

asteroid_dataframe

February 29, 2020

```
[11]: # core
import numpy as np
import pandas as pd

# utility
from datetime import datetime

# MSE imports
from astro_utils import datetime_to_mjd
from horizons_files import load_pos_jpl, load_ast_jpl, load_obs_jpl, \
    ↪load_obs_ast_jpl
from asteroid_integrate import load_data
from asteroid_dataframe import load_ast_data, spline_ast_vec, spline_ast_obs, \
    ↪spline_ast_vec_obs
from asteroid_dataframe import compare_df_vec, compare_df_obs
```

0.0.1 Position of Earth according to JPL

```
[2]: # Data directories
dir_name_hourly = '../data/jpl/testing/hourly'
dir_name_daily = '../data/jpl/testing/daily'

# Build DataFrame for earth and mars position at 3 hour frequency
# df_earth = load_pos_jpl(body_name='earth', dir_name=dir_name_hourly)

# Earth at daily frequency
df_earth_jpl = load_pos_jpl(body_name='earth', dir_name=dir_name_daily)
```

```
[3]: df_earth_jpl
```

```
[3]:
```

	mjd	JulianDate	time_key	X	Y	Z	VX	\
0	55197.0	2455197.5	1324728	-0.179765	0.970347	-0.000017	-0.017202	
1	55198.0	2455198.5	1324752	-0.196939	0.967049	-0.000017	-0.017145	
2	55199.0	2455199.5	1324776	-0.214053	0.963453	-0.000016	-0.017083	
3	55200.0	2455200.5	1324800	-0.231103	0.959559	-0.000015	-0.017017	
4	55201.0	2455201.5	1324824	-0.248085	0.955369	-0.000014	-0.016945	
...	

3648	58845.0	2458845.5	1412280	-0.100787	0.986067	-0.000022	-0.017416
3649	58846.0	2458846.5	1412304	-0.118187	0.984147	-0.000021	-0.017382
3650	58847.0	2458847.5	1412328	-0.135550	0.981922	-0.000020	-0.017343
3651	58848.0	2458848.5	1412352	-0.152871	0.979393	-0.000019	-0.017298
3652	58849.0	2458849.5	1412376	-0.170144	0.976560	-0.000018	-0.017248

	VY	VZ	LT	RG	RR
0	-0.003148	8.961125e-07	0.005700	0.986858	0.000038
1	-0.003447	9.036109e-07	0.005700	0.986899	0.000044
2	-0.003745	8.653246e-07	0.005700	0.986945	0.000049
3	-0.004042	7.855759e-07	0.005700	0.986997	0.000054
4	-0.004339	6.725245e-07	0.005701	0.987054	0.000059
...
3648	-0.001767	9.809367e-07	0.005725	0.991204	0.000013
3649	-0.002073	9.327289e-07	0.005725	0.991218	0.000015
3650	-0.002377	8.590659e-07	0.005725	0.991234	0.000017
3651	-0.002681	7.650397e-07	0.005725	0.991251	0.000019
3652	-0.002984	6.558216e-07	0.005725	0.991271	0.000021

[3653 rows x 12 columns]

0.0.2 Positions of First 16 Asteroids from JPL

```
[4]: # Load the asteroid position and velocity from JPL
df_ast_jpl = load_ast_jpl(ast_num0=1, ast_num1=16, dir_name=dir_name_daily)
```

```
[5]: df_ast_jpl
```

```
[5]:
```

	asteroid_num	mjd	JulianDate	time_key	X	Y	\
0	1	55197.0	2455197.5	1324728	-1.660333	-2.123236	
1	1	55198.0	2455198.5	1324752	-1.652706	-2.130370	
2	1	55199.0	2455199.5	1324776	-1.645053	-2.137472	
3	1	55200.0	2455200.5	1324800	-1.637376	-2.144542	
4	1	55201.0	2455201.5	1324824	-1.629675	-2.151580	
...
3648	16	58845.0	2458845.5	1412280	2.517677	-0.513079	
3649	16	58846.0	2458846.5	1412304	2.519245	-0.501865	
3650	16	58847.0	2458847.5	1412328	2.520770	-0.490641	
3651	16	58848.0	2458848.5	1412352	2.522251	-0.479409	
3652	16	58849.0	2458849.5	1412376	2.523687	-0.468169	

	Z	VX	VY	VZ	LT	RG	RR
0	0.238962	0.007615	-0.007150	-0.001627	0.015628	2.705909	0.000794
1	0.237334	0.007640	-0.007118	-0.001630	0.015633	2.706703	0.000794
2	0.235702	0.007665	-0.007086	-0.001634	0.015637	2.707497	0.000795
3	0.234066	0.007689	-0.007054	-0.001637	0.015642	2.708293	0.000796
4	0.232427	0.007713	-0.007022	-0.001641	0.015646	2.709088	0.000796

```

...      ...      ...      ...      ...      ...      ...
3648 -0.043698  0.001590  0.011210 -0.000568  0.014842  2.569797 -0.000671
3649 -0.044266  0.001546  0.011219 -0.000568  0.014838  2.569129 -0.000665
3650 -0.044834  0.001503  0.011228 -0.000567  0.014834  2.568466 -0.000660
3651 -0.045400  0.001459  0.011236 -0.000566  0.014830  2.567809 -0.000655
3652 -0.045966  0.001415  0.011245 -0.000565  0.014827  2.567157 -0.000650

```

[58448 rows x 13 columns]

0.0.3 Observations of First 16 Asteroids from JPL

```

[6]: # Load the asteroid observations from JPL
df_obs_jpl = load_obs_ast_jpl(ast_num0=1, ast_num1=16,
    ↳ observer_name='geocenter', dir_name=dir_name_daily)

```

```

[7]: df_obs_jpl

```

```

[7]:      asteroid_num      mjd  JulianDate  time_key      RA_jpl      DEC_jpl  \
0                1  55197.0   2455197.5   1324728  243.215442 -17.105913
1                1  55198.0   2455198.5   1324752  243.625145 -17.196033
2                1  55199.0   2455199.5   1324776  244.034084 -17.284935
3                1  55200.0   2455200.5   1324800  244.442231 -17.372621
4                1  55201.0   2455201.5   1324824  244.849560 -17.459094
...
3648            16  58845.0   2458845.5   1412280  332.583400 -12.175911
3649            16  58846.0   2458846.5   1412304  332.963279 -12.044021
3650            16  58847.0   2458847.5   1412328  333.344527 -11.910963
3651            16  58848.0   2458848.5   1412352  333.727108 -11.776749
3652            16  58849.0   2458849.5   1412376  334.110983 -11.641395

      ux_jpl  uy_jpl  uz_jpl  RA_apparent  DEC_apparent      delta  \
0  -0.430702 -0.899812  0.069523   243.358581   -17.131844  3.437877
1  -0.424384 -0.902835  0.069195   243.768548   -17.221645  3.430618
2  -0.418063 -0.905804  0.068867   244.177730   -17.310227  3.423244
3  -0.411741 -0.908720  0.068539   244.586099   -17.397589  3.415755
4  -0.405417 -0.911583  0.068211   244.993632   -17.483728  3.408150
...
3648  0.867713 -0.496854 -0.014471   332.842722   -12.079671  3.017646
3649  0.871109 -0.490873 -0.014611   333.222363   -11.947459  3.027660
3650  0.874478 -0.484841 -0.014750   333.603364   -11.814086  3.037593
3651  0.877821 -0.478758 -0.014889   333.985688   -11.679564  3.047446
3652  0.881136 -0.472625 -0.015026   334.369299   -11.543908  3.057216

      delta_dot  light_time
0  -12.468091   28.591952
1  -12.668422   28.531584
2  -12.868277   28.470254

```

```

3    -13.067723    28.407966
4    -13.266749    28.344720
...
3648  17.406609    25.096998
3649  17.268707    25.180280
3650  17.128990    25.262894
3651  16.987592    25.344833
3652  16.844636    25.426089

```

[58448 rows x 14 columns]

0.0.4 Position of Asteroids & Earth from MSE Integration

```

[8]: # alias inputs
n0 = 1
n1 = 16
mjd0 = datetime_to_mjd(datetime(2010,1,1))
mjd1 = datetime_to_mjd(datetime(2020,1,2))

```

```

[9]: # Load first block of asteroid data
df_ast_mse, df_earth_mse, df_sun_mse = load_ast_data(n0=n0, n1=n1, mjd0=mjd0,
↪mjd1=mjd1)

```

```

[12]: # DataFrame of asteroid snapshots
ast_elt = load_data()
# ast_elt

```

0.0.5 Check Position of Earth vs. JPL

```

[13]: df_earth_mse

```

```

[13]:
      mjd  time_key    qx    qy    qz    vx    vy  \
0   55197.0   1324728 -0.179770  0.970346 -0.000018 -0.017202 -0.003150
1   55198.0   1324752 -0.196943  0.967047 -0.000017 -0.017144 -0.003449
2   55199.0   1324776 -0.214057  0.963449 -0.000016 -0.017082 -0.003747
3   55200.0   1324800 -0.231106  0.959554 -0.000015 -0.017015 -0.004044
4   55201.0   1324824 -0.248085  0.955362 -0.000015 -0.016943 -0.004339
...
3648  58845.0   1412280 -0.100788  0.986066 -0.000022 -0.017416 -0.001767
3649  58846.0   1412304 -0.118188  0.984146 -0.000021 -0.017382 -0.002073
3650  58847.0   1412328 -0.135551  0.981921 -0.000020 -0.017343 -0.002377
3651  58848.0   1412352 -0.152872  0.979391 -0.000019 -0.017298 -0.002681
3652  58849.0   1412376 -0.170145  0.976559 -0.000018 -0.017247 -0.002984

      vz    a    e    inc  Omega  omega    f
0   8.432308e-07  0.999049  0.015785  0.000050  2.230747 -0.423944 -0.056025

```

1	9.008784e-07	0.999023	0.015754	0.000052	2.205479	-0.405460	-0.031460
2	9.135747e-07	0.999051	0.015779	0.000053	2.202614	-0.409563	-0.006712
3	8.801033e-07	0.999132	0.015860	0.000051	2.220296	-0.433715	0.017540
4	8.042460e-07	0.999260	0.015988	0.000046	2.260180	-0.478972	0.040696
...
3648	9.773340e-07	1.000857	0.017568	0.000062	2.475880	-0.676480	-0.129783
3649	9.268695e-07	1.000770	0.017493	0.000059	2.520142	-0.715584	-0.117150
3650	8.513399e-07	1.000654	0.017387	0.000056	2.586981	-0.777772	-0.104008
3651	7.558548e-07	1.000516	0.017257	0.000052	2.678579	-0.865408	-0.090176
3652	6.455791e-07	1.000360	0.017108	0.000048	2.797421	-0.981128	-0.075507

[3653 rows x 14 columns]

```
[14]: # Run comparison on earth
compare_df_vec(df_mse=df_earth_mse, df_jpl=df_earth_jpl, name='earth')
```

Mean absolute error for df_earth_mse vs. df_earth_jpl:

mjd: 0.00e+00 days

q: 3.92e-06 AU (max 1.13e-05)

v: 8.57e-07 AU/day (rel 4.98e-05)

0.0.6 Check Position of Asteroids vs. JPL

```
[15]: df_ast_mse
```

```
[15]:
```

	asteroid_num	mjd	time_key	qx	qy	qz	\
0	1	55197.0	1324728	-1.660334	-2.123236	0.238962	
1	1	55198.0	1324752	-1.652706	-2.130370	0.237334	
2	1	55199.0	1324776	-1.645054	-2.137472	0.235702	
3	1	55200.0	1324800	-1.637377	-2.144542	0.234067	
4	1	55201.0	1324824	-1.629676	-2.151580	0.232428	
...
58443	16	58845.0	1412280	2.517677	-0.513080	-0.043698	
58444	16	58846.0	1412304	2.519246	-0.501866	-0.044266	
58445	16	58847.0	1412328	2.520770	-0.490642	-0.044834	
58446	16	58848.0	1412352	2.522251	-0.479410	-0.045400	
58447	16	58849.0	1412376	2.523688	-0.468170	-0.045966	

	vx	vy	vz	a	e	inc	Omega	\
0	0.007615	-0.007150	-0.001627	2.765732	0.079223	0.184765	1.403138	
1	0.007640	-0.007118	-0.001630	2.765729	0.079223	0.184765	1.403138	
2	0.007665	-0.007086	-0.001634	2.765726	0.079222	0.184765	1.403138	
3	0.007689	-0.007054	-0.001637	2.765723	0.079222	0.184765	1.403137	
4	0.007713	-0.007022	-0.001641	2.765720	0.079221	0.184765	1.403137	
...
58443	0.001590	0.011210	-0.000568	2.922647	0.133480	0.054046	2.618716	
58444	0.001546	0.011219	-0.000568	2.922646	0.133480	0.054046	2.618716	

```

58445  0.001503  0.011228 -0.000567  2.922645  0.133480  0.054046  2.618716
58446  0.001459  0.011236 -0.000566  2.922644  0.133480  0.054046  2.618716
58447  0.001415  0.011245 -0.000565  2.922643  0.133480  0.054046  2.618716

```

```

           omega          f
0      1.268764  1.371390
1      1.268752  1.375296
2      1.268740  1.379200
3      1.268728  1.383101
4      1.268717  1.387000
...
58443 -2.286344 -0.535517
58444 -2.286339 -0.531126
58445 -2.286333 -0.526732
58446 -2.286328 -0.522336
58447 -2.286322 -0.517938

```

[58448 rows x 15 columns]

```

[16]: # Filter MSE asteroids down to just the first 16 to match JPL data
mask = df_ast_mse.asteroid_num <= 16
df_ast_mse_16 = df_ast_mse[mask]

```

```

[17]: # Run comparison on asteroids
compare_df_vec(df_mse=df_ast_mse_16, df_jpl=df_ast_jpl, name='asteroids')

```

Mean absolute error for df_asteroids_mse vs. df_asteroids_jpl:

```

mjd: 0.00e+00 days
  q: 7.90e-07 AU      (max 3.52e-06)
  v: 2.55e-09 AU/day (rel 2.38e-07)

```

0.0.7 Review Solar DataFrame

```

[18]: df_sun_mse

```

```

[18]:      mjd  time_key    qx    qy    qz    vx    vy  \
0    55197.0  1324728 -0.003747  0.002926  0.000004 -0.000003 -0.000006
1    55198.0  1324752 -0.003750  0.002921  0.000005 -0.000003 -0.000006
2    55199.0  1324776 -0.003753  0.002915  0.000005 -0.000003 -0.000006
3    55200.0  1324800 -0.003756  0.002910  0.000005 -0.000003 -0.000006
4    55201.0  1324824 -0.003759  0.002904  0.000005 -0.000003 -0.000006
...
3648  58845.0  1412280 -0.003765  0.007447  0.000022 -0.000008 -0.000002
3649  58846.0  1412304 -0.003773  0.007445  0.000022 -0.000008 -0.000002
3650  58847.0  1412328 -0.003782  0.007443  0.000023 -0.000008 -0.000002
3651  58848.0  1412352 -0.003790  0.007441  0.000023 -0.000008 -0.000002
3652  58849.0  1412376 -0.003798  0.007439  0.000023 -0.000008 -0.000002

```

```

          vz
0      6.981105e-08
1      6.965225e-08
2      6.949627e-08
3      6.934233e-08
4      6.918960e-08
...
3648  2.306296e-07
3649  2.305600e-07
3650  2.304893e-07
3651  2.304177e-07
3652  2.303451e-07

```

[3653 rows x 8 columns]

Conclusion Loading daily integration with `load_ast_data` works. Integration agrees with JPL to tolerance of **7.9E-7 AU**.

0.0.8 Splined Asteroid DataFrame

```

[19]: # Load the JPL data run at 3 hour intervals
df_earth_jpl_3h = load_pos_jpl(body_name='earth', dir_name=dir_name_hourly)
df_ast_jpl_3h = load_ast_jpl(ast_num0=1, ast_num1=16, dir_name=dir_name_hourly)

# Load observation from palomar at 3h intervals
df_obs_jpl_3h = load_obs_ast_jpl(ast_num0=1, ast_num1=16,
    ↪observer_name='palomar', dir_name=dir_name_hourly)

```

```

[36]: # Inputs for spline_ast_vec()
n0 = 1
n1 = 16
mjd = df_earth_jpl_3h.mjd.values

```

```

[21]: # Spline asteroid data on the same schedule as JPL
df_ast_out, df_earth_out, df_sun_out = spline_ast_vec(n0=n0, n1=n1, mjd=mjd)

```

```

[22]: df_ast_out

```

```

[22]:
   asteroid_num  mjd  time_key    qx    qy    qz  \
0              1  55197.000  1324728 -1.660334 -2.123236  0.238962
1              1  55197.125  1324731 -1.659382 -2.124130  0.238759
2              1  55197.250  1324734 -1.658429 -2.125023  0.238556
3              1  55197.375  1324737 -1.657476 -2.125915  0.238352
4              1  55197.500  1324740 -1.656523 -2.126807  0.238149
...           ...    ...      ...    ...    ...
467467         16  58848.500  1412364  2.522975 -0.473791 -0.045683

```

467468	16	58848.625	1412367	2.523154	-0.472386	-0.045754
467469	16	58848.750	1412370	2.523332	-0.470981	-0.045825
467470	16	58848.875	1412373	2.523510	-0.469575	-0.045895
467471	16	58849.000	1412376	2.523688	-0.468170	-0.045966

	vx	vy	vz	a	e	inc	Omega \
0	0.007615	-0.007150	-0.001627	2.765732	0.079223	0.184765	1.403138
1	0.007618	-0.007146	-0.001627	2.765732	0.079223	0.184765	1.403138
2	0.007622	-0.007142	-0.001628	2.765732	0.079223	0.184765	1.403138
3	0.007625	-0.007138	-0.001628	2.765731	0.079223	0.184765	1.403138
4	0.007628	-0.007134	-0.001628	2.765731	0.079223	0.184765	1.403138
...
467467	0.001437	0.011240	-0.000566	2.922643	0.133480	0.054046	2.618716
467468	0.001431	0.011242	-0.000566	2.922643	0.133480	0.054046	2.618716
467469	0.001426	0.011243	-0.000566	2.922643	0.133480	0.054046	2.618716
467470	0.001420	0.011244	-0.000565	2.922643	0.133480	0.054046	2.618716
467471	0.001415	0.011245	-0.000565	2.922643	0.133480	0.054046	2.618716

	omega	f
0	1.268764	1.371390
1	1.268763	1.371879
2	1.268761	1.372367
3	1.268760	1.372855
4	1.268758	1.373344
...
467467	-2.286325	-0.520137
467468	-2.286324	-0.519588
467469	-2.286323	-0.519038
467470	-2.286323	-0.518488
467471	-2.286322	-0.517938

[467472 rows x 15 columns]

```
[23]: # Run comparison on asteroids
compare_df_vec(df_mse=df_ast_out, df_jpl=df_ast_jpl_3h, name='asteroids')
```

Mean absolute error for df_asteroids_mse vs. df_asteroids_jpl:

mjd: 0.00e+00 days

q: 7.97e-07 AU (max 3.52e-06)

v: 2.60e-09 AU/day (rel 2.43e-07)

```
[24]: df_earth_out
```

	mjd	time_key	qx	qy	qz	vx	vy \
0	55197.000	1324728	-0.179770	0.970346	-0.000018	-0.017202	-0.003150
1	55197.125	1324731	-0.181920	0.969950	-0.000018	-0.017195	-0.003188
2	55197.250	1324734	-0.184069	0.969550	-0.000018	-0.017188	-0.003225

3	55197.375	1324737	-0.186217	0.969144	-0.000018	-0.017181	-0.003262
4	55197.500	1324740	-0.188364	0.968734	-0.000018	-0.017174	-0.003300
...
29212	58848.500	1412364	-0.161515	0.978013	-0.000019	-0.017273	-0.002832
29213	58848.625	1412367	-0.163673	0.977657	-0.000018	-0.017267	-0.002870
29214	58848.750	1412370	-0.165831	0.977296	-0.000018	-0.017261	-0.002908
29215	58848.875	1412373	-0.167989	0.976930	-0.000018	-0.017254	-0.002946
29216	58849.000	1412376	-0.170145	0.976559	-0.000018	-0.017247	-0.002984

	vz	a	e	inc	Omega	omega	\
0	8.432308e-07	0.999049	0.015785	0.000050	2.230747	-0.423944	
1	8.527142e-07	0.999043	0.015778	0.000050	2.226164	-0.420203	
2	8.615735e-07	0.999038	0.015772	0.000051	2.222007	-0.416898	
3	8.697954e-07	0.999033	0.015767	0.000051	2.218268	-0.414015	
4	8.773666e-07	0.999029	0.015763	0.000051	2.214936	-0.411541	
...
29212	7.022431e-07	1.000439	0.017185	0.000050	2.734436	-0.919592	
29213	6.883381e-07	1.000420	0.017166	0.000050	2.749502	-0.934274	
29214	6.742523e-07	1.000400	0.017147	0.000049	2.765018	-0.949420	
29215	6.599960e-07	1.000380	0.017128	0.000049	2.780989	-0.965036	
29216	6.455791e-07	1.000360	0.017108	0.000048	2.797421	-0.981128	

	f
0	-0.056025
1	-0.052986
2	-0.049936
3	-0.046875
4	-0.043806
...	...
29212	-0.082955
29213	-0.081115
29214	-0.079260
29215	-0.077391
29216	-0.075507

[29217 rows x 14 columns]

```
[25]: # Run comparison on earth
compare_df_vec(df_mse=df_earth_out, df_jpl=df_earth_jpl_3h, name='earth')
```

Mean absolute error for df_earth_mse vs. df_earth_jpl:

mjd: 0.00e+00 days

q: 3.92e-06 AU (max 1.13e-05)

v: 8.57e-07 AU/day (rel 4.98e-05)

Conclusion Cubic splining of daily integration with spline_ast_vec works. Integration agrees with JPL to tolerance of **3.9E-6 AU**. The spline has introduced slightly more error, but it is still very small.

0.0.9 Build Splined Observation & Compare vs. JPL

```
[26]: df_obs_jpl_3h
```

```
[26]:      asteroid_num      mjd      JulianDate      time_key      RA_jpl      DEC_jpl  \
0              1  55197.000  2455197.500  1324728  243.214830 -17.106252
1              1  55197.125  2455197.625  1324731  243.266342 -17.117471
2              1  55197.250  2455197.750  1324734  243.318051 -17.128756
3              1  55197.375  2455197.875  1324737  243.369682 -17.140123
4              1  55197.500  2455198.000  1324740  243.420999 -17.151530
...
29212          16  58848.500  2458849.000  1412364  333.918987 -11.709509
29213          16  58848.625  2458849.125  1412367  333.967430 -11.692635
29214          16  58848.750  2458849.250  1412370  334.015569 -11.675789
29215          16  58848.875  2458849.375  1412373  334.063332 -11.658913
29216          16  58849.000  2458849.500  1412376  334.110877 -11.641955

      ux_jpl      uy_jpl      uz_jpl      RA_apparent      DEC_apparent      delta  \
0  -0.430710 -0.899809  0.069515  243.357955  -17.132205  3.437890
1  -0.429917 -0.900191  0.069477  243.409452  -17.143375  3.437011
2  -0.429121 -0.900574  0.069438  243.461181  -17.154603  3.436114
3  -0.428325 -0.900956  0.069397  243.512878  -17.165916  3.435195
4  -0.427533 -0.901335  0.069354  243.564287  -17.177279  3.434263
...
29212  0.879482 -0.475698 -0.014963  334.177362  -11.612170  3.052380
29213  0.879899 -0.474925 -0.014984  334.225801  -11.595248  3.053587
29214  0.880313 -0.474156 -0.015003  334.273964  -11.578362  3.054780
29215  0.880724 -0.473391 -0.015020  334.321743  -11.561454  3.055976
29216  0.881133 -0.472629 -0.015035  334.369269  -11.544470  3.057186

      delta_dot      light_time
0  -12.102732  28.592060
1  -12.282233  28.584749
2  -12.585595  28.577286
3  -12.849298  28.569644
4  -12.933136  28.561893
...
29212  16.859446  25.385873
29213  16.591743  25.395910
29214  16.504155  25.405834
29215  16.637661  25.415774
29216  16.903294  25.425841
```

```
[467472 rows x 14 columns]
```

```
[27]: # Build MSE splined observations at palomar
```


0.0.10 Test All in One spline_ast_vec_obs()

```
[37]: mjd = df_earth_jpl_3h.mjd.values
      df_ast2_mse, df_earth2_mse, df_obs2_mse = spline_ast_vec_obs(n0=1, n1=16,
      ↪mjd=mjd, site_name='palomar')
```

```
[38]: compare_df_obs(df_obs2_mse, df_obs_jpl_3h, name='asteroid')
```

Mean absolute error for asteroid observations: MSE vs. JPL

mjd: 0.00e+00 days

Angle Difference: jpl vs. mse

Mean : 0.000271 deg (0.974 seconds)

Median: 0.000277 deg (0.999 seconds)

Max : 0.000899 deg (3.236 seconds)

```
[ ]:
```