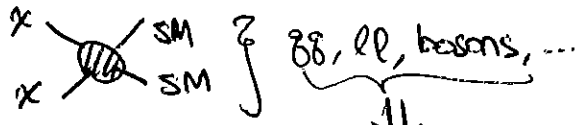
Shunsaku : DM ANNIHILATION 101

28 OCT '13

ASSUMPTIONS ① DM is a WIMP (GeV - TeV)
↑ otherwise not in FERMI RANGE

② THEY ANNIHILATE / DECAY



⇓

CASCADE & PROPAGATE INTO $\gamma, e^+e^-, \nu, p^+p^-$

WHAT WE CAN SEE

Galactic Signal ← PRIMARY

ANN: $$\frac{dN}{dE\,d\Omega\,dA\,d\Omega} = \frac{\langle\sigma v\rangle}{2}\,\frac{(\rho/M_\chi)^2}{4\pi\eta}\,\frac{dN}{dE}\int \rho^2(r)\,ds$$

$\frac{1}{2}$ b/c ann w/ identical particle

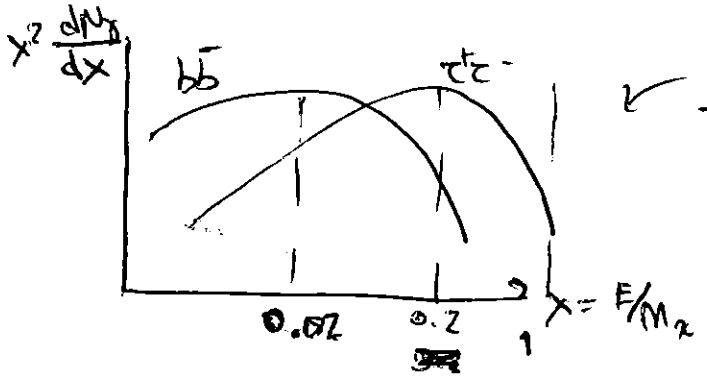
BOOST FACTOR

DECAY: $$= \frac{1}{\tau_\chi}\,\frac{(\rho/M_\chi)^2}{4\pi}\,\frac{dN}{dE}\int \rho(r)\,ds$$

PARTICLE — ASTRO

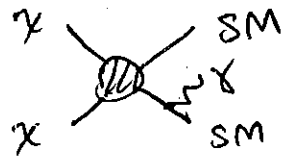
ASTRO PEOPLE ASSUME EXTREME CASES, TYPICALLY

eg γ RAYS: HARD SPEC FROM τ SOFT FROM π^0



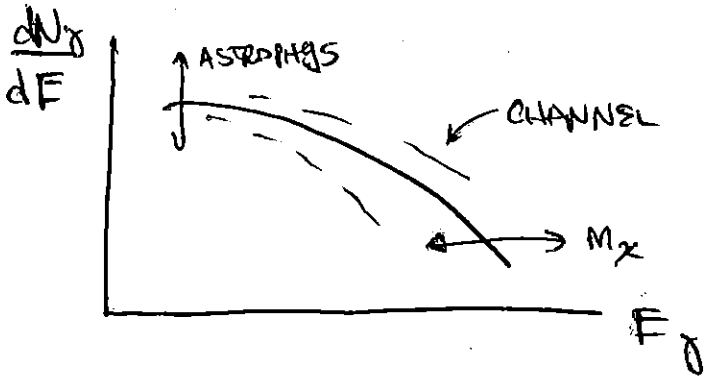
← eg IN GALAC CENTER THIS IS A STATISTIC. SIG. DIFFERENCE

also: final state radiation:



↓ spectra

MAKES THINGS HARDER (LARS BERGSTROM)



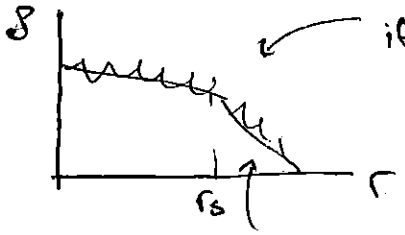
HOW PHYSICS AFFECT THESE PLOTS

$\rho(r)$ DM DENSITY, CALC. NUMERICALLY FROM SIMULATION.

ISSUES:

- RESOLUTION (HAVE TO EXTRAPOLATE TO GO TO GALACTIC CENTER)
- BARYON EFFECTS (HARD TO MODEL, BIG EFFECT?) ← BARYON DISK
  - ↳ related to core vs. cusp

SUBSTRUCTURE CAN HAVE ~~BIG~~ BIG EFFECT



if $dN \sim \rho^2$, THESE CAN GIVE A SUBSTRUCTURE BOOST

Straight lines: NFW PROFILE
- 2 PARAM FIT TO DENSITY

$$\rho(r) = \frac{\rho_0}{(r/r_s)(1+r/r_s)^2}$$

OTHER PROFILES

$$\rho(r) = \frac{\rho_0}{(r/r_s)^{\gamma}(1+r/r_s)}$$

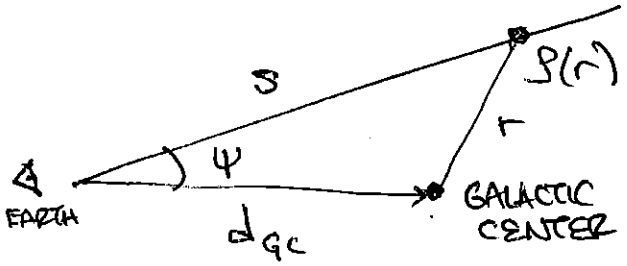
$$\rho(r) = \frac{\rho_0}{(r_s/r_c)(1+r/r_c)(1+r/r_s)^2}$$

typical

$\rho_\odot \sim 0.3\ \mathrm{GeV\,cm^{-3}}$

$r_s \sim 20\ \mathrm{kPc}$

Diagram



WHAT HAPPENS TO THE e ⇄ p? (SECONDARY)

↑ of PRIMARY - ANN. PROD + CASCADE (hard process)

Propagation ⇄ E loss

e ⇄ p BEND IN MAG FIELDS, LOSE ENERGY ↑ SYNCH + INV. COMP.

↳ DIFFUSION EQUATION.

$$\frac{\partial f}{\partial t} - \nabla\left[K(E,x)\nabla f\right] - \frac{\partial}{\partial E}\left[b(E,x) f\right] = Q(E,\vec{x})$$

$f = \frac{dN}{dE}$ — ↑ DIFFUSION — E-LOSS — SOURCE

DEP ON MAG FIELDS, GALACTIC INFO

$$b(E,\vec{x}) = \frac{4\sigma_1}{3m_e^2} E^2 \underbrace{u(\vec{x})}_{\text{PHOTON + B FIELD}}$$

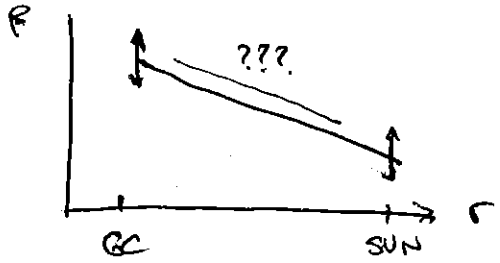
FERMI RES ~ .1, .2 deg

~.7 deg

(I) B-fields

- GC field: $10\ \mu G \sim 10^3\ \mu G$ on $\Theta(100)$ pc.
  ↑ from radio sources, can extract mag field
- B @ SOLAR RADIUS (ie B where we are) ~ $1\ \mu G \sim 10\ \mu G$

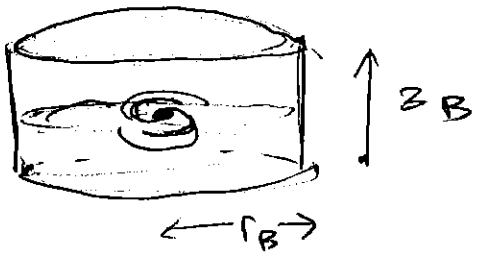
SO WHAT WE KNOW:



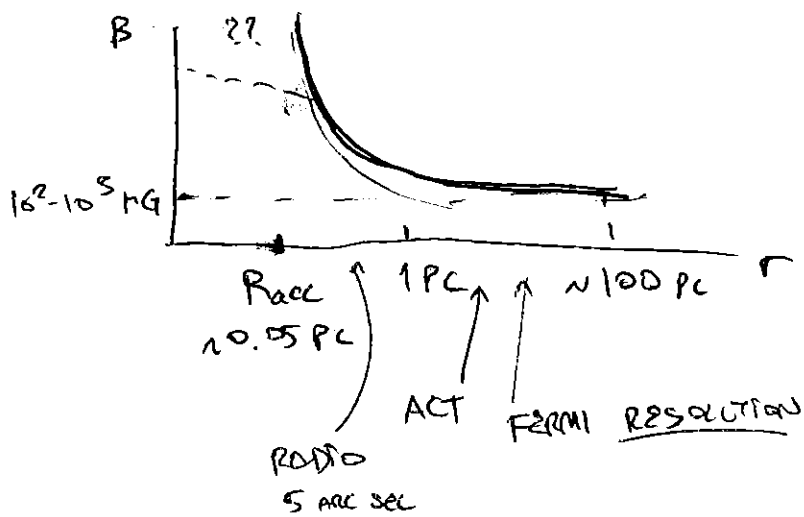
model: $B(r,z) = B_0 e^{-(r-r_0)/r_B - |z|/z_B}$

r_B: 10 KPC, z_B: 2 KPC

cyl. coords:

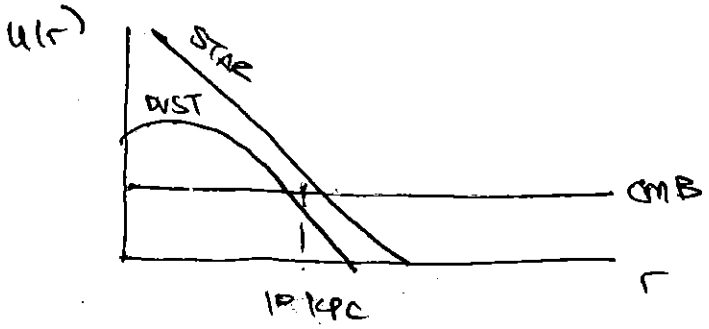


EQUIPART. & MODEL: < PC CENTRAL BH RELEVANT



(II) PHOTONS

1. CMB ~ .3 eV cm^{-3}
2. STARLIGHT ~ .1 - 1 eV
3. DUST ~ 10^{-2} eV (?) IR



DEP ON NORMALIZ OF MAG FIELD,
USUALLY INV. COMPTON DOMINATES OVER MAG. FIELD
EXCEPT @ r ~~SMALL~~ ~~HIGH ENERGY~~

⇒ inverse Compton dominates
except for $E_\gamma \gg m_e c^2$

(THOMP σ NO LONGER APPLIES,
KLEIN-NISHINA SUPPRESSION)

$$\sigma = \begin{cases} \sigma_T & E_\gamma < m_e c^2 \\ \sim E^{-1}(1 + 2\ln E) & E_\gamma > m_e c^2 \end{cases}$$

by the way

pc ~ 10^{18} cm ↑ DIST TO CLOSEST STAR

r_{SCHW} FOR $m_{BH} \sim 10^7$ cm

$K(E, \vec{x})$ IS COMPLICATED, CAN'T BE WRITTEN. ☹

SO SAY: $K = K_0 e^{\delta}$

↳ CAN GET AWAY W/ THIS FOR DM ANN. PAPER. BUT NOT FOR PROPAR. PAPER.

z/kpc	K [kpc²/m s]	δ
1	0.006	.55
4	0.0112	.70
15	0.0765	.46

Practically

- GALPROP — DOES DIFFUSION EQN
  - ↳ online mode is easy but not useful for DM source, have to DL.
- OR USE ESTIMATES HERE

Useful ref: CIRELLI 2010-11

↳ POOR PARTICLE PHYS COOKBOOK FOR INDIR. DET.
very introductory.
+ Mathematica Notebook.