
cta
cherenkov telescope array

Probing physics beyond the standard model with CTA -

Summary
(better: introduction to the discussions)

Jim Hinton

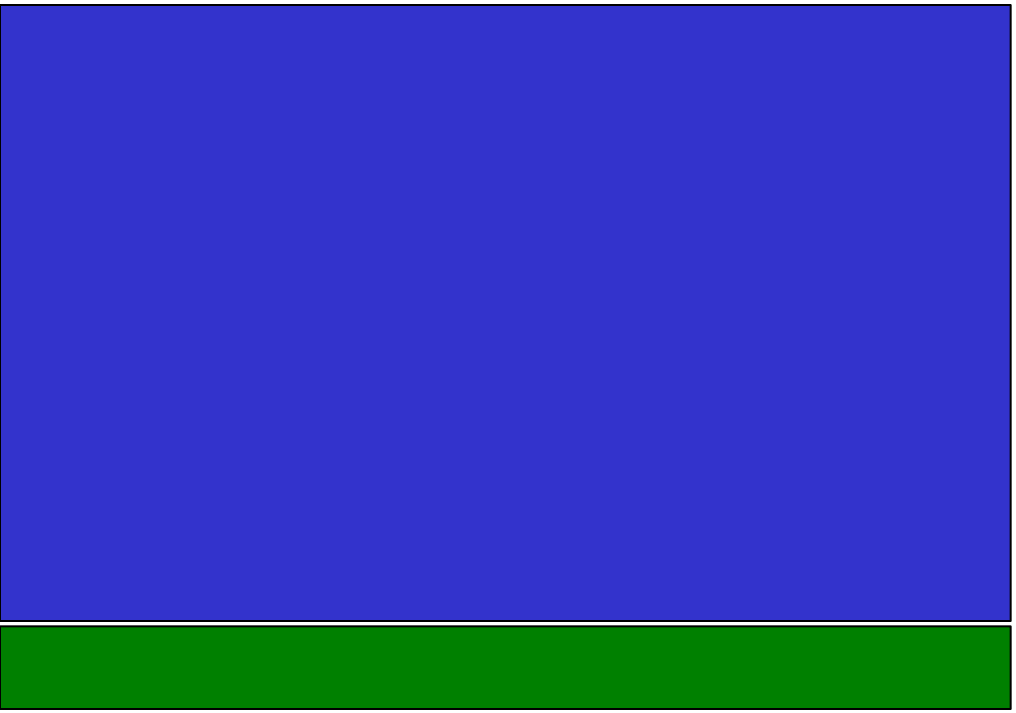
University of Leicester

Cosener's House, 12th Nov. 2010

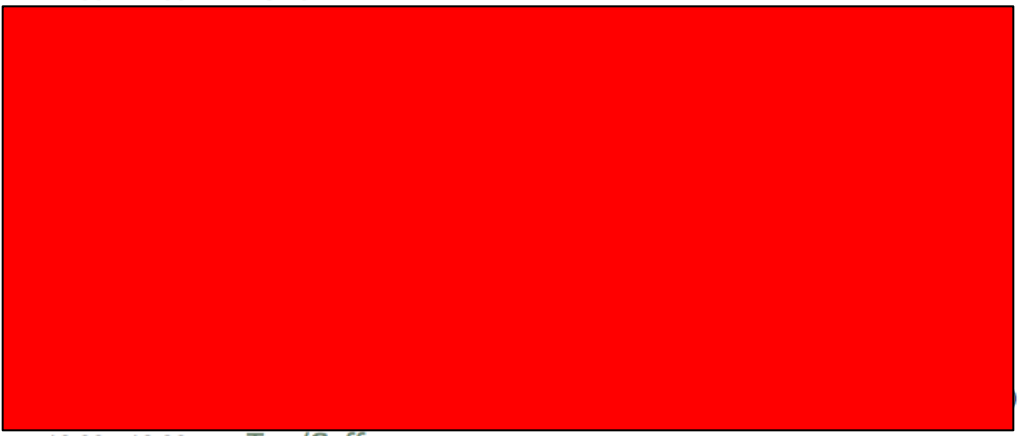
Friday 12 November 2010

09:00 - 09:05 Welcome *05'*

Speaker: Werner Hofmann (MPI Heidelberg)



12:35 - 14:00 Lunch



16:00 - 16:30 Tea/Coffee

16:30 - 17:00 Summary *30'*

Speaker: Jim Hinton (University of Leicester)

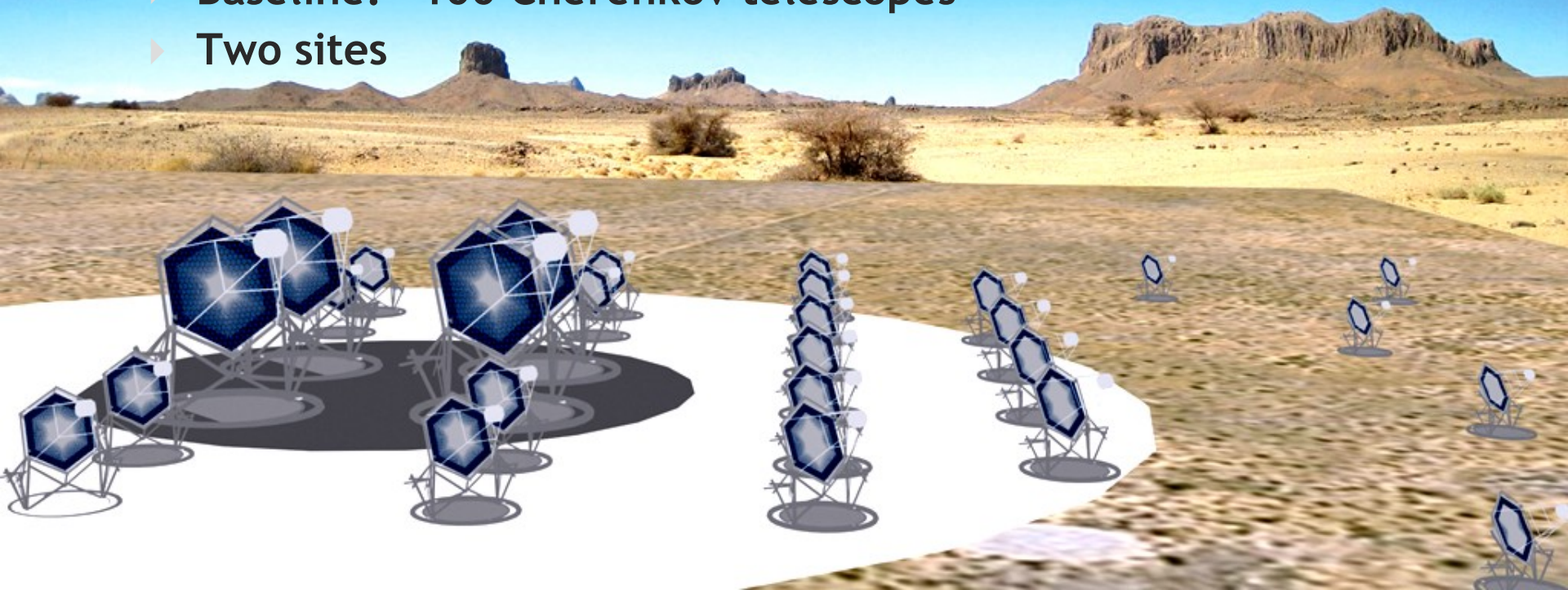
Themes

- Indirect Detection of Dark Matter
- Searches for Lorentz Invariance Violation

+Other (even more exotic stuff?)

The Cherenkov Telescope Array

- A factor 10 more sensitive than current instruments
  - Plus - much wider energy coverage, substantially better angular and energy resolution & wider field of view
- A ~€150M international project
  - Almost 700 people (220 here this week) in 24 countries
  - Design 2008-2011, Prototyping 2011-13, Construction 2013-18
  - Baseline: ~100 Cherenkov telescopes
  - Two sites



5 1st CTA LINK Workshop

- LINK?
  - Preparatory Phase of CTA
    - Successful FP7 proposal – €5.2M in EU support
  - LINK is a "Work Package"
    - "Linking with science communities towards refining and preparing the science goals and utilization of CTA"

- One **large international conference** (the first of a series?) towards months 20-24 of the FP7
  - i.e., towards or before September 2012)

- Two/three main communities and research problems to link with identified in FP7, for which smaller **workshop like conferences** are envisioned:
  - Dark matter / particle physicists and CTA
  - Linking with X-ray observatories and observers, common problems, future perspectives
  - Linking with GeV and neutrino observatories and observers: acceleration of particles from a MW perspective

From FP7 proposal – Diego Torres – LINK Coordinator

First LINK Workshop: Probing physics beyond the Standard Model with CTA

chaired by Gianfranco Bertone (IAP Paris) , Jan Conrad (Stockholm University) , Manel Martinez (IFAE Barcelona) , Subir Sarkar (University of Oxford)

Friday 12 November 2010 from **09:00** to **17:00** (GB)
at The Cosener's House, Abingdon

Description This workshop will take stock of the physics potential of the forthcoming Cherenkov Telescope Array regarding the detection of dark matter annihilation/decay signals, tests of Lorentz invariance violation and other new phenomena beyond the Standard Model.

On Thurday 11th November afternoon there will be a meeting of the Physics Working Group of the CTA Collaboration (*now moved to Rutherford Laboratory to accomodate everyone*), followed by an all-day workshop on Friday 12th November (at Cosener's House).

We acknowledge support by the "Astroparticle Physics Group" of the UK Institute of Physics and by the EU Framework Programme 7.

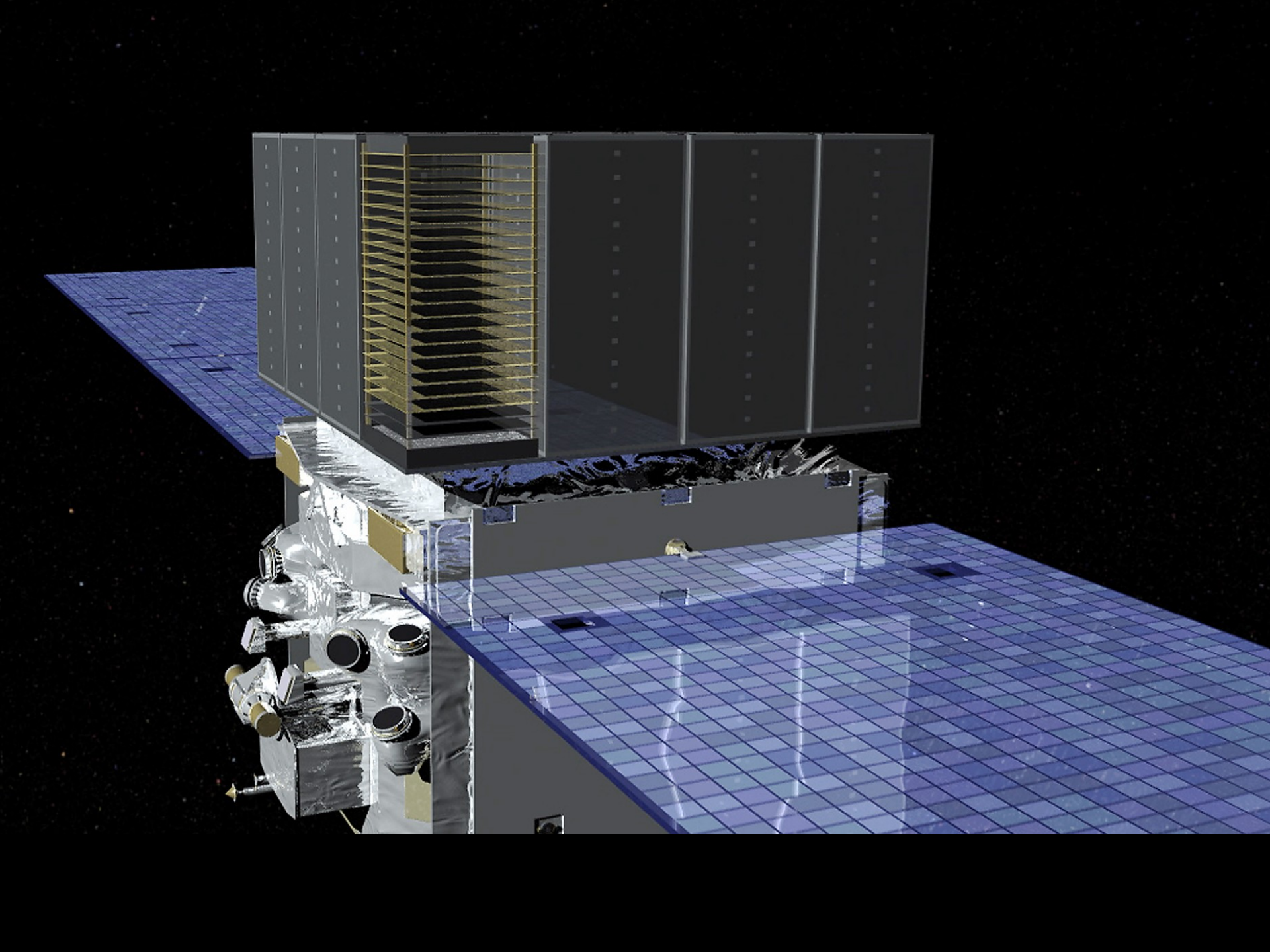
Participants Jelena Aleksic (Fri); Lucio Angelo Antonelli (Thu); Aya Bamba (Thu); Yvonne Becherini (Thu); Wlodek Bednarek (Thu); Wystan Benbow; Lars Bergstrom* (Fri); Adrian Biland; Steven BIller* (Fri); Catherine Boisson (Thu); Paul Brook; James Buckley; Tomasz Bulic (Fri); Rodolfo Canestrari (Thu); Matteo Cerruti; Sergio Colafrancesco*; David Colling* (Fri); Valerie Connaughton (Thu); Jose Luis Contreras (Thu); Heide Costantini (Fri); Michael Daniel; Elisabete de Gouveia Dal Pino (Thu); Okkie de Jager (Thu); Emma de Ona Wilhelmi (Thu); Federico Di Pierro (Thu); Arache Djannati-Atai (Thu); Michele Doro; Florent Dubois (Thu); John Ellis* (Fri); Dimitrios Emmanoulopoulos (Fri); Jean-Pierre Ernenwein (Thu); Alberto Etchegoyen (Thu); Christian Farnier; Lluis Font (Thu); Mads Toudal Frandsen (Fri); Beatriz Garcia (Thu); Nikola Godinovic; Jonathan Granot; Tim Greenshaw; German Hermann; Jim Hinton; Dirk Hoffmann (Thu); Werner Hofmann; Ben Huber; Susumu Inoue (Thu); Yoshiyuki Inoue (Thu); Kunihito Ioka (Thu); Agnieszka Jacholkowski; Tobias Jogler (Thu); Sonia Karkar (Thu); Karl Kosack (Fri); Luca Latronico* (Fri); Jean Philippe Lenain; Elina Lindfors (Thu); Saverio Lombardi ; Alicia Lopez Oramas (Thu); Eckart Lorenz; Aaron Manalaysay; Sera Markoff (Thu); Manel Martinez; David Maurin* (Fri); Philipp Mertsch ; Néstor Mirabal (Thu); Felix Mirabel (Thu); Abelardo Moralejo Olaizola; Emmanuel Moulin* (Thu); Christopher Naumann; Jacek Niemiec (Thu); Kyoshi Nishijima (Fri); Paul O'Brien; Akira Okumura; Julian Osborne; Michal Ostrowski; Igor Oya (Thu); Giovanni Pareschi (Thu); Giovanna Pedaletti; Irene Puerto Gimenez (Thu); Michael Punch (Thu); Olaf Reimer (Thu); Joachim Ripken; Bronislaw Rudak ; Cameron Rulten; Takayuki Saito (Thu); Federico Sanchez (Thu); Subir Sarkar; Cornelia Schultz; Anneli Schulz (Thu); Ullrich Schwanke; Thomas Schweizer (Thu); Maksim Shayduk; Aimo Sillanpaa (Thu); Hélene Sol; Roberta Sparvoli (Fri); Victor Stamatescu (Thu); Tim Sumner* (Fri); Hajime Takami (Thu); Diego Torres; Justin Vandenbroucke; Stefano Vercellone (Thu); Jacco Vink; Robert Wagner; Stefan Wagner; Scott Wakely (Thu); Alan Watson; Amanda Weinstein (Thu); Richard White; David Williams (Thu); Ralph Wischnewski

- A truly international workshop
  - Italy, France, Germany, Poland, UK, USA, Switzerland, Japan, Spain, Sweden, Finland, Netherlands, …
- And not all of you are in CTA!










z=0.0
Cold Dark Matter simulations (Via Lactea II , J. Diemand & al, 2008)
Lars Bergström
If this dark matter-only simulation is right, there should be lots of clumps of Cold Dark Matter in the halo of the Milky Way! Also, the highest DM density near the galactic center
80 kpc

z=0.0

Cold Dark Matter simulations (Via Lactea II , J. Diemand & al, 2008)

For annihilation $F_\gamma \propto V\, n^2 / d^2 \propto M_{halo}\, n / d^2$

- Galaxy clusters
  - Very massive (but far!)
- The Galactic Centre / Halo
  - Nearby and massive (but other γ-ray sources)
  - Very extended emission tricky for IACTs
- Dwarf Galaxies
  - Relatively nearby, very high mass to light ratios

Uncertainty in halo shape
Astrophysics factor – J
(or for a non-ideal detector Jeff)
Is a big issue

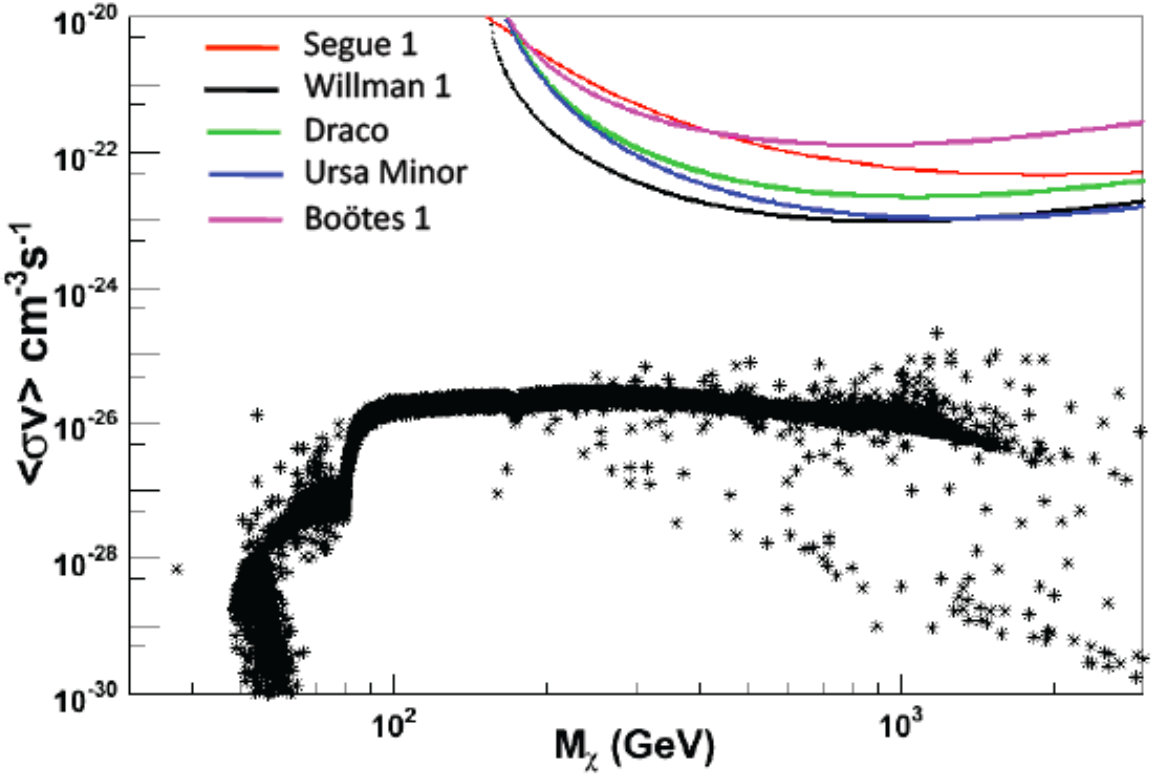
If this dark matter-only simulation is right, there should be lots of clumps of Cold Dark Matter in the halo of the Milky Way! Also, the highest DM density near the galactic center

80 kpc

Particle Constraints

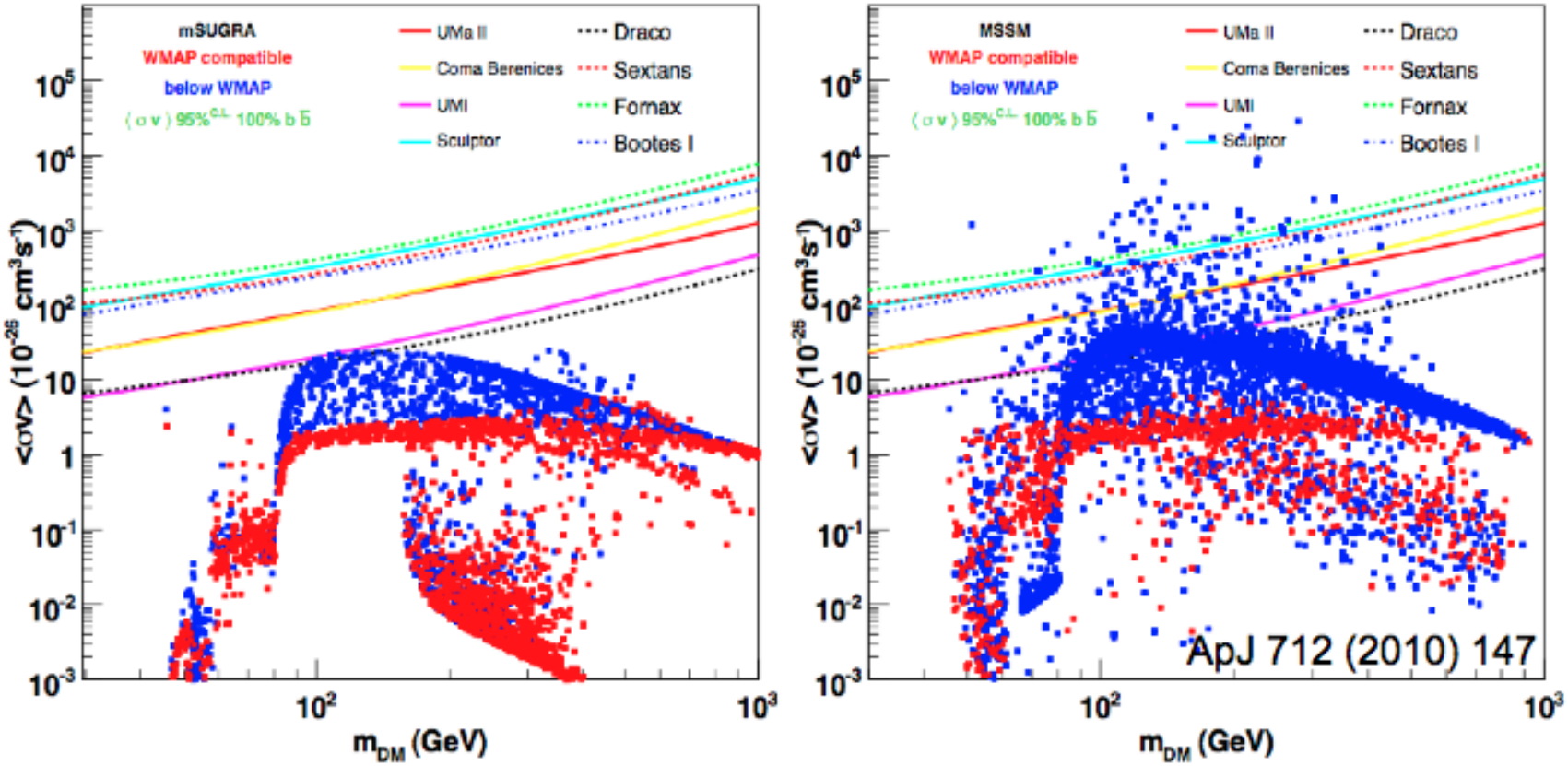
$$\frac{R_\gamma(95\%\ \mathrm{C.L.})}{\mathrm{hr}^{-1}} > \frac{J}{1.09\times10^4}\left(\frac{\langle\sigma v\rangle}{3\times10^{-26}\mathrm{cm}^3\mathrm{s}^{-1}}\right) \times\int_0^\infty \frac{A(E)}{5\times10^8\mathrm{cm}^2}\left(\frac{300\ \mathrm{GeV/c}^2}{m_\chi}\right)^2\frac{EdN/dE(E,m_\chi)}{10^{-2}}\frac{dE}{E}$$

- MSSM model points from DarkSUSY within 3 standard deviations of WMAP relic density.
- 95% CL upper limits



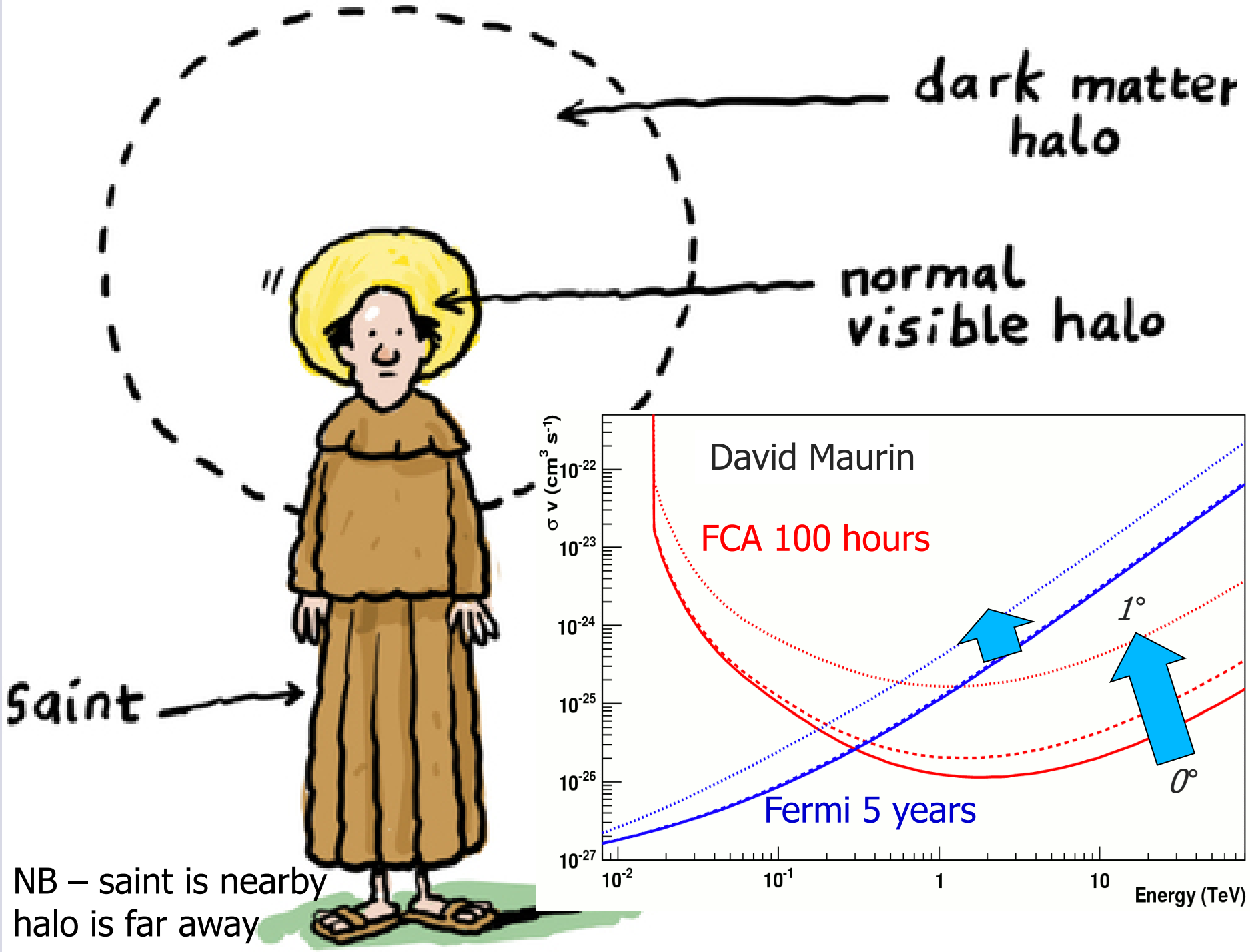
From Jm Buckley

DM models constraints from dSphs



Red points are models with a cosmological WIMP thermal relic density compatible with WMAP data

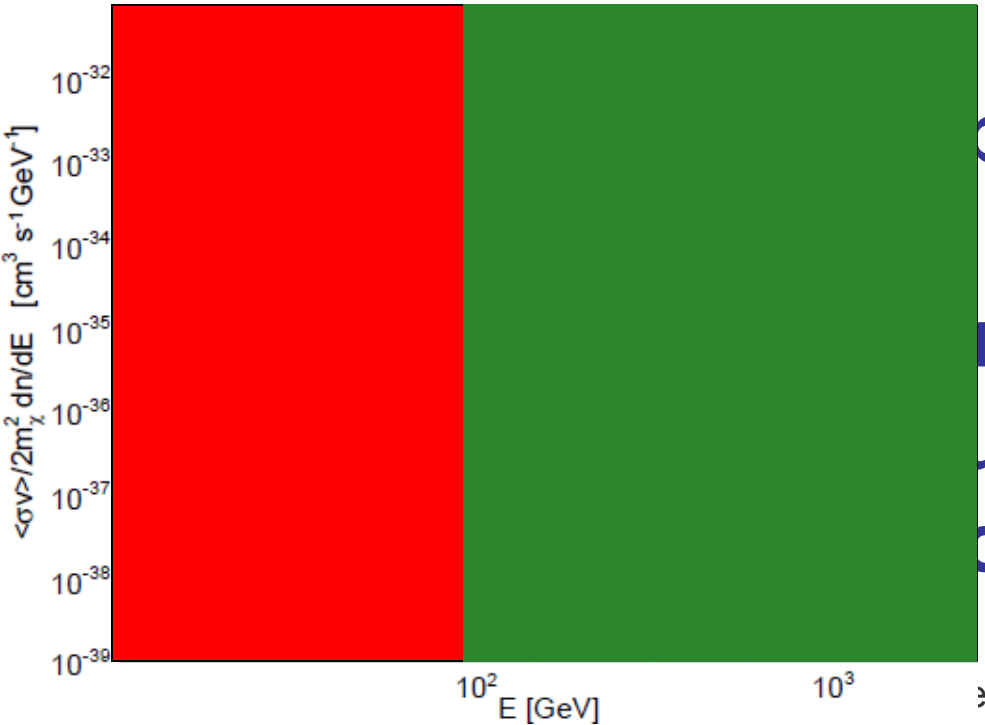
Work in progress to combine all dwarfs into a single limit (expected sensitivity improvement on flux ~40% TBC)



NB – saint is nearby
halo is far away

UFOs Unidentified Fermi Objects

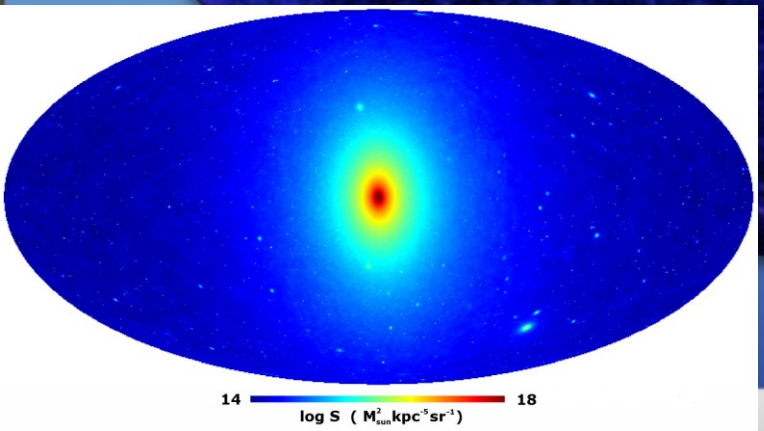
smoking gun: Fermi finds several objects
- without counterpart in other wavelengths
- all having same spectrum
(spectrum compatible with a DM model ?)



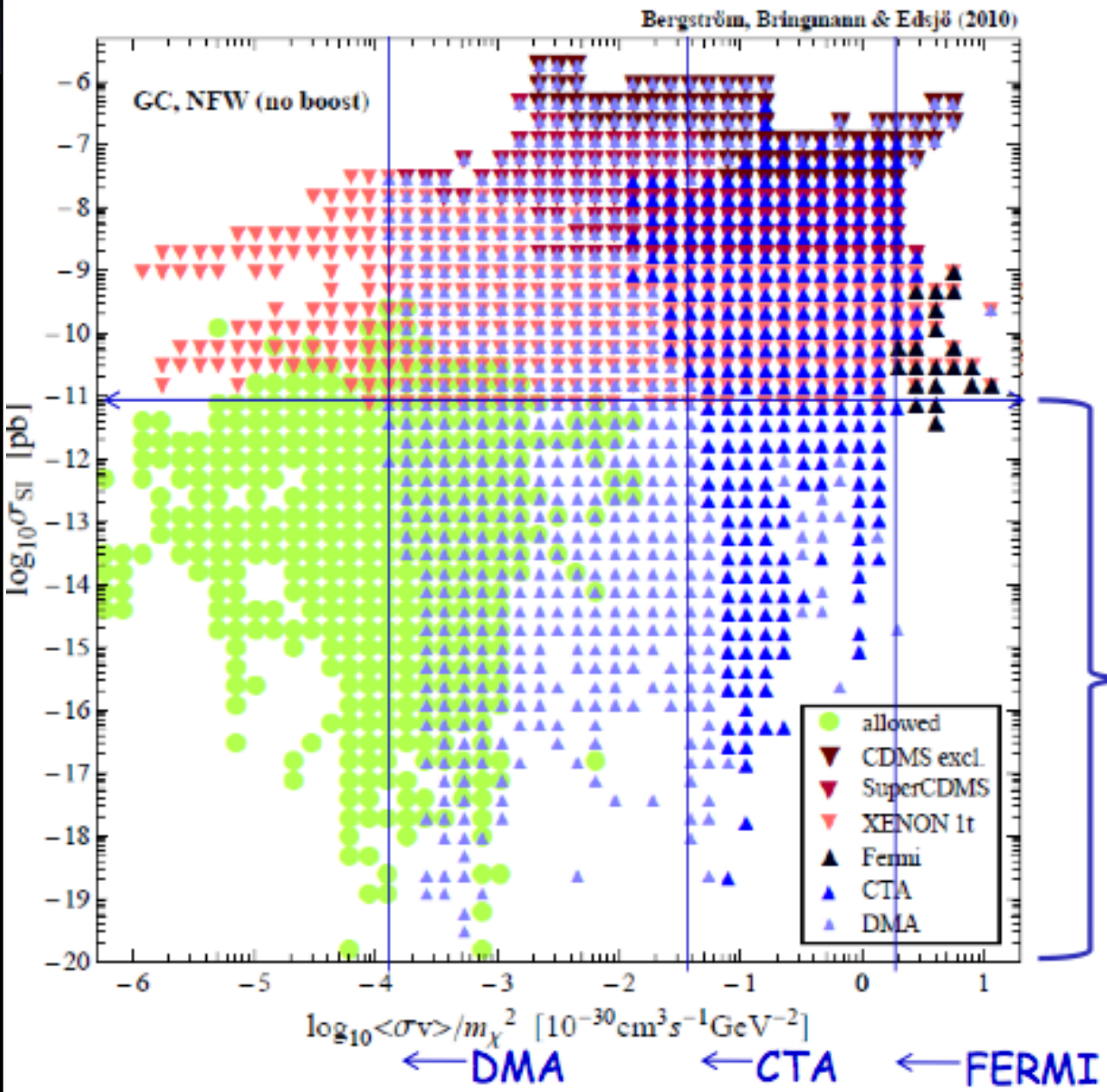
probably,
energy range
fficient to
re spectrum
cially cutoff)

Unidentified Fermi Objects

- Fermi-LAT long-term data ideal dataset
- Emerge as otherwise dark and thus unid sources



1FGL 1452 Sources



Assume background according to S. Digel, Fermi Symposium, 2009 (extrapolated as power-law for E > 100 GeV).

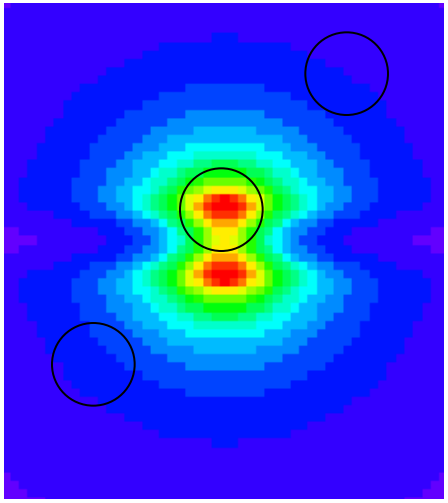
Check if $S/(S+B)^{0.5} > 5$ in the "best" bin (and demand $S > 5$)

9 orders of magnitude in direct detection cross section - usually not shown!

Lars Bergström

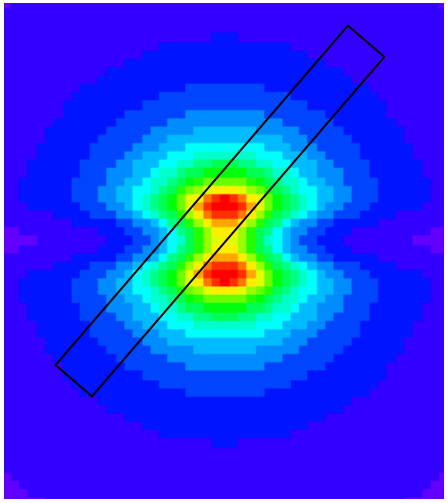
Observation Modes

ON-OFF mode: Use an offset in RA



- Same zenith/azimuth angle range covered
- Standard operation mode
- More exposure close to GC
- Exposure only at selected positions

Drift-scan mode: Point telescopes to zenith and take data

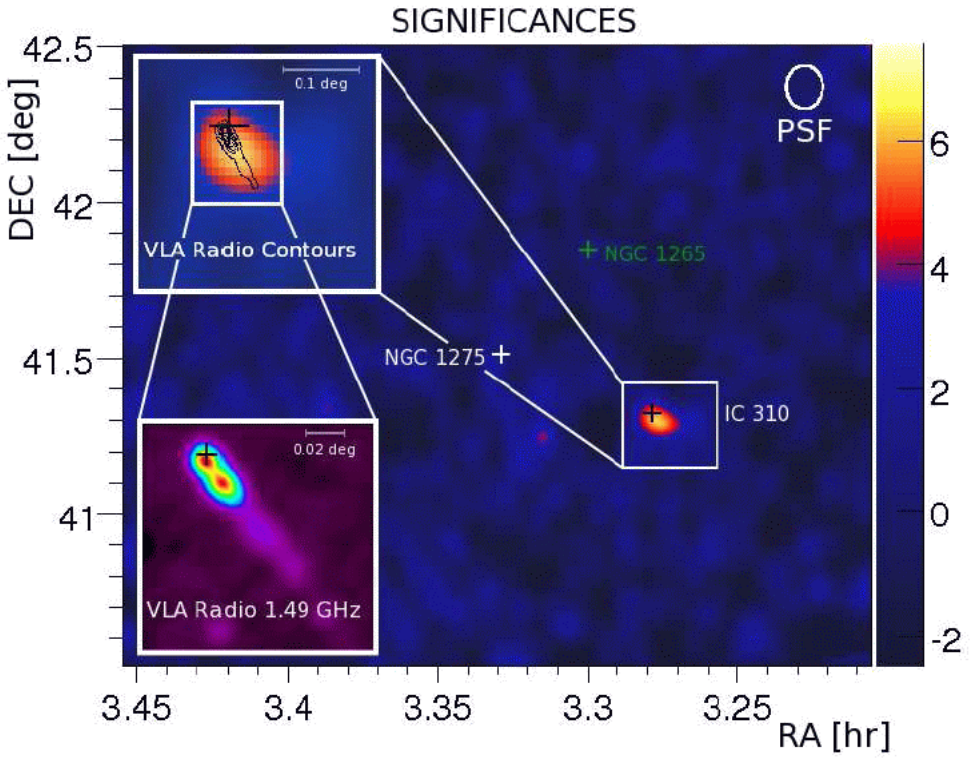


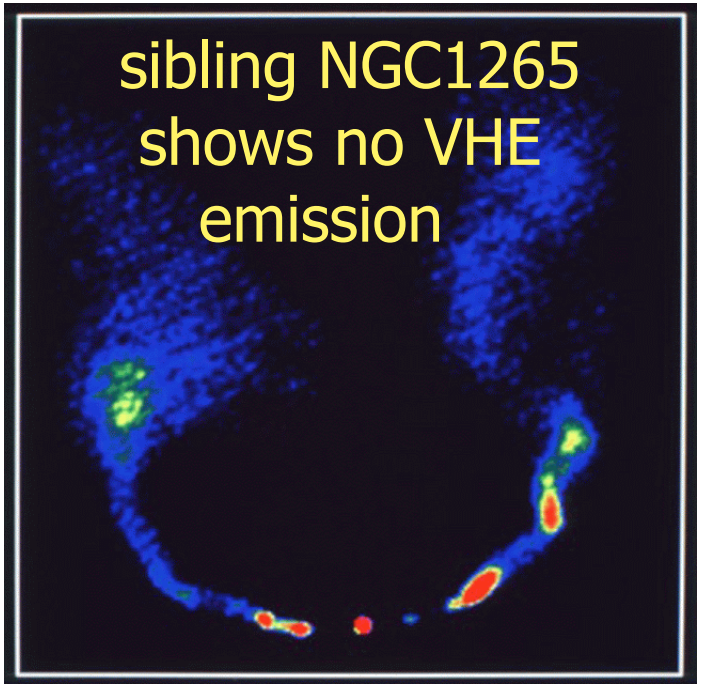
- Truly constant acceptance!
- Data (probably) not (easily) usable for existing analyses
- Less exposure close to GC
- Smooth exposure profile
- No tracking errors ;-)

Perseus Cluster / IC310

MAGIC: ApJ 723, L207 (2010)

2010 Stereo Observation:





serendipity detection of first head-tail galaxy (VHE emission from shock-waves or AGN ?)

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biland@phys.ethz.ch

Comparison between reaches of direct and indirect detection through gamma-rays

Lars Bergström

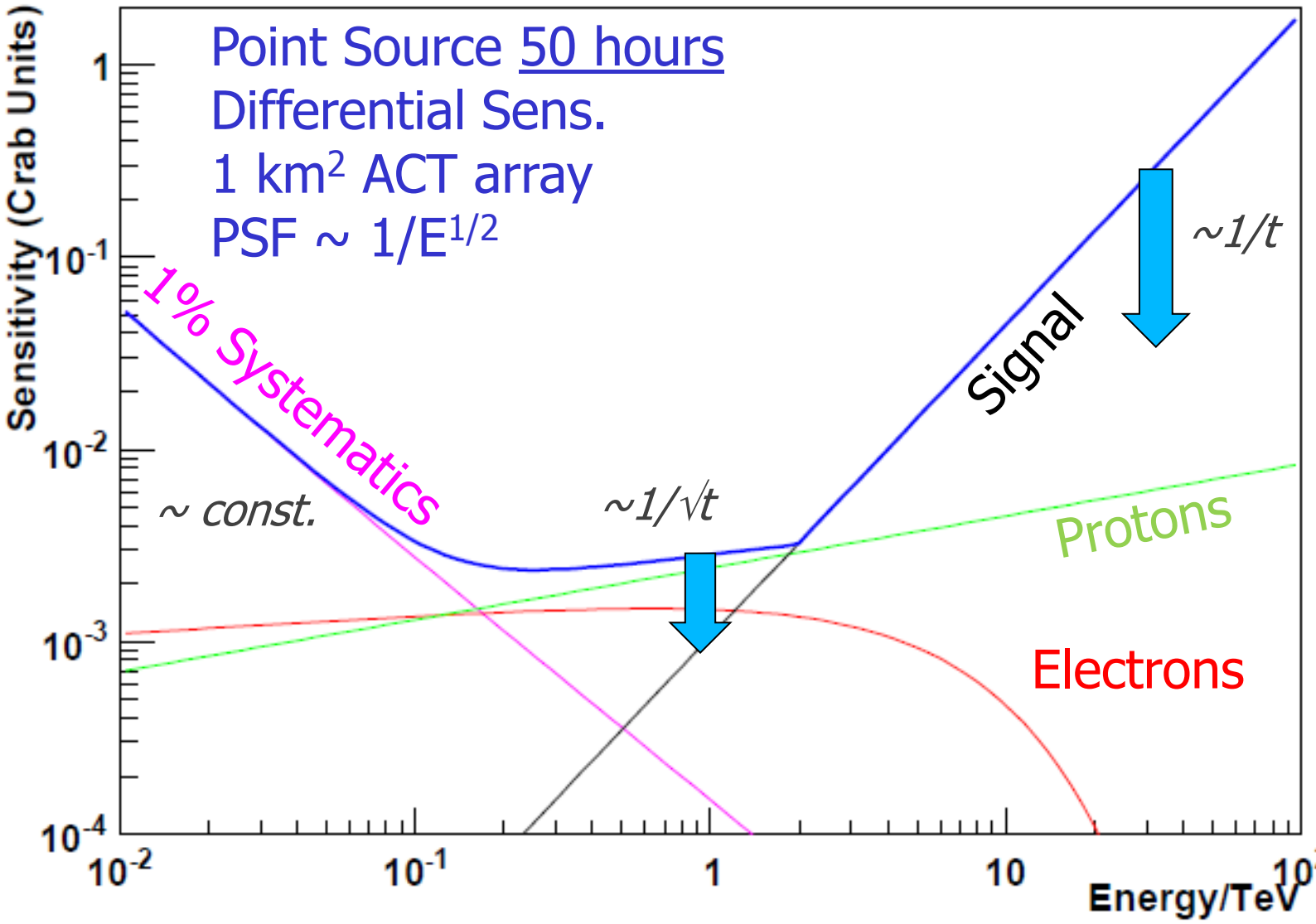
DMA - The Dark Matter Array: A dedicated detector for indirect detection of Dark Matter?

Parameters for the first try of this thought experiment:

Area = 10 x CTA
Exposure time (over 10 years) 5000 h
Energy threshold 10 GeV
PSF 0.02° (as CTA), but 0.1° below 40 GeV. Maybe a SuperCTA at the ALMA site?

This would be a particle physics experiment (Cost: 1000 MEUR ? Roughly one year of CERN running cost...)

20 Toy Model Sensitivity

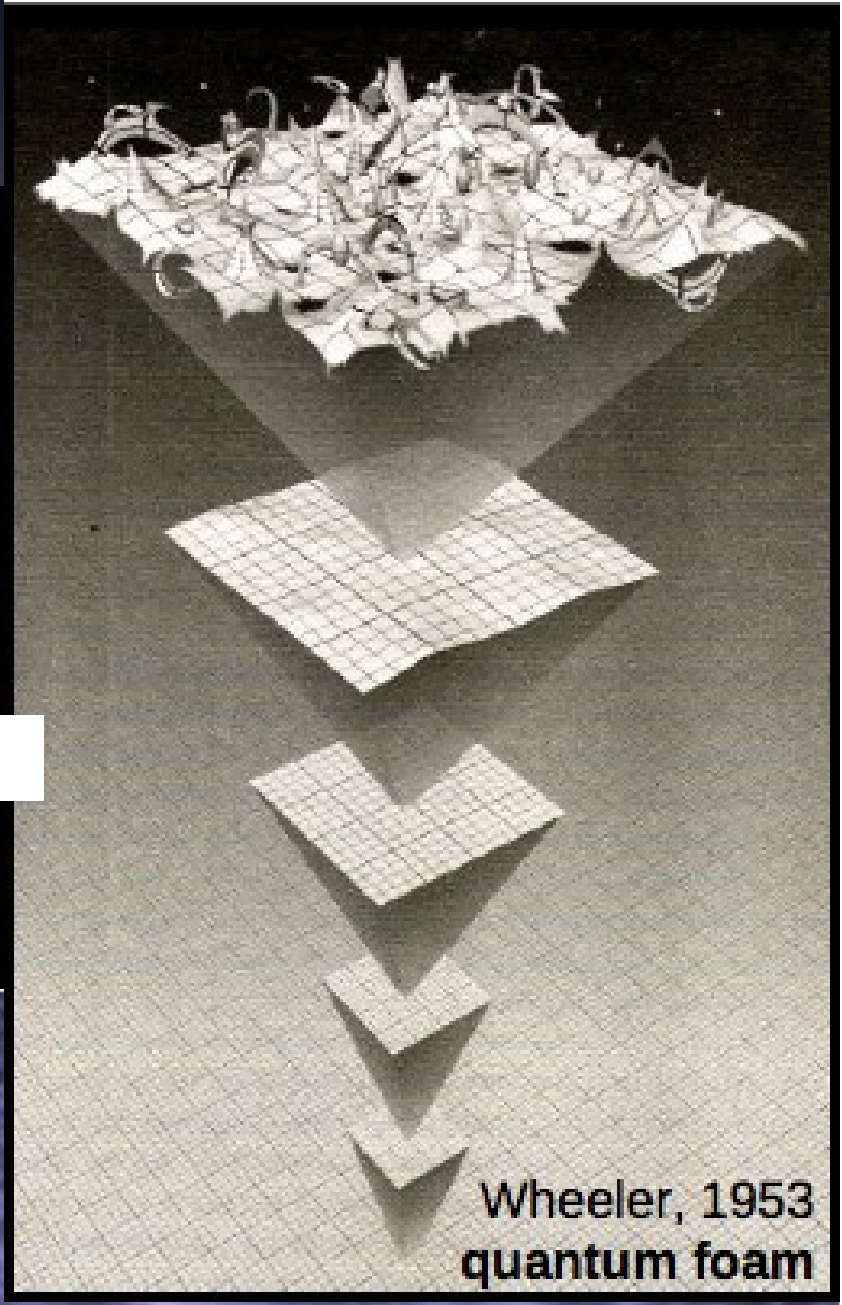


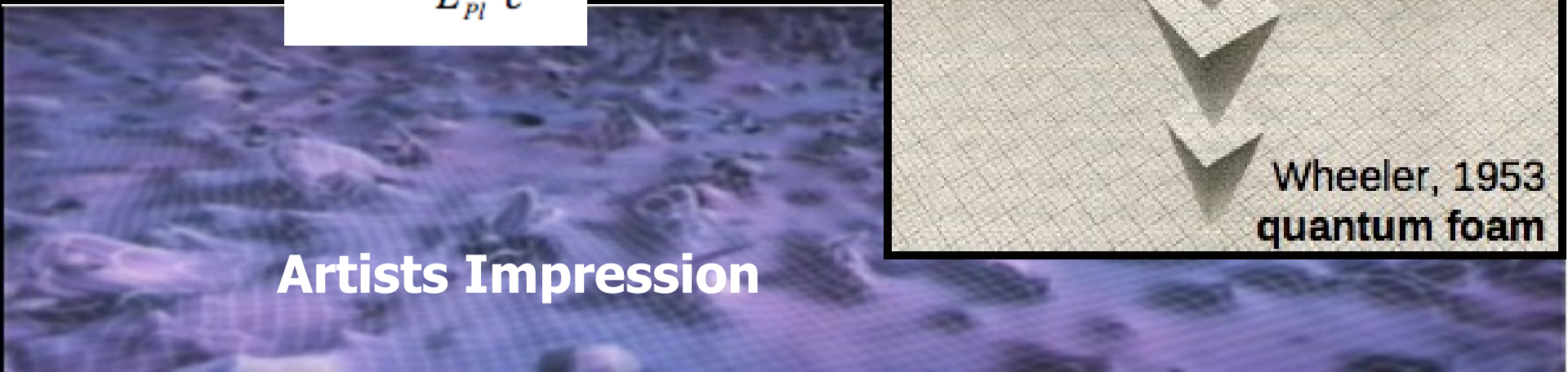
21 Photon Racing

- Possible consequence of Quantum Gravity:
- Time-of-flight differences for very high energy (approaching E_p) photons?

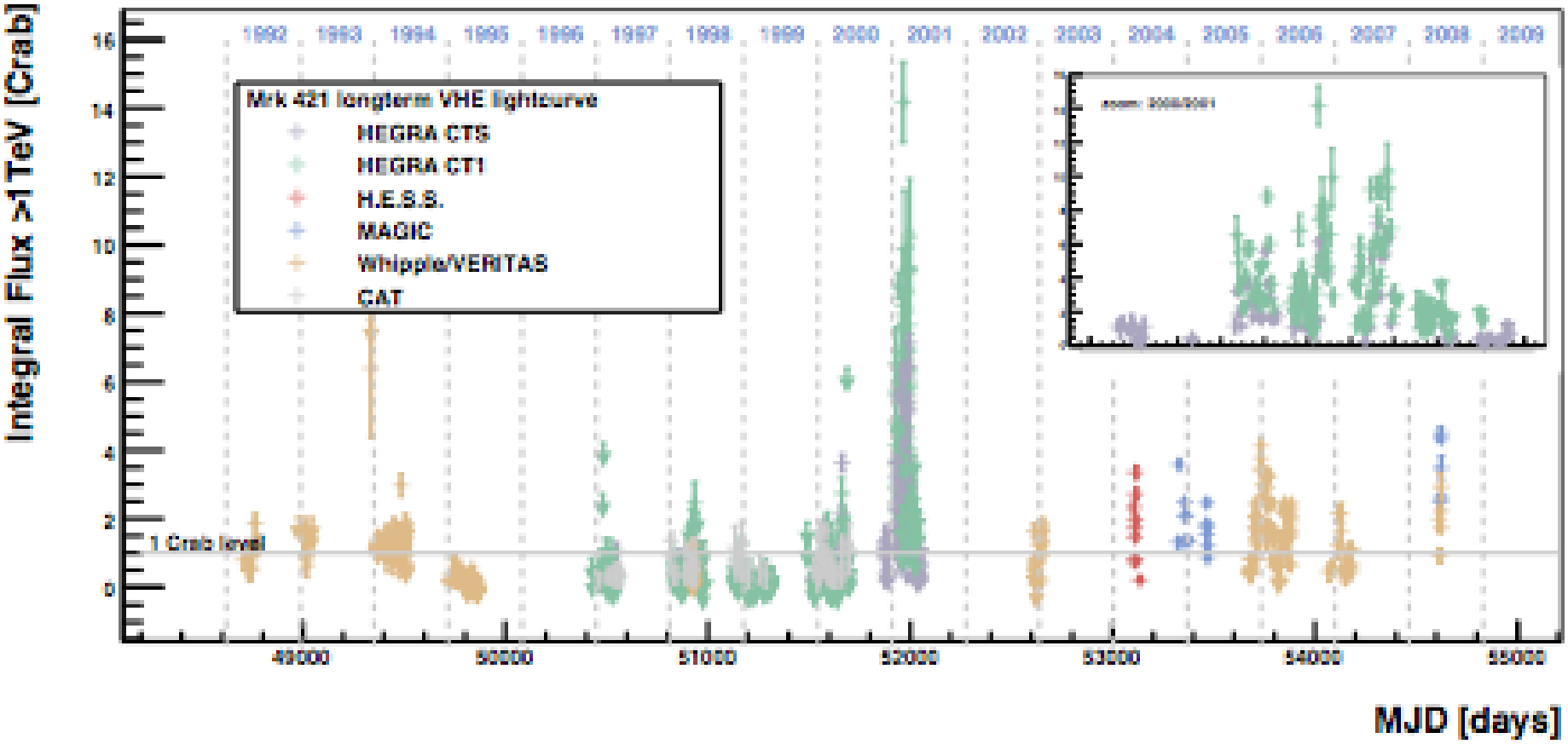
$$v = \delta E / \delta \vec{p} = c(1 - \xi (E/E_p) + \zeta (E/E_p)^2)$$

$$\delta t \approx \xi \frac{\Delta E}{E_{Pl}} \frac{L}{c}$$





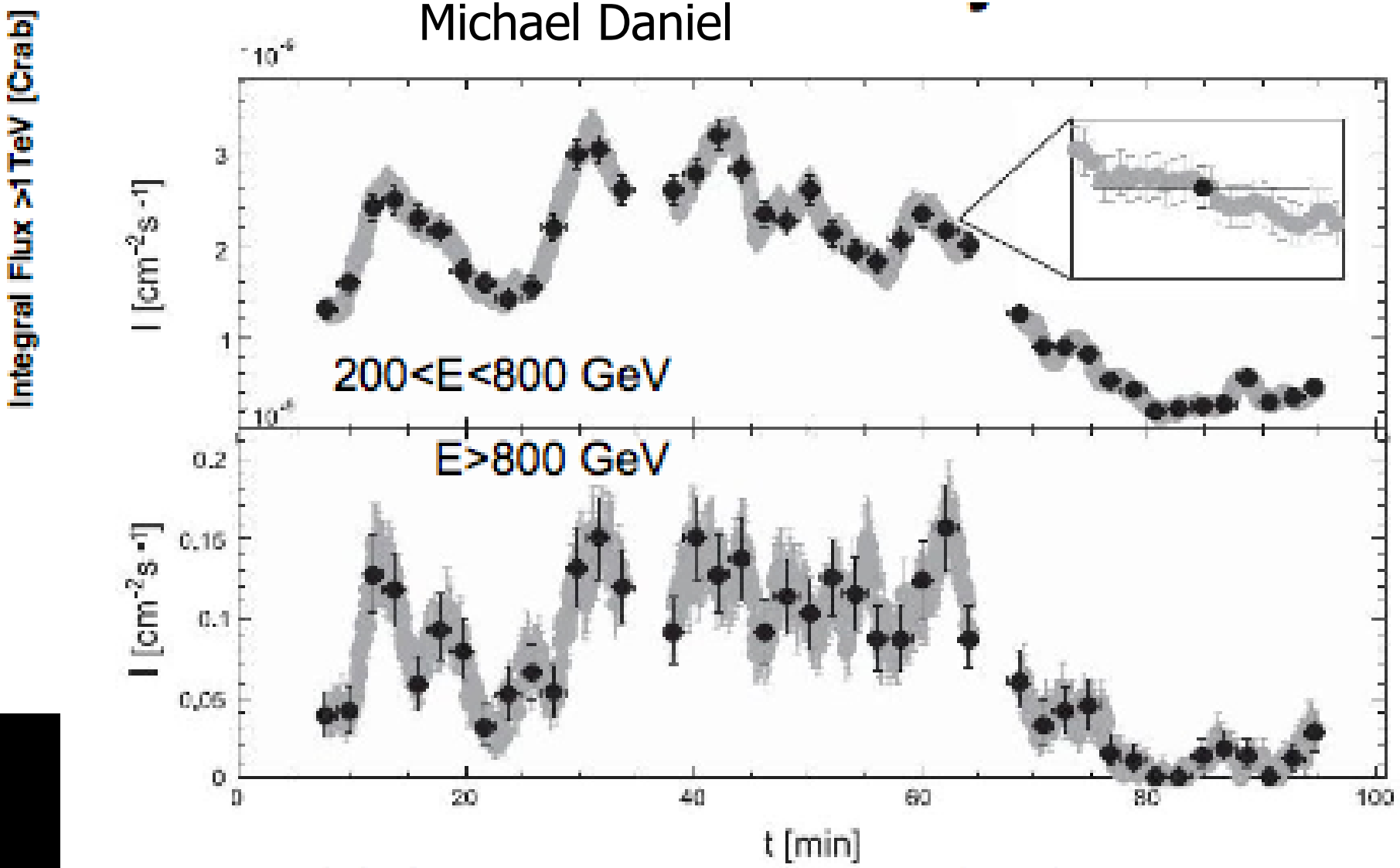
22 TeV Blazars



Dimitrios Emmouloulos

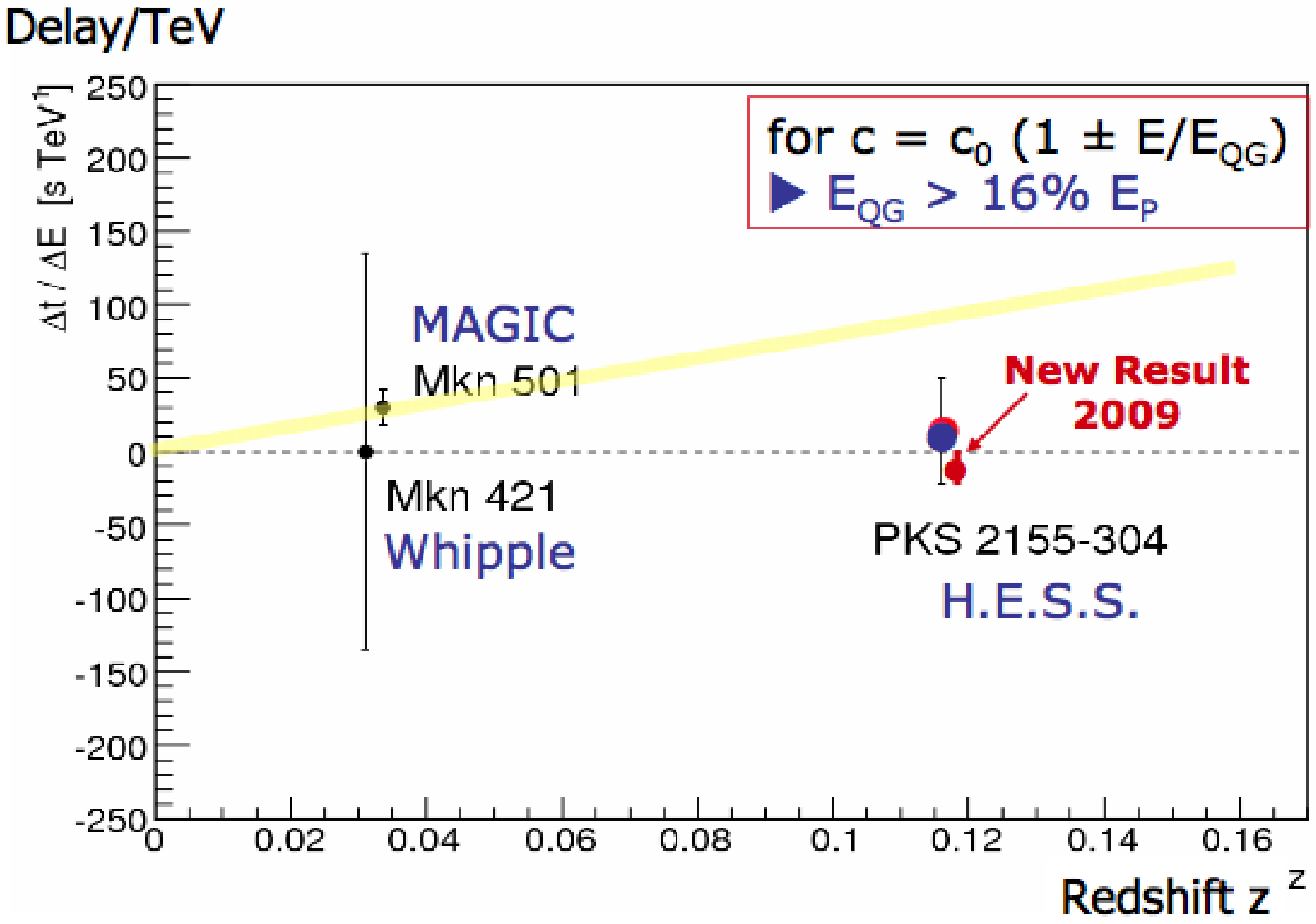
TeV Blazars

Michael Daniel



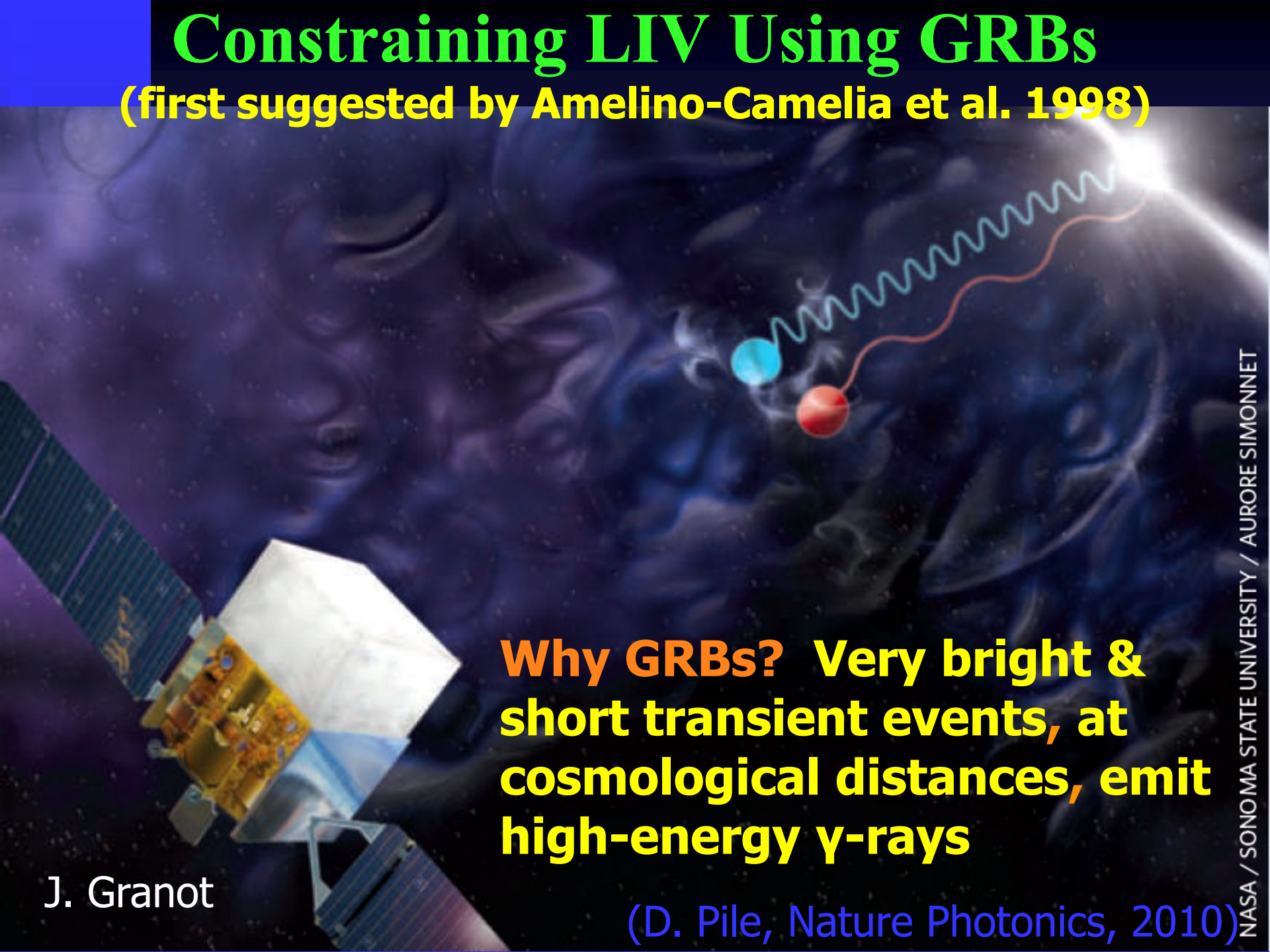
H.E.S.S. Collaboration *PRL* **101**, 170402 (2008).

AGN limits on LI Violation mass scales



Constraining LIV Using GRBs

(first suggested by Amelino-Camelia et al. 1998)



Why GRBs? Very bright & short transient events, at cosmological distances, emit high-energy γ-rays

J. Granot

(D. Pile, Nature Photonics, 2010)

NASA / SONOMA STATE UNIVERSITY / AURORE SIMONNET

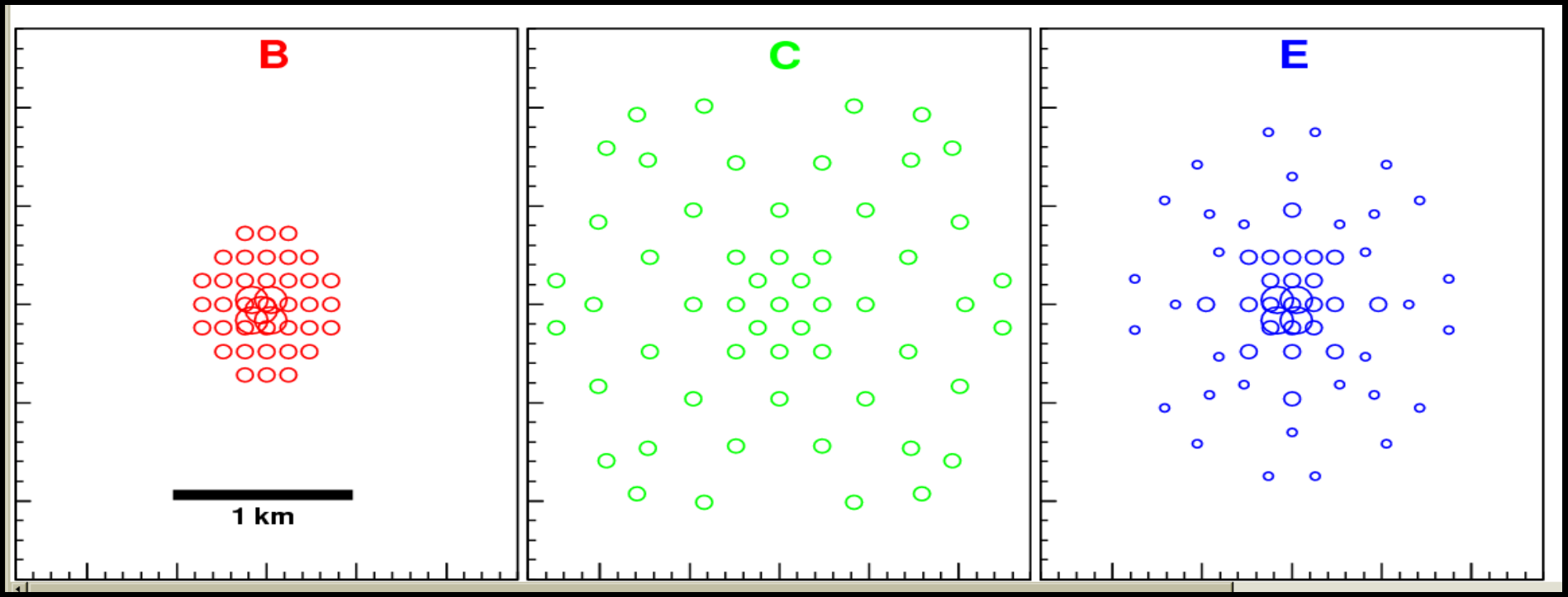
Present results from T-o-F studies

Source	Experiment	Method	Results linear, quadratic (GeV)
Mrk 421	Whipple	Likelihood	$E_{QG} > 0.6 \times 10^{17}$
Mrk 501	MAGIC	ECF + Likelihood	$E_{QG} > 0.3 \times 10^{18}$, $> 0.3\ 10^{11}$
PKS 2155-304	H.E.S.S.	MCCF + Wavelets + Likelihood	**$E_{QG} > 2.1 \times 10^{18}$, $> 0.5\ 10^{11}$**
GRB 021206	RHESSI	Fit + Mean arrival time in a spike	$E_{QG} > 1.5 \times 10^{17}$
GRB 080916C	Fermi GBM + LAT	Δt = t(Photon with highest E) – t_0	$E_{QG} > 1.5 \times 10^{18}$
GRB 090510	Fermi GBM + LAT	CCF, cost function/Shannon	**$E_{QG} > 1.2 \times 10^{19}$, $> 0.5\ 10^{11}$**
9 GRBs	BATSE + OSSE	Wavelets	$E_{QG} > 0.6 \times 10^{16}$
15 GRBs	HETE-2	Wavelets	$E_{QG} > 0.4 \times 10^{16}$
17 GRBs	INTEGRAL	Likelihood	$E_{QG} > 0.4 \times 10^{11}$
35 GRBs	BATSE + HETE-2 + SWIFT	Wavelets	$E_{QG} > 1.4 \times 10^{16}$
CRAB pulsar	EGRET	Δt of photons > 2 GeV	$E_{QG} > 0.2 \times 10^{16}$

The exotic tour

- Tau-neutrino searches
- Axions searches
- Magnetic monopoles
- Gravitational waves
- CR searches

28 Optimisation?



- What does this mean for the design of CTA?
  - Complex optimisation – need quantitative studies
- A range of array options exist and can be tested
  - Collection area/precision/energy-range trade-offs

29 Final Remarks

- Lots of ideas and lots of potential – especially for Dark Matter and LIV science with CTA
  - Your input is needed to make sure we design the right kind of instrument to maximise the discovery space

- Let's discuss