Dark Matter searches with radio observations

IDM 2012
Chicago, 23-27 July
Search for DM with astrophysical observations

Gamma-rays

Microwave

Radio

neutrinos

X-rays
Search for DM with astrophysical observations

Radio - Microwave  \quad X-rays  \quad \text{gamma-rays}
Search for DM with astrophysical radio observations

Annihilations or decays of DM produces $e^\pm$

e$^\pm$ spiraling in the magnetic field produce synchrotron radiation

$$\nu \sim 30 \text{ MHz} \frac{B}{6 \mu\text{G}} \left( \frac{E_e}{1 \text{ GeV}} \right)^2$$
Search for DM with astrophysical radio observations

Different frequencies probe different regions of the electron spectrum. Predictions affected by uncertainties on electrons propagation & Magnetic Fields

$$\nu \sim 30 \text{ MHz} \frac{B}{6 \, \mu \text{G}} \left( \frac{E_e}{1 \, \text{GeV}} \right)^2$$
Probing Galactic Magnetic field & CR electron spectrum

Synchrotron probes both the interstellar CR electron density & Galactic magnetic field.
Use also Cosmic-Rays data and Faraday rotation measurements to break the degeneracy

See also Strong et al. 2011, Jaffe et al. 2011

Sun et al. 2008
Radio maps: a tool to study CRs and magnetic fields

Consistent model of GMF and CRs propagation to tune against synchrotron diffuse emission.

Strong, Orlando, Jaffe 2011

Bringmann, Donato, Lineros 2011
Radio maps: a tool to study CRs and magnetic fields

Low/high frequency surveys probe different parts of the interstellar electron spectrum

Strong, Orlando, Jaffe 2011
Galactic DM radio signal at different frequencies

Low frequencies particularly useful to test light DM: electrons < few GeV give a synchrotron peak at 5-50 MHz (1-10 μB GMF)
Radio surveys from 22MHz to 1420 MHz
Galactic DM radio signal

The usual suspect: Galactic Center
Larger DM signal & astro uncertainties!

\[ T \propto (v/\text{MHz})^{2.5} \]

\[ M_{\text{DM}} = 10 \text{ GeV} \]

\[ 45 \text{ MHz} \]

\[ \text{MIN, MED, MAX} \]

\[ \text{NFW, Isothermal} \]

Galactic latitude [degrees]
Constraints on DM

Radio constraints competitive with those from other searches depending on the annihilation channel

Many constraints from radio! e.g. Barger+ 09, Bertone+ 09, Bergstrom +09, Boehm+ 09, Borriello+ 09, Cholis+09, Cuoco 09, Caceres+ 08, Delahaye+ 10, Hooper 08, Ischiwata+ 09, Linden+ 10, Pato+ 10, Siffert 11, Zhang+ 09, .....

Galli et al. 2009
Slatyer et al. 2009
Fornengo, Lineros, Regis, MT 2011

Similar analysis in Mambrini+ 12
Galactic center

Radio image of the Galactic center from VLT and GBT

Advantage of radio: closer look thanks to the good angular resolution

DM signal may lie somewhere here
Galactic center


DM is an option

Linden Hooper Yusef-Zadeh 2011

Credit: NRAO/AUI/NSF Yusef-Zadeh, et.al.
Galactic center


DM is an option  Linden Hooper Yusef-Zadeh 2011
Galactic center

Combination of radio and gammas to test the origin of unknown emission
Claim that Fermi GeV emission correlates with 20cm radio emission
Suggested a common origin in terms of electrons emission: synchrotron (radio) and bremsstrahlung (gamma)
A multi-wavelength perspective should be followed to look for DM signals

Zadeh et al. 2012
Constraints on DM

Multiwavelength constraints from the GC region

- Crocker et al 2010
- Ullio Regis 2008
What do we look for?

Bright emission around GC

Shape, normalization & spectra consistent with realistic assumption on DM

Need to remove the astro emission. Hard work!!!!

We have something similar! The microwave haze!
WMAP Haze

Discovered in WMAP data after subtraction of CMB and foregrounds
Roundish spot around GC. Finkbeiner 2004
Spectrum suggest synchrotron from hard population of electrons

K-band 7-year WMAP haze/bubbles

Dobler 2012
WMAP Haze & DM

DM works fine with reasonable assumptions on B field and propagation
No real preference for the DM mass: from GeV to TeV DM
Light WIMPs (around 10 GeV) need large magnetic fields close to the GC

Hooper, Linden 2011
WMAP Haze & Fermi bubbles

These 2 emissions seem to be correlated
WMAP Haze can be the synchrotron counterpart of IC Fermi bubbles
DM option for haze seems more involved
Maybe with prolate halos + anisotropic diffusion?  

Su et al. 2010

Dobler et al. 2011

http://www.nasa.gov/mission_pages/planck
Searches of DM signals

Microwave haze: DM is an option

WMAP haze and Fermi bubbles show that the GC region has complicated dynamics: a complication for DM searches and potential issue for the robustness of the constraints.

To search DM signals we need good templates to understand the bkg:

- LOFAR (10-240 MHz)
- PLANCK microwave

Multiwavelength analysis to check the mechanism at work
Where to look for DM signals?

Diffuse extragalactic radio emission can be extracted from the maps looking at high latitudes.
Extragalactic isotropic radio background

Data from low frequency surveys 22 MHz 45 MHz 408 MHz 1420 MHz + ARCADE-2 3.2 GHz – 90 GHz

Galactic emission estimated with 2 methods:
Extragalactic isotropic radio background

Removing the CMB monopole the extragalactic bkg is detected < 10 GHz
Consistent with a power law with index -2.62

Fixsen et al. 2009
Source number counts

\[ \log[L(\text{W Hz}^{-1}) \text{ at } (z)=0.8] \]

\[ \nu = 1.4 \text{ GHz} \]

Radio Loud AGN

Star Forming Galaxies

Vernstrom, Scott, Wall 2012
Source number counts

CRB inferred by ARCADE-2 is 480 mK!

Expected contribution of radio sources to CRB

Vernstrom, Scott, Wall 2012
ARCADE excess

Also counts at other frequencies give the same result: the extragalactic radio bkg is a factor 5 higher than expected

See also Singal et al. 2010, Ponente et al. 2011, Gervasi et al. 2008

Vernstrom et al 2011

See also Singal et al. 2010, Ponente et al. 2011, Gervasi et al. 2008
Possible explanation of the ARCADE excess

Undetected population of radio sources with $< \mu\text{Jy}$ fluxes

Potential problems with standard astro-sources, e.g. constraints from gamma and X-rays (diffuse emission intragalactic) or Infrared (for Star Forming galaxies)

Singal et al. 2010, Lacki 2010, Ponente et al. 2010
DM interpretation of the ARCADE excess

Fornengo, Lineros, Regis, M.T. 2011

Faint and numerous extragalactic DM halos can explain the excess.
Good fit only with leptonic channels.
DM interpretation of the ARCADE excess

Extragalactic DM signal can explain the excess.
Ok with bounds from extragalactic gamma-ray background
DM interpretation of the ARCADE excess

Hooper, Belikov, Jeltema, Linde, Profumo, Slatyer 2012

DM interpretation can work for reasonable assumption of clustering and Bfields Ok with gamma-ray constraints.
ARCADE-2 mystery, possible options:

1) The radio background estimated by ARCADE-2 collaboration is off, for instance because it is contaminated by galactic foreground.

2) There is an undetected population of faint and numerous radio sources with small enough emission at other wavelengths.

DM is an option. Difficult to test it since the the signal is featureless.
Milder assumption:

DM contribution to the ERB intensity comparable to astro contribution

DM can dominate number counts at sub $\mu$Jy fluxes

Future telescopes: EVLA and ASKAP soon, SKA (long term project)
Conclusions

Radio observations set interesting constraints on the DM parameters
DM possible option for some puzzling observation

Potentially interesting prospects for extra-galactic DM searches with future surveys.
However many uncertainties both in the modeling of DM signal and astro-background

Need data from Planck, LOFAR, EVLA, ASKAP, SKA + other wavelengths

THANKS