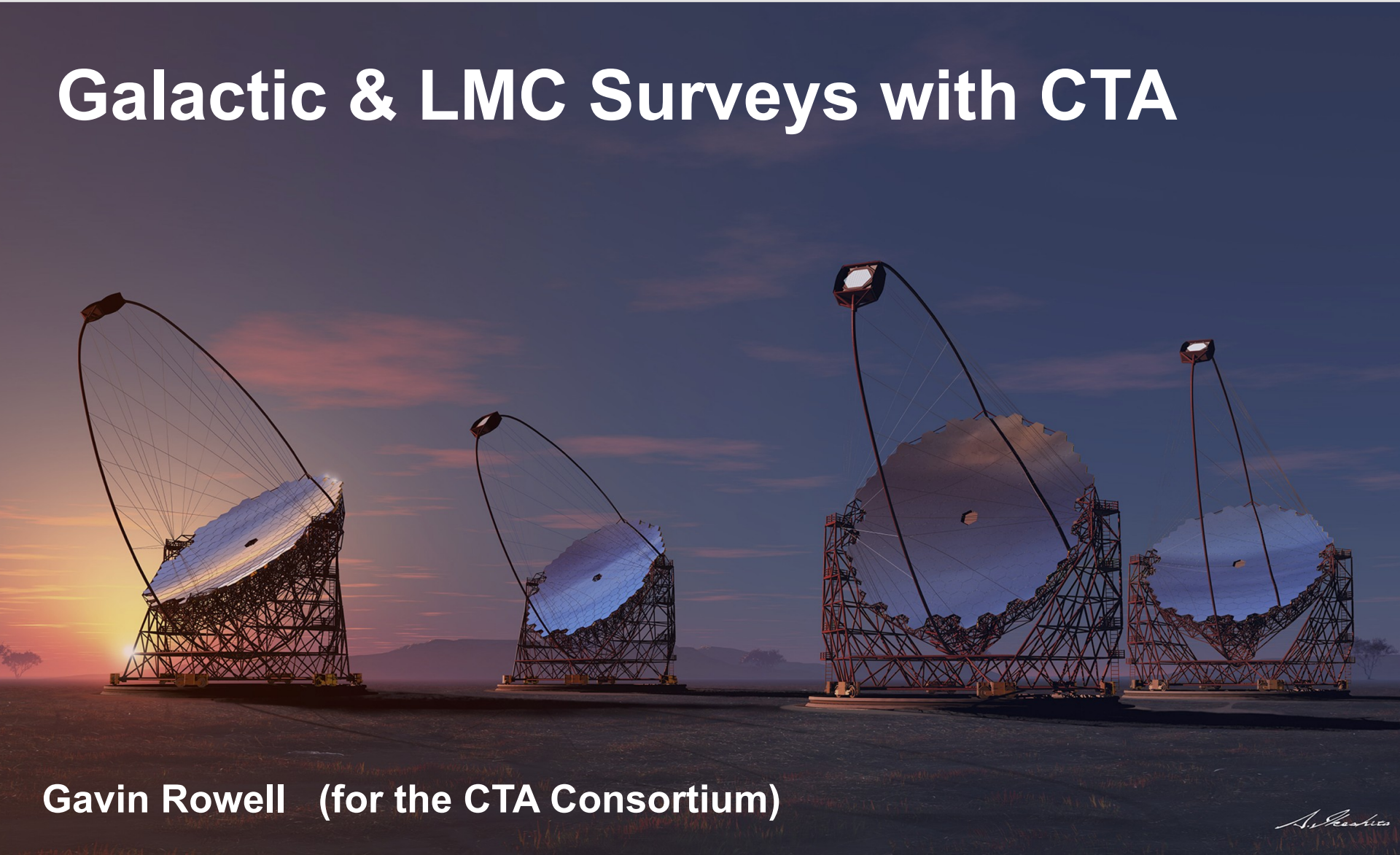
cherenkov telescope array

THE UNIVERSITY of ADELAIDE

Galactic & LMC Surveys with CTA



Gavin Rowell (for the CTA Consortium)

Galactic Surveys in CTA's Key Science Projects

Science with CTA

Key Science Projects

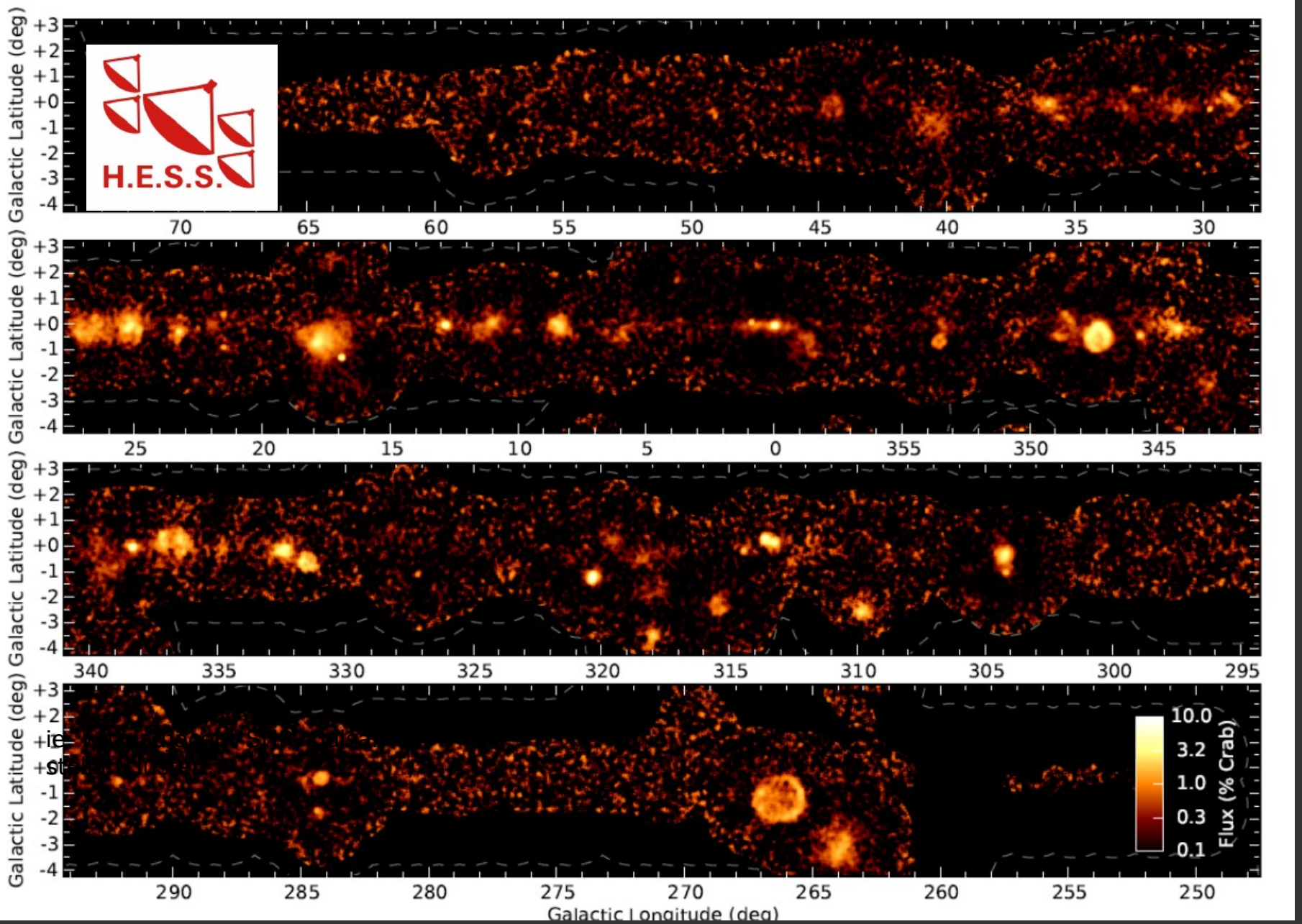
- Dark Matter Programme
- Galactic Centre
- Galactic Plane Survey
- Large Magellanic Cloud Survey
- Extragalactic Survey
- Transients
- Cosmic-Ray PeVatrons
- Star-forming Systems
- Active Galactic Nuclei
- Cluster of Galaxies
- Beyond Gamma Rays

https://www.worldscientific.com/worldscibooks/10.1142/10986

HESS Galactic Plane Survey (HGPS)

→ 78 sources (13 new sources)

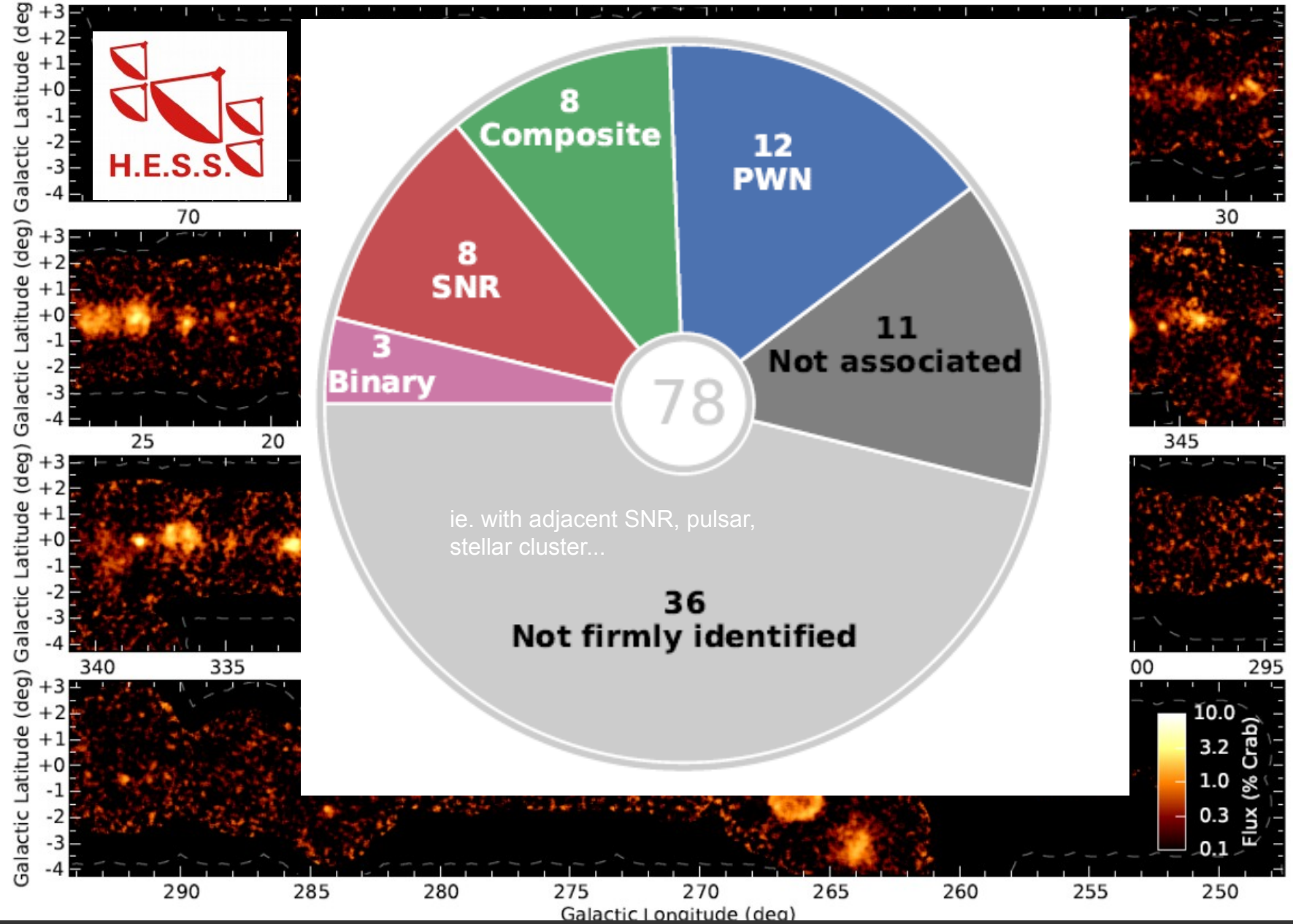
HESS 2018



HESS Galactic Plane Survey (HGPS)

→ 78 sources (13 new sources)

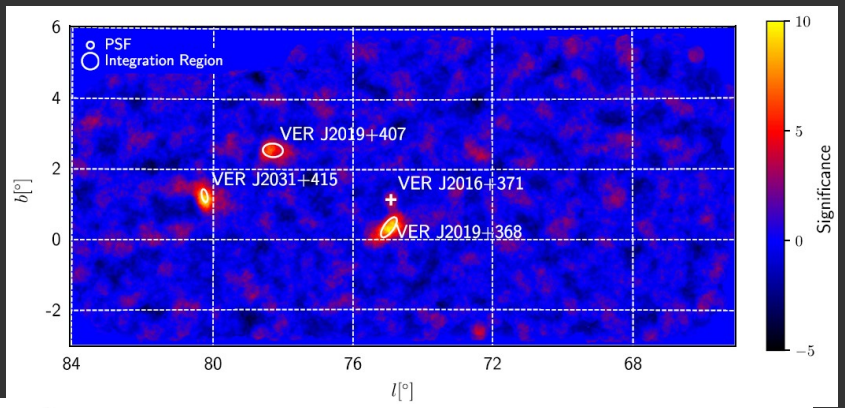
HESS 2018

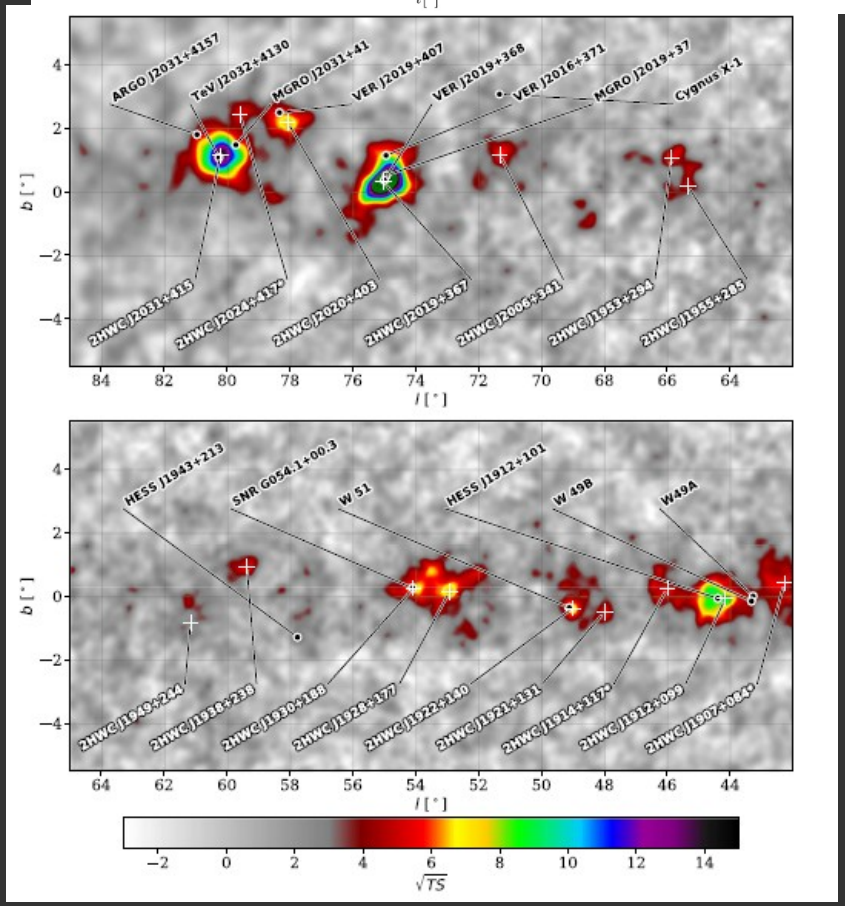


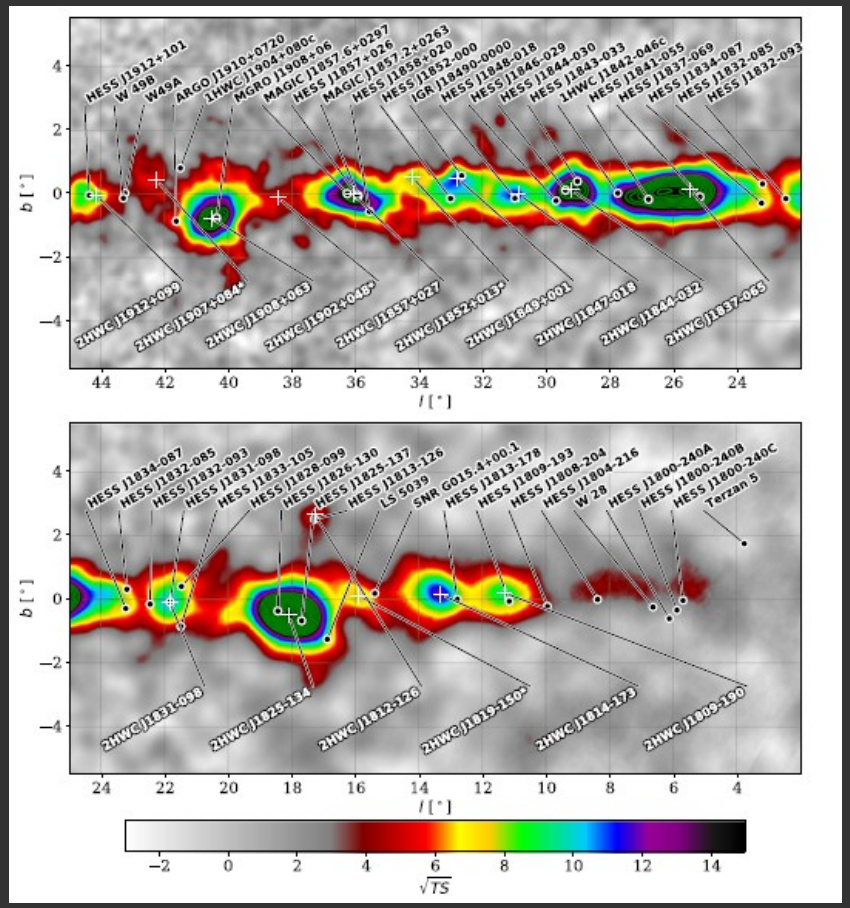
VERITAS and HAWC Galactic Plane Surveys (2HWC)

2HWC 39 sources (17 new sources)

Abeysekara et al (VERITAS) 2018
Abeysekara etal (HAWC) 2017

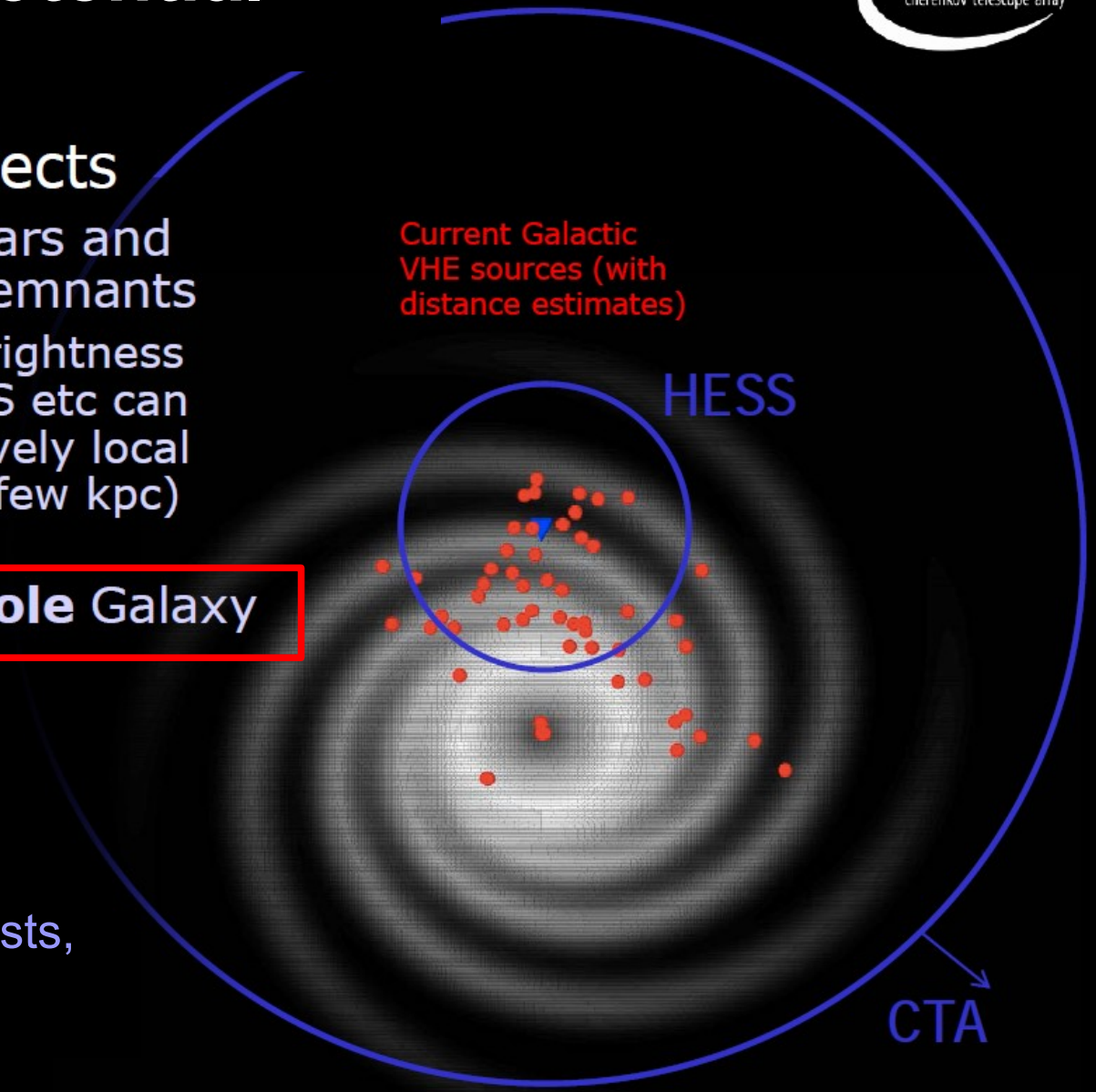






CTA Science Potential

- e.g. Galactic objects
  - Newly born pulsars and the supernova remnants
    - have typical brightness such that HESS etc can see only relatively local (typically at a few kpc) objects
  - CTA will see **whole** Galaxy
- Survey speed ~300×HESS



Extragalactic
AGN z>0.5, GRBs, Star-bursts, Gal. clusters, AGN haloes..

Astro-particle
Dark matter, Lorentz invariance....

Optical
Intensity Interferometry, milli-mag photometry

10-year sensitivity (mCrab units)

STP – Short Term Programme

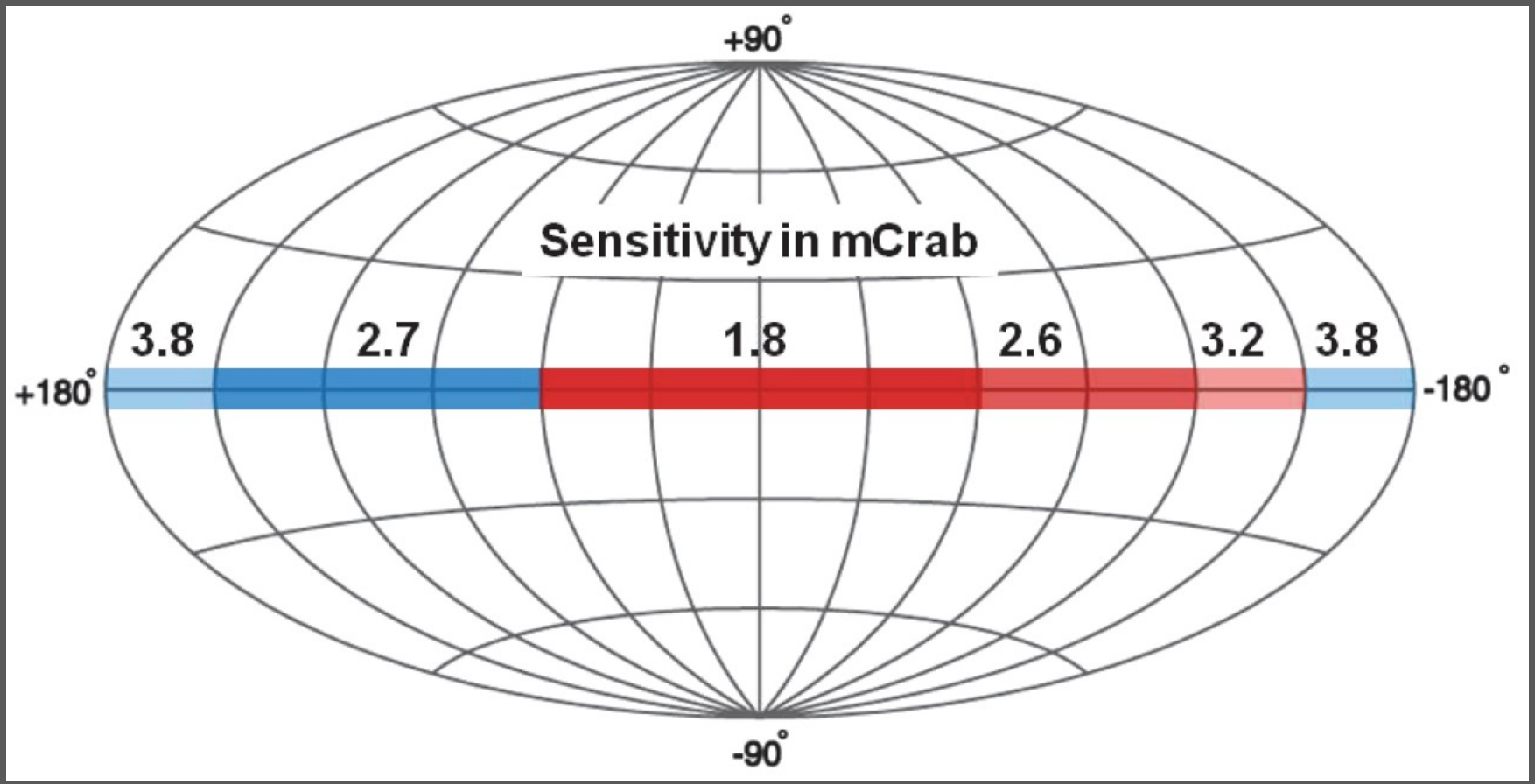
LTP – Long Term Programme

E > 125 GeV

Galactic Longitude	STP (years 1–2) Hours	STP (years 1–2) Sensitivity	LTP (years 3–10) Hours	Total (years 1–10) Hours	Total (years 1–10) Sensitivity
SOUTH					
300°–60°, Inner region	300	**2.7 mCrab**	480	780	**1.8 mCrab**
240°–300°, Vela, Carina			180	180	**2.6 mCrab**
210°–240°			60	60	**3.1 mCrab**
				1020	
NORTH					
60°–150°, Cygnus, Perseus	180	**4.2 mCrab**	270	450	**2.7 mCrab**
150°–210°, anti-Centre, etc.			150	150	**3.8 mCrab**
				600	

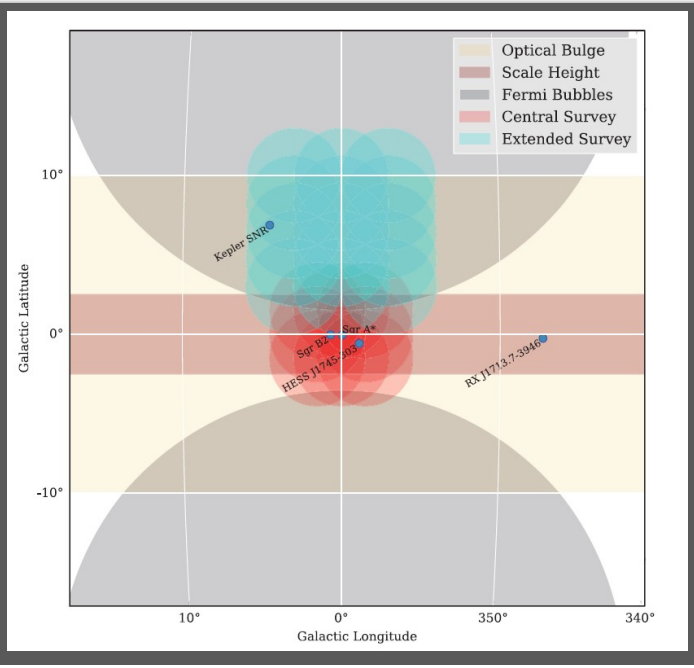
cherenkov telescope array

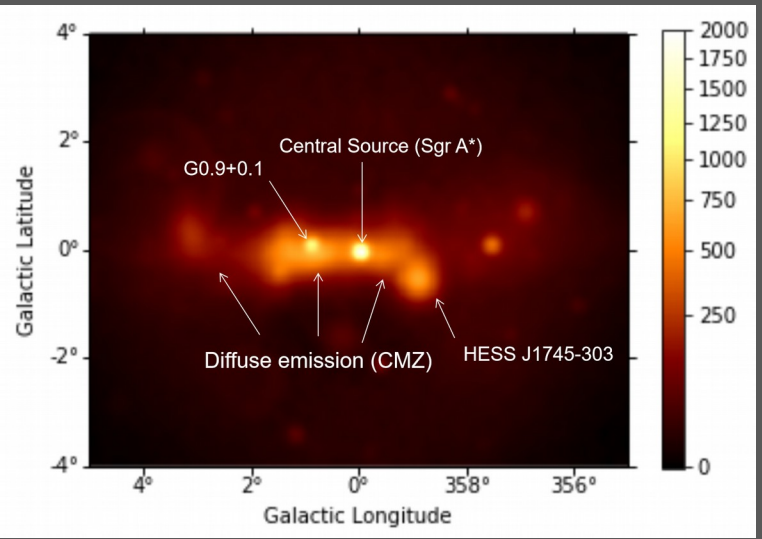
10-year sensitivity (mCrab units)



Galactic Centre Survey with CTA

- Deeper coverage of GC regions |l| < 3 deg
- Probe north Fermi bubble “foot” towards GC region
- Overlaps with Dark matter searches





Simulated CTA view of GC region (excess counts). Viana et al 2019

Table 5.1: Exposure summary for the Galactic Centre KSP.

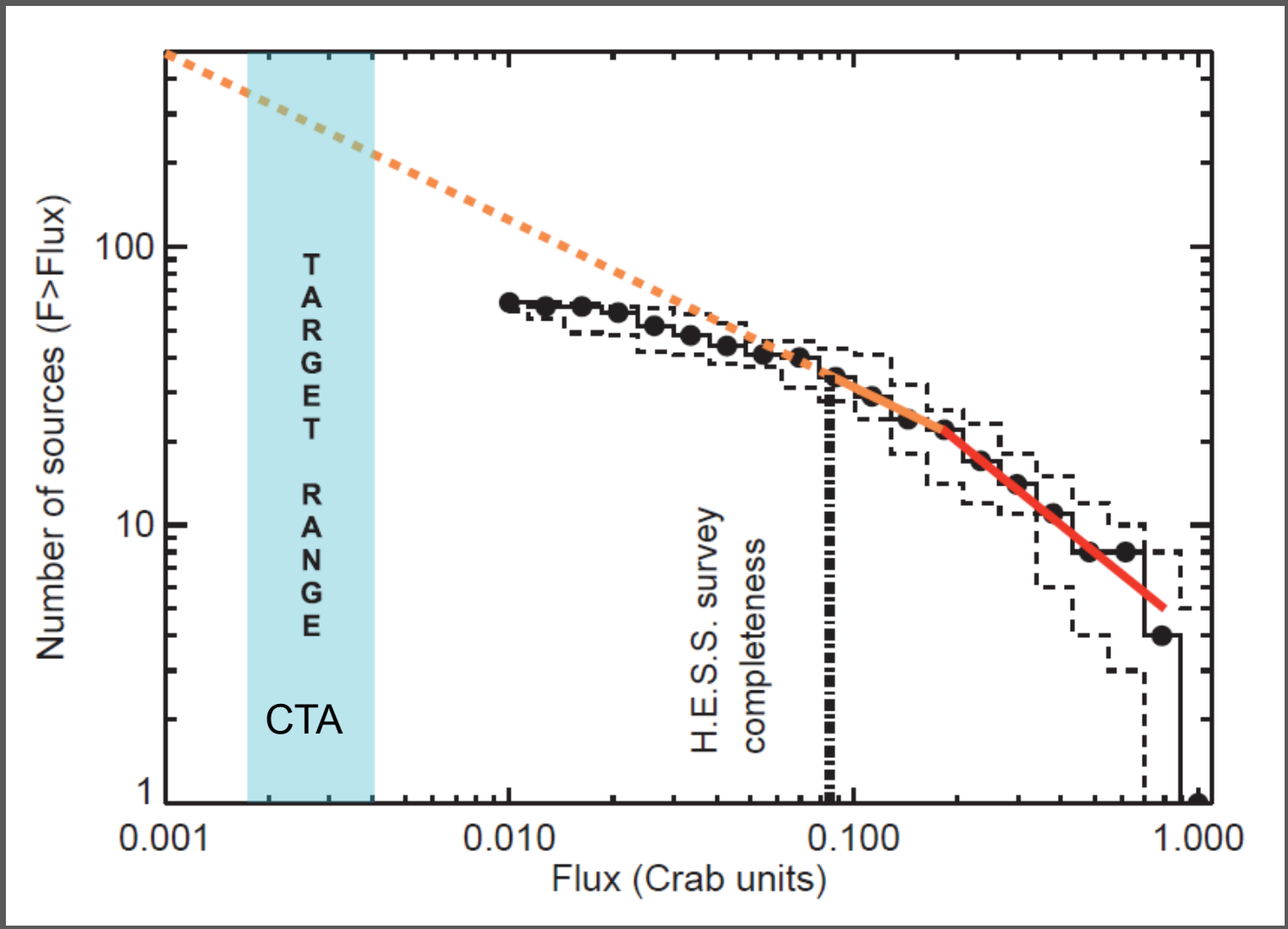
	Deep exposure	Extended survey	Monitoring+multi-waveband
Time requested	525 h	300 h	(Co-ordinated with other instruments)
Priority	1	3	2
Strategy	survey	survey	Periodic + coordinated
Site	S	S	S
Sub-array	Full	Full	Full
Zenith Range	<40°	<50°	<40°
Atmosphere Quality	high	high	Medium
Targets Covered	multiple	multiple	Multiple

cherenkov telescope array

How many CTA Galactic sources?

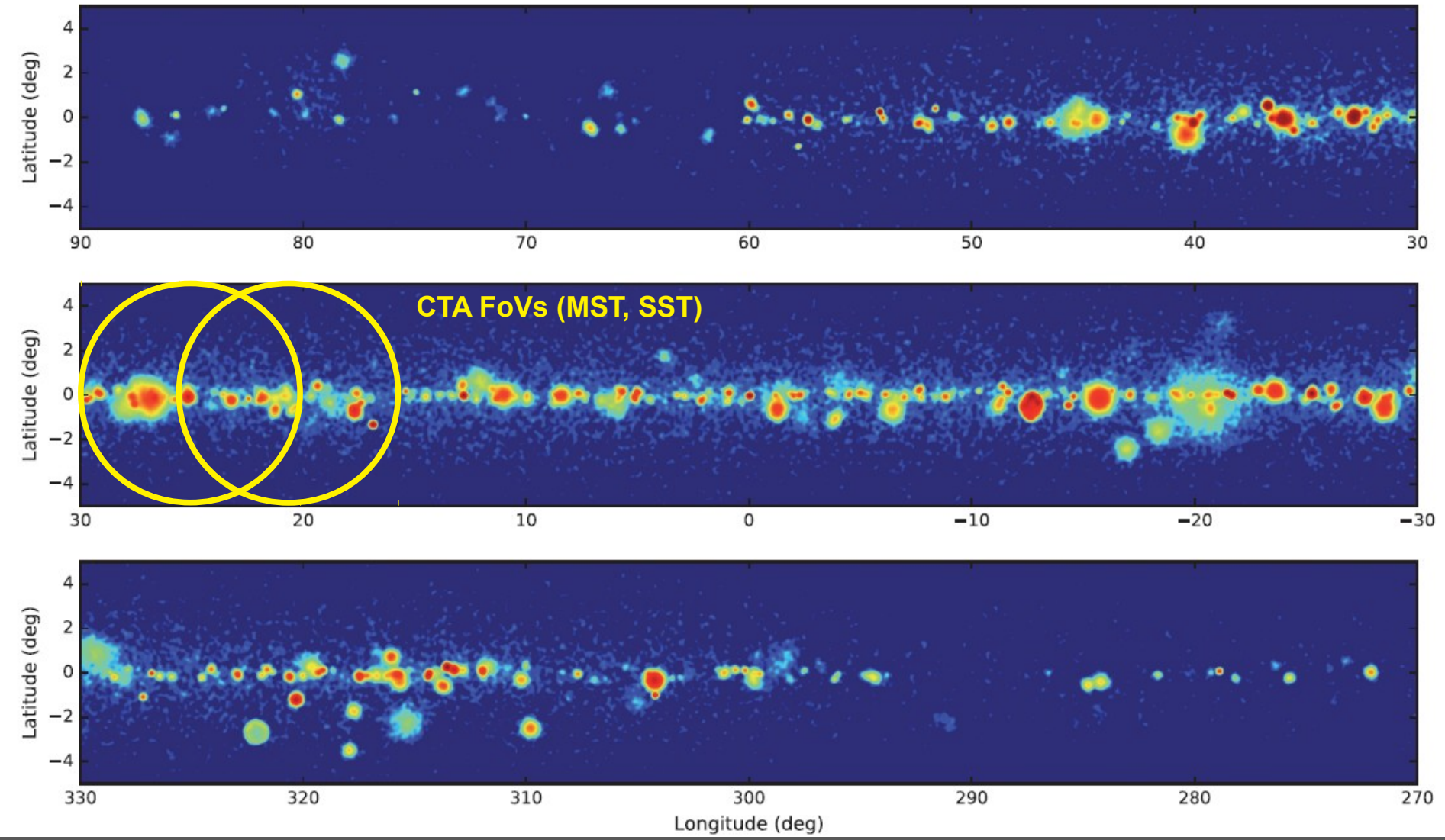
→ Extrapolate HESS Log N vs. Log S

→ >~1000 sources



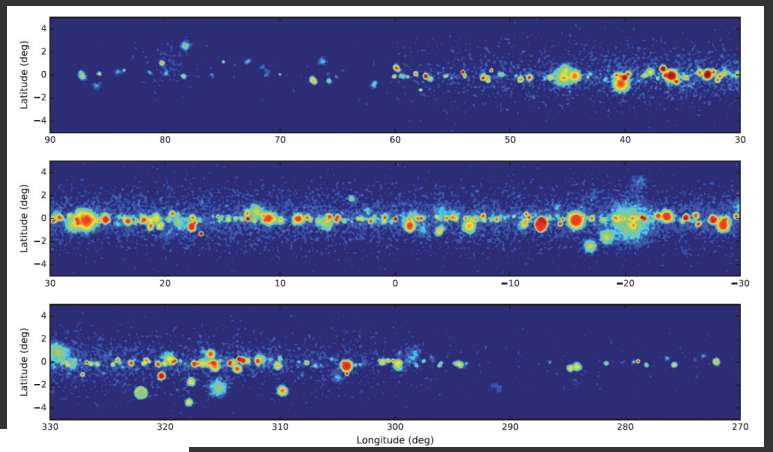
cherenkov telescope array

Simulated Galactic Plane with CTA



Galactic Plane with CTA

1. Diffuse gammas from CR/e 'sea'
2. Diffuse gammas from local CR/e escaping accelerators
3. Gammas from local sources



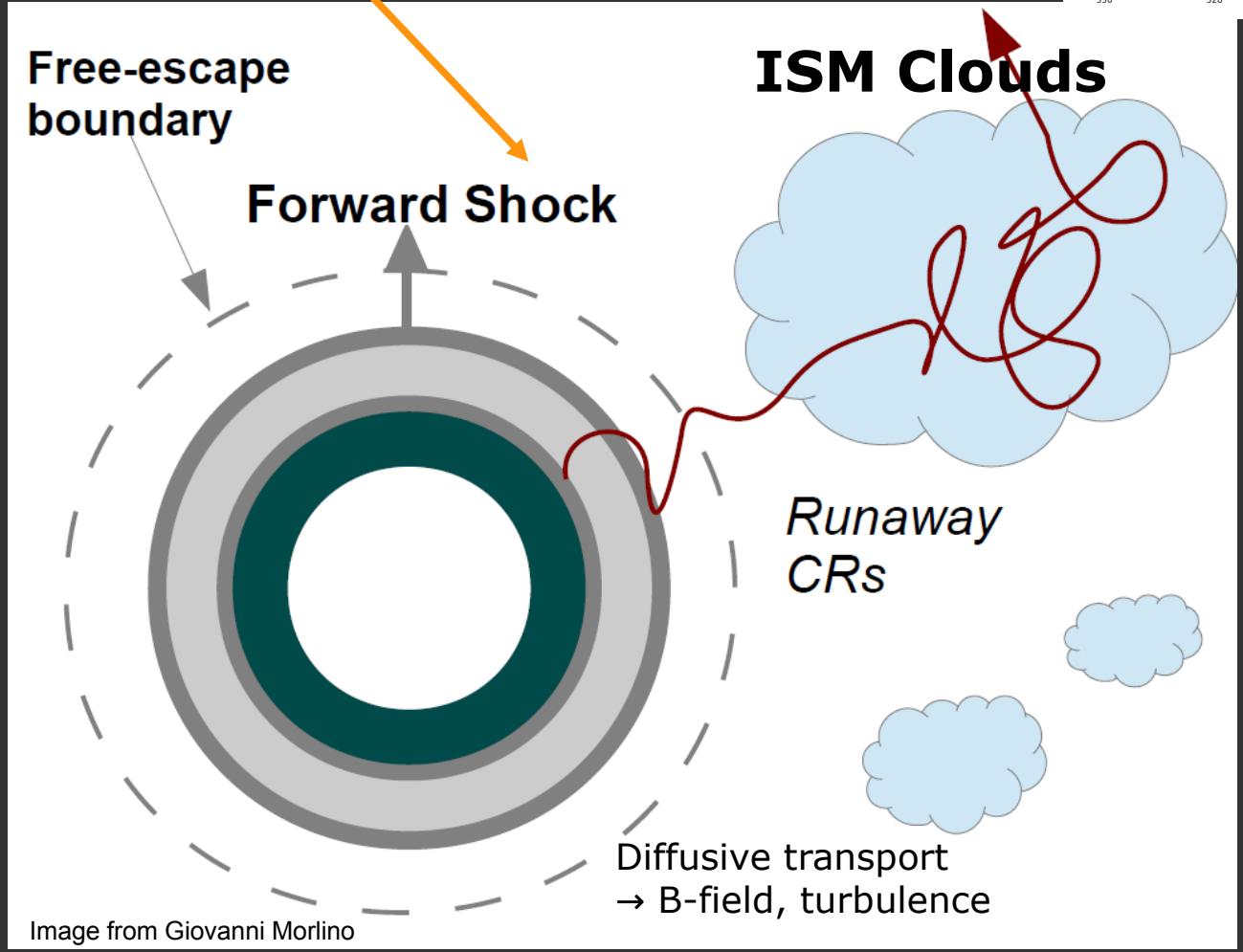


Image from Giovanni Morlino

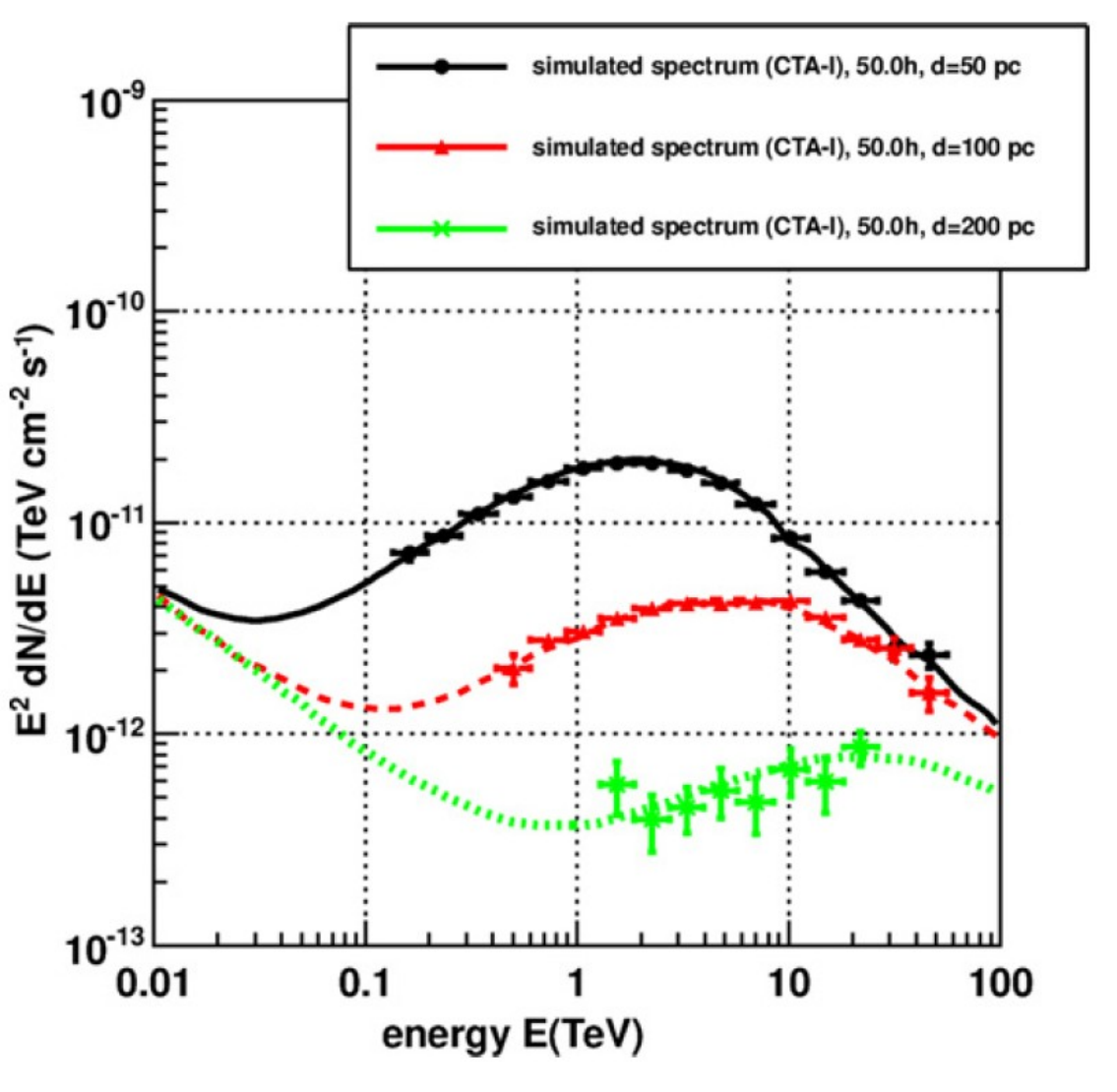
Need to model all three components over degree areas at arc-min scales to >100 TeV.

→ A new challenge for models

e.g. GALPROP, PICARD (large scale)….plus many small-scale models

CRs escaping local accelerators – CTA will see them! (50hr)

Acero etal 2013



SNR age 2000 yr

Cloud mass 10^5 M_{sun}

d = 1 kpc

$D=10^{28}(E/10GeV)^{0.5}$ cm^2/s

PeV CRs escape first and arrive at the cloud first!

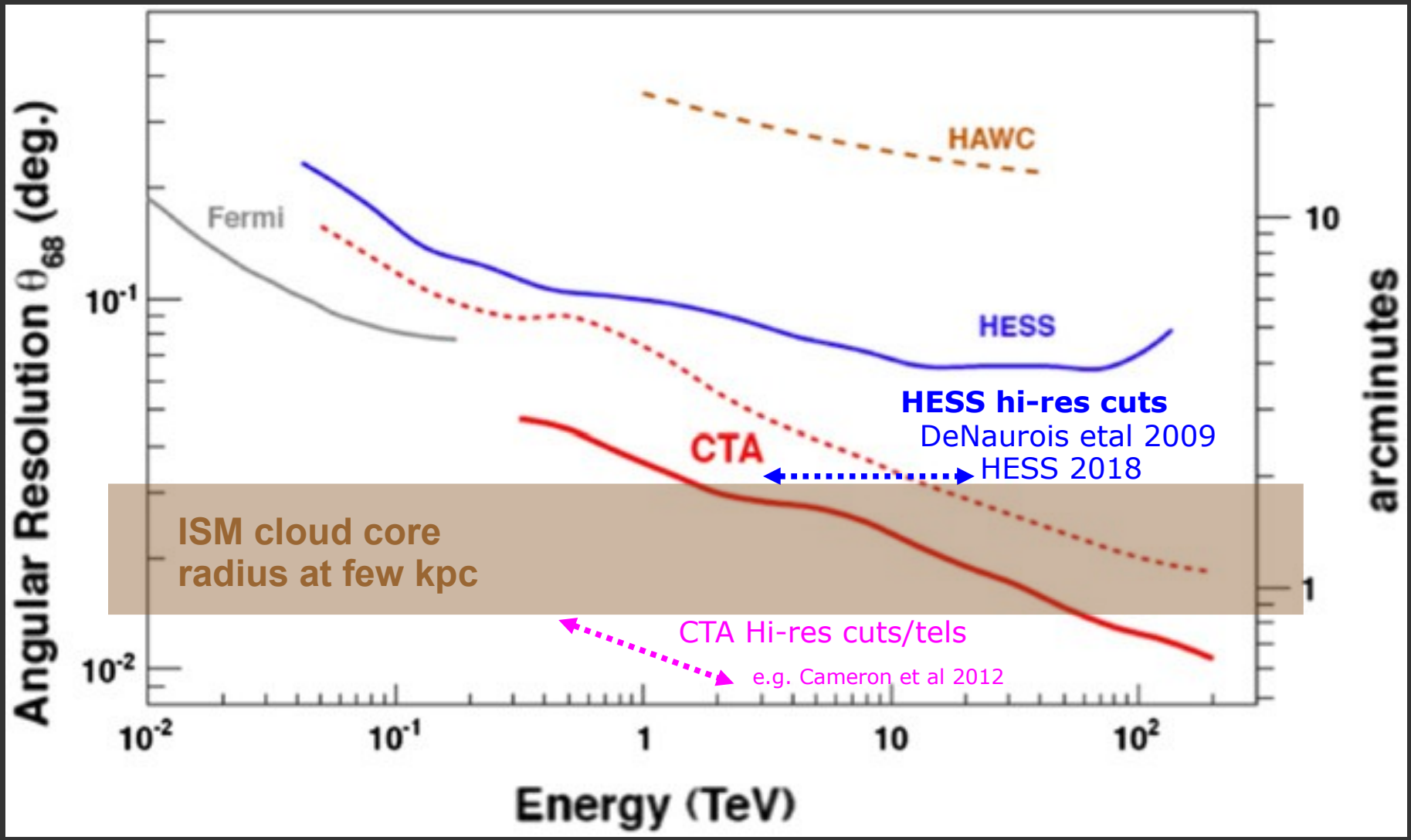
Probe for CR PeVatrons

But confusion guaranteed in Gal. Plane!

Need wide ISM surveys

Angular Resolution 68% PSF (HESS, CTA, etc..)

Acharyara etal 2013



→ **CTA will resolve ISM cloud cores/clumps**

→ **CTA will need <= arc-min ISM surveys**

Synergies with interstellar gas surveys

HI (atomic H), OH, CS

CO

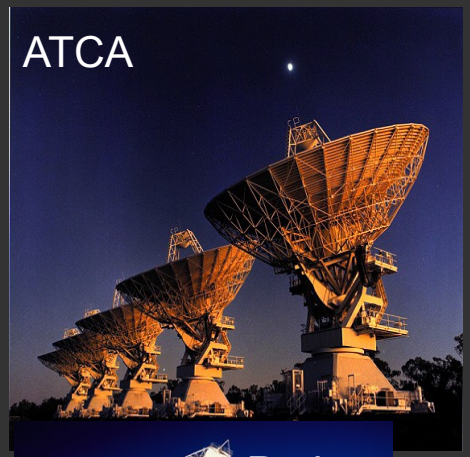
CO, NH_3, CS, SiO...

Gas density

$\sim 10^{1 \text{ to } 4}$ cm^{-3}

$\sim 10^{3}$ cm^{-3}

$>10^{3 \text{ to } 4}$ cm^{-3}

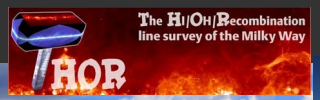


NANTEN
Submillimeter Observatory
なんてん電波天文台

国立天文台
NAOJ
National Astronomical Observatory of Japan

Mopra Telescope
CSIRO

CSIRO



GASKAP

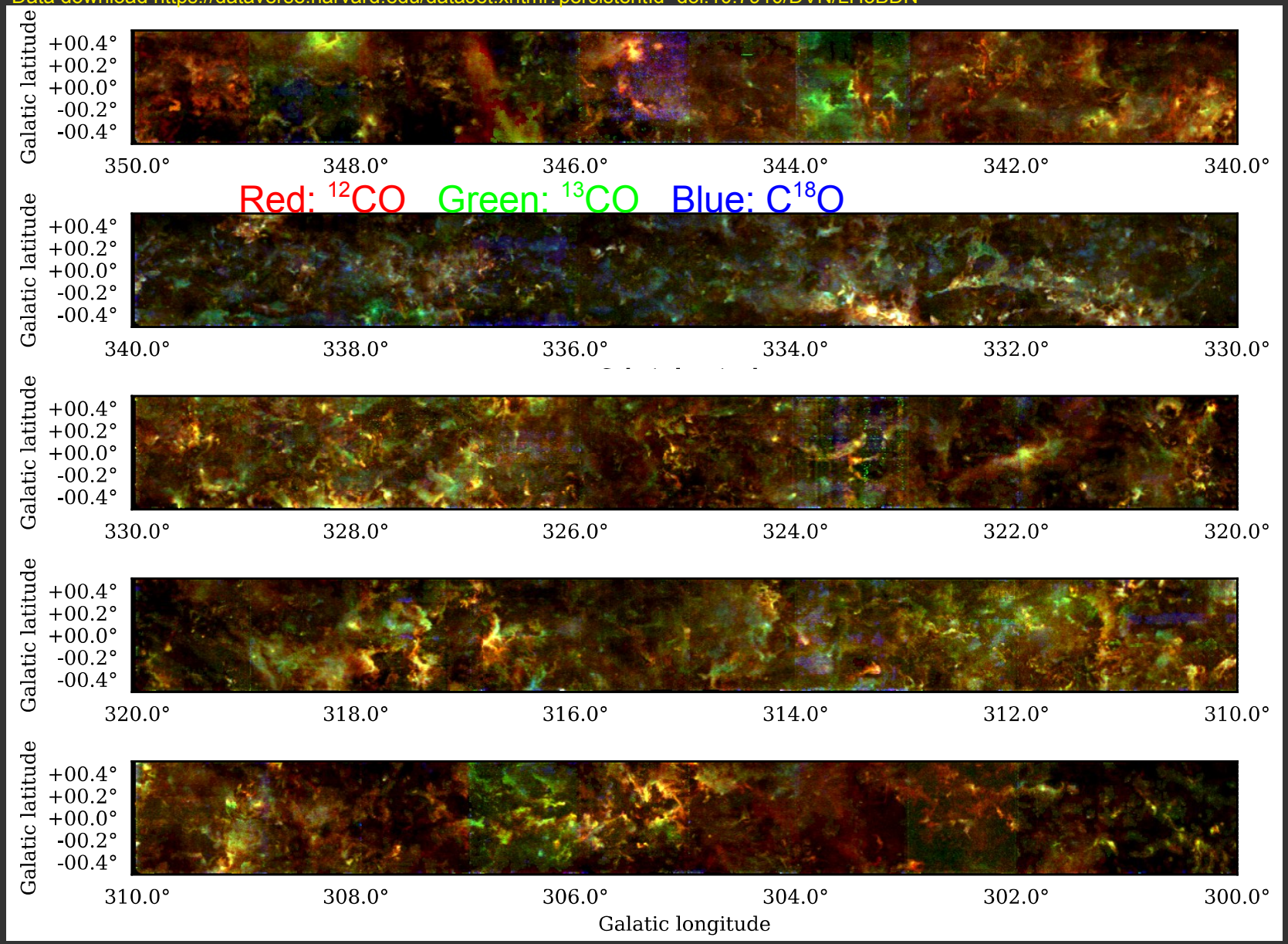
THz (Antarctica & High-alt)
[CI] + [CII]

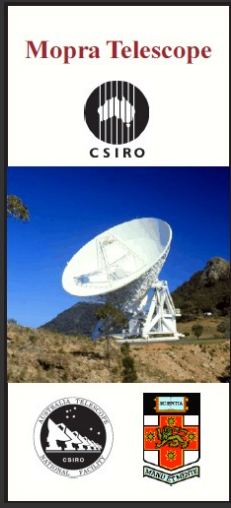
CSIRO
NATIONAL FACILITY

SCIENTIA
MANU ET MENTE

Mopra CO Peak Intensity (Braiding etal 2018) @ 35 arc-sec beam

Data download https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/LH3BDN



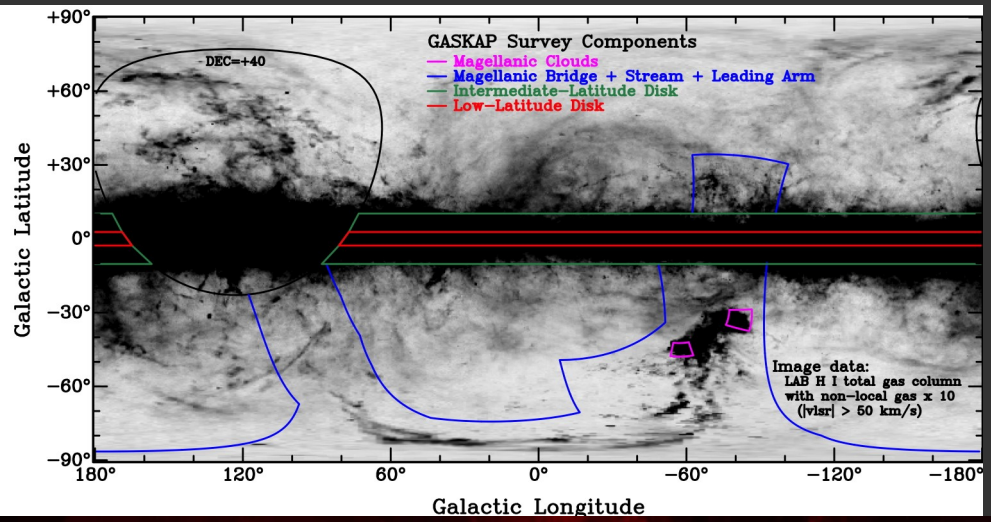


→ Extension to |b| = 1, l>250 deg done → legacy ISM survey for CTA

GASKAP

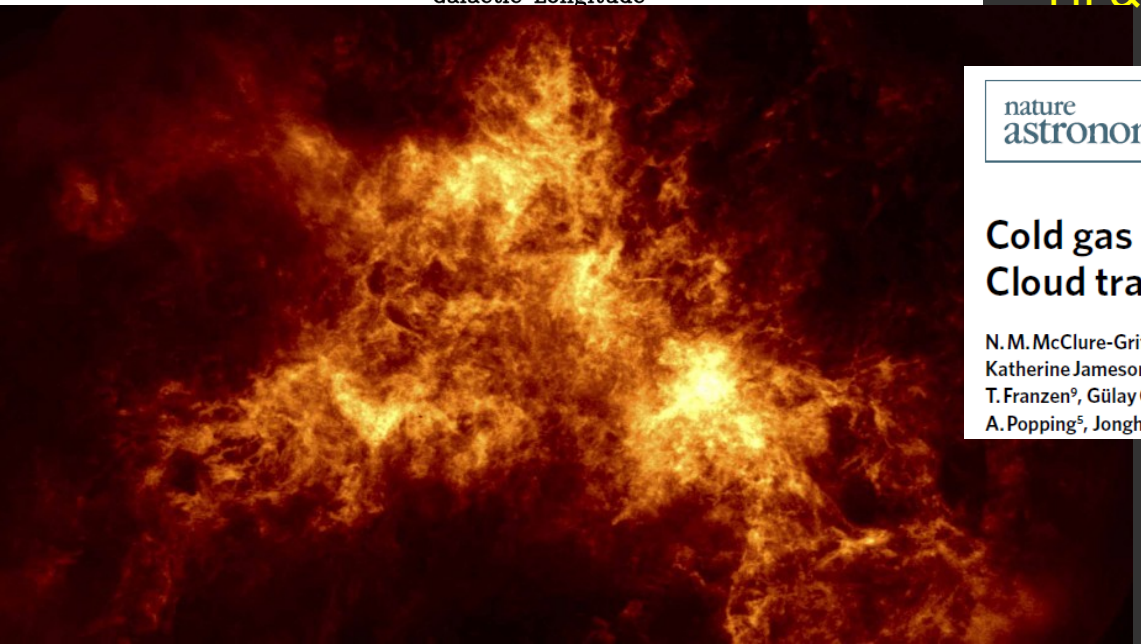
New HI + OH survey with the ASKAP
- ~30 arc-sec resolution
- Commencing 2019

www.atnf.csiro.au/research/GASKAP/



ASKAP - Australian Square Kilometre Array Pathfinder

- HI & OH lines, B-field & turbulence



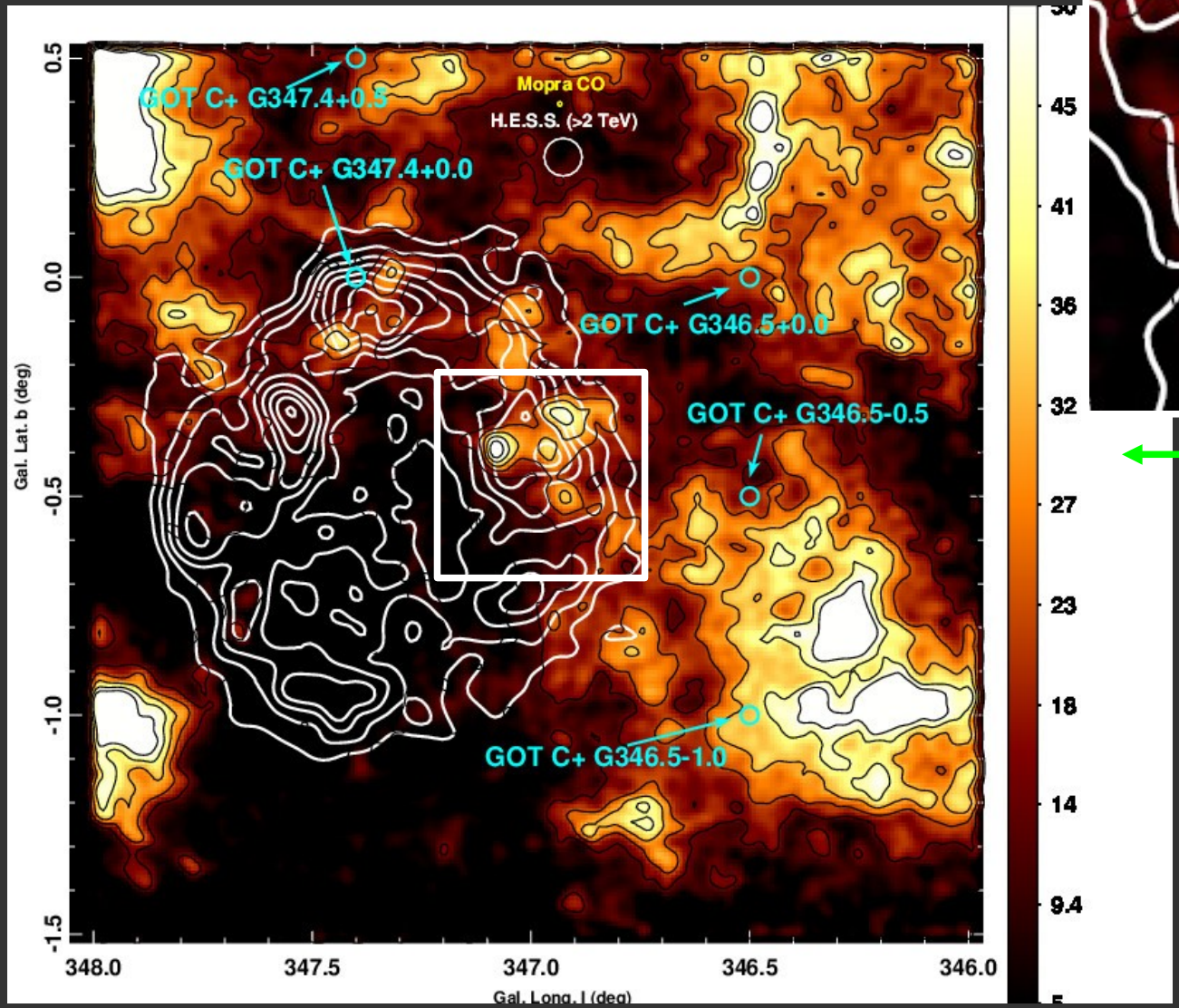
nature astronomy — LETTERS
https://doi.org/10.1038/s41550-018-0608-8

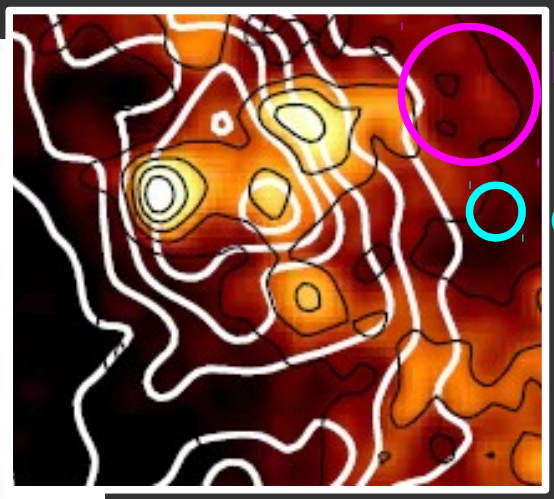
Cold gas outflows from the Small Magellanic Cloud traced with ASKAP

N. M. McClure-Griffiths[1*], H. Dénes[1,2], J. M. Dickey[3], S. Stanimirović[4], L. Staveley-Smith[5,6], Katherine Jameson[1], Enrico Di Teodoro[1], James R. Allison[6,7], J. D. Collier[2,8], A. P. Chippendale[2], T. Franzen[9], Gülay Gürkan[9], G. Heald[9], A. Hotan[9], D. Kleiner[2], K. Lee-Waddell[2], D. McConnell[2], A. Popping[5], Jonghwan Rhee[5], C. J. Riseley[9], M. A. Voronkov[2] and M. Whiting[2]

Young SNR RXJ1713 TeV and ISM on Parsec Scales!

Mopra CO(1-0) Image + HESS > 2 TeV contours





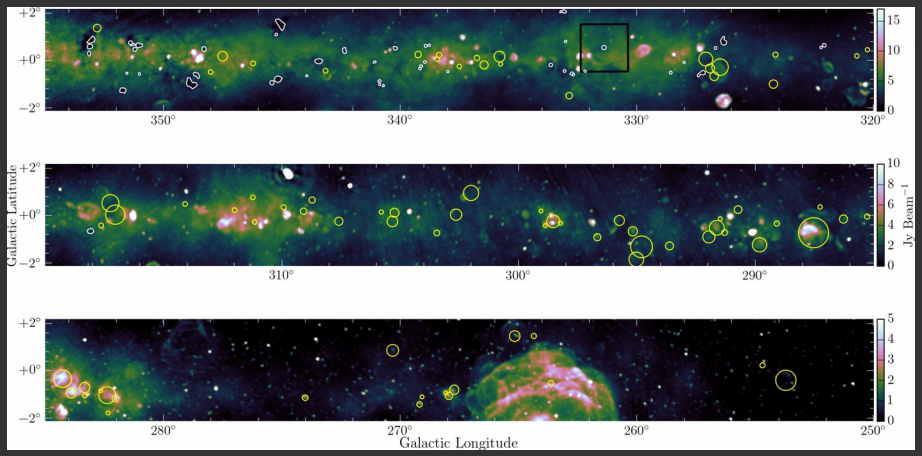
CTA will be able to probe diffusion properties of cosmic rays and electrons (e.g. Gabici etal 2007)

Synergies with Radio Continuum Surveys

- Radio synchrotron & TeV gamma-ray (esp. hadronic) are often 'relics' of earlier particle acceleration.

- Dark TeV Sources:
  → Old/evolved SNRs & PWNe?
  → Missing Supernova remnants?

ASKAP – EMU, POSSUM, SCORPIO
MWA - GLEAM



MWA GLEAM 88 MHz (MWA Prelim 2016)

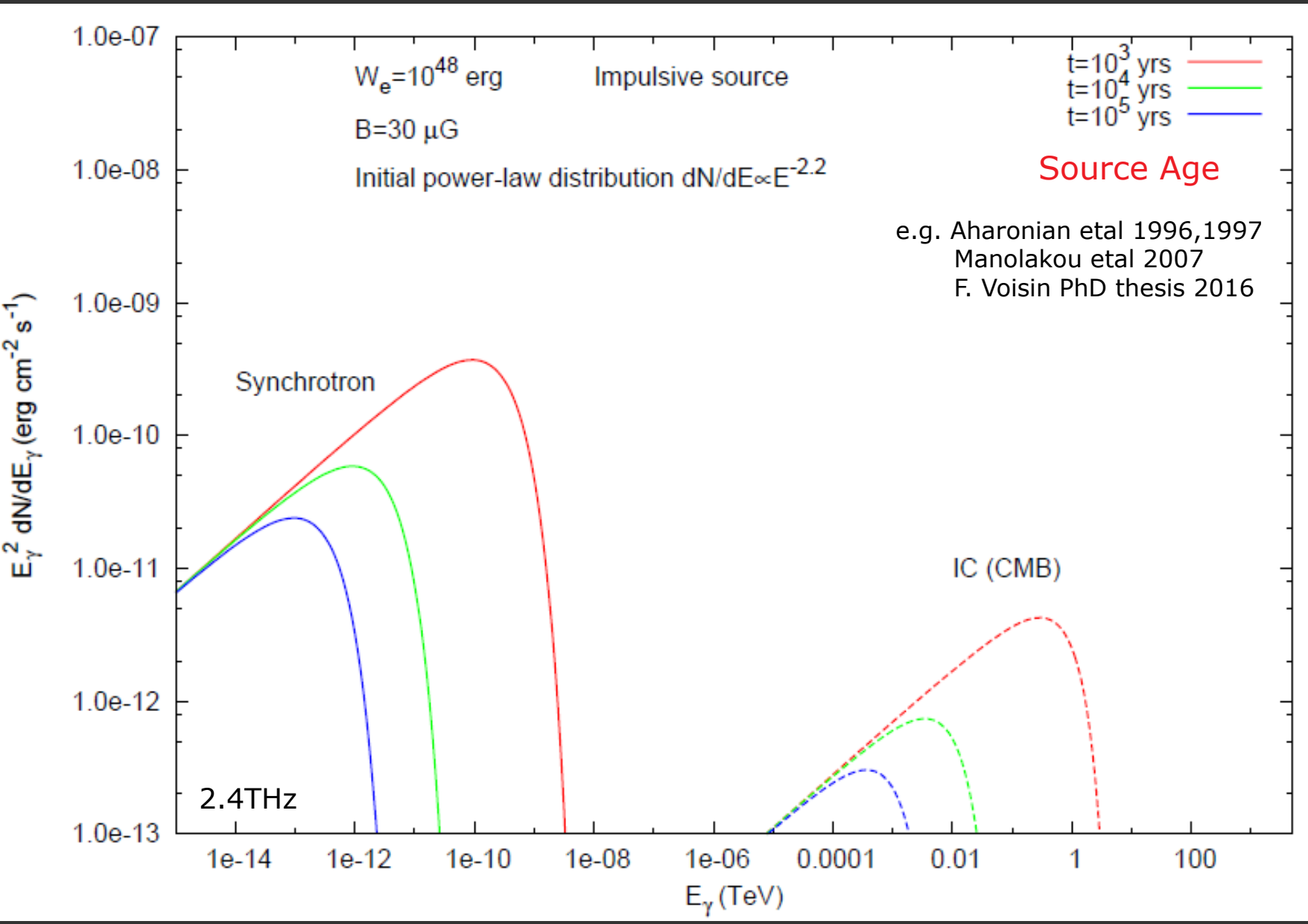
ASKAP EMU
Evolutionary Map of the Universe

POSSUM
POLARISATION SKY SURVEY OF THE UNIVERSE'S MAGNETISM

GLEAM

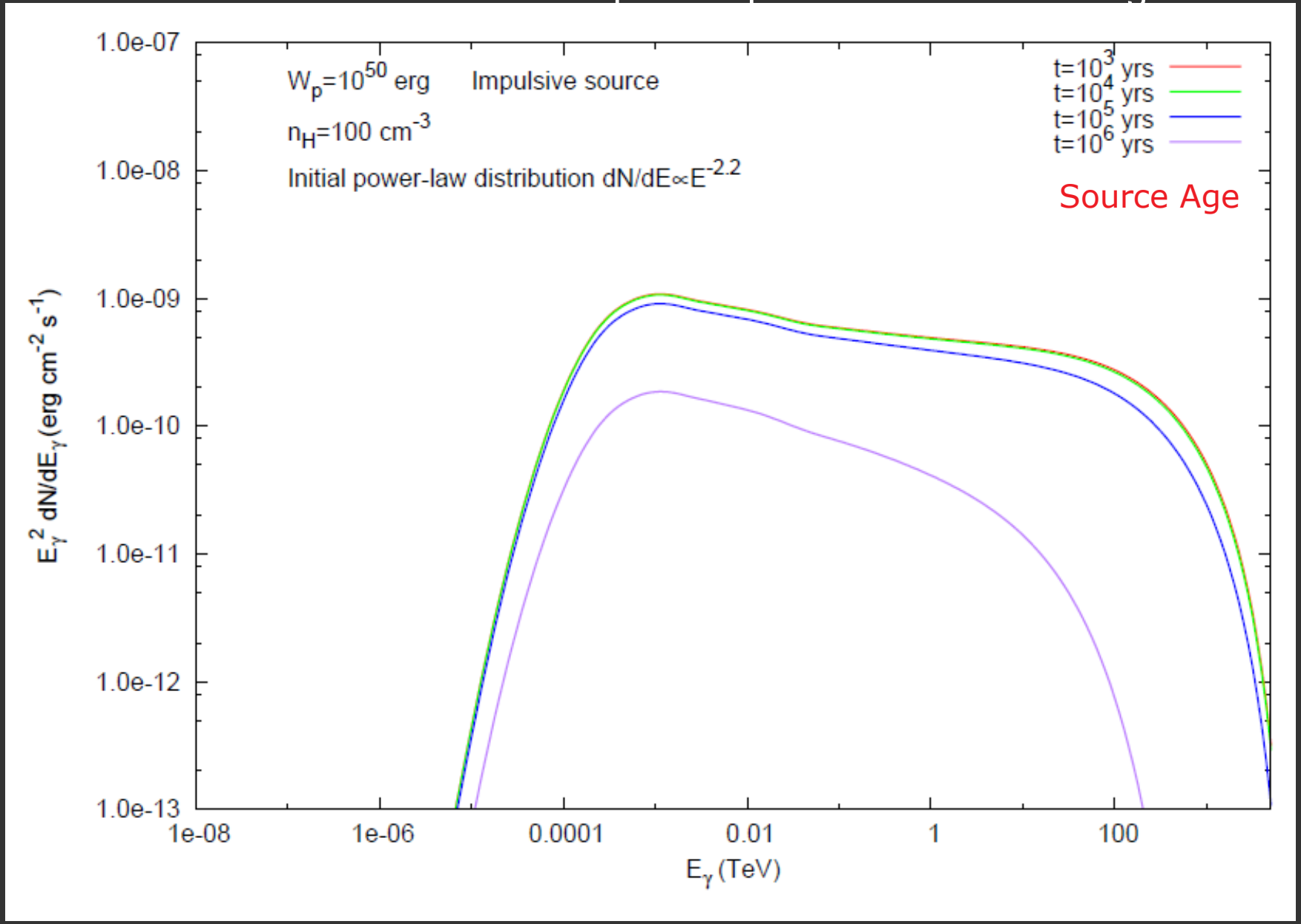
Leptonic: Synchrotron + Inverse-Compton Evolution

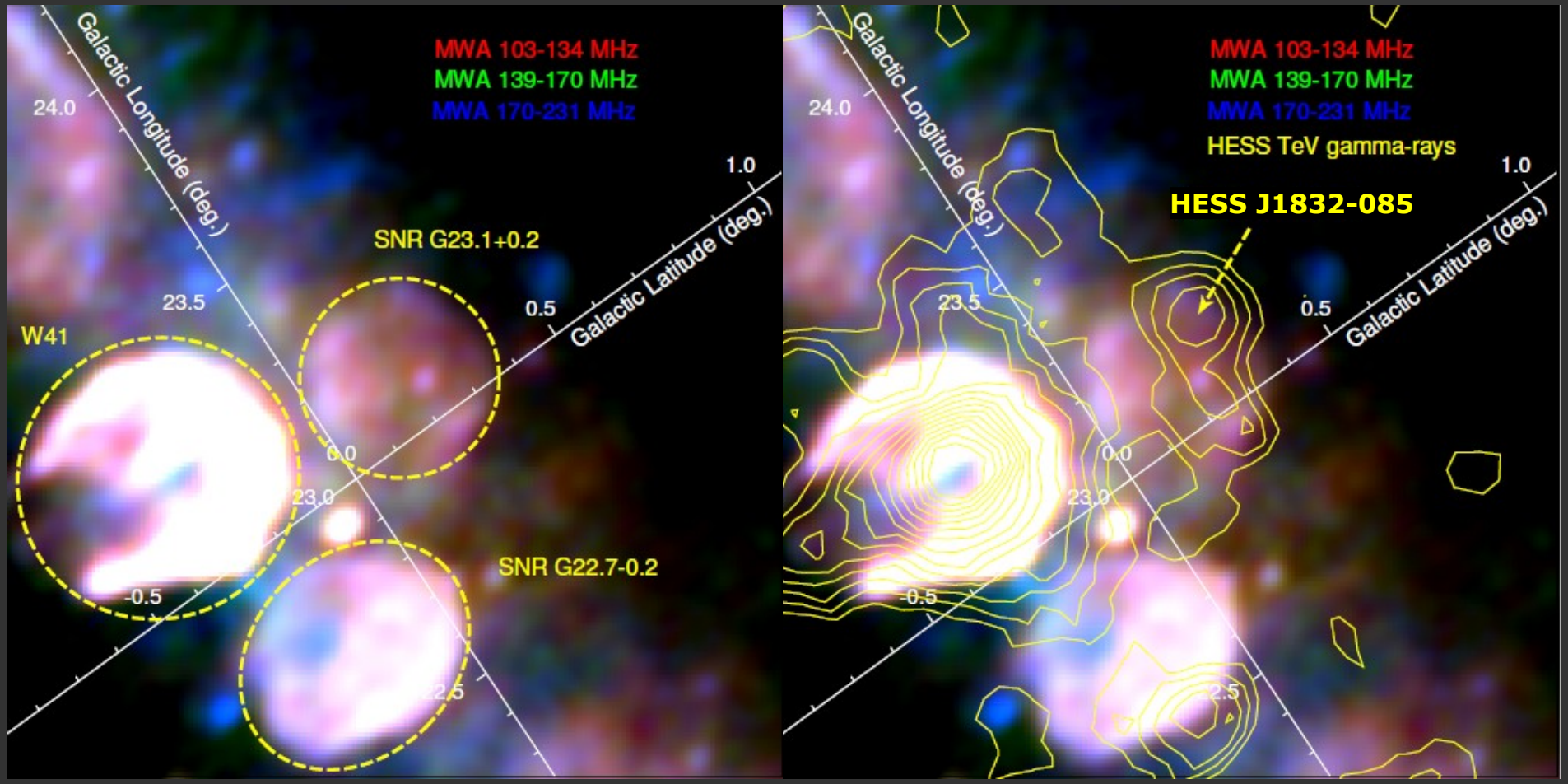
Impulsive particle accelerator e.g. SNR



Hadronic: CR + ISM Interaction – Spectral Evolution

Impulsive particle accelerator e.g. SNR





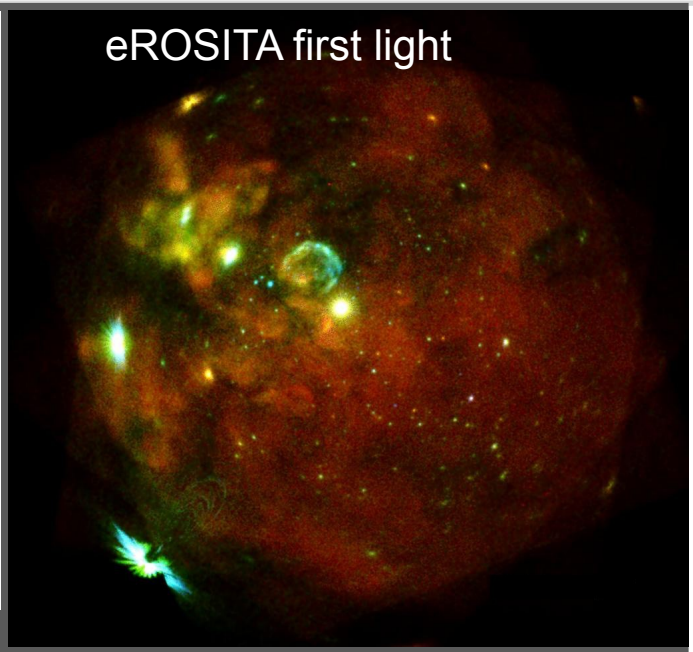
- MWA SNR candidate G23.11+0.18; Also seen with VLA THOR (Anderson et al 2017)
- Overlaps unidentified TeV gamma-ray source HESSJ1832-085
- No X-ray emission → old-ish (>~10kyr) SNR?

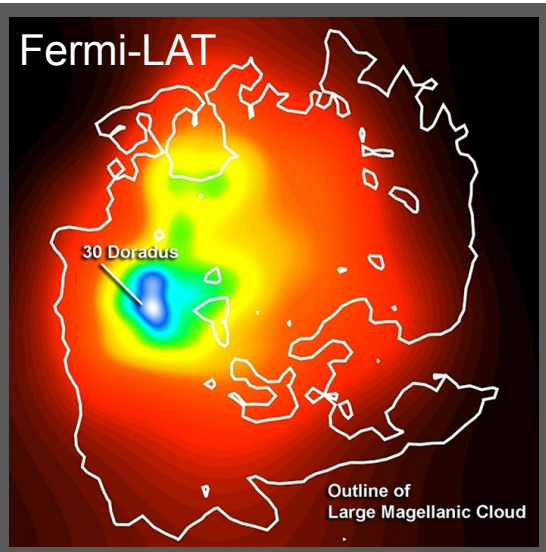
Maxted etal. 2019

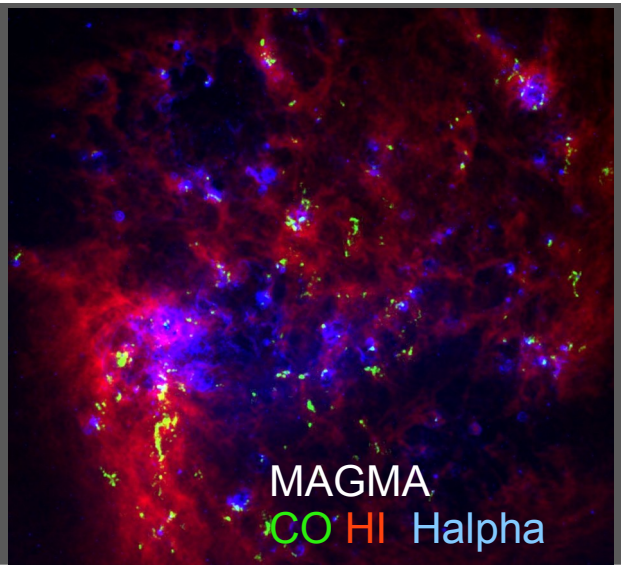
Large Magellanic Cloud Survey with CTA

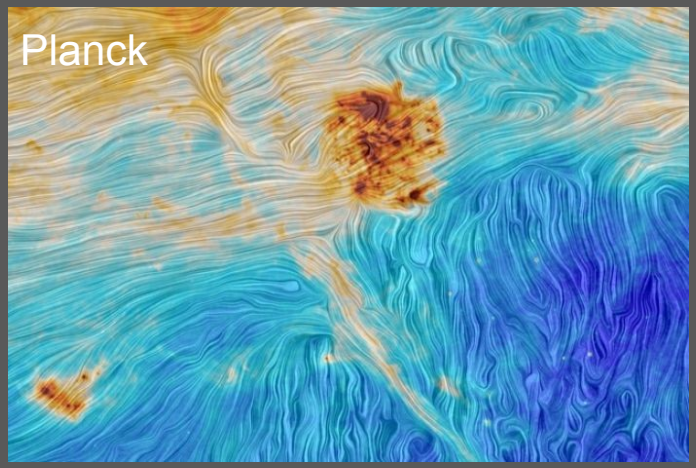
- 30 Doradus, the largest star-forming region of the local group of galaxies [209],
- SN 1987A, the remnant of the nearest naked-eye supernova since Kepler in 1604 [210],
- about 60 well-established and 20 good-candidate SNRs [211],
- one of the densest stellar clusters known: R136 [212],
- the most massive stars known [212],
- hundreds of HII regions [213],
- more than a dozen superbubbles [214],
- about 20 supershells and a hundred giant shells [215],
- two of the most powerful pulsars known and their nebulae [216, 217], and
- a well-studied population of star clusters, with ages from a few Myr up to 10Gyr [218].

CTA Science 2018



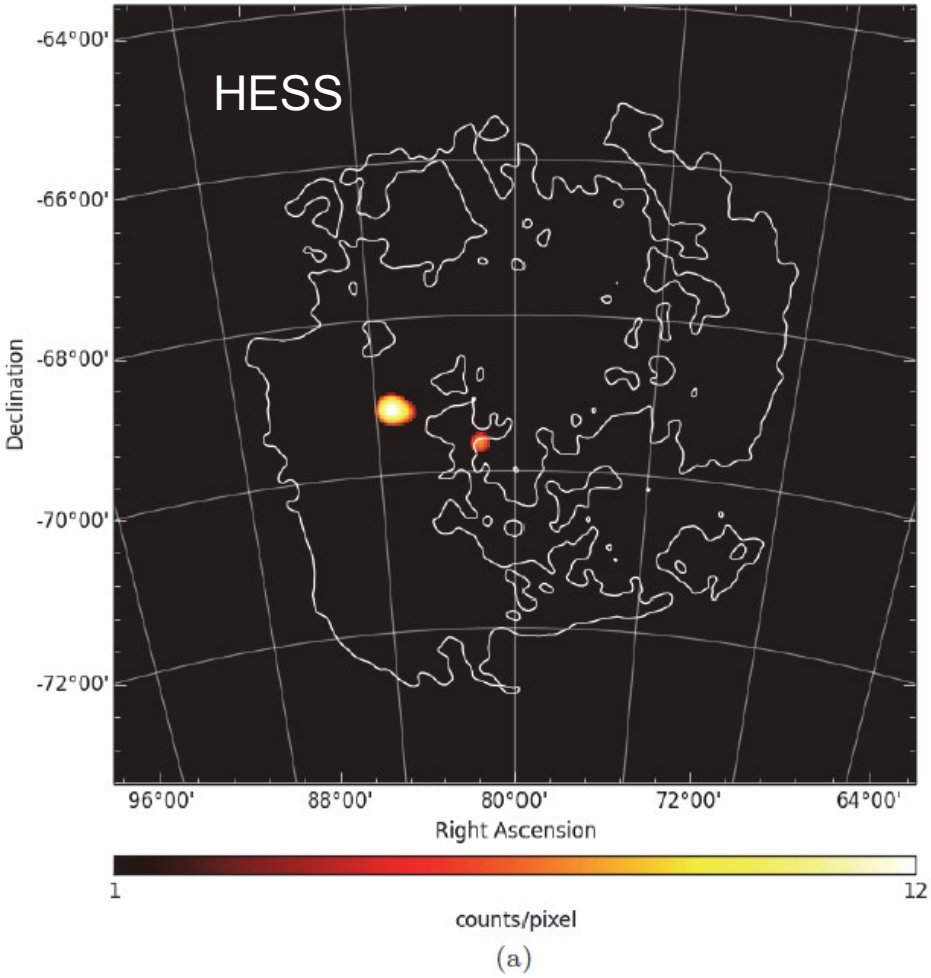


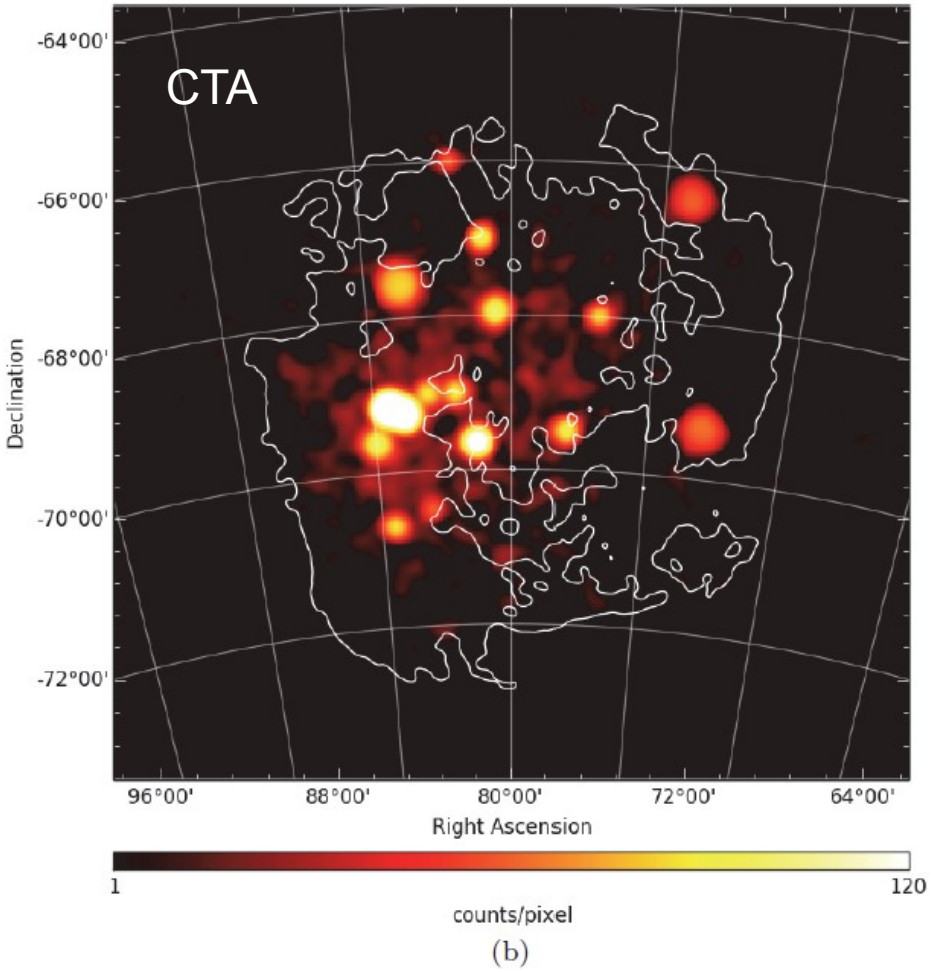




cherenkov telescope array

Simulated LMC with CTA





Summary: CTA's Galactic/LMC Surveys

- CTA will conduct several major surveys

  Galactic Plane; Galactic Centre Region; Large Magellanic Cloud

  They will be 5-20 times more sensitive than current TeV surveys

- Complete Galactic census (at HESS detection luminosity)

- TeV source population ~1000 sources or more.

- Intimate links with radio and optical facilities in Australia
  (steady sources; transient sources)

- ISM surveys; Radio continuum surveys; Optical/Radio followup