Nigel Maxted
ISM Meeting, Bamberg
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The Mopra Southern Galactic Plane CO Survey

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Western Sydney University, Penrith, Australia
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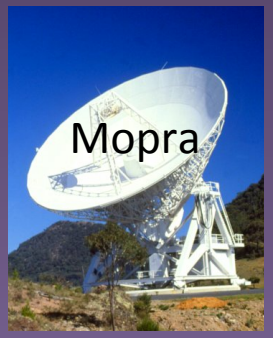
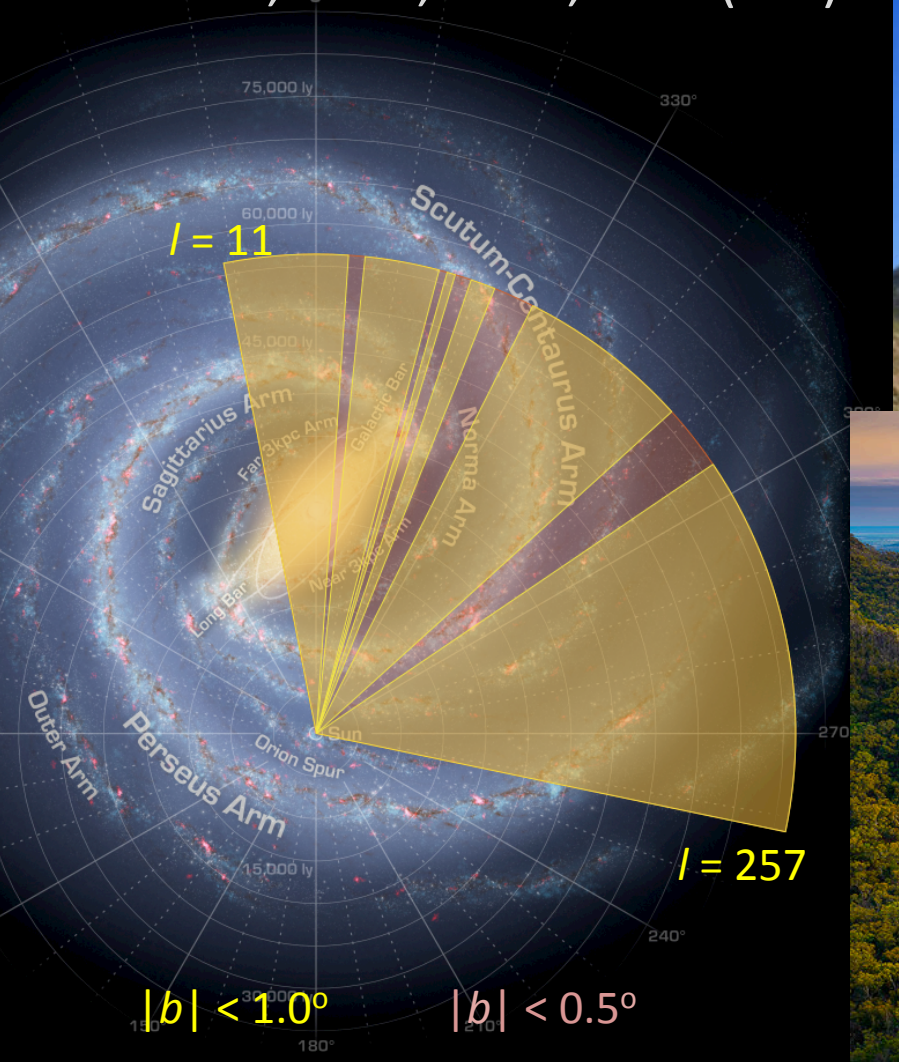
University of Adelaide, Adelaide, Australia
CSIRO Astronomy & Space Science, Australia Telescope National Facility, Epping, Australia
Universidad de Chile, Santiago, Chile

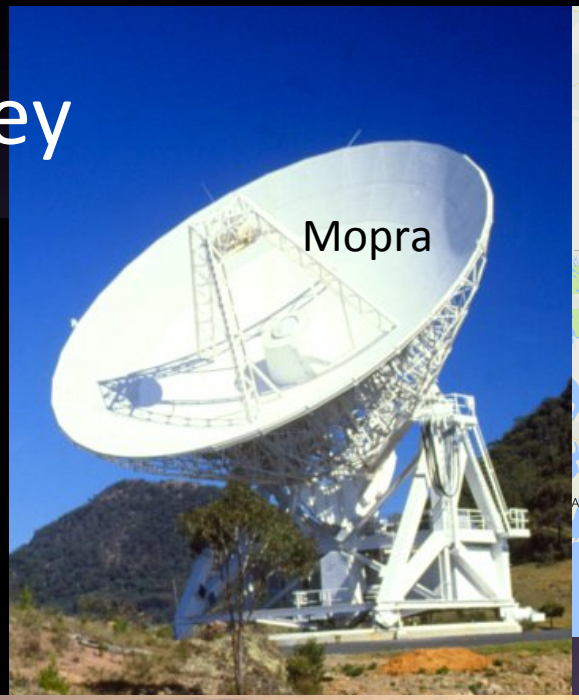


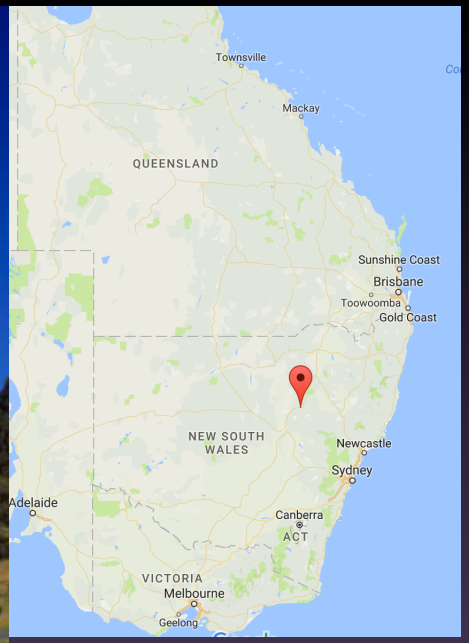
#Team Mopra

The Mopra Southern Galactic Plane CO Survey

^{12}CO, ^{13}CO, $C^{18}O$, $C^{17}O$(1-0)







CO GPS Observing Strategy

*Scans the Galactic plane at a speed of ~3 square degrees every 4 nights for orthogonal scans.

7mm

CS(1-0)
SiO(1-0)
CH_3N, CH3OH

Beam ~1'
Vel Res. ~0.21 km/s

12mm

$NH_3(1,1)$
$NH_3(2,2)$
$NH_3(3,3)$
H alpha

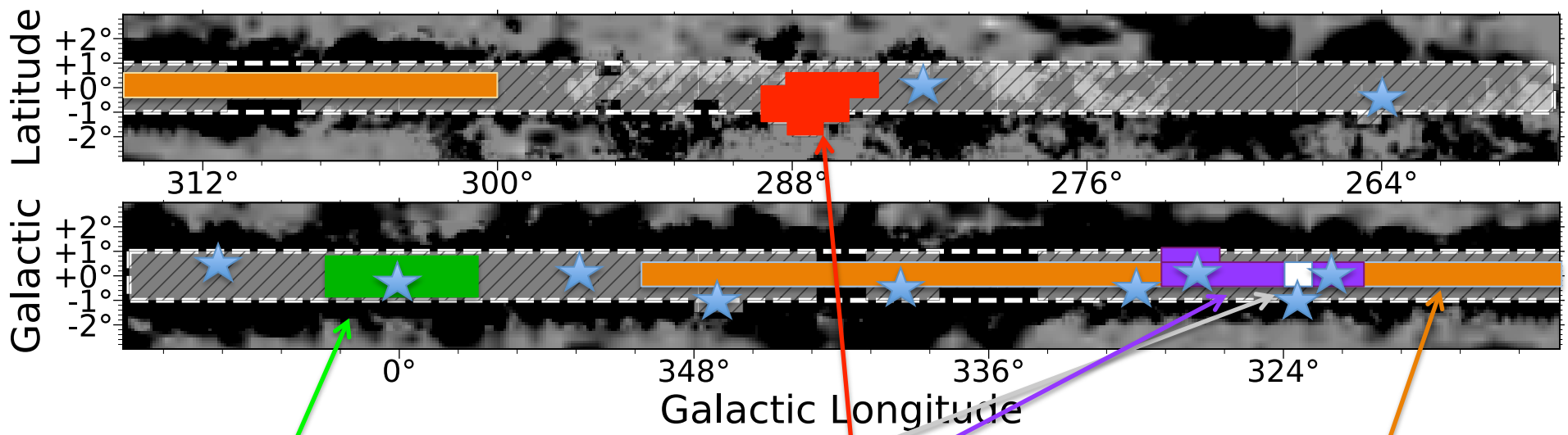
Beam ~2'
Vel Res. ~0.4 km/s

3mm

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

Beam ~36''
Vel. Res. ~0.12 km/s

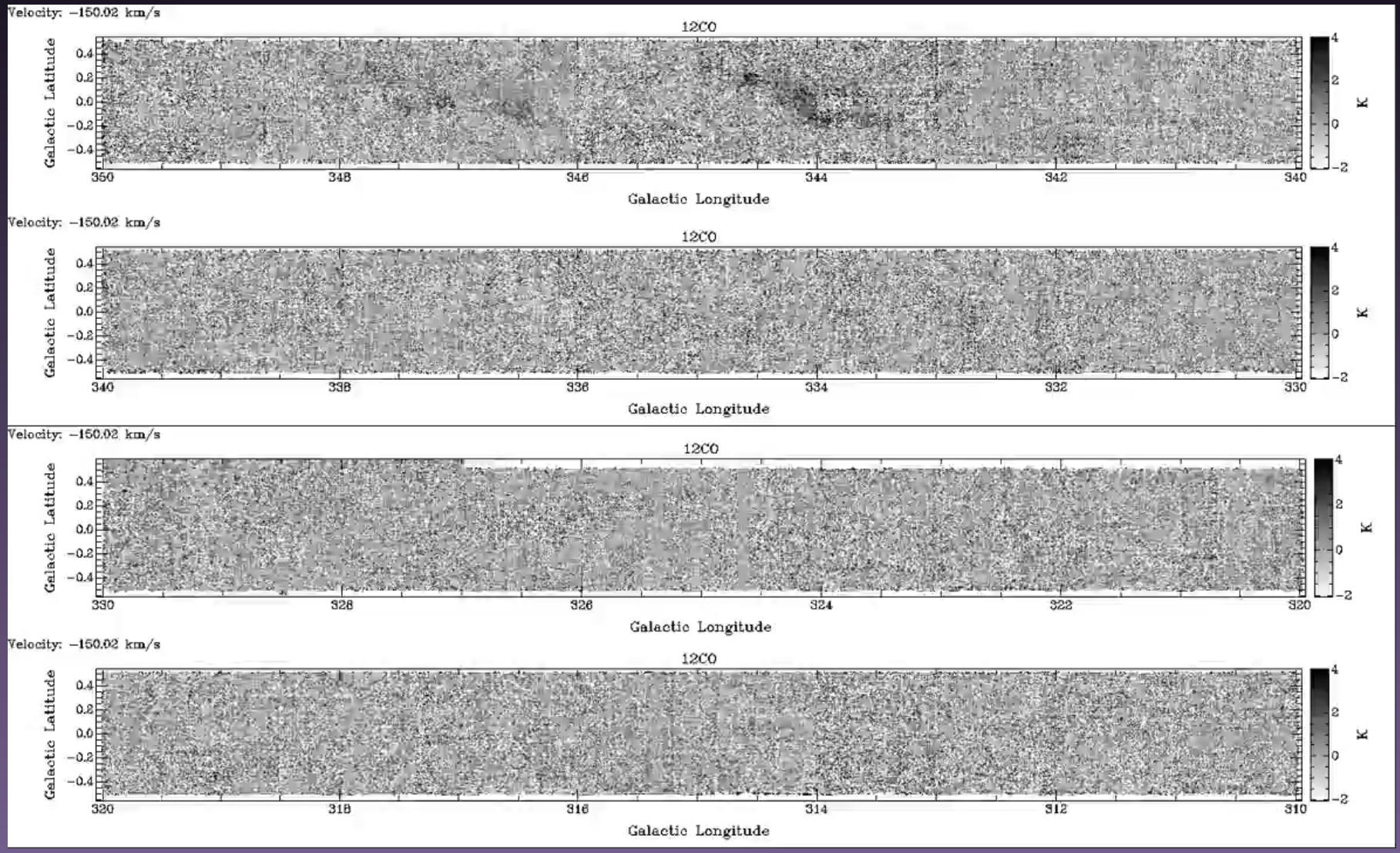
Mopra CO SGPSurvey: Availability



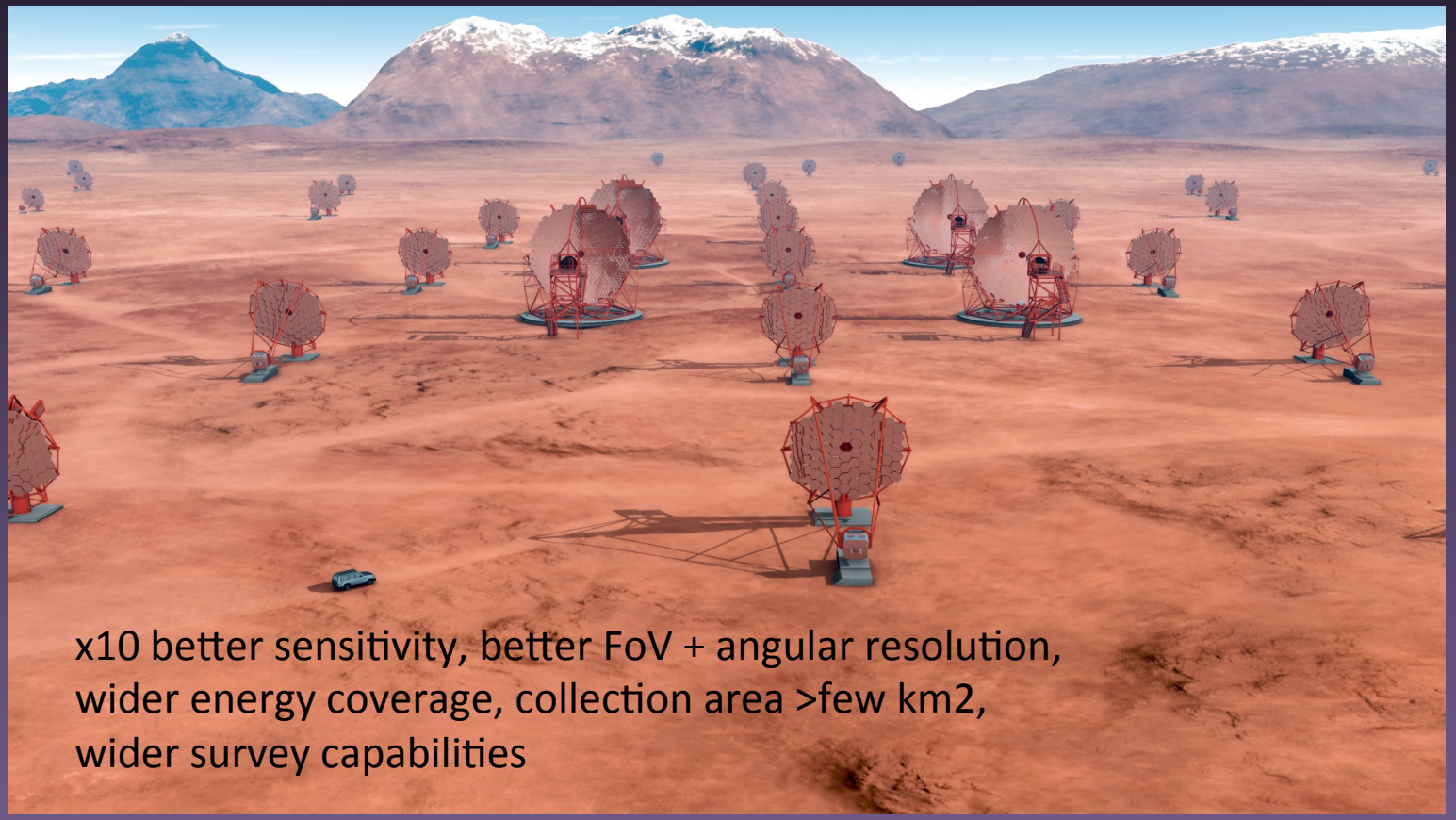
- Pilot region G328 (Burton, *et al.*, 2013)
- **Data release I (Braiding, *et al.*, 2015)**
- Data release II: Carina nebula (Rebolledo, *et al.*, 2016)
- Central Molecular Zone (Blackwell, *et al.*, in prep.)
- **Data release III: G300 to G350, |b| < 0.5 (Braiding, *et al.*, 2018, accepted Feb)**

★ Other Mopra studies http://www.physics.adelaide.edu.au/astrophysics/MopraGam/

Data Release III (DR3)
l=300 – 350°

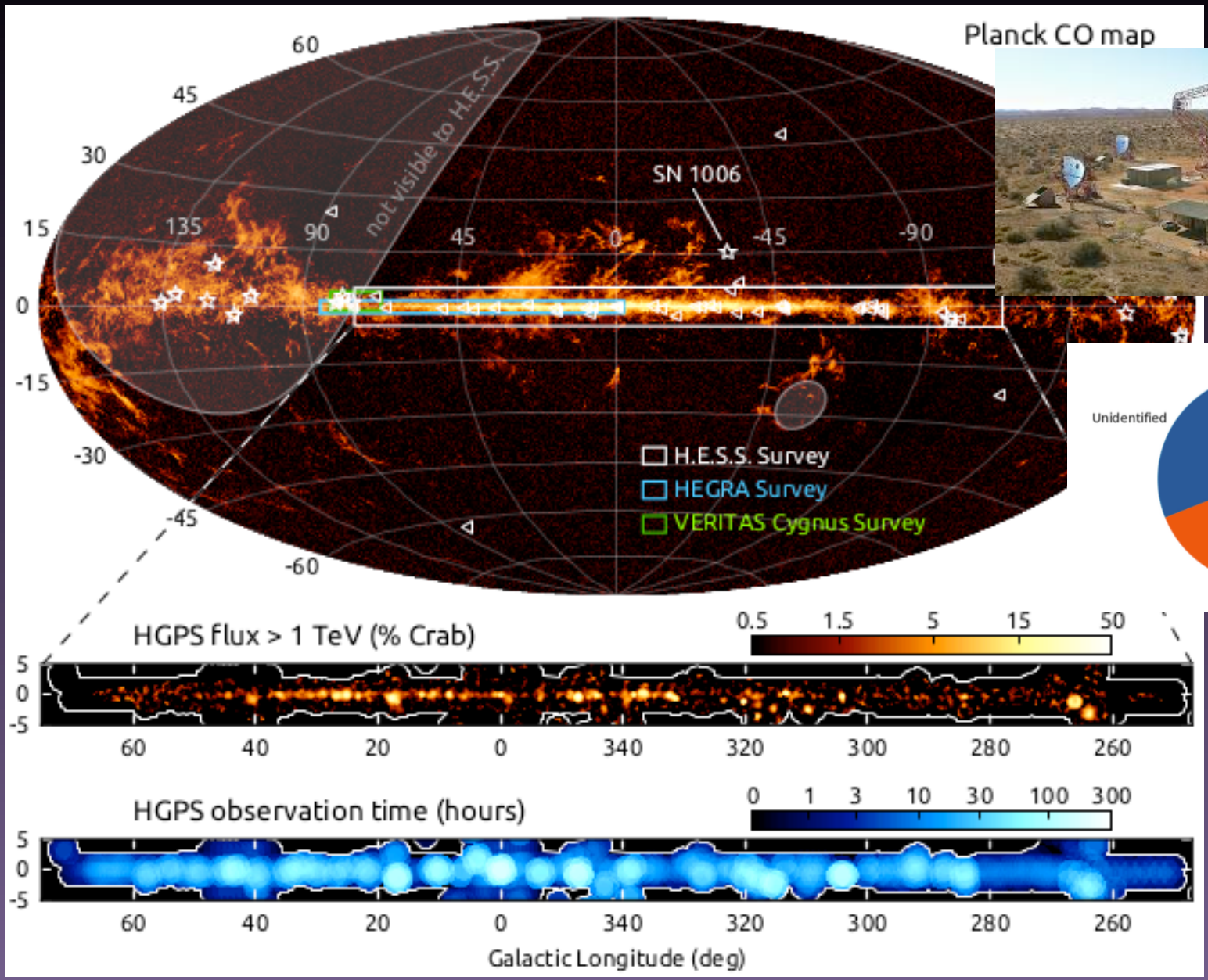


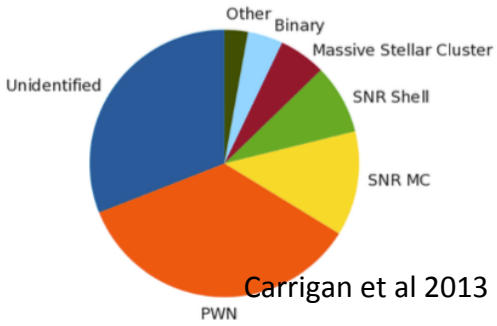
Cherenkov Telescope Array (CTA): The next generation gamma-ray telescope



x10 better sensitivity, better FoV + angular resolution,
wider energy coverage, collection area >few km2,
wider survey capabilities

The HESS Galactic Plane Survey

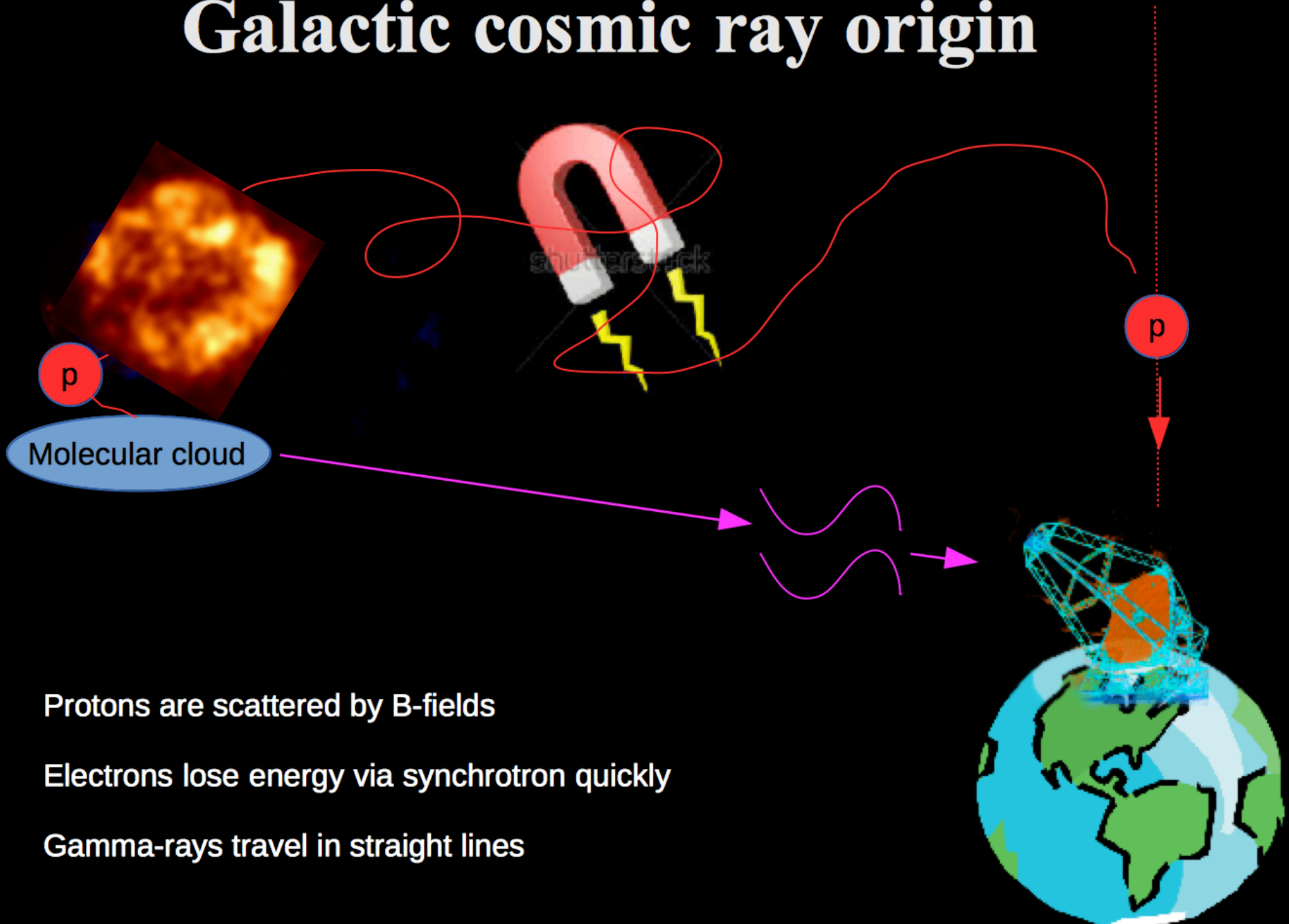




Carrigan et al 2013

Abdalla et al 2018

Galactic cosmic ray origin



Protons are scattered by B-fields

Electrons lose energy via synchrotron quickly

Gamma-rays travel in straight lines

Gamma-ray emission from particles

p-p interaction:

p

TeV Proton

Gas

π+

π -

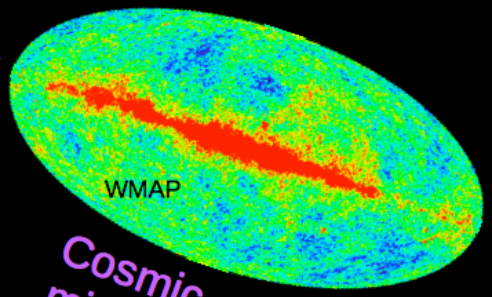
π0

TeV gamma-rays

Inverse Compton Scattering:

e

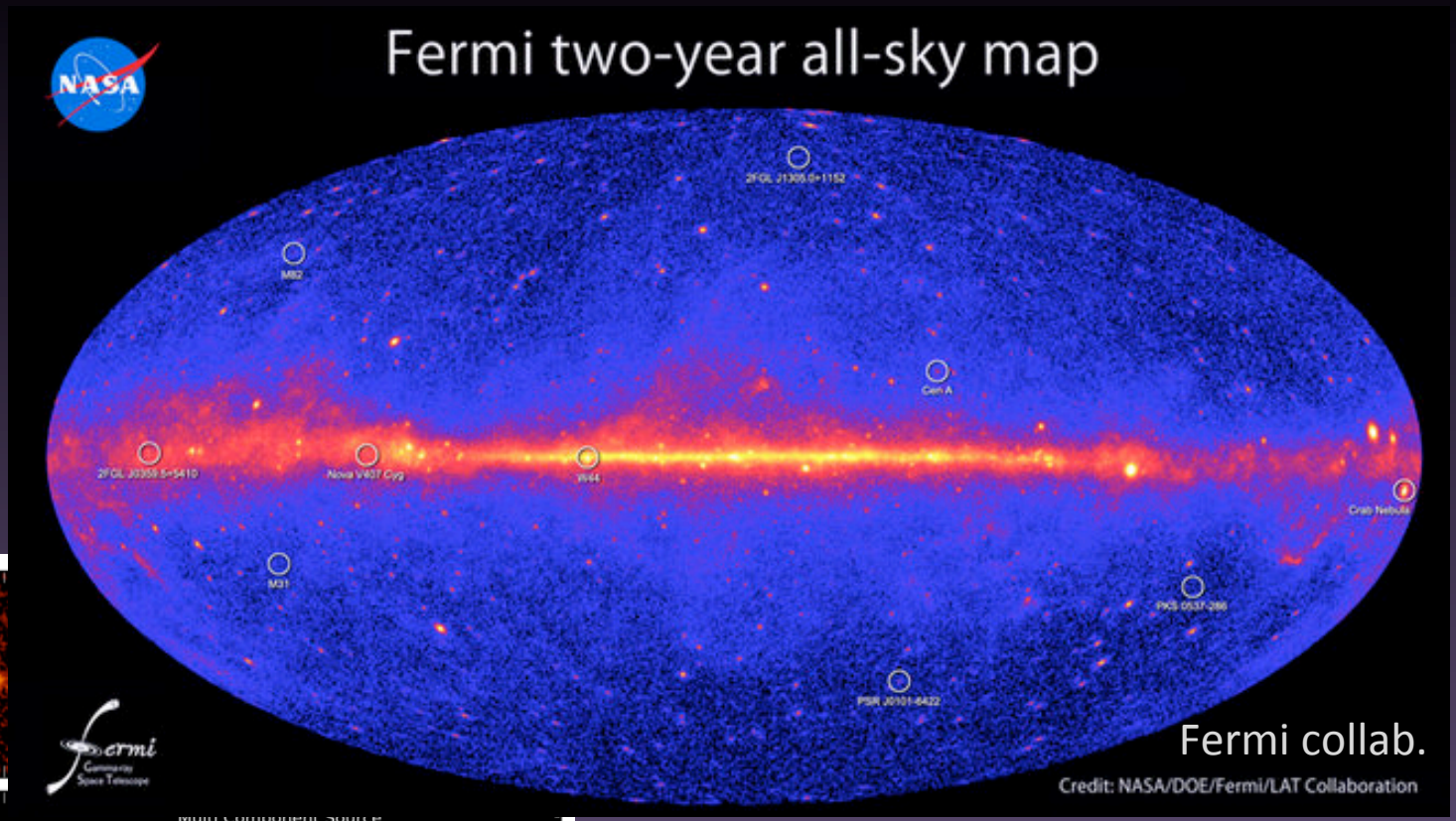
TeV electron

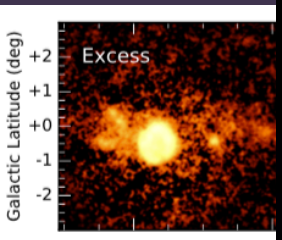


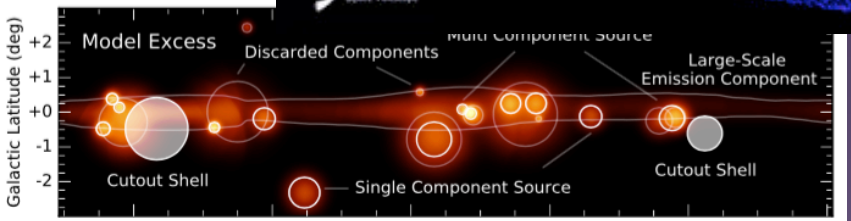
Cosmic microwave background (& other radiation!)

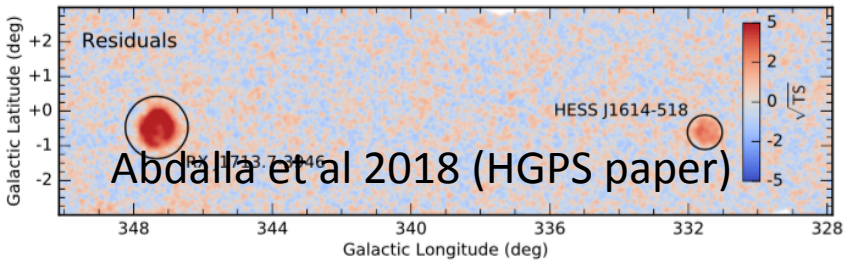
e -

TeV gamma-ray





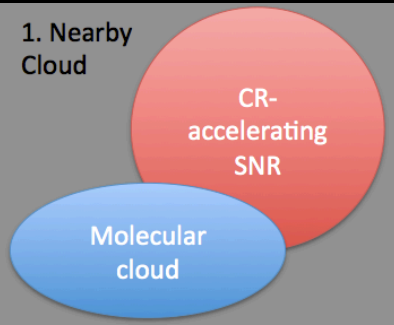




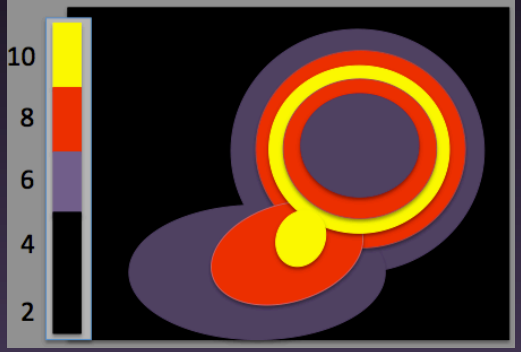
Abdalla et al 2018 (HGPS paper)

Looking for CR sources with gamma-ray astronomy

1. Nearby Cloud



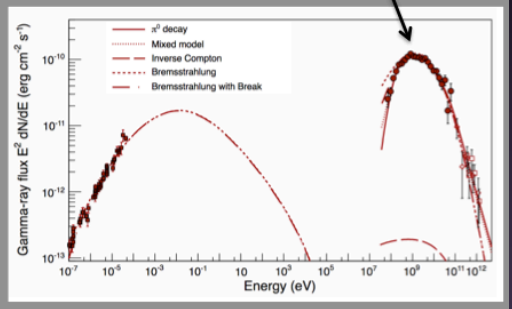
TeV gamma-ray significance



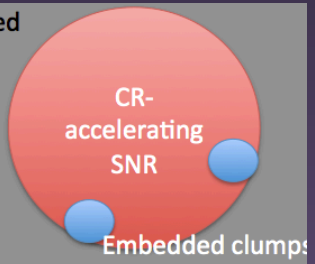
2. Pion bumps

Bump feature indicates clear cosmic-ray interactions...

(e.g. In W44 and IC443, Ackemann et al 2013)



3. Embedded clumps



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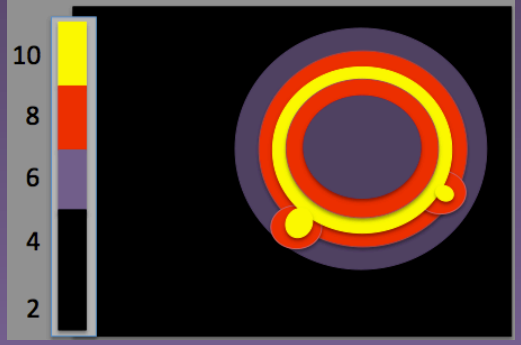
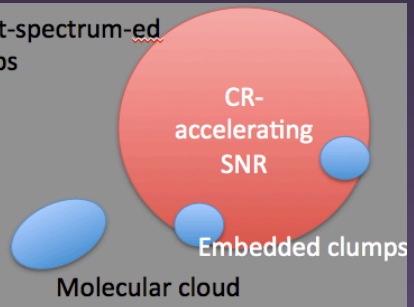
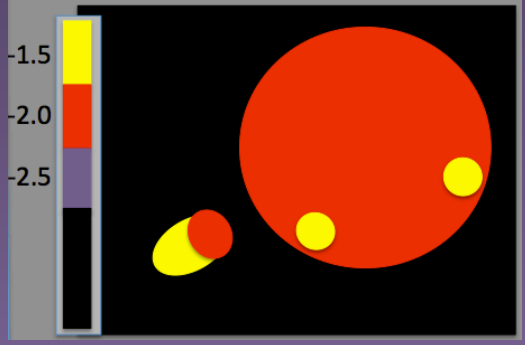
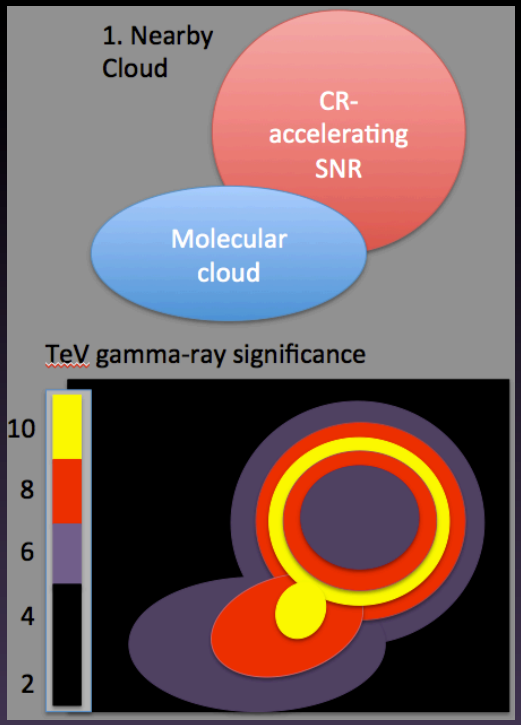


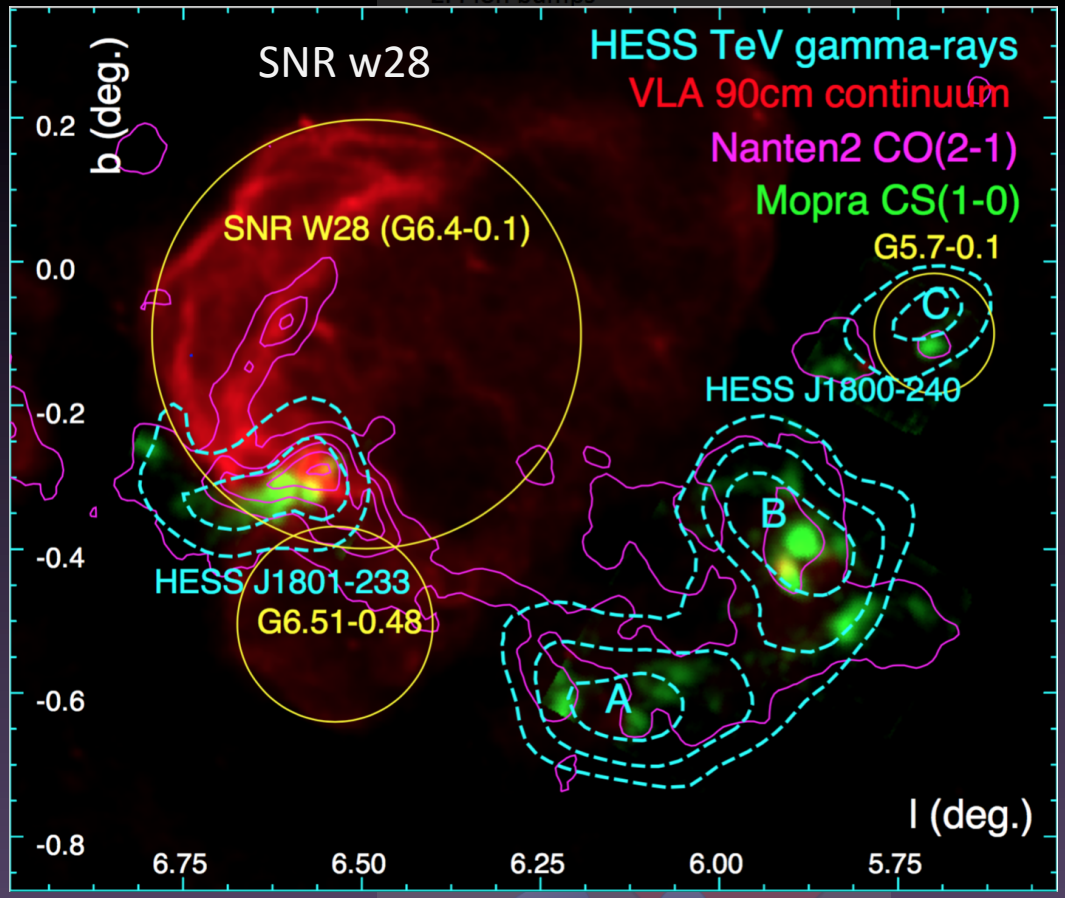
4. Flat-spectrum-ed clumps



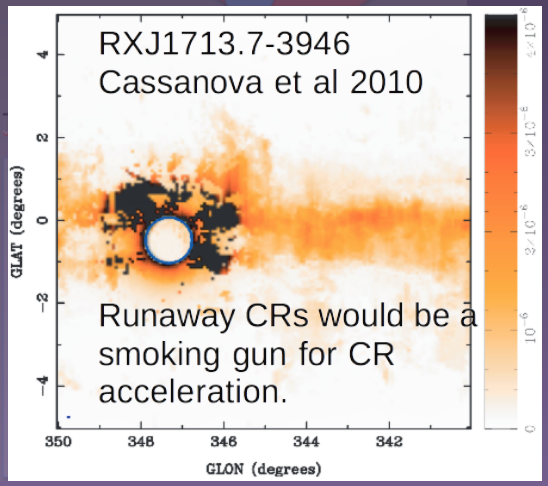
Gamma-ray spectral index (F ~ A E ^ a)

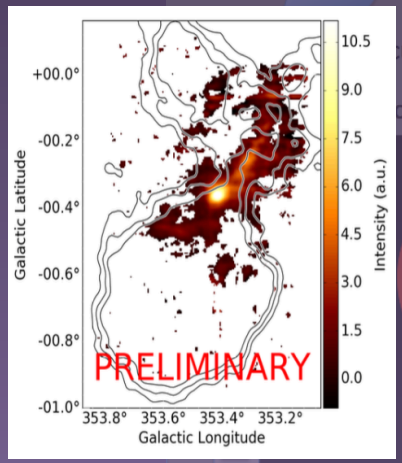






e.g.
Aharonian et al 2005
Fukui et al 2008
Arikiawa et al 2004
Nicholas et al 2011
Nicholas et al 2012
Maxted et al 2016
Maxted et al 2017





HESS J1731-347

Prelim HESS TeV gamma-rays
And Mopra CS(1-0) at 3.2kpc
(Capasso et al 2017)

(Note competing distance at
5.2-6kpc, Fukuda et al 2014

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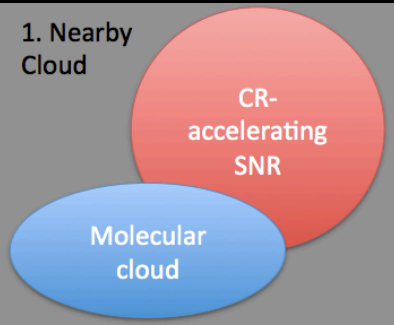

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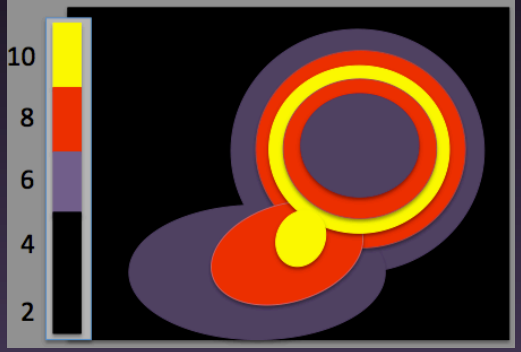

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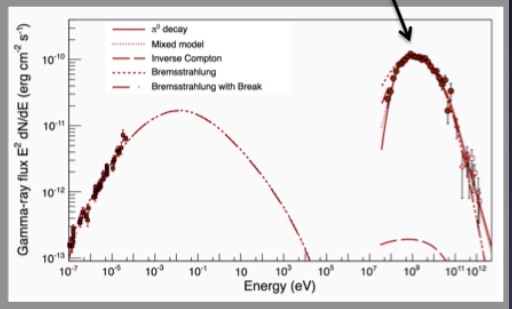
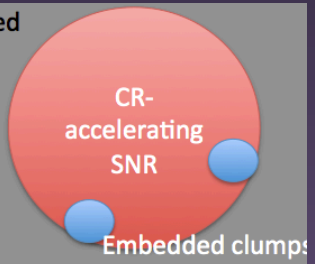


3. Embedded clumps



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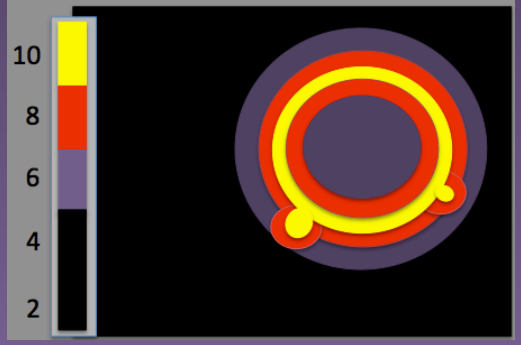

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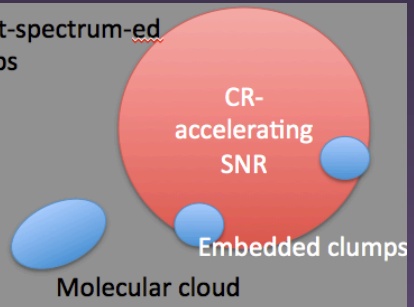
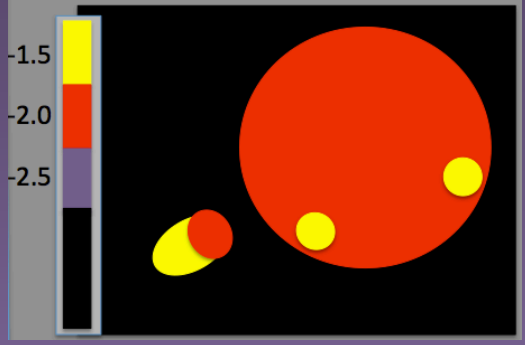
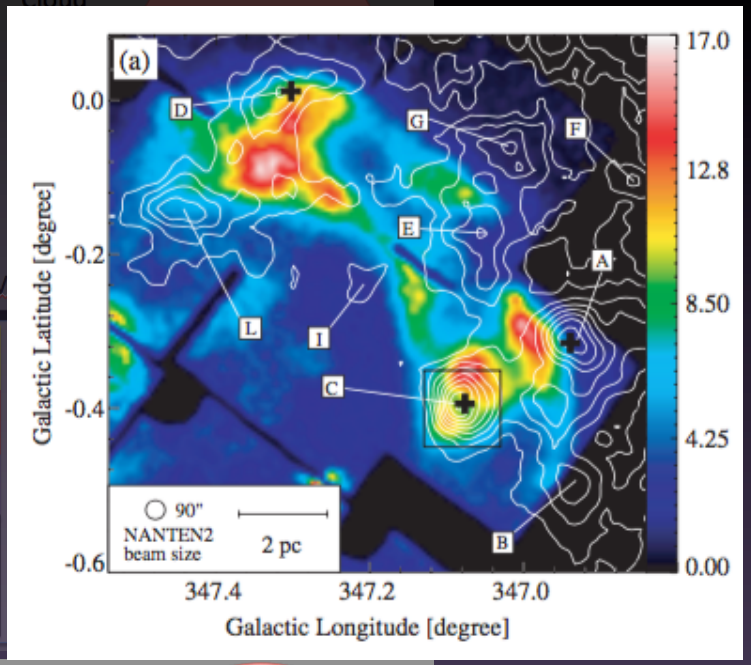


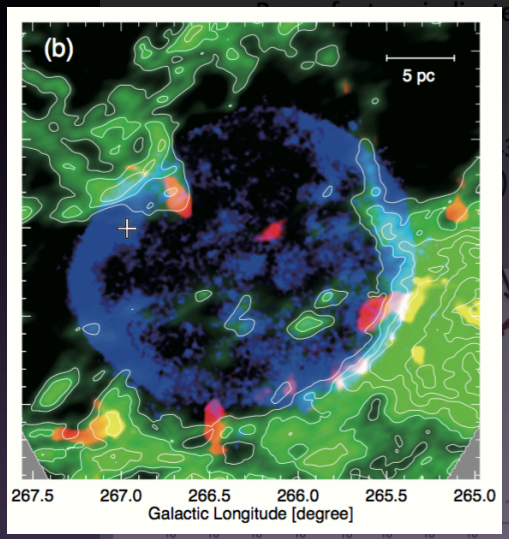
Gamma-ray spectral index (F ~ A E ^ a)



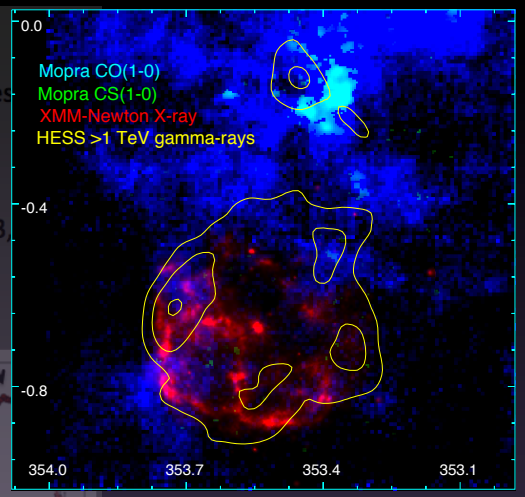
RXJ1713.7-3946 (X-rays and CO, Sano et al 2010)



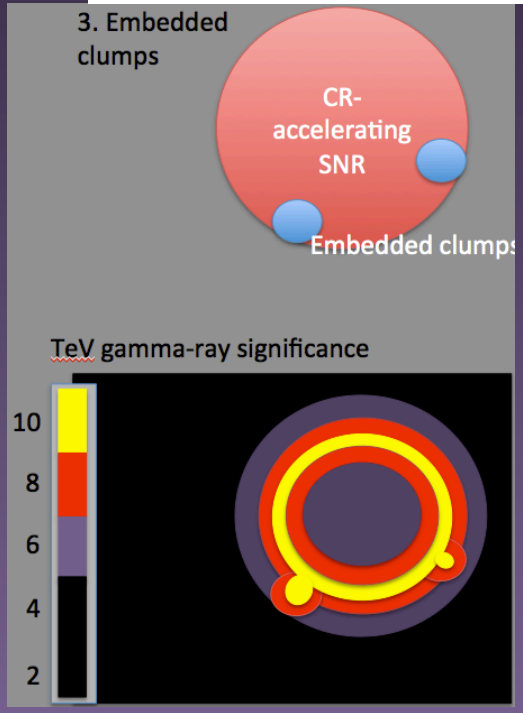
Fukui et al 2014

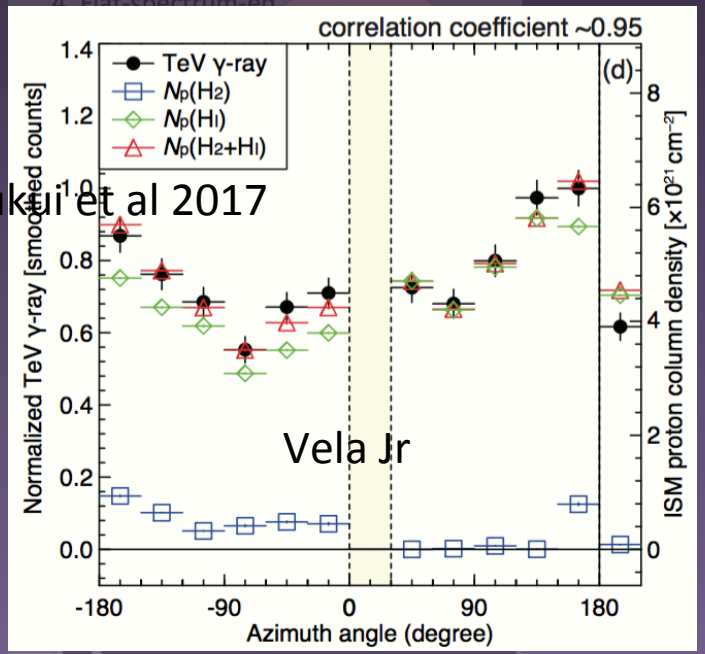


Vela Jr (HI, CO and gamma-rays, Fukui et al 2017)



HESS J1731-347 (see Fukuda et al, 2014)



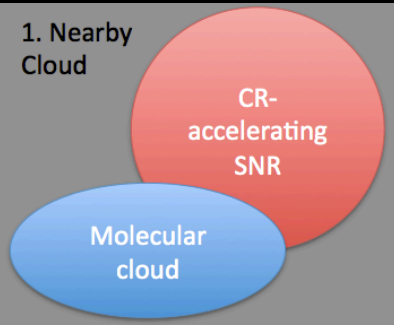


Fukui et al 2017

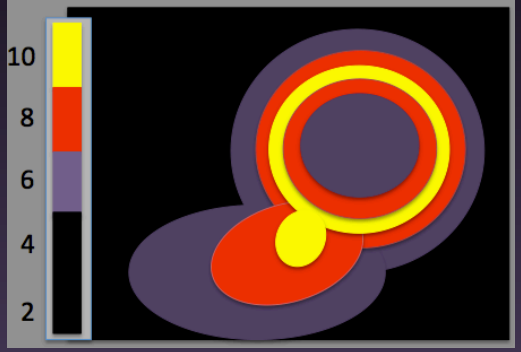
Vela Jr

Looking for CR sources with gamma-ray astronomy

1. Nearby Cloud



TeV gamma-ray significance



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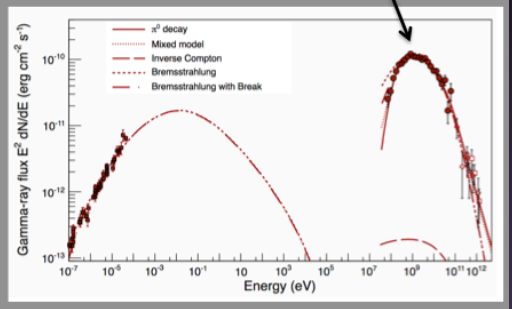
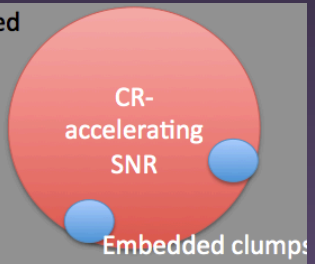
Bump feature indicates clear cosmic-ray interactions...

(e.g. In W44 and IC443, Ackemann et al 2013)



3. Embedded clumps



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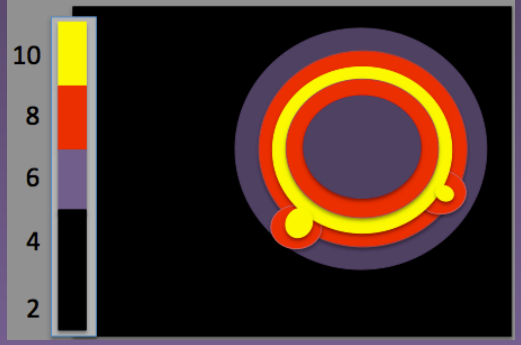
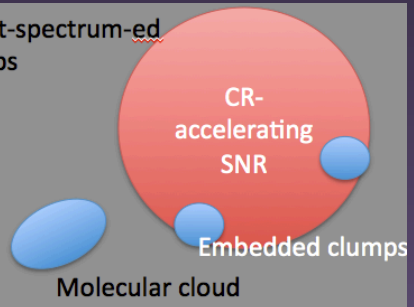
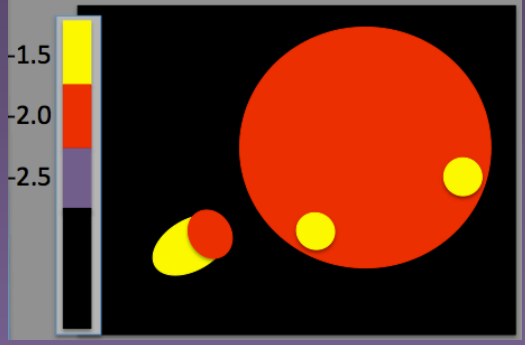


4. Flat-spectrum-ed clumps

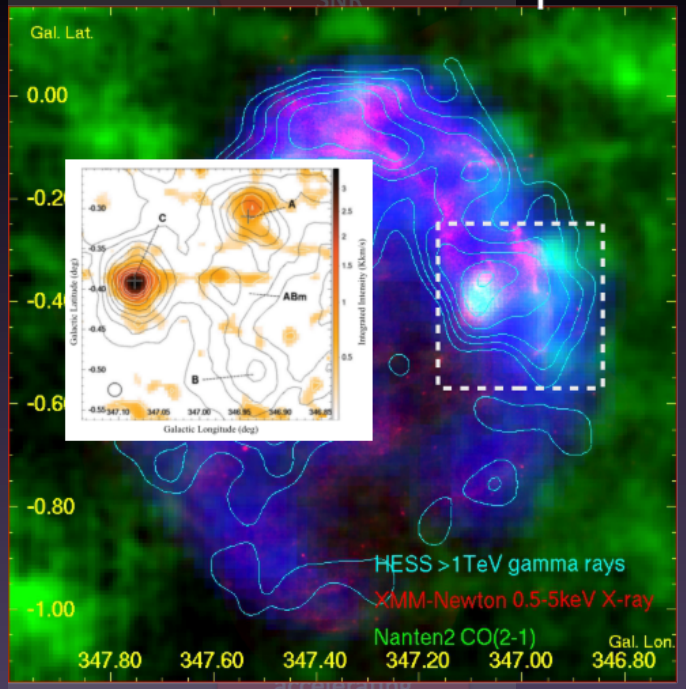


Gamma-ray spectral index (F ~ A E ^ a)

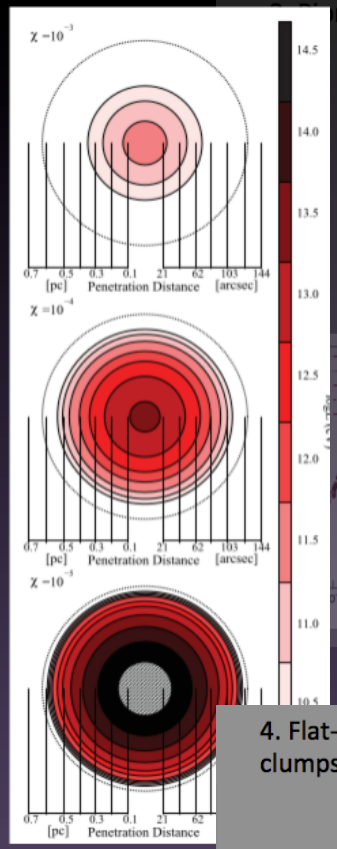


RX J1713.7-3946

Diffusion into clumps?



Maxted et al 2012



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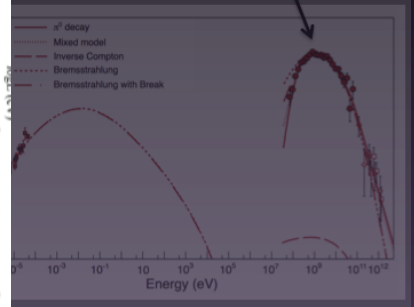

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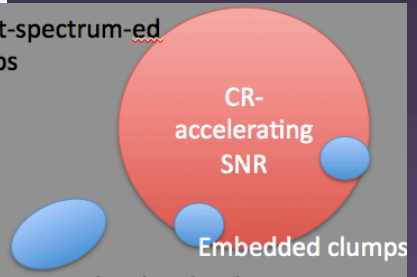

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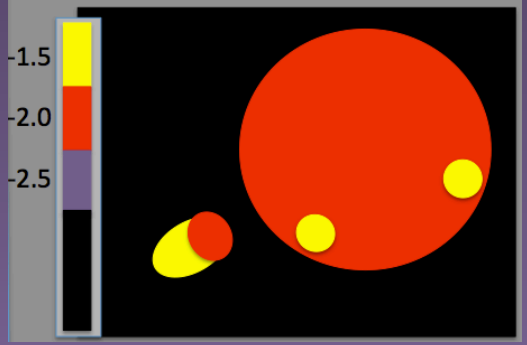
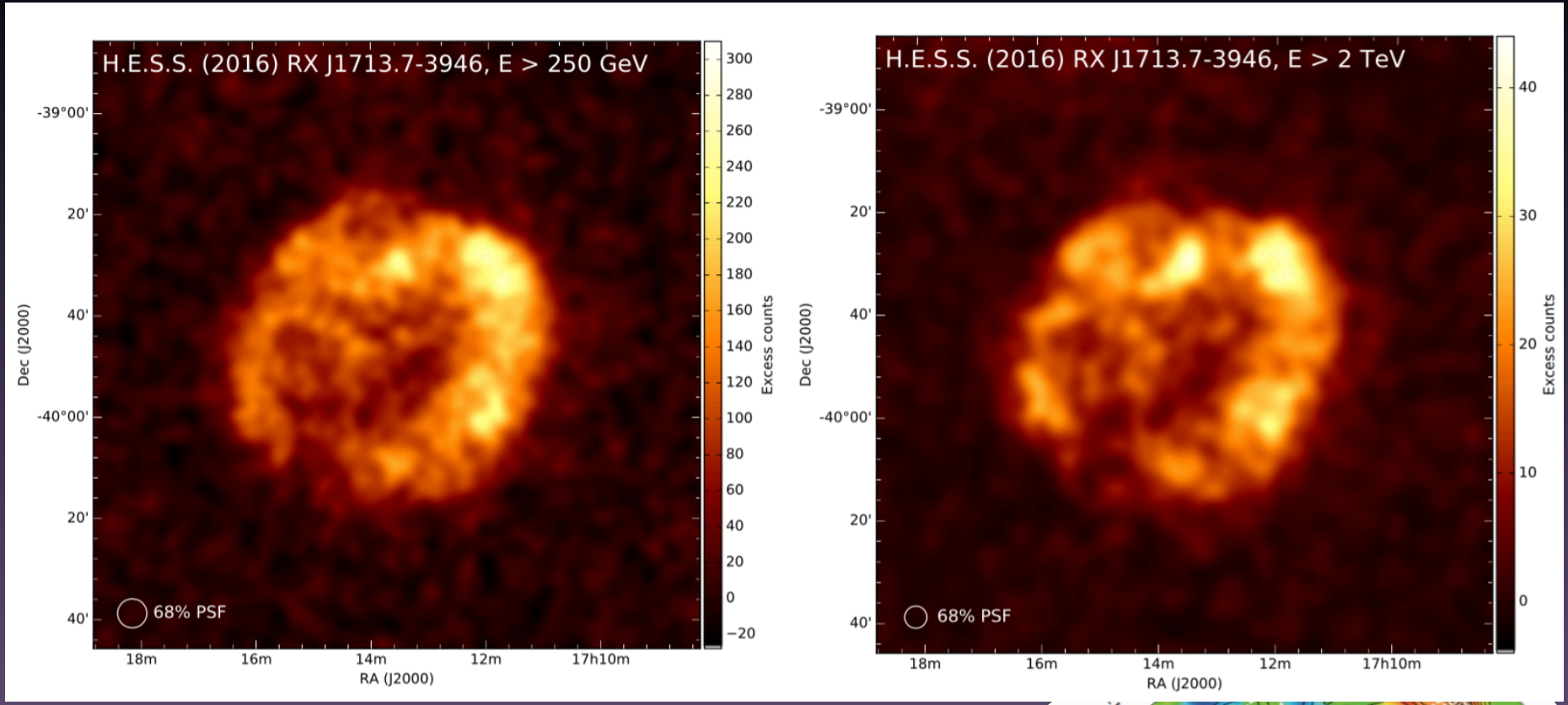


TeV gamma-ray significance

Abdalla et al, 2017.

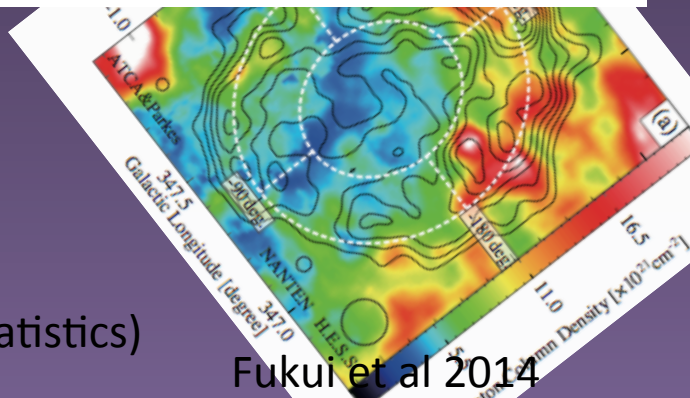
RX J1713.7-3946



H.E.S.S. angular resolution of 0.048◦ (0.036◦ above 2 TeV)

Current highest res gamma-ray image ~100 arcsec

No spectral variation on a scale of ~10 arcmin (limited by statistics)



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The future –CTA (South)