Dark Matter
Multi-wavelenght/Multi-messengers constraints with synchrotron and Inverse Compton radiation

Based on

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Indirect Detection of Dark Matter: the General Framework

1) WIMP Annihilation
   Typical final states include heavy fermions, gauge or Higgs bosons

2) Fragmentation/Decay
   Annihilation products decay and/or fragment into some combination of electrons, protons, deuterium, neutrinos and gamma rays

3) Synchrotron and Inverse Compton
   Relativistic electrons up-scatter starlight to MeV-GeV energies, and emit synchrotron photons via interactions with magnetic fields
the Pamela/ATIC Anomalies: e+e- excesses w.r.t. the background

Both the signals seem to have the same origin:
- Astrophysical explanation?
- DM explanation?
CRe Fermi spectrum from 20 GeV to 1 TeV

\[ E^3 J(E) \text{ (GeV}^2\text{m}^{-2}\text{S}^{-1}) \]

- AMS (2002)
- ATIC-1,2 (2008)
- PPB-BETS (2008)
- HESS (2008)
- FERMI (2009)
- Kobayashi (1999)
- HEAT (2001)
- BETS (2001)

\[ \Delta E/E = \pm 5\% \quad 10\% \]

**diffusive model based on pre-Fermi data**
Astrophysical vs Dark Matter Fits

Bergström, Edsjo & Zaharias 2009

$M_{DM} = 1.6 \text{ TeV}, 100\% \mu^+\mu^-, E_{e}=1100$

Grasso et al. 2009
Indirect Detection With Synchrotron and Inverse Compton Radiation

- Charged leptons and nuclei strongly interact with gas, Interstellar Radiation and Galactic Magnetic Field.
- During the process of thermalization HE $e^+e^-$ release secondary low energy radiation, in particular in the radio and X-ray/soft Gamma band.

ICS on the Galactic ISRF  
Synchrotron on the GMF
Details of the Calculations

Propagation equation for e+e−

\[
\frac{\partial}{\partial t} \frac{dn_e}{dE_e} = \nabla \cdot \left[ K(E_e, \vec{r}) \nabla \frac{dn_e}{dE_e} \right] + \frac{\partial}{\partial E_e} \left[ b(E_e, \vec{r}) \frac{dn_e}{dE_e} \right] + Q(E_e, \vec{r})
\]

\( (13) \)

=0 Steady State Solution

Source Term: Injection Spectrum

\[ Q(r, E) = \rho^2 \langle \sigma_A v \rangle / 2m^2_\chi \times dN_e/dE. \]

Diffusion

Energy Losses: ICS and Synchrotron

full numerical approach employing Galprop, Moskalenko & Strong 98-08
The Microwave sky

- In addition to CMB photons, WMAP data is “contaminated” by a number of galactic foregrounds that must be accurately subtracted.

- The WMAP frequency range is well suited to minimize the impact of foregrounds.

- Substantial challenges are involved in identifying and removing foregrounds.
After known foregrounds are subtracted, an excess appears in the residual maps within the inner ~20° around the Galactic Center.

DM constraints in the $m_\chi - \langle \sigma_A v \rangle$ plane

**Borriello, Cuoco, Miele 2008**

- Constraints in the $m_\chi - \langle \sigma_A v \rangle$ plane for various frequencies, without assuming synchrotron foreground removal.

- DM spectrum is harder than background, thus constraints are better at lower frequencies.

- Constraints from the WMAP 23 GHz foreground map and 23 GHz foreground cleaned residual map (the WMAP Haze) for the TT model of magnetic field (filled regions) and for a uniform 10 $\mu$G field (dashed lines).

- With a fine tuning of the MF is possible to adjust the DM signal so that to match the Haze, like in Hooper et al.
The Gamma Sky

Galactic Contribution from:
1. Pion Decay
2. Inverse Compton
3. Electron Bremsstrahlung

Galprop Foregrounds Model:

Gamma Sky at 1477.86 MeV $E^2dN/dE$

Also, detector resolution, charged particle background...
Similarly to the synchrotron case, IC signal produces an extremely peculiar “ICS Haze” peaking around 10-100 GeV which provides a further mean to discriminate the DM signal from the astrophysical backgrounds and/or to check for possible systematics.
ICS and background Spectra from Pamela/ATIC and forecast for Fermi

- The Pamela/Atic electrons produce a large excess of Inverse Compton Radiation w.r.t to the galactic backgrounds
- EGRET already disfavor the excess, while Fermi can easily detect it

See also:
Meade et al. 2009,
Panci & Cirelli 2009,
Regis & Ullio 2009,
Cholis et al. 2008,
Zhang et al. 2008.
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Comparison with EGRET and another forecast for Fermi

• Upper panel: EGRET data compared the annihilation model and the decaying model. Annihilating DM produces a too much broad peak to fit the data, beside producing an excessively high normalization.

• Lower Panel: forecast of the Fermi ability to discriminate among the astrophysical and annihilating DM scenario. Also shown is the Decaying DM scenario.
Comparison with the Extra-Galactic Inverse Compton

• Constraints from the Extra-Galactic Inverse Compton can be in principle stronger than the galactic ones but are generally more model dependent.

Jeltema & Profumo 2009
Belikov & Hooper 2009
Hütsi, Hektor, Raidal 2009
See also Zaharias’s Talk
Summary and Conclusions

• Inverse Compton and Synchrotron Radiation provide a model independent test of the origin of the PAMELA/ATIC/FERMI electrons.

• Data from Egret already disfavor significantly the DM interpretation of the signal, while data of the diffuse from Fermi can definitely rule out/confirm the DM interpretation.

• More in general Inverse Compton and Synchrotron Radiation provide a powerful and complementary mean to test/find possible DM signatures.

• So, check your model against secondary radiation constraints!