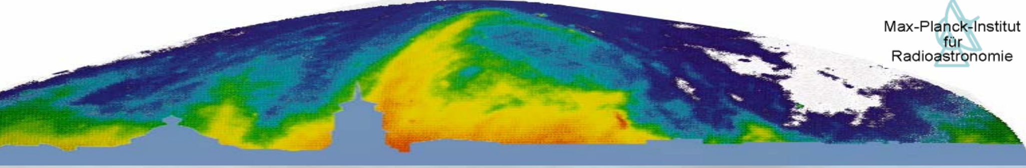
ICMM

Max-Planck-Institut für Radioastronomie



# TURBULENCE IN THE MAGNETIZED INTERSTELLAR MEDIUM

*German-Russian Open Workshop,*
*Perm, Russia, September 6-8, 2006*

## Programme and Abstracts

SPONSORED BY

# TURBULENCE IN THE MAGNETIZED INTERSTELLAR MEDIUM

## German-Russian Open Workshop

6-8 September 2006

## Programme and Abstracts

Perm, Russia

ORGANIZED BY:
Institute of Continuous Media Mechanics UB RAS

SUPPORTED BY:
Russian Foundation for Basic Research
German Research Foundation
Ural Branch of the Russian Academy of Sciences
Administration of the Perm Region

CO-CHAIRMEN
Prof. Peter Frick (Institute of Continuous Media Mechanics, Perm, Russia)
Dr. Rainer Beck (Max Planck Institute for Radio Astronomy, Bonn, Germany)

LOCAL COMMITTEE:
P. Frick
R. Stepanov
G. Tsaplina

# Programme

| Sept. 6 | | Sept. 7 | | Sept. 8 | |
|---|---|---|---|---|---|
| **Sec.I** | | **Sec.V** | | **Sec.IX** | |
| **Opening remarks** | **15** | **Krause M.** | **30** | **Raedler K.-H.** | **30** |
| **Reich W.** | **30** | **Beck R.** | **30** | **Sokoloff D.** | **30** |
| **Kothes R.** | **30** | **Tabatabaei F.** | **15** | **Akhmetiev P.** | **30** |
| **Haverkorn M.** | **30** | **Mao S.A.** | **15** | | |
| **Sec.II** | | **Sec.VI** | | **Sec.X** | |
| **Schnitzeler D.** | **30** | **Kitchatinov L.** | **30** | **Frick P.** | **30** |
| **Waelkens A.** | **15** | **Ruediger G.** | **30** | | |
| **Newton-McGee K.** | **15** | **Elstner D.** | **30** | **Closing remarks** | |
| **Stepanov R.** | **30** | | | | |
| **Sec.III** | | **Sec.VII** | | | |
| **Fletcher A.** | **30** | **Moss D.** | **30** | **VISIT** | |
| **Schaefer-Rolffs U.** | **30** | **Schekochikhin A.** | **30** | **TO** | |
| **Mizeva I.** | **15** | **Artyukh V.** | **30** | **ICMM** | |
| **Popova E.** | **15** | **Tarbeeva S.** | **15** | | |
| **Zamorina A.** | **15** | | | | |
| **Sec.IV** | | **Sec.VIII** | | | |
| **Dogiel V.** | **30** | **ROUND-** | **60** | | |
| **Shchekinov Yu.** | **30** | **TABLE** | | | |

9:00 breakfast
9:30 - 11:15 section
11:15 - 11:45 coffee-break
11:45 - 13:15 section
13:15 - 14:30 lunch
14:30 - 16:15 section
16:15 - 16:45 coffee-break
16:45 - 18:00 section
19:00 diner

# Faraday screens: Do they mimic turbulence ?

W. Reich

Recent polarization observations have revealed the existence of passive large diameter Faraday screens in the interstellar medium, which have rather regular and strong magnetic fields compared to interstellar values. Such features were not known so far and their origin is still to be determined. The identification of Faraday screens by a clear polarization signature is limited to a narrow frequency range, although their effect on the polarized background emission exists everywhere. It seems possible that a number of Faraday screens with different physical properties may explain the observed Galactic polarization from the magnetized ISM.

# Studying the interstellar magneto-ionic medium through the Canadian Galactic Plane Survey

R. Kothes

The Canadian Galactic Plane Survey is a study of the Galactic ecosystem in the outer Milky Way, comprising HI and CO observations, reprocessed IRAS surveys, and radio continuum observations in Stokes I at 408 and Stokes I, Q, and U at 1420 MHz. The CGPS covers an area between Galactic Latitude of -3.5 and +5.5 degrees and Galactic Longitude of 55 and 192 degrees. I will give an overview of our polarization measurements and present some first results of studies into the local and global magneto-ionic medium.

# Small-scale structure in the Galactic ISM, from depolarization of polarized extragalactic sources.

M. Haverkorn

Fluctuations in the interstellar gas density and magnetic field of the Milky Way extend over many orders of magnitude. At larger scales (parsecs to kiloparsecs) this structure can be probed by various techniques such as Faraday rotation of extragalactic point sources, synchrotron radiation, and starlight or dust polarization. On scales much smaller than a parsec the turbulent ISM is probed mostly by way of pulsar scintillation experiments. Structure in the magnetized ISM on intermediate scales has been probed with radiopolarization observations of slightly extended extragalactic sources like double-lobed radio galaxies. Here, I will present measurements of depolarization of extragalactic sources due to the Milky Way ISM, indicating fluctuations in electron density and/or magnetic field on these (sub)parsec scales. From depolarization models fitted to the data we obtain values for the random magnetic field and a typical scale of structure in the Galactic plane, where we attempt to make a distinction between spiral arms and interarm regions.

## The WENSS & Dwingeloo surveys and the Galactic magnetic field

D. Schnitzeler, P. Katgert, M. Haverkorn, G. de Bruyn

I will present results we obtained from the WENSS survey in the second Galactic quadrant. By including data from the single-dish survey by Brouw and Spoelstra we could correct for some of the large-scale structure missing from WENSS. The WENSS data indicate strong gradients in polarization angle with Galactic latitude, but hardly any gradients with Galactic longitude. We found similar gradients in the single-dish RM data when the large-scale structure is not too bright. We derived the strength of the parallel component of the magnetic field by calculating dispersion measures from the Cordes and Lazio model. By combining our data with the estimates by Haverkorn et al. of the magnetic field component perpendicular to the line-of-sight we derived the strengths of all 3 components of the magnetic field vector, and in particular we could estimate the strength of the magnetic field component perpendicular to the Galactic plane.

## Simulation and Analysis of Polarized Intensity Maps

A. Waelkens, T. Ensslin A. Schekochihin

We present the latest version of a software tool for simulating galactic polarized synchrotron emission. We also present results of a related work where we develop a technique for analysing high frequency, Faraday depolarization-free synchrotron maps to study MHD trubulence.

# The Nature of Depolarisation Canals in the southern Galactic Plane

K. Newton-McGee, M. Haverkorn, R. Ekers,
B. Gaensler, A. Green

Measurements of the Galactic radio polarized background have revealed many complicated structures in the interstellar medium (ISM). Recently there has been an interest in the dark and narrow depolarization canals. I will present a study of three regions in the southern Galactic Plane taken with the Australian Telescope Compact Array (ATCA). ATCA is a radio synthesis telescope and these three regions were taken using a mosaicking technique at a range of frequencies around 1.4 and 1.7 GHz, at two different angular resolutions. At these frequencies the canals are ubiquitous in regions of strong polarization. The range of frequencies and resolutions combined with statistical analysis of the relevant Stokes parameters and position angle maps have led us to conclude that at these frequencies the majority of the canals are caused by differential Faraday rotation. It will be these canals that we are focusing on, rather than those caused by beam depolarization. We discuss the evidence that canals are contours following nulls in differential Faraday rotation by presenting rotation measure maps and analysis of the angular separation of the canals.

# Galactic magnetic field reconstruction form the Faraday rotation measures

R. Stepanov, P. Frick, D. Sokoloff, A. Shukurov

The problem under consideration deals with the determination of the large-scale structure of the magnetic field of our galaxy according to the RM data. The idea is to combine extragalactic and pulsar RM data in an analysis. This substantially increased observation base and gave a sufficient degree of accuracy and stability of 3D reconstruction. On basis wavelet transform the method of analysis is developed. It gives a possibility to perform the differentiation of observant data. As a result of processing it was obtained the resistant to measurement errors features of the global structure of the magnetic field of galaxy, which it possible to draw a number of the essential conclusions: to determine direction of the magnetic field in the spiral arms, to reveal the presence of the shift between the arms of ionized gas and the magnetic field arms

# Depolarization canals and interstellar turbulence.

A. Fletcher and A. Shukurov.

Recent radio polarization observations have revealed a plethora of unexpected features in the polarized Galactic radio background that arise from propagation effects in the random (turbulent) interstellar medium. The canals are especially striking among them, a random network of very dark, narrow regions clearly visible in many directions against a bright polarized Galactic synchrotron background. There are no obvious physical structures in the ISM that may have caused the canals, and so they have been called Faraday ghosts. They evidently carry information about interstellar turbulence but only now is it becoming clear how this information can be extracted. We will discuss the physical nature of the canals and how they can be used to explore statistical properties of interstellar turbulence. This opens studies of magnetized interstellar turbulence to new methods of analysis, such as contour statistics and related techniques of computational geometry and topology. In particular, we can hope to measure such elusive quantities as the Taylor microscale and the effective magnetic Reynolds number of interstellar MHD turbulence.

# About the generation of cosmic magnetic fields

U. Schaefer-Rolffs

In this presentation I will give some recent applications of the Weibel instability. On the one hand, the Weibel instability offers a possibility to generate magnetic fields of galaxies in the early universe - most theories which describe the present field strengths depend on a seed field without an explanation where it come from. However, the Weibel instability results from an unmagnetized plasma and calculations have shown that it can generate fields up to a strength of about 10^-6 G. Furthermore, most astrophysicist agree that the radiation of gamma-ray bursts (GRB) stems from a relativistic shock wave. Again, an overall explanation lacks to now. I present a model of such a shock wave generated by the Weibel instability which is consistent to the observations that most GRB's are domiciled in regions with a high component of neutral gas.

# Statistical analysis of polarized radio maps

I.Mizeva, R.Beck, P.Frick, W.Reich, D.Sokoloff

Polarized intensity and polarization angles are calculated from Stokes parameters Q and U in a nonlinear way. Polarization observations require data processing steps different from those in total intensity, which might largely influence the results.The statistical properties of polarized emission hold information about the structure of magnetic fields in a large range of scales. However, the contribution of different stages of data processing to the statistical properties should first be understood. We use 1.4~GHz polarization data from the Effelsberg 100-m telescope of emission in the Galactic plane, near the plane and far out of the plane. We analyze the probability distribution function and the wavelet spectrum of the original maps in Stokes parameters Q, U and corresponding PI. Then we apply absolute calibration (i.e. adding the large-scale emission), source subtraction and denoising. We show how each procedure affects the statistical properties of the data. We find a complex behaviour of the statistical properties for the different regions analyzed which depends largely on the intensity level of polarized emission. Absolute calibration changes the morphology of the polarized structures. The statistical properties change in a complex way: Compact sources in the field flatten the spectrum over a substantial range. Adding large-scale emission does not change the Q and U spectral slopes at small scales, but changes PI in a complex way. Denoising significantly changes the p.d.f. of PI and raises the entire spectrum. The final spectra are flat in the Galactic plane, probably due to magnetic structures, but steeper at high Galactic latitude and in the anticenter. For a reliable study of the statistical properties of magnetic fields and turbulence in the ISM based on radio polarization observations, several steps of data processing are required, in particular absolute calibration and source subtraction.

# Multifrequency analysis of quasiperiodical astrophysical signals

E. Popova and P. Frick

We describe a novel technique, called the Double Wavelet Analysis (DWA), introduced for the determination of stellar rotation periods from time serial data. This first application aims narrowly at the discussion, introduction and application of the DWA technique to records of surface magnetism in solar-type (relatively old) lower main sequence stars that are obtained by the Mount Wilson Observatory (MWO) HK Project. The technique takes a series of careful steps that seek to optimize wavelet parameters and normalization schemes, ultimately allowing fine-tuned, arguably more accurate, estimates of rotation-modulated signals (with, e.g., periods of days to months) in records that contain longer periodicities such as stellar magnetic activity cycles (with, e.g., period of years). The apparent rotation periods estimated from the DWA technique are generally consistent with results from both first-pass" (i.e., ordinary) global wavelet spectrum and earlier classical periodogram analyses. But there are surprises as well. For example, the rotation period of the ancient subdwarf Goombridge 1830 (HD 103095), previously identified as approximately 31 days, suggests under the DWA technique a significantly slower period of 60 days. DWA spectra also generally reveal a shift in the cycle period toward high frequencies (hence shorter periods) compared to the first-pass wavelet spectrum. For solar-type stars analyzed here, the character of the DWA spectrum and slope of the first-pass global wavelet spectrum produce a classification scheme that allows a star's record to be placed into one of three categories.

## Modeling of depolarization effects in ISM

A. Zamorina and R. Stepanov

Several artificial distributions of the magnetic field components, thermal and relativistic electron densities are considered in a data cube with $256^3$ mesh points. Faraday rotation and mixing of waves with different polarization angles result in depolarization effects. We try to define a relation between spectral property of magnetic field and polarization map.

## Interaction between charged particles and magnetic turbulence in the interstellar medium

V. Dogiel

We consider processes of particle propagation and acceleration in the interstellar plasma. From spectra of electromagnetic turbulence we derive coefficients of kinetic equations describing variations of the particle distribution function. As an example we analyze processes of particle penetration into molecular clouds and acceleration there under the influence of a neutral gas turbulence. We analyze also a spectrum of MHD- turbulence excitation by a flux of cosmic rays escaping from galaxies.

# Dynamics of dust in magnetized interstellar shock waves.

Yu. Shchekinov

Destruction of dust particles in the interstellar medium is connected with strong shock waves. In standard paradigm collisional dust destruction -- sputtering -- behind radiative shocks is greately boosted by betatron acceleration of charged grains. We argue, however, that several instabilities behind the magnetized shocks, such as the interchange instability, or the mirror instability (particularly important behind radiative shocks with $p_{\perp} >> p_{\parallel}$) can strongly suppress betatron acceleration. As a result, the rate of collisional destruction of dust particles saturates, and even for sufficiently strong shocks ($v_s$>200 km $s^{-1}$) the fraction of sputtered dust can be relatively small: ~ 0.1 for graphite grains. Dust destruction rate can be also strongly suppressed behind shock waves propagating through a magnetized turbulent medium. In this case, the instabilities develop behind the front in a medium where strong perturbations are initially present, and localized structures like magnetic traps can form and isolate dust particles from a hostile environment. At such conditions dust particles easily survive against sputtering behind shock waves. This can explain recent observations of dust survived behind strong shocks

.

# Star formation and magnetic fields in spiral galaxies of different morphological types

M. Krause

I will present radio observations of spiral galaxies of different morphological types that all have a low star formation rate. These galaxies still follow the radio-FIR correlelation for their total radio emission. Their thermal fraction, however, is larger than usually assumed for normally star-forming galaxies. Hence, the fraction of nonthermal (synchrotron) emission in these galaxies is /smaller/ than for normally star-forming galaxies and –as expected- also their magnetic field strengths are lower than usual and belong to the lowest field strengths found in spiral galaxies. The low degree of linear polarization indicates that the magnetic fields are also less ordered than in normally star-forming galaxies. These observations support the view that star formation plays a significant role for the magnetic field amplification and its structure formation. Further, I can discuss the radio observations of the Sombrero galaxy in more detail. We could reveal for the first time a large-scale magnetic field in an Sa galaxy in the radio range. Its configuration resembles very much that of other edge-on galaxies despite the different optical appearance of the galaxy. Expecially in view of galaxy evolution as bar formation and dissolving, this result is rather surprising and may help to constrain important parameters of dynamo action.

# Properties of interstellar magnetic fields derived from radio polarization observations

R. Beck

The strength and structure of interstellar magnetic fields have been studied by observations of radio continuum emission, its polarization and its Faraday rotation. Fields with a well ordered spiral structure exist in grand-design, barred, flocculent and even irregular galaxies. Total field strengths in spiral arms and bars 10 - 30 MicroGauss. In spiral galaxies the fields are aligned parallel to the optical spiral arms, but the strongest regular fields are found in interarm regions, sometimes forming ``magnetic spiral arms" between the optical ones. The turbulent field is compressed in the spiral arm or bar shock, generating strong anisotropic random fields which give rise to polarization but not to Faraday rotation. The regular field decouples from the cold gas and is hardly compressed. Within spiral arms with massive star formation, field lines are tangled so that very little polarization is observed. Faraday rotation measures reveal patterns which are signatures of coherent large-scale fields in galactic disks. Magnetic fields are also observed in galactic halos at large distances from the disks. The largest halos and strongest fields result from galactic winds, from interaction, or from ram pressure in an intercluster medium. Present-day radio polarization observations are limited by sensitivity. Next-generation radio telescopes (LOFAR and the Square Kilometer Array) will be able to reveal the full wealth of magnetic structures in galaxies.

# The radio-(F)IR correlation in M33

F. Tabatabaei, M. Krause, R. Beck,
E. Berkhuijsen

The origin of the tight radio-(F)IR correlation in galaxies has not been understood. One reason is the uncertainty about which heating sources (stars, diffuse interstellar radiation field) provide the energy that is absorbed by the dust and re-radiated in FIR. The nearest Scd galaxy, M33 (NGC598), is ideal to investigate possible energy sources of the FIR and radio emission from late type galaxies. We have used the Wavelet analysis for the Spitzer (24, 70, and 160 $\mu$m MIPS), radio ($\lambda$3.6 cm Effelsberg and $\lambda$20 cm VLA) and H$\alpha$ data of M33 to a) separate the diffuse emission from that of compact sources, b) study the spectral characteristics, and c) find the cross–correlation coefficients for each pair of maps.

Our results indicate that the FIR emission from M33 at 24 and 70 $\mu$m originates mostly from the young O/B stars in HII regions. At 160 $\mu$m, the emission emerges from more extended regions and shows less correlation with the ionized gas. On the other hand, perfect correlations between the radio $\lambda$3.6 cm and H$\alpha$ maps implicate thermal free–free emission dominance in the $\lambda$ 3.6 cm continuum emission from M33. The effect of the thermal emission on the small–scale turbulence is important even at $\lambda$20 cm . The studied wavelet spectra of the radio, FIR, and H$\alpha$ emissions from M33 do not show the three–dimensional Kolmogorov–type of turbulence. It is confirmed that the local radio–FIR correlation is due to a correlation between the warm dust and the thermal radio emission, and between the cool dust and the nonthermal radio emission.

# The Magnetic Field of the Small Magellanic Cloud and the Magellanic Bridge

S.A. Mao, B. Gaensler, M. Haverkorn, J. Dickey, S. Stanimirovic, J. Gelfand, N. MacClure-Griffiths, L. Staveley-Smith

We have studied the magnetic field strength and structure of the Small Magellanic Cloud (SMC) and the Magellanic Bridge using 1.4-GHz polarization data taken at the Australia Telescope Compact Array, covering 40 square degrees. We extracted the Faraday Rotation measures of 70 polarized sources from the SMC data, 7 of which lie directly behind the SMC. After subtracting foreground rotation measures of the Milkway, we find large negative rotation measures for sources that lie directly behind the SMC. This suggests that the line of sight component of the magnetic field of SMC points towards us. We will present the result of this study and its implications for the subject of galactic magnetic fields

.

# Global modes of MRI in galactic disks

L. Kitchatinov

A linear but global numerical model of MRI in a disk geometry is applied to estimate the MRI parameters for galaxies. The low bound on the field strengths producing the instability $\sim 10^{-25}$G is very small compared to any primordial galactic fields currently discussed. The characteristic growth time of the instability is about the rotation period (~ 0.1 Gyr) of the inner rigidly rotating cores. Global MRI excites preferentially magnetic fields of quadrupolar symmetry. The instability remains active up to field strengths of about $10^{-5}$G. The possibility of galactic dynamos driven by the turbulence produced by MRI is discussed.
Ambipolar diffusion does not change the range of field strengths producing MRI in galaxies. Hall effect, though generally small, may be significant. The effect is accounted by a nonlinear term in the induction equation. Accordingly, the mean electromotive force attains a new contribution also. The new term is responsible for a conversion of fluctuating magnetic fields into global fields in presence of nonuniform global flows. This process can compete with Biermann battery effect in producing seed fields for galactic dynamos.

## Magnetorotational instability in the MHD Taylor-Couette experiment PROMISE

G. Ruediger

To obtain the magnetorotational instability in the laboratory one needs Reynolds numbers exceeding $10^6$ due to the small magnetic Prandtl number Pm of the liquid metals. We have shown, however, that in the presence of combined axial and azimuthal magnetic fields a new solution appears beyond the Rayleigh line which does not depend on Pm. The critical Reynolds number can now be reduced to about 1000 which does not make any technical difficulty. For liquid gallium between conducting cylinders the necessary axial magnetic field is ~50 Gauss and the axial current which produces the azimuthal field must have ~3500 Amp. The vertical cell structure of the instability strongly depends on the magnetic geometry. The pattern travels upwards or downwards in correspondence to the helicity of the spiral magnetic field. The design of the PROMISE (PotsdamROssendorfMagneticInStabilityExperiment) prototype is given. The experiment (which is fullly numerically simulated) is currently under construction in the MHD department of the Forschungszentrum Rossendorf and starts to work.

## The magnetorotational instability in galaxies.

D. Elstner

Global simulations of the MRI in galactic disks are presented. Following the time evolution of different initial field configurations, we look for dynamical impacts of magnetic fields on the gasous disk evolution.

## Dynamo models for the large barred galaxy NGC 1365

D. Moss

A dynamo model is constructed for the magnetic field of the barred galaxy NGC 1365. The velocity and density fields are taken from a gas dynamical model, that fits well the HI and CO observations of the interstellar gas. The modelling is robust, in that its most important features are controlled by the relatively well established properties of the density and velocity distributions. We evaluate our models by producing synthetic radio maps that allow qualitative comparison with the observed maps. We conclude that if the cosmic ray energy distribution varies less strongly across the galaxy than the magnetic energy density, then a quite satisfactory agreement can be obtained - i.e. it appears that large-scale deviations from equipartition between cosmic rays and the energy of large-scale magnetic fields are unavoidable. Regular (large-scale) fields can be strong enough in the inner regions of the galaxy for magnetic stresses to drive a mass inflow at a rate of a few solar masses a year. It follows that it is not permissible to assume that magnetic effects are unimportant when constructing gas dynamical models of barred galaxies.

# Magnetised turbulence in the weakly collisional plasma of the ISM.

A. Schekochihin, S. Cowley, W. Dorland

Theoretical approaches to the low-frequency magnetized turbulence in collisionless and weakly collisional astrophysical plasmas are reviewed. The starting point for an analytical description of these plasmas must be kinetic theory, not fluid equations. Above the ion gyroscale, it can be shown rigourously that the Alfven waves decouple from the electron-density and magnetic-field-strength fluctuations and satisfy the Reduced MHD equations. These form part of a hybrid fluid-kinetic description of the low-frequency turbulence valid independently of collisionality. The density and field-strength fluctuations (slow waves and the entropy mode in the fluid limit), determined kinetically, are passively mixed by the Alfven waves. In the absence of finite-gyroradius effects, these fluctuations do not develop small scales along the perturbed magnetic field and may be undamped above the ion gyroscale. Below the ion gyroscale, the turbulent cascade is partially converted into a cascade of kinetic Alfven waves, damped at the electron gyroscale. The development of these theoretical models is motivated by observations of the turbulence in the solar wind and interstellar medium. In the latter case, the turbulence is spatially inhomogeneous and the anisotropic Alfvenic turbulence in the presence of a strong mean field may coexist with isotropic MHD turbulence that has no mean field.

## Investigations of physical conditions in AGNs by the radio astronomy method.

V. Artyukh

Investigations of physical conditions in AGNs, that contain compact radio sources, are carried out at Pushchino Radio Astronomy Observatory (PRAO) of the Lebedev Physical Institute of RAS. It is a short review of the investigations.

## Cosmological magnetic field evolution in the early Uuniverse

S.Tarbeeva, V.Semikoz, D.Sokoloff

Magnetic field of galaxies is believed to be generated by galactic dynamo based on a joint action of differential rotation and alpha-effect. The dynamo needs however a seed magnetic field. The origin of the seed field remains obscure. It could be produced in protogalaxies by battery effects and then amplified by small-scale dynamo. A cosmological origin of the seed magnetic field is however widely discussed in the literature. Several mechanisms of magnetic field excitement in the early Universe was suggested. In particular, the cosmological magnetic field can be exited due to violating of the mirror symmetries in weak interactions. Preliminary investigations of the process gave optimistic results. Here we present a detailed description of the evolution of the magnetic field generated at the above process and arrive to the conclusion that the present-day spatial scale of the field is about 1 km only. We argue that the bound obtained is of a general nature and is valid for various excitation mechanisms of cosmological magnetic fields. We conclude that the concept that the seed magnetic field for galactic dynamos is not connected with cosmological magnetic field looks preferable.

# On the effects of turbulence on a screw dynamo

K.-H. Rädler and R. Stepanov

In the Perm dynamo experiment a non--stationary screw dynamo should be realized with a helical flow of liquid sodium in a torus. The flow is necessarily turbulent, that is, may be considered as a mean flow and a superimposed turbulence. The induction processes of the turbulence have been investigated within the framework of mean--field electrodynamics. They imply of course a part which leads to an enhanced dissipation of the mean magnetic field. As a consequence of the helical mean flow there are also helical structures in the turbulence. They lead to some kind of alpha-effect, which might basically support the screw dynamo. The peculiarity of this alpha-effect explains measurements made at a smaller version of the device envisaged for the dynamo experiment. The helical structures of the turbulence lead also to other effects, which in combination with a rotational shear are potentially capable of dynamo action. A part of them can basically support the screw dynamo. Under the conditions of the experiment all induction effects of the turbulence prove to be rather weak in comparison to that of the main flow. Numerical solutions of the mean--field induction equation show that all the induction effects of the turbulence together let the screw dynamo threshold slightly, at most by one per cent, rise. The numerical results give also some insights into the action of the individual induction effects of the turbulence.

# Saturation and quenching in alpha-square dynamo

D. Sokoloff, R. Stepanov, P. Frick

The evolution of the large-scale magnetic field in a turbulent flow of conducting fluid is considered in the framework of a multi-scale alpha-square dynamo model, which includes the poloidal and the toroidal components for the large-scale magnetic field and a shell model for the small-scale MHD-turbulence. The conjugation of the mean-field description for the large-scale field and the shell formalism for the small-scale turbulence is based on severe conformity to the conservation laws. The model displays a substantial magnetic contribution to the alpha-effect in spite of magnetic helicity conservation and the absence of the magnetic helicity sharing. It has been shown that a large-scale magnetic field can be generated solely by current helicity. The alpha quenching and the role of the Pm are studied. We have determined the dynamic nature of the saturation mechanism of dynamo action. A simultaneous cross-correlation of alpha and large-scale magnetic field energy is negligible, whereas coupling between alpha and magnetic field energy becomes substantial for moderate time lags. An unexpected result is the behavior of the large-scale magnetic energy with variation of the Pm. Diminishing of the Pm does not have inevitable ill effect on the magnetic field generation. The most efficient large-scale dynamo operates under relatively low Pm - then the small-scale dynamo is suppressed and the decrease of Pm can lead even to superequipartition of the large-scale magnetic field. In contrast, the growth of the Pm does not promote the large-scale magnetic field generation. A growing counteraction of the magnetic alpha-effect reduces the level of mean large-scale magnetic energy at saturated state.

# Topological consideration for magnetic fields

P. Akhmetiev

For a pair of divergence-free vector fields $B$, $\tilde{B}$ localized in two flux tubes $U, \tilde{U}$ in $R^3$ respectively an integral $W$ of the order 4 is proposed. An interrelation between the integral $W$ and the higher topological invariant $\beta = \beta(l, \tilde{l})$ (the Generalized Sato-Levine invariant) are expressed by the formula $W = \beta(l, \tilde{l})\Phi^2\tilde{\Phi}^2$. Here $l, \tilde{l}$ are the linked middle lines of the considered tubes and $\Phi$, $\tilde{\Phi}$ are the fluxes of $B$, $\tilde{B}$ through transversal sections of $U, \tilde{U}$ respectively. By means of the integral $W$ a higher analog of the current helicity integral in MHD (i.e., a higher analog of the integral $\int(B, rotB)dx$) is constructed. The talk is based on a joint paper with O.V.Kunakovskaya.

# MHD-dynamo experiments

P. Frick

At the very end of the XX century the long -standing experimental efforts to realize self- excitation of magnetic fields by MHD dynamo was crowned with success. First dynamo experiments performed in Riga (a screw-dynamo in a cylinder) and Karlsruhe (a two-scale dynamo model) gave an essential impulse to the MHD studies. A new generation of dynamo experiments is in preparation at several physical centers: the dynamo action in a von Karman flow of liquid sodium will be studied in the experiment which is prepared in Cadarache (France), two experimental teams in the United States (the University of Maryland and the University of Madison) are working on dynamo experiments in spherical flows. A non-stationary dynamo experiment in a toroidal screw-flow is developed in Perm (Russia).

The Perm dynamo project suggests to study the dynamo action in a nonstationary screw flow in an abruptly braked toroidal channel filled with liquid sodium. The experiment intends to realize a Ponomarenko like dynamo, and differs from the Riga experiment by the toroidal geometry and nonstationary character of the flow. The experimental scheme developed in Perm allows one to avoid the use of large masses of liquid sodium and high power consumption, but leads to complex mechanical problems which concern the rotating channel and the braking system construction. Two kind of experimental studies are planned to be performed at the sodium dynamo set-up. Firstly, the peculiarities of Ponomarenko dynamo in toroidal geometry should be examined. Secondly, we plan to perform an extended study of dynamo actions, provided by essentially nonstationary processes. As the first stage of experimental studies of nonstationary induction processes in turbulent screw flows of liquid metals we performed a number of experiments in which the magnetic field of simplest toroidal and poloidal configurations was imposed on the turbulent screw flow of liquid gallium, excited in the smaller toroidal channel, and the magnetic field induced by the flow was measured. In spite of the fact that the flow is characterized by strong turbulence (hydrodynamic Reynolds number $\mathrm{Re} \approx 10^6$ and magnetic Reynolds number Rm $\approx 1$), our measurements do not provide clear evidence of the small-scale turbulent effects (all results can be interpreted in terms of the mean velocity field only). We show that during the transition to the screw flow the poloidal magnetic field get a burst of energy from the imposed toroidal field.