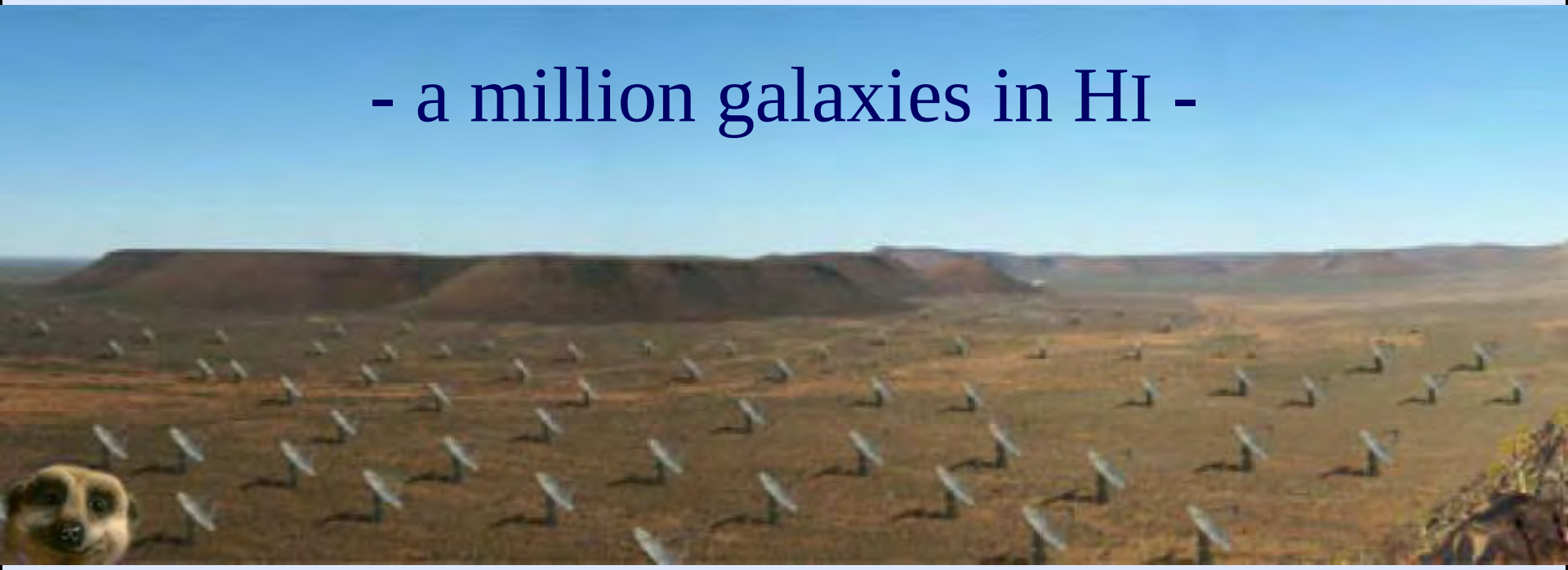
SKA Precursors surveys



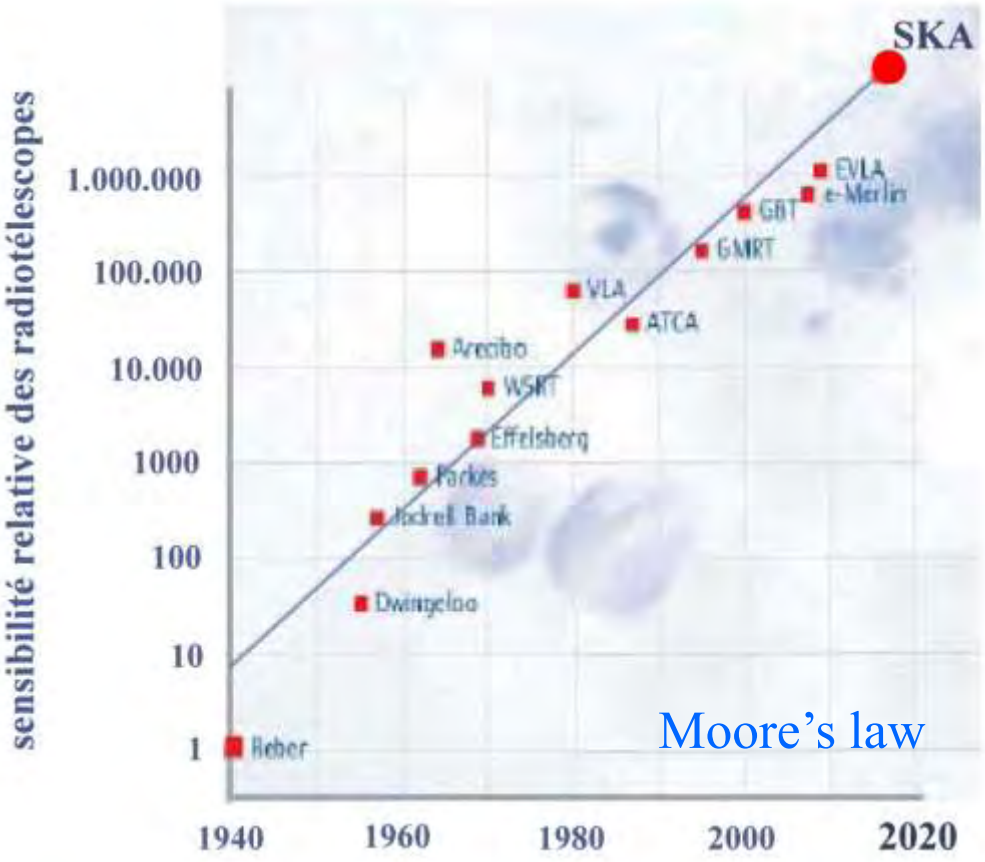
- a million galaxies in HI -

Wim van Driel
GEPI, Paris Observatory

PNCG Workshop Strasbourg, 08.10.09

Radio telescopes keep getting more sensitive

radio telescope sensitivity has doubled every 3 years:
a factor 100,000 in 60 years



Building up survey speed

- **Blind HI line survey**: complete sampling of

  - an area on the sky
  - down to a certain flux density (mJy)
  - out to a certain radial velocity (km/s) $\rightarrow$ space volume

- **Survey speed**: depends on

  field-of-view of telescope
  collecting area and system temperature $\rightarrow$ sensitivity
  bandwidth (radial velocity coverage)

- Commensal observations (piggy-back / using same data)
  different lines + continuum: versatile back-end (correlator)

HI line surveys – past and present 1.

- **Single-dish telescopes**

  single pixel on the sky (main telescope beam)
  several 100m-class telescopes, one 300m diameter (Arecibo)

- Multi-beam receivers on single-dish telescopes

  sampling of entire focal plane; multiple receiver horns
  → 13 beams (Parkes 64m); 7 beams (Arecibo 305m)
  improvement in many-channel correlators
  → larger radio velocity coverage (0 – 20,000 km/s)

  Parkes HIPASS; Arecibo ALFALFA surveys

HI line surveys – past and present 2.

- **Radio synthesis telescopes**

Westerbork: 14×25m (7000 m^2) ; E-W array,
one resolution only (13" EW), NS beam δ-dependent
VLA: 27×25m (13,000 m^2) ; Y-shaped array, round beam
resolution 3" - 60" ; need to move telescopes in one-year cycle
FoV: primary beam 30 arcmin for both arrays

Upgrades:

EVLA: complete frequency coverage, no extra antennas
Westerbork: APERTIF: greatly enlarge Field-of-view
Phased Array Feeds: FoV 0.25 deg^2 → 8 deg^2
→ all-sky blind HI legacy surveys become feasible

At the origins of the SKA: HI line surveys

Early 90's: need instrument to detect

Milky Way-like galaxies
in the 21cm HI line
out to redshift z~1

Need a square kilometre collecting surface:

"Hydrogen Telescope" (1kT, SKAI, …)
→ became the SKA

Science scope has broadened since then…

The SKA as a Hydrogen Telescope

SKA: conceived for overwhelmingly large surveys

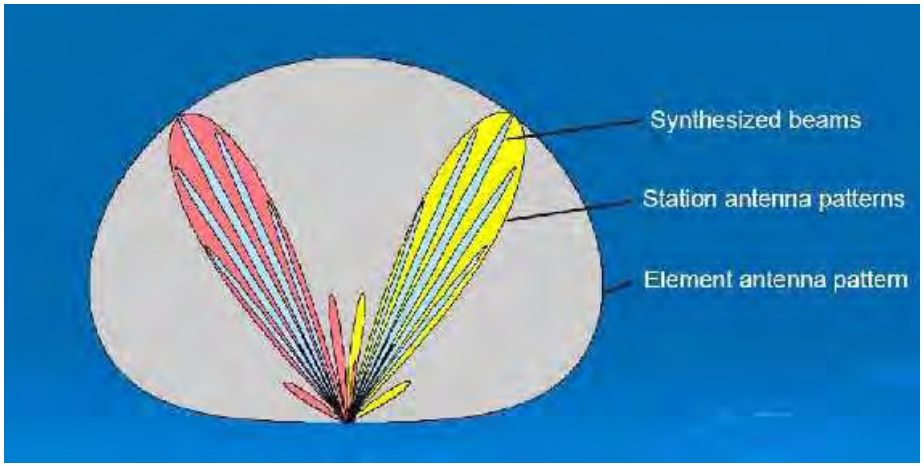
- 100 times better sensitivity

  - HI rich galaxies out to cosmological distances (MW)
  - HI poor galaxies (dwarfs, early-types)
  - low HI surface density (stuff around galaxies, cosmic web)

- 100 times larger field-of-view

  - all-sky surveys
  - find extremely rare cases

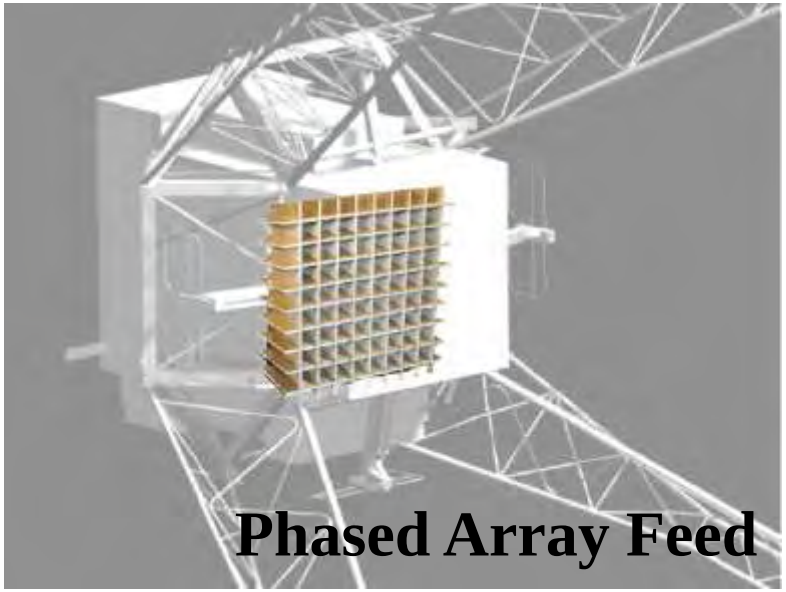
SKA – phased array technology



Phased array

Small individual antennas, each with all-sky FoV
+ electronic beam-forming

Put in focal plane of parabola:
radio synthesis imaging over large FoV (tens of deg^2)



SKA survey speed – shifting into fifth gear

Example: obtain HI line profiles/imaging

- over X square degrees of sky, of N galaxies
- down to low noise level of Y μJy

Comparison of VLA and SKA survey speed (assume T_{sys} equal):

- VLA field-of-view 0.25 sq.deg; SKA 50 sq.deg → gain factor of 200 in time
- SKA 50 times more sensitive → gain factor of 50^2 = 2500 in time

Total gain in survey time = 200 × 2500 = 500,000 times faster

What would take 500 years at the VLA, takes only 10 hours with the SKA

→ **Now: 20,000 galaxy HI survey with Arecibo,**

a million with SKA Precursors (2013), a billion with SKA (2022)

The two SKA Precursor instruments

- SKA site selection:

  Australia and South Africa pre-selected in 2006
  final choice will be made in 2011(?)

Two SKA Precursors:

- Fully funded, in construction on the two potential SKA sites

  ASKAP in Australia
  MeerKAT in South Africa

SKA Precursors - characteristics

- **ASKAP** (Australia)

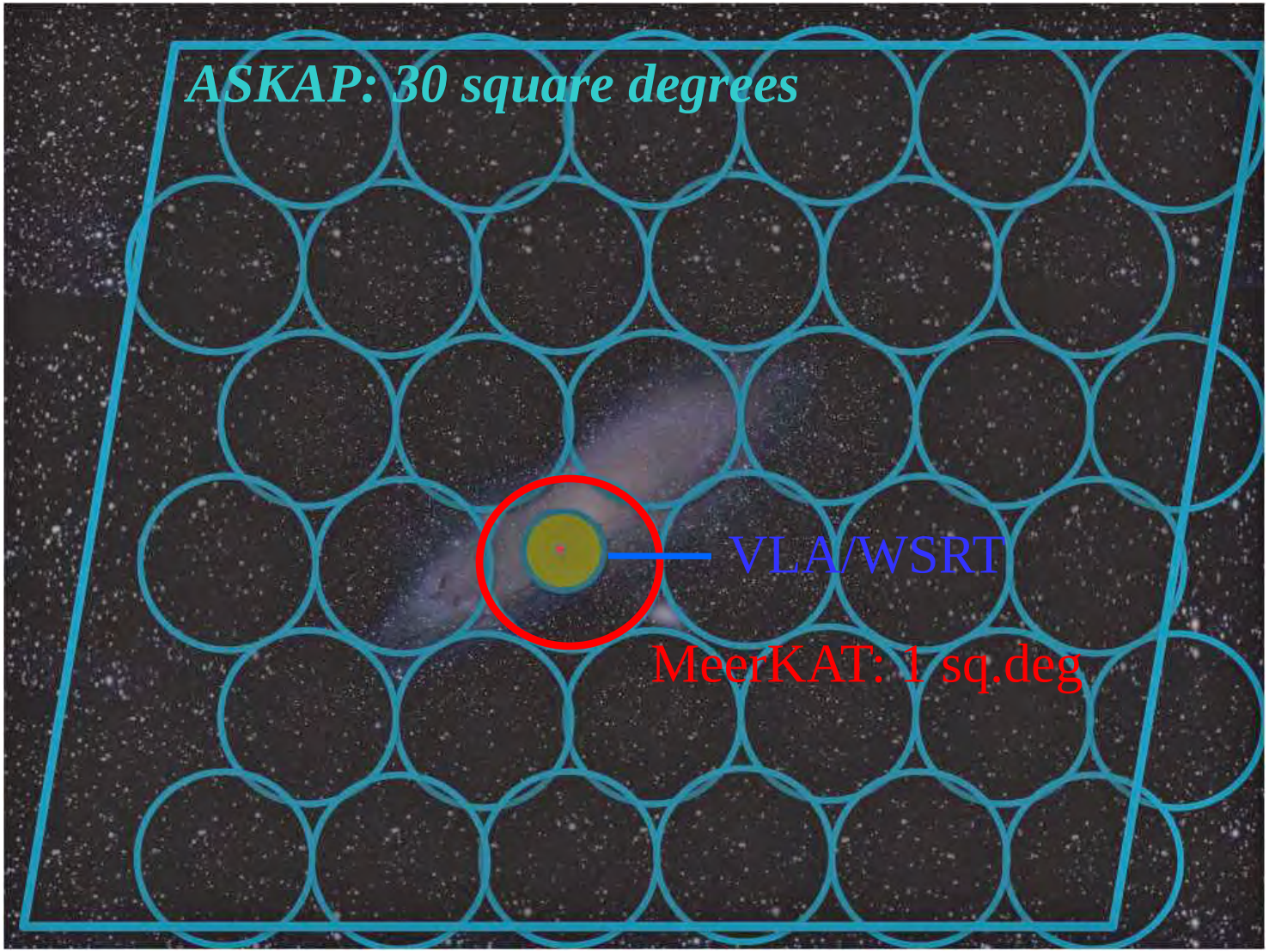
  36 × 12m parabolic antennas: collecting surface 4000 m^2
  multi-beam Phased Array Feeds: field-of-view 30 sq.degrees
  instantaneous bandwidth: 300 MHz
  optimised for 30 arcsec resolution

- **MeerKAT** (South Africa)

  80 × 12m parabolic antennas: collecting surface 8000 m^2
  single-pixel feeds: field-of-view 1 sq.degree
  instantaneous bandwidth: 1 GHz
  versatile in resolution: 6-80 arcsec

Both: construction started, fully operational early 2013

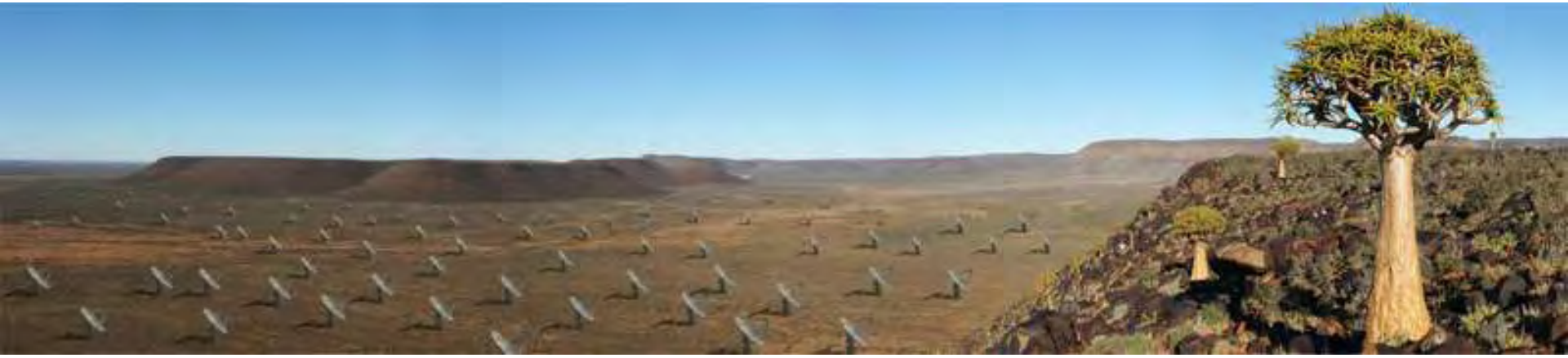
SKA Precursors – fields-of-view



SKA Precursors – survey speeds

Instrument	Relative speed
Parkes multi-beam (single-dish)	1.6
VLA	**1**
WSRT+APERTIF PAF	18
ASKAP +PAF	22
MeerKAT	5

Playing with array configurations



Many 12m parabolic dishes:
ASKAP 36, MeerKAT 80

Configure array for maximum sensitivity

- for one resolution, optimized: 30", ASKAP
- for a range of resolutions, equalized: 6"-80", MeerKAT

SKA Precursors – complementarity

ASKAP:
- large fields/all-sky, relatively shallow surveys

MeerKAT
- smaller fields, deeper surveys, higher/lower resolution

WSRT + APERTIF:
- northern hemisphere, overlap in δ +25°-30° strip only ...*if funded*

VLA:
- deep integration of small fields, down to δ -40 ° only

ASKAP and MeerKAT surveys: science drivers

- Detection of a million galaxies in HI out to z~0.2/1
  to understand galaxy formation and gas evolution in the nearby Universe.
- Detection of 70 million galaxies in continuum
  to determine the evolution, formation and population of galaxies
- Detection of polarized radiation from 500,000 galaxies
  to explore the evolution of magnetic fields in galaxies
- Understanding of the evolution of the ISM of our own Galaxy
  and the processes that drive its chemical and physical evolution.
- Characterization of the radio transient sky
- Discovery and timing of up to 1000 new radio pulsars
  find exotic objects and to pursue the direct detection of gravitational waves.
- High-resolution imaging of energetic phenomena through VLBI

ASKAP and MeerKAT surveys: HI science drivers

- Obtain the HI Mass Function up to z ~0.5
- HI content of the Universe, HI out to high redshift (z ~1).
- Identify and quantify gas inflow into galaxies: “cold accretion”
- Group dynamics of galaxies, faint member stats and properties
- Search for the markers of CDM in the HI of nearby galaxies; their dynamics and star formation cycle
- Map parts of the Cosmic Web in HI
- Identify the Great Attractor in the Zone of Avoidance

SKA Precursors – calls for proposals

MeerKAT:
- expected: end of this year

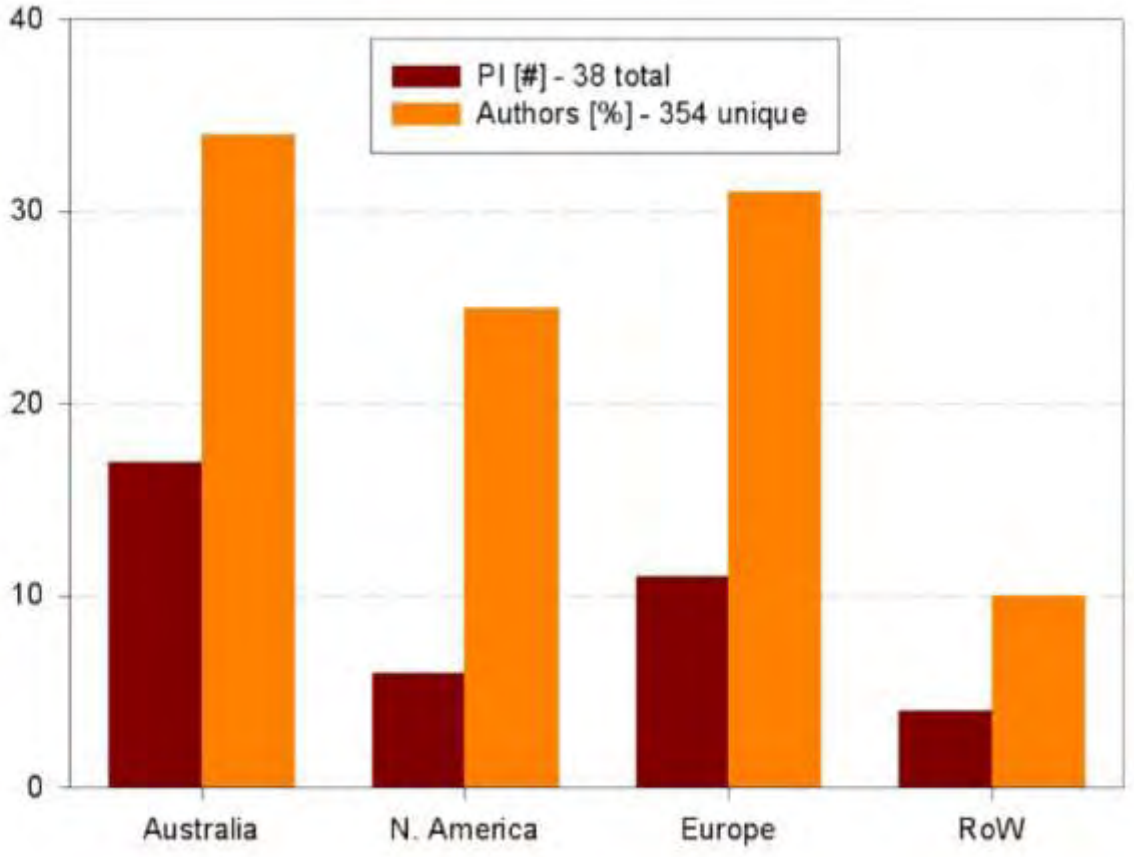
ASKAP:
- call for Expressions of Interest (EoI): 12/2008
  for first 5 years of full telescope operation (2013-2018)
- 38 EoI received, for total of 25 years of telescope time
- EoI merged, etc.: 27 final proposals submitted 15 June
- Proposals selected and prioritized in September 2009

Both: access to instrument during deployment phase
Public data release

Concertation on surveys started between ASKAP and MeerKAT

SKA Precursors – ASKAP call for pre-proposals

Science areas:
1. Extragalactic spectral line
2. Continuum
3. Polarization
4. Galactic spectral line
5. Slow transients
6. Fast transients
7. Pulsars
8. VLBI



Participation in proposals remains open…

ASKAP Survey Science Projects – priorities 1.

A Group: ATNF will provide full support to these

EMU:	all-sky/deep field continuum
WALLABY:	all-sky HI line survey

A- Group: ATNF will make all reasonable efforts to support these

DINGO:	deep HI line
ASKAP-FLASH:	HI absorption line survey
VAST:	variables and slow transients
GASKAP:	Galactic spectral lines
POSSUM:	polarization, magnetism
Craft:	fast transients, commensal

ASKAP Survey Science Projects – priorities 2.

Strategic Priorities Group : ATNF will work to ensure that capabilities defined by these SSPs are enabled to the extent possible.

- The High Resolution Components of ASKAP: Meeting the Long Baseline Specifications for the SKA

- COAST: Compact Objects with ASKAP: Surveys and Timing

ASKAP HI surveys: WALLABY

Widefield ASKAP L-band Legacy All-sky Blind surveY

PI: Bärbel Koribalski (ATNF, AUS), Lister Staveley-Smith (UWA, AUS)
59 others: AUS 26; Europe 23 (FRA 2, GER 4 NL 7, UK 10); USA 6; JAP 2, SA 2

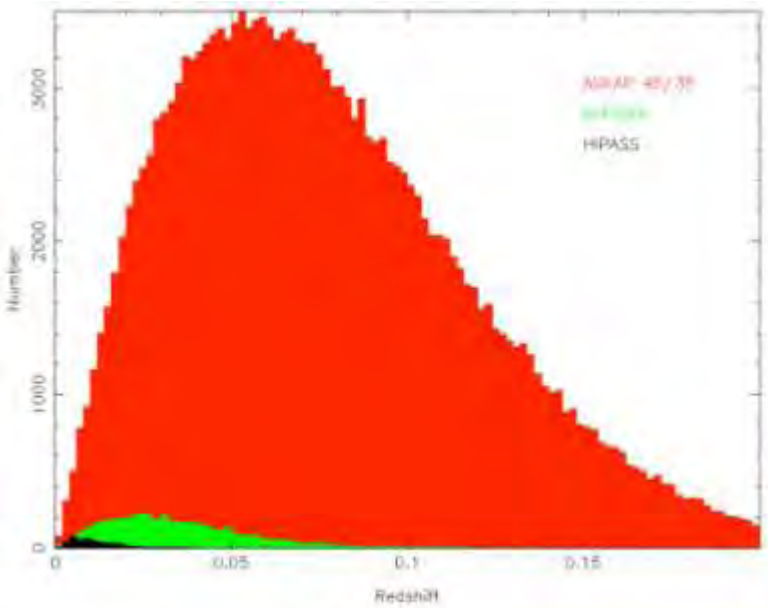
Large-field, relatively shallow HI line survey
δ° -90° to +30°, 30 arcsec beam, resolution 4 km/s

one year of observing time (9600 hours; 1200 pointings)
radial velocity coverage -2,000 to +60,000 km/s
rms noise level 0.7 mJy

Local Group galaxies: HI mass detection limit 5,000 $M_{\odot}$
400,000 galaxies detected; 1000 highly resolved; 30,000 angular momentums

Deep HI survey: DINGO HI out to z~1

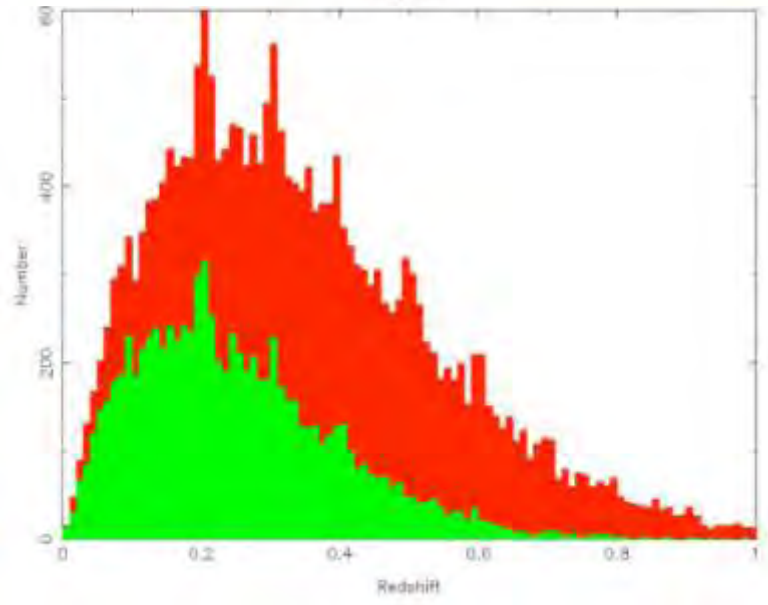
ASKAP surveys: HI all-sky & deep



WALLABY-like (v.2008)

ASKAP
Arecibo 305m,7bms ALFALFA
Parkes 64m,13bms HIPASS

Peak z~0.06 v~18,000 km/s
Tail z~0.18 v~55,000 km/s

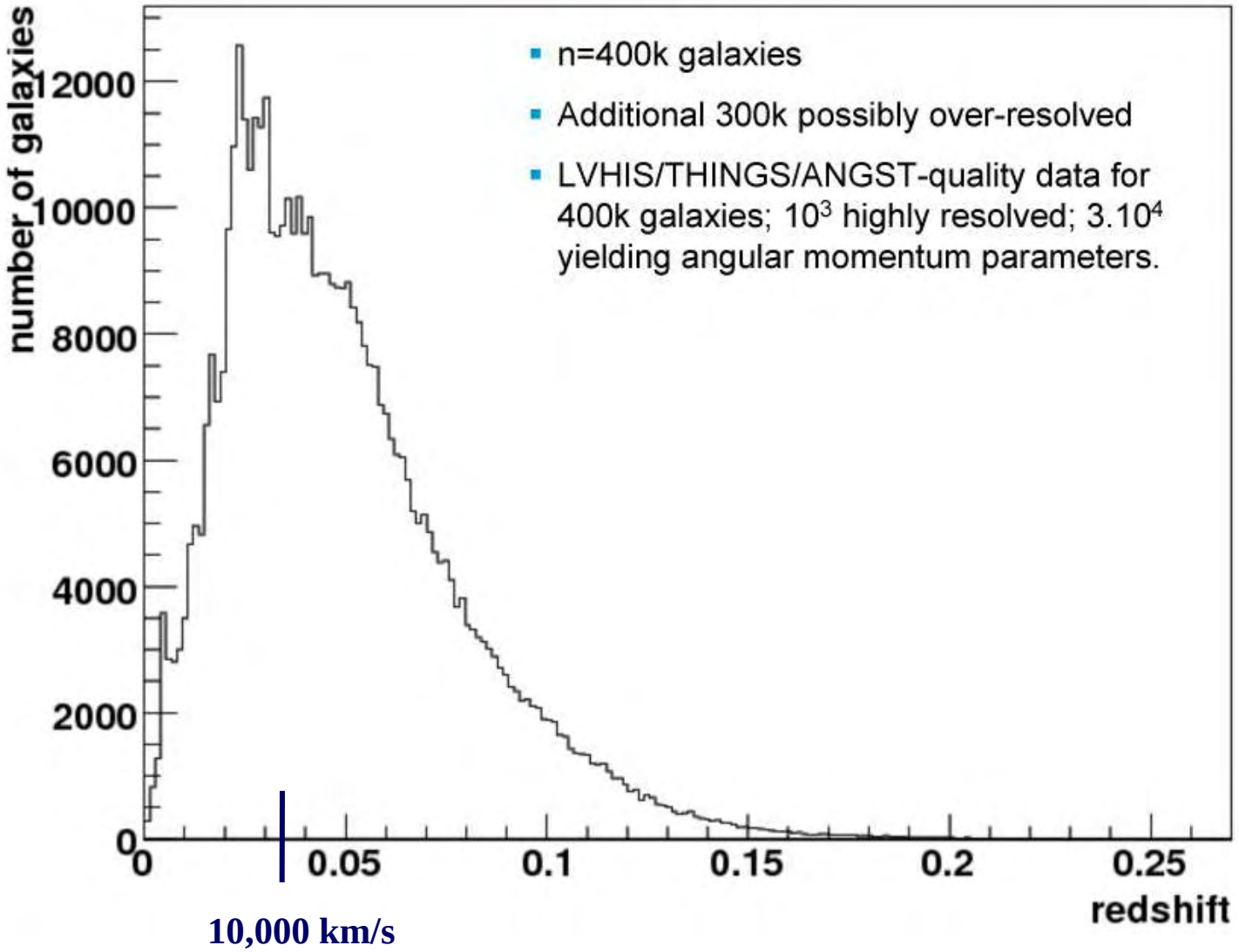


DINGO-like

ASKAP

Peak z~0.25 v~75,000 km/s
Tail z~0.8

ASKAP surveys: WALLABY



ASKAP surveys: EMU

Evolutionary Map of the Universe

PI: Ray Norris (ATNF, AUS), Andrew Hopkins (AAO, AUS)
90 others; 15 working groups

- EMU-wide:

δ° -90° to +30°, 30 arcsec beam, rms 10 μJy; 70 million sources

- EMU-deep:

30 sq.degrees, 30 arcsec beam, rms 1 μJy; 0.5 million sources

Two years of observing time

Star-forming galaxy evolution: z<2 (wide), z<5 (deep)
Black hole evolution, relation with star formation

MeerKAT surveys

Possible HI key surveys:

- Mosaic of nearby group or cluster:
  details and large structures, due to flexible beam size
  e.g., 100 sq.deg Virgo field, limit M_{HI} $5 \cdot 10^6$ $M_\odot$ in 100 days
- MeerKAT Deep field(s):
  HI mass function and HI content out to larger z than ASKAP
- Galaxy portraits + cosmic web:
  deep observations, sub-kpc resolution out to 20 Mpc
- Zone of Avoidance: large scale structure ; Great Attractor

ASKAP and MeerKAT surveys: possible French contributions

- Nearby galaxies (z<0.2):
  - New Generation Virgo Survey
  - 3D-NTT Fabry-Pérot Hα velocity fields

- More distant galaxies (z<1):
  - VLT IFU velocity fields

- Modeling of results:
  - Galaxy mergers, interactions

- Could play key role in a MeerKAT project (Virgo?)
- PNCG 2010-2012 proposal: French Workshops, travel