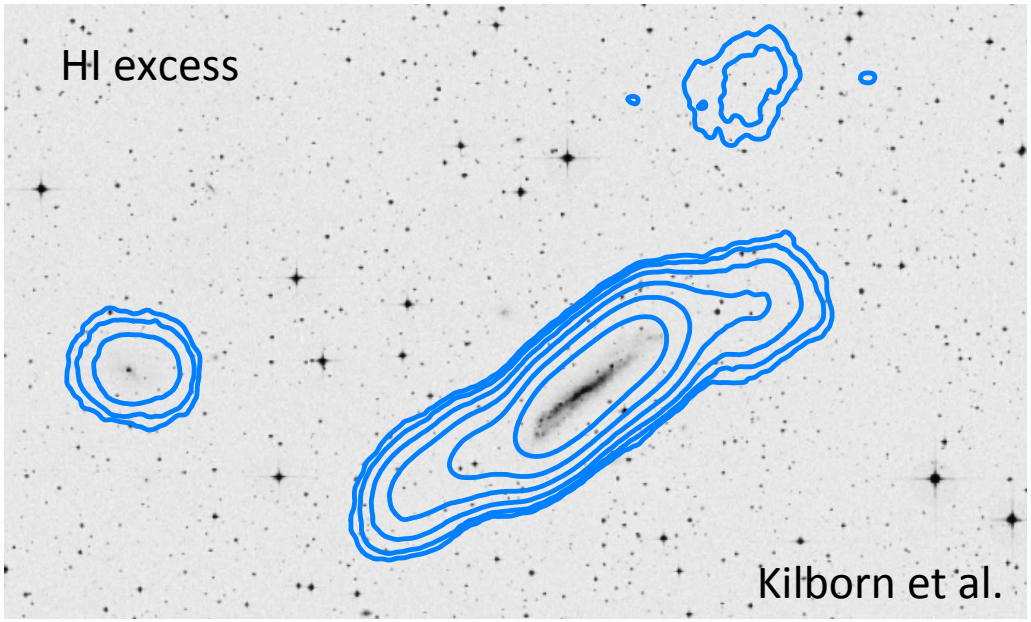
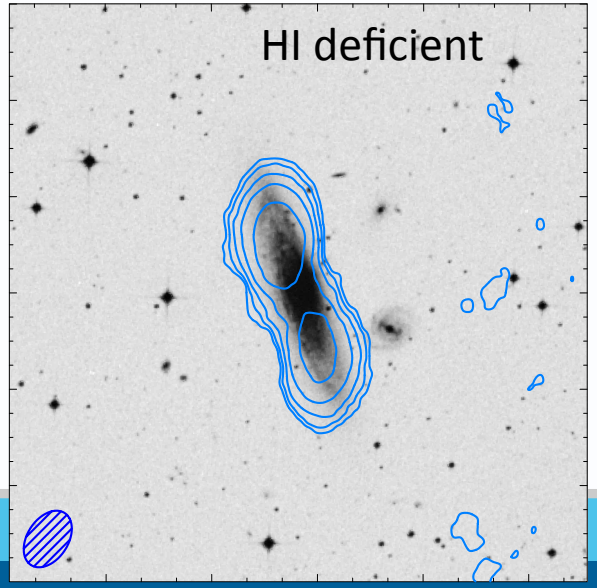
- gaseous filaments/bridges between galaxies
- intra-group/cluster gas

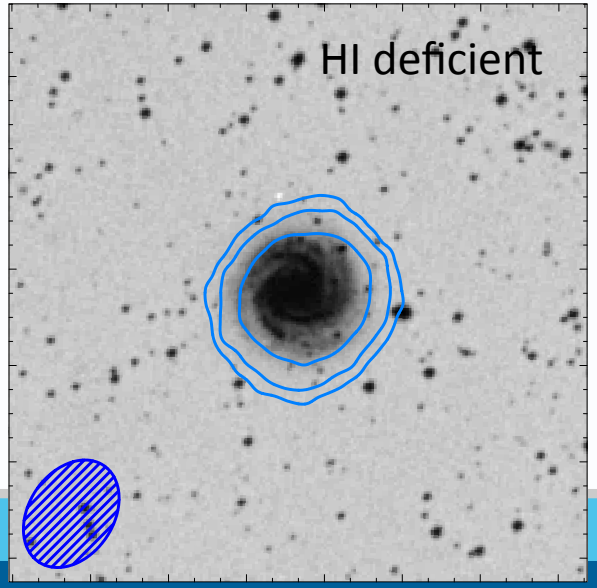
Using HI maps to determine the morphology of HI deficient and HI excess galaxies:

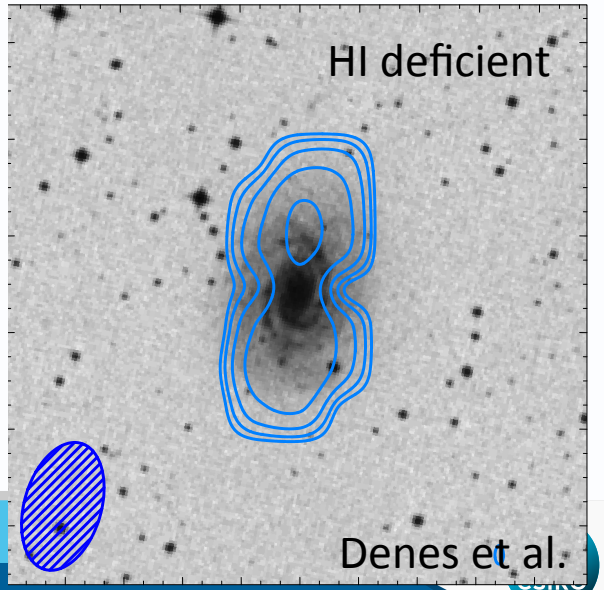
HI stripping and HI accretion methods in spiral galaxies

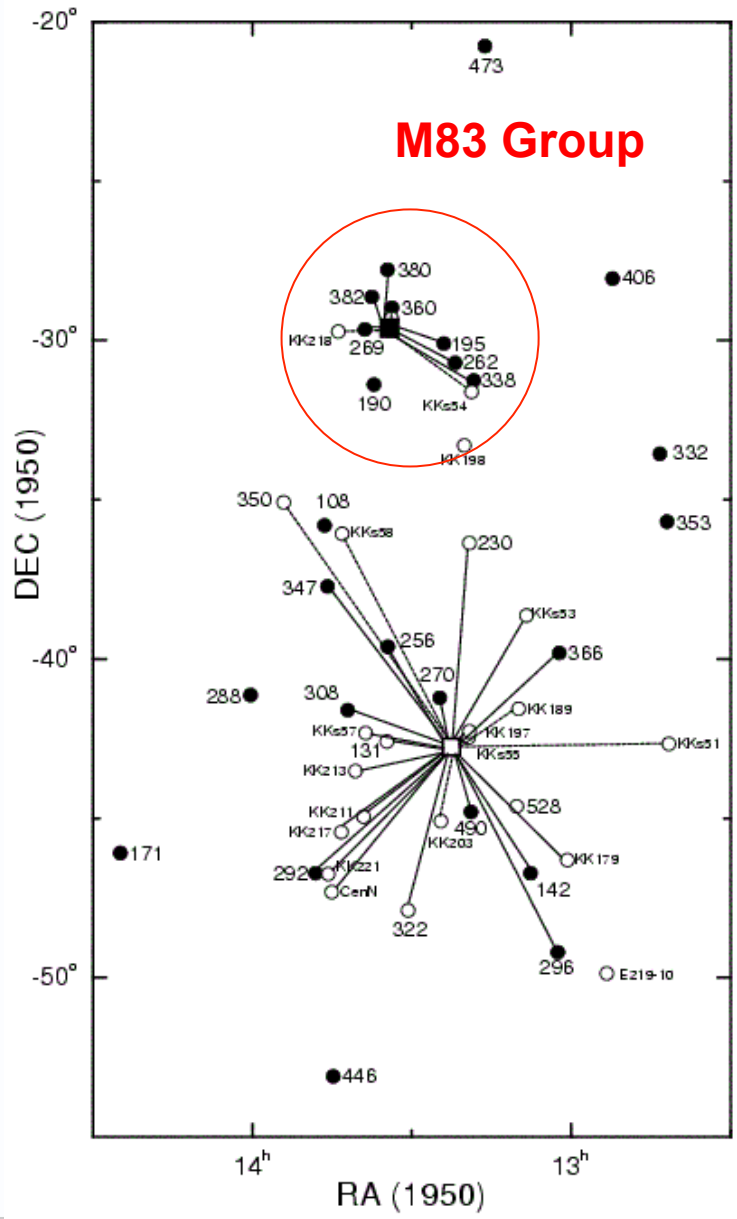


slide by Virginia Kilborn

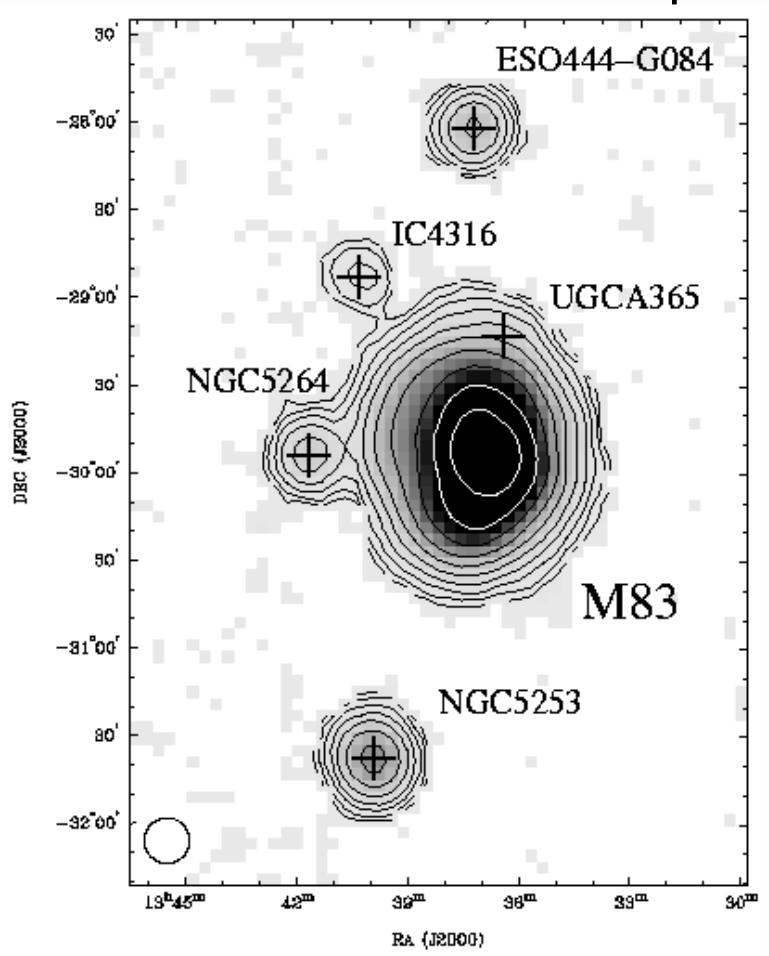






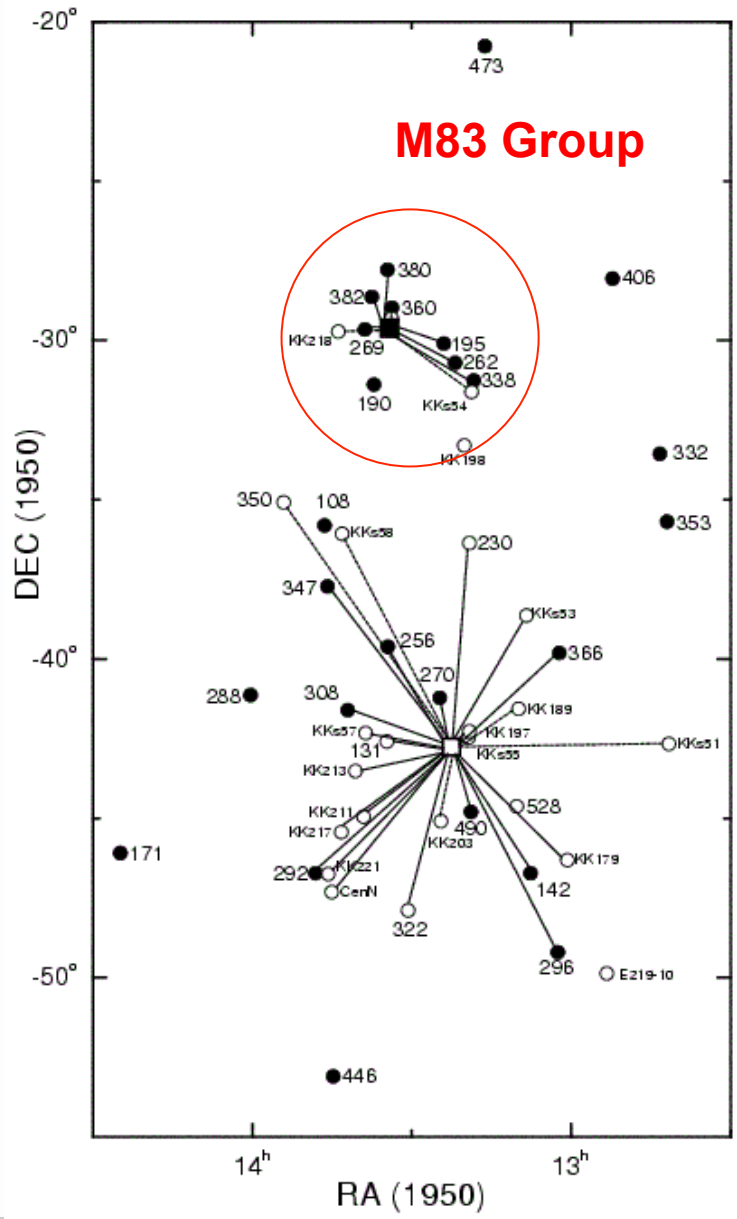


HIDEEP – mom0 map

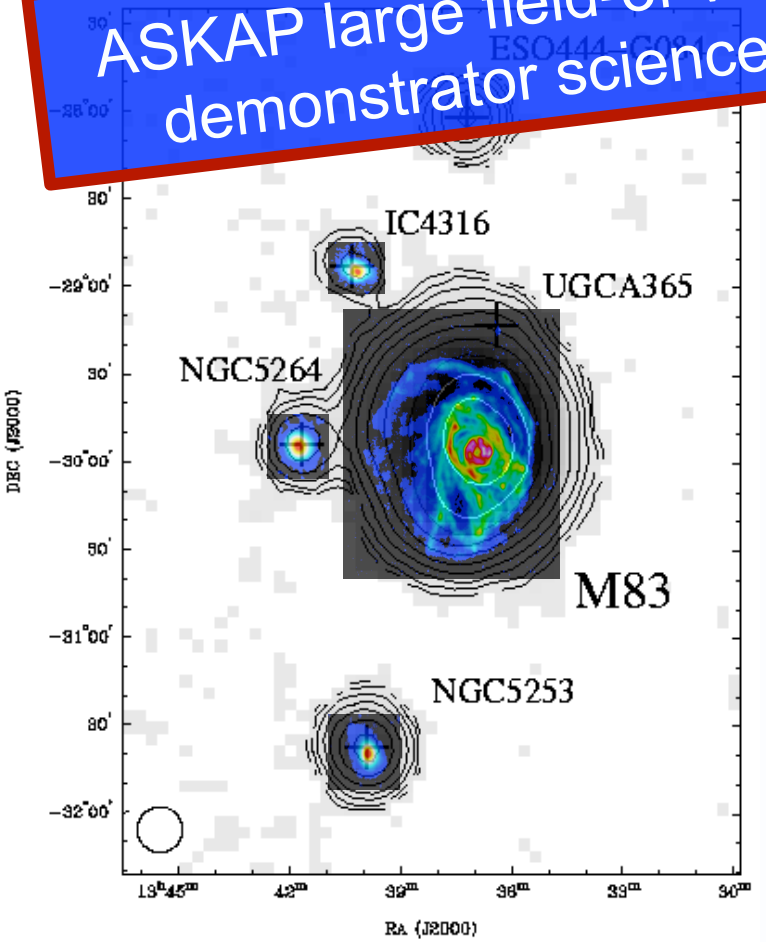


5°

ATCA primary beam



ASKAP large field-of-view demonstrator science

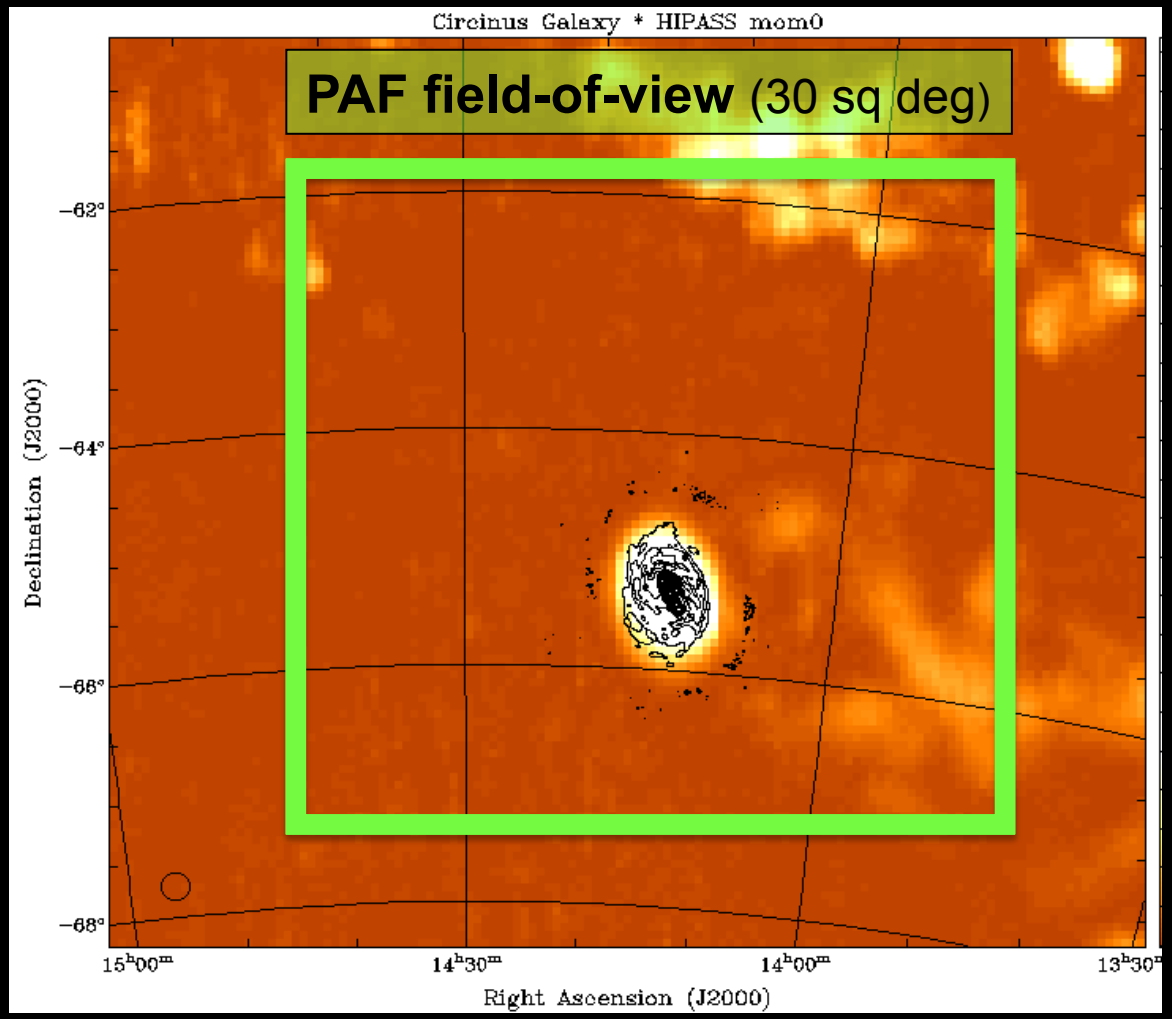


5°

ATCA primary beam

BETA / ASKAP Early Science Fields

ASKAP-ADE
6 – 12+ dishes

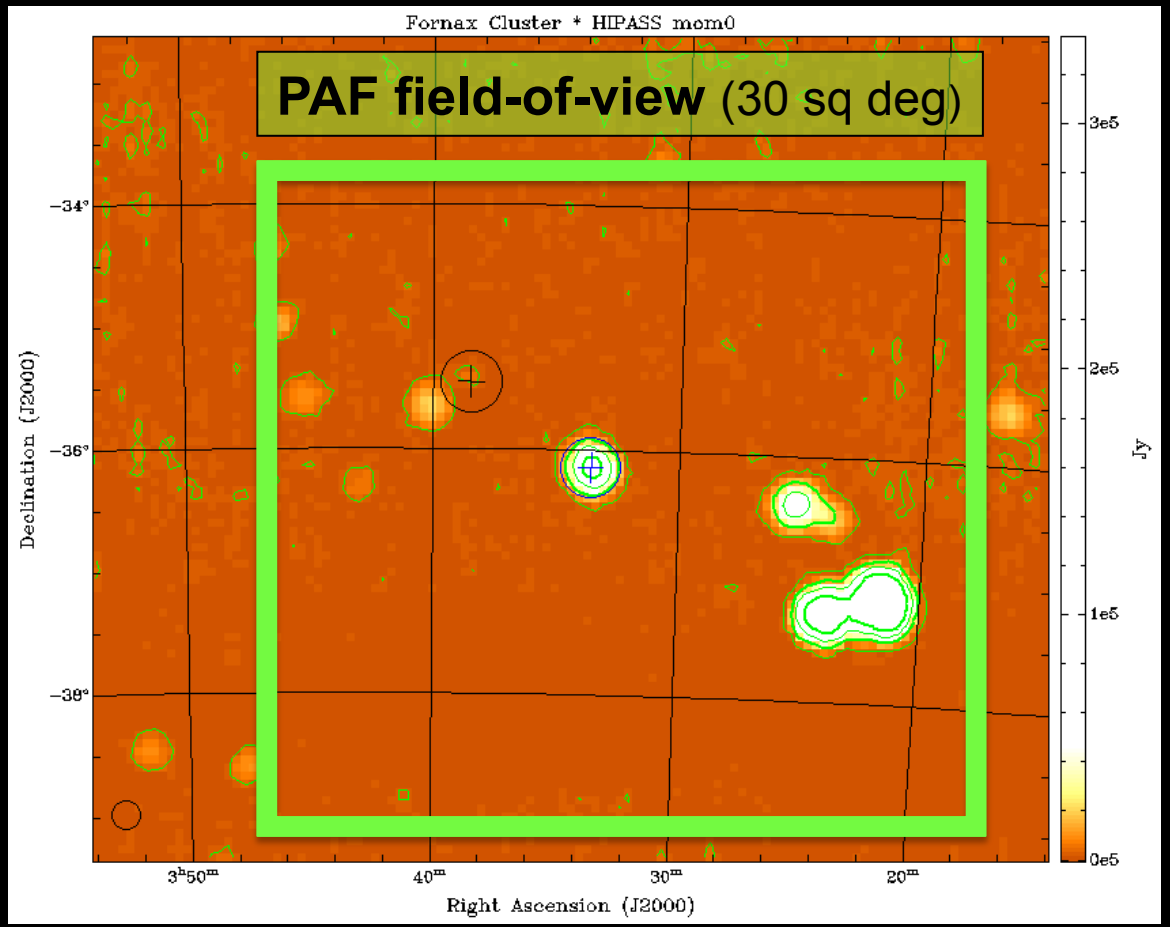


Moon to scale

Circinus field: isolated nearby galaxy

BETA / ASKAP Early Science Fields

ASKAP-ADE
6 – 12+ dishes



Moon to scale

Fornax field: a nearby galaxy cluster

ASKAP-12 HI Early Science

- ASKAP-ADE12 HI line sensitivity and configuration studies (WALLABY Memos 13 & 14; Tobias Westmeier et al.)
- HI Early Science – our *"umbrella theme"*:

> Study the evolution of galaxies, their transformation and star formation as a function of environment.

- Approx. **10 target fields** – observe for **≥60 hours each** (resulting in HI line rms per 4 km/s channel of ~1.6 mJy/beam and angular resolution of ~20-30 arcsec)

HI Spectral Line Sensitivity

ASKAP-ADE12 HI survey speed

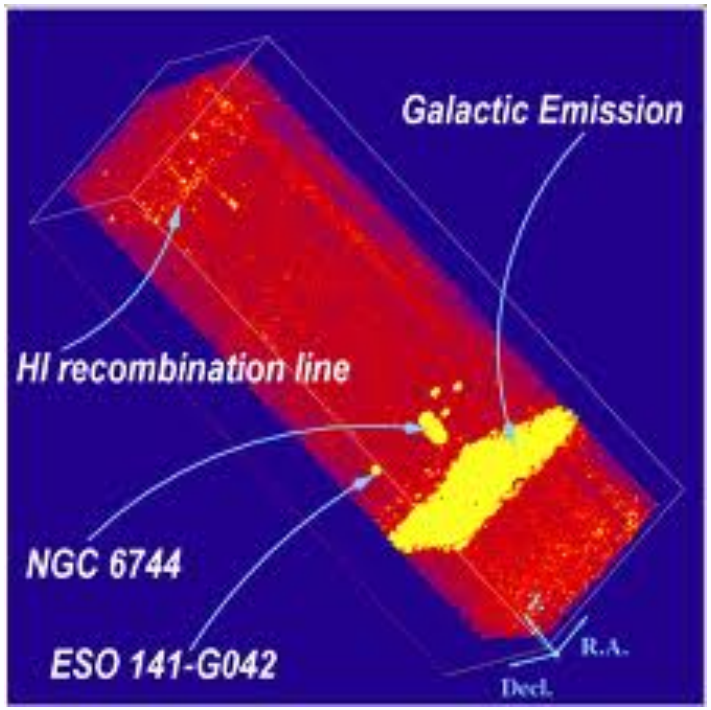
≥ VLA HI survey speed

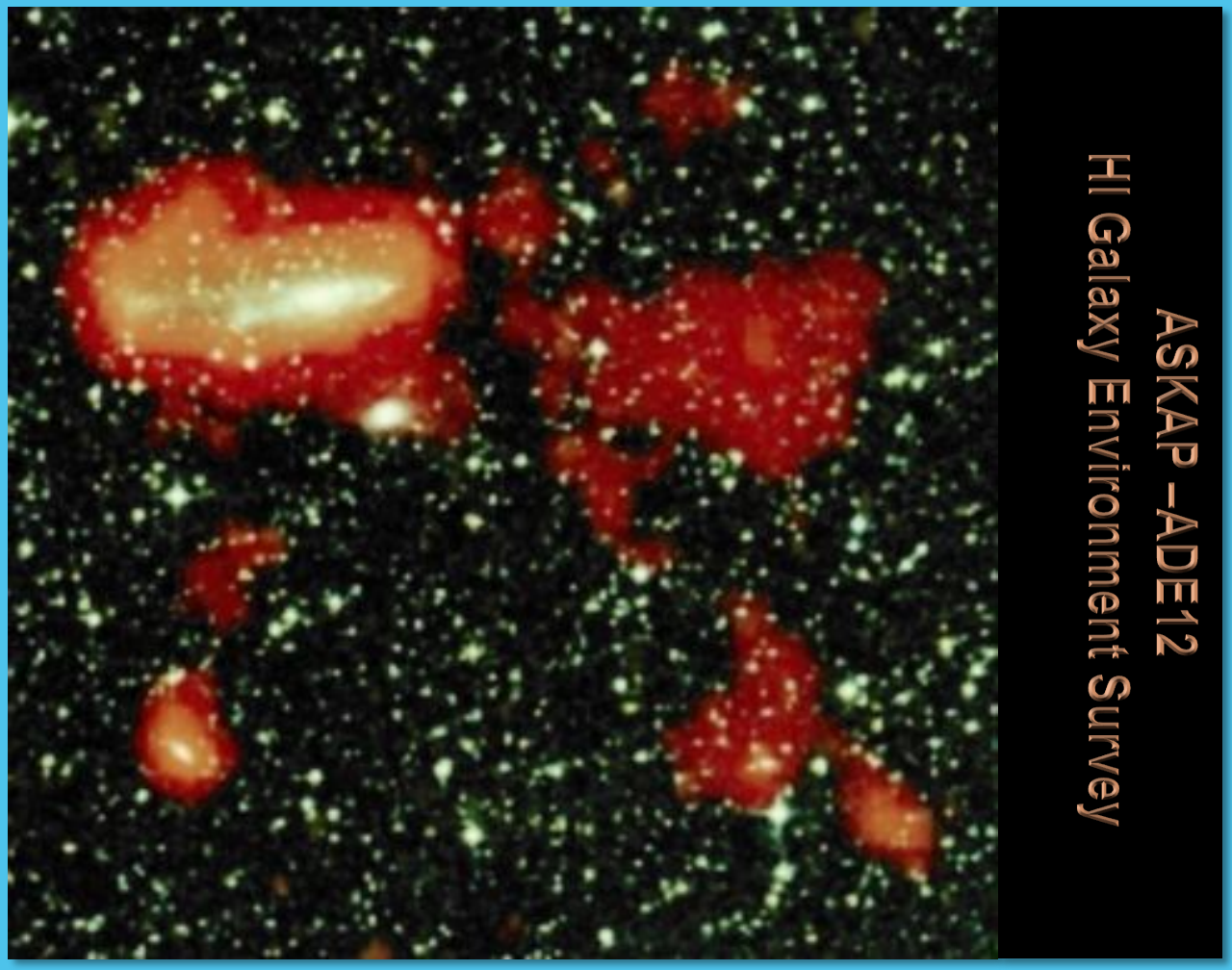
(assuming ASKAP-ADE T_{sys} = 50 K @ 1.1 - 1.4 GHz, efficiency η = 0.8)

	Time on source to reach an rms of 4-5 mJy/beam	Mapped area for 8 hour integration reaching an rms of 4-5 mJy/beam
ATCA	50 minutes	9-point HI mosaic (pbeam ~ 34')
VLA	10 minutes	48-point HI mosaic (pbeam ~ 30')
ASKAP-ADE12	480 minutes	PAF field-of-view (≈30 sq degr) eq to 36-point HI mosaic (pbeam ~ 63')
ASKAP-ADE30	74 minutes	6.5 PAF fields

ASKAP-12 HI Observations

- Each field: ≈60h on-source, ie about 6-10 nights observing
  - ➢ dither or choose offset pointing position each night (Nyquist sample)
- FOV ≈ 30 sq degr (approx. 5.5 degr x 5.5 degr)
- syn. beam 20”-30” (6” pixels?)
- 16384 channels, each 18.5 kHz
- keep visibilities until imaging is complete
- shared risk observing





Target ~10 fields

≥ 60 h each

Umbrella Theme:
Galaxy evolution as a function of environment.

How do physical processes affect the HI morphology and kinematics of galaxies in voids, groups & clusters.

CSIRO Astronomy and Space Science * Contact: Baerbel.Koribalski@csiro.au
www.csiro.au

ASKAP HI All-Sky Survey

WALLABY PIs: Bärbel Koribalski & Lister Staveley-Smith

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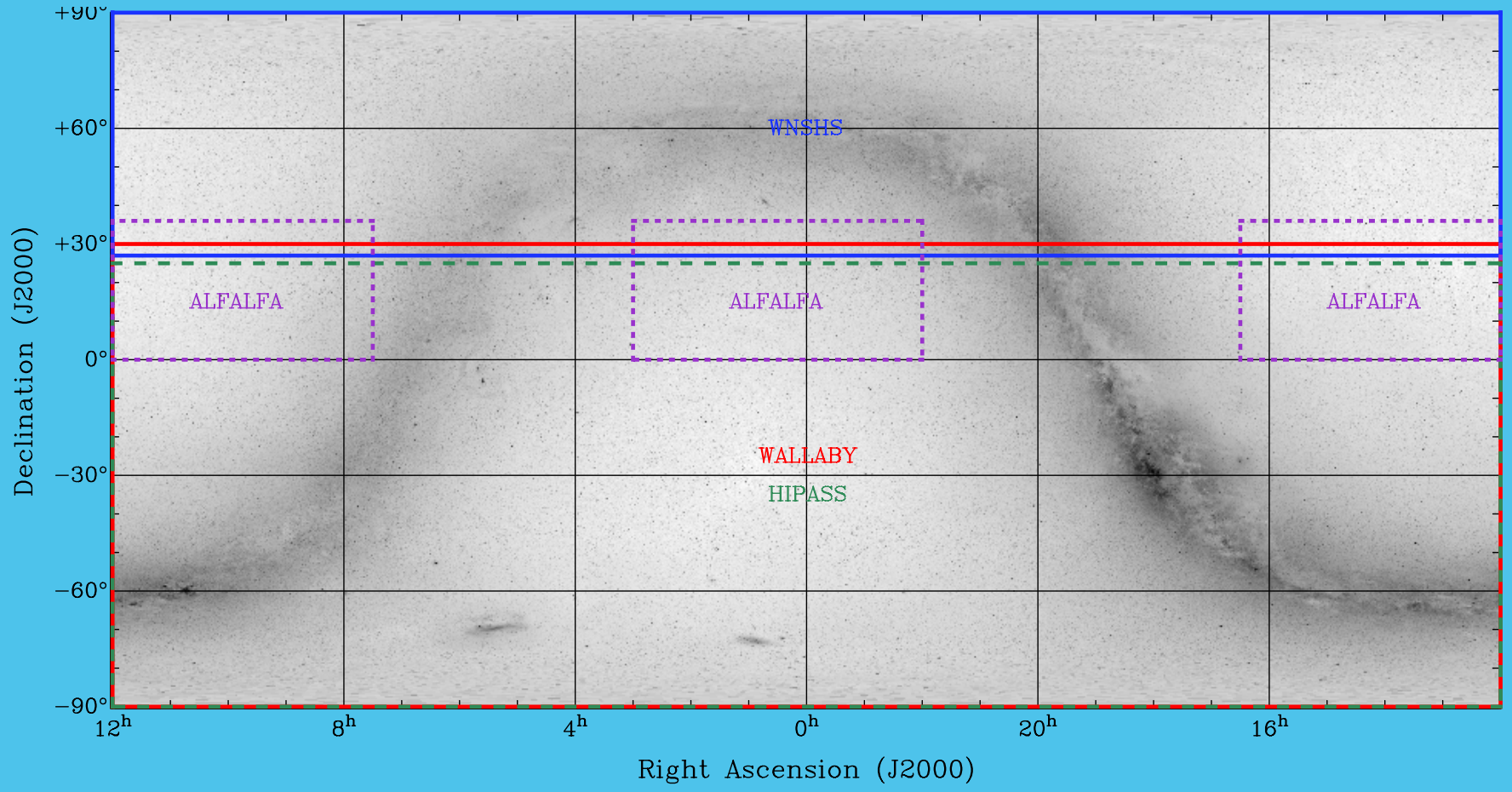
ASKAP HI All-Sky Survey

WALLABY PIs: Bärbel Koribalski & Lister Staveley-Smith



WALLABY overview paper (Koribalski et al, 2014, in prep.) Figure by Tobias Westmeier.

ASKAP: 36 antennas assembled.
(Picture credit: Simon Johnston)

WALLABY Predictions
(Duffy et al. 2012)

. . . step by step

in future: SKA Phase 1+2 HI Surveys

WALLABY – the ASKAP HI All-Sky Survey

LVHIS – the Local Volume HI Survey

HIPASS – the HI Parkes All-Sky Survey

ASKAP: 36 antennas assembled.
(Picture credit: Simon Johnston)

WALLABY parameters:

- survey time: ~ one year
- **sky coverage:** **$-90^o < \delta < +30^o$** (max. $+50^o$)

  FOV = 30 sq deg (i.e. 400× ATCA primary beam)
- **velocity coverage: −2,000 to 77,000 km/s (z = 0.26)**

  BW = 300 MHz divided into 16,384 channels
- **resolution:** **30”, 4 km/s** (+ 10” postage stamps)
- integration time: 8 (12) hours per pointing
- line sensitivity: ~1.5 (1.3) mJy/beam per channel
- 330 TB total storage for Stokes-I cubes

ASKAP: 36 antennas assembled.
(Picture credit: Simon Johnston)

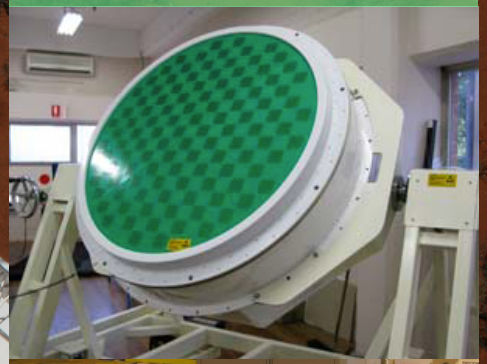
WALLABY science goals:

We will examine the HI properties and large-scale distribution of ~ 600,000 galaxies out to z = 0.26 and study, for example:

- **their gas content as a function of environment**
- **their disk kinematics and dark matter distribution**
- **signatures of gas accretion and ram pressure stripping**
- **the HI mass function and its variation with galaxy density**
- **large-scale structures of galaxies, bulk flow motions**

ASKAP: 36 × 12-m antennas.
(Picture credit: Simon Johnston)

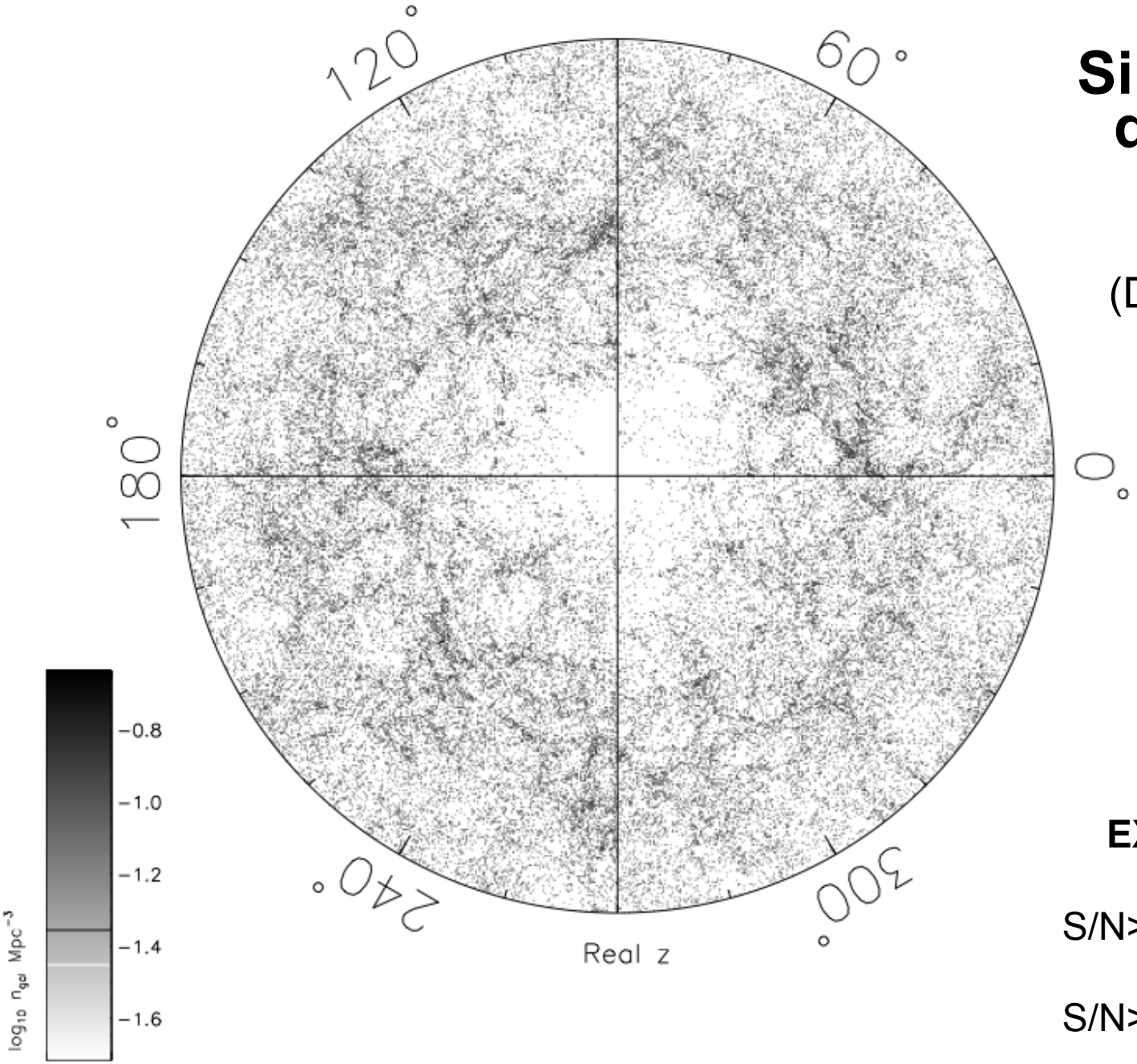
Phased Array Feeds



WALLABY + WNSHS (Koribalski 2012)

- **ASKAP HI All-Sky Survey ($\delta < +30^o$)**

- **Westerbork Northern Sky HI Survey ($\delta > +27^o$)**



Simulated sky distribution

<12,000 km/s

(Duffy et al. 2012)

EXPECTED TOTAL

S/N>5: 825k galaxies

S/N>10: 249k galaxies

ASKAP HI All-Sky Survey

WALLABY Team – developing & testing new tools, commissioning

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WALLABY – Working Groups

Representatives on ASKAP working groups

1) ASKAP Simulations & Imaging: Matthew Whiting

2) Source Finding: Tobias Westmeier

3) Survey Strategy: BK & LSS

4) BETA & Commissioning: Ivy Wong

5) ASKAP Data Archive: Paolo Serra (Ian Heywood)

WALLABY – Working Groups

Science Working groups

- SWG1 – Local Group: E Ryan-Weber
- SWG2 – Local Universe: B Koribalski & G Meurer
- SWG3 – Galaxy Environments: V Kilborn
- SWG4 – Intergalactic HI: B Wakker
- SWG5 – HI Mass Function: M Zwaan
- SWG6 – Large-scale structure: J Mould
- SWG7 – Galaxy clusters: M Verheijen & P Serra
- SWG8 – Galactic Halo: J Kerp

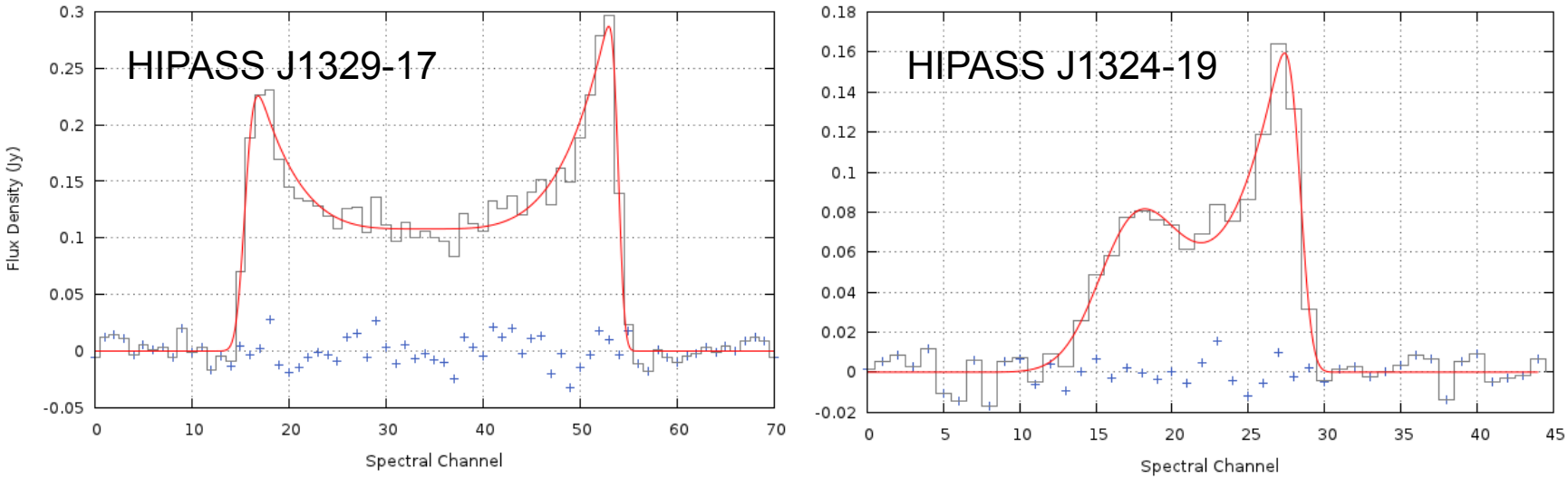
WALLABY – Working Groups

Technical Working groups

- TWG1 - Numerical Simulations & Mock Surveys: C Power (C Blake)
- TWG2 - Survey Strategy & Commissioning: BK & LSS
- TWG3 – Data Processing and Imaging: M Whiting
- TWG4 - Source Finding and Parametrisation: T Westmeier
- TWG5 - Data Format, Access & Visualisation: C Fluke (R Jurek)
- TWG6 - Stacking: M Meyer
- TWG7 - RFI Mitigation: L Staveley-Smith

The Busy Function:

a new analytic function for describing the integrated 21-cm spectral profile of galaxies



Westmeier, T., Jurek, R., Obreschkow, D., Koribalski, B.S., Staveley-Smith, L. 2014, MNRAS 438, 1176

*http://www.atnf.csiro.au/people/Tobias.Westmeier/**tools_software_busyfit.php***

CSIRO

SoFiA - our new Source Finding Application

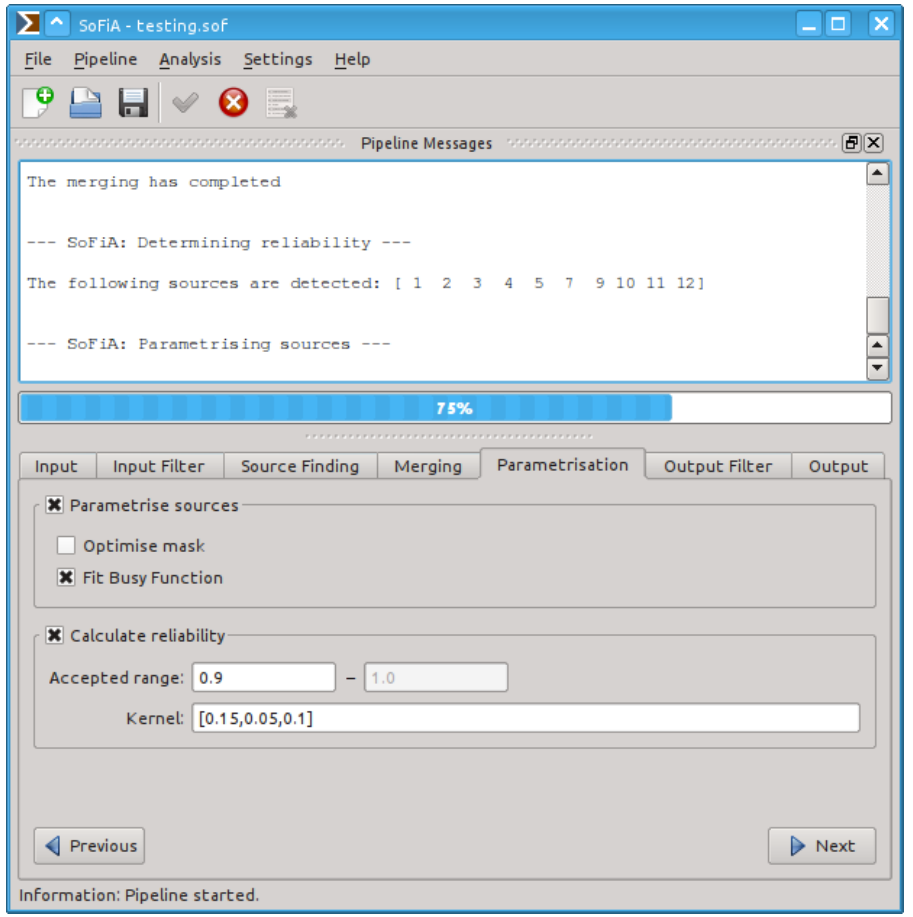
SoFiA

Source Finding Application

developed by members of the **WALLABY source finding working group (TWG4)**

Tobias Westmeier, Paolo Serra, Nadine Giese, Russell Jurek, Lars Flöer, Attila Popping and Benjamin Winkel

* SoFiA Handbook (on-line)

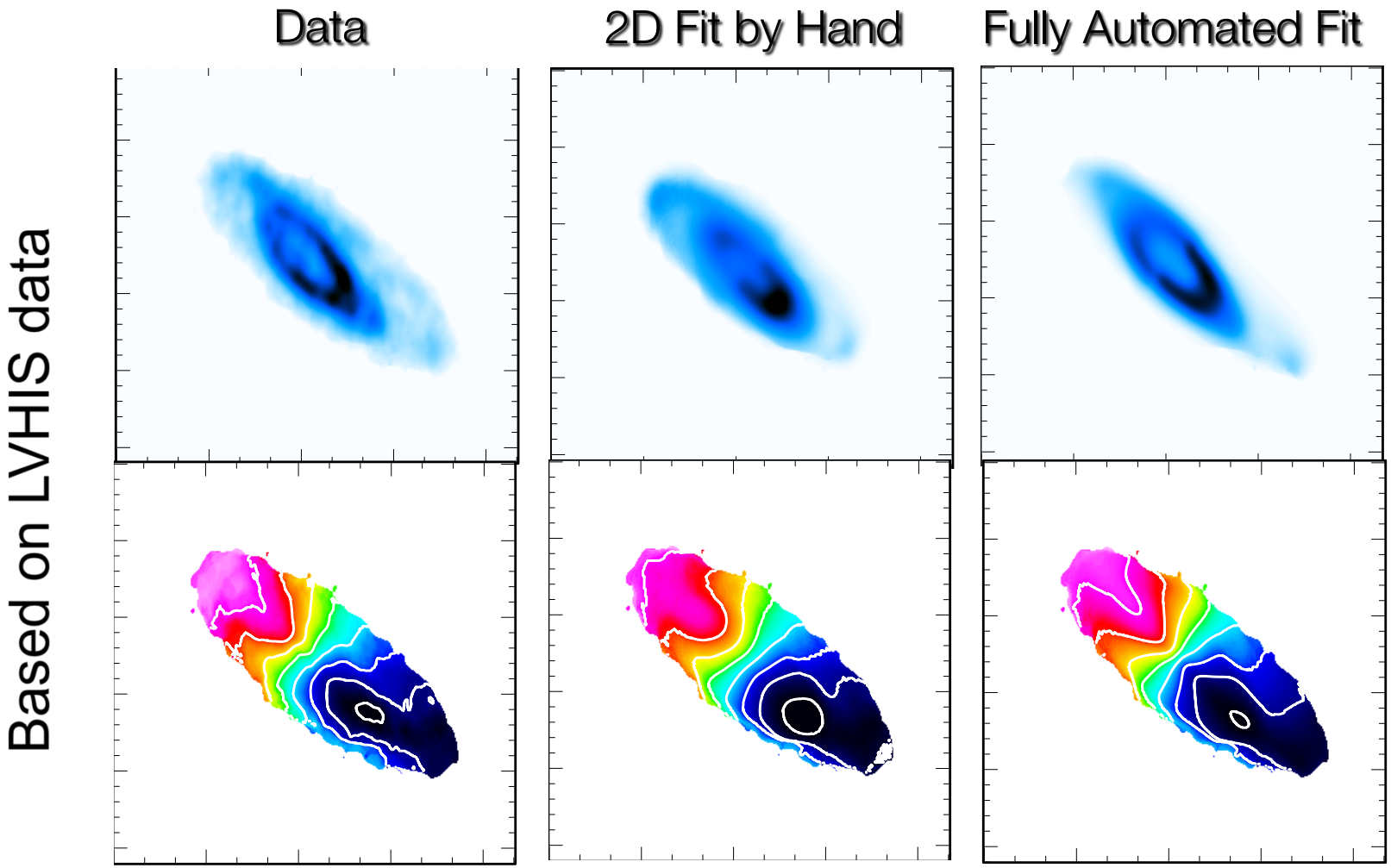


*http://www.atnf.csiro.au/people/Tobias.Westmeier/**tools_software_sofia.php***

CSIRO

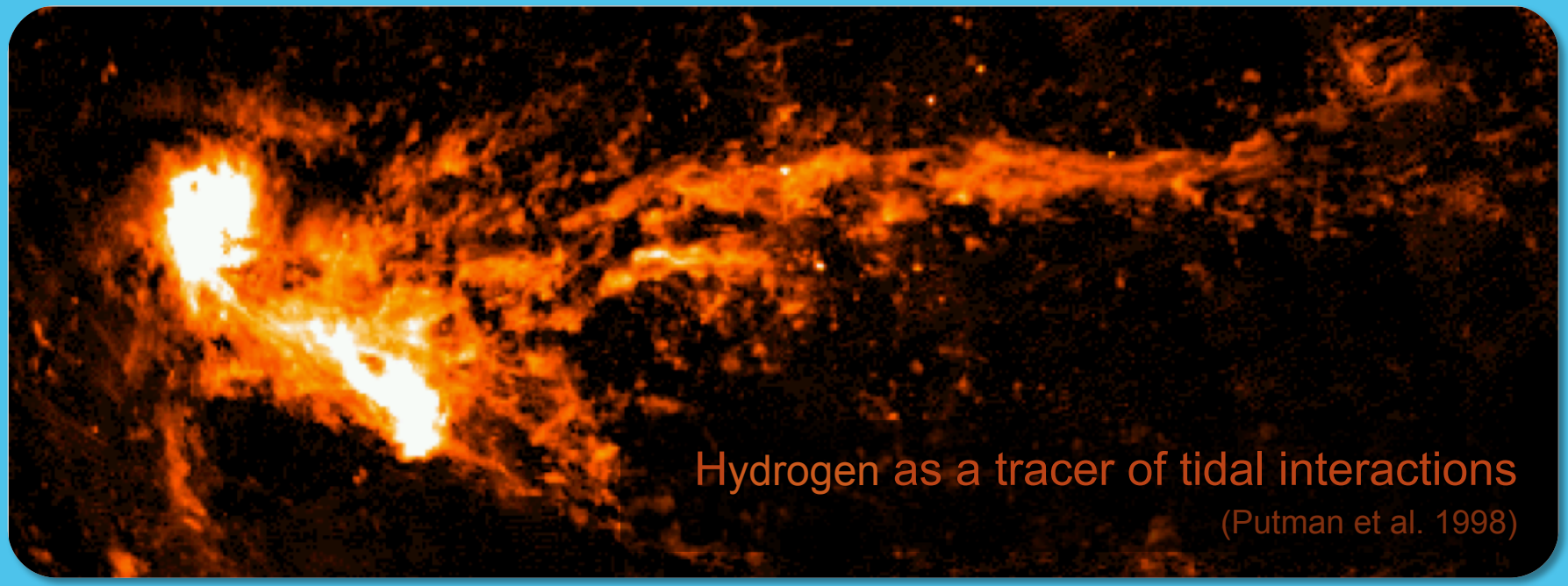
WALLABY Kinematic Working Group

(led by Kristine Spekkens)



(Peter Kamphuis, Se-Heon Oh, Gyula Jozsa, Ed Elson, et al.)

CSIRO



HI Parkes All-Sky Survey (HIPASS)

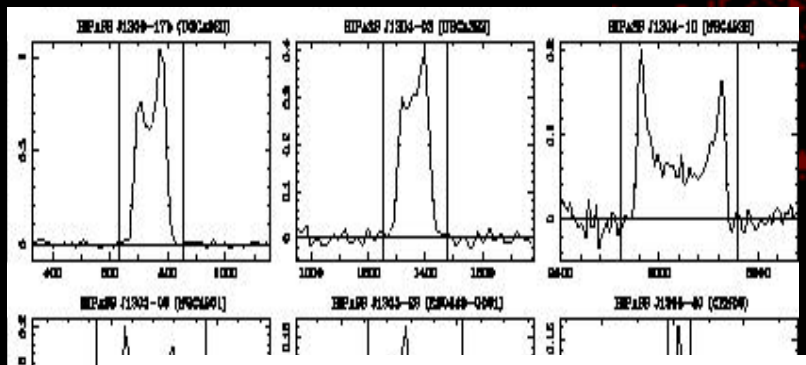
Bärbel Koribalski

CSIRO Astronomy and Space Science
www.csiro.au

HIPASS-1 and soon HIPASS-2

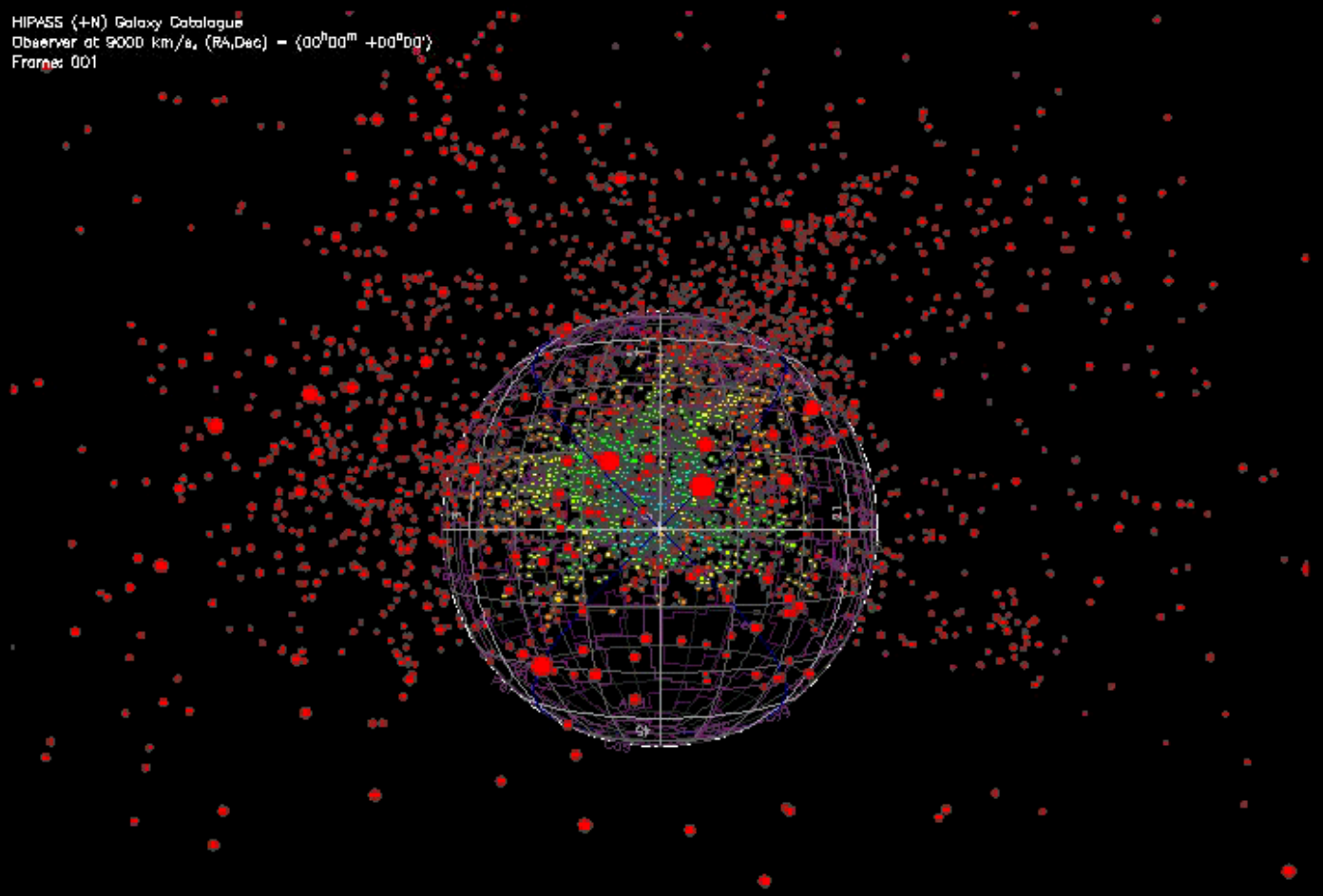
Apply new Source Finding and Parametrisation tools

(2012 PASA Special Issue)



RA (J2000.0) (2)	Decl. (J2000.0) (3)	l (deg) (4)	b (deg) (5)	NED ID (6)	$S_{\rm peak}$ (Jy) (7)	$\pm\sigma$ (Jy) (8)	$F_{\rm H\,I}$ (Jy km s^{-1}) (9)	$\pm\sigma$ (Jy km s^{-1}) (10)	$v_{\rm sys}$ (km s^{-1}) (11)	$\pm\sigma$ (km s^{-1}) (12)	w_{50} (km s^{-1}) (13)	w_{20} (km s^{-1}) (14)	$v_{\rm LG}$ (km s^{-1}) (15)	log $M_{\rm H\,I}$ ($M_\odot$) (16)
00 47 45	−09 54 58	119.9	−72.8	UGCA 014	0.135	0.016	18.5	3.3	1342	5	144	166	1419	9.19
00 47 46	−11 27 14	119.6	−74.3	NGC 0255	0.339	0.023	42.8	4.4	1585	4	148	193	1656	9.69
00 49 35	−21 01 07	118.9	−83.9	UGCA 015	0.144	0.018	3.9	1.5	294	4	25	41	322	7.23
00 50 59	−07 03 22	122.6	−69.9	NGC 0274/5	0.185	0.014	36.6	3.4	1730	6	233	316	1817	9.70
00 51 57	−00 28 21	123.2	−62.4	MCG+00-03-018	0.138	0.016	14.7	2.7	1621	4	169	188	1737	9.27
00 52 43	−31 12 17	299.1	−85.9	NGC 0289	0.877	0.046	159.1	10.6	1629	2	274	300	1610	10.24
00 54 52	−37 40 25	299.2	−79.4	NGC 0300	17.078	0.856	1972.6	156.1	146	2	147	166	98	9.29*
00 54 57	−07 20 15	125.5	−70.2	NGC 0298	0.233	0.017	36.6	3.7	1756	3	209	230	1839	9.72
00 56 39	−09 55 33	127.3	−72.8	NGC 0309	0.128	0.017	21.1	3.8	5661	7	206	236	5732	10.46
00 59 50	−07 35 08	129.1	−70.4	NGC 0337	0.248	0.019	51.2	4.6	1648	4	233	272	1726	9.81
01 01 34	−07 35 22	130.4	−70.3	NGC 0337A	1.231	0.064	98.1	9.7	1074	2	87	106	1151	9.74
01 03 01	−03 36 30	130.1	−66.3	MCG-01-03-079	0.122	0.015	8.9	2.2	2587	5	85	103	2679	9.43
01 05 01	−06 13 06	132.3	−68.8	MCG-01-03-085	0.475	0.028	62.7	5.5	1096	2	171	189	1176	9.56
01 07 30	−69 52 30	300.9	−47.2	NGC 0406	0.241	0.018	48.3	4.4	1508	3	240	261	1333	9.56
01 09 41	−02 15 52	133.7	−64.8	MCG-01-04-005	0.140	0.016	16.4	2.9	1864	5	149	173	1957	9.42

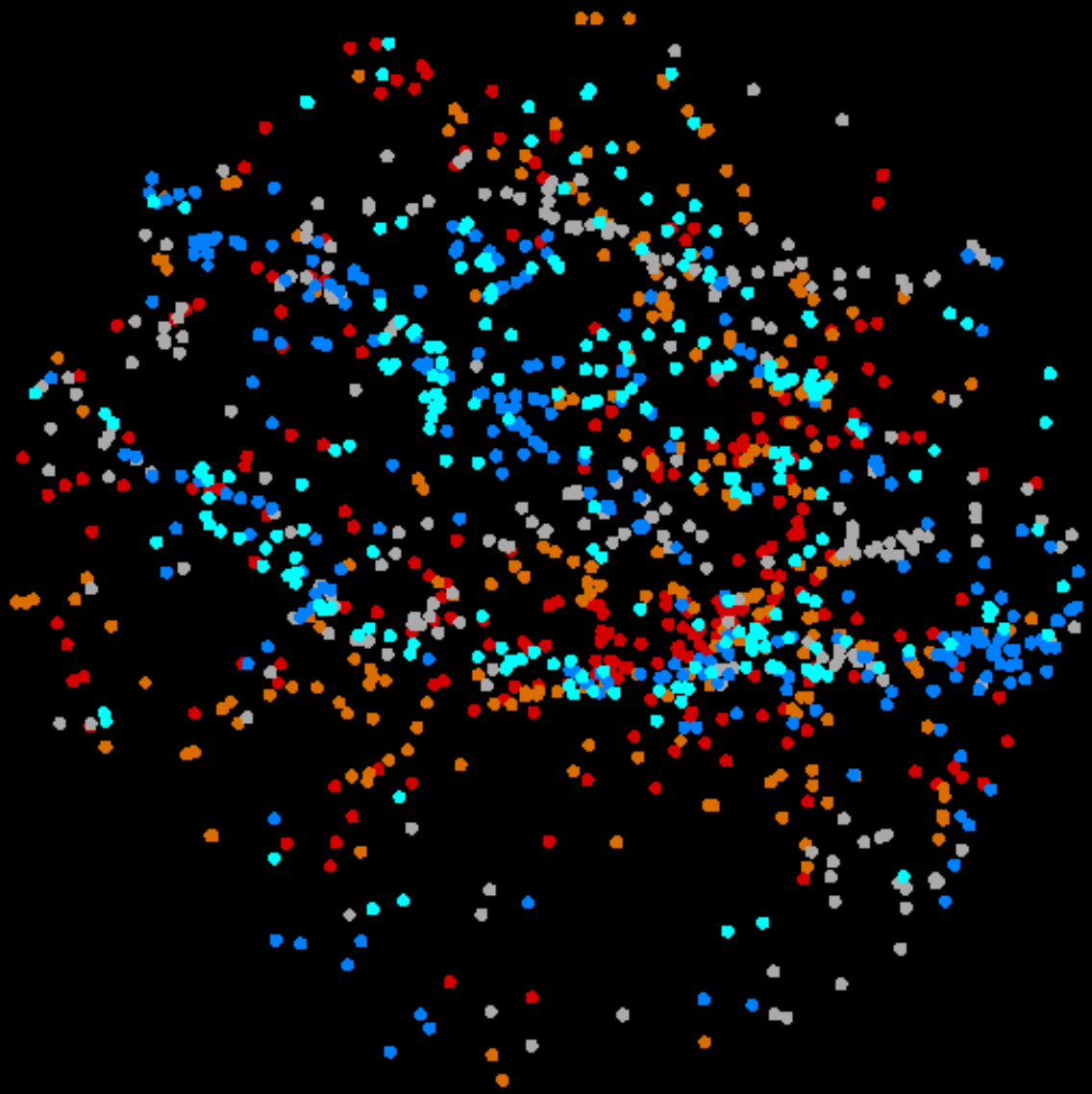
3D visualisation of HIPASS galaxies



by Mark Calabretta

HIPASS references: Koribalski et al. (2004), Meyer et al. (2004), Wong et al. (2006).

The HIPASS Bright Galaxy Catalog * Koribalski et al. (2004)



< 1000

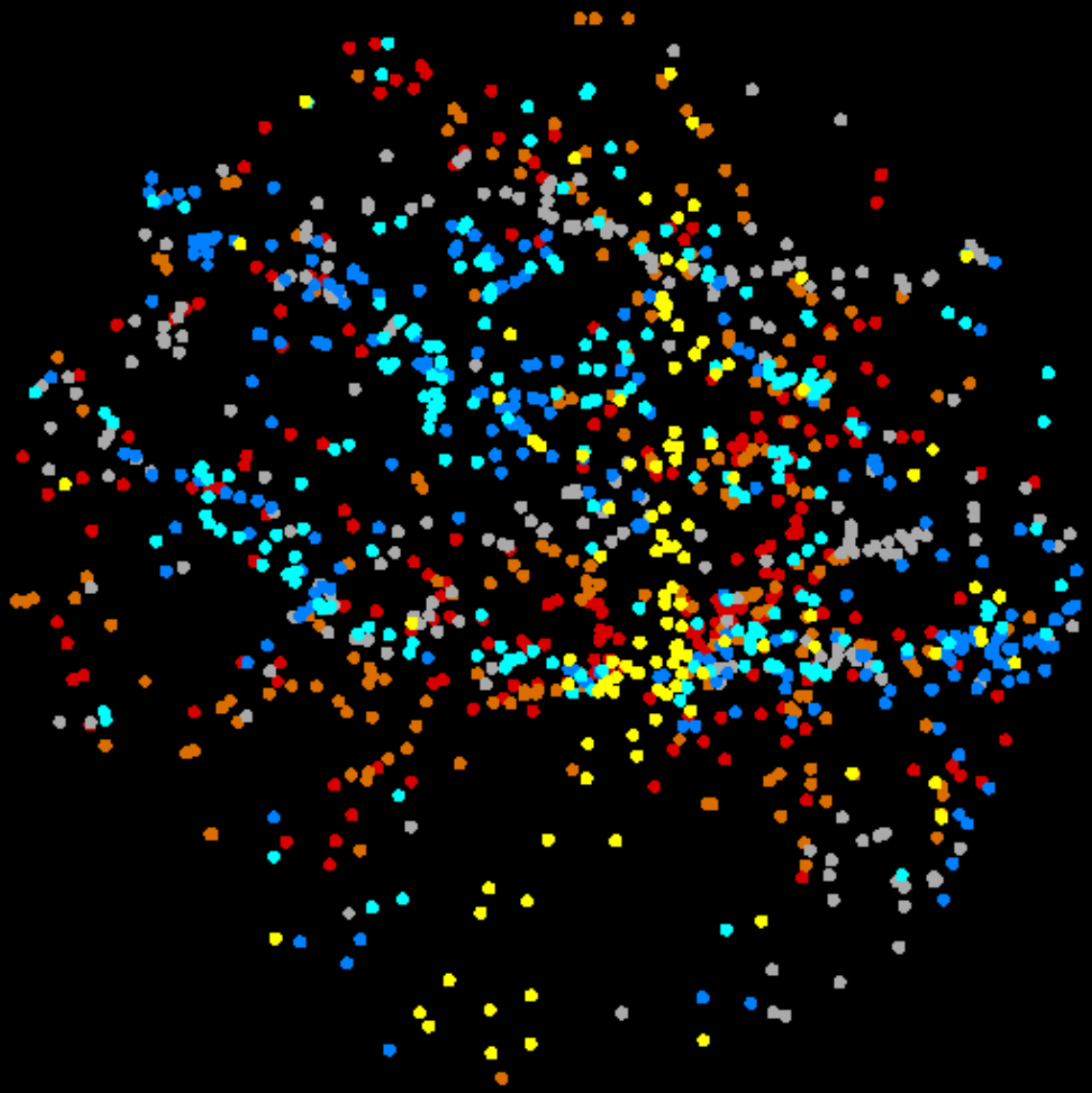
1100-1600

1600-2100

2100-2900

> 2900

The HIPASS Bright Galaxy Catalog * Koribalski et al. (2004)



new galaxies (111)

and

HI clouds (4)

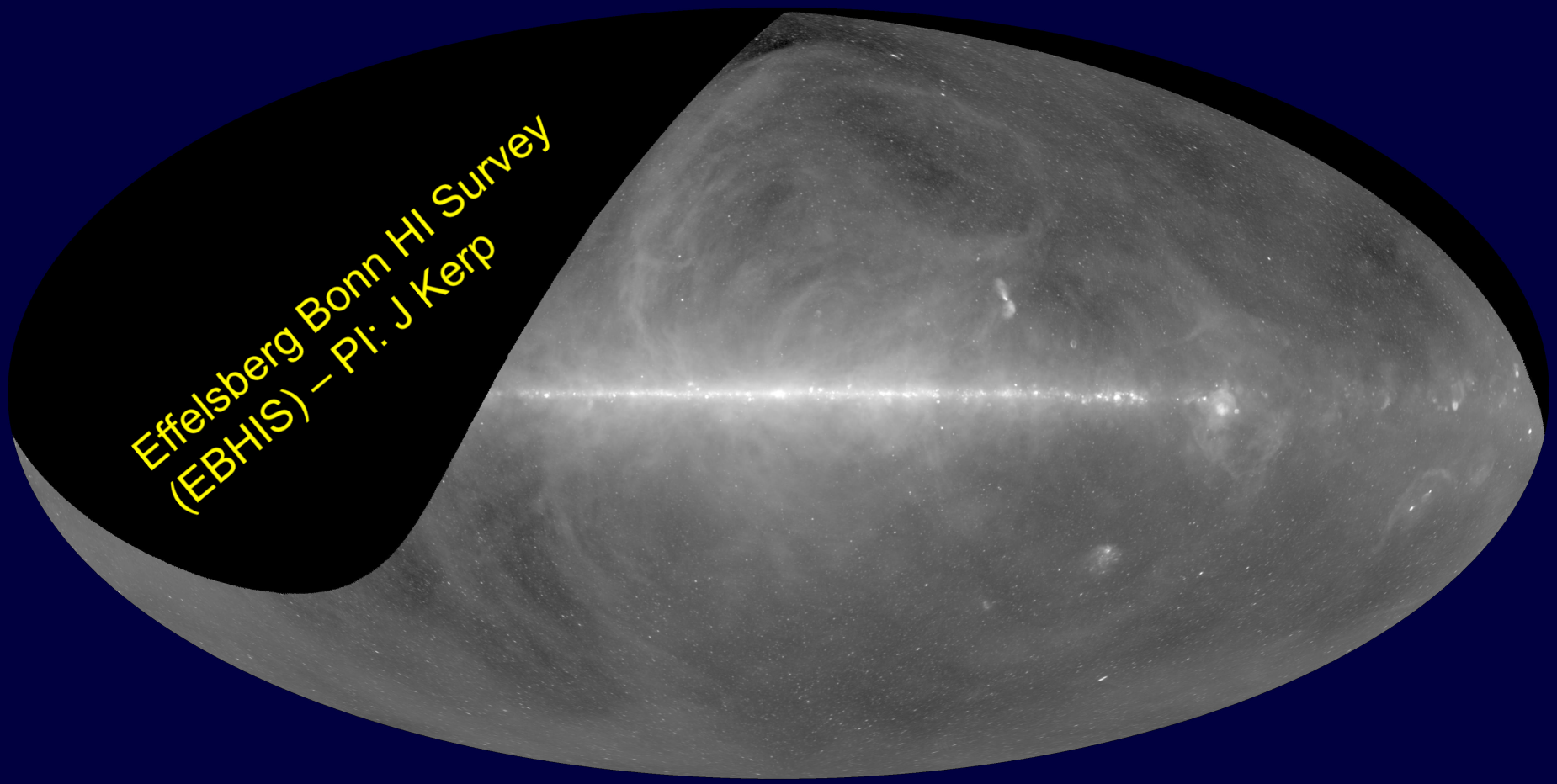
< 1000

1100-1600

1600-2100

2100-2900

> 2900

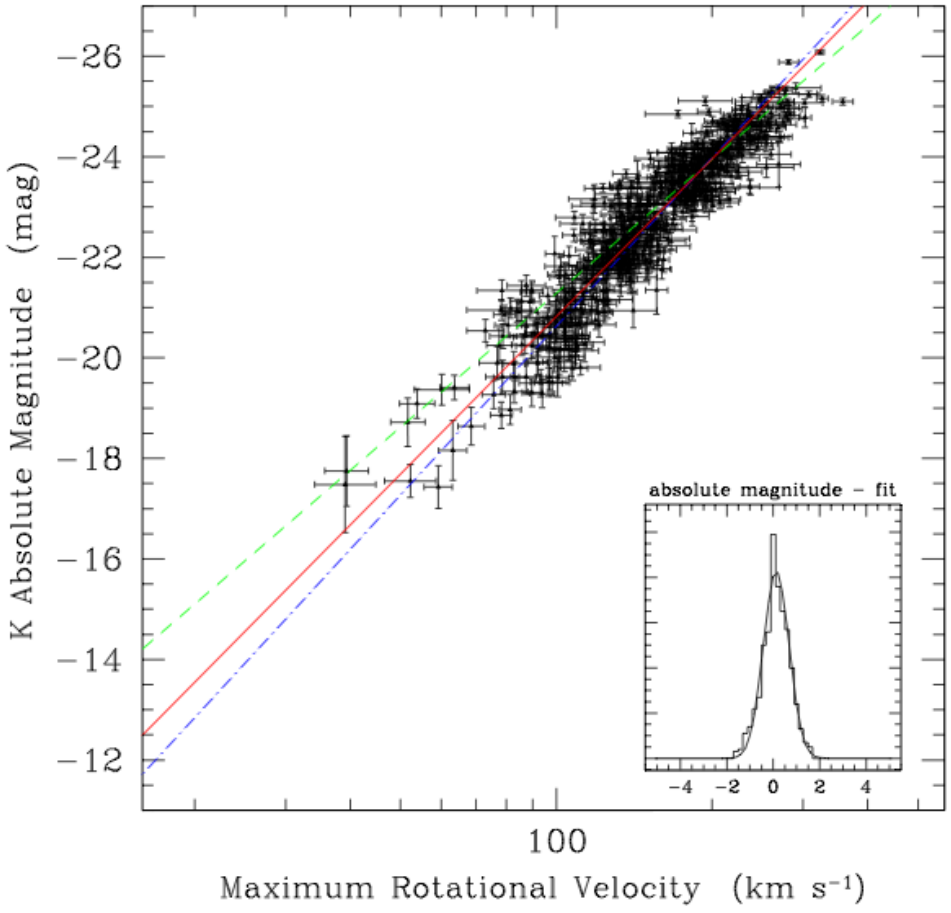


1.4GHz radio continuum map of the sky south of declination +25°

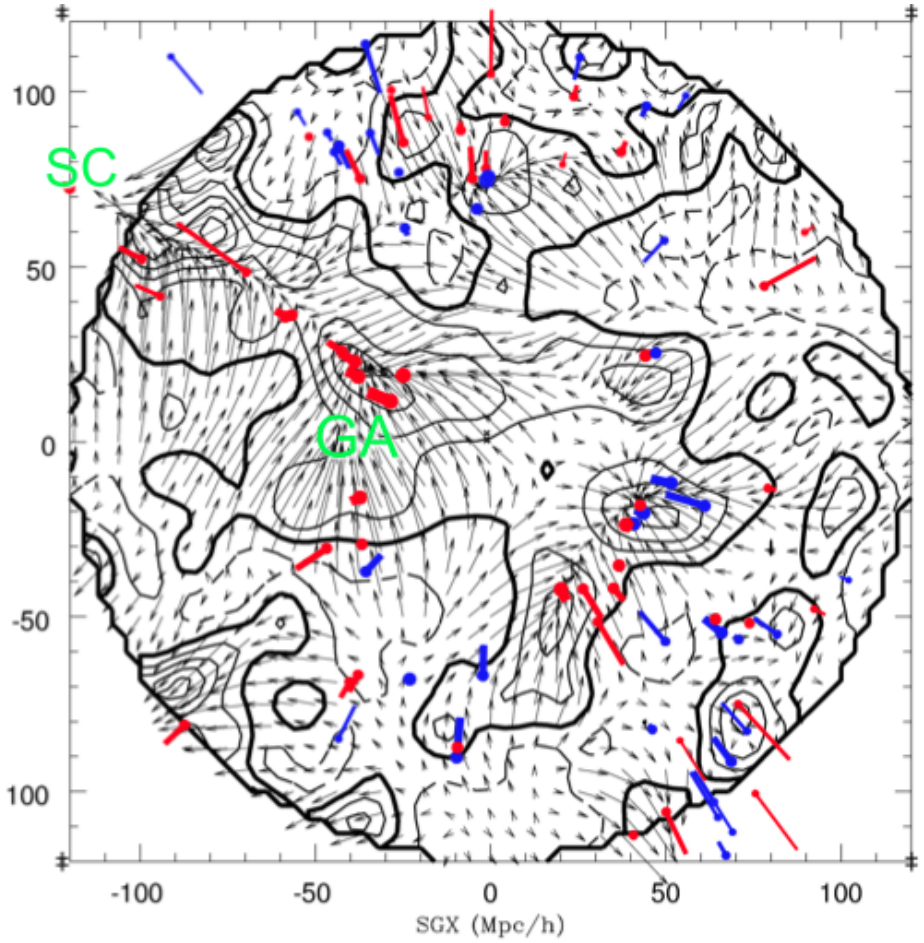
Calabretta, Staveley-Smith, & Barnes (2014)

CHIPASS (Calabretta, Staveley-Smith & Barnes 2013)

Tully-Fisher Relation – Bulk Flow Field

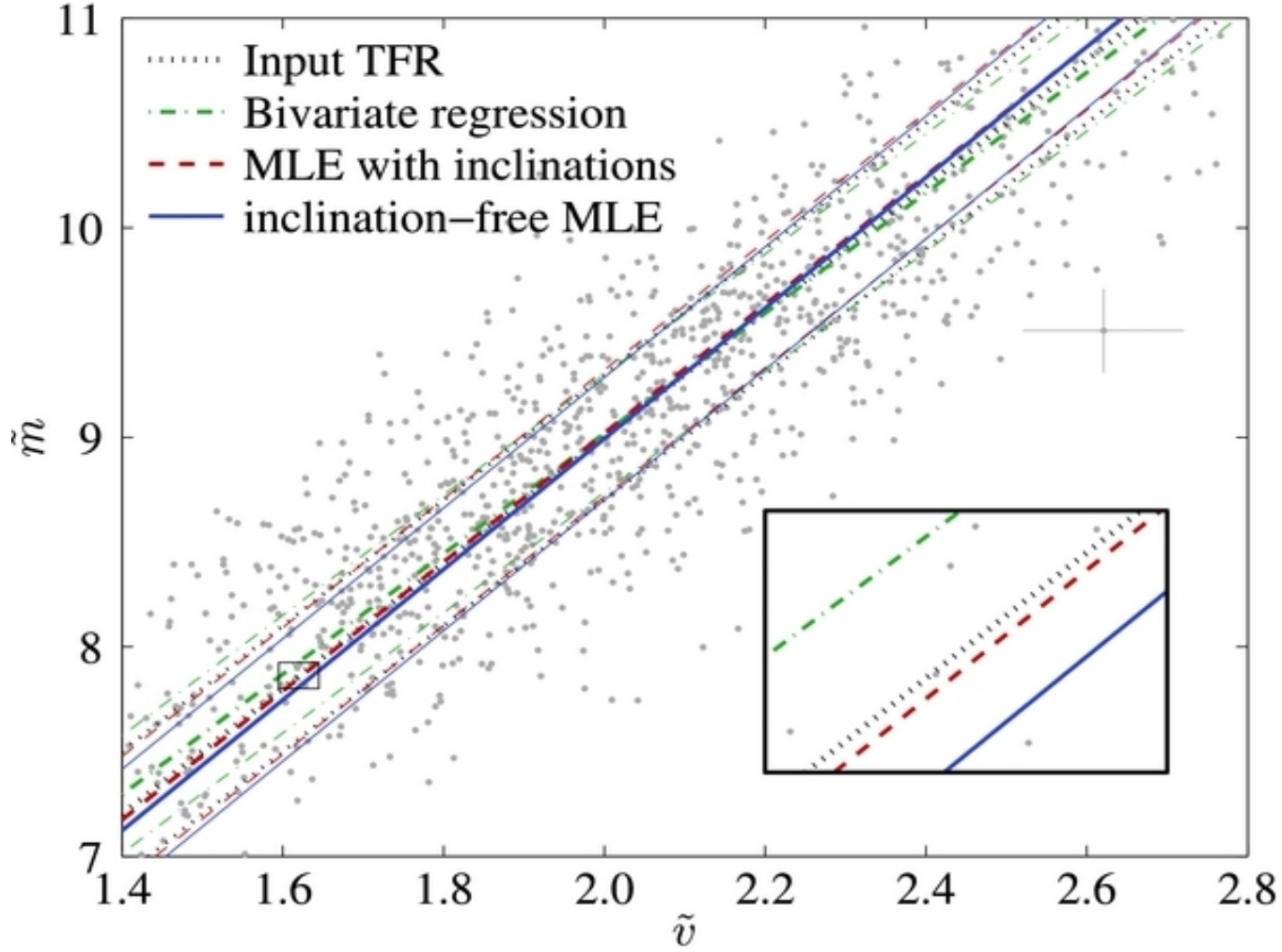


HIPASS Tully-Fisher relation
(Meyer et al. 2008)



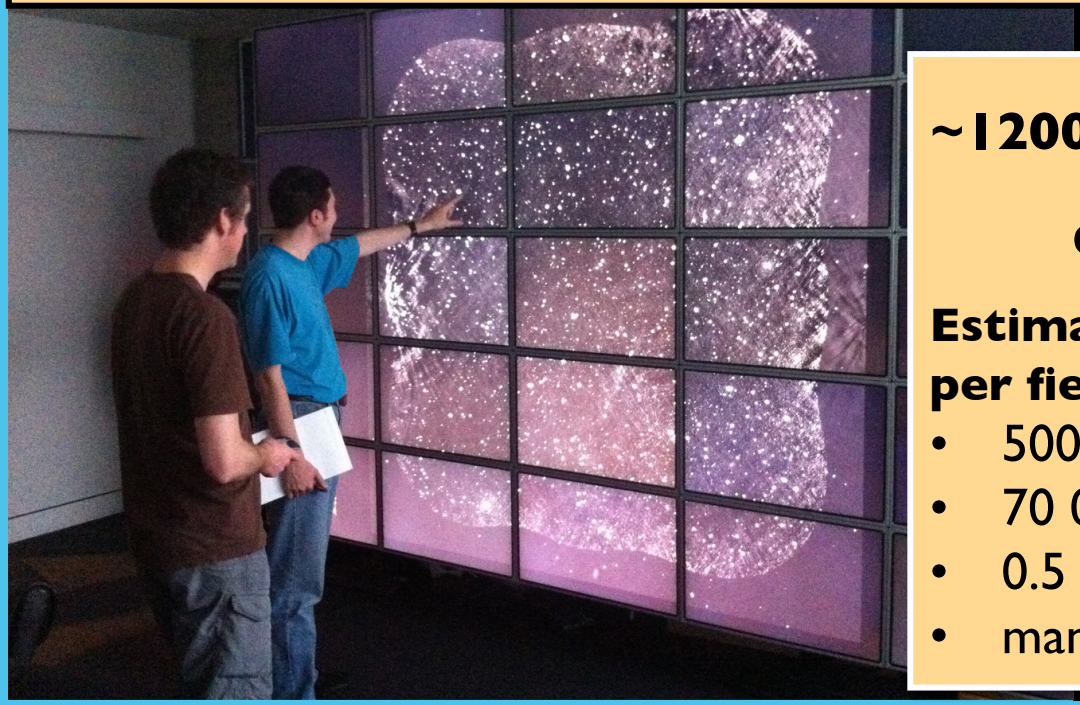
Local Universe flow field
(Hudson/EFAR/SMAC)

Tully-Fisher Relation without galaxy inclinations



See Obreschkow & Meyer (2013)

WALLABY – the ASKAP HI / 21-cm All-Sky Survey



~1200 fields (t_{int}~ 8h)

each 30 sq

36 beams

Estimated detections per field:

- 500 HI galaxies
- 70 000 continuum sources
- 0.5 HI absorbers
- many transients

http://www.atnf.csiro.au/research/WALLABY

Thank you

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
PHISCC 2014 – 18 Mar 2014

www.csiro.au

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