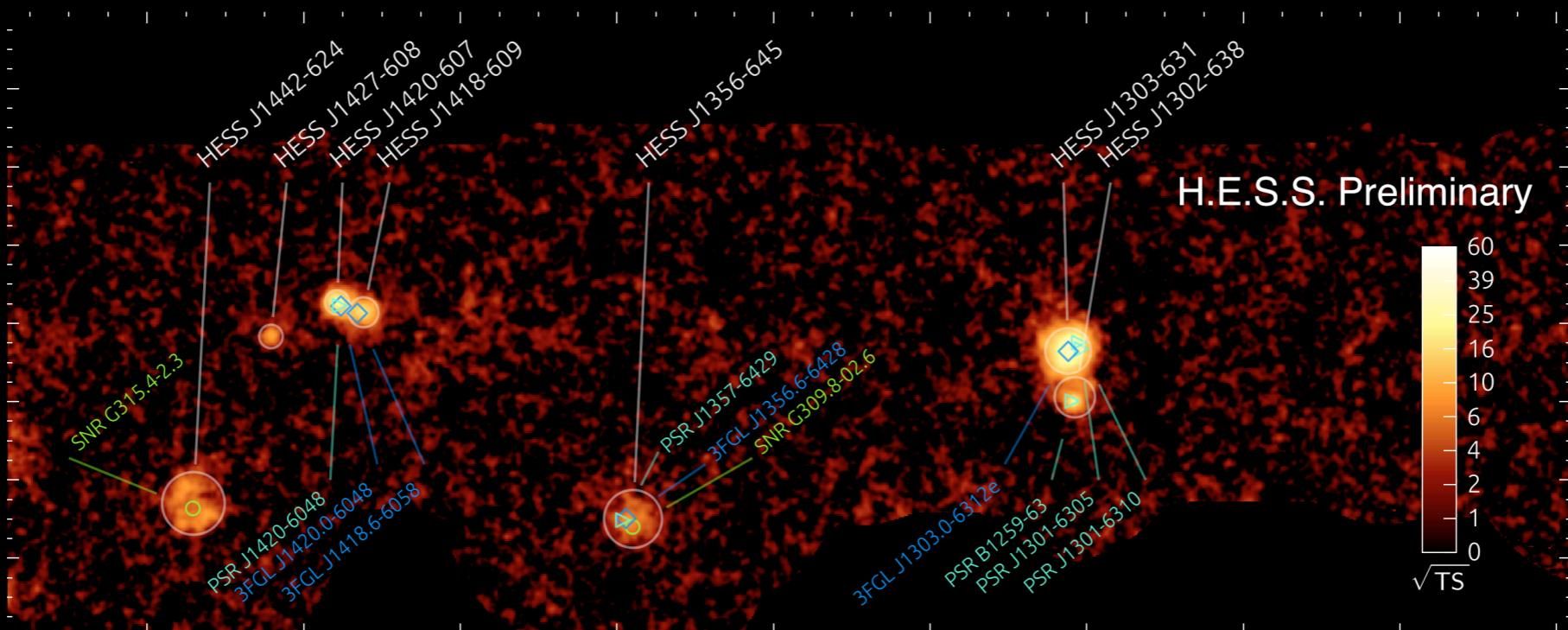


High-energy gamma-ray astronomy

An experimental overview



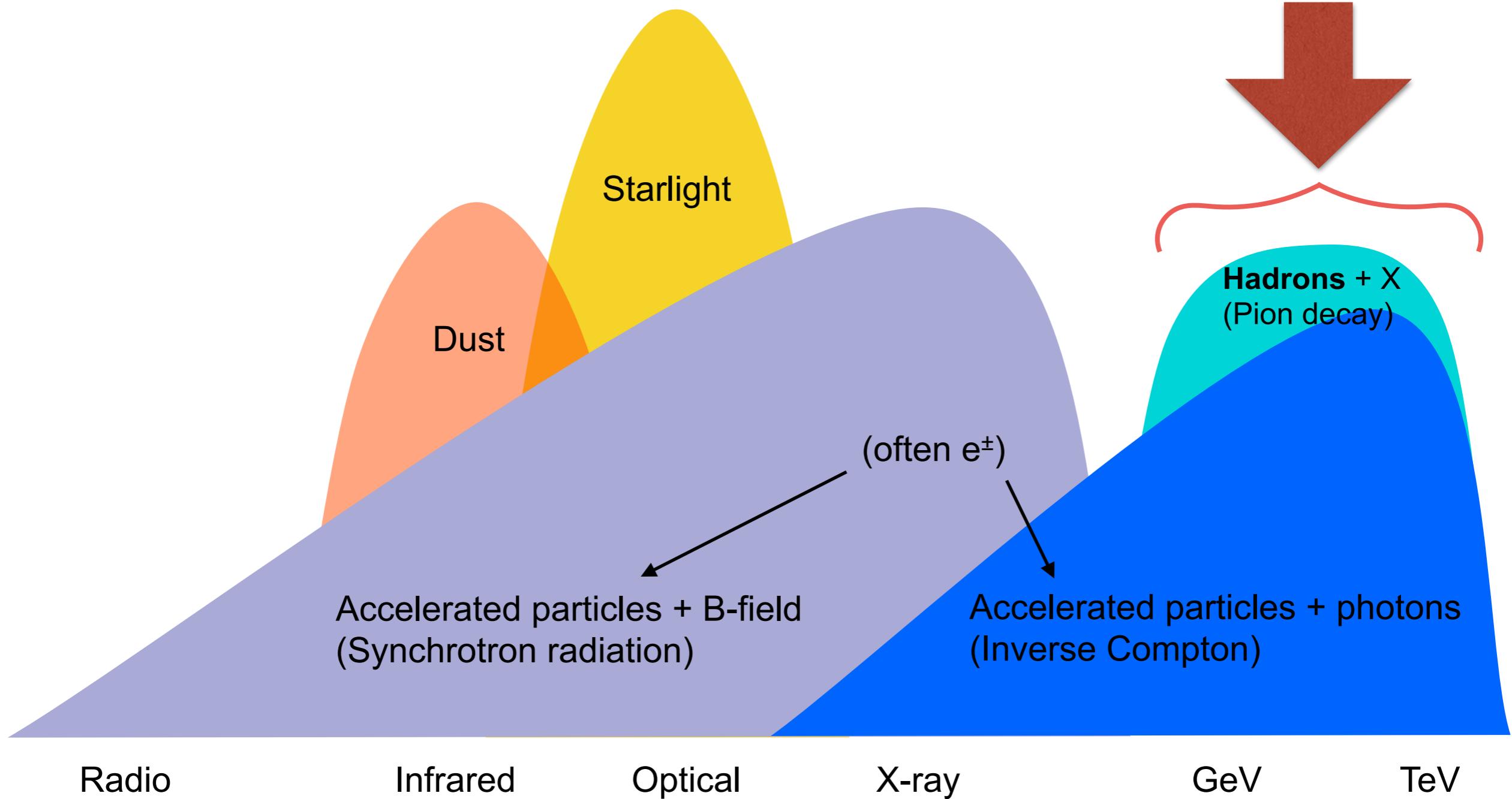
Stefan Klepser

Solvay–Francqui Workshop on Neutrinos
Brussels, May 2015

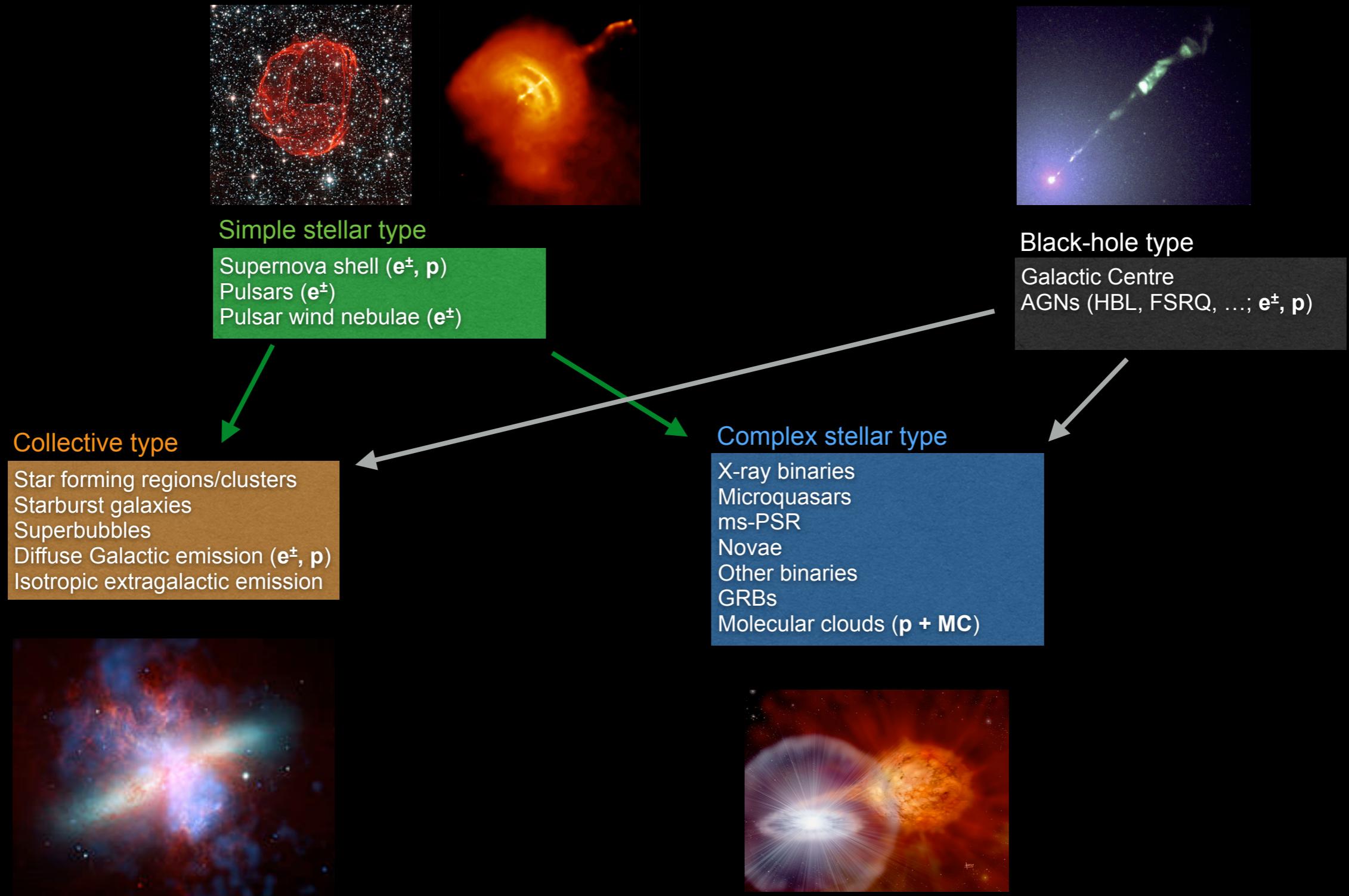
Displaying Cosmic Particle Accelerators

> ...and places where their outflow interacts

This talk



Displaying Cosmic Particle Accelerators



Plot of this talk

- > The gamma-ray window
 - Experimental coverage, surveys, detectors, upgrades



- > Recent findings
 - Subjectively chosen remarkable new results 2014/15



- > Recent not-yet findings
 - ...like neutrino-emitting sources



- > The future



Plot of this talk

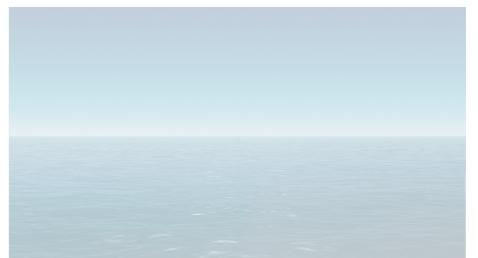
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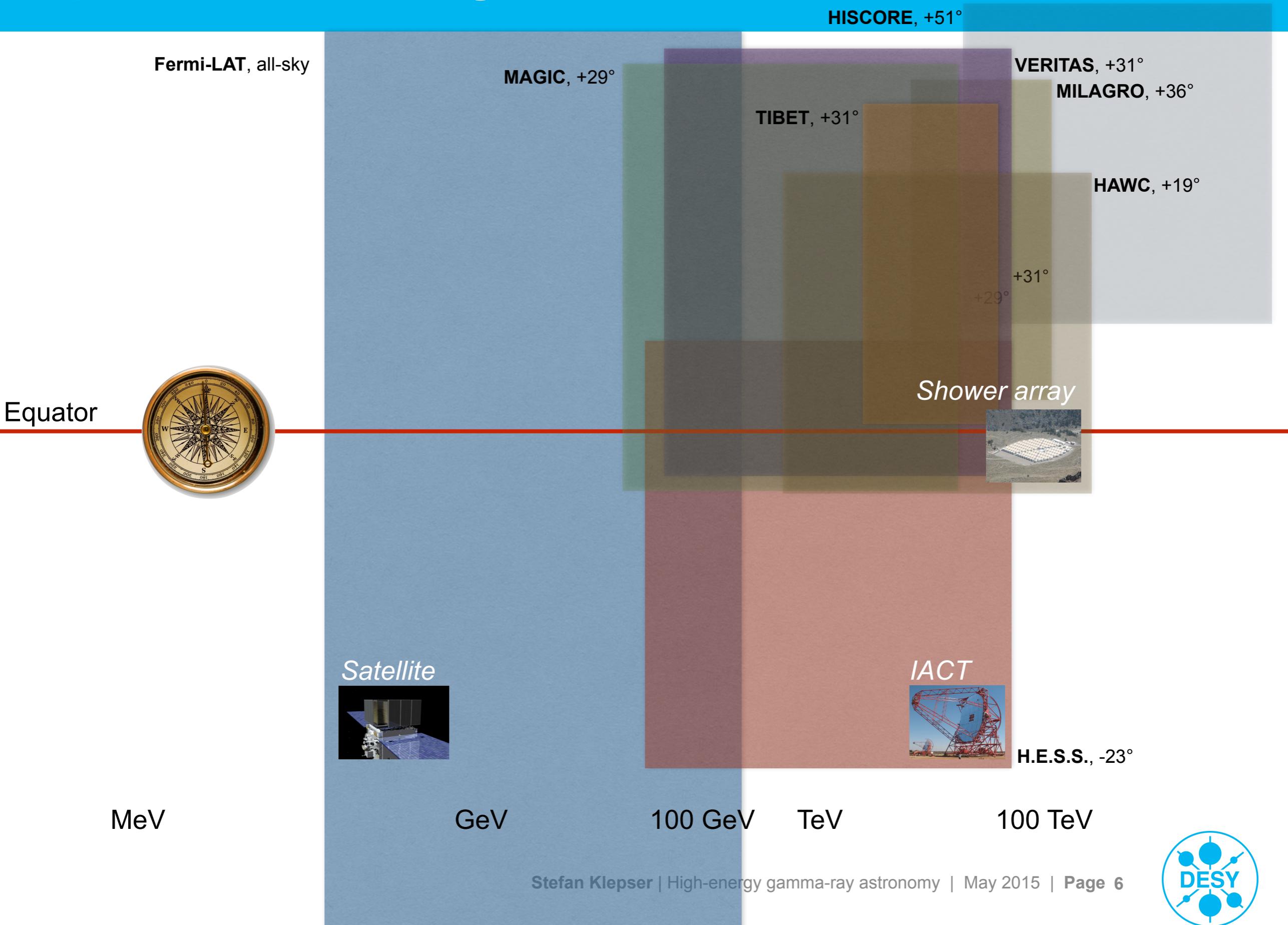
- > Recent not-yet findings
 - ...like neutrino-emitting sources



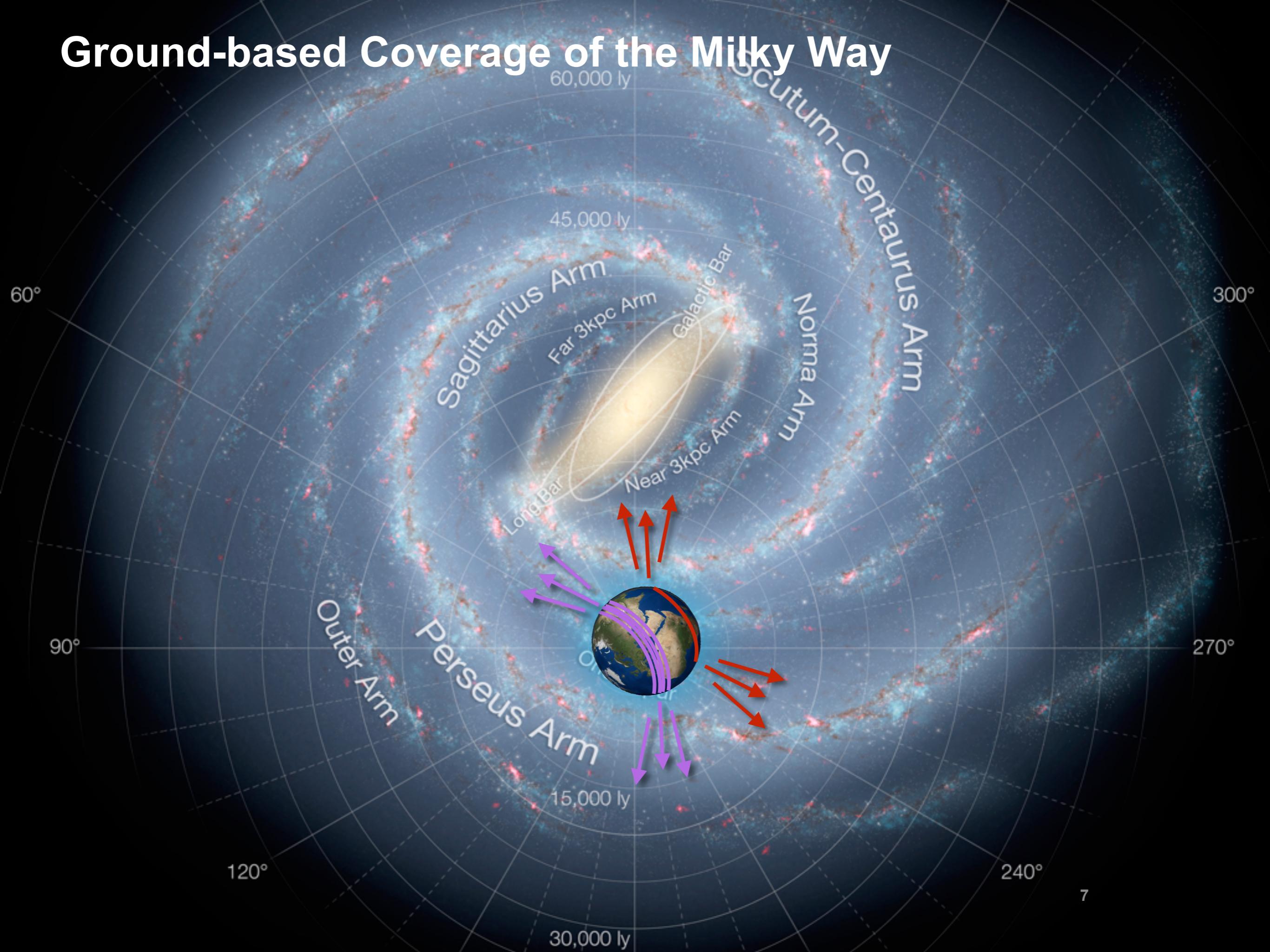
- > The future



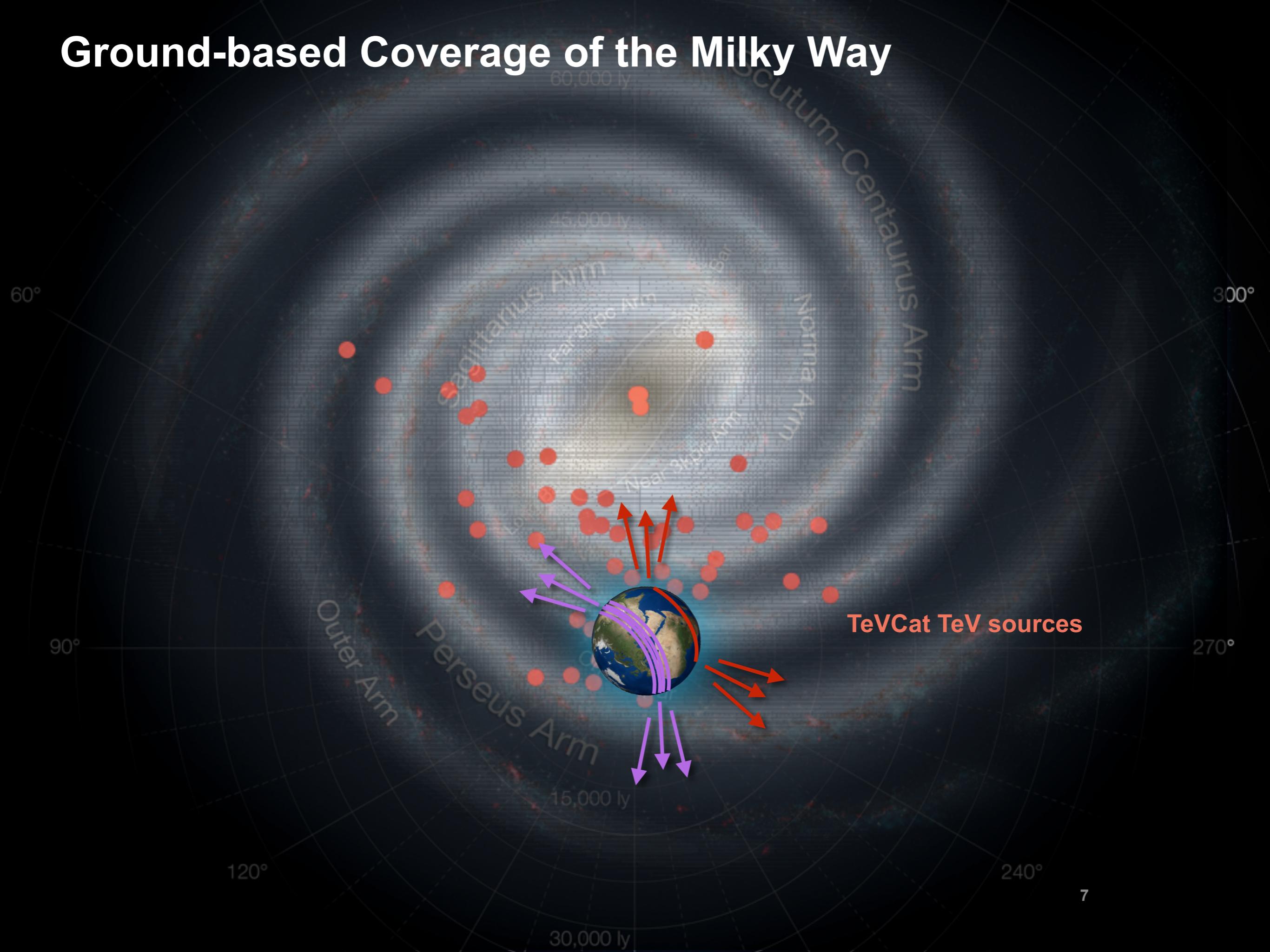
Experimental Coverage



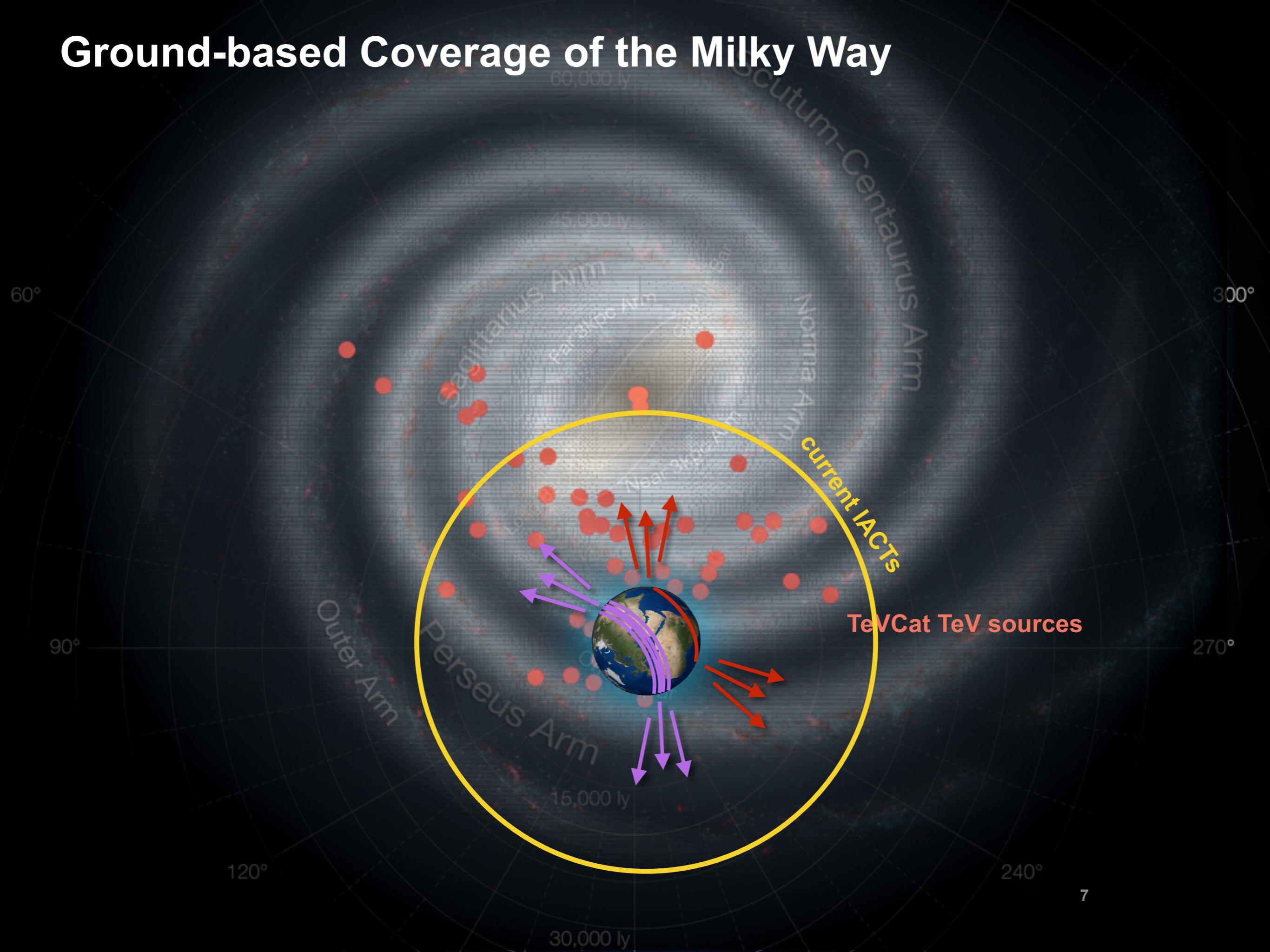
Ground-based Coverage of the Milky Way



Ground-based Coverage of the Milky Way



Ground-based Coverage of the Milky Way



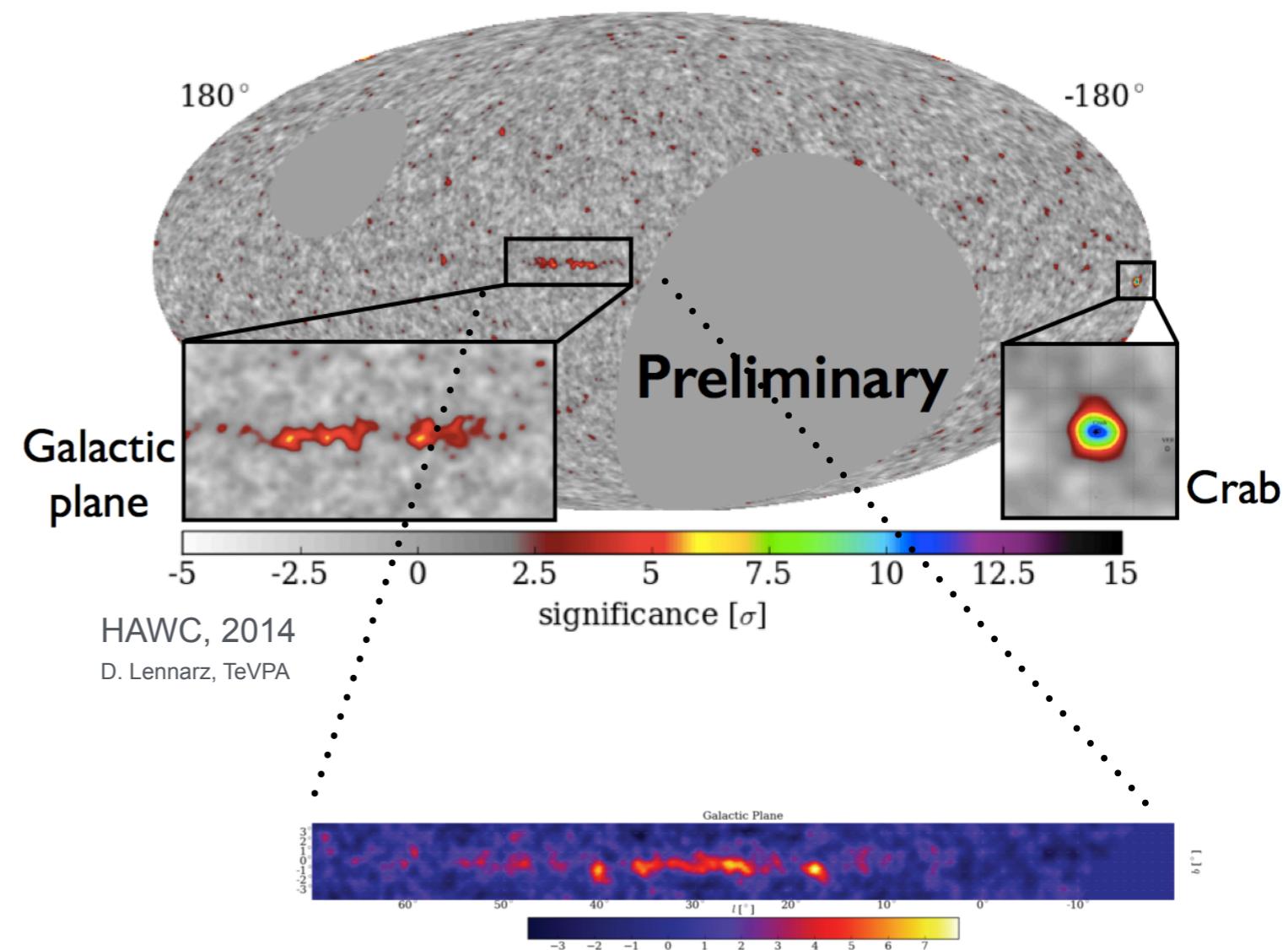
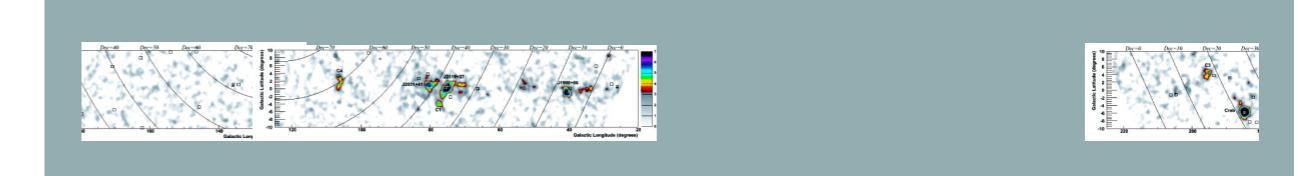
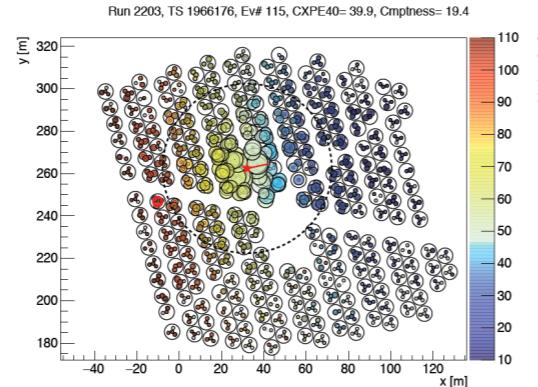
Surveys of Survey Instruments - MILAGRO and HAWC

> Air shower arrays

- Wide field-of-views

> HAWC

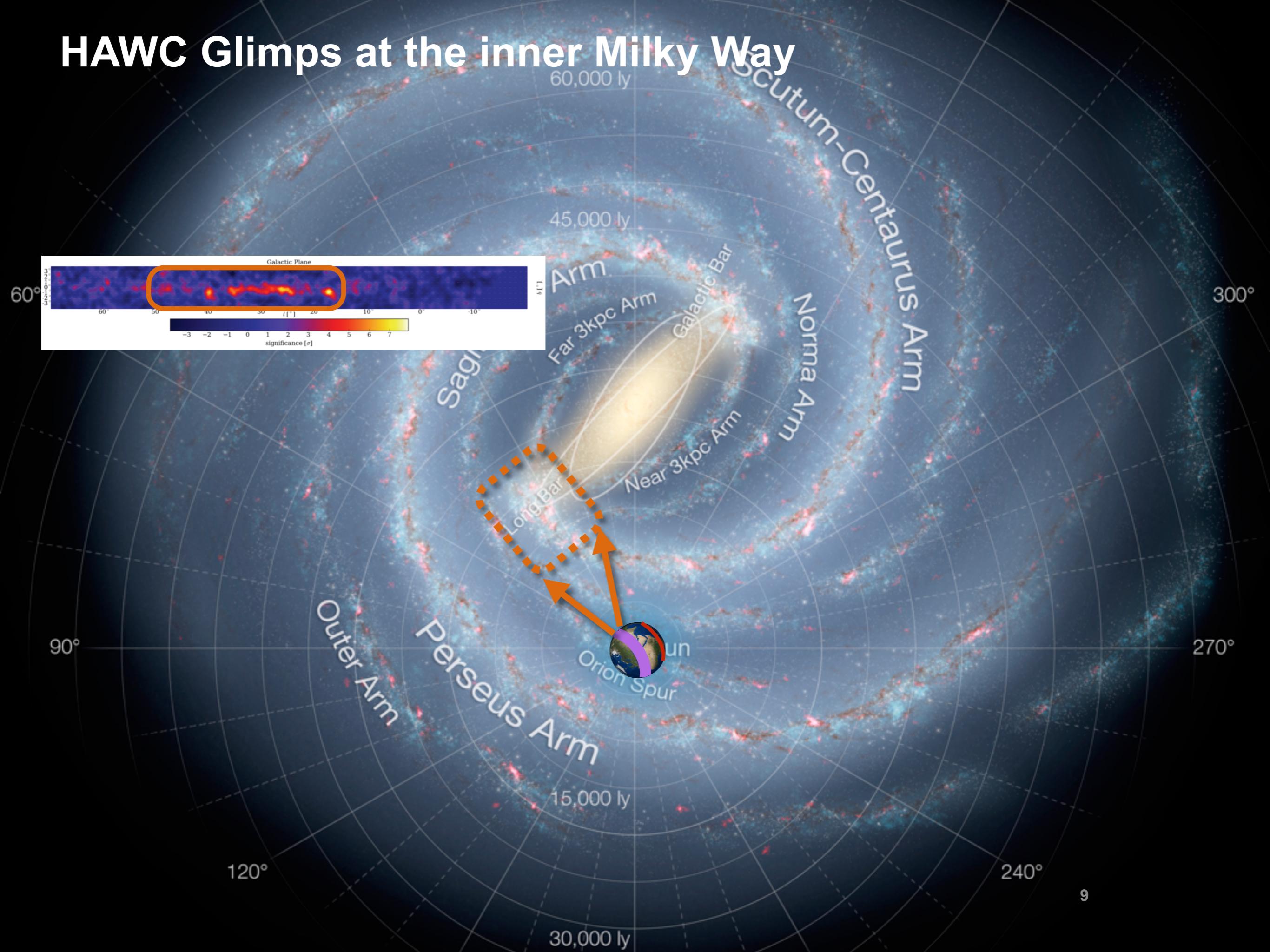
- Inaugurated Mar 20, 2015
- 100 GeV - 100 TeV
- Angular resolution: 0.4 - 2.0 deg
- Energy resolution: 40 - 100%



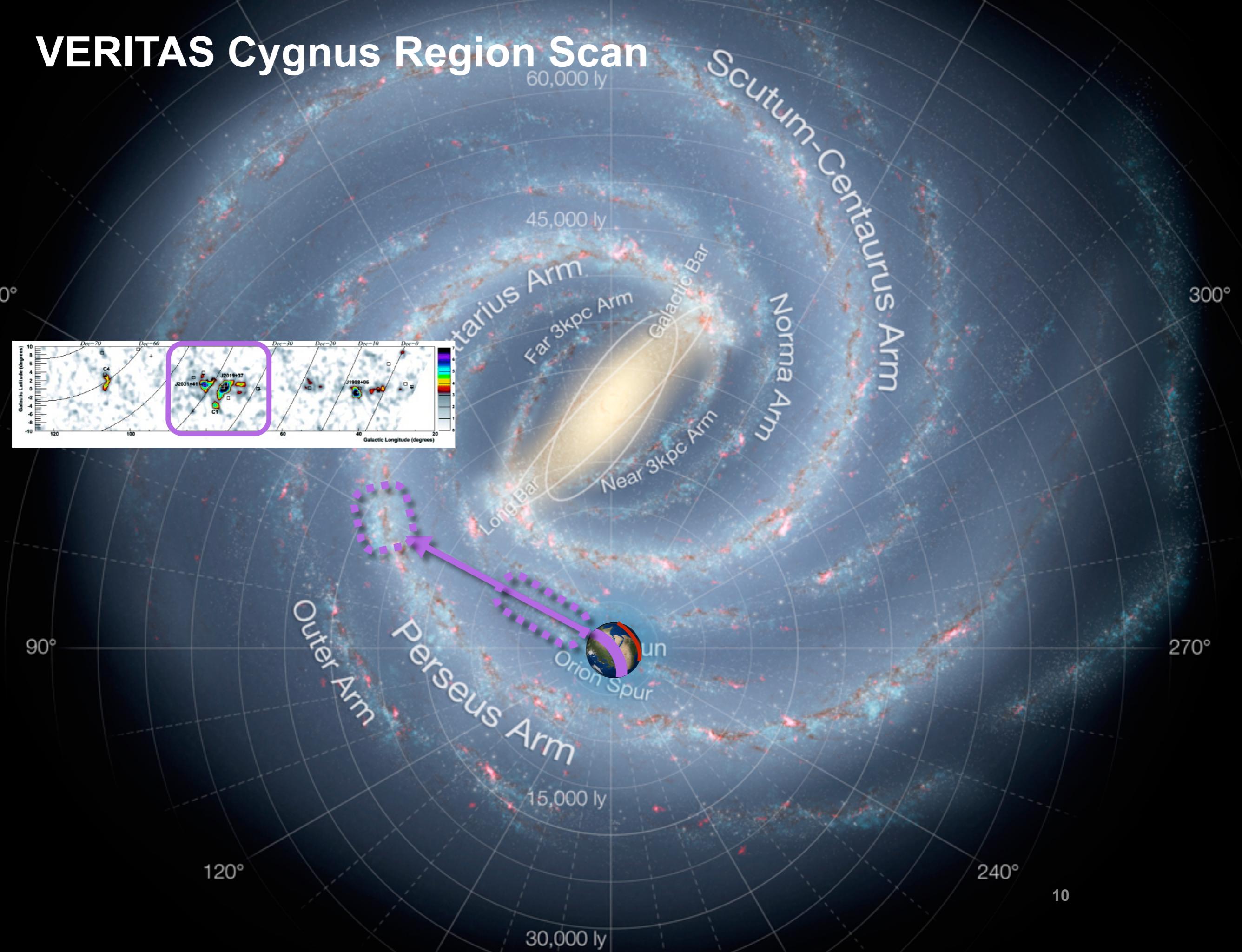
HAWC, 2014
D. Lennarz, TeVPA

HAWC, 2015
S. Benzvi, IPA

HAWC Glimpses at the inner Milky Way



VERITAS Cygnus Region Scan

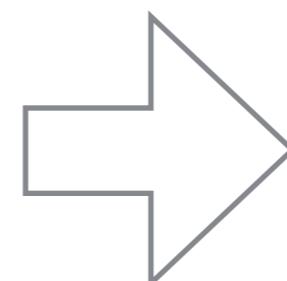
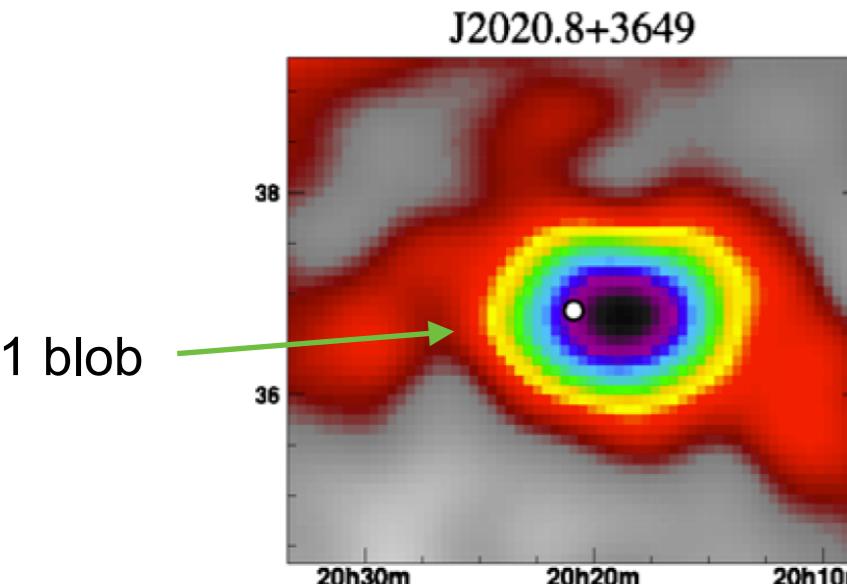


Surveys of IACTs: VERITAS Cygnus Region Scan

- Published in bits
- Some sources newly resolved:

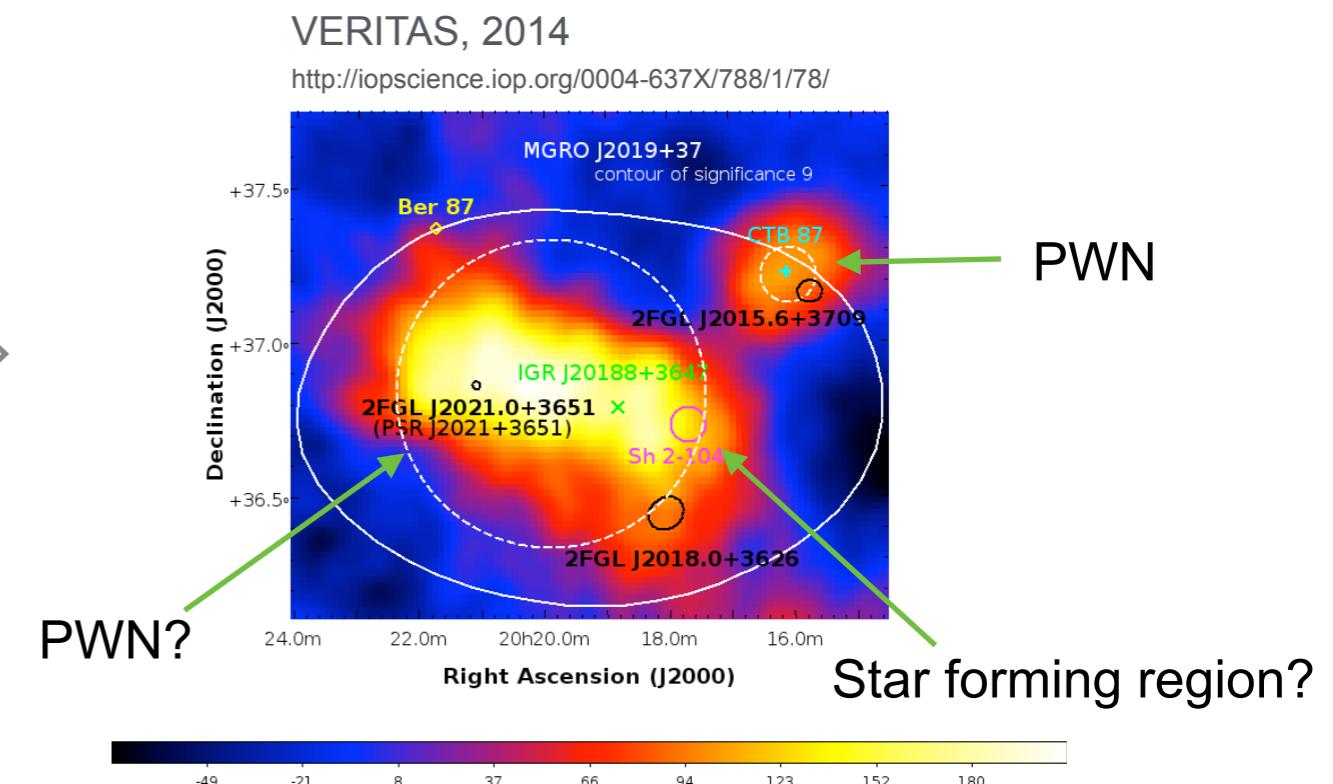
MILAGRO, 2009

<http://iopscience.iop.org/1538-4357/700/2/L127>

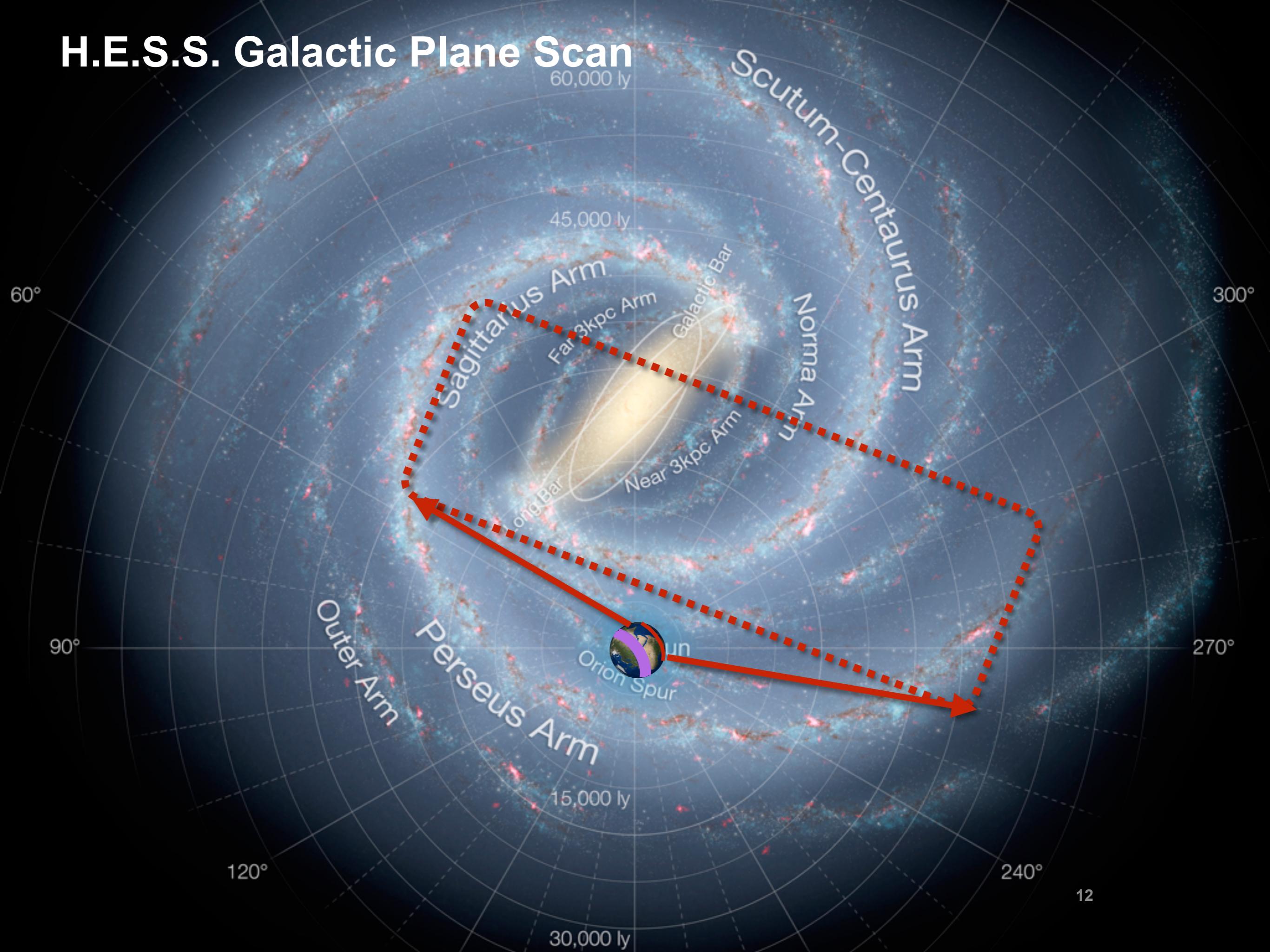


VERITAS, 2014

<http://iopscience.iop.org/0004-637X/788/1/78/>



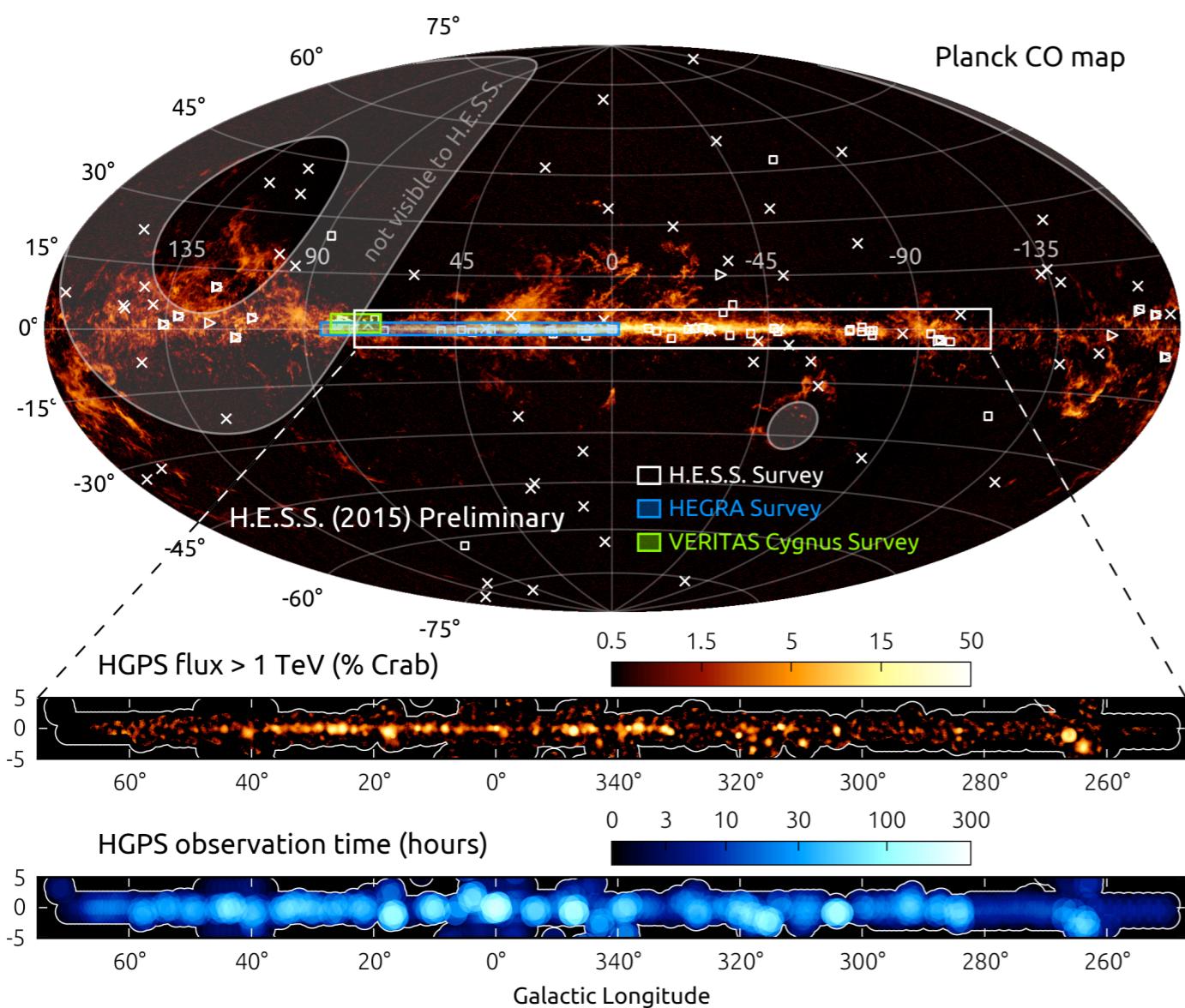
H.E.S.S. Galactic Plane Scan



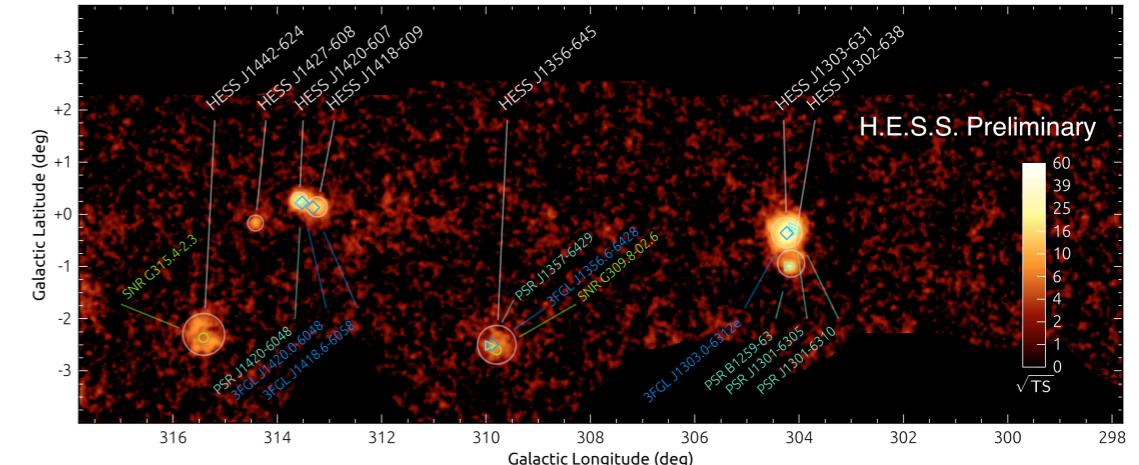
Surveys of IACTs

> H.E.S.S. Galactic Plane Survey

- 10-year survey
- 1% Crab sensitivity



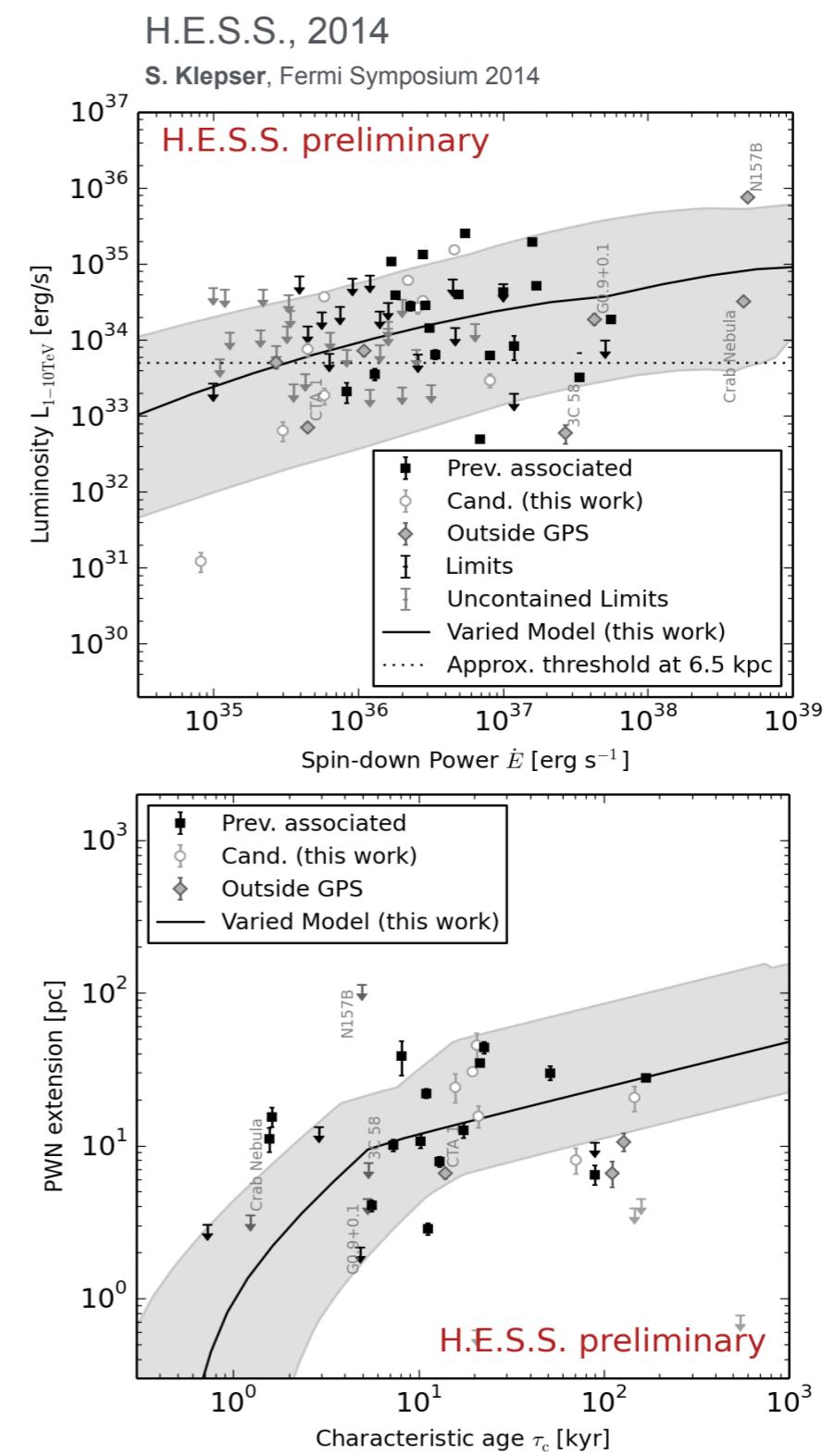
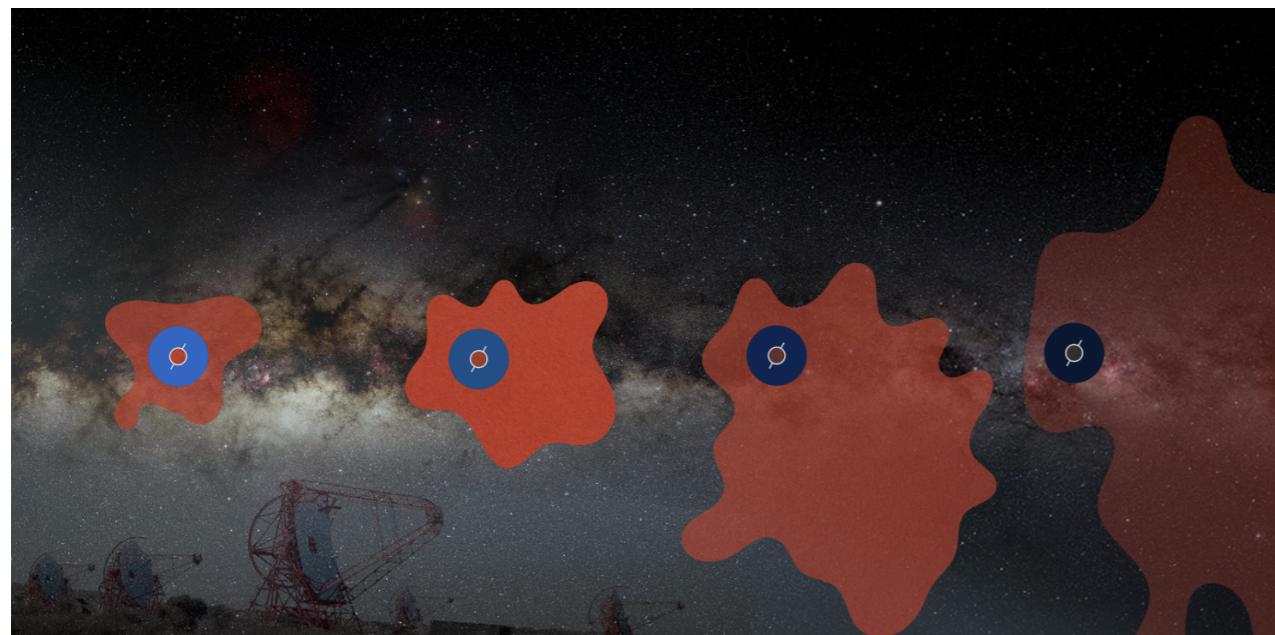
H.E.S.S., in prep.
...hopefully 2015



- > 66 + 11 VHE sources
- > Many extended sources (SNRs, PWNe)

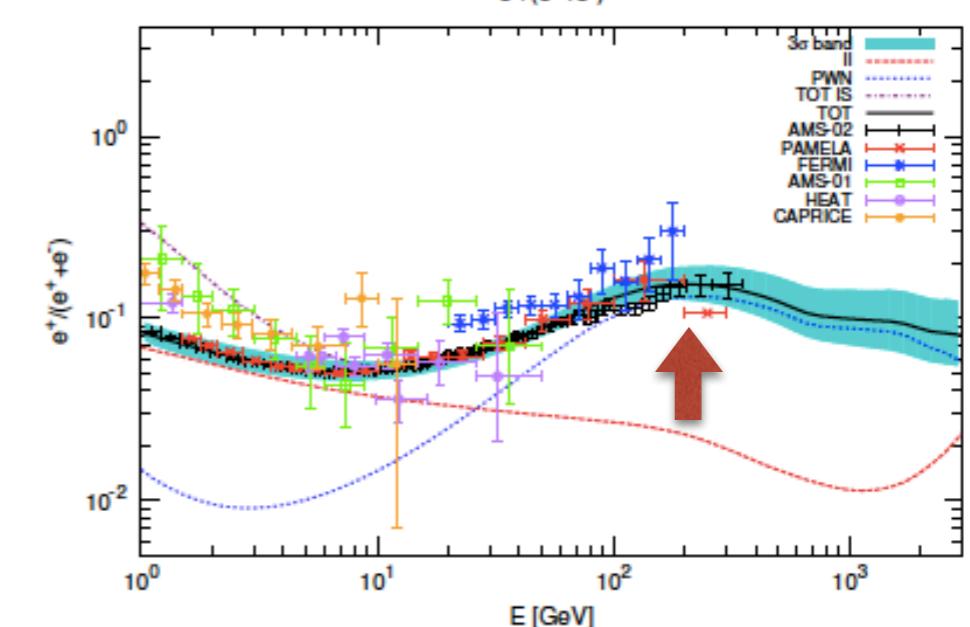
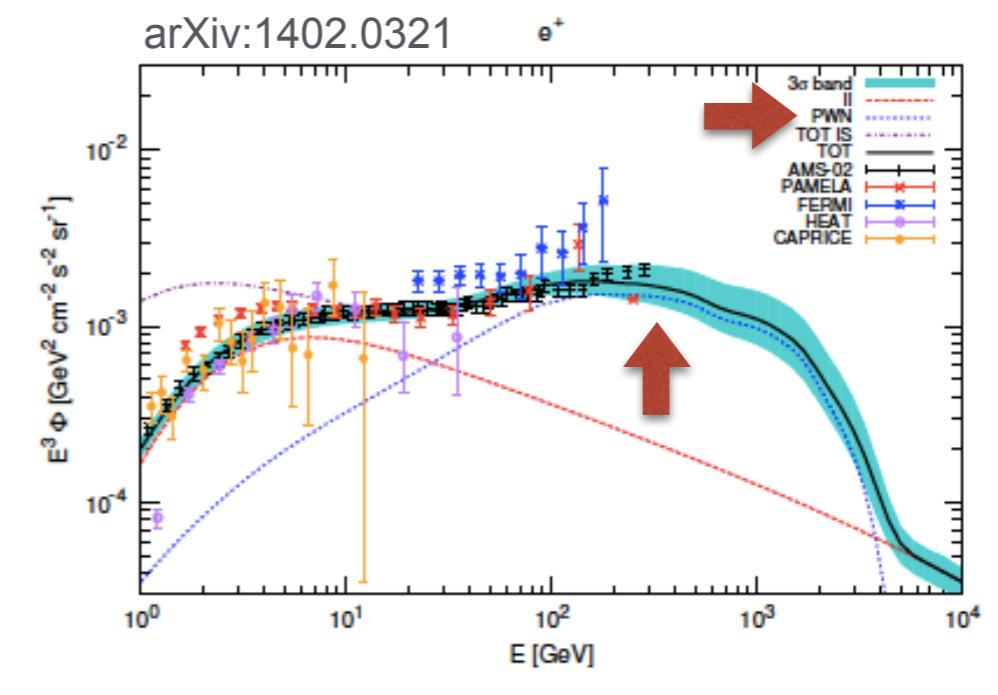
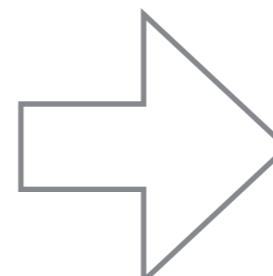
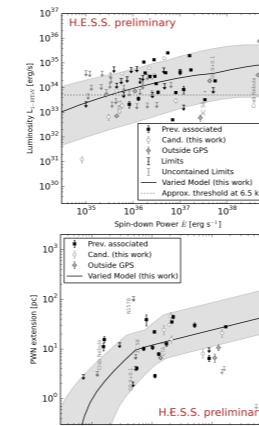
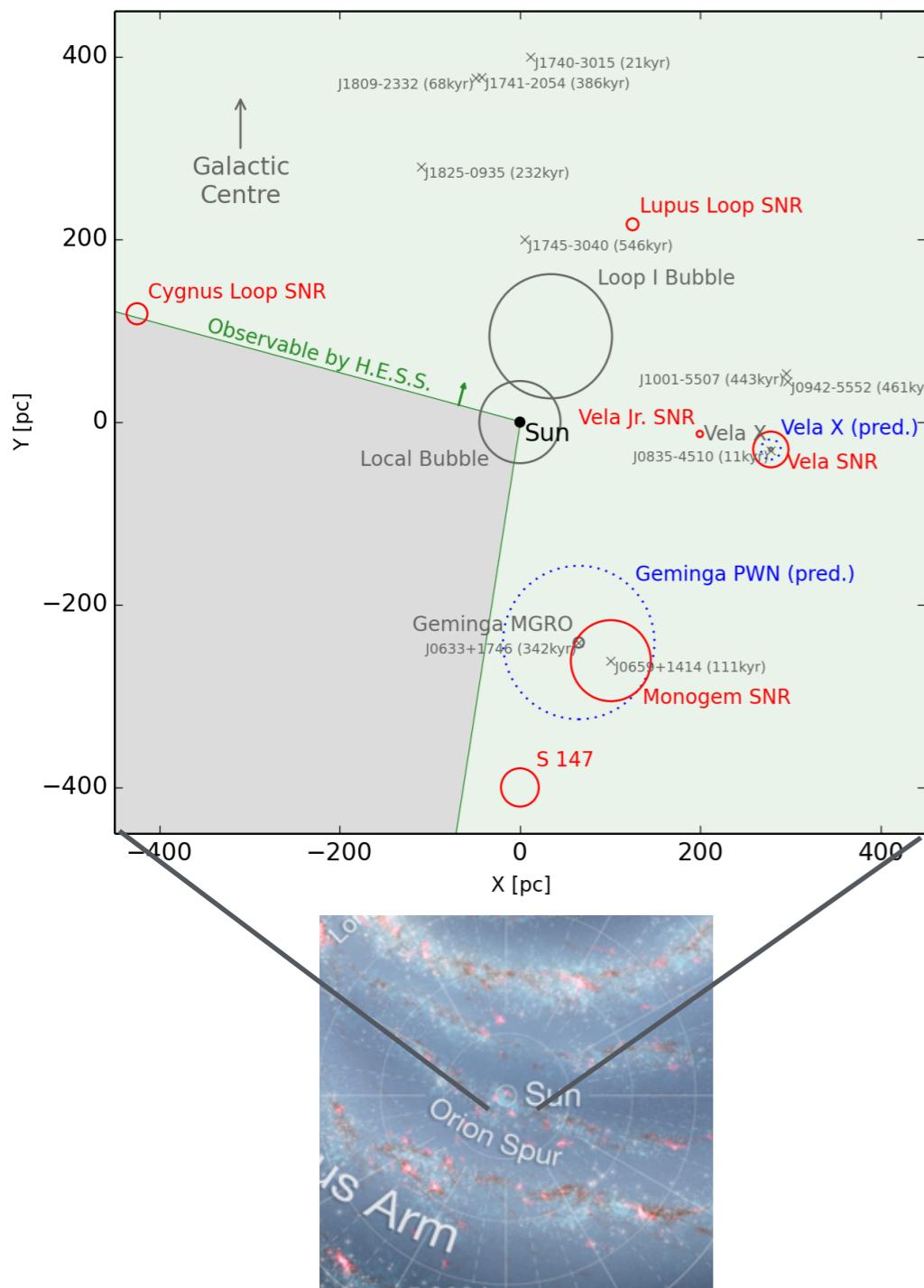
What Surveys Are Good for

> Evolution of pulsar wind nebulae



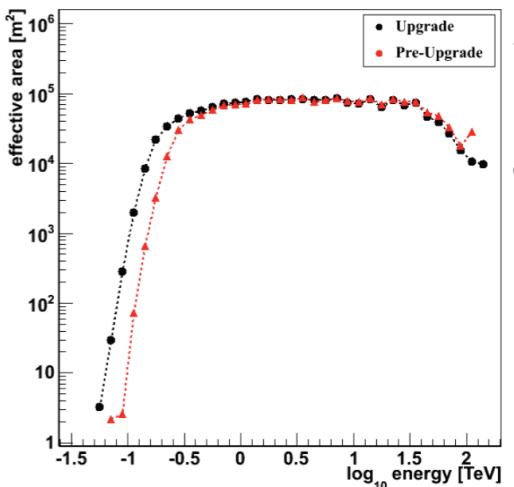
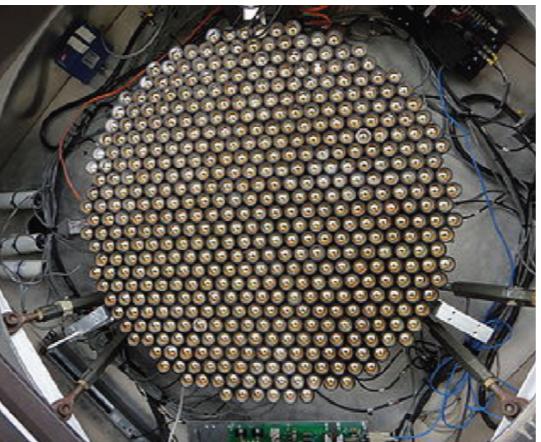
...Essential Ingredients to Unriddle Non-thermal Neighbourhood

➤ Local pulsar systems produce positrons!

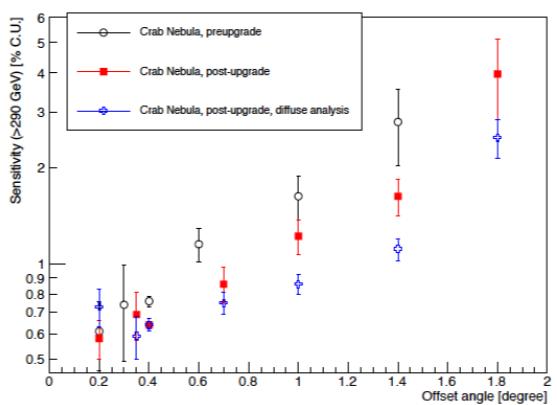


Recent and Current Detector Upgrades

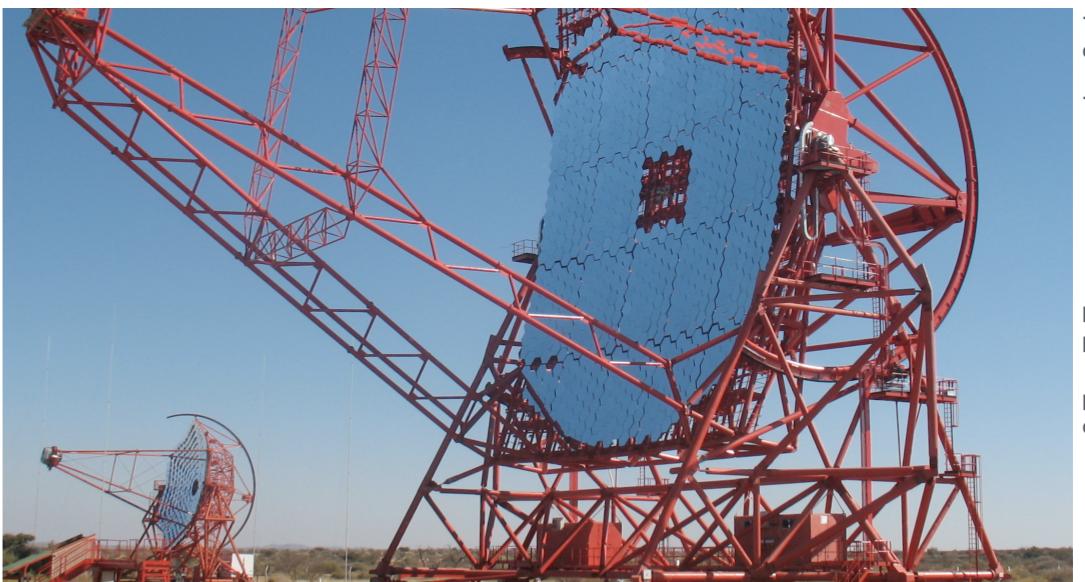
- VERITAS: PMT, trigger, finished 2012
- MAGIC: camera pixeling, readout, trigger
- H.E.S.S.
 - 2012: New 28m telescope (CT5 aka "H.E.S.S. II")
 - 2015/16: Major H.E.S.S. I Camera Upgrade...



VERITAS, 2013
<http://arxiv.org/abs/1308.4849>



MAGIC, 2014
<http://arxiv.org/abs/1409.6073>
<http://arxiv.org/abs/1409.5594>

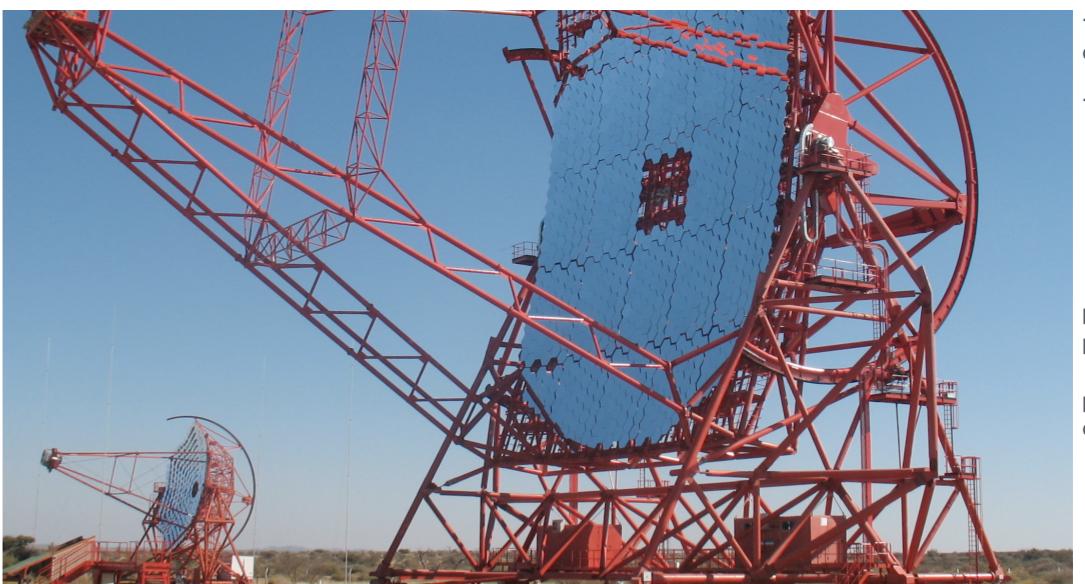
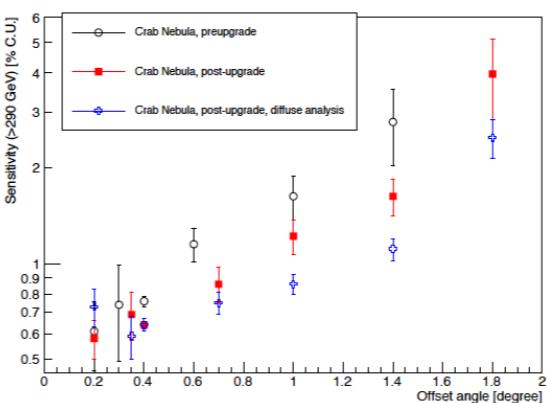
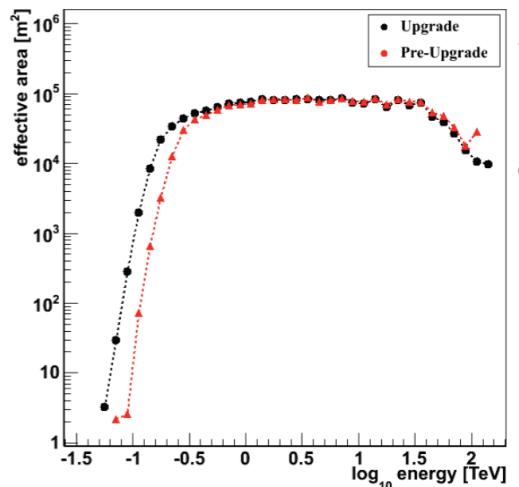
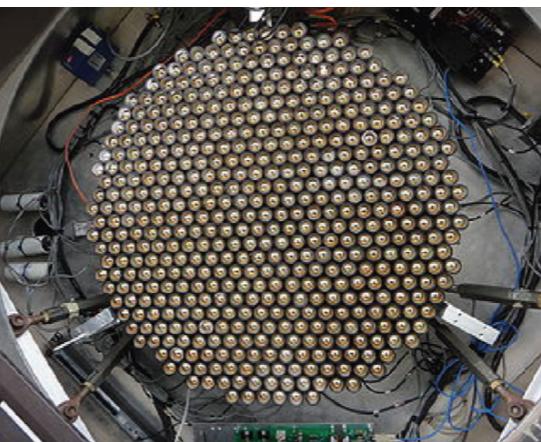


H.E.S.S., 2012

http://www.mpi-hd.mpg.de/hfmr/HESS/pages/press/2012/HESS_II_first_light/

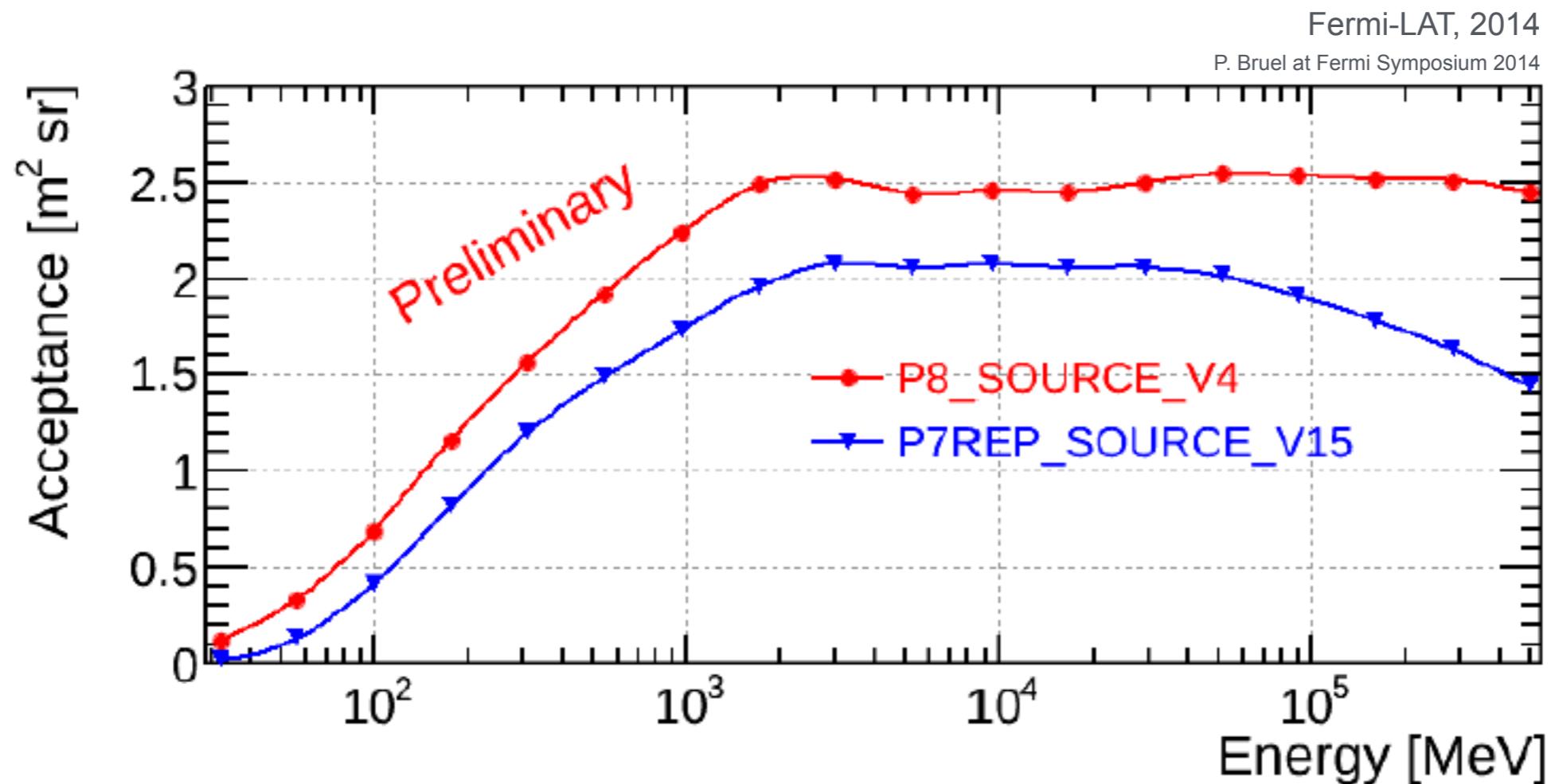
Recent and Current Detector Upgrades

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- MAGIC: camera pixeling, readout, trigger
- H.E.S.S.
 - 2012: New 28m telescope (CT5 aka "H.E.S.S. II")
 - 2015/16: Major H.E.S.S. I Camera Upgrade...



Fermi-LAT "Upgrade": Pass 8

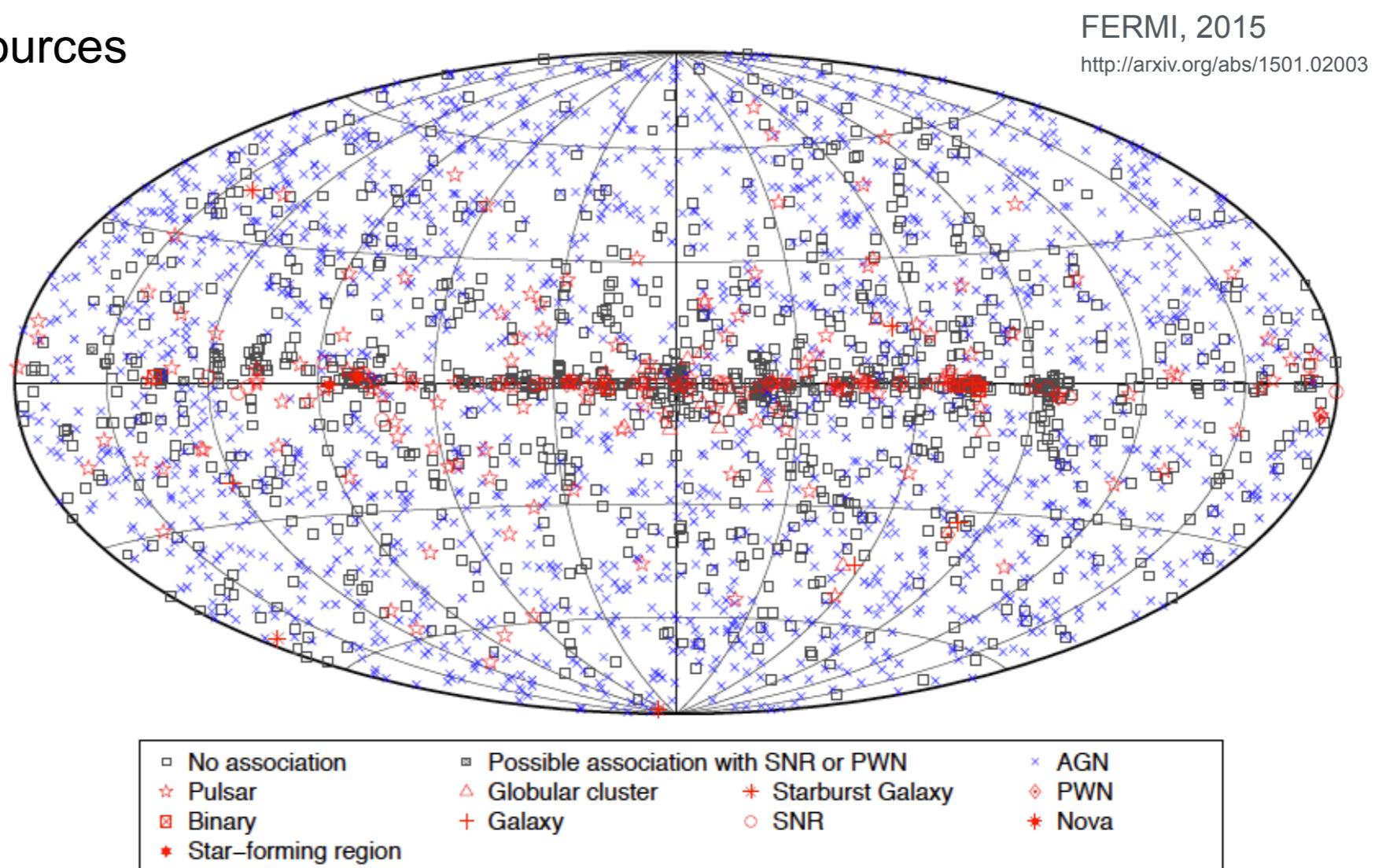
- > Software update, including major data release
- > Many tree- or MVA-based reconstruction parts
 - Better resolution, more events
- > Wider energy range: 10 MeV to 3 TeV



Surveys of Survey Instruments - Fermi-LAT

> Fermi-LAT

- 3FGL: 3033 sources
- 58% AGN, 33% Unassoc., 5% PSRs
- 99.2% point sources



Plot of this talk

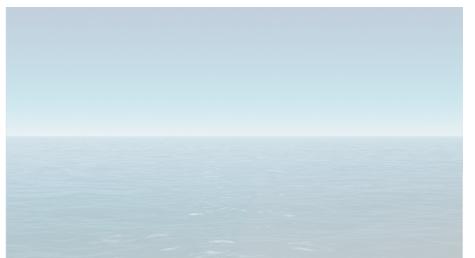
- > The gamma-ray window
 - Experimental coverage, surveys, detectors, upgrades



- > Recent findings
 - Subjectively chosen remarkable new results 2014/15



- > Recent not-yet findings
 - ...like neutrino-emitting sources



- > The future



Modern-Day Strategies for IACTs

- > Most low-hanging fruits have been picked
- > All experiments started multi-year key science programmes
 - Deep observations
 - Surveys
 - Complex ToOs (GRBs, galactic transients, AGNs, neutrinos, ...)
 - Long-term monitoring (AGNs)



Anyway...

- > ...turns out there still *are* some low-hanging fruits



Top of the Pops 2014/15 - Black-hole Type

> IC 310

- AGN, black hole size ~ 23 min
- Flare in November 2012 (few hrs)
 - $\Delta t/(1+z) \sim 4.8$ min
 - Cannot be shock acceleration in jet

> Possible explanations?

- Cloud/star falling into jet
- Subjet structure
- Plasma or accretion turbulence of polar vacuum gap

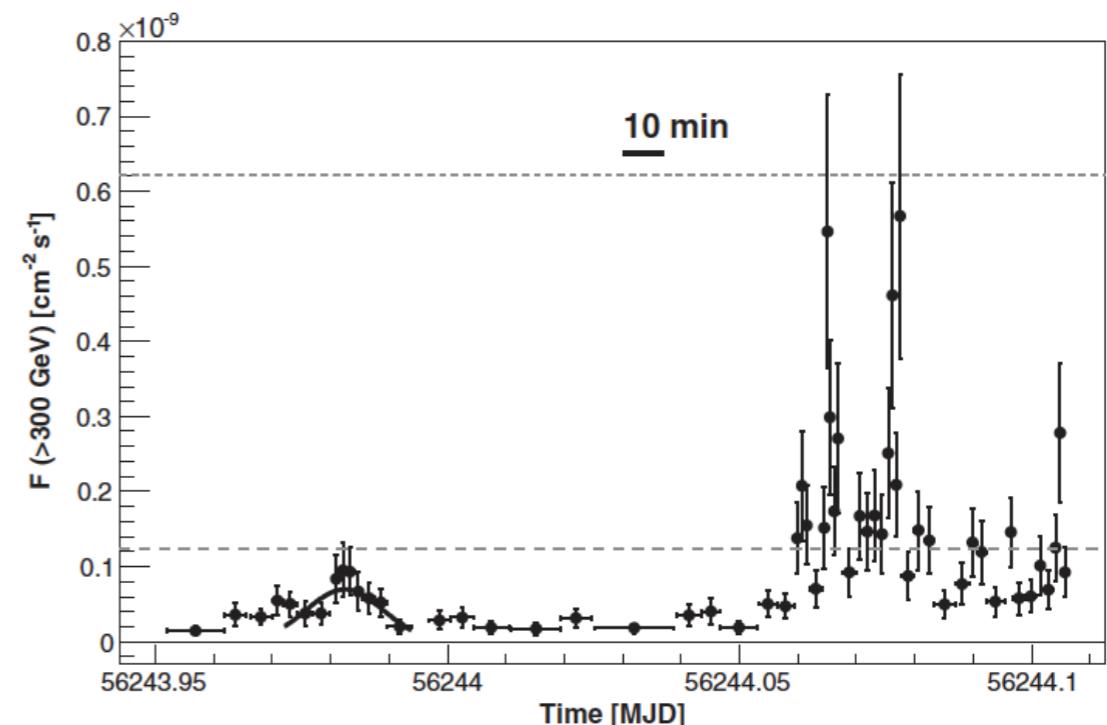
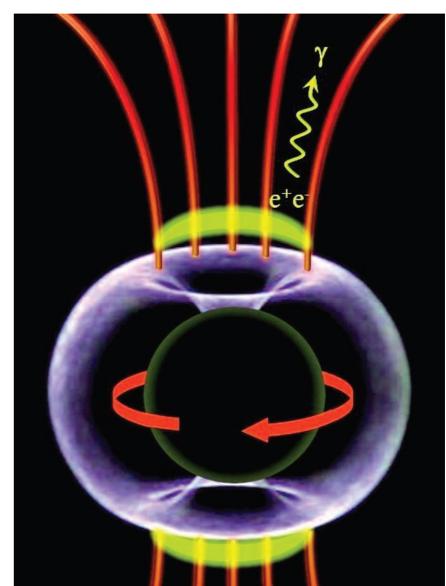


Fig. 4. Light curve of IC 310 observed with the MAGIC telescopes on the night of 12/13 November 2012, above 300 GeV. As a flux reference, the two gray lines indicate levels of 1 and 5 times the flux level of the Crab Nebula, respectively. The precursor flare (MJD 56243.972-56243.994) has been fitted with a Gaussian distribution. Vertical error bars show 1 SD statistical uncertainty. Horizontal error bars show the bin widths.

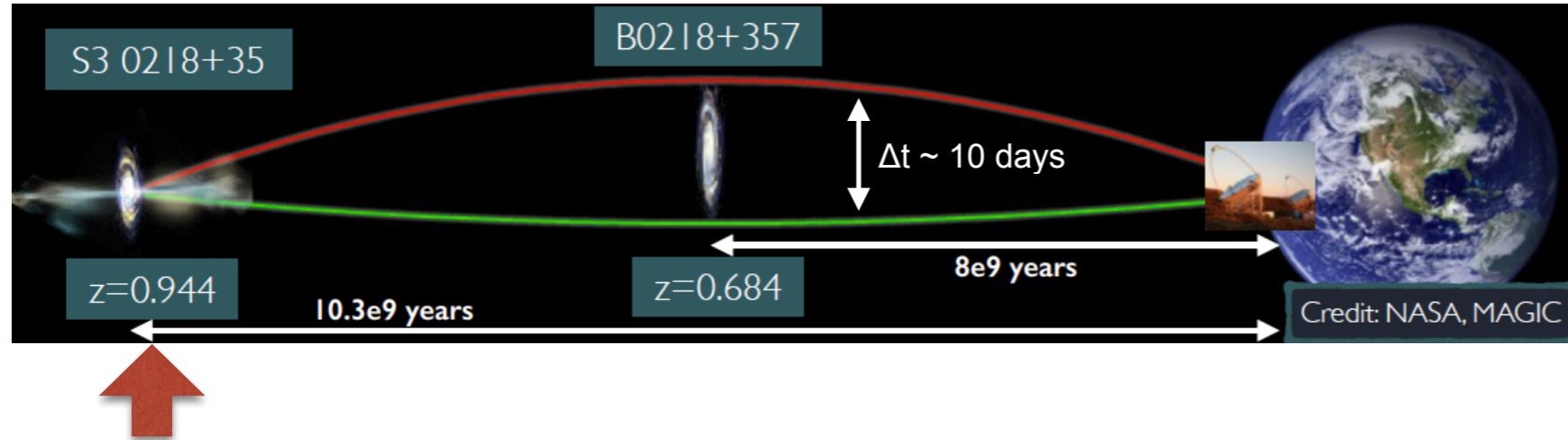
MAGIC, 2014
<http://adsabs.harvard.edu/abs/2014Sci...346.1080A>



Top of the Pops 2014/15 (- Black-hole Type)

> Gravitationally Lensed Blazar S3 0218+357

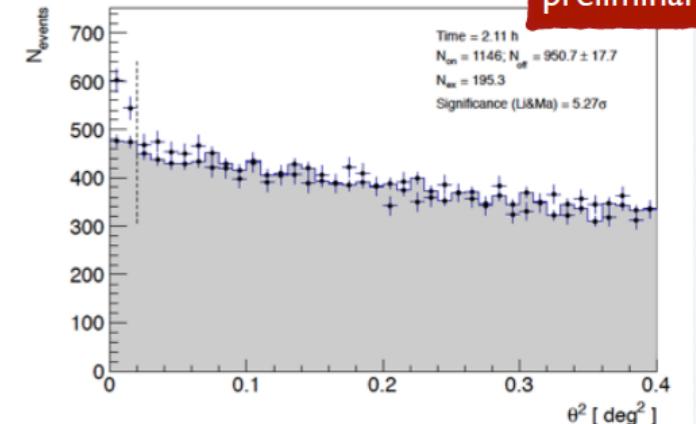
- ...or tunneling the full moon period using general relativity



MAGIC, in prep.

D. Mazin, Fermi Symposium 2014

preliminary



> April 2015: Atels on another very distant AGN!

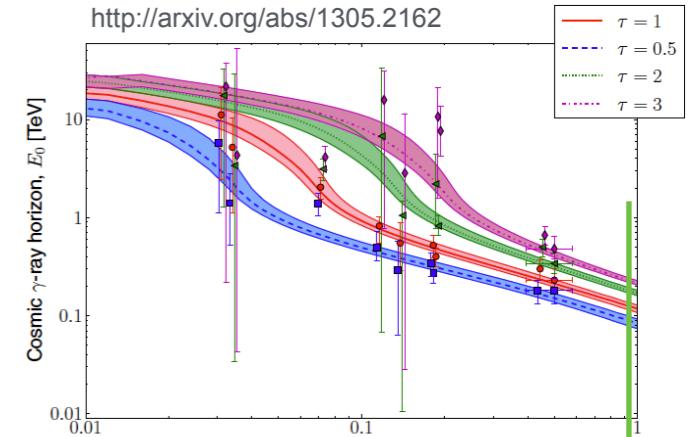
- FSRQ PKS 1441+25, $z = 0.939$
- MAGIC & VERITAS detections (Atels #7416, #7433, #7459)
- Papers not out yet

> New constraints on extragalactic background light?

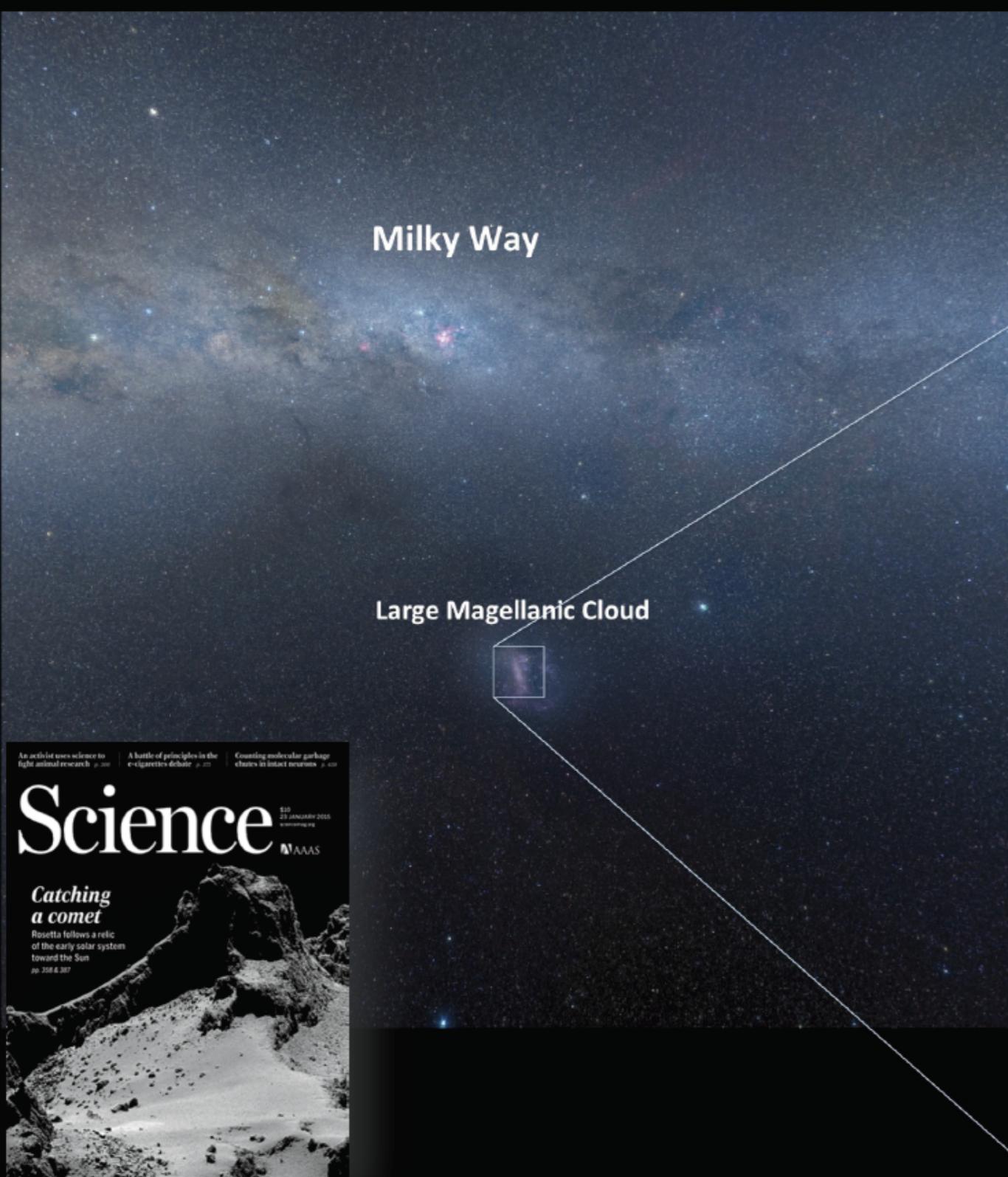
- I.e. opacity of the Universe!

Dominguez et al., 2013

<http://arxiv.org/abs/1305.2162>



Top of the Pops 2014/15

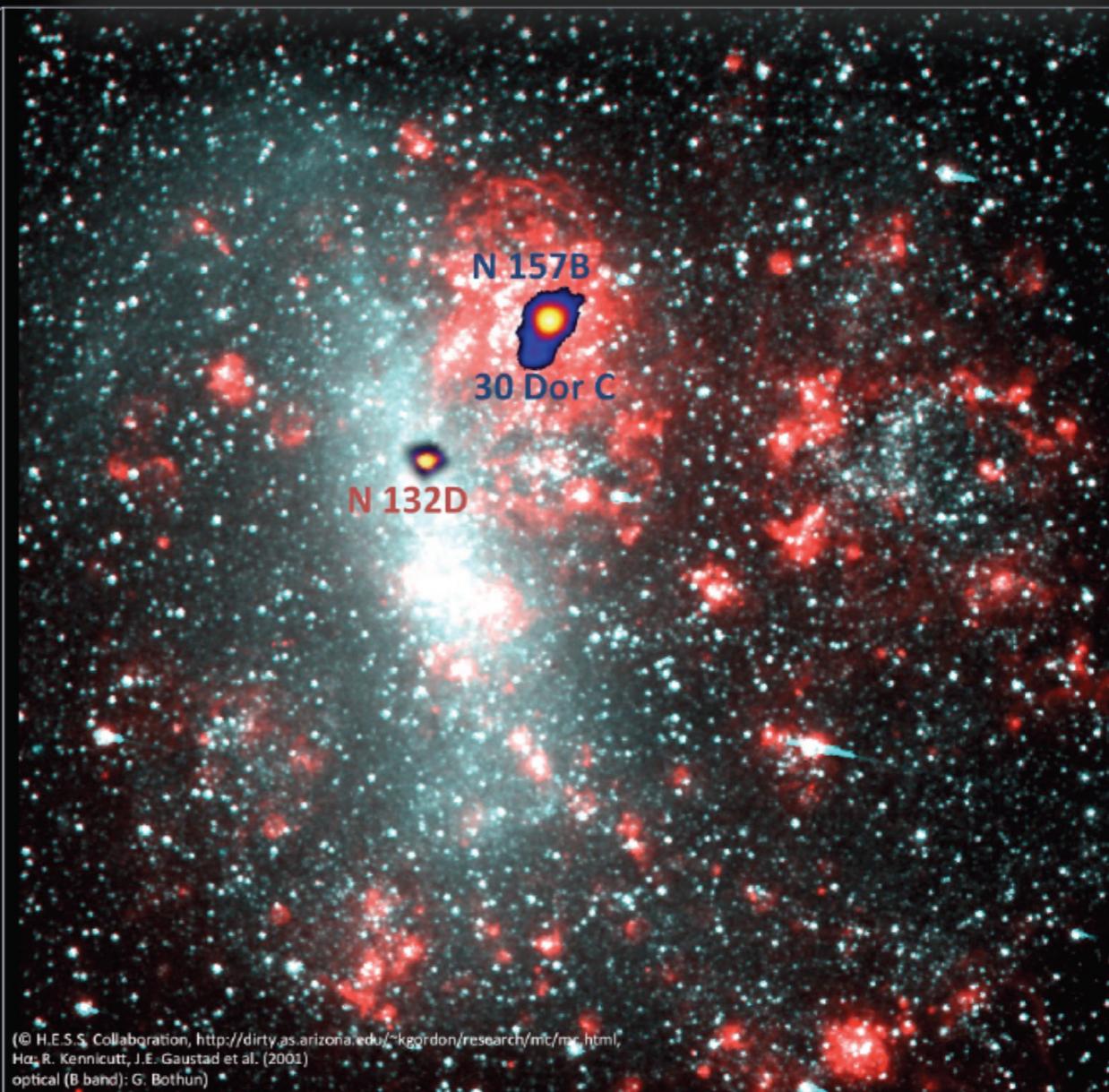


REPORTS

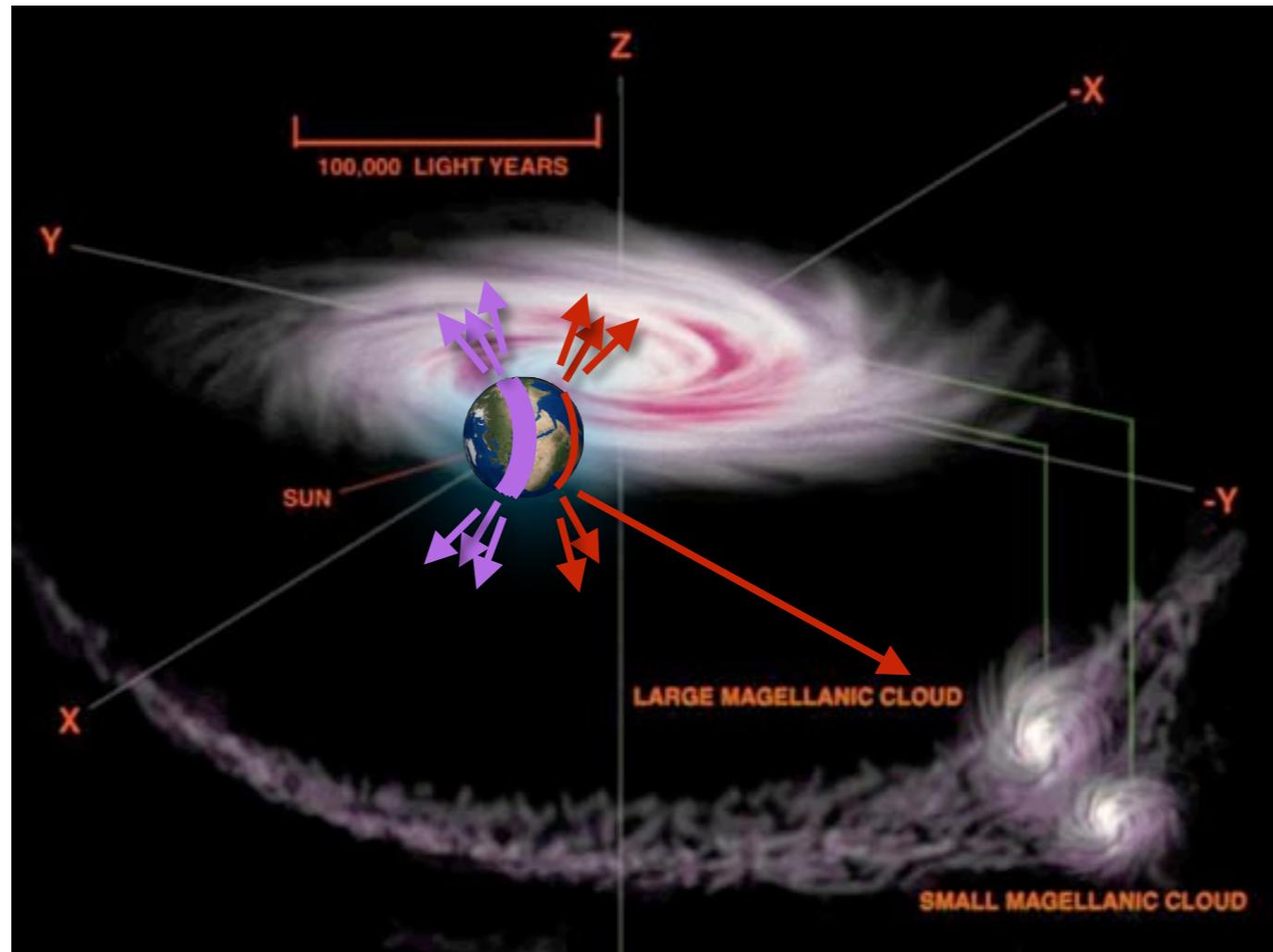
ASTROPHYSICS

The exceptionally powerful TeV γ -ray emitters in the Large Magellanic Cloud

The H.E.S.S. Collaboration*†

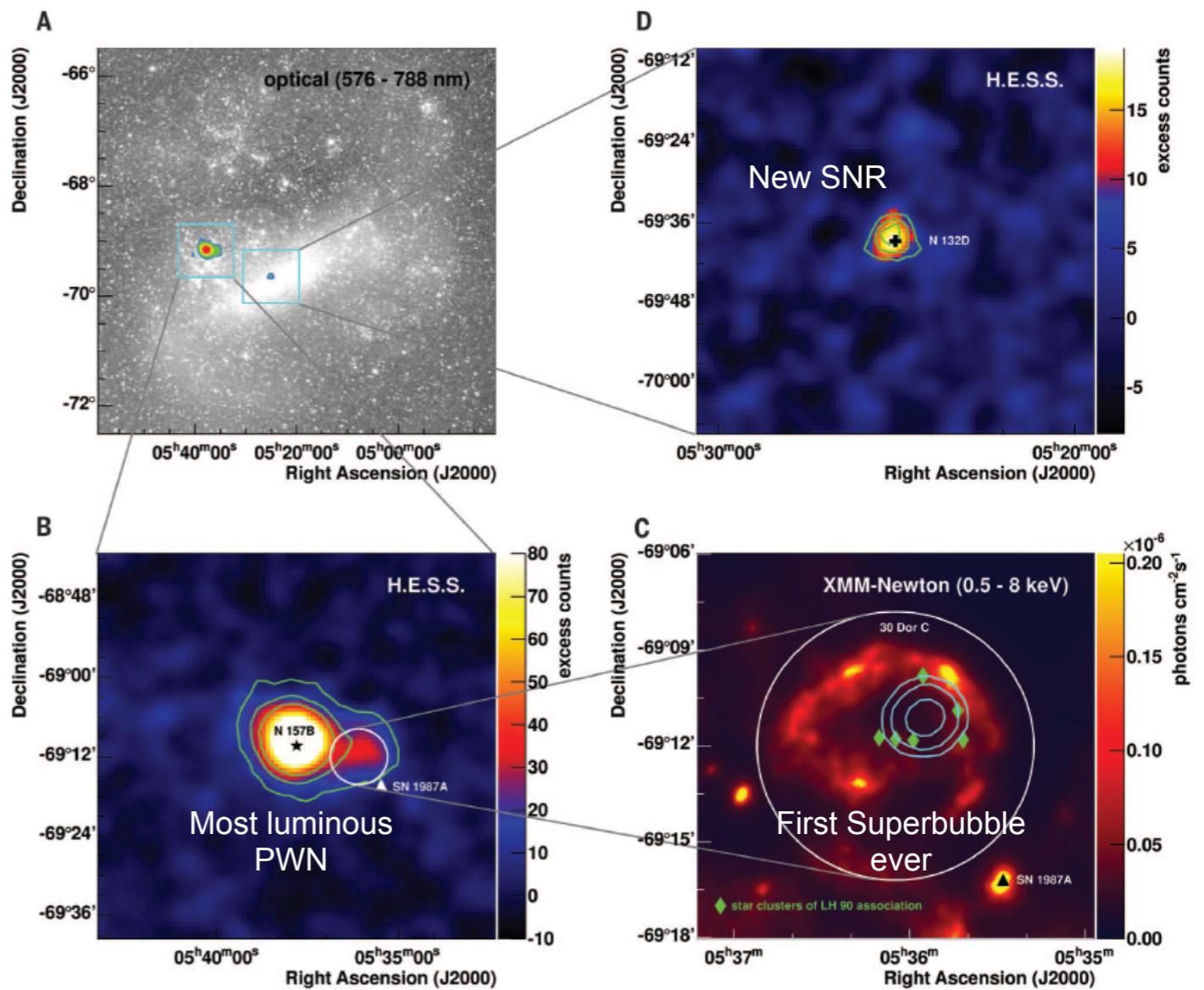
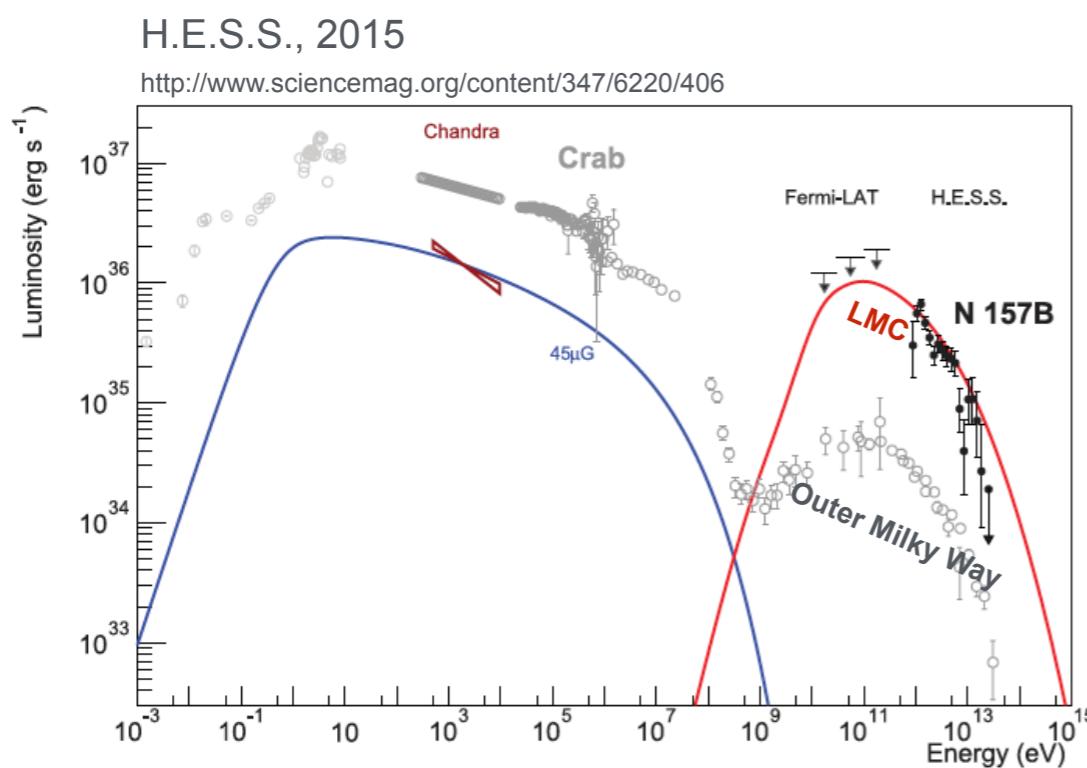


...more Southern Territory



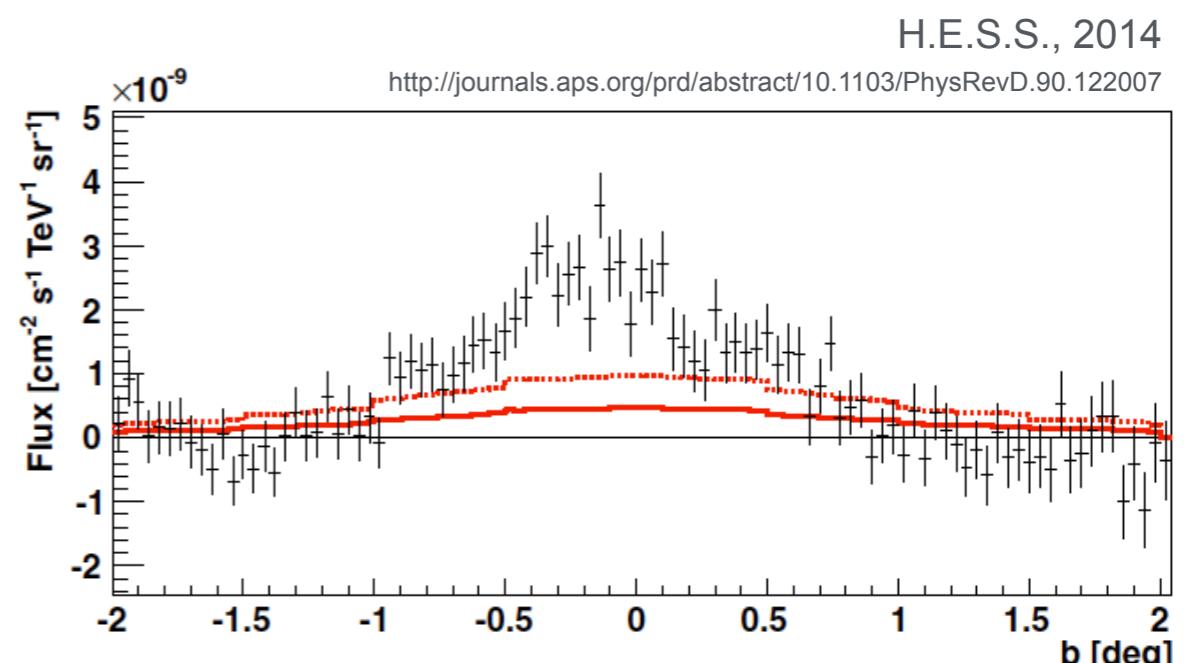
Top of the Pops 2014/15 - Simple Stellar / Collective Type

- First glimpse of the LMC population of (stellar-type) particle accelerators



Top of the Pops 2014/15 - Collective Type

- > Diffuse Galactic TeV emission
 - 2485 hours of data
 - Analysing all data in between known sources
- > First-time detection (apart from galactic bulge)
- > Components:
 - π^0 decay
 - IC scattering of e^\pm
 - Unresolved sources



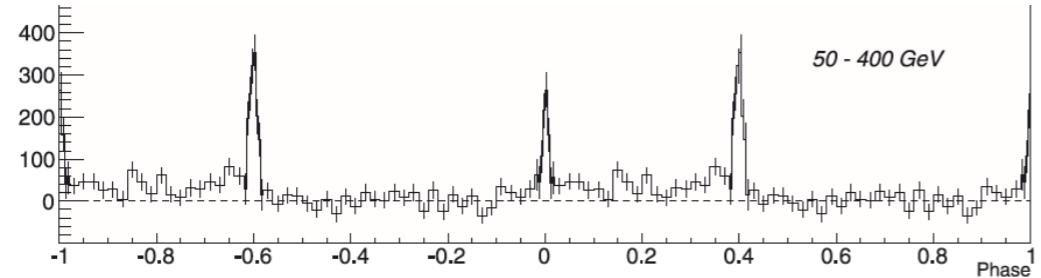
Top of the Pops 2014/15 - Simple Stellar Type

> Pulsars

- Hot topic since the Crab PSR detection by MAGIC
- > Second IACT pulsar: Vela
- > Refined Crab PSR measurements

MAGIC, 2014

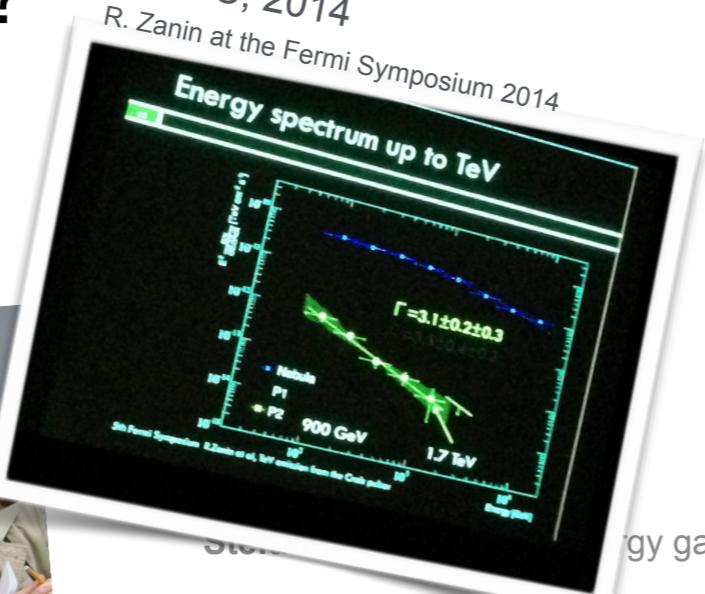
<http://www.aanda.org/articles/aa/abs/2014/05/aa23664-14/aa23664-14.html>



- > Upper limit on Geminga from VERITAS
- > Newest: A TeV pulsar?

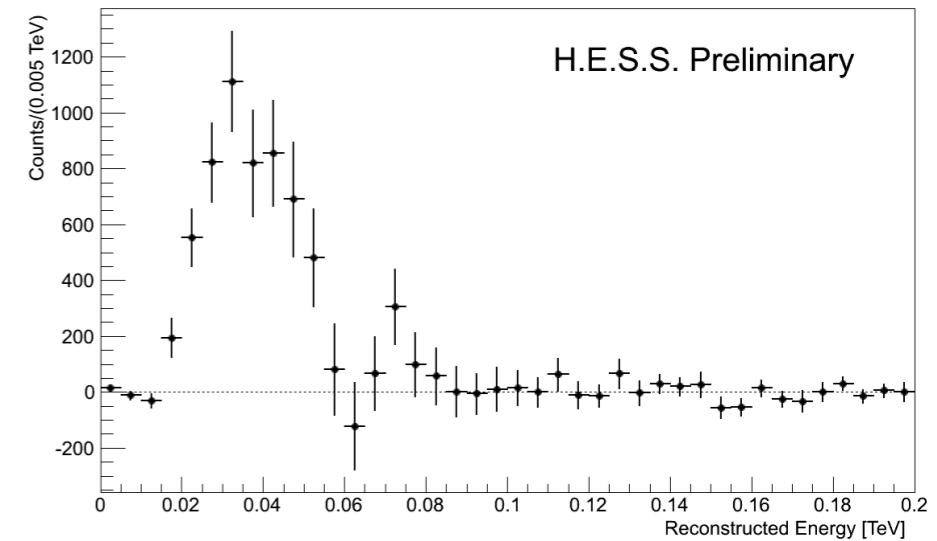
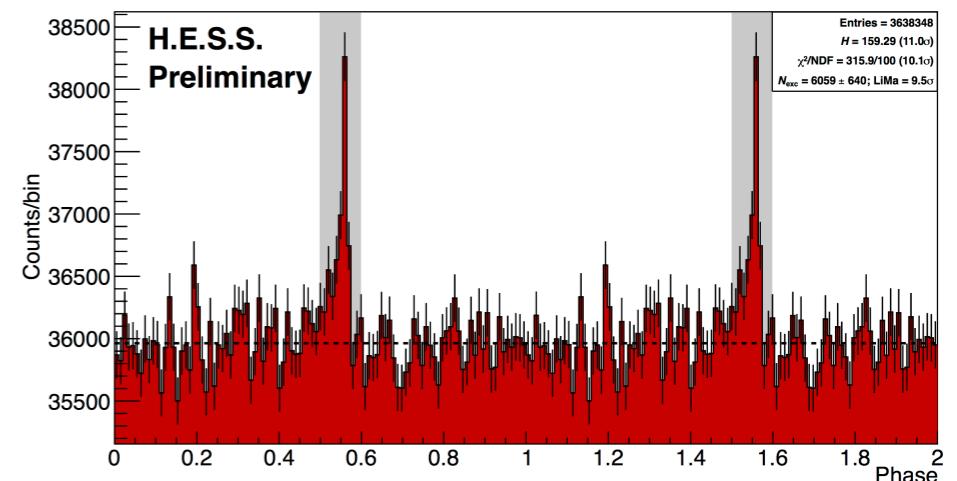
MAGIC, 2014

R. Zanin at the Fermi Symposium 2014



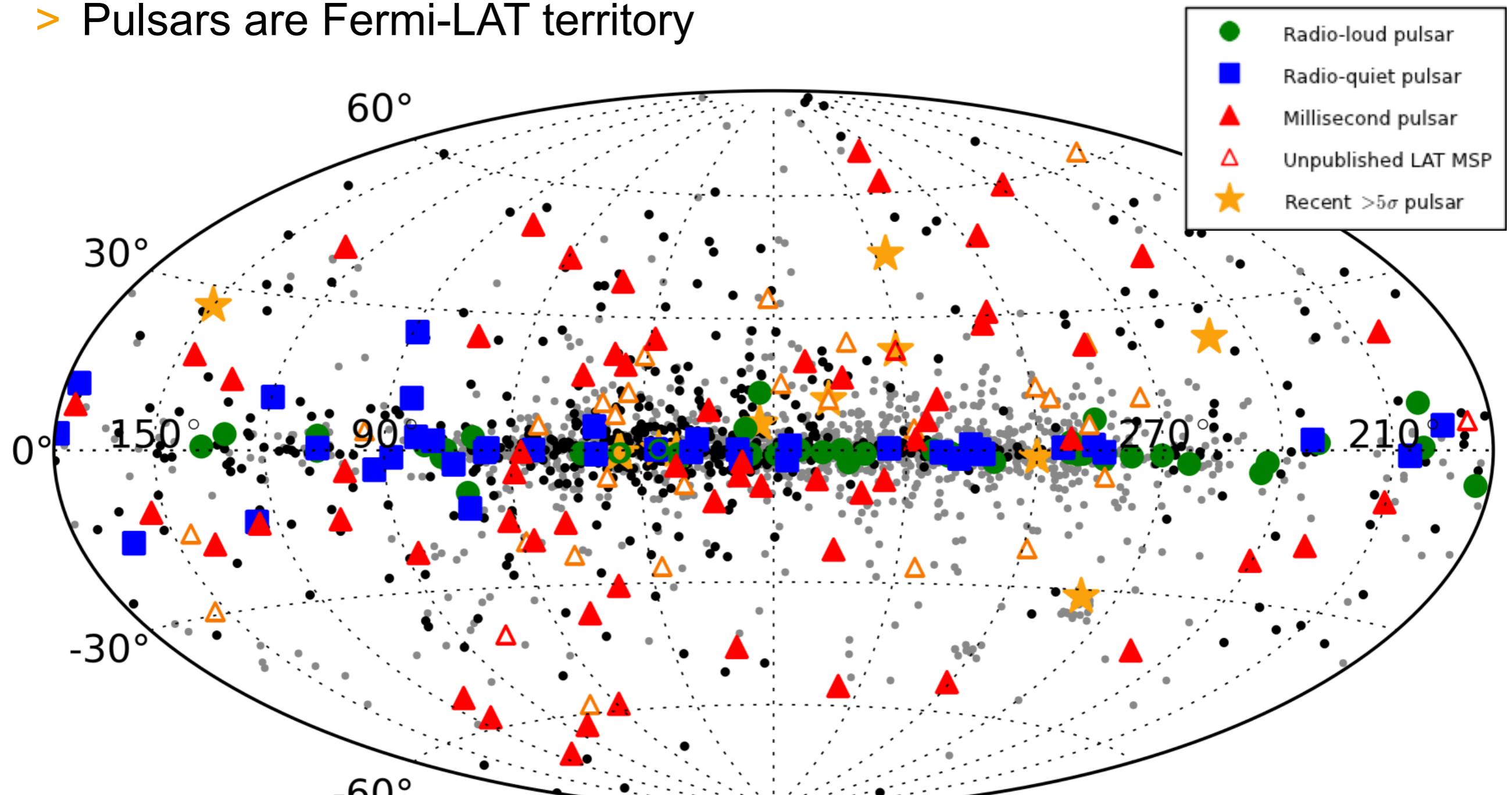
H.E.S.S., 2014

<http://www.desy.de/news/@@news-view?id=8361>



Talking of which...

> Pulsars are Fermi-LAT territory



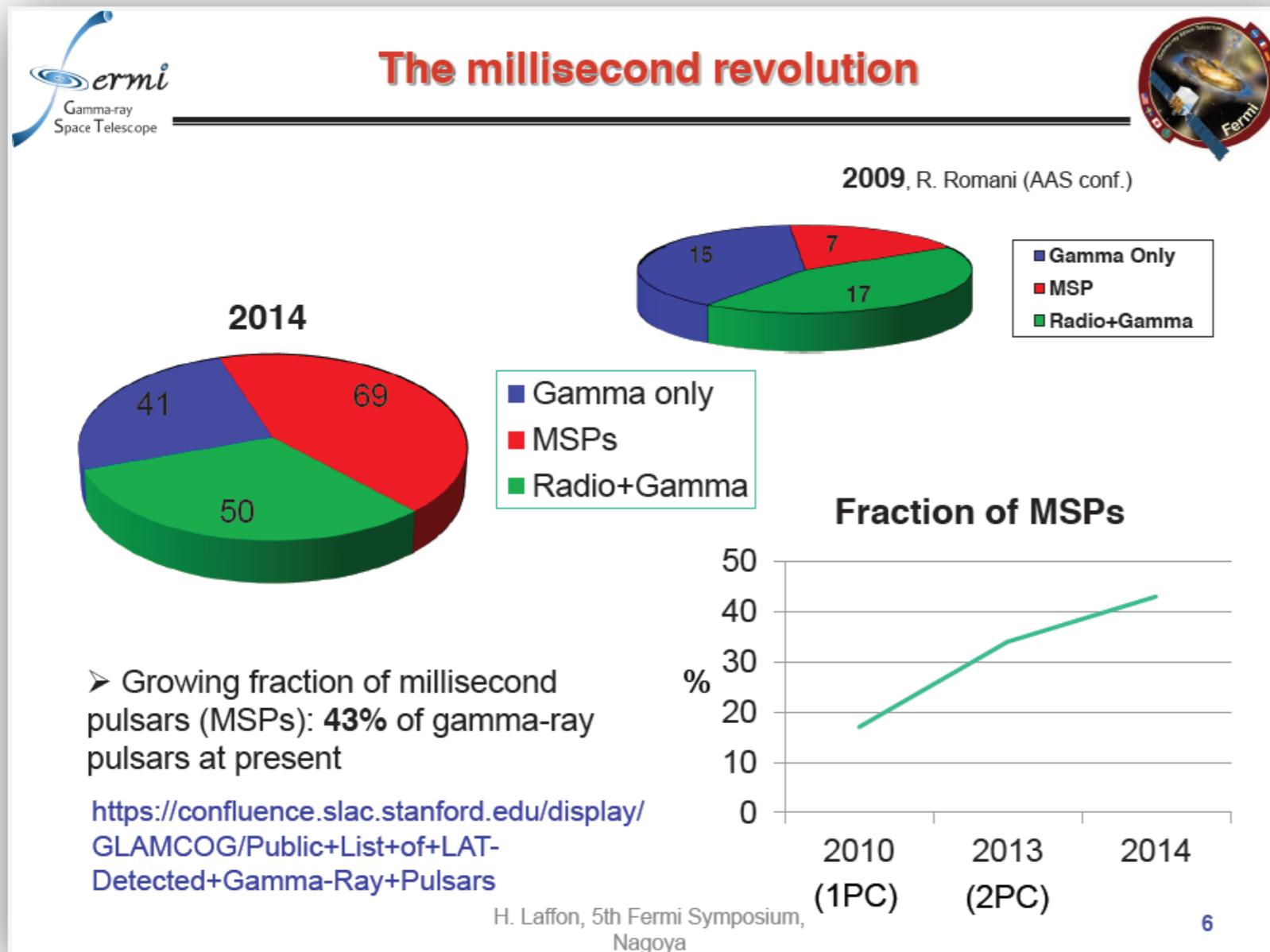
Fermi-LAT, 2014

H. Laffon at the Fermi Symposium 2014

Top of the Pops 2014/15 - Simple / Complex Stellar Type

Fermi-LAT, 2014

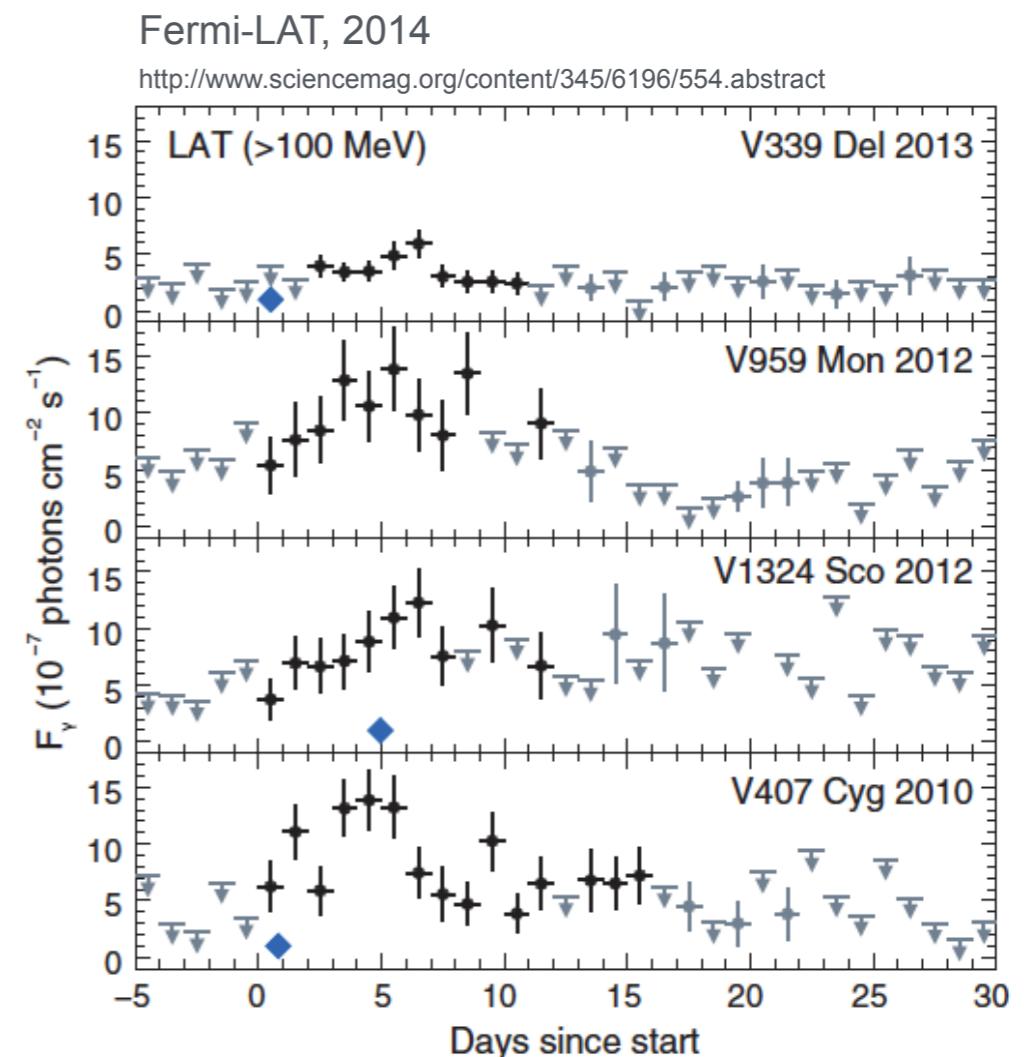
H. Laffon at the Fermi Symposium 2014



- > MSPs = old pulsars, powered by accretion of binary partner
- > "Recycled pulsars"

Top of the Pops 2014/15 - Complex Stellar Type

- > New, small population of GeV accelerators
- > White dwarf + stellar companion
- > Thermonuclear explosion for \sim 2 weeks
- > Unexpected HE particle acceleration



Plot of this talk

- > The gamma-ray window
 - Experimental coverage, surveys, detectors, upgrades



- > Recent findings
 - Subjectively chosen remarkable new results 2014/15



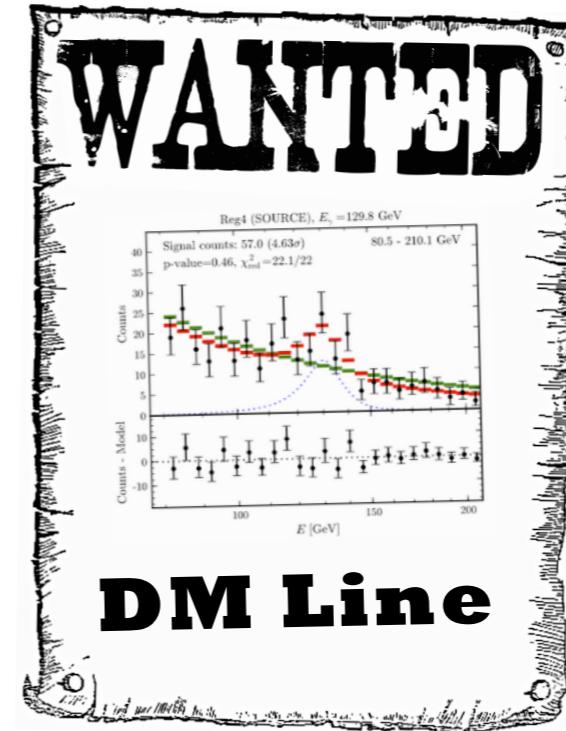
- > Recent not-yet findings
 - ...like neutrino-emitting sources



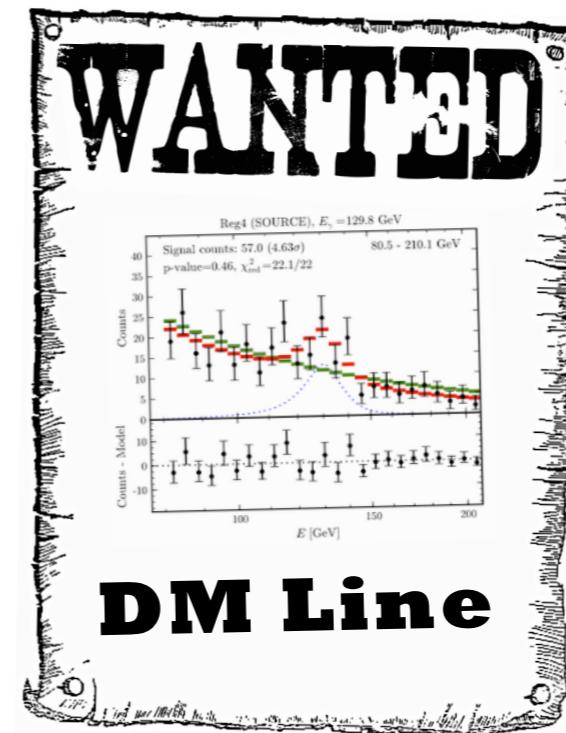
- > The future



Still wanted

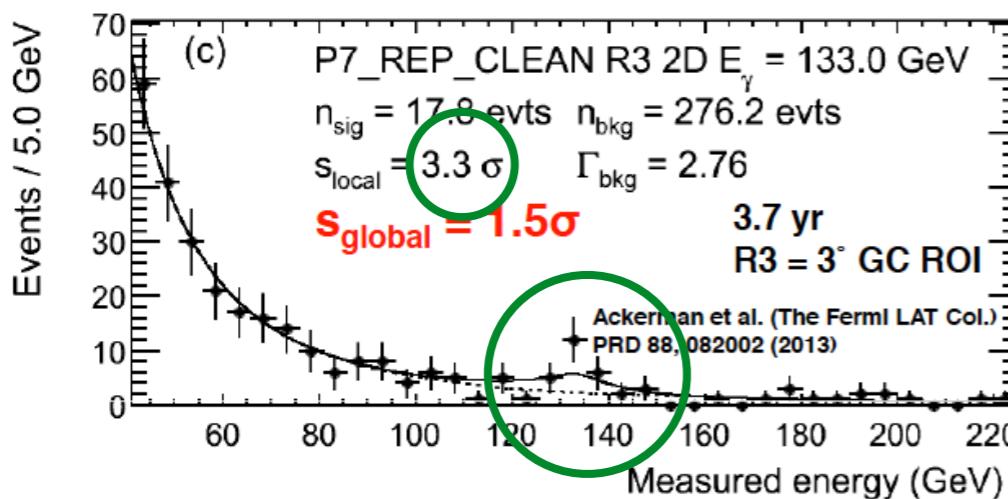


Still wanted

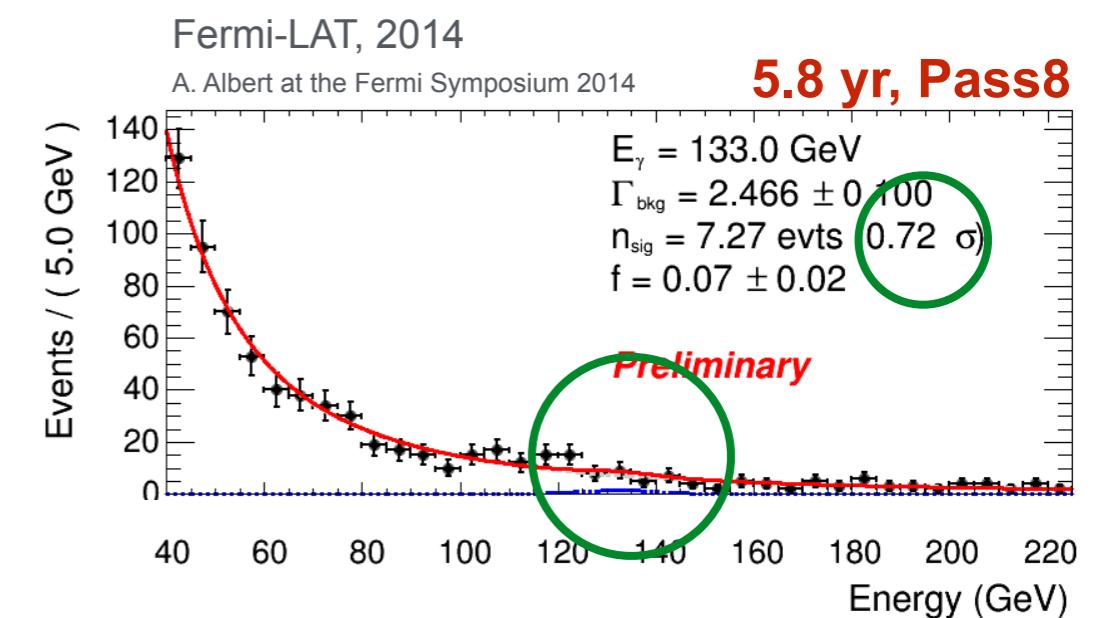


Dark Matter Lines 2014/15

- > The 133 GeV Galactic Centre line has disappeared

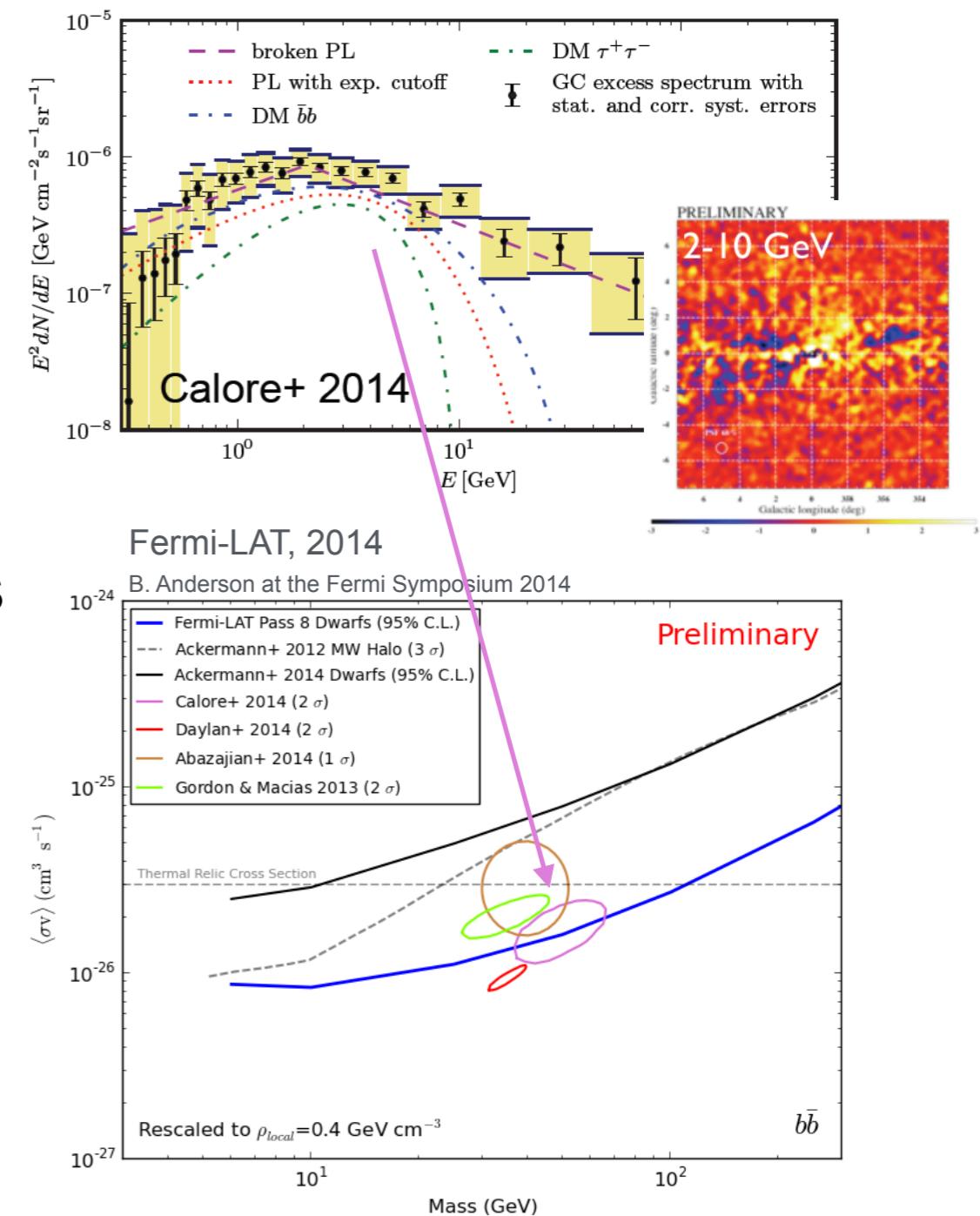


Pass8
More data
Trial factor

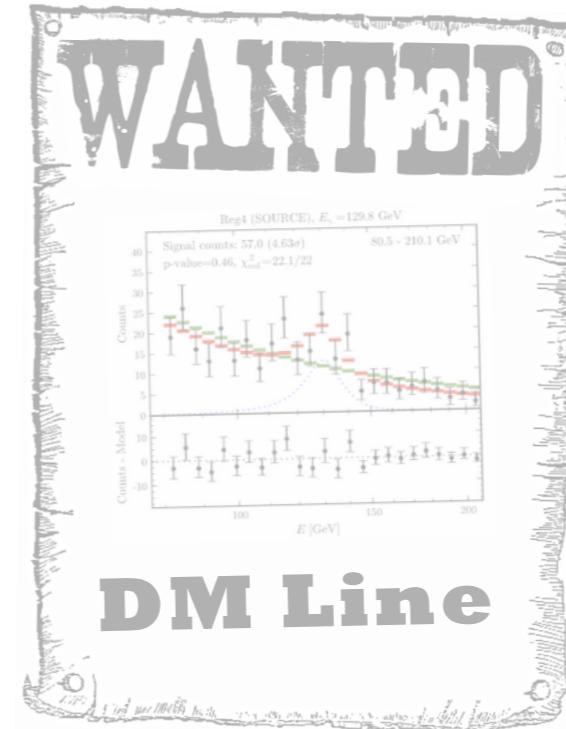


Dark Matter Lines 2014/15

- > The new Galactic Centre feature and other DM searches
- > New feature:
 - Broad in energy (peaking at few GeV)
 - Broad in space ($\sim 10^\circ$, spherical)
 - Fermi team sort-of confirms, but denotes strong dependence on Galactic model, systematics, etc.
- > In tension with Fermi dwarf galaxy limits
- > Alternative scenarios (msPSRs, ...) in discussion



Still wanted

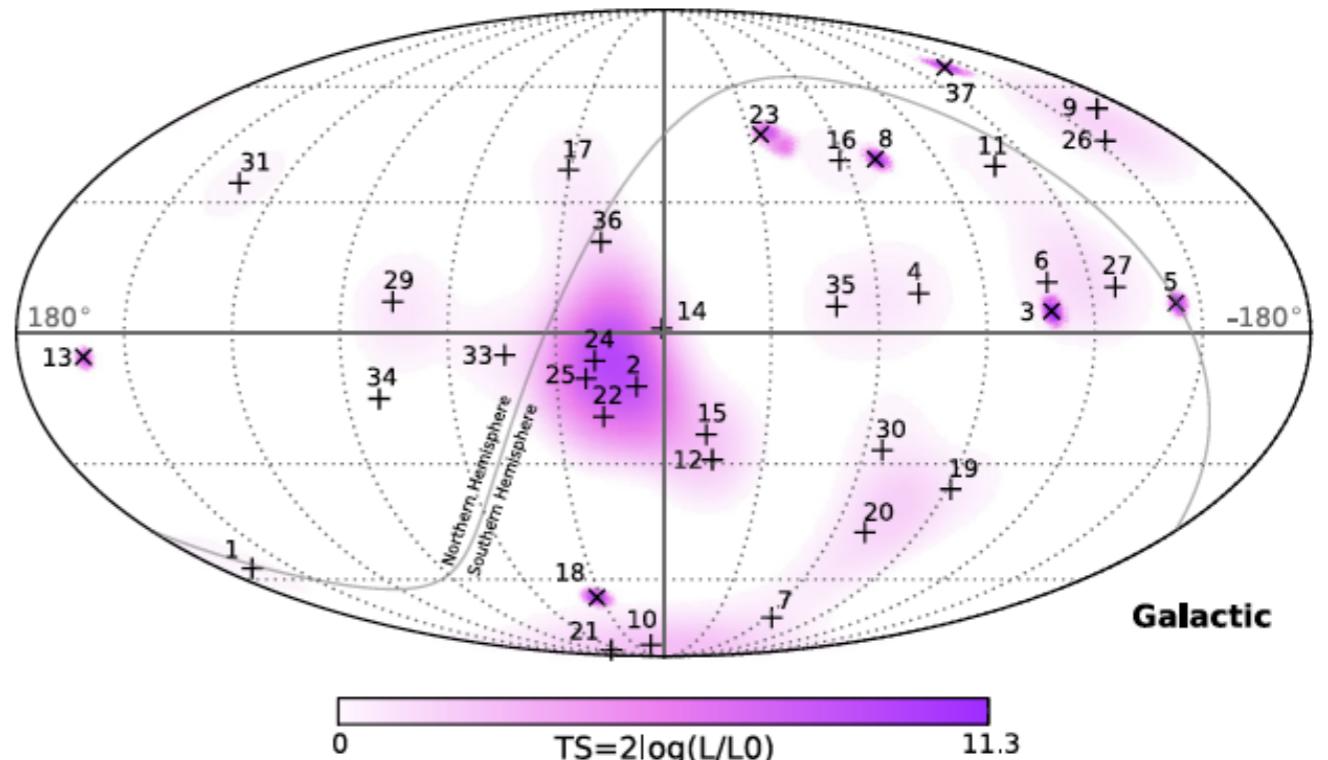


Neutrino + Gamma = Hadronic Accelerator

> Approach 1: Time-independent follow-up

- Observations of well-tracked neutrinos
- Based on public data or mutual non-public agreements
- Observations/analyses non-public
- No publication yet

IceCube, 2014
<http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.113.101101>



Neutrino + Gamma = Hadronic Accelerator

> Approach 2: Triggered, time-focused follow-up (ToOs)

- Approach 2a: Pre-defined target list
 - Running: IceCube+MAGIC, IceCube+VERITAS since 2012
 - In preparation for IceCube+H.E.S.S., Antares+H.E.S.S.
 - Lists are not public
- Approach 2b: All-sky best-pointing events
 - Multiplets, any energy (100s of GeV - PeV)
 - Possibly public (GCN alerter?), in prep.
- Approach 2c: High-energy (background-free) events
 - > some 100 TeV
 - Possibly public (GCN alerter?), in prep.

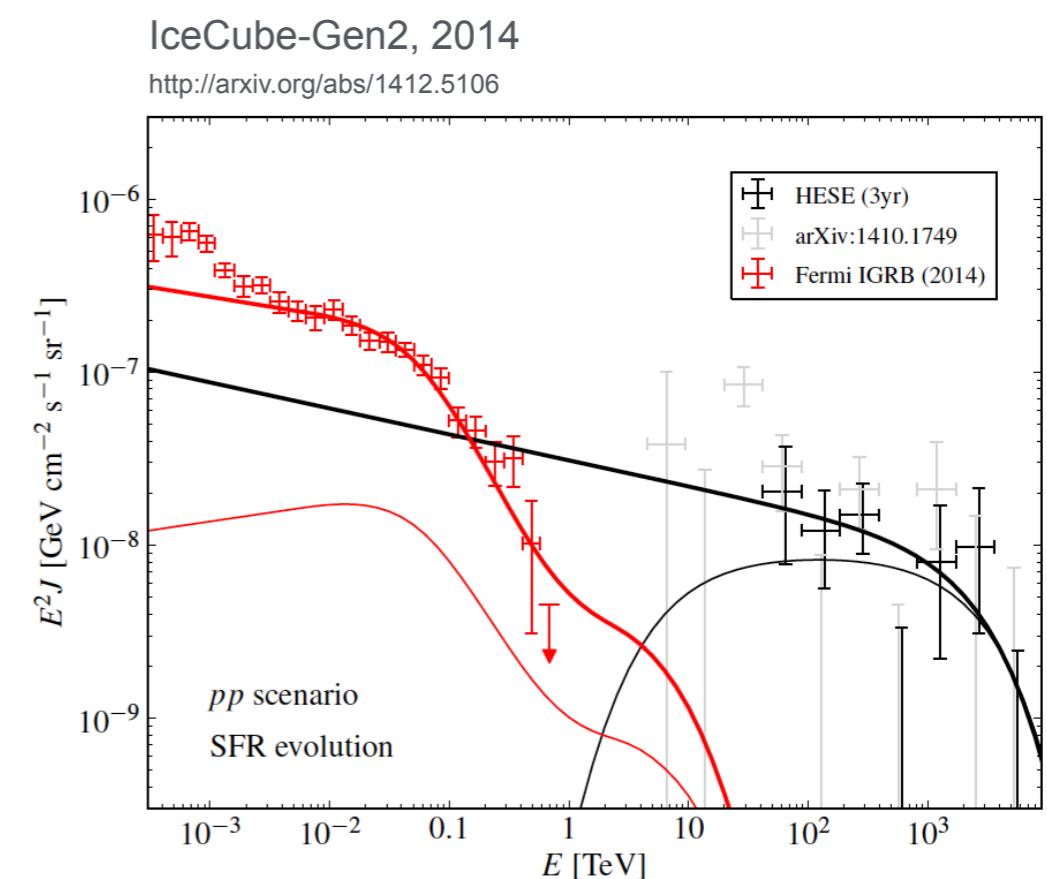
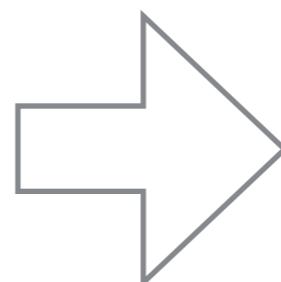
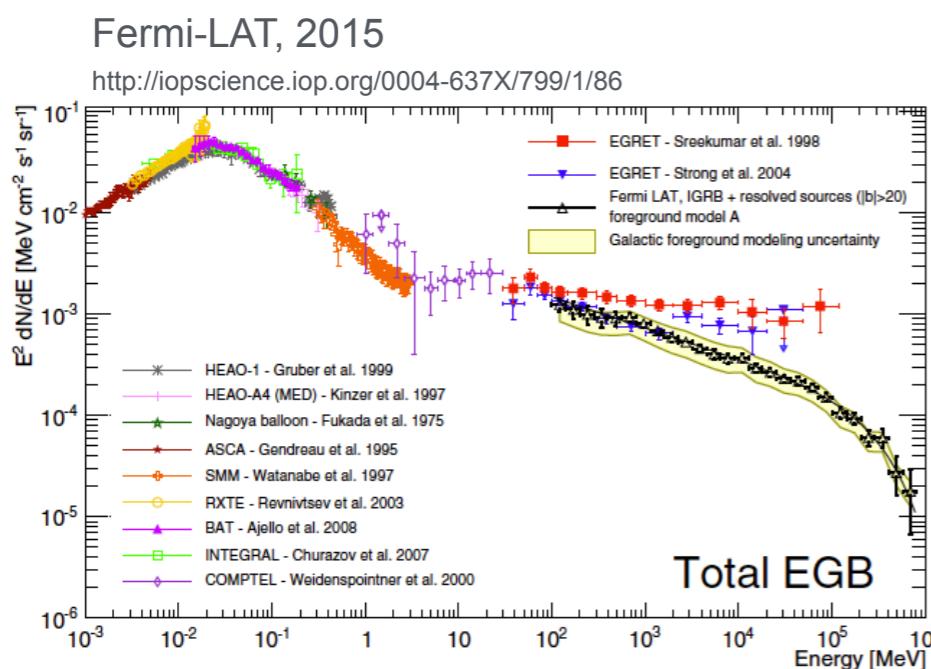
> Publications

- Technical proceedings exist
- Around IceCube: 2 technical publications in prep, one more planned
- Physics results publication in prep.



Is it about Point-Like Sources at all?

- > Distantly produced pions as a main source of background gammas and neutrinos



Plot of this talk

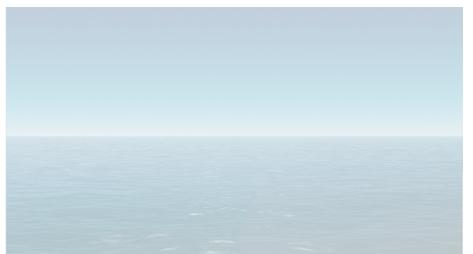
- > The gamma-ray window
 - Experimental coverage, surveys, detectors, upgrades



- > Recent findings
 - Subjectively chosen remarkable new results 2014/15



- > Recent not-yet findings
 - ...like neutrino-emitting sources



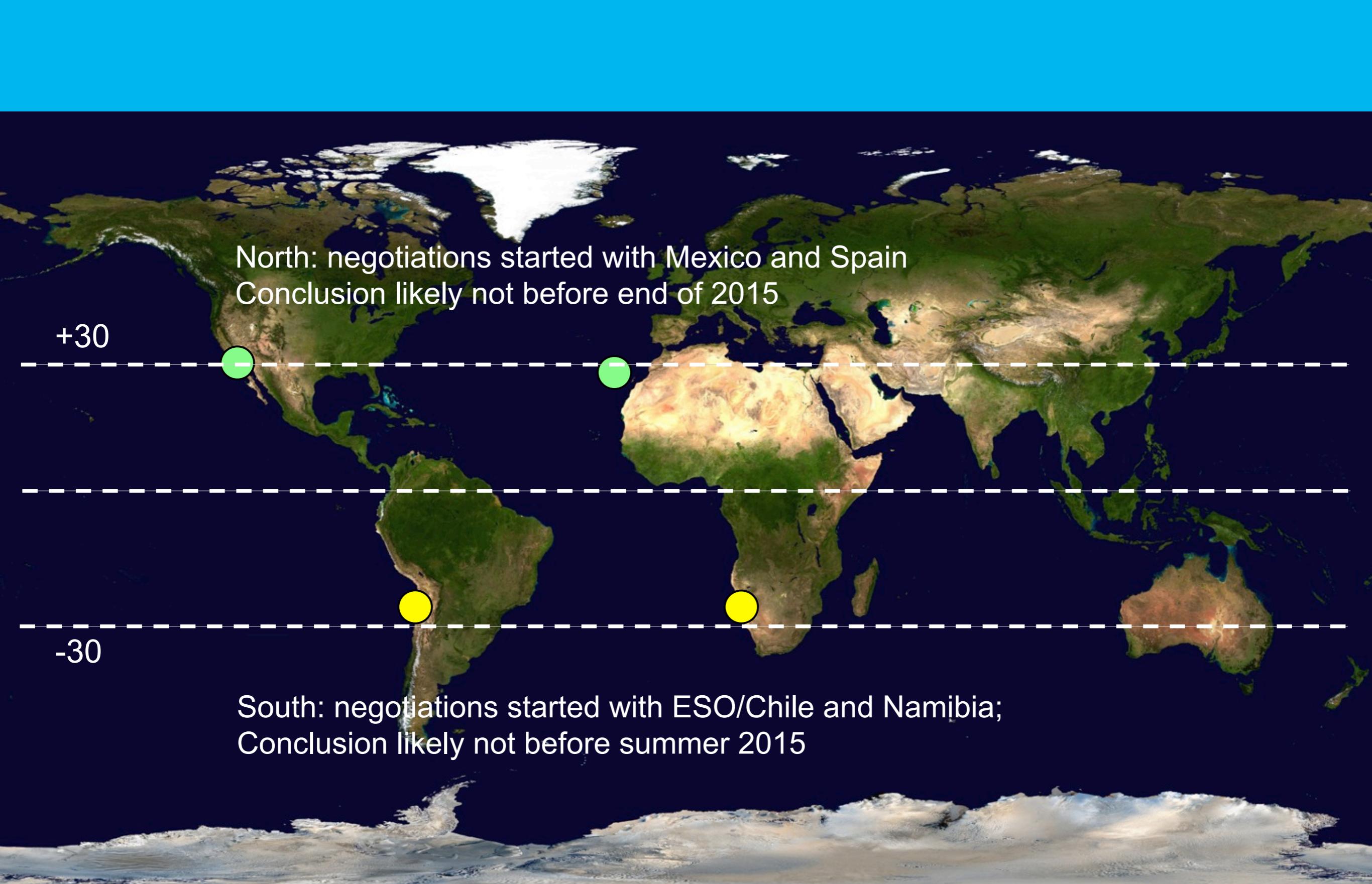
- > The future



Outlook: CTA

- > A huge improvement in all aspects of performance
 - A factor ~10 in sensitivity, much wider energy coverage, much better resolution, field-of-view, full sky, ...
- > A user facility / proposal-driven observatory
 - With two sites with a total of >100 telescopes
- > A 27 nation ~200M€ project
 - Including everyone from HESS, MAGIC and VERITAS





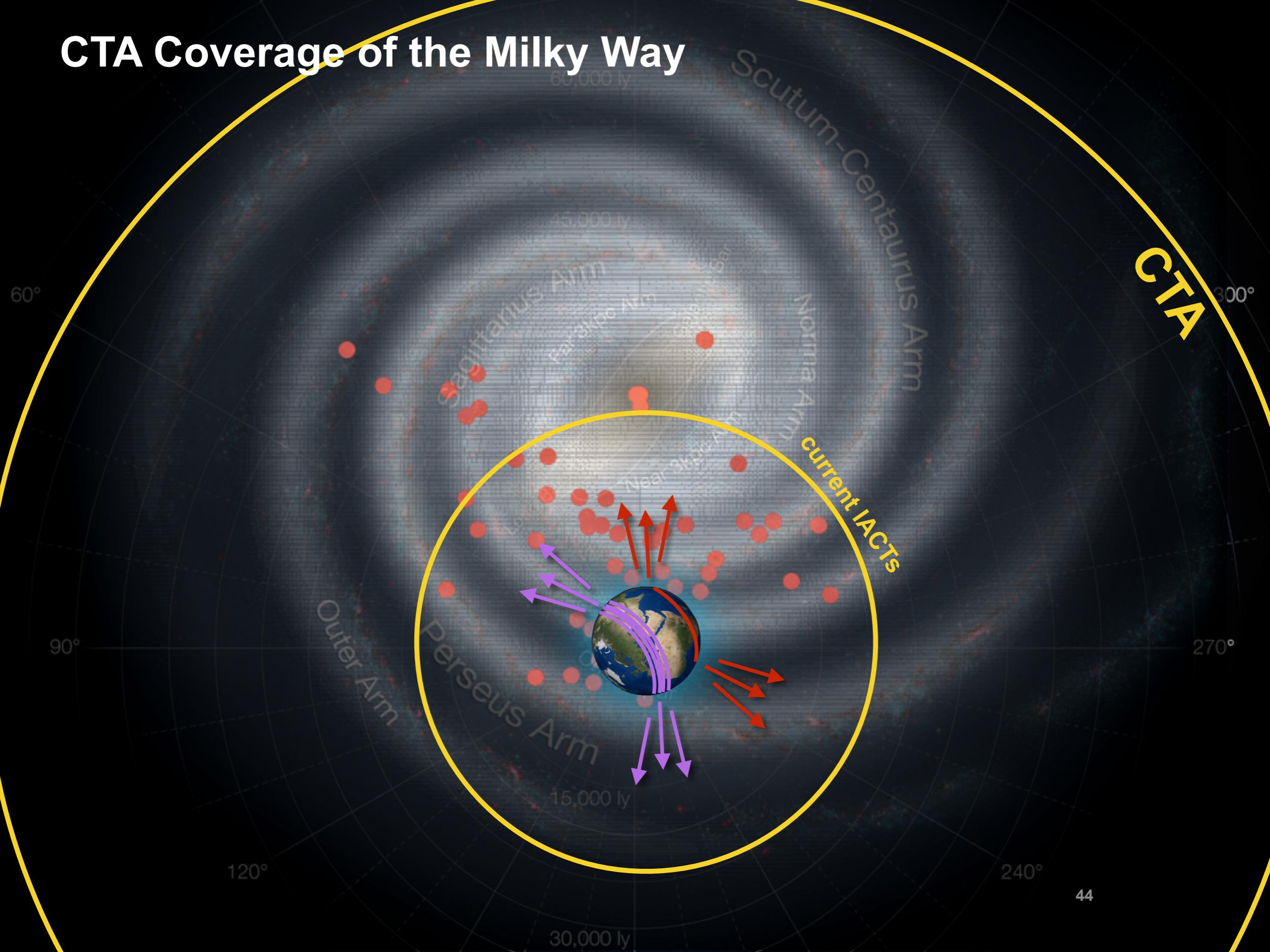
North: negotiations started with Mexico and Spain
Conclusion likely not before end of 2015

+30

-30

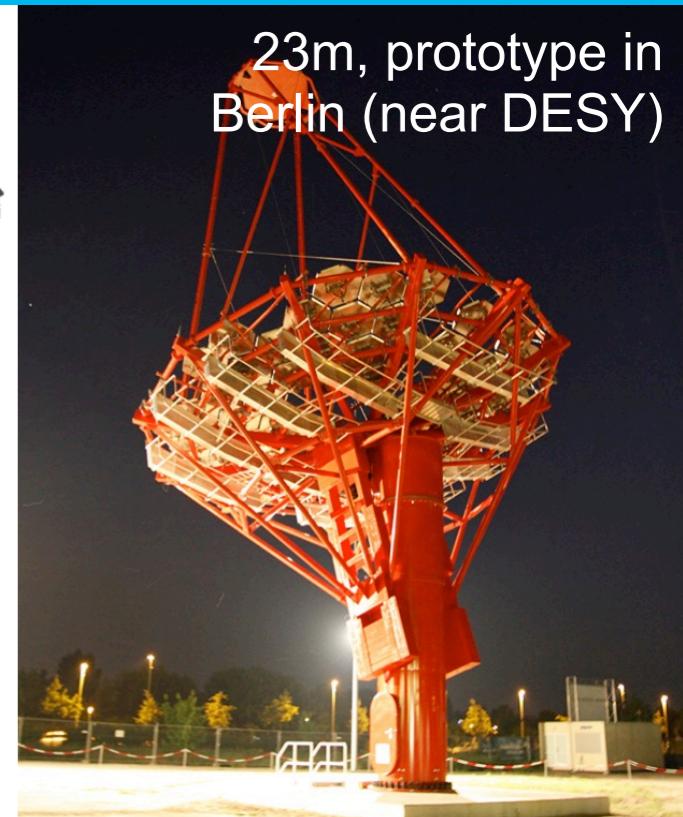
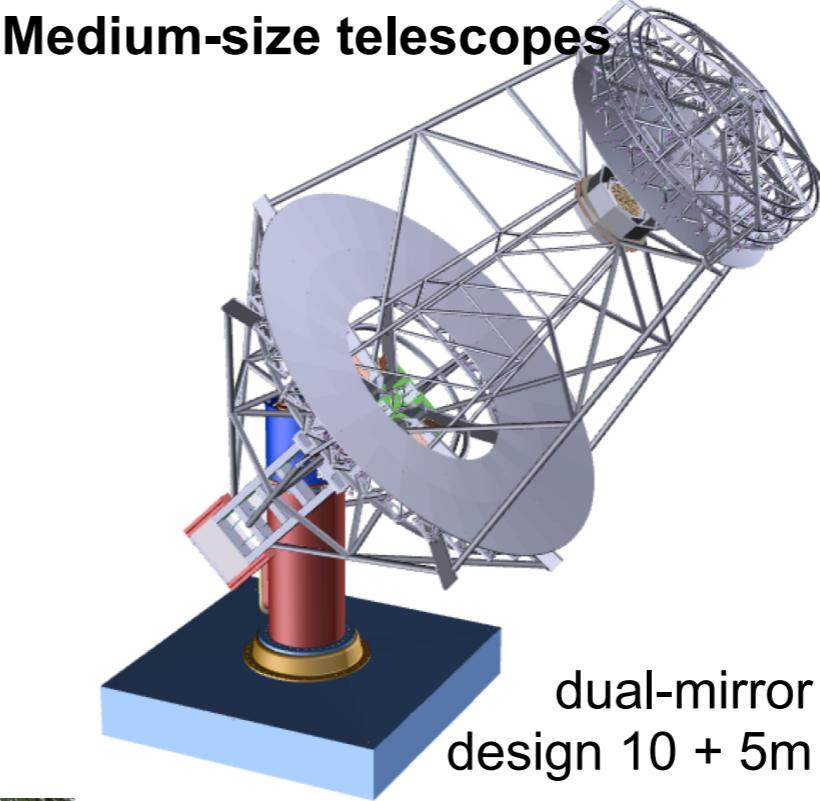
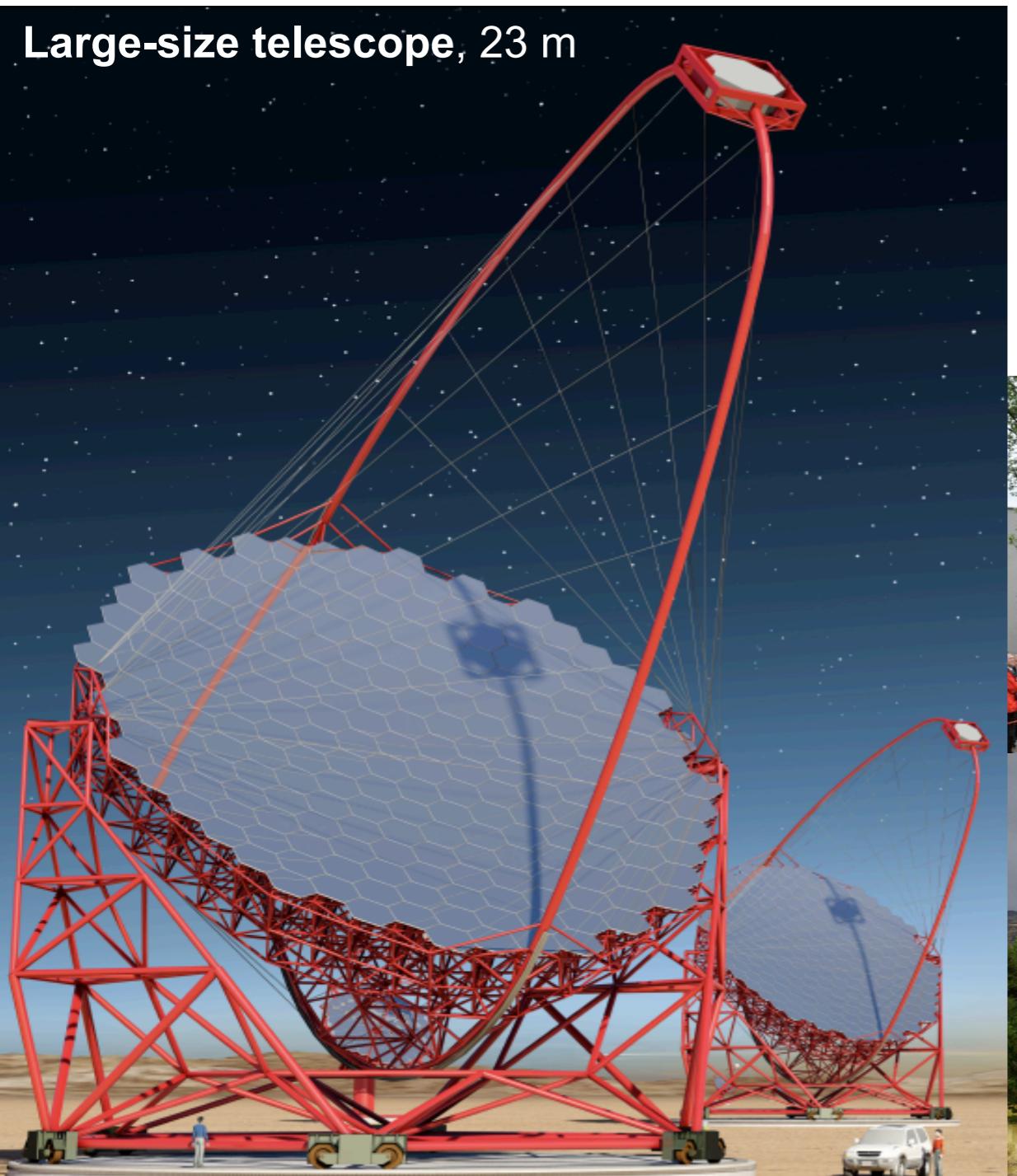
South: negotiations started with ESO/Chile and Namibia;
Conclusion likely not before summer 2015

CTA Coverage of the Milky Way

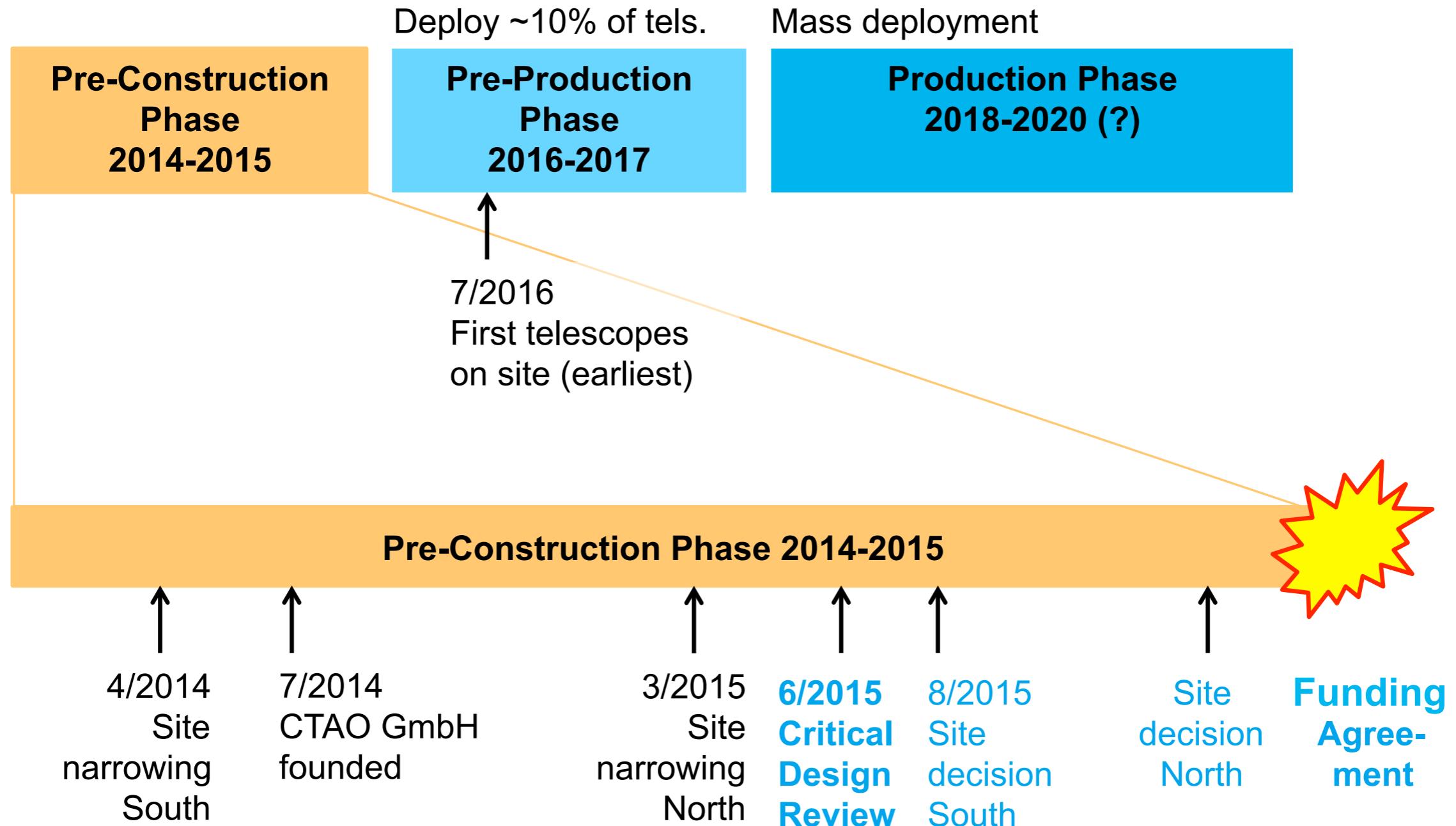


3 Telescope Sizes

> ...many possible designs



CTA Timeline



Summary

- > The gamma-ray sky is being explored quite comprehensively
- > Surveys and large observation programs are becoming the way to go
 - Great interest in first HAWC results!
- > Current instruments approach "saturation", but the sky is too spectacular to stop surprising us
- > CTA will be the Fermi-LAT of TeV astronomy!

Thx.



July 2015: H.E.S.S. I Camera Upgrade

> Goals

- Reducing readout deadtime
(= more mixed-size stereo events)

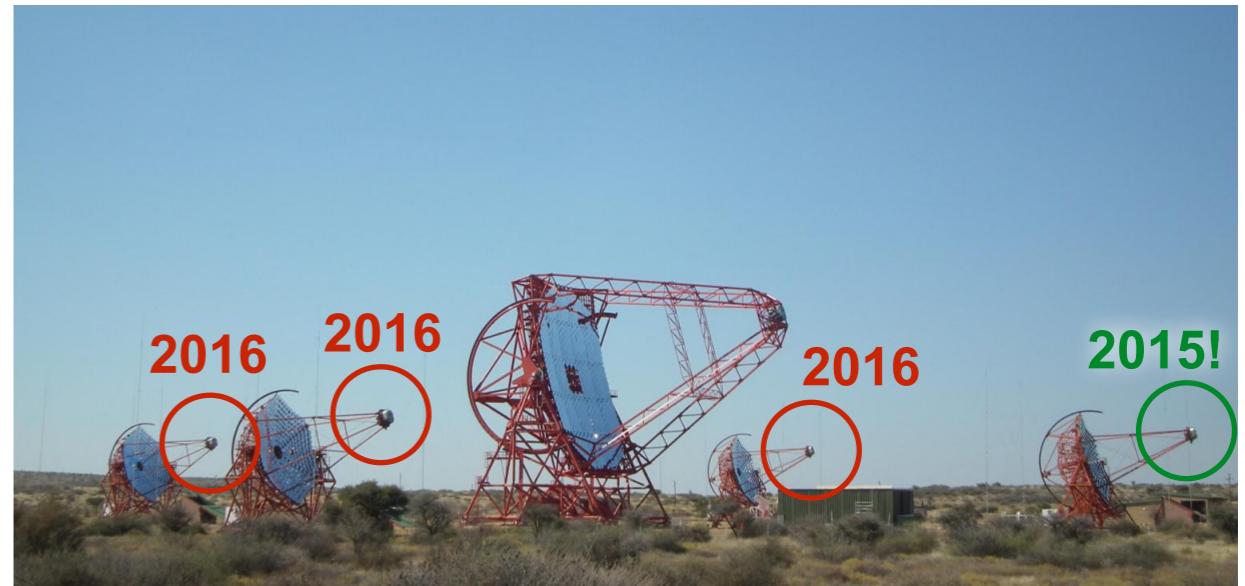
- Reducing downtime

> Scope

- 4 old H.E.S.S. I cameras
- All camera electronics
- Camera ventilation system
- Pneumatics

> Spin-off CTA technology

- Using NECTAR chips
- Ethernet-based readout



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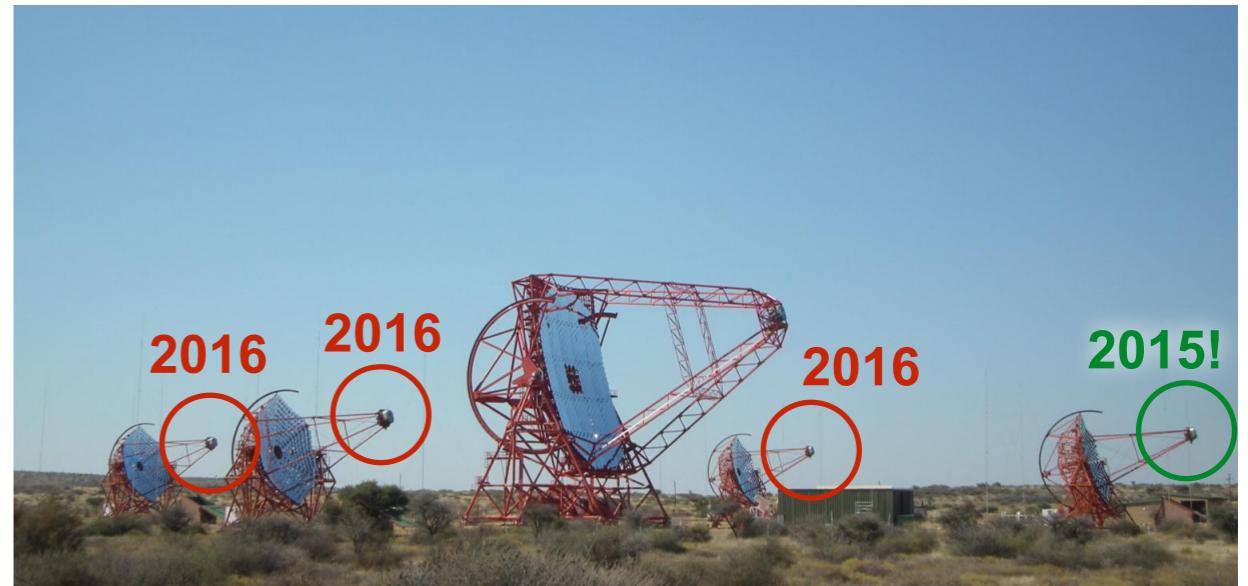
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> Scope

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Experimental Coverage - Other subtleties between IACTs

	field of view	GRB repointing time	threshold
MAGIC	3.5°	24 s	~50 GeV
VERITAS	3.5°	100 - 200 s	~100 GeV
H.E.S.S. II / I	3.2° / 5°	40 - 60 s	~30 / 100 GeV*

More Top of the Pops 2014/15

- > Other Fermi highlights I can't cover here:
 - Fermi bubbles: <http://adsabs.harvard.edu/abs/2014ApJ...793...64A>
 - GRB 130427A: <http://adsabs.harvard.edu/abs/2014Sci...343...42A>
 - Gamma-rays from the sun: <http://adsabs.harvard.edu/abs/2014ApJ...787...15A>
 - ...and even from behind-the-limb: <http://arxiv.org/abs/1505.03480>

Top of the Pops 2014/15 - Simple Stellar Type

- HESS J1641-463
- Very hard SNR
 - Index 2.07
 - Data points until 20 TeV
 - Lower limit on cutoff energy: 100 TeV
- A potential PeVatron?

H.E.S.S., 2014
<http://iopscience.iop.org/2041-8205/794/1/L1/>

Stefan Klepser | High-ene

