Astro2

October 18, 2016

```
In [1]: import pandas
        import altair
        from astropy import units as u
        from numpy import sin, cos, arccos, sqrt
```

First, we load the data and format the types accordingly:

```
In [2]: data = pandas.read_table('moon.dat', sep='\s+')
        data['date'] = pandas.to_datetime(data['date'], format='%d-%m-%Y')
```

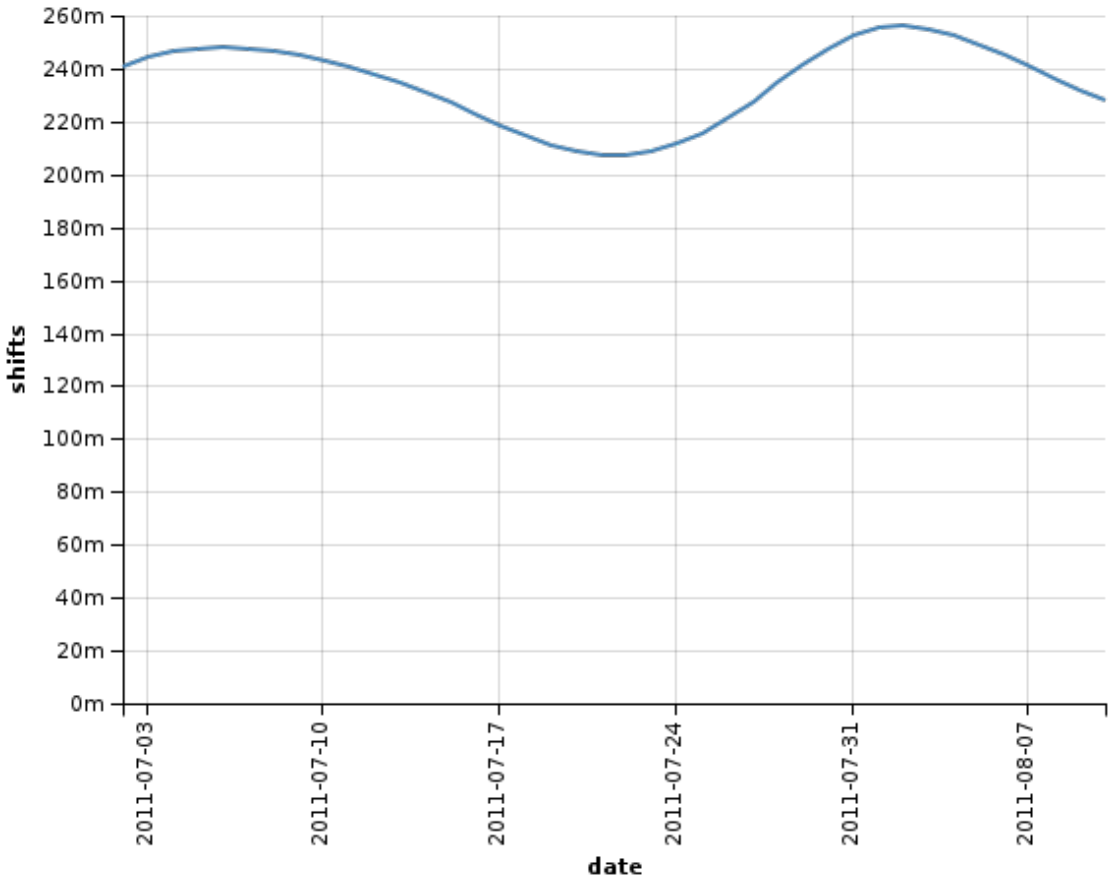
Now we construct a new column containing the respective angle shifts:

```
In [3]: def angle_between_points(i,j):
            alpha_i = data.iloc[i]['rect'] * u.hourangle
            alpha_j = data.iloc[j]['rect'] * u.hourangle
            delta_i = data.iloc[i]['decl'] * u.degree
            delta_j = data.iloc[j]['decl'] * u.degree
            angle = arccos(sin(delta_i)*sin(delta_j) +
                           cos(delta_i)*cos(delta_j)*cos(alpha_i-alpha_j))
            return angle.to(u.rad).value

        angle_shifts = [None]
        rows = len(list(data.iterrows()))
        for i in range(1, rows):
            angle_shifts.append(angle_between_points(i, i-1))

        data['shifts'] = pandas.Series(angle_shifts)
        data.head()
```

Out[3]:

	date	rect	decl	shifts
0	2011-07-01	6.96722	20.91167	NaN
1	2011-07-02	7.91667	17.78417	0.240692
2	2011-07-03	8.84167	13.60361	0.244187
3	2011-07-04	9.74028	8.63583	0.246491
4	2011-07-05	10.61861	3.18389	0.247641

```
In [4]: altair.Chart(data).mark_line().encode(x='date', y='shifts')
```



Since by Kepler's second law we have:

$$r_{max}^2 \cdot \varphi_{min} = r_{min}^2 \cdot \varphi_{max}$$

Let us denote the ratio of r_{max} and r_{min} as k:

$$k = \frac{r_{max}}{r_{min}} = \sqrt{\frac{\varphi_{max}}{\varphi_{min}}}$$

Then using $r_{min} = a(1-e)$ and $r_{max} = a(1+e)$ we get:

$$k = \frac{1+e}{1-e}$$

and finally:

$$e = \frac{k-1}{k+1}$$

```
In [5]: phi_min = min(data.dropna()['shifts'])
        phi_max = max(data.dropna()['shifts'])
        k = sqrt(phi_max/phi_min)
        e = (k-1)/(k+1)
        print e
```

0.0529938798589