CTA and the ISM

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THE UNIVERSITY OF ADELAIDE
AUSTRALIA
SUB CRUCE LUMEN

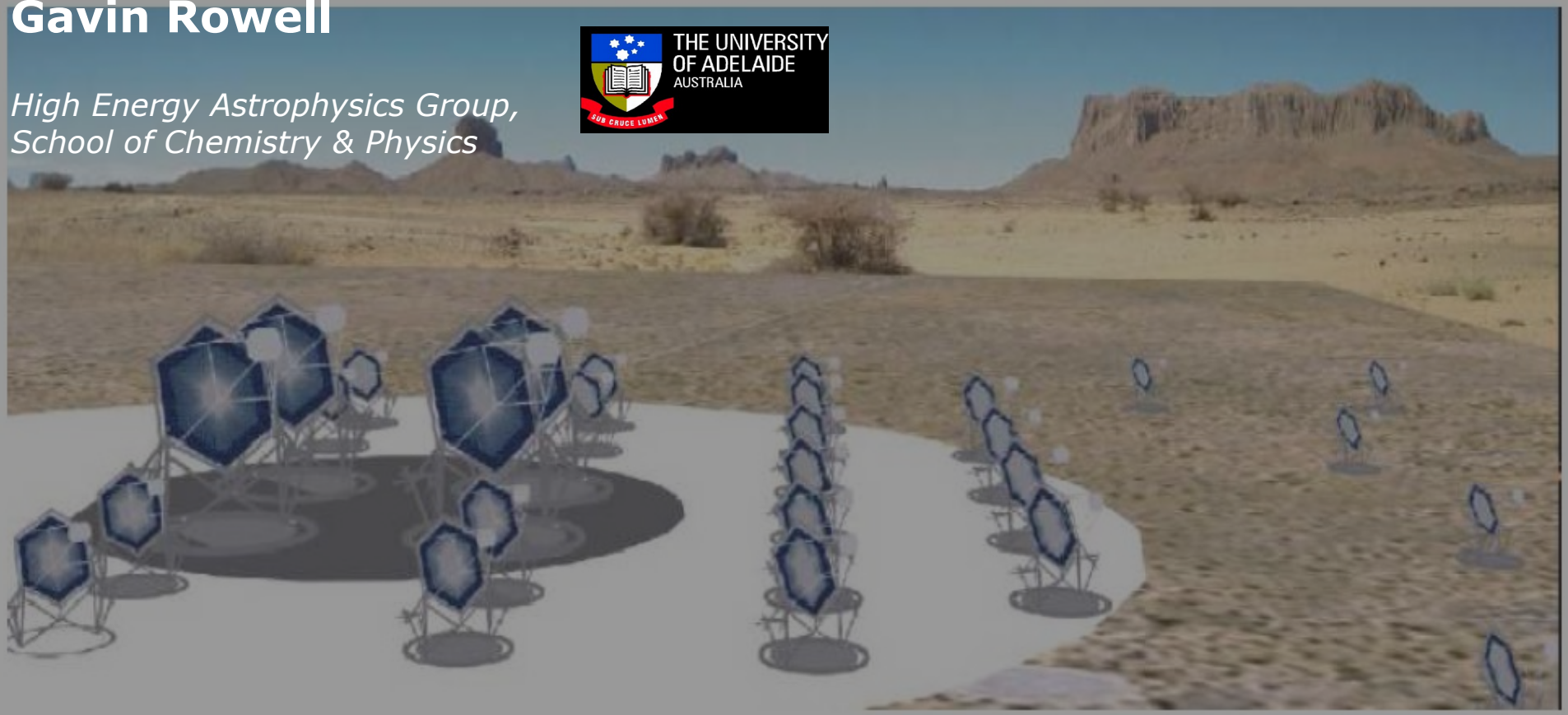
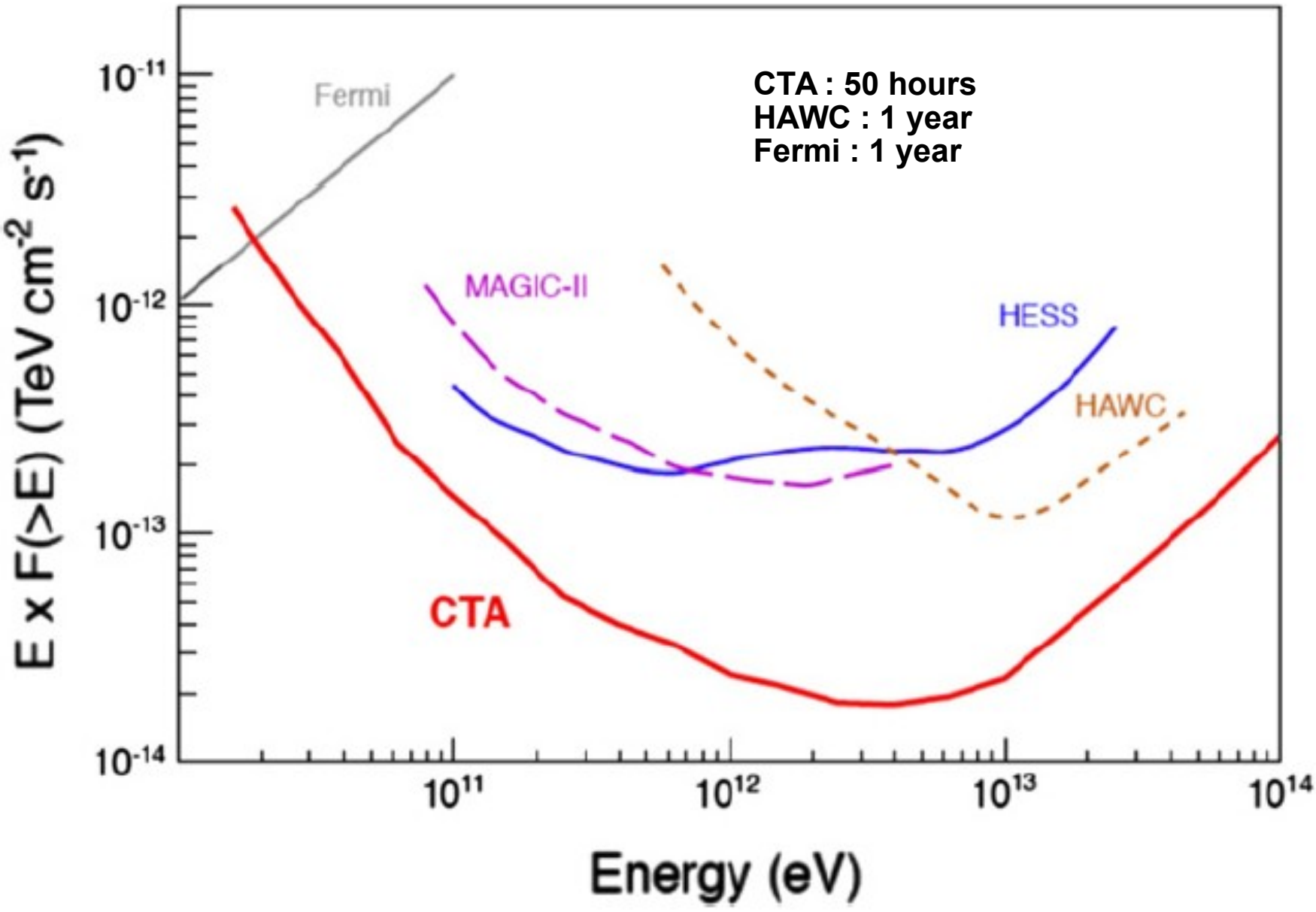


Figure 3: Artistic view of the compound different size telescopes CTA system. The area coverage is of $1 - 10\ \mathrm{km}^2$.

Nanten2 Meeting (Adelaide) Feb. 2014

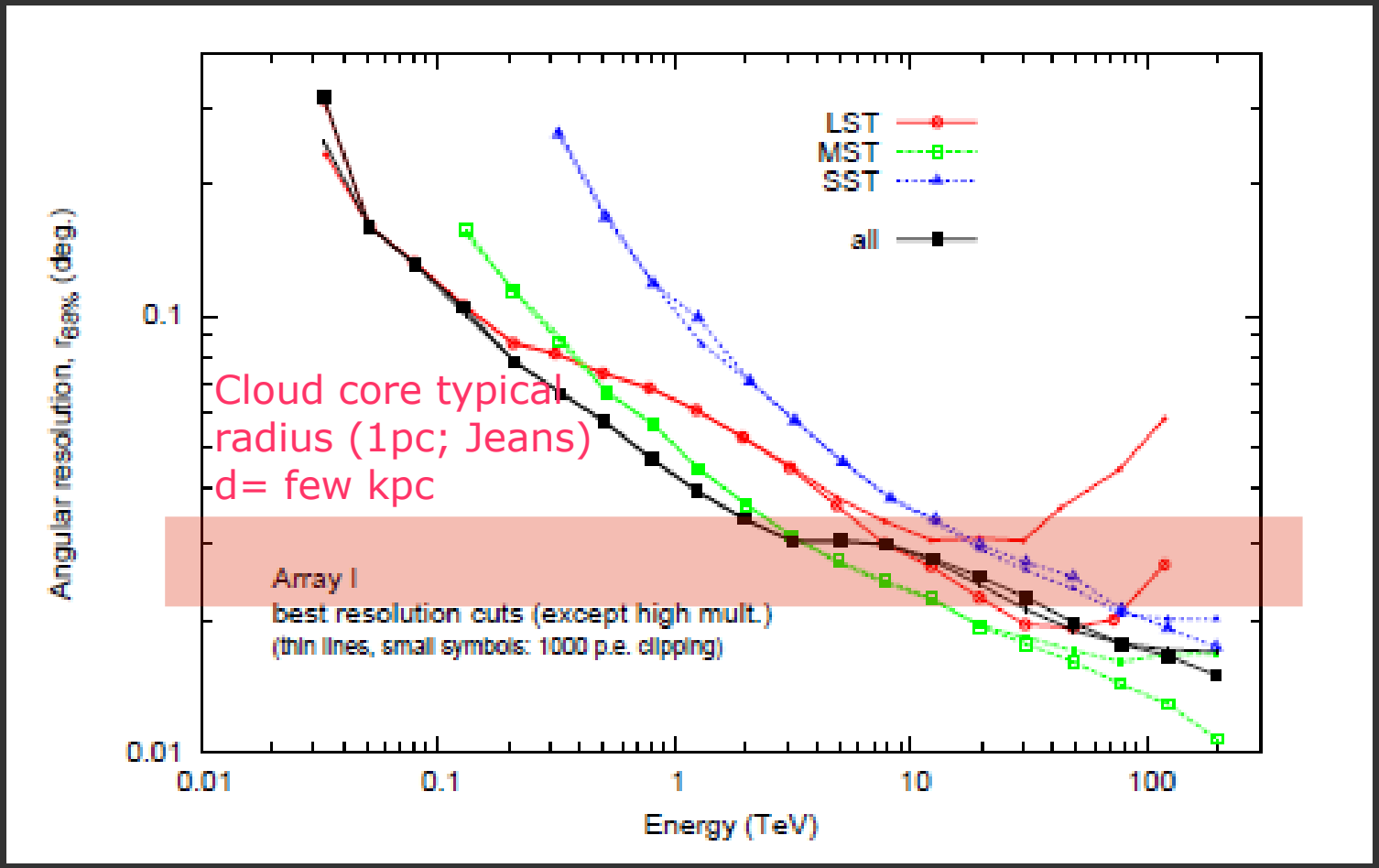
CTA Integral Flux Sensitivity

Bernloehr etal 2013



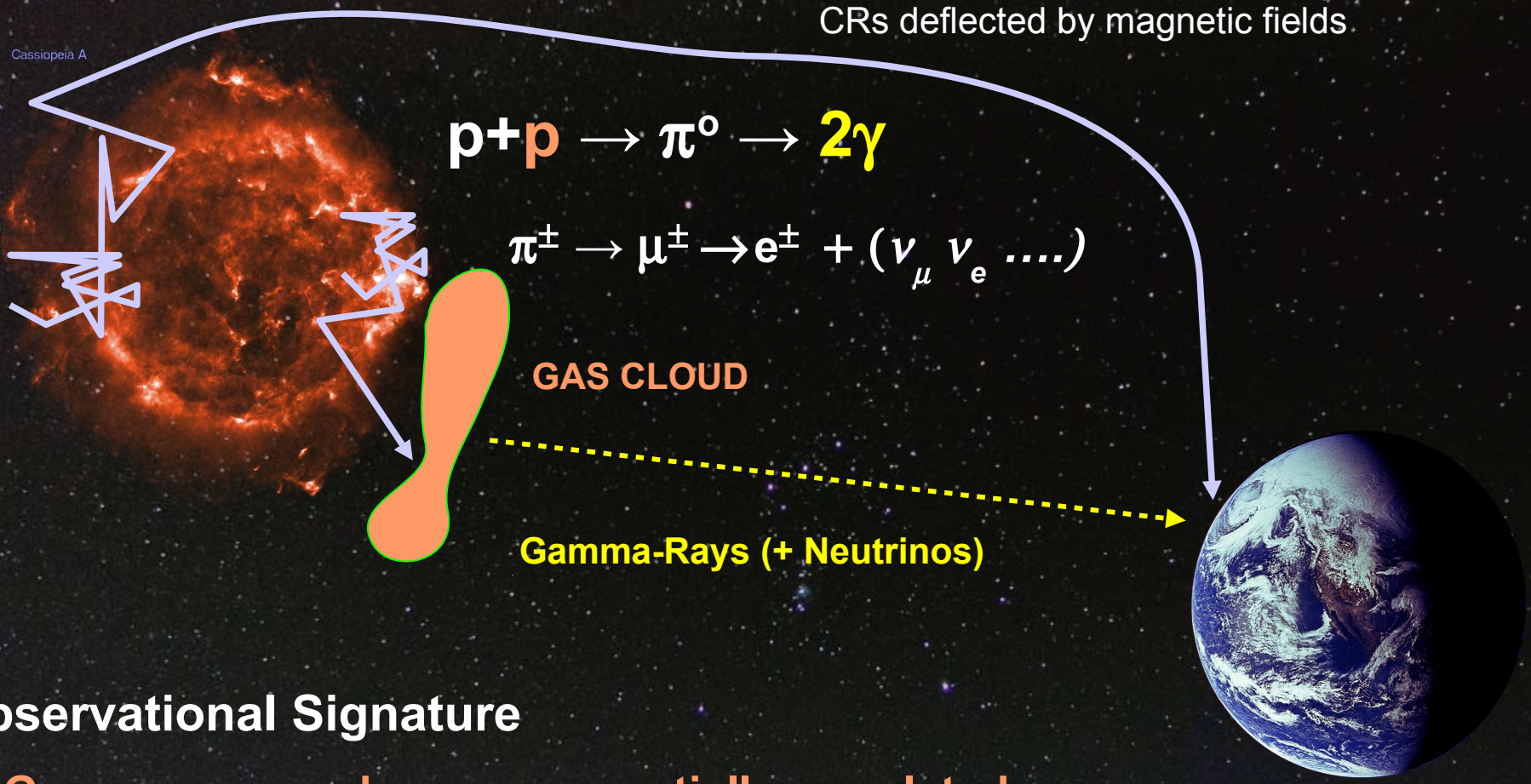
CTA Angular Resolution

Bernloehr etal 2013



→ CTA will likely detect and possibly resolve molecular cloud cores (few 100M_{sun} near CR accelerators)

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

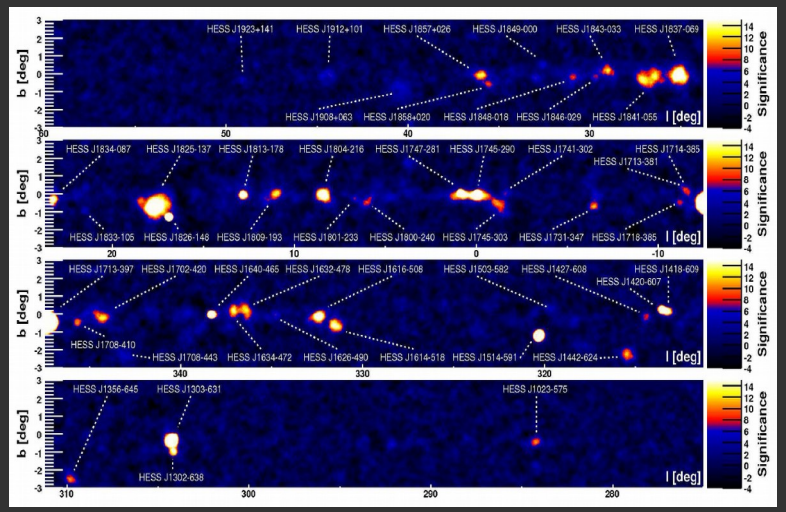


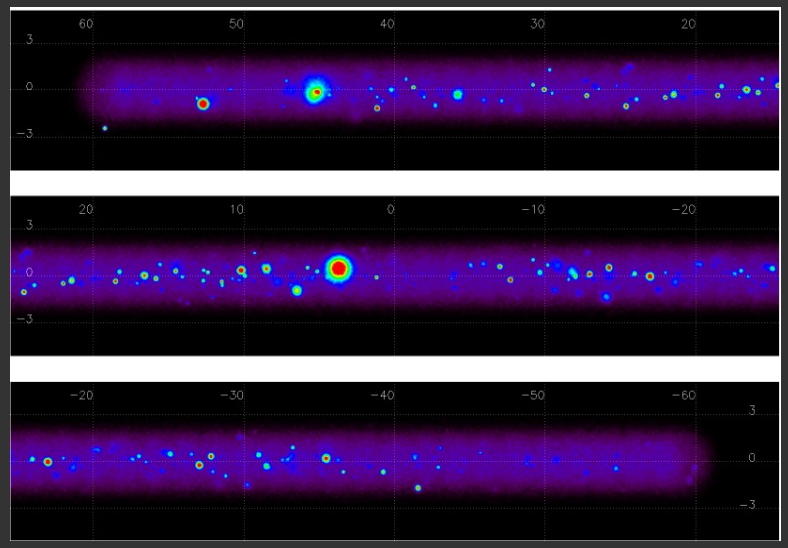
Observational Signature

→ Gamma-rays and gas are ~ spatially correlated
(need to measure gas in all chemical states)

→ 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





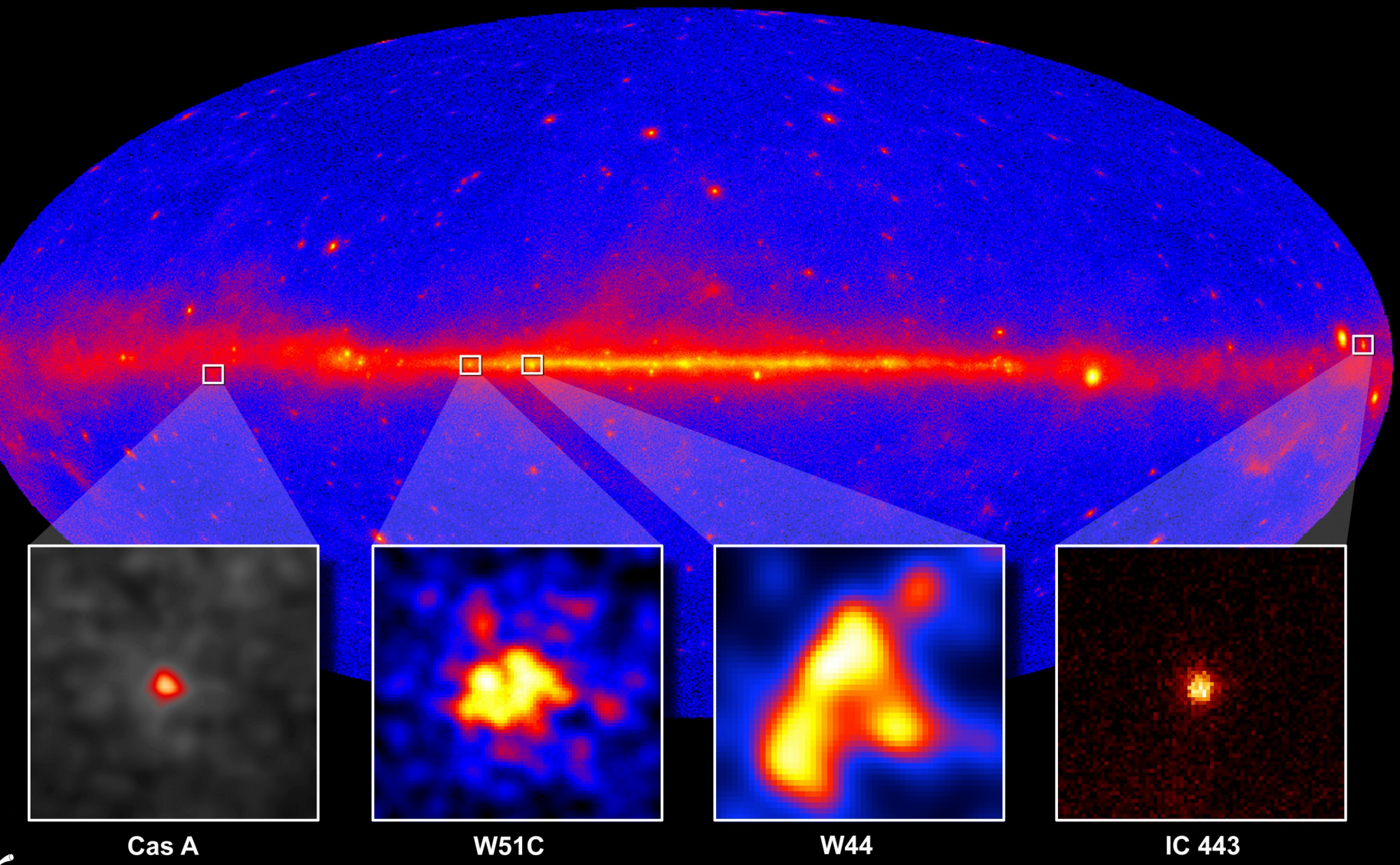
- CTA will provide Galactic Plane TeV Gamma-ray maps on ~1-3 arc-min scales.

- >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

NASA's Fermi telescope resolves supernova remnants at GeV energies



Cas A

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W44

IC 443

Fermi
Gamma-ray
Space Telescope

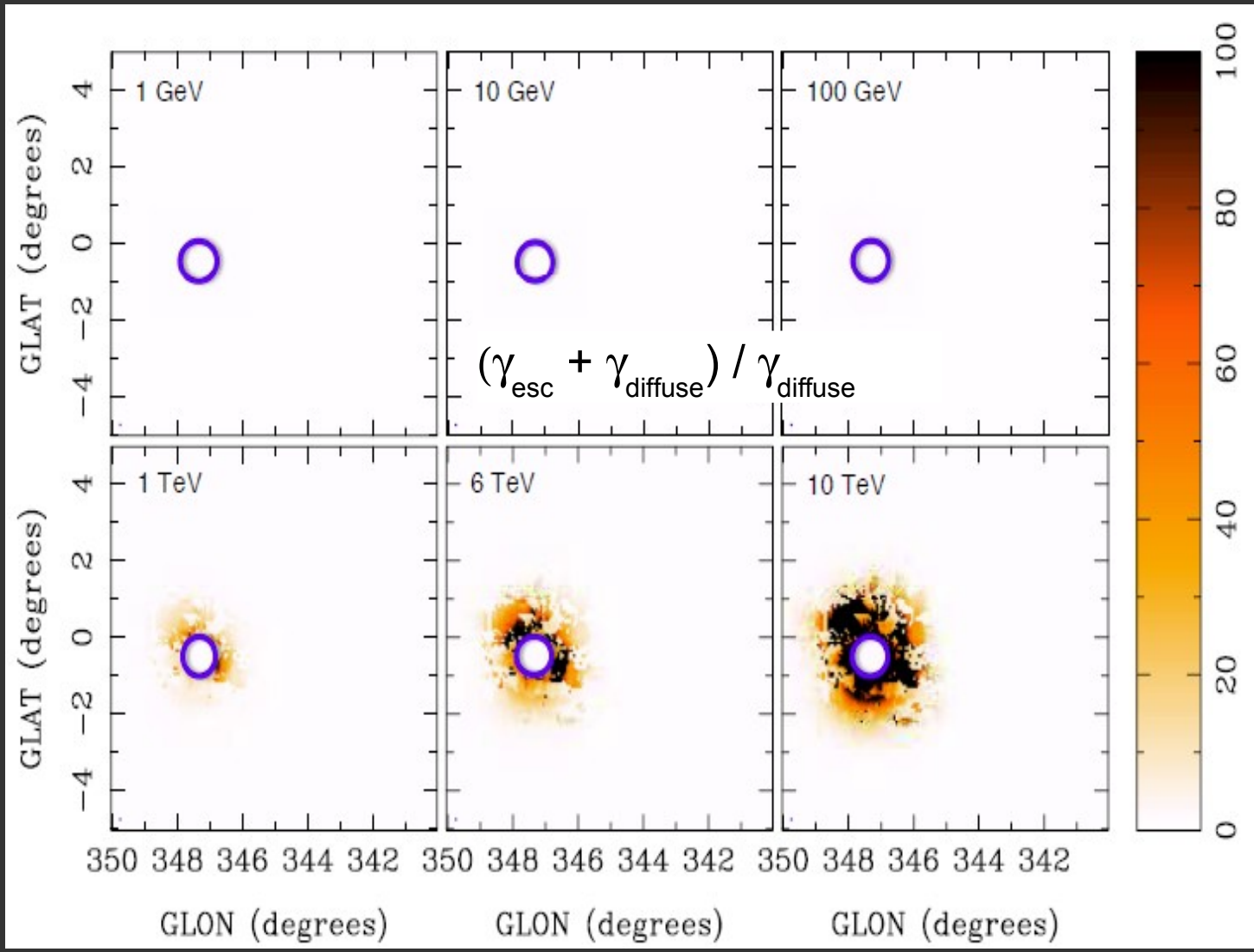
Gamma-Rays from Escaping Cosmic-Rays

Casanova etal 2010
(Gabici etal 2009)

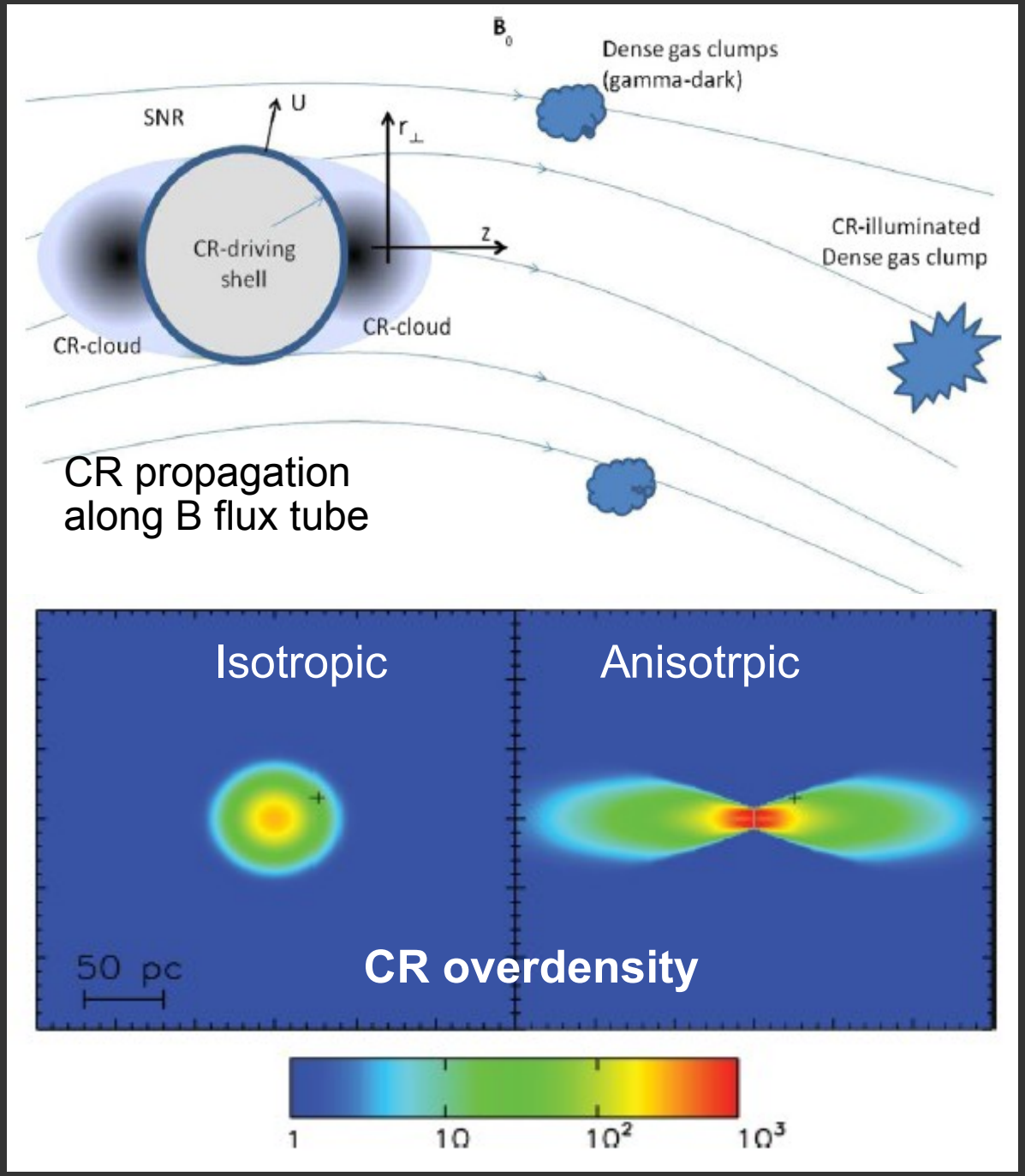
$t_{esc} \sim (E/E_{max})^{2.3}$

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

CR Diffusion *Into* Molecular Clouds

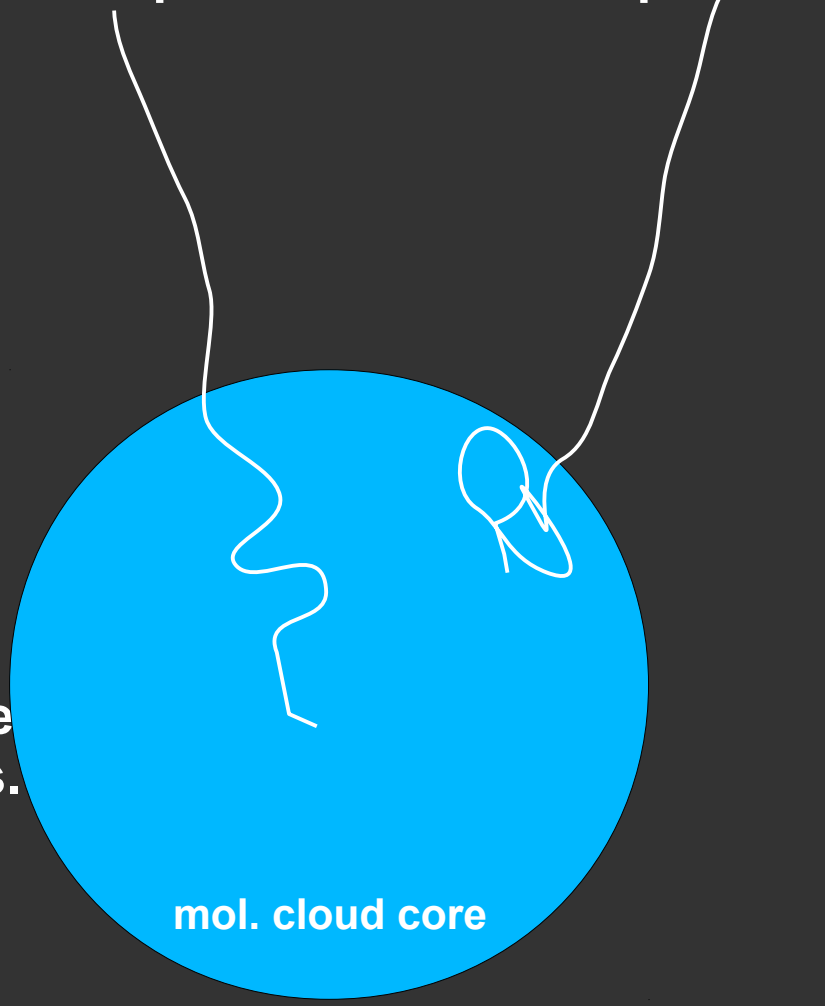
Gabici etal 2007

R = distance CR travels into molecular cloud core

$$R = 0.62 - \sqrt{6D(E_P, B)[1600 - t_0]} \quad [\mathrm{pc}]$$

$$D(E_P, B(r)) = \chi D_0 \left(\frac{E_P/\mathrm{GeV}}{B/3\,\mu\mathrm{G}} \right)^{0.5} \quad [\mathrm{cm}^2\,\mathrm{s}^{-1}],$$

$$B(n_{H_2}) \sim 100 \sqrt{\frac{n_{H_2}}{10^4\ \mathrm{cm}^{-3}}} \quad [\mu\mathrm{G}]$$



χ=diffusion suppression

→ Low energy CRs can't reach cloud core
→ Expect harder TeV spectra from cores.
→ *Don't expect electrons to penetrate!!*
(due to sync. losses)

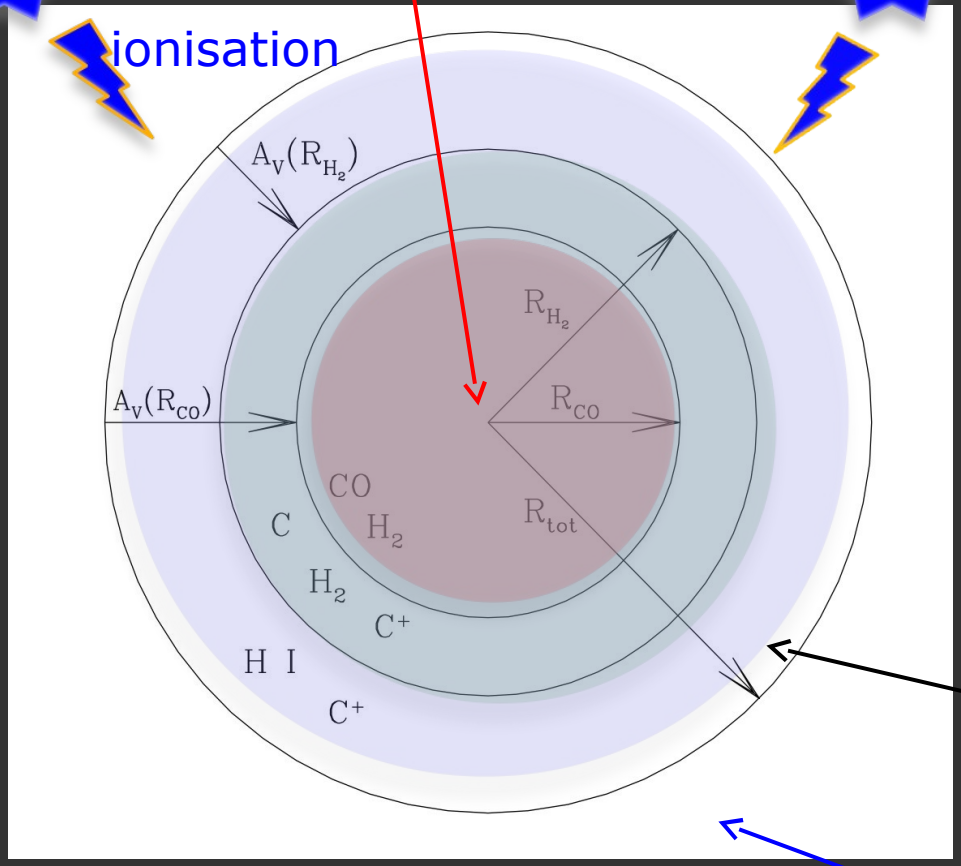
→ Need to map dense cloud cores

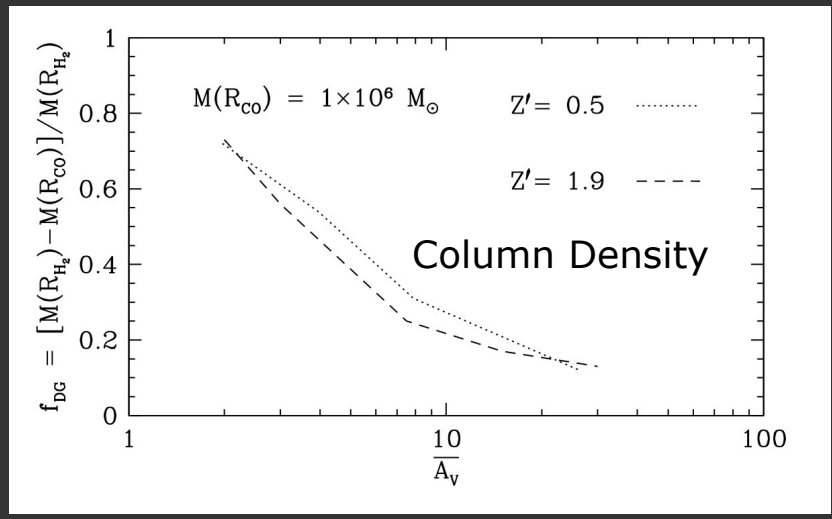
Missing Molecular Gas :"Dark" H_2

Inferred by MeV/GeV gamma-ray observations
e.g. Greiner etal 2005, Ackermann etal 2011

Perhaps one-third of the molecular gas is "dark"?!

'Normal' CO Molecular Gas





Dark molecular gas.
No CO, but carbon still present
→ CI, C+ ~THz lines

Wolfire, Hollenbach & McKee, 2010

Atomic Gas

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

HI (atomic H)

Gas density

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

CO (H_2) CI

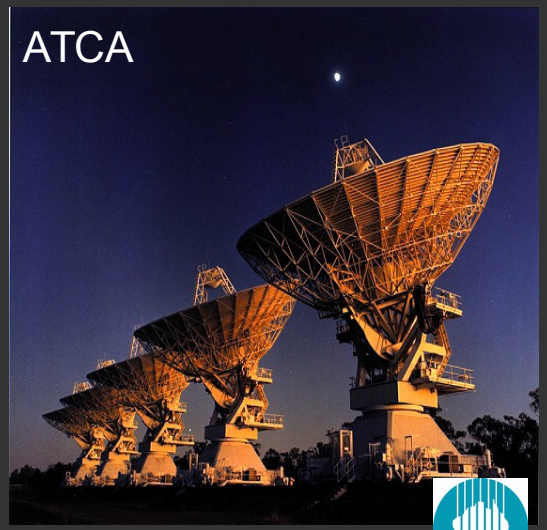
>~10^3 cm^{-3}

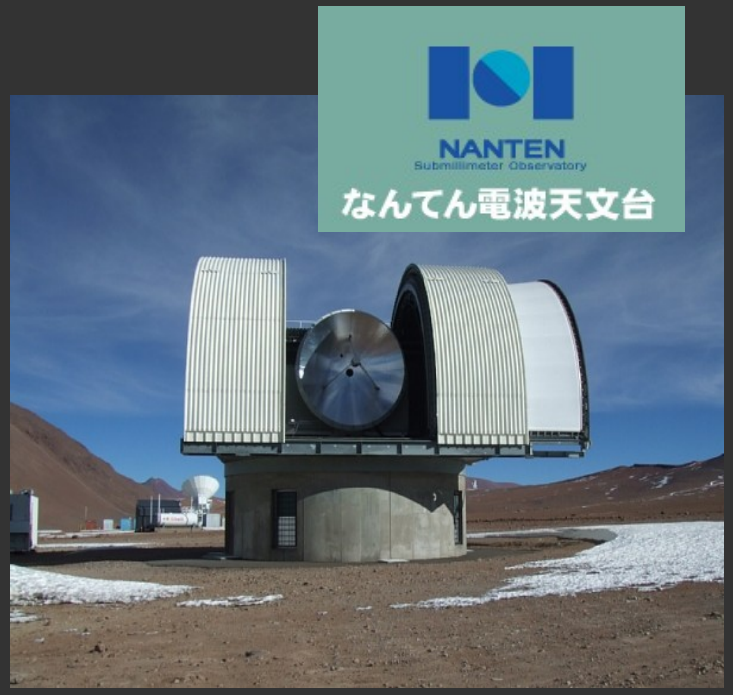
1-4' beam FWHM

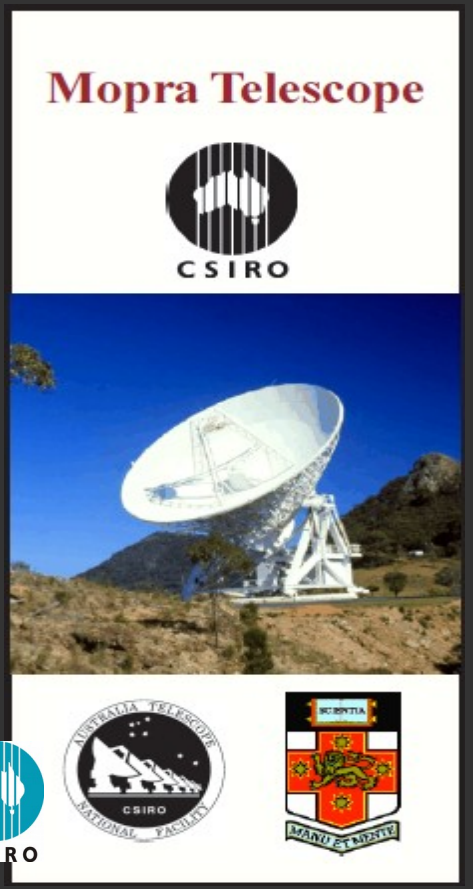
NH_3, CS, SiO... (H_2)

>10^4 cm^{-3}

CO as well!







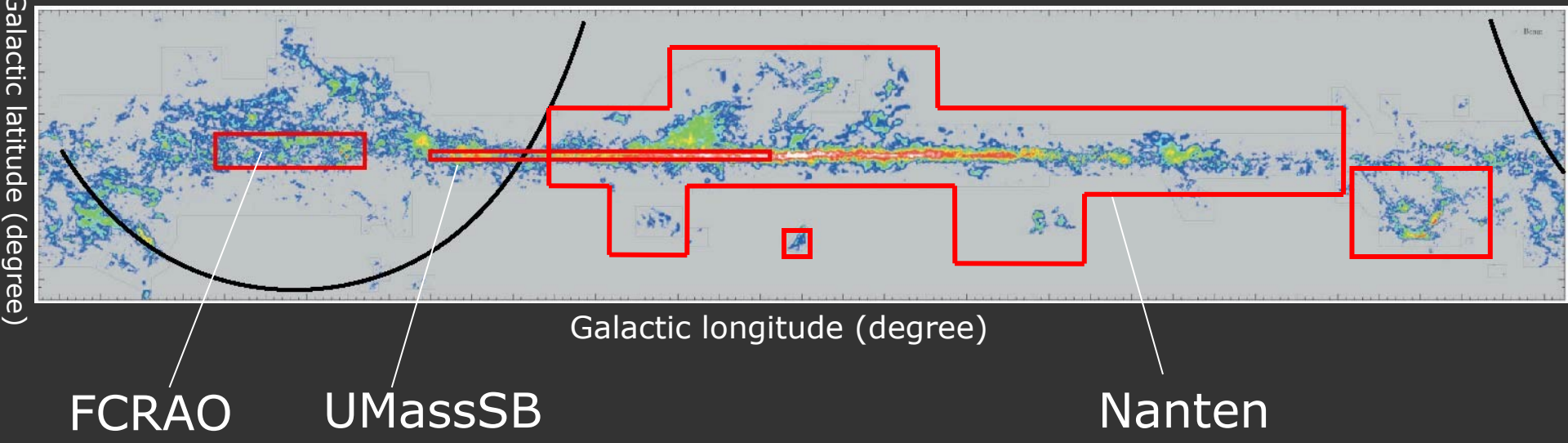
HEAT

STO

Tracing atomic and ionised Carbon

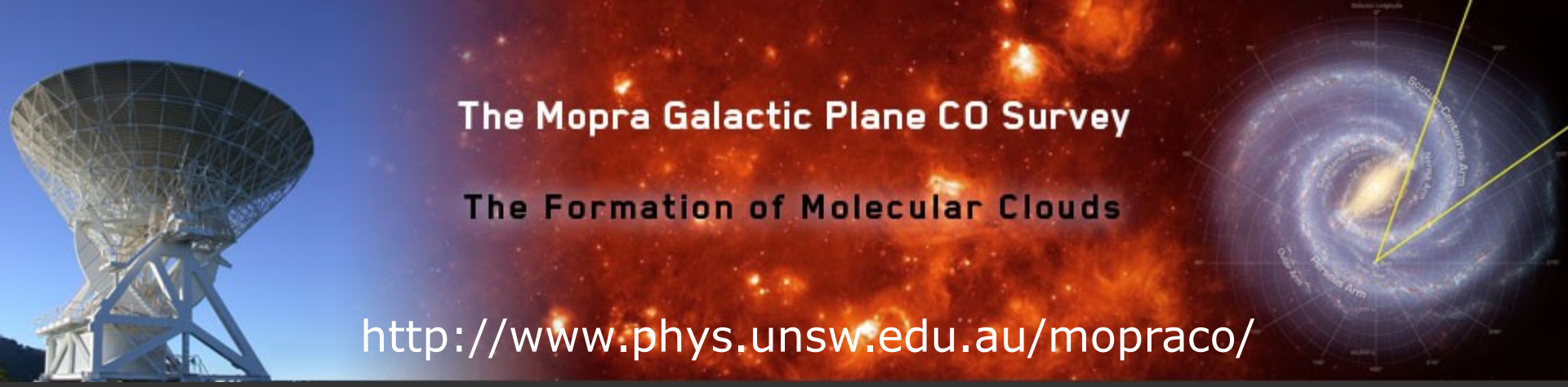
[CII] + [NII] + [CI] + CO(7-6) Freq 400 to 1900 GHz

CO Galactic plane surveys



name	diam.	beam	grid	lat. range	covered area
Columbia	1.2m	8.7′	8-15’	|b| < 10-25°	(complete)
Mass.-S.B.	14m	45″	3-6’	|b| < 1°	(inner Galaxy, ^{13}CO)
FCRAO	14m	45″	50”	|b| < 4°	(outer Galaxy)
Nanten	4m	2.6′	4-8’	|b| < 10-25°	(220°< l < 60°)
Nanten2	4m	2.6'	1'	Most of south sky CO(1-0), ^{13}CO(1-0)	
(NASCO)		1.3'	0.5'		CO(2-1) .^{13}CO(2-1) CI, CO(4-3)

Note: Columbia & Nanten surveys not fully (Nyquist) sampled!



IF	Frequency (GHz)	Isotopologue	V_{low} (km/s)	V_{high} (km/s)
1+2	110.1	^{13}CO (1-0)	-475	+270
3+4	109.7	C^{18}O (1-0)	-495	+255
5	112.3	C^{17}O (1-0)	-235	+130
6+7+8	115.2	^{12}CO (1-0)	-550	+525

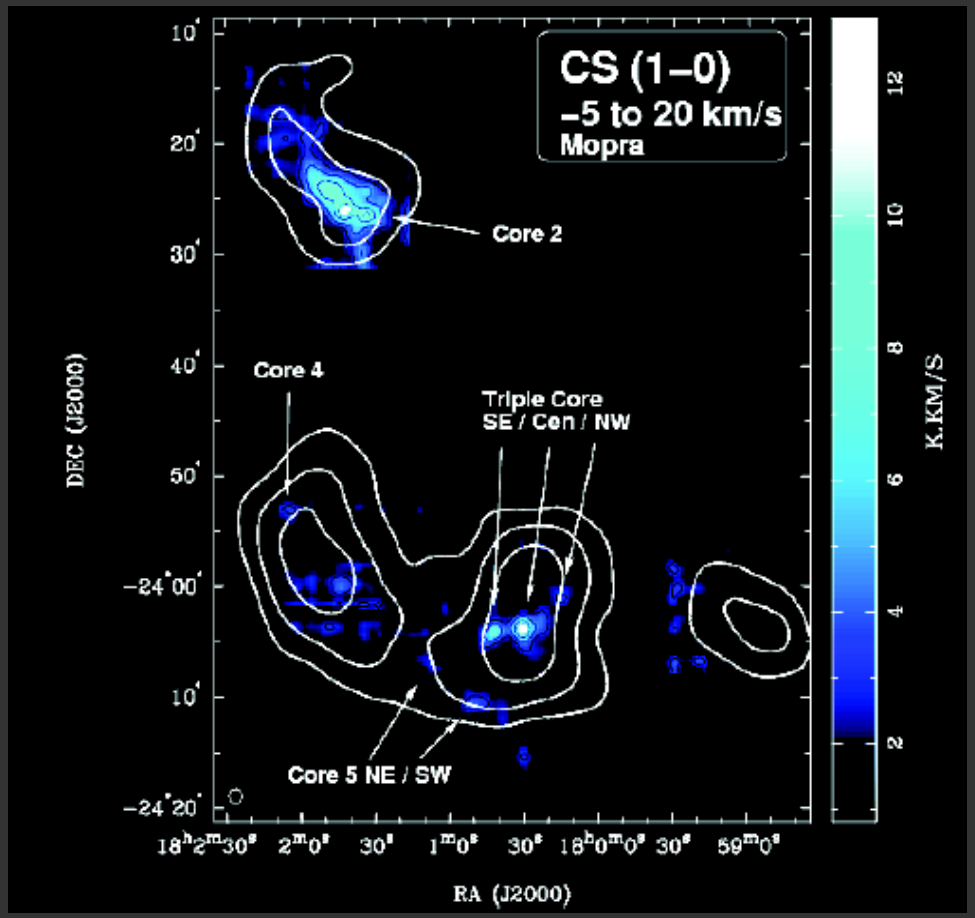
~35” Beam @ ~0.1 km/s resolution
Complementary to new Nanten2 CO surveys

Molecular Gas towards TeV Sources e.g. Mature SNRs

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

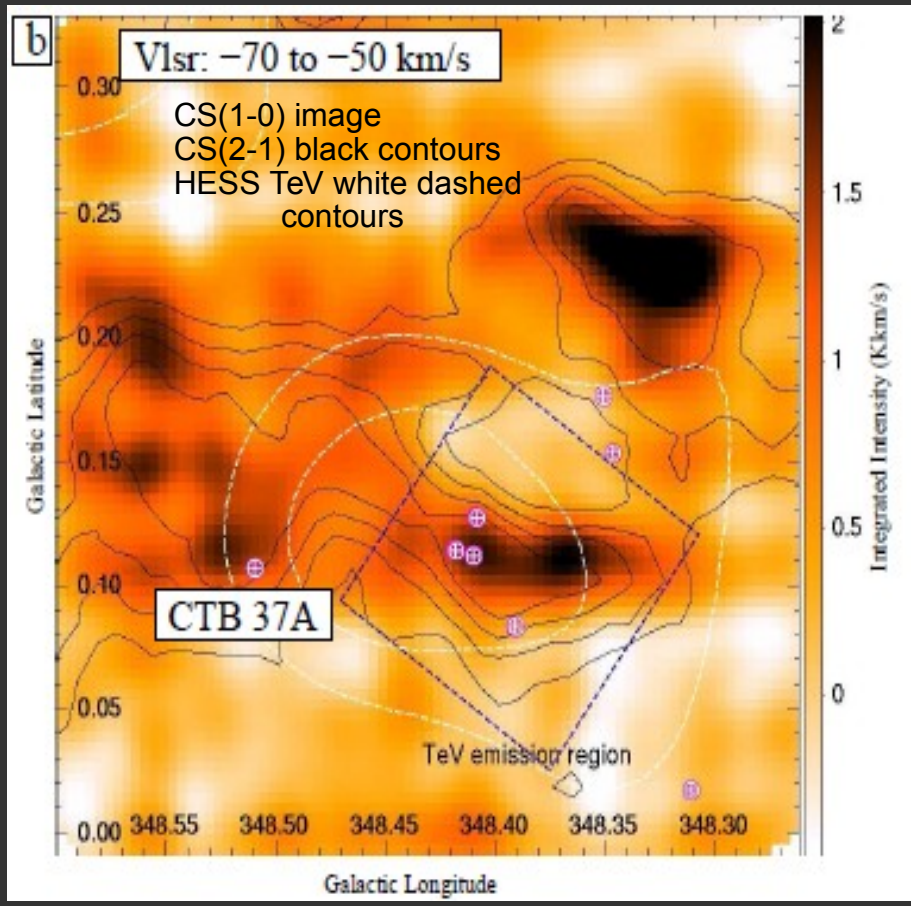
W28

Good TeV/ISM match



CTB 37A

Partial TeV/ISM match



Mopra HOPS + HESS TeV Surveys DeWilt etal 2012,2013

HESS J1745-303

HOPS

Survey of NH_3, H_20 masers, plus other 12mm lines

Walsh etal 2011,
Purcell etal 2012

http://awalsh.ivec.org/hops/public/index.php

Where are the ions in pulsar Winds?

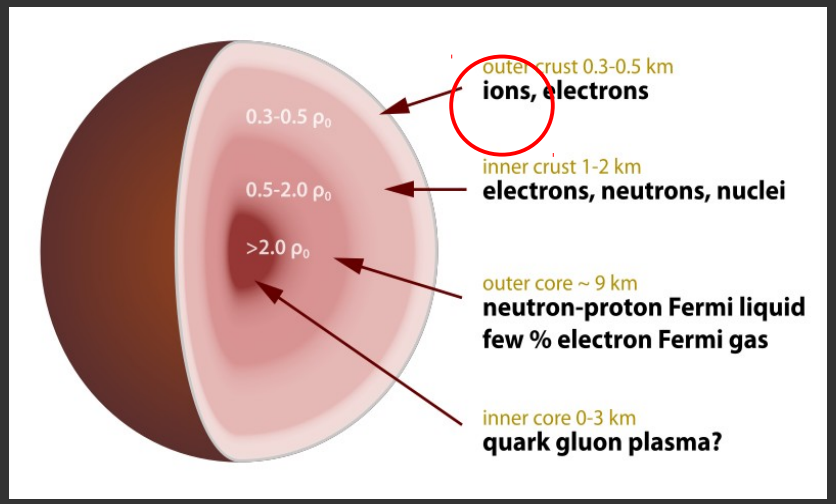
- **Ions expected in pulsar winds?**
  e.g. Gallant & Arons 1994
- **Only indirect evidence X-ray wisps**
  Gaensler etal 2002

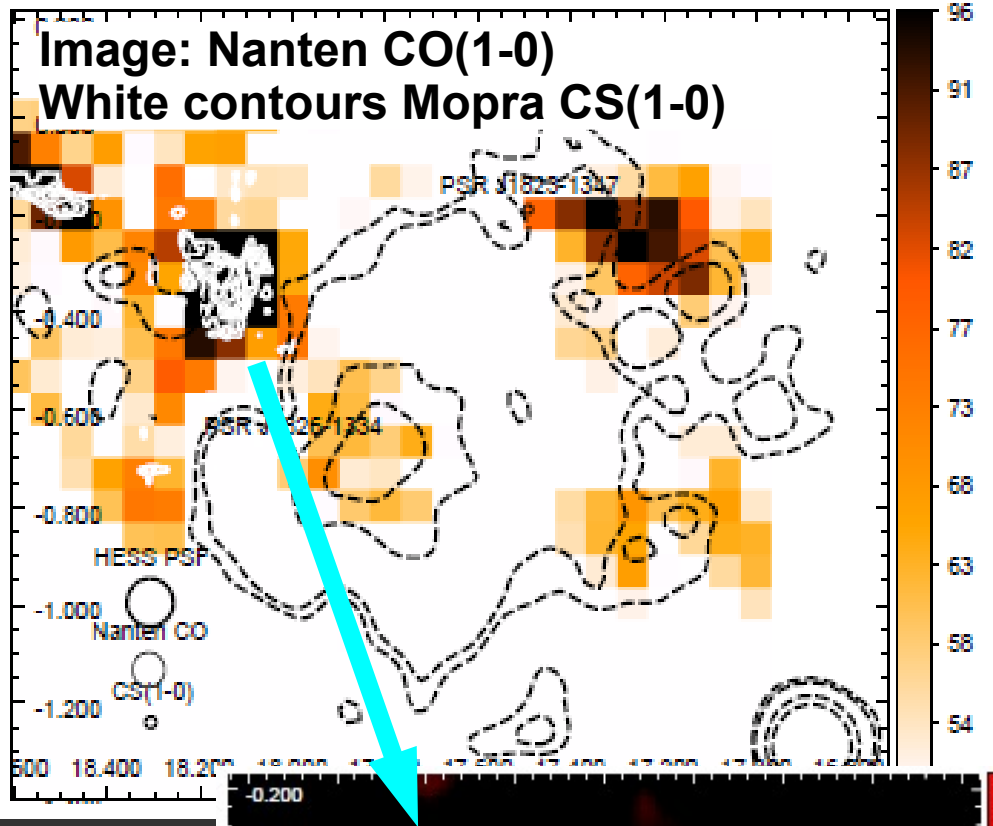
→ **Look at dense mol. gas**

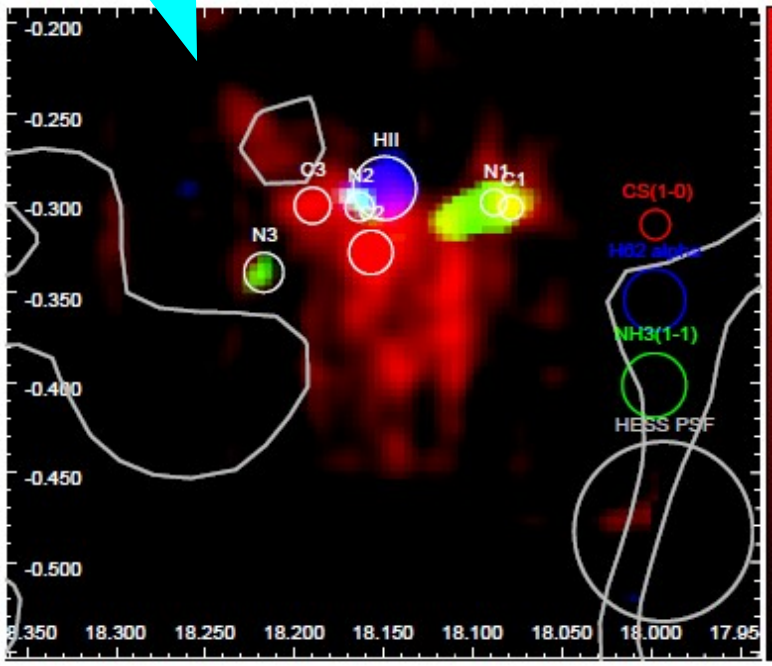
Best case: HESSJ1825-137

Voisin etal 2013

Nanten CO
Mopra CS, NH_3, SiO

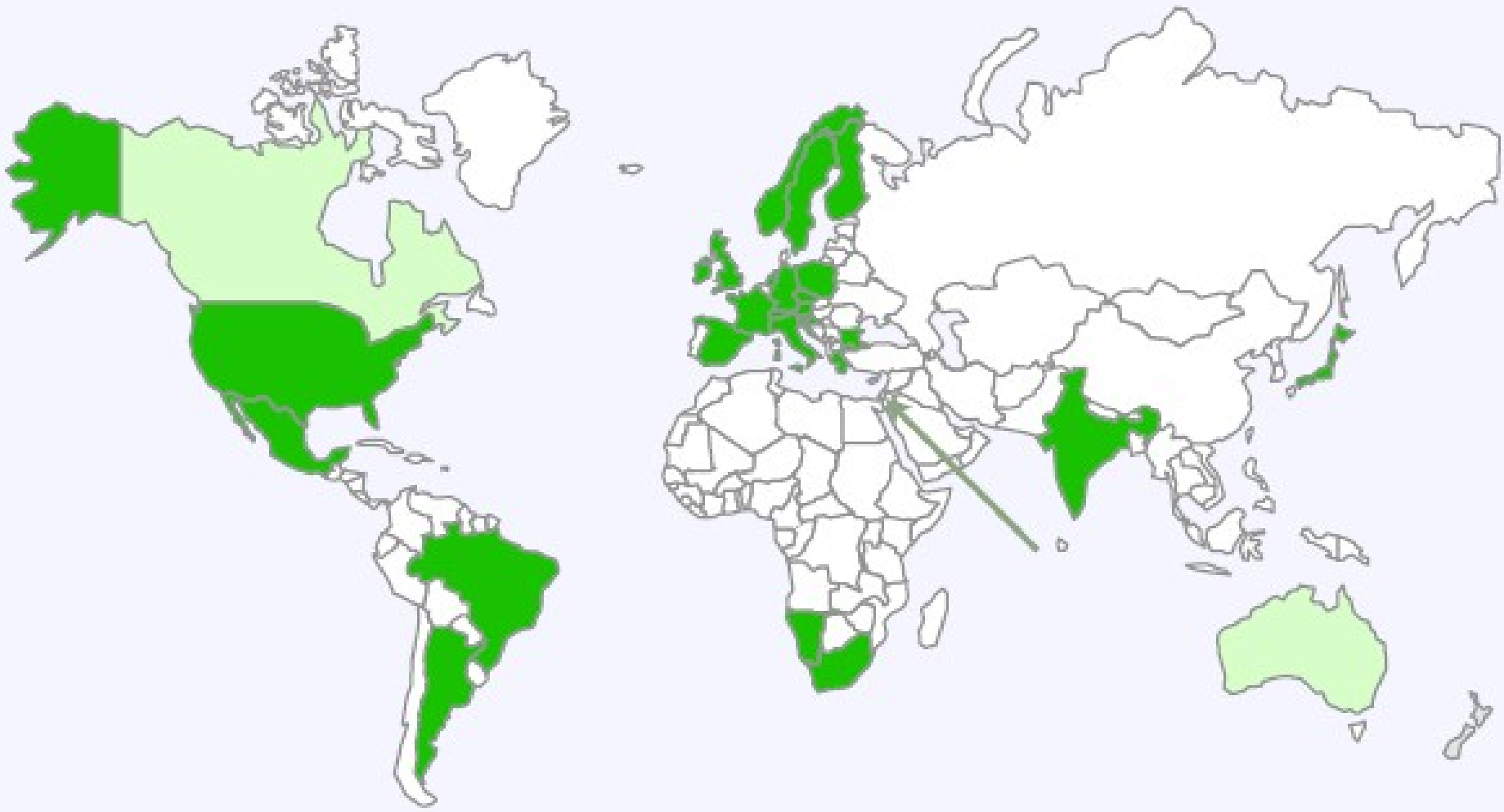




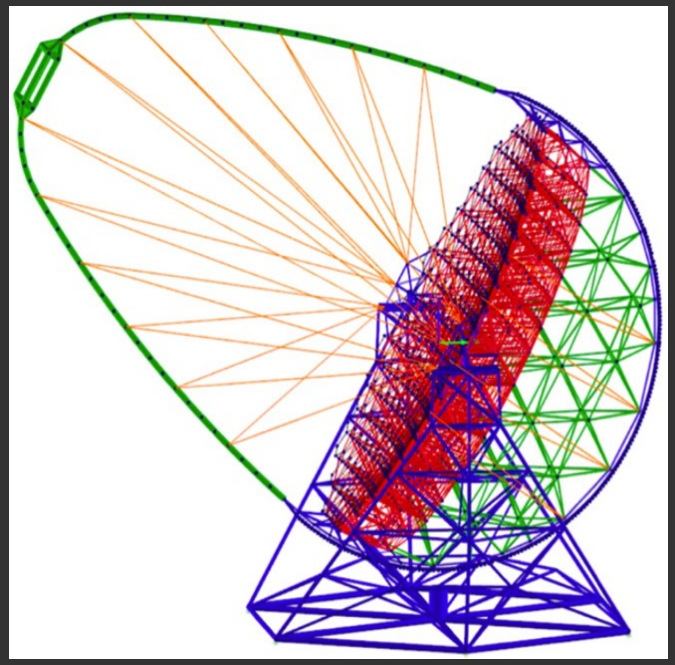


CTA Membership

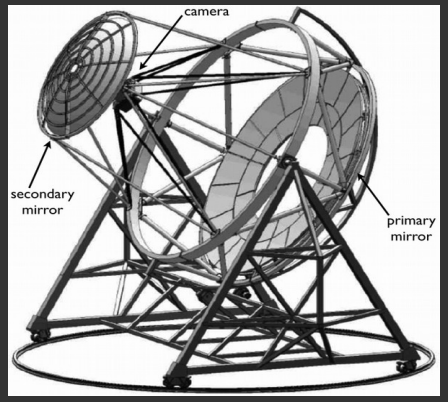
May 2013
> 1000 scientists

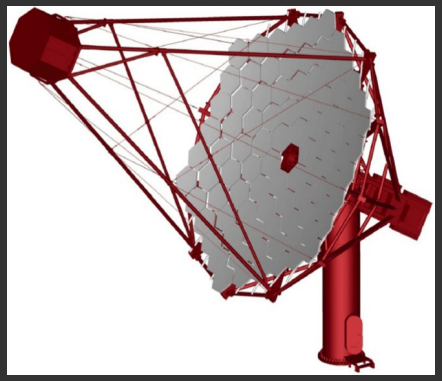


LST

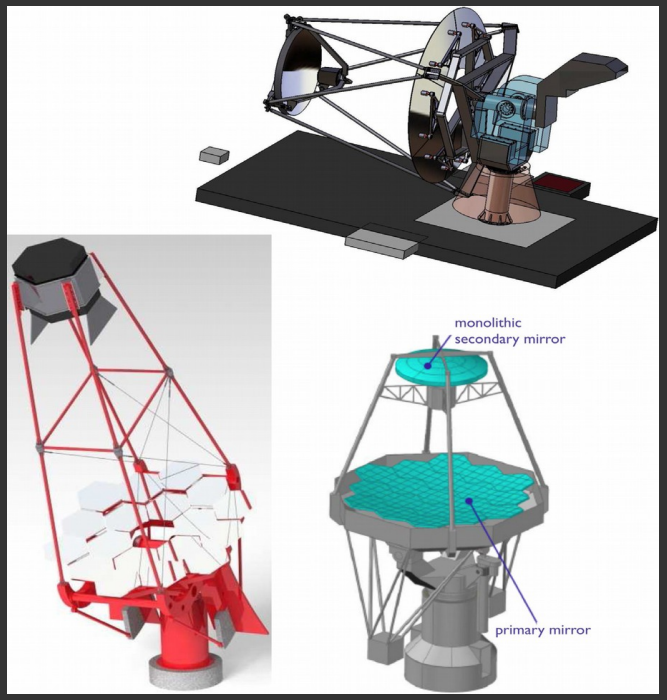


MST



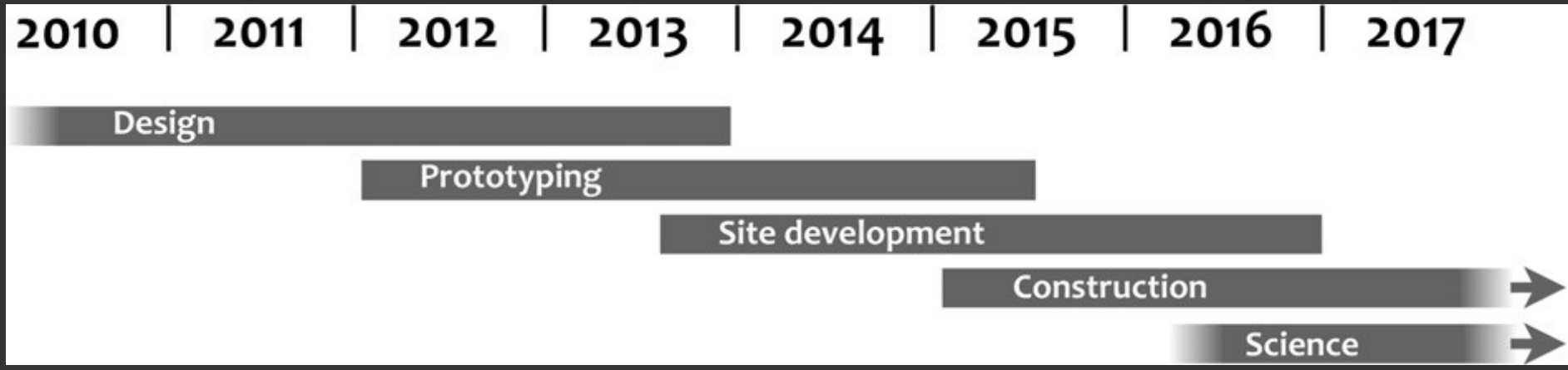


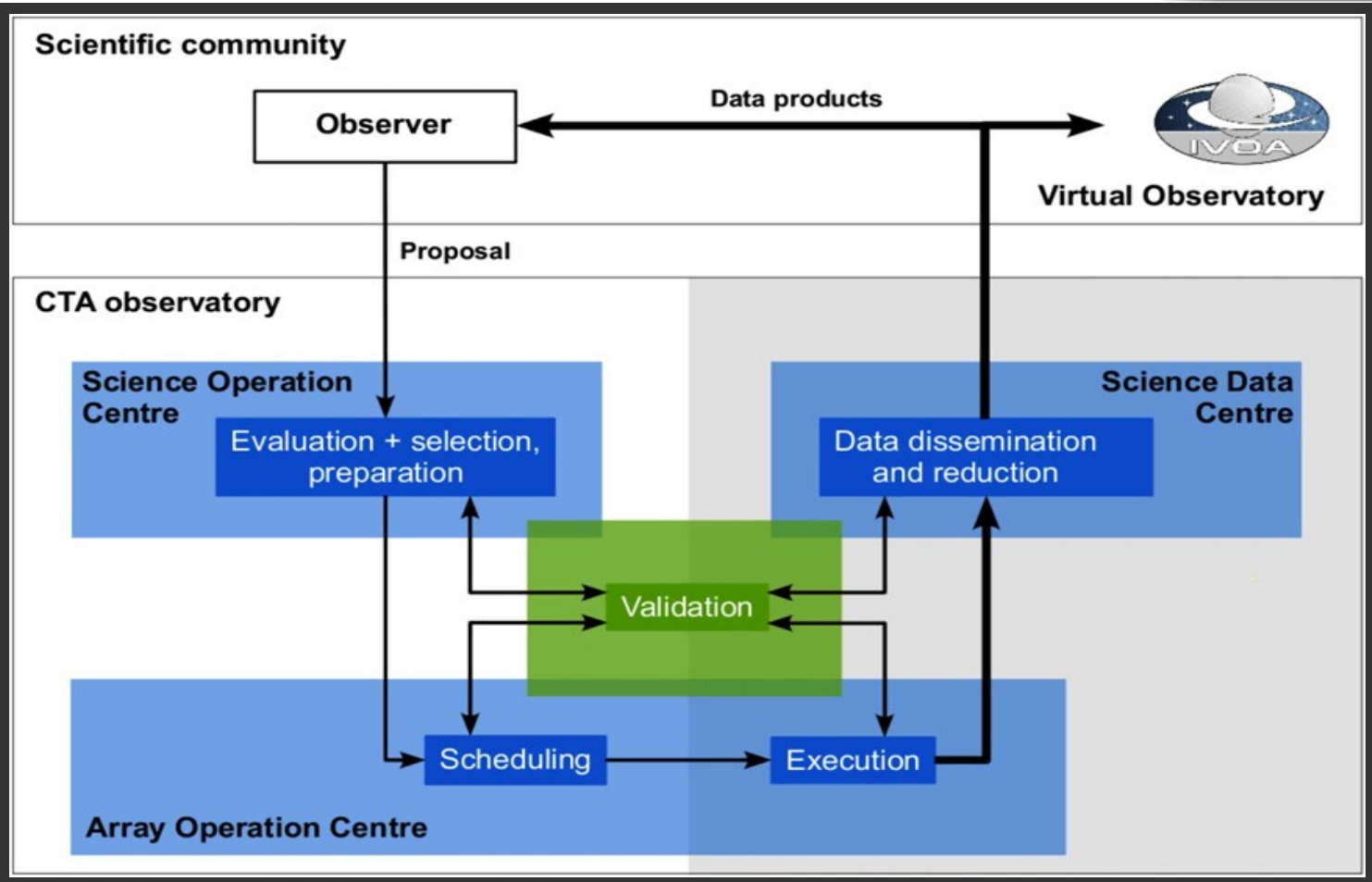
SST



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

MST Prototype (DESY Berlin)


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

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+.

Summary/Conclusions

- CTA will provide ~1-2 arc-min scale TeV maps

- CTA will need ~1-2 arc-min scale ISM maps

- ISM maps from low to high density
  → diffuse gas to molecular cloud cores
  → dark molecular gas (CI, C+)

- Nanten2 (new Nyquist surveys)
  CO(1-0), CO(2-1) 4', 2' beam

- Mopra
  CO(1-0), CS(1-0), CS(2-1), NH_3 0.5', 1', 2' beam
  user pays model 2013-2015

- New OH & radio recomb. Line surveys (MWA, ASKAP)