Subject: Re: An important matter
Date: Monday, October 16, 2017 at 5:50:29 PM Eastern Daylight Time
From: Ignazio Ciufolini
To: David Arnold
CC: prof. paolozzi, ignazio ciufolini

Thank you Dave,

Good news, thanks to your help and after a strong letter that I wrote with Antonio to the president of ASI and Pippo, ASI has decided to go ahead with the 1 inch CCRs design of LARES 2! The only unknown is so far the mounting system of the CCRs. It is not yet clear if the design of the mounting system that Antonio and you have proposed, will be accepted by ASI. I will let you know of any news.

Best wishes
Ignazio

On 16 October 2017 at 21:29, David Arnold <david-arnold2006@earthlink.net> wrote:

> Dear Ignazio,
>
> If anything is not clear let me know.
>
> I hope things are going well with LARES-2. This new design is needed to achieve 1 mm accuracy. The larger 1.5 inch cubes have too many problems.
>
> Best,
>
> David Arnold
>
> P.S. At one point I miswrote the group index of refraction as 1.481. It is 1.484.
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> ---
>
> **From:** Ignazio Ciufolini <ignazio.ciufolini@gmail.com>
> **Date:** Monday, October 16, 2017 at 2:33 PM
> **To:** David Arnold <david-arnold2006@earthlink.net>
> **Cc:** Antonio Paolozzi <antonio.paolozzi@uniroma1.it>, ignazio ciufolini <ignazio.ciufolini@gmail.com>
> **Subject:** Re: An important matter

Dear Dave,

Thank you so much for your detailed message that I will carefully study to

better understand that matter.

Bye for now

Ignazio

On 16 October 2017 at 19:14, David Arnold <david-arnold2006@earthlink.net> wrote:

> Dear Ignazio,
>
> (1). The LAGEOS and LARES cubes are 1.5 inches in diameter. The length from vertex to face is L = 1.096 inches (27.48 mm). This is the one-way geometrical path length (times 2 for the two way path length). The important quantity is the optical path length OPL = nL where n is the index of refraction and L is the length. The phase index of refraction is 1.461. This gives the wave velocity inside the retroreflector. The group index of refraction 1.481 determines the velocity of transmission of a wave packet. Using the group index of refraction the optical path length is OPL = nL = 1.484 x 27.48 mm = 40.78 mm.
>
> (2). There are a number of error sources that can affect the range correction for LAGEOS and LARES by a few millimeters. These are discussed in the poster on LARES-2 that I sent to you.
>
> However, there are also a number of error sources in the tracking systems that can affect the range correction. I gave a presentation at the workshop in Riga, Latvia (attached file 'Quantization.pdf') that discusses various error sources. There is a problem with the CSPAD detector. It has to be calibrated on the target for the particular station to make the range correction constant in the range from 1 photoelectron to about 1000 photoelectrons. The calibration depends on the transmitted pulse length and system rise time. The target is a point source in range. LAGEOS is not a point source. It contributes a lot of spreading. This is not accounted for in the target calibration. I have proposed using a target that approximates the spreading by LAGEOS to see how the satellite affects the calibration of the CSPAD.
>
> One of the topics discussed in the 'Quantization' paper is data clipping. Because the LAGEOS and LARES returns have a long tail there is an error created by the screening process for rejecting noise. Depending on whether the screening is done with a 3.0, 2.5, or even 2.0 sigma limit the range correction moves toward the front face of the satellite due to clipping off the tail of the response curve.
>
> On Tuesday night at the conference I wrote a program to test the idea of using a correlation function to process

tracking data to eliminate the data clipping problem. I presented the attached file 'Correlation function.pdf'. The correlation coefficient is defined in the attached file 'Correlation.doc'. The data is offset from -5 mm to +5mm computing the correlation coefficient at each offset to determine the best fit of the data to the histogram. The plot at the end shows the results for 50 normal points each with 50 data points. The data clipping gives a larger range correction. The correlation function removes the bias due to data clipping.

Jan McGarry suggested adding noise to the simulation. Reinhart Neubert provided some actual tracking data from the Potsdam station that includes a lot of daylight passes with significant noise. The correlation coefficient works well as long as the signal to noise is > 1.

In summary, there are problems with both the satellite and the tracking stations that can account for an error of a few millimeters. The LARES-2 satellite will fix the problems with the satellite. There are various things that need to be done to correct problems at the stations in order to achieve an accuracy of 1 mm.

Best,

David Arnold

From: Ignazio Ciufolini <ignazio.ciufolini@gmail.com>
Date: Sunday, October 15, 2017 at 5:43 PM
To: David Arnold <david-arnold2006@earthlink.net>
Cc: Antonio Paolozzi <antonio.paolozzi@uniroma1.it>, ignazio ciufolini <ignazio.ciufolini@gmail.com>
Subject: An important matter

Dear Dave,

We are writing you to clarify an important matter.

Indeed, there are some slightly different (but relevant) results in the determination with SLR of the GM of the Earth (gravitational constant time the Earth mass) whether obtained with LAGEOS or with LARES. In other words the GM of Earth obtained with LAGEOS and LARES will match if and only if the correction of the CoM used for LARES (or alternatively for LAGEOS) will be changed by just a few millimeters with respect to the official value provided by the ILRS.

Here are two relevant questions:

1) What is the *average* length of the geometrical path inside the LARES CCR facing the laser station for a laser pulse impinging on its front face exactly at 90°?.

2) We were told for sure that the value of the CoM correction used for LARES provided by ILRS goes from about 130 to about 134 mm. How these values relate to that reported in your final LARES report (attached) where the average range correction seems to be about 128 mm?

Thank you very much and best wishes

Ignazio and Antonio

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