13th International Congress of Speleology
4th Speleological Congress of Latin América and Caribbean
26th Brazilian Congress of Speleology

Brasília DF, 15-22 de julho de 2001

Intensity of Prolonged Solar Luminosity Cycles and Their Influence Over Past Climates and Geomagnetic Field

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Abstract

Calcite speleothems luminescence depends exponentially upon soil temperatures that are determined primarily by solar visible and infrared radiation. So microzonality of luminescence of speleothems was used as an indirect Solar Insolation (SI) proxy index. For Cold Water cave, Iowa, US we obtained high correlation coefficient of 0.9 between a luminescence record and the experimentally observed Solar Luminosity Sunspot index.

We measured a luminescent speleothem record from Jewel Cave, South Dakota, US. It is still the first available experimental solar insolation proxy record with sufficiently long duration to reproduce the orbital variations. This record covers 89300- 138600 yrs B.P. with high resolution. It reveals determination of millennial and century cycles in the record.

This solar insolation proxy record contains not only orbital variations, but also solar luminosity self variations, producing many cycles with duration from several centuries to 11500 years. The most powerful non- orbital cycle is 11500 years cycle (as powerful as the 23000 a. orbital cycle in our record). It was found previously to be the most intensive cycle in the delta C-14 calibration record and was interpreted to be of geomagnetic origin. Our recent studies suggest, that this is a solar cycle modulating the geomagnetic field. We found also cycles with duration of 6000, 4400, 3300, 2500, 2300, 1900 and 1460, years (in order of decreasing intensity) with amplitude ranging respectively from 3 to 0.7 % of the Solar Constant.

Latest results suggest that these millennial solar luminosity cycles can produce climatic variations with intensity comparable to that of the orbital variations. Known decadal and even century solar cycles have negligible intensity (100 times less intensive) relatively to this cycles. Solar luminosity (SL) and orbital variations both cause variations of solar insolation affecting the climate by the same mechanism. In spite their influence over the geomagnetic field involve fundamentally different mechanisms, determined by the properties of the solar wind.

Introduction

J. CROLL (1864) and M.MILANKOVICH (1920) demonstrated that orbital variations of the Earth's orbit cause significant variations of the amount of solar radiation received by the Earth's surface (solar insolation- SI). Since 1930 most scientists started to believe that glacial periods (ice ages) are result of such variations.

Recent measurements (WINOGRAD et al, 1988, 1992) of a cave deposit from Devils Hole (DH), USA which is the best dated paleoclimatic record, demonstrated that the end of the former glaciation (Termination II) came 10 000 year before the moment suggested by the orbital theory. Some scientists consider this as a denial of the orbital origin of glaciations, because it demonstrates that the result appears far before the reason.

Up to now there were no quantitative proxy records able to demonstrate how big were variations of the solar luminosity in geological time scales. In the last years (SHOPOV et. al., 1994, 1996) measured such records covering a sufficiently long period to contain orbital variations.

Results and Discussion

We measured a luminescent solar insolation proxy record in a speleothem (JC11) from Jewel Cave, South Dakota, USA (SHOPOV et al.,1998, STOYKOVA et al., 1998). This record covers 89300- 138600 yrs BP with high resolution (34 years) and precision of measurements better than 1%. It reveals determination of millennial and century cycles in the record.

We extracted orbital variations from the JC11 record by a band-pass Tukey filter set for frequencies of 41, 23 and 19 kyrs. So the remaining signal contains only SL self-variations. The most powerful cycle in this record with period of 11.5 kyrs appears to be a bit more powerful than the precession cycle and a bit less than the total orbital component of the SI variations.

This TIMS U/Th dated JC11 record exhibits a very rapid increasing in solar insolation at 139 kyrs ±5.5 kyrs BP (95% confidence level) responsible for the termination II. This increasing precedes that one suggested by the Orbital theory with about 10 kyrs and is due to the most powerful cycle of the solar luminosity with period of 11.5 kyrs superposed on the orbital variations curve. This cycle was found previously to be the most intensive one in the $\Delta^{14}C$ calibration record (DAMON & SONETT, 1991) and was interpreted to be of geomagnetic origin. Our studies suggest that this is a solar cycle modulating the geomagnetic field. The Devils Hole ^{18}O record suggests that termination II had happened at 140 ±3 kyrs B.P (WINOGRAD ET AL, 1992). It follows precisely the shape of our experimental solar insolation record. This result is confirmed by an other U/Th dated luminescent solar insolation proxy record in a speleothem from a Duhlata cave, Bulgaria 10 000 km far form the JC11 site. These records suggest that the solar luminosity contribution to the solar insolation curves has been severely underestimated so far.

The Orbital theory pressumes that the solar luminosity is constant during geological periods of time. Recent studies demonstrated that this presumption is not precise. Direct satellite measurements of the solar constant demonstrated that it varies with time as much as 0.4% during the observation time span (HICKEY et al., 1980), but there are experimental data suggesting that it varied much greater during geological periods (SONETT, 1984, STUIVER & BRAZIUNAS, 1989). SONETT (1984) analysing the 14-C solar proxy record found that the cycle with a period of about 900 yrs has intensity 5- 7 times higher than that of the century cycle. STUIVER & BRAZIUNAS (1989) calculated MEM spectra of the same record and demonstrated, that longer solar cycles are more than one order of magnitude stronger, than the solar cycles covered by direct measurements. In order to compare quantitatively intensities of all cycles presented in our data we designed a special algorithm and relevant computer program, which plots the periodogramme in coordinates (Cycle Intensity/Period). Calculated periodogrammes of the JC11 luminescent record demonstrated, that the solar cycle of about 900 years has intensity only 3-4% of the 11500-yr cycle and the solar cycle about 420 years has intensity less than 2.5 % of the 11500-yr cycle. So the 11500-yr cycle should have intensity of several orders of magnitude higher, than the observed century and sub- century cycles.

We obtained many other cycles, more intensive of them with duration of 6000, 4400, 3300, 2500, 2300, 1900 and 1460, years (in order of decreasing intensity) with amplitude ranging respectively from 3 to 0.7 % of the Solar Constant (tab. 1).

A cycle with duration 10026 (+1254/ -834) yrs. was found in records of the intensity of the geomagnetic field of the Earth (TRIC et al., 1992). We identified this cycle with the 11.5 yrs. one in the luminescent record and we calibrated intensity of all other cycles in the geomagnetic record to the luminescent cycle. The cycles which are found in both records are with duration of 4400, 2500, 3950, 2770, 1950,1460,2090, 1200, 900 (tab. 1).

Increasing of the ice volume and related sea level change during glaciations produces changes in the inertial moment of the Earth and resulting changes in the speed of Earth's rotation (TENCHOV et al., 1993).. Orbital variations cause also some deformation of the solid Earth and redistribution of the Ocean masses (MOERNER, 1976, 1983). In result theoretical curves can be used only for qualitative reference. For quantitative correlation it is necessary to use experimental records of the solar insolation, because they contain also variations of the solar luminosity and number of others not covered by the Orbital theory.

Conclusions

Strongest solar luminosity cycle (with period of 11500 yrs) modulates the geomagnetic field and production of cosmogenic isotopes. It is as intensive as orbital variations, so modulates the Earth's climate. A number of shorter intensive SL cycles have intensity far stronger that the known century solar luminosity cycle.

Cycle [Yrs]	VSC [W/m2]	PSC [%]	GEOM [%]	C14 [%]
11500	100.6	7.33	7.33	7.33
7800	27.5	2.00		
6160	41.5	3.02		
4400	24.4	1.78	6.2	
3950	25.1	1.83	4.32	
3400	24.1	1.76		
2770	12.6	0.92	3.25	
2500	16.3	1.19	4.70	
2300	12.5	.91		
2090	7.28	.53	2.26	
1958	11.26	.82	2.82	
1770	8.5	.62		
1670	9.1	.66	1.01	0.73
1460	10.0	.73	2.42	
1280	4.8	.35	0.71	
1195	4.5	.33	1.22	0.40
1145	4.5	.33	1.92	
1034	4.26	.31	1.62	
935	3.02	.22	1.2	
835	3.6	.26	0.6	0.56
814	2.6	.19		
775	2.3	.17		
750	2.6	.19		0.56
670	2.06	.15		
660	2.47	.18		
610	1.78	.13		0.48
570	2.06	.15		
550	1.78	.13		
538	2.06	.15		

***Table 1** Cycles of the Solar Luminosity (in Years), relevant variations of the Solar Constant expressed in W/m2 (VSC) and in % from the Solar Constant (PSC) compared to cycles of Solar Wind proxies- Intensity of the Dipole of the Geomagnetic Field (GEOM) and inverted rate of production of 14C*

Acknowledgements

This research was funded by a CNR- NATO outrich fellowship to Y. Shopov, Bulgarian Science Foundation by research grant 811/98 to Y. Shopov and by a NSERC strategic research grant to D.C.Ford.

References

.CROLL J., (1864): On the physical cause of the change of climate during geological epochs, *Philosophical Magazine*, 28, pp. 121-137

.DAMON P., SONETT C., (1991): Solar and Terrestrial Components of the Atmospheric 14-C Variation Spectrum In The Sun in Time, p.p. 360-388.

.HICKEY J. et al. (1980): *EOS*, 61,355.

.MILANKOVICH M. (1920): book: Theorie mathematique des phenomenes thermiques produits per la radiation solaire, Gauthier-Villrs, Paris

.MOERNER N.-A (1976): *J.Geol*.,84,123.

.MOERNER N.-A (1983): In: "*Mega- Morphology*" (R. Gardner and H. Scooging, eds.), 73, Oxford Univ. Press.

.SHOPOV Y.Y.,FORD D.C., SCHWARCZ H.P.(1994): Luminescent Microbanding in speleothems: High resolution chronology and paleoclimate.- *Geology*, v.22, p.407 -410, May 1994.

.SHOPOV Y.Y., L.TSANKOV, L.N.GEORGIEV, A.DAMYANOVA, Y. DAMYANOV, E. MARINOVA, D.C. FORD, C.J.YONGE, W. MACDONALD, H.P.R.KROUSE (1996): Speleothem Luminescence proxy Records of Annual Rainfall in the Past. Evidences for "The Deluge" in Speleothems."- in book "Climatic Change- the Karst Record", Ed. by S.E. Lauritzen. KWI , Bergen, p. 155-156.

.SHOPOV Y.Y., D. A. STOYKOVA, D.C. FORD, L.N. GEORGIEV, L. TSANKOV, (1998): Powerful Millennial-scale Solar Luluminosity Cycles in an Experimental Solar Insolation Record and their Significance to the Termination- II. - *Abstracts of AGU Chapman Conference on Mechanisms of Millennial- Scale Global Climate Change,* June 14- 18, 1998, Snowbird, Utah, p.25

.SONETT C.P. (1984): *Very Long Solar Period and the Radiocarbon Record In Review of Geophysics and Space Physics*, v. 22, N. 3, p.p. 239-254.

.STOYKOVA D.A., Y.Y.SHOPOV, D.FORD, L.N.GEORGIEV, L.TSANKOV. (1998): Powerful Millennial-scale Solar Luluminosity Cycles and their Influence over Past Climates and Geomagnetic Field-Abstracts of AGU Chapman Conference on Mechanisms of Millennial- Scale Global Climate Change, June 14- 18, 1998, Snowbird, Utah, p.26.

.STUIVER M., BRAZIUNAS T. (1980): Atmospheric ^{14}C and Century- Scale Solar Oscilations. *Nature,* v.338, pp.405- 407.

.TENCHOV G. G., TENCHOV Y. G. (1993): An Estimation of Geological Factors Affecting the Long Time Earth Spin Rotation- *Compt. Rend. l'Acad. Bulg. Sci.,* v.46, N.12, pp.37- 40.

.WINOGRAD I. J., RIGGS A., LUDVIG K.R., SZABO B. J., KOLESAR P.T., REVESZ B.M. (1992): *Science,* v.258, pp.