The ~~Final~~ Next Word

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CCAPP

NSF

Opening Remarks

Dark Matter and Gamma Rays

From Where Did Hope Grow?

Dark matter
Zwicky 1933

Thermal relics
Zel'dovich 1965

Heavy neutrinos
Lee, Weinberg 1977

Annihilation signals
Gunn et al. 1978

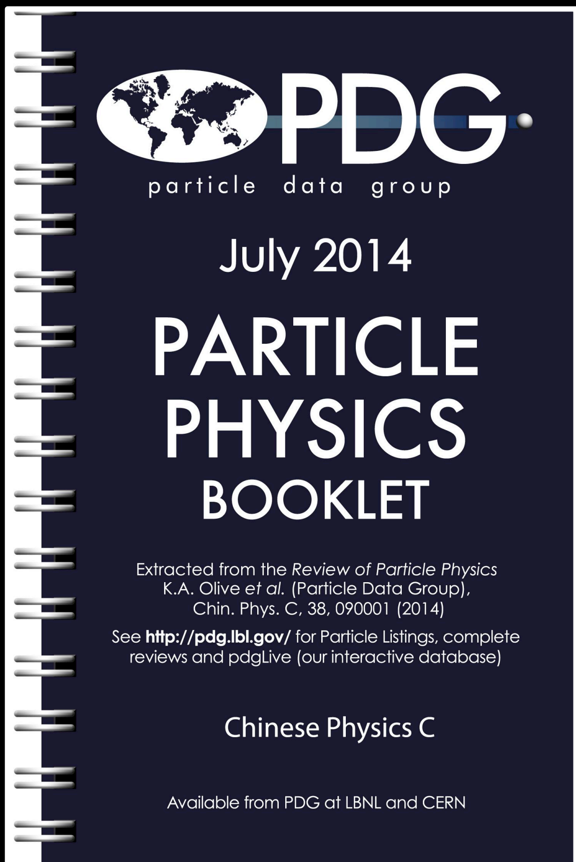
Annihilation signals
Stecker 1978

Gamma-ray astro
Morrison 1958

many papers

Discovering Dark Matter

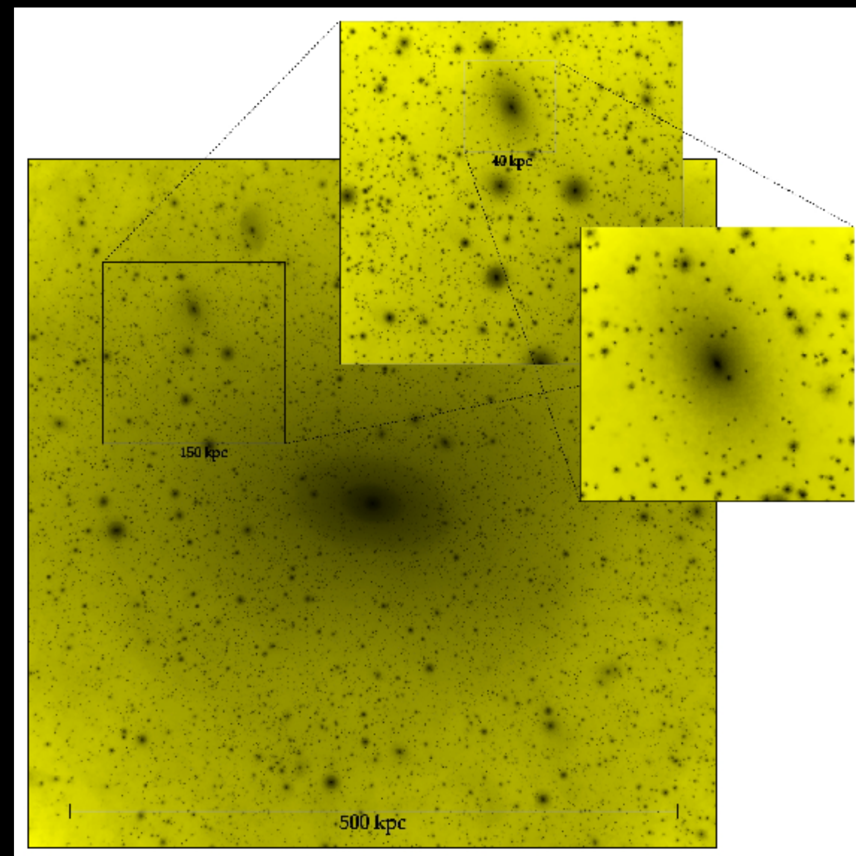
Particle Properties



+

(consistency)

Cosmological Clustering



But this is the wrong question

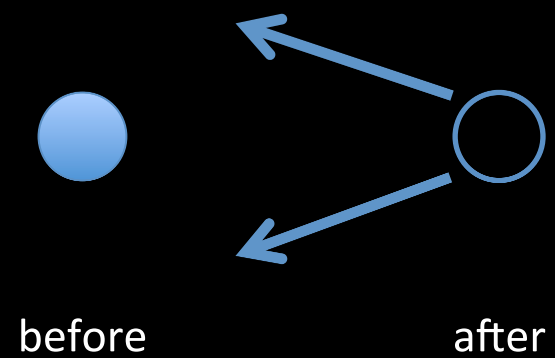
Examples of Failure: Many

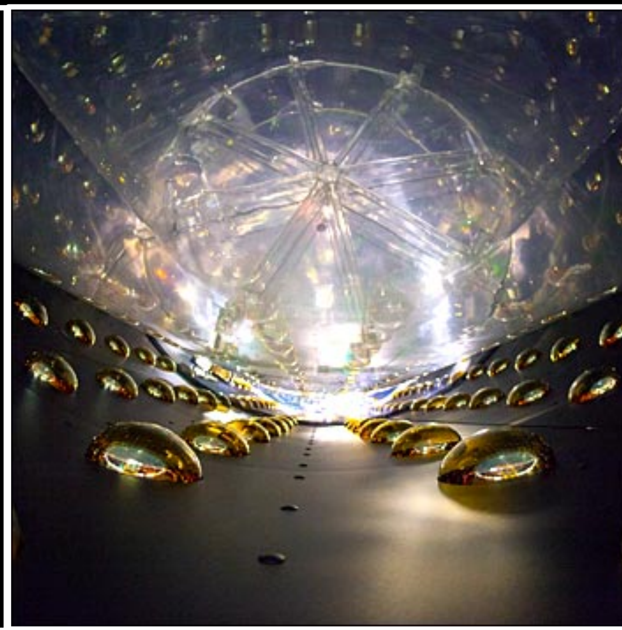
But failure is worse than death

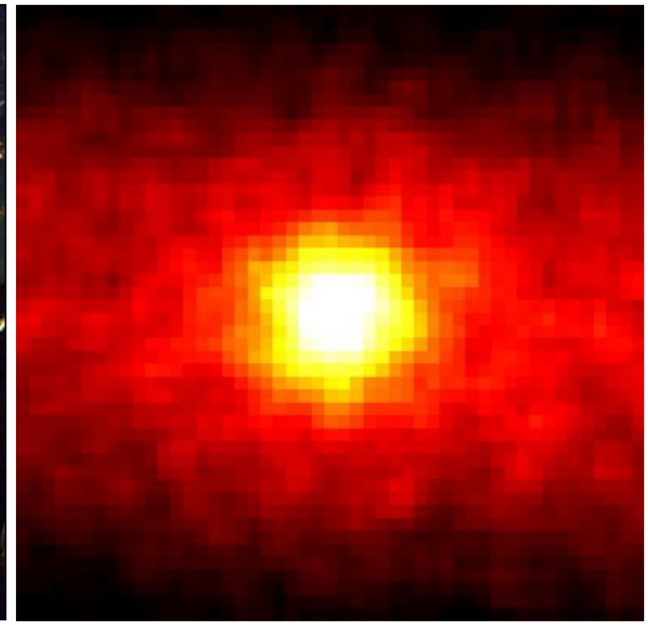
Example of Success: Neutrinos

Concepts	Realities	Messengers

$$n \rightarrow p + e^{-}$$



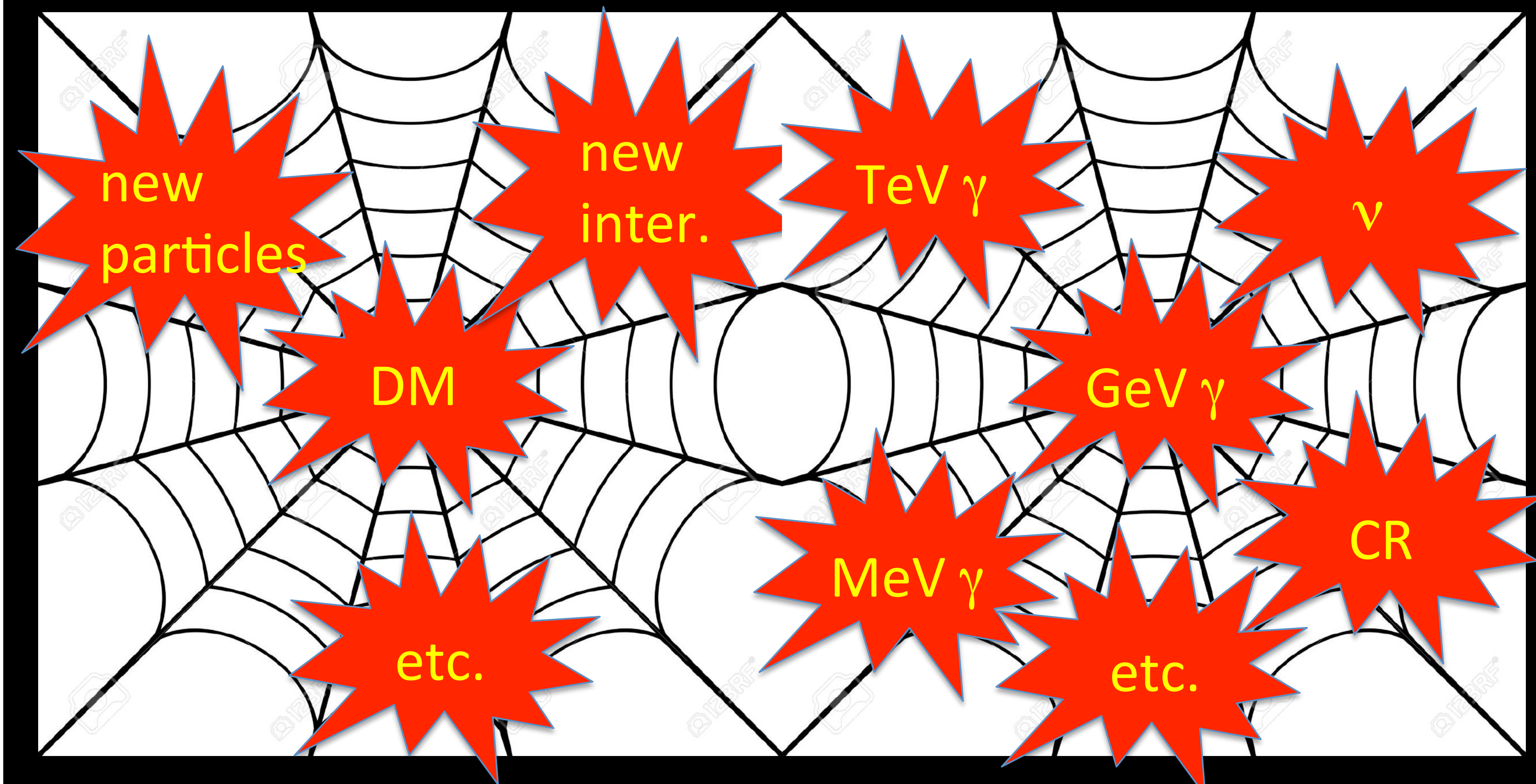




But why was this successful?

Enlarge the Scope of Inquiry

Particle Physics Astrophysics



But are we actually doing this?

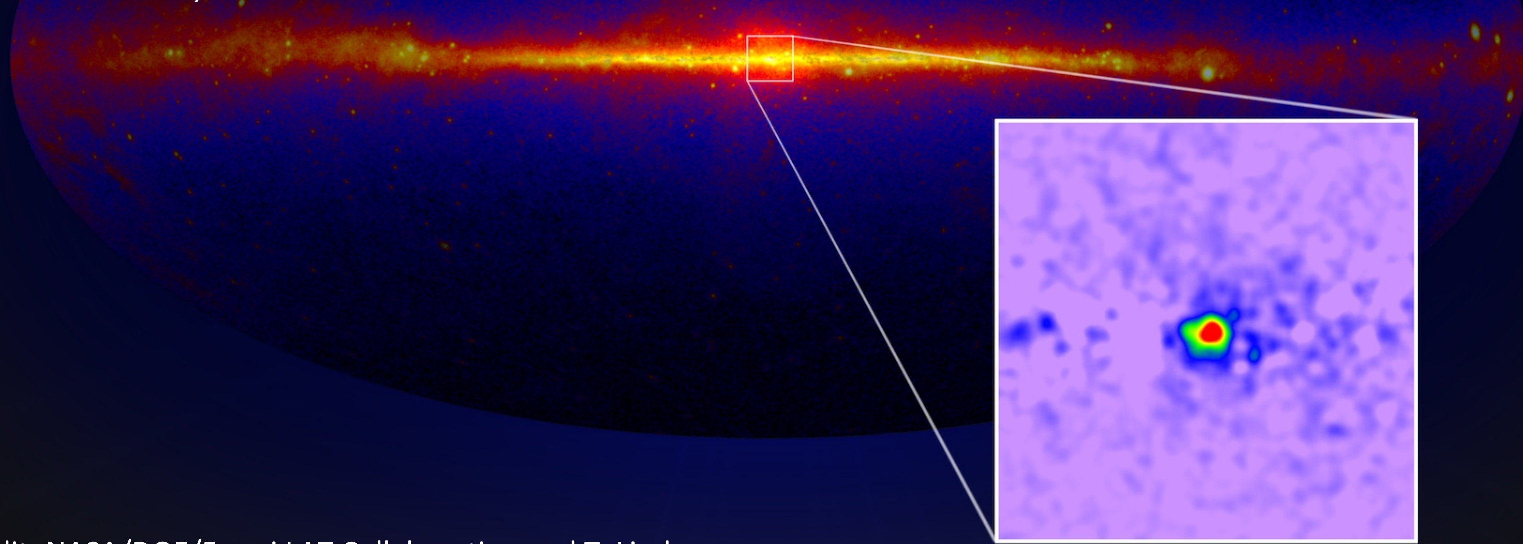
Galactic Center and Environs

Focus on giant explosions

The GeV Excess

Many studies

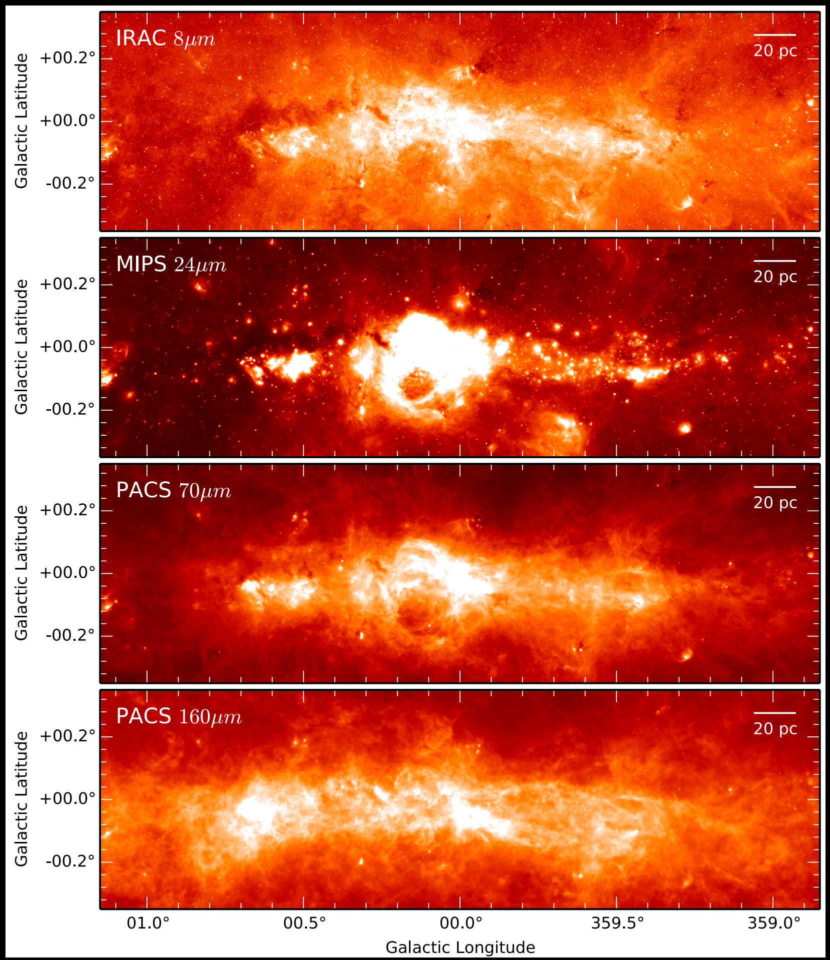
Goodenough & Hooper 2009, Vitale+ (Fermi coll.) 2009, Hooper & Goodenough 2011, Hooper & Linden 2011, Boyarsky+ 2011 (no signal), Abazajian & Kaplinghat 2012, Hooper & Slatyer 2013, Huang+ 2013, Gordon & Macias 2013, Macias & Gordon 2014, Zhou+2014, Abazajian+ 2014, Daylan+2014, Calore+ 2014, Gaggero + 2015, Carlson+ 2015 ......



Credit: NASA/DOE/Fermi LAT Collaboration and T. Linden

Slide from Ryan O'Leary

Intense Star Formation in GC



Koepferl+2014

Central Molecular Zone

Star Formation & Supernovae Rates Uncertain.

~3% Free-Free Emission

Longmore+2013

~10% YSOs

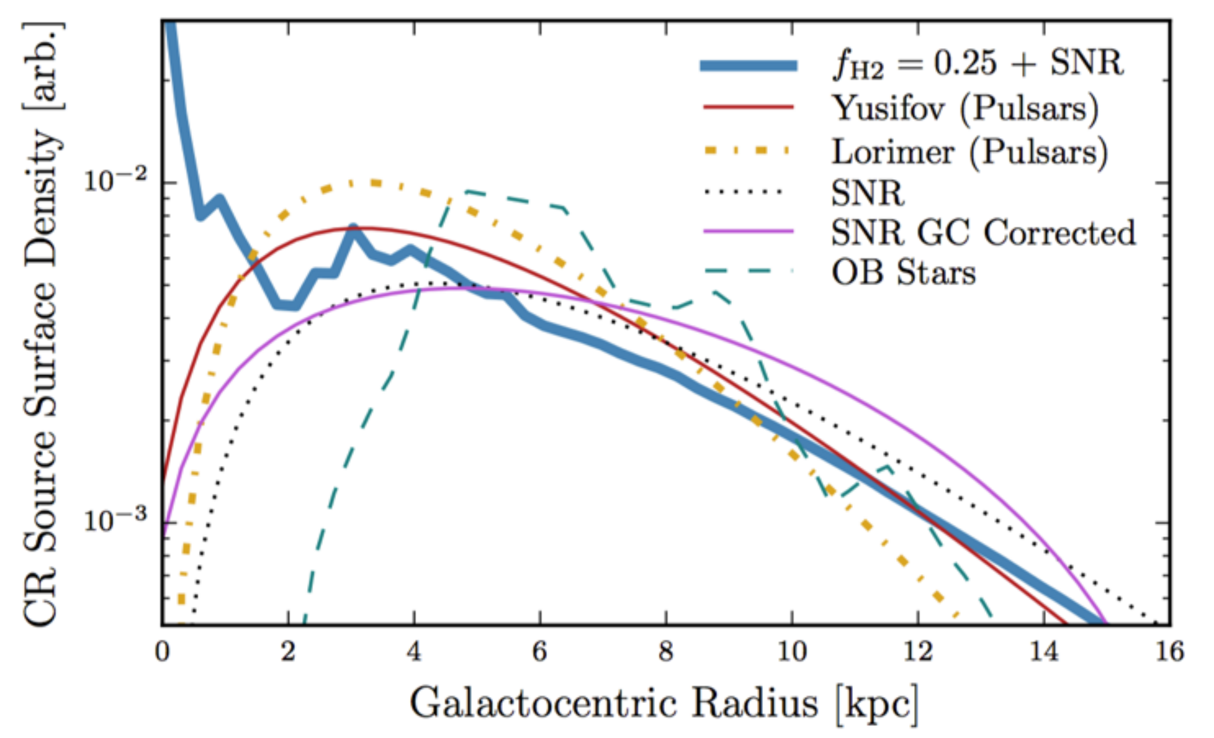
Yusef-Zudah+ 2009

~20% Wolf-Rayet Stars

Rosslowe & Crowther 2015

Slide from Tim Linden

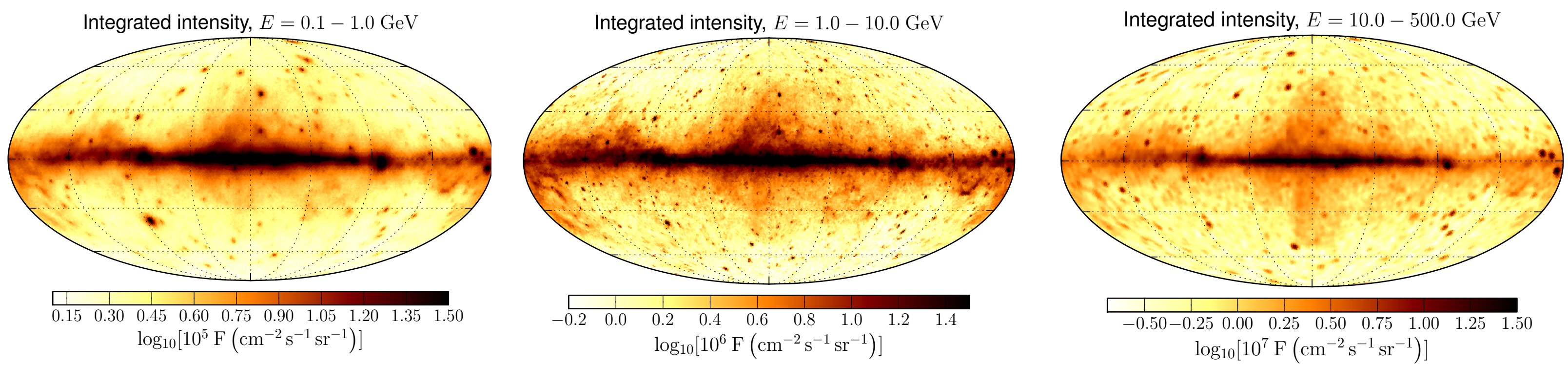
Adding a Molecular Gas Component



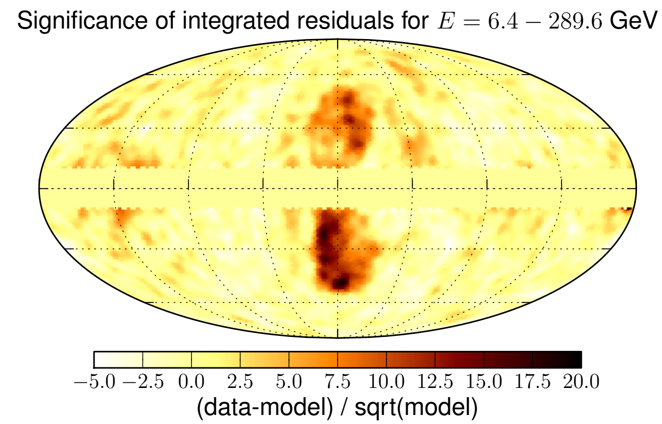
Adds significant cosmic-ray injection to the inner galaxy, and additionally a large bar structure.

Hard Spectrum

- **50 months of data**
- **Pass 7 reprocessed data set**
- **Ultraclean class**



Bubbles template closer to the plane: see talk by Dmitry Malyshev on Monday



Ackermann et al. (the Fermi-LAT Collaboration, ApJ, 793 (2014)

A.

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Notes

Search for new astrophysics instead of dark matter
Connect Fermi Bubbles to Galactic Center Excess
Look away from Galactic Center; look to Cygnus Region

Work to distinguish transient and steady-state sources
Careful about cosmic rays from star formation

Work to distinguish star formation and AGN activity
Positrons and 26Al could help with this and transients

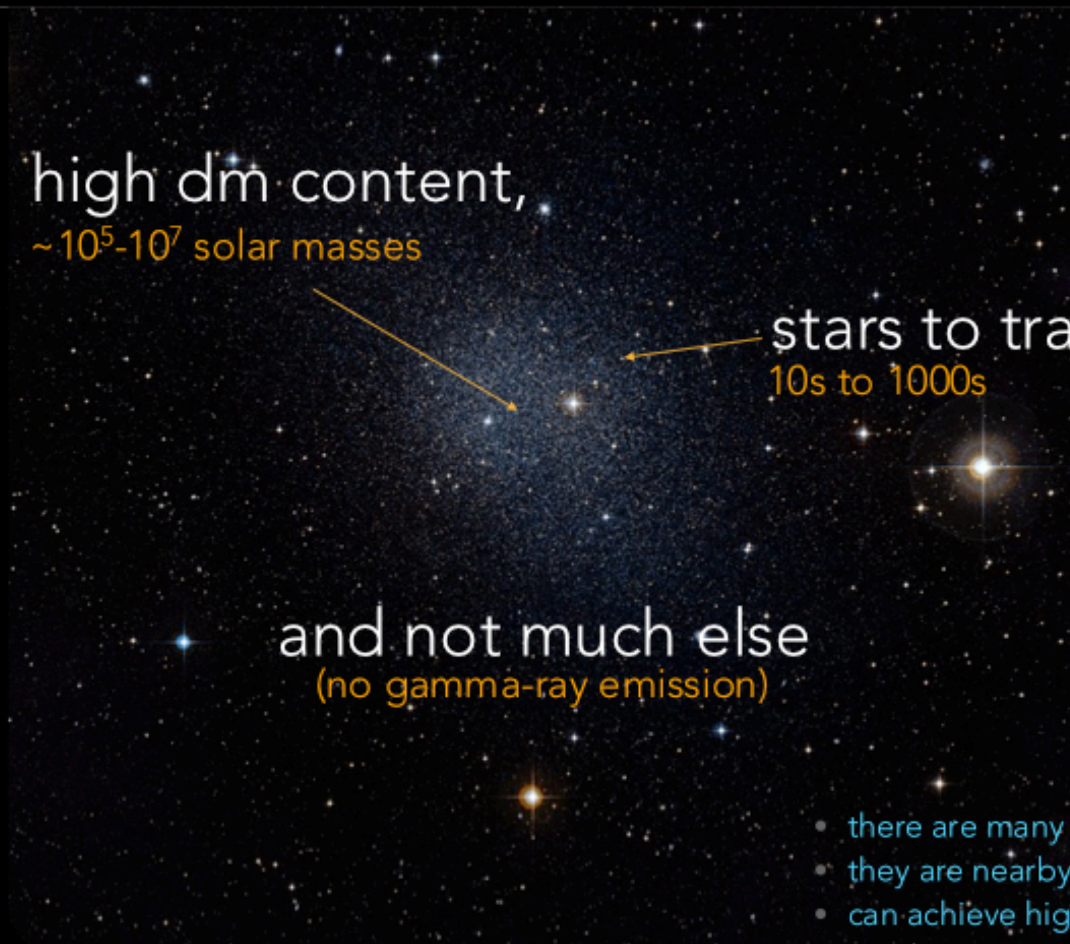
Dwarf Galaxies

Focus on nature of dark matter

Slide from Brandon Anderson

dwarf spheroidals
as DM laboratories

ESO DSS2



- there are many (20+ so far)
- they are nearby (<250 kpc)
- can achieve high sensitivity by combining many of them

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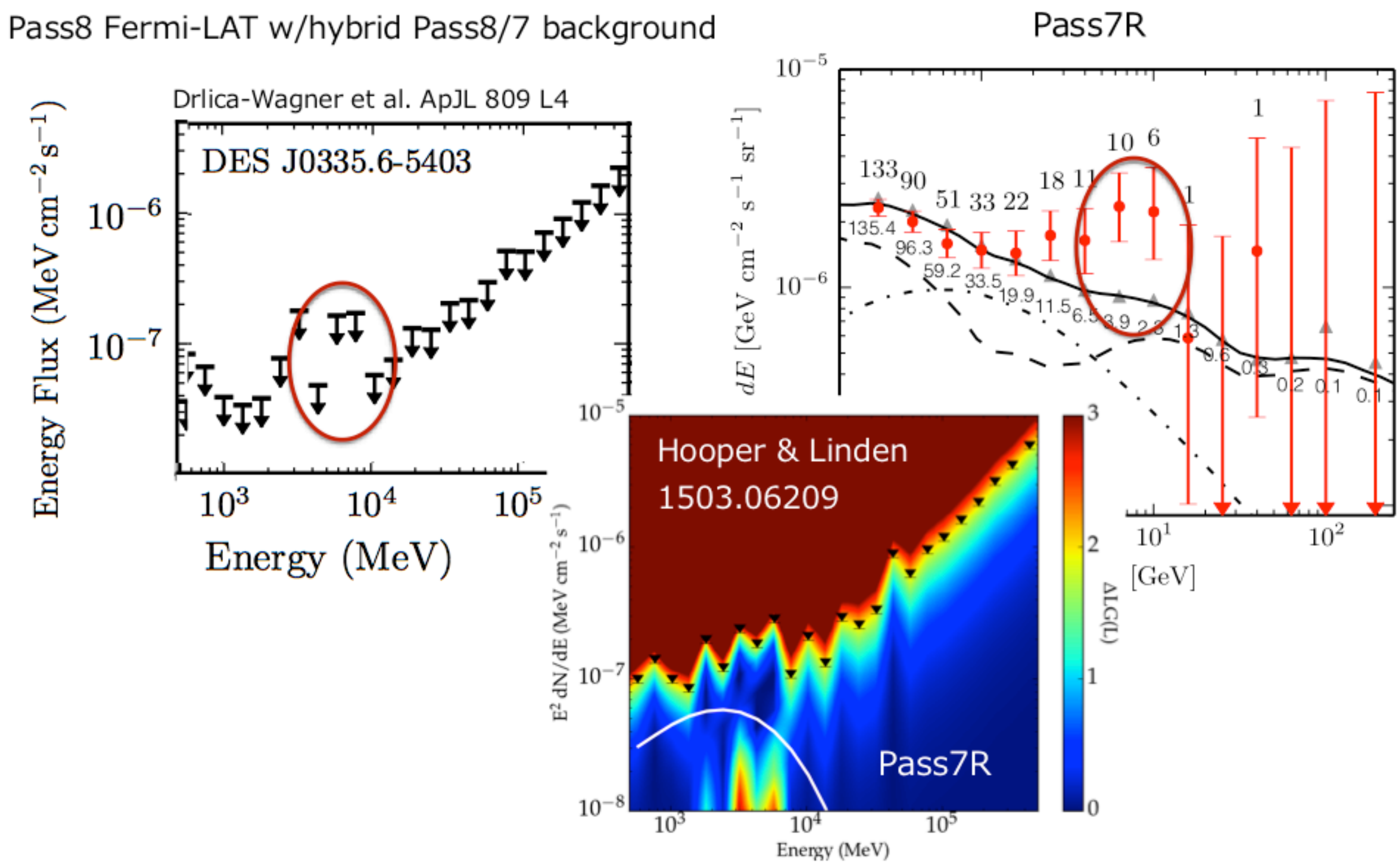
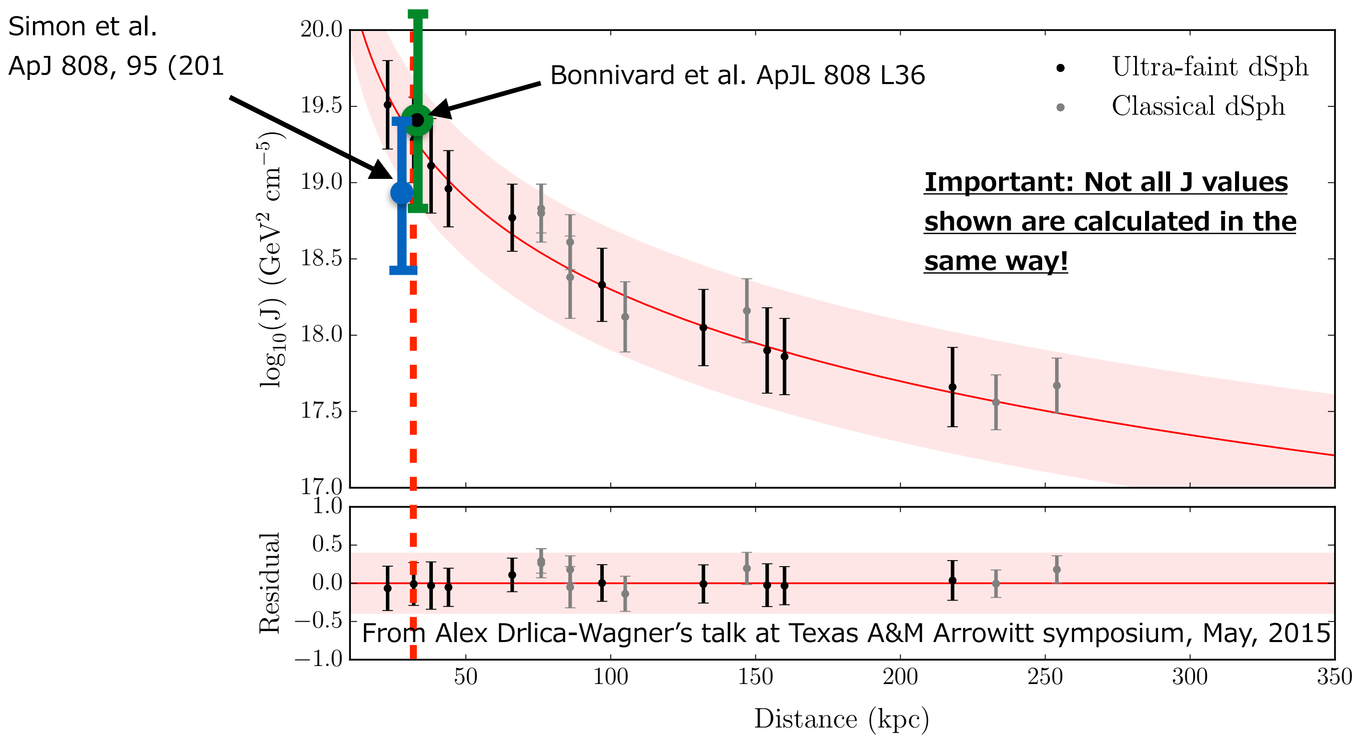
Slide from Savvas Koushiappas

Reticulum II in gamma-rays



Slide from Savvas Koushiappas

The dark matter content of Reticulum II



Slide from Brandon Anderson

outlook

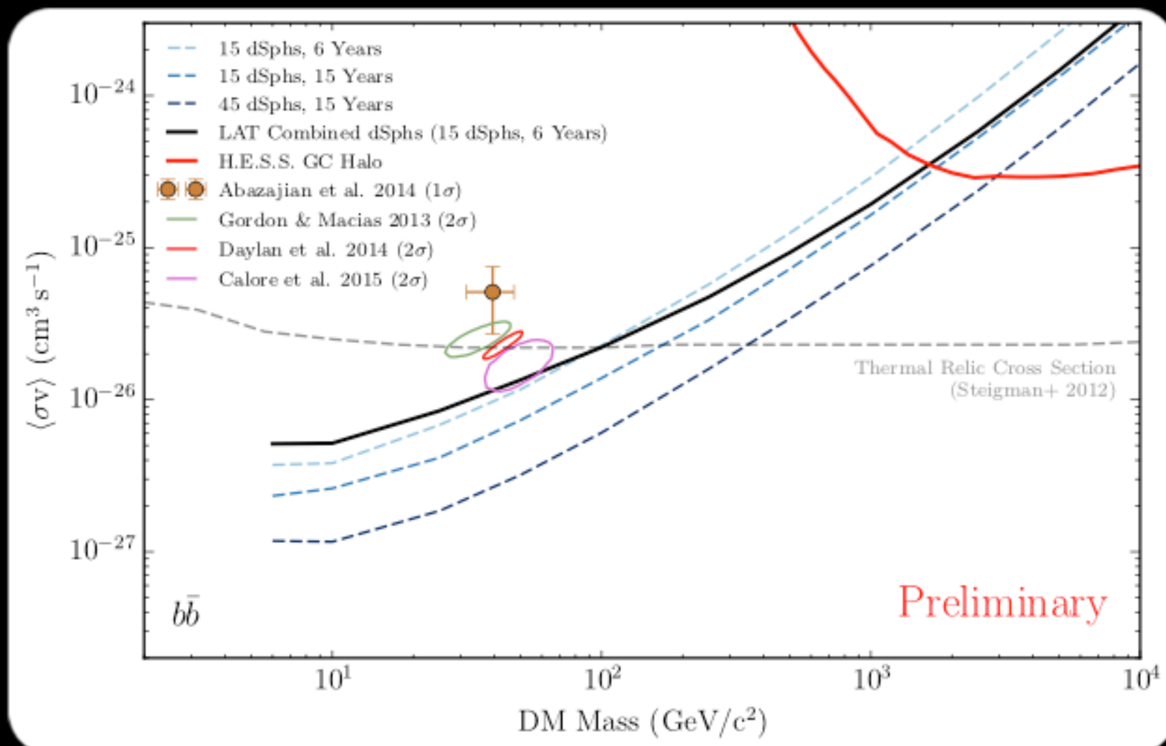
time+targets

$\sqrt{N}$

In lieu of detection

we can realistically hope to:

- confirm / refute GC models



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Notes

Improve comparisons of different analyses

Need more details of data, inputs, and interpretation

Find more dwarfs

Within reach; important for dark matter and astronomy

Improve interpretation of dark matter limits

Need new efforts to limit the total cross section

(see first discussion in Beacom, Bell, Mack 2007)

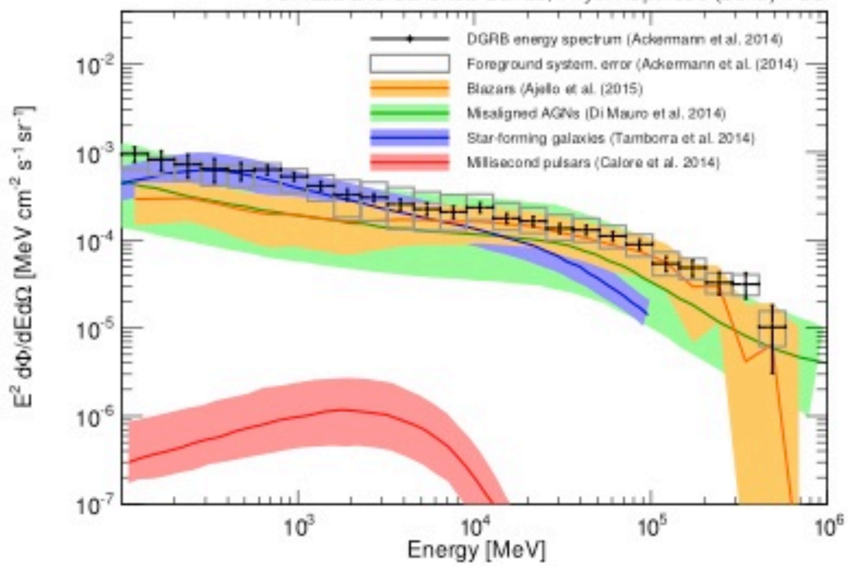
Galactic and Cosmic Diffuse

Focus on cosmic energy budget

Slide from Mattia Fornasa

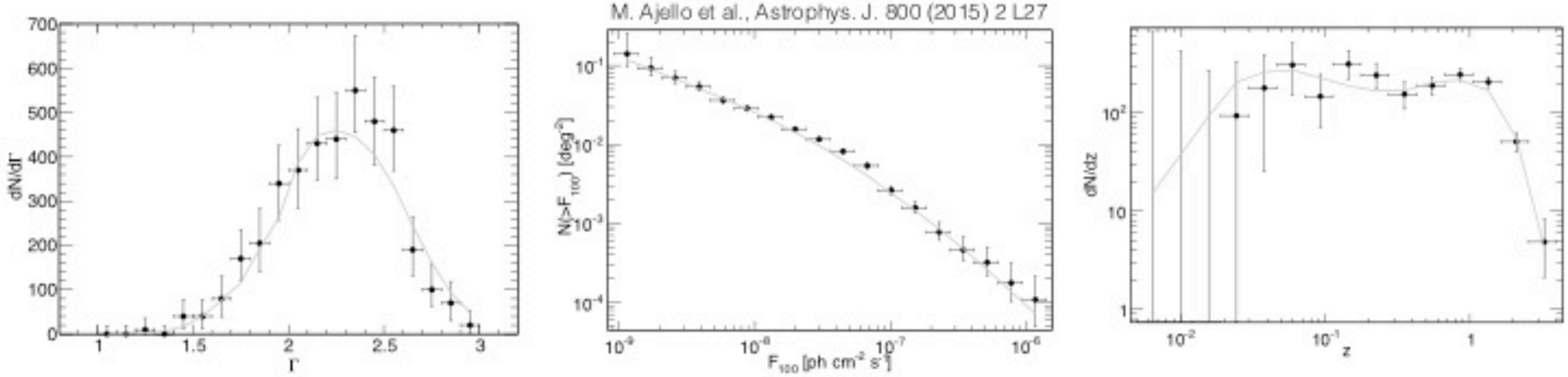
Interpretation (astrophysics)

Fornasa and Sanchez-Conde, Phys. Rept. 598 (2015) 1-58



- improving modelling of astrophysical sources
- DGRB provides the only source of information on unresolved sources
- maximisation of the number of sources detected in gamma rays

M. Ajello et al., Astrophys. J. 800 (2015) 2 L27

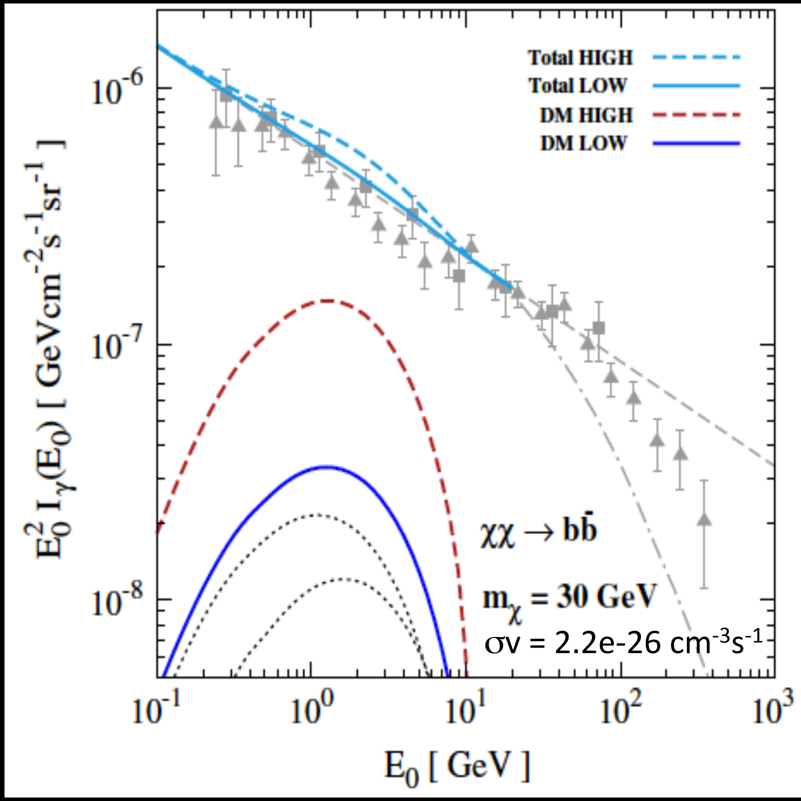


The anisotropic Diffuse Gamma-Ray Background 3/15

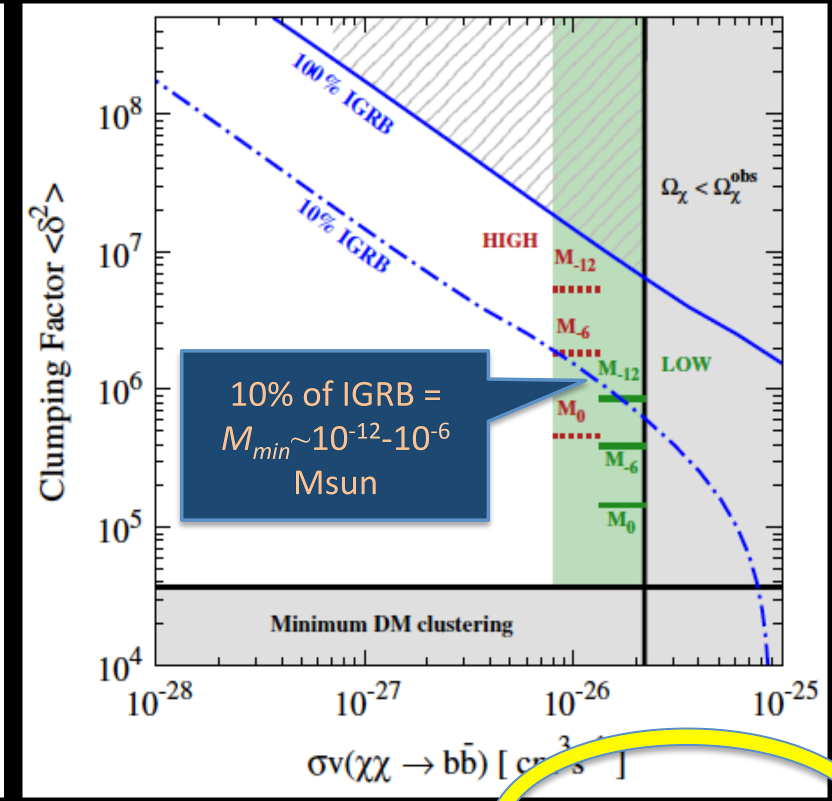
Slide from Shunsaku Horiuchi

Probing the minimum halo mass

Contribution from dark matter motivated by the Galactic Center Excess



Connection to the minimum halo mass

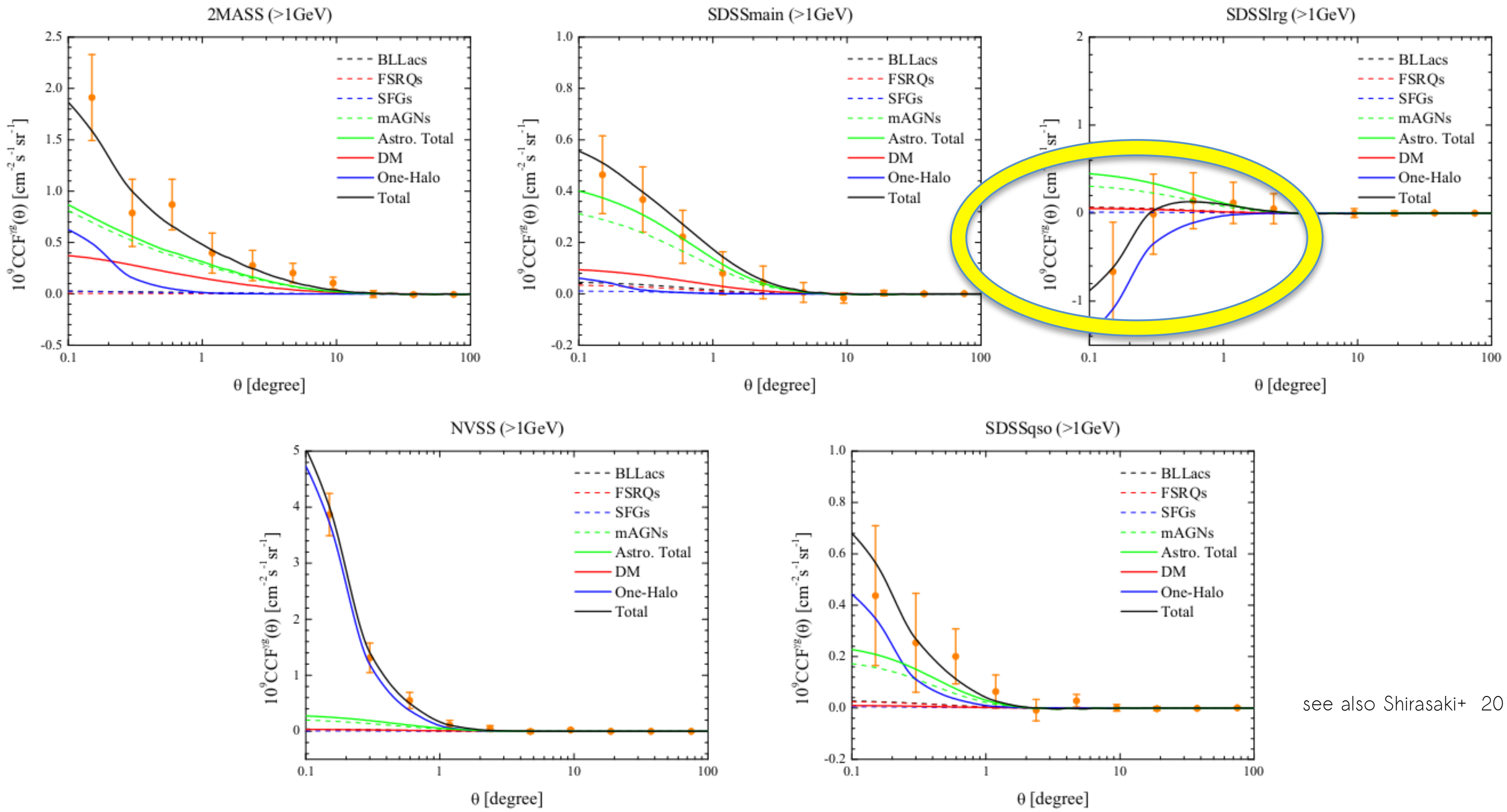


Ng et al (2014)

Slide from Marco Regis

Observations of cross correlations between Fermi-LAT maps and galaxy catalogues

Xia, Cuoco, Branchini, Viel, ApJS 2015



see also Shirasaki+ 2015

Gamma Rays and Dark Matter Workshop, Obergurgl, 08/12/2015 *Marco Regis*

Slide from H.-S. Zechlin

Results - MBPL Approach

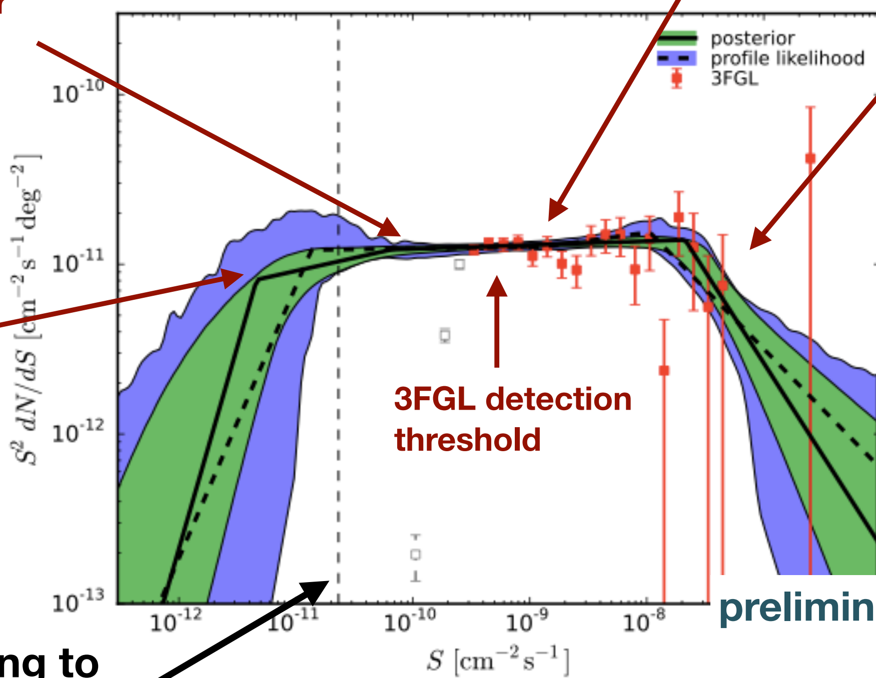
- **MBPL approach**:
  fit of a pure multiply broken PL; 3 free breaks

intermediate flux range fit with high accuracy; index $n_2 = 1.98 \pm 0.03$

fit prefers a flat behavior for unresolved sources; index $n_3 = 1.85^{+0.18}_{-0.25}$

bright-source end correctly reproduced; first break resolved fairly well

sensitivity cutoff



3FGL detection threshold

preliminary

flux corresponding to 2 photons per pixel

(a) MBPL, $N_b = 3$

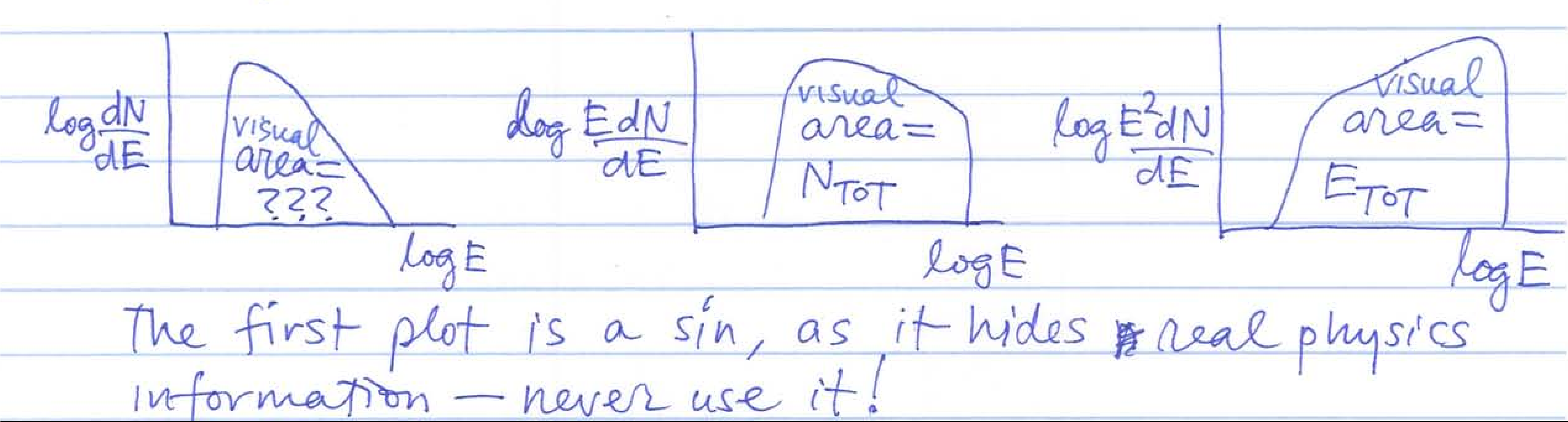
Notes

Search for new astrophysics instead of dark matter
Solve the problems of Galactic and cosmic backgrounds
Break models by checking with MeV and TeV energy data

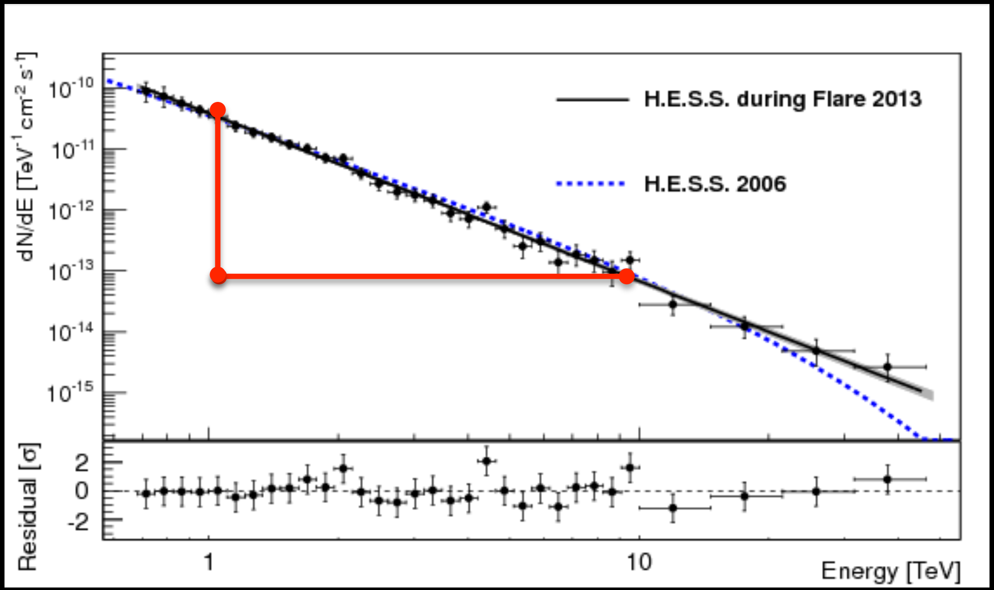
Improve correlation analyses
Solve mystery of conflicting galaxy correlations
Campbell 2015 revises uncertainty for Fermi

Find more sources
Continue exciting work on sub-threshold point sources!

Logs, Logs, Logs



See "SLAC Summer Institute 2010 Beacom" (Third Lecture)



1 Tip of Physics Success:

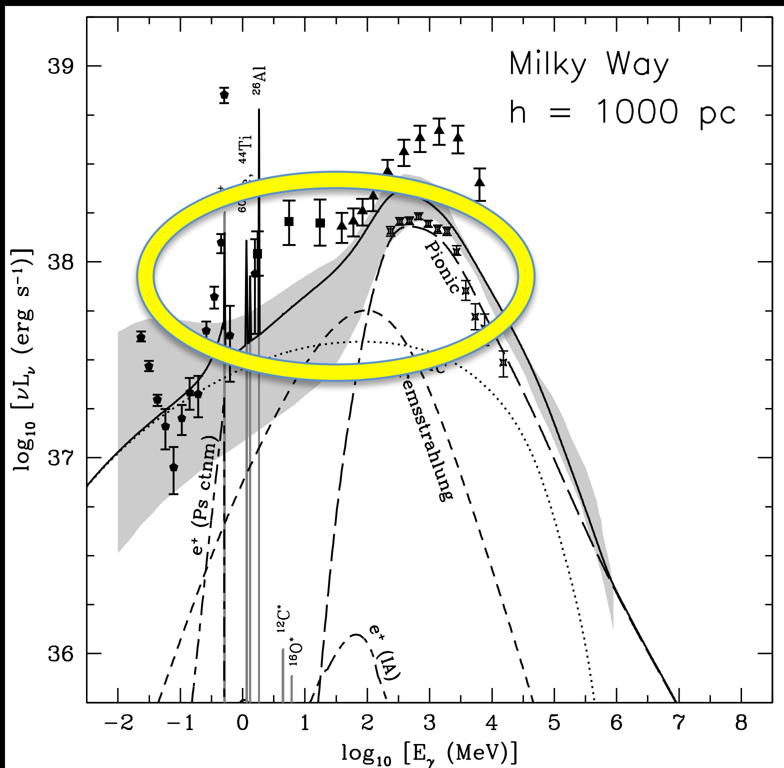
Never plot dN/dx on a log(x) scale!

Use x dN/dx or x^2 dN/dx depending on your physics point

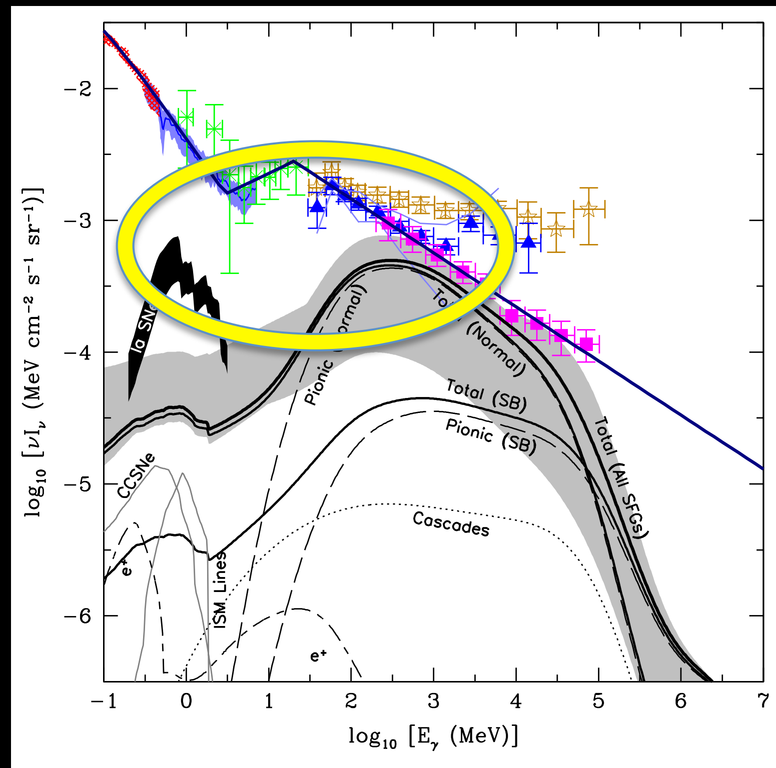
Closing Remarks

MeV Messes are Holding Back Progress

MeV Excess: Galactic



MeV Excess: Cosmic



Lacki, Horiuchi, Beacom 2014

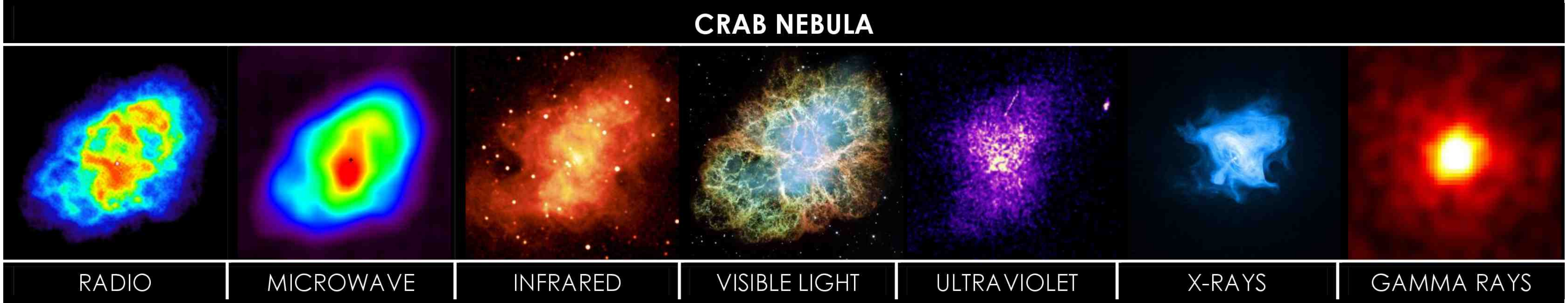
see also Strong, Moskalenko, Reimer 2004 (x2)

Also: 511 keV excess unsolved, Type Ia supernovae not understood, MeV sky never properly studied

New MeV missions are essential and urgent

First Goal: New Astrophysics

What makes astrophysical objects shine at high energies?
Use knowledge of subatomic physics … *listen to theorists*



Example successes: solar and supernova neutrinos
Example searches: GRB neutrinos; CR sources in MW

Second Goal: New Particle Physics

What are the properties of familiar and of unmet particles?
Use knowledge of astrophysics … *listen to theorists*

Example successes: DM is cold and feeble; neutrino mixing
Example searches: DM properties; LIV at high energies

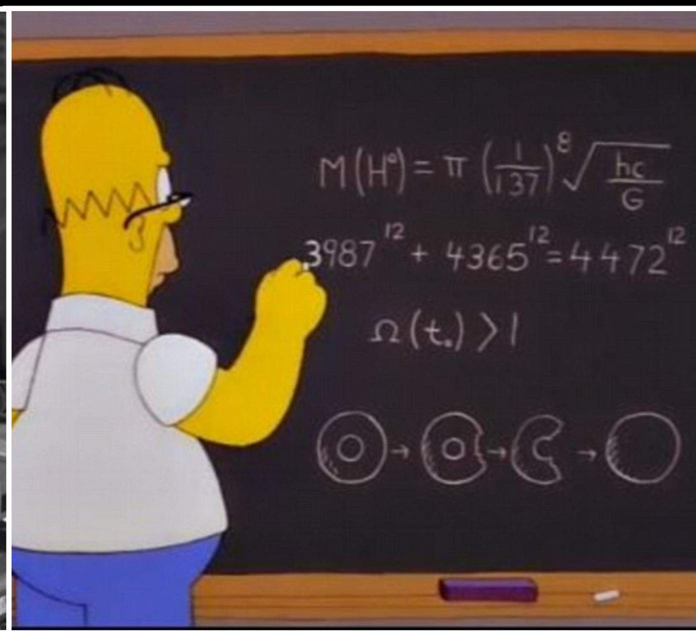
Third Goal: New Surprises

What haven't we thought of?
Develop flexible, powerful searches … *don't listen to theorists*

Example successes: discovery of DM, GRBs, CR anisotropy
Example searches: unknown unknowns!

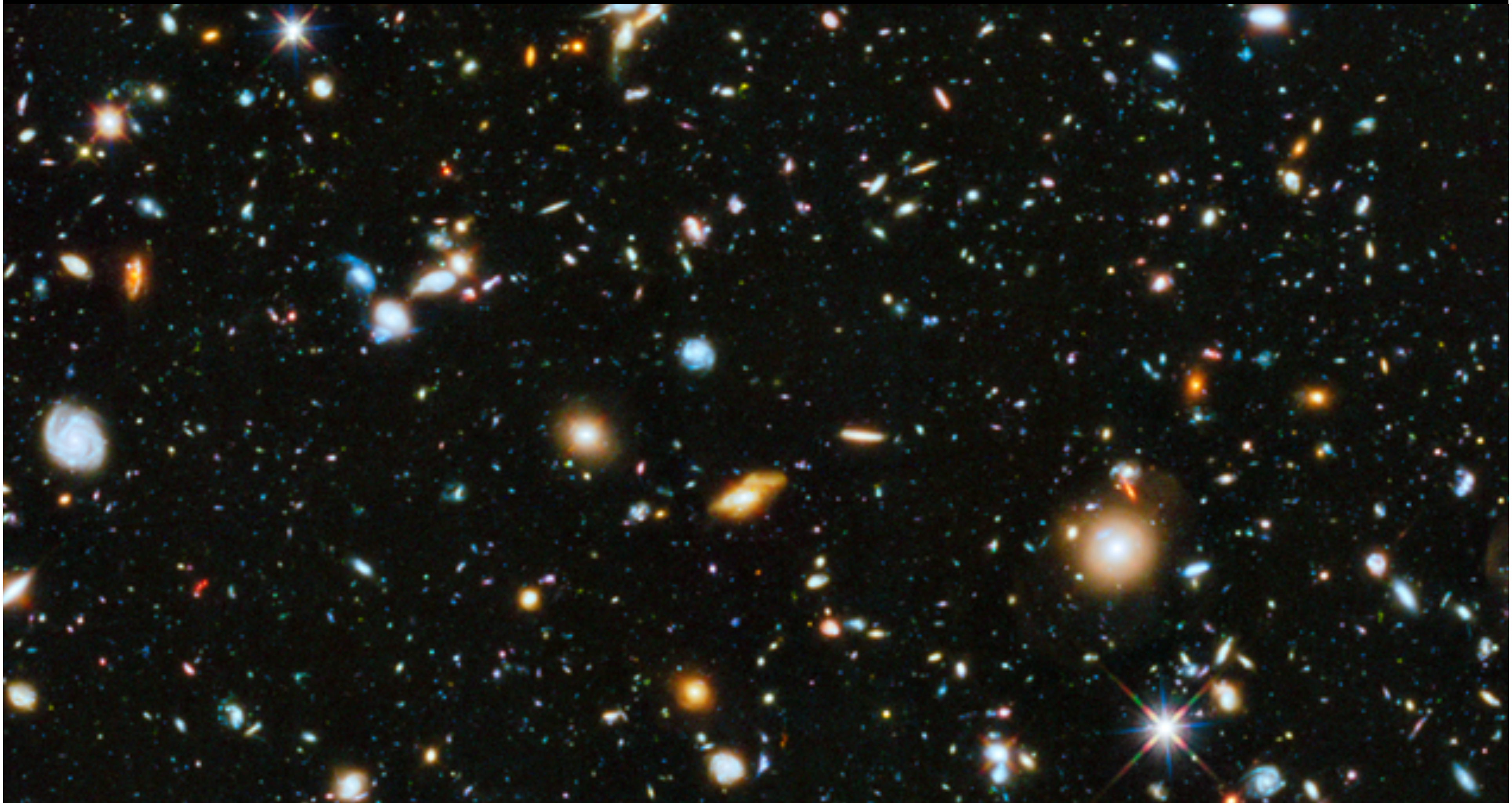
What Must We Do Different?

Experimentalists | Theorists | Community



I look forward to our cooperation in the field of mutual interest

Same Sky, Different Views



When we try to pick out anything by itself, we find it hitched to everything else in the Universe --- John Muir (1911)

Center for Cosmology and AstroParticle Physics

The Ohio State University's Center for Cosmology and AstroParticle Physics

CCAPP

Columbus, Ohio: 1 million people (city), 2 million people (city+metro)
Ohio State University: 56,000 students
Physics: 55 faculty, Astronomy: 20 faculty
CCAPP: 30 faculty, 15 postdocs from both departments
Placements: *In 2014 alone, 12 CCAPP alumni got permanent-track jobs*

ccapp.osu.edu

Recent faculty hires: Linda Carpenter, Chris Hirata, Annika Peter
Newest faculty hires: Adam Leroy, Laura Lopez
Recent PD hires: M. Bustamante, A. Nierenberg, A. Ross, A. Zolotov
Newest PD hires: K. Auchettl, J. Hanson, T. Linden

CCAPP Postdoctoral Fellowship applications welcomed each Fall