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

An update on ASKAP and WALLABY

The ASKAP HI All-Sky Survey

Bärbel Koribalski

CSIRO Astronomy and Space Science
www.csiro.au

The Australian SKA Pathfinder

- **ASKAP**: 36 ×12-m dishes equipped with *phased array feeds (PAFs)* delivering 30 sq degr field of view (freq 0.7 – 1.8 GHz, baselines up to 6 km) ➔ ASKAP is a 21-cm survey machine !
- 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**)

Apr 2014:
six PAFs on ASKAP
working together

Phased Array Feed Mk I

FOV = 30 sq degrees

ASKAP Survey Science Projects

- **WALLABY** (Koribalski/Staveley-Smith) All sky HI survey to *z*~0.2
- **EMU** (Norris) All sky continuum to 10 µJy rms

- POSSUM (Gaensler/Landecker/Taylor) Polarization / RM grid
- FLASH (Sadler) HI absorption to *z*~1
- VAST (Murphy/Chatterjee) Transients and variables (>5 sec)
- CRAFT (Dodson/Macquart) Fast transients (<5 sec)

- GASKAP (Dickey) Galactic and Magellanic HI and OH
- DINGO (Meyer) Deep HI emission survey

- COAST (Stairs) Pulsar timing and searching
- VLBI (Tingay) ASKAP as part of the LBA

- 25% of ASKAP time for other projects (ATNF TAC)

ASKAP Survey Science Projects

- **WALLABY** (Koribalski/Staveley-Smith) All sky HI survey to *z*~0.2
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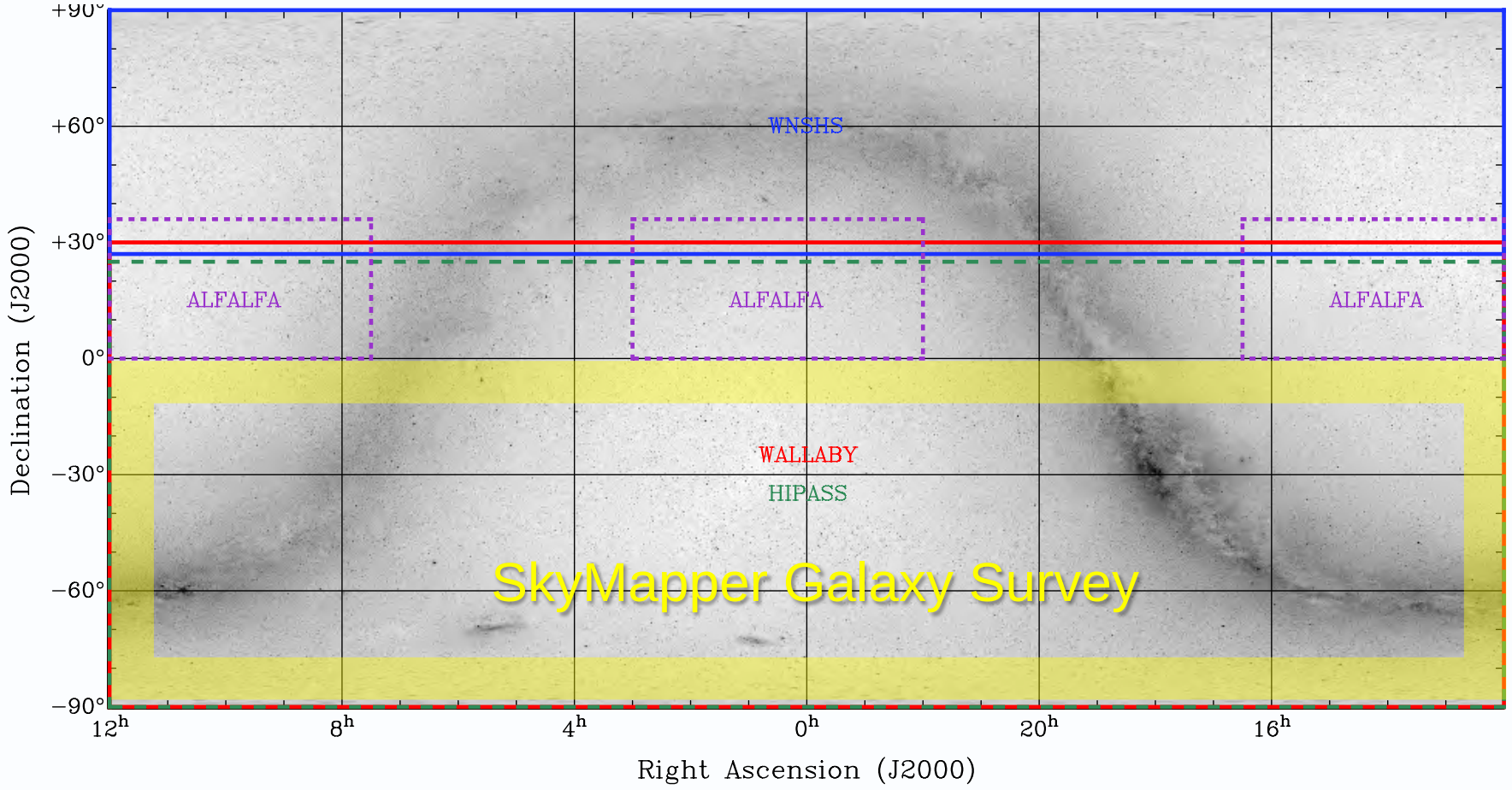
- POSSUM (Gaensler/Landecker/Taylor) Polarization / RM grid

Large-area (Dec < 30^{o})
ASKAP 21-cm survey
delivers all three !

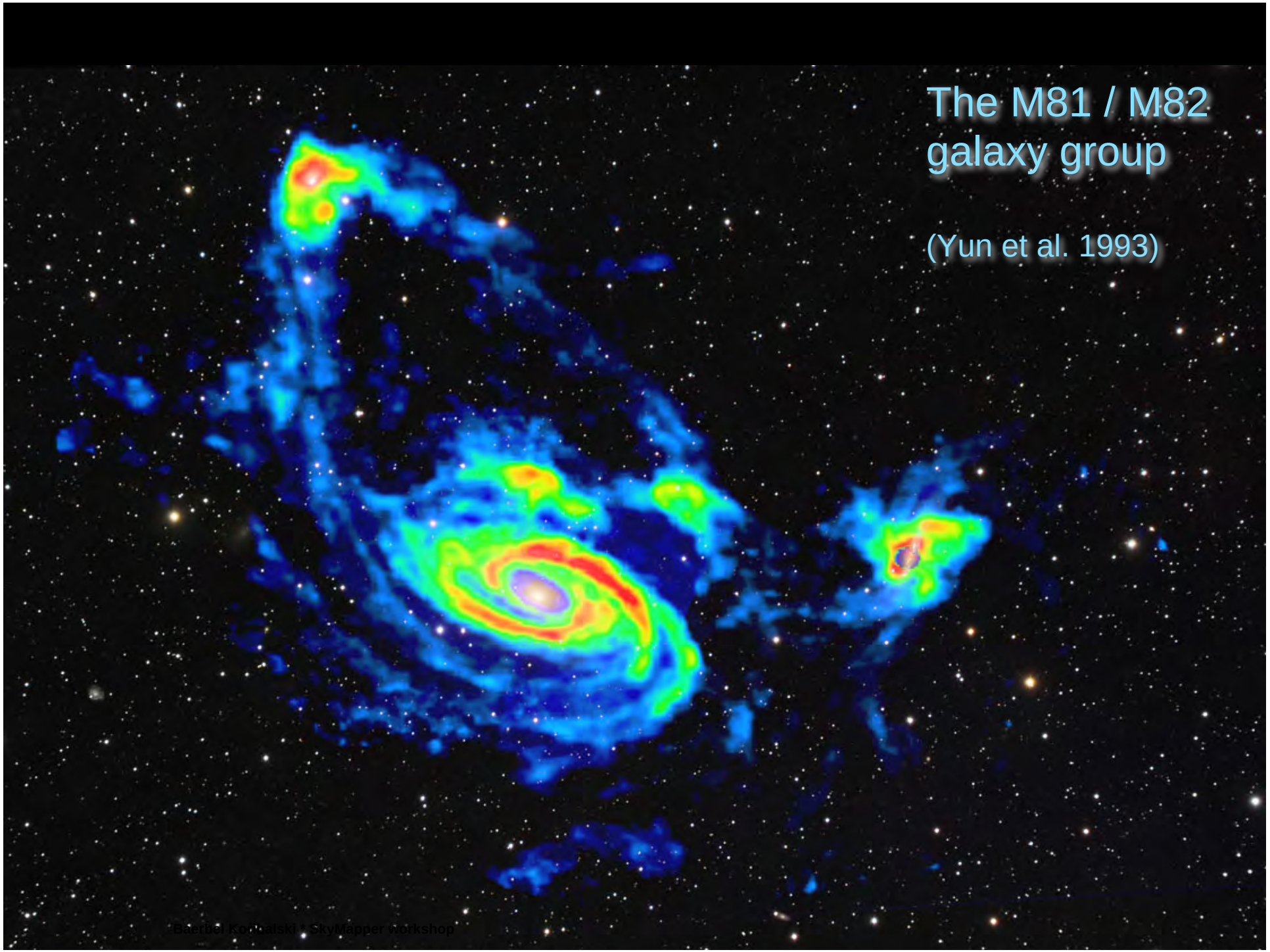
About one year,
~1300 pointings

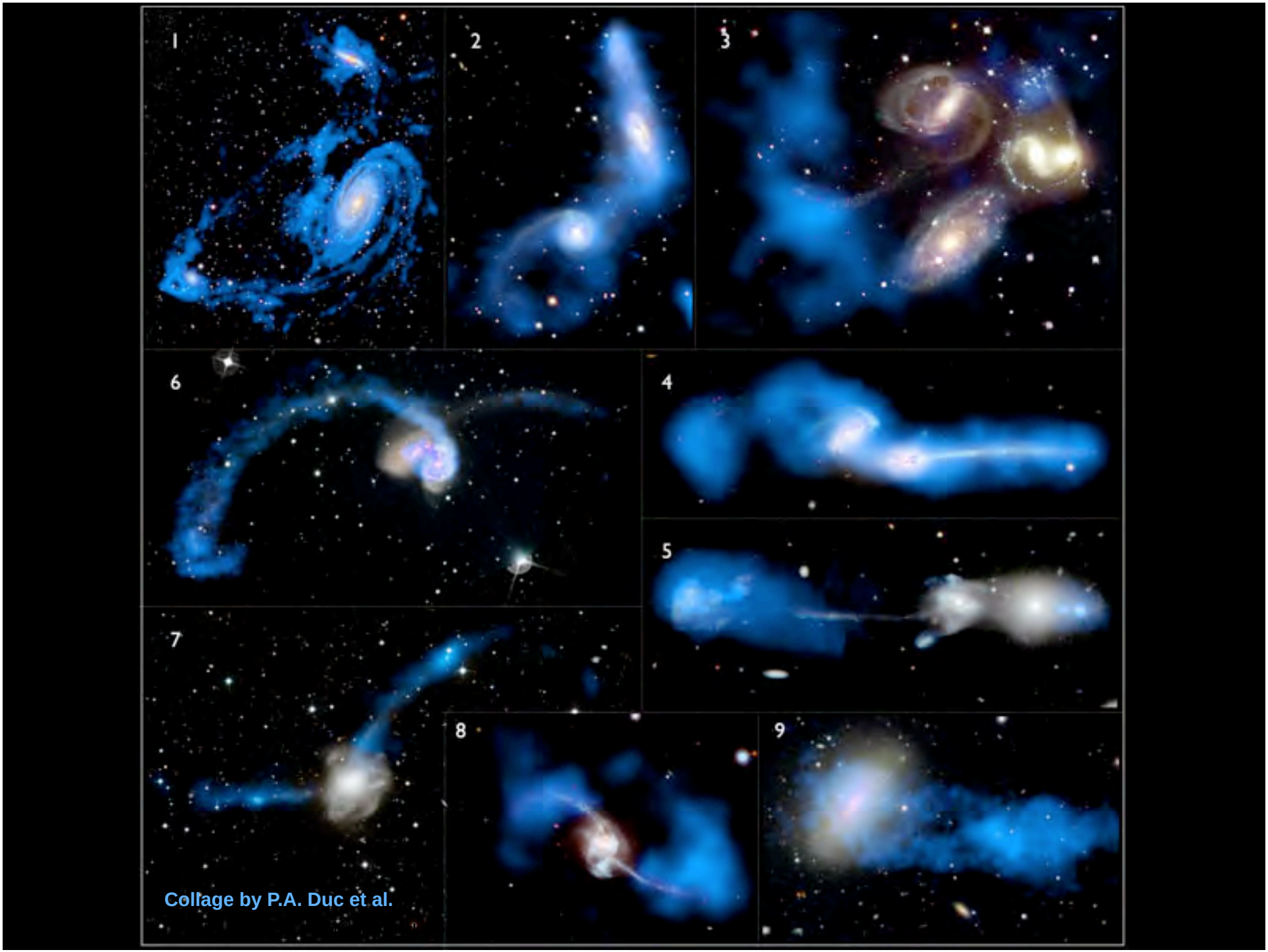
ASKAP HI All-Sky Survey

WALLABY PIs: Bärbel Koribalski & Lister Staveley-Smith



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


The M81 / M82
galaxy group
(Yun et al. 1993)


1
2
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8
9
Collage by P.A. Duc et al.

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 ($\delta > +27^o$)**

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

WALLABY Predictions
(Duffy et al. 2012)

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 Predictions
(Duffy et al. 2012)

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**

WALLABY will explore

- the *Gaseous* Universe
- the *Dynamic* Universe
- the *3D* Universe
- the *Dark* Universe

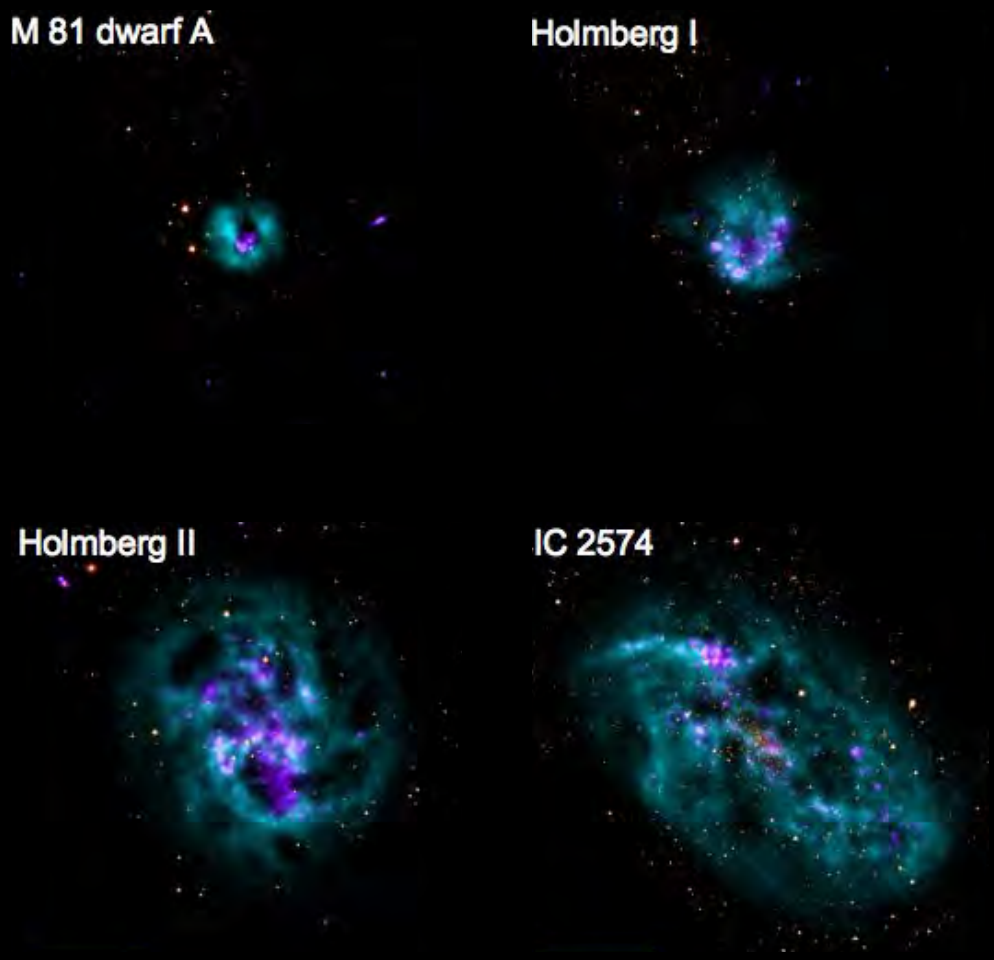
and

- the *Unknown* Universe

… probing the Gaseous Universe

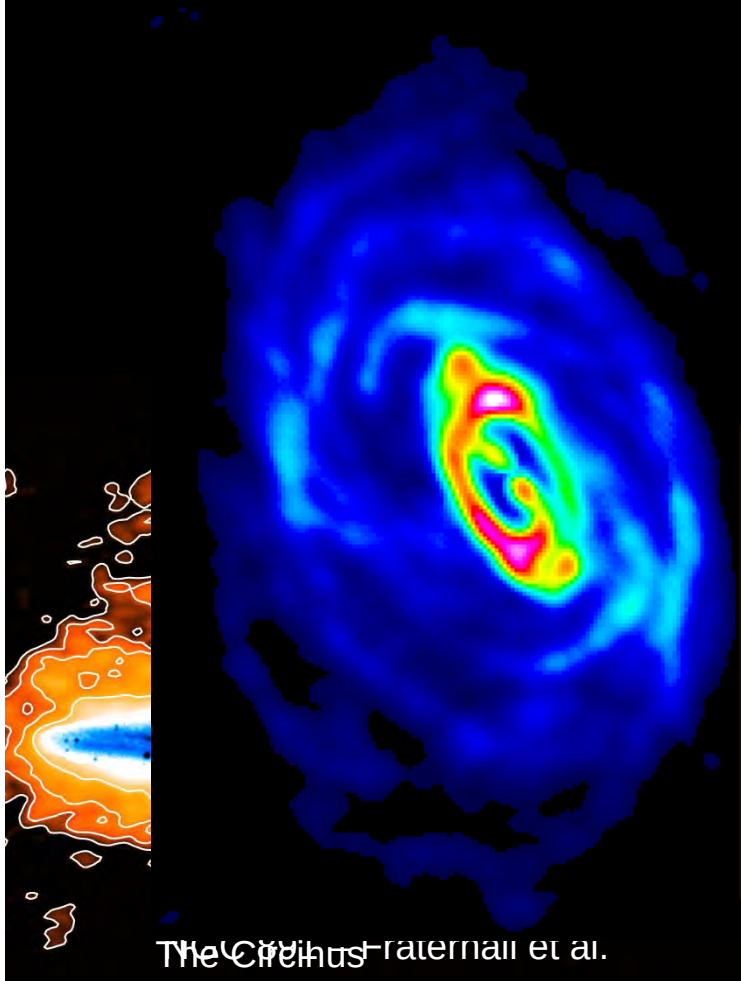
WALLABY will discover

- new dwarf galaxies in the *Local Group*
- hundreds of dwarfs in the *Local Volume* (5 x 10^6 $M_\odot$ out to 10 Mpc)
- diffuse HI clouds, tails and filaments connecting galaxies
- 10^8 $M_\odot$ out to 60 Mpc



VLA HI + Spitzer MIR + Galex UV; Walter et al. (2009)

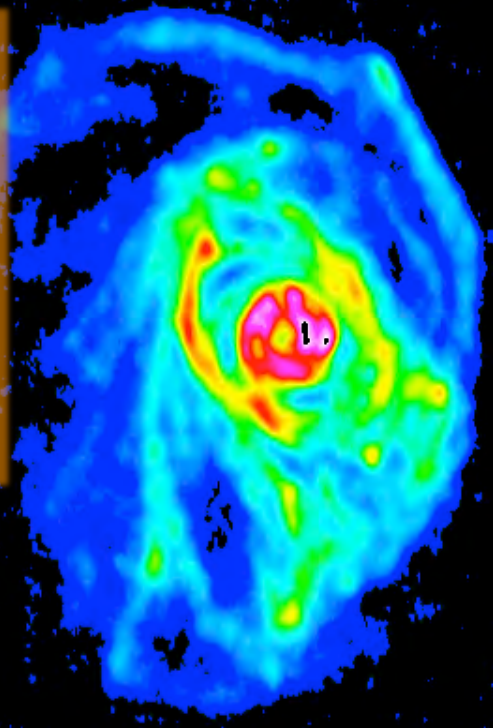
… probing the Gaseous Universe



The Circinus Galaxy

Cayatte, Kraternali et al.

M 83 + UGC 365

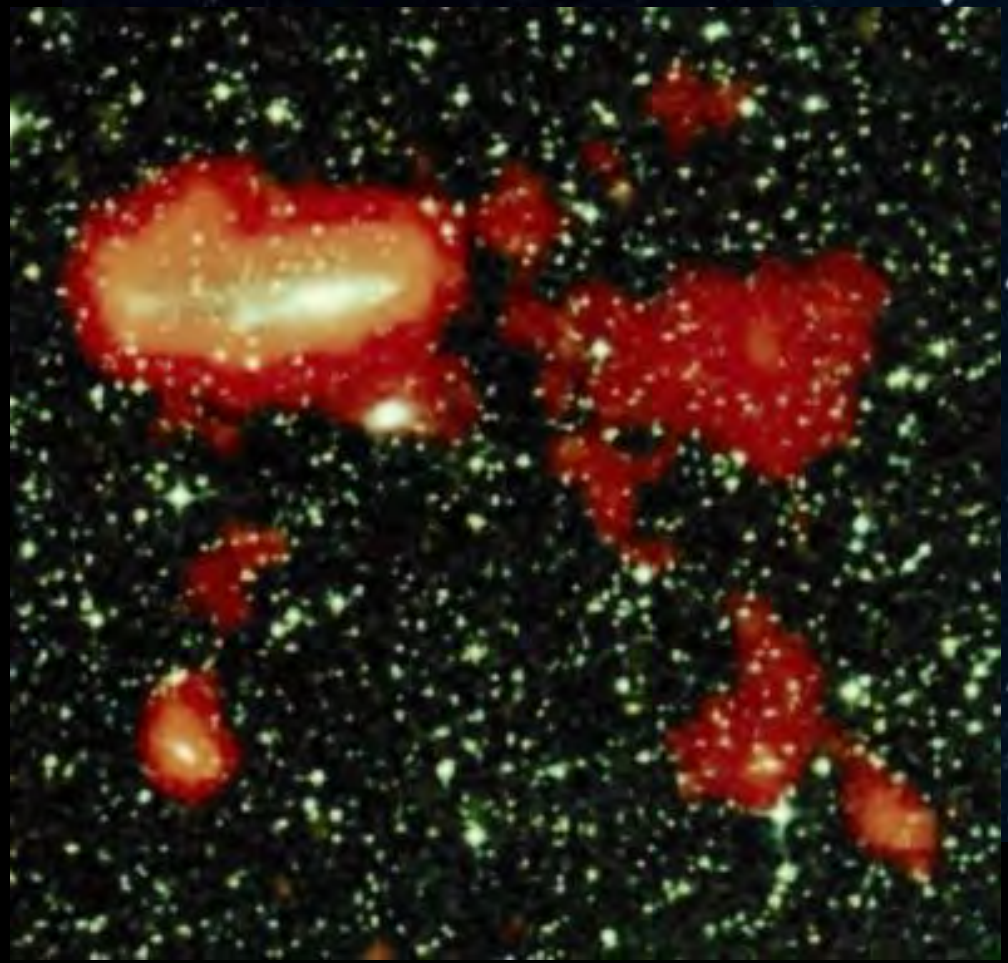


WALLABY will reveal

- the large-scale HI disks of spiral galaxies
- HI streams in galaxy haloes resulting from the accretion of neighbouring dwarf galaxies

… probing the Gaseous Universe

NGC 3263 group – English, BK et al. (2010)



WALLABY will discover

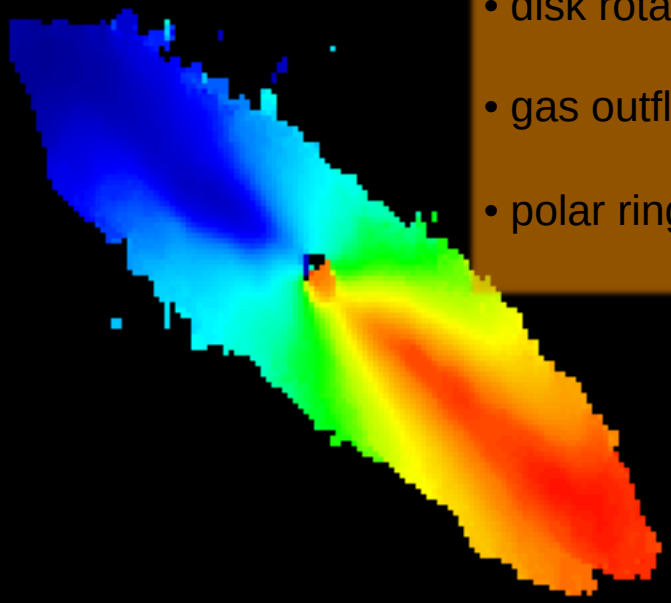
- tidal tails and HI plumes as the signatures of interacting galaxies
- distant high-density HI clouds and filaments, most likely in groups & clusters

IC 2554 – BK, Gordon & Jones (2003)

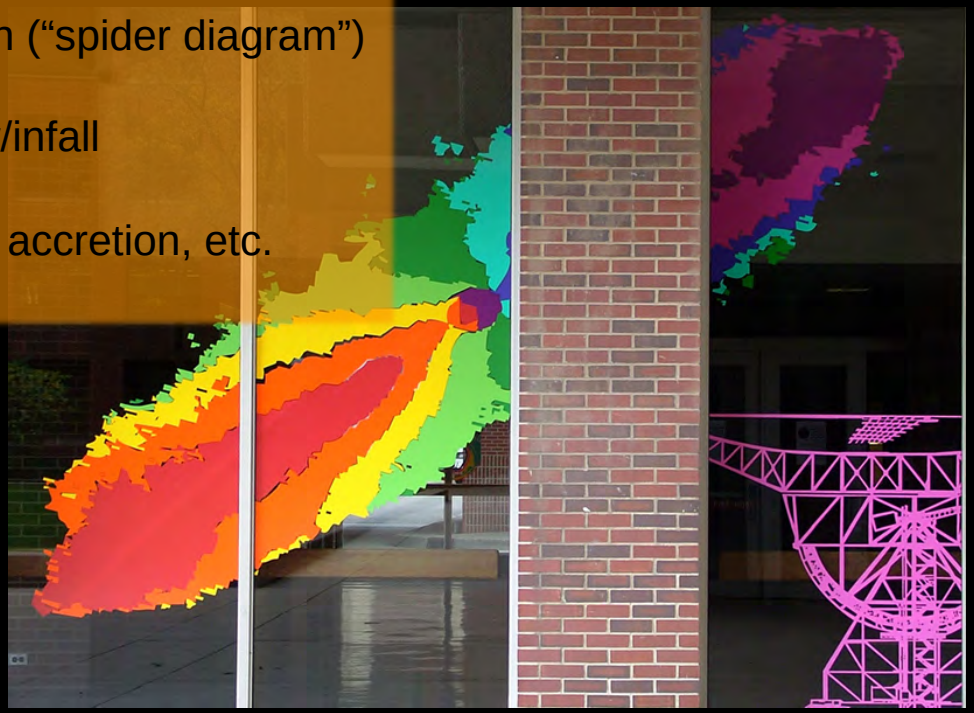
… explore the Dynamic Universe

WALLABY will reveal

- the large-scale HI velocity fields of spiral galaxies
- disk rotation (“spider diagram”)
- gas outflow/infall
- polar rings, accretion, etc.

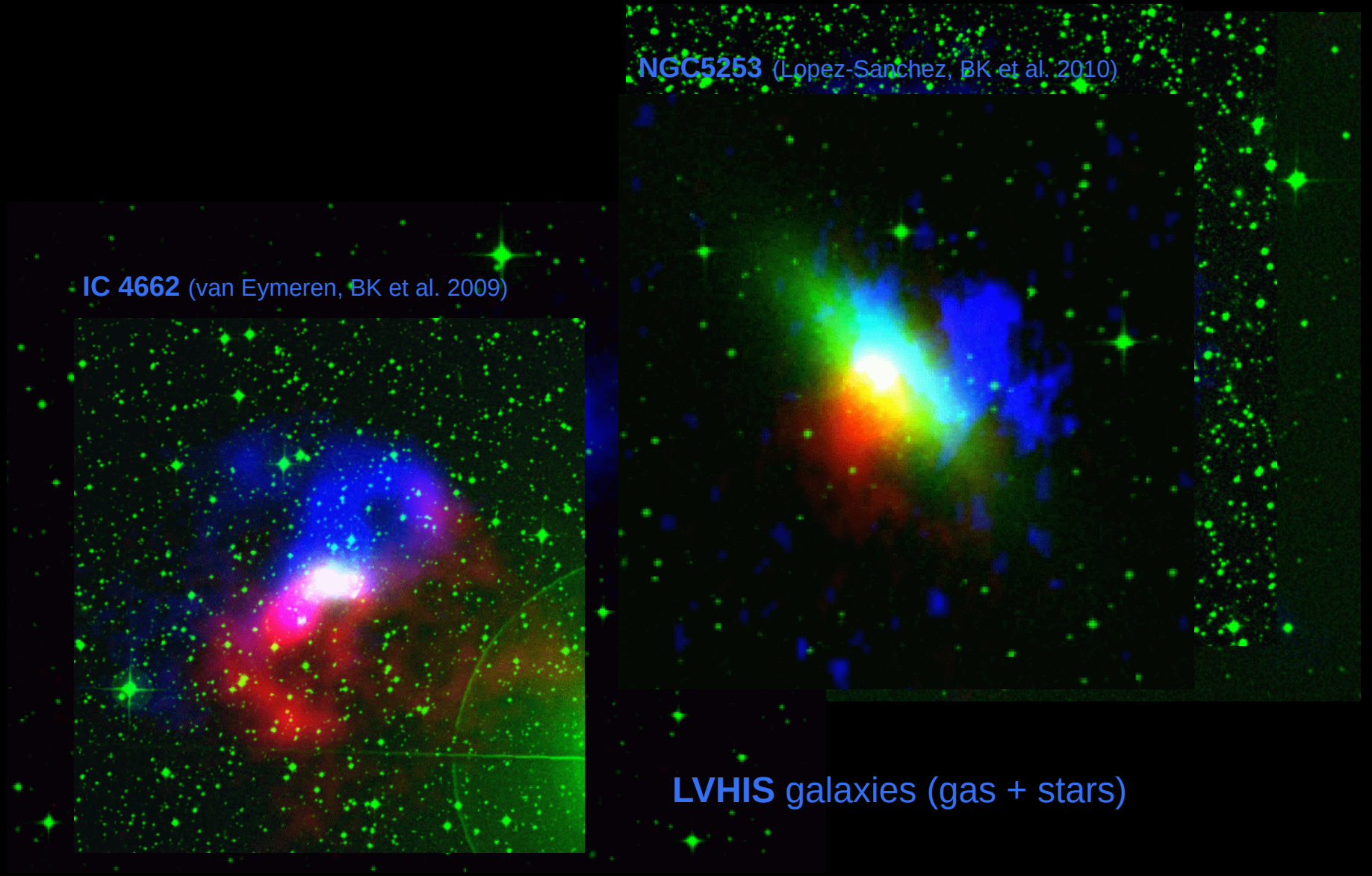


The starburst galaxy NGC 253

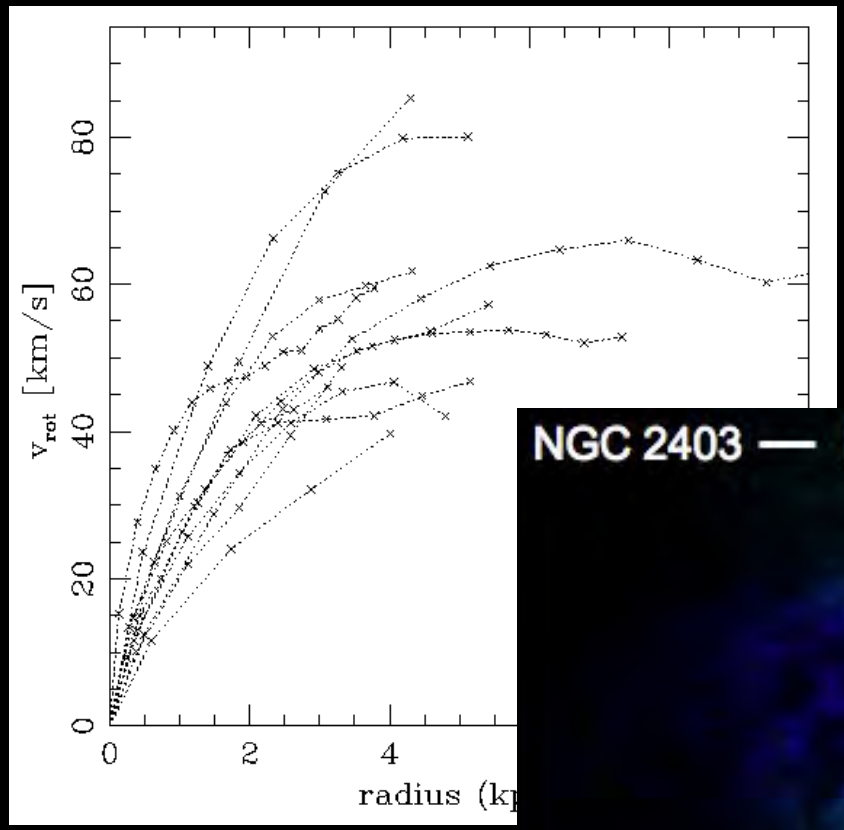


Dennison Mural @ U Michigan, IYA2009:
The Universe – Yours to Discover

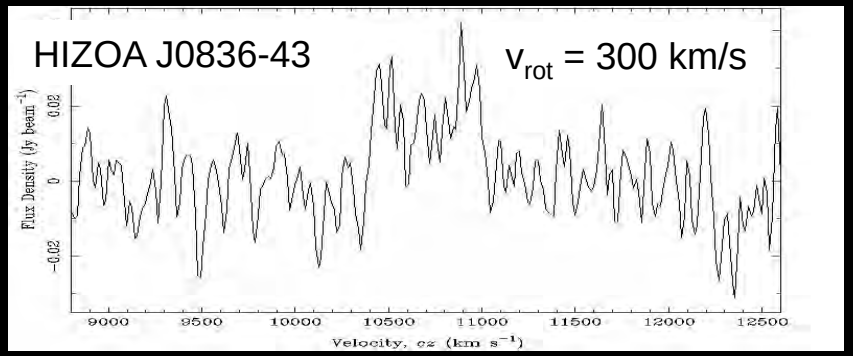
… explore the Dynamic Universe

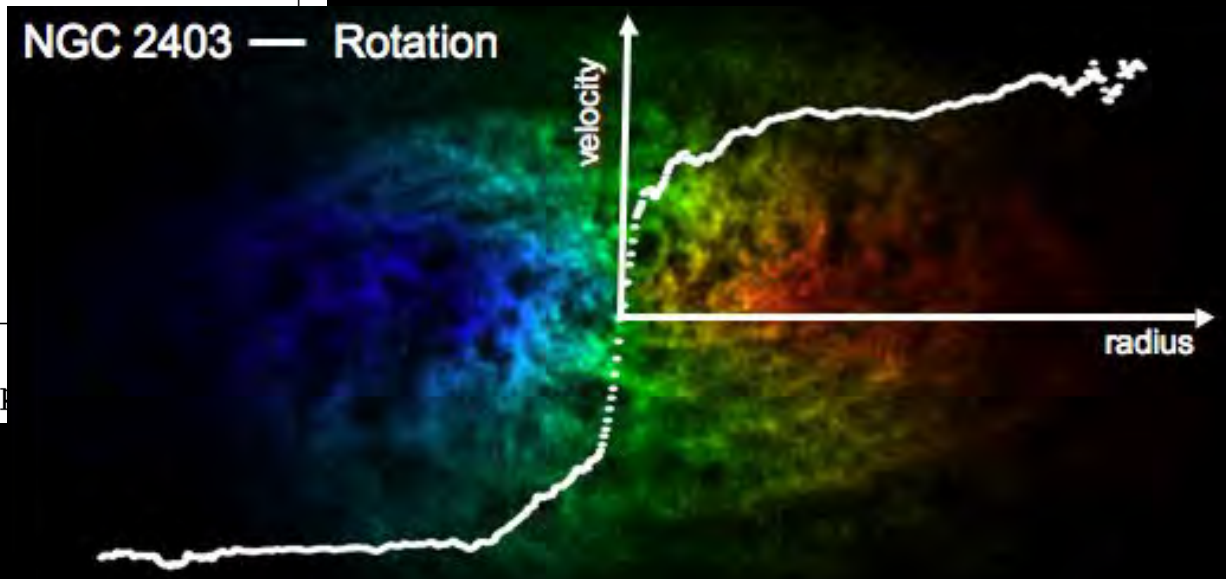


… uncover the Dark Universe



LVHIS: Kirby, BK et al. (2010)

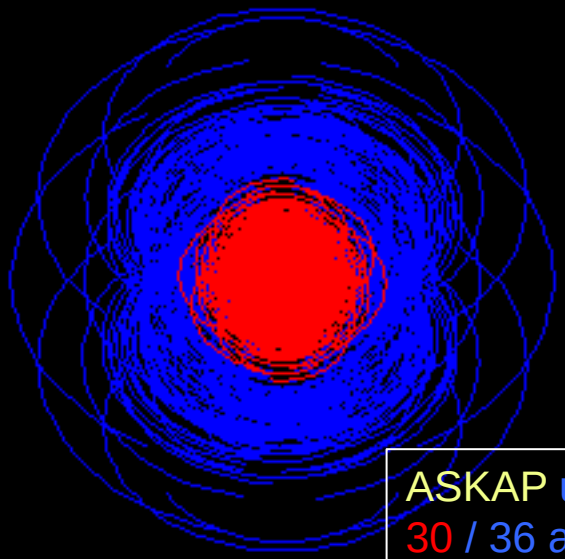




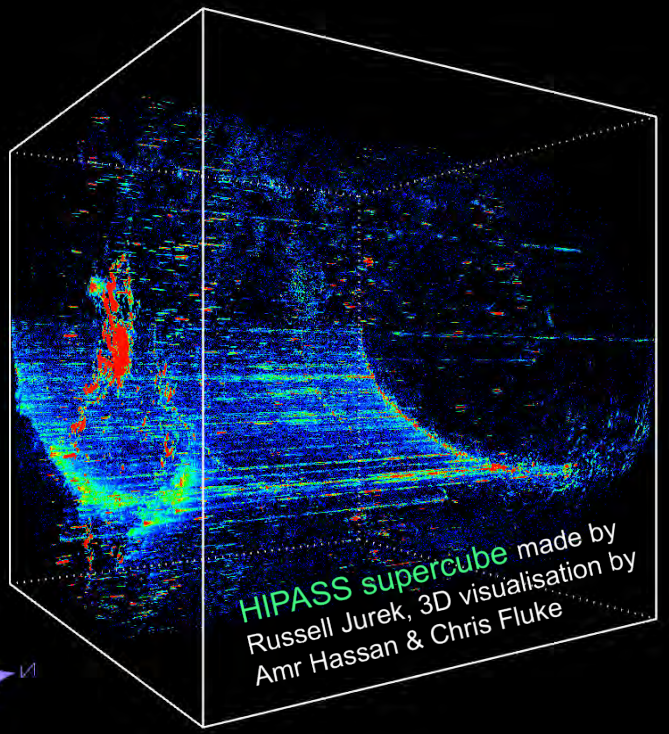
$M_{dyn} = 2.31 \times 10^5 R_{kpc} v_{rot}^2$

THINGS: Walter et al. (2009)

… exploring the 3D Universe



ASKAP uv-coverage:
30 / 36 antennas

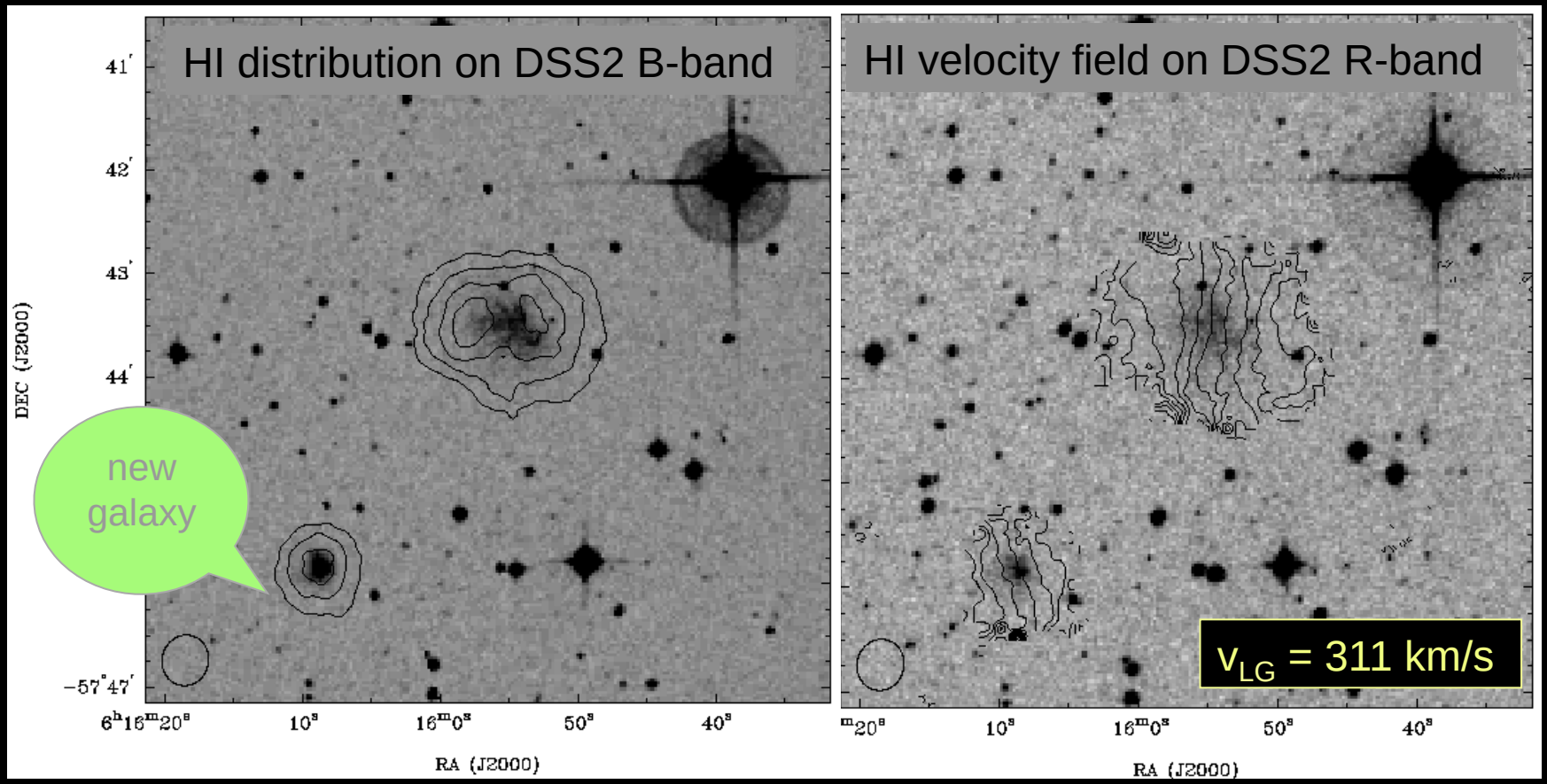


Archive

1200 ×

ASKAP
HI cube

WALLABY redshift range: z = 0 to 0.26

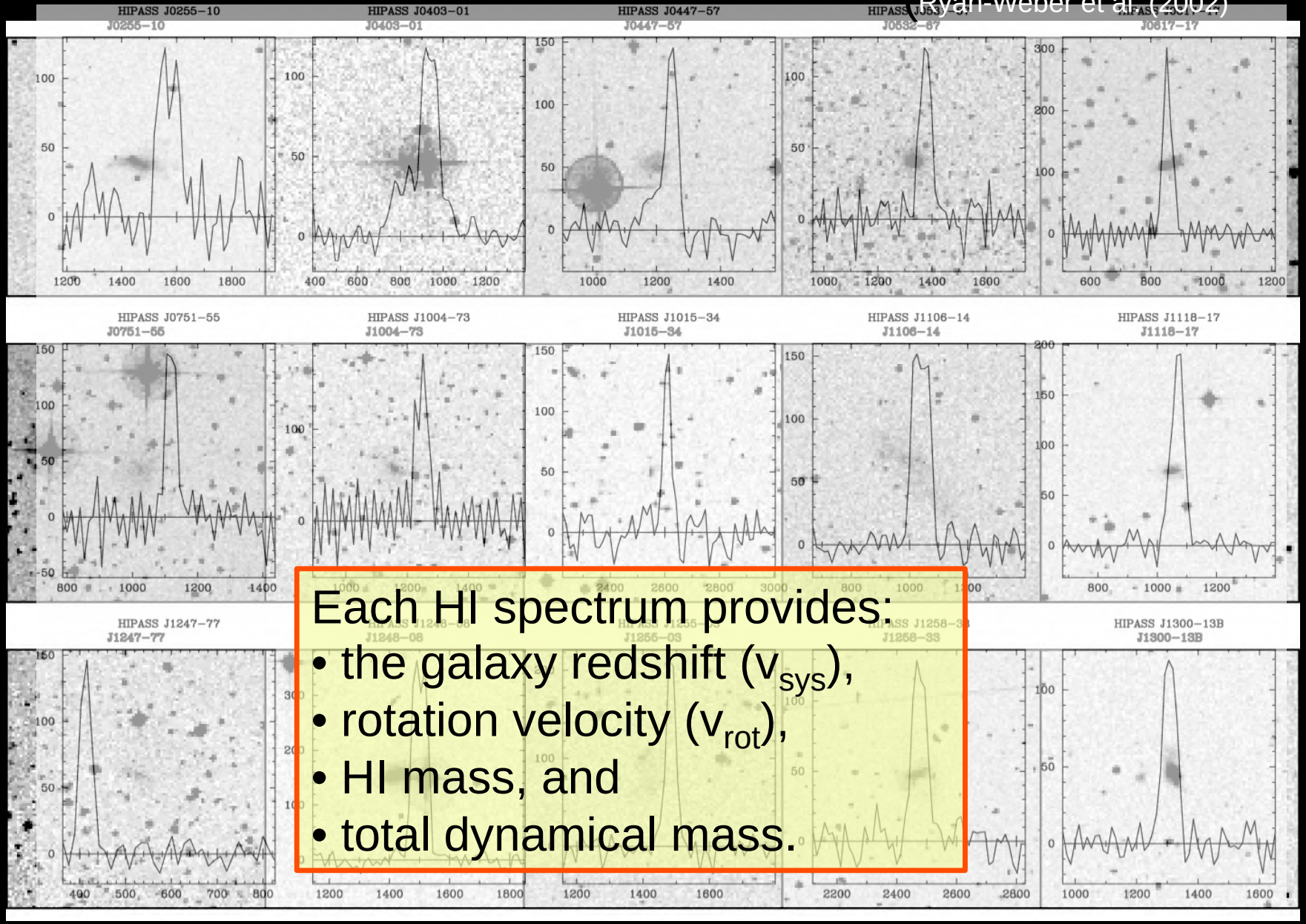


ATCA HI maps for HIPASS J0615-57 at D_{TRGB} = 6.05 Mpc

M_{HI} = 2.6 x 10^7 $M_\odot$ (ESO121-G020) + M_{HI} = 6.1 x 10^6 $M_\odot$ (companion)

(Warren et al. 2004)

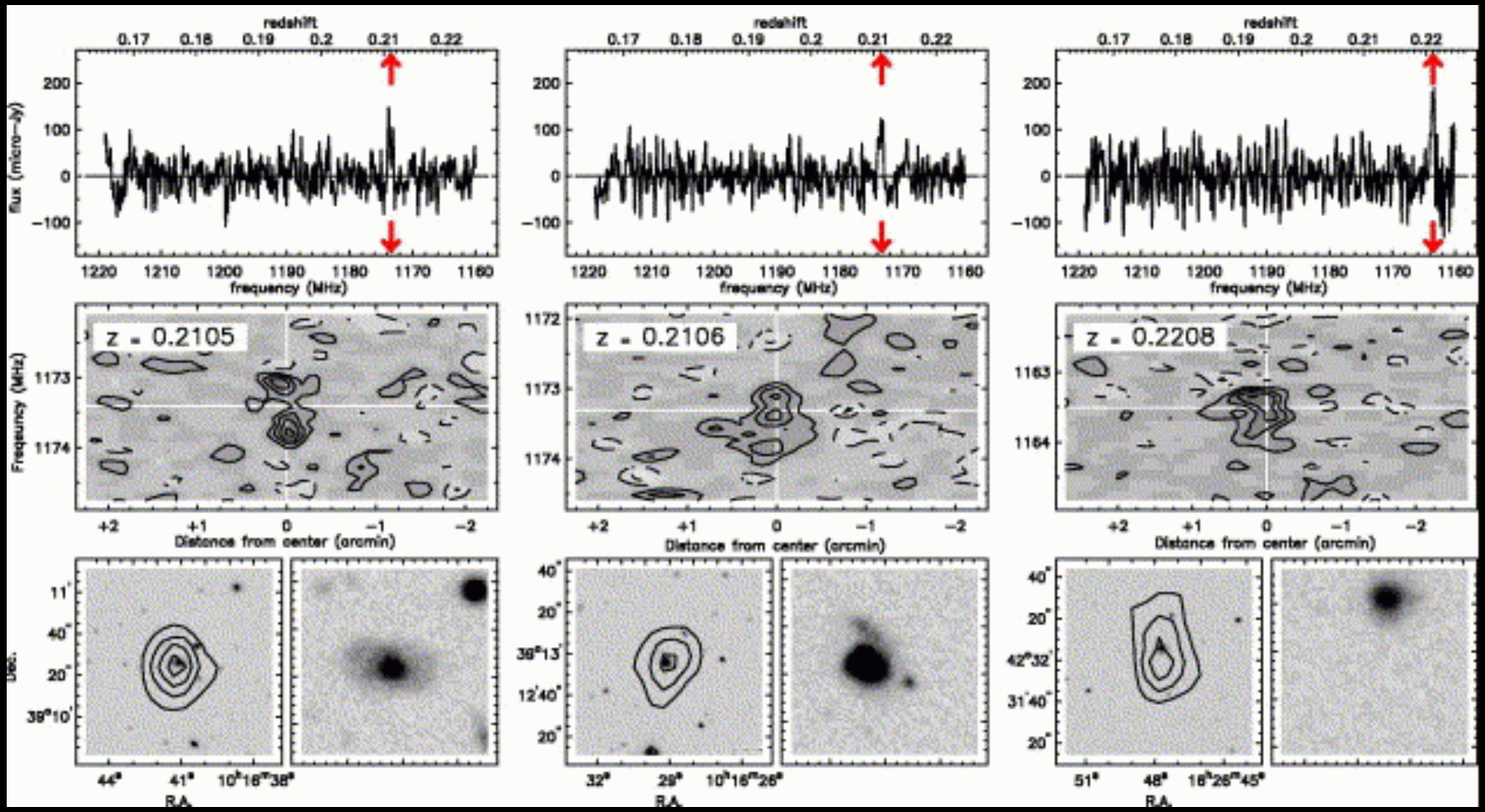
Ryan-Weber et al. (2002)



Each HI spectrum provides:

- the galaxy redshift (v_{sys}),
- rotation velocity (v_{rot}),
- HI mass, and
- total dynamical mass.

WALLABY redshift range: z = 0 to 0.26



Verheijen et al. 2007

SoFiA - our new **So**urce **Fi**nding **A**pplication

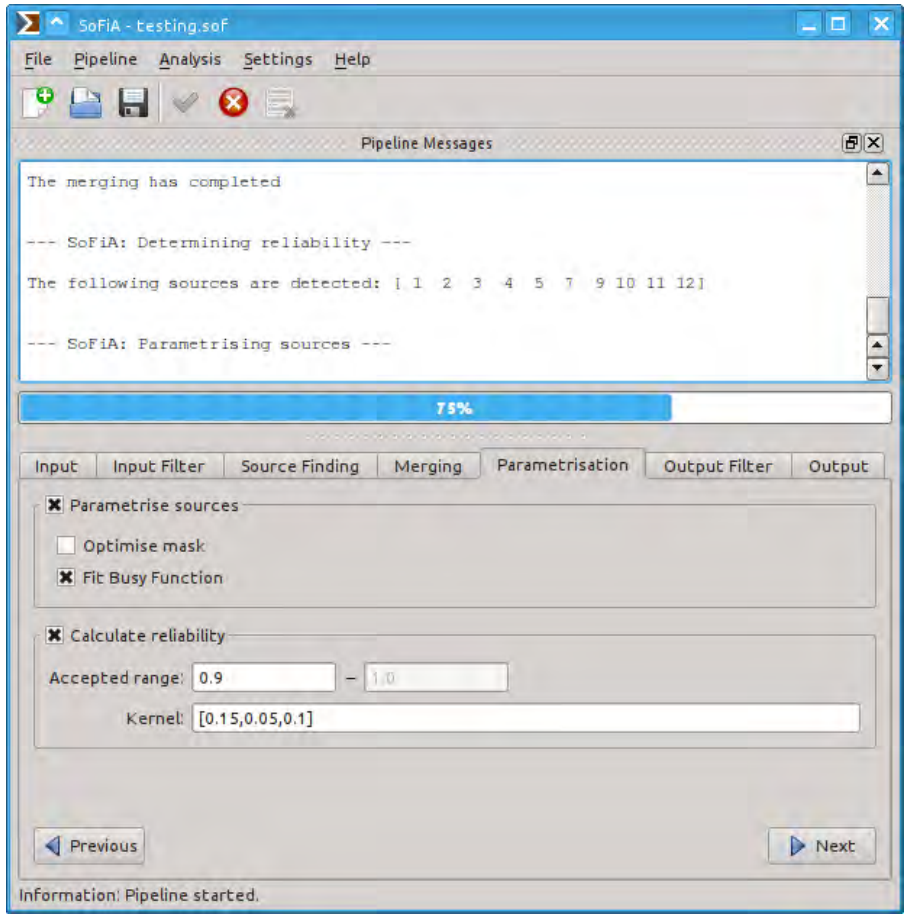
SoFiA

Source Finding Application

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

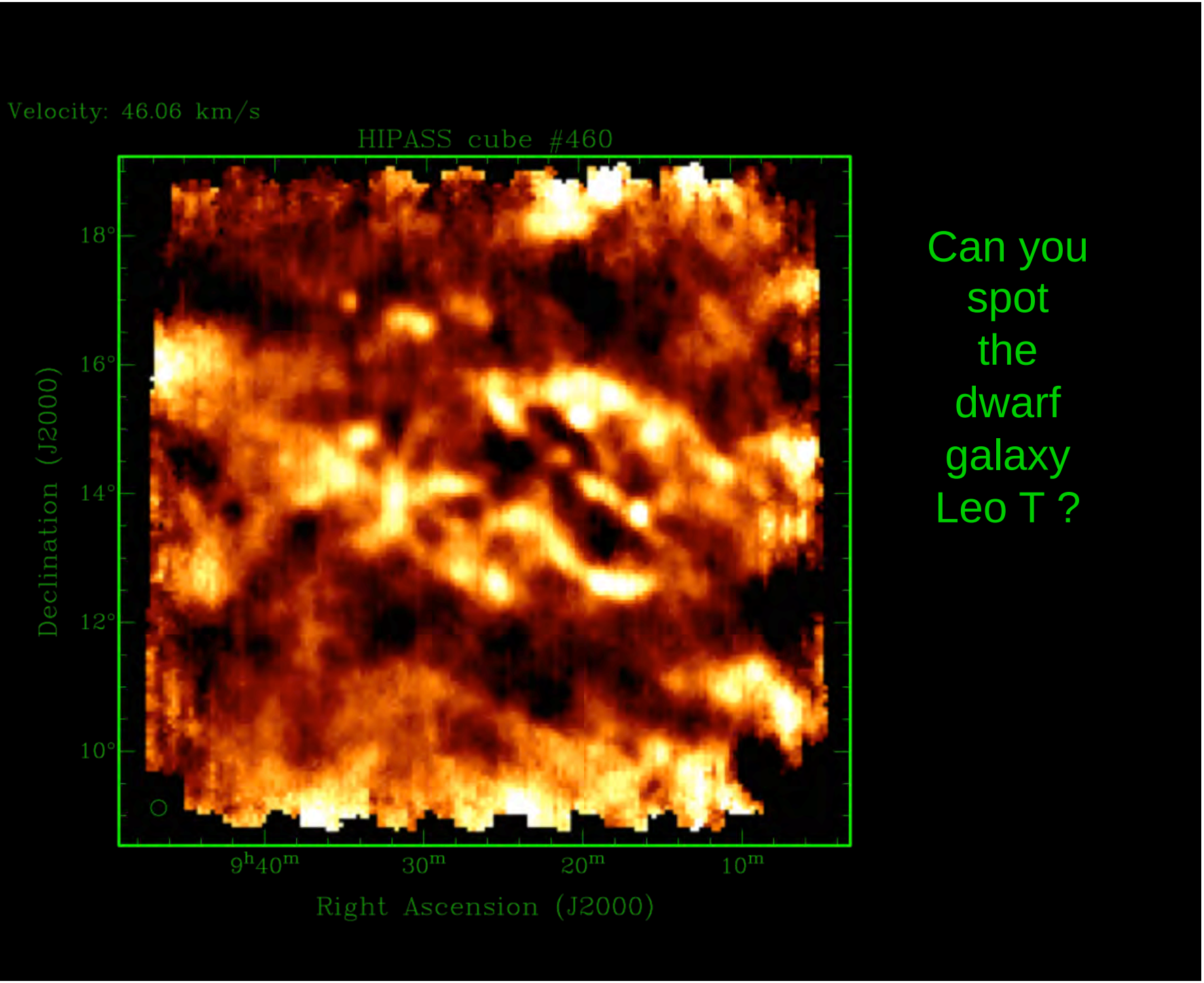
Tobias Westmeier, Paolo Serra, Nadine Giese, Russell Jurek, Lars Flöer, Attila Popping and Benjamin Winkel

* SoFiA Handbook (on-line)

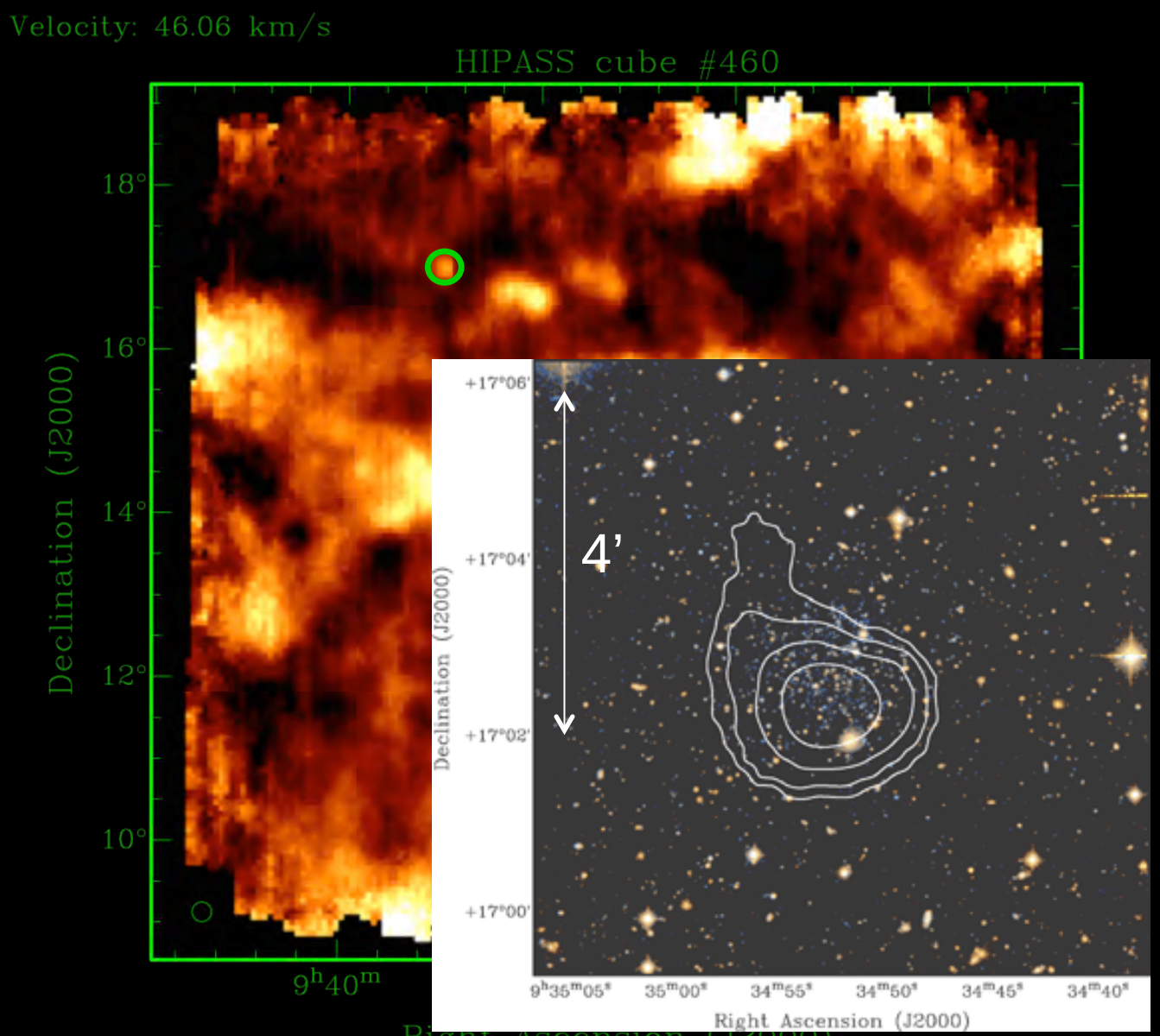


*http://www.atnf.csiro.au/people/Tobias.Westmeier/**tools_software_sofia.php***

CSIRO



Can you spot the dwarf galaxy Leo T ?



Can you spot the dwarf galaxy Leo T ?

WALLABY and SkyMapper Science

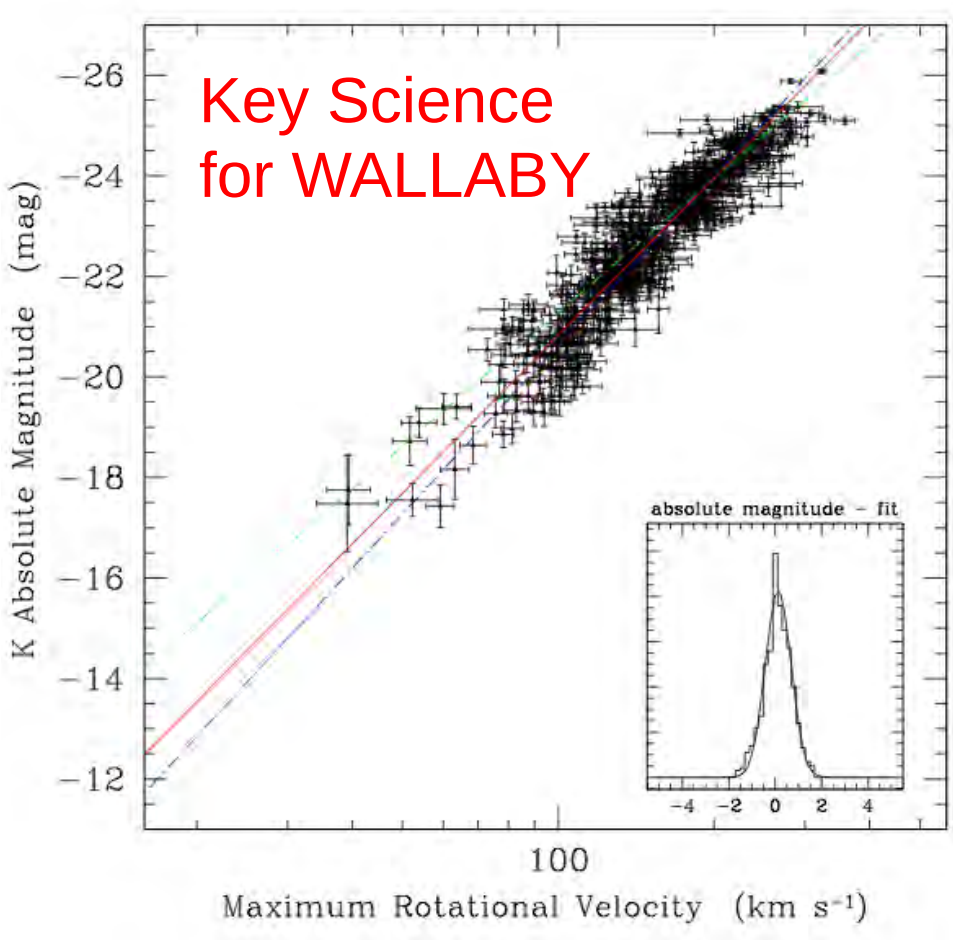
- **WALLABY** will detect **~ 600 000 galaxies** in HI (z < 0.25)
  - HI positions (accurate astrometry; uncertainty <10")
  - HI systemic velocity (accurate to a few km/s)
  - HI velocity width ➔ rotational velocity

- **Optical identifications !**
  - nearby dwarf galaxies
  - star-forming spiral galaxies
  - tidal tails, plumes and clouds

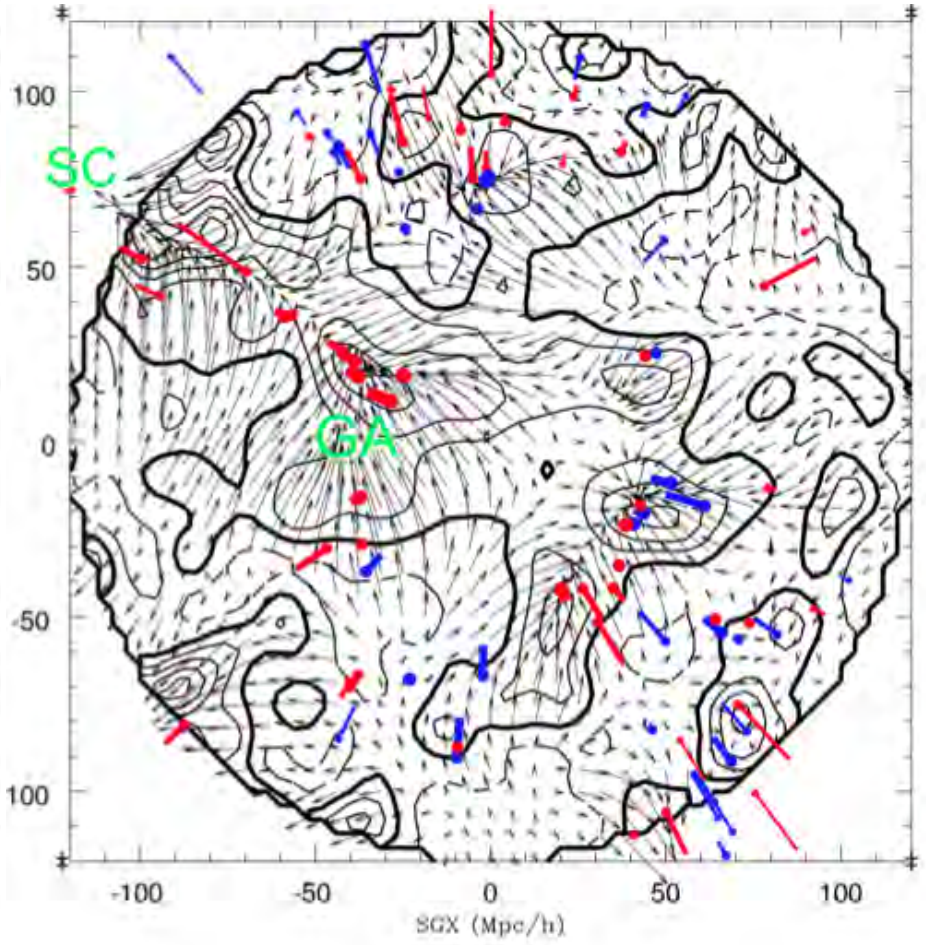
- **Galaxy properties: optical and HI**
  - disk major and minor diameters
  - *accurate inclination angles !*

    ➔ TFR, total dynamical mass

Tully-Fisher Relation – Bulk Flow Field



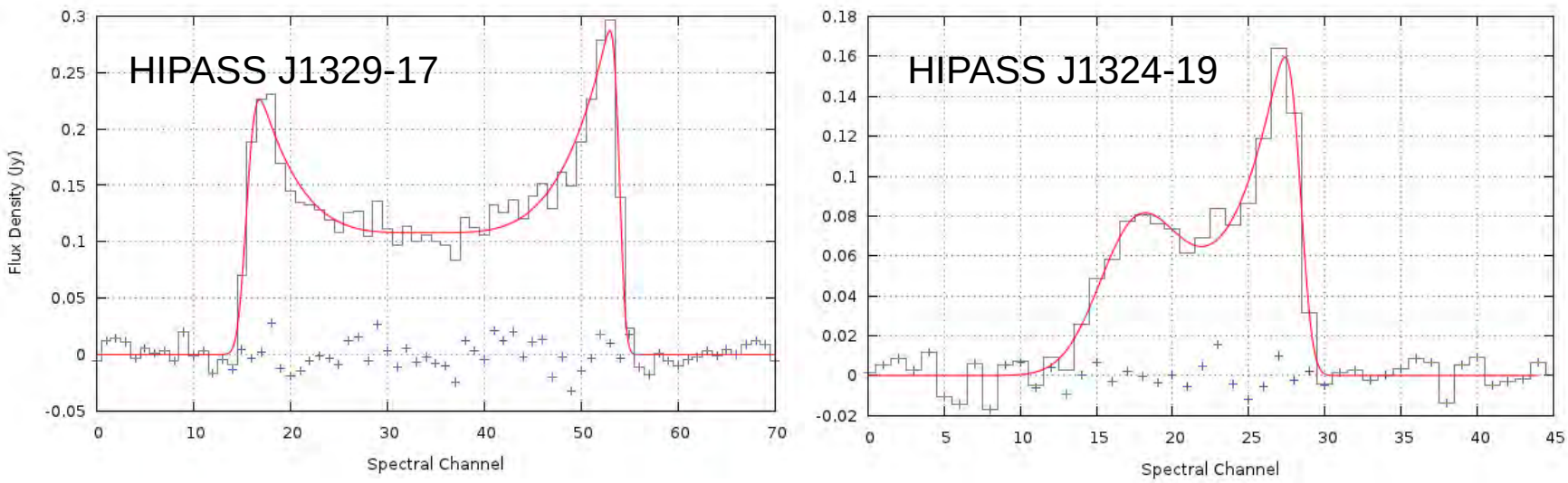
HIPASS Tully-Fisher relation
(Meyer et al. 2008)



Local Universe flow field
(Hudson/EFAR/SMAC)

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

WALLABY and SkyMapper Science

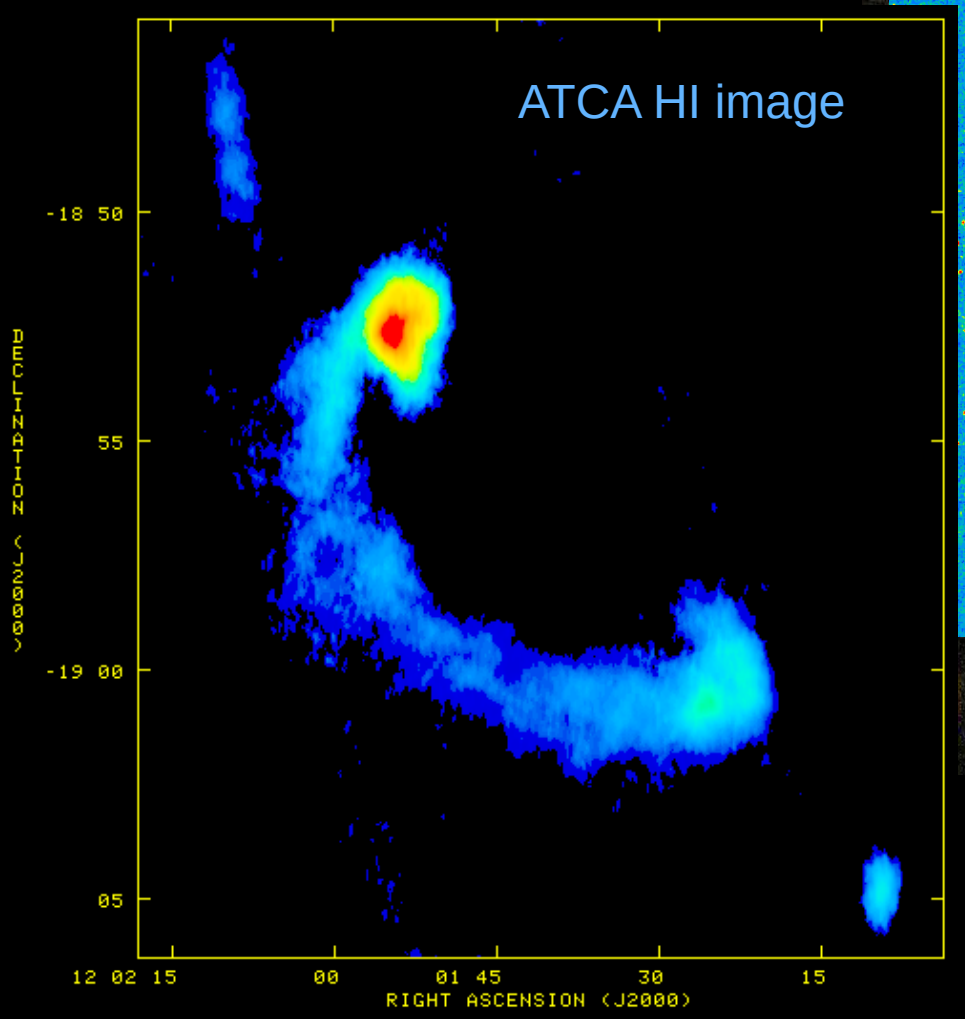
- **SkyMapper Galaxy Survey**
  - galaxy morphologies (disk/bulge decomposition)
  - galaxy colours
- **TAIPAN Galaxy Redshift Survey**
  - many galaxies undetected in HI
  - HI spectral stacking
- **HI – optical scaling relations**
  - diameters, magnitudes
- **SkyMapper deep fields at 5” seeing ?**
  - nearby galaxies, pairs and groups
  - image the faint outer disk
  - search for stars in HI tidal tails

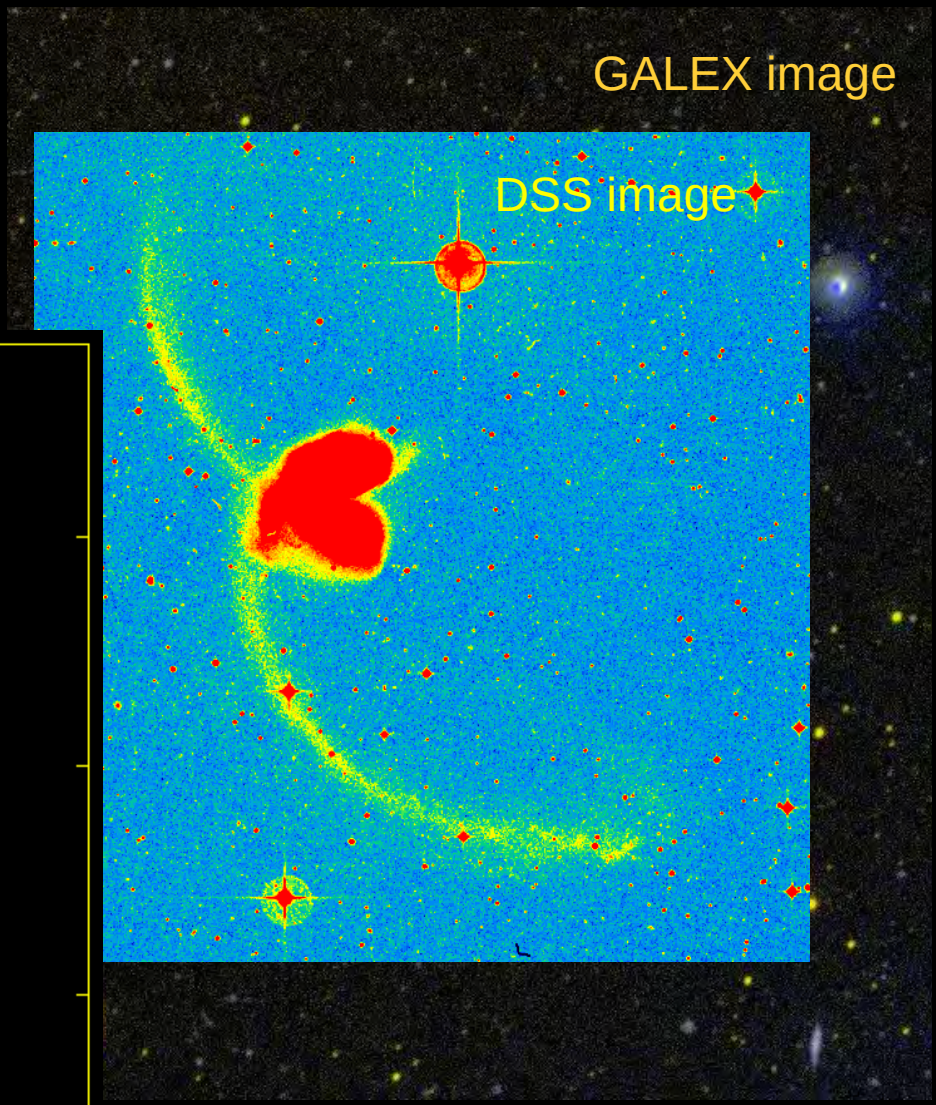
SkyMapper

The Antennae

Merging Galaxy Pair NGC4038/9

Gordon, Koribalski et al. 2003

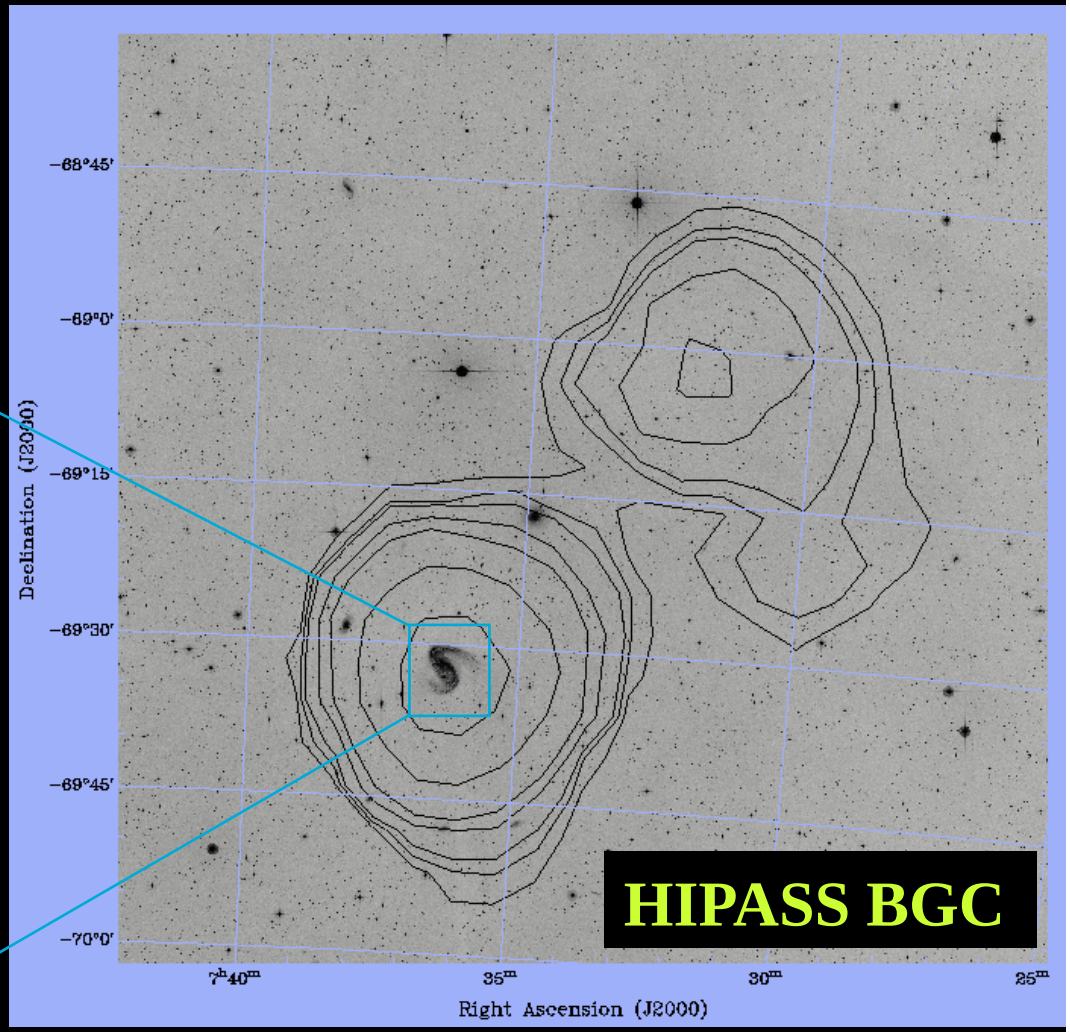




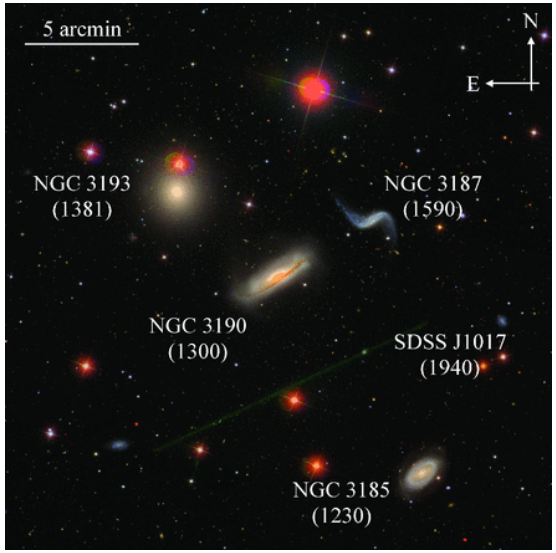
HIPASS J0739-69: NGC2442 + intra-group HI gas

(Ryder, Koribalski et al. 2001)

- 10^9 $M_\odot$ intra-group HI gas
- 250 kpc projected separation from the galaxy NGC 2442
- no optical counterpart
- resolved into numerous clumps with the ATCA



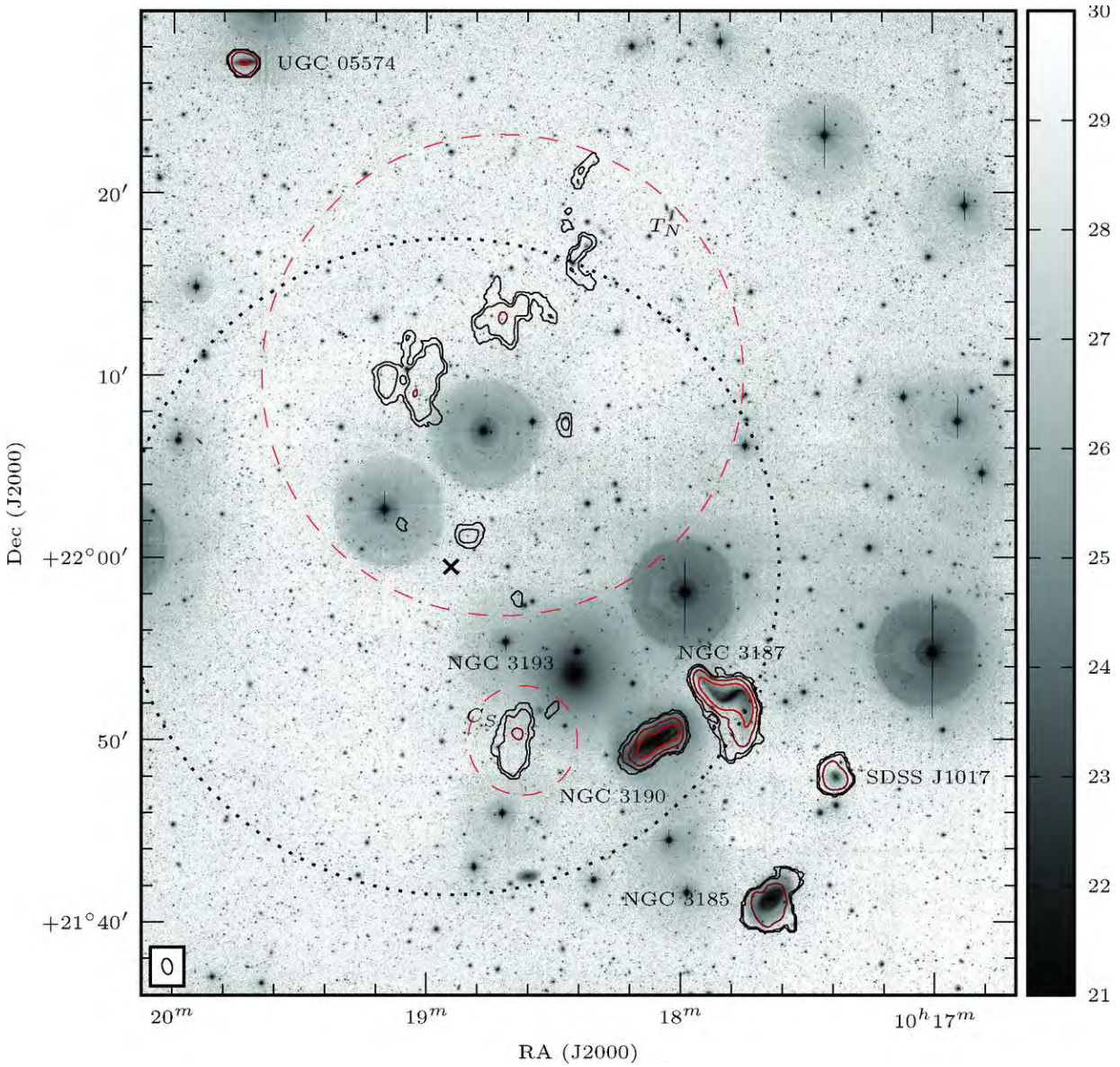
HCG 44



Sloan Digital Sky Survey (SDSS) optical colour image of HCG 44 (Data Release 8).

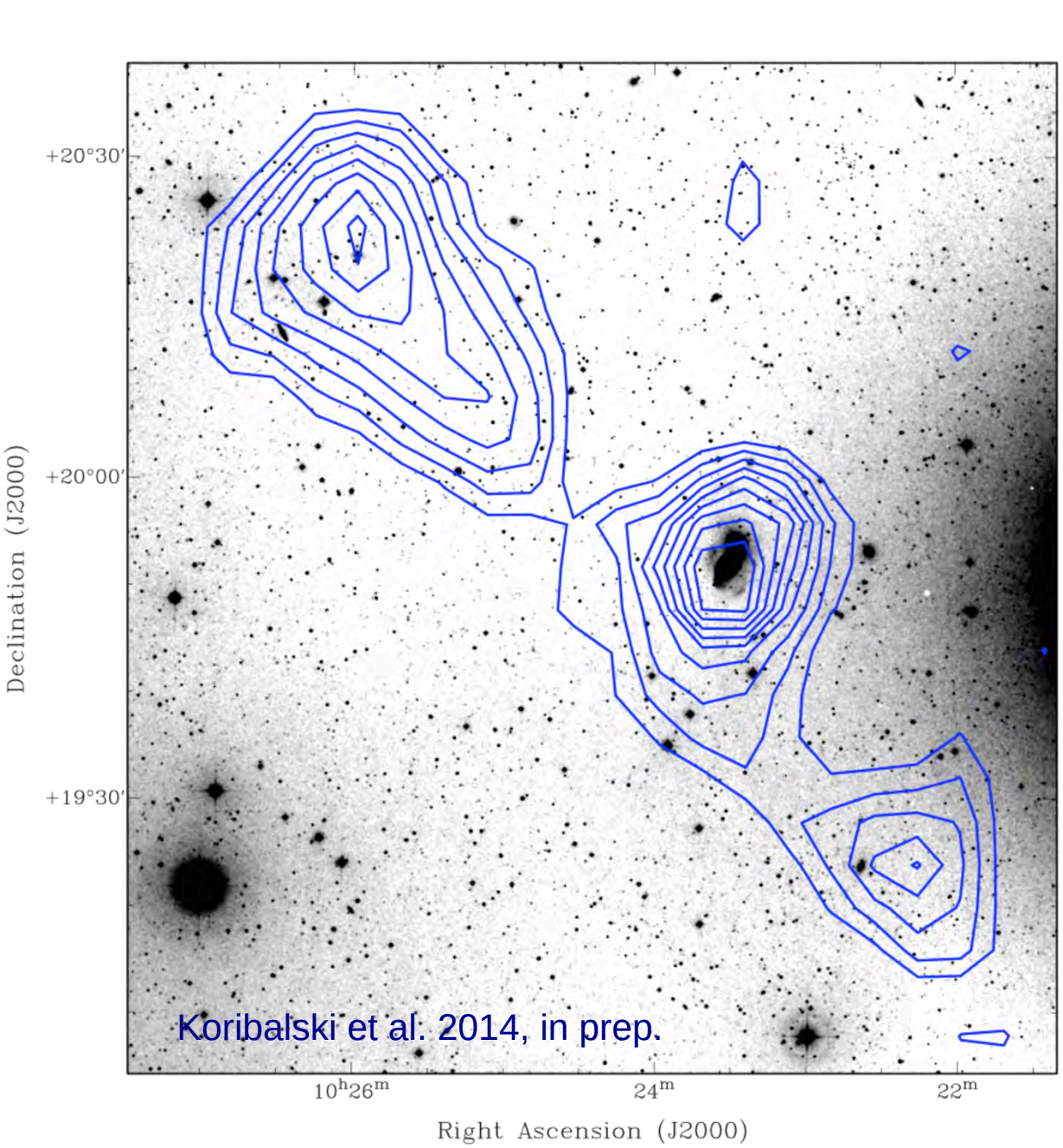
Serra, Koribalski, Duc et al. 2013, MNRAS 428, 370

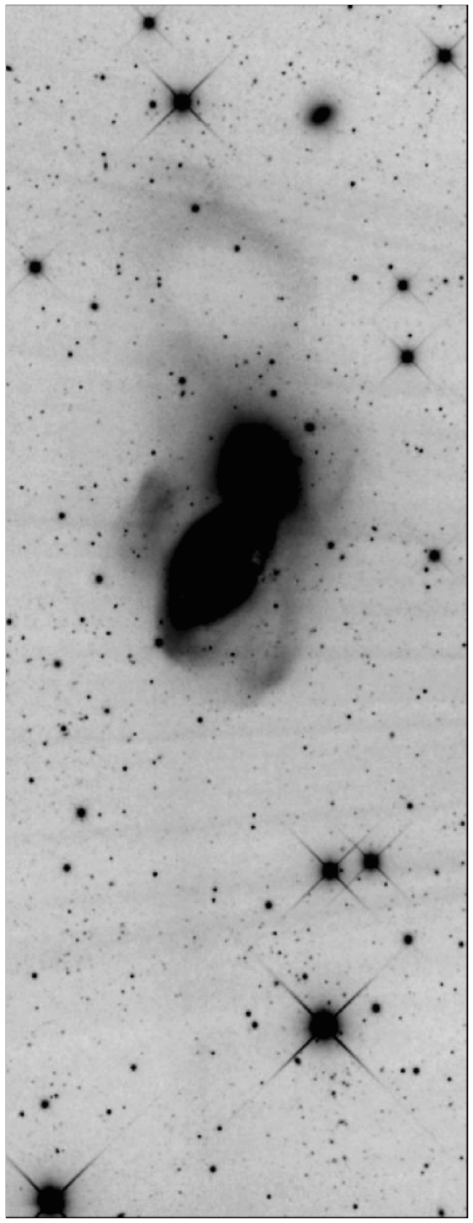
HCG 44



Constant-column-density HI contours overlaid on the g-band CFHT/MegaCam image.

Serra, Koribalski, Duc et al. 2013, MNRAS 428, 370





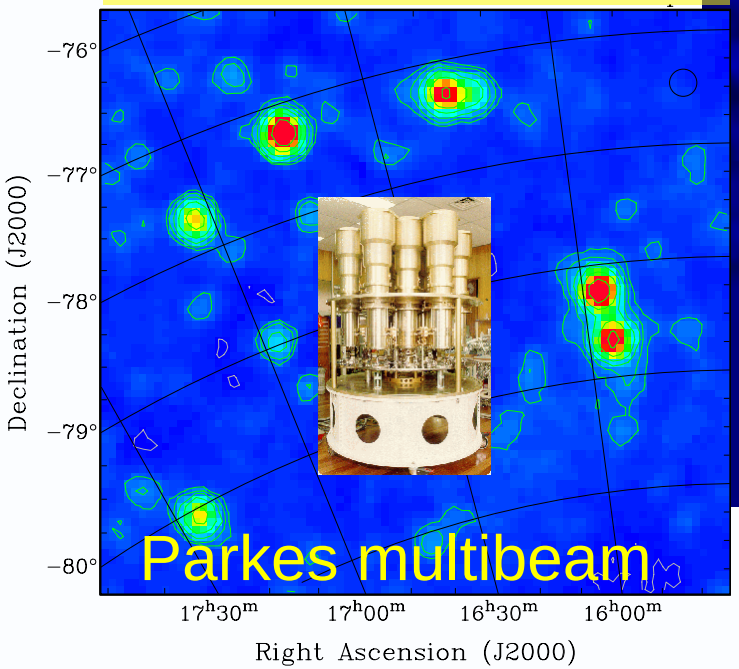
(by Bob Franke)

ASKAP Commissioning

BETA = Boolardy Engineering Test Array (six antennas)

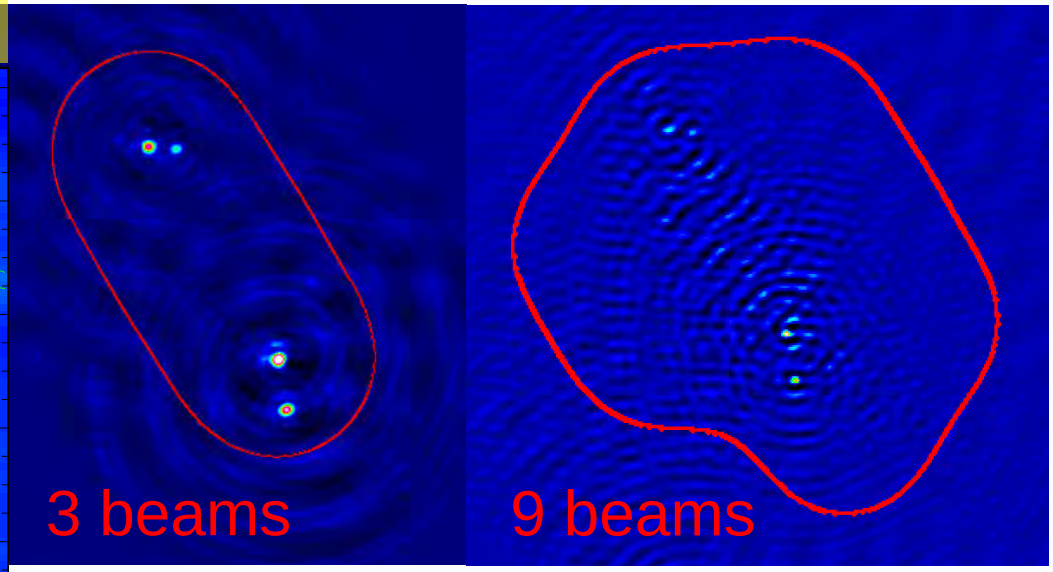
BETA Mk1 PAFs – an engineering testbed

HIPASS 20-cm radio continuum map



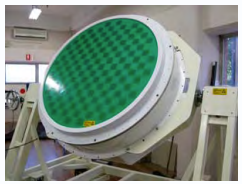
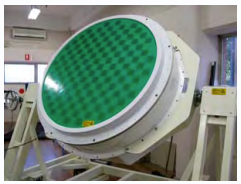
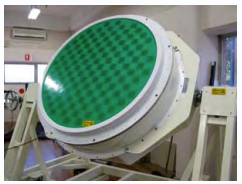
BW = 64 MHz (1024 ch)
8 min/pointing, 2 pols
15.5 arcmin resolution

3 & 9 beam continuum images achieved with 3 PAFs



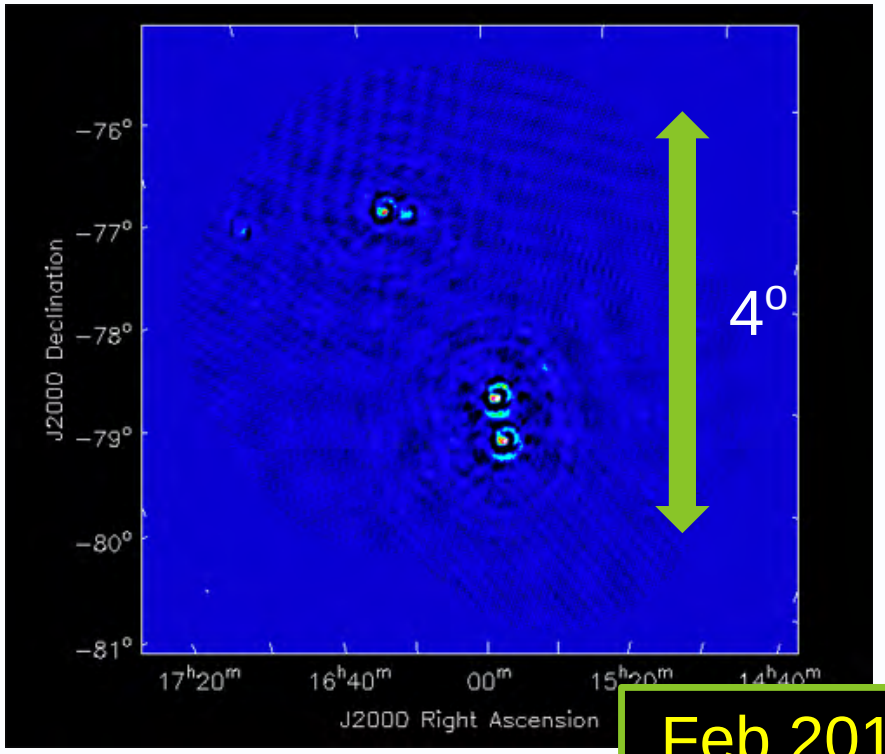
BW = 16 x 1 MHz
12h, 1p, 928 MHz

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

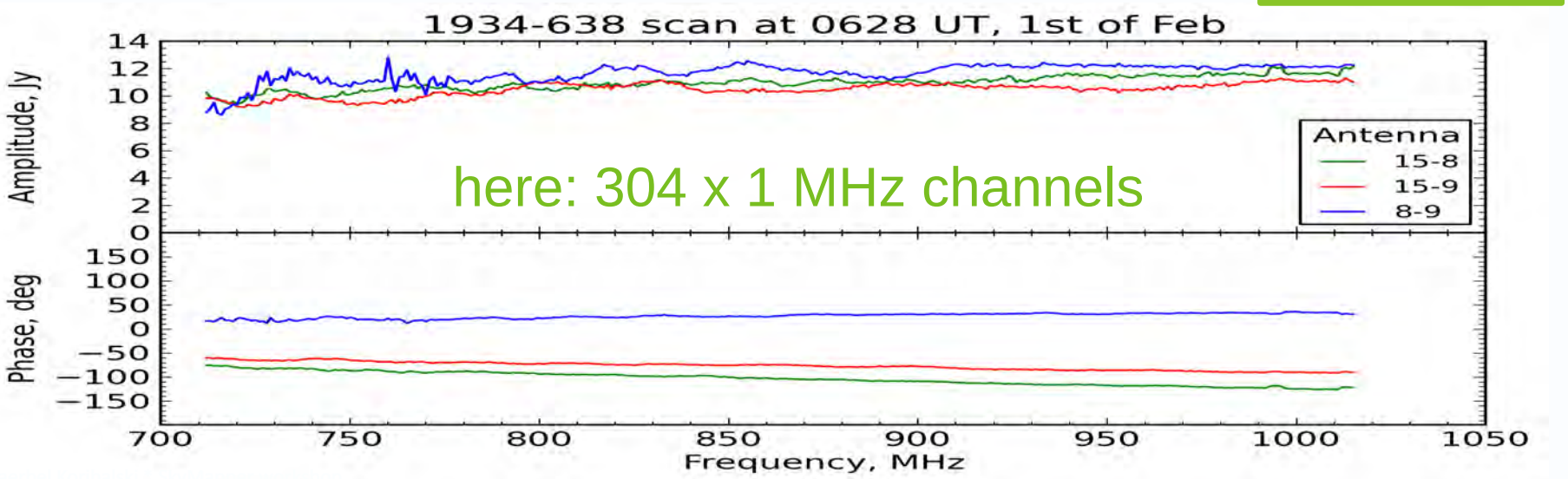




First 9-beam image with six PAFs on ASKAP antennas

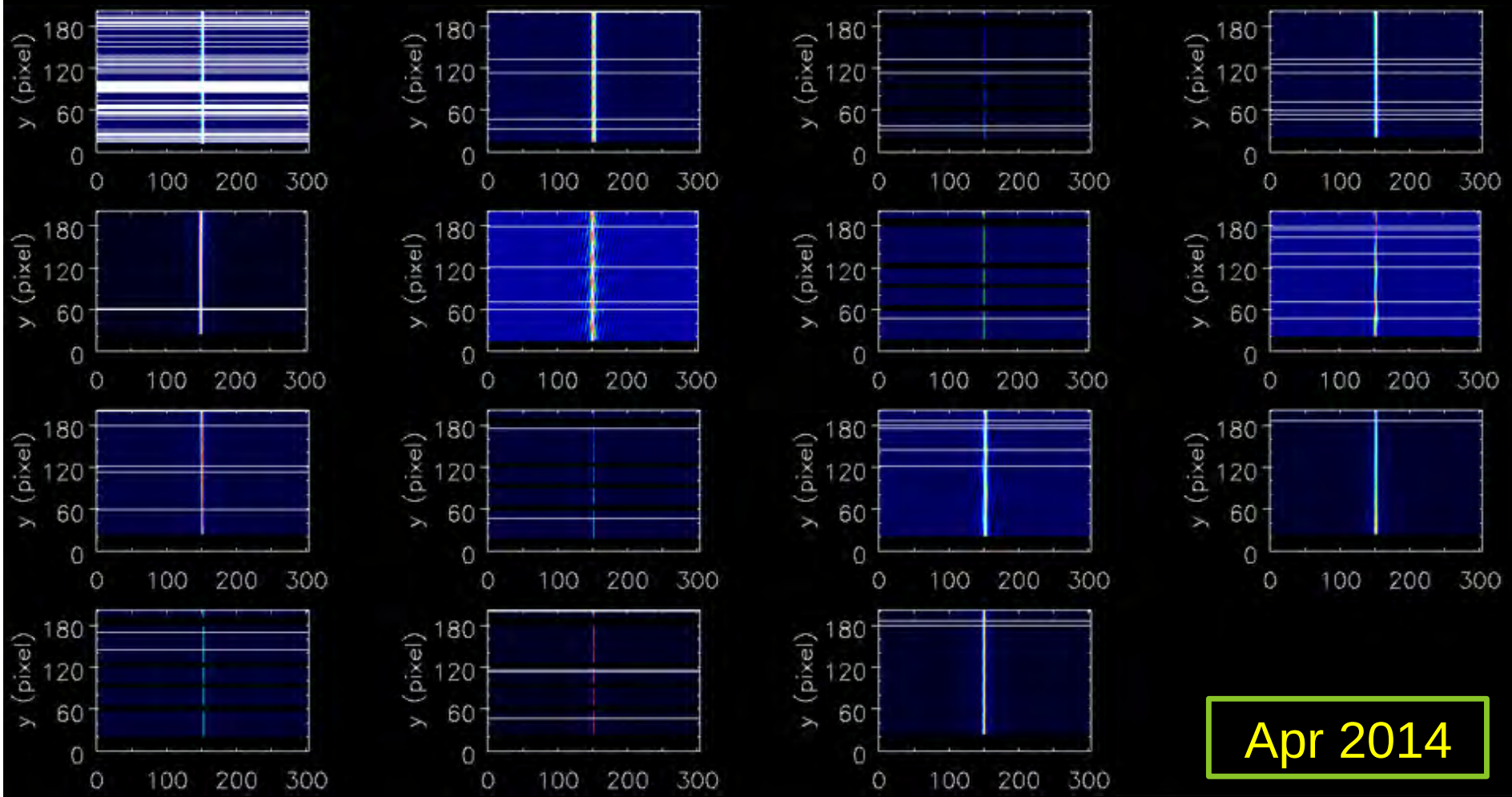
- 6 antennas (36)
- 2 x 3 baselines (630)
- **9 beams** (36)
- 304 MHz bandwidth ✓



Feb 2014



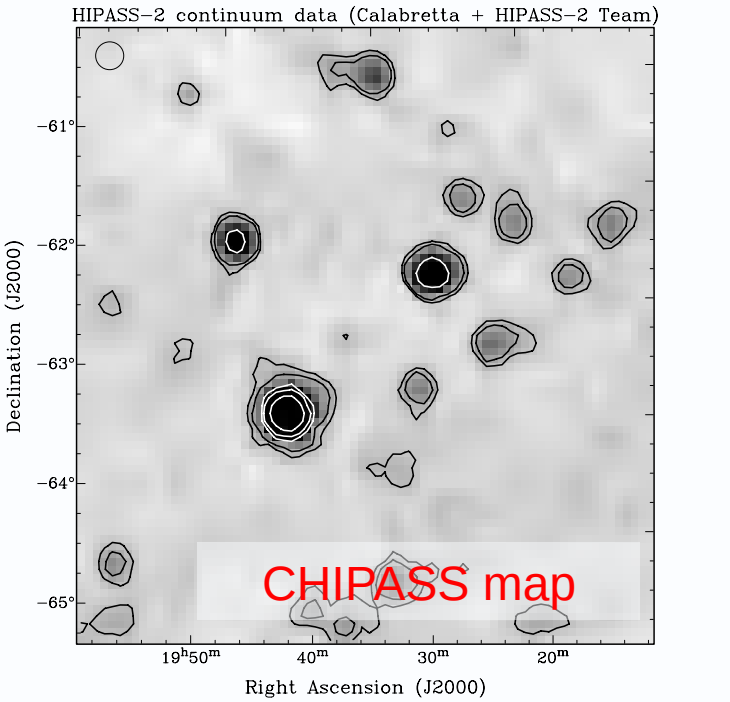
First BETA results: 15 baselines working !



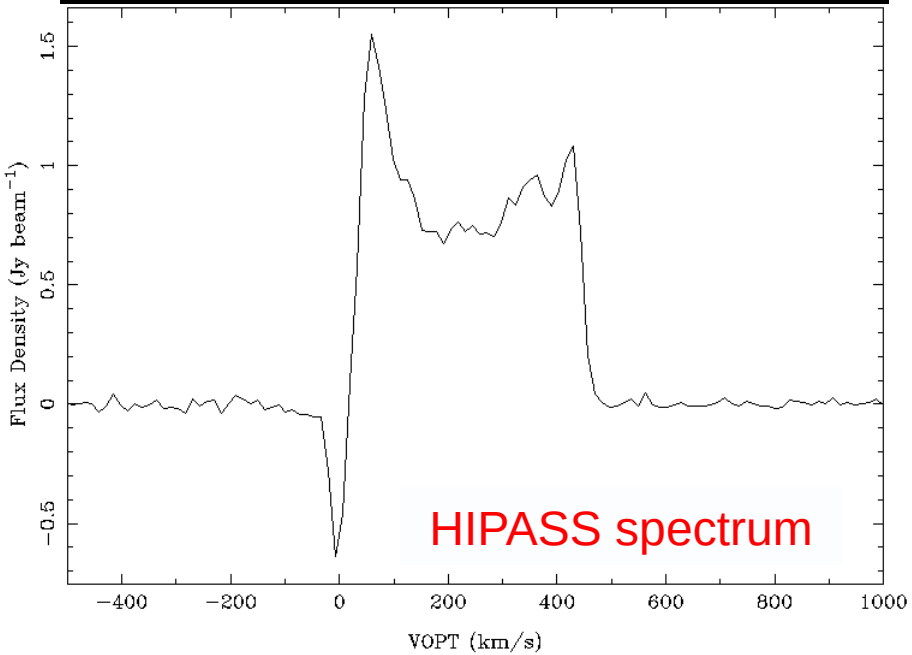
Apr 2014

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.

ASKAP Commissioning – Part 2

with Mk II PAFs or ADE PAFs

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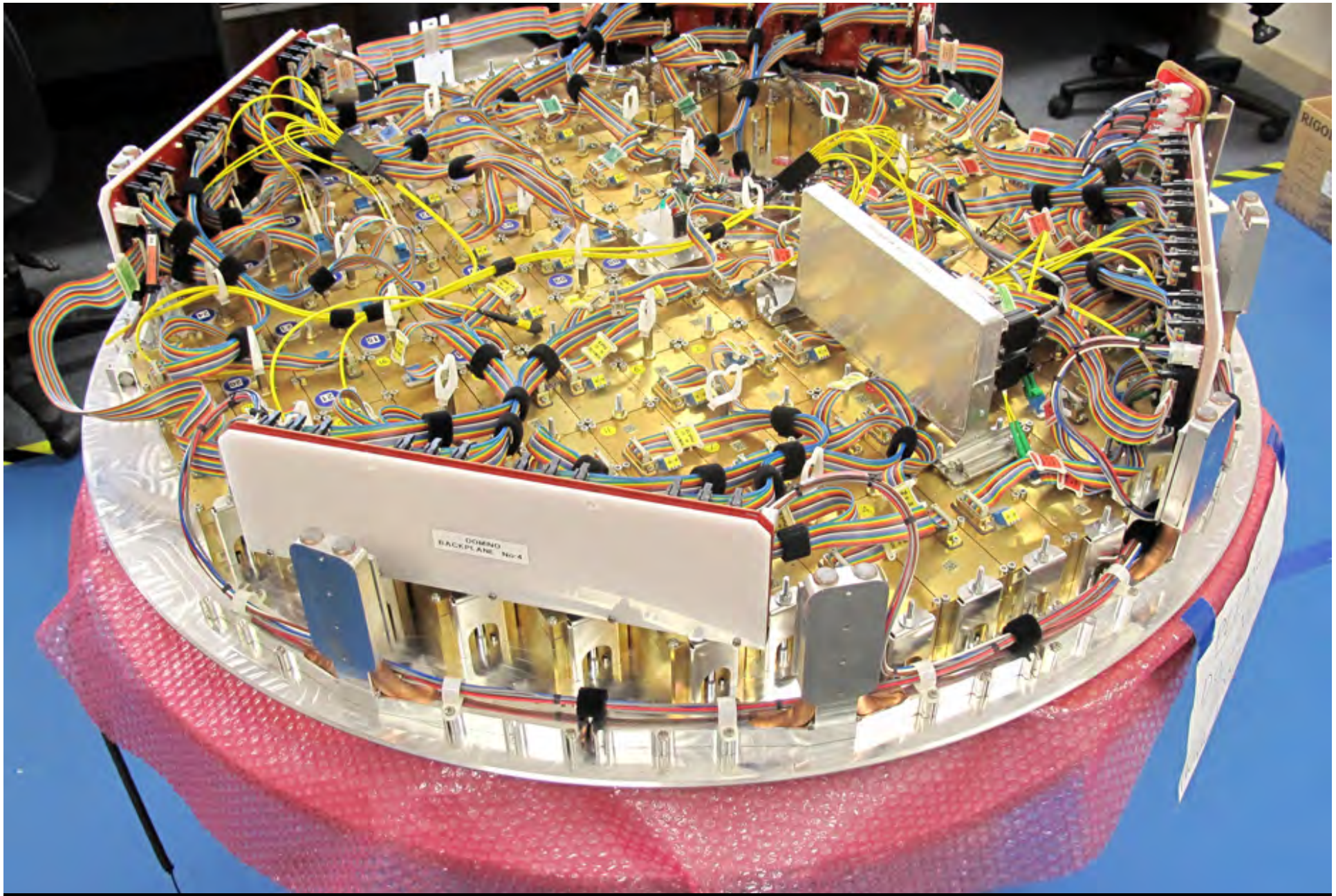
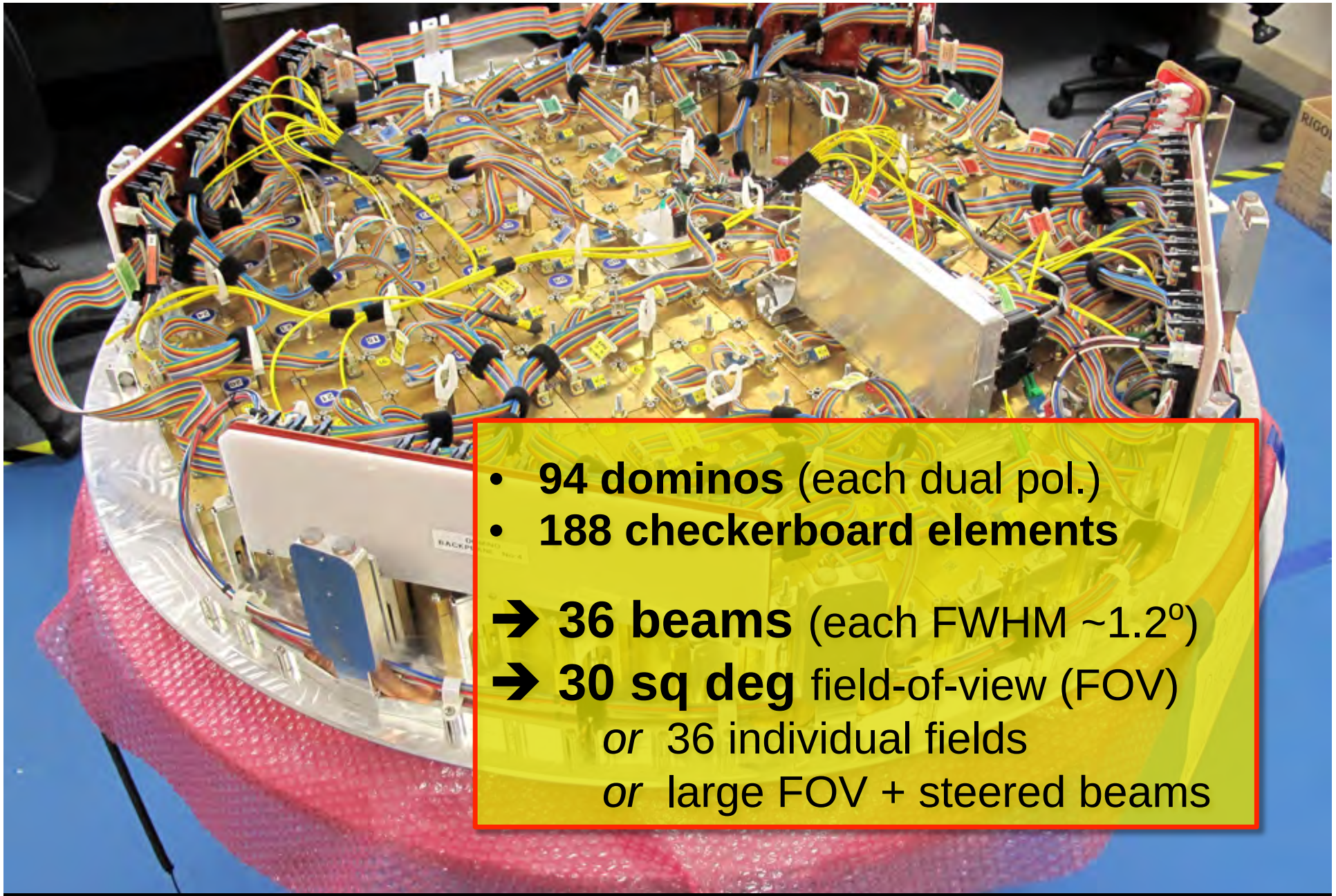
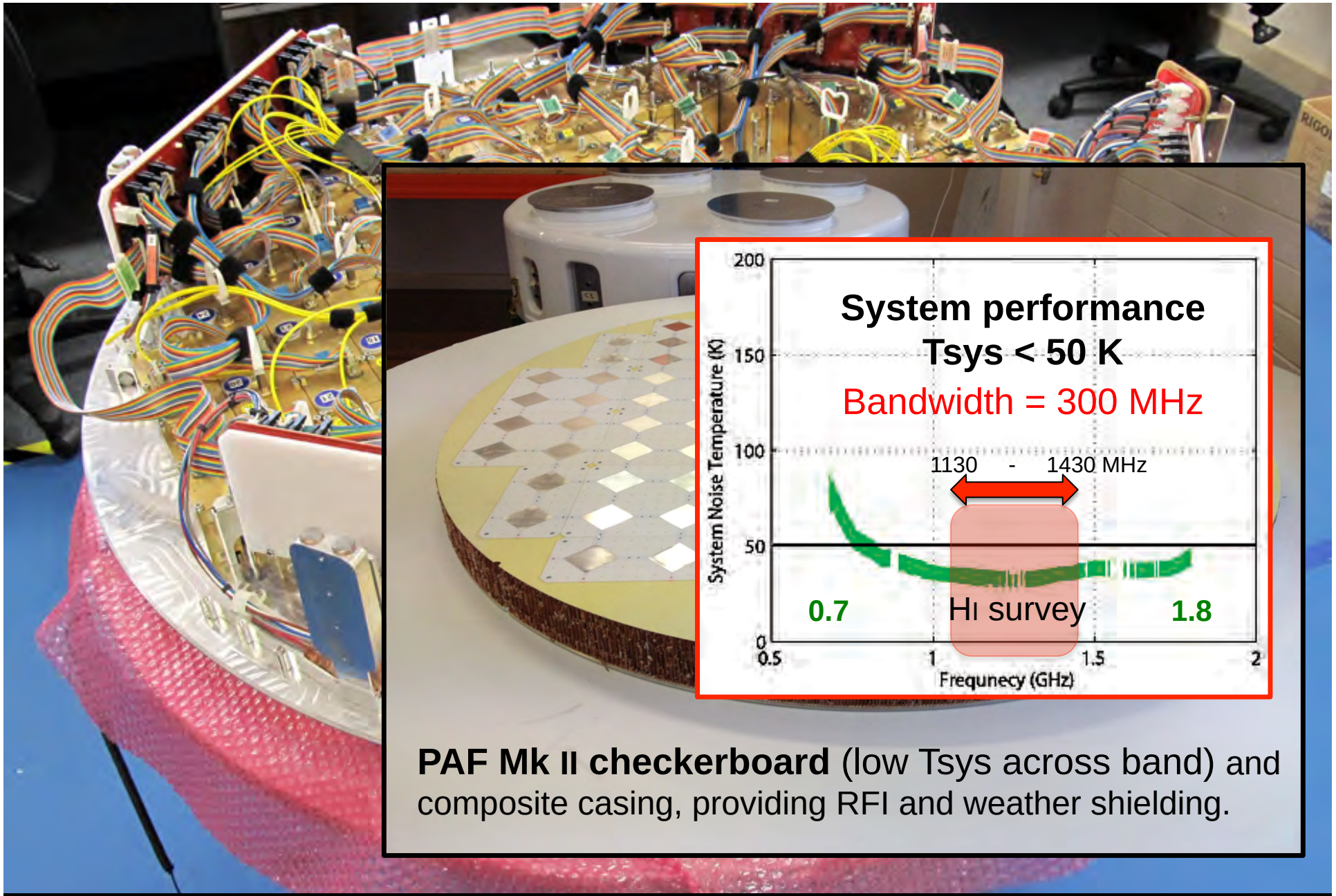


ASKAP Mk II Phased Array Feed (PAF) assembly

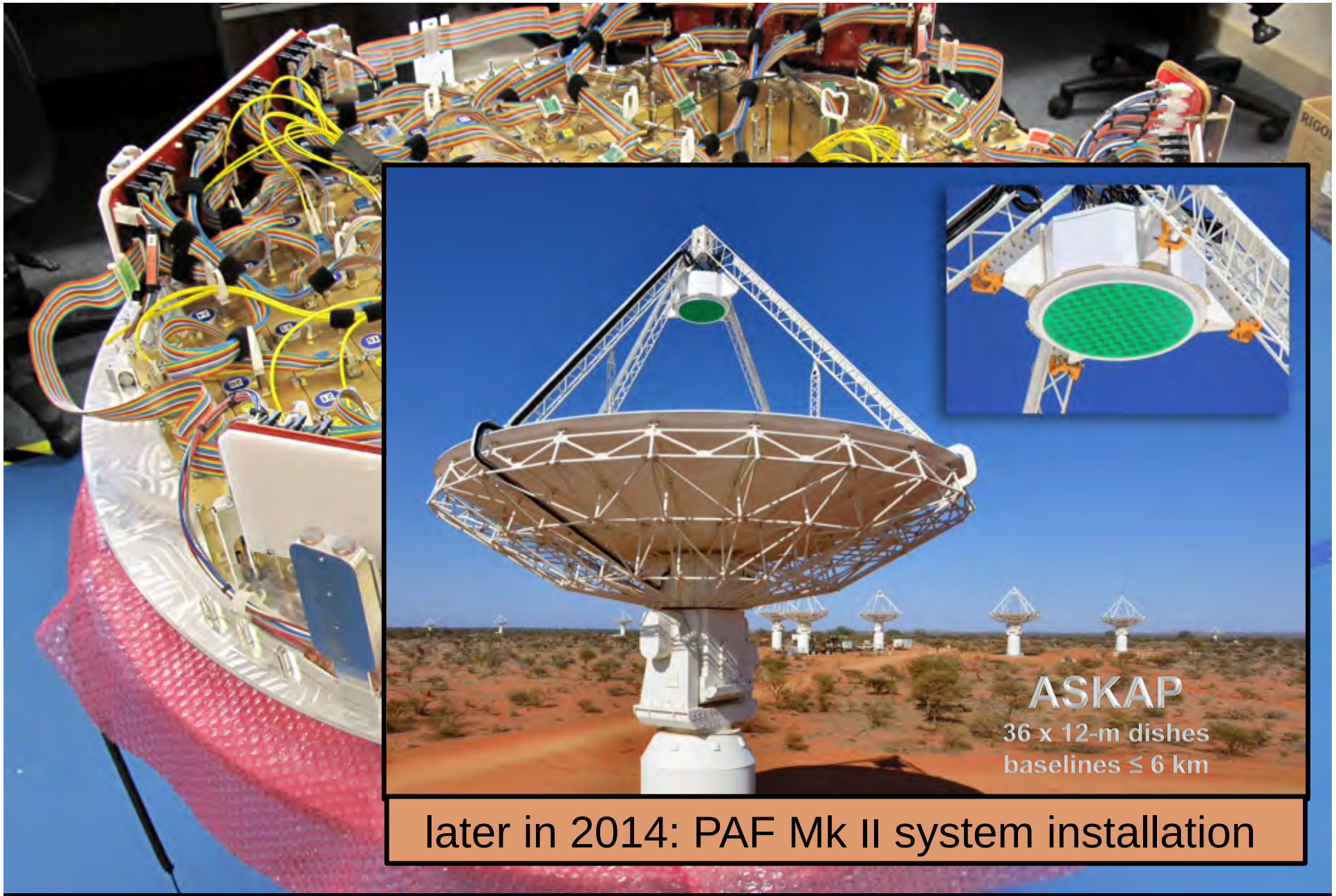


ASKAP Mk II Phased Array Feed (PAF) assembly

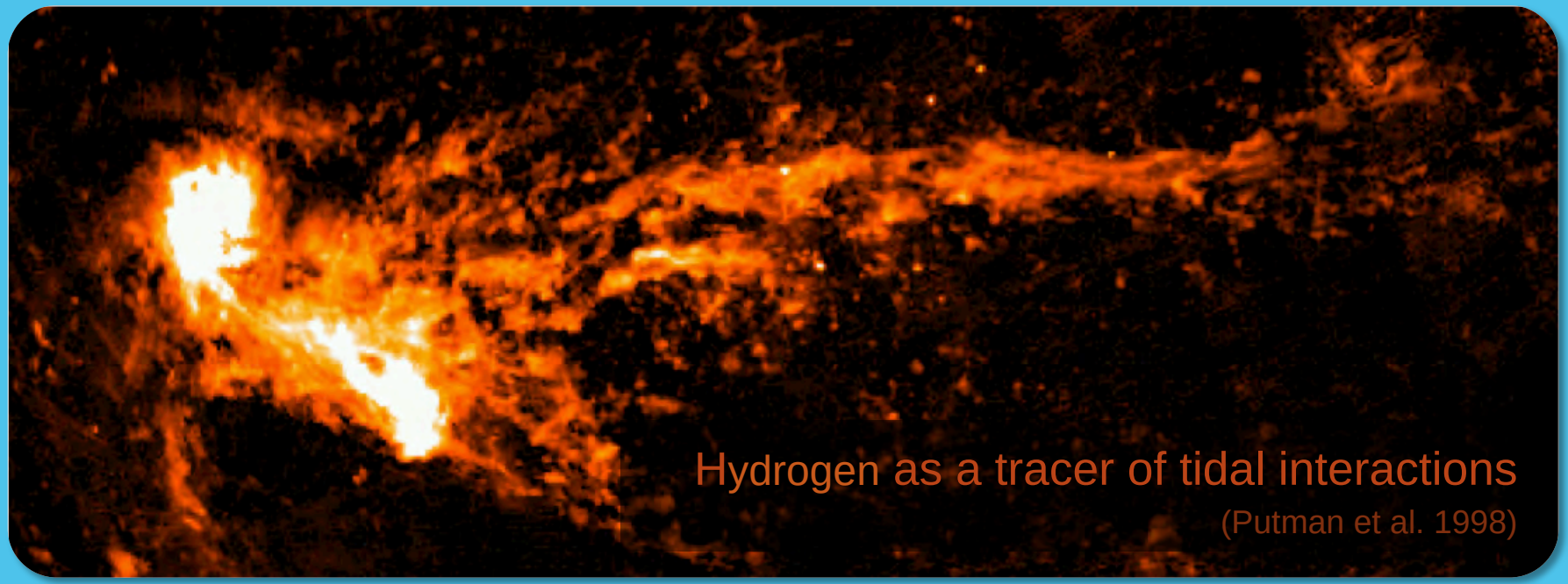


PAF Mk II checkerboard (low Tsys across band) and composite casing, providing RFI and weather shielding.

ASKAP Mk II Phased Array Feed (PAF) assembly



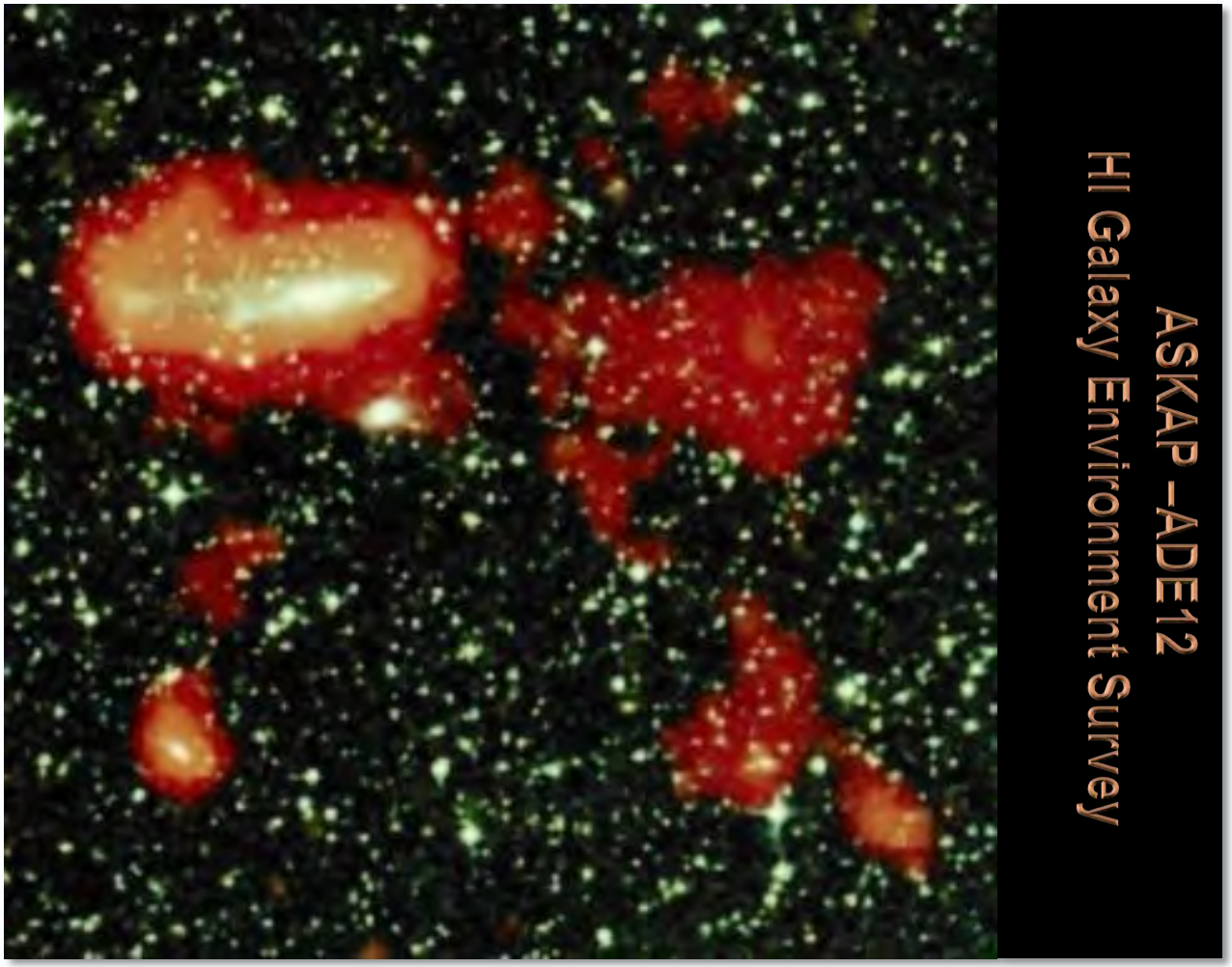
ASKAP Mk II Phased Array Feed (PAF) assembly



HI Early Science with ASKAP-12

Bärbel Koribalski

CSIRO Astronomy and Space Science
www.csiro.au



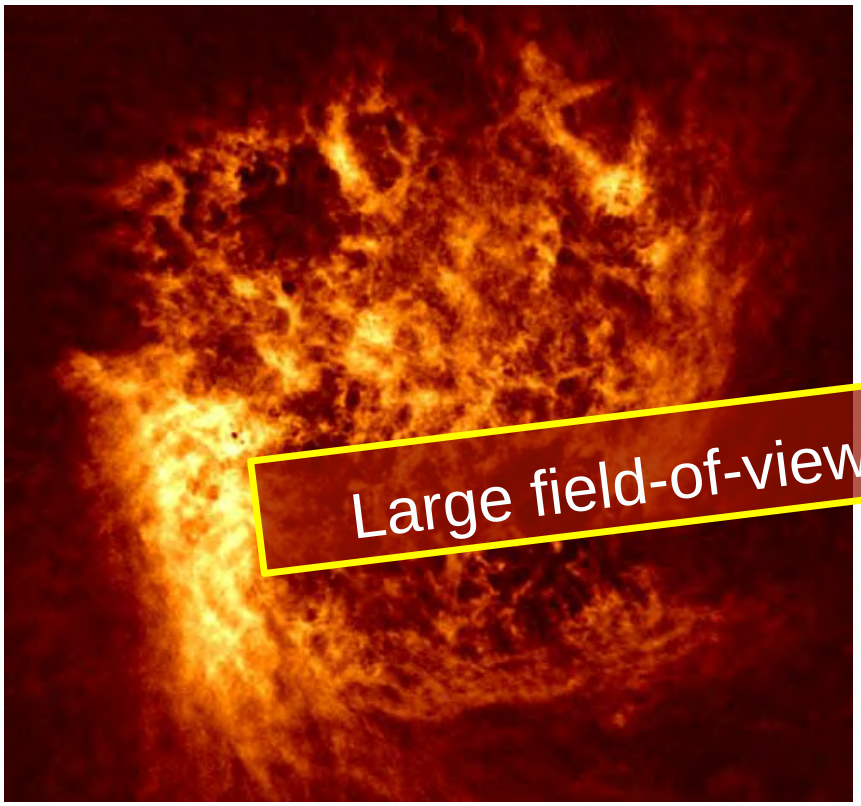
Target ~10 fields

≥ 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.

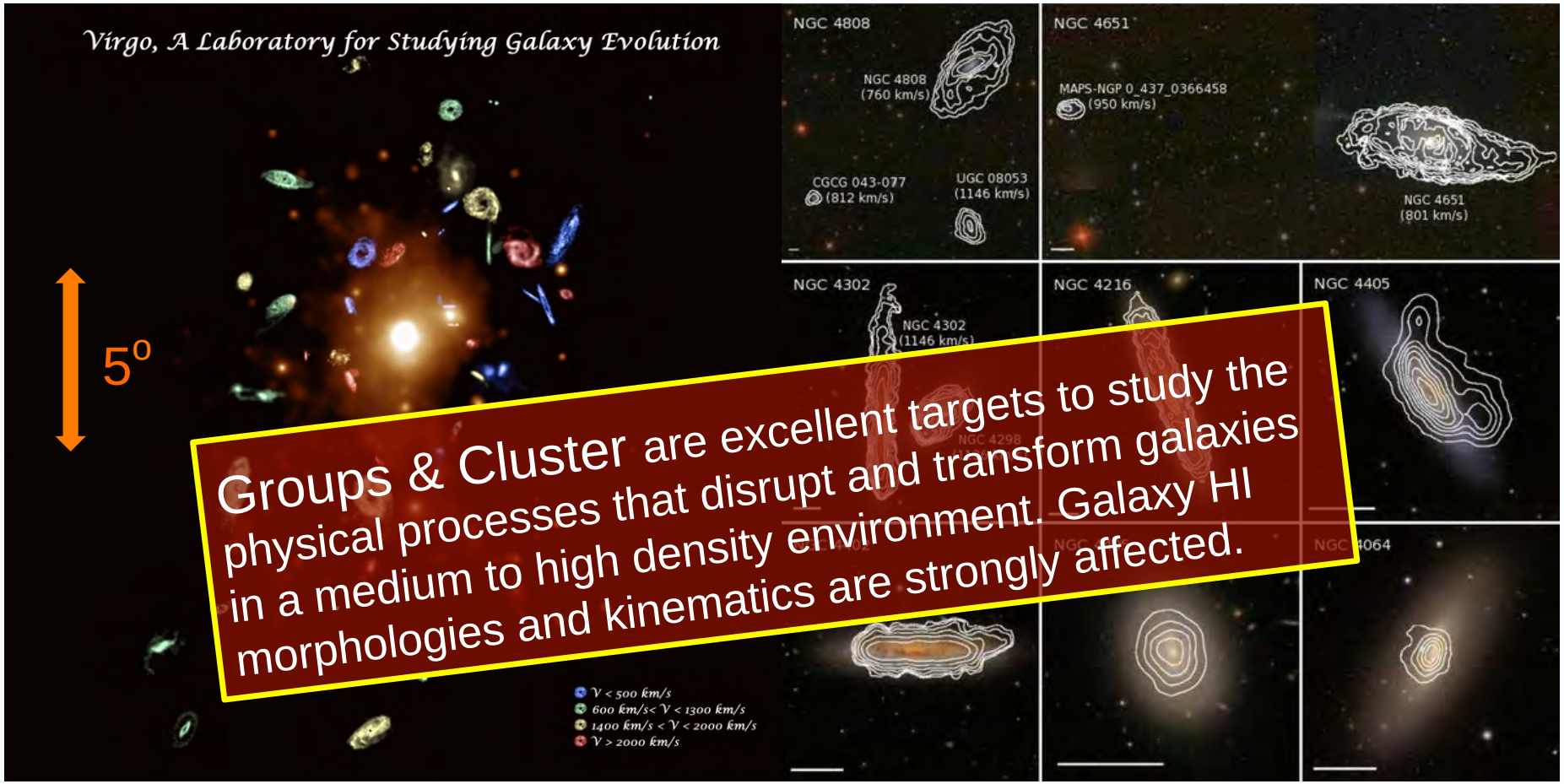
Six MkII PAFs working together could produce this:



Large field-of-view demonstrator science.

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

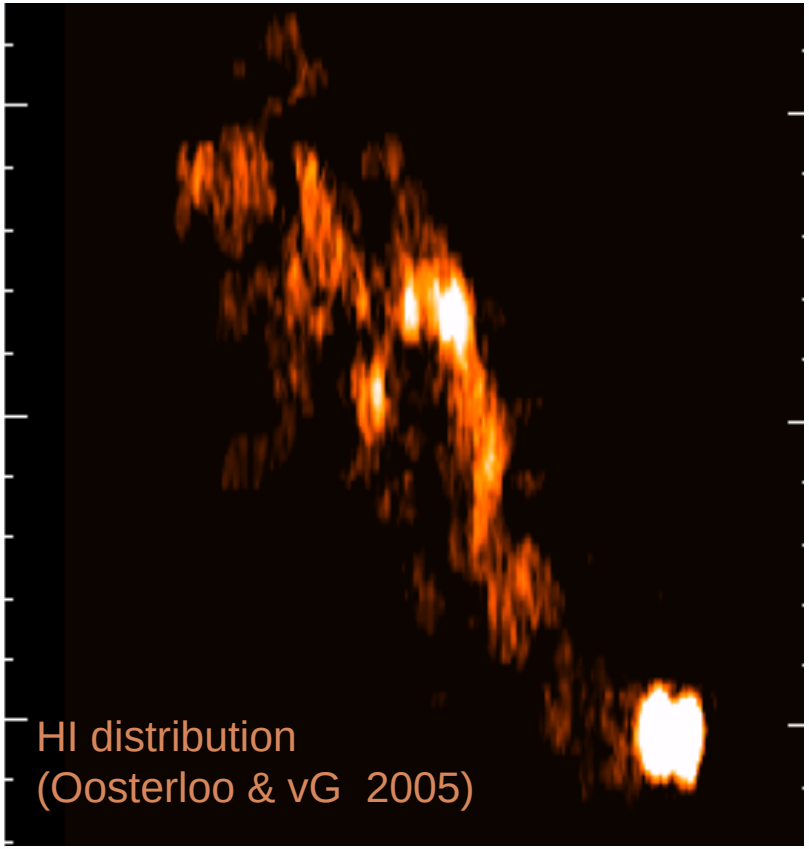
Infrared Portrait of the LMC
(Spitzer + Herschel)



VLA HI Study of the Virgo Cluster.

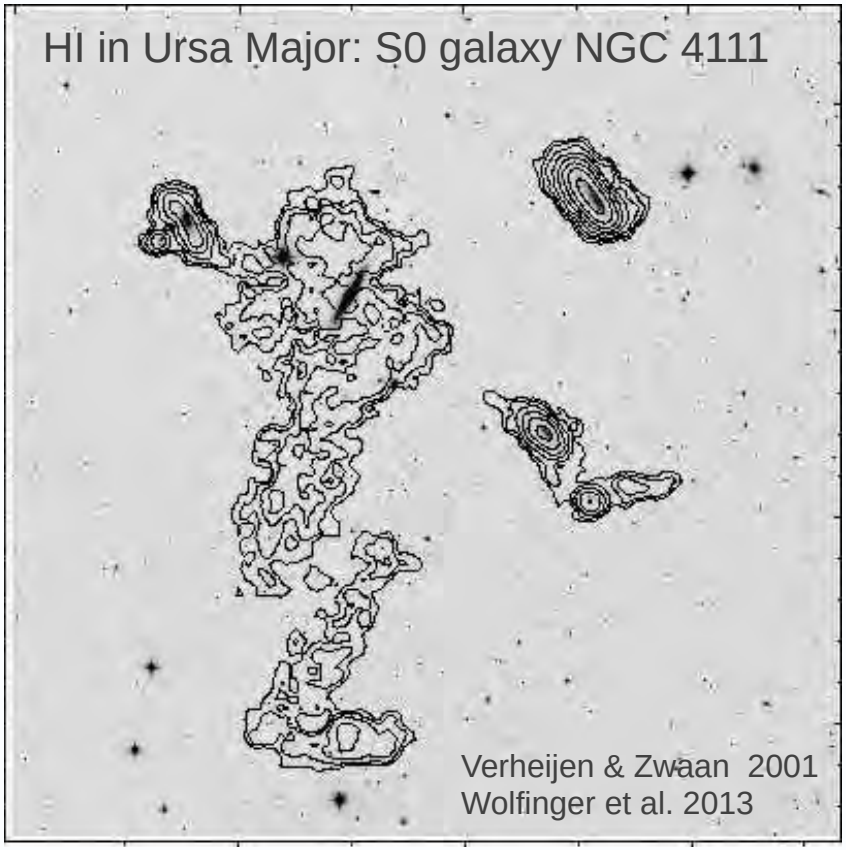
About **400h** to obtain single pointings of 53 late-type Virgo cluster galaxies.

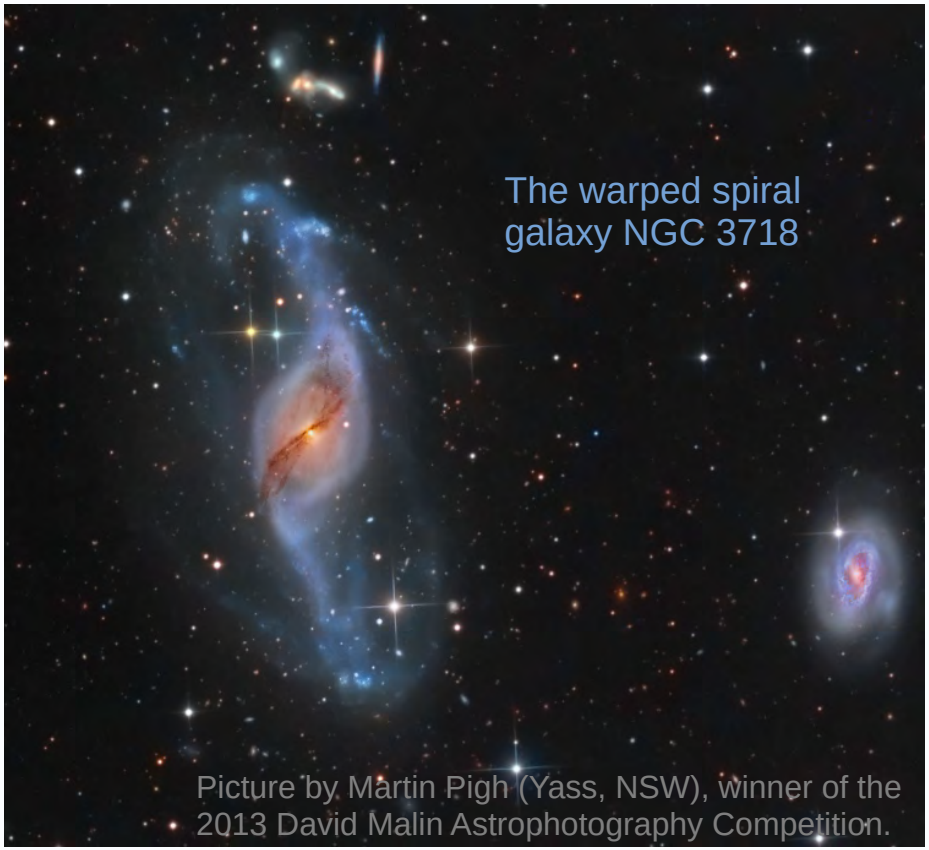
SDSS + HI contours (Chung et al. 2009).



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



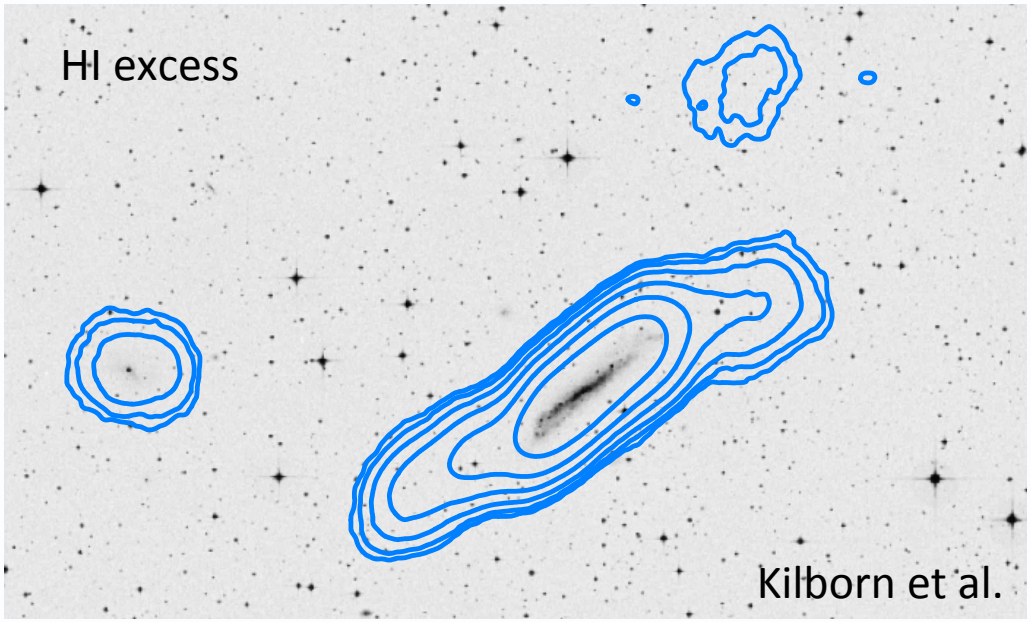


The 21-cm spectral line allows us to study

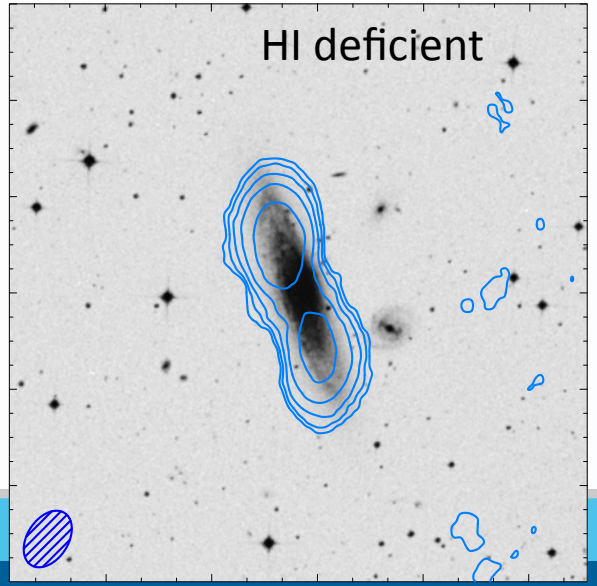
- the physical processes affecting galaxy disks
- star-formation locations in the outer disk
- gaseous filaments/bridges between galaxies
- intra-group/cluster gas

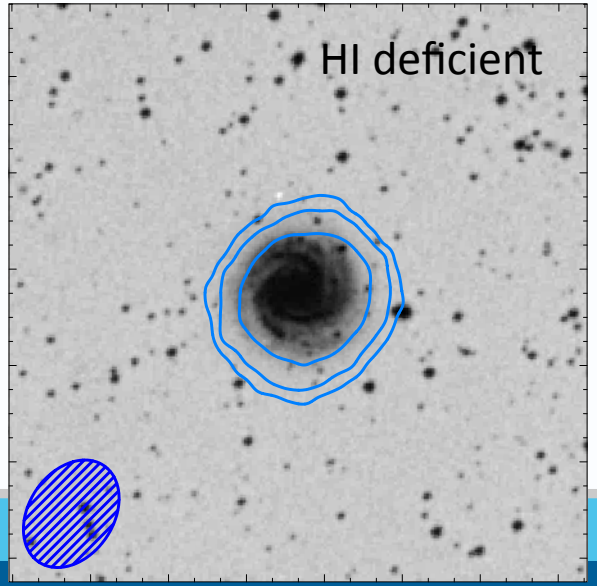
Using HI maps to determine the morphology of HI deficient and HI excess galaxies:

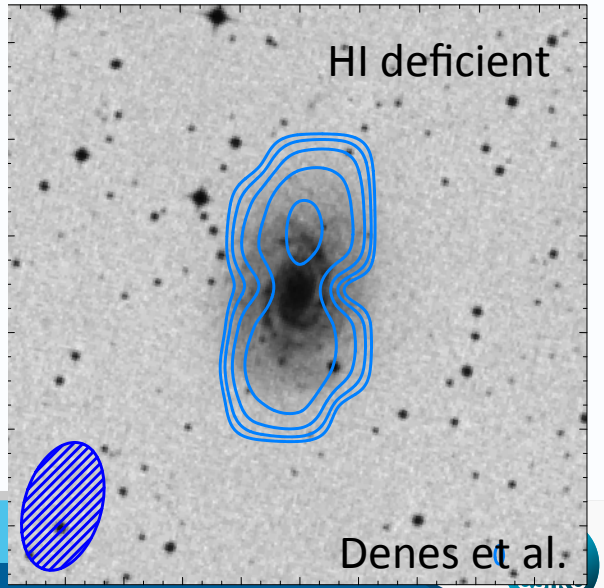
HI stripping and HI accretion methods in spiral galaxies



slide by Virginia Kilborn

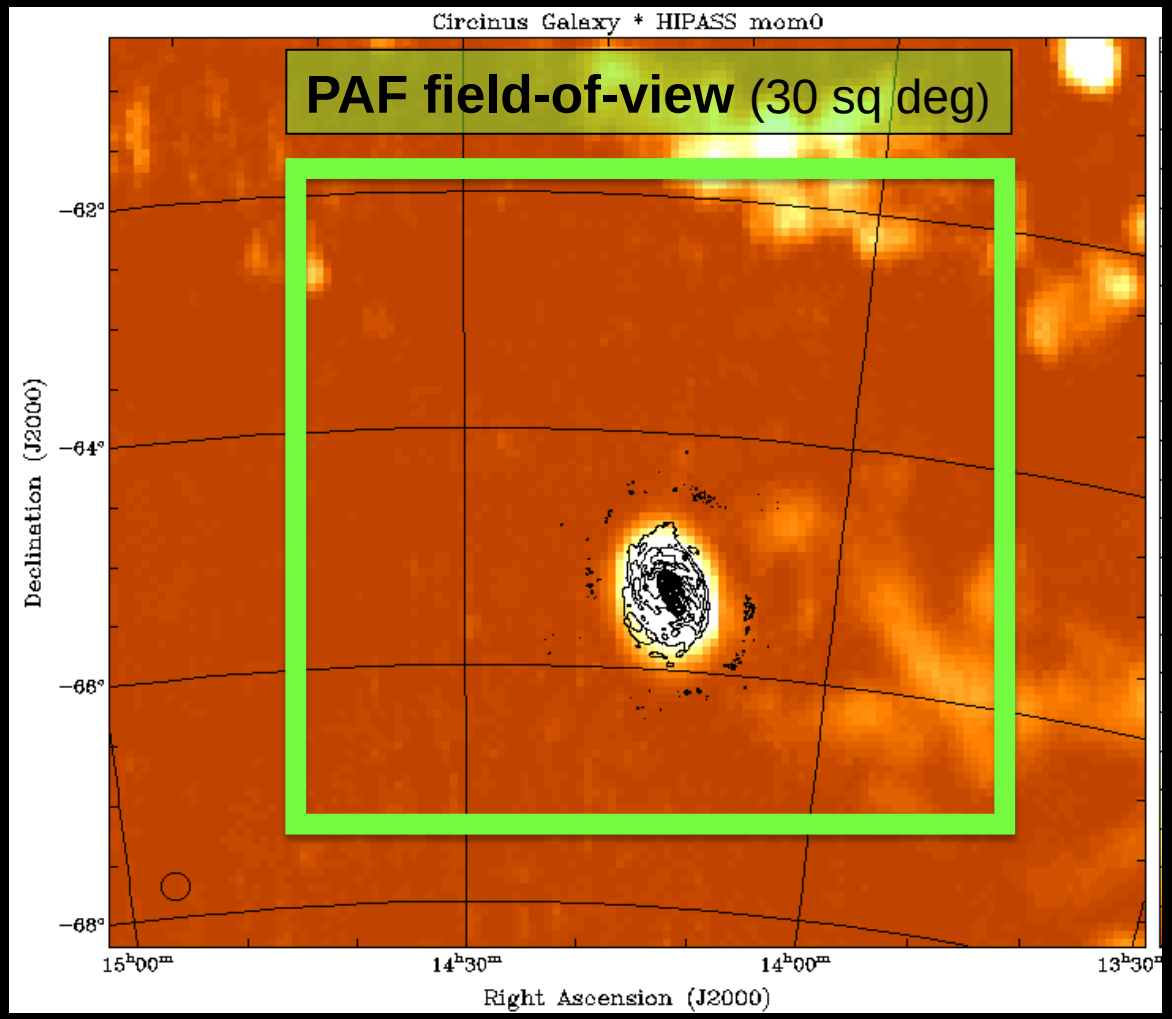






BETA / ASKAP Early Science Fields

ASKAP-ADE
6 – 12+ dishes

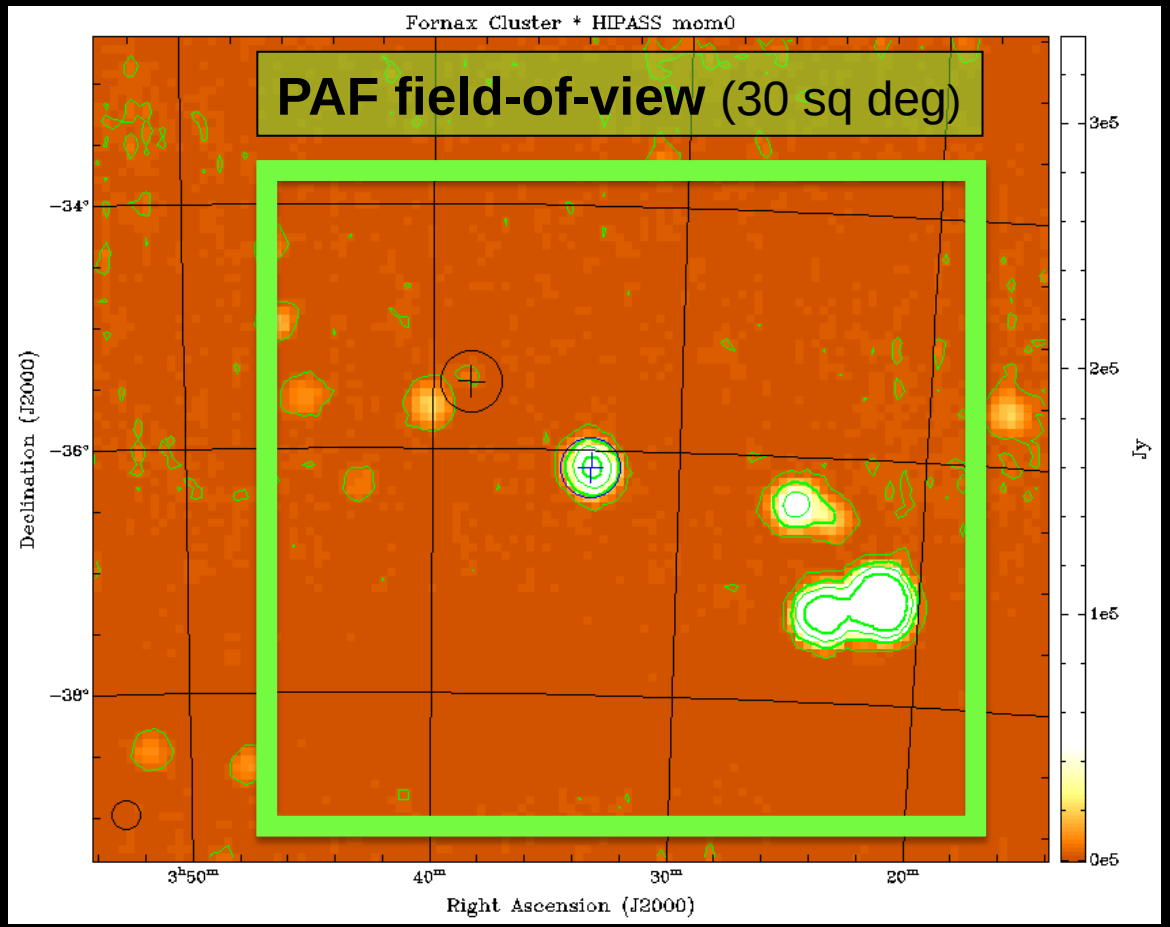


Moon to scale

Circinus field: isolated nearby galaxy

BETA / ASKAP Early Science Fields

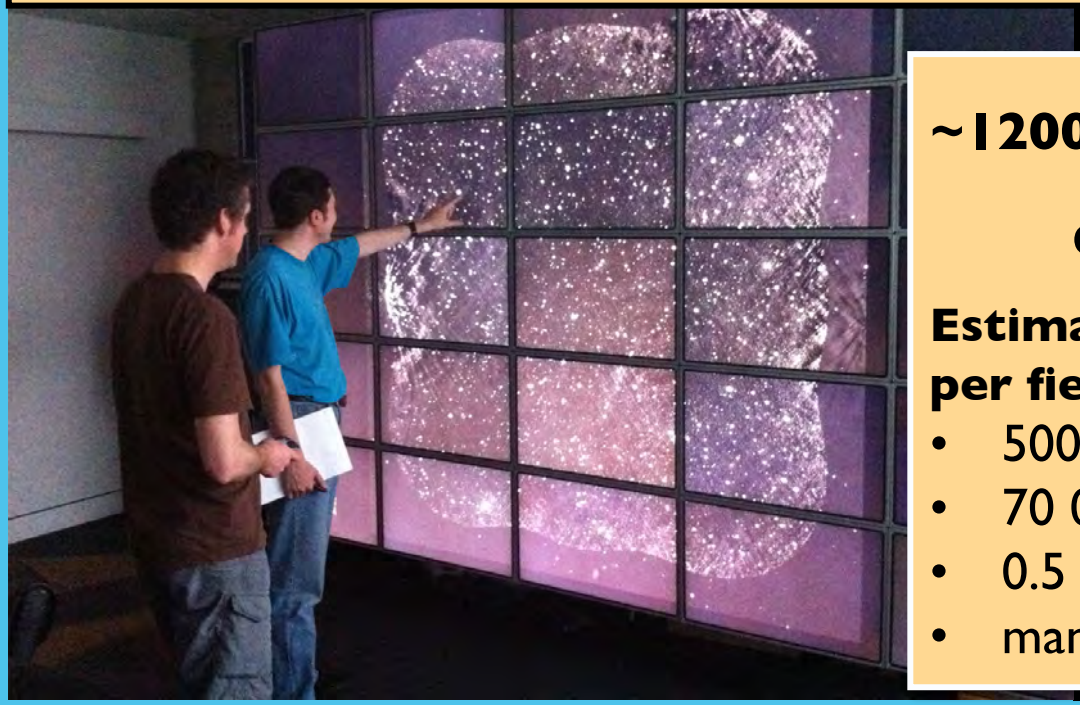
ASKAP-ADE
6 – 12+ dishes



Moon to scale

Fornax field: a nearby galaxy cluster

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

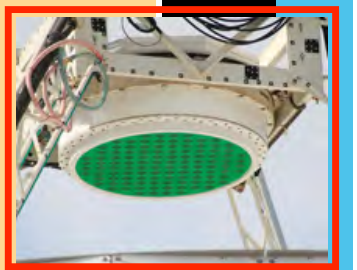


~1200 fields (t_{int}~ 8h)

each 30 sq

Estimated detections per field:

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



36 beams

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

Thank you

Dr. Bärbel Koribalski
CSIRO Astronomy and Space Science
Australia Telescope National Facility
SkyMapper workshop – 8 Apr 2014

www.csiro.au

CSIRO

The Galaxy M83

(Koribalski et al., in prep.)

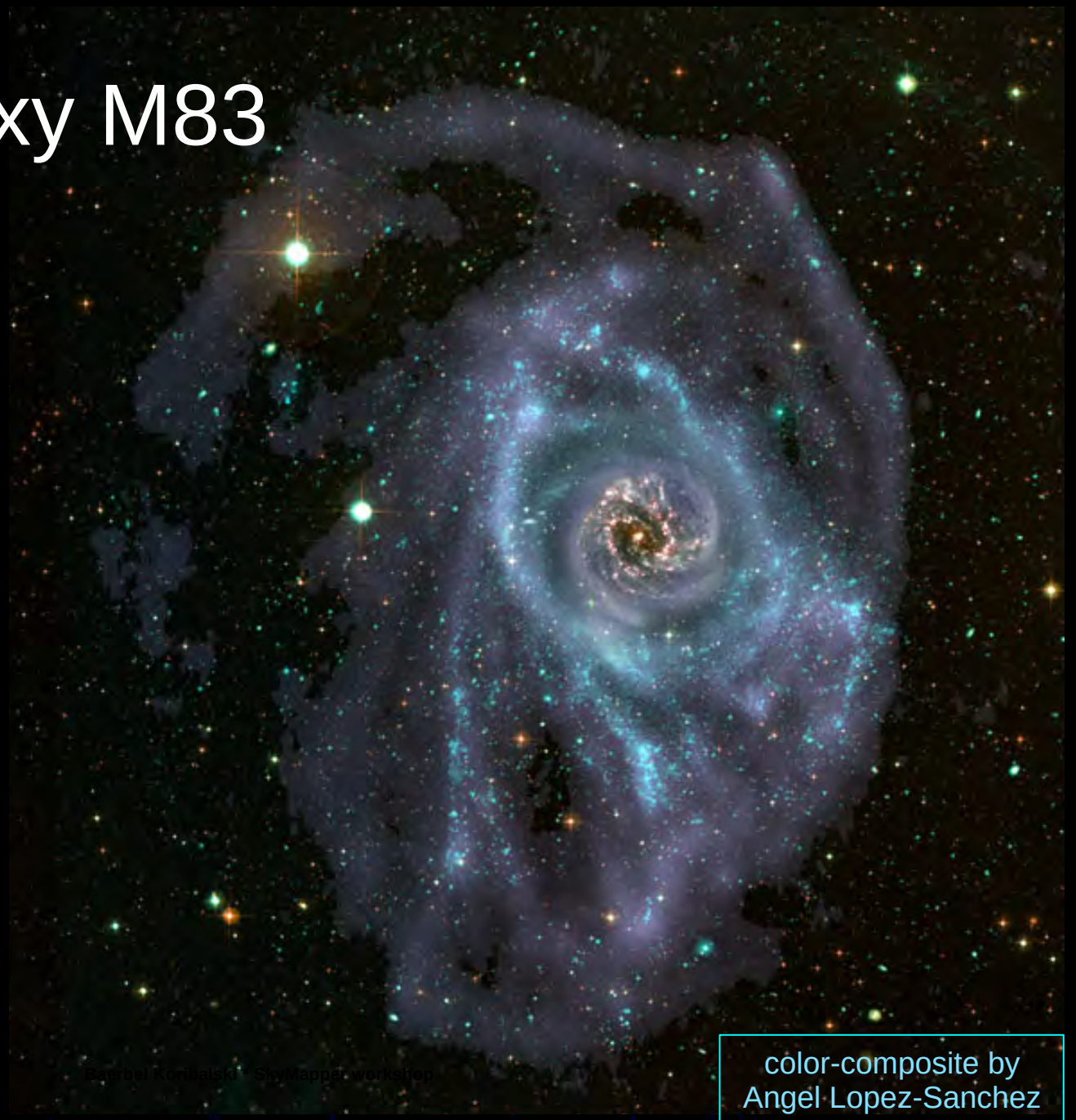
HIPASS J1336−29

D ≈ 4.5 Mpc

HI extent > 80 kpc

$M_{HI} = 8 \times 10^9 M_\odot$

HI is an excellent tracer for SF in the outer disk



color-composite by Angel Lopez-Sanchez