Magnetic fields and CRs in the disk-halo interface of spiral galaxies

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B-field & CRs possibly important... (e.g., talks by Burkhart, McClure-Griffiths)

Implications of MHD Turbulence

- ISM/AGN Feedback
- Galactic Evolution
- ISM Pressure Support
- Star formation
- Magnetic Field Amplification
- Magnetic Reconnection
- Cosmic Rays
- MHD Interstellar Turbulence
- ISM/magnetized plasma, clouds, etc.
Magnetic Fields and Cosmic Rays contribute significantly to the energy density:

\[ U_{\text{rad}} \sim U_B \sim U_{\text{CR}} \sim U_{\text{kin}} \]
SIMULATIONS OF DISK GALAXIES WITH COSMIC RAY DRIVEN GALACTIC WINDS

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FIG. 3. — Edge-on maps of the temperature in a thin slice around the MW (top panels) and SMC galaxies (bottom panels) for both the thermal feedback (left panels) and CR feedback (right panels). CR feedback has a large effect on the temperature structure of the halo gas. The plots show the median velocity (left panels) and outward pressure force (right panels) as a function of height from the disk for the same two simulations. All quantities are calculated in a cylinder of radius 250 kpc centered on the galactic disk. It is clear that the effect of the CRs is to increase the outward pressure force in the halo by a factor of 5-5 at all z. This pressure gradient slowly accelerates the wind into the halo. The wind in the thermal feedback simulations is accelerated abruptly from the disk and maintains a constant velocity thereafter.

the prototypical galactic wind M82 (?)
M82 in X-rays / XMM (Wezgowiec, et al. in prep.)

cosmic ray transport in M82

Adebahr et al. 2013, A&A
analysis of CR transport (ATCA 6&20cm)

V. Heesen, R.-J. Dettmar et al. in prep.
NGC 5775 comparison at three wavelengths

Soida, Krause, Dettmar, Urbanik A&A 2011

NGC 6946
6cm VLA+Effelsberg
Polarized intensity on HI
(Beck 2007)

polarization asymmetry
very important step:

solution by quadrupol halo field

The Westerbork SINGS survey II
Global magnetic field topology
R. Braun¹, G. Held², and R. Beck²

and even more general description:

Analytical models of X-shape magnetic fields in galactic halos
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ABSTRACT

Context. External spiral galaxies seen edge-on exhibit X-shape magnetic fields in their halos. Whether the halo of our own Galaxy also hosts an X-shape magnetic field is still an open question.

Aims. We would like to provide the necessary analytical tools to test the hypothesis of an X-shape magnetic field in the Galactic halo.

Methods. We propose a general method to derive analytical models of divergence-free magnetic fields whose field lines are assigned a specific shape. We then utilize our method to obtain four particular models of X-shape magnetic fields in galactic halos. In passing, we also derive two particular models of predominantly horizontal magnetic fields in galactic disks. All our field models have spiraling field lines with spatially varying pitch angle.

Results. Our four halo field models do indeed lead to X patterns in synthetic synchrotron polarization maps. Their precise topologies can all be explained by the action of a wind blowing outward from the galactic disk or from the galactic center. In practice, our field models may be used for fitting purposes or as inputs to various theoretical problems.

Key words. Galaxies: magnetic fields – galaxies: halos – galaxies: spirals – Galaxy: halo – Galaxy: disk – ISM: magnetic fields
that's what is observed:

large scale magnetic field structure in halos

the global magnetic fields in disk galaxies typically have a significant poloidal component (based now on 6+ cases studied, Dettmar & Soida 2006, Soida 2005)
Making use of the JVLA

**Changes:**
Continuum HAlos in Nearby Galaxies
- an Evla Survey

35 edge-on galaxies

- inclination > 75 deg
- DEC > 25 deg
- 4 arcmin > D < 15 arcmin
- flux > 23 mJy

PI: Judith Irwin, Kingston (ONT/CANADA)

„averaged“ radio continuum halo
HBA at Jülich (FZ Jülich- RU Bochum)
Summary:

- Halos of spiral galaxies have a significant poloidal magnetic field component (quadrupol field)
- New broad-band multichannel receivers provide higher sensitivity and allow for new analysis techniques such as Rotation Measure Synthesis
- CR driven winds could be important for the evolution of galaxies
- Surveys aiming at measurements of magnetic fields and CRs in halos of a larger number of objects are underway
Thank you for your attention