EPSC Abstracts
Vol. 5, EPSC2010-426, 2010
European Planetary Science Congress 2010

Seasonal variations of polarization in polar regions of Jupiter

O. Shalygina (1,2), V. Korokhin (1), L. Starukhina (1), E. Shalygin (1), Yu.Velikodsky (1), G. Marchenko (1).
(1) Institute of Astronomy of Kharkiv V. N. Karazin National University, Kharkiv, Ukraine, (2) Max Planck Institute for Solar System Research, Katlenburg-Lindau, Germany (o.shalygina@mps.mpg.de)

1. Polarimetric observations of Jupiter

As known, ground-based and cosmic polarimetric observations of Jupiter in visual spectrum range show the dependence of linear polarization degree *P* on phase angle and on wavelength. Polarization increasing with latitude is observed. Even at zero orbital phase angle (angle between the Sun – Jupiter and the Earth) the polarization degree increases from zero (equatorial regions) to 7–8% (polar regions). Polarization plane has radial orientation. Also it is known, that there is a north-south asymmetry of linear polarization of light reflected by Jupiter (for example, [4, 5]). To explain these observational facts, the regular polarimetric observations of Jupiter near opposition in blue light were started in 1981 in Kharkiv observatory. On the base of 18 years of observations the long-term variations of polarization asymmetry (P_N–P_S) have been found. Parameter of asymmetry P_N–P_S is defined as a difference between modules of values of linear polarization degree on north and south at the latitudes ±60° at the central meridian. We will continue this work.

1.1 North-South asymmetry of linear polarization

Dependence of *P* asymmetry on Jupiter's orbital location with new data of observations is presented in the Figure 1. It is shown that periodic jump-like dependence of polarization parameter P_N–P_S on orbital location take place. One can conclude that there is a seasonal inverse dependence of polarization on insolation (polarization is higher in colder hemisphere) that has jump-like nature.

2. Causes of seasonal variations of polarization

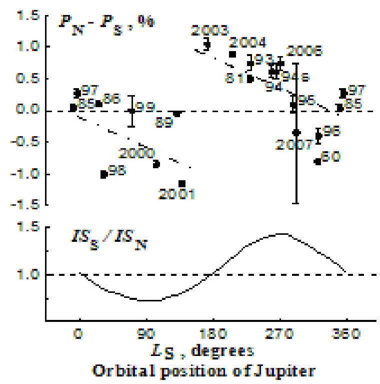

Figure 1: *top* – dependence of North-South asymmetry of polarization P_N–P_S on Jupiter's orbital location (L_S – planetocentric orbital longitude of the Sun). Points correspond to the data obtained by averaging over all Jovian longitudes in L_{III} system. Bars are the errors of mean. Chain line is approximating curve. *Bottom* – relation of insolations in the south and in the north at latitudes ±60º.

How changes of insolation may led to changes of polarization? As known, data of polarimetric observations in visible, infrared and ultraviolet range are sensitive to presence of stratospheric aerosols' haze in Jovian atmosphere, observed at top levels of Jupiter stratosphere at high latitudes (on pressure level p ~ 20 mbar) [5]. Aerosols in haze may be unstable, and temperature changes may influence upon generation and destruction of aerosol particles. According to [3], the observed aerosol haze is consists of benzene and polycyclic aromatic hydrocarbons (PAH) like naphthalene, phenanthrene, pyrene. Explanation of inverse dependence of polarization asymmetry on insolation may be following. As known, condensation rate depends on temperature exponentially. When temperature increases the velocity should decreases. It cause decreasing of aerosol concentration and as a result led to decrease of the values of observed polarization. And we should expect jump in seasonal changes of concentration and polarization (as shown on Fig. 1).

2.1 Temperature effect on aerosol haze formation

Average temperature in polar regions of jovian stratosphere is about 150 K [3]. This temperature is lower than triple points of naphthalene and benzene (359 K and 278 K), so they should produce crystal nucleus from gaseous phase. Let's consider homogeneous particle's nucleation. Such process proceeds without additional condensation centers. Equilibrium condition for nuclei of a crystal with radius r and surrounding gas is defined as [2]:

$$r = r_c = \frac{2\alpha\Omega}{\Delta\mu(T,\xi)} \quad (1)$$

where r_c – critical radius (nuclei with smaller radius evaporates, and bigger ones grows); Ω is specific volume of molecule in crystal; $\Delta\mu = kT\xi$ is chemical potential; $\xi = \ln[p(T)/p_0(T)]$ is supersaturation, $p(T)$ is vapor pressure in atmosphere; $p_0(T)$ is saturated vapor pressure; α is surface tension coefficient; for particles in solid phase α is close to the value in liquid phase near melting temperature.

Equilibrium (1) is unstable. For formation of a nucleus with radius r, the system should overcome potential barrier ΔG:

$$\Delta G(\xi, r) = -\frac{4}{3}\pi r^3 \frac{\Delta\mu(T,\xi)}{\Omega} + 4\alpha\pi r^2 \quad (2)$$

where G is Gibbs potential. Homogeneous nucleation takes place when radius of critical nucleus is close to molecular sizes; at the same time, supersaturation ξ is about or larger than 1. For example, for naphthalene (α=30 erg/cm^2) at T=150 K and ξ = 10 critical radius r_c = 6 A, i. e., in jovian stratosphere homogeneous nucleation can occur.

To study the effect of temperature changes on PAH formation we have used altitude concentration profiles from [3]. As known, season changes of temperature in Jupiter's polar regions amount to ±30 K [1]. So, our estimates show (Figure 2) that temperature changes have strong effect on processes of homogeneous nucleation in Jupiter stratosphere: benzene never condenses (negative supersaturation means vapour undersaturation), whereas probability of homogeneous nucleation of naphthalene and phenanthrene at T=120 K and T = 150 K is considerable. No of the studied PAHs condenses at T = 180 K.

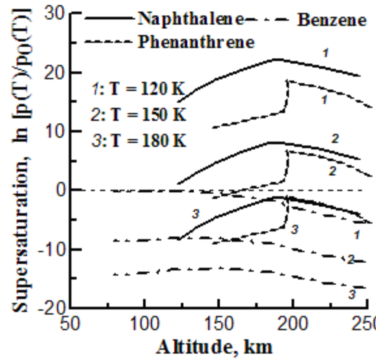

Figure 2: Altitude distributions of PAH's supersaturation in Jupiter atmosphere for different temperatures.

3. Summary and Conclusions

(1) Inverse seasonal dependence of polarization asymmetry on insolation was found: polarization is higher in colder hemisphere (2) Seasonal fluctuations of temperature in the stratosphere of Jupiter are shown to control formation the polar aerosol haze that consists most probably of solid particles of polycyclic aromatic hydrocarbons (naphthalene, phenanthrene). This can explain the seasonal changes of polarization in the polar areas of Jupiter.

References

[1] Caldwell, J. et al.: Temporal characteristics of the Jovian atmosphere, Astrophys. J., Vol. 234, pp. 155-158, 1984.

[2] Chernov, A.: Modern Crystallography III, Springer, pp. 3-120, 1984.

[3] Friedson, A. et al.: Models for polar haze formation in Jupiter's stratosphere, Icarus, Vol. 158, #2, pp. 389-400, 2002.

[4] Shalygina, O. et al.: The North-South asymmetry of polarization of Jupiter: the causes of seasonal variations, Solar System Research, Vol. 42, #1, pp. 8-17, 2008.

[5] Smith, P. and Tomasko, M.: Photometry and polarimetry of Jupiter at large phase angles, Icarus, Vol.58, pp. 35-73, 1984.