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# LARGE-SCALE MAGNETIC FIELDS AND THE ACTIVITY OF LATE-TYPE STARS

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# The Abstract

Magnetic fields determine many physical processes in the universe. Magnetic field influences a star throughout its life. It is the reason of a complicated set of solar-type activity phenomena, which are widely spread among the low-mass stars. On the Sun, these phenomena are mainly related to the evolution of local magnetic fields. Large-scale magnetic fields on the Sun (comparable in size scale to the solar radius) determine the formation of coronal holes and streamers, and thus of solar wind (high-speed fluxes originate from coronal holes, low-speed ones are from streamers). These fields have an influence on the development of such long-duration non-stationary processes in solar corona as coronal mass ejections (CME) and flares. On the Sun, their influence is weaker than it can occur on more active stars.

The dissertation develops the idea that large-scale magnetic fields play more significant role in the formation of activity on late-type stars rather than local magnetic fields. Observations of active late-type stars with several space missions: EUVE, BeppoSAX and Chandra, are used as a basis for our study. Solar magnetic fields data obtained from ground-based observations at Wilcox Solar observatory at Stanford University.

In Chapter 1, an analysis of the total magnetic field of the Sun (‘Sun-as-a-star’) over several cycles of activity is performed. This analysis confirms that the rotational modulation (over years) of a similar signal from a star can serve as a good characteristic to describe the behavior of large-scale magnetic fields on active late-type stars.

In Chapter 2, a numerical MHD-simulation of long-term X-ray flares in late-type subgiants is carried out. It demonstrates that these flares exist as long as significant amount of energy arrives to the upper part of the giant magnetic loop system. It allows us to reliably determine physical conditions of plasma and size of the soft X-ray source. A new method for estimating the energy of powerful non-stationary processes on active late-type stars is proposed. It is based on determining the variation of component of the current of a large-scale magnetic field.

In Chapter 3, it is performed an assessment of the mass loss by active components of chromospherically active RS CVn-type binary systems, based on the interpretation of data on excess radiation in Fe XVIII – Fe XXIII ion lines in the extreme ultraviolet and soft X-ray and on the solving the stellar wind collision problem. The rate of quasi-stationary and non-stationary outflow in this case is 3-4 orders of magnitude greater than the solar mass loss and can reach $10^{-10}\,M_{\odot}$ per year.

## The Bibliography


[1] Anan’ev I.V., Obridko V.N. // Astron. Rep. 1999. V.43. P.831

[2] Badalyan O.G., Livshits M.A. // Astron. Zhurnal. 1992. V.69. P.138

[3] Boyarchuk A.A., Bisikalo D.V., Kuznetsov O.A., Chechetkin V.M. // "Double stars" / Ed. Masevich A.G. Moscow, 1997, P.18

[4] Veselovskiy I.S. // Geomagn. Aehron. 1996. V.36. No.6. P.1

[5] Getman K.V., Livshits I.M. // Bulletin of the Russian Academy of Sciences: Physics. 1998. V.62. No.6. P.1255

[6] Getman K.V., Livshits I.M. // Moscow University Physics Bulletin (Allerton Press, NY). 1999. V.54. No.1. P.77

[7] Getman K.V., Livshits M.A. // Astron. Rep. 1999. V.43. P.615

[8] Getman K.V., Livshits M.A. // Astron. Rep. 2000. V.44. P.255

[9] de Jager, Cornelis. "Structure and Dynamics of the Solar Atmosphere". 1959. Handbuch der Physik. Volume 52. P.80

[10] Ermakov F.A. // In: "Physics of the Solar Activity". / Ed. Mogilevskiy E.I. Moscow: Nauka. 1988. P.25

[11] Kosovichev A.G., Popov Iu.P. // Zhurnal Vychislitel'noi Matematiki i Matematicheskoi Fiziki (ZVMMF). V.19. P.1253

[12] Kotov V.A., Severnyi A.B. // "Magnetic field of the Sun as a Star. Catalog 1968 – 1976" / Ed. Dubov E.E. Moscow: MGK AN U.S.S.R. 1983.

[13] Kotov V.A., Haneychuk V.I., Tsap T.T. // Aston. Rep. 1999. V.43. P.185

[14] Livshits I.M. // Conf. Proc. "Large-scale structure of the solar activity". Pulkovo, 21-25.06.1999. St. Petersburg. GAO RAN. P.139

[15] Livshits I.M. "Rotational Modulation of the Global Magnetic Field of the Sun" // Conf. Proc. "The Sun in the period of changing the sign of polarity of the magnetic field". 2001. St. Petersburg. GAO RAN. P.241

[16] Livshits I.M., Livshits M.A. // Astron. Rep. 2002. V.46. P.327

[17] Livshits M.A., Badalyan O.G., Belov A.V. // Astron. Rep. 2002. V.46. P.597

[18] Makarov V.I. // Solnechnye Dannye. Bulletin Akademie Nauk USSR. 1984. No.9. P.59

[19] Makarov V.I., Fatyuanov M.P. // Soviet Astronomy Letters. 1982. V.8. P.340

[20] Molodenskii M.M., Filippov B.P. "The magnetic fields of solar active regions". Moscow: Nauka. 1992

[21] Obridko V.N., Shelting B.D. // Aston. Rep. 2000. V.44. P.103 and 262

[22] Prilutskii O.F., Usov V.V. // Aston. Zhurnal. 1976. V.53. P.6

[23] Savanov I.S., Savel'eva Yu.Yu. // Aston. Rep. 1997. V.41. P .821

[24] Samarskii A.A., Popov Yu.P. "Difference methods for solving problems of gas dynamics". Moscow: Nauka. 1992.

[25] Severnyj A.B. Some problems of solar physics. Moscow: Nauka. 1988. Chapter 6.

[26] "Illustrated Glossary for Solar and Solar-Terrestrial Physics" / Eds. Bruzek A., Durrant C.J. Dordrecht, Holland. 1977 (in russian translation: Moscow: Nauka. 1980)

[27] Somov B.V., Syrovatskii S.I. // In: "Neutral current layers in a plasma". Moscow: Nauka. 1974. P.14

[28] Stepanov A.V., Somov B.V., Syrovatskiy S.I. // Izvestiya GAO. N.211 St.Petersburg. 1996. P. 5

[29] Tarasova T.N., Plachinda S.I., Rumyantsev V.V. // Aston. Rep. 2001. V.45. P.475

[30] Haneychuk V.I. // Aston. Rep. 1999. V.43. P.330

[31] Kharshiladze A.F., Ivanov K.G. // Geomagn. Aehron. V.34. No.4. P.22

[32] Schatten K.H. // In: "The observations and the prognosis of the solar activity" / Eds. P.McIntosh, M.Draer. Moscow: Mir. 1976

[33] Baliunas et al. // ApJ. 1995. V.438. P.269

[34] Baliunas S.L., Vaughan A.H. // Ann. Rev. Aston. Astrophys. 1985. V.23. P.379

[35] Betta R.M., Peres G., Reale F., Serio S. // Astron. Astrophys. Suppl. 1997. V.122. P.585

[36] Brickhouse N.S. // Astrophysics in the Extreme Ultraviolet. / Eds. S.Bowyer, R.F.Malina. 1996. Dordrecht: Kluwer. P.105

[37] Canfield R.C., Hudson H.S., McKenzie D.E. // Geophys. Res. Lett. 1999. V.26. P.627

[38] Chertok I.M. // Solar Phys. 2001. V.198. P.367

[39] Chertok I.M., Fomichev V.V., Gnezdilov A.A., Gorgutsa R. // Solar Phys. 2001. V.204. P.139

[40] Cully S.L., Fisher G., Abbott M.J., Siegmund O.H.W. // Astrophys. J. 1994. V.435. P.449

[41] Dempsey R.C., Linsky J.L., Fleming T.A., Schmitt J.H.M.M. // Asrophys. J. Suppl. 1993. V.86. No.2. P.599

[42] Dupree A.K. // Ann.Rev.Aston.Astrophys. 1986. V.24. P.377

[43] Dupree A.K. // in: "Cool Stars, Stellar Systems, and the Sun". ASP Conf. Ser. 1996. V.109. P.237

[44] Dupree A.K. // in: "Cool Stars, Stellar Systems, and the Sun". ASP Conf. Ser. 2001. V.223. P.333

[45] Dupree A.K., Brickhouse N.S. // Stellar Surface Structure. (Poster Proc. IAU Symp. 176) / Ed. K.G.Strassmeier. Univ.of Vienna. 1995. P.190

[46] Dupree A.K., Brickhouse N.S., Doschek G.A., Green J.C., Raymond J.C. // Astrophys.J. 1993. V.418. P.141

[47] Favata F., Schmitt J.H.M.M., Micela G., Reale F., Sciortino S. // Astron. and Astrophys. 2000. V.362. P.628

[48] Feldman P.A., Taylor, A.R., Gregory P.C., Seaquist E.R., Balonek T.J., Cohen N.L. // Astron. J. 1978. V.83. P.1471

[49] Forbes T.G., Acton L.W. // Astrophys. J. 1996. V.459. P.330

[50] Graffagnino V.G., Wonnacott D., Schaeidt S. // Mon. Not. R. Astron. Soc. 1995. V.275. P.129

[51] Güdel M., Linsky J.L., Brown A., Nagase F. // Astrophys. J. 1999. V.511. P.404

[52] Haisch B. // Irish AJ. 1986. V.17. P.200

[53] Haisch B., Schmitt J.H.M.M. // Publ. Astr. Soc. Pacific. 1996. V.108. No.720. P.113

[54] Haisch B., Strong K.T., Rodono M. // Ann. Rev. Aston. Astrophys. 1991. V.29. P.275

[55] Haisch B., Rodono M.(eds.) // Solar and Stellar Flares. Dordrecht: Kluwer. 1989.

[56] Hartmann L., Noyes R.W. // Ann.Rev.Aston.Astrophys. 1987. V.25. P.271

[57] Hoeksema J.T. Solar Magnetic Field 1985 through 1990. Boulder: WCDA. 1991.

[58] Hubrig S., Plachinda S.I., Hunsch M., Schroder K.-P. // A&A. 1994. V.291. P.890

[59] Johns-Krull C.M., Valenti J.A., Hatzes A.P., Kanaan A. // ApJ. 1999. V.510. P.141

[60] Katsova M.M. // Stellar Surface Structure. (Poster Proc. IAU Symp. 176) / Ed. K.G.Strassmeier. 1995. Univ.of Vienna. P.187

[61] Katsova M.M., Drake J., Livshits M.A. // Astrophys. J. 1999. V.510. P.986

[62] Katsova M.M., Shcherbakov A.G. // Astron.Astrophys. 1998. V.329. P.1080

[63] Kopp R.A., Pneuman G.W. // Solar Phys. 1976. V.50. P.85

[64] Koutchmy S., Livshits M.A. // Space Sci.Rev. 1992. V.61. P.393

[65] Kiirster M. // Stellar Surface Structure. (Proc. IAU Symp. 176) / Eds. K.G.Strassmeier, J.L.Linsky. 1996. Dordrecht: Kluwer. P.477

[66] Lafon J.-P.J., Berruyer N. // A&AR. 1991. V.2. P.249

[67] Landstreet J.D. // A&AR. 1992. V.4. P.35

[68] Lestrade J.-F. // Stellar Surface Structure. (Proc. IAU Symp. 176) / Eds. K.G.Strassmeier, J.L.Linsky. 1996. Dordrecht: Kluwer. P.173

[69] Linsky J.L., Andrielis C., Saar S.H. et al. // in: "Cool Stars, Stellar Systems, and the Sun". ASP Conf. Ser. 1994. V.64. P.438

[70] Linsky J.L., Wood B.E., Brown A., Osten R.A. // ApJ. 1998. V.492. P.767.

[71] Livshits I.M. // Astronomical and Astrophysical Transactions. 2001. V.20. P.587

[72] I.M.Livshits, M.A.Livshits // In: "Stellar Coronae in the Chandra and XMM-Newton era" / Ed. F.Favata, J.Drake. Astronomical Society of the Pacific Conference Series. 2002. V.277. P.527

[73] Livshits I.M., Livshits M.A. // The 35th ESLAB Symposium "Stellar Coronae in the Chandra and XMM-Newton era". Noordwijk, The Netherlands. 25-29 June 2001. Abstract Book. P.69

[74] Maggio A., Pallavicini R., Reale F., Tagliaferri G. // Astron. and Astrophys. 2000. V.356. P.627

[75] Makarov V.I., Makarova V.V. // Synoptyc Solar Phys. ASP Conf. Ser. 1998. V.140. P.347

[76] Makarov V.I., Sivaraman K.R. // Solar Phys. 1983. V.85. P.227

[77] Makarov V.I., Sivaraman K.R. // Solar Phys. 1989. V.119. P.35

[78] Makarov V.I., Tlatov A.G. // Proc. 9th European Meeting of Solar Physics. / Ed. Wilson A. 1999. P.125

[79] Makarov V.I., Tlatov A.G., Obridko V.N. et al. // Solar Phys. 2001. V.198. P.409

[80] Marcy G.W., Basri G.S. // Astrophys. J. 1989. V.345. P.480

[81] McAllister A., Dryer M., Mclntosh P., Singer H. // J. Geophys. Res. 1996. V.101(A6). P.13497

[82] Mewe R. // A&AR. 1991. V.3. P.127

[83] Mewe R., Kaastra J.S., Liedahl D.A. // Legacy. 1995. V.6. P.16

[84] Obridko V.N., Shelting B.D. // Solar Phys. 1999. V.184. P.187

[85] Osten R., Brown A. // Astrophys.J. 1999. V.515. P.746

[86] Pallavicini R. // Astron.Astrophys.Rev. 1989. V.1. P.177

[87] Pallavicini R., Tagliaferri G. // Palermo Astronomy Preprints. 1998. No.4. (The Activity X-ray Sky: Results from BeppoSAX and Rossi-XTE Symposium)

[88] Pallavicini R., Tagliaferri G., Stella L. // Astron. Astrophys. 1990. V.228. P.403

[89] D.Pease, J.J .Drake, V.Kashyap et al. // In: "Stellar Coronae in the Chandra and XMM-Newton era" / Ed. F.Favata, J.Drake. Astronomical Society of the Pacific Conference Series. 2002. V.277. P.551

[90] Peres G., Rosner R., Serio S., Vaiana G.S. // Astrophys. J. 1982. V.252. P.791

[91] Plachinda S.I., Johns-Krull C.M., Tarasova T.N. // Odessa Astronomical Publications. 2001. V.14. P.219

[92] Plachinda S.I., Tarasova T.N. // ApJ. 1999. V.514. P.402

[93] Robinson R.D., Worden S.P., Harvey J.W. // ApJ. 1980. V.236. P.1155

[94] Rosner R., Golub L., Vaiana G.S. // Ann. Rev. Aston. Astrophys. 1985. V.23. P.413

[95] Saar S.H. // The Solar Photosphere: Structure, Convection, and Magnetic Fields. (Proc. IAU Symp. 138) / Ed. Stenflo J.O. 1990. Dordrecht: Kluwer. P.427

[96] Sanz-Forcada J., Dupree A.K., Brickhouse N.S. // Astroph. J. 2002. V.570. P.799

[97] Sanz-Forcada J., Dupree A.K., Brickhouse N.S. // In: "Stellar Coronae in the Chandra and XMM-Newton era" / Ed. F.Favata, J.Drake. Astronomical Society of the Pacific Conference Series. 2002. V.277. P.585

[98] Siarkowski M. // Monthly Notices R.Astron.Soc. 1992. V.259. P.453

[99] Siarkowski M. // Stellar Surface Structure. (Poster Proc. IAU Symp. 176) / Eds. K.G.Strassmeier. 1995. Univ.of Vienna. P.190

[100] Siarkowski M. // Stellar Surface Structure. (Proc. IAU Symp. 176) / Eds. K.G.Strassmeier, J.L.Linsky. 1996. Dordrecht: Kluwer. P.469

[101] Strassmeier K.G., Hall D.S., Zeilik M., Nelson E., Eker Z., Fekel F.C. // Astron. Astrophys. Suppl. 1988. V.72. P.291

[102] Sturrock P.A. // Nature. 1966. V.211. P.695

[103] Svestka Z., Farnik F., Hudson H.S., Uchida Yu., Hick P., Lemen J.R. // Solar Phys. 1995. V.161. P.331

[104] Franciosini E., Pallavicini R., Tagliafierri G. // Astron. Astrophys. 2001. V.375. P.196

[105] Trigilio C. et al. // Physics of Solar and Stellar Coronae / Eds. J.L.Linsky, S.Serio. 1993. Dordrecht: Kluwer. P.413

[106] Tsuneta S. // Astrophys. J. 1996. V.456. P.840

[107] Tsuru T., Makishima K., Ohashi T. // Publ. Astron. Soc. Japan. 1989. V.41. P.679

[108] Valenti J.A., Marcy G.W., Basri G.S. // Astrophys. J. 1995. V.439. P.939

[109] van den Oord G.H.J., Zuccarello F. // Stellar Surface Structure. (Proc. IAU Symp. 176) / Eds. Strassmeier K.G., Linsky J. 1996. Dordrecht: Kluwer. P.433

[110] Veselovsky I.S. // in: Proc.9th European Meeting on Solar Physics, Magnetic Fields and Solar Processes. Florence, Italy. 12-18 September 1999. ESA SP-448. 1999. P.1217

[111] Vilhu O. // 1984. Astron. Astrophys. V.133. P.117

[112] Vilhu O., Walter F.M. // 1987. Astrophys. J. V.321. P.958

[113] Wang H., Goode P.R., Denker C. at all. // Astrophys.J. 2000. V.587. P.971

[114] Zastenker G.N.et all. // J. Geophys. Res. 1978. V.83. No.3. P.1035