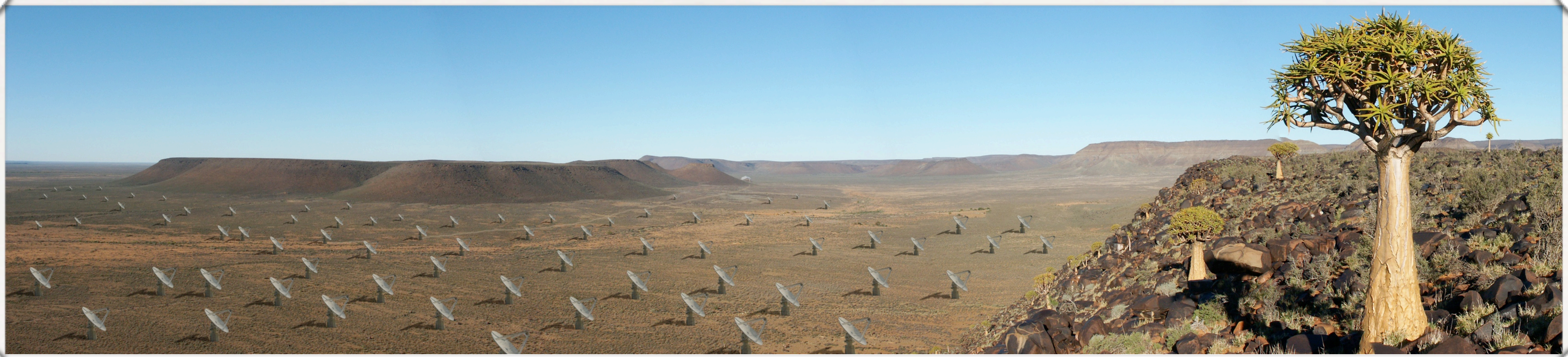


HI Science with MeerKAT

and some thoughts on the array configuration

Erwin de Blok

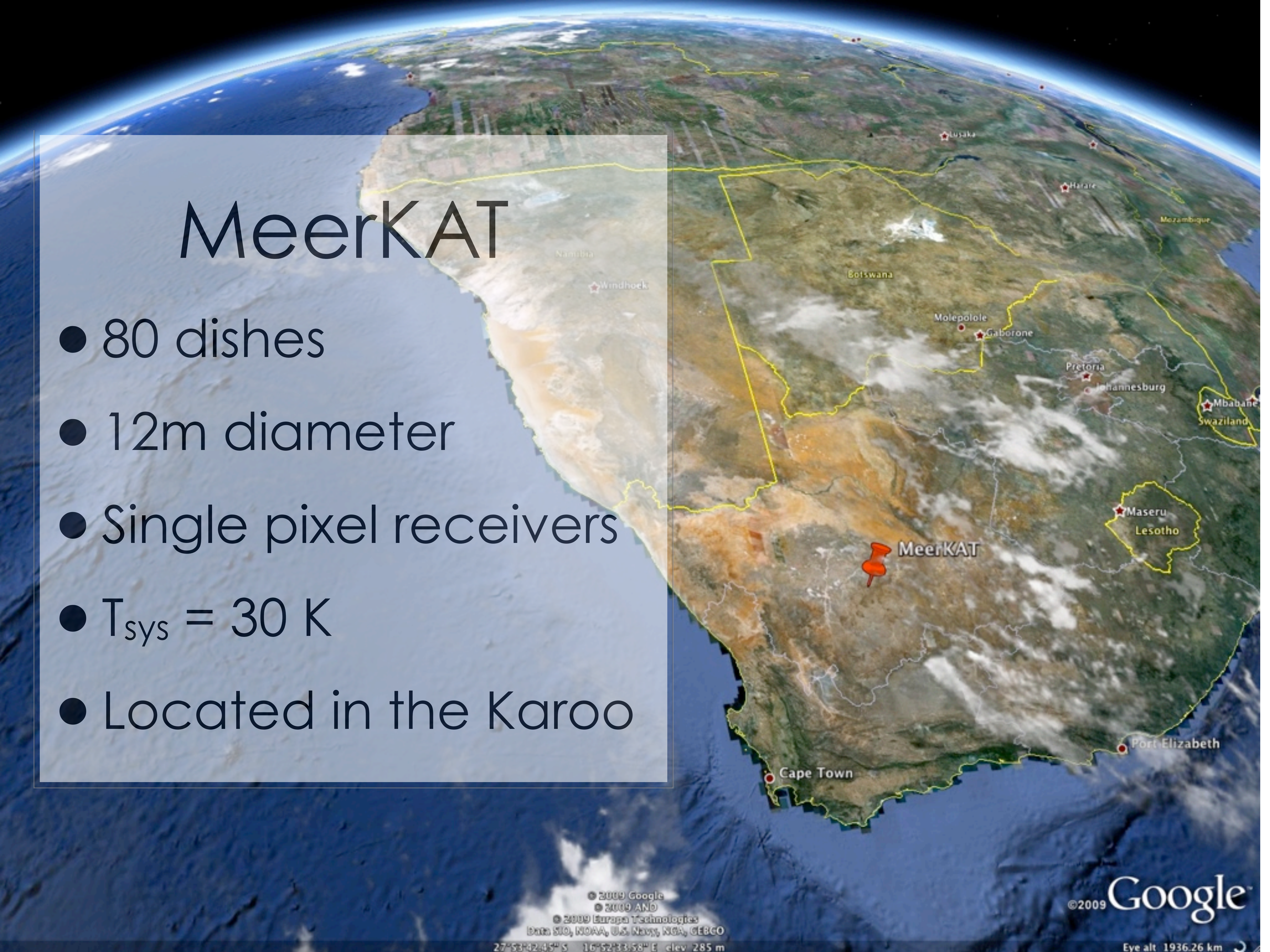
University of Cape Town

Outline

- MeerKAT Configuration
- Low HI column density
- High resolution
- Further MeerKAT talks this week about
    - high-redshift observations,
    - HIMF,
    - morphology,
    - groups,
    - clusters and parallel surveys

MeerKAT

- 80 dishes
- 12m diameter
- Single pixel receivers
- T_{sys} = 30 K
- Located in the Karoo



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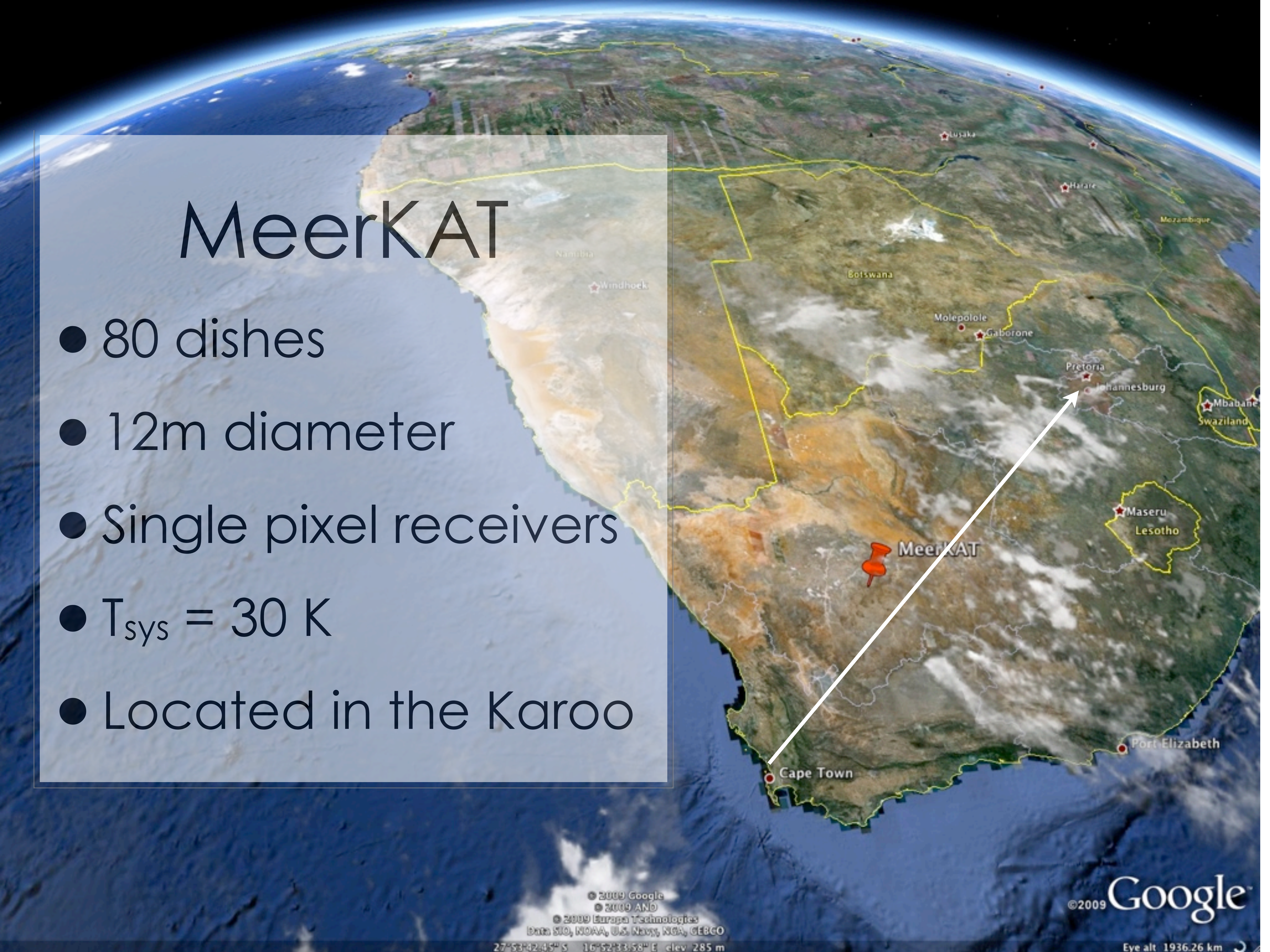

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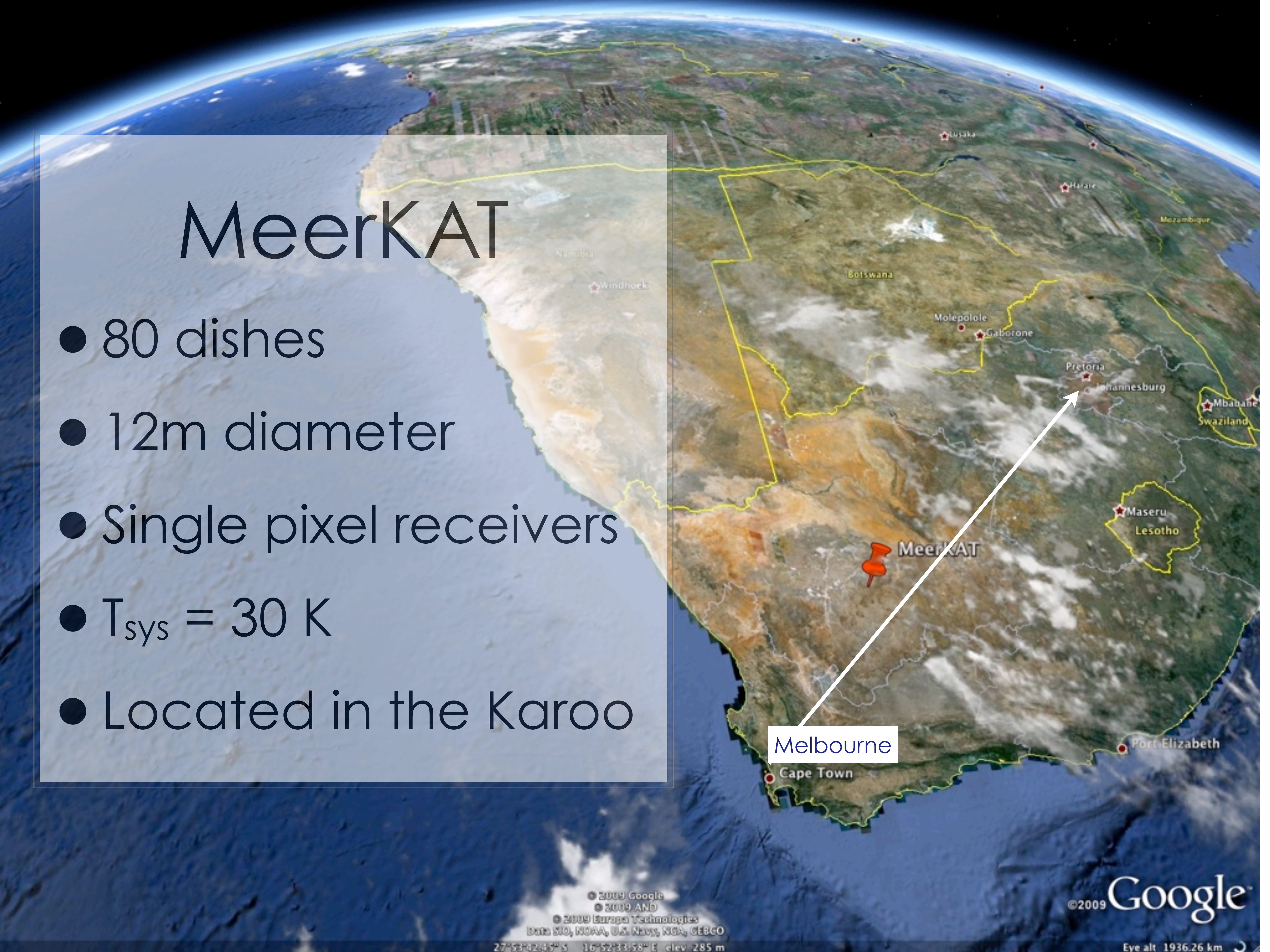

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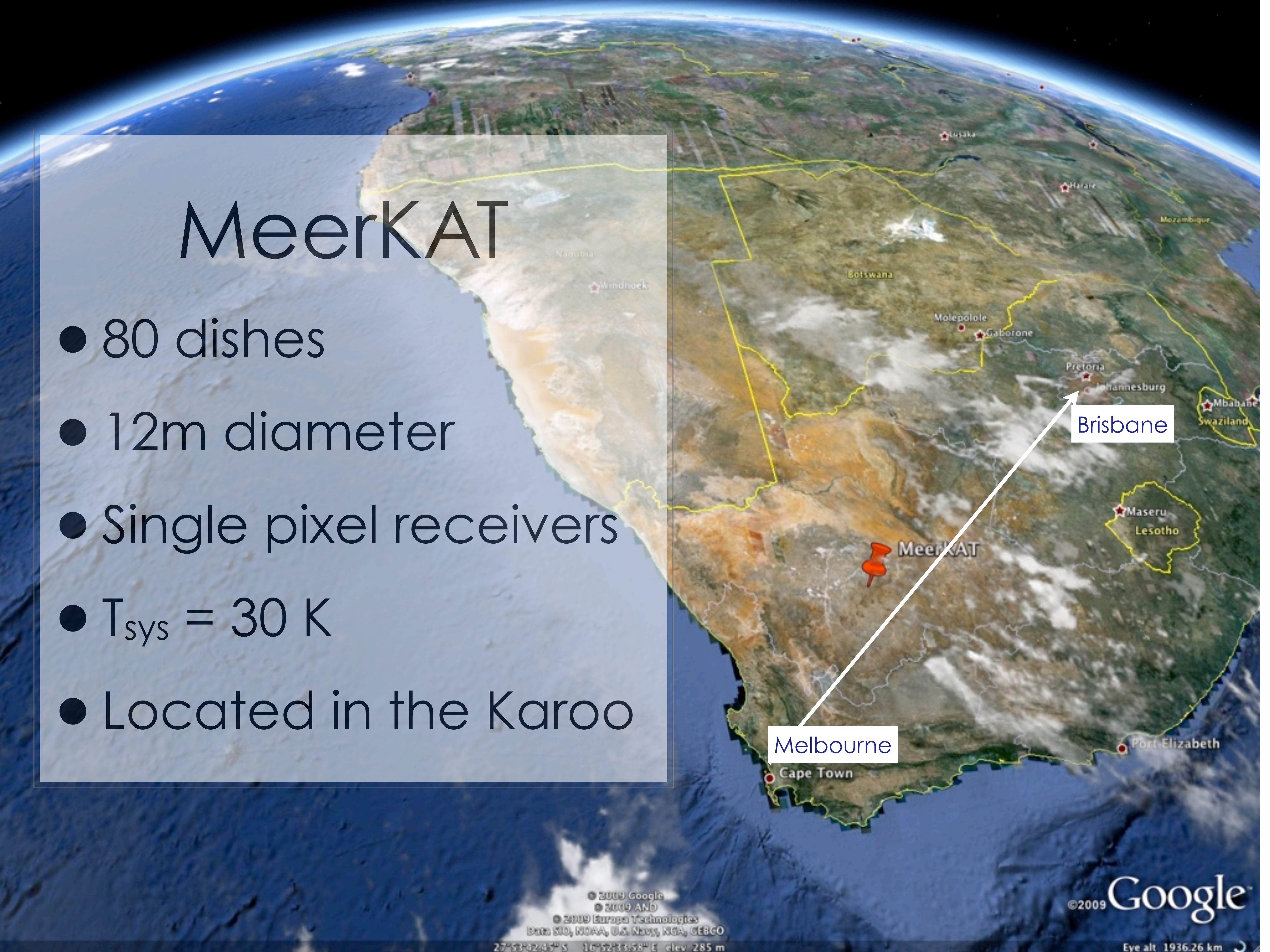

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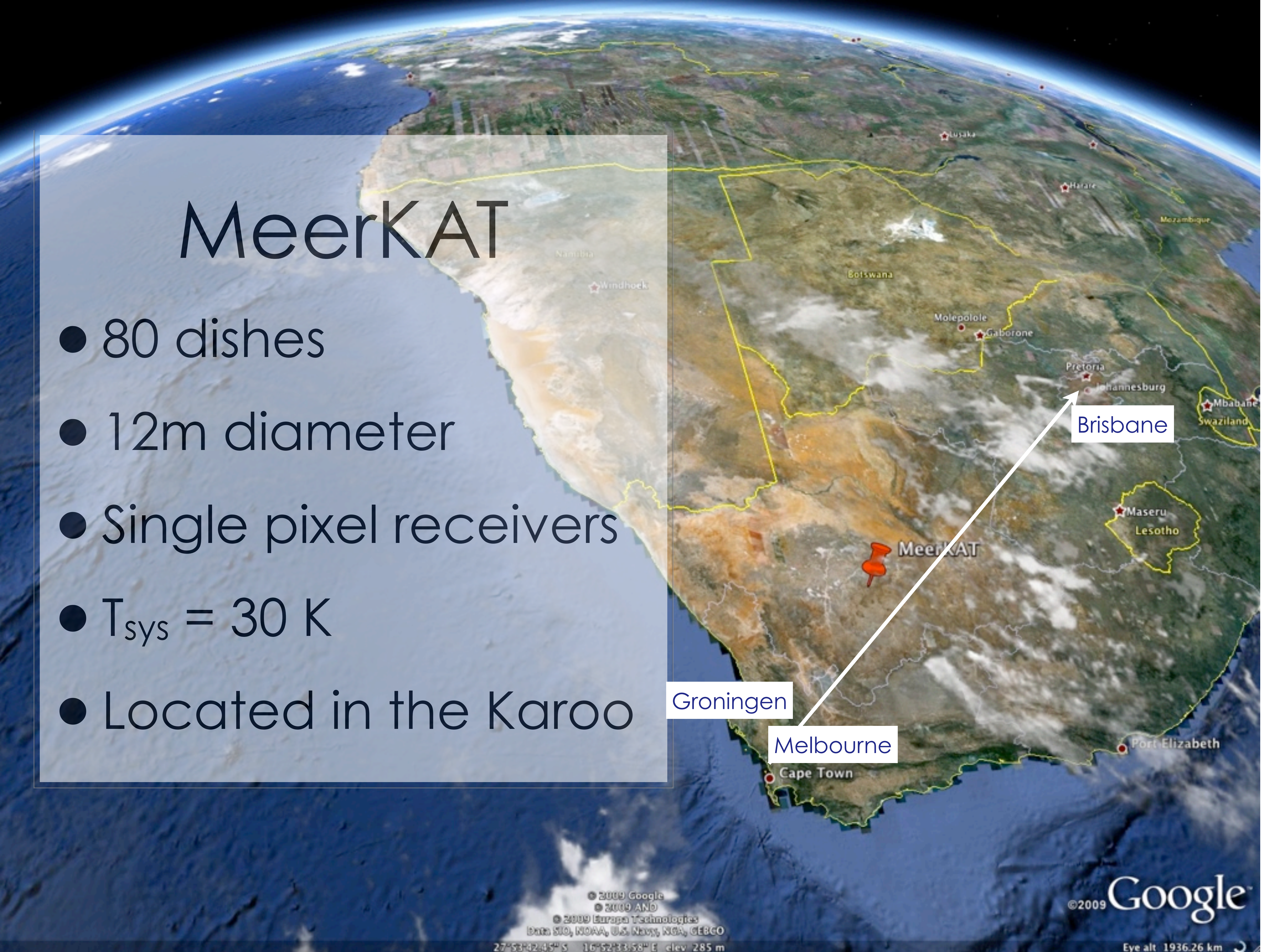

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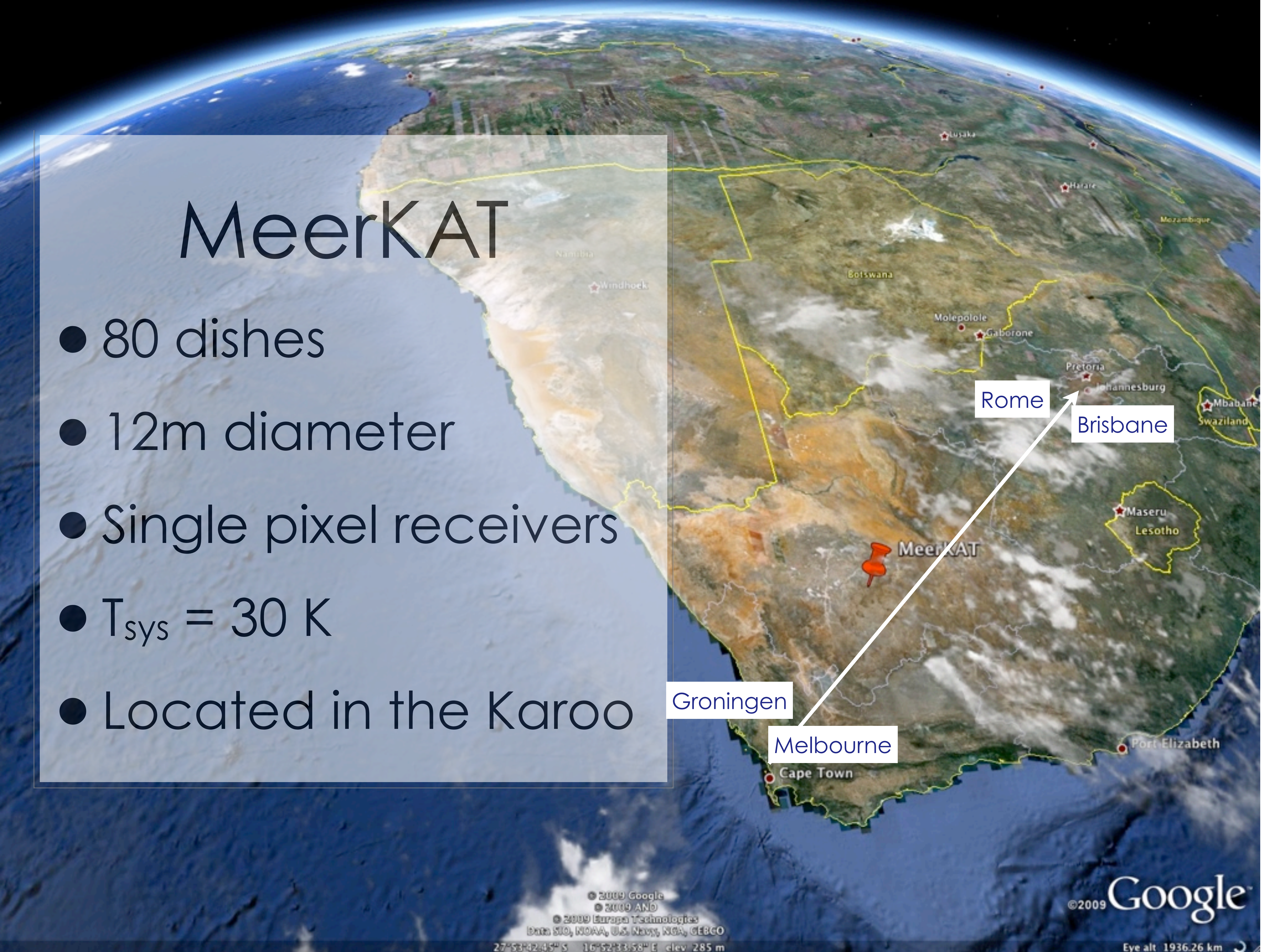


Array Configuration

- Design choices
  - Single resolution array: optimal sensitivity, but science choices must be made
  - Multiple resolution array: wide range of resolution and science, but sub-optimal sensitivity
- Ideal: find array close to sensitivity of single resolution array over a large range in resolution

Configuration

- MeerKAT: multi-resolution configuration
- HI Science goals:
  - *low resolution (~100"):* low column densities, outskirts, cosmic web, ...
  - *medium resolution (~30"):* high-z studies, ...
  - *high resolution (~8"):* detailed galaxy studies, ...

Configuration

- Find a configuration that has sensitivity over ~8” to ~100” closest to that of single resolution configurations

with Brad Frank, MSc UCT

Configuration

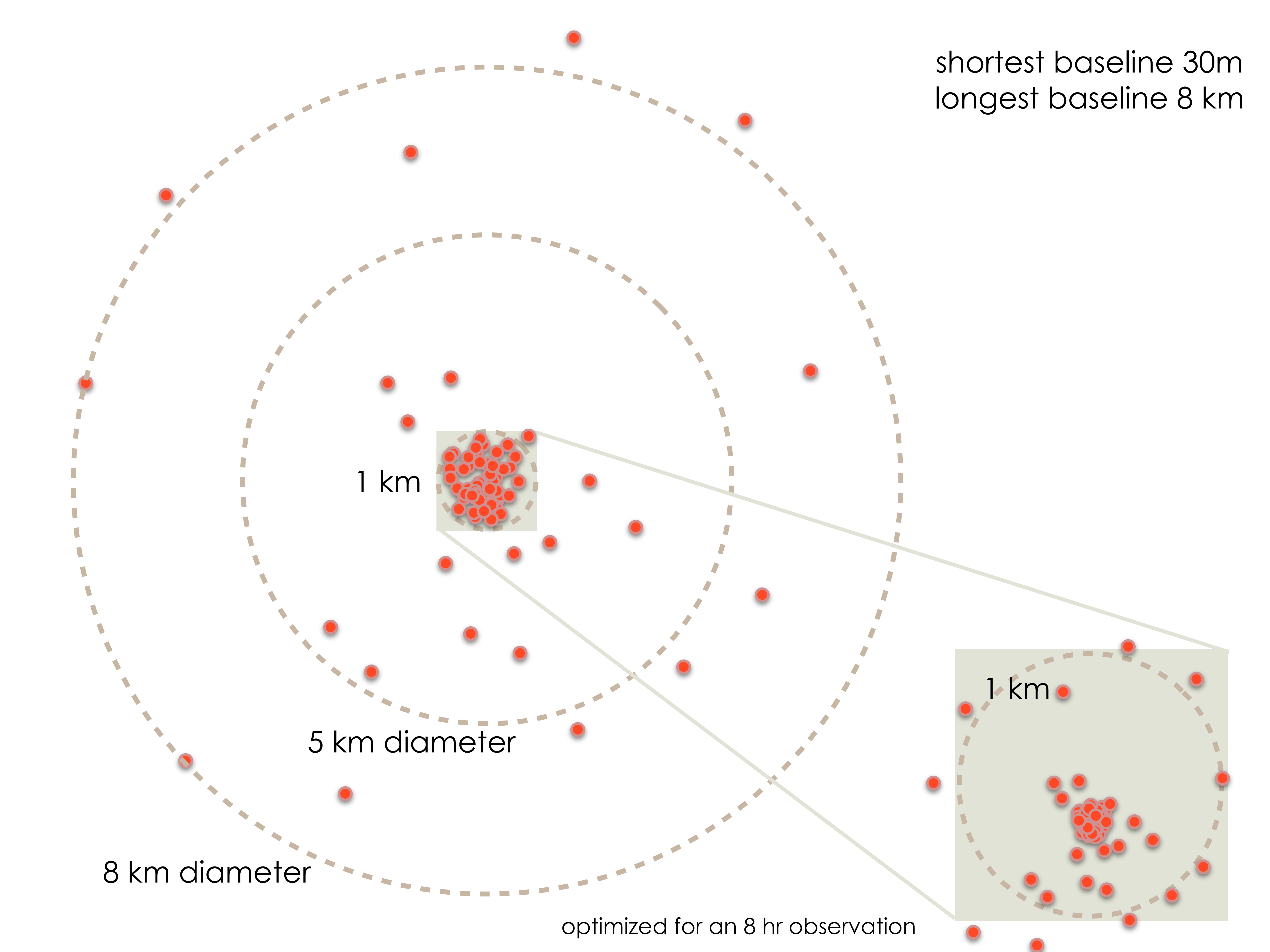
- MeerKAT configuration thoughts:
  - Hybrid array:
    - ~70% of antennas in compact core with <1 km baselines
    - ~30% at longer baselines out to ~8 km

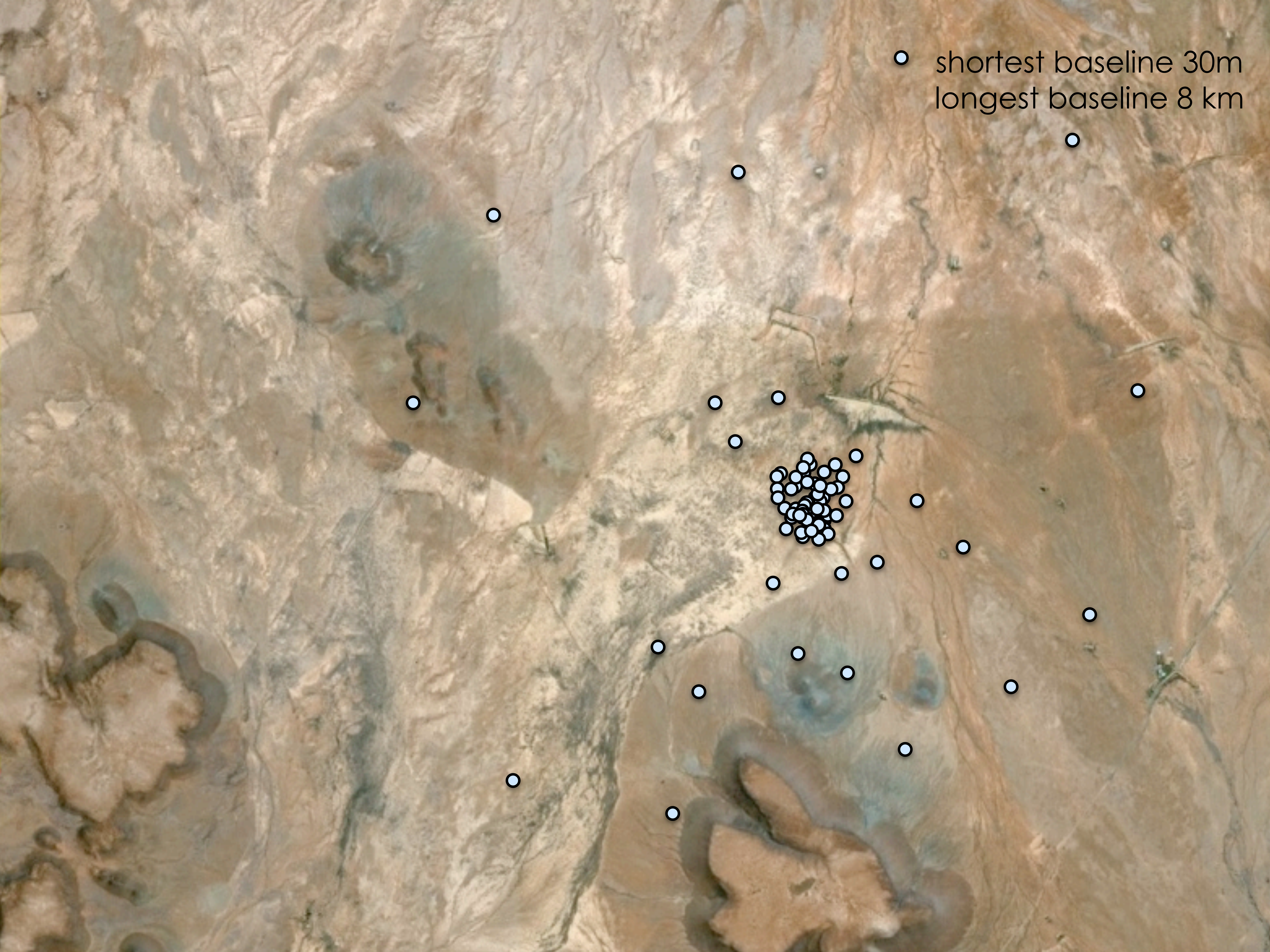
Configuration

- Aim for ~constant point source sensitivity over resolution range
- No “natural” resolution, use weighting/tapering to control beam size

Configuration

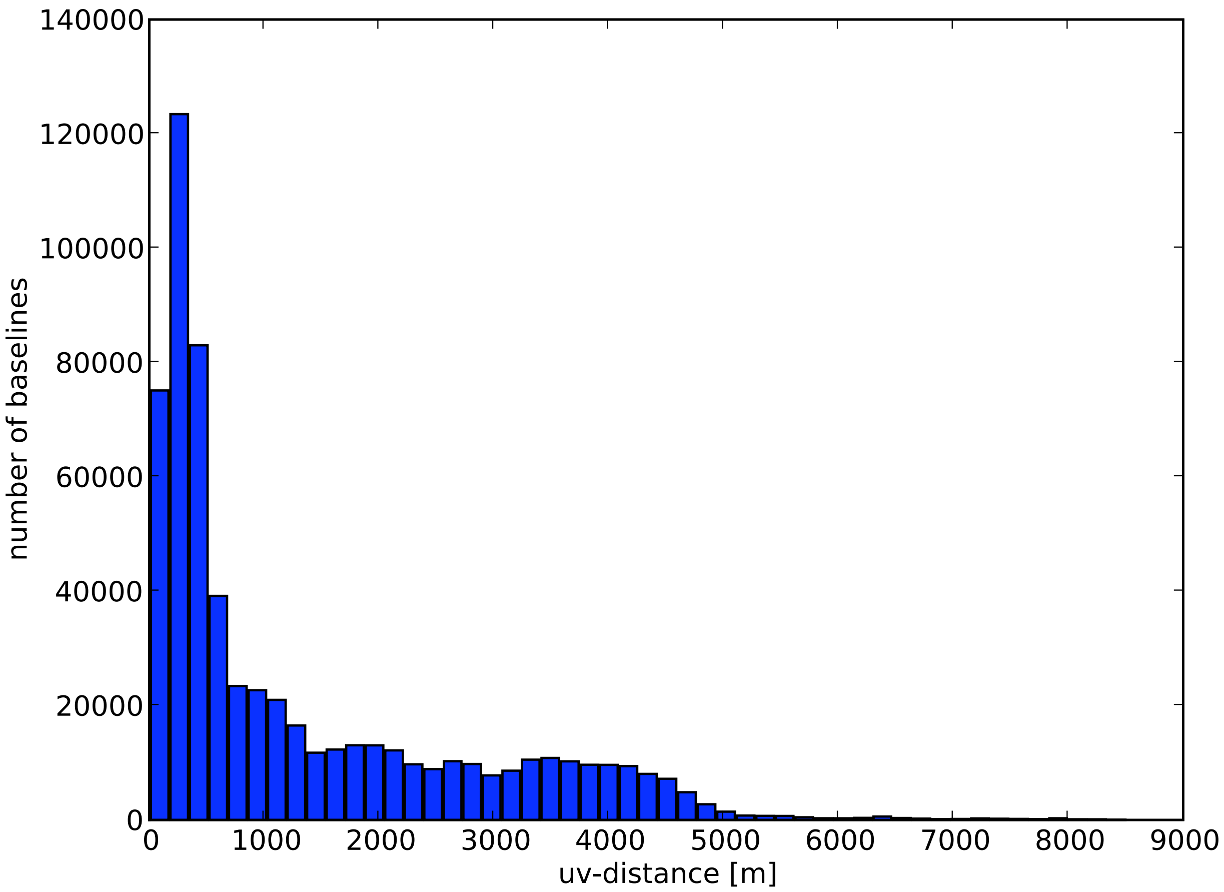
- **central Gaussian core:**
- dispersion 300 m, max baseline ~1 km
- **Gaussian outer component:**
- dispersion 2.5 km, max baseline ~8 km
- **"Pinching"** to emphasise number of short baselines: $(d/d_{max})^{0.2}$

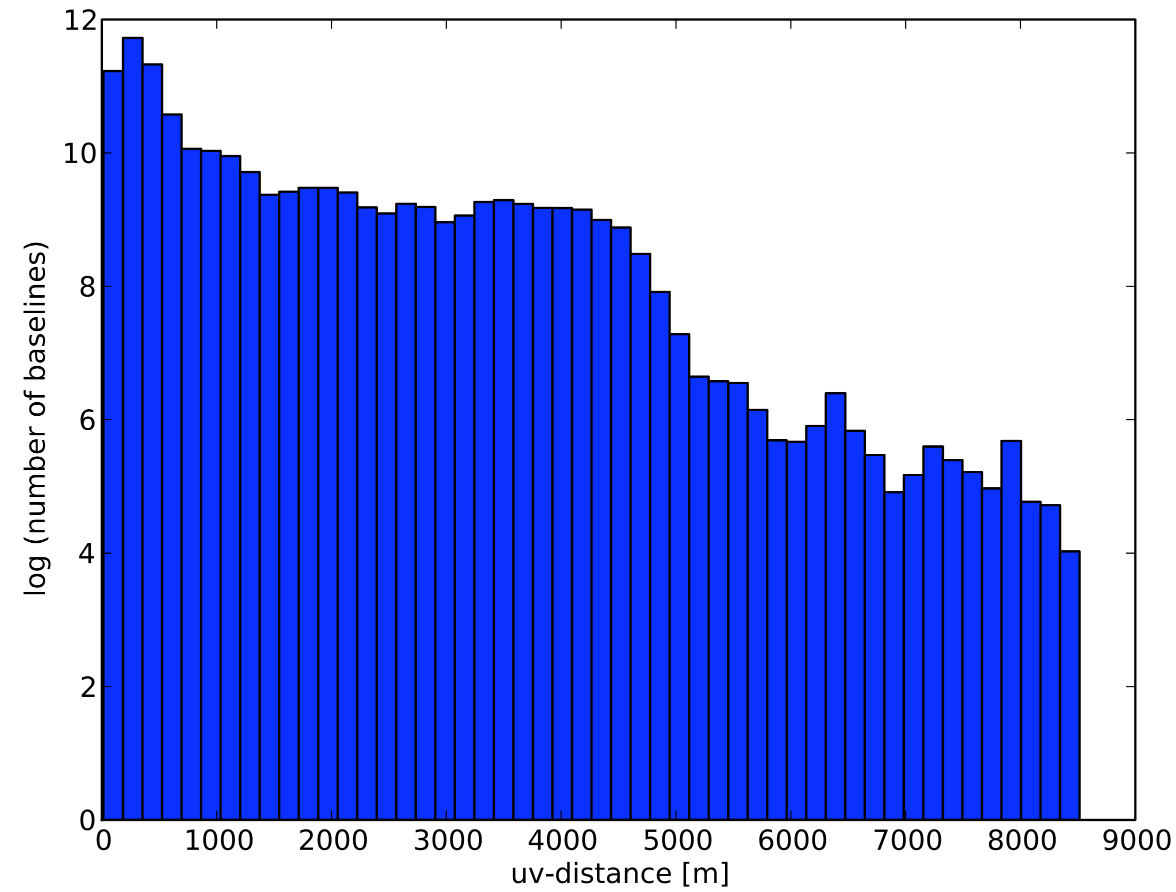

shortest baseline 30m
longest baseline 8 km
1 km
1 km
5 km diameter
8 km diameter
optimized for an 8 hr observation


shortest baseline 30m
longest baseline 8 km

Baselines

- Example: cumulative baseline length distribution for 8 h observation towards δ = -70°



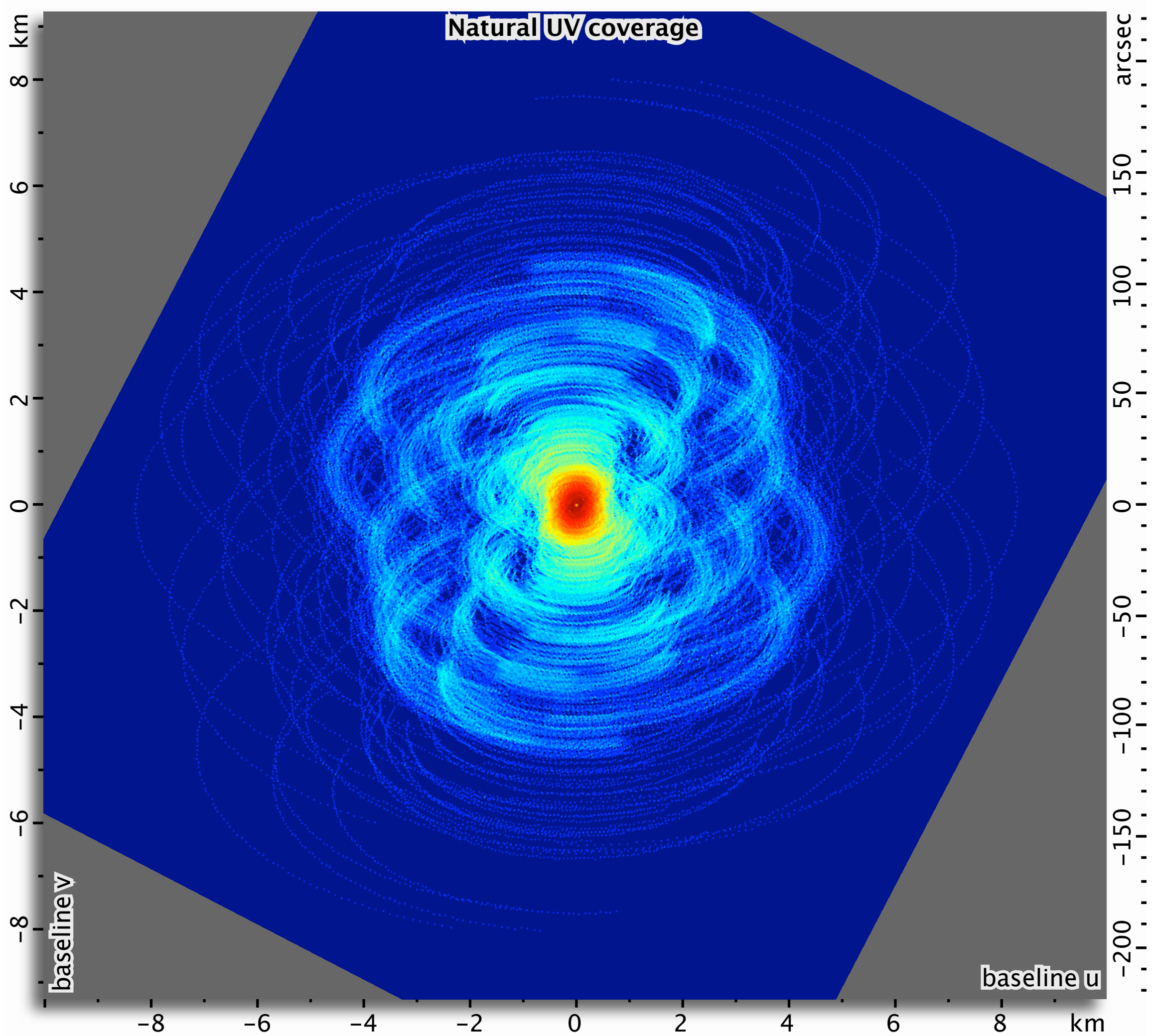


Beams

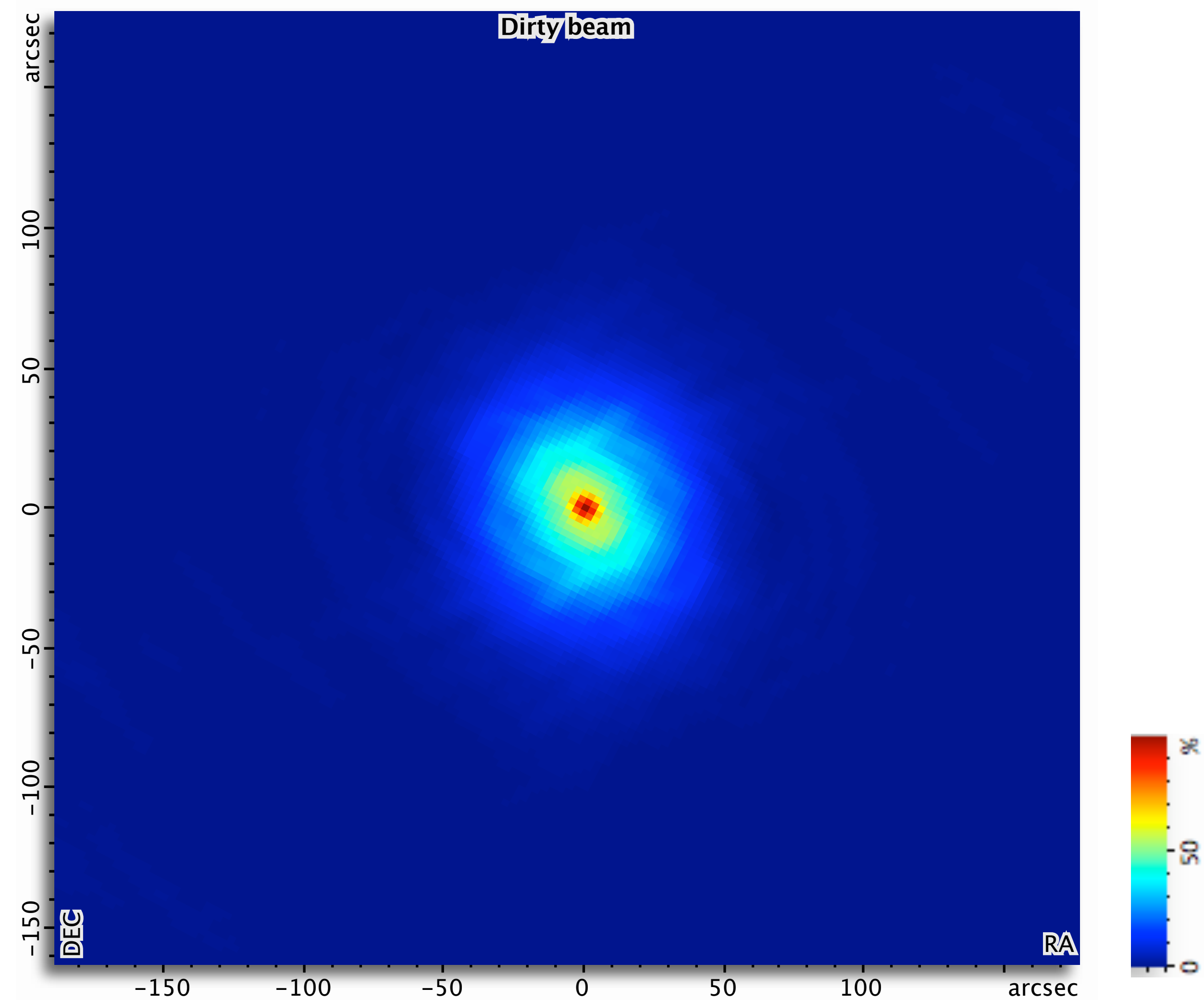
- Use weighting/tapering to control beam
- Example using M. de Villiers *iAntConfig*
- Weights uv samples in modified polar plane to force beam to be Gaussian

Weights and beams

example: t=8h, δ=-30°

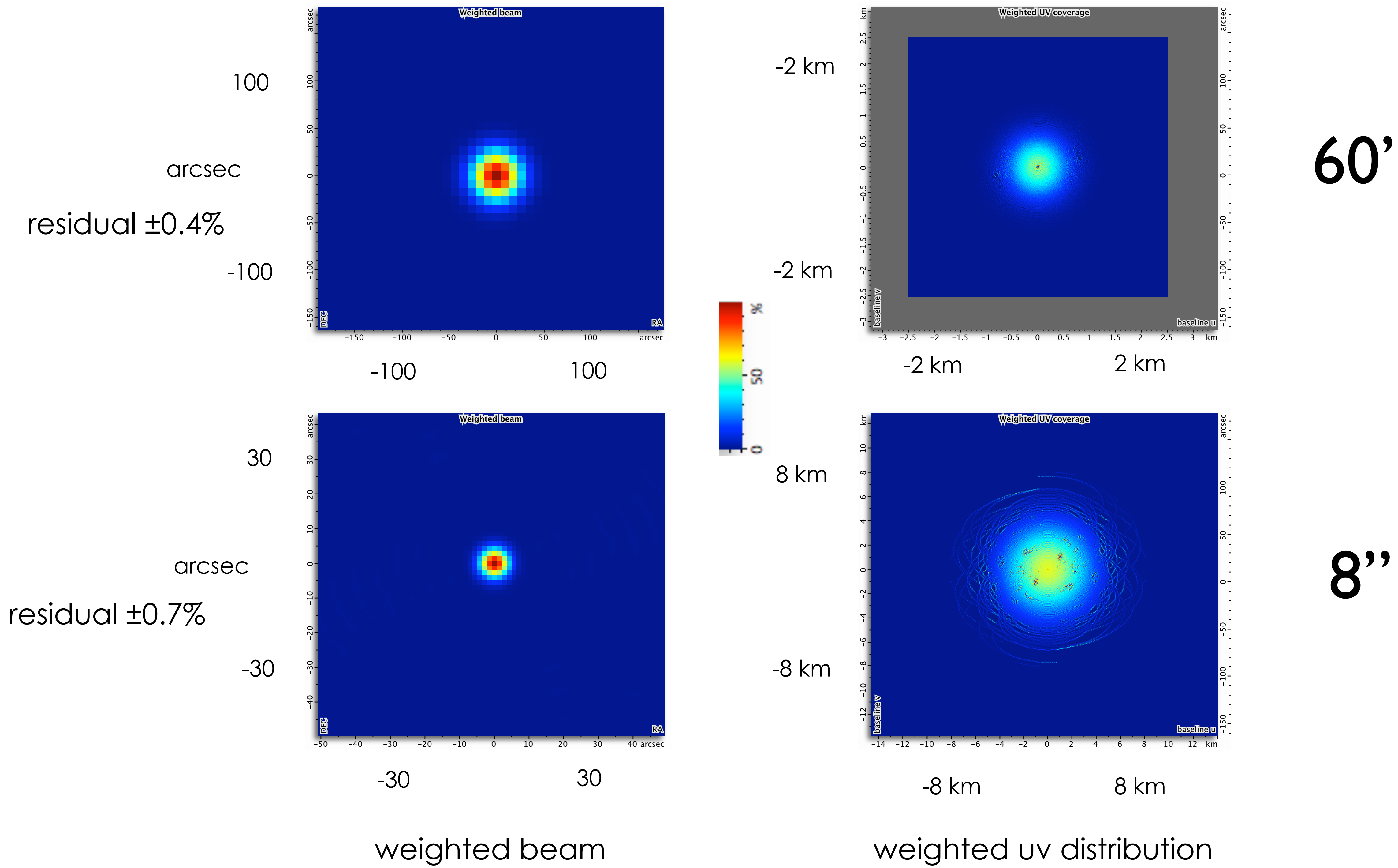


natural uv distribution



dirty beam (natural)

Weights and beams



t=8h, δ=-30°

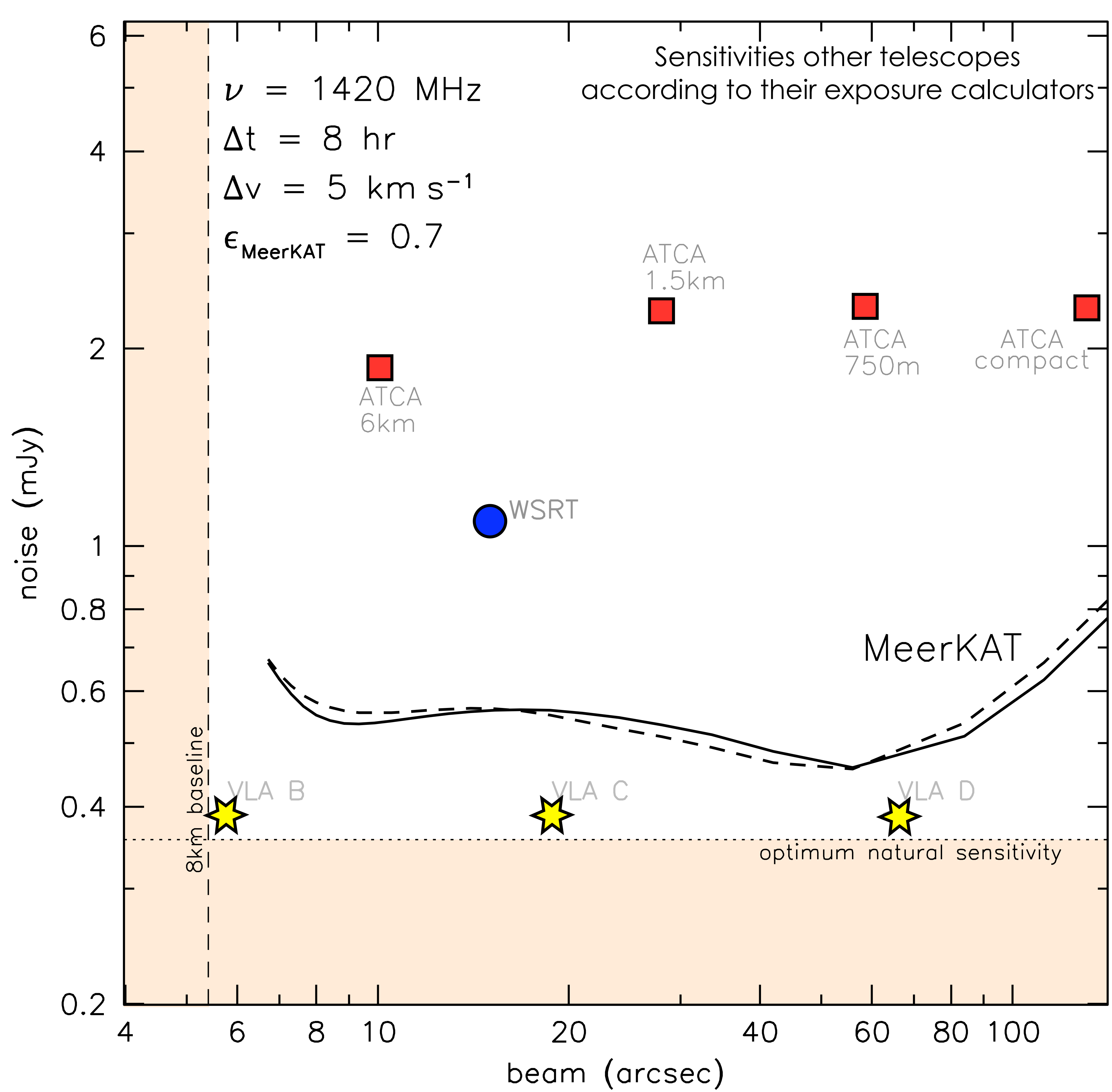
In progress

- Optimization for different declinations and observing times
- Evaluate sidelobe levels, dynamic ranges, ...
- Evaluate weighting schemes

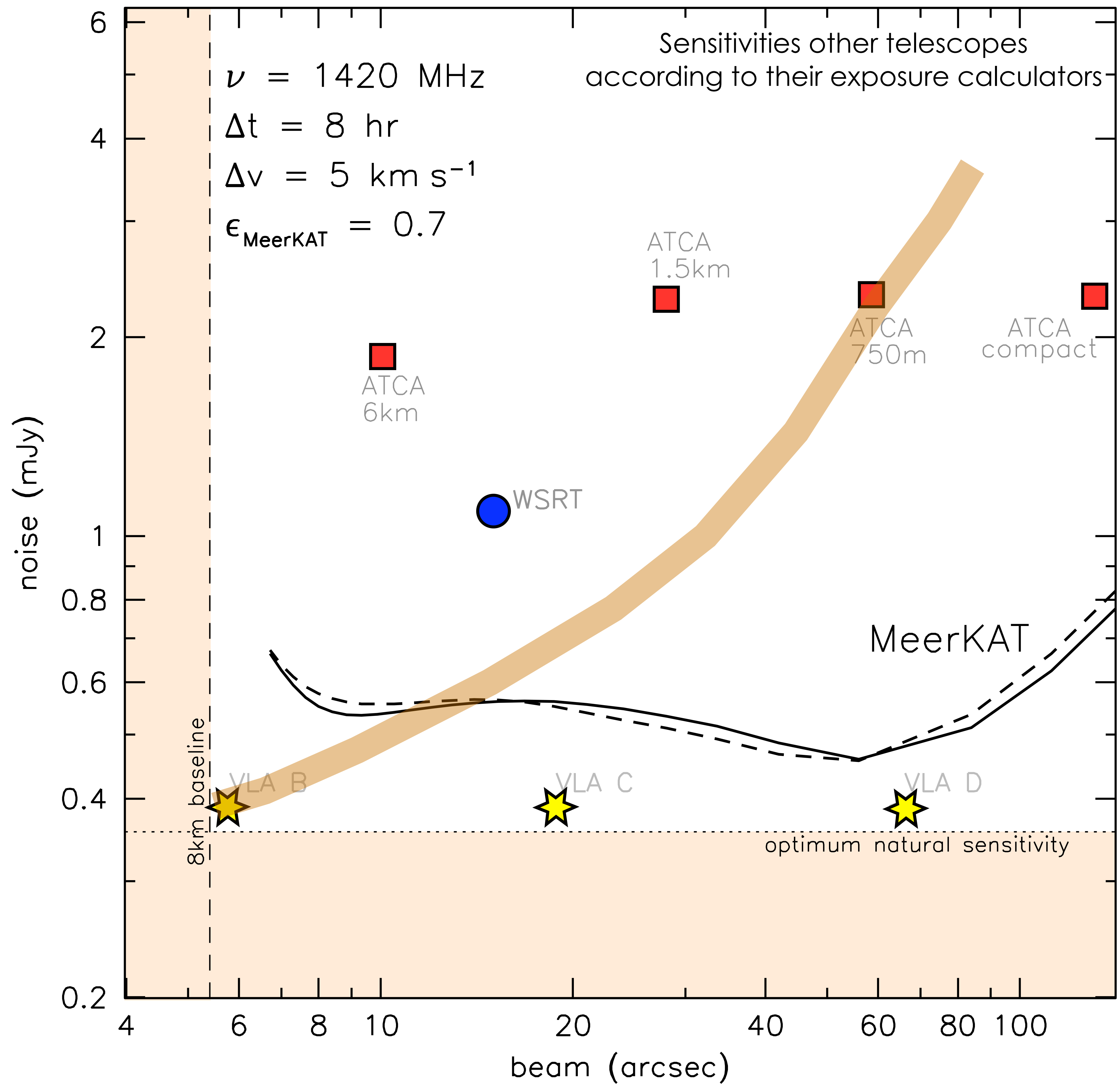
Sensitivities

- Natural weighting represents optimum sensitivity
- Desired resolution and beam shape determined by weighting
- Tapering, weighting, “ideal” weighting
- Use *AntConfigServer/iAntConfig*

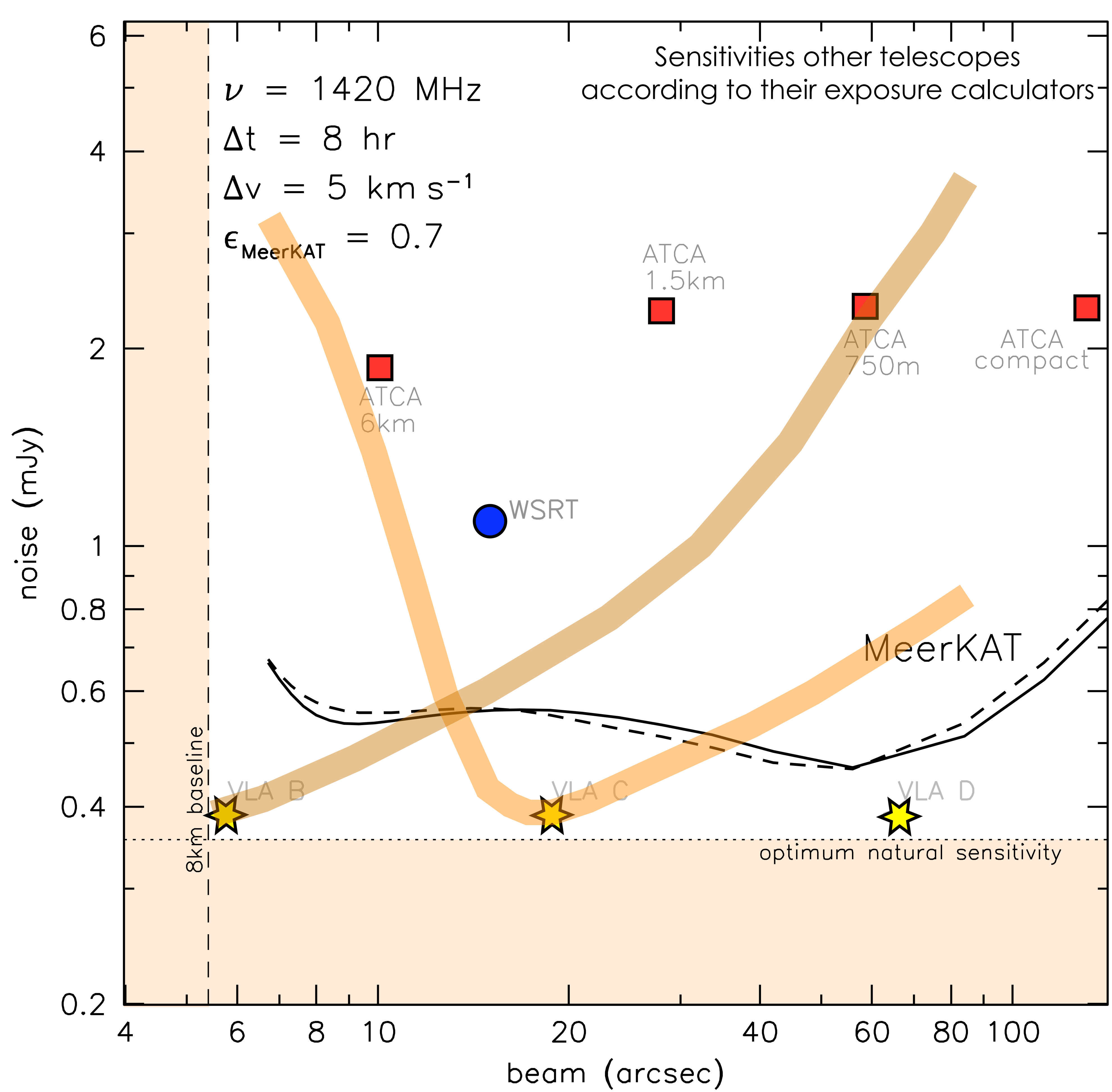
Point source sensitivity



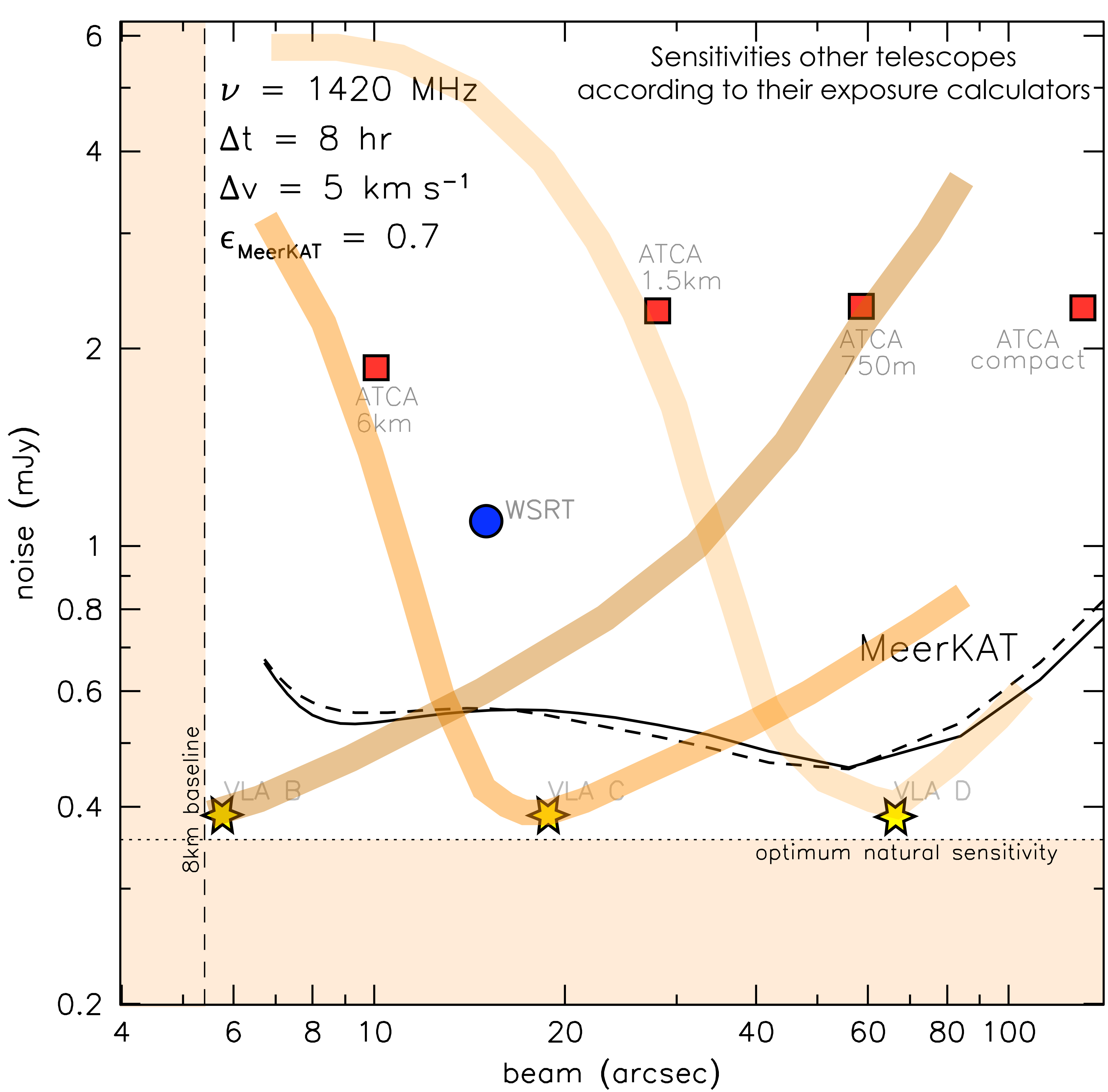
Point source sensitivity



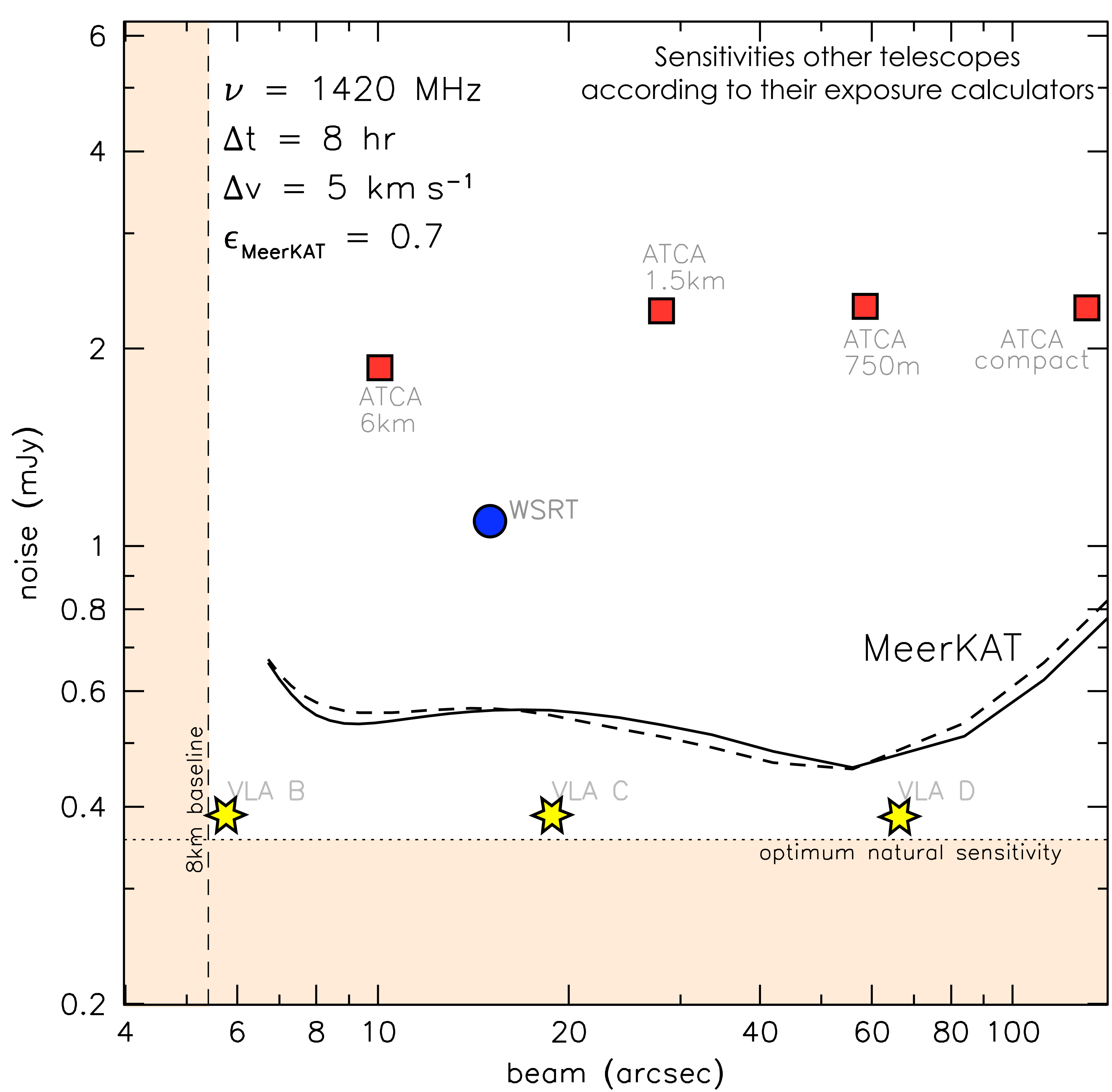
Point source sensitivity



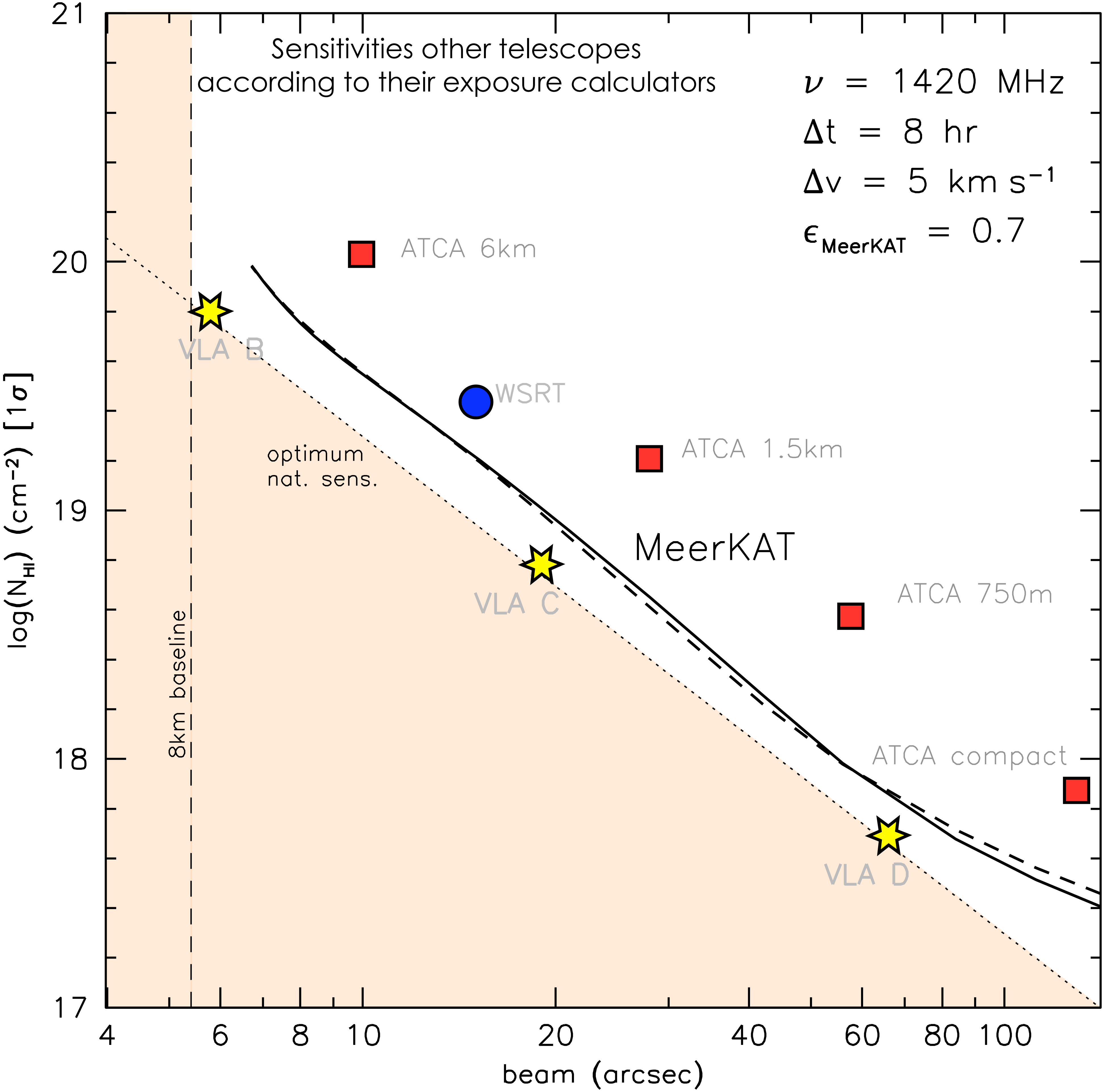
Point source sensitivity



Point source sensitivity



Column density sensitivity



MeerKAT HI Science

- *low resolution (~100"):* low column densities, outskirts, cosmic web, ...
- *medium resolution (~30"):* high-z studies, ...
- *high resolution (~8"):* detailed galaxy studies, ...

Low column density

- Map outer parts of galaxies and cosmic web

σ_{vel} = 8 km s^{-1} (FWHM = 20 km s^{-1})	$N_{HI} = 10^{18}$ cm^{-2} (5σ detection)	$N_{HI} = 10^{19}$ cm^{-2} (5σ detection)
1 channel, 20 km s^{-1}	*155 h* *90''* ↺	155 h 23'' ↻

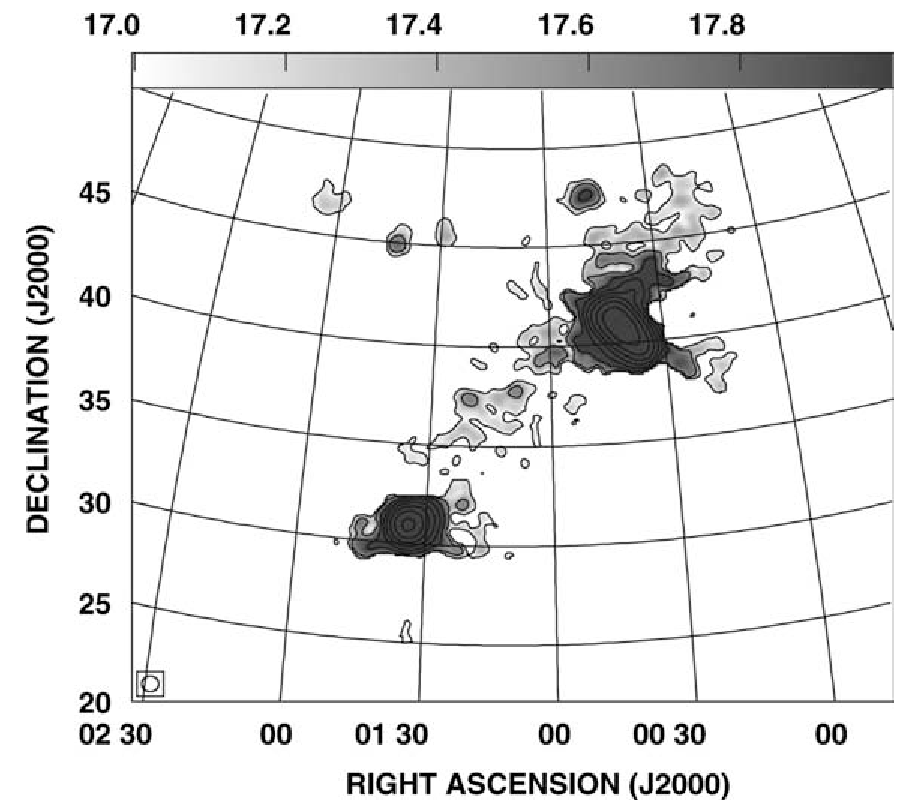
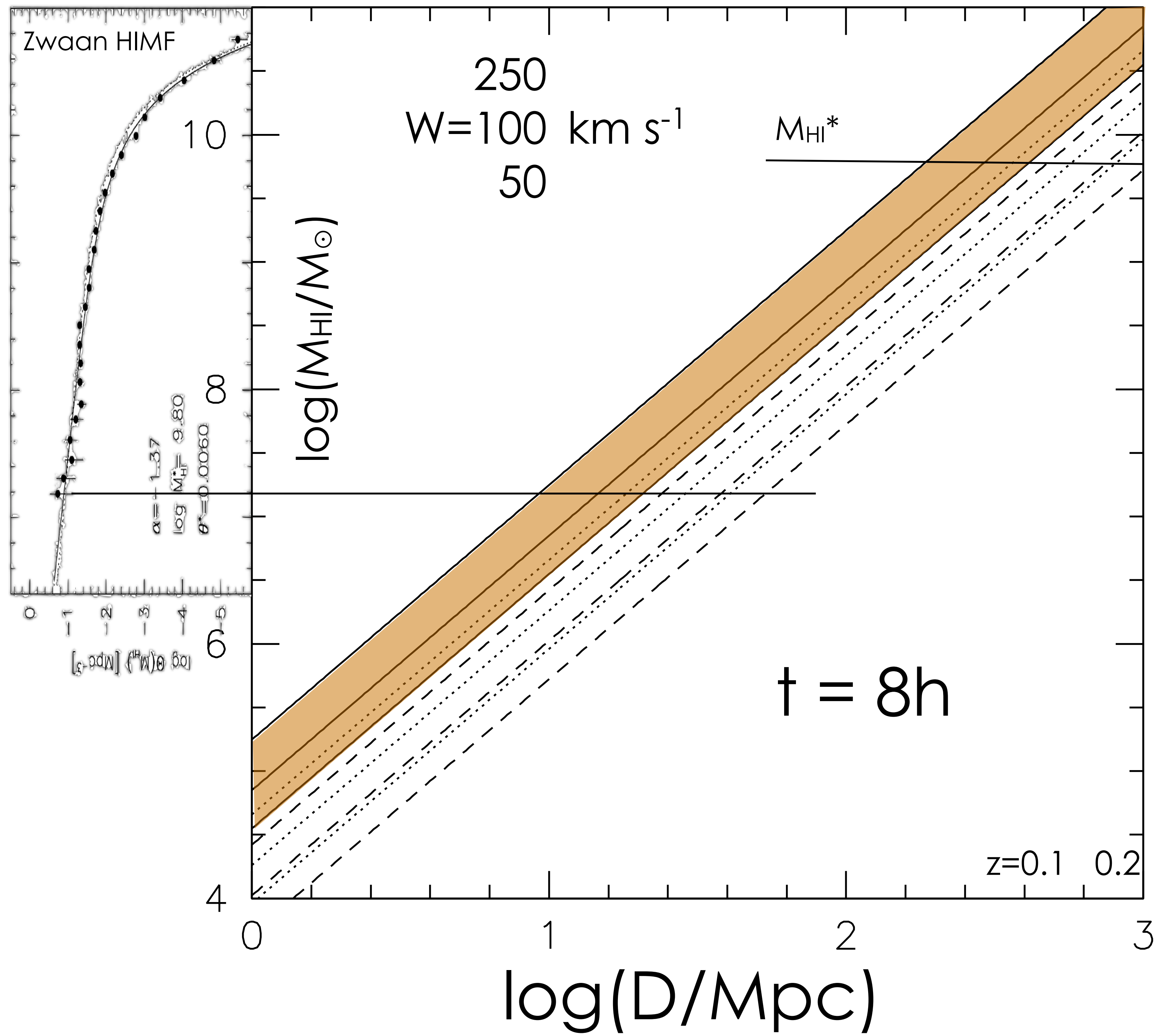


Fig. 1. Integrated HI emission from features which are kinematically associated with M31 and M33. The grey-scale varies between $\log(N_{HI})$ = 17–18, for N_{HI} in units of cm^{-2}. Contours are drawn at $\log(N_{HI})$ = 17, 17.5, 18, . . ., 20.5. M31 is located at (RA, Dec) = (00:43, +41°) and M33 at (RA, Dec) = (01:34, +30°), The two galaxies are connected by a diffuse filament joining the systemic velocities.

Braun 2004

HI Mass limits

- Assume unresolved galaxy with width W, top-hat profile and 5σ peak flux



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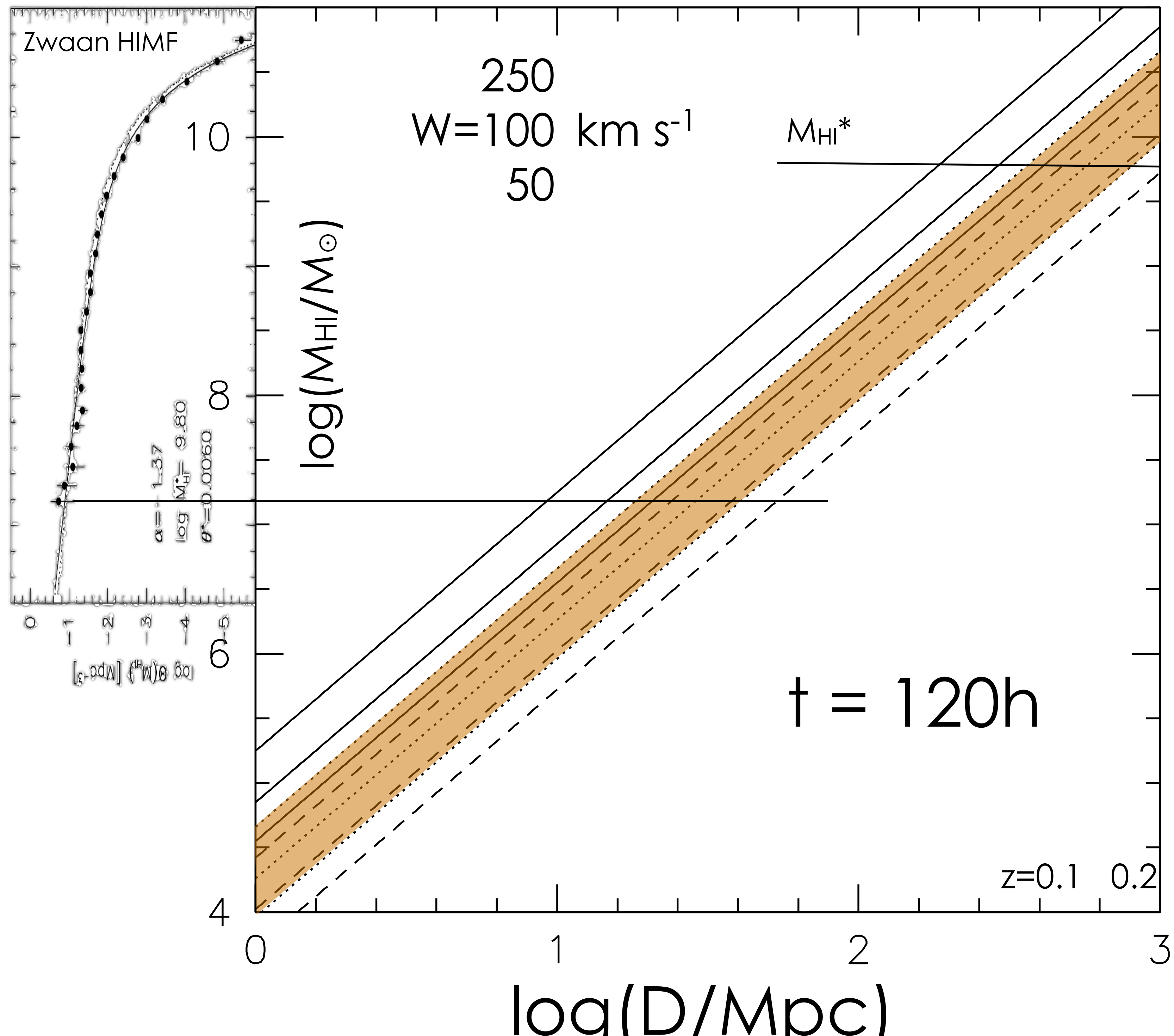

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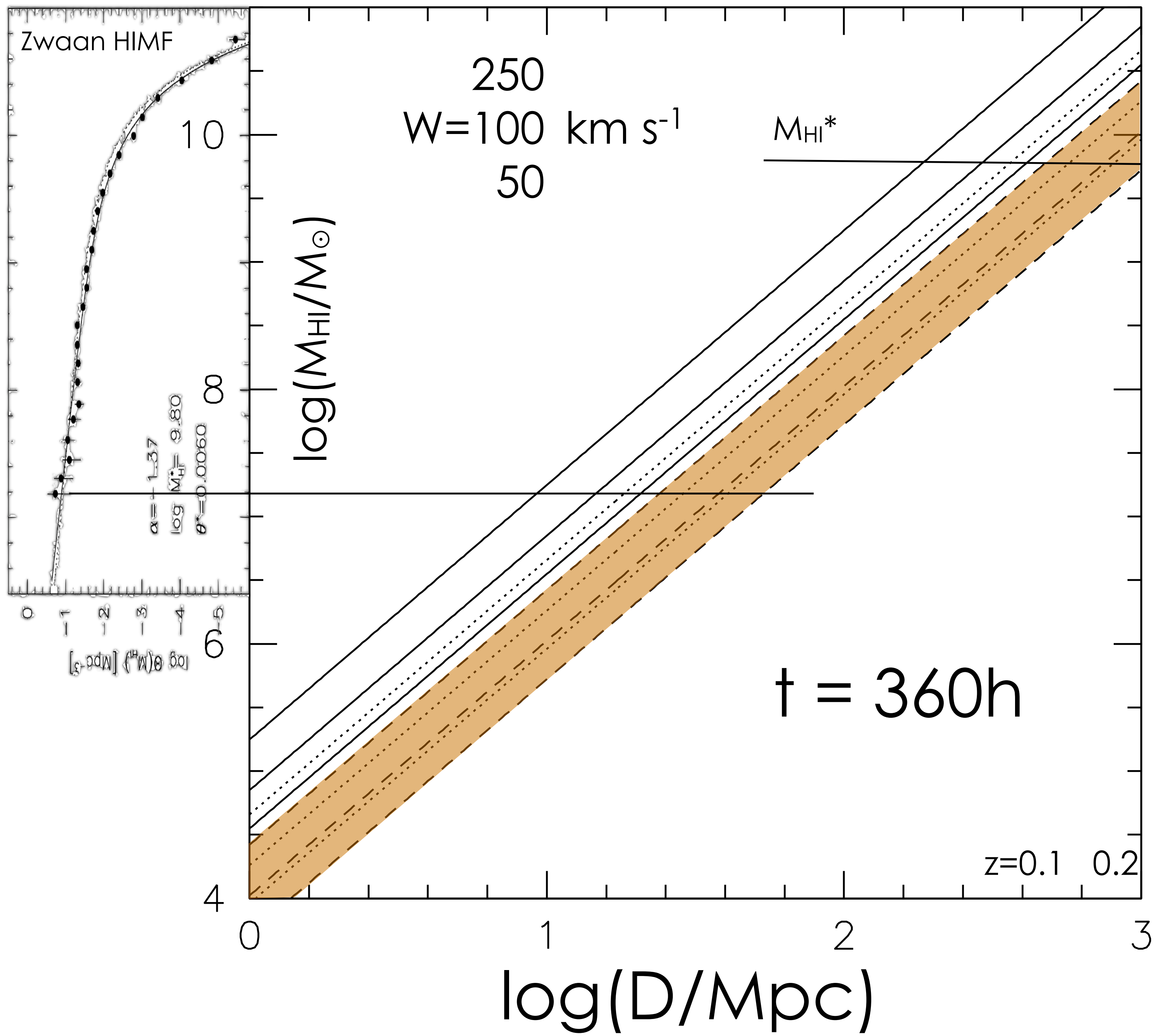
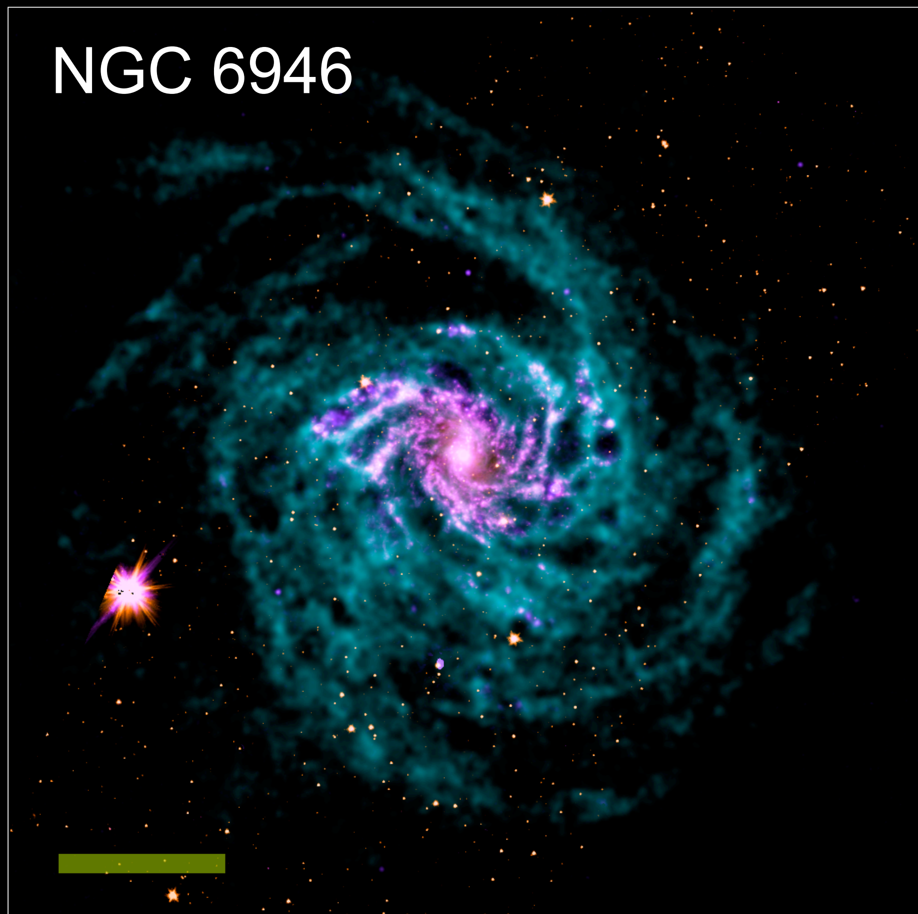


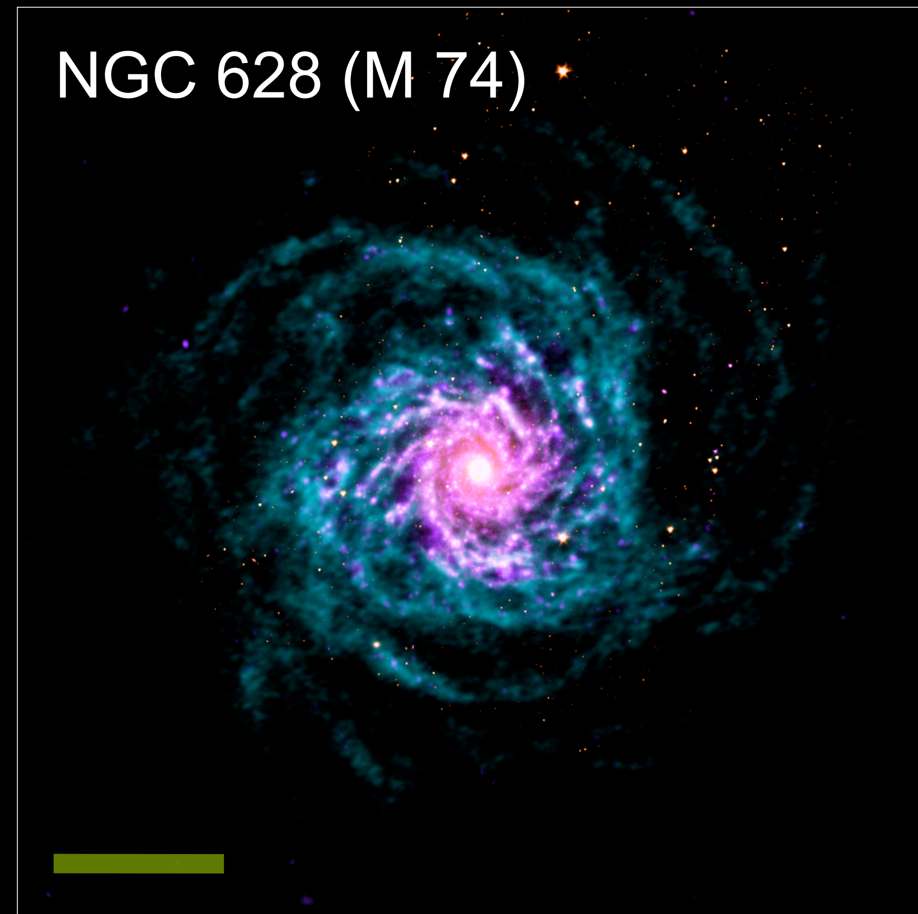
Galaxy Portraits

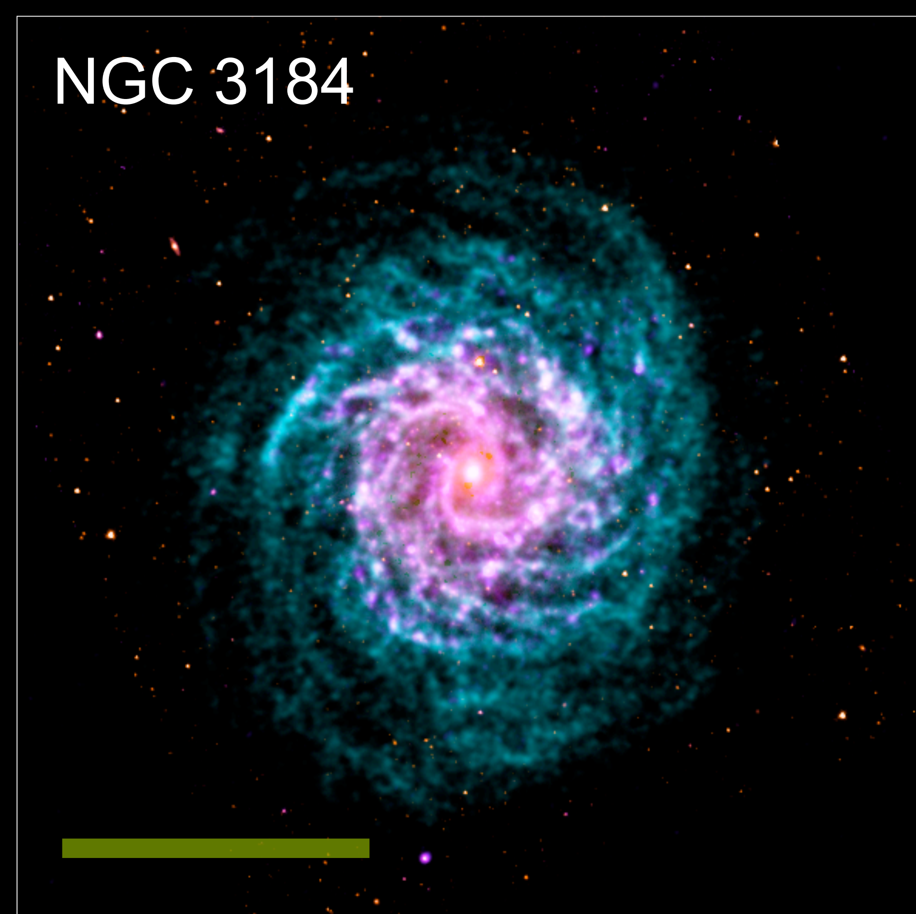
- Recent surveys such as THINGS show importance of resolution in studying
  - dark matter distribution
  - baryonic physics
  - star formation conditions


THINGS
The HI Nearby Galaxy Survey
NGC 2841
NGC 3621
NGC 7331
NGC 4826 (M64)
NGC 3198
NGC 6946
NGC 3184
NGC 925
NGC 3351 (M95)
NGC 5194 (M51)
NGC 5236 (M83)
NGC 3521
NGC 4214
NGC 2976
DDO 53
NGC 1569
M81dwB
NGC 2366
Our Galaxy
HI
stars
M81dwA
IC 2574
NGC 4449
NGC 3627 (M66)
Holmberg II
NGC 7793
DDO 154
NGC 4736 (M94)
NGC 3077
Holmberg I
NGC 5055
NGC 2903
10 kpc
NGC 628 (M74)
NGC 5457 (M101)
NGC 3031 (M81)
NGC 2403
Data: Walter et al 2008
Milky Way HI map: Oort et al (1958)
Milky Way art: NASA/JPL, R. Hurt (SSC)

Spiral Galaxies in T*HI*NGS — The *HI* Nearby Galaxy Survey







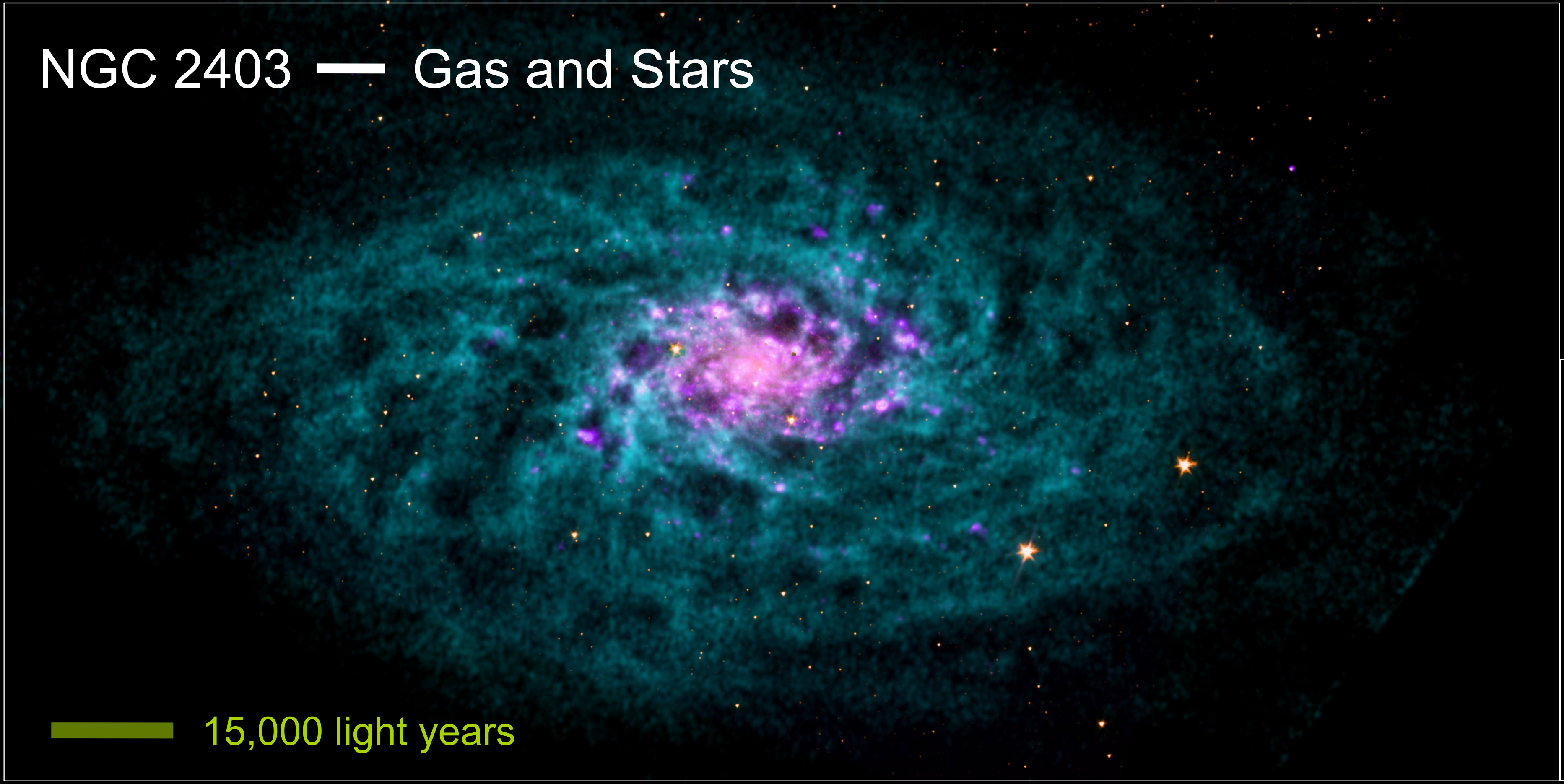
‘Face-on’
Spiral Galaxies
in T*HI*NGS

scale:
10 kpc
30.000 light years

Color Coding:
Atomic Hydrogen (HI)
(Very Large Array)
Old stars
(Spitzer)
Star Formation
(Galex & Spitzer)

Image credits:
VLA THINGS: Walter et al.
Spitzer SINGS: Kennicutt et al.
Galex NGS: Gil de Paz et al.

Galaxy Dynamics in THINGS — The HI Nearby Galaxy Survey



THINGS

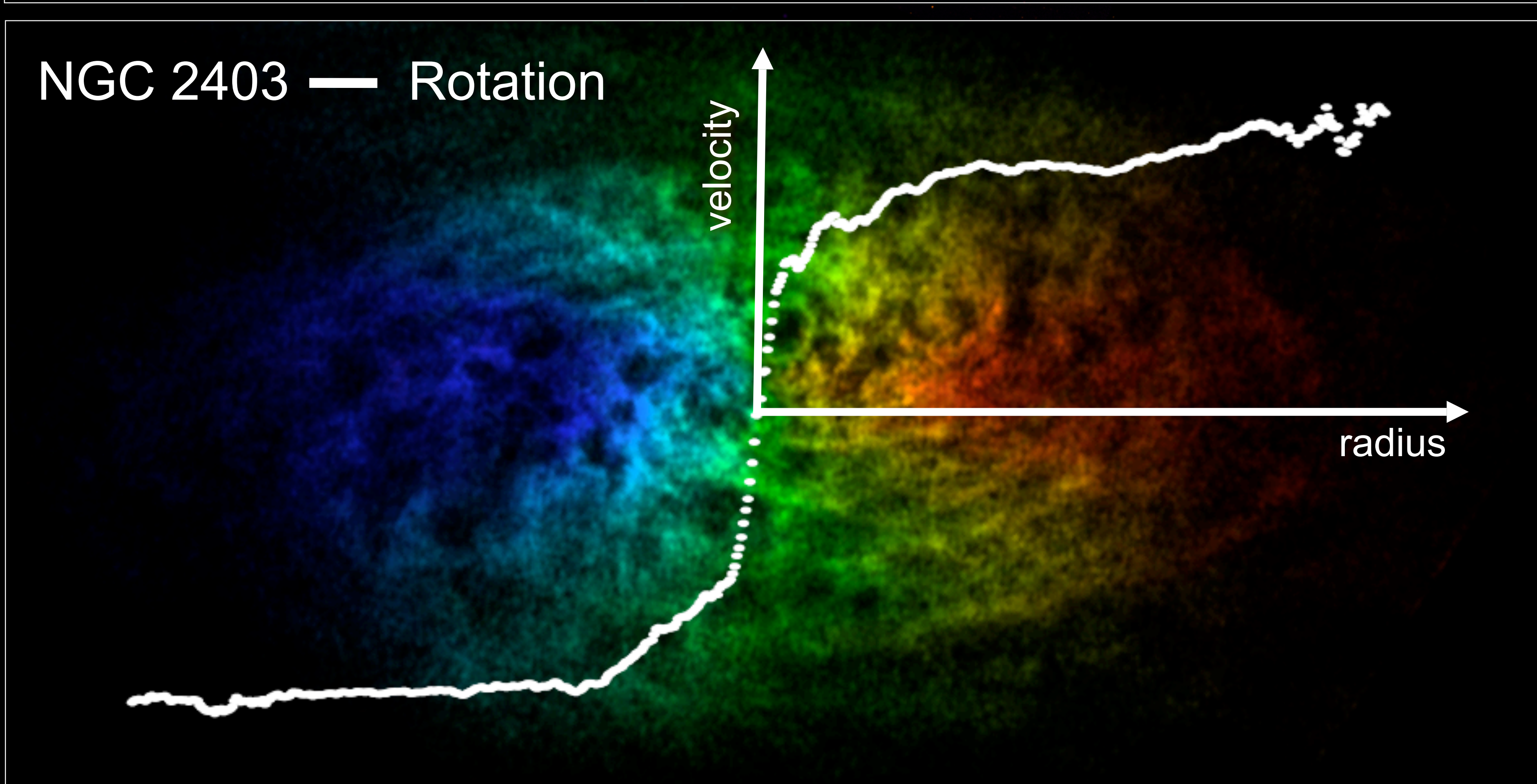
The HI Nearby Galaxy Survey

Color Coding:

THINGS Atomic Hydrogen
(Very Large Array)

Old stars
(Spitzer Space Telescope)

Star Formation
(GALEX & Spitzer)



Color coding:

THINGS HI distribution:

Red-shifted (receding)

Blue-shifted (approaching)

Rotation Curve

Max-Planck-Institut für Astronomie Heidelberg
Max Planck Institute for Astronomy Heidelberg

NRAO

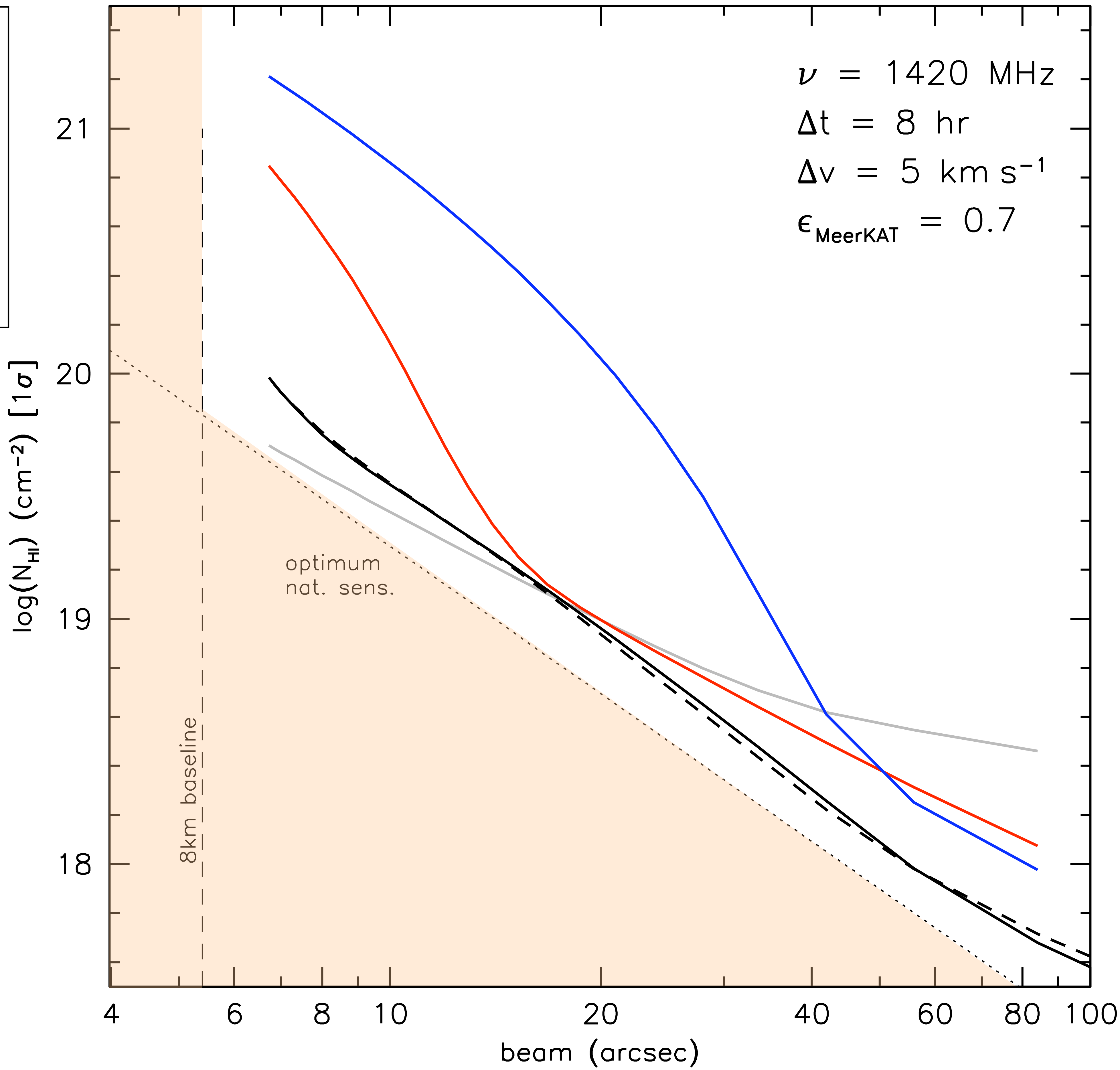
Image credits:
VLA THINGS: Walter et al. 08
Spitzer SINGS: Kennicutt et al. 03
GALEX NGS: Gil de Paz et al. 07
Rotation Curve: de Blok et al. 08

MeerKAT THINGS

- THINGS: ~500 h
- VLA B, C and D on 34 galaxies
- per galaxy:
  - 7.5h in B
  - 2.5h in C
  - 1.5h in D

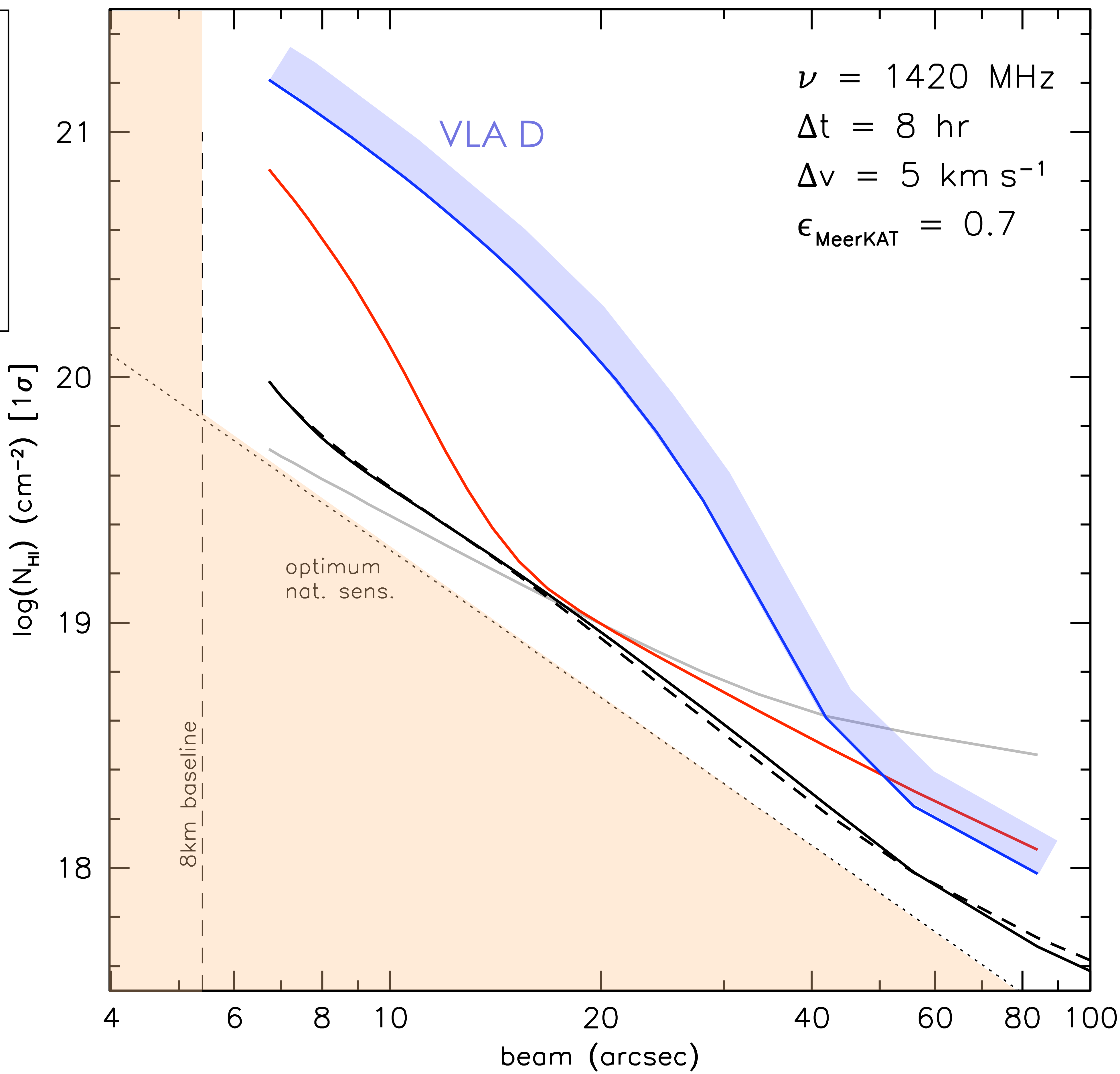
MeerKAT THINGS

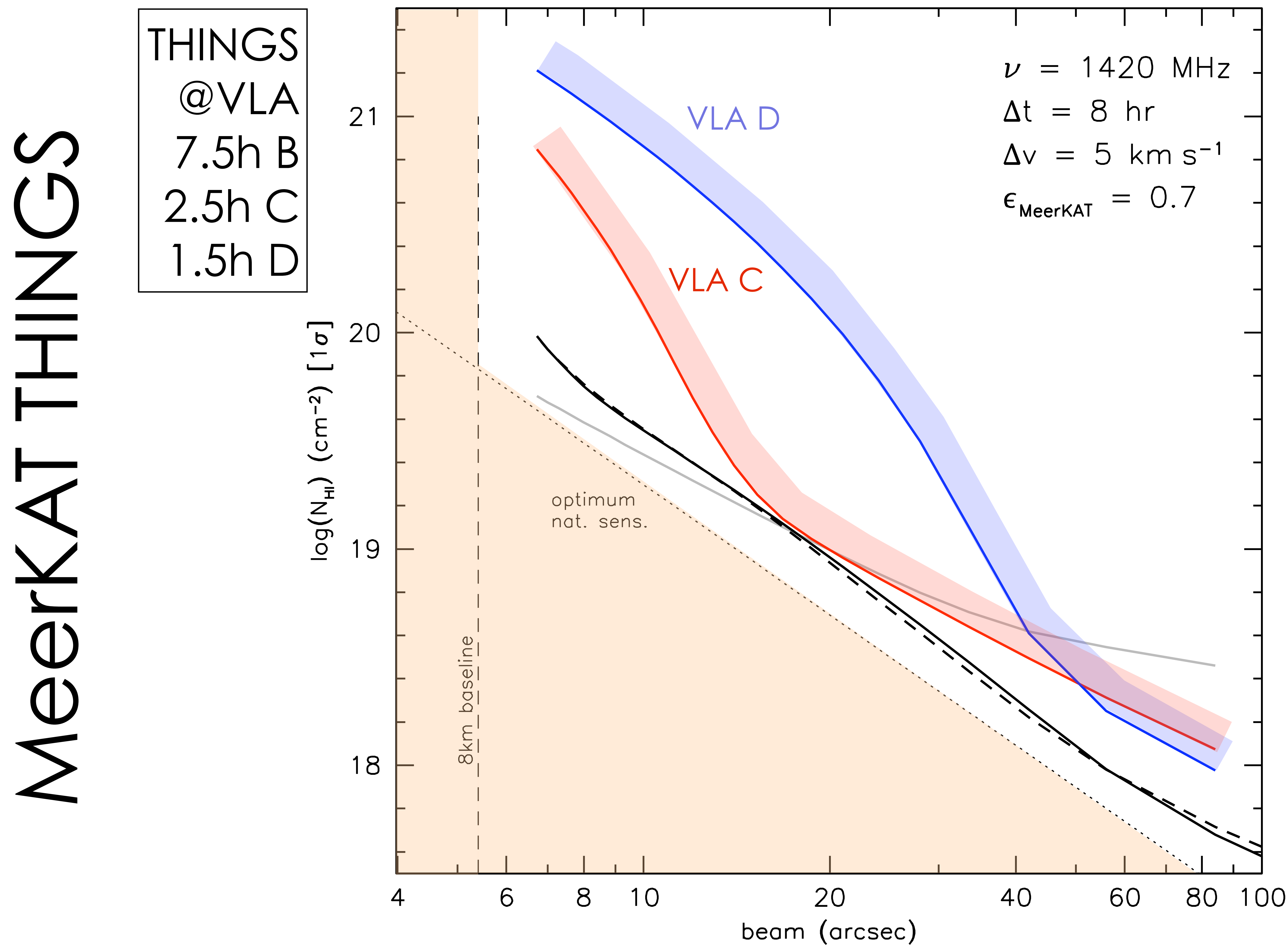
THINGS
@VLA
7.5h B
2.5h C
1.5h D



MeerKAT THINGS

THINGS
@VLA
7.5h B
2.5h C
1.5h D

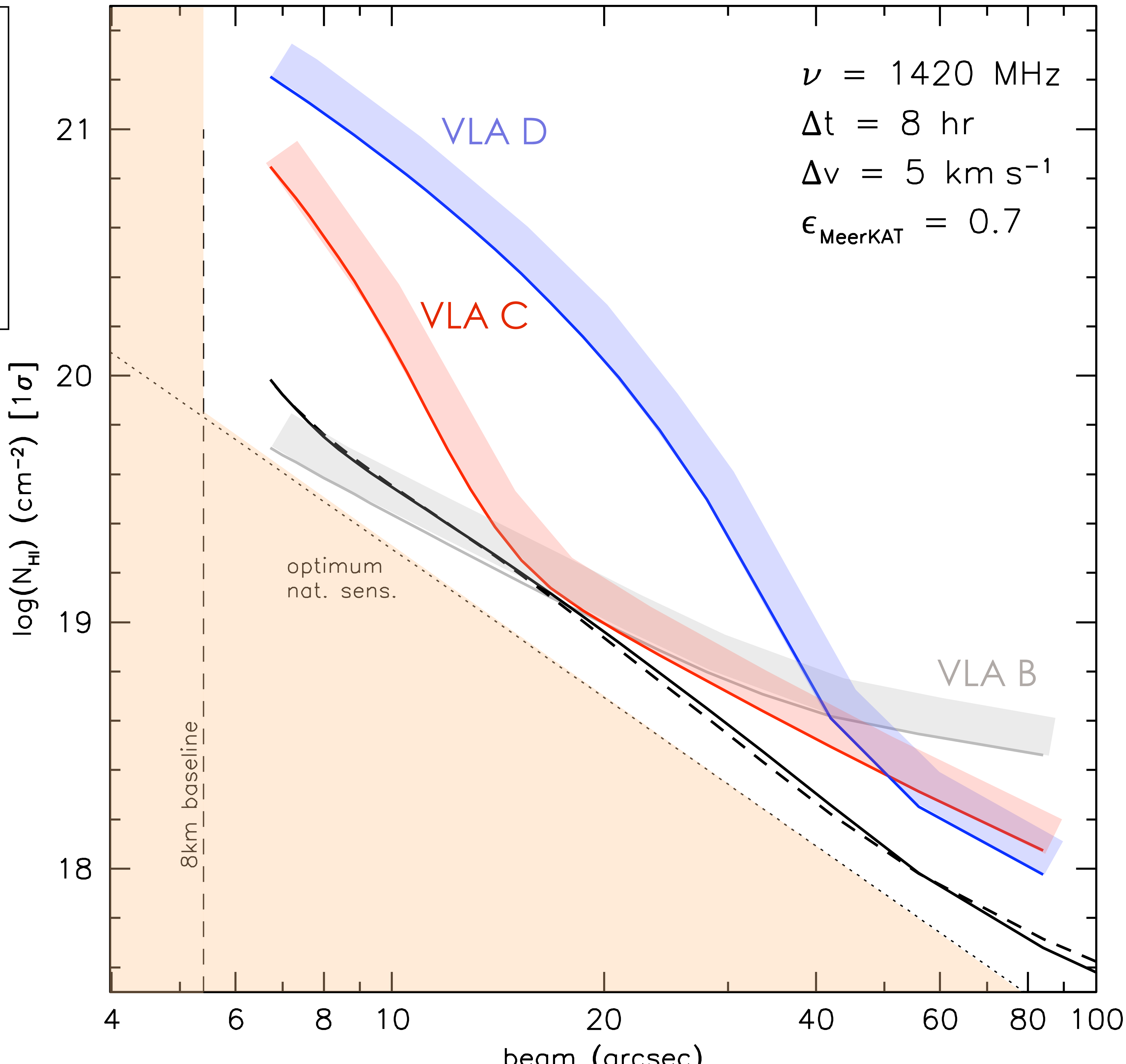




MeerKAT THINGS
THINGS
@VLA
7.5h B
2.5h C
1.5h D
ν = 1420 MHz
Δt = 8 hr
Δv = 5 km s⁻¹
ε MeerKAT = 0.7
VLA D
VLA C
optimum
nat. sens.
8km baseline
log(N HI) (cm⁻²) [1σ]
beam (arcsec)
21
20
19
18
4
6
8
10
20
40
60
80
100

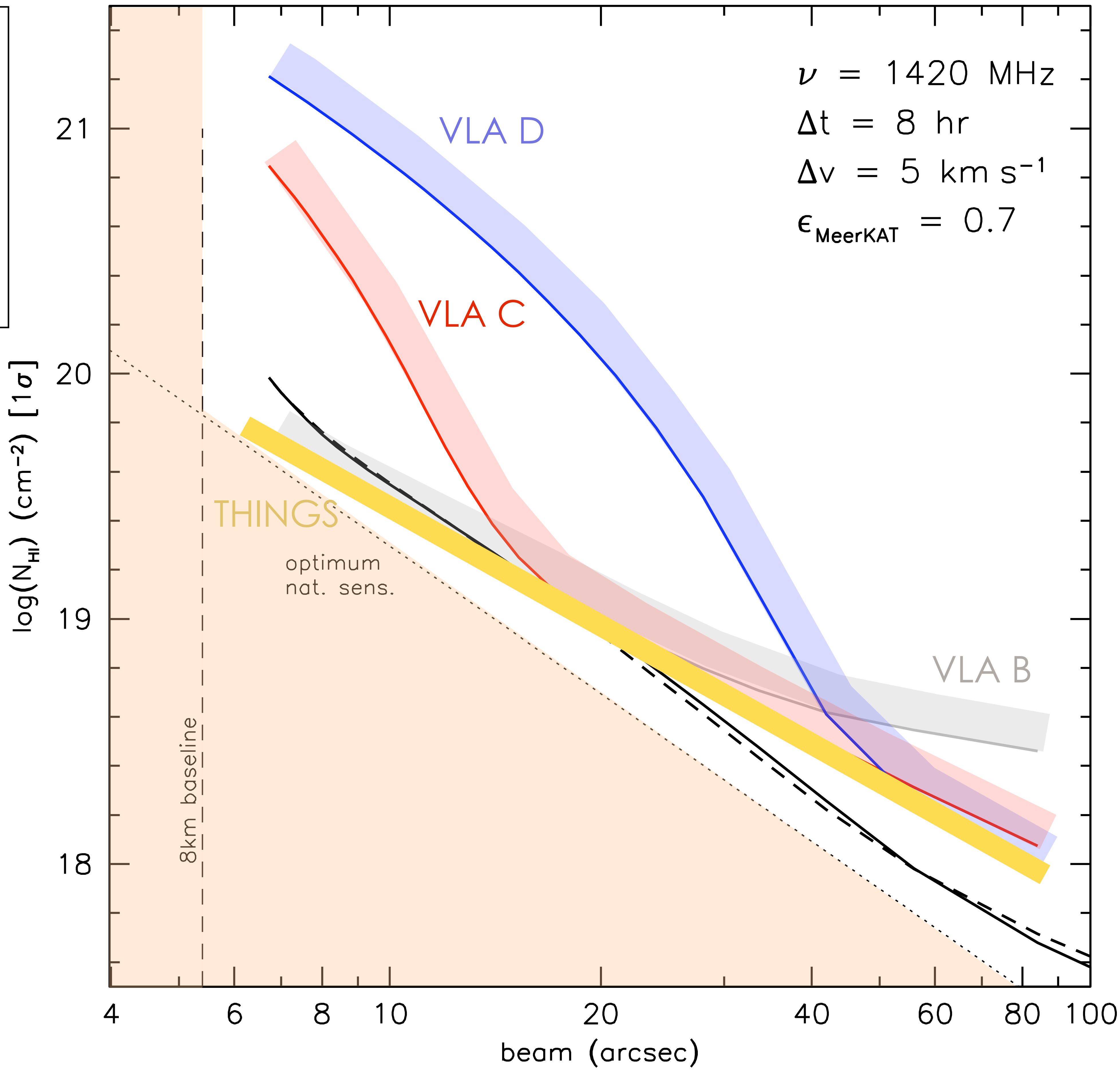
MeerKAT THINGS

THINGS
@VLA
7.5h B
2.5h C
1.5h D

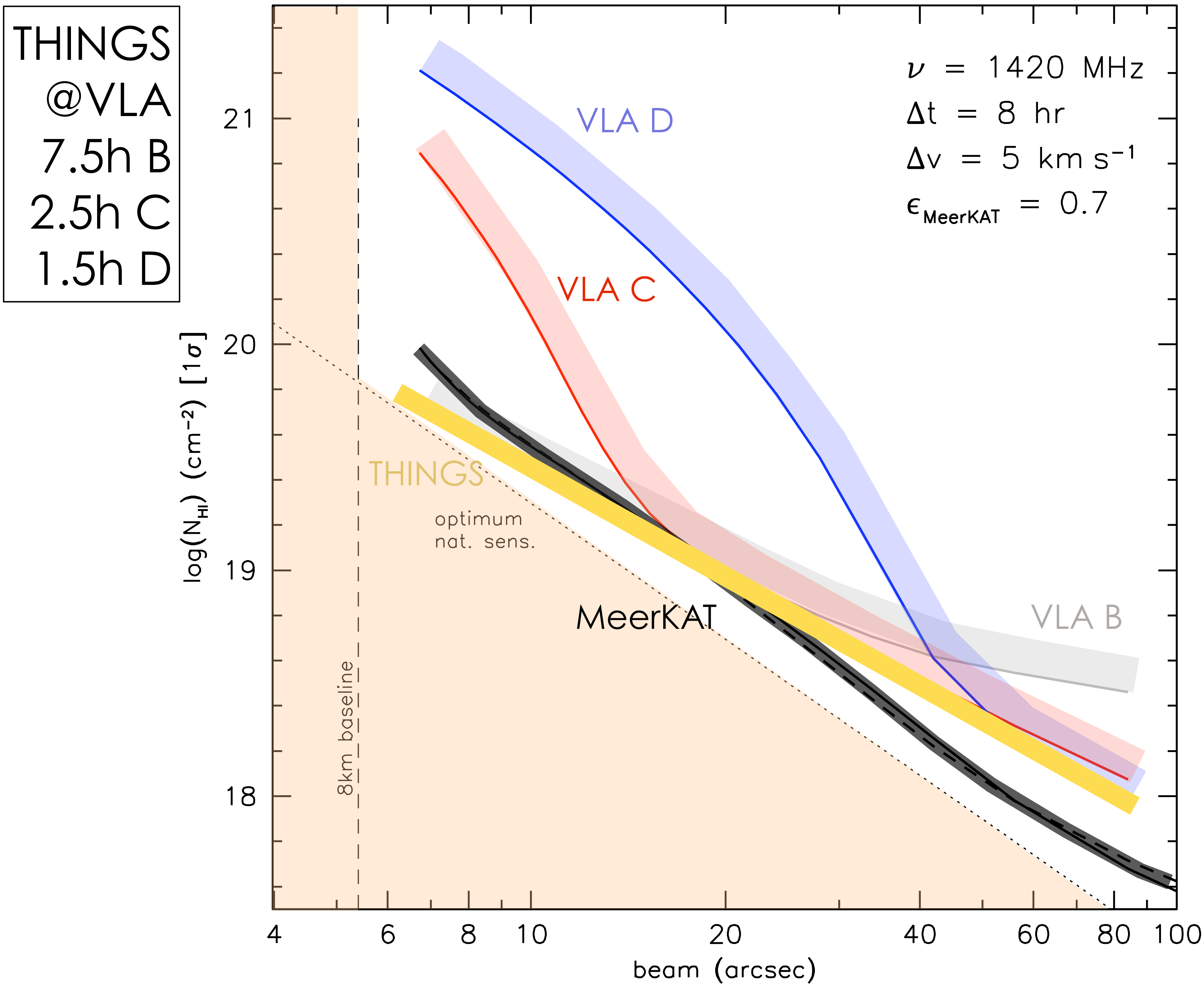


MeerKAT THINGS

THINGS
@VLA
7.5h B
2.5h C
1.5h D



MeerKAT THINGS



MeerKAT THINGS

- Detailed maps of nearby galaxies can be obtained in same time and ~same sensitvity as VLA-B array observation, but with the C & D short baselines (and more) included

Summary

- MeerKAT will be a multi-resolution array, concentrating on low-column densities and high resolution
- Complementary to ASKAP
- Further MeerKAT talks this week about
    - high-redshift observations,
    - HIMF,
    - morphology,
    - groups,
    - clusters and parallel surveys