Relativistic Implications of Solar Astrometry
& the role of solar physics for the development of new physics

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CLAVIUS project on solar diameter measurement: IRSOL – IAP - ON – Sapienza - FRAEN corporation - Insubria University & IOTA

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Introduction

The advancements of modern physics in the last 150 years are strictly related with the studies on our closer star: the Sun.

The understanding of nucleosynthesis, also in cosmology; the neutrino phase oscillation and the Einstenian gravitational theory are examples evident to all physicists. The knowledge of the mechanisms driving and modulating the solar activity over centuries, and even decades, is still incomplete, and the accurate measurements of the solar diameter and of the solar irradiance (once called "solar constant") will help to fill this gap.

Sun and Climate

The influence of the Sun on the climate of our planet is obvious: all the human activity energetic output is less than 0.01% of solar input in the delicate climatic system. One hour of exposition to the Sun is equivalent to all energy produced by the human activities in a whole year. A predicting model of the solar activity is still lacking either on secular and shorter timescales, but also a climatic model based on past solar activity lacks of irradiation data, expected now from past solar eclipses diameters combined with actual W=dLog R/dLog L.

Problems in solar diameter's measurements

The following major problems affect the accurate measurements of the solar diameter (see table), since at least two centuries of research: for Mercury transits: the irradiation effect (diffraction); for the drift-scan: the seeing below 0.01 Hz*; for the eclipses: solar mesospheric line emission* (* CLAVIUS project discovery).

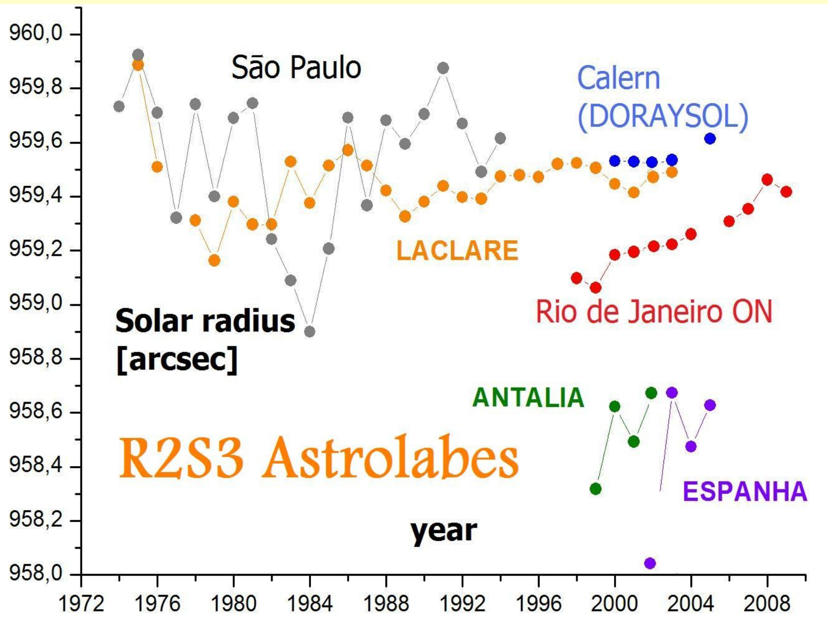

Fig. 1 Data from various astrolabes of the Réseau de Suivi au Sol du Rayon Solaire R2S3 (S. Boscardin, PhD thesis ON, 2011): they are in different wavebands and represent the longer series available for the last 40 years.

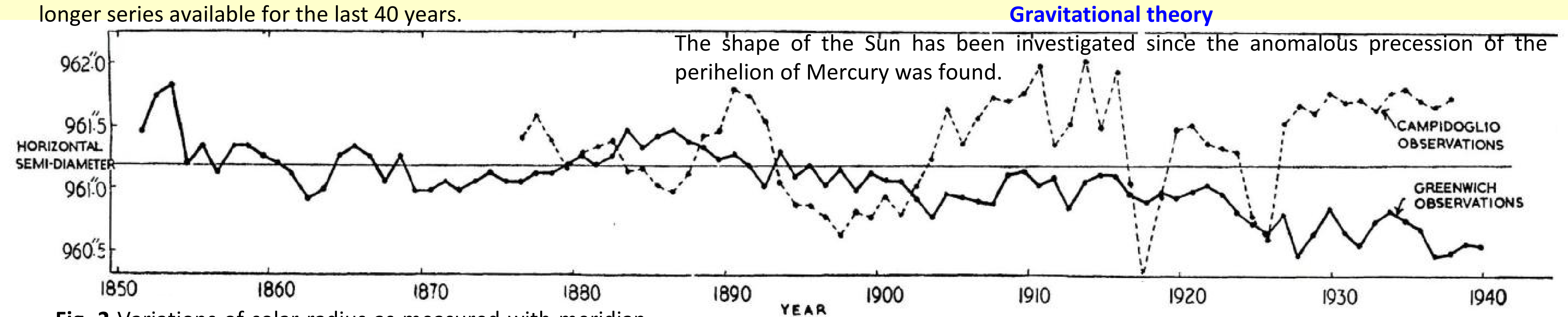

Fig. 2 Variations of solar radius as measured with meridian transits in Greenwich and in Rome at Capitol Observatory. (P. Gething MNRAS **115,** 558, 1955) Recent SOHO data show no variation beyond ±10 milliarcsec within 11 years. The standard solar model would not expect ΔR > 0.04%, unless the shell involved in the change is very thin.

References

More information about CLAVIUS project available on icra.it/solar

Methods for solar astrometry

Ground-based			Above the atmosphere	
Drift-scan	**Heliometer**	**Astrolabe R3S2 d=9cm**	**Balloon borne**	**Satellite**
CLAVIUS project: IRSOL d= 45 cm (CH)	Koenigsberg Fraunhofer,Bessel 1824 d=15cm	**Rio de Janeiro (1999 - now)**	SDS (1992-2009) Diameter and Oblateness d = 20 cm	SOHO MDI (1999-2010) Diameter and oblateness
CLAVIUS project: Carte du Ciel d=33 cm (IAP Paris)	Goettingen (1895)	**São Paulo (1975-1990)**	**Eclipses & Planetary Transits**	RHESSI (2008) oblateness
Greenwich d=15 cm (1850-1955)	**Rio de Janeiro (2009-now)**	Calern (FR) (1975 - 2008)	Baily's beads (1973 – 2010) **Easter Island ON mission**	SDO Diameter, magnetic field
R ome–Capitol d=11cm(1877-1937)	Antalya (TK) Santiago (Chile) 1975-1995	San Fernando (ES)	Mercury transits (1832 -2006) Venus transits (2004-2012)	Picard (2010-2013) Diameter, oblateness, irradiance

Nucleosynthesis

The age of the Earth from geological evidences ruled out the gravitational energy (H. von Helmoltz 1854) as source of solar heat.

The radioactive decay (discovered in 1904 by H. Becquerel and P. Curie) first, and the mass-energy relativistic conversion (Einstein, 1905) could account for the several billion years of solar lifetime with rather constant energetic output.

P-P cycle (Eddington and Bethe, 1926) and CNO (Weiszaecker, 1938) contributed to build the current Solar Standard Model. All stellar evolutionary models are based upon this. The Alpher Bethe Gamow theory (1948) on **cosmological nucleosynthesis** comes from here. Nowadays no satisfactory model can explain secular variations of solar activity, nor the difference between the 11-years cycles of solar spots. The aim of the Picard satellite mission is to measure W=dlogR/dlogL to recover past solar L from past R values, obtained from ancient eclipses and so to feed the opportune climate models.

Neutrino oscillation

The history of the neutrino oscillation is an "Italian brand" either for the measurements (Gran Sasso National Laboratory) and for the interpretation (N. Cabibbo). The experimental determinations of the solar neutrino flux (Homestake Goldmine 1967, and after GALLEX and SAGE in the Gran Sasso mountain (Italy), Kamiokande and Super-Kamiokande) show a deficit compared to what is predicted by the standard solar model. The solar neutrino defect is attributed to the oscillation of massive neutrinos from one type to another. GALLEX has been the gallium solar neutrino experiments at the Laboratori Nazionali del Gran Sasso from1991 to 1997. The BOREXINO experiment is measuring the 7Be neutrino flux. The **Fermion** role in early cosmology has been clarified.

Fig. 3 Nicola Cabibbo (1935-2010) invented in 1962 the "**Cabibbo angle**", extended by Kobayashy and Maskawa in a 3x3 matrix used later to explain the phase mixing of neutrinos. Only the two Japanese received the Nobel prize in 2008: Cabibbo was the president of the Pontifical Academy of Science (composed by lay people and among them 33 Nobel laureates) and the Nobel commission thought right to hit in this way the prestige of that Catholic institution.

Gravitational theory

The shape of the Sun has been investigated since the anomalous precession of the perihelion of Mercury was found.

The transition between Newtonian and Einstenian gravitation starts in 1855 with Le Verrier's measurements on Mercury's perihelion, completed by Newcomb in 1890s. Einstein published his General Relativity theory in 1916 and Eddington steered the eclipse observational campaign succesfull in Sobral (BR) Island on May 29, 1919 where the gravitational light bending was first observed. Studies on **Solar Oblateness** were carried by Dicke (1960s) Hill and Stebbins (1975), with the Solar Disk Sextant (1992 – 2009), and with the satellites RHESSI and Picard (2010-2013). The Newtonian origin of the perihelion precession was ruled out by the very small oblateness, which resulted anti-correlated with solar activity.