CTA Overview + Links with ISM Studies

Gavin Rowell

THE UNIVERSITY OF ADELAIDE AUSTRALIA

High Energy Astrophysics Group,
School of Chemistry & Physics

cta cherenkov telescope array

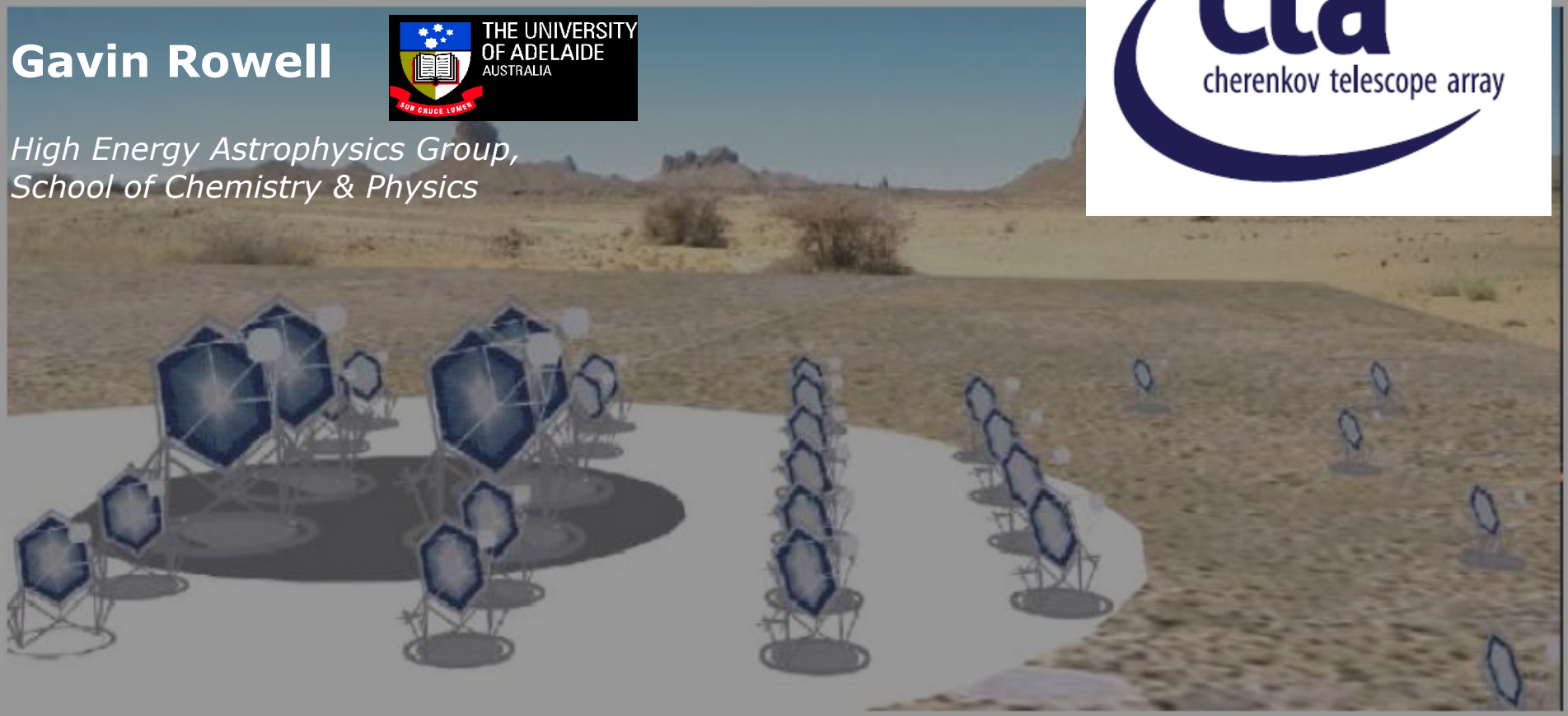


Figure 3: Artistic view of the compound different size telescopes CTA system. The area coverage is of 1 – 10 km^2.

H.E.S.S. Cherenkov Imaging Telescopes (22° S 1800m a.s.l. Namibia)

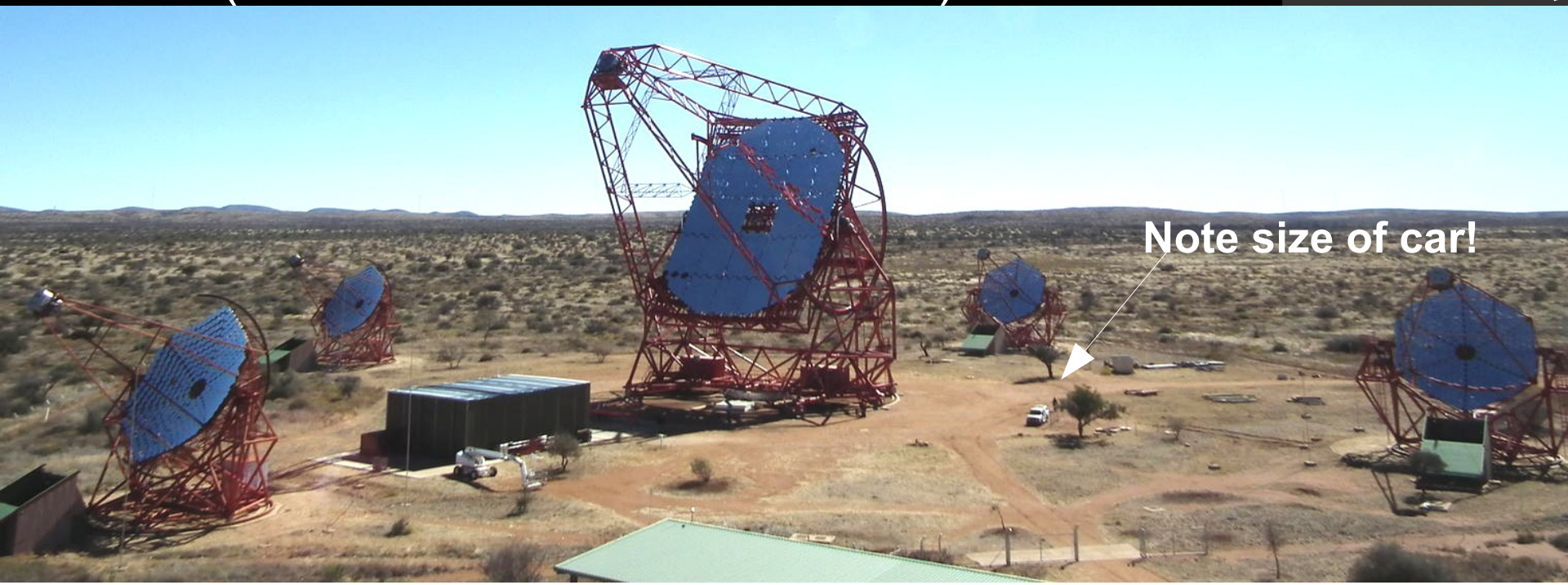
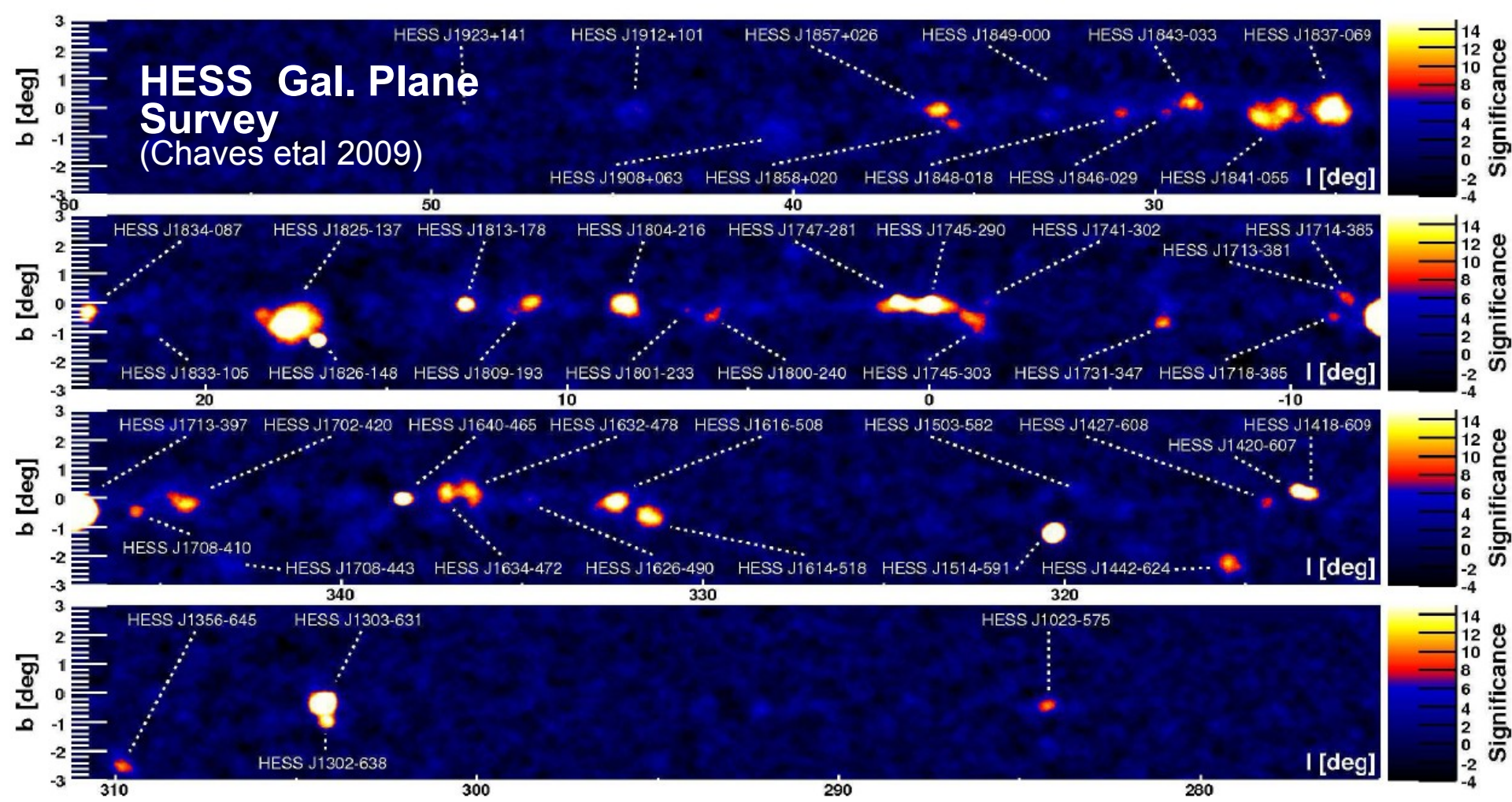


Table 1
Properties of selected air-Cherenkov instruments, including three of historical interest (Whipple, HEGRA and CAT). Adapted from ref. [15]. Significances relate to a point-like source detectable at the 5σ significance level in a 50 h observation.

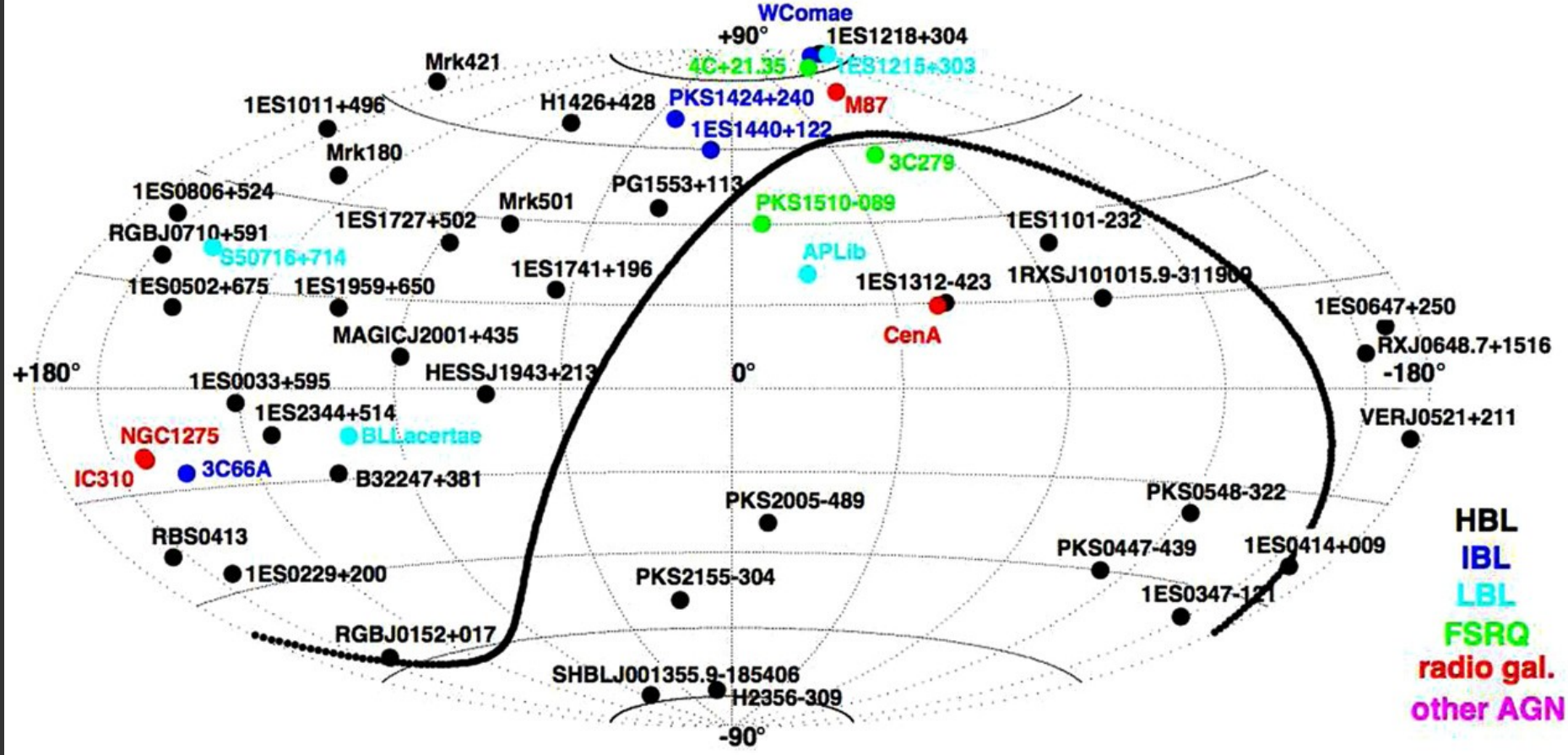
Instrument	Lat (°)	Long (°)	Alt (m)	Telescopes	Area (m^2)	Pixels per camera	FoV (°)	Threshold (TeV)	Sensitivity (% Crab) > 1 TeV
H.E.S.S.	−23	16	1800	4	107	960	5	0.1	0.7
H.E.S.S. II	−23	16	1800	1	614	2048	3.2	tbd	tbd
VERITAS	32	−111	1275	4	106	499	3.5	0.07	0.7
MAGIC I+II	29	−18	2225	2	234	1039	3.5	0.03	0.8
CANGAROO-III	−31	137	160	3	57.3	427	4	0.4	15
Whipple	32	−111	2300	1	75	379	2.3	0.3	15
HEGRA	29	18	2200	5	8.5	271	4.3	0.5	5
CAT	42	2	1650	1	17.8	600	4.8	0.25	15

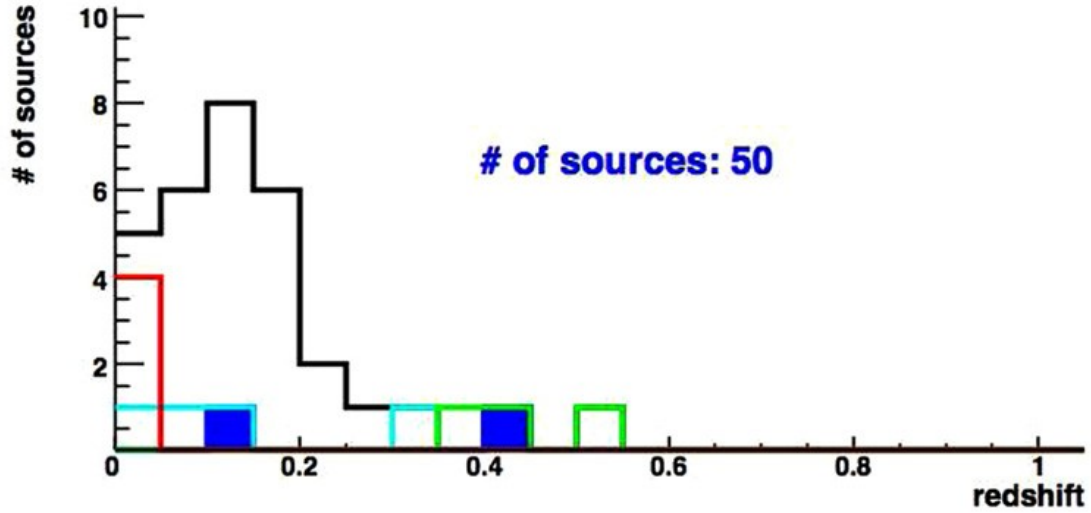


SuperNova remnants ~ 15%
Pulsar Wind Nebulae ~ 35%
Unidentified ~ 35%
Binary (XRBs etc.) ~10%
Stellar Cluster ~ 3%
Diffuse ~ 2%

QUESTIONS

- Parent particles hadrons and/or leptons?
- Particle acceleration – how and where?
- Particle & photon transport/diffusion?
- Mystery of unidentified sources!
- New types of particle accelerators?


WComae
+90°
1ES1218+304
Mrk421
4C+21.35
1ES1215+303
1ES1011+496
H1426+428
PKS1424+240
M87
1ES1440+122
Mrk180
3C279
1ES0806+524
PG1553+113
Mrk501
PKS1510-089
RGBJ0710+591
1ES1727+502
1ES1101-232
S50716+714
APLib
1ES1741+196
1ES1312-423
1RXSJ101015.9-311909
1ES0502+675
1ES1959+650
1ES0647+250
CenA
MAGICJ2001+435
RXJ0648.7+1516
+180°
HESSJ1943+213
0°
-180°
1ES0033+595
1ES2344+514
VERJ0521+211
NGC1275
BLLacertae
IC310
3C66A
B32247+381
PKS2005-489
PKS0548-322
RBS0413
PKS0447-439
1ES0414+009
1ES0229+200
PKS2155-304
1ES0347-121
RGBJ0152+017
SHBLJ001355.9-185406
H2356-309
-90°
HBL
IBL
LBL
FSRQ
radio gal.
other AGN


# of sources
10
8
6
4
2
0
0.2
0.4
0.6
0.8
1
redshift
# of sources: 50

Gamma-rays (GeV to TeV Energies)

- Gamma rays: Highly effective tracer of particle acceleration

- Now many TeV gamma-ray source types + astro/particle physics impact:

- Data analysis techniques – extended sources

- Supernova remnants

- Pulsars & pulsar-wind nebulae

- X-ray binaries, jets and ISM, transients

- Galactic centre region

- Unidentified TeV sources

- Massive stellar clusters and star formation regions

- Formation of molecular gas; ISM dynamics; magnetic fields

- Active Galaxy Cores – supermassive black holes

- Starburst galaxies

- Globular clusters

- Constraints on extragal. IR background → cosmology

- Indirect search for dark matter, quantum gravity (Lorentz invariance), axions

- Cosmic ray electrons

→ Many successes with HESS et al. but we want/need to do more.....

CTA (Cherenkov Telescope Array) 0.05 to >100 TeV coverage

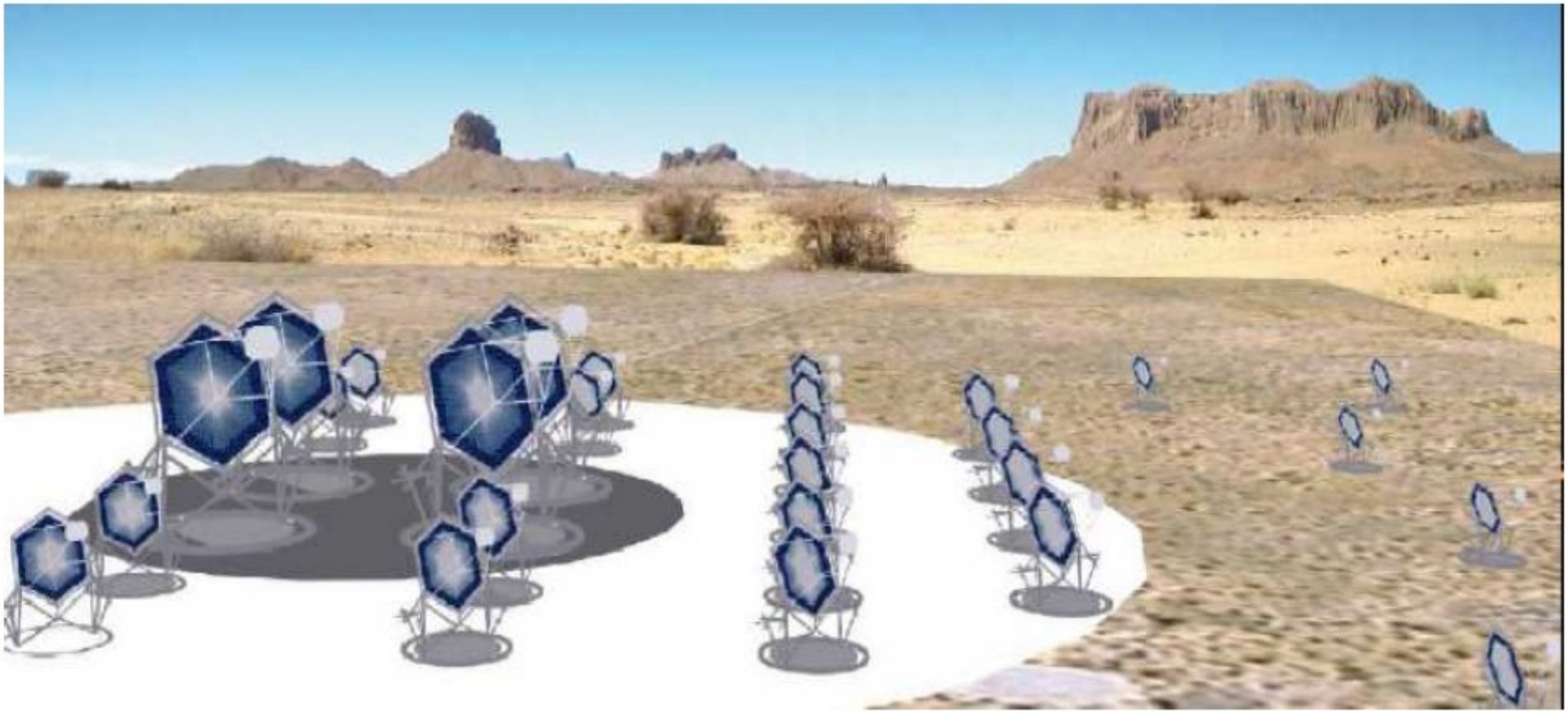


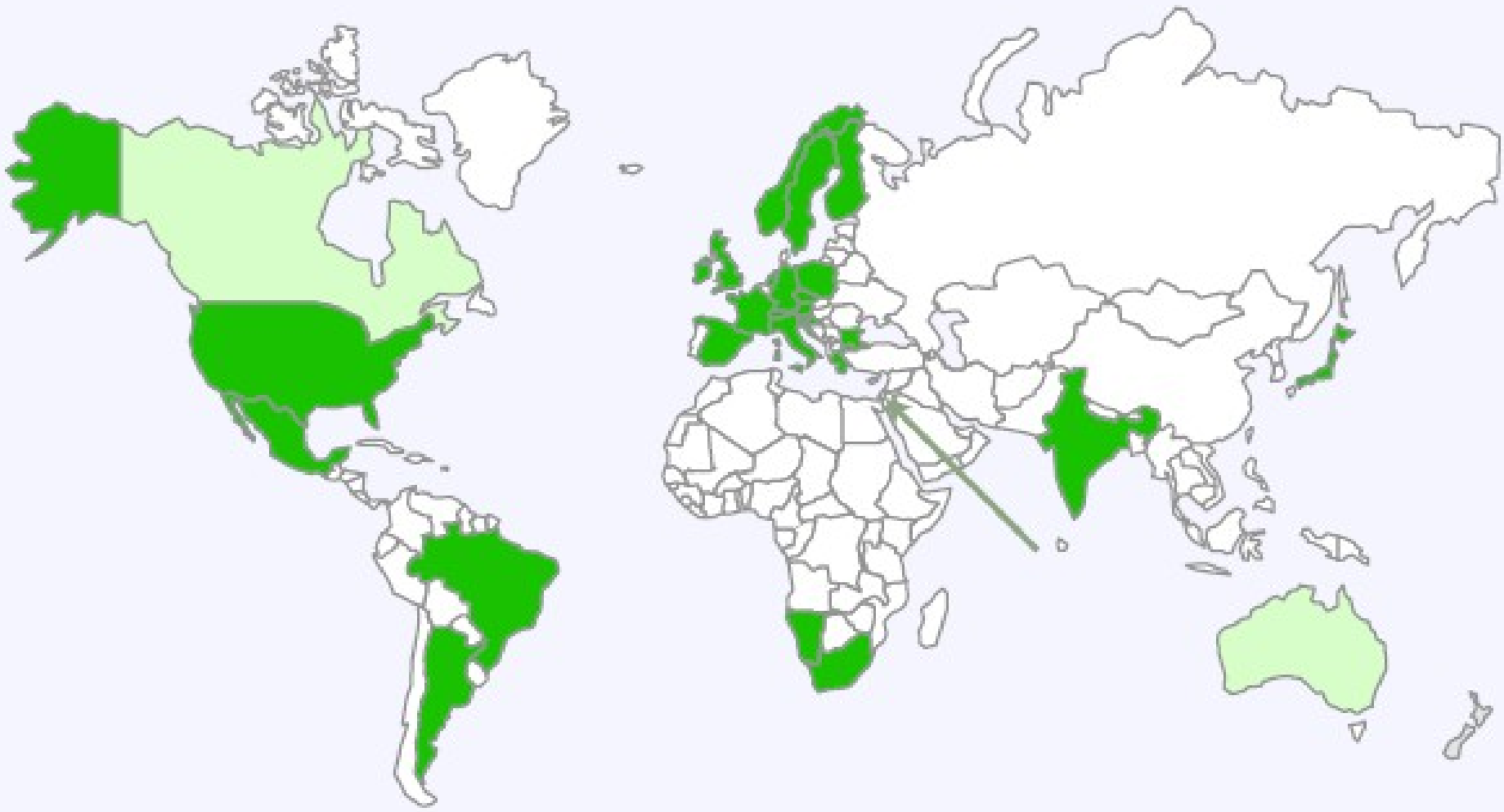
Figure 3: Artistic view of the compound different size telescopes CTA system. The area coverage is of $1 - 10\ km^2$.

→ >10x more sensitive than HESS et al.

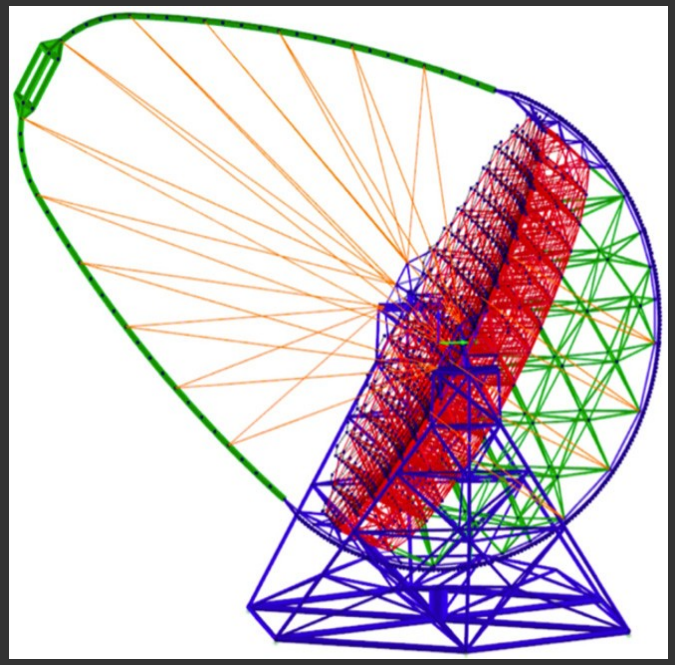
http://www.cta-observatory.org/

CTA Membership

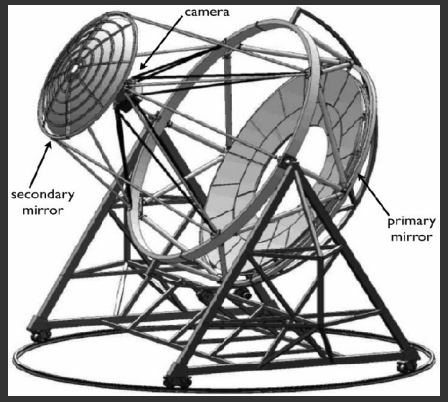
May 2013
> 1000 scientists

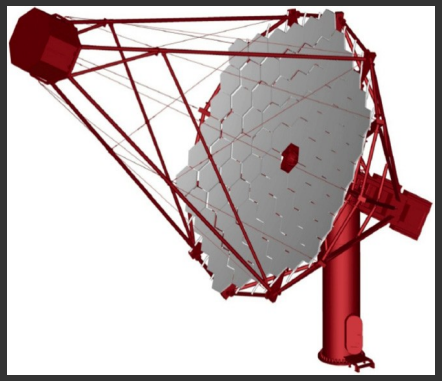


LST

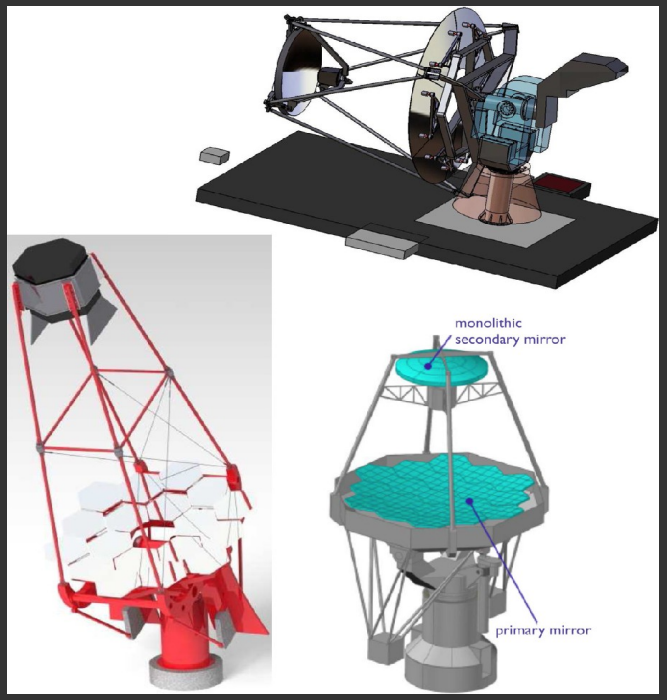


MST





SST



LST – Large Size Telescope (28m diam)
MST – Medium Size Telescope (12m diam)
SST – Small Size Telescope (4-6m diam)

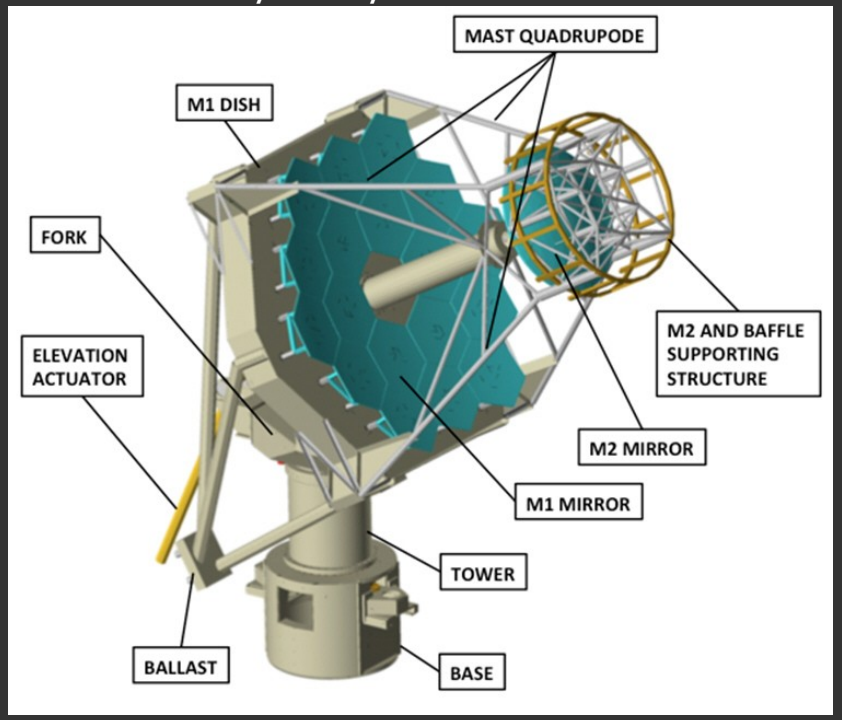
MST Prototype (DESY Berlin)

CTA SSTs – ASTRI

http://www.brera.inaf.it/astri/

- Led by INAF (Italy)
- 8 MEuro funding
→ Mini-Array of 3-5 SSTs

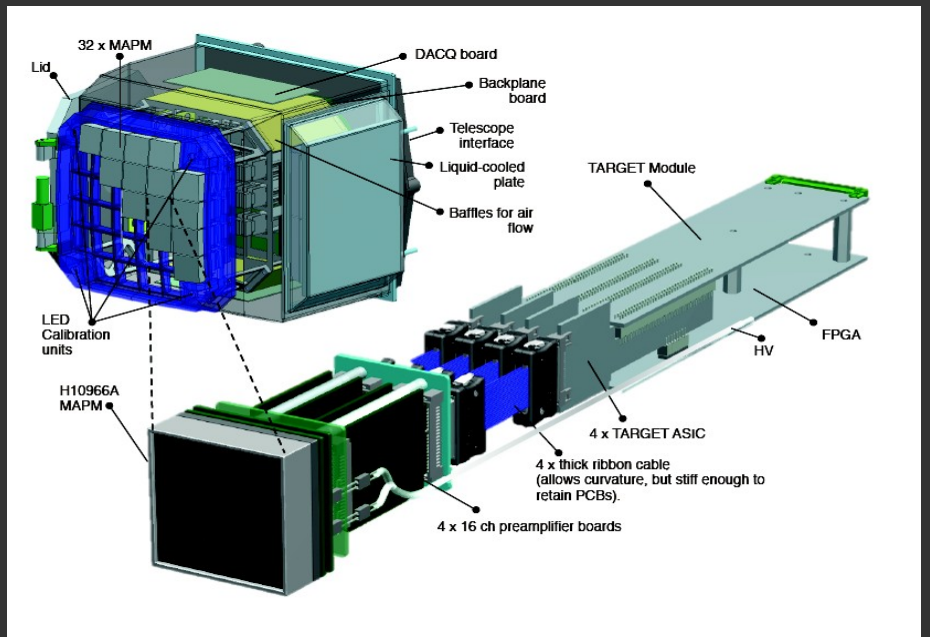
- SST prototype 2014
- SCT optics
- Mini-array 2016 at CTA South Site
- Several Camera Development Groups



UK-Led Camera CHEC
(Compact High Energy Camera)

- Funding for two prototypes

- CHEC-M MAPMTs
  'conventional' PMTs
- CHEC-S SiPMTs
  silicon PMTs



CTA – Possible Telescope Layout at Southern Site (~70 tels.)

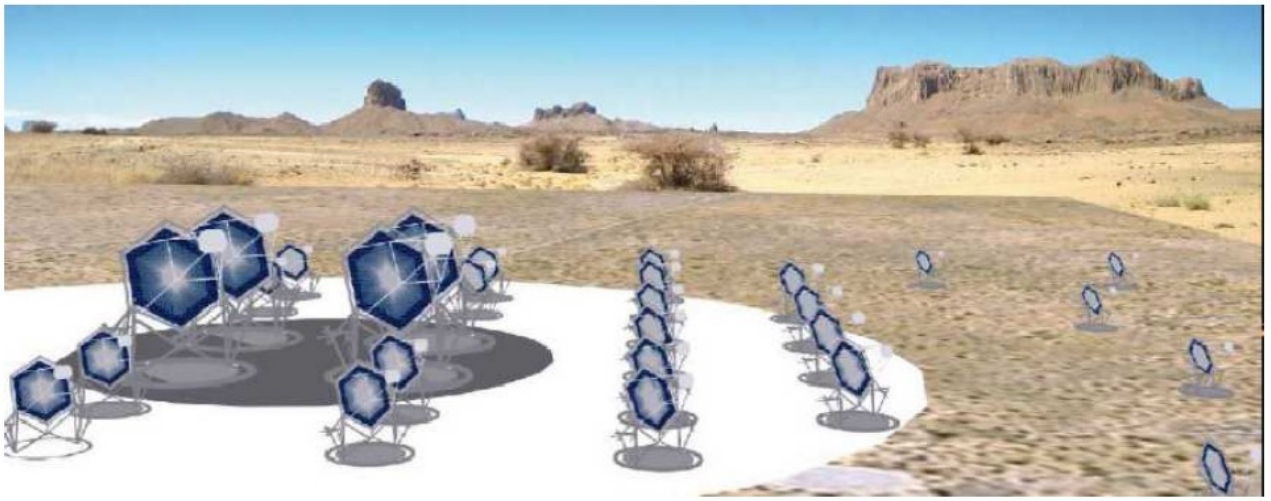
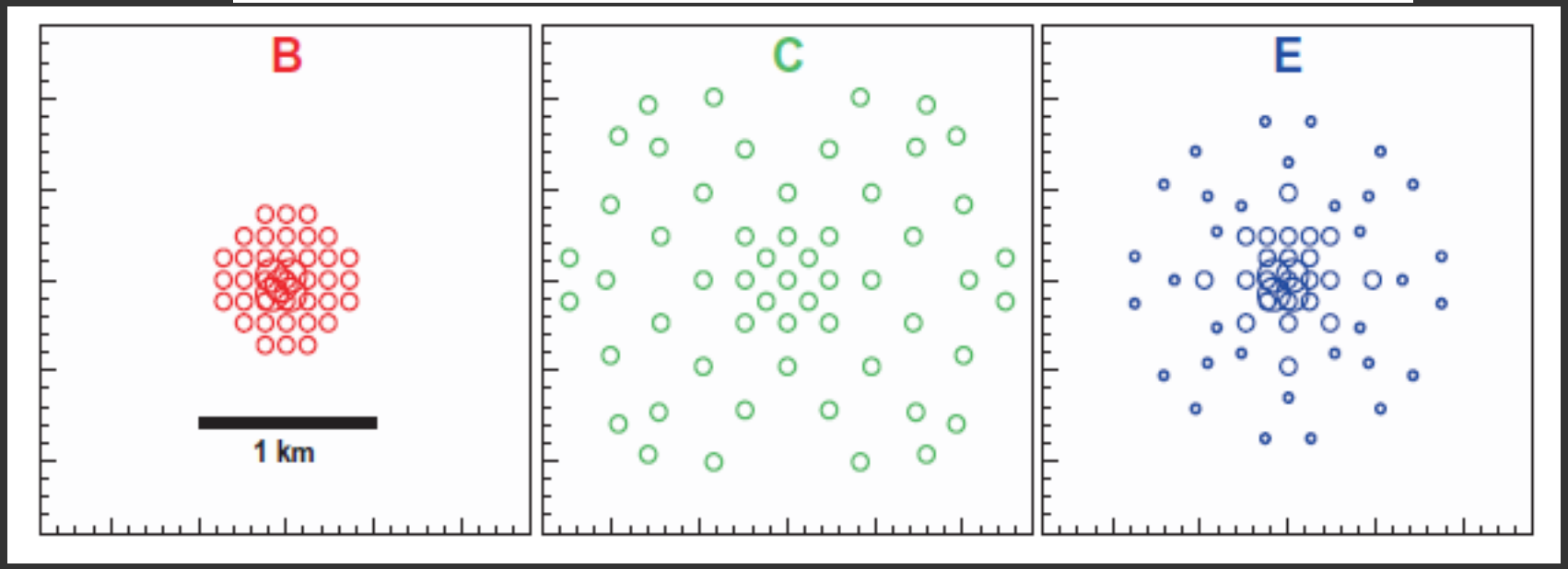


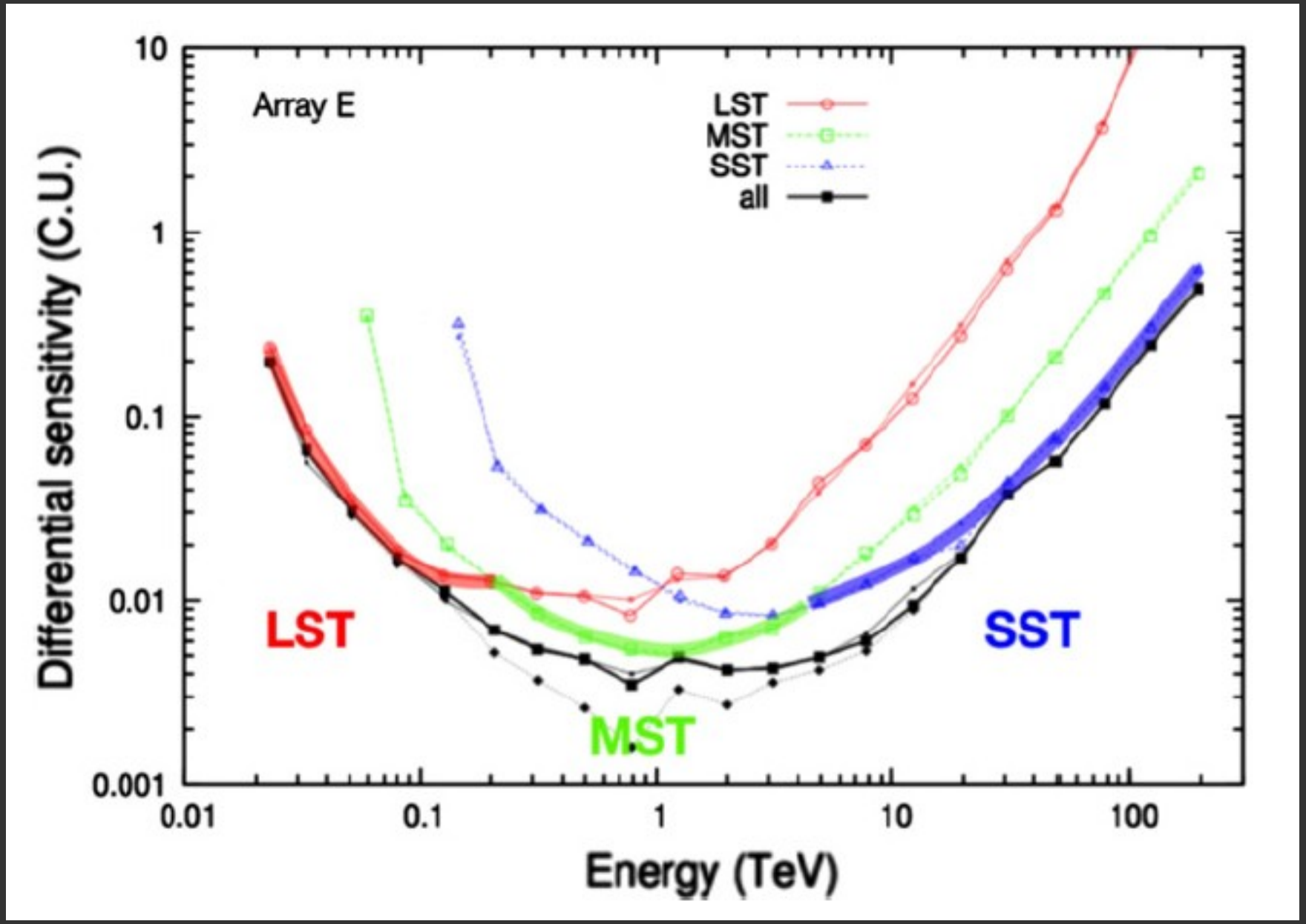
Figure 3: Artistic view of the compound different size telescopes CTA system. The area coverage is of 1 – 10 km^2.



Note: Smaller array at Northern Site (~10 tels.)

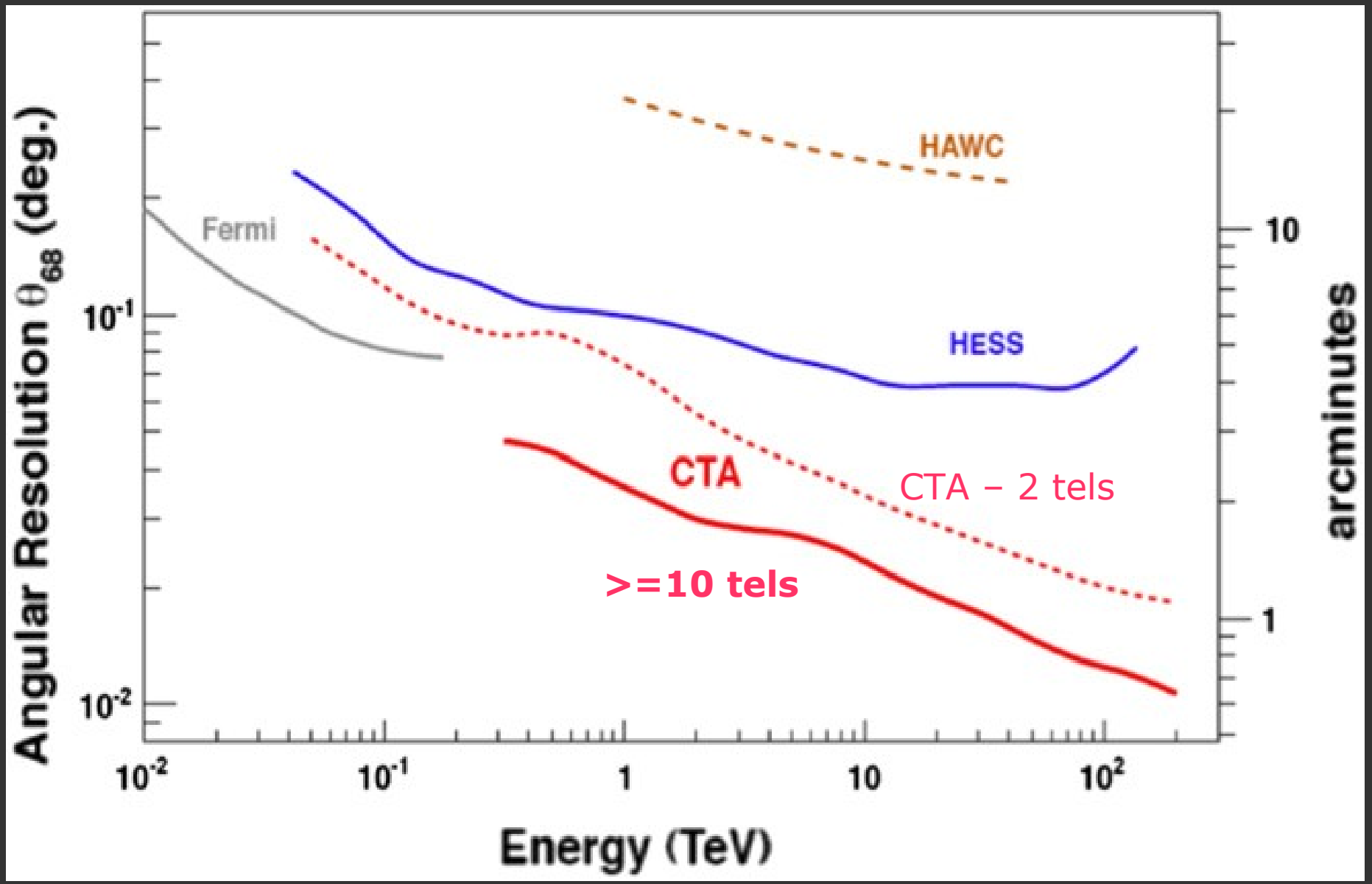
CTA Diff.Flux Sensitivity (Crab units)

Bernloehr etal 2013



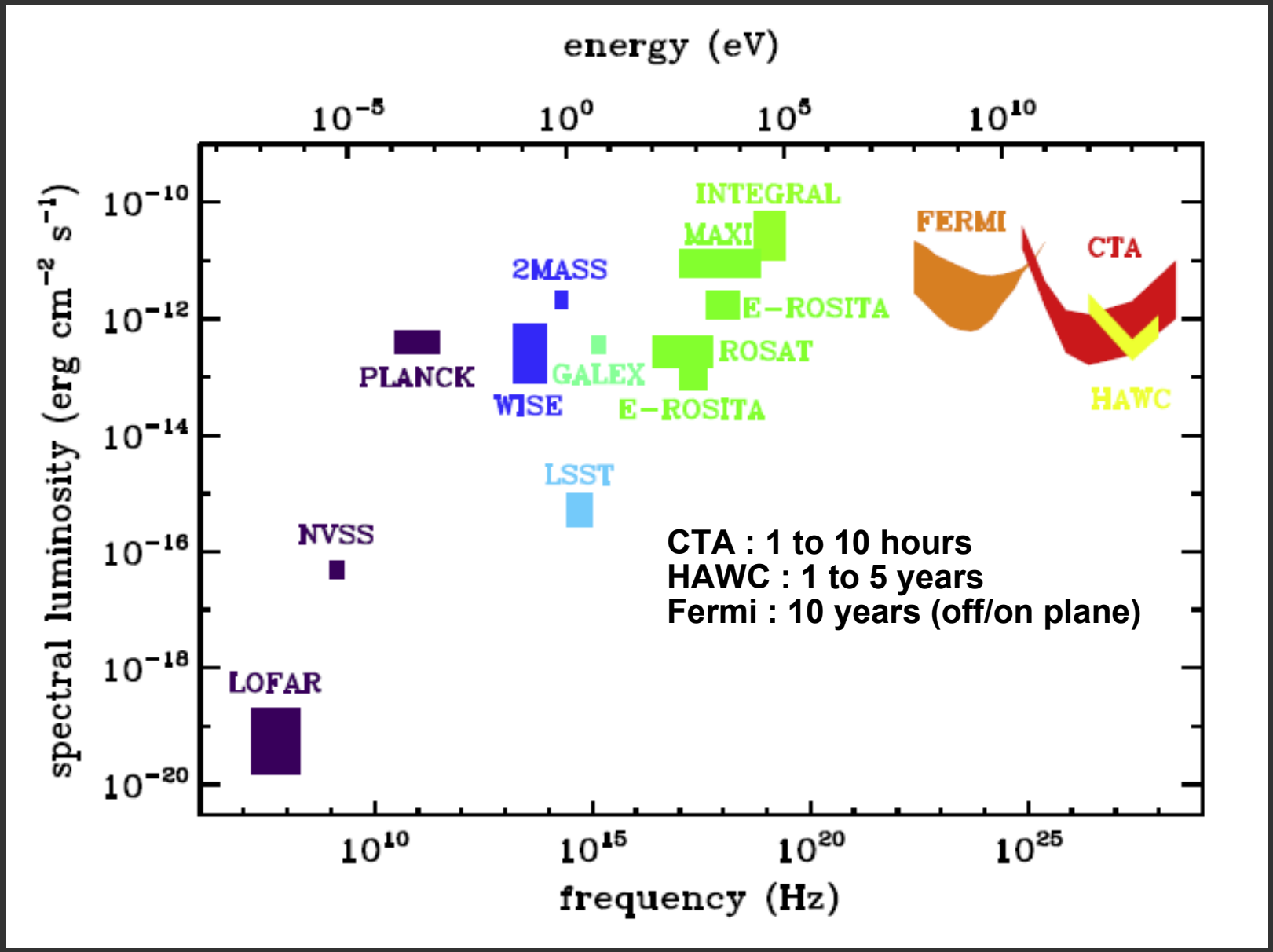
CTA Angular Resolution

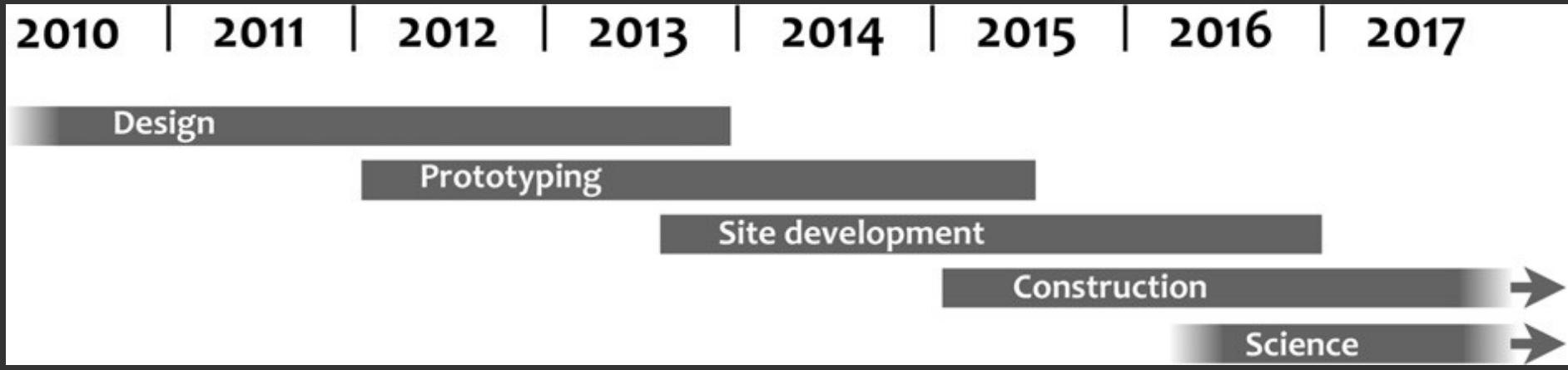
Acharyara etal 2013

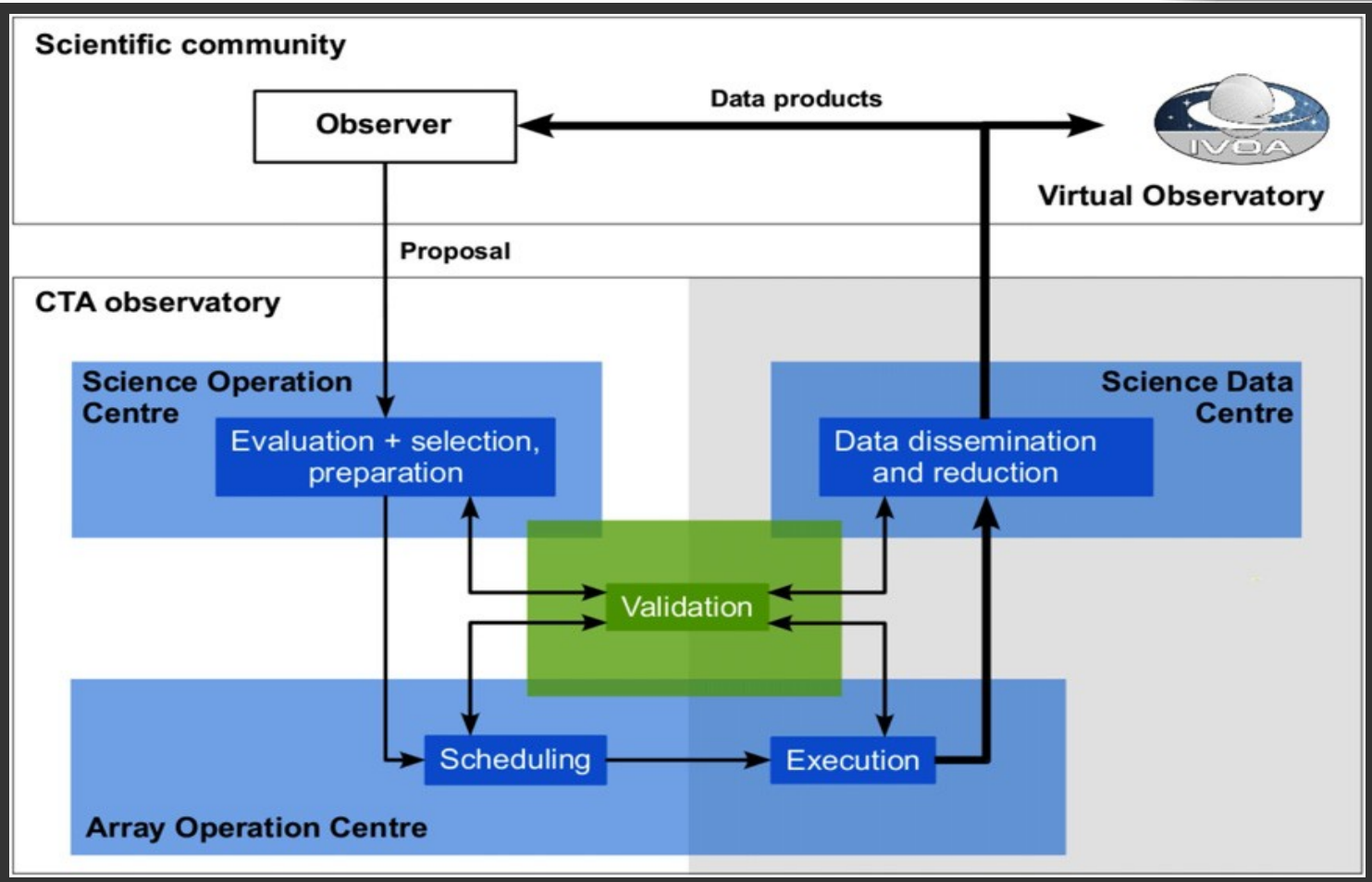


CTA Survey Sensitivity

Dubus etal 2013

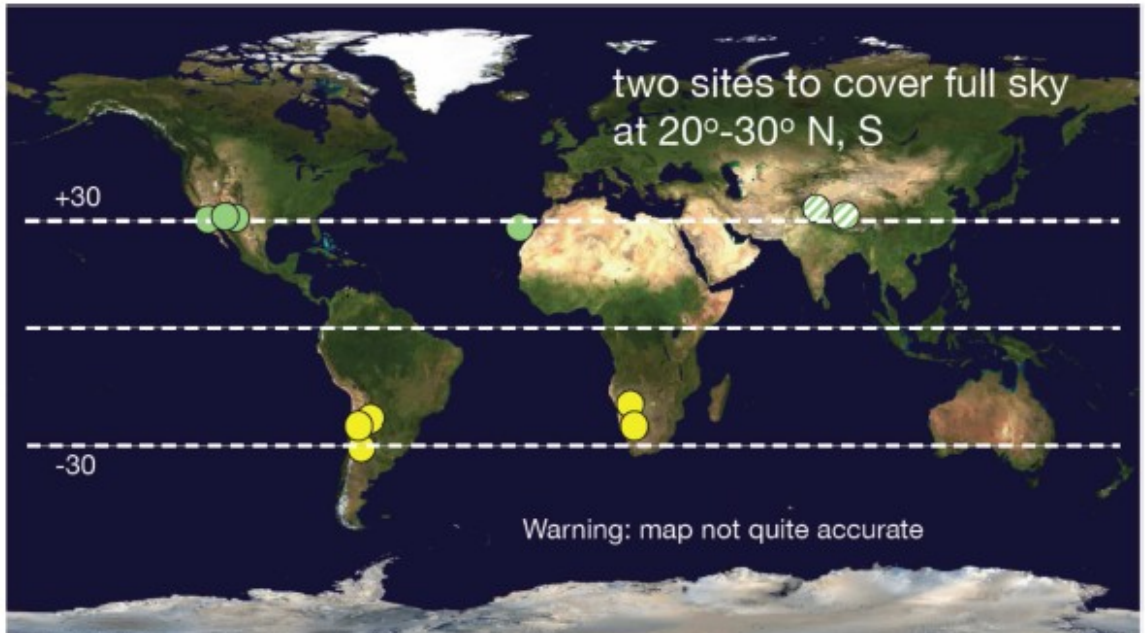



2010
2011
2012
2013
2014
2015
2016
2017
Design
Prototyping
Site development
Construction
Science


Scientific community
Observer
Data products
IVOA
Virtual Observatory
Proposal
CTA observatory
Science Operation Centre
Evaluation + selection, preparation
Science Data Centre
Data dissemination and reduction
Validation
Scheduling
Execution
Array Operation Centre

Candidate Sites

Site recommendation at Warsaw CTA general meeting (23-27 Sept)

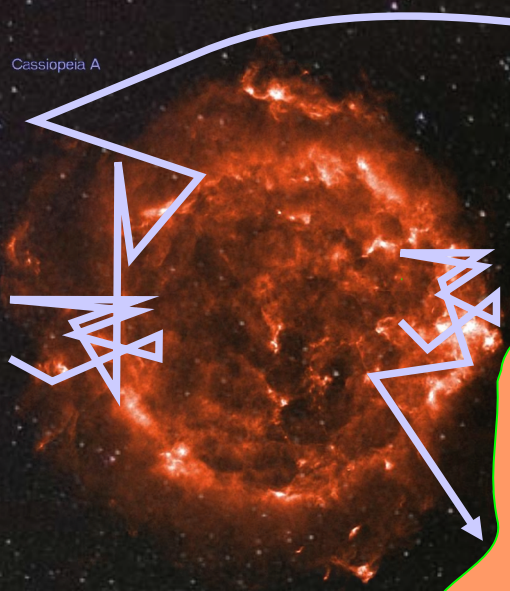


	Country	Site Name	Latitude	Longitude	Altitude	Slope % NS/EW	Area available	Land ownership	Priority for study
North	Mexico	San Pedro Martir	31.01° N	115.48° W	2434m	0.5 / 0.5	1 km^2	government	high
	Spain	Teide	28.28° N	16.54° W	2290m	3.2 / 3.9	> 1 km^2	government	high
	USA	Meteor Crater	35.04° N	111.034° W	1680m	0.7 / 0.5	> 1 km^2	private	high
	USA	Yavapai	35.14° N	112.87° W	1670m	3.5 / 3.5	1 km^2	private	medium
South	Argentina	San Antonio	24.05° S	66.24° W	3610m	1.5 / 0.9	10 km^2	government	medium
	Argentina	Leoncito	31.72° S	69.27° W	2640m	1.5 / 6.9	> 10 km^2	government	high
	Chile	Armazones	24.58° S	70.24° W	2500m	3.7 / 3.2	10 km^2	ESO	high
	Namibia	HESS	23.27° S	16.50° E	1810m	1.0 / 0.5	10 km^2	private	medium
	Namibia	Aar	26.69° S	16.44° E	1650m	2.0 / 1.6	10 km^2	private	high

Table 8: Candidate sites retained with high and medium priority for study. The distinction between high and medium priority is used, at this time, solely to organize the work to be done to evaluate the sites. Note the priority for Argentina was changed by the proponents on 11 July 2013.

CTA & ISM Surveys....

Gamma Rays from multi-TeV Cosmic-Rays (p, He ...etc)



CRs deflected by magnetic fields

$$p+p \rightarrow \pi^{o} \rightarrow 2\gamma$$

$$\pi^{\pm} \rightarrow \mu^{\pm} \rightarrow e^{\pm} + (\nu_{\mu}\ \nu_{e} \ldots.)$$

GAS CLOUD

Gamma-Rays (+ Neutrinos)

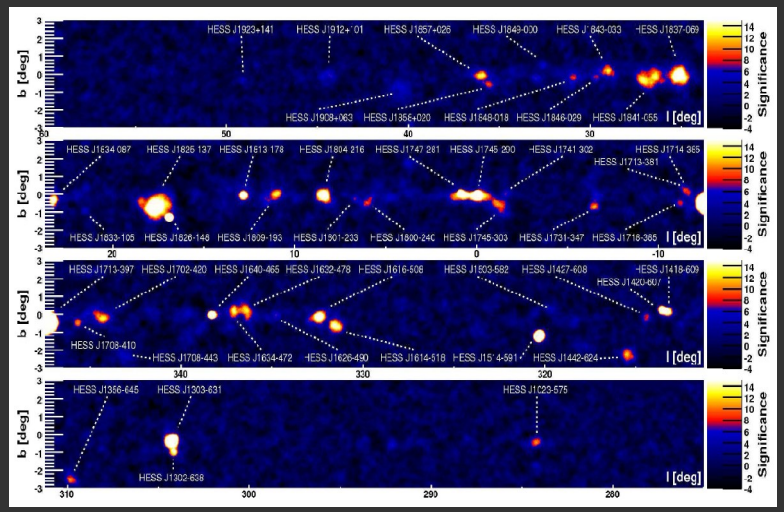
Observational Signature

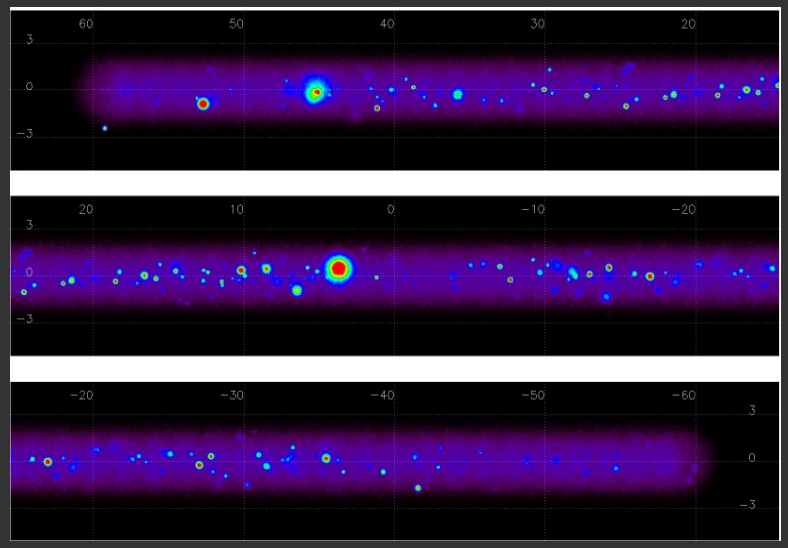
→ Gamma-rays and gas are spatially correlated

→ Intimate connection with mm- radio astronomy (tracing gas)

.....we expect gamma-ray flux $F_{\gamma} \sim k_{CR}\ M_{gas}$

Galactic Plane: CTA Survey Issues





- **CTA will provide Galactic Plane TeV Gamma-ray maps on ~1-3 arc-min scales.**

- **>3 sources per deg^2 $|b|<0.2°$ $|l|<30°$** (Dubus etal 2013)

- **Diffuse TeV components visible?**
  - **from CR sea – maybe**
  - **local CR accelerator enhancements – yes**
- **Confusion guaranteed.**

- **Mapping the ISM on arc-min scales will be essential**

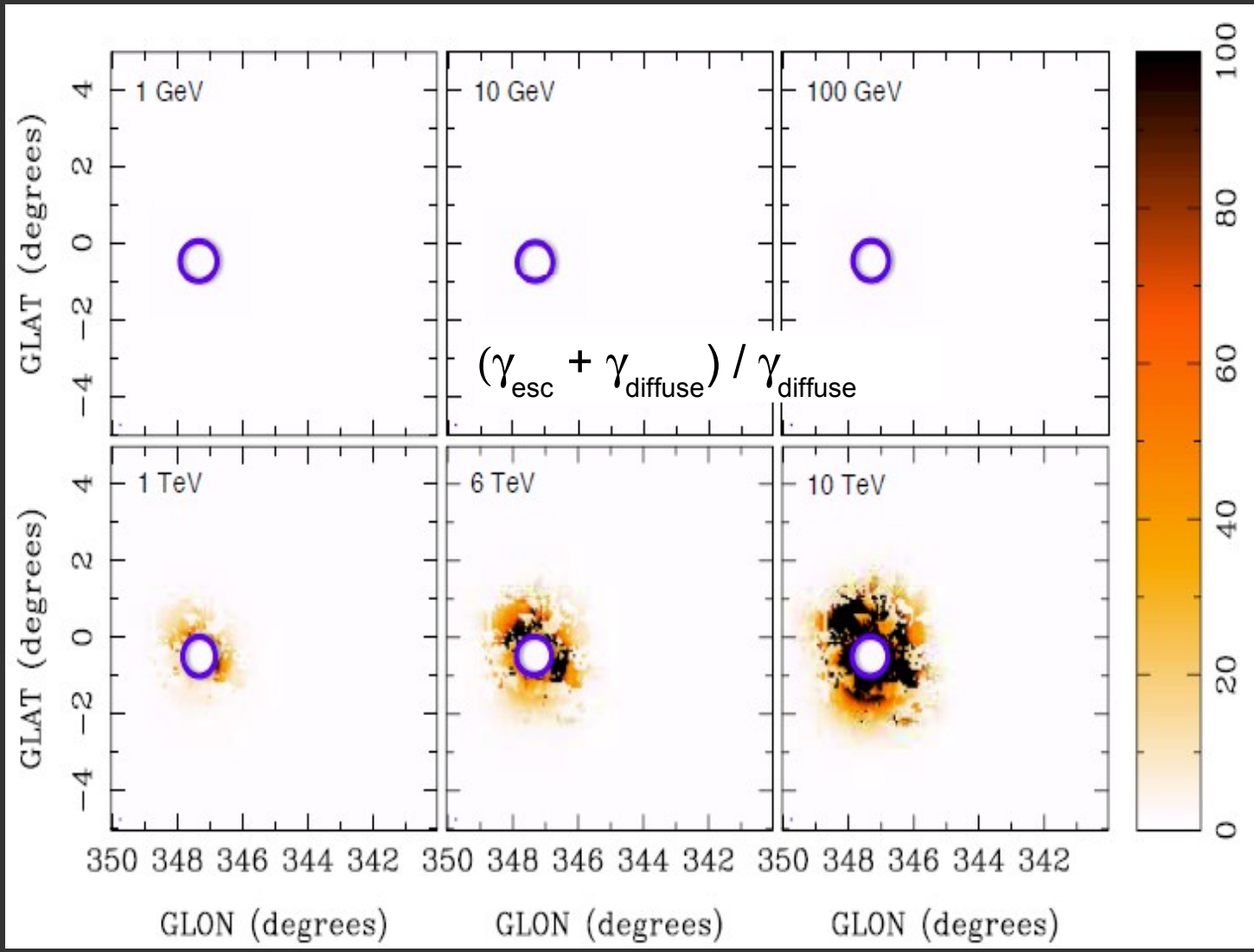
Gamma-Rays from Escaping Cosmic-Rays

Casanova etal 2010
(Gabici etal 2009)

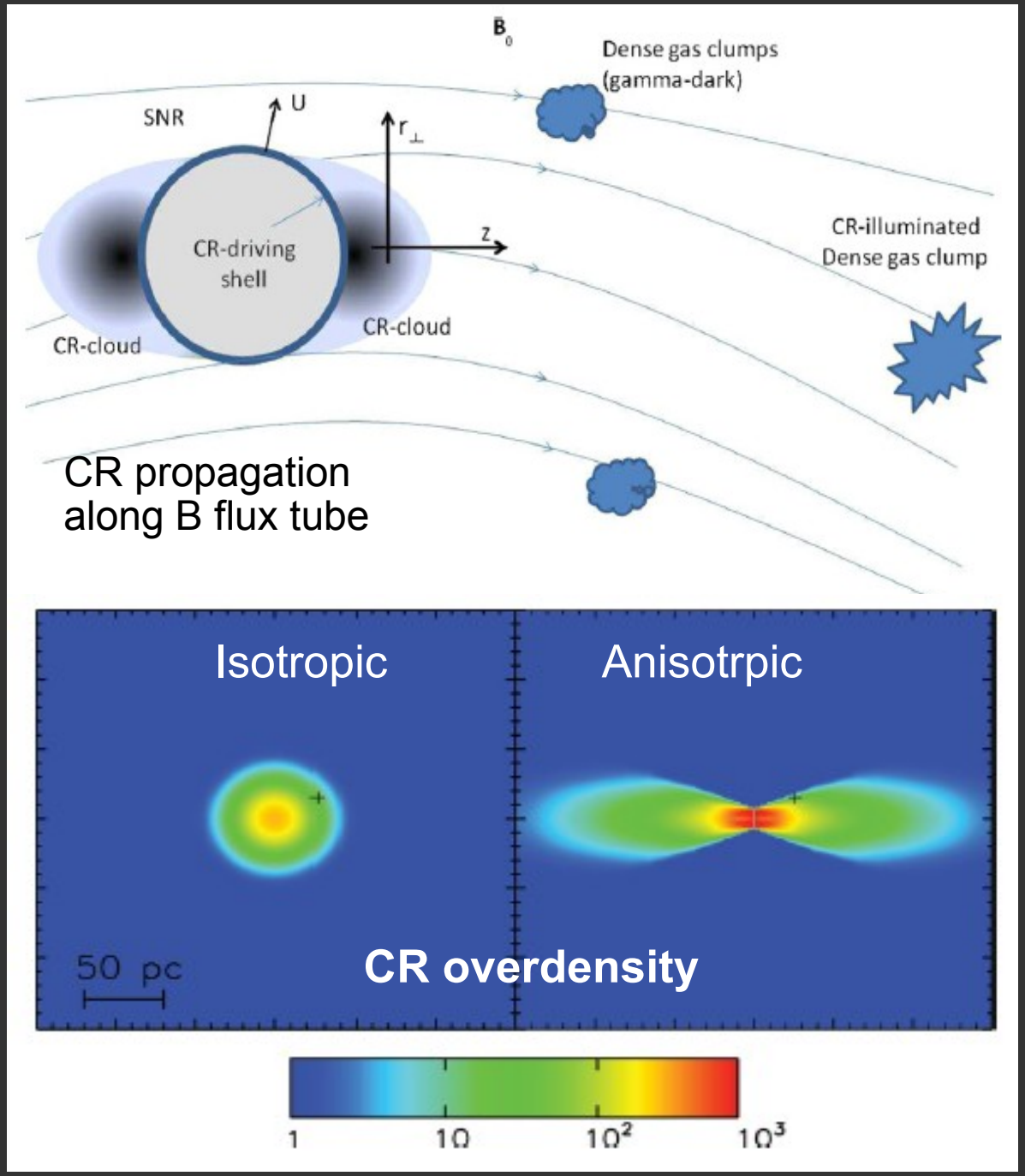
$t_{esc} \sim (E/E_{max})^{2.3}$

Age = 1600 yr,
d = 1 kpc

Slow diffusion
D = 10^{26} cm^2/s



→ **Expect ~degree-scale TeV emission**



CR diffusion – not necessarily Isotropic!

Malkov etal 2013
Nava & Gabici 2013

→ Nearby clouds will see different CR densities

→ Need detailed maps of ISM gas + B-field direction

Gamma-Rays from Escaping Cosmic-Rays

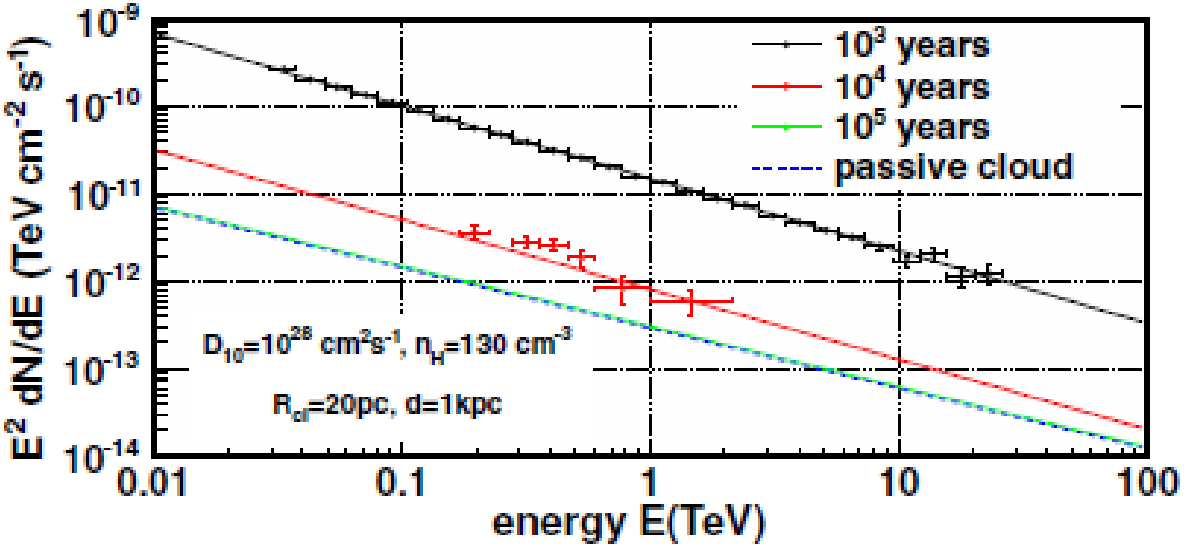
e.g. Aharonian & Atoyan 1996, Gabici etal 2009, Casanova etal 2010 Malkov etal 2013, Nava & Gabici 2013

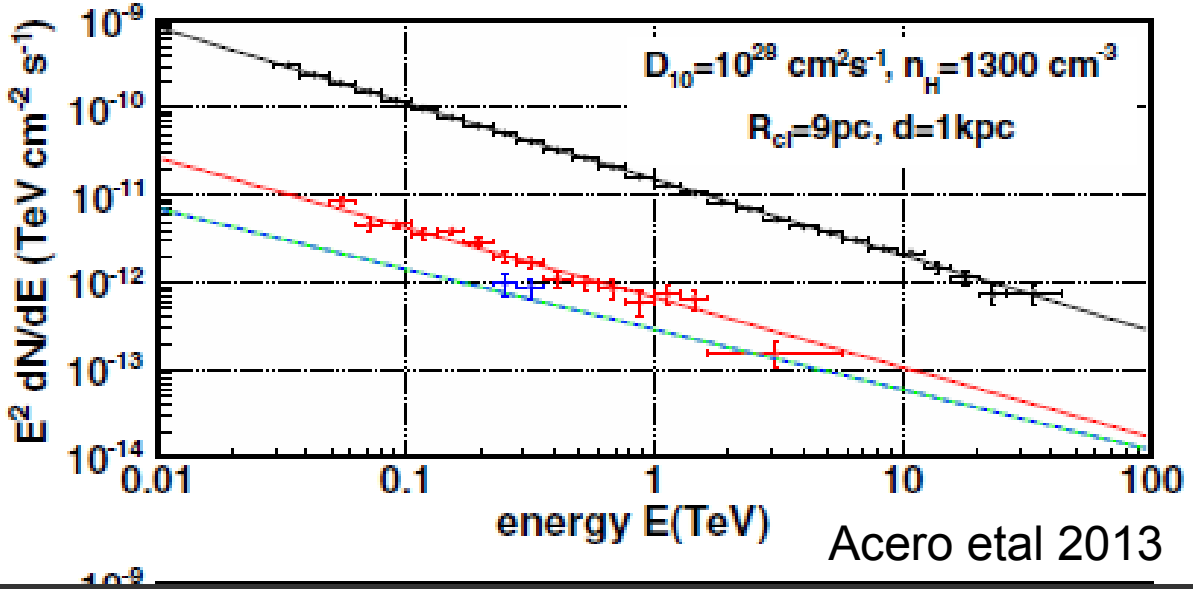
CR accelerator inside cloud 10^5 M_{sun}

CTA Detections (50hr)

→ Passive clouds nearby CR accelerators detectable by CTA

→ Need arc-min ISM maps to disentangle CTA survey sources

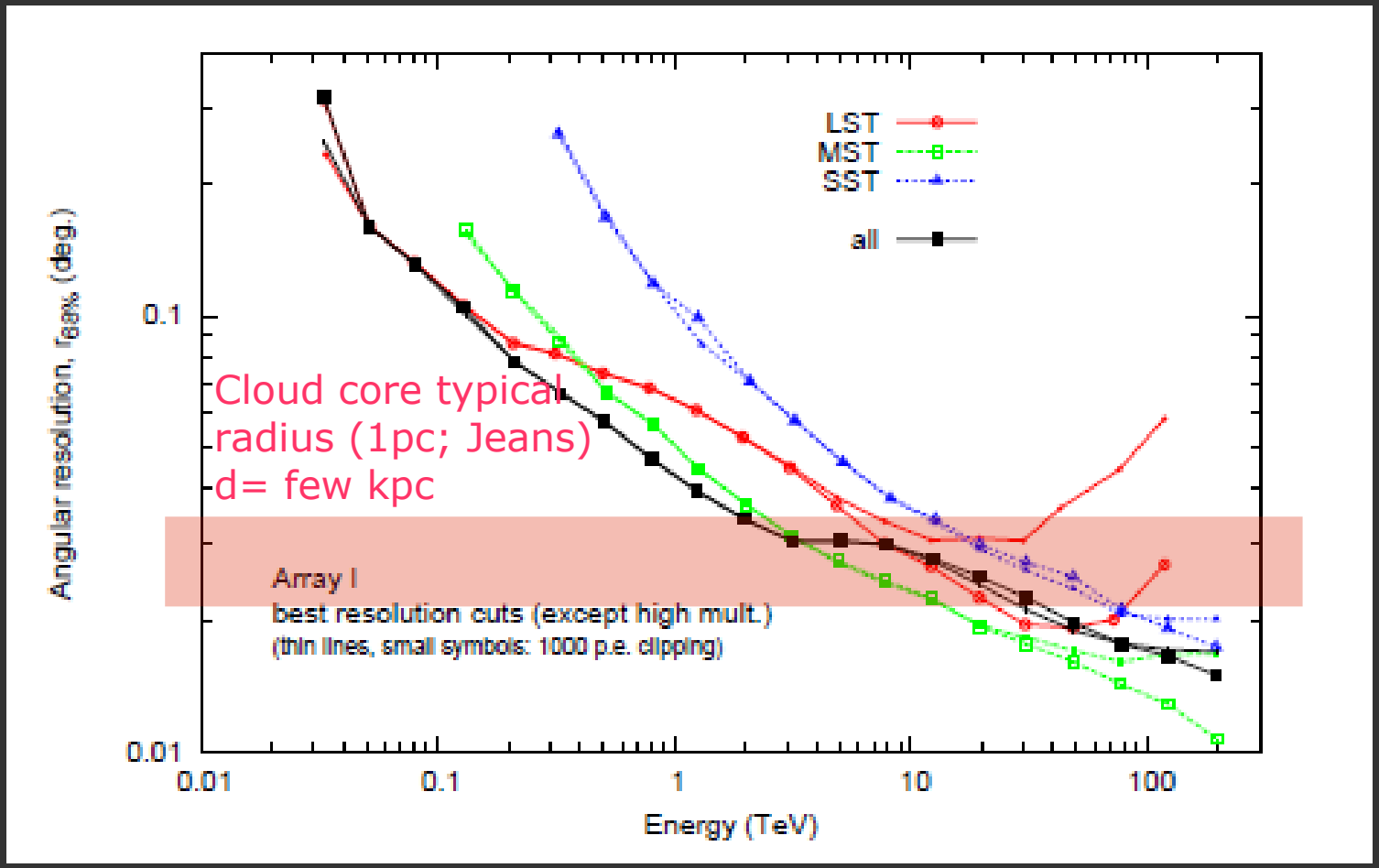




Acero etal 2013

CTA Angular Resolution

Bernloehr etal 2013



→ **Arc-min resolution!**

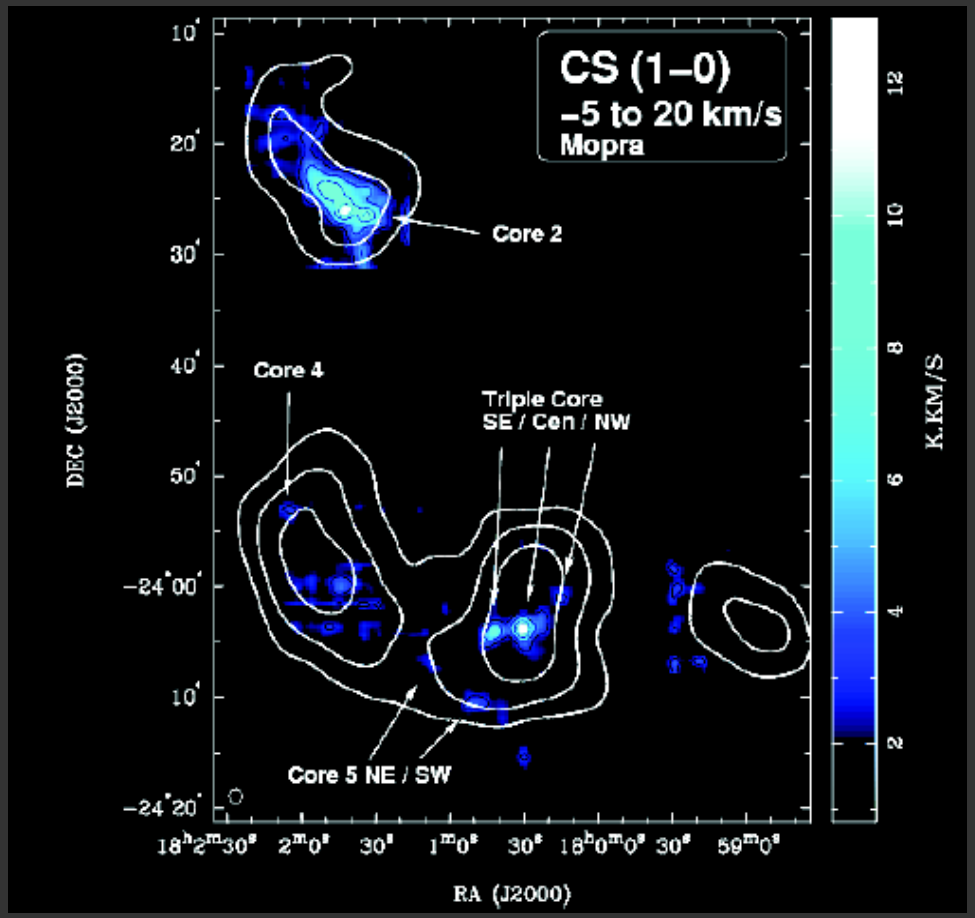
→ **CTA may detect & resolve molecular cloud cores (few 100M_{sun} near CR accelerators)**

Molecular Gas towards TeV Sources e.g. Mature SNRs

(e.g. Nicholas et al 2011, 2012, Maxted et al 2013)

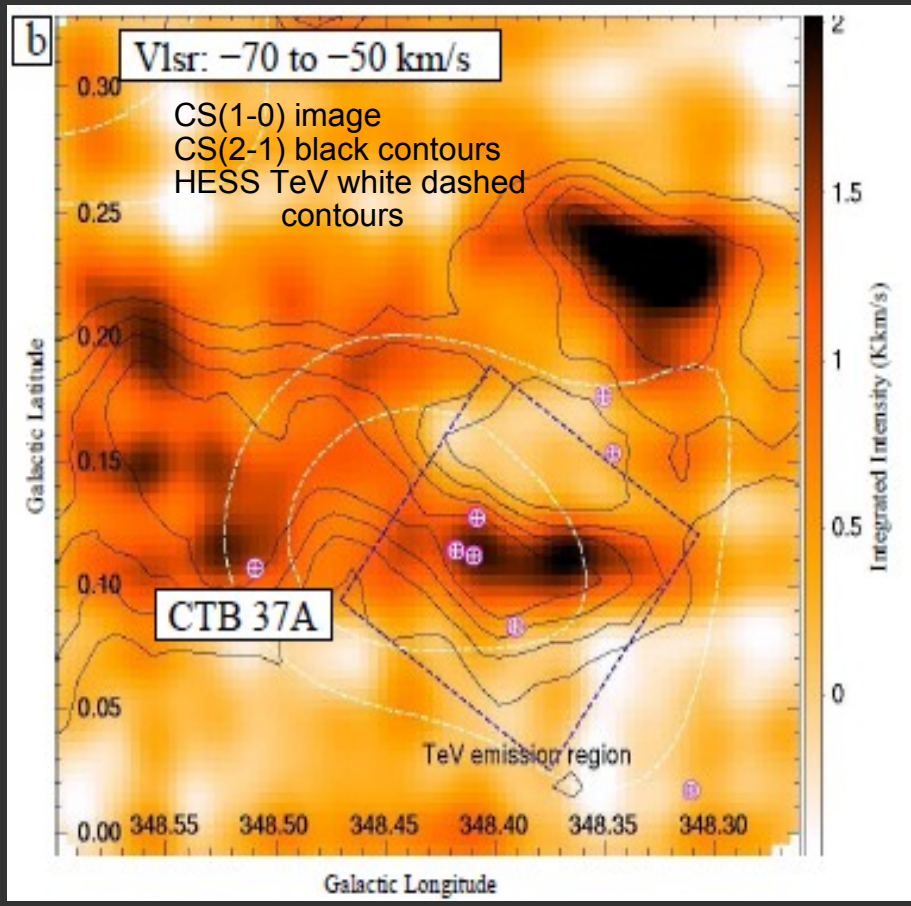
W28

Good TeV/ISM match



CTB 37A

Partial TeV/ISM match

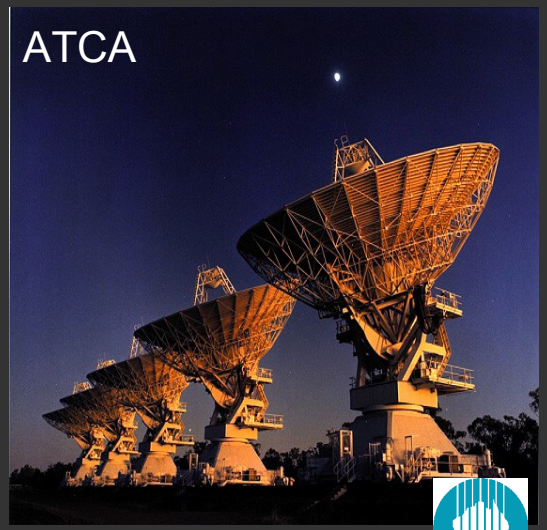


How do we trace the gas? Use radio lines...

HI (atomic H)

Gas density

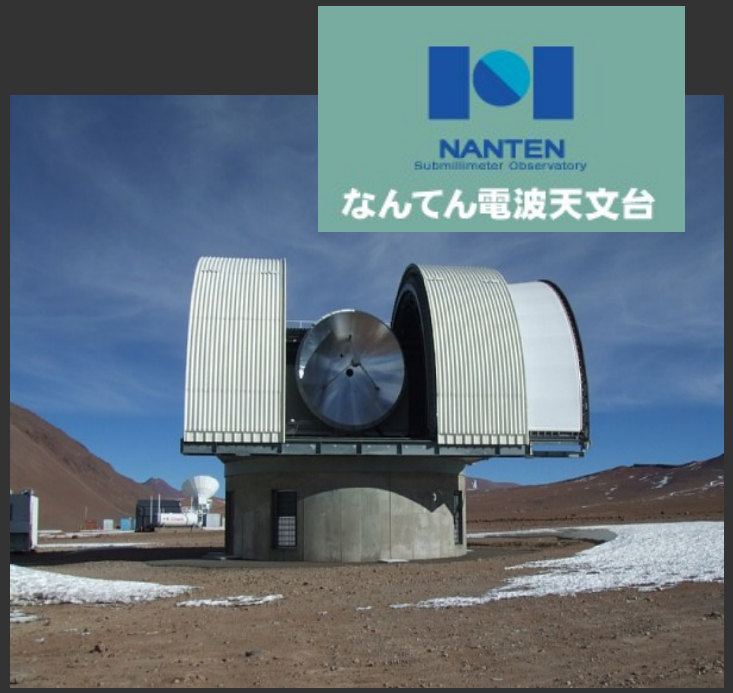
~$10^{1 \text{ to } 2}$ cm^{-3}



CO (H_2)

~10^3 cm^{-3}

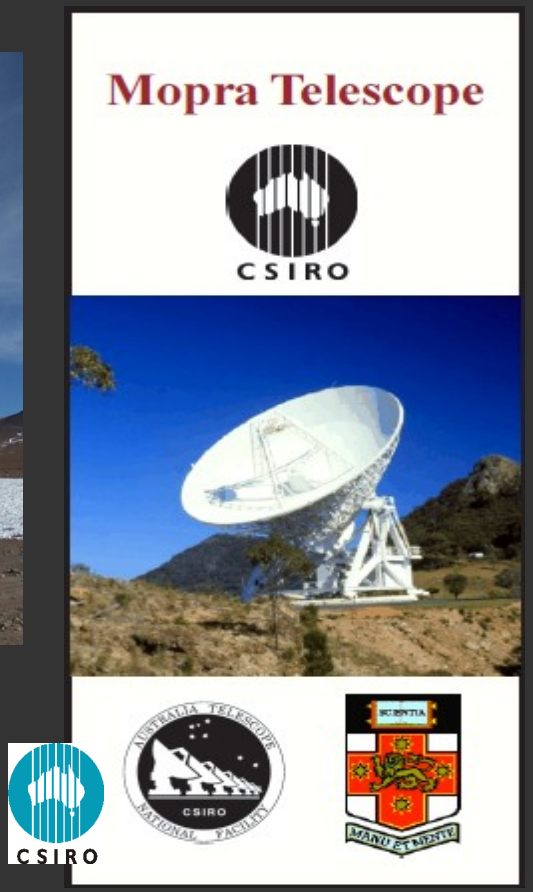
4' beam FWHM



NH_3, CS, SiO... (H_2)

>10^4 cm^{-3}

CO as well!



HEAT

STO

Tracing atomic and ionised Carbon

[CII] + [NII] + [CI] + CO(7-6) Freq 400 to 1900 GHz

CTA – Australian Interests

- Relevant ISM surveys/studies (talk: Burton)
- Array layout and analysis techniques (talk: Stamatescu)
- Camera hardware (talks: Clay, Jackson)
- Atmospheric characterisation (talk: Veitch)
- Astroparticle physics – dark matter (talk: White)
- Radio facilities in Australia (talk: Edwards)
- Theoretical high energy astrophysics
- X-ray astronomy

Institution	Personnel (+ FTE)	Expertise	CTA Work Package(s)
University of Adelaide	Gavin Rowell (0.1), Res.Assoc.[1] (0.1), PhD student[2] (0.1), Bruce Dawson (0.05), Roger Clay (0.1), Neville Wild (technician 0.05), Martin White (0.05), David Ottaway (0.05), Peter Veitch (0.05),	γ-ray, millimetre, CR, neutrino astronomy, astrophysics theory, particle physics, LIDAR systems, atmospheric monitoring, detectors, electronics	MC, PHYS, OBS, ATAC, SITE, FPI
University of New South Wales	Michael Burton (0.1), Catherine Braiding (0.1)	millimetre, sub-millimetre, infrared astronomy, antarctic astronomy	PHYS, ATAC, OBS
University of Sydney	Anne Green (0.05), Sean Farrell (0.05)	radio astronomy	PHYS, OBS
Australian National University	Geoff Bicknell (0.1), Roland Crocker (0.1)	γ-ray, neutrino astrophysics theory	PHYS, OBS
Monash University	Duncan Galloway (0.05), Csaba Balazs (0.05)	X-ray astronomy, particle and astroparticle physics	PHYS, OBS
University of Western Sydney	Miroslav Filipovic (0.05), Nick Tothill (0.05)	γ-ray, X-ray, radio astronomy	PHYS, OBS

1. Research Associate commencing from Sept. 2013 for $\geq$4 months.
2. Based on current in-kind contributions from 2 PhD students.

Table 1: Australian Consortium for CTA Associated Party Membership. FTE estimates are for 2013+.

Institution	Personnel (+ FTE)	Expertise	CTA Work Package
University of Adelaide	Ray Protheroe, Gary Hill, Greg Thornton, Paul Jackson, Anthony Thomas, Anthony Williams, Derek Leinweber, Ross Young, Murray Hamilton	neutrino astronomy, astrophysics theory, astroparticle theory, particle physics, LIDAR systems, atmospheric monitoring,	MC, PHYS, OBS, ATAC, FPI, SITE
University of New South Wales	Michael Ashley, Yvonne Wong	infrared astronomy, remote monitoring, antarctic astronomy, astroparticle theory	PHYS, OBS, SITE
University of Sydney	Davide Burlon, Kevin Varvell, Bruce Yabsley	X-ray, radio astronomy, particle physics	PHYS
Monash University	Jasmina Lazendic, Alina Donea	infrared, X-ray, γ-ray, millimetre, neutrino astronomy, astrophysics theory, astroparticle theory	PHYS, OBS
Curtin University	Andrew Walsh	millimetre, sub-millimetre astronomy	PHYS, OBS
University of Melbourne	Geoff Taylor, Elisabetta Barberio, Martin Sevior, Ray Volkas, Nicole Bell, Andrew Melatos	astroparticle and particle physics, cosmology	PHYS

Table 2: Additional personnel expressing an interest in CTA.