Radio Signals of Particle Dark Matter.

Marco Regis (Torino)
Is it possible to infer something “unknown” (non-gravitational signals of DM) by means of something “well-known” (radio-astronomy)?
Is it possible to infer something “unknown” (non-gravitational signals of DM) by means of something “well-known” (radio-astronomy)?

Maybe..
Gravitational evidences and DM properties

Cosmology

\[ \Omega_M \sim 6 \Omega_b \] (DM relic density)

Stable

Thermally produced

Structure formation

Cold (bottom-up hierarchy)

Cluster dynamics

Weak self-interactions

Galactic dynamics

Dissipationless
WIMP miracle

Assume DM in **thermal equilibrium** in the early Universe and **cold** at structure formation epoch.

Relic density:

- DM mass $\sim$ GeV – tens of TeV

$\Omega_X h^2 \approx \frac{3 \times 10^{-27} \text{cm}^3 \text{s}^{-1}}{\langle \sigma v \rangle}$

The observed relic density **requires weak interactions**!

Physics beyond the standard model addresses EW symmetry breaking

$\rightarrow$ **new particles are expected at $\sim$ EW scale**

**Examples**: LSP in Supersymmetry, LKP in flat or warped extra-dimension models, LTP in Little-Higgs, ...

*EPS HEP 2011 (Grenoble), 21/07/2011*

Regis Marco (University of Turin and INFN)
Annihilations (or decays) of DM particles inject relativistic electrons and positrons.

Emitted in a medium with magnetic field, they give raise to a radio continuum diffuse emission associated to synchrotron radiation.

\[ E^2_{\text{GeV}} \sim 200 \frac{\text{v}_{\text{GHz}}}{\text{B}_{\mu\text{G}}} \]
Whatever is the WIMP model, (namely the dominant annihilation channel, except for DM annihilating in neutrinos only), DM injects sizable electron/positron yields.

Comparable yields for γ-rays and electrons/positrons (MULTI-WAVELENGTH STRATEGY)
**WHERE?**

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<th>Possible Targets</th>
<th>Images from Baltz et al., 2008 (S.Murgia talk)</th>
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**POSSIBLE TARGETS**
Extragalactic / Isotropic

Recent measurements by the ARCADE collaboration (Fixsen et al., 2009)

Total intensity can be estimated through differential number counts:

\[ I(\nu) = \int_{S_{\text{max}}}^S \frac{dN}{dS}(\nu) \cdot S \, dS, \]

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Regis Marco (University of Turin and INFN)
Recent measurements by the ARCADE collaboration (Fixsen at al., 2009) Extragalactic / Isotropic

Extragalactic radio background extrapolated from number counts is a factor of 6 below the measured one.

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Regis Marco (University of Turin and INFN)
Simplest solution for ARCADE excess:
Radio background is produced by radio sources taking over at sub-\(\mu\)Jy
(Singal et al, 2010)

**DRAWBACK** for “normal” astrophysical sources explanation:
- *ad hoc* evolutionary model (Singal et al, 2010, Ponente et al., 2011)
- constraints from gamma-rays (Lacki, 2010)
Simplest solution for ARCADE excess:

Radio background is produced by radio sources taking over at sub-μJy

(Singal et al, 2010)

The DM source can fit the excess!

(MR, Fornengo, Lineros, Taoso, in prep.)
Low multipoles dominated by Galactic foreground.
Number of DM sources at brightness $< m\text{Jy}$ is non-negligible.
Dwarf Spheroidal Galaxies

- Closest DM dominated objects other than the Galaxy (Flux\sim d^{-2}).

- Baryons highly subdominant: low background and more reliable DM distribution from simulations.

- Recent discovery by SDSS of new ultra-faint satellites in the Local Group.
Dwarf Spheroidal Galaxies

“Continuum and HI emissions from Local Group Dwarf Spheroidal Galaxies”
(MR, Colafrancesco, de Blok, Massardi, Profumo, Richter, Ullio)
Continuum rms sensitivity: 10 μJy/beam (130 observing hours in July/August with ATCA)

annihilation channel $b \rightarrow \bar{b}$, $m_{DM} = 100$ GeV, $\sigma_{\text{aT}} = 3 \times 10^{-26} \text{ cm}^3/\text{s}$, NFW profile
smoothed on 3' (CDS) and 1.4' (UDS)

Spatial diffusion neglected

$B = 1$ μG

Angular distance from the center [arcmin]

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Continuum and HI emissions from Local Group Dwarf Spheroidal Galaxies
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Continuum rms sensitivity: 10 μJy/beam (130 observing hours in July/August with ATCA)

annihilation channel $b \bar{b}$, $M_{DM} = 100$ GeV, $\sigma v = 3 \times 10^{-26}$ cm$^3$/s, NFW profile
smoothed on 3' (CDS) and 1.4' (UDS)

Intensity

Angular distance from the center [arcmin]

STAY TUNED!

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Regis Marco (University of Turin and INFN)
Radio versus gamma

**GOOD**

Better angular resolution
Typically better sensitivity (signal to rms noise)
No contamination from Galactic foreground (for extra-galactic objects)

**BAD**

It's an indirect\(^2\) method (additional unknowns)
Conclusions

Isolating a DM signal from astrophysical background through a spectral analysis only is rather difficult. Mapping the spatial profile is essential and for this purpose radio astronomy is a superior tool among DM indirect searches.

Probably, radio signals won't be the last word on the DM nature, but they could be one of the first evidences of non-gravitational DM interactions.