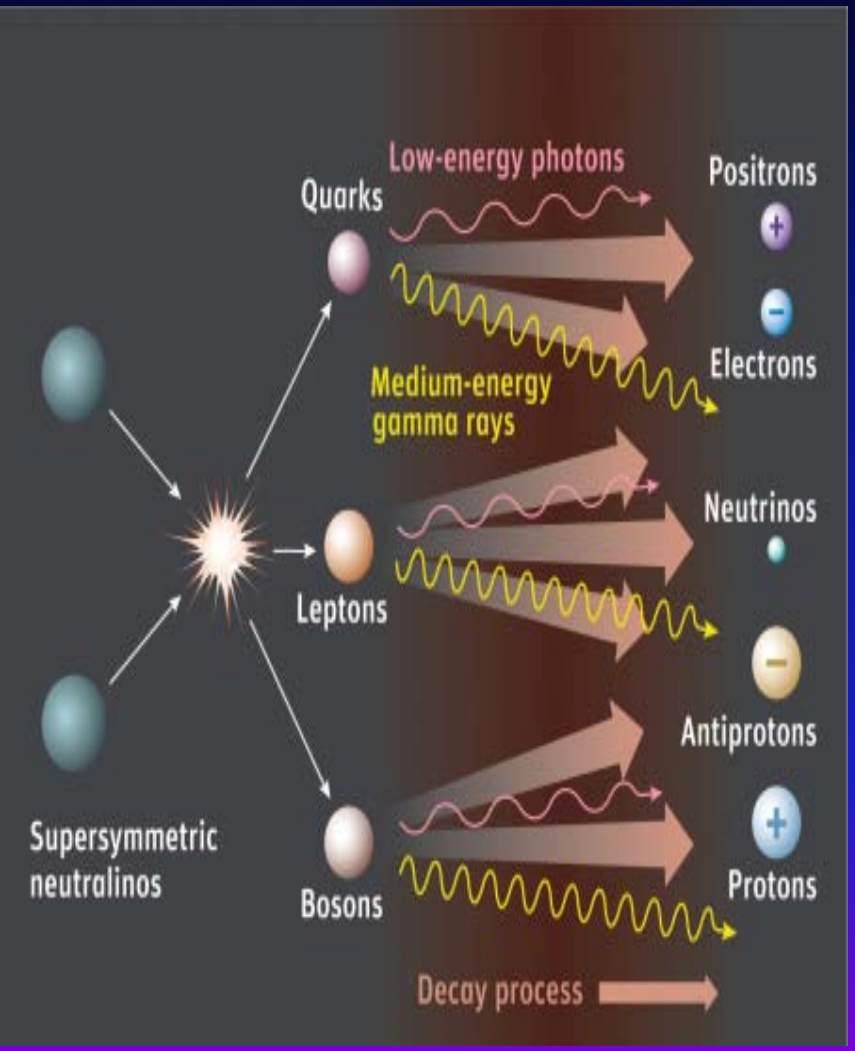
Indirect Dark Matter Signatures for Dark Matter Annihilation



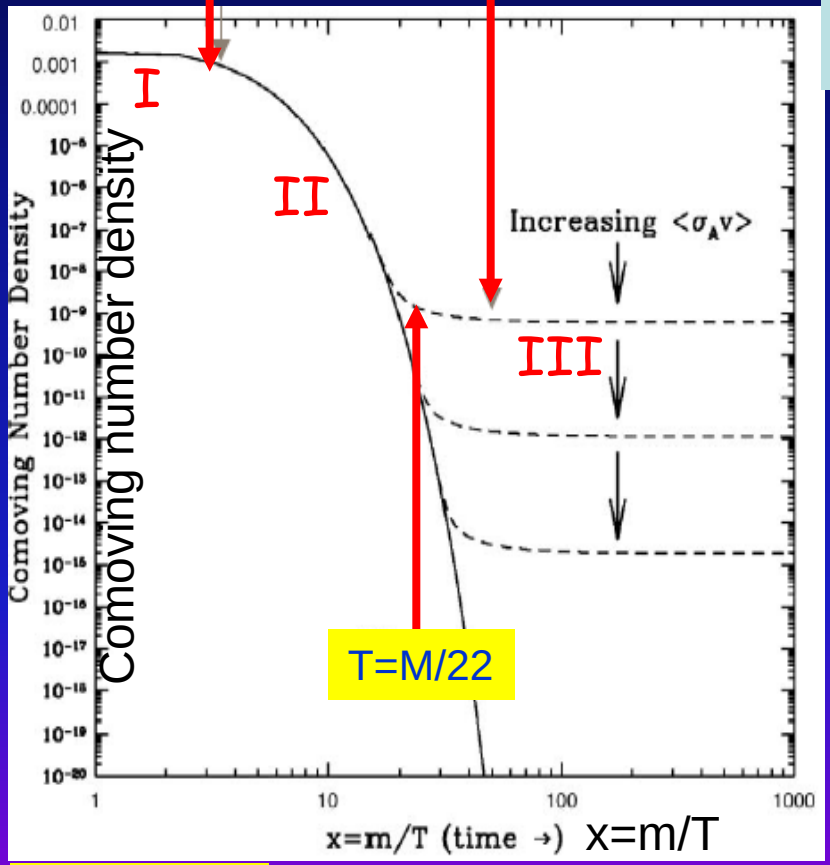
Annihilation products from dark matter annihilation:

Gamma rays
(FERMI -> arXiv:1002.1576v1)
(Aldo Morselli)
Positrons (PAMELA, arXiv:1001.3522)
(Francesco Cafagna)
Antiprotons (PAMELA)

Neutrinos (Icecube, no results yet)

e+ + e- (ATIC, FERMI, HESS, PAMELA)
e-, p drown in cosmic rays?

Expansion rate of universe determines thermal relic annihilation cross section



G. Steigman

I: T>>M: $\bar{f}+f \rightarrow \bar{M}+M$; $\bar{M}+M \rightarrow \bar{f}+f$

II: T<M: $\bar{M}+M \rightarrow f+f$

III: T=M/22 M decoupled, stable density (wenn annihilation rate ≅ expansion rate, i.e. $\Gamma=\langle\sigma v\rangle n_\chi(x_{fr}) \cong H(x_{fr})$!)

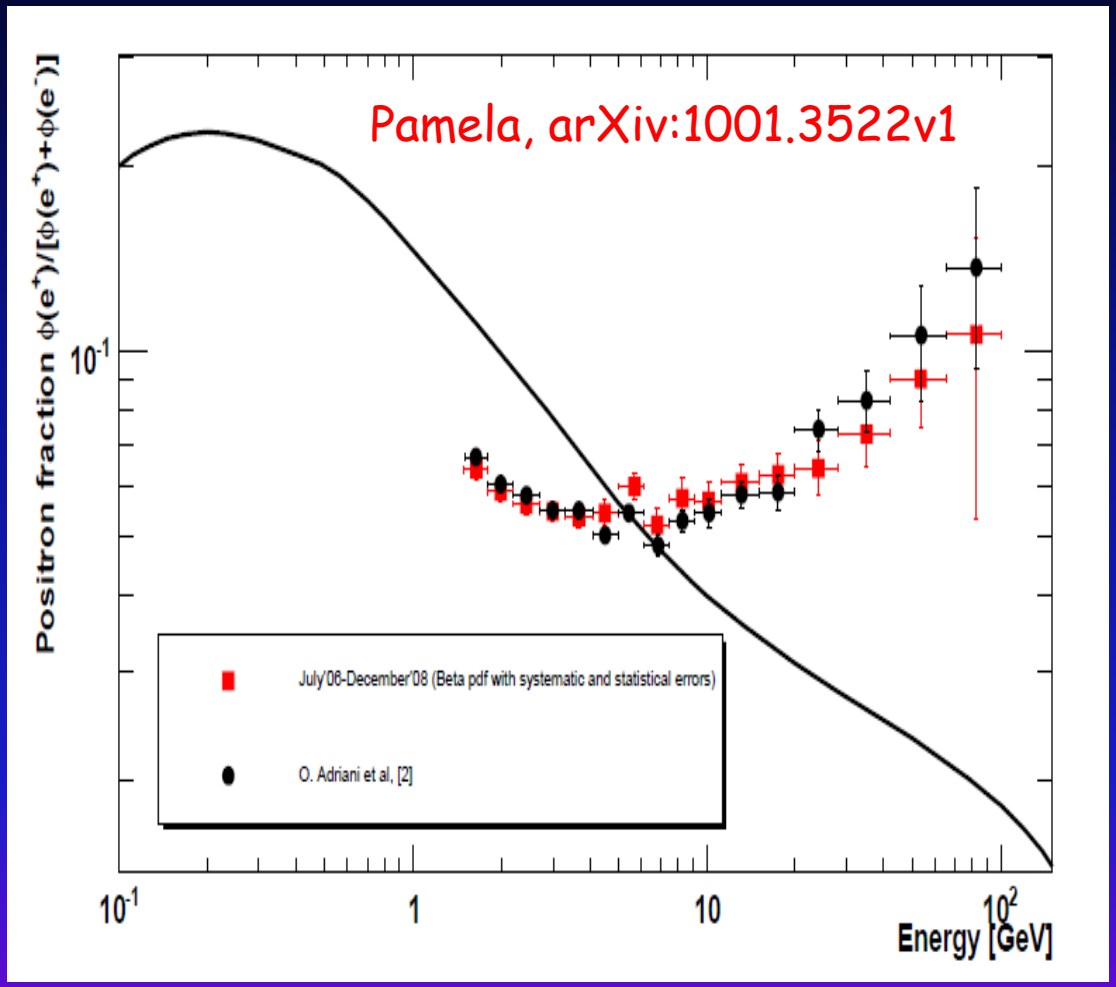
WMAP -> $\Omega h^2=0.113\pm0.009 \propto 1/\langle\sigma v\rangle$ -> $\langle\sigma v\rangle=2.10^{-26}$ cm^3/s

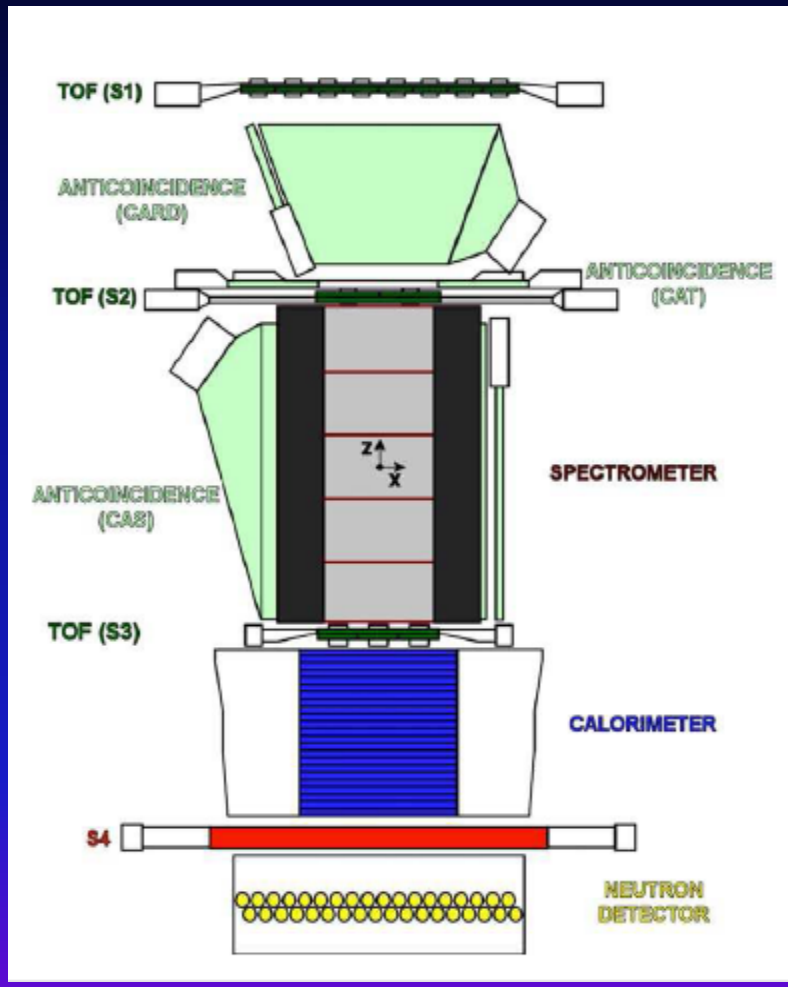
DM increases in Galaxies:
≈1 100 GeV WIMP/coffee cup ≈10^5 $\langle\rho\rangle$.
DMA ($\propto\rho^2$) restarts again..

Only assumption:
WIMP = STABLE THERMAL RELIC!

Note: annihilation cross section 10 orders of magnitude larger than upper limit on scattering x-section on nuclci, AS PREDICTED BY SUPERSYMMETRY

PAMELA Positron excess confirmed with new data and new analysis





Origin?

Depends on whom you ask!

My assumption:

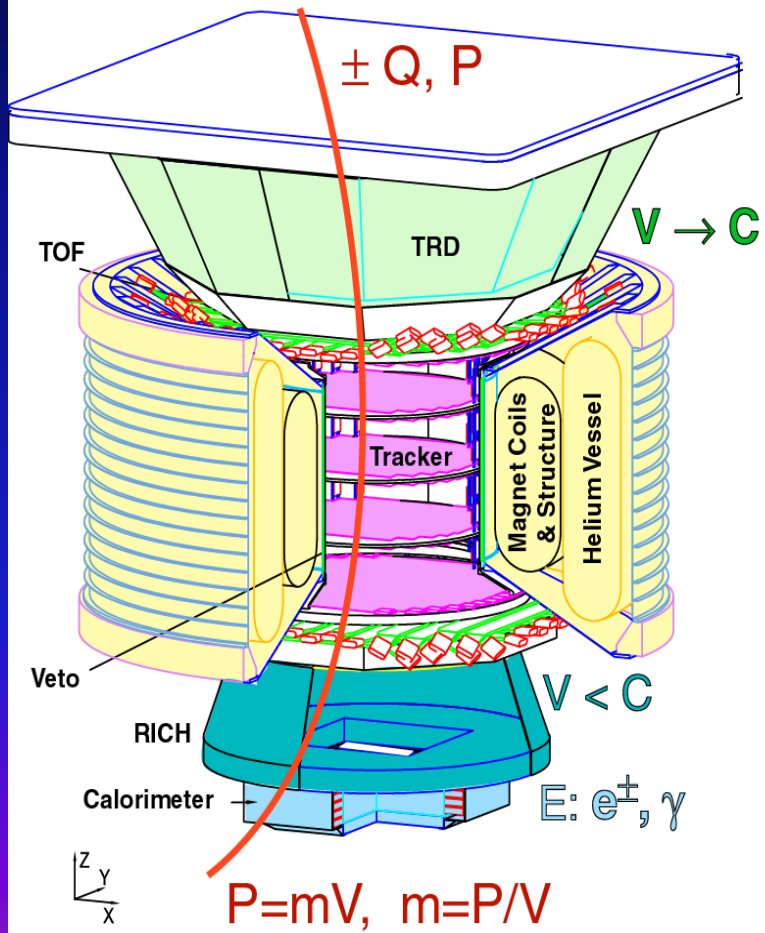
$$|\text{Data}\rangle = a_{p->\pi 0}\,|\text{Background}\rangle + a_{DMA}\,|\text{DMA}\rangle + a_{sec}\,|\text{SNR}\rangle + a_{local}\,|\text{SNR(x)}\rangle + a_{pulsar}\,|\text{Pulsar}\rangle$$

Unitarity must be fulfilled. However, each component has enough uncertainty to saturate observations

For details: WdB, AIP Conf.Proc.1200:165-175,2010. arXiv:0910.2601 [astro-ph.CO]

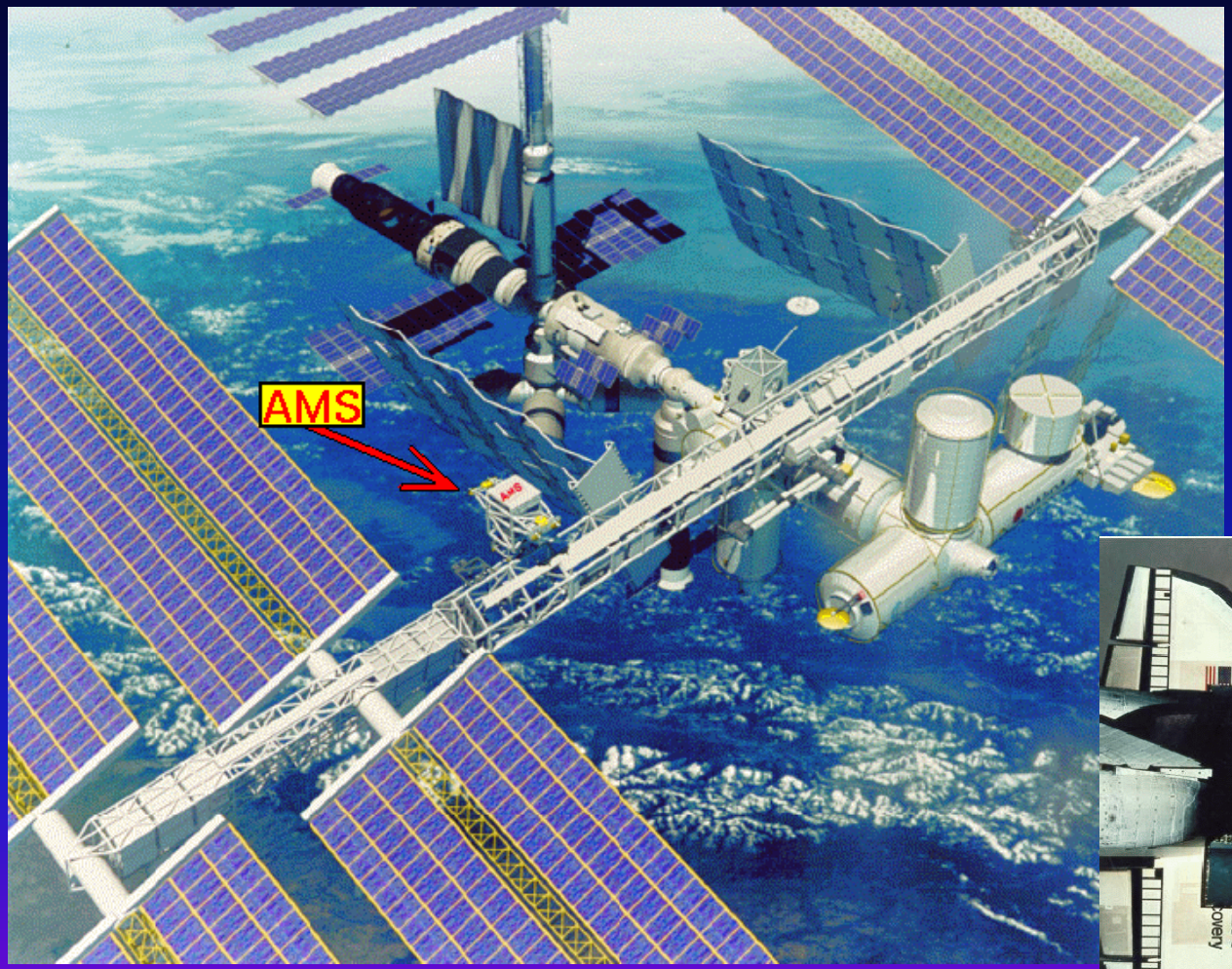
AMS: large magn. spectrometer with redundant particle ID

AMS-02

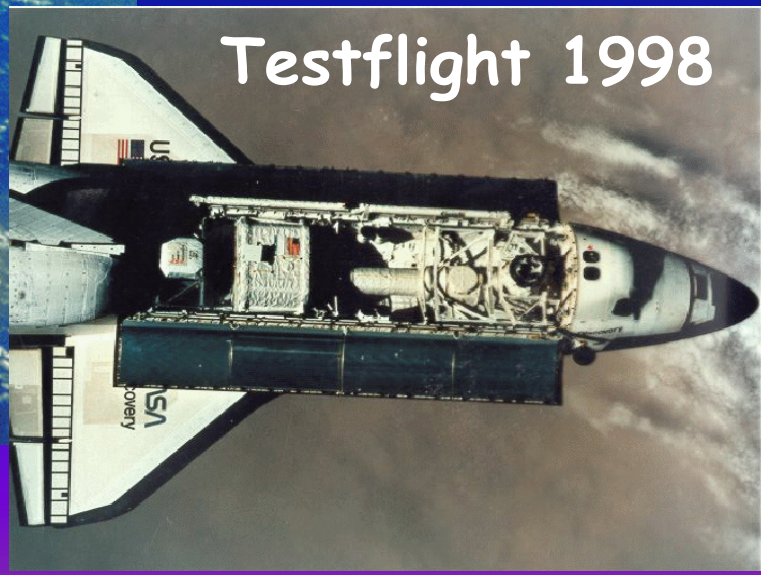


300 GeV	e-	e+	P	$\bar{He}$	γ	γ
TRD						
TOF						
Tracker						
RICH						
Calorimeter						

AMS to be installed on ISS



Schedule:
Transport with ST-134 Space Shuttle Flight in Feb. 2011

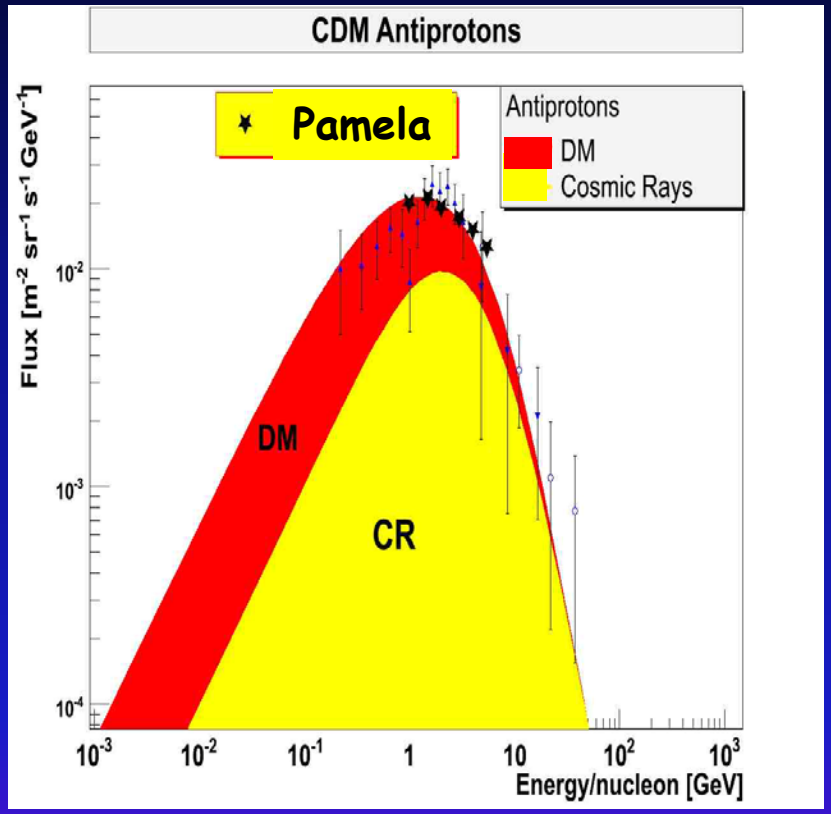


AMS-02 from CERN to Cape Canaveral on 26.08.2010

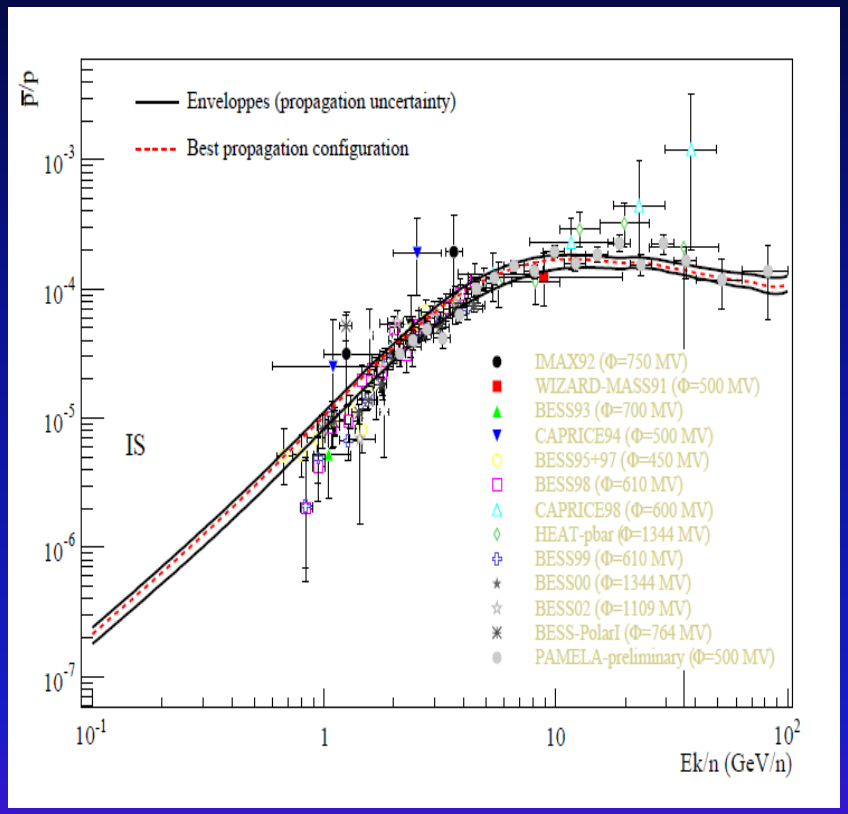
Antiprotons: saturated by background?

Gebauer and WdB, arXiv:0910.2027

GALPROP Antiprotons

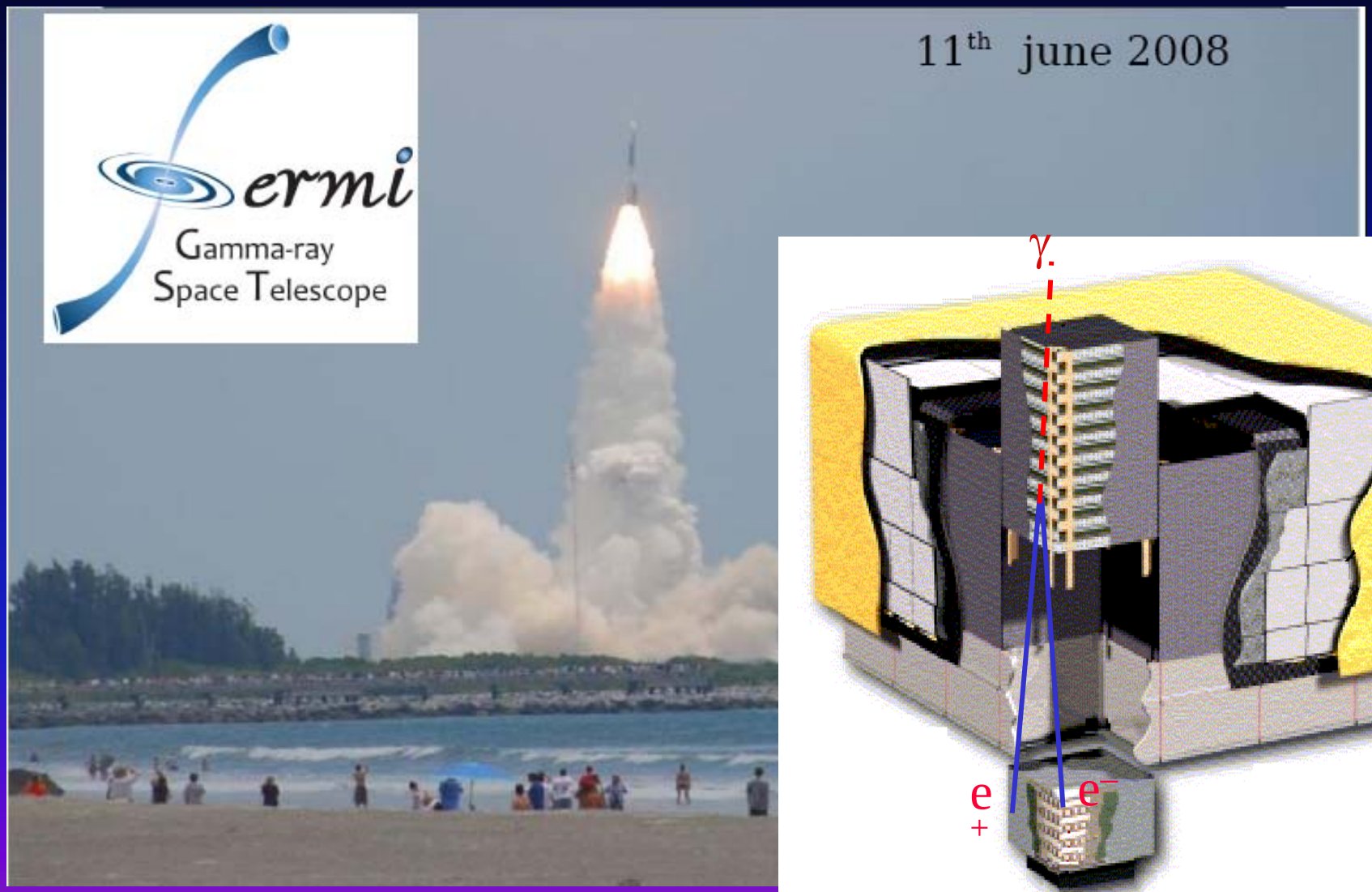


Donata et al. [0810.5292]



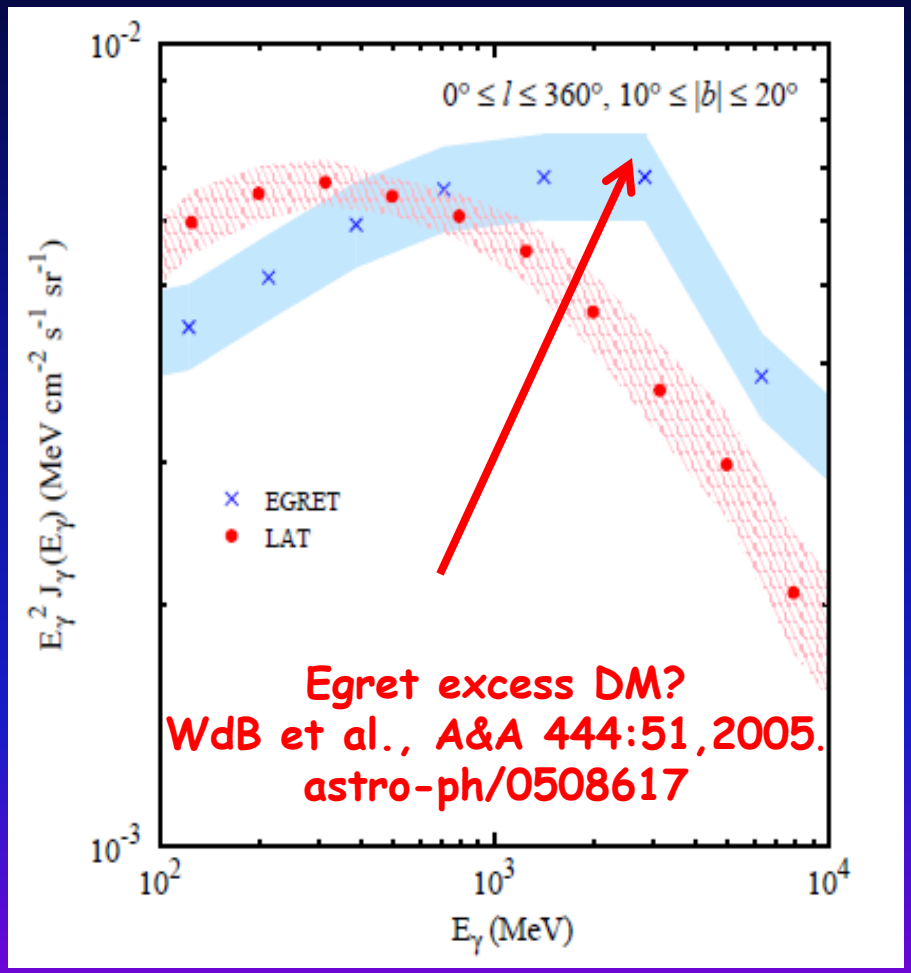
GALPROP (with and without) convection has deficit of antiprotons. Darksusy and others (which only look into charged particles, no gamma rays) can saturate data.

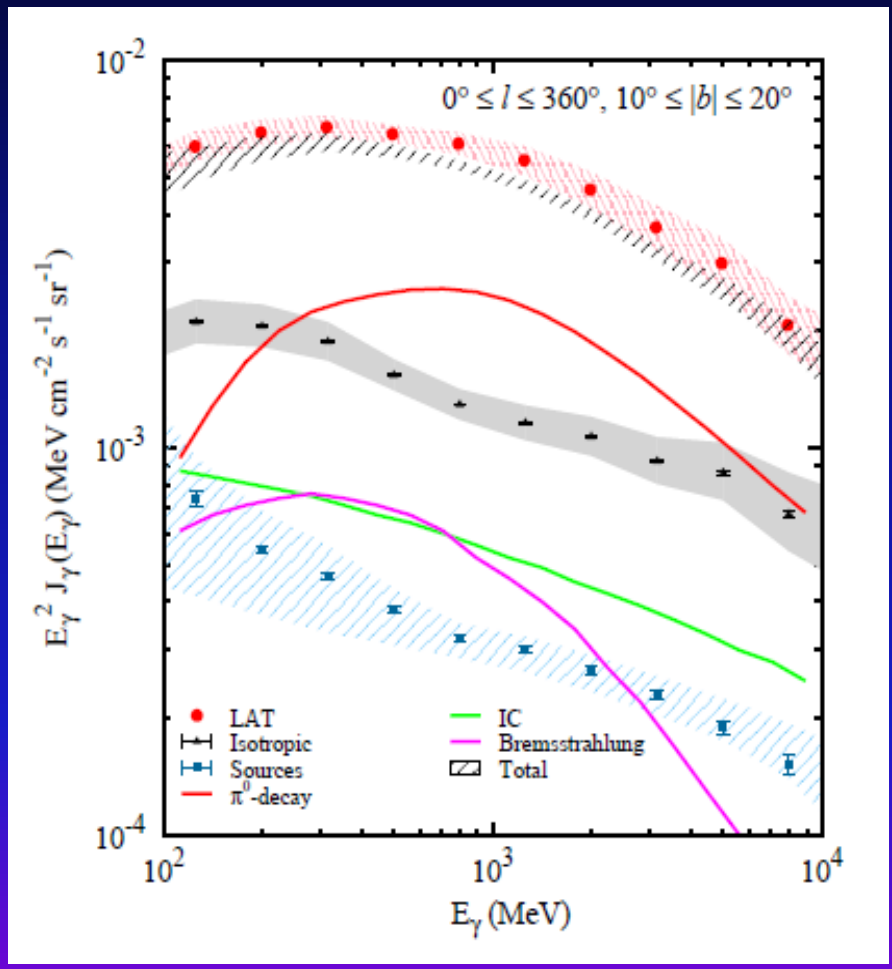
FERMI measures GeV gamma rays + electrons



EGRET (predecessor from FERMI) excess disappeared?

Only latitudes between 10 and 20 degrees considered

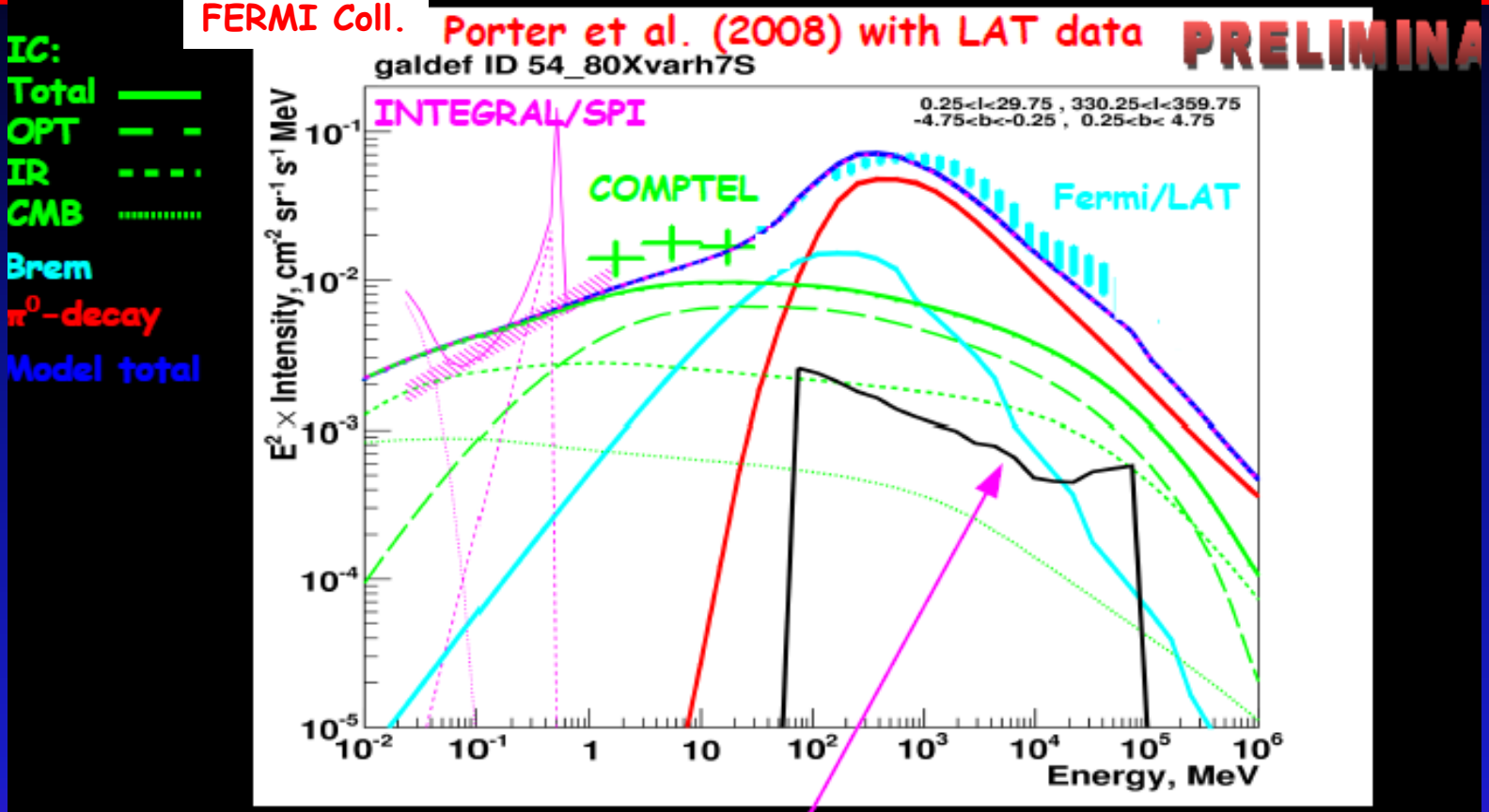




FERMI-LAT Coll., arXiv:1002.1576v1, 8 Feb 2010

Inner Galaxy: keV to ~ 100 GeV

FERMI Coll.



- Initial model okay, but too low → increase CRs to compensate
- Electrons *= 1.75, protons *= 1.15

Data driven analysis of FERMI gamma ray data (publicly available from NASA archive)

Idea:
Fit known shapes of 3 main components:

Inverse Compton:(IC) $\propto$ CR electron density x ISRF
Bremstrahlung:(BR) $\propto$ CR electron density x gas density
$P_{CR}P_{Gas}$ scattering:(π^0) $\propto$ CR proton density x gas density

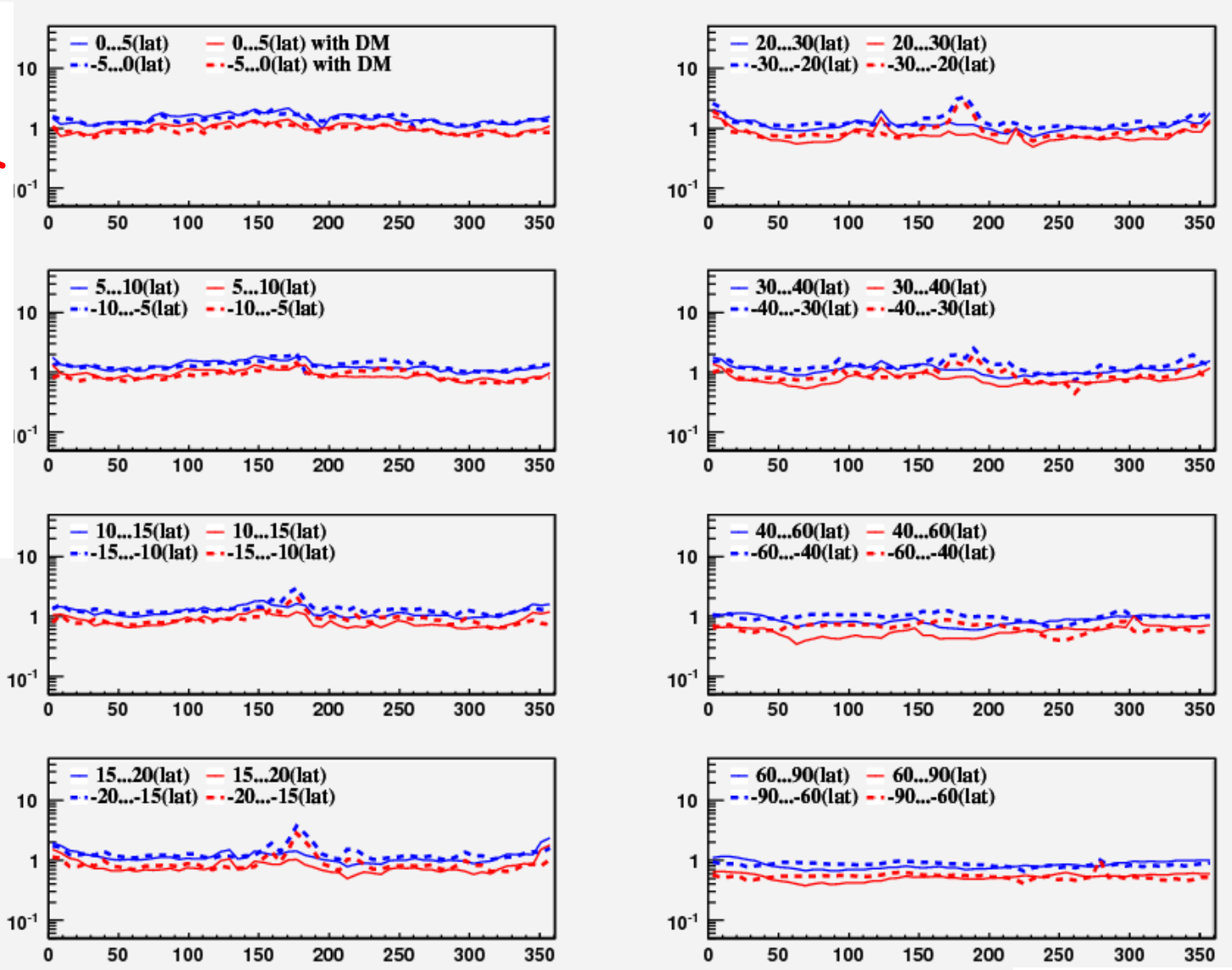
Main unknowns: CR electron density
CR proton density
(both measured locally, i.e. at a single point in Galaxy)

Alternative to data driven analysis:
compare data with Galactic Propagation Model
Best publicly available model: GALPROP (Moskalenko,Strong…)

Fitted background in broad agreement with GALPROP

ca. 1000 different sky directions with 21 data points each->20.000 data points

Proton CR density scale



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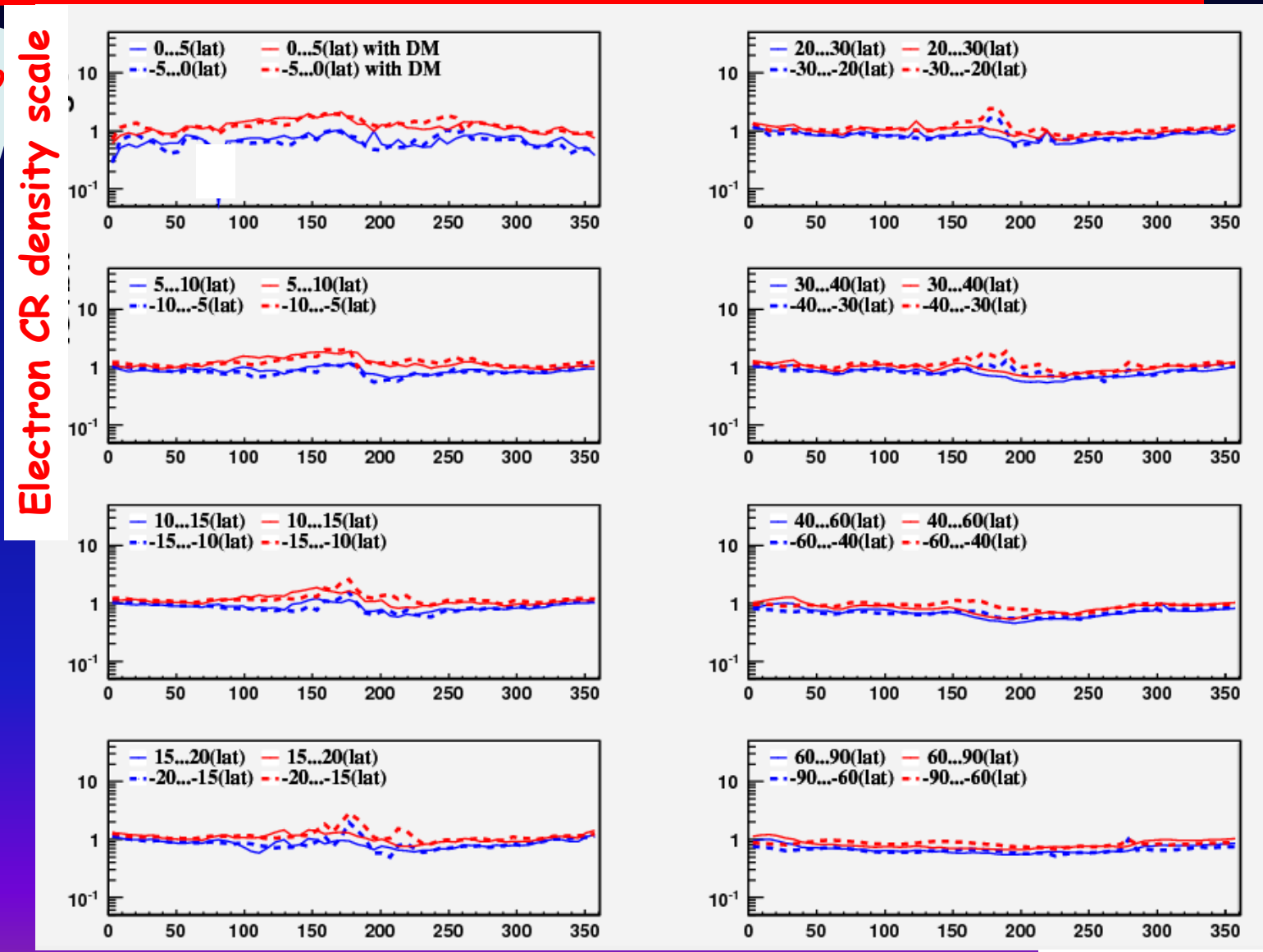
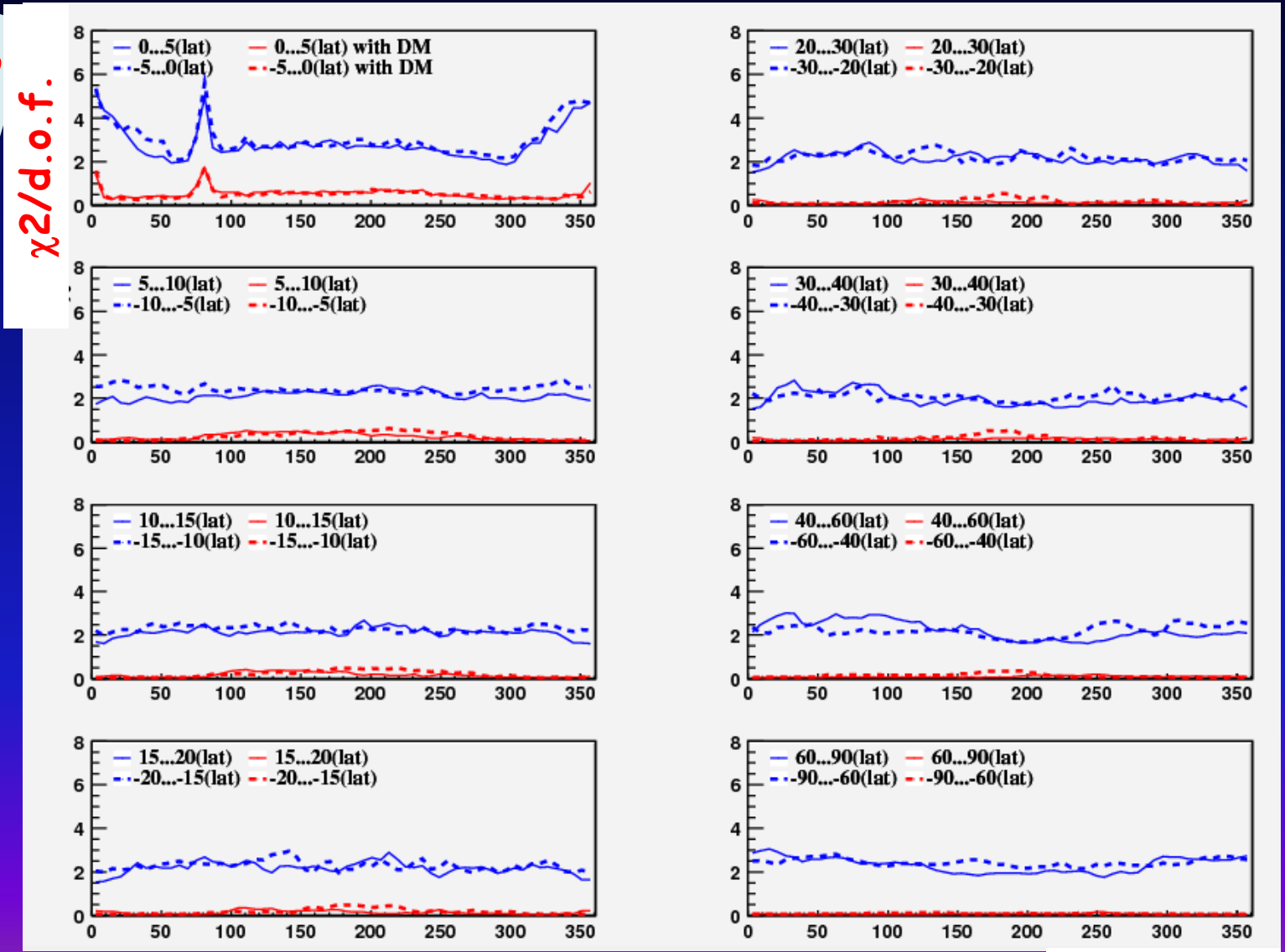


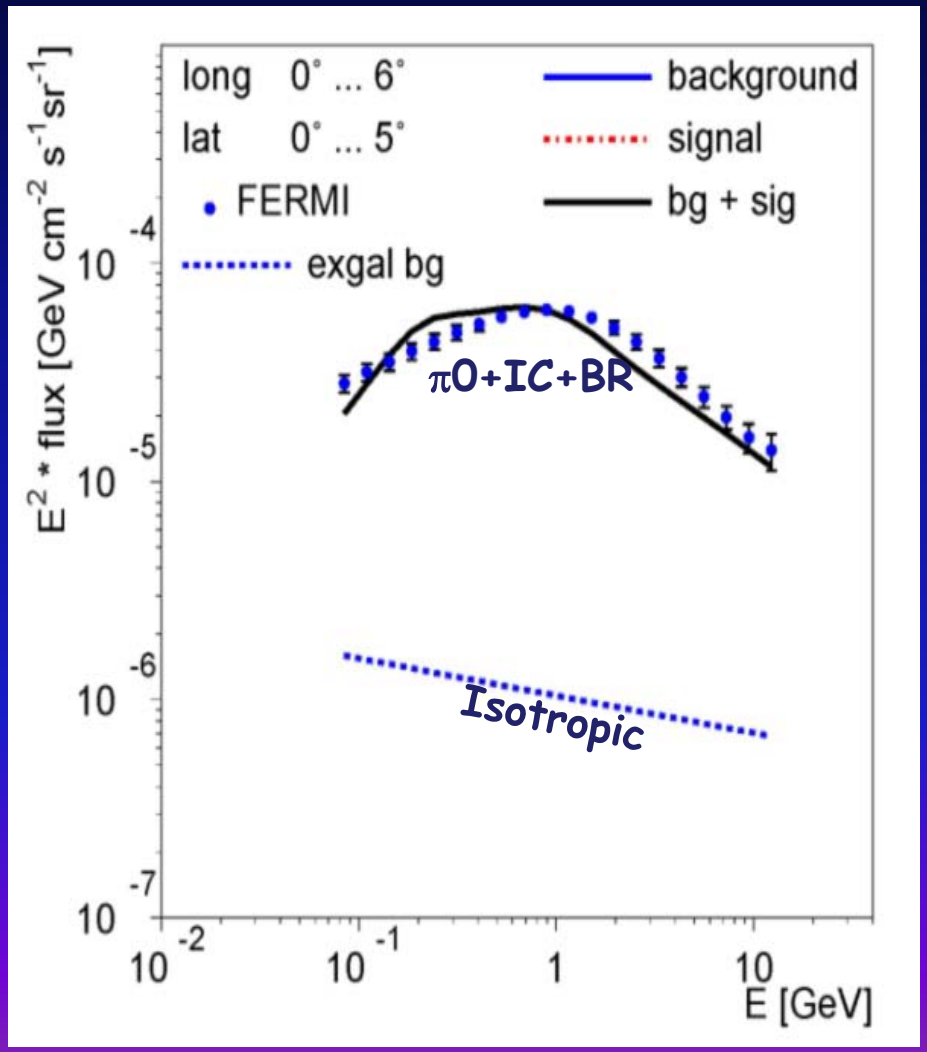
χ2 much improved by adding DM

ca. 1000 different sky directions with 21 data points each->20.000 data points

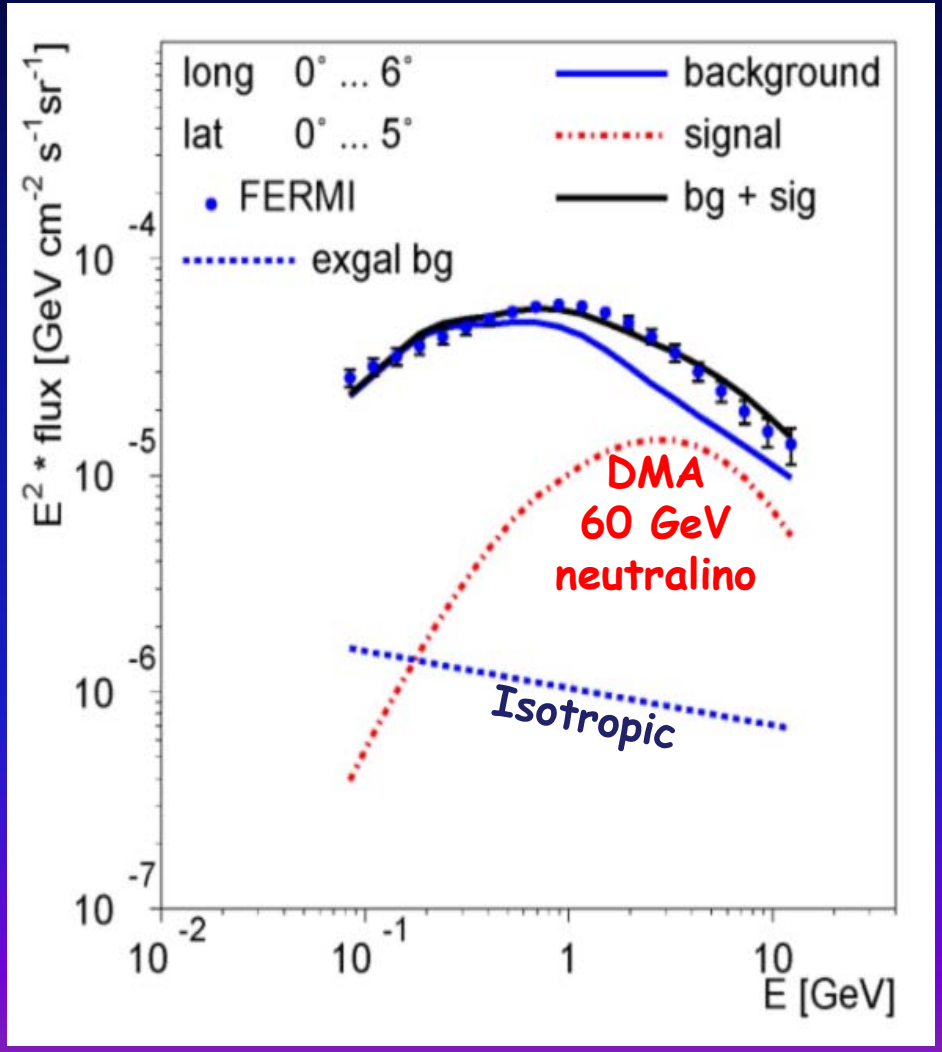


FERMI diffuse spectra from Galactic centre

without DMA



with DMA



What is DM haloprofile?

Given DM contribution in 960 directions,
can one determine haloprofile?

Procedure:

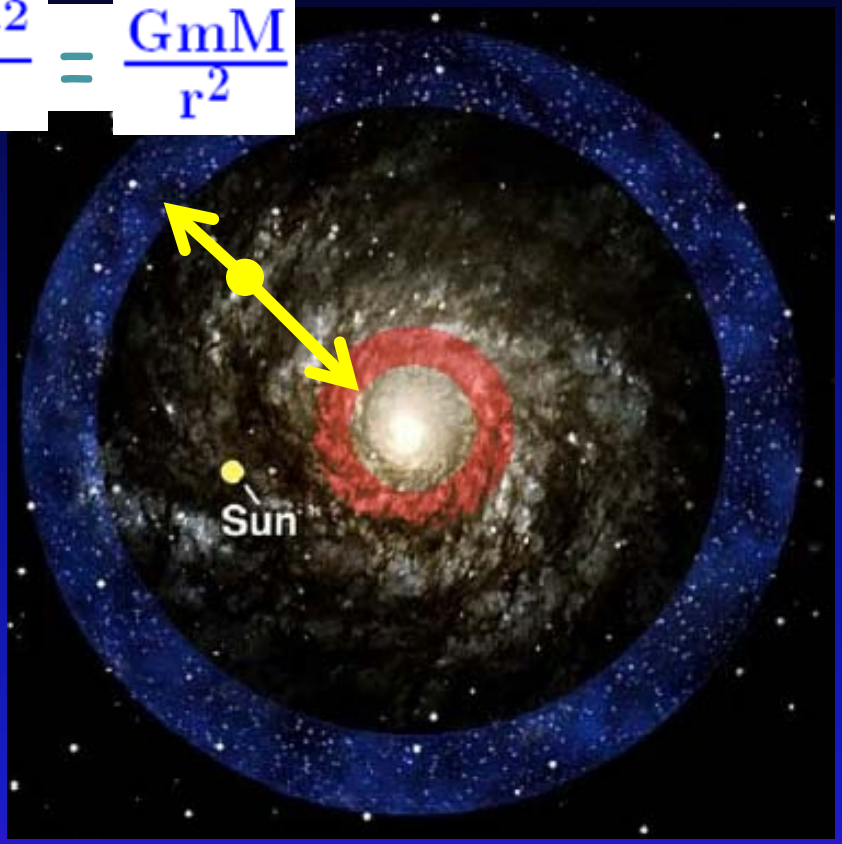
i) assume haloprofile ii)normalize to rotation curve
iii) calculate l.o.s. of gamma rays in 960 directions
iv) find optimum haloprofile parameters by minimum χ^2

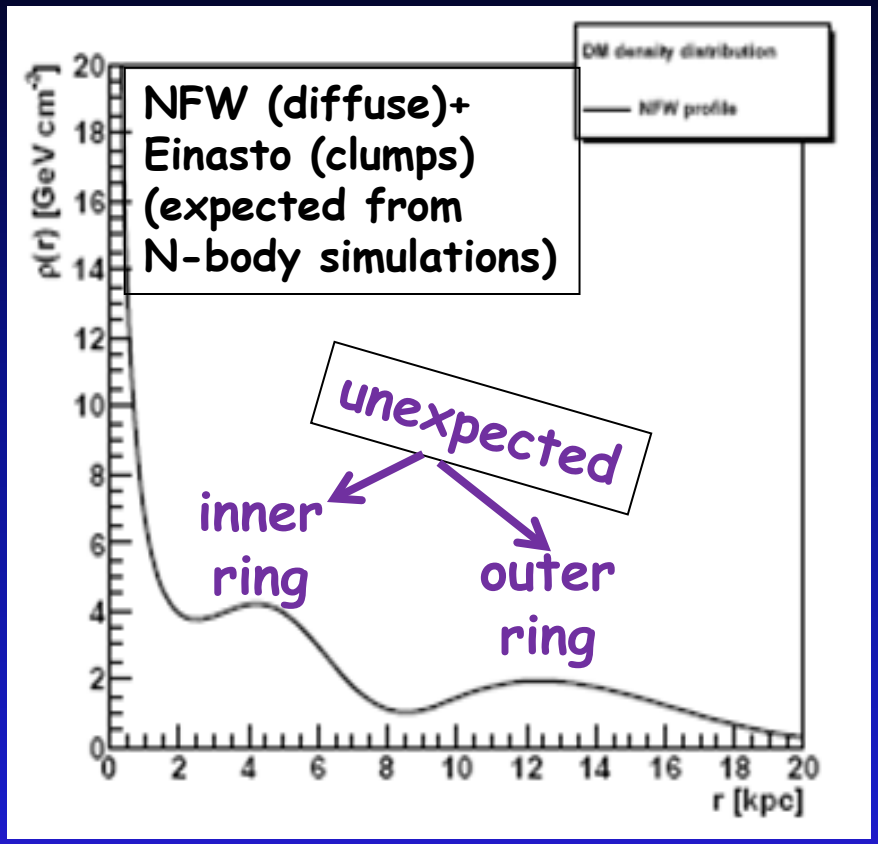
Result:

1) NFW haloprofile for diffuse DM (>90% of mass) with boostfactor 1 and signal $\propto \rho^2$ +
2) clumpy halo profile with Einasto profile (~5% of mass and signal $\propto \rho$ +
3) two doughnut like ring structures with few % of mass

FERMI provides DM contribution in all directions-> HALO PROFILE

$$\frac{mv^2}{r} = \frac{GmM}{r^2}$$



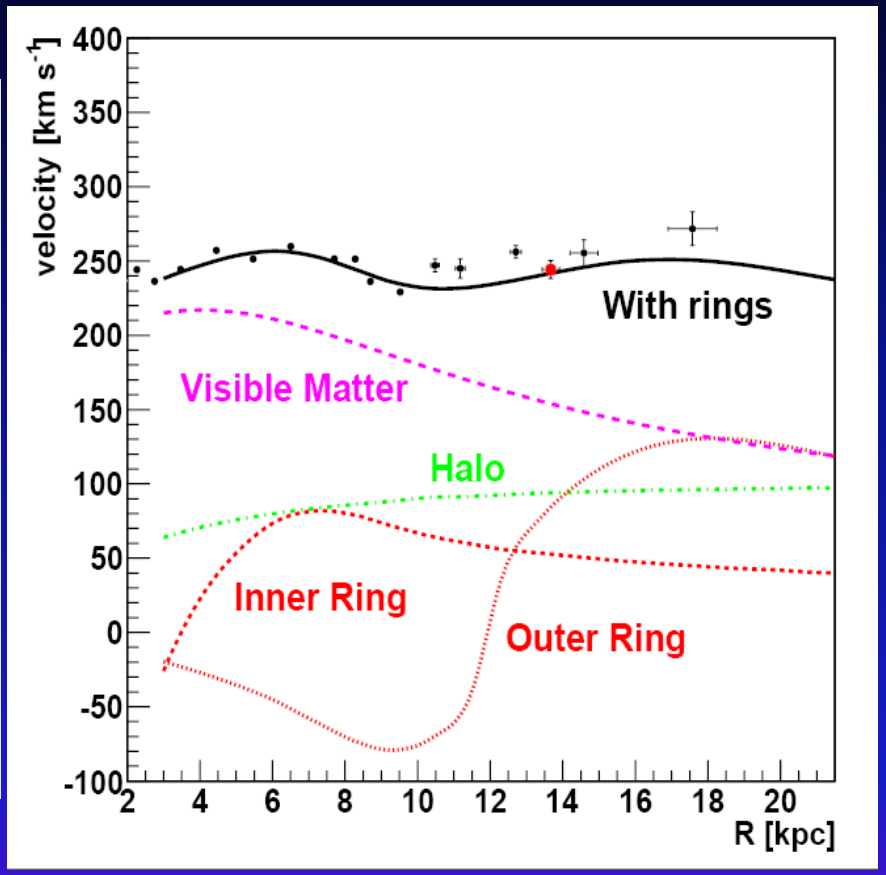


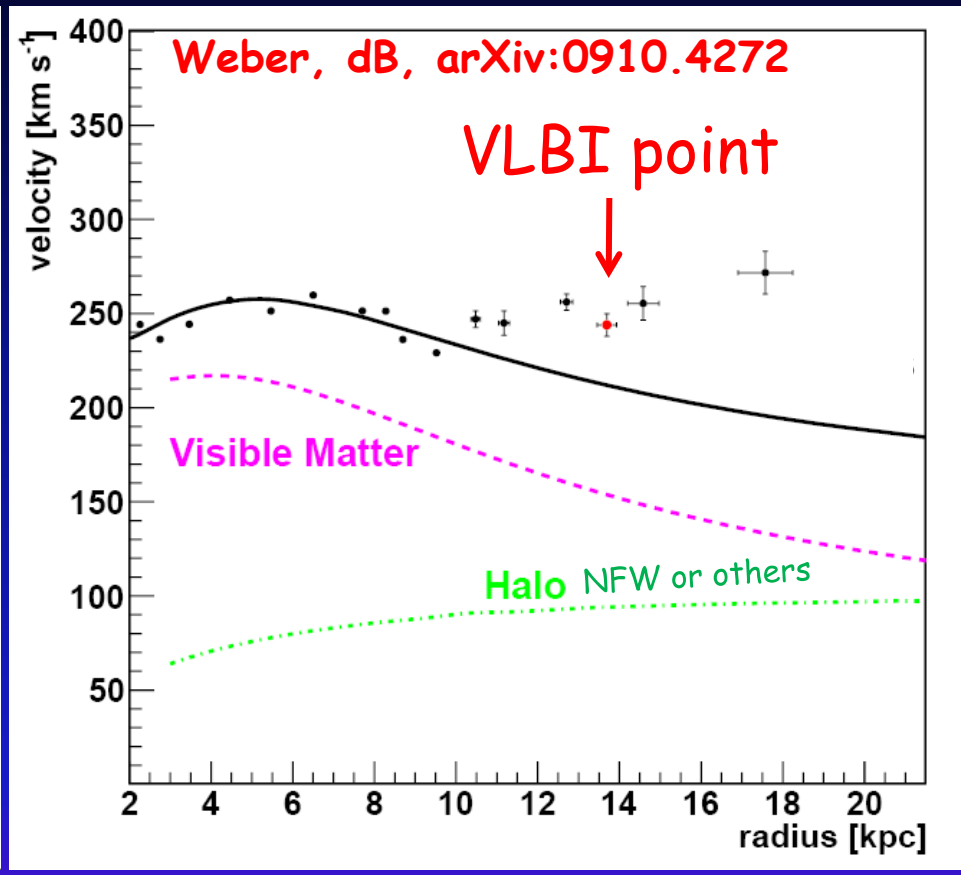
Motivation for "outer ring": Monocerus ring of stars (SDSS, 2002), discussed as tidal disruption of Canis Major dwarf AND gas flaring

Motivation for "inner ring": dust ring

Rotation curve Milky Way

Weber, Thesis, 2010. KIT

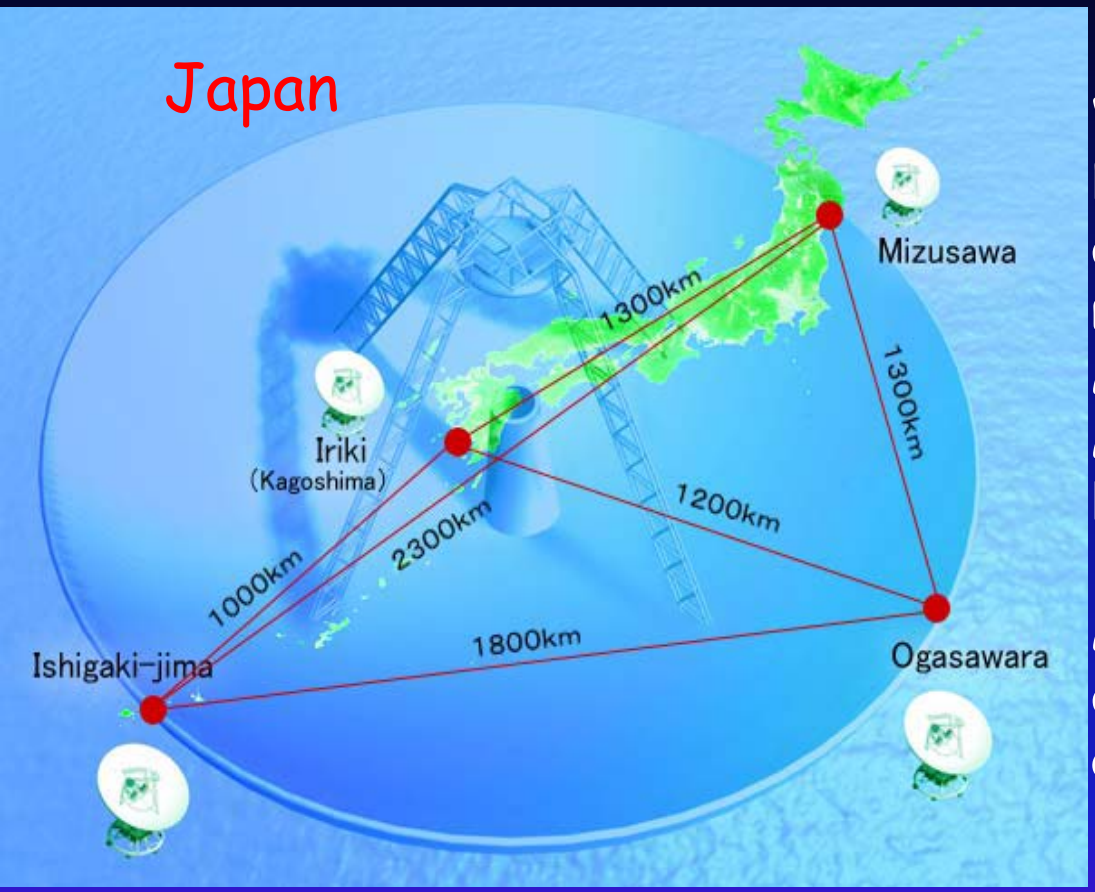




Oort limit on local density prevents larger DM contr.

$$\rho_{\odot,\mathrm{tot}} = \rho_{\odot,\mathrm{vis}} + \rho_{\odot,\mathrm{DM}} \approx 0.09 + 0.01\ \mathrm{M}_\odot\ \mathrm{pc}^{-3}$$
$$= 0.102 \pm 0.01\ \mathrm{M}_\odot\ \mathrm{pc}^{-3}$$ (Hipparcos dat

VERA: VLBI Exploration of Radio Astrometry

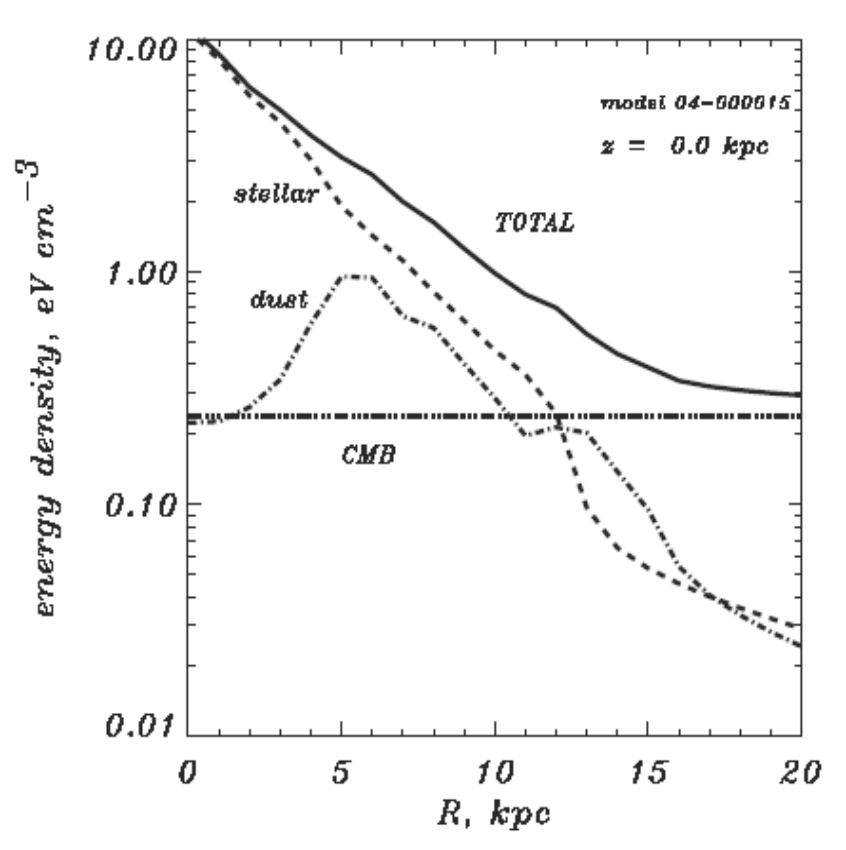


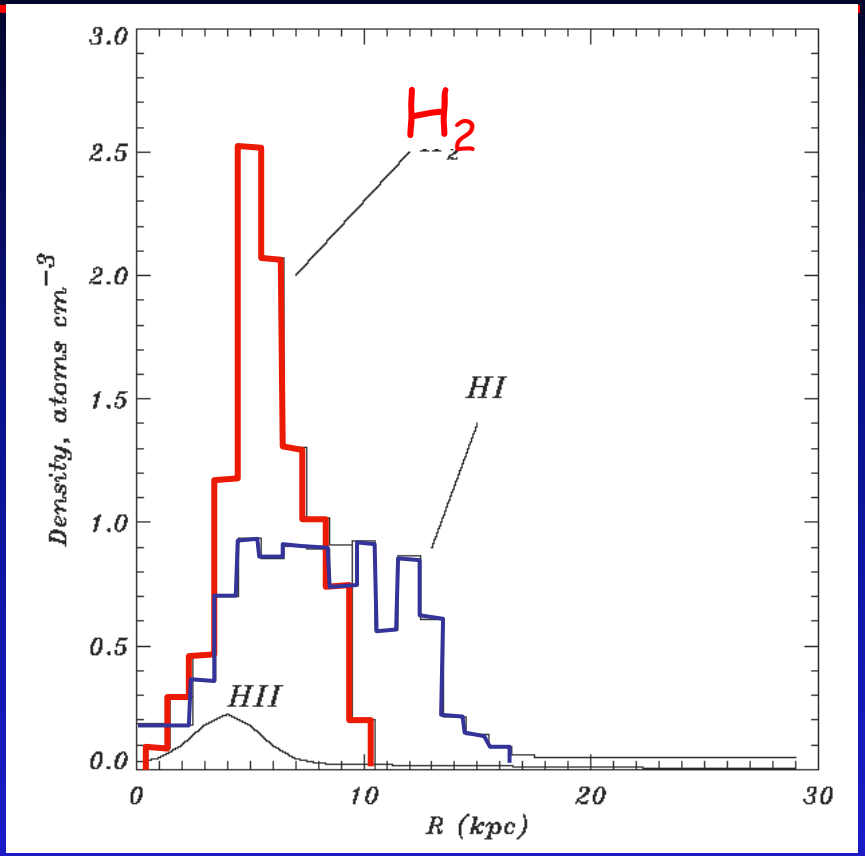
VLBI = Very Large Baseline Interferometry allows very precise parallax measurements.
Maser light from Molecular Clouds allows large distance interferometry

Measured parallax of 189±6μas at distance of >5 kpc over ≈1 yr-> rotation velocity

A. Honma et al, PASJ 2007, Astrometry of Galactic Star-Forming Region Sharpless 269 with VERA:Parallax Measurements and Constraint on Outer Rotation Curve at 13 kpc

Inner Ring coincides with ring of dust and H_2 -> gravitational potential well!

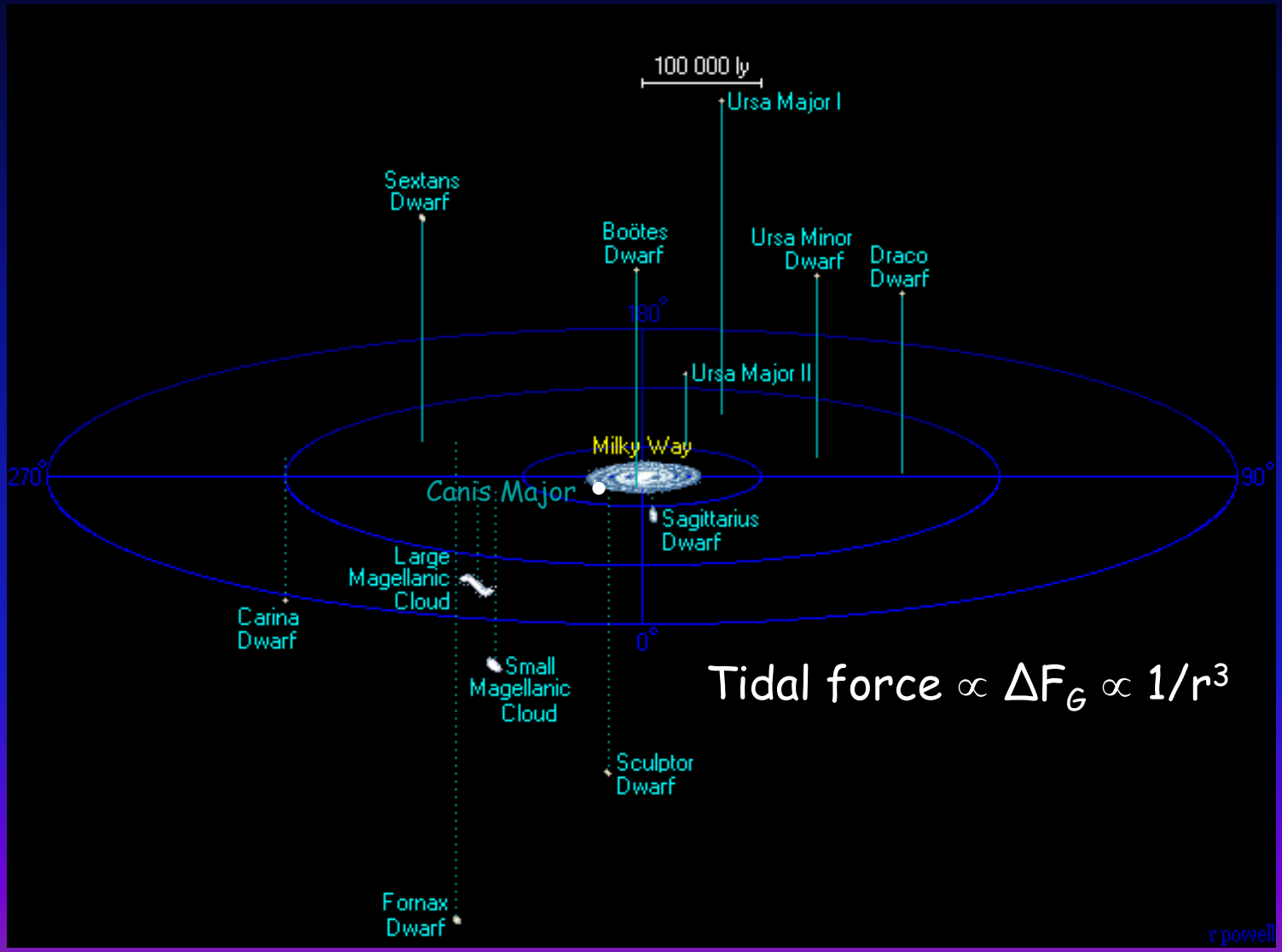




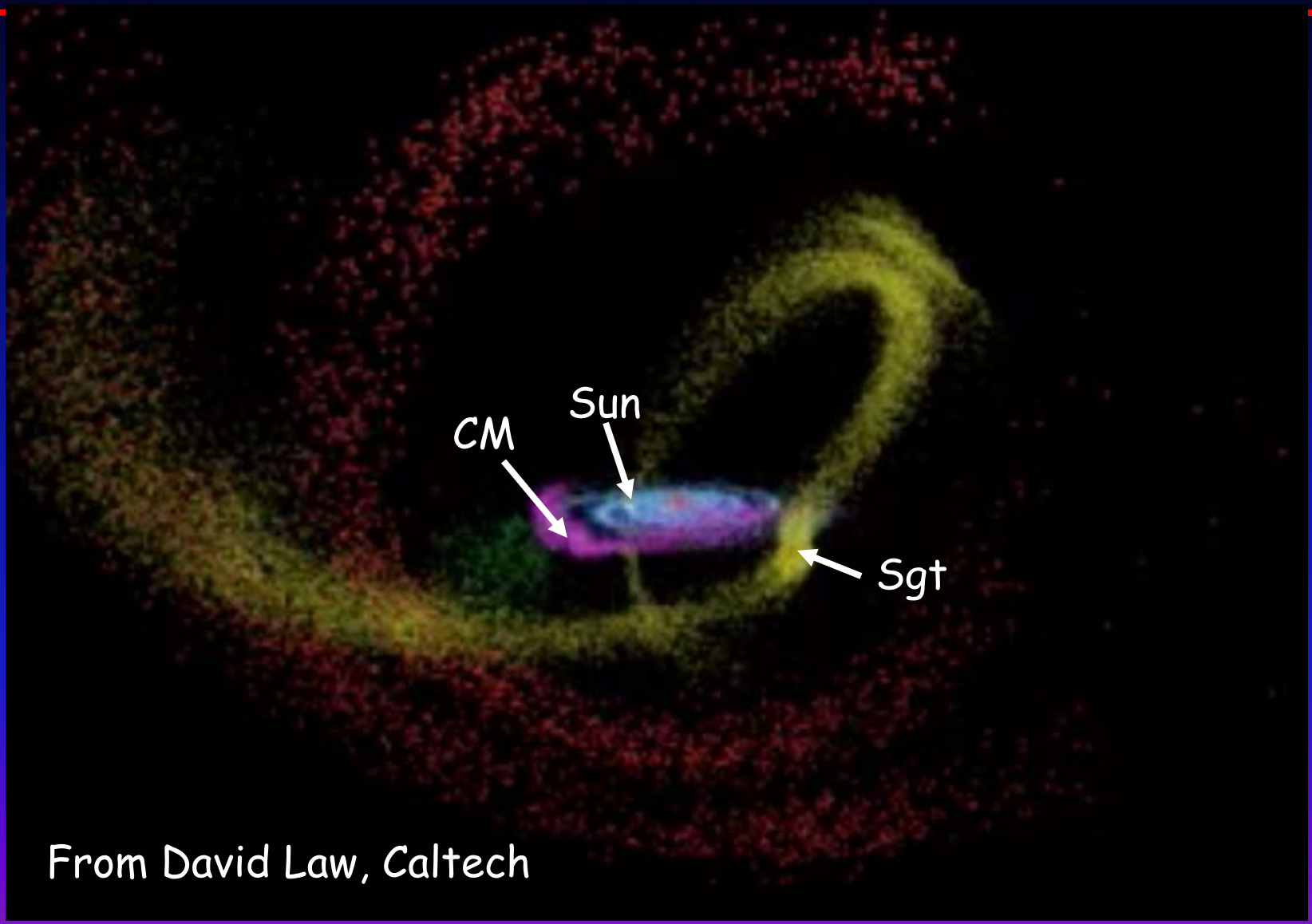
Dust ring at 4 kpc

4 kpc coincides with ring of neutral hydrogen molecules! $H+H->H_2$ in presence of dust-> grav. potential well at 4-5 kpc.

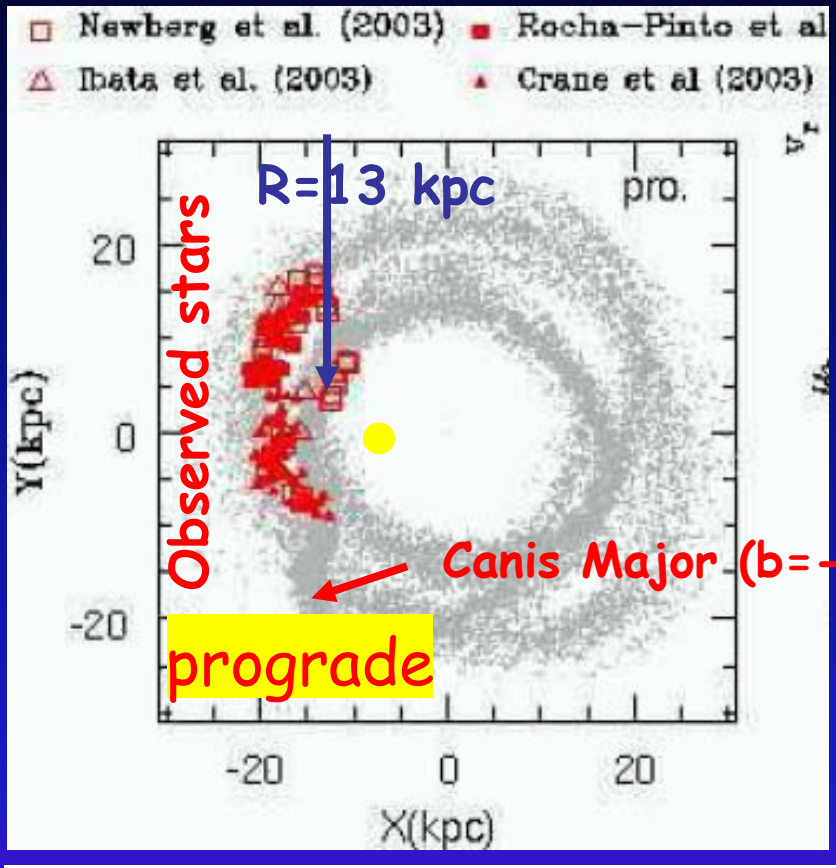
The Milky Way and its satellite galaxies

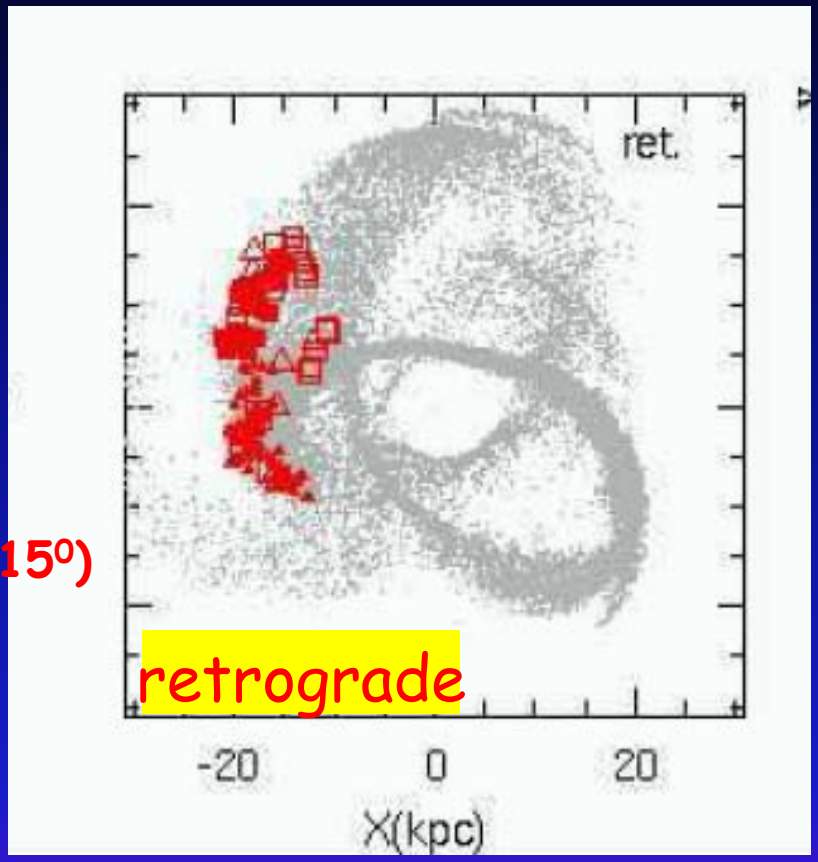


Tidal streams of dark matter from CM and Sgt



N-body simulation from Canis-Major dwarf galaxy

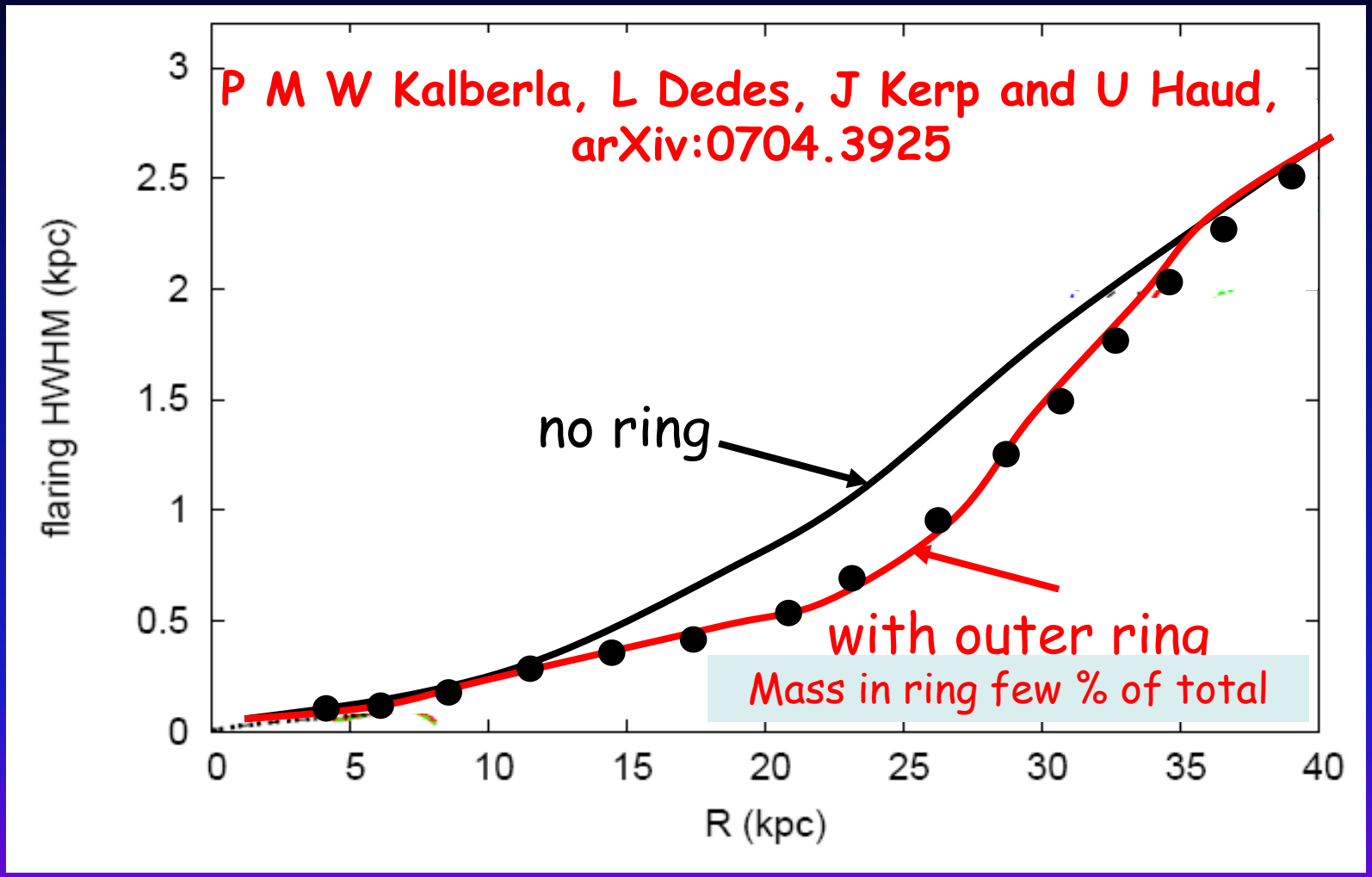




A comprehensive model for the Monoceros tidal stream

J. Peñarrubia[1], D. Martínez-Delgado[1], H.W. Rix[1], M.A Gómez-Flechoso[2], J. Munn[3], H. Newberg[4], E.F. Bell[1], B. Yanny[5], D. Zucker[1], E. K. Grebel[6]

Gas flaring in the Milky Way



Gas flaring needs also outer ring with mass of $2.10^{10} M_{\odot}$!

Summary

Fermi data show excess of diffuse Galactic gamma rays w.r.t GALPROP (see also DM claim using Fermi data by Goodenough and Hooper, arX 0910.2998)

Excess compatible with DMA (using data driven spectral shape fits instead of relying on GALPROP (but systematic errors in FERMI data?).

HOWEVER, FERMI DATA PREL. WAIT FOR NEXT REPROCESSING WITH BETTER BG REJECTION FOR ANY CONCLUSION

DMA interpretation compatible with rotation curve (RC) if doughnut-like DM structures used in disc, as required independently by new data on rotation curve and gas flaring.

Conclusion saying no excess in antiprotons is model dependent. GALPROP still allows up to 50% of antiprotons from DMA