Title: Behind the Scenes of the Universe: From the Higgs to Dark Matter

Date: May 07, 2014 07:00 PM

URL: http://pirsa.org/14050022

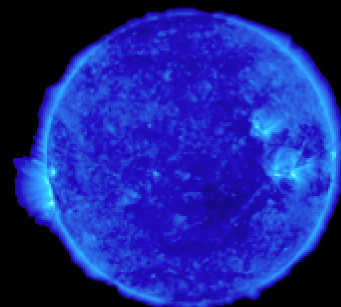
Abstract:

Behind the Scenes of the Universe

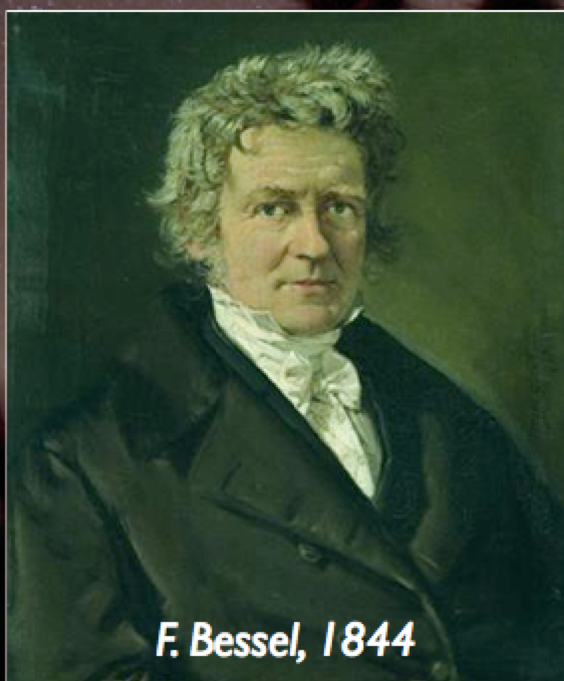
From the Higgs to Dark Matter

Gianfranco Bertone
gianfrancobertone.net

The Cosmic Show



*"The extraordinary show offered by the Cosmos — the dance of planets around stars, the delicate appearance of distant nebulae, the violent clash of giant galaxies, and ultimately the very mystery of our own existence — takes place on a colossal stage made of ever-growing halos of invisible, **dark**, matter"*



2. *Relative Right Ascension of Sirius.*

		s	
Fundamenta Astron.	1755	0·000	
Maskelyne	1767	−0·079	Derived from a new reduction of the observations; this result differs by −0·288 from that contained in the Catalogue for 1770; the reason of which I do not know.
Piazzi	1800	+0·033	
Maskelyne	1806	+0·016	Derived from a new computation of the observations of 1803, and agreeing nearly with the Catalogue for 1805.
Bessel	1815	−0·036	
Pond	1819	−0·083	Derived from a new computation of the observations, but agreeing with Mr. Pond's own result.
Bessel	1825	0·000	
Struve	1825	−0·006	
Argelander	1828	−0·003	
Airy	1830	+0·049	This is the mean of seven results derived from the observations from 1829 to 1835; it is, for reasons mentioned above, preferred to the result derived from the Catalogue of 1112 Stars.
Pond	1832	+0·084	
Konigsberg Obs. ...	1835	+0·188	
Ditto, with both instruments ...	1843	+0·321	

Read the original article at http://articles.adsabs.harvard.edu/

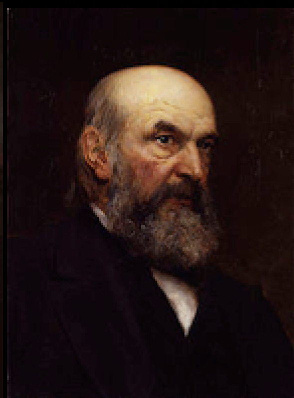

F. Bessel, 1844
“If we were to regard Procyon and Sirius as double stars, their change of motion would not surprise us.”
Read the original article at http://articles.adsabs.harvard.edu/


F. Bessel, 1844
“Light is no real property of mass. The existence of numberless visible stars can prove nothing against the evidence of numberless invisible ones.”
Read the original article at http://articles.adsabs.harvard.edu/


Sirius A and B as seen by the
Hubble Space Telescope
A small companion star, Sirius B, was
discovered in 1862. We now know that it is a
White Dwarf
Read the original article at http://articles.adsabs.harvard.edu/

The discovery of Neptune

U. Le Verrier

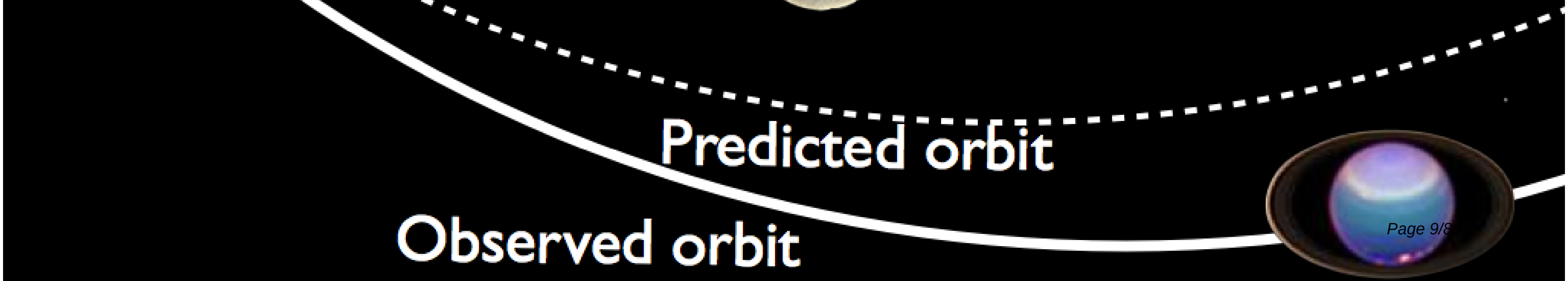


J. C. Adams

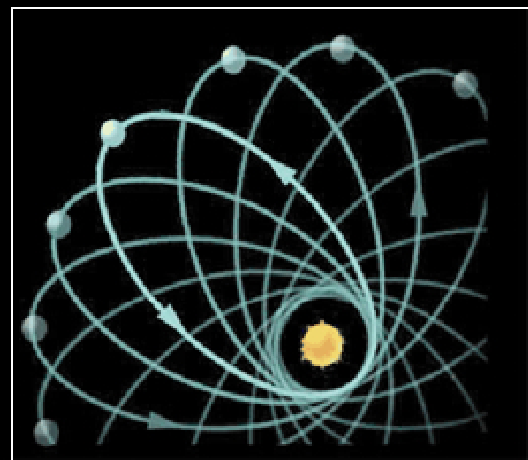
1846: Astronomers show that Uranus' anomalous orbit could be explained by a new planet, which will soon be discovered and baptised ***Neptune***

F. Arago

"M. le Verrier <u>saw the new planet at the tip of his pen</u>, without any other instrument than the strength of his calculations"

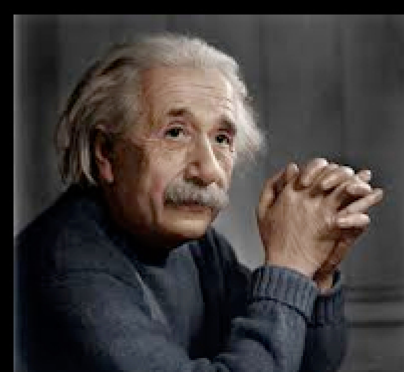


The case of Mercury



1859: suggested that the motion of Mercury could be explained by a new planet: Vulcan

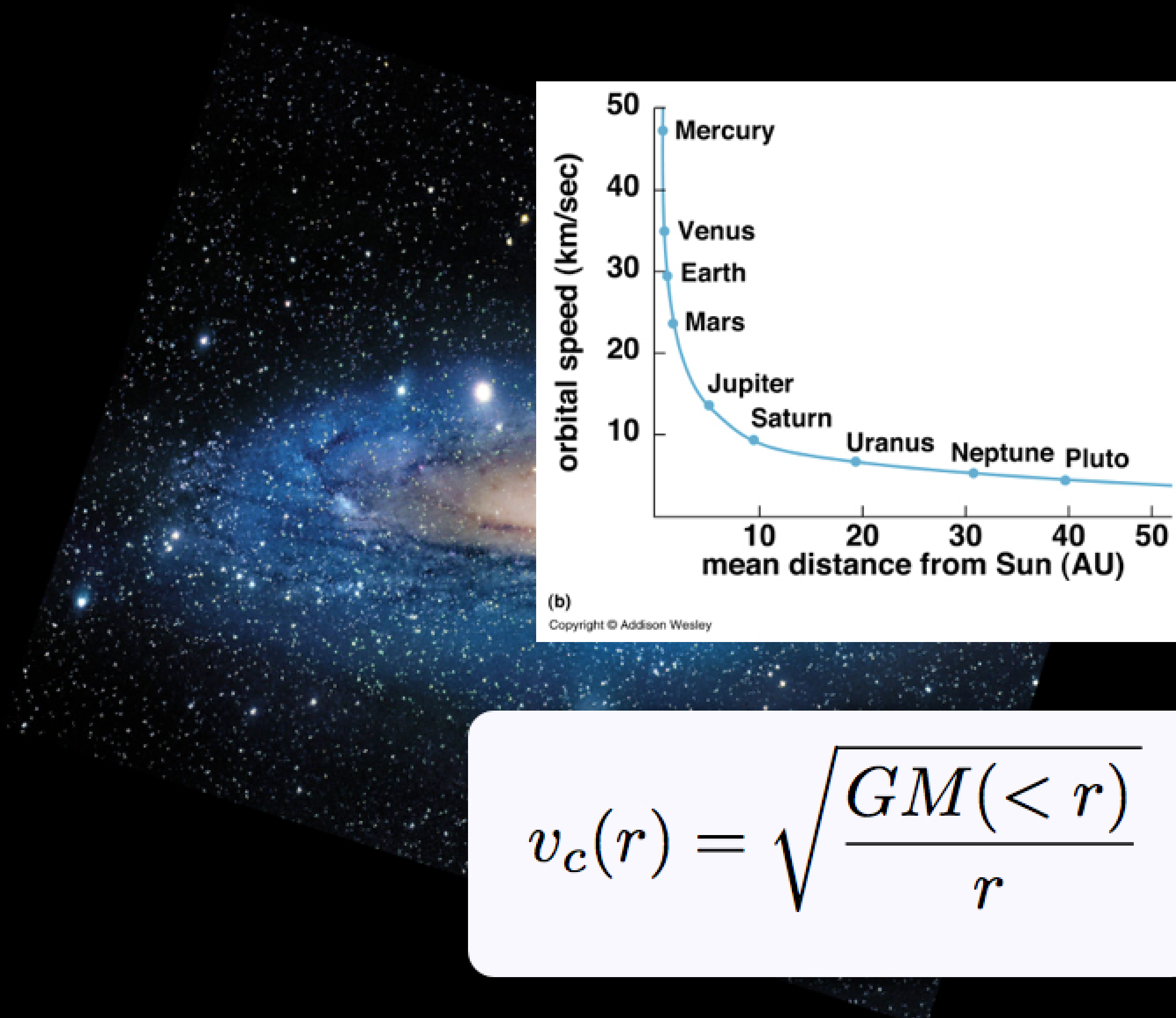
U. Le Verrier



Vulcan was never discovered. The orbit of Mercury was finally explained by Einstein's theory of General Relativity

U. Le Verrier

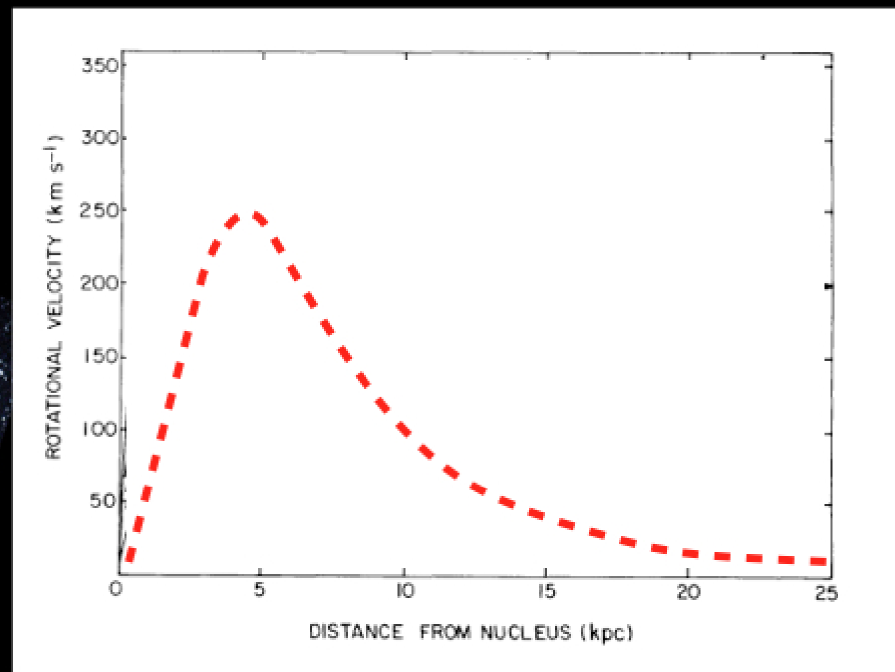
1970s: Rotation Curves



$$v_c(r) = \sqrt{\frac{GM(< r)}{r}}$$

1970s: Rotation Curves

Roberts, Bosma, Rubin, et al.



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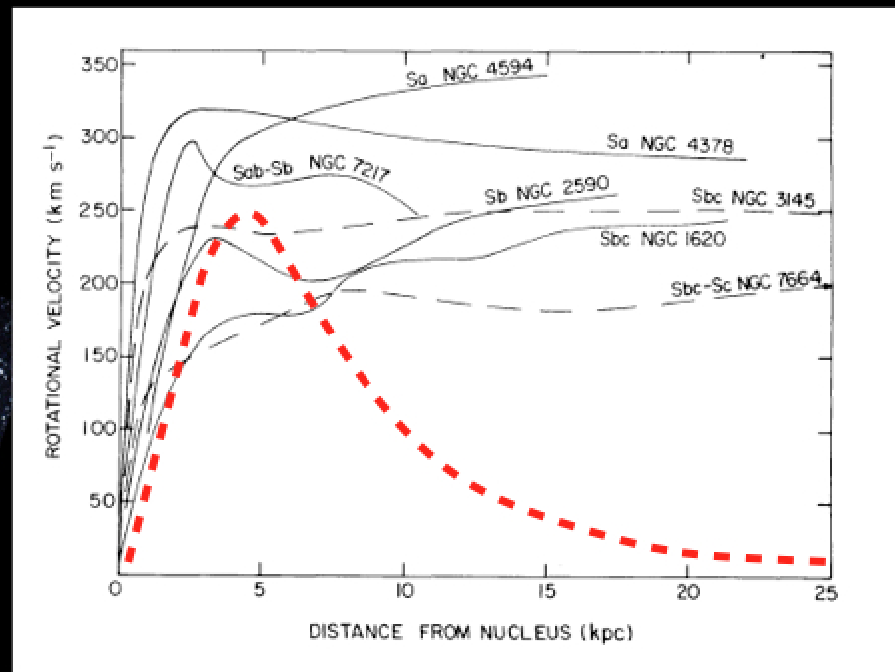
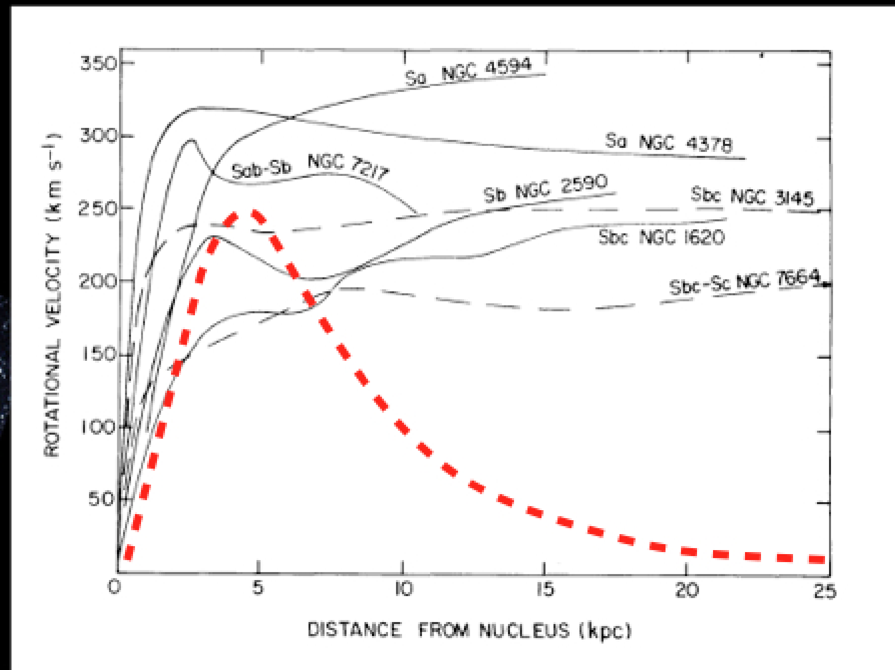


$$v_c(r) = \sqrt{\frac{GM(<r)}{r}}$$

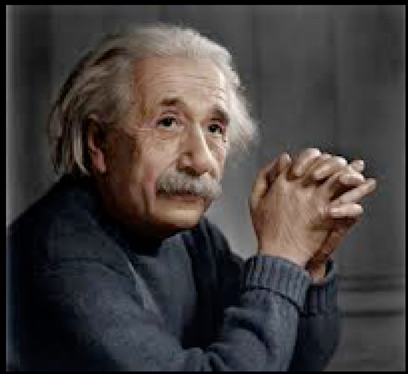
Dark Matter or Modified Gravity?

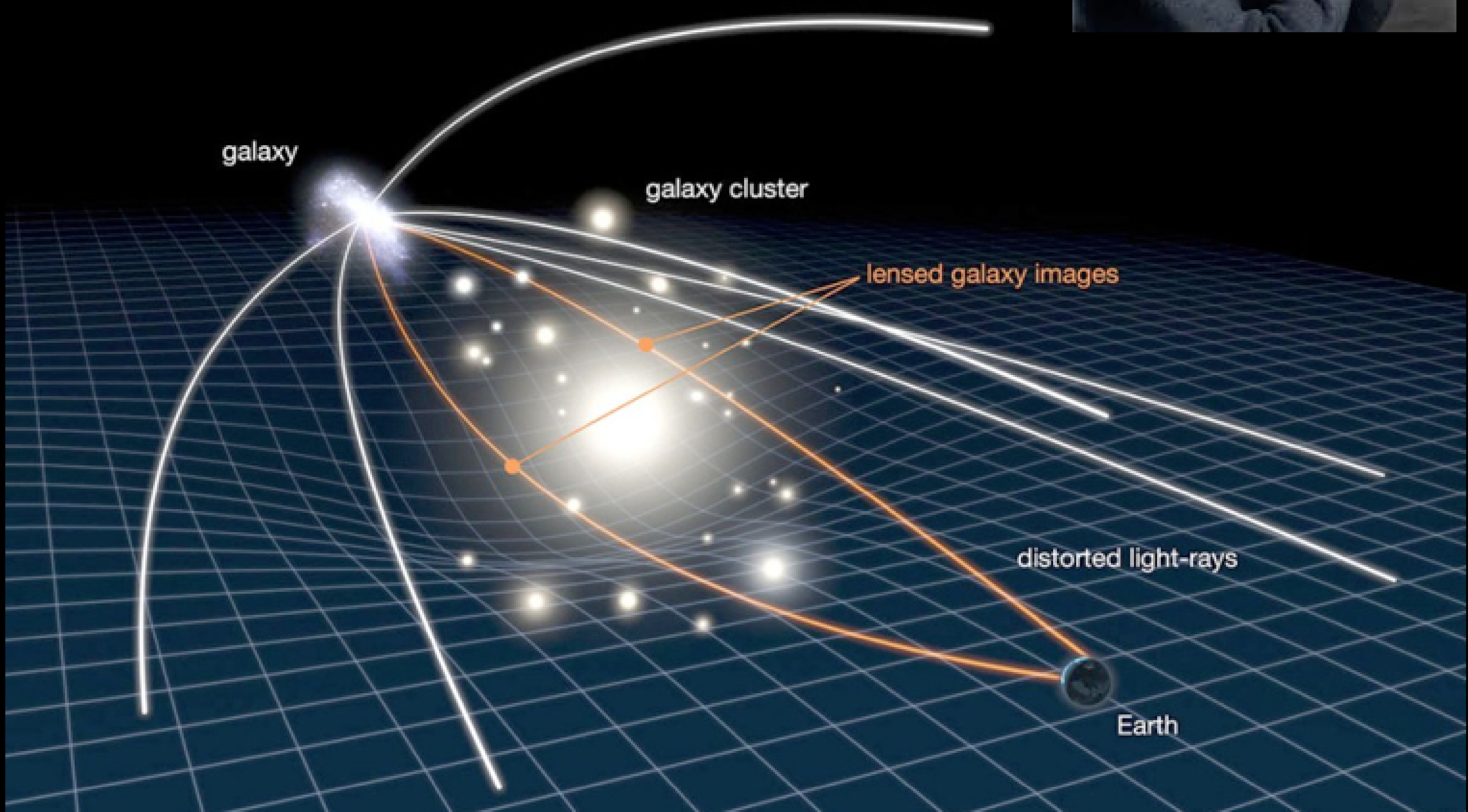


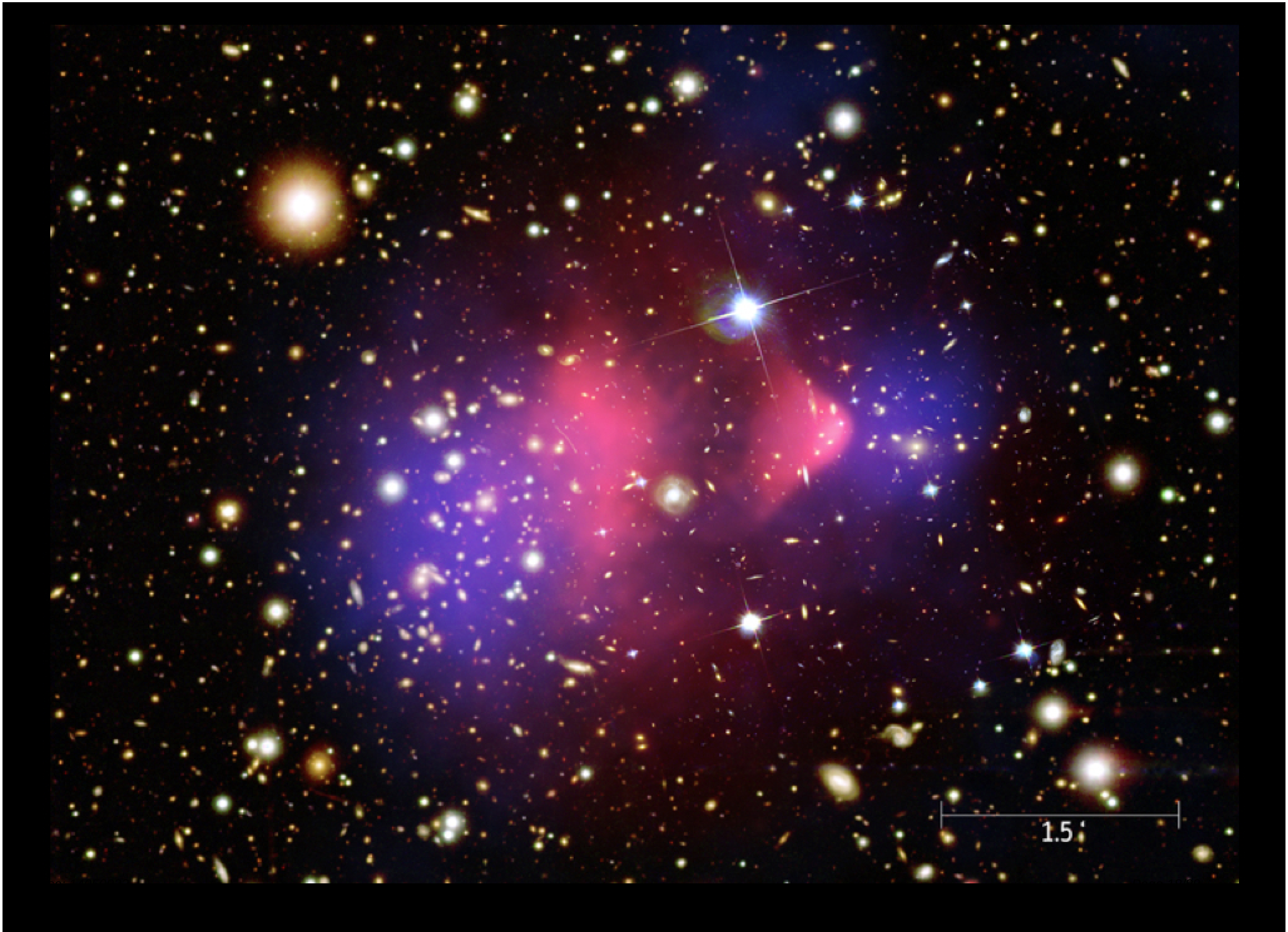
$$v_c(r) = \sqrt{\frac{GM(<r)}{r}}$$

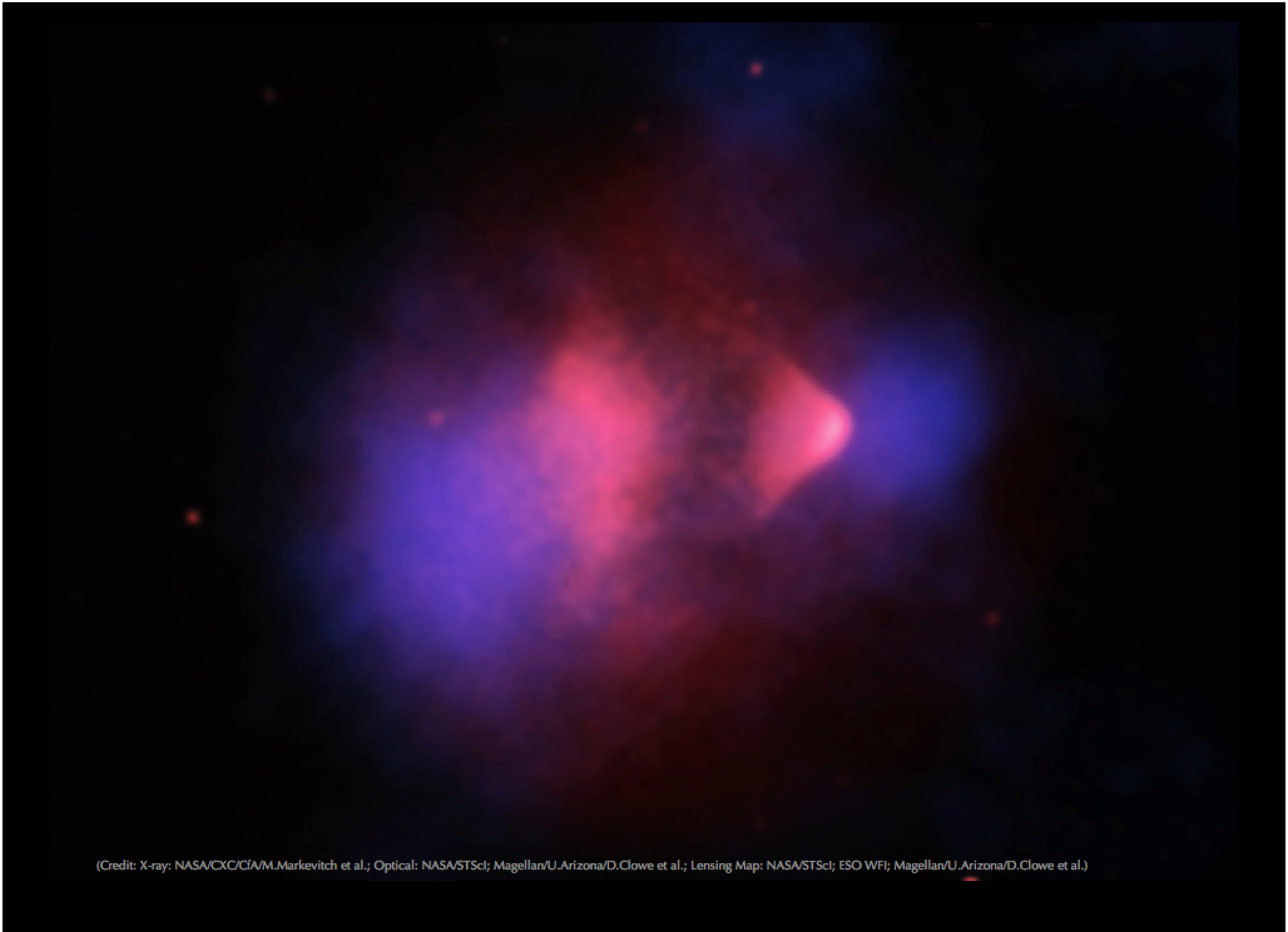
Gravitational Lensing

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$






1.5 '



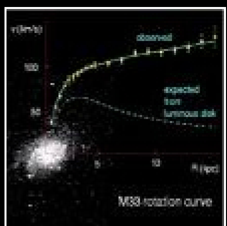
(Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.)


Dark matter
≠
ordinary matter
(Credit: X-ray: NASA/CXC/CfA/M.Markevitch et al.; Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.; Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.)

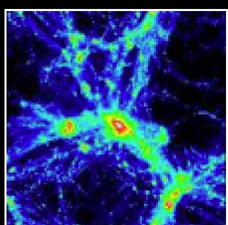
Evidence for Dark Matter

Evidence for the existence of an unseen, "*dark*", component in the energy density of the Universe comes from several independent observations at different length scales

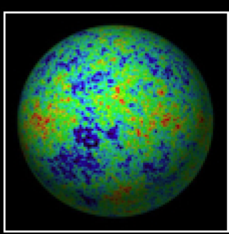
COSMOLOGICAL OBSERVATIONS



- Rotation Curves



- Clusters of galaxies



- CMB

- Type Ia Supernovae

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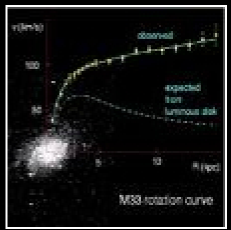
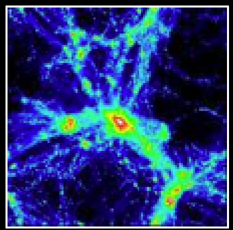
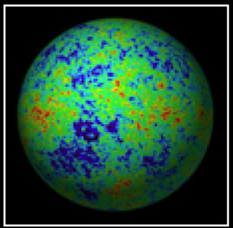


• Rotation Curves

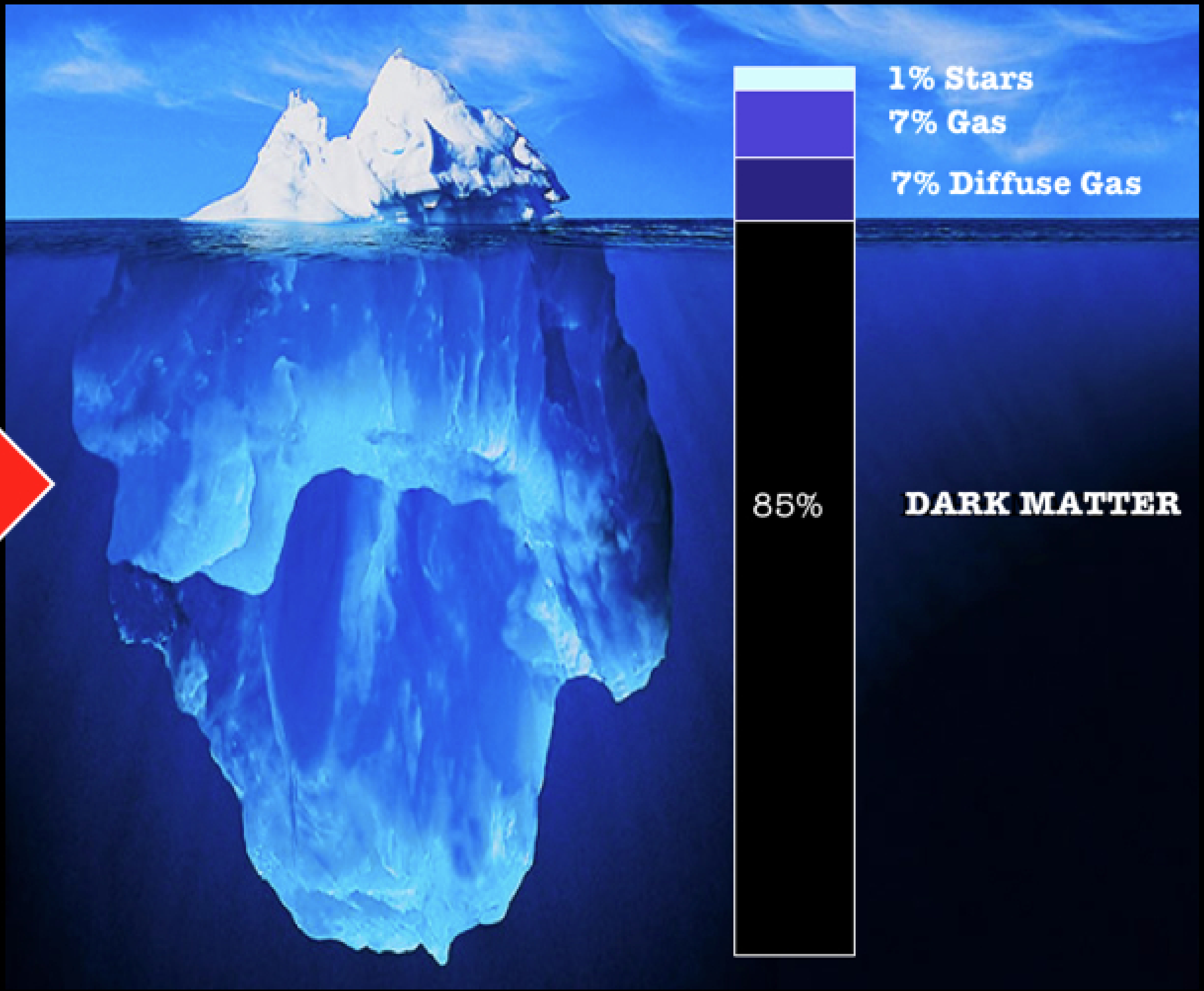


• Clusters of galaxies



•CMB

•Type Ia Supernovae



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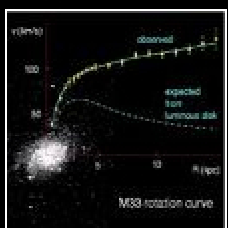
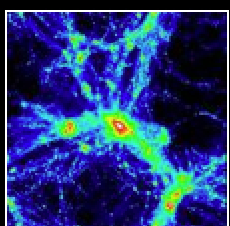
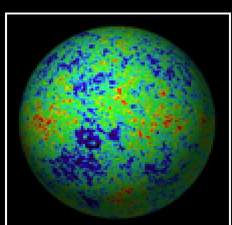
COSMOLOGICAL OBSERVATIONS



- Rotation Curves

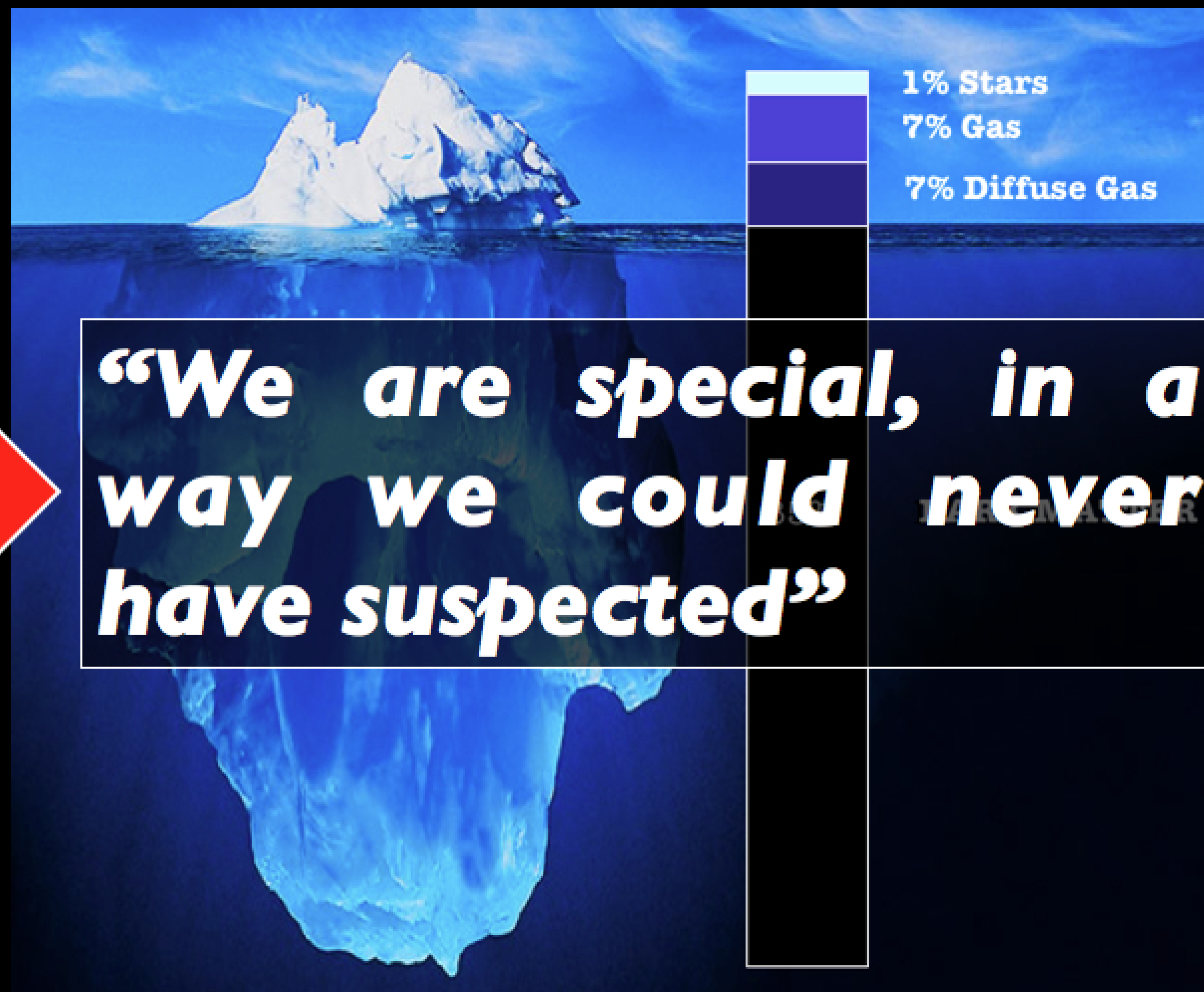


- Clusters of galaxies

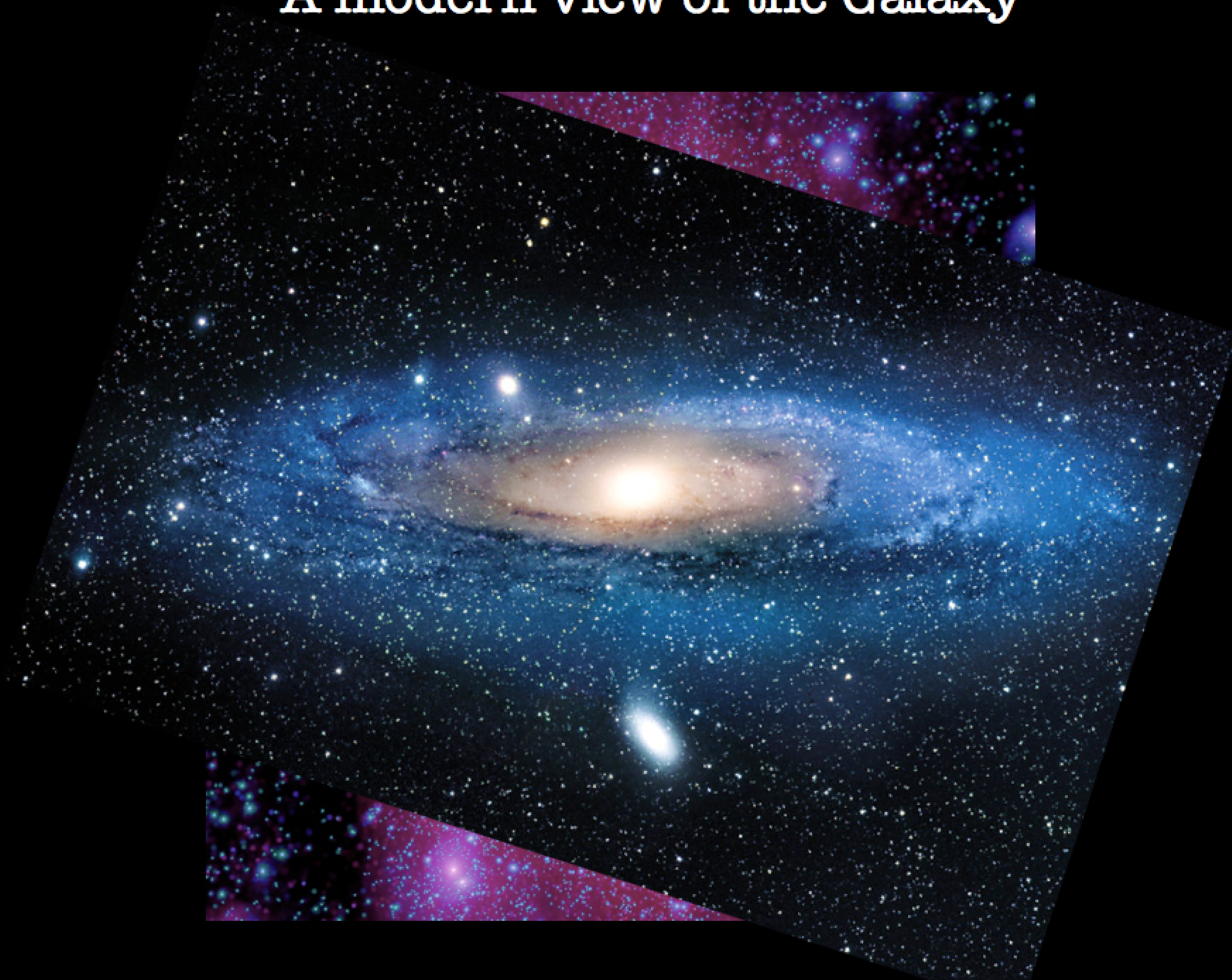


- CMB

- Type Ia Supernovae



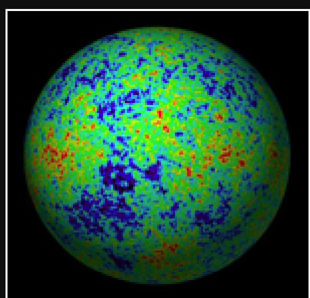
A modern view of the Galaxy



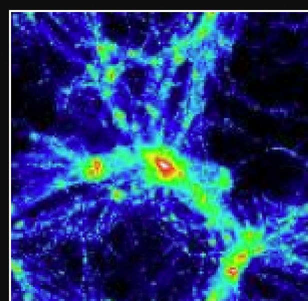
What do we know?

An extraordinarily rich zoo of non-baryonic Dark Matter candidates! In order to be considered a viable DM candidate, a new particle has to pass the following 10-point test

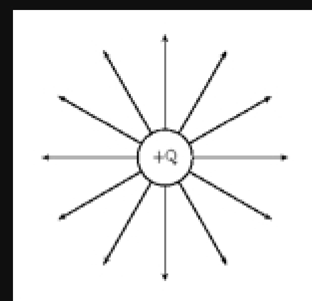
1) Abundance ok?



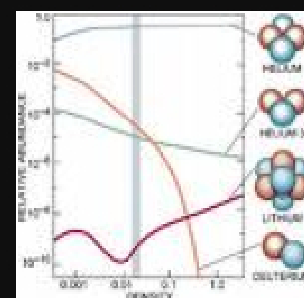
2) Cold?



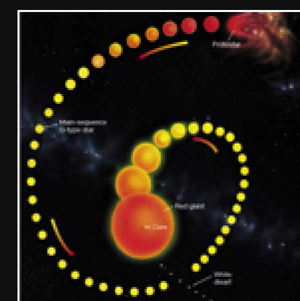
3) Neutral?



4) BBN ok?

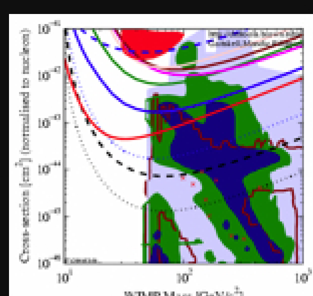


5) Stars OK?

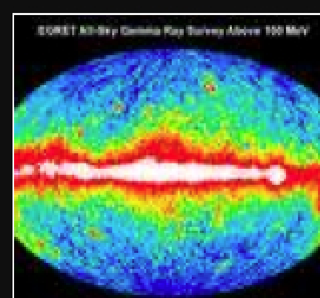


6) Collisionless?

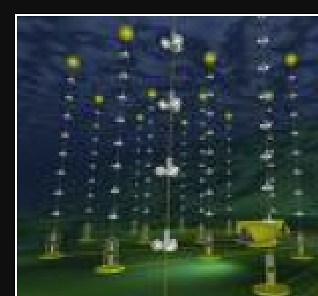
7) Couplings OK?



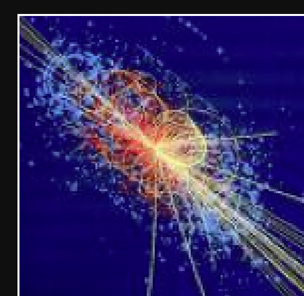
8) γ-rays OK?



9) Astro bounds?



10) Can probe it?



Dark Matter candidates

Dark Matter candidates

- Neutralino?

Like ancient geographers..

14050022

Psalter map, drawn in 1260, conserved at the British Library in London

So geographers, in Afric maps,
With savage pictures fill their gaps,
And o'er unhabitable downs
Place elephants for want of towns.

Jonathan Swift (1667 - 1745)

Monsters?

Harley MS 3244, ca. 1250. British Library

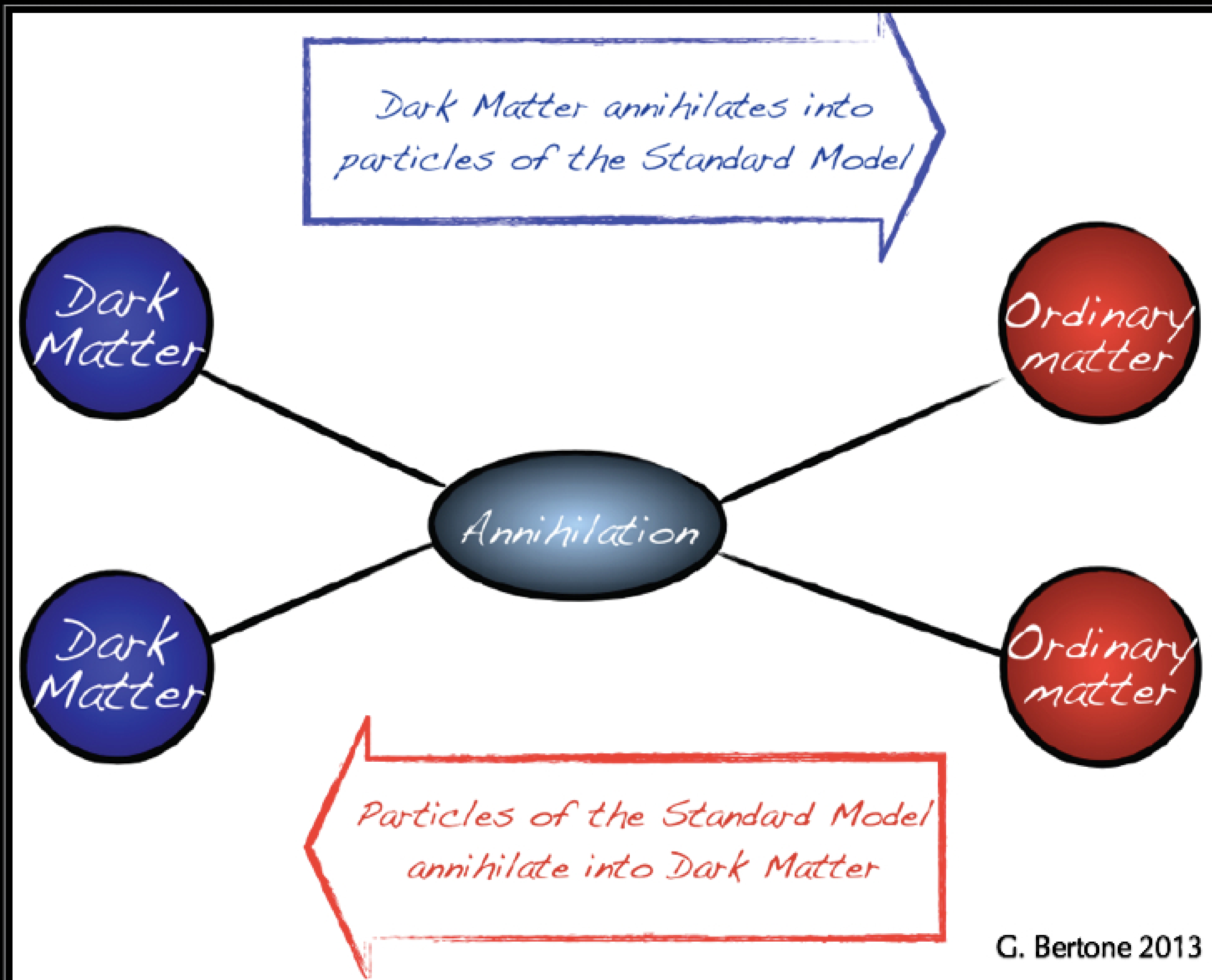
Monsters?

Just like some of these monstruous creatures turned out to be (somewhat distorted perceptions of) real animals

we hope that one - or perhaps more! - than the particles proposed will actually exist and constitute the dark matter in the Universe.

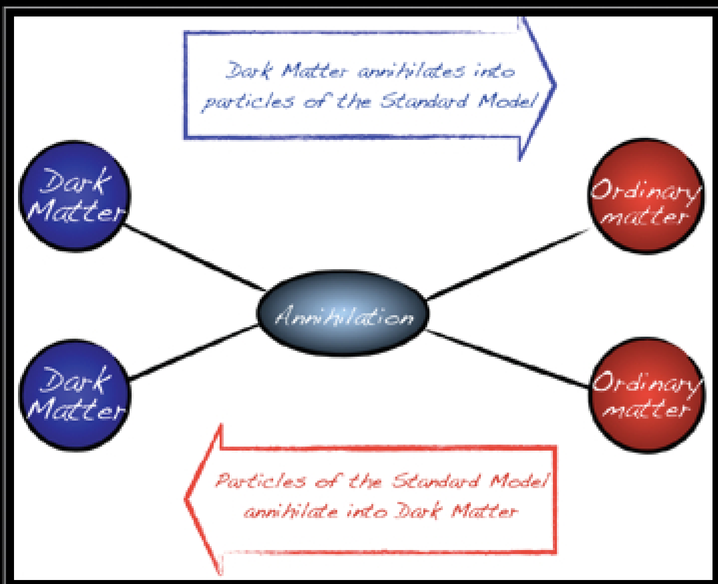
WIMPs

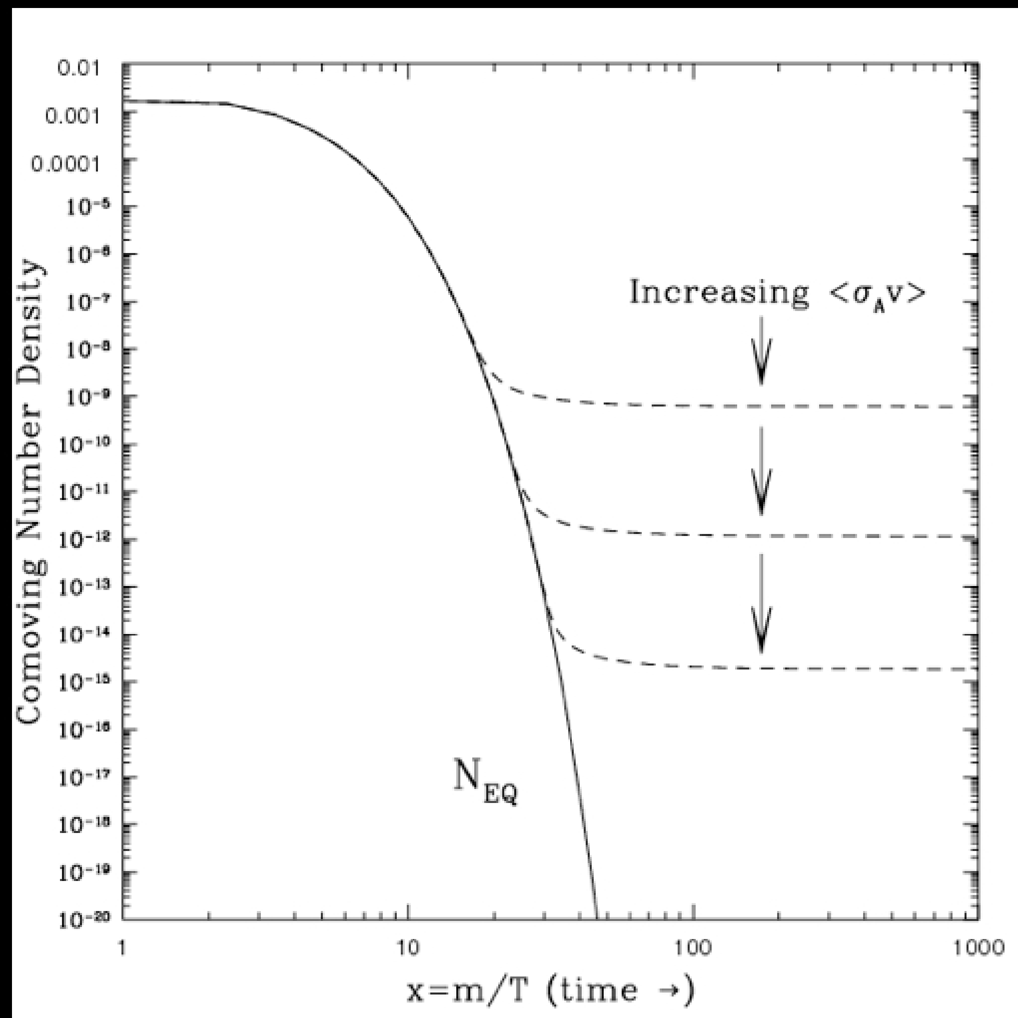
Weakly Interacting Massive Particles



WIMPs

Weakly Interacting Massive Particles



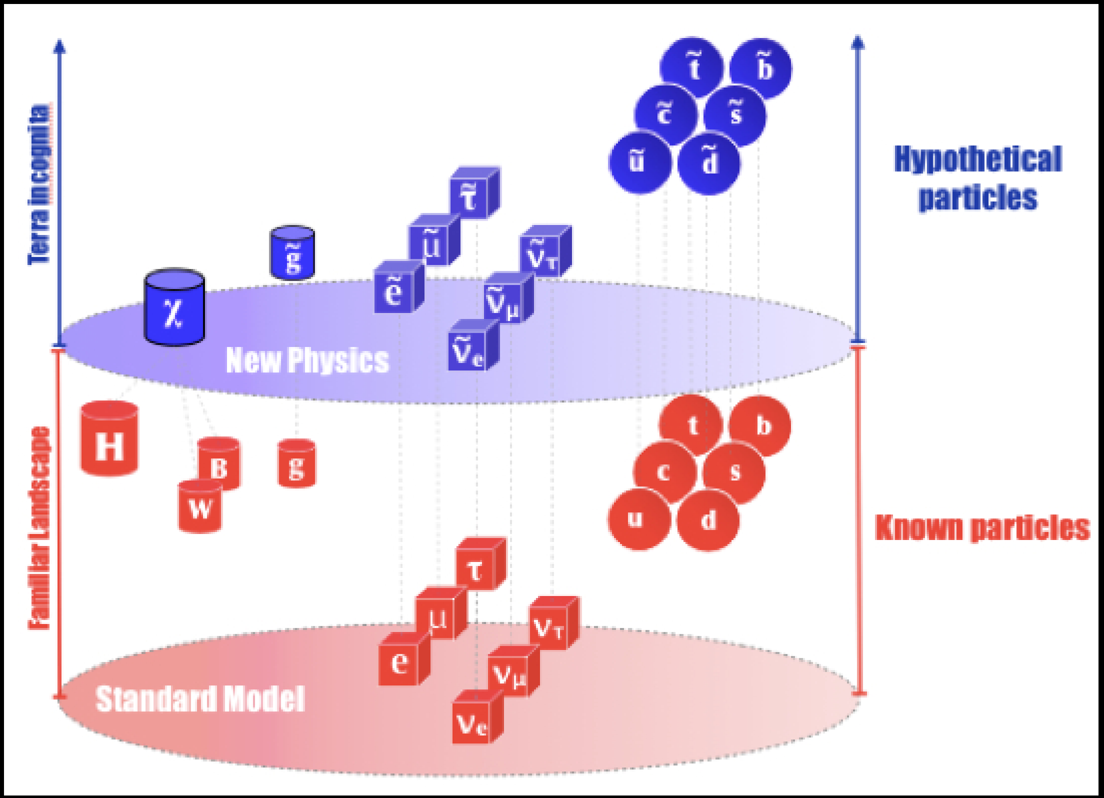


Particles with "weak-scale" interactions would naturally be produced in the 'right' amount

WIMPs

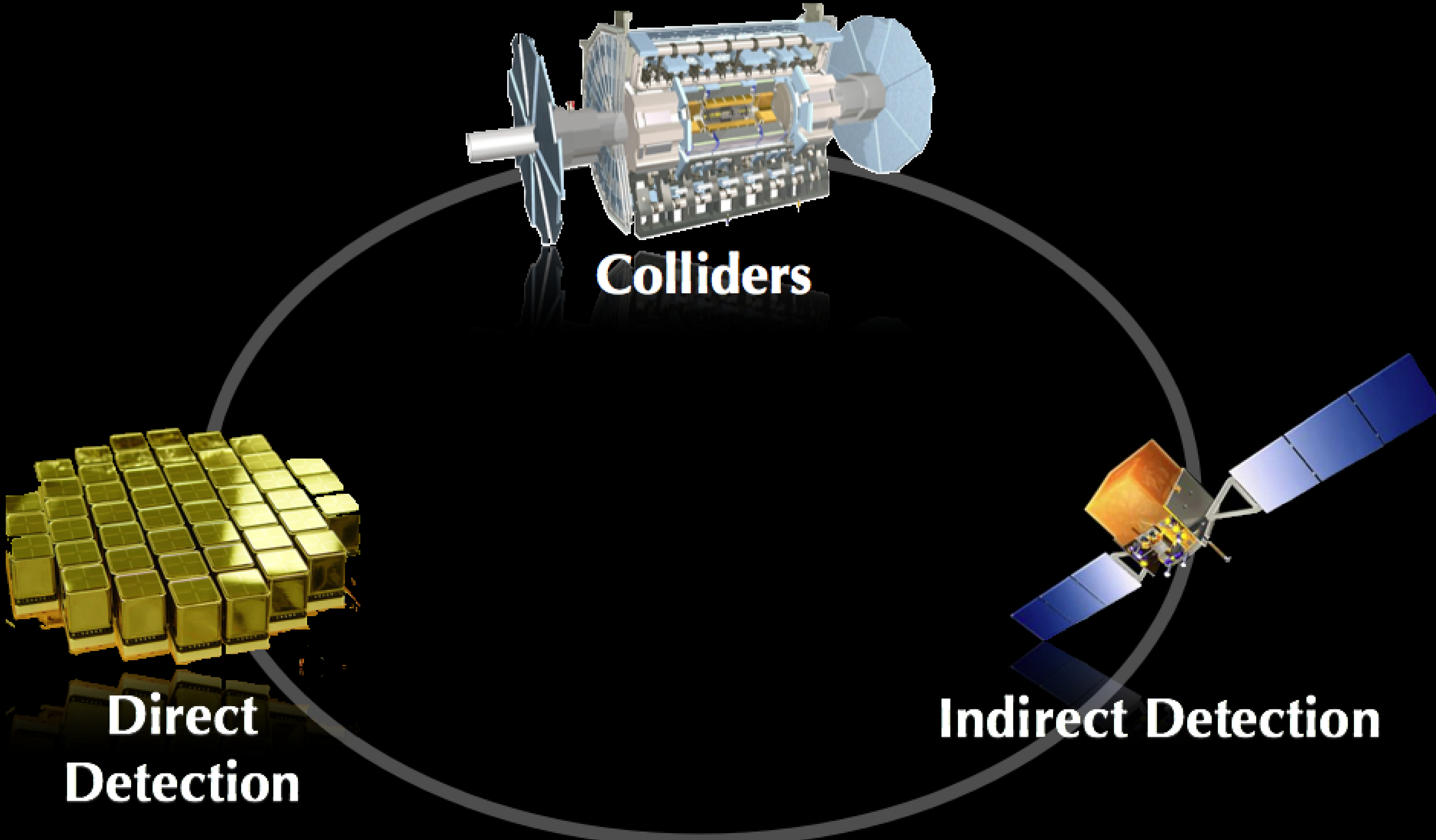
Weakly Interacting Massive Particles

That's interesting! Because particle physicists proposed new particles with <u>exactly these properties</u> to solve problems of the Standard Model of Particle Physics!

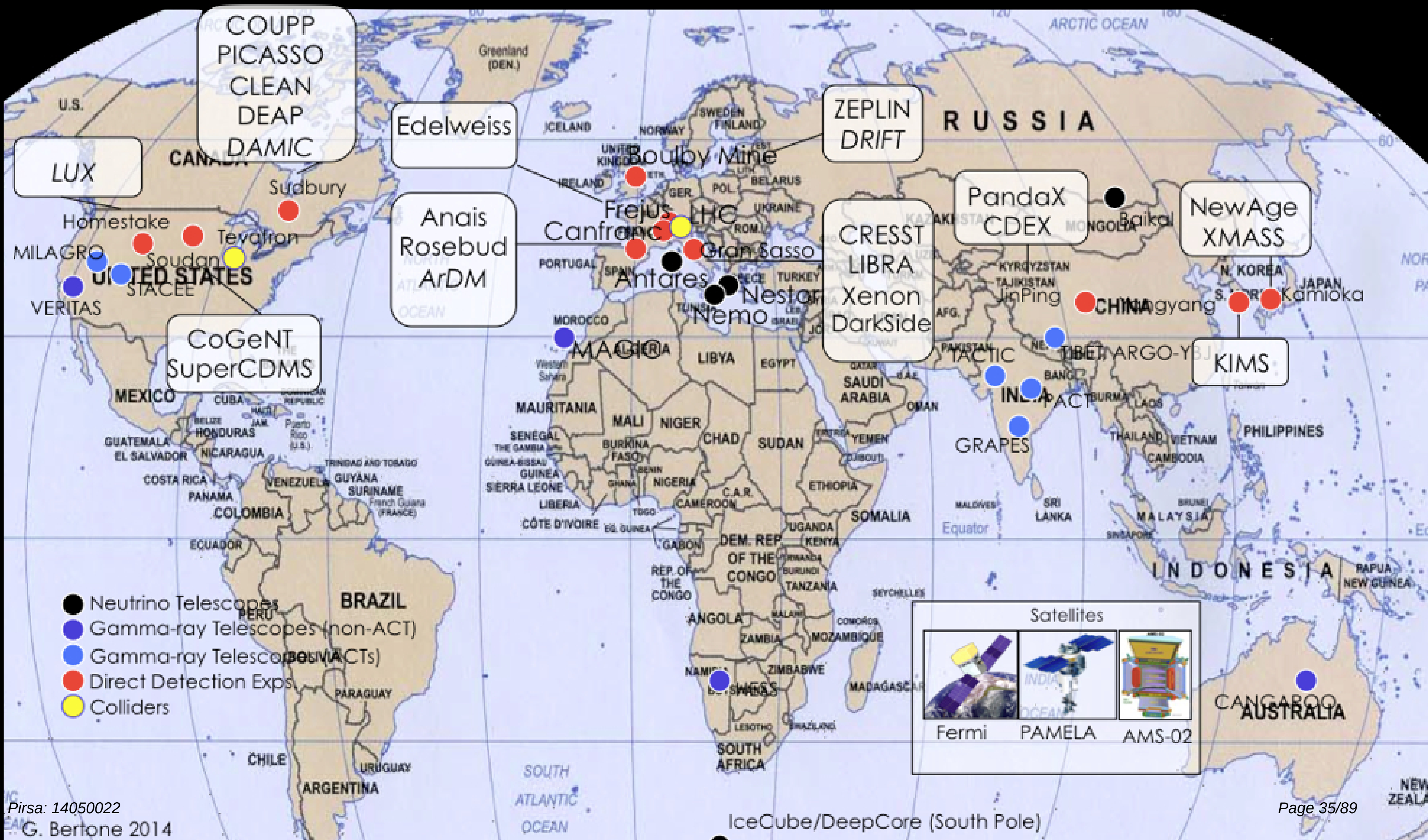


Discovering WIMPs may therefore provide a solution to the Dark Matter problem and lead to a more fundamental understanding of Elementary Particles

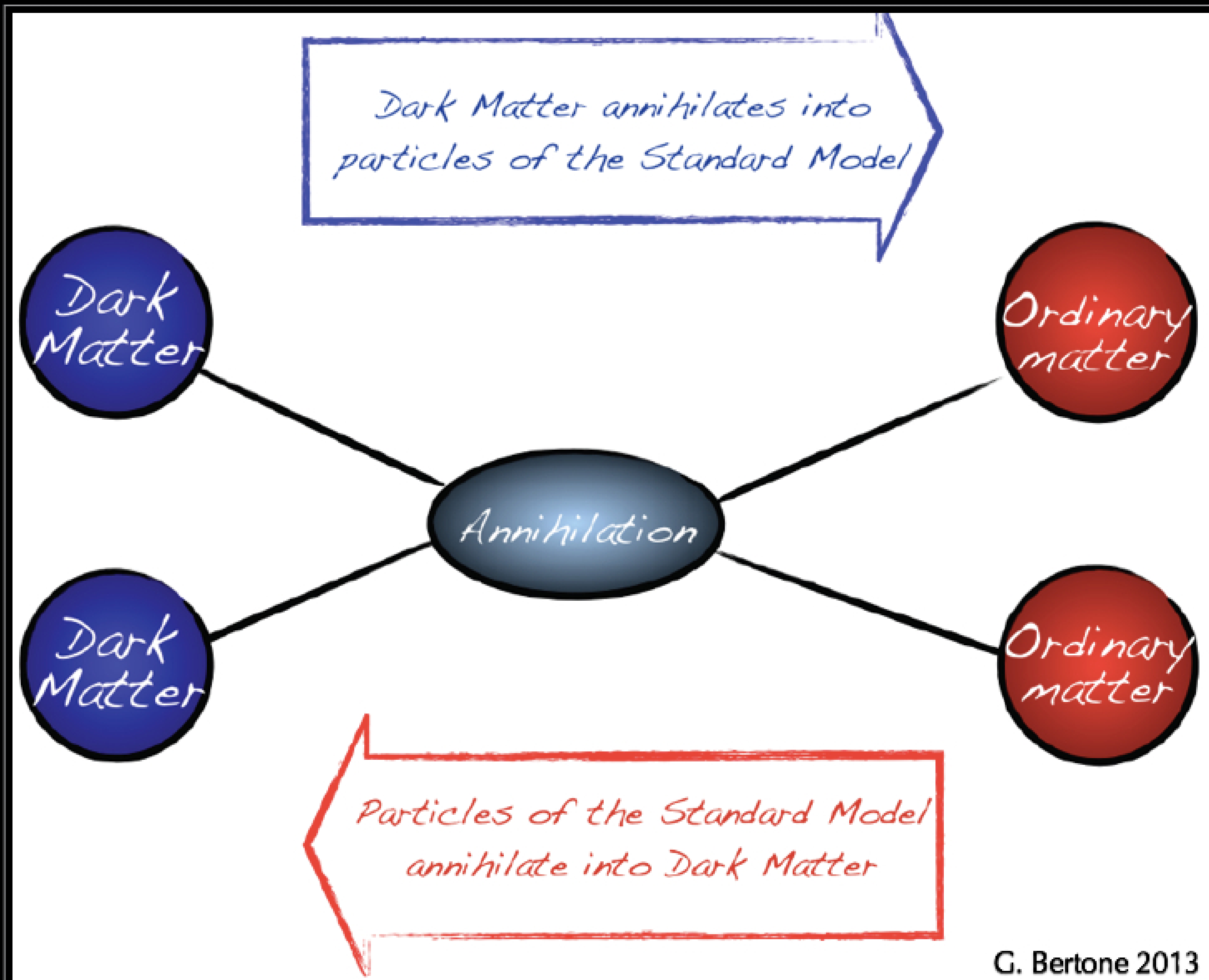
WIMPs searches



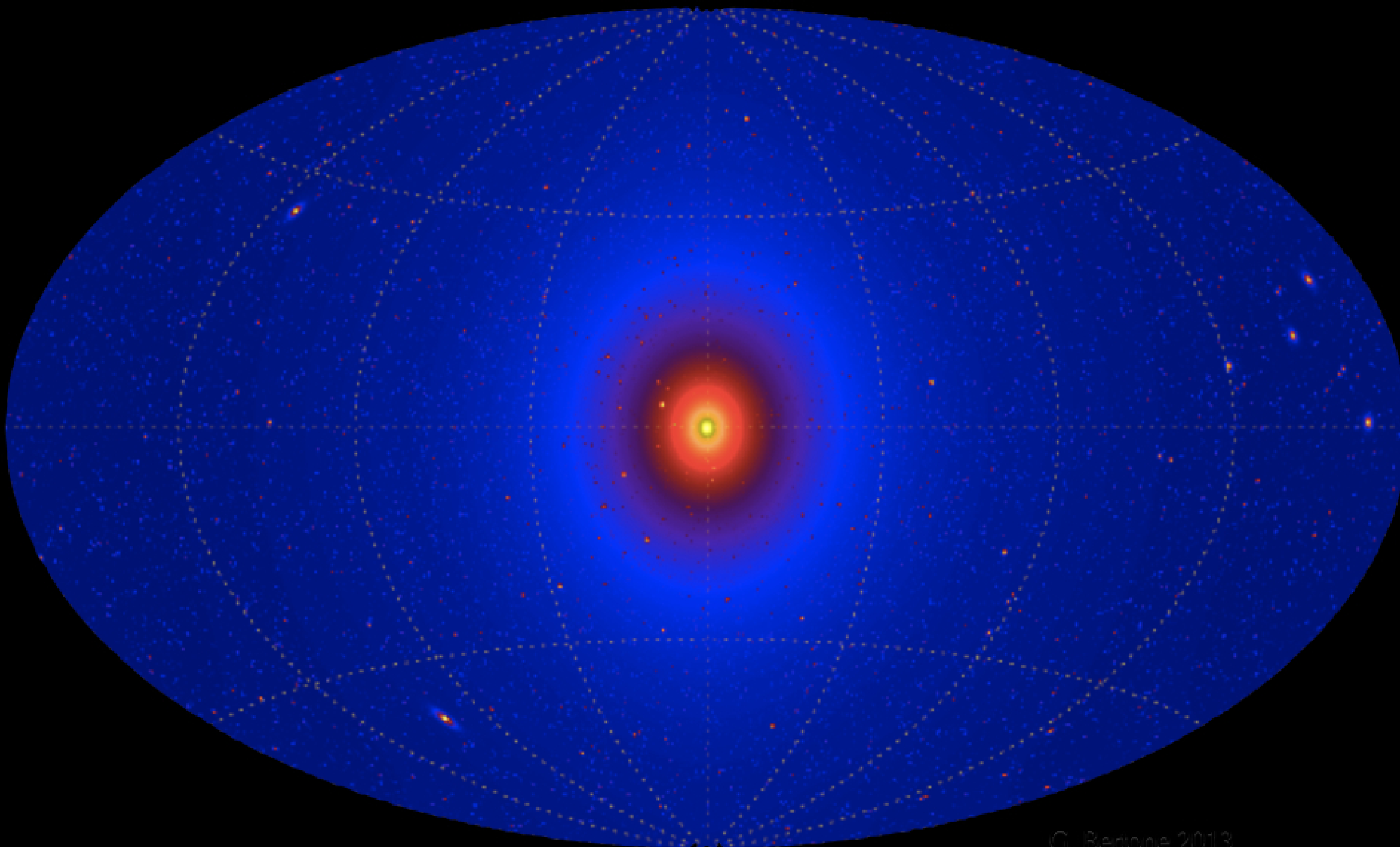
The worldwide race



Indirect Detection



Predicted gamma-ray signal

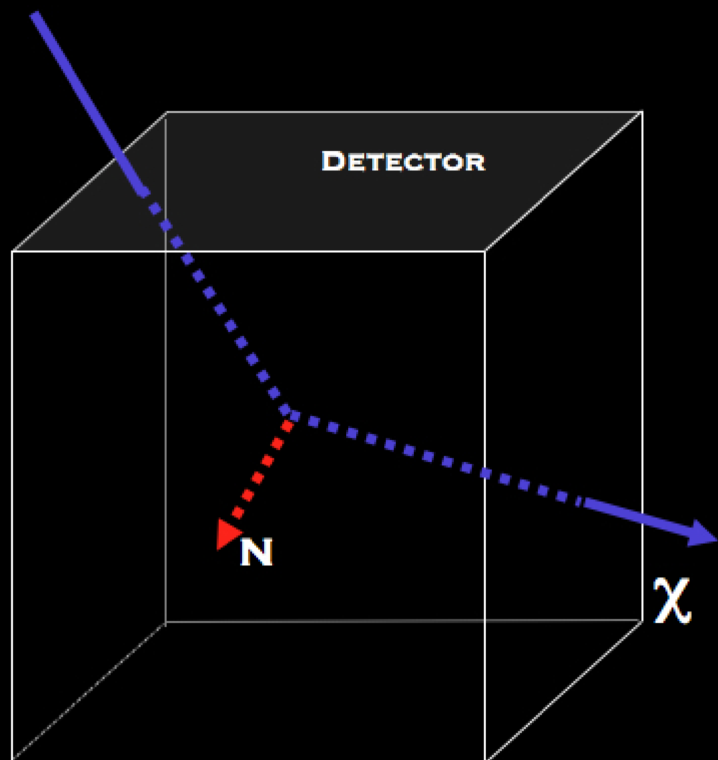


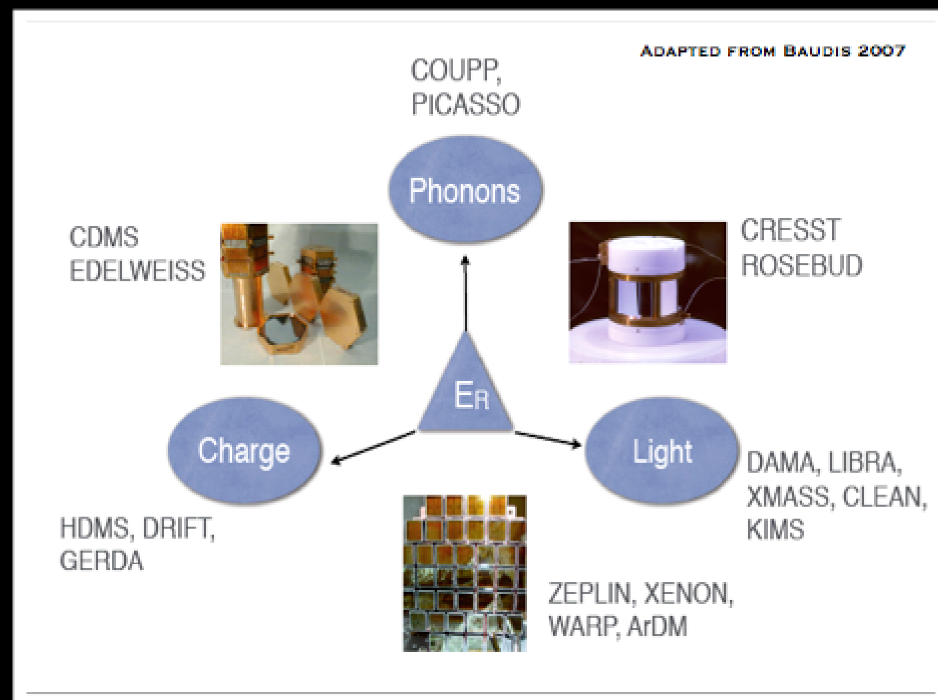
Press release last month

http://www.nasa.gov/content/goddard/fermi-data-tantalize-with-new-clues-to-dark-matter

Direct Detection

Principle and Detection Techniques





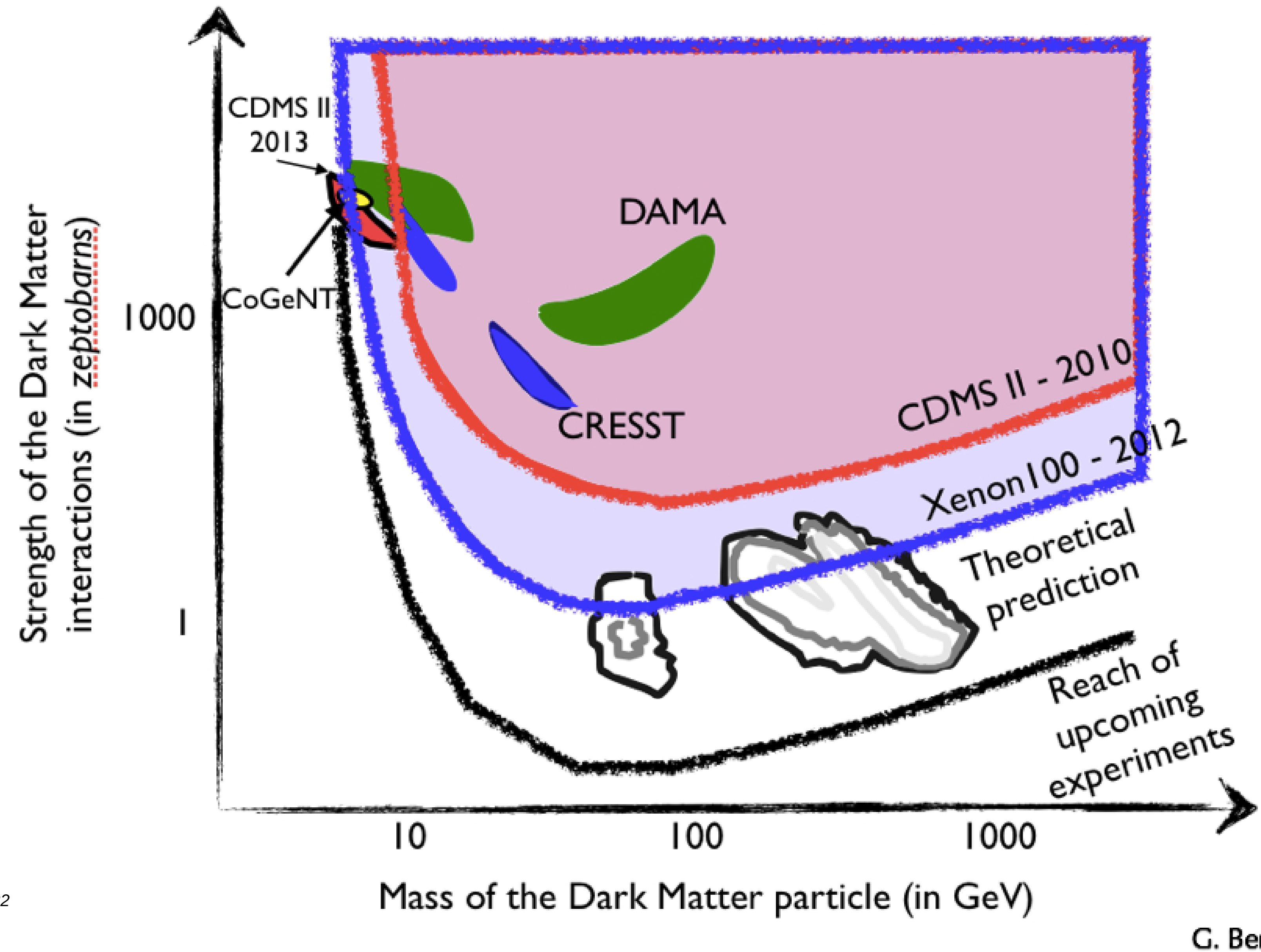
DM collides with nuclei in the detector

Recoil energy of nuclei detected via ionization (charge), scintillation (light) and heat (phonons)

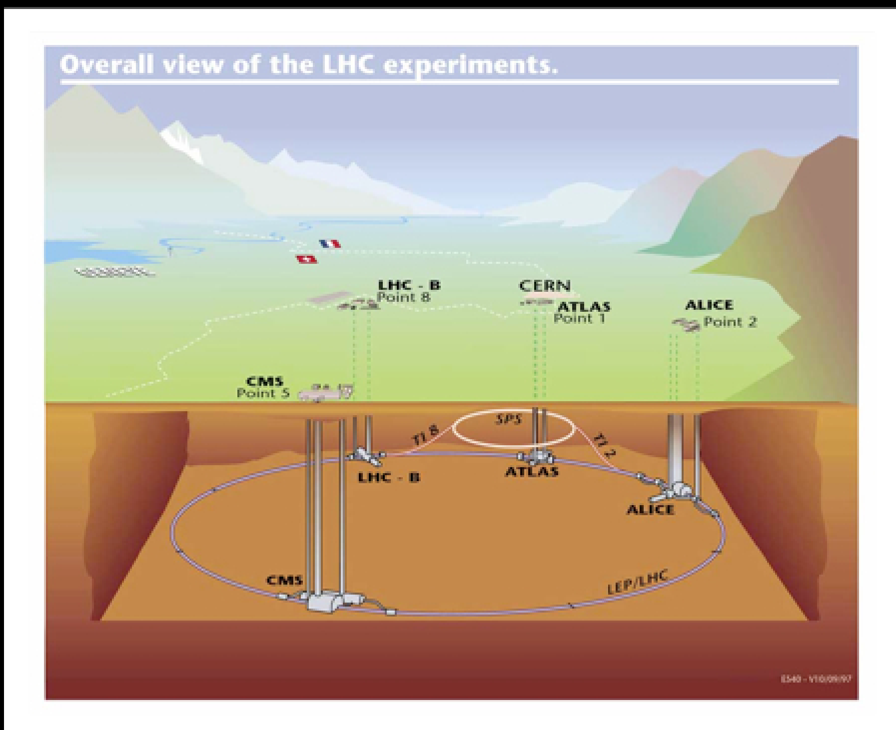
Xenon detectors

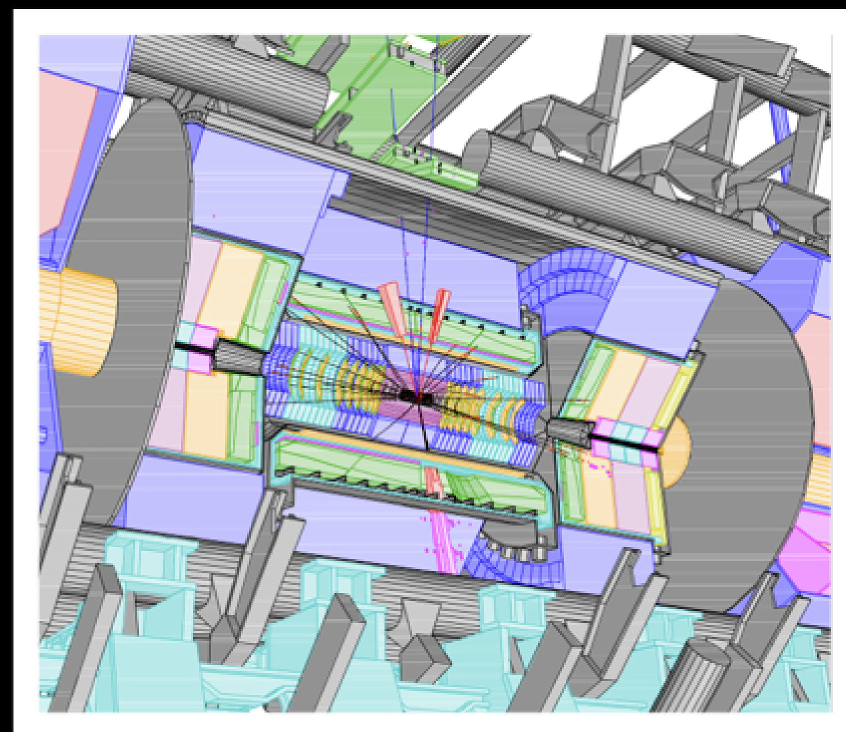
(e.g. LUX and Xenon100)

Status of Direct Searches

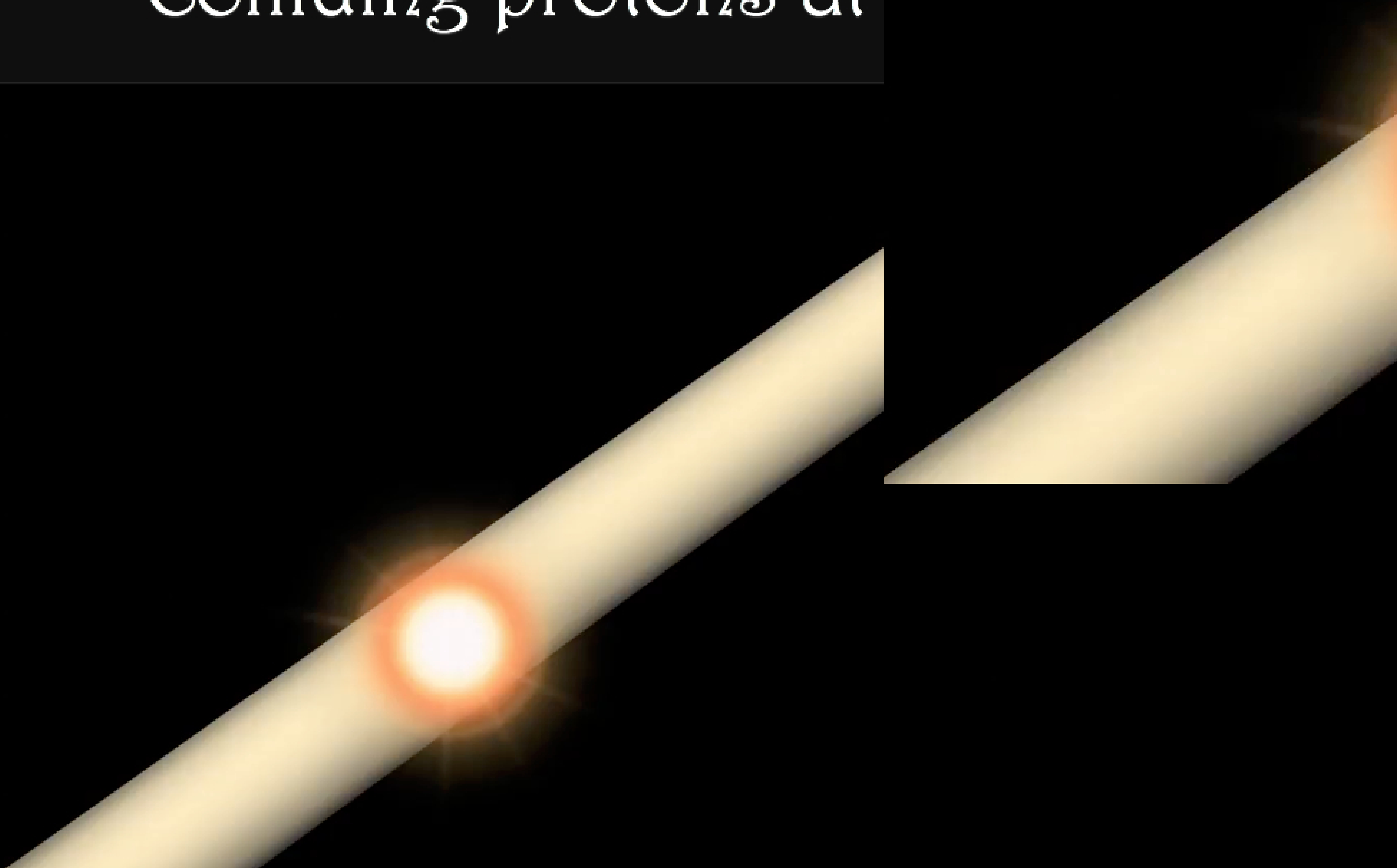


The Large Hadron Collider

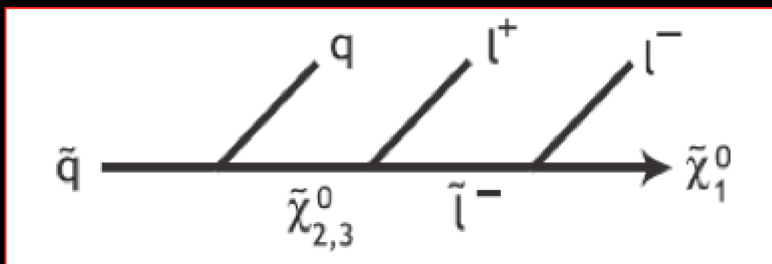


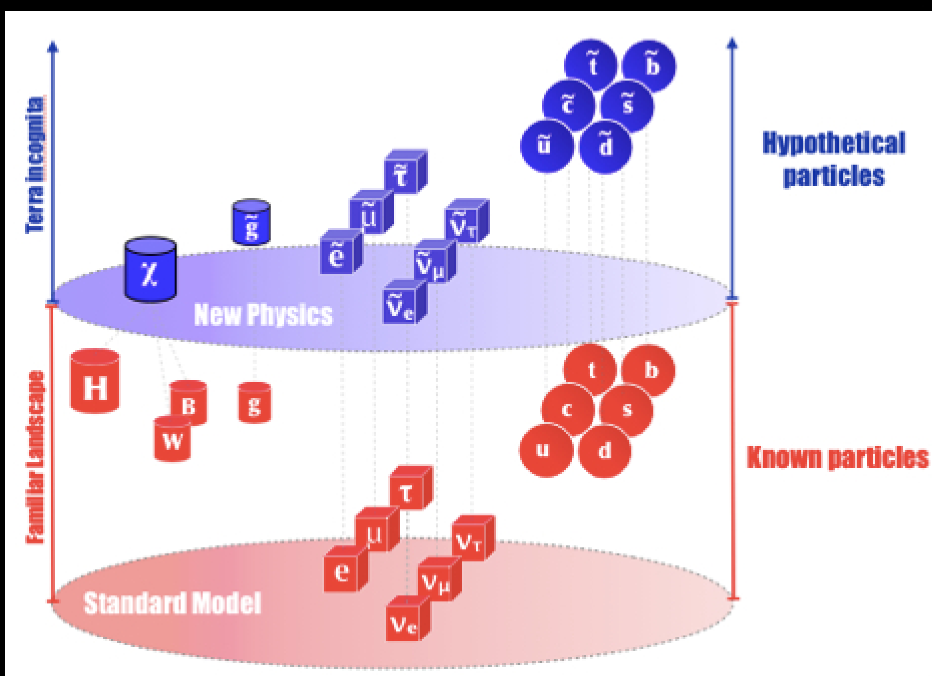


Colliding protons at



WIMPs searches at the LHC





SUSY particles can decay into lighter SUSY particles and SM particles.

When the lightest SUSY particles is produced, it cannot decay into anything else, and it leaves the detector carrying away an energy

It is this imbalance in energy that can lead to the detection of new particles

WIMPs have not been found yet though, is it possible that we are on the wrong track?

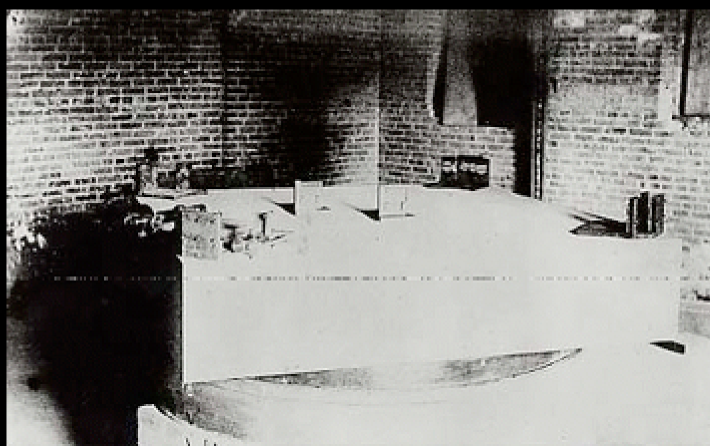
WIMPs have not been found yet though, is it possible that we are on the wrong track?

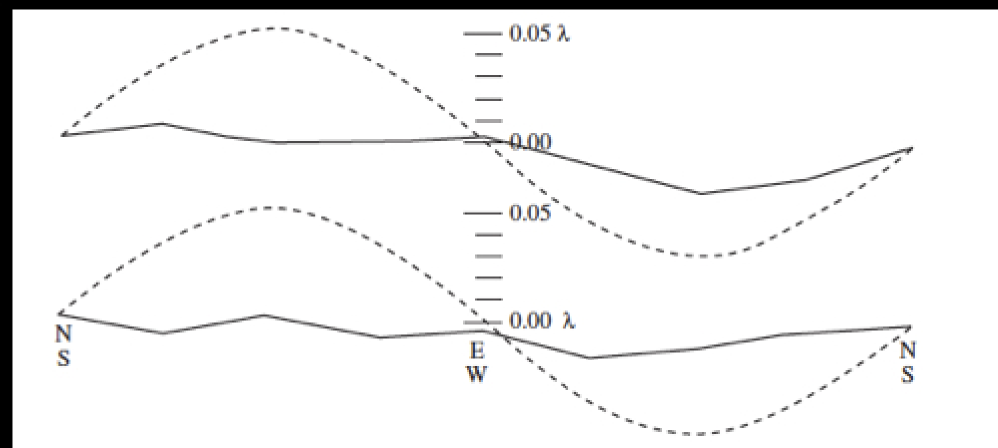
An old saying attributed to Confucius comes to mind:

"It is difficult to search for a black cat in a dark room, especially when there is no cat"

Perhaps WIMPs will not be found...

Still good science! See e.g. the importance of the (null) Michelson-Morley experiment that allowed to rule out the existence of the 'ether' in 1887





"The great tragedy of Science—the slaying of a beautiful hypothesis by an ugly fact" A. Huxley

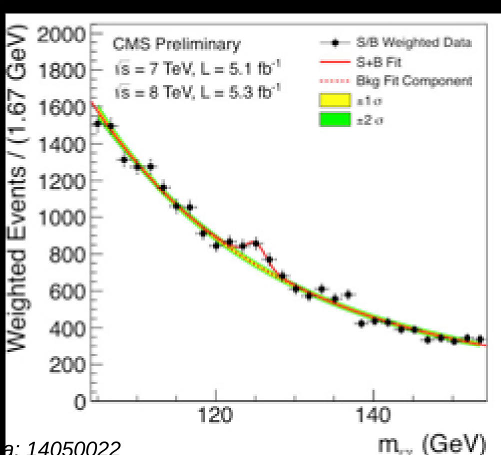
BUT it stimulated the ideas of Lorentz, Poincaré, and others, paving the way for Einstein's theory of special relativity

Perhaps WIMPs will ~~not~~ be found...

Just like the Higgs boson, proposed in the 1960s, on the agenda of at least two generations of physicists, more and more constrained..

"The skeptics proposed ways of getting rid of it. The contrarians criticized the search strategies. Two overly anxious men even pursued a lawsuit in a Federal court in Hawaii alleging that accelerator physicists were threatening the safety of our planet."

And then, in 2012, the Higgs boson was found!



What if WIMPs are discovered?

... we will have to figure out what they are!

The buddhist parable of six blind men

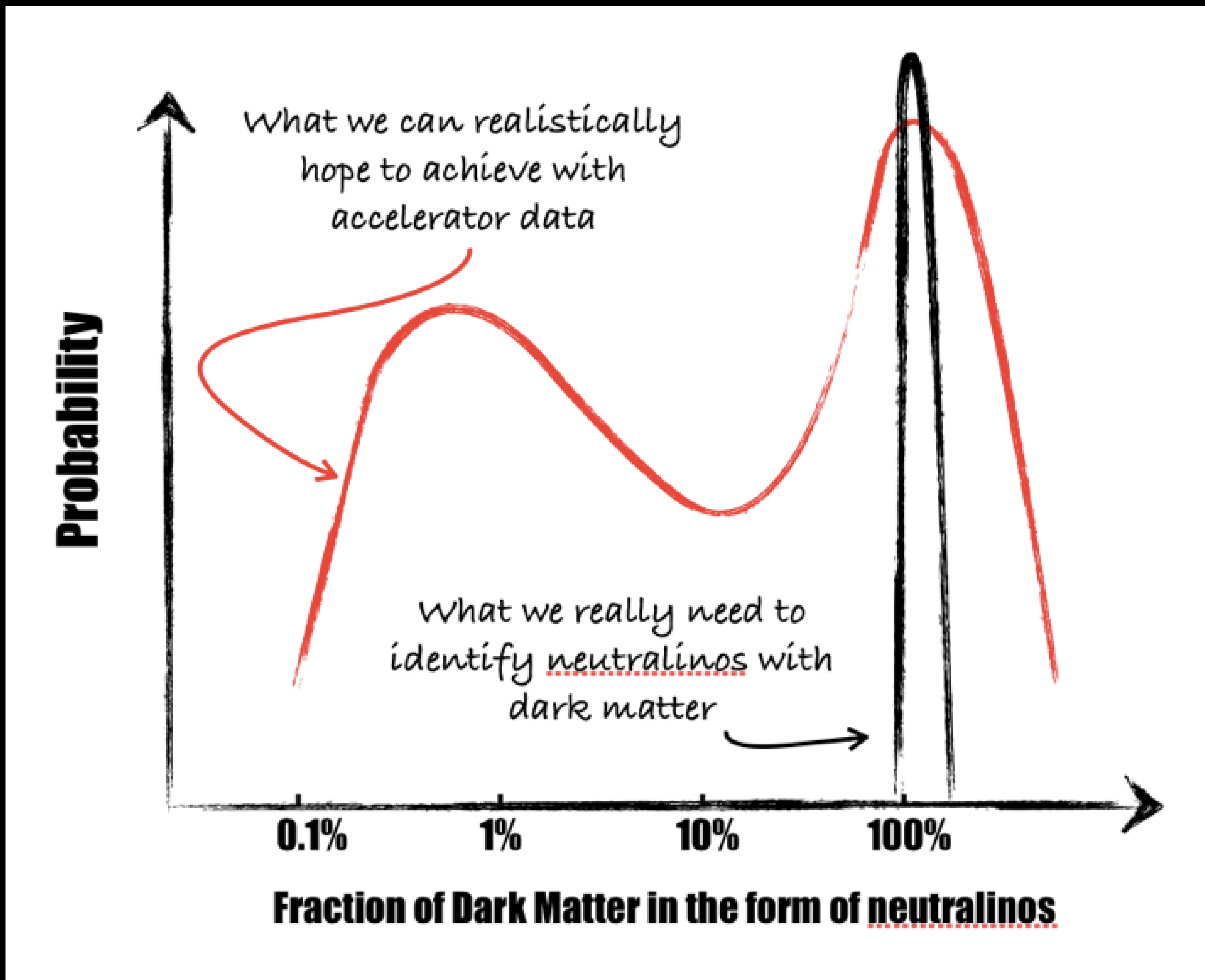
Buddhist scripture known as the Udana, in which the Buddha tells a parable of six blind men who are asked to describe an elephant.

Each of them touches a different part of the animal. Is a pot? a brush? Buddha says:

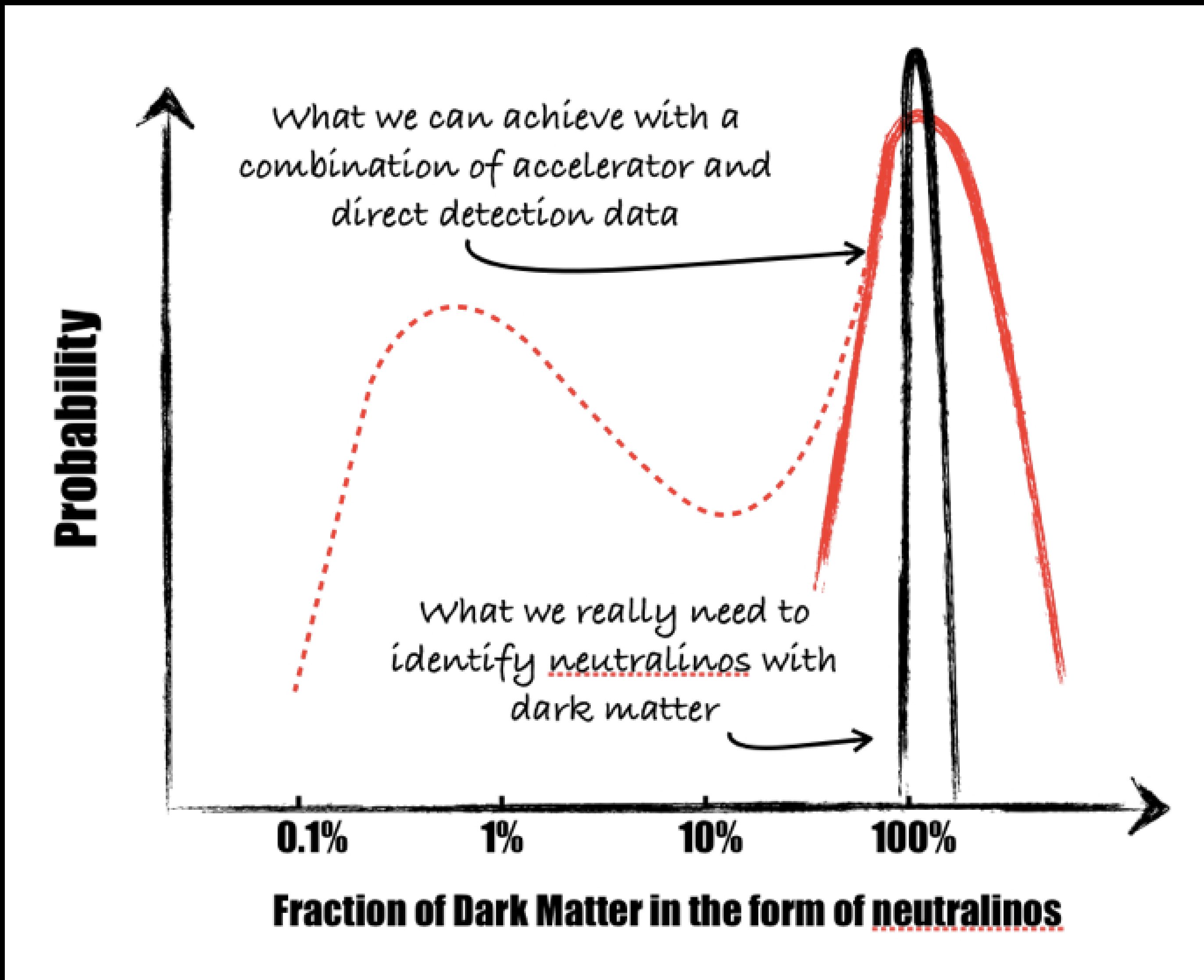
Blind Monks Examining an Elephant. Ukiyo-e by the Japanese artist Hanabusa Itcho (1652–1724)

"O how they cling and wrangle, some who claim
For preacher and monk the honored name!
For, quarreling, each to his view they cling.
Such folk see only one side of a thing".

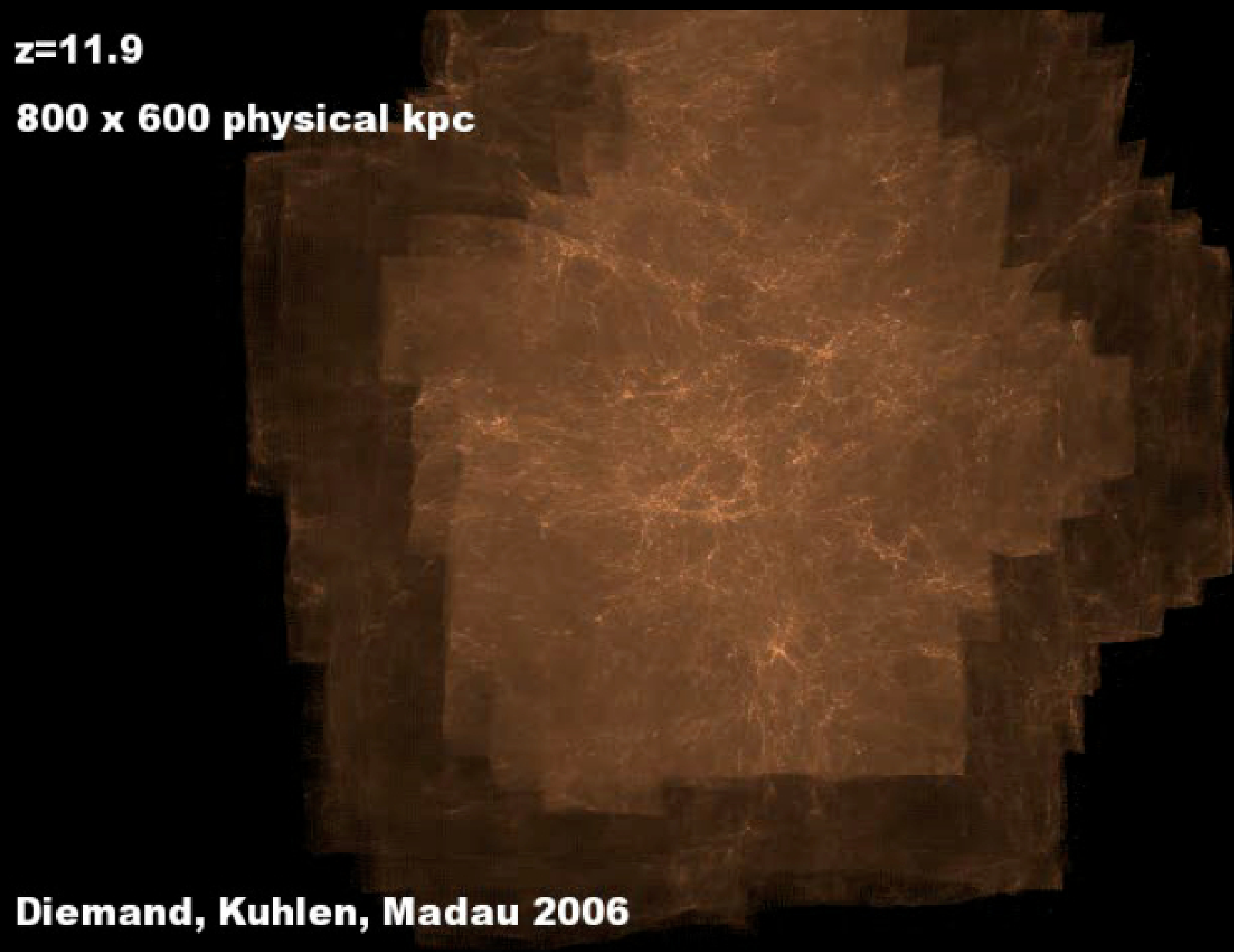
What if WIMPs are discovered?



What if WIMPs are discovered?



Simulating Galaxy Formation



Including baryons (= gas and stars)

z=99.00

2 kpc

Agertz et al. (2009)

Evolution of the gas density (blue), temperature (red) and metallicity (green)

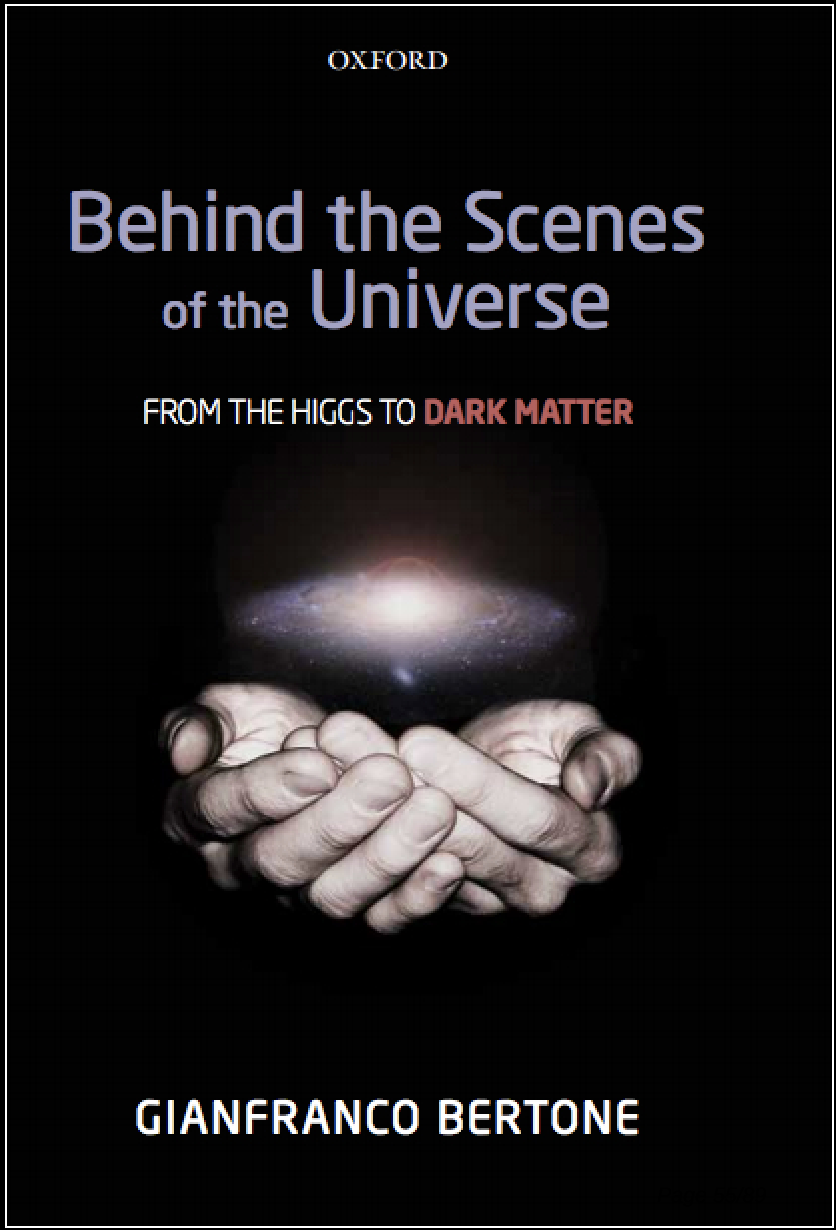
In conclusion:

These are exciting times! Within the next ~5 years we should be able to:

.. rule out WIMPs, and move on with new ideas to explain Dark Matter, perhaps by some of the young people here tonight?

or

.. finally discover WIMPs and be remembered as those who, just like Le Verrier did with Uranus, discovered Dark Matter "*at the tip of their pen*"



Behind the Scenes of the Universe

From the Higgs to Dark Matter

Gianfranco Bertone

gianfrancobertone.net

A little history of Dark Matter: Jacobus Kapteyn

First Attempt at a Theory of the Arrangement and Motion of the Sidereal System

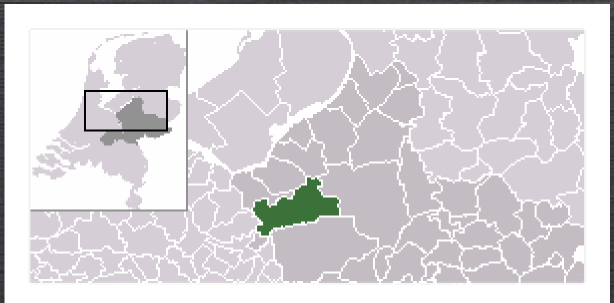
Astrophysical Journal, vol. 55, p.302 (1922)

FIRST ATTEMPT AT A THEORY OF THE ARRANGEMENT AND MOTION OF THE SIDEREAL SYSTEM[1]

By J. C. KAPTEYN[2]

ABSTRACT

First attempt at a general theory of the distribution of masses, forces, and velocities in the stellar system.—(1) *Distribution of stars.* Observations are fairly well represented, at least up to galactic lat. 70°, if we *assume that the equidensity surfaces are similar ellipsoids of revolution*, with axial ratio 5.1, and this enables us to compute quite readily (2) *the gravitational acceleration at various points due to such a system*, by summing up the effects of each of ten ellipsoidal shells, in terms of the acceleration due to the average star at a distance of a parsec. The *total number of stars* is taken as 47.4×10^9. (3) *Random and rotational velocities.* The nature of the equidensity surfaces is such that the stellar system cannot be in a steady state unless there is a general rotational motion around the galactic polar axis, in addition to a random motion analogous to the thermal agitation of a gas. In the neighborhood of the axis, however, there is no rotation, and the behavior is assumed to be like that of a gas at uniform temperature, but with a gravitational acceleration (G_η) decreasing with the distance ρ. Therefore the density Δ is assumed to obey the barometric law: $G_\eta = -\bar{u}^2(\delta\Delta/\delta\rho)/\Delta$; and taking the mean random velocity $\bar{u}$ as 10.3 km/sec., the author finds that (4) *the mean mass of the stars* decreases from 2.2 (sun = 1) for shell II to 1.4 for shell X (the outer shell), the average being close to 1.6, which is the value independently found for the average mass of both components of visual binaries. In the galactic plane the resultant acceleration—gravitational minus centrifugal—is again put equal to $-\bar{u}^2(\delta\Delta/\delta\rho)/\Delta$, $\bar{u}$ is taken to be constant and the average mass is assumed to decrease from shell to shell as in the direction of the pole. The angular velocities then come out such as to make the linear rotational velocities about constant and equal to 19.5 km/sec. beyond the third shell. If now we suppose that part of the stars are rotating one way and part the other, the relative velocity being 39 km/sec., we have a quantitative explanation of the phenomenon of star-streaming, where the relative velocity is also in the plane of the Milky Way and about 40 km/sec. It is incidentally suggested that when the theory is perfected it may be possible to determine *the amount of dark matter* from its gravitational effect. (5) The *chief defects of the theory* are: That the equidensity surfaces assumed do not agree with the actual surfaces, which tend to become spherical for the shorter distances; that the *position of the center of the system* is not the sun, as assumed, but is probably located at a point some 650 parsecs away in the direction galactic long. 77°, lat. −3°; that the average mass of the stars was assumed to be the same in all shells in deriving the formula for the variation of G_η with ρ on the basis of which the variation of average mass from shell to shell and the constancy of the rotational velocity were derived—hence either the assumption or the conclusions are wrong; and that no distinction has been made between stars of different types.



Born in January 19, 1851, Barneveld,Gelderland

Jacobus Kapteyn

First appearance of the term 'Dark Matter' in scientific literature

Remark. Dark matter. It is important to note that what has here been determined is the total mass within a definite volume, divided by the number of luminous stars. I will call this mass the average effective mass of the stars. It has been possible to include the luminous stars completely owing to the assumption that at present we know the luminosity-curve over so large a part of its course that further extrapolation seems allowable.

Now suppose that in a volume of space containing l luminous stars there be dark matter with an aggregate mass equal to Kl average luminous stars; then, evidently the effective mass equals $(l+K)\times$average mass of a luminous star.

We therefore have the means of estimating the mass of dark matter in the universe. As matters stand at present it appears at once that this mass cannot be excessive. If it were otherwise, the average mass as derived from binary stars would have been very much lower than what has been found for the effective mass.

Fritz Zwicky

applies the virial theorem to the Coma Cluster and finds...

THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

VOLUME 86 OCTOBER 1937 NUMBER 3

ON THE MASSES OF NEBULAE AND OF CLUSTERS OF NEBULAE

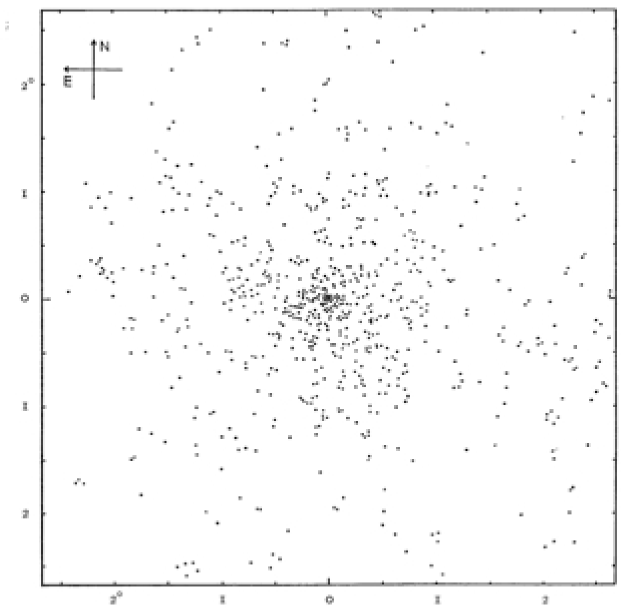


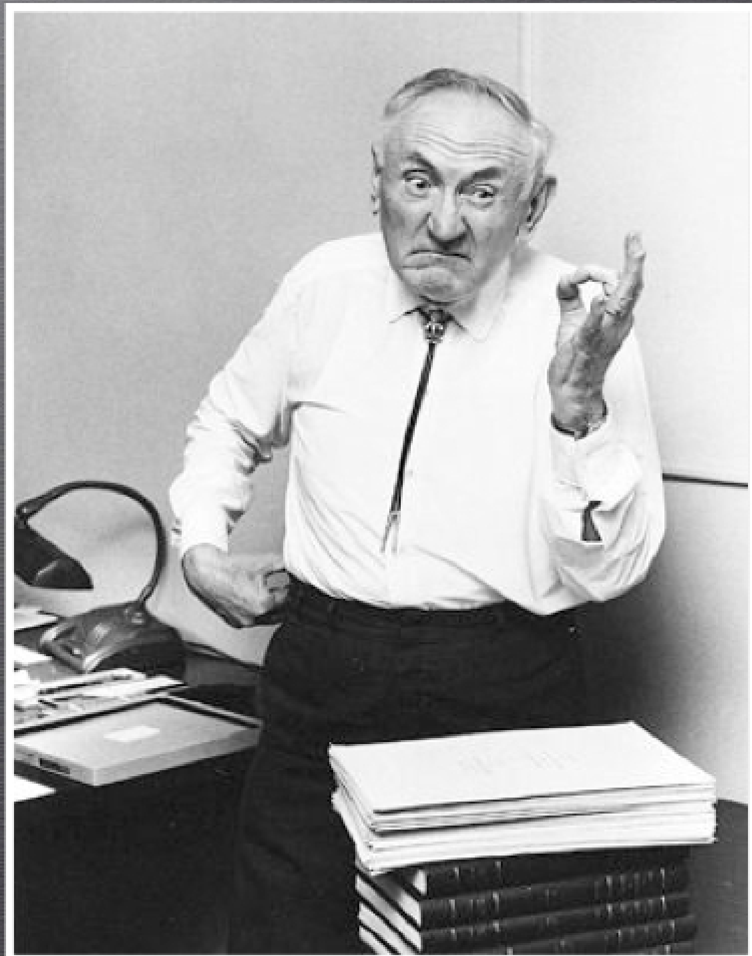
Fig. 3.—The Coma cluster of nebulae

Fritz Zwicky

applies the virial theorem to the Coma Cluster and finds...

In his 1933 paper (in german) he writes

*"If this would be confirmed we would get the surprising result that **dark matter** is present in much greater amount than luminous matter."*



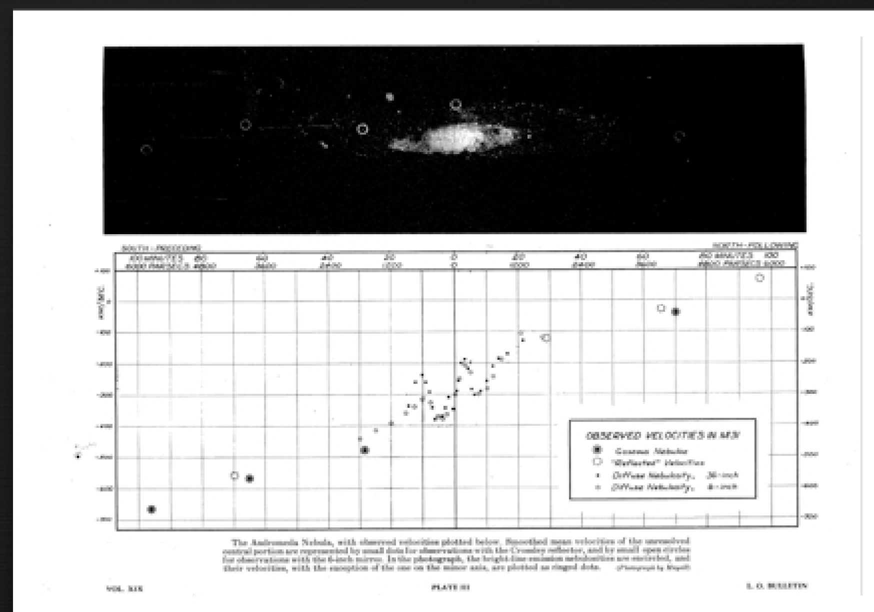
Evidence Slowly Mounts..

Smith 1936.

Mass of Virgo Cluster *"It is possible that [mass estimates] are correct, and that the difference represents a great mass of intranebular material in the cluster"* ApJ, vol. 83, p.23

Babcock 1939.

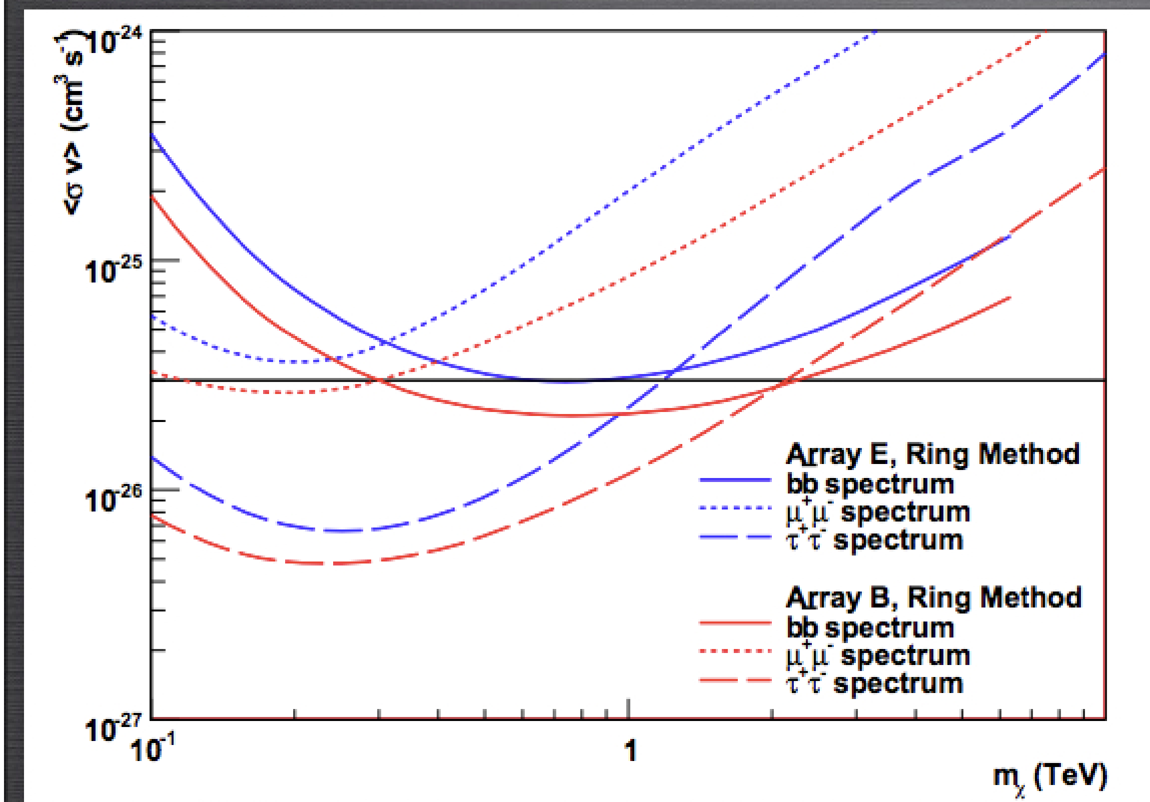
Rotation Curve of M31 *"The obvious interpretation of the nearly constant velocity for 30′ outward is that a that a very great portion of the mass of the nebula must lie in the outer regions"*



Kahn & Woltjer 1959.

Local Group, Mass of the M31-MW system *"The Discrepancy seems to be well outside the observational errors"*

Prospects for observing DM annihilation with CTA



arxiv:1208.5356

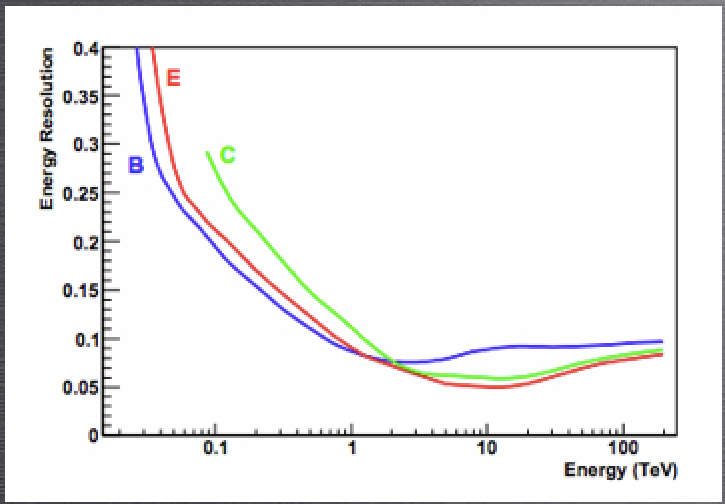
	LST	MST	SST
A	3 (5°)	41 (8°)	-
B	5 (5°)	37 (8°)	-
C	-	29 (8°)	26 (10°)†
D	-	41 (7.4°)	16 (10°)†
E	4 (4.6°)	23 (8°)	32 (10°)
F	6 (4.8°)	29 (6.3°)	-
G	6 (5°)	9 (8°)	16 (10°)
H	-	25 (7°)	48 (10°)
I	3 (4.9°)	18 (8°)	56 (9°)
J	3 (4.9°)	30 (8°)	16 (9°)†
K	5 (5°)	-	72 (9.5°)
NA	4 (5°)	17 (6°)	-
NB	3 (5°)	17 (6°)	8 (8°)

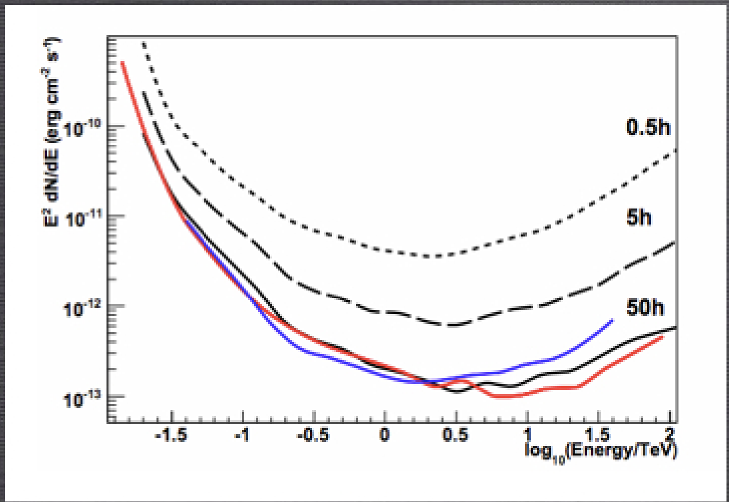
† With wide-field versions of MSTs instead of actual

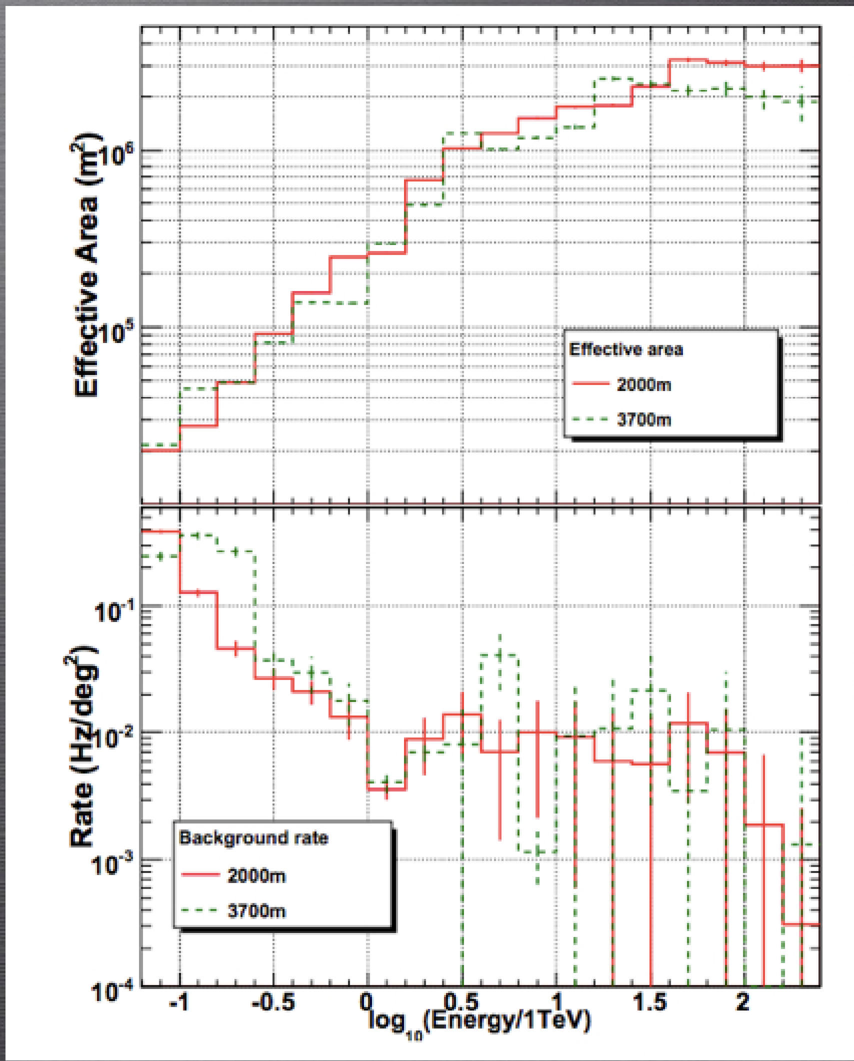
arxiv:1210.3503

The 130 GeV Line

Parameters adopted in Bergstrom, GB et al. http://arxiv.org/pdf/1207.6773.pdf







http://arxiv.org/abs/1008.3703 http://arxiv.org/abs/1111.2183

The 130 GeV Line

Internal Bremsstrahlung

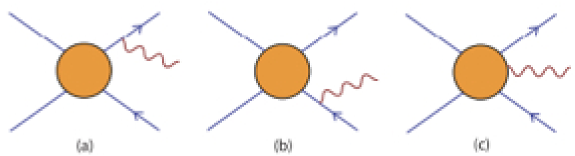
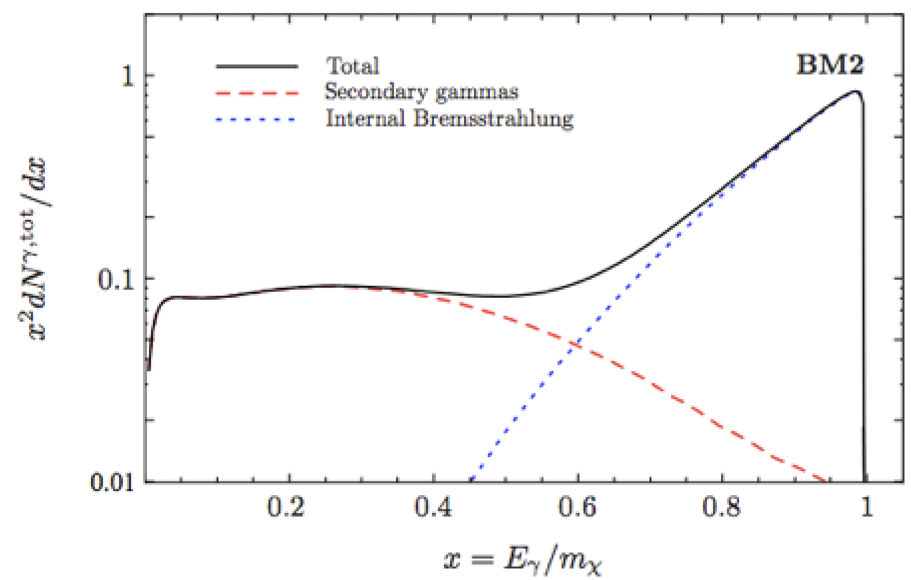


FIG. 1: *Types of diagrams that contribute to the first order QED corrections to WIMP annihilations into a pair of charged particle final states. The leading contributions to diagrams (a) and (b) are universal, referred to as* final state radiation *(FSR), with a spectral distribution which only depends slightly on the final state particle spin and has been calculated, e.g., in [16]. Internal bremsstrahlung from virtual particles (or* virtual internal bremsstrahlung, *VIB) as in diagram (c), on the other hand, is strongly dependent on details of the short-distance physics such as helicity properties of the initial state and masses of intermediate particles.*



Bringmann, Bergstom and Edsjo

http://arxiv.org/pdf/0710.3169v3.pdf

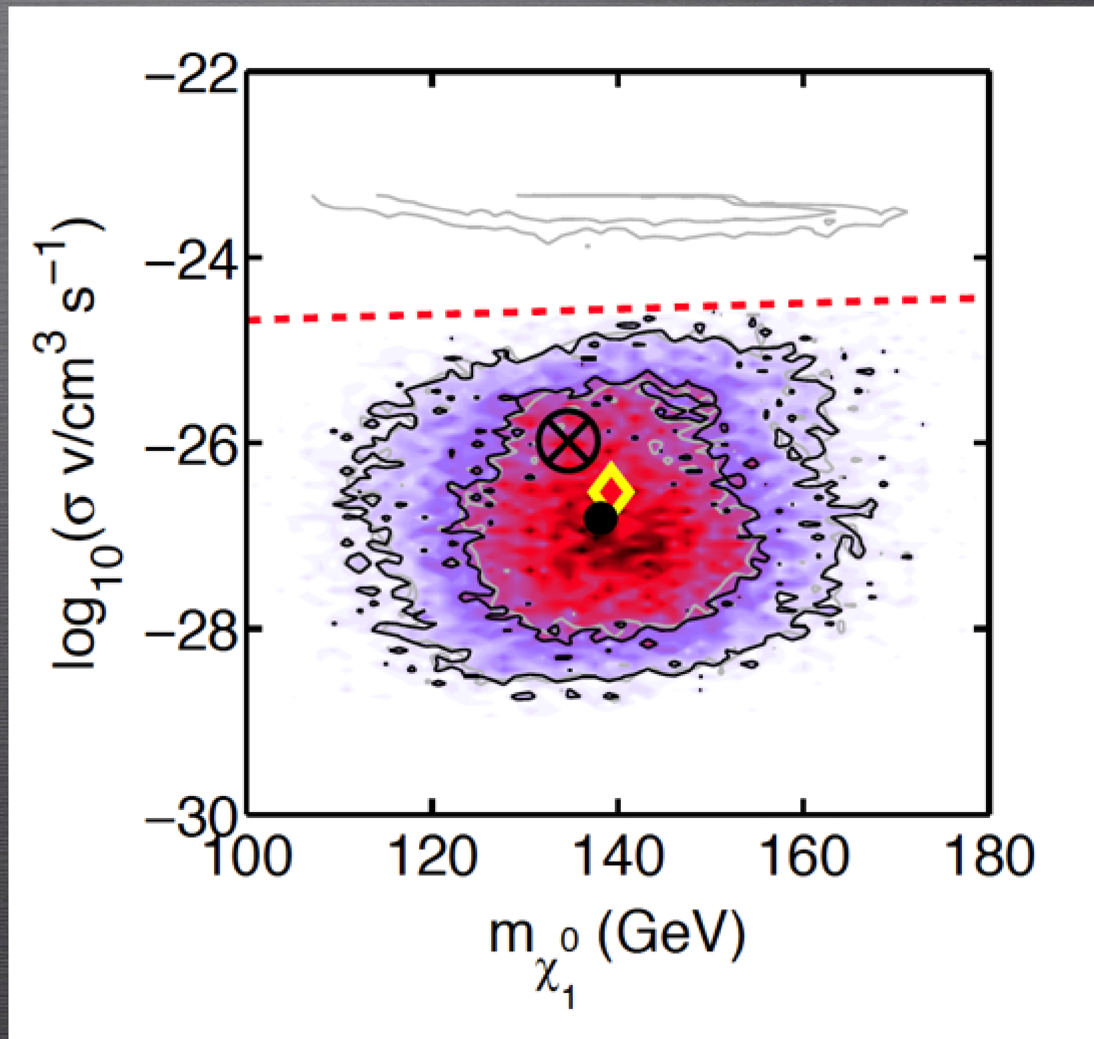
What happens if we add these constraints to the LHC posterior?

LHC + ID

What happens if we add these constraints to the LHC posterior?

LHC + ID

...since we are basically ruling out the region corresponding to large annihilation cross sections



Indirect Detection

Recent AMS-02 results

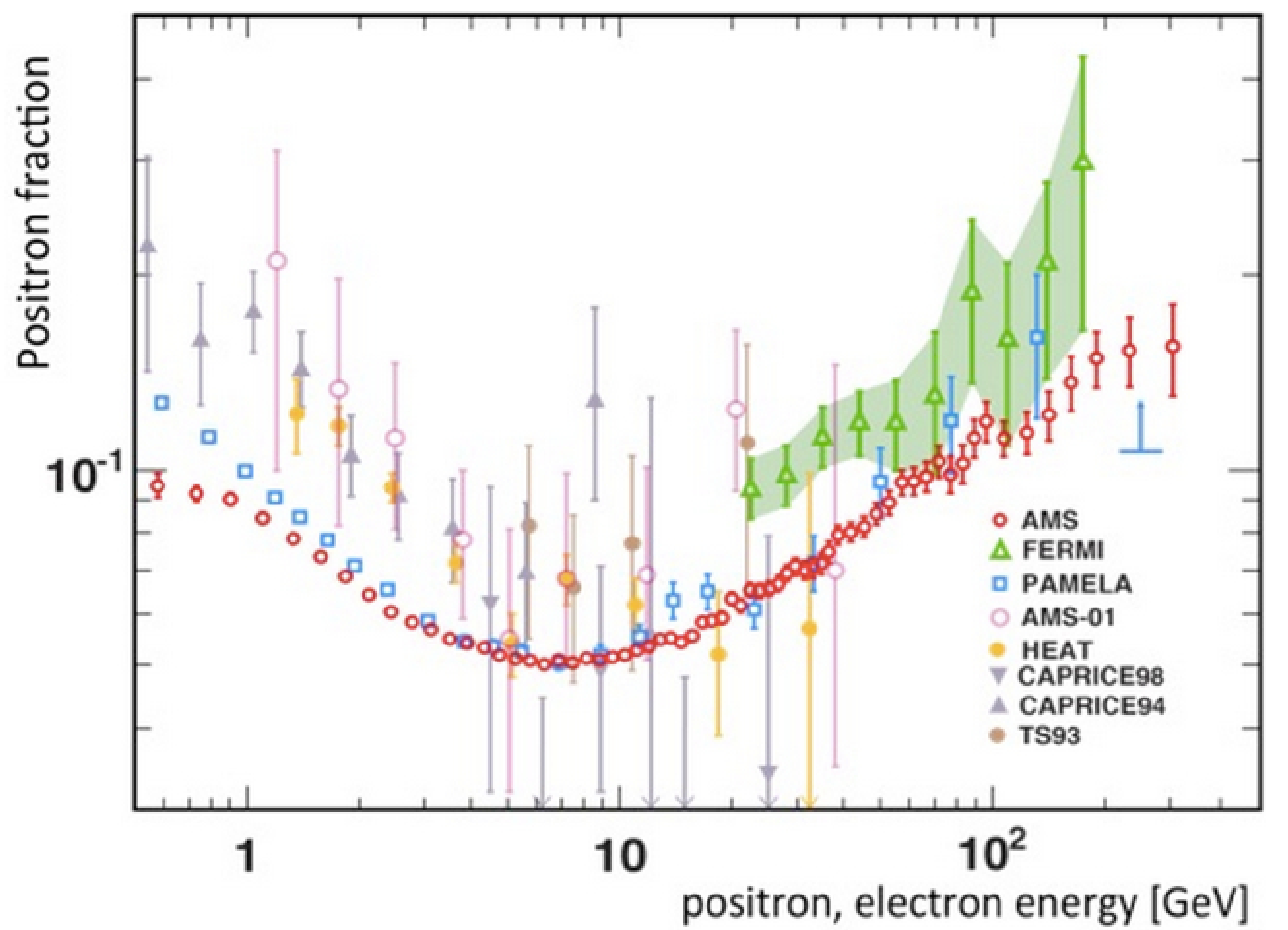
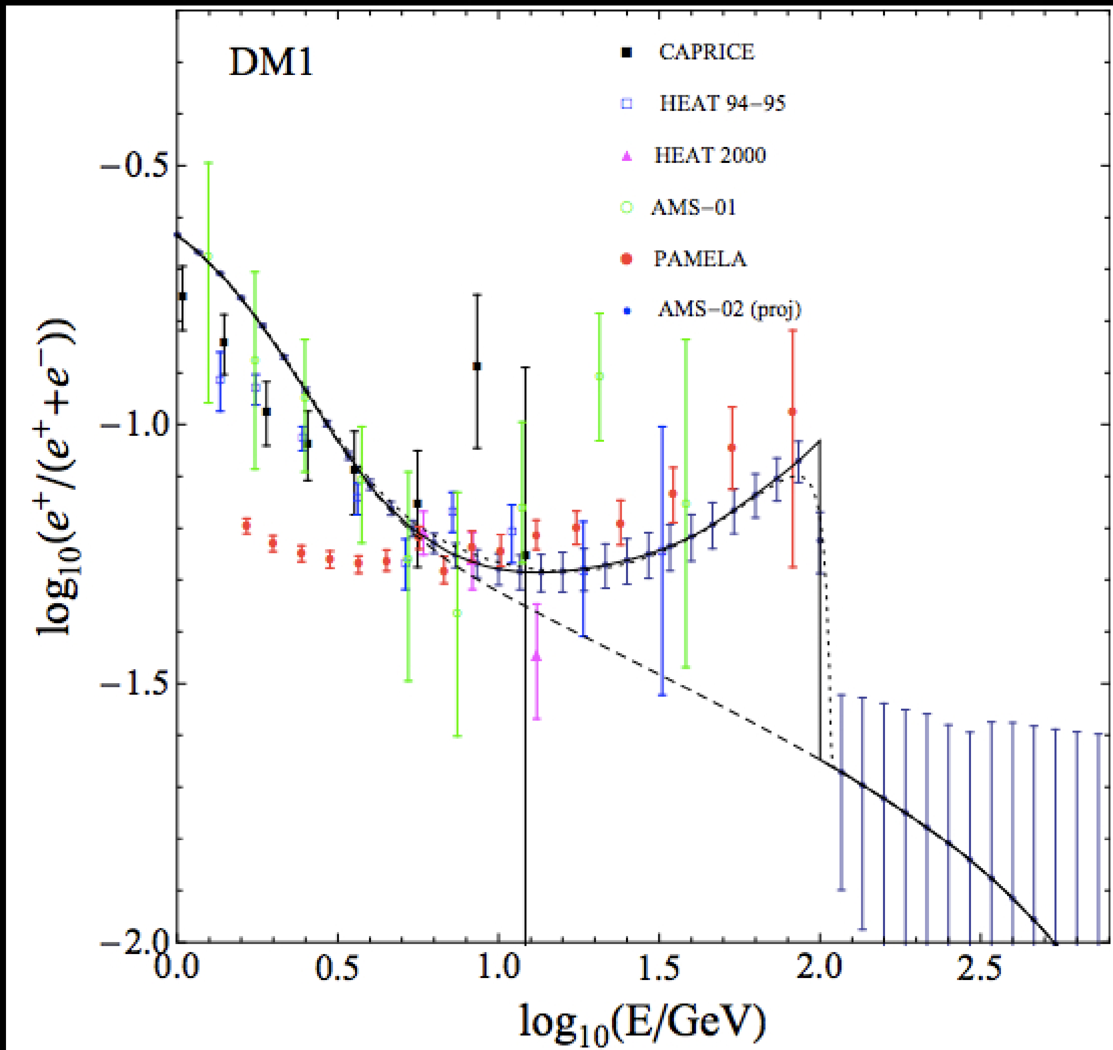


Figure 3: A comparison of AMS results with recent published measurements. With its magnet and precision particle detectors, high accuracy and statistics, the first result of AMS, based on only ~10% of the total data expected, is clearly distinguished from earlier experiments (see References).

Indirect Detection

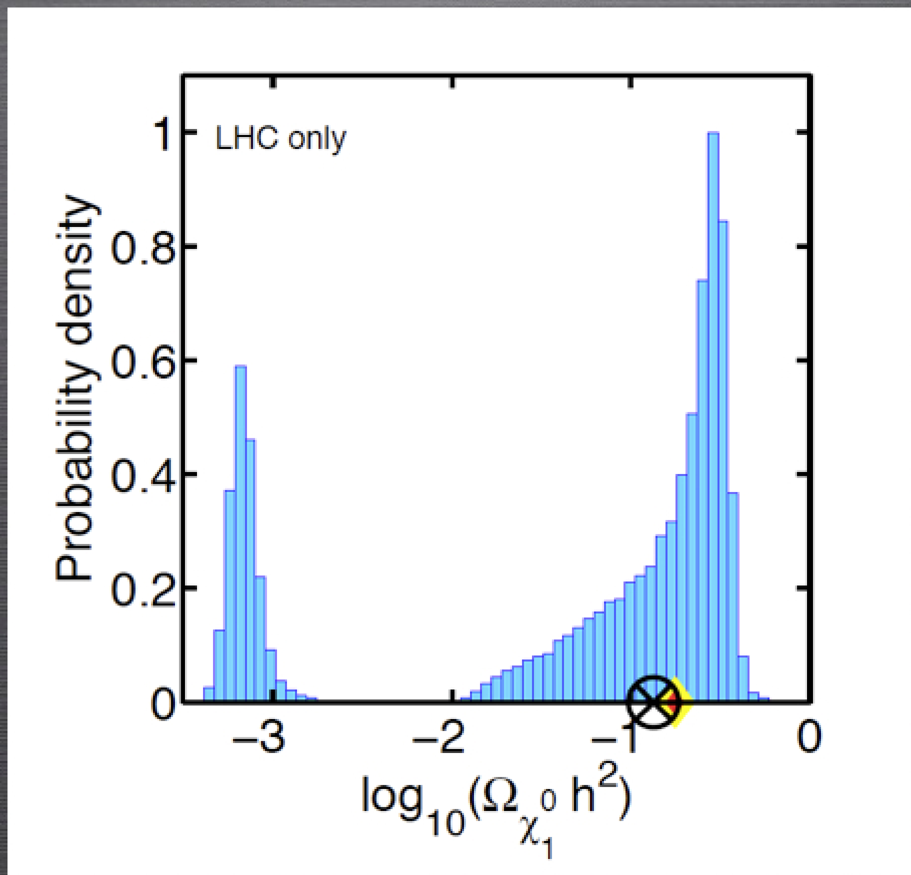
Recent AMS-02 results



Pato, Lattanzi & GB 2010

Example of Inverse problem at LHC

what we will most probably get
(example in the stau coannihilation region, 24 parms MSSM)



Abundance of DM

GB, Cerdeno, Fornasa, Ruiz de Austri & Trotta, 2010

Example of Inverse problem at LHC

what we will most probably get
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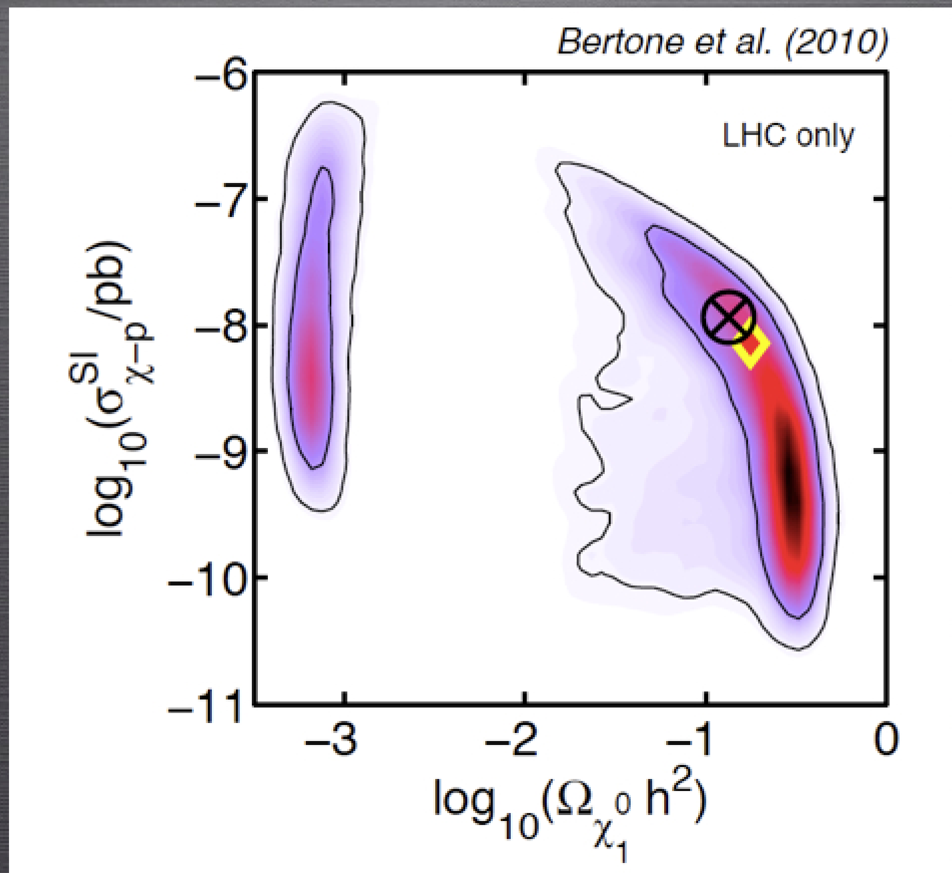


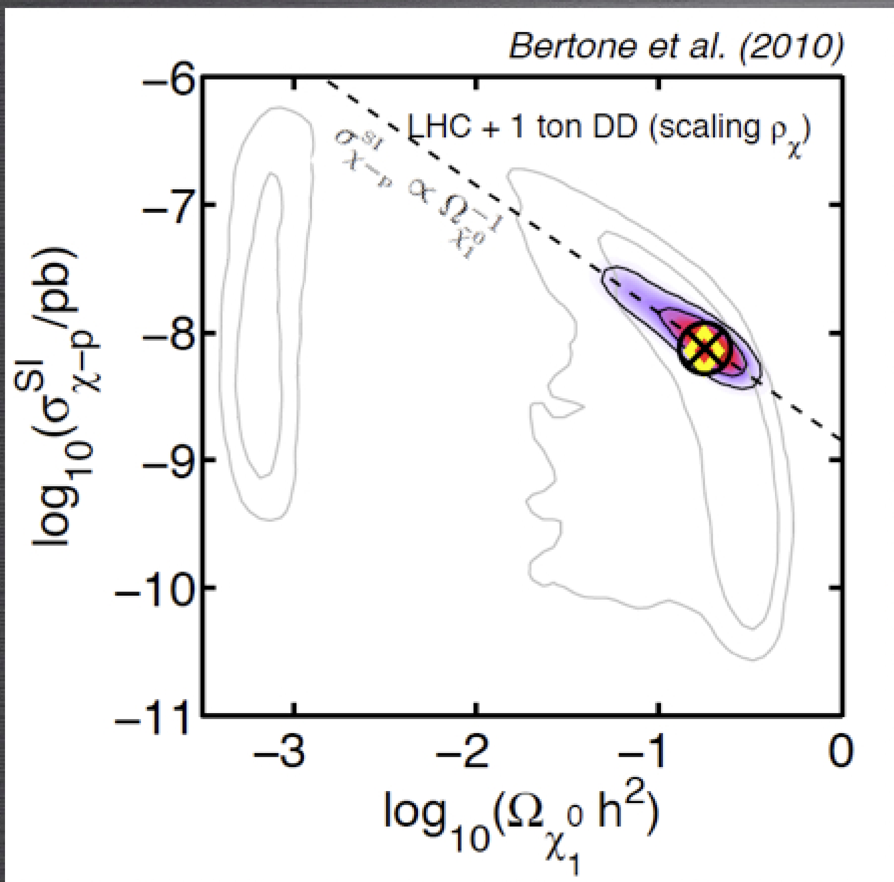
STRENGTH OF DM INTERACTIONS WITH ORDINARY MATTER

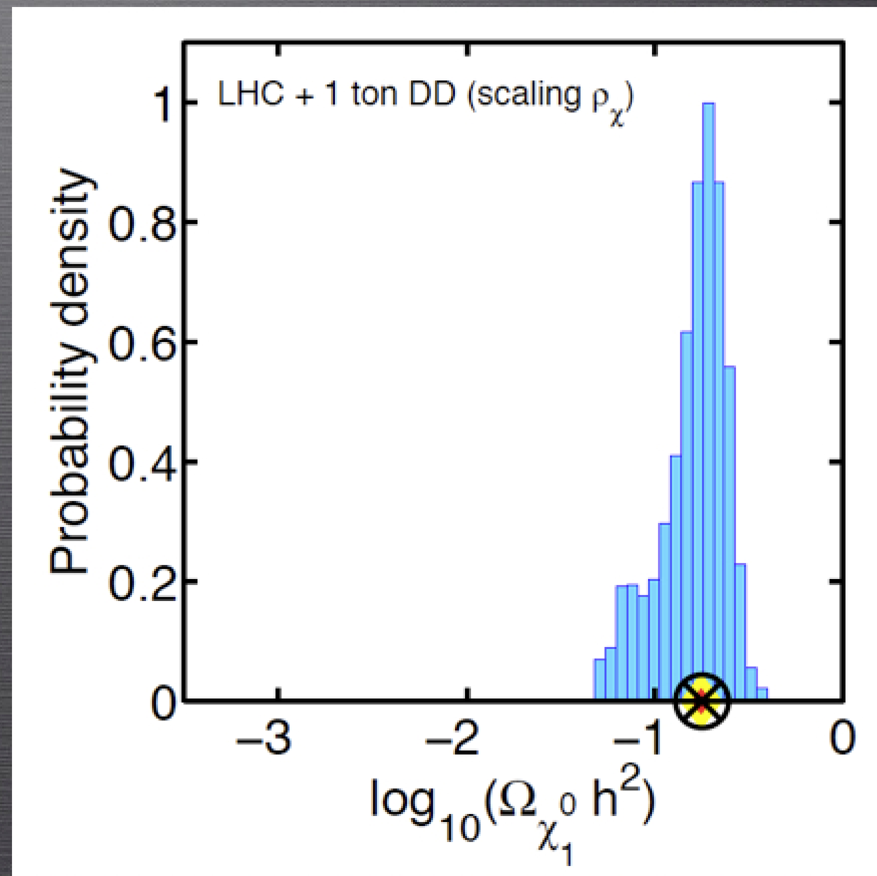
ABUNDANCE OF DM

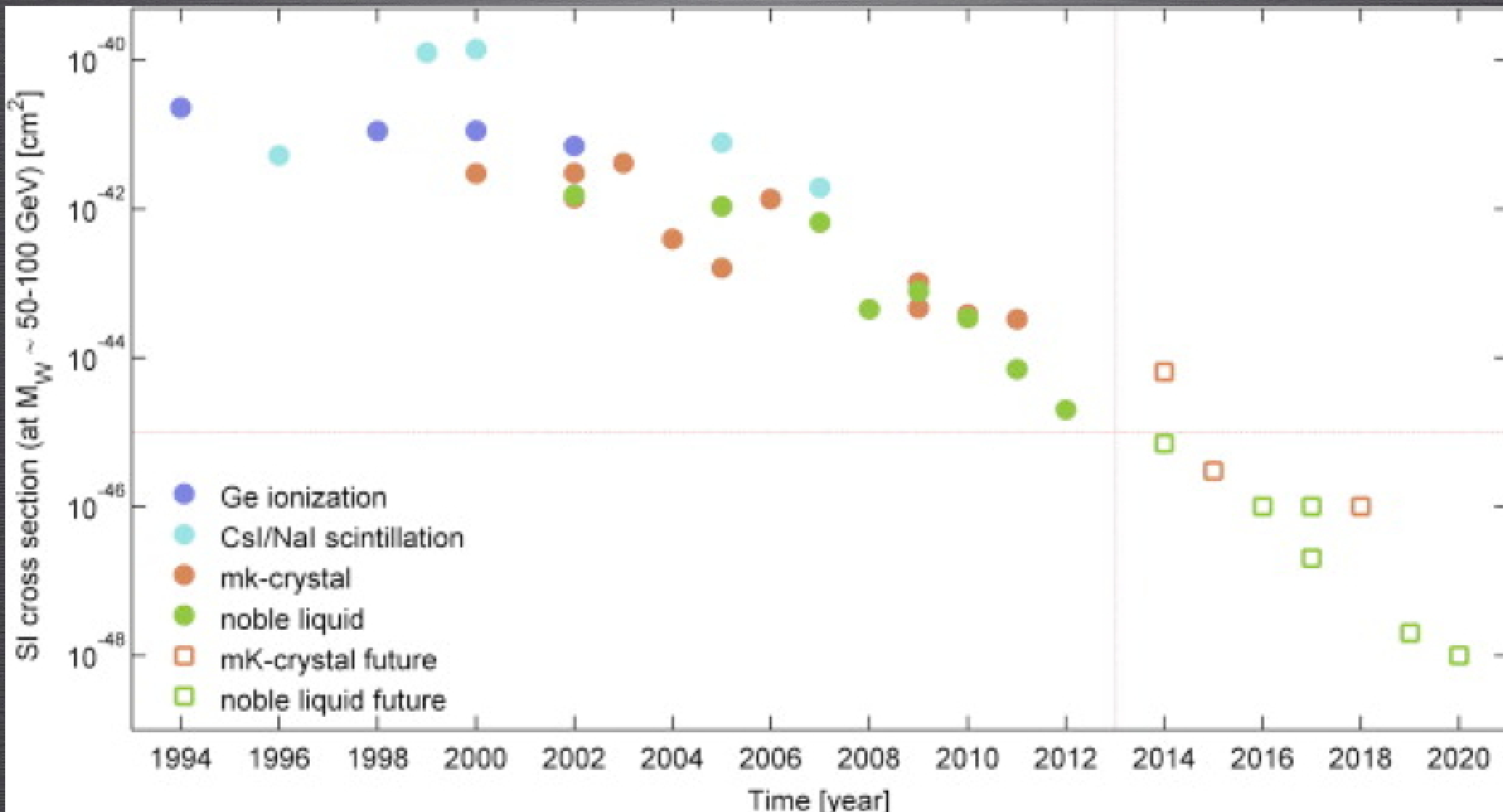
DD+LHC

"Scaling" Ansatz

$$\frac{\rho_\chi}{\rho_{dm}} = \frac{\Omega_\chi}{\Omega_{dm}}$$



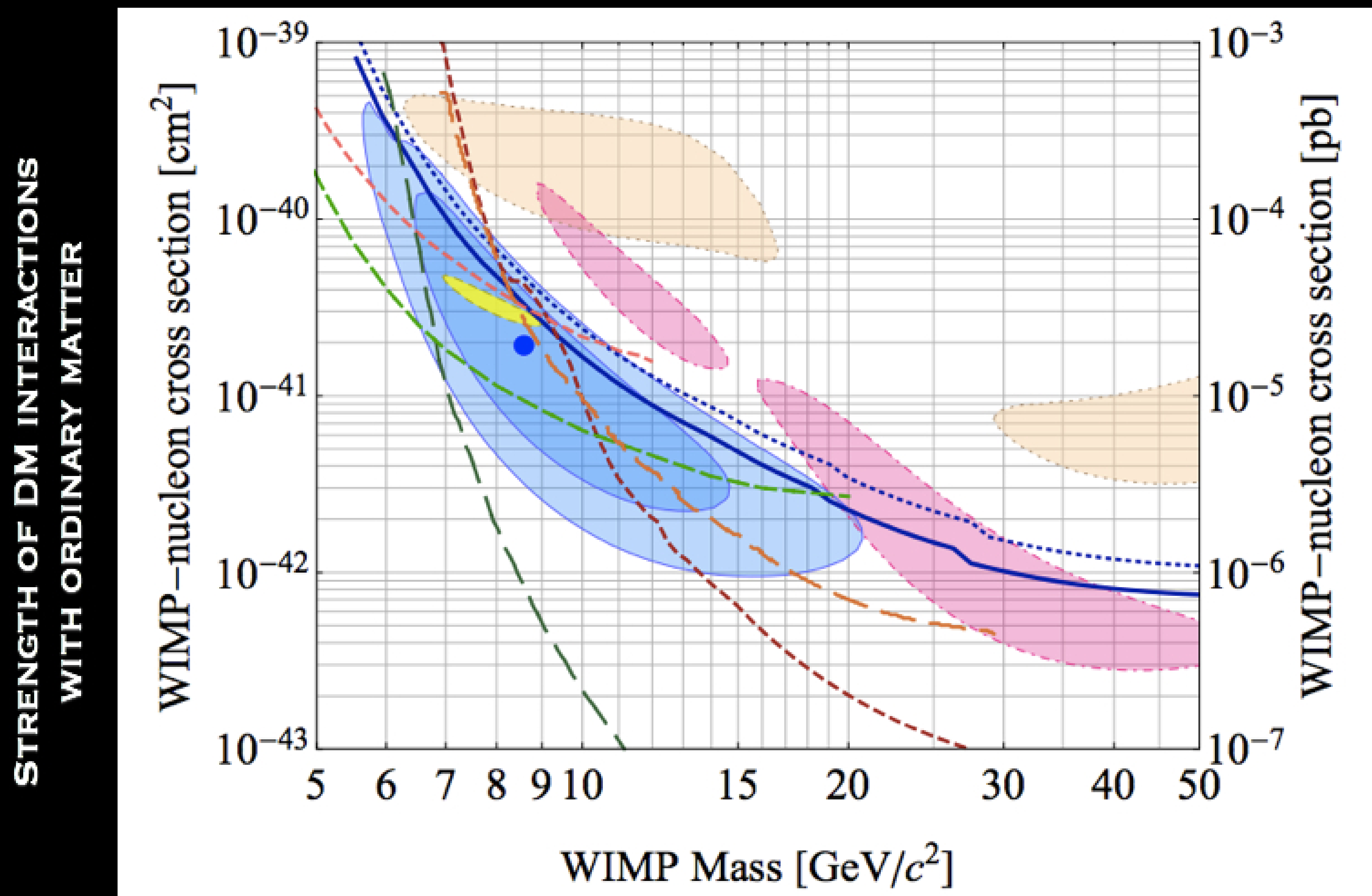




SI cross section (at M_W ~ 50-100 GeV) [cm^2]
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
Ge ionization
CsI/NaI scintillation
mk-crystal
noble liquid
mK-crystal future
noble liquid future
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Time [year]

Latest CDMS II results

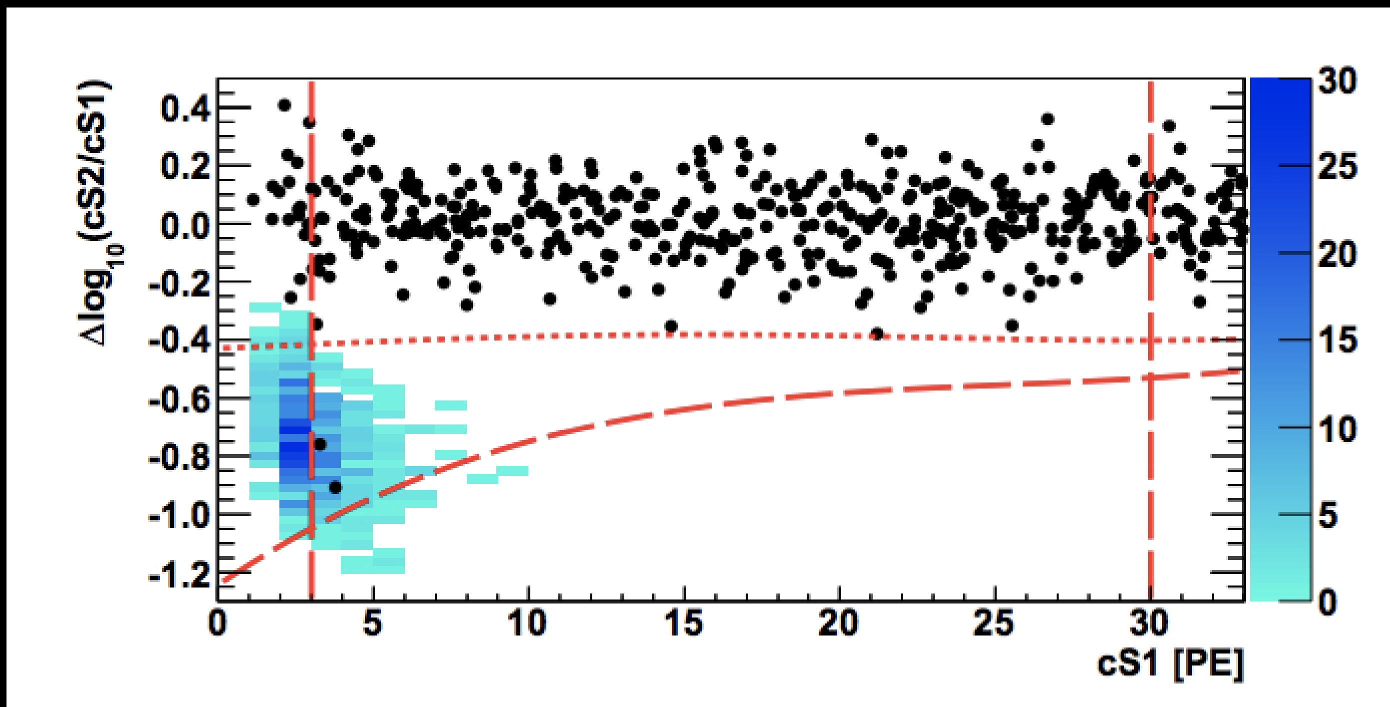
RELEASED ON APRIL 15, 2013



http://cdms.berkeley.edu/CDMSII_Si_DM_Results.pdf

Results of Xenon100

1 week later, arXiv:1304.1427

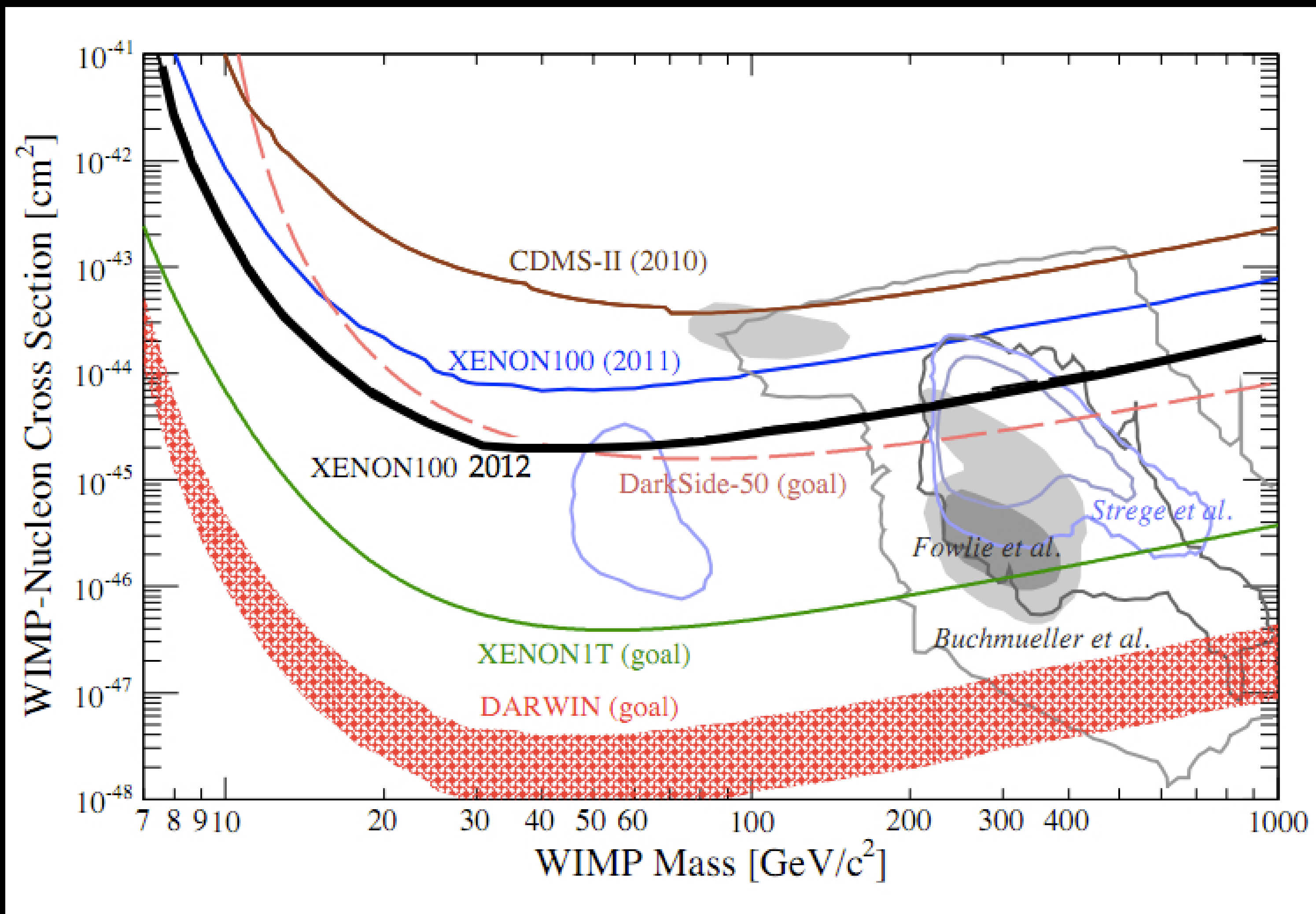


For a ~8 GeV, sigma_SI = 3 × 10−41 cm^2, expected 270 (+330,−80) events, observed 2!

Direct Detection

Status

Strength of DM interactions with ordinary matter

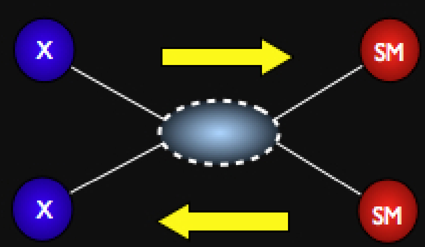


Adapted from Baudis (Darwin Collab.) [arXiv:1201.2402]

Indirect Detection

X = DARK MATTER   SM = STANDARD MODEL PARTICLE

Early Universe



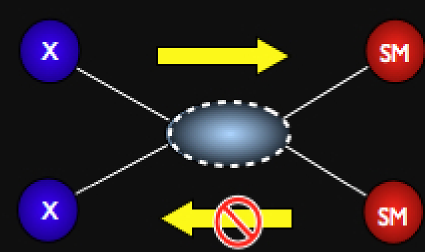
$$\frac{dn_\chi}{dt} - 3Hn_\chi = -\langle\sigma v\rangle \left[n_\chi^2 - (n_\chi^{eq})^2\right]$$

relic density (NR freeze-out)

$$\Omega h^2 \approx \frac{3 \times 10^{-27} cm^3 s^{-1}}{< \sigma v >}$$

Electroweak-scale cross sections can reproduce correct relic density.

Today



$$\frac{dn_\chi}{dt} = -(\sigma v)_o n_\chi^2$$

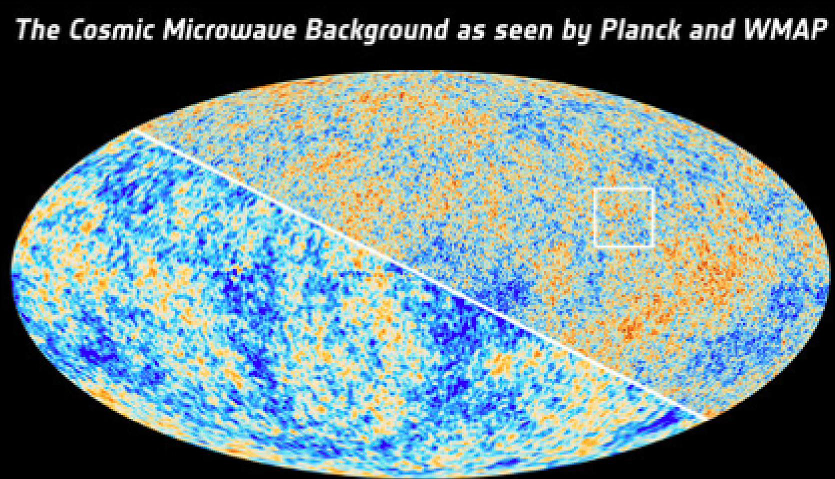
Annihilation Flux

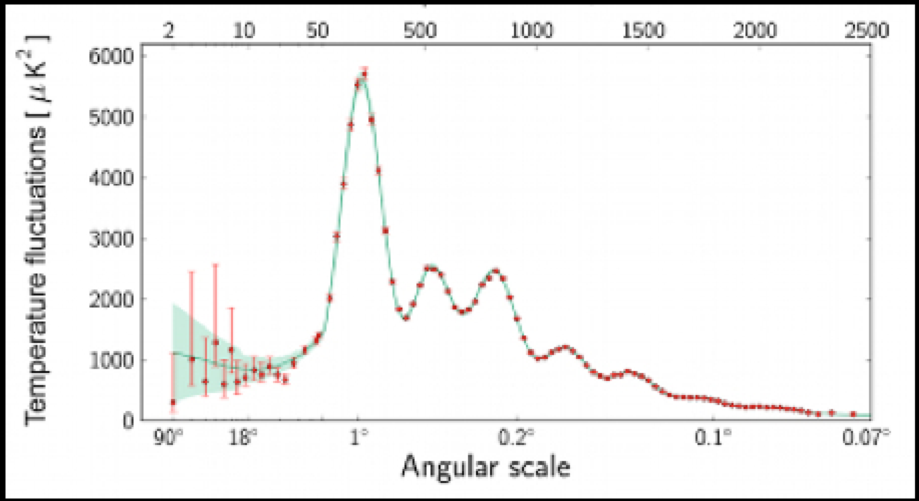
$$\Phi_i(\Omega, E_i) = \frac{dN}{dE_i} \frac{\langle\sigma v\rangle}{8\pi m_\chi^2} \int_{los} \rho_\chi^2(\ell, \Omega) d\ell$$

Particle physics input from extensions of the Standard Model. Need to specify distribution of DM along the line of sight.

What do we know?

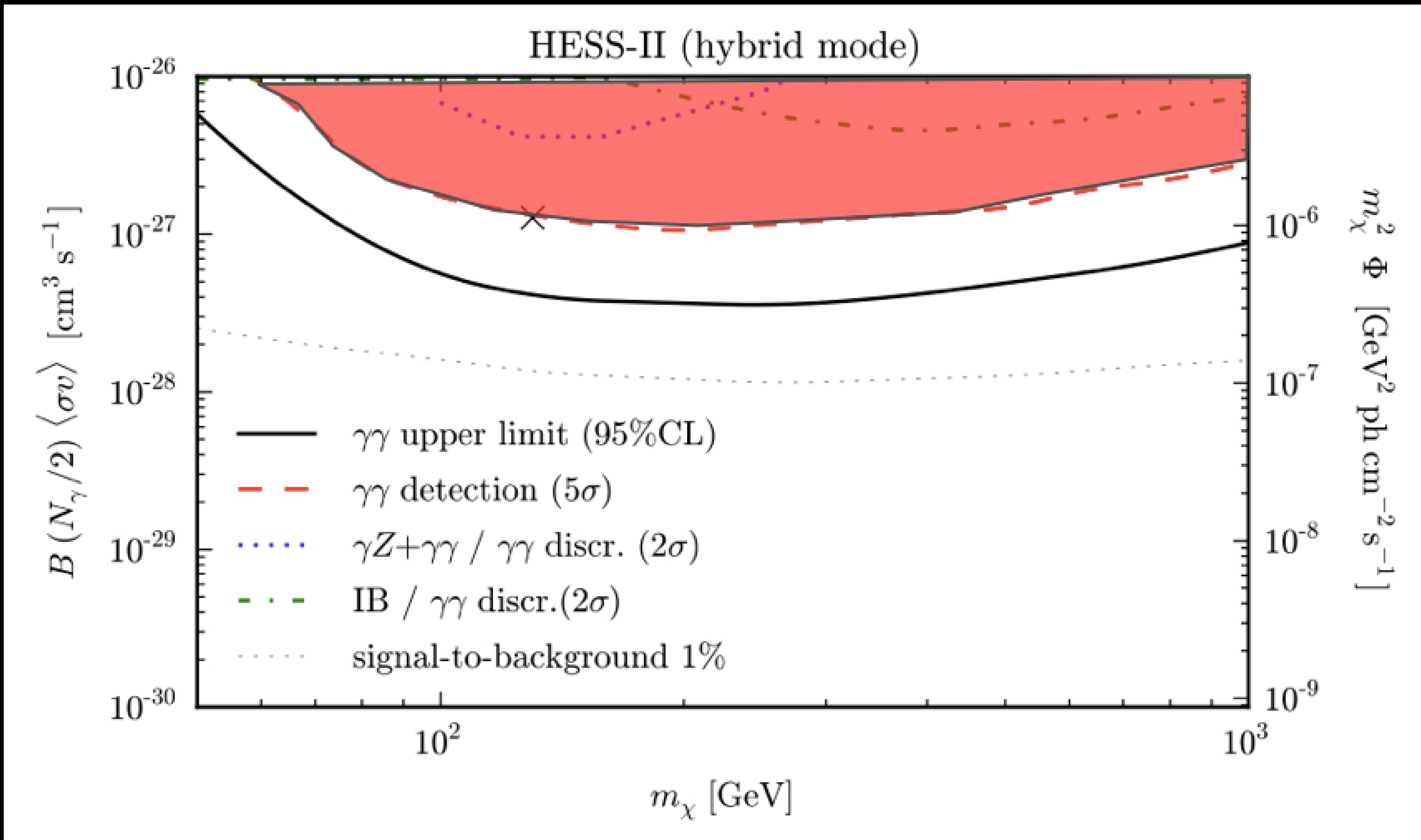
Planck results (announced on March 22, 2013)





The 130 GeV Line

Intensity of the Line



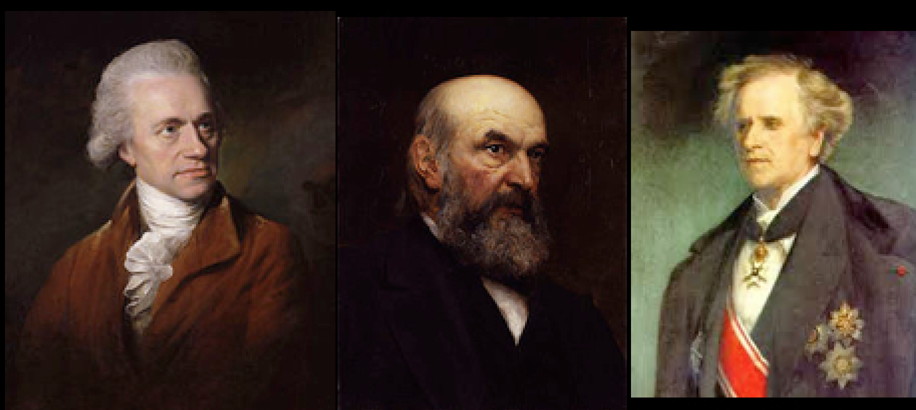
Bergstrom, GB et al. http://arxiv.org/pdf/1207.6773.pdf


80
DEUTSCHE BUNDESPOST
FRIEDRICH WILHELM BESSEL
1784 Astronom und Mathematiker 1846
1984
Wally Pacholka / AstroPics.com

Dark Matter or Modified Gravity?

Neptune

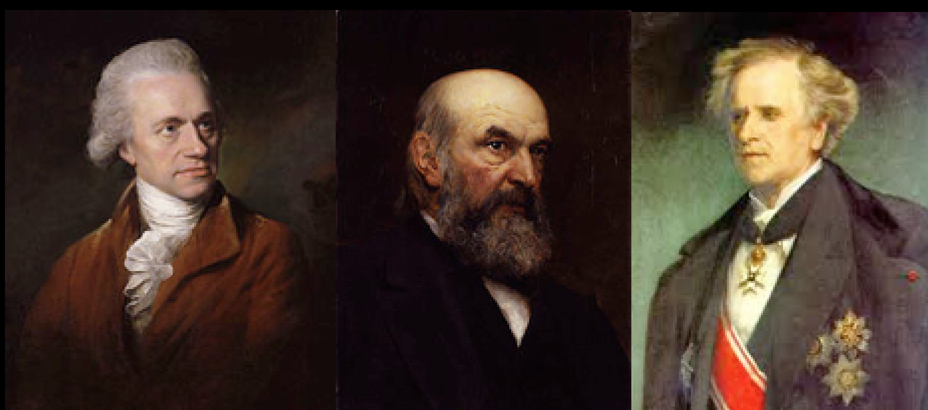
"There are more things in heaven and earth, Horatio, ..." – W. Shakespeare



"DARK" PLANETS

Dark Matter or Modified Gravity?

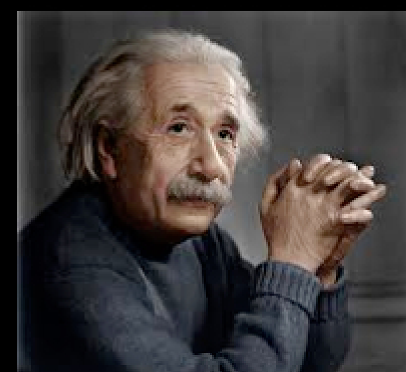
Uranus



"*There are more things in heaven and earth, Horatio, …*"

W. Shakespeare

Mercury

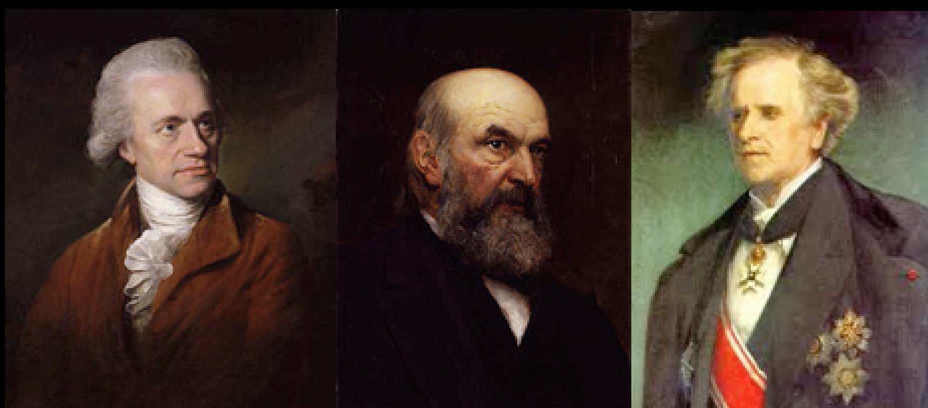


"*The invisible & the non-existent look very much alike.*"

Delos B. McKown

Dark Matter or Modified Gravity?

Uranus



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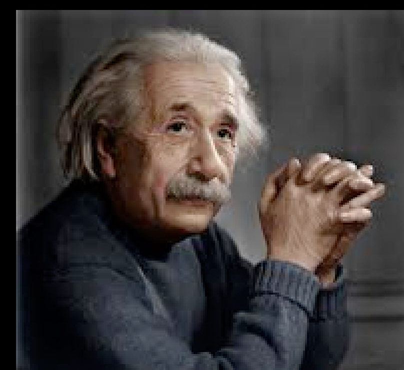
Mercury



"*The invisible & the non-existent look very much alike.*"

Delos B. McKown

Gravitational Lensing

Galaxy Cluster Abell 2218
Hubble Space Telescope • WFPC2

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

Dark Matter candidates

WIMPs

Weakly Interacting Massive Particles

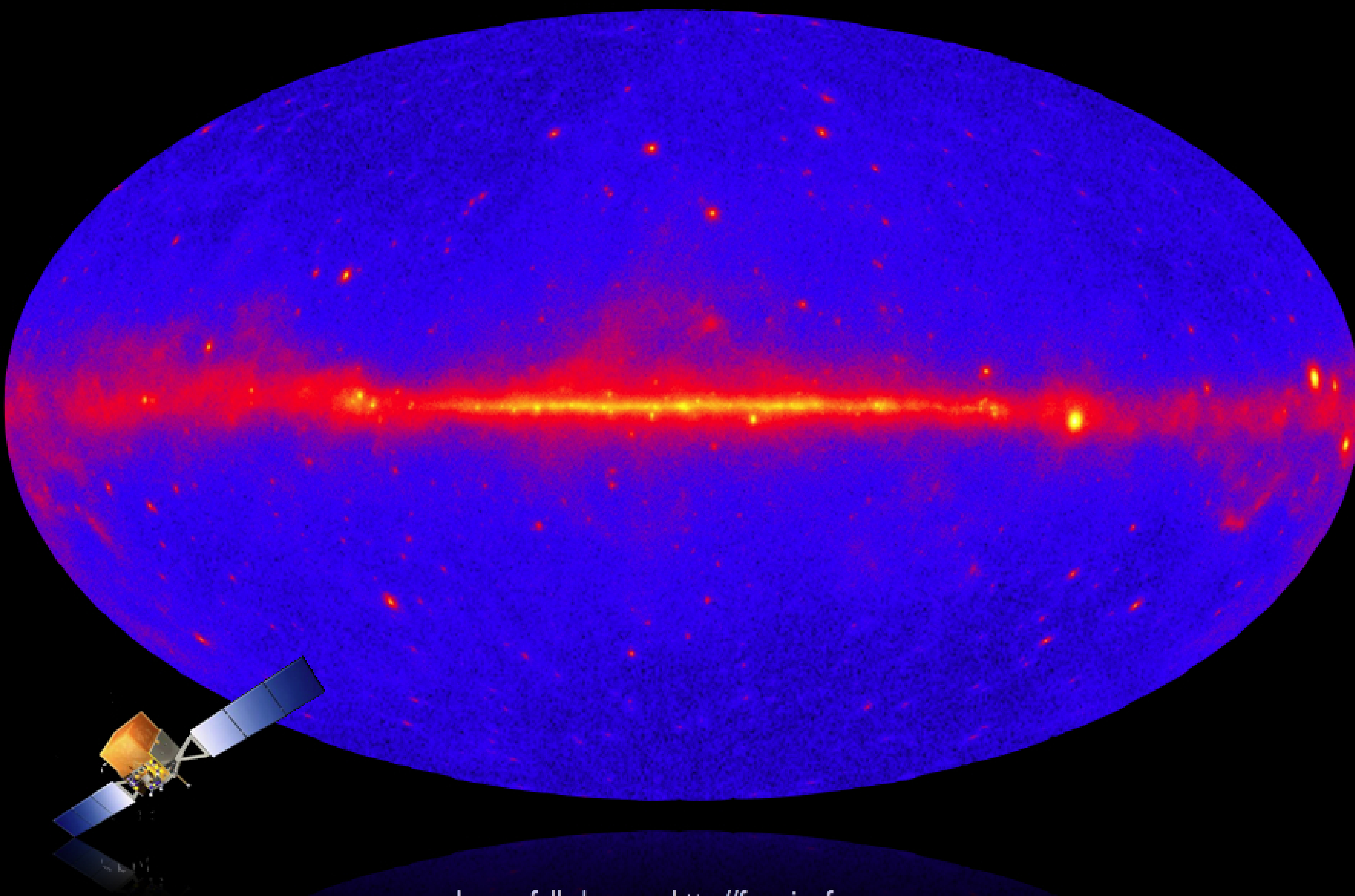
Natural Candidates: Arising 'as a bonus' from theories addressing the fundamental problems of particle physics

Ad-Hoc Candidates: Postulated to solve the DM Problem

Others

• Axions, Sterile Neutrinos, SuperWIMPs, WIMPless, Axino, Q-balls, etc.

The gamma-ray Sky



The 130 GeV Line

arXiv:1204.2797v2 [hep-ph] 8 Aug 2012

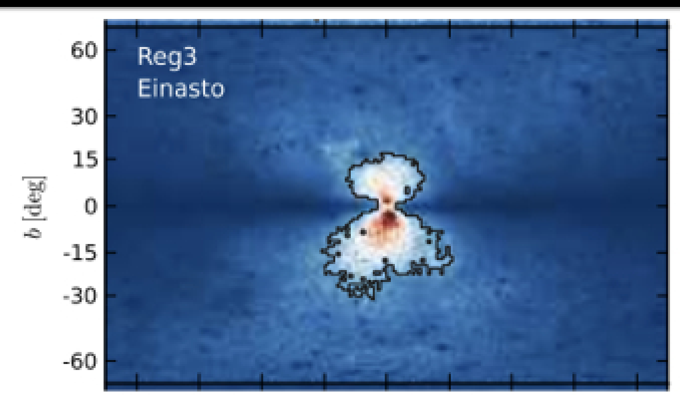
A Tentative Gamma-Ray Line from Dark Matter Annihilation at the Fermi Large Area Telescope

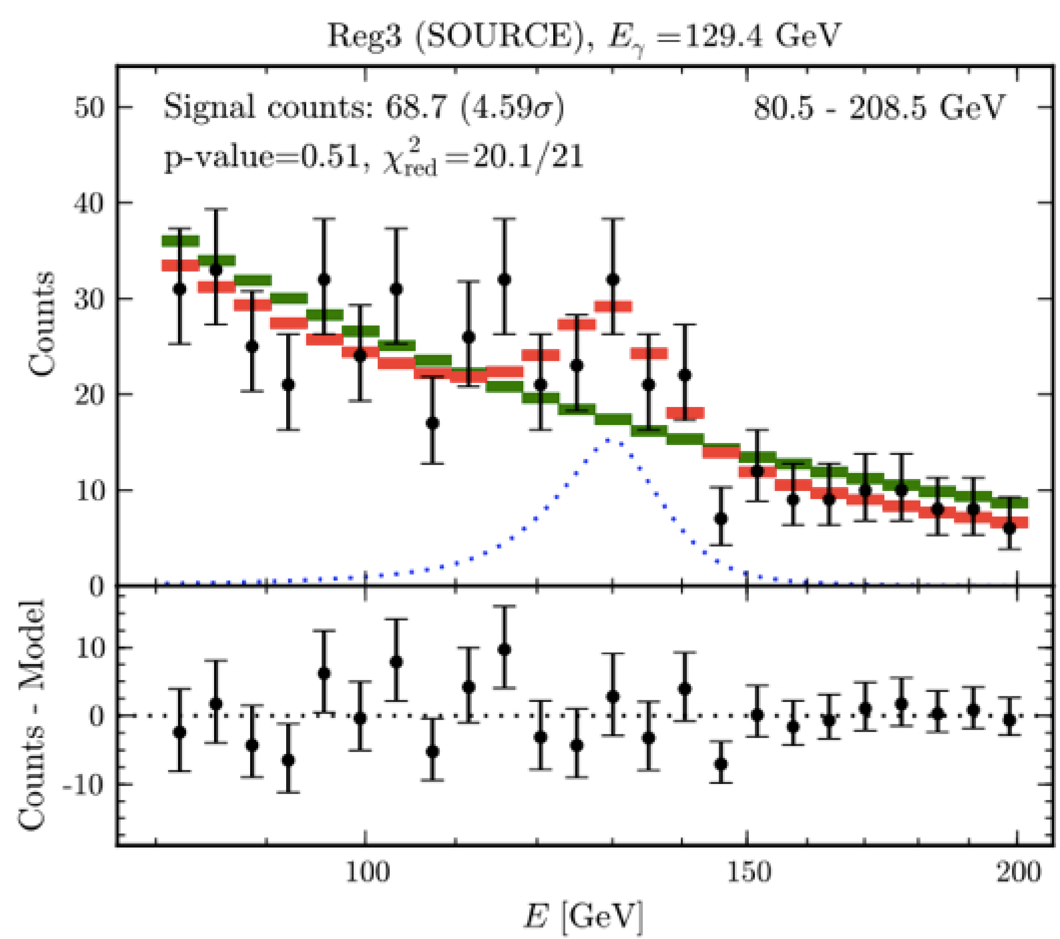
Christoph Weniger

Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany

E-mail: weniger@mppmu.mpg.de

Abstract. The observation of a gamma-ray line in the cosmic-ray fluxes would be a smoking-gun signature for dark matter annihilation or decay in the Universe. We present an improved search for such signatures in the data of the Fermi Large Area Telescope (LAT), concentrating on energies between 20 and 300 GeV. Besides updating to 43 months of data, we use a new data-driven technique to select optimized target regions depending on the profile of the Galactic dark matter halo. In regions close to the Galactic center, we find a 4.6σ indication for a gamma-ray line at $E_\gamma \approx 130$ GeV. When taking into account the look-elsewhere effect the significance of the observed excess is 3.2σ. If interpreted in terms of dark matter particles annihilating into a photon pair, the observations imply a dark matter mass of $m_\chi = 129.8 \pm 2.4^{+7}_{-13}$ GeV and a partial annihilation cross-section of $(\sigma v)_{\chi\chi\to\gamma\gamma} = (1.27 \pm 0.32^{+0.18}_{-0.28}) \times 10^{-27}$ cm^3 s^{-1} when using the Einasto dark matter profile. The evidence for the signal is based on about 50 photons; it will take a few years of additional data to clarify its existence.





The faint glow from the GC

arXiv:1204.2797v2 [hep-ph] 8 Aug 2012

A Tentative Gamma-Ray Line from Dark Matter Annihilation at the Fermi Large Area Telescope

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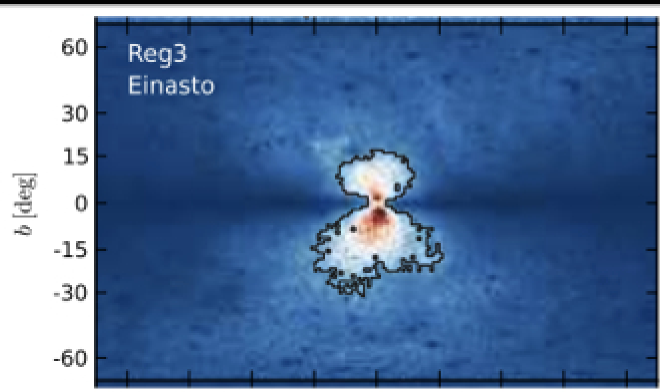
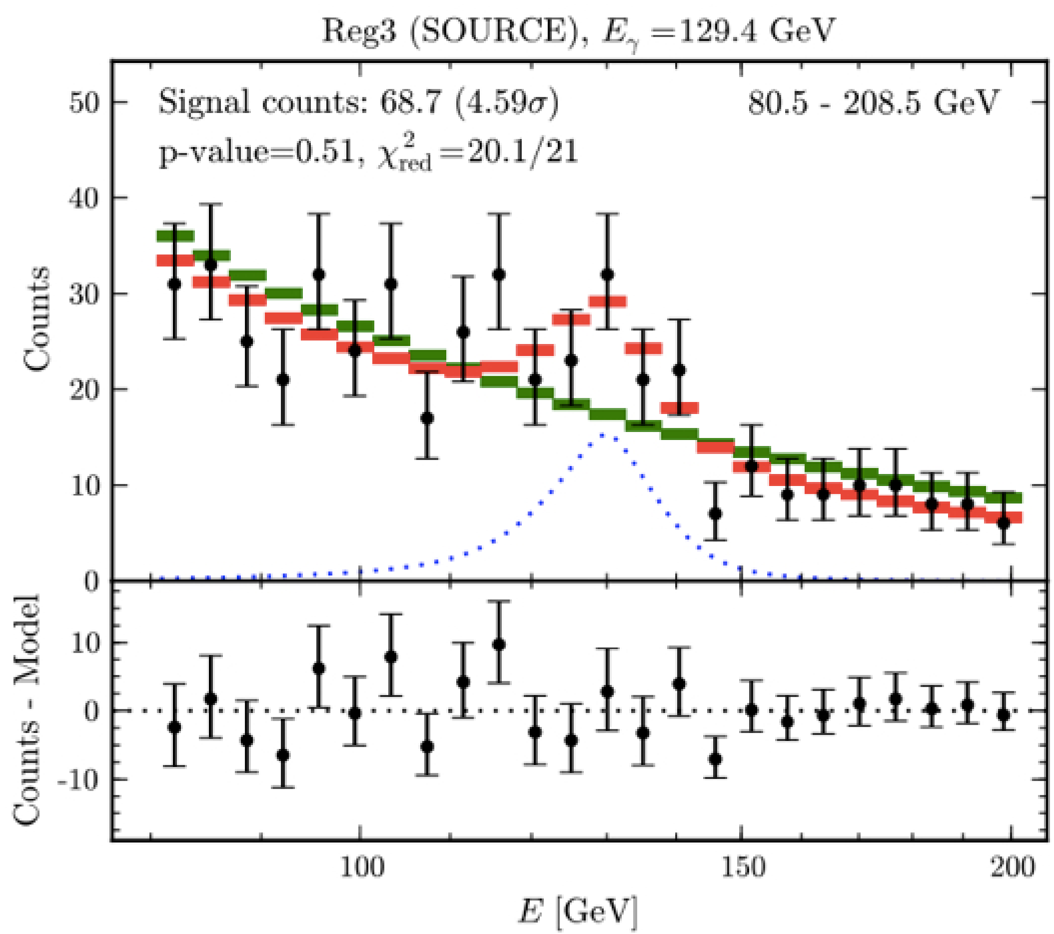
Abstract. The observation of a gamma-ray line in the cosmic-ray fluxes would be a smoking-gun signature for dark matter annihilation or decay in the Universe. We present an improved search for such signatures in the data of the Fermi Large Area Telescope (LAT), concentrating on energies between 20 and 300 GeV. Besides updating to 43 months of data, we use a new data-driven technique to select optimized target regions depending on the profile of the Galactic dark matter halo. In regions close to the Galactic center, we find a 4.6σ indication for a gamma-ray line at $E_\gamma \approx 130$ GeV. When taking into account the look-elsewhere effect the significance of the observed excess is 3.2σ. If interpreted in terms of dark matter particles annihilating into a photon pair, the observations imply a dark matter mass of $m_\chi = 129.8 \pm 2.4^{+7}_{-13}$ GeV and a partial annihilation cross-section of $\langle\sigma v\rangle_{\chi\chi\to\gamma\gamma} = (1.27 \pm 0.32^{+0.18}_{-0.28}) \times 10^{-27}$ cm^3 s^{-1} when using the Einasto dark matter profile. The evidence for the signal is based on about 50 photons; it will take a few years of additional data to clarify its existence.





How to cross-check?

The HESS-II telescope in Namibia