Parameters of new version Lunar Ephemeris EPM2016 at the base of LLR observations 1970-2016 years:

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INTRODUCTION

- **Current state:**
- Ephemeris of the Moon is developing by the following institutes: JPL (USA), IMCCE (France), IAA RAS (Russia)
- LLR (Lunar Laser Ranging) – is the basis of Moon ephemeris
- The most number of LLR observations are obtained at: MLRS2 (McDonald), CERGA (GRASS), APACHE (Apollo)
- (Matera, Wettzell, HartRAO?)

Evolution of Lunar ephemeris IAA RAS:

1. At the base of the Krasinsky model orbital-rotational motion of the Moon and ERA(1-7) system from 1989 till 2014year (EPM-ERA)
2. The DE430 lunar model and another models up-to-date terrestrial models and solutions of IERS Conventions within new version of ERA system (ERA8) 2016.(Pavlov. D. et al)

Table 1. Distribution of LLR observations 1970-2016 by stations and RMS corresponding every station and special time intervals of observations

Station	Time Interval	Number of normal points	Used	Deleted	One-way wrms, cm
McDonald	1970 – 1985	3604	3545	43	**20.3**
MLRS1	1983 – 1988	631	588	43	**11.3**
MLRS2	1988 – 2015	3653	3221	449	**3.5**
Haleakala	1984 – 1990	770	743	27	**5.5**
Cerga (Ruby)	1984 – 1986	1188	1109	3	**16.9**
Cerga (Yag)	1987 – 2005	8324	8164	152	**2.4**
Cerga (Meo)	2009 – 2016	1617	1602	15	**1.8**
Matera	2003 – 2015	117	103	14	**3.3**
Apache	2006 - 2016	2370	2349	21	**1.4**
Total	1970 - 2016	21424	22191	767	

N	Parameter name	Parameter value	N	Parameter name	Parameter value
1	Moon X	-137136473.636 ± 0.047 m	12	ψ	$(128918873 \pm 2) \cdot 10^{-8}$ rad
2	Moon Y	-311514603.648 ± 0.034 m	13	$\dot{\varphi}$	-74.5385 ± 0.0008 ″/day
3	Moon Z	-141738600.360 ± 0.028 m	14	$\dot{\theta}$	-37.0239 ± 0.0002 ″/day
4	Moon V_x	962372275.33 ± 0.09 μm/sec	15	$\dot{\psi}$	47501.8549 ± 0.0007 ″/day
5	Moon V_y	-375608189.65 ± 0.13 μm/sec	16	h_2 Moon	0.0470 ± 0.0006
6	Moon V_z	-268439309.89 ± 0.05 μm/sec	17	β	$(631018.6 \pm 0.4) \cdot 10^{-9}$
7	ω_x	$(-866 \pm 3) \cdot 10^{-6}$ rad/day	18	γ	$(227727.5 \pm 0.5) \cdot 10^{-9}$
8	ω_y	$(-6505 \pm 6) \cdot 10^{-6}$ rad/day	19	τ	0.104 ± 0.001 day
9	ω_z	$(229.79 \pm 0.03) \cdot 10^{-3}$ rad/day	20	$\mu_E + \mu_M$	403503.2350 ± 0.0001 km^3/sec^2
10	φ	$(-5823809 \pm 1) \cdot 10^{-8}$ rad	21	K_v/C_t	$(14.9 \pm 0.2) \cdot 10^{-9}$ day^{-1}
11	θ	$(39511625 \pm 1) \cdot 10^{-8}$ rad	22	f_c	$(0.270 \pm 0.003) \cdot 10^{-3}$

Fig. 1 Post-fit residuals for Apache station

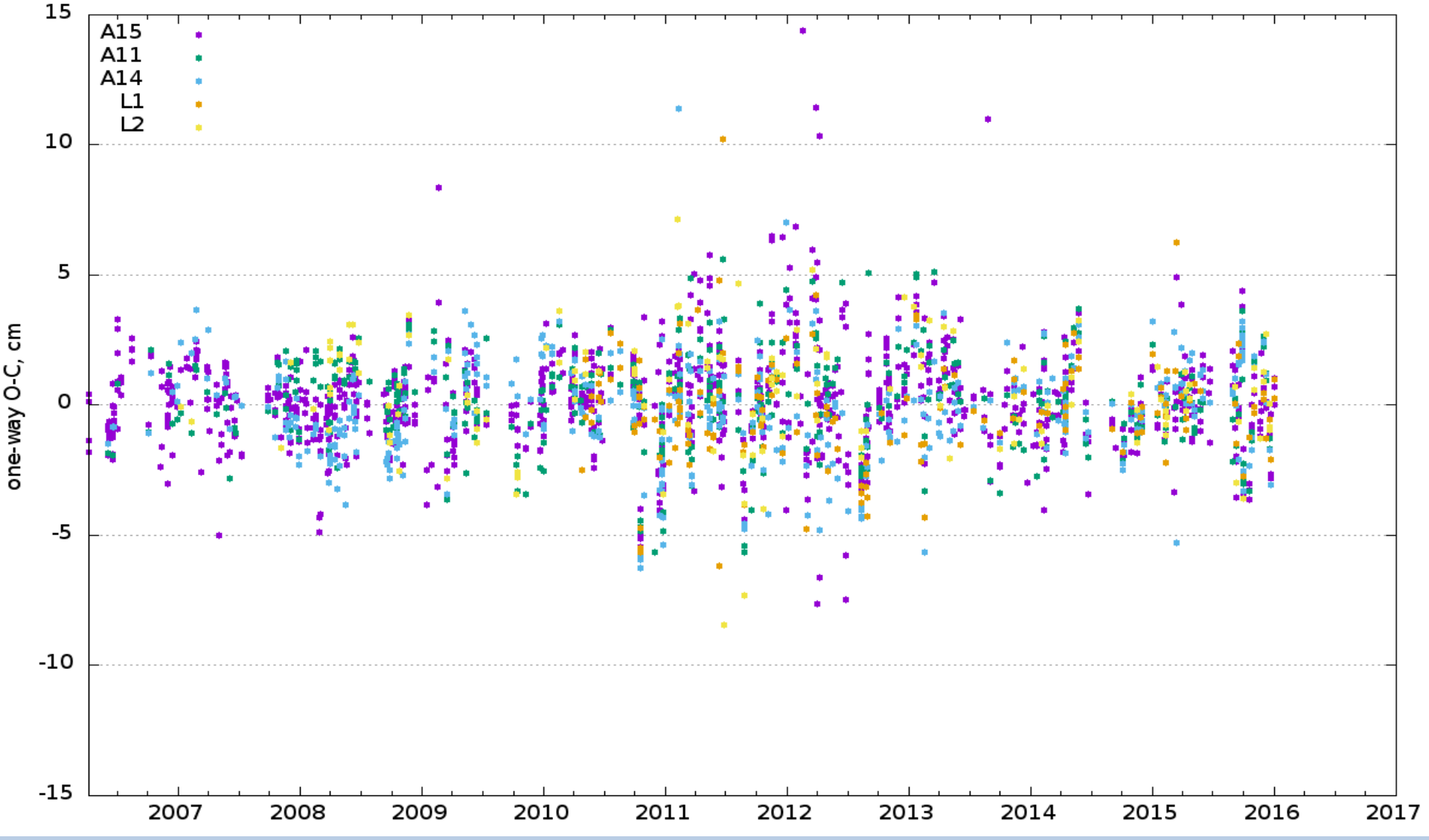
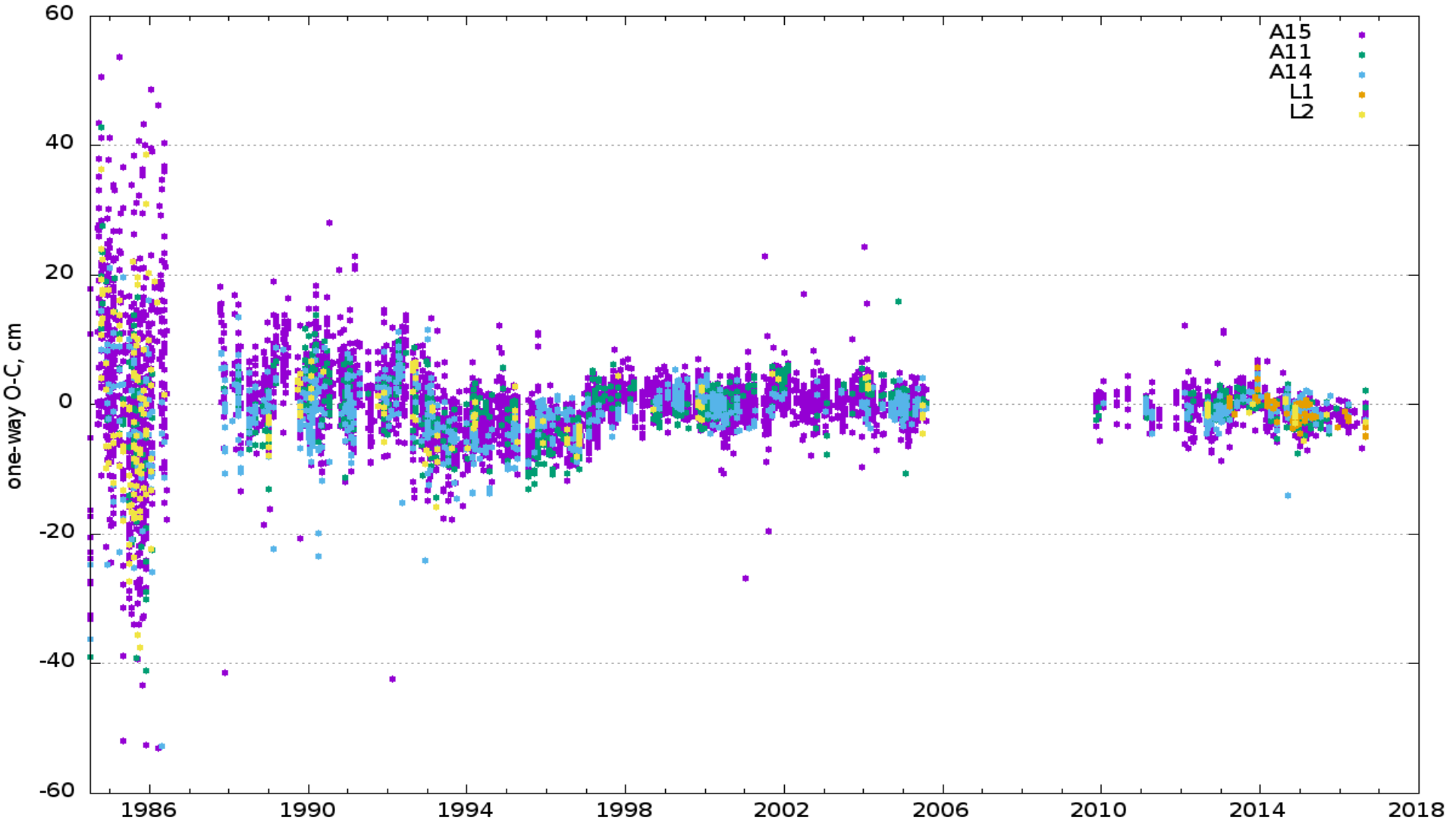


Fig. 2 Post-fit residuals for CERGA station



Station	SOLUTION 2013				SOLUTION 2016			
	Data span	used	reject.	wrms (cm)	Data span	used	reject.	wrms (cm)
McDonald	1970 - 1985	3545	59	**19.9**	1970 – 1985	3545	43	**20.3**
MLRS1	1983 – 1988	587	44	**11.0**	1983 – 1988	588	43	**11.3**
MLRS2	1988 – 2013	3210	443	**3.5**	1988 – 2015	3221	449	**3.5**
Haleakala	1984 – 1990	748	22	**5.4**	1984 – 1990	743	27	**5.5**
CERGA (Ruby)	1984 – 1986	1109	79	**17.2**	1984 – 1986	1109	3	**16.9**
CERGA (YAG)	1987 – 2005	8272	52	**2.3**	1987 – 2005	8164	152	**2.4**
CERGA (MeO)	2009 – 2013	645	9	**2.2**	2009 – 2016	1602	15	**1.8**
Apache	2006 – 2012	1546	27	**1.4**	2006 – 2016	2349	21	**1.4**
Matera	2003 - 2013	64	19	**3.8**	2003 – 2015	103	14	**3.3**

Conclusion

1. Using new version of EPM Lunar ephemeris2016 the processing of LLR observations(2800) at interval 1970-2016 were carried out.
2. The result is in good accordance with previous solution and uncertainties of parameters are very good.
3. Some small changings were made during iterative processing. All parameters from last solution in good agreement with solutions recommended by IERS Conventions and are compatible with lunar theory.
4. “Mixed” new version of EPM Lunar ephemeris is in progress

THANK YOU FOR YOUR ATTENTION