LSST Variable Star Classification

Tanner Leighton

Perhaps most important thing from this slideshow…

- This ppt details a lot of work I did summer 2017. Later in the ppt, I include many light curves, many of which may want to be used for zooniverse project (not this LC but the found source), so I have detailed above each LC information about it that will enable one to 're-find' it!
  - The way I did this (in general): star#.tbl – RA DEC coordinate – period – where I found it
  - Here is a specific example: lyrae9.tbl – 20 48 14.9 +00 07 05 – period: 0.5851614753091116 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

Week 1:

```
""" lightCurve.py

    This purpose of this program is to produce a light curve with error bars.
    Language: Python 3

    Tanner Leighton

    Written for CIERA Summer Internship, Northwestern University.
    6/25/17
"""
import matplotlib.pyplot as plt
import numpy as np
from scipy.optimize import curve_fit

def plotLightCurve(filename):
    """ This function just works with time, mag, and error,
        i.e. does not filter by oid.

        Arguments:
            filename (string) : name of data txt file
    """
```

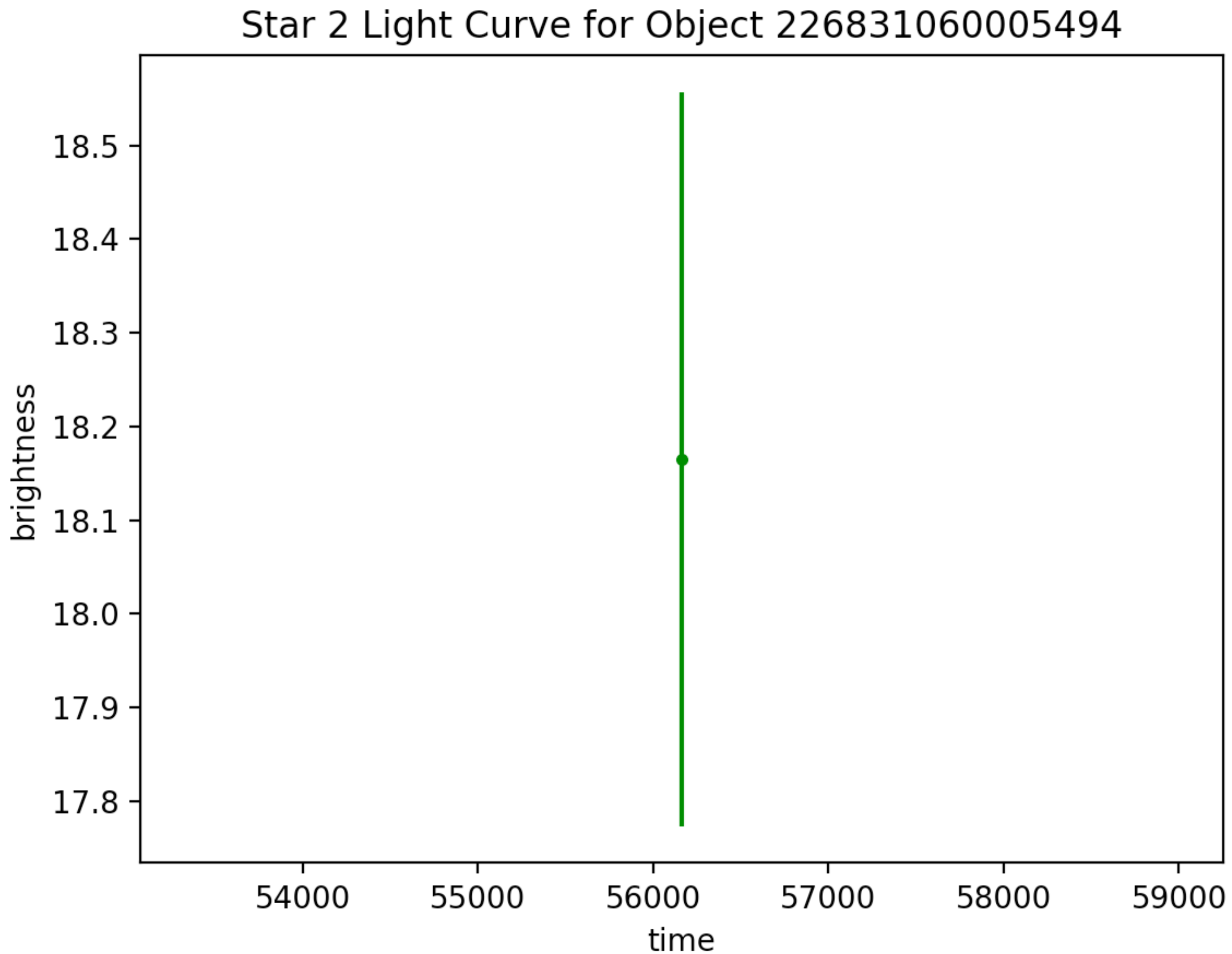
```
def plotLightCurvePrime(filename):
    """ This function works with time, mag, error and DOES filter by oid.
        Takes in four lists of data for each of the above mentioned things
        and then makes three plots (of the three objects), which is what
        is meant by filtering by oid

        Arguments:
            filename (string) : name of data txt file
    """
```

Week 1:

Light curves for star 2 (not phase-folded. Not yet. In time)

(RA = 20:50:00.91, dec = -00:42:23.8)

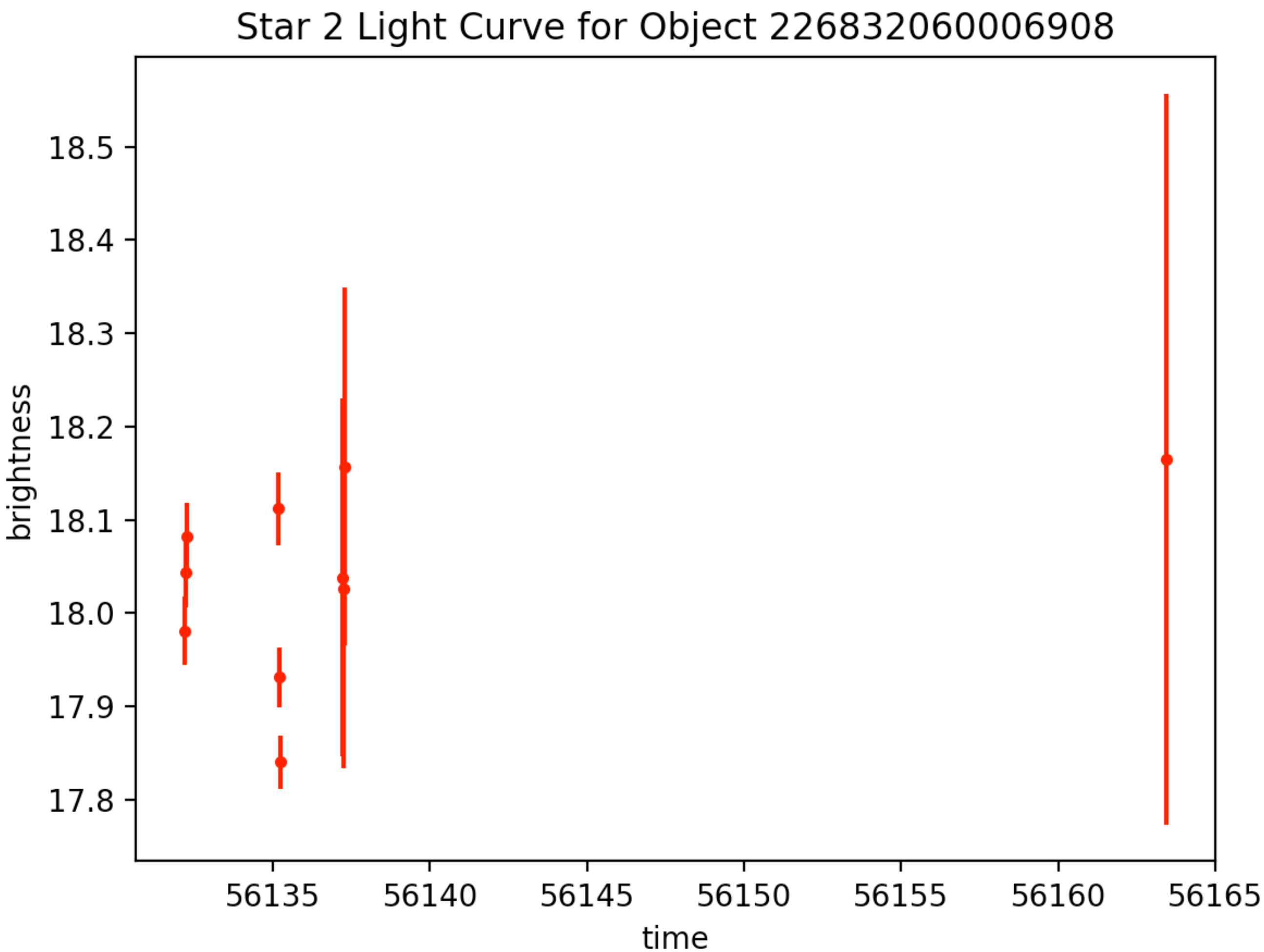
(separate plots for different oid's)



Week 1:

Light curves for star 2 cont.

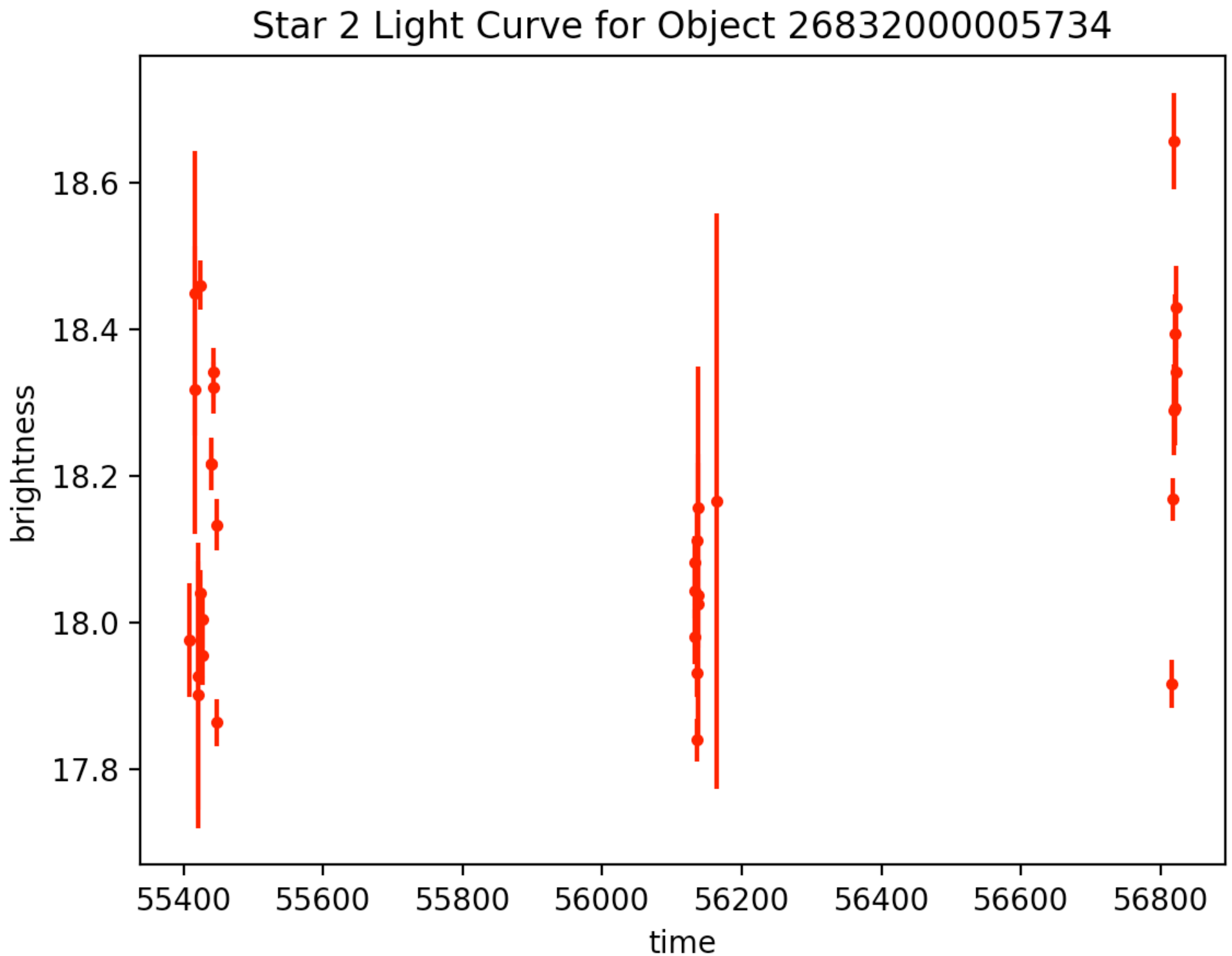
for object 226832060006908, best-fit period = 0.191486



Week 1:

Light curves for star 2 cont.

for object 26832000005734, best-fit period = 2.440220



Week 2:

- First ran a query on the PTF Objects table to return sources with bestChiSQ > 100 and nbestobs > 100. Selected one of those sources to download the light curve data for that source from the Lightcurve table.
  - This was the third star I have worked with.
  - For this task, I had to augment my light curve plotting software.

ra (degrees)	dec (degrees)	oid
291.3357640	45.5357760	46572060016052
291.3214130	45.2865570	46572060009302
291.2950440	45.3245710	46572060010416
291.6238810	45.4078980	46572060012596
291.5652660	45.5394100	46572060015890
291.4838910	45.4171650	46572060012923
291.5288120	45.1965170	46572060006845
290.5968200	46.3058500	46562050004847
290.9010910	46.1357600	46562050001391
290.8111950	46.1450470	46562050001569
290.6892240	46.1892020	46562050002381
290.7686110	46.2176340	46562050003047
290.7230300	46.1973900	46562050002653
290.7816770	46.1222950	46562050000990
290.7832590	46.1893310	46562050002480
290.7481460	46.1787460	46562050002193

Query of first few listings…

Week 2:

Star 3

Catalog Search Result for PTF Lightcurve Table

Object/Coordinate	Source	Type	Glon	Glat	Equatorial J2000
291.3357640 45.5357760	Coordinate		77.49192	+13.50568	19h 25m 20.58s +45d 32m 08.8s

As I have plotted more and more lightcurves, I have made my plotting software more and more general (it worked perfectly fine for the first two stars not being completely general). However, there are sources with only one object id and others with >3, so I took the time when generalizing the code to work for star 3 to be completely generalize (to work for star 3 or any star!). Now, the code can handle sources with any number of OID's.

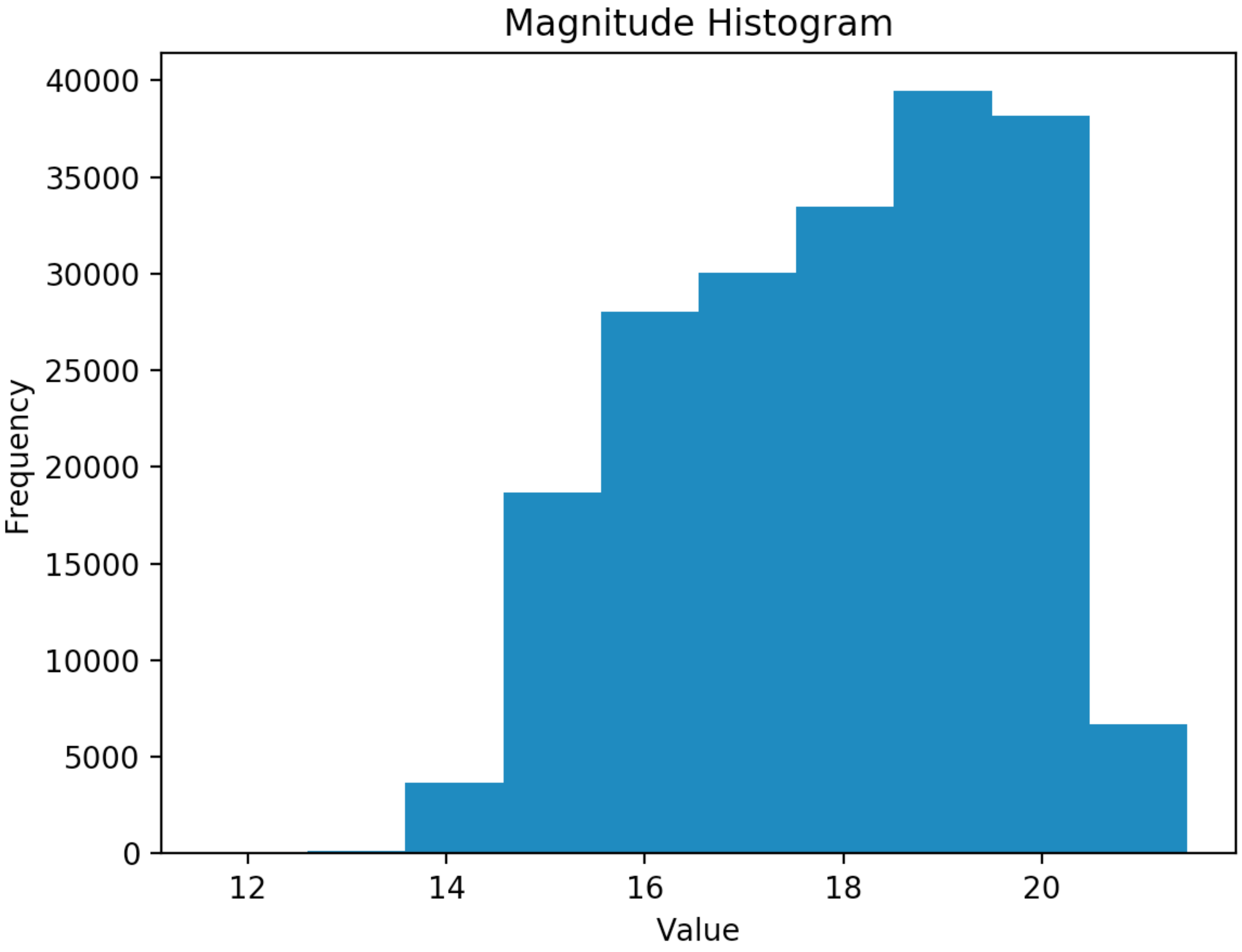
```
def plotLightCurve(filename):
    """ This function works with time, mag, error and DOES filter by oid.
        Takes in four lists of data for each of the above mentioned things
        and then makes of light curves (one for each object ID).

        Note: This function is most general, i.e. it can deal with sources with any number
        of object ID's!

        Arguments:
            filename (string) : name of data txt file
    """
```

Week 2:

Histogram of Magnitudes

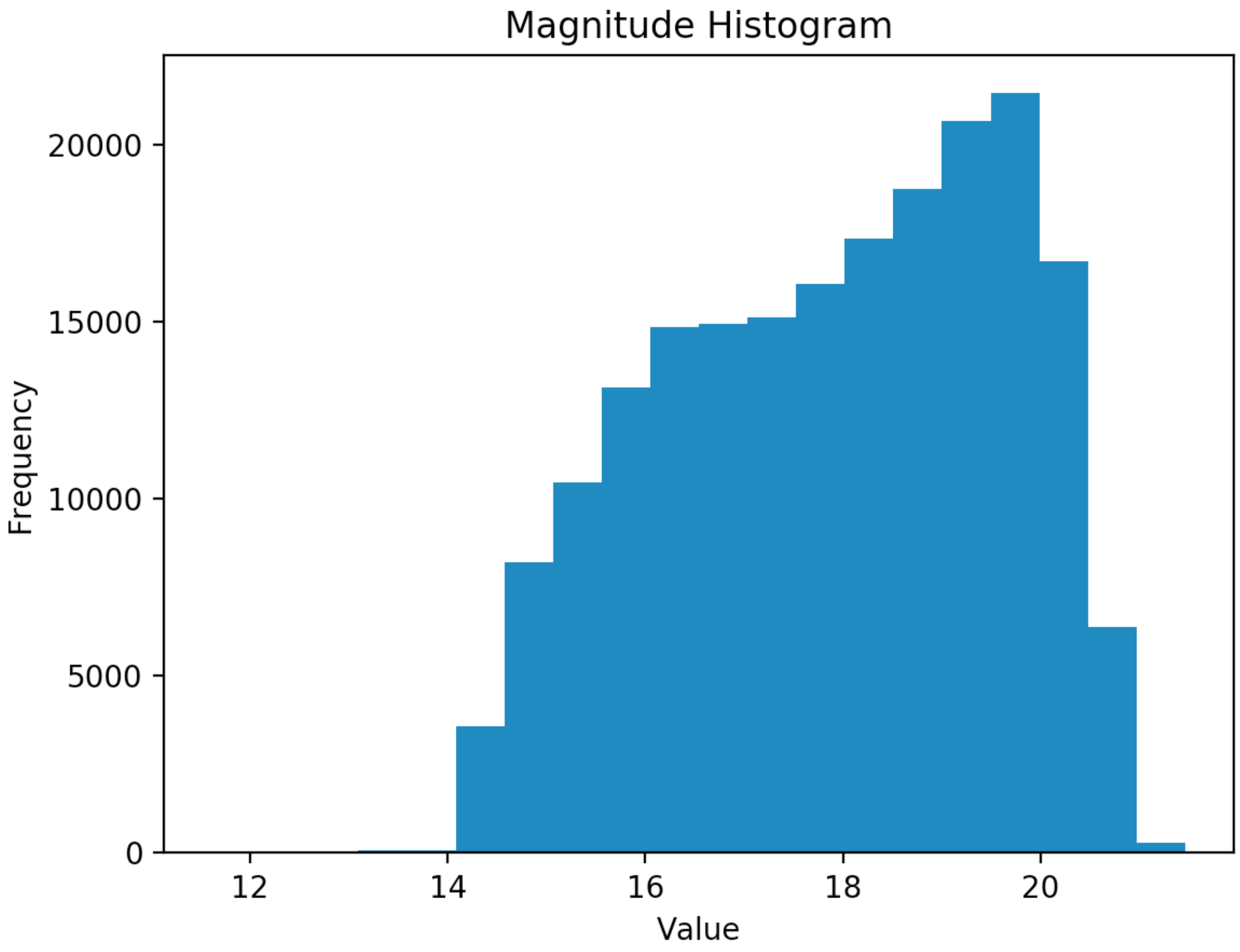
- Next I went to object table (on Caltech IRSA website) and did a query for all sources with bestchiSQ > 10 and ngoodobs > 250.
  - Downloaded the results of that table
  - Made a histogram plot of the magnitudes

Week 2:

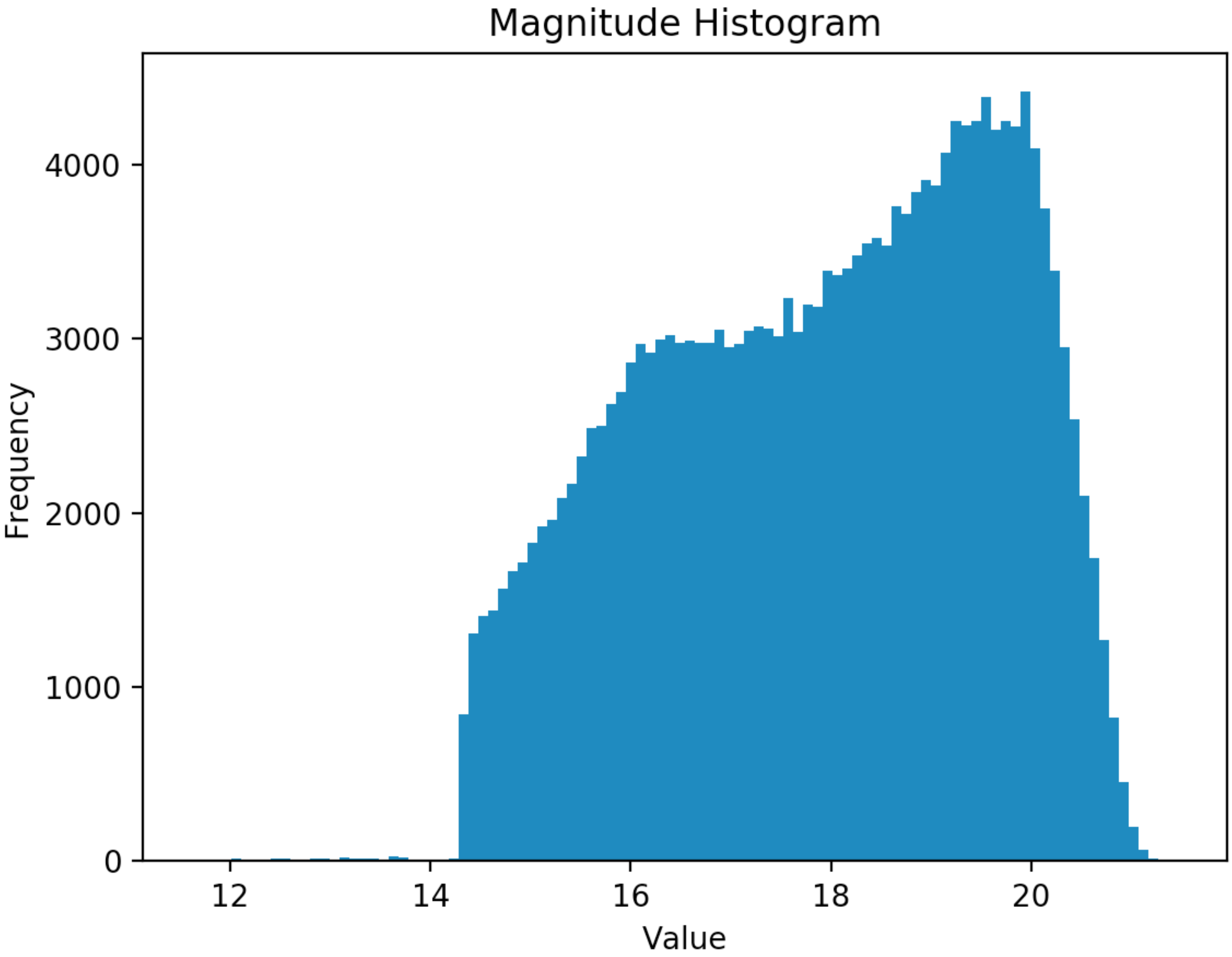


Magnitude Histogram
40000
35000
30000
25000
20000
15000
10000
5000
0
Frequency
12
14
16
18
20
Value

Week 3 Update: More bins!



*Week 3 Update: Even more bins!



Week 2:

Used cesium-ml package to determine frequency -> period -> phase-folding!

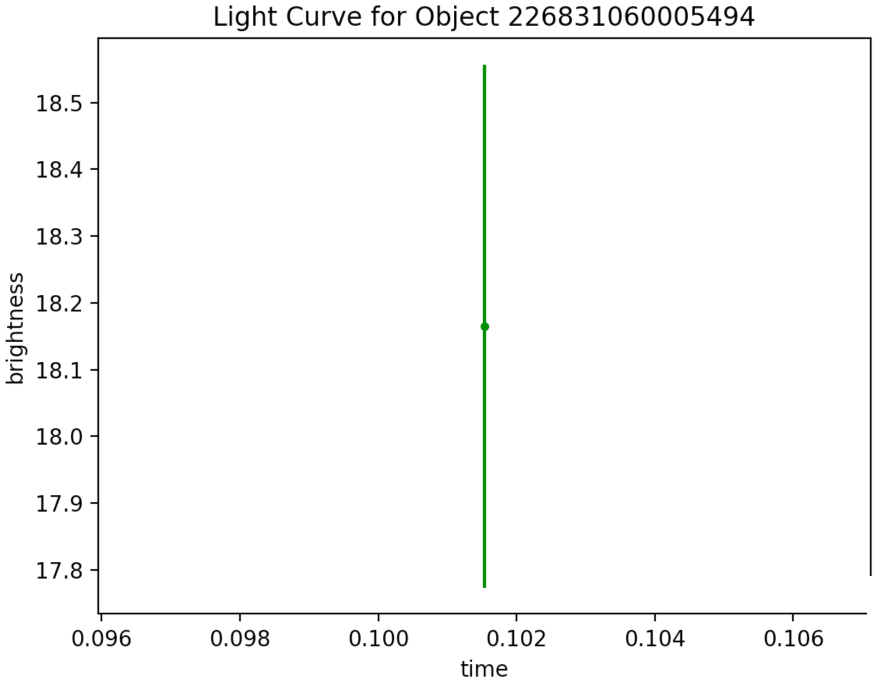
```
def printFrequency(filename): # give it star2.tbl to featurize for star 2

    features_to_use = ["freq1_freq"]

    dataTable = Table.read(filename, format='ipac')

    fset_cesium = featurize.featurize_time_series(times=dataTable["obsmjd"],
                                                  values=dataTable["mag_autocorr"],
                                                  errors=dataTable["magerr_auto"],
                                                  features_to_use=features_to_use)

    print(fset_cesium)

def plotLightCurve(filename, period):
```

Week 2:

Phase folding software

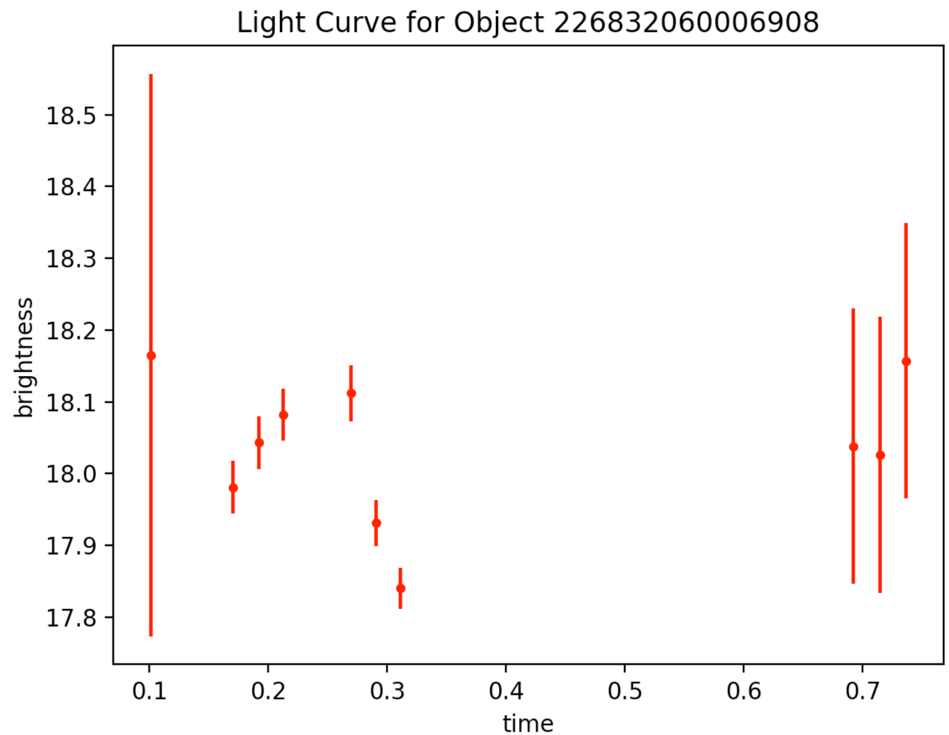
```
while newOID != tempOID:

    firstIndexOfNextOid = index+1

    tempOID = oidList[firstIndexOfNextOid]
    for i in range(oidListLength):
        if tempOID == oidList[i]:
            xListTemp.append(xList[i])
            yListTemp.append(yList[i])
            errorListTemp.append(errorList[i])
            if fidList[i] == 1:
                fmtToBeUsed = 'go'
            else:
                fmtToBeUsed = 'ro'

    xListTempLength = len(xListTemp)

    # Now let's "normalize," if you will, for phase-folding
    xListPhaseFolded = []
    for i in range(xListTempLength):
        xListPhaseFolded.append((xListTemp[i] % period) / period)

    plt.errorbar(xListPhaseFolded, yListTemp, yerr = errorListTemp, fmt=fmtToBeUsed, markersize=3)
    plt.title("Light Curve for Object {}".format(tempOID))
    plt.xlabel("time")
    plt.ylabel("brightness")
    plt.show()
```

Week 2:



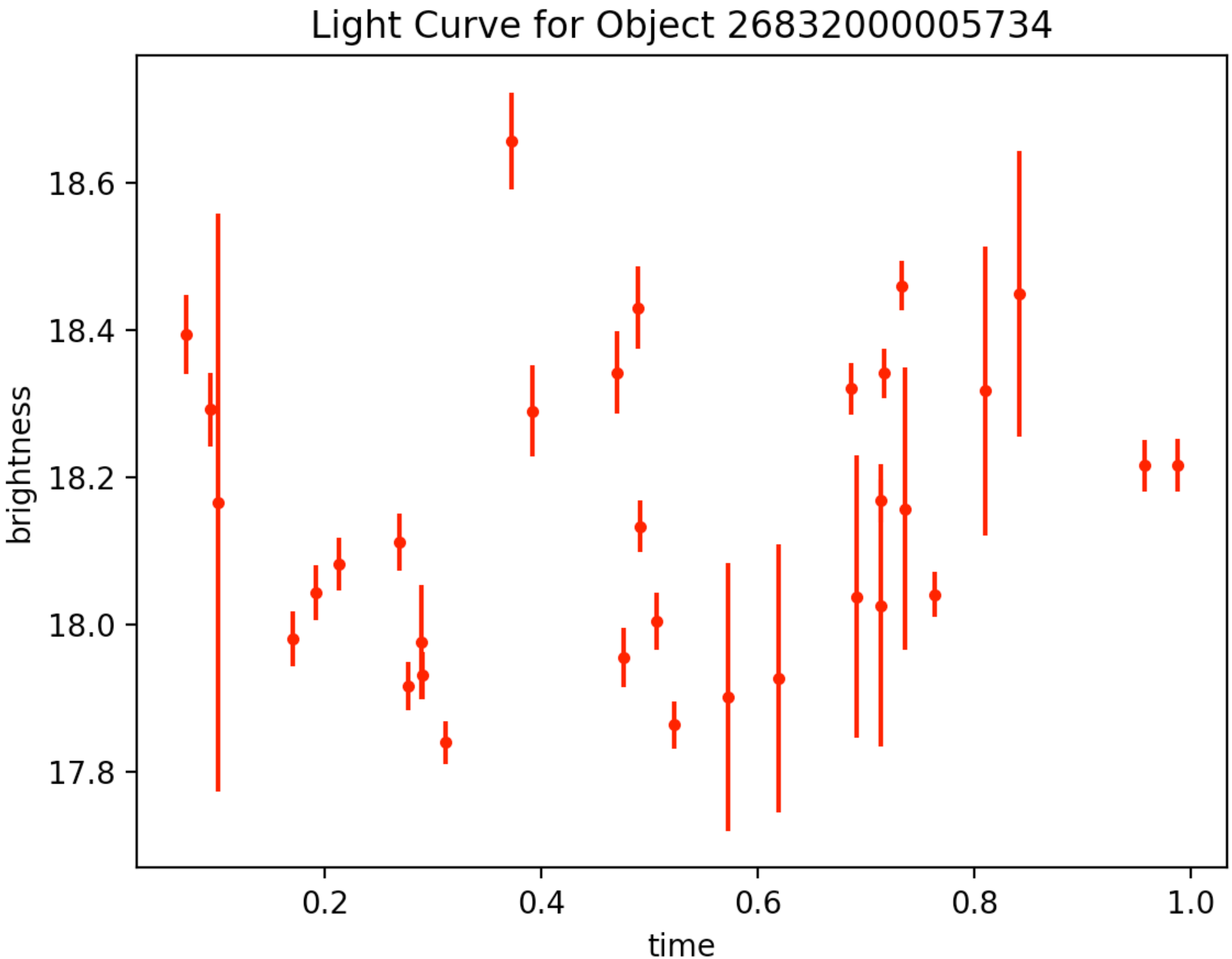
Star 2 Phase-folded Light Curves

Limited observations!



Week 2:

Star 2 Best Phase-folded Light Curve

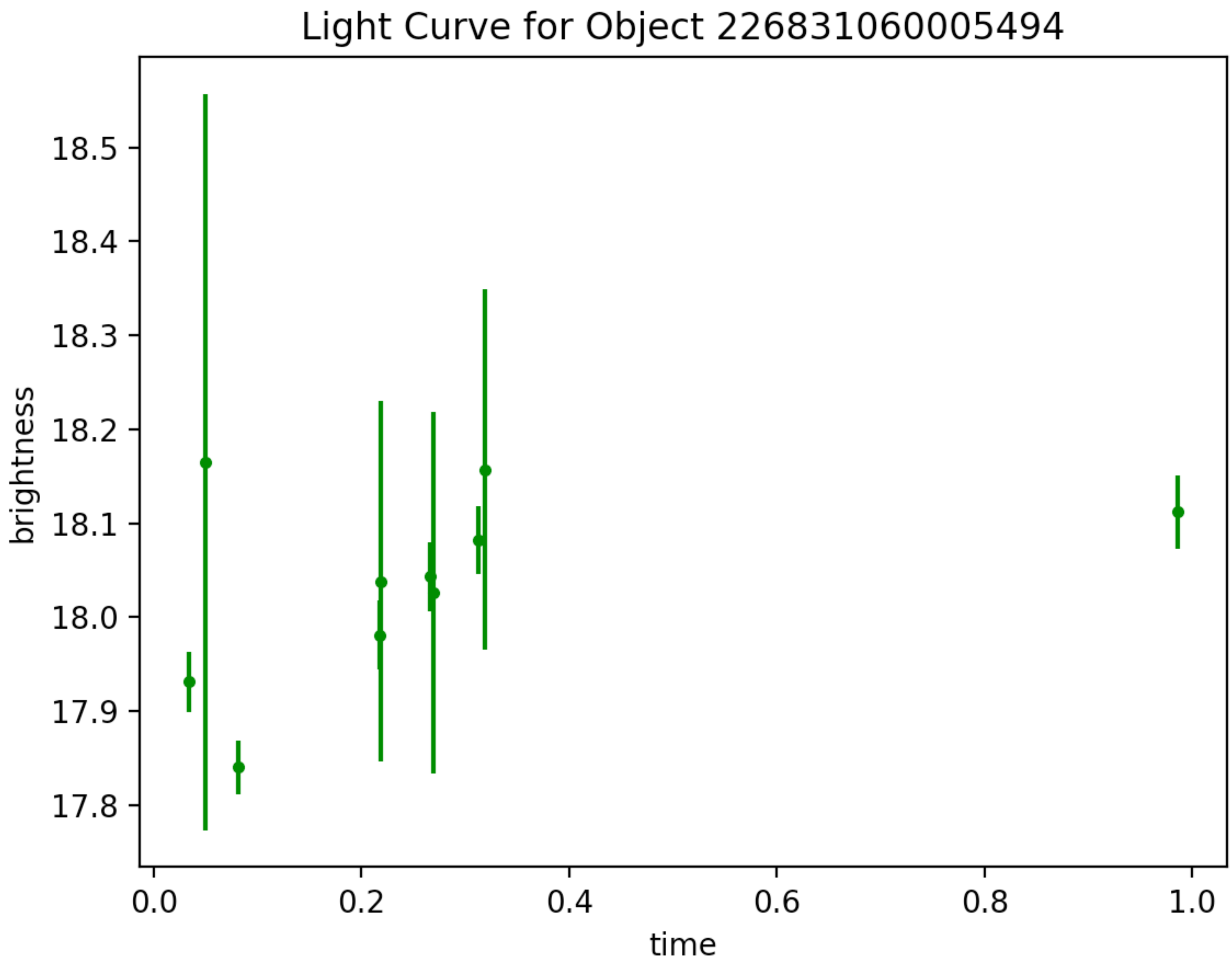


Week 3:

- Updated light curve software further…
  - Instead of loading the IRSA data in a dot .tbl file to use with cesium to obtain the period (for phase-folding) and also loading the IRSA data as a .txt file where I copy and pasted just the data, I updated the code so that it only loads the data once (just as a .tbl file)
  - Loaded the data using the cone feature search and did radius = 5 arcseconds (what I thought we had done before b/c -> 3 oid’s, whereas using the standard 10 arcsec -> 6 oid’s and light curves)
    - But the three light curves look different?
      - Will come back to this

Week 3:

Star 2 Round 2



****There should not be more than one observation?****

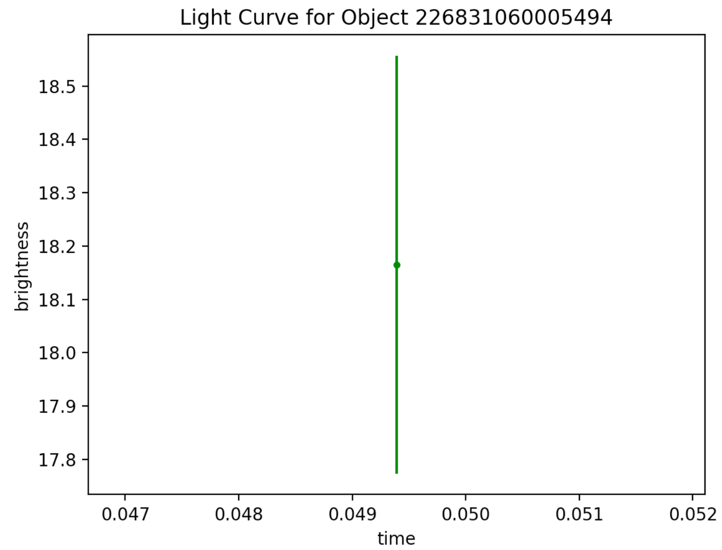
Week 3:

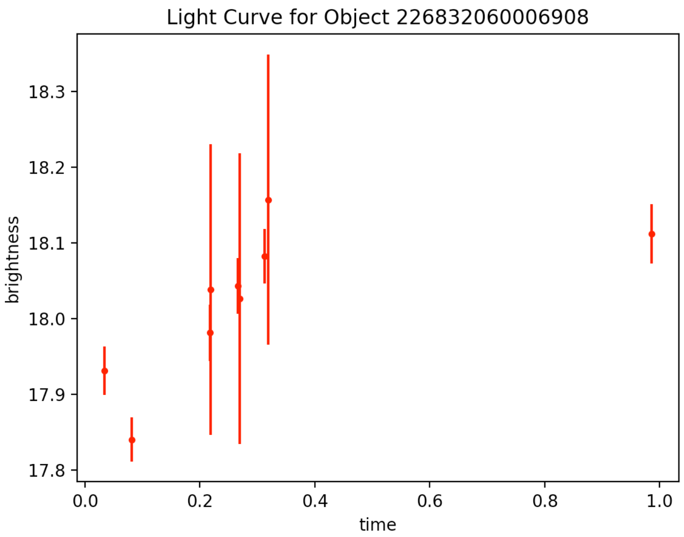
→ Went back to editing the light curve software → reworked using strongest coding practices I know → one while loop that produces phase-folded light curves for any number of oid's, i.e. however many there happen to be for the star we are working with (while loop instead of for loop precisely because number of oid's is not fixed

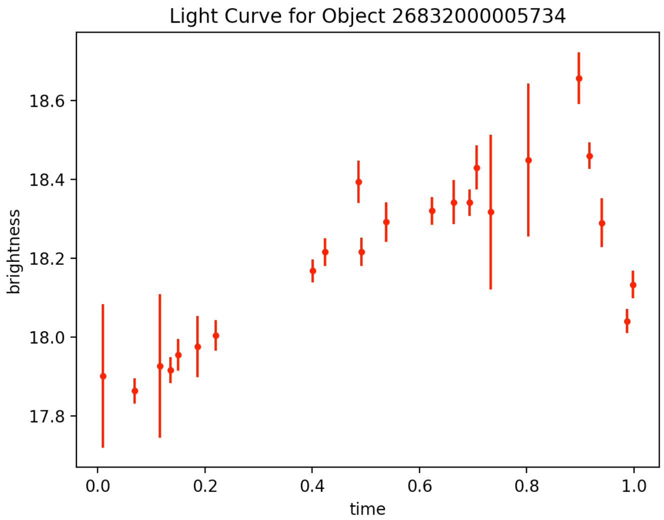
Week 3:

→ debugging → more debugging

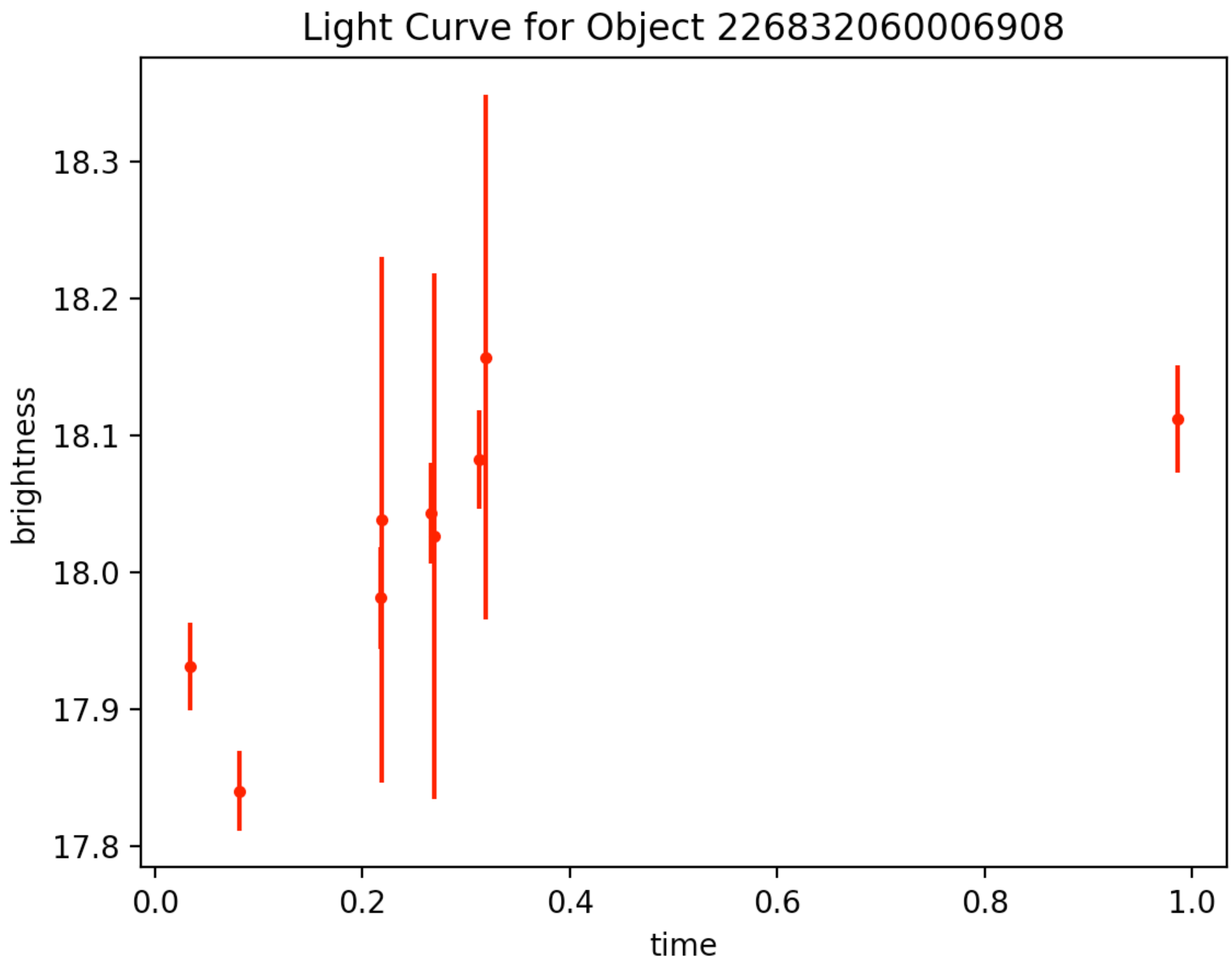
Then one fine morning ---





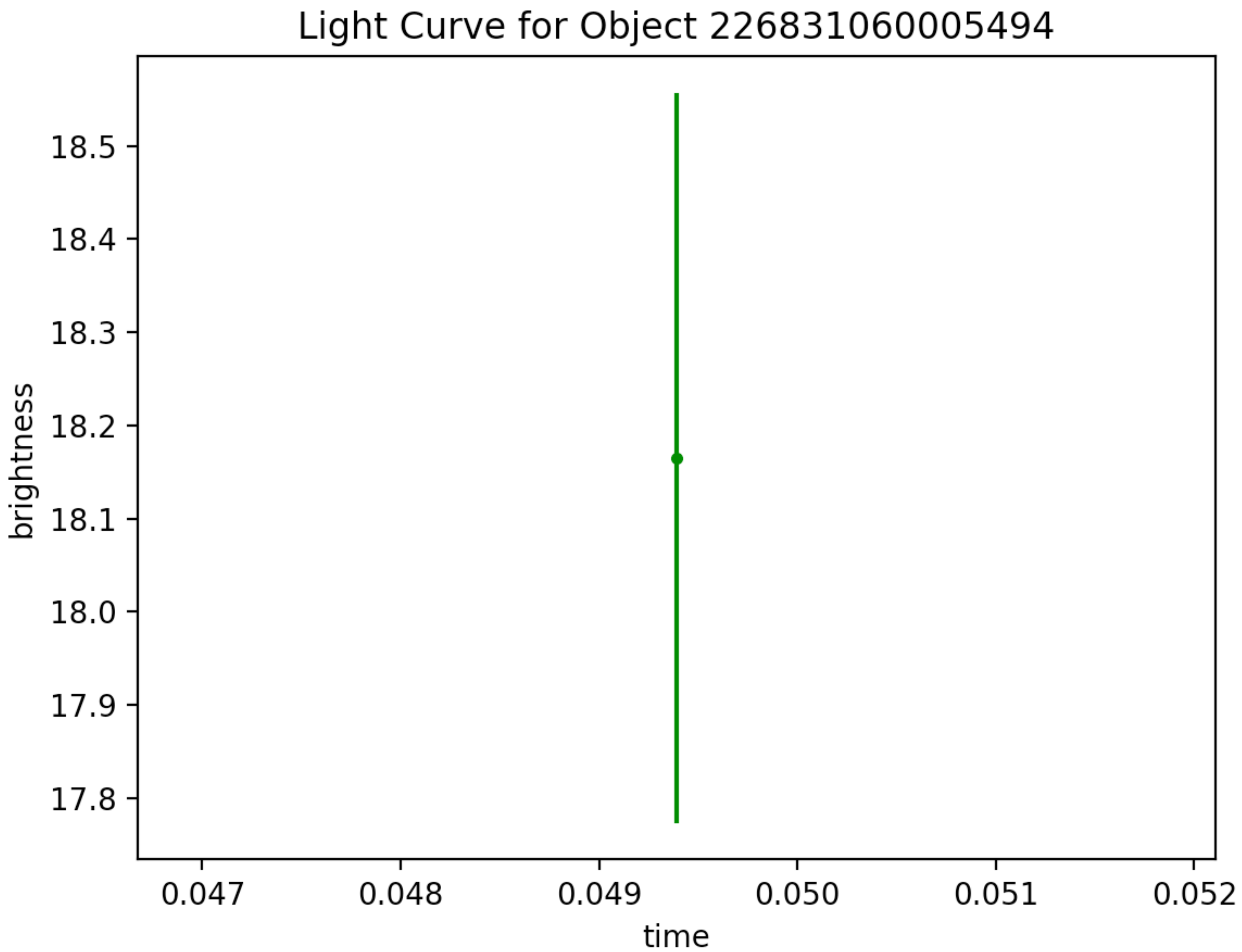


Week 3:



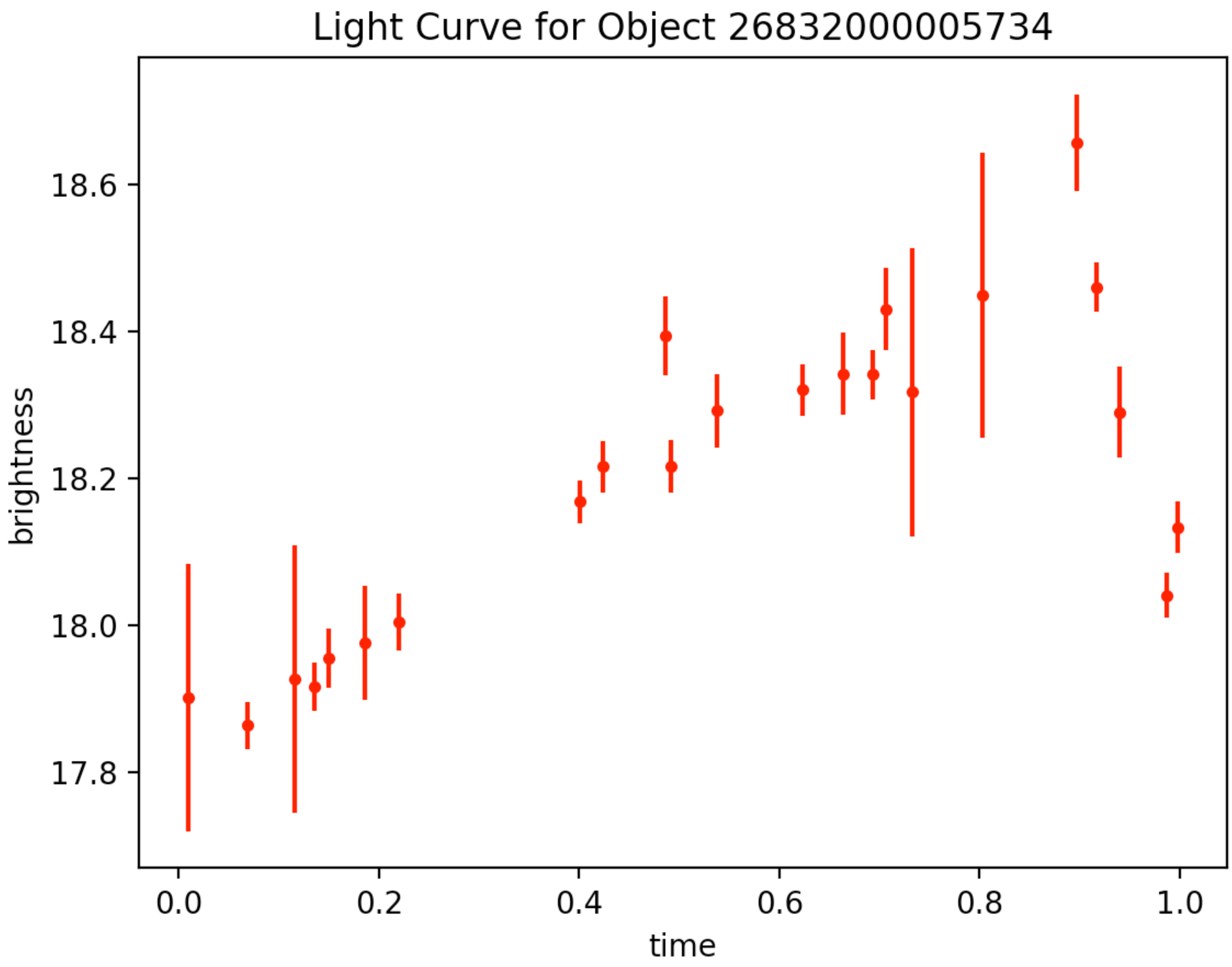
Light Curve for Object 226832060006908
brightness
18.3
18.2
18.1
18.0
17.9
17.8
0.0
0.2
0.4
0.6
0.8
1.0
time

Week 3:



Light Curve for Object 226831060005494
brightness
18.5
18.4
18.3
18.2
18.1
18.0
17.9
17.8
0.047
0.048
0.049
0.050
0.051
0.052
time

Week 3:


Light Curve for Object 268320000005734
brightness
18.6
18.4
18.2
18.0
17.8
time
0.0
0.2
0.4
0.6
0.8
1.0

Week 3:

Verification of correctness

(print statements are powerful!)

- (NUREU17) Tanners-MBP:code tannerleighton$ python3 lightCurve.py
- Enter .tbl filename: star2.tbl
- feature freq1_freq
- channel 0
- 0 1.594401
- Enter the frequency: 1.594401
- oid: 226832060006908
- 18.026
- 18.038
- 17.931
- 18.112
- 17.981
- 17.84
- 18.082
- 18.157
- 18.043
- oid: 226831060005494
- 18.165
- oid: 26832000005734
- 17.976
- 18.342
- 18.43
- 18.656
- 18.29
- 18.168
- 17.917
- 18.394
- 18.292
- 18.341
- 18.32
- 18.216
- 18.216
- 17.955
- 18.004
- 17.902
- 17.927
- 18.041
- 18.46
- 18.449
- 18.317
- 18.133
- 17.864

mag_autocorr (mag)	magerr_auto (mag)	oid
18.026	0.192	226832060006908
18.038	0.192	226832060006908
17.931	0.032	226832060006908
18.112	0.039	226832060006908
17.981	0.037	226832060006908
17.840	0.029	226832060006908
18.082	0.036	226832060006908
18.157	0.192	226832060006908
18.043	0.037	226832060006908
18.165	0.392	226831060005494
17.976	0.078	26832000005734
18.342	0.056	26832000005734
18.430	0.056	26832000005734
18.656	0.066	26832000005734
18.290	0.062	26832000005734
18.168	0.029	26832000005734

Screenshot of Caltech IRSA table reveals perfect match for star 2!

Week 3:

- 2nd star known RR Lyrae
  - Period is approximately 0.6 days (known)
  - Did I get this? Yes. Got 0.627 using cesium.

Week 3:

Recommendation for Next step

- -> Matching light curves with types and understanding why various variable stars have the light curves that they do
  - Did research on pulsating variable stars (ch. 6 in Understanding Variable Stars and Google)
- Can plot phased-folded light curves for others stars (plotting more stars -> training set)

Week 3:

- In approaching next step, decided to go ahead and produce more phase-folded light curves.
  - bestChiSQ > 100 and nbestobs > 100 results
  - But…

Was unable to generate PTF light curve data table. I tried increasing the radius from 10 to 20 arcseconds then to 30 arcseconds, but still -> "no sources found"

Also tried the box search….

Confused as I was able to get a table of data for this before…

ra (degrees)	dec (degrees)	oid
291.3357640	45.5357760	46572060016052
291.3214130	45.2865570	46572060009302
291.2950440	45.3245710	46572060010416
291.6238810	45.4078980	46572060012596
291.5652660	45.5394100	46572060015890
291.4838910	45.4171650	46572060012923
291.5288120	45.1965170	46572060006845
290.5968200	46.3058500	46562050004847
290.9010910	46.1357600	46562050001391
290.8111950	46.1450470	46562050001569
290.6892240	46.1892020	46562050002381
290.7686110	46.2176340	46562050003047
290.7230300	46.1973900	46562050002653
290.7816770	46.1222950	46562050000990
290.7832590	46.1893310	46562050002480
290.7481460	46.1787460	46562050002193

Object/Coordinate	Source	Type	Glon	Glat	Equatorial J2000
291.3214130 -45.2865570	Coordinate		352.86832	-24.59348	19h 25m 17.14s -45d 17m 11.6s

Cone Search   Constraints: No   **No sources are found.**

Week 3:

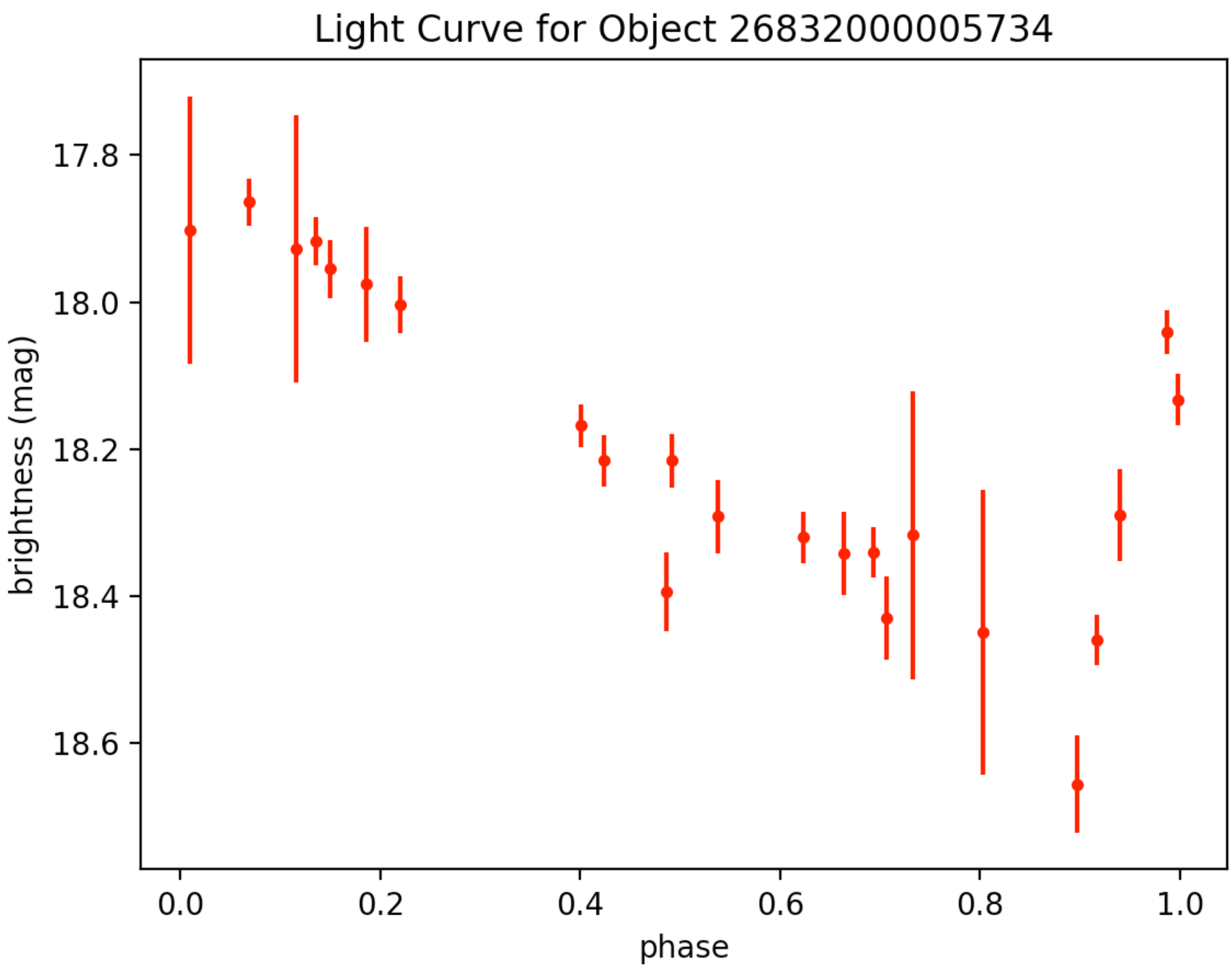
Recommendation for (future) next steps

- goal of this project: develop list of thousands of stars where we know their classifications (-> training set)
- My initial idea: using a variable star's position on H-R diagram along with its light curve -> more success in classifying
- Although we do not at this time have sufficient information ot place on H-R diagram, we do have magnitude and color (though both are variable at some level). So we could make a color-magnitude diagram. The issue is that we don't have distance or redenning or metallicity information. So there's no easy way to precisely compare one star to another.
- →GAIA: survey using parallax to measure distances will be done in the next year => something should keep in mind and may be able to incorporate down the road!

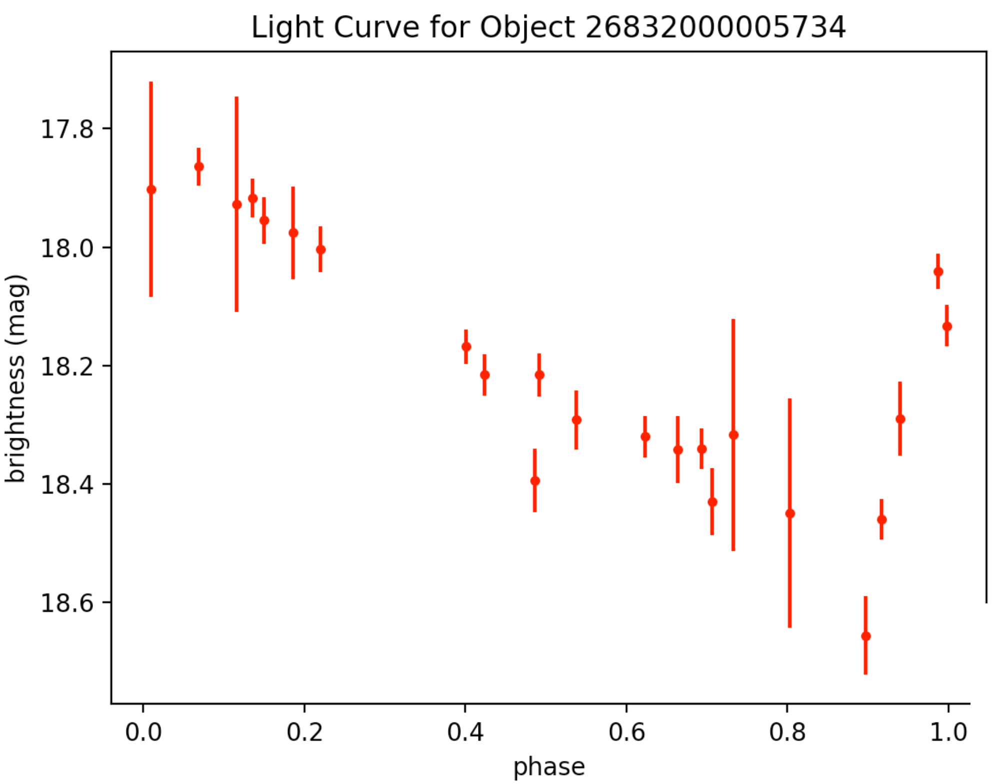
Monday, July 10, 2017

Week 3:

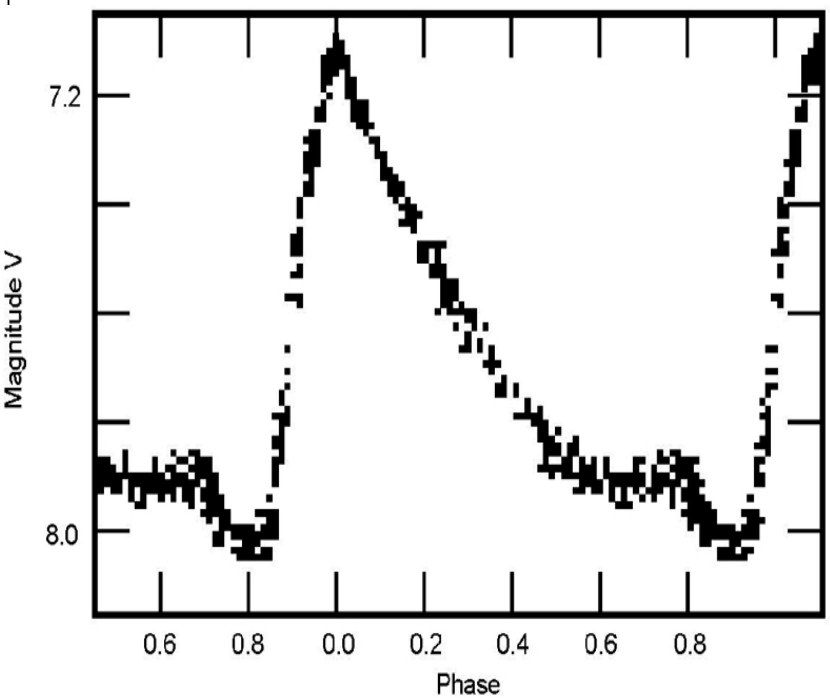
Re-plotting star 2 (RR Lyrae) with proper axes



Week 3:



RR Lyrae

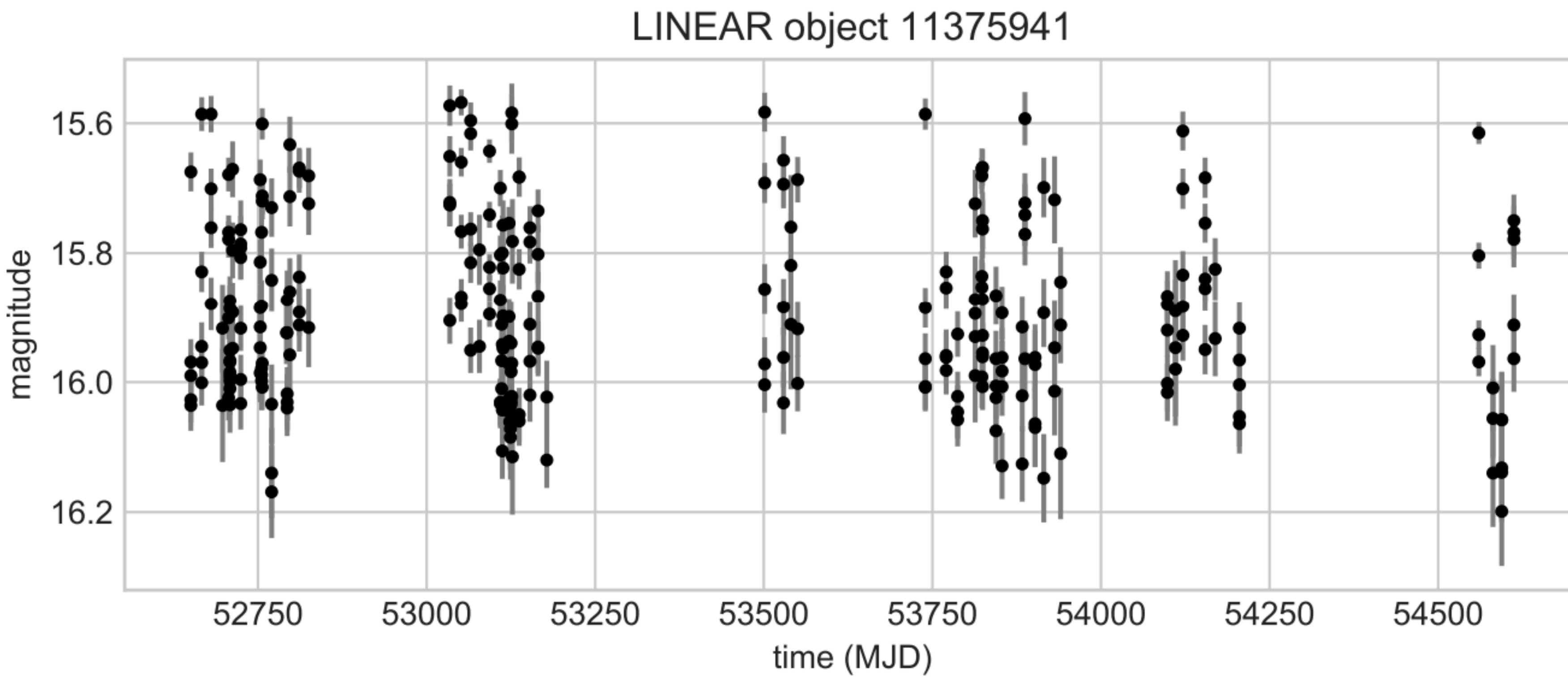


Comparing ‘experimental’ to ‘theoretical’

Week 3:

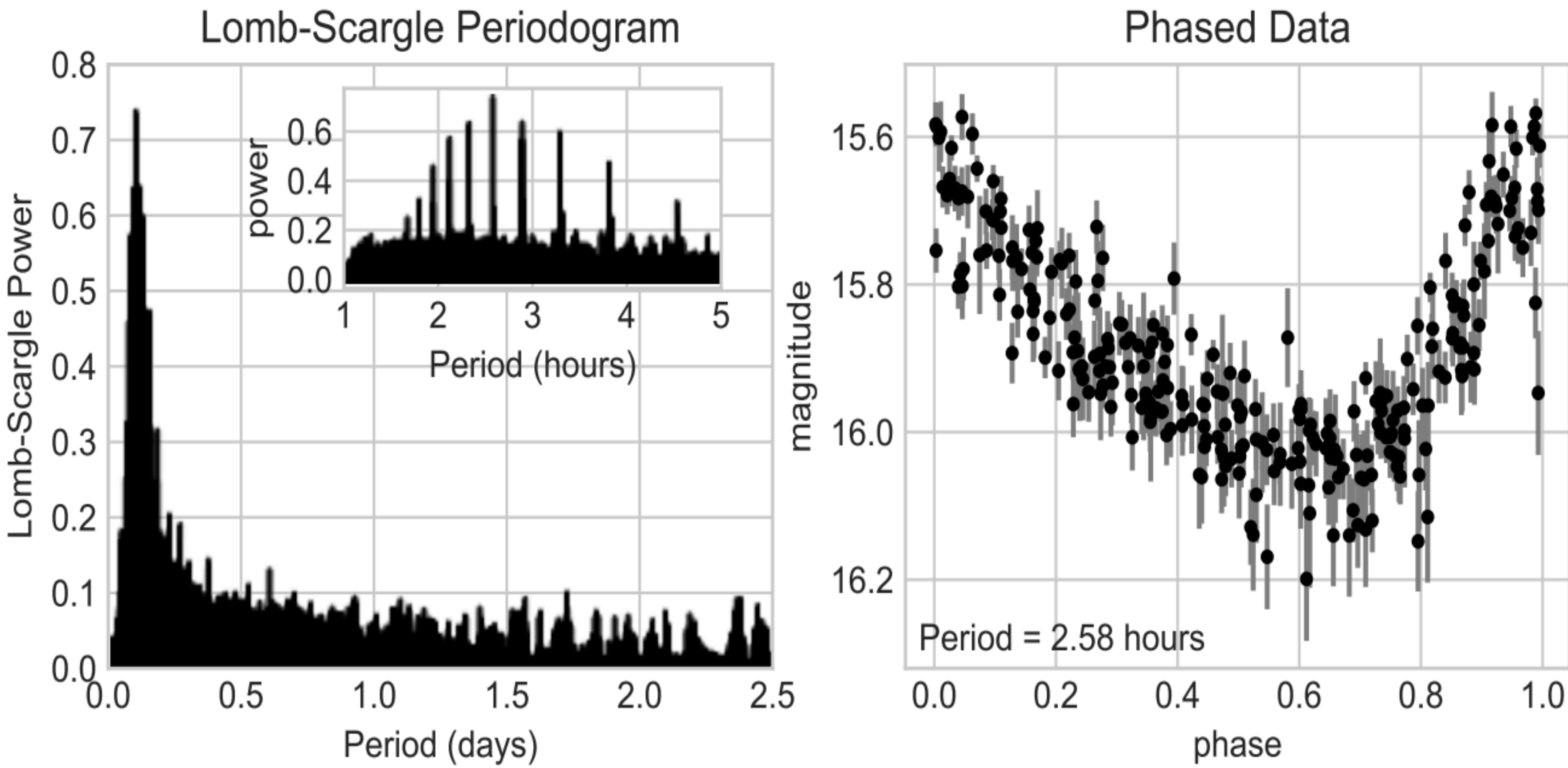
Lomb-Scargle Paper (VanderPlas)

- The Lomb-Scargle periodogram is a well-known algorithm for detecting and characterizing periodic signals in unevenly-sampled data.



------------------------> (see next slide)

Week 3:



Lomb-Scargle Periodogram
Lomb-Scargle Power
Period (days)
power
Period (hours)
Phased Data
magnitude
phase
Period = 2.58 hours

Week 3:

Back to the software…

```python
times = dataTable["obsmjd"]
values = dataTable["mag_autocorr"]
errors = dataTable["magerr_auto"]
oids = dataTable["oid"]
fids = dataTable["fid"]

length = len(oids)
oidsArray = np.empty(length)

for i in range(length):
    oidsArray[i] = oids[i]

oidsArraySorted = np.sort(oidsArray)

# good! now use oidsArraySorted instead of oids going forward...

fmtToBeUsed = 'ro'

# Let's make a variable called index (to represent the index of a list) and set it equal to 0.
index = 0
swapVar = 0
tempOID = 0
newOID = oidsArraySorted[index]

"""
for i in range(length):
    print("oidsArraySorted[{}]: {}".format(i, oidsArraySorted[i]))
"""

while newOID != tempOID: # while loop because number of unique OID's is not fixed
```

Week 3:

Updates to software

- Improved further
  - Not plotting for all oids (went back and got ride of lists)
  - Not plotting for all of them and no errors (and code is robust :)
  - What if the oids are not grouped? -> np.where
  - Put the object id's in order so doesn't make same light curve mulitple times
- Future improvements
  - improve light curve for object 1232.0 (get rid of .0)
  - for lyrae9.tbl plotting two extra plots that I don't see in the table on IRSA?
  - downloaded it again with 1 arc sec and did not get desired result

Week 3:

RRL ab, c, d

- Cepheid stars and RR Lyrae stars are variable because they pulsate in and out
- Variable stars of RR Lyrae type are a prime tool to obtain distances to old stellar populations in the Milky Way, and one of the main aims of the Vista Variables in the Via Lactea (VVV) near-infrared survey is to use them to map the structure of the Galactic Bulge. **Due to the large number of expected sources, this requires an automated mechanism for selecting RR Lyrae, and particularly those of the more easily recognized type ab (i.e., fundamental-mode pulsators)**, from the 10^6-10^7 variables expected in the VVV survey area. In this work we describe a supervised machine-learned classifier constructed for assigning a score to a K_s-band VVV light curve that indicates its likelihood of being ab-type RR Lyrae.
- => RRL ab (fundamental-mode pulsators) -> c, and d pulsating in non-fundamental modes (and different modes from each other <=> otherwise they wouldn't be different categories of c and d)
- RR Lyrae stars pulsating in the fundamental mode have long been used to measure interstellar reddening (what is that?), based on their observed uniformity of B−V color at minimum light after small corrections for metallicity and period are applied. **However, little attention has been paid to the first overtone pulsators (RRc or RR1).** We present new V−I observations of field RRc stars, supplemented with published data from uncrowded RRc in globular clusters. Preliminary results indicate the RRc colors are correlated with period, but appear to be independent of the stars' metallicity. The scatter around the period-color relation is slightly larger than a comparable relation for RRab. Thus, RRc can be useful indicators of line of sight reddening toward old stellar systems, particularly when multiple stars are available as in Oosterhoff II globular clusters and metal-poor galaxies.
- => RRL type c (first overtone pulsators) => RRL d (second overtone?)
- so we need to decide if we want to differentiate between the various RR Lyrae types on zooniverse or if we want to just group them as one
- does being different mode of pulsating -> different period and light curve? (It has to if we do want to differentiate them)

Week 3:

RR Lyrae

- Period: 0.1 – 1 day
- Going after 3 golden examples and 3 average examples for zooniverse project
- Will find the following at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes
  - Then change preference to ascii text/plain and hit submit

  Came from here:

  http://adsabs.harvard.edu/abs/
  2009MNRAS.398.1757W

Week 4

Week 4:

Task: Find 3 ‘golden’ and 3 ‘average’ examples for RRab and RRc

lyrae	light curve shape	'bump' (y/n)	period	type
lyrae32.tbl	asymmetric	yes	0.66	RRab?
lyrae36.tbl	asymmetric	yes	0.72	RRab?
lyrae40.tbl	asymmetric	yes	0.466	RRab?
lyrae24.tbl	asymmetric	blurry	0.63	RRab?
lyrae26.tbl	asymmetric	blurry	0.64	RRab?
lyrae19.tbl	asymmetric	blurry	0.63	RRab?
lyrae1.tbl	asymmetric	blurry	0.56	RRab?
lyrae13.tbl	asymmetric	blurry	0.63	RRab?
lyrae9.tbl	asymmetric	yes	0.59	RRab?
lyrae10.tbl	asymmetric	yes	0.47	RRab?
lyrae15.tbl	asymmetric	yes	0.66	RRab?
lyrae7.tbl	asymmetric	yes	0.58	RRab?
lyrae12.tbl	asymmetric	yes	0.48	RRab?
lyrae4.tbl	asymmetric	yes	0.47	RRab?
lyrae20.tbl	asymmetric	yes	0.48	RRab?
lyrae21.tbl	sinusoidal	no	0.34	RRc?
lyrae27.tbl	sinusoidal	no	0.38	RRc?
lyrae3.tbl	sinusoidal	no	0.38	RRc?
lyrae8.tbl	sinusoidal	no	0.32	RRc?
----------	----------	----------	----------	----------
lyrae34.tbl	sinusoidal (roughly)	no	0.31	RRc?
lyrae37.tbl	sinusoidal (roughly)	no	0.33	RRc?
lyrae39.tbl	sinusoidal (roughly)	no	0.31	RRc?
lyrae35.tbl	sinusoidal (roughly, sparse)	no	0.267	RRc?

General Findings / Take-aways / What is physically different?:

RR Lyrae periods 0.1 - 1 day (Understanding Variable Stars textbook)

asymmetric => steep up then gradual decline <==> ‘bump’ (or blurry)

sinusoidal <==> no 'bump’

sinusoidal: period between 0.32 - 0.38 days for best (i.e. most clear) plots sampled and 0.31 - 0.38 days including ‘roughly’ sinusoidal plots and 0.267 - 0.38 days including a plot that is roughly sinusoidal and whose data points are sparse.

asymmetric: period between 0.466 - 0.72 days (didn't have the same tiers of data)

extrapolating -> something like 0.30 - 0.435 days for sinusoidal & no 'bump' (i.e. RRc) whereas approximately 0.44 - 0.75 days for asymmetric & 'bump’ (i.e. RRab)

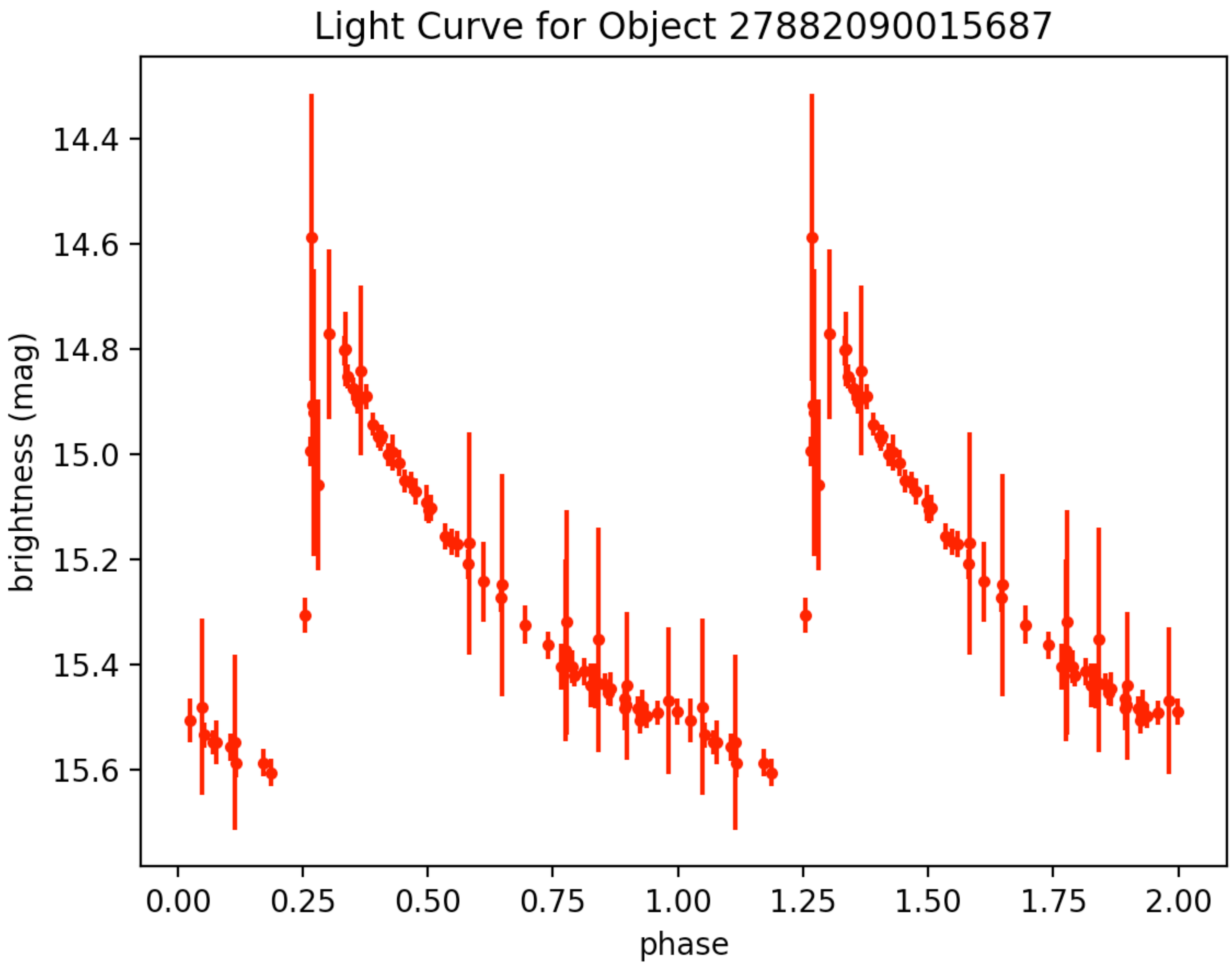
=>? RRd could have period like 0.1 - 0.25 days and/or 0.75 - 1 day (how do frequencies add like $f = f_1 + f_2$ or reciprocals?)

Another possibility is that RRd is distinguished by light curve character

Consistent with: http://iopscience.iop.org/article/10.1086/300883/fulltext/ => “With the discovery of new RR Lyrae variables, the mean periods of the RRab and RRc variables are $\langle P_{ab} \rangle = 0.685 \pm 0.022$ days and $\langle P_c \rangle = 0.333 \pm 0.013$ days, respectively.”

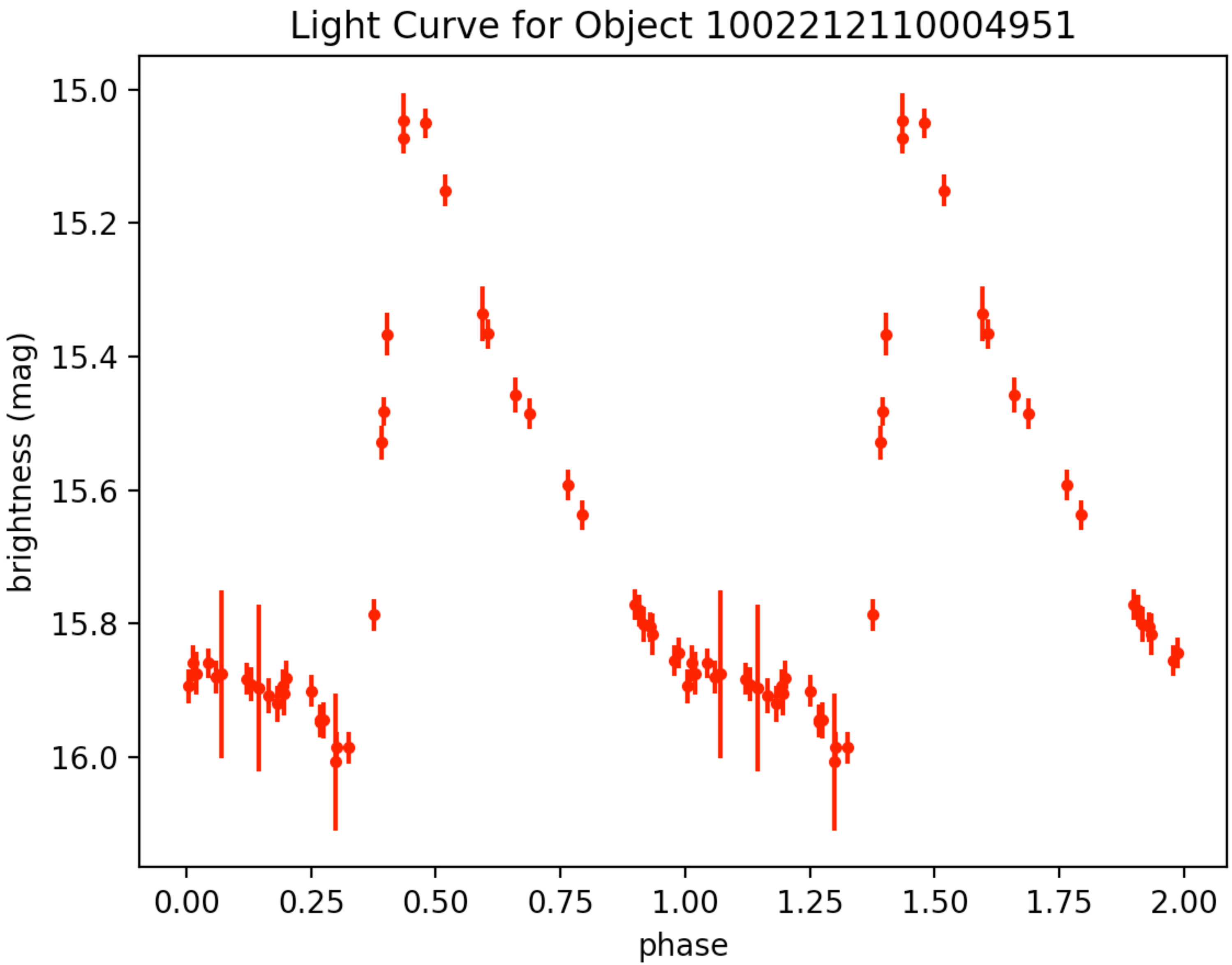
Week 4:

lyrae32.tbl – 20 56 40.2 +01 02 44 – period: 0.6633169162396564 – RRab Golden 1 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



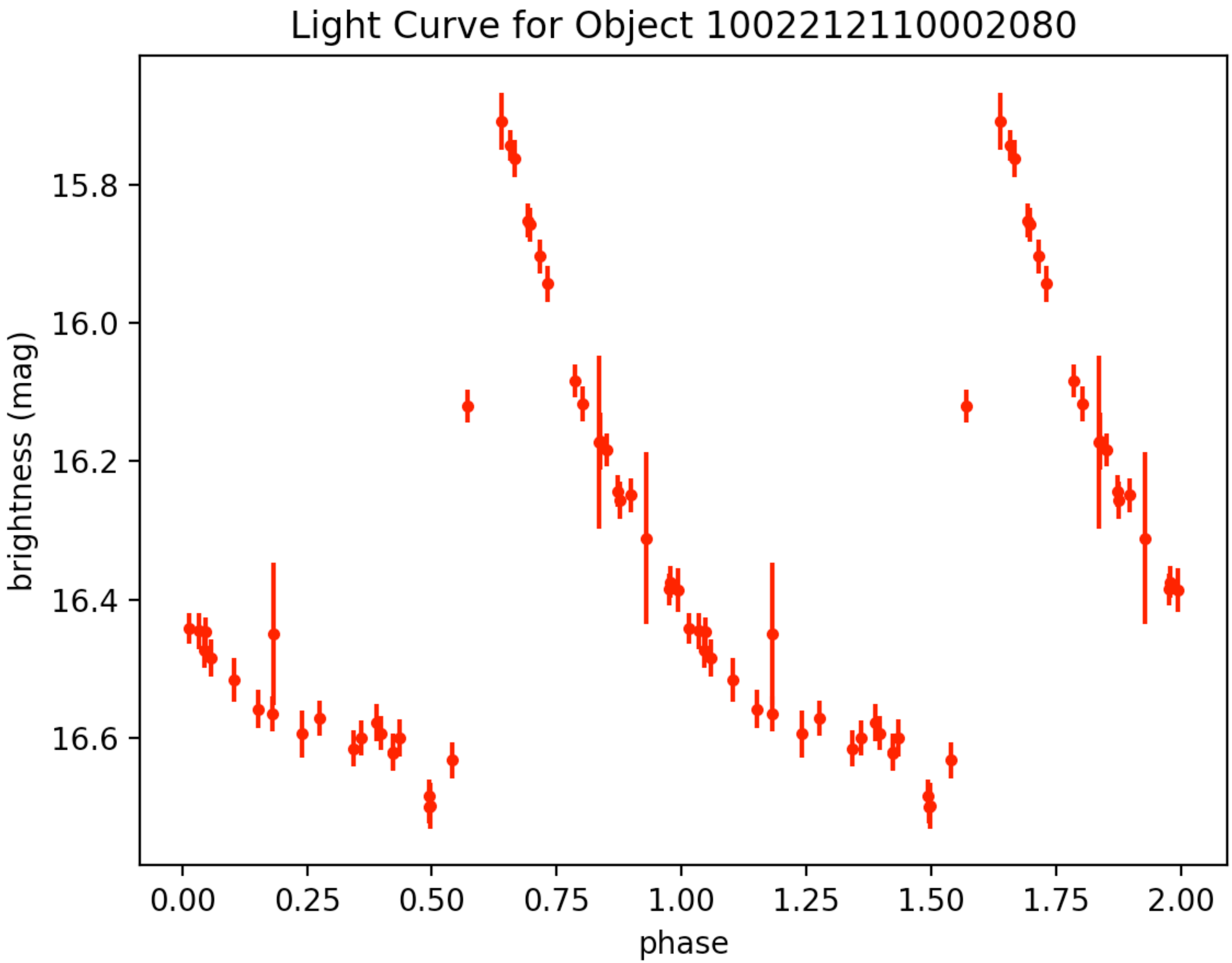
Week 4:

lyrae9.tbl – 20 48 14.9 +00 07 05 – period: 0.5851614753091116 – RRab Golden 2 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

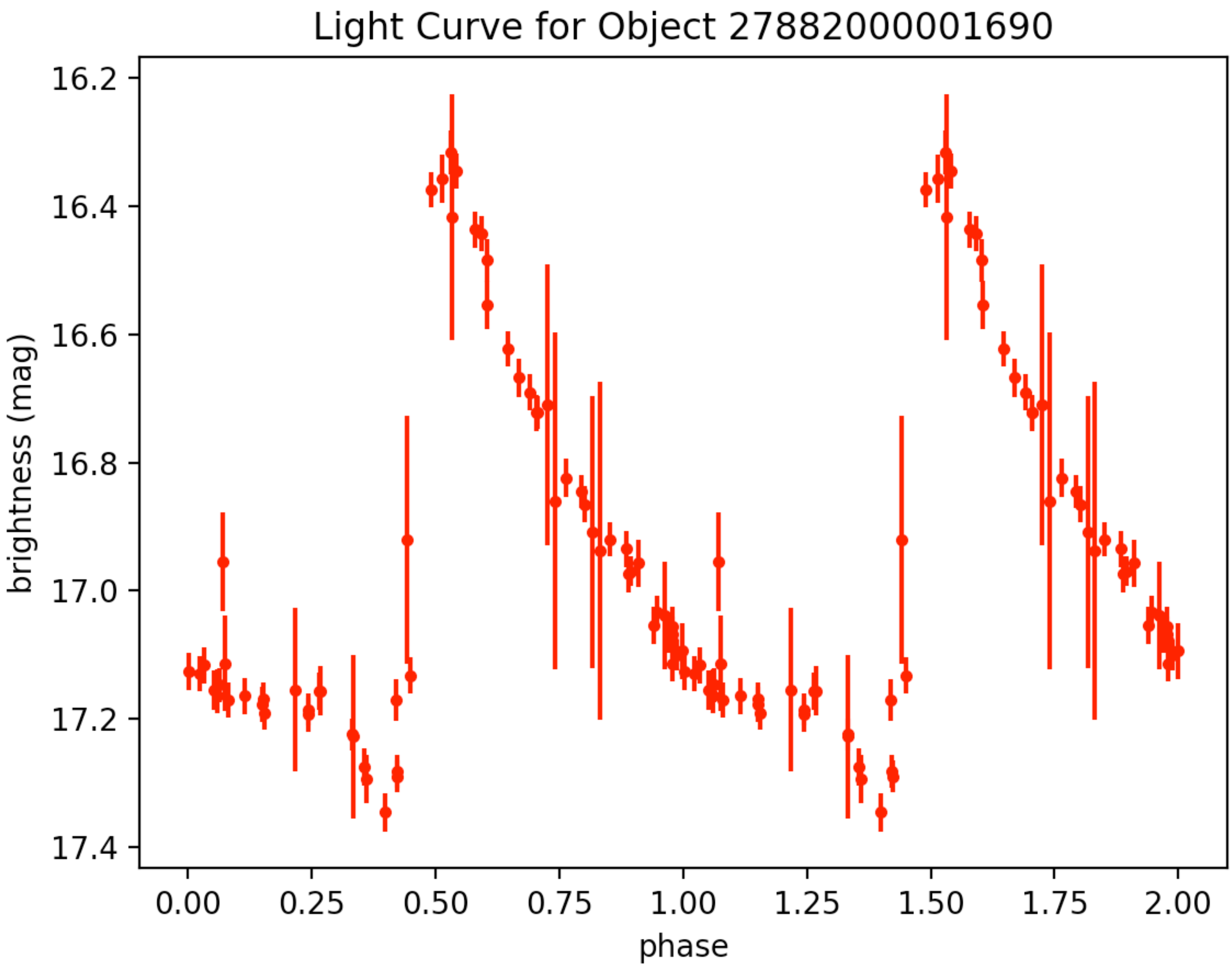


Week 4:

lyrae10.tbl – 20 48 30.5 -00 04 26 – period: 0.4700500556304241 – RRab Golden 3 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

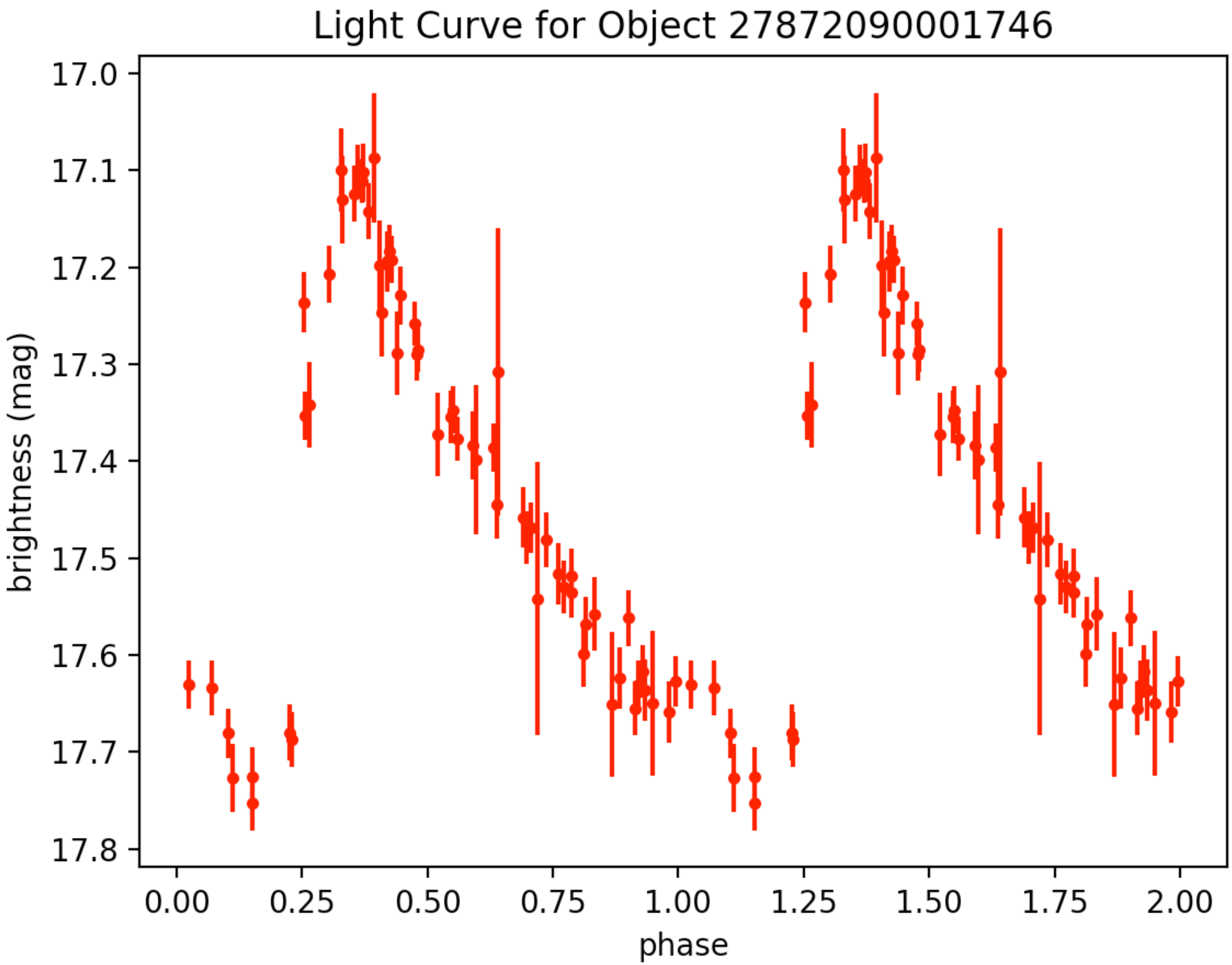


Week 4: lyrae20.tbl – 20 50 01.9 +01 12 50 – period: 0.47739464735573495 – RRab Average 1 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



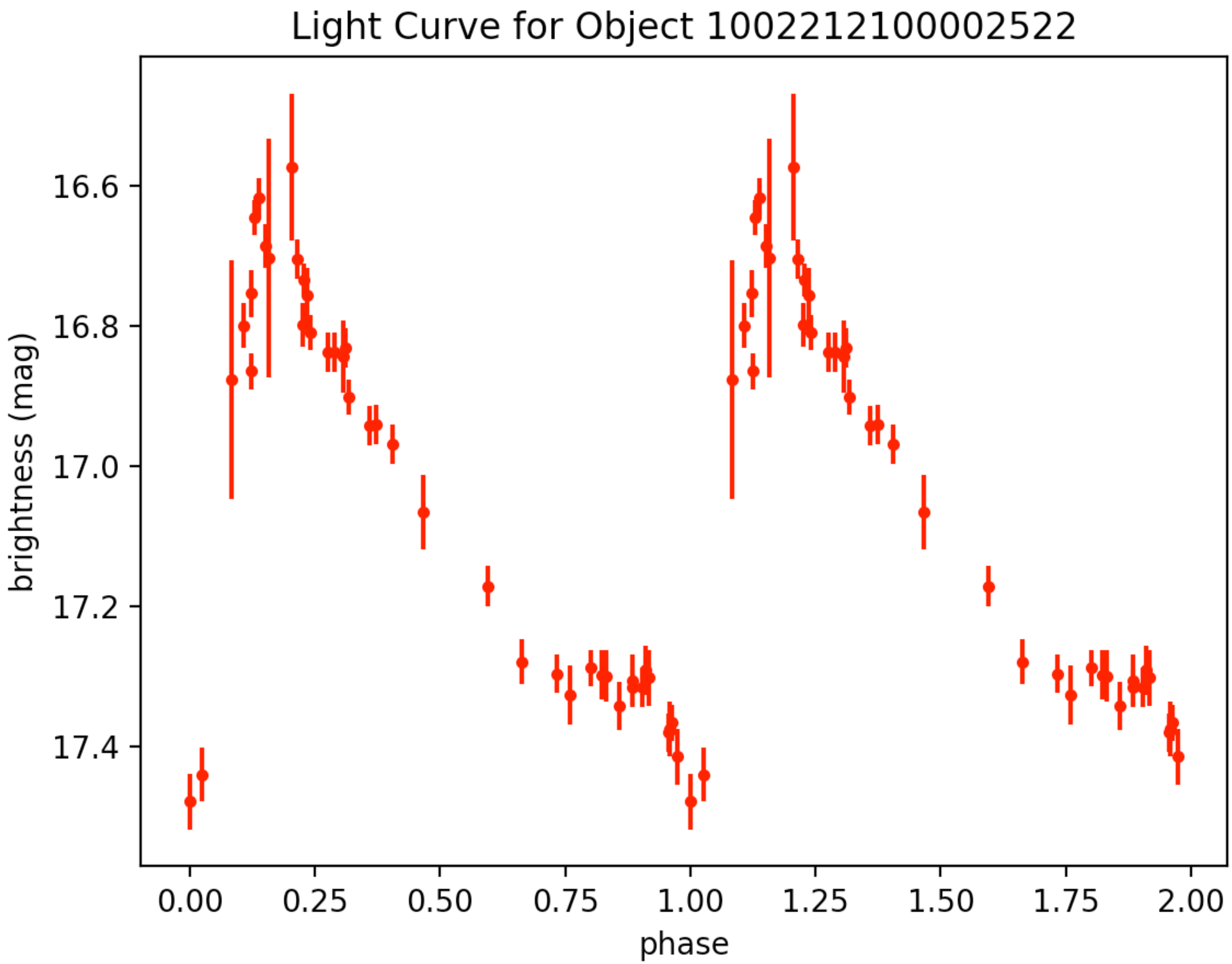
Week 4:

lyrae1.tbl - 20:42:47.8 00:03:52 – period: 0.561844783636383 – RRab Average 2 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



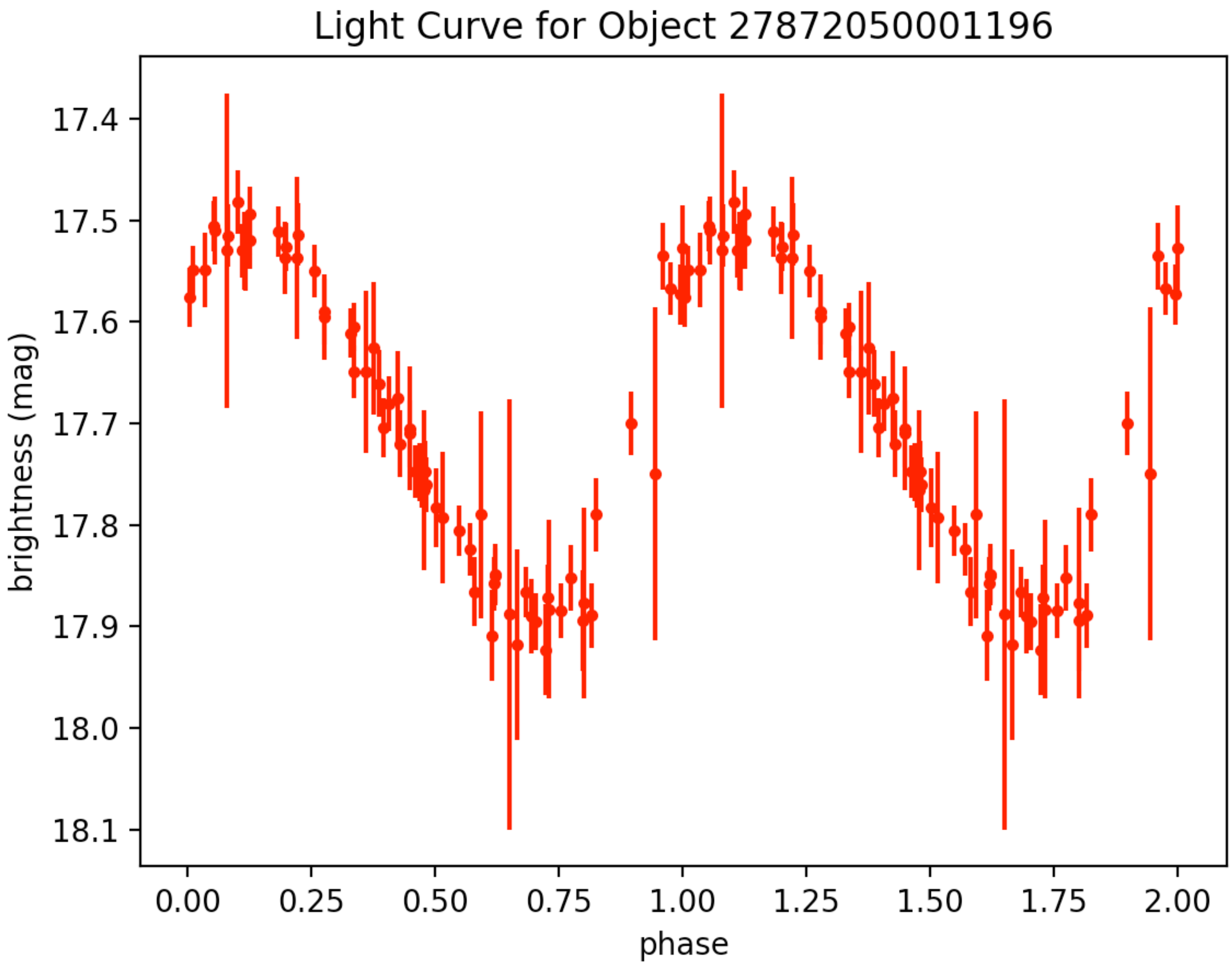
Week 4:

lyrae7.tbl – 20 46 11.2 -00 02 33 – period: 0.5821477409465838 – RRab Average 3 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



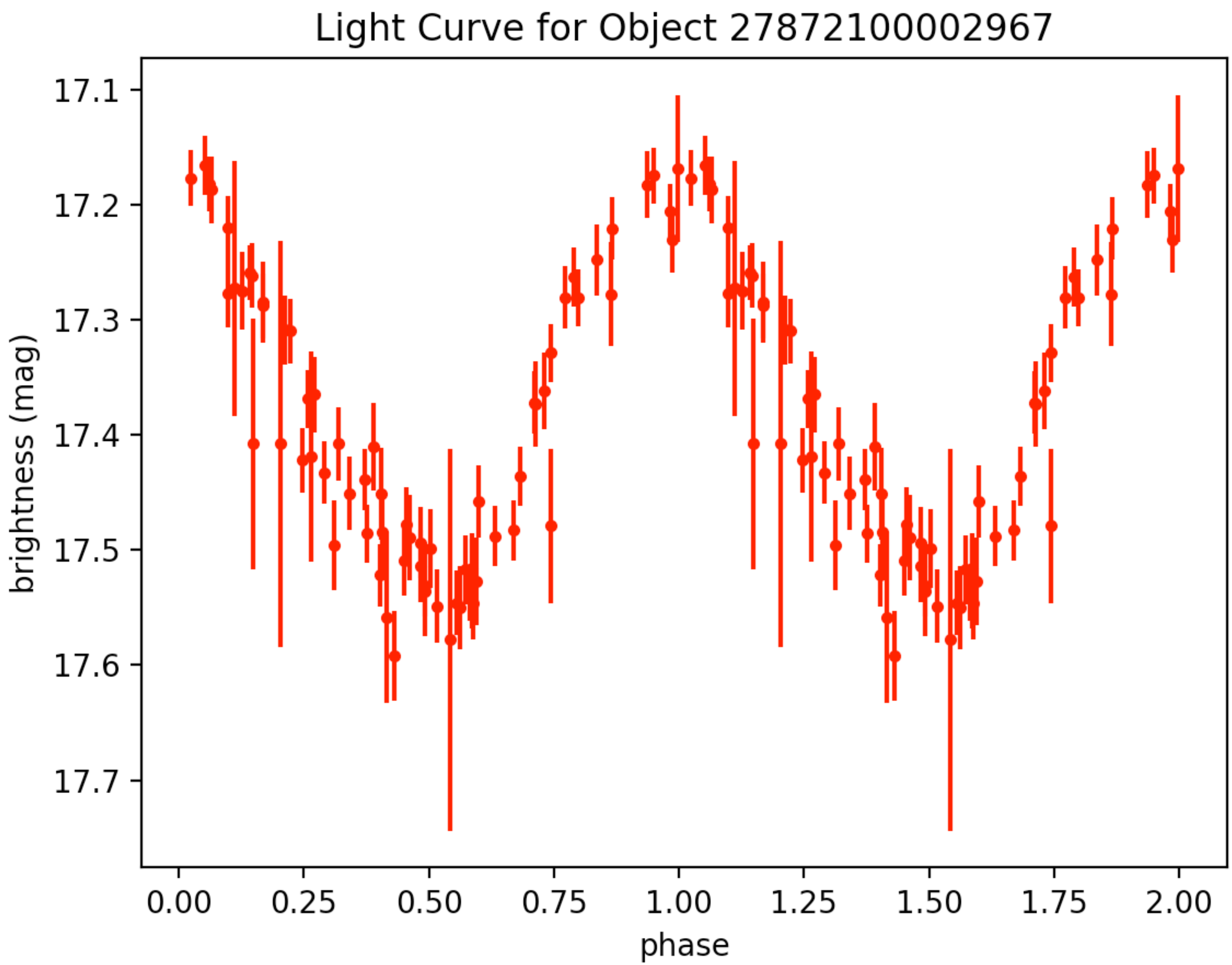
Week 4:

lyrae8.tbl – 20 46 24.8 +01 11 55 – period: 0.32499810688602737 – RRc Golden 1 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



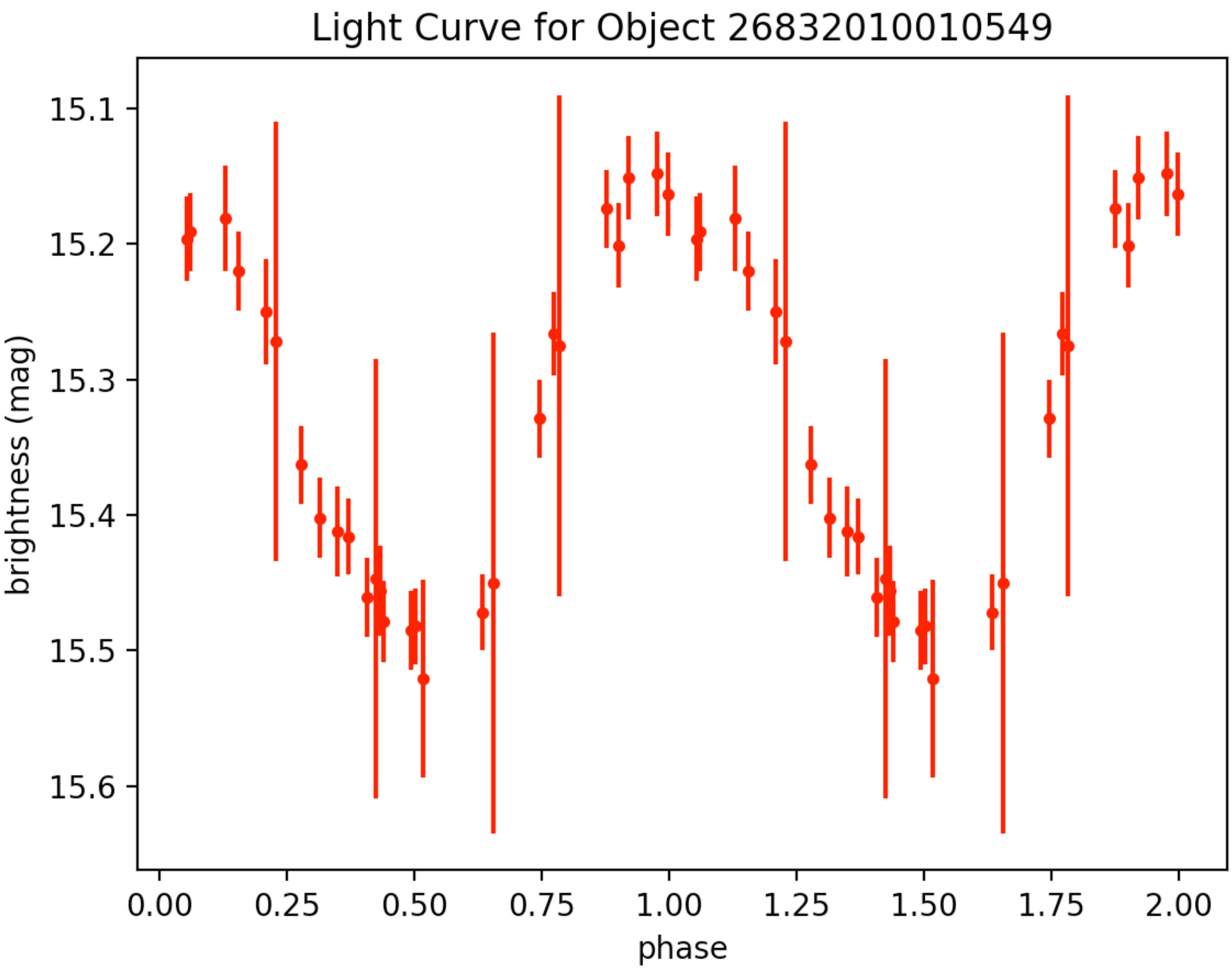
Week 4:

lyrae3.tbl – 20 44 50.9 +00 11 20 – period: 0.37561549293711405 – RRc Golden 2 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



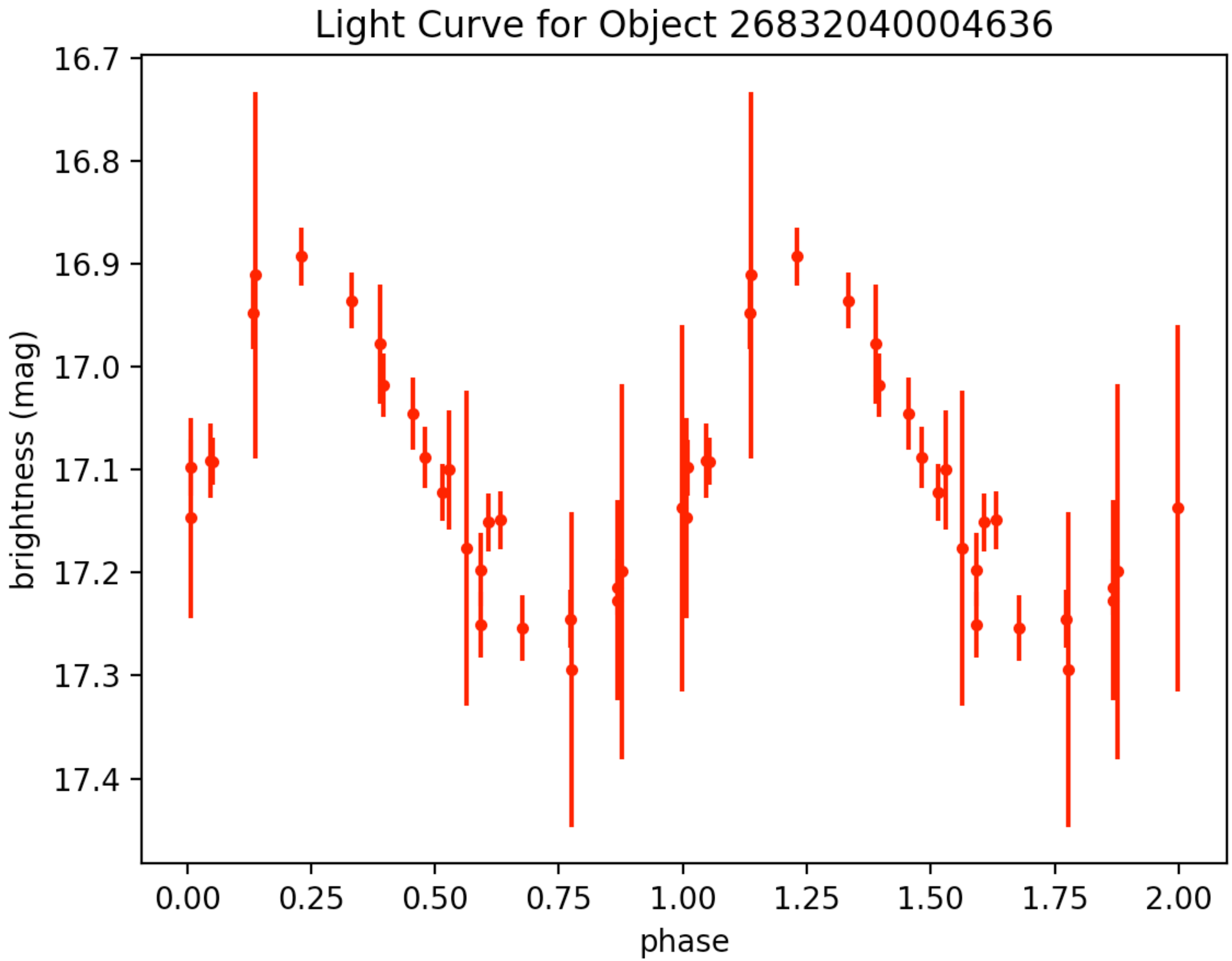
Week 4:

lyrae21.tbl – 20 50 15.7 -00 08 52 – period: 0.3401154623971746 – RRc Golden 3 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

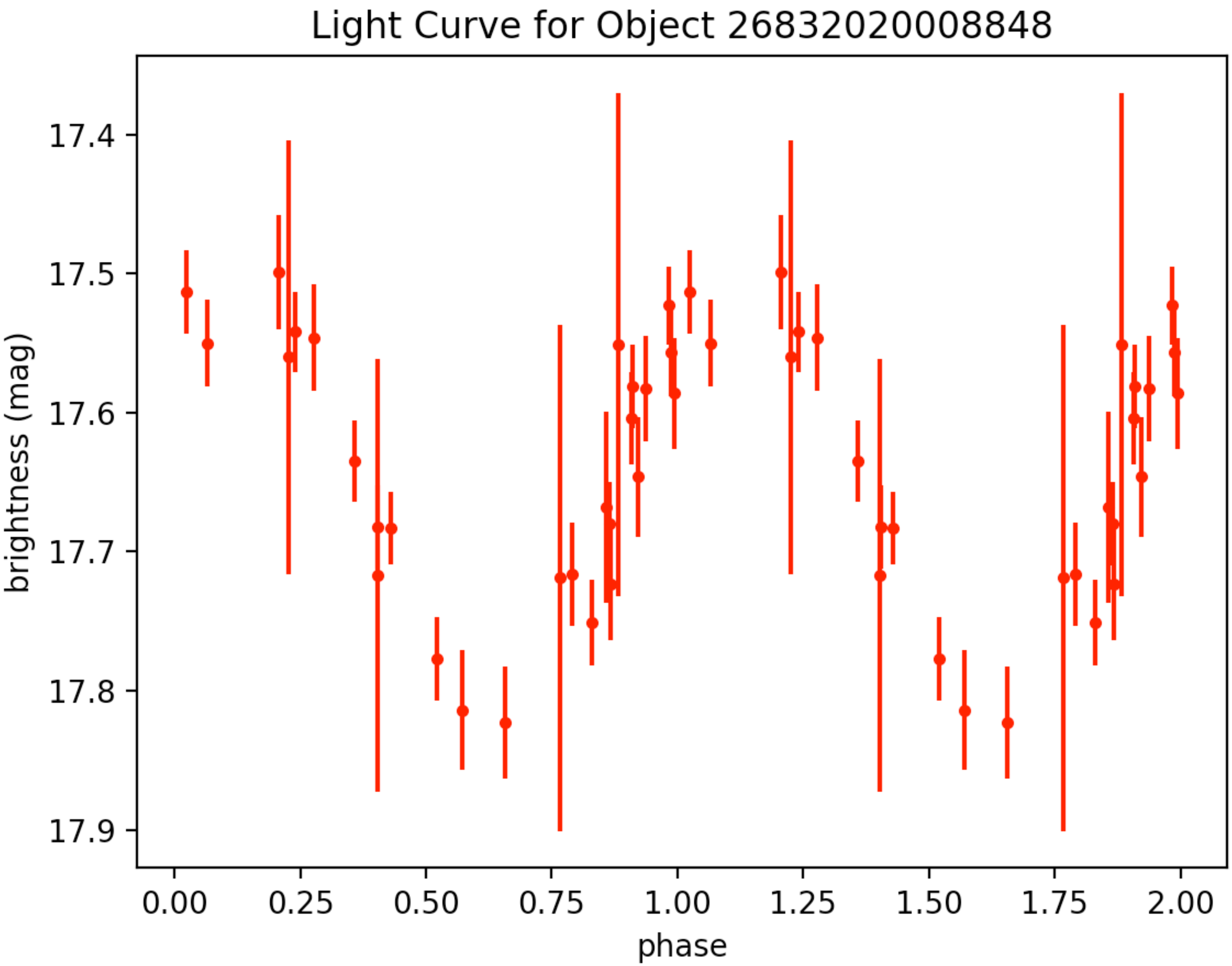


Week 4:

lyrae34.tbl – 20 57 43.8 -00 44 50 – period: 0.3132667202979292 – RRc Average 1 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

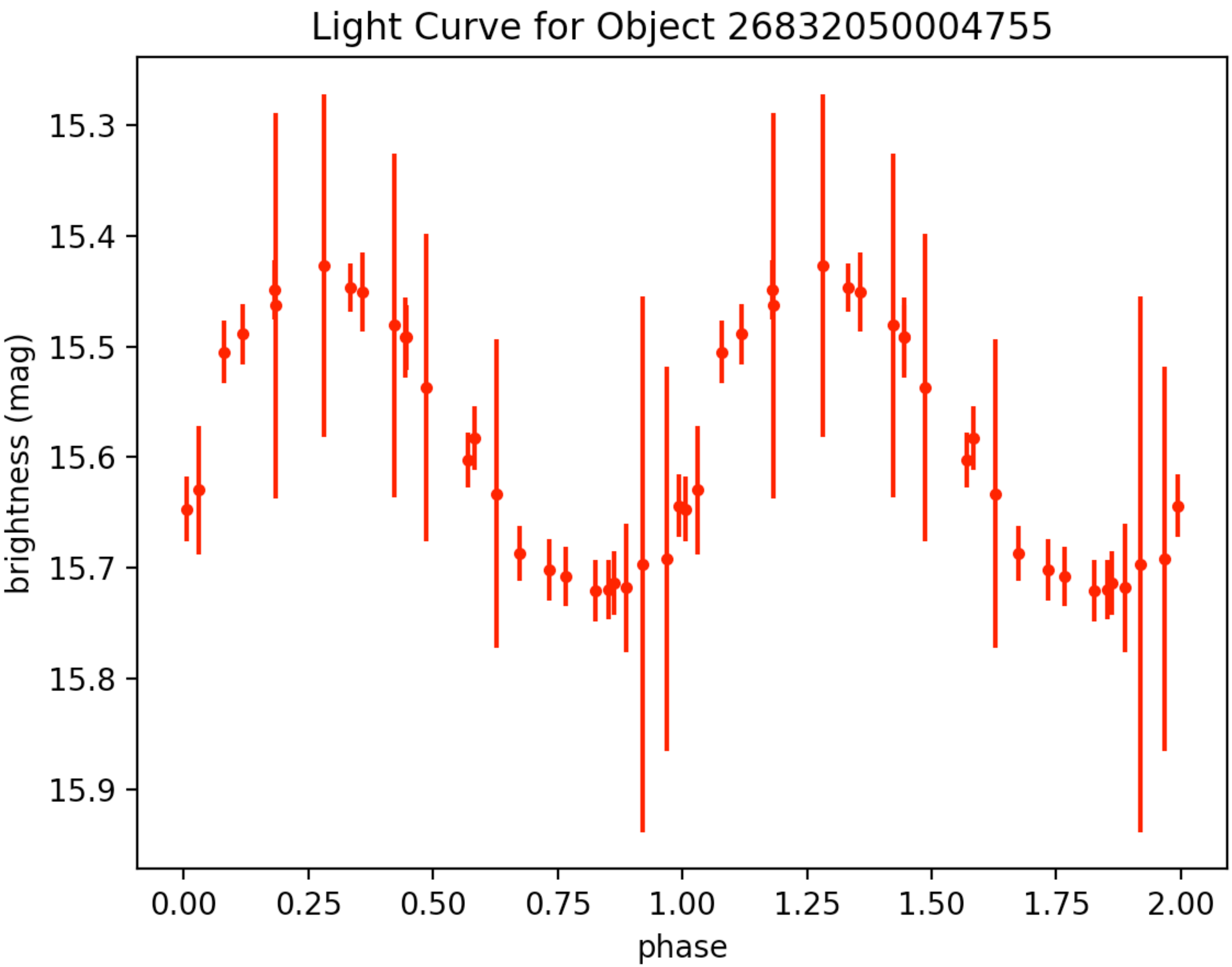


Week 4: lyrae27.tbl – 20 53 21.3 -00 20 50 – period: 0.3763623375714241 – RRc Average 2 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



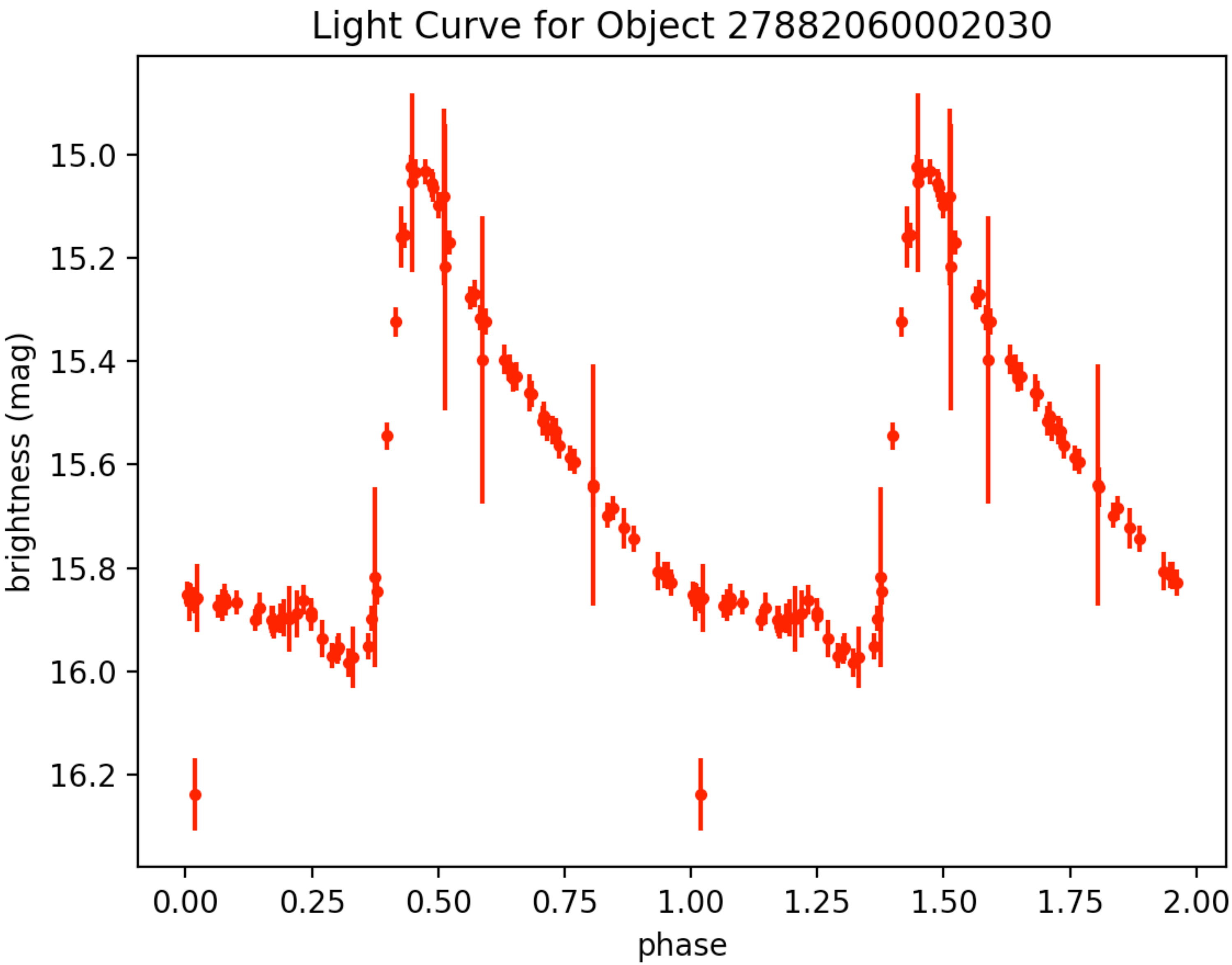
Week 4:

lyrae39.tbl – 20 59 55.2 -00 42 44 – period: 0.31028610861503175 – RRc Average 3 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

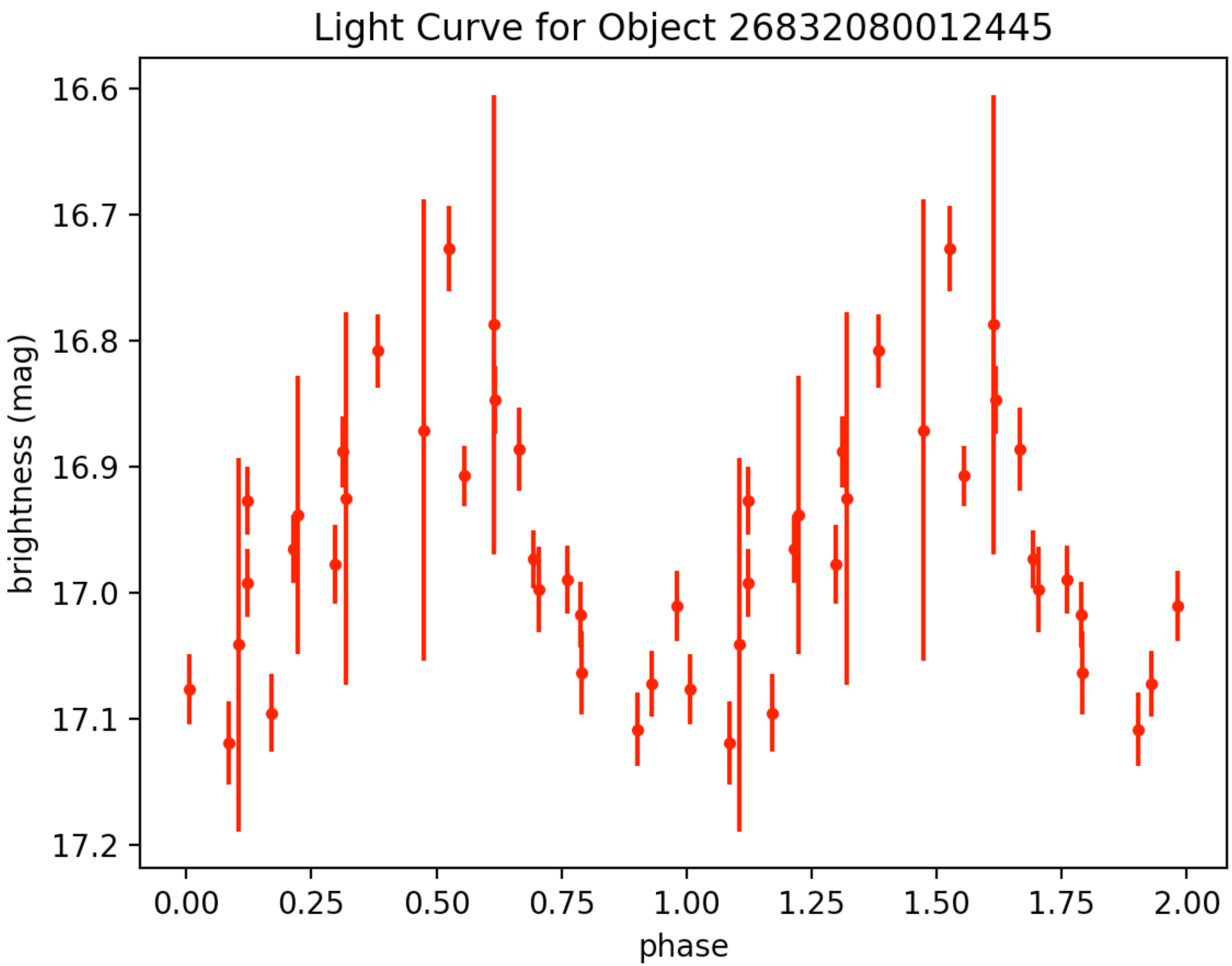


EXTRA (RR Lyrae)

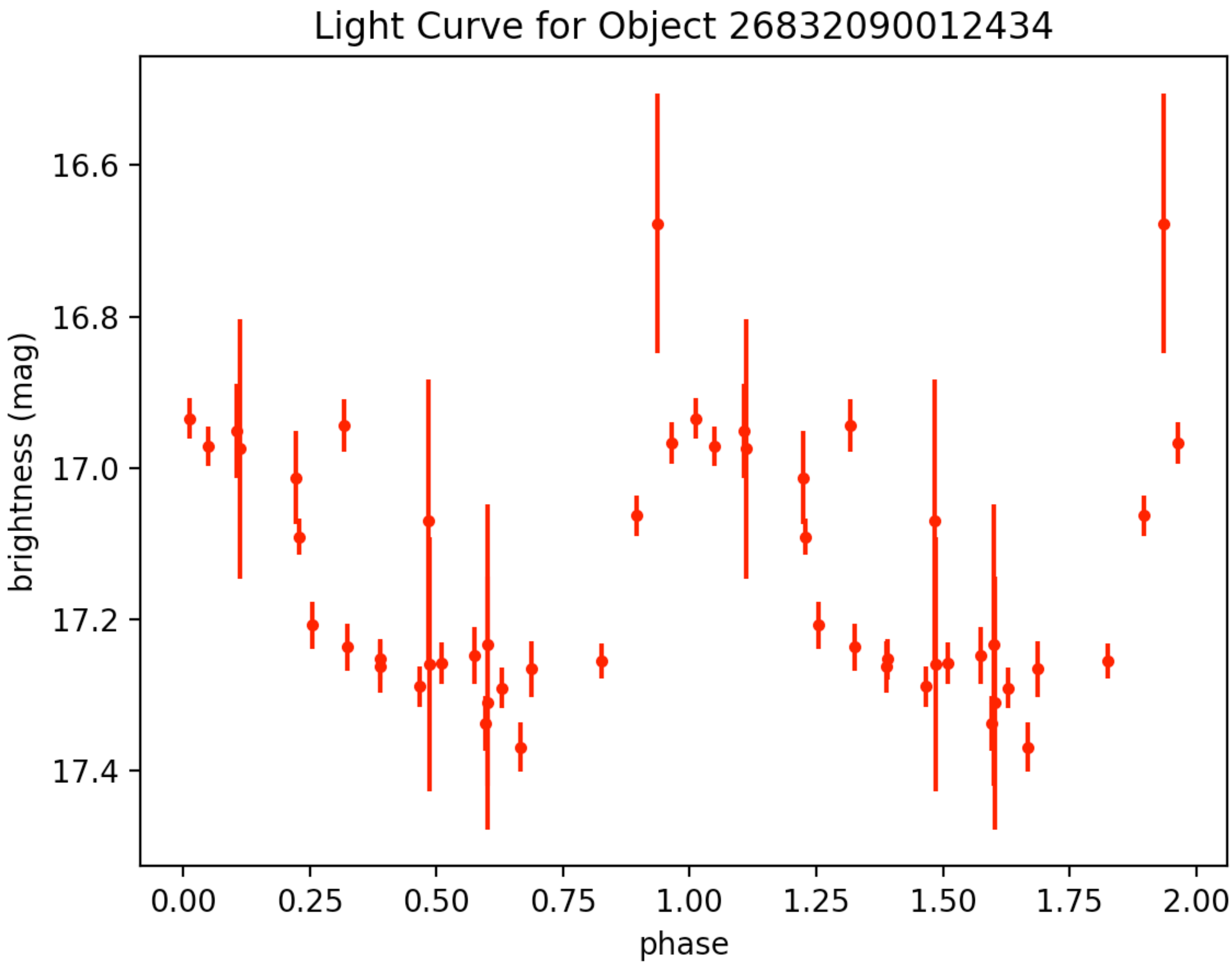
lyrae9.tbl – 20 48 14.9 +00 07 05 – period: 0.5851614753091116 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



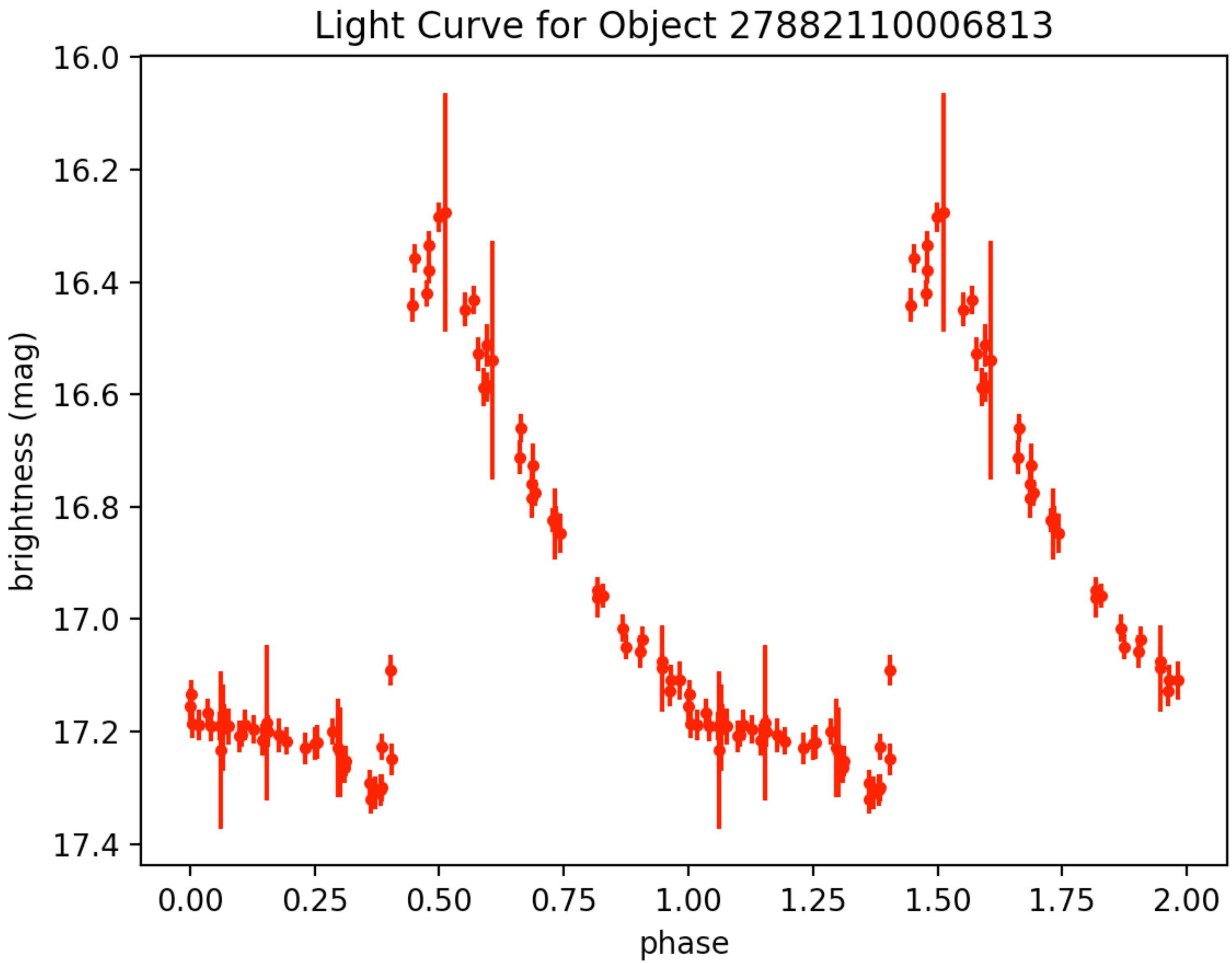
lyrae25.tbl – 20 52 42.7 -01 11 25 – period: 0.31165385977072246 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



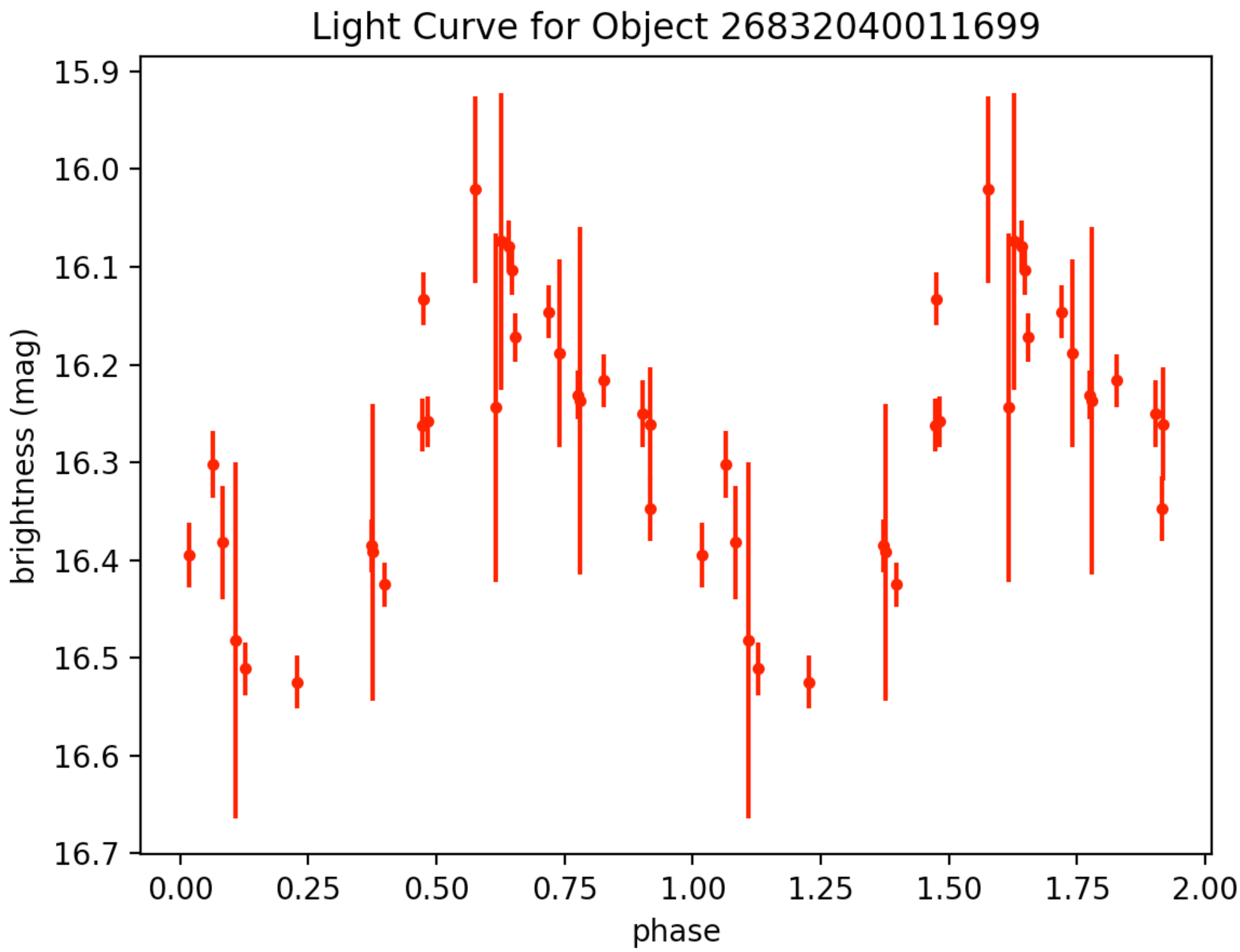
lyrae31.tbl – 20 55 21.3 -01 10 47 – period: 0.37669820258452635 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



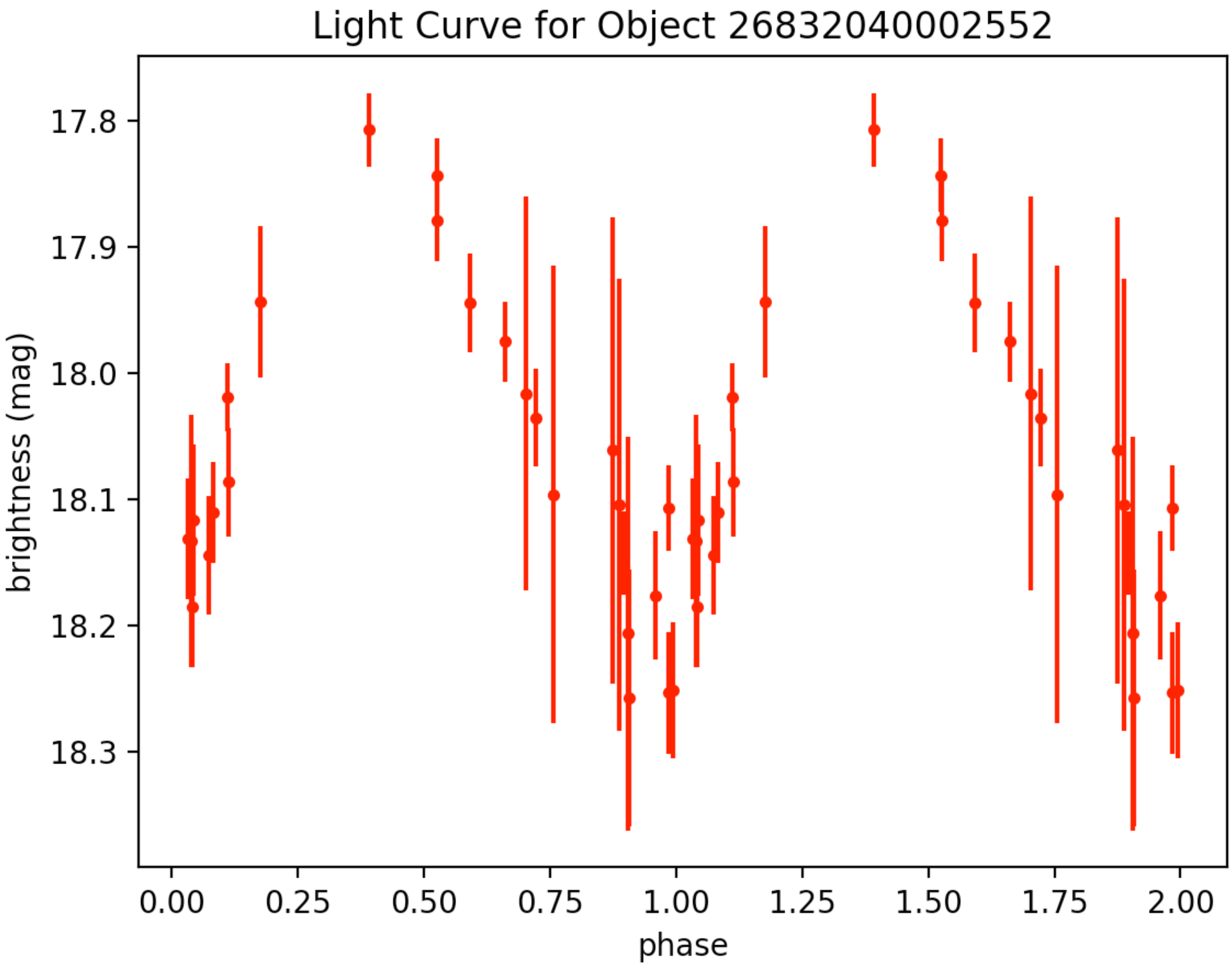
lyrae4.tbl – 21 00 08.7 +00 27 02 – period: 0.4661441811921079 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



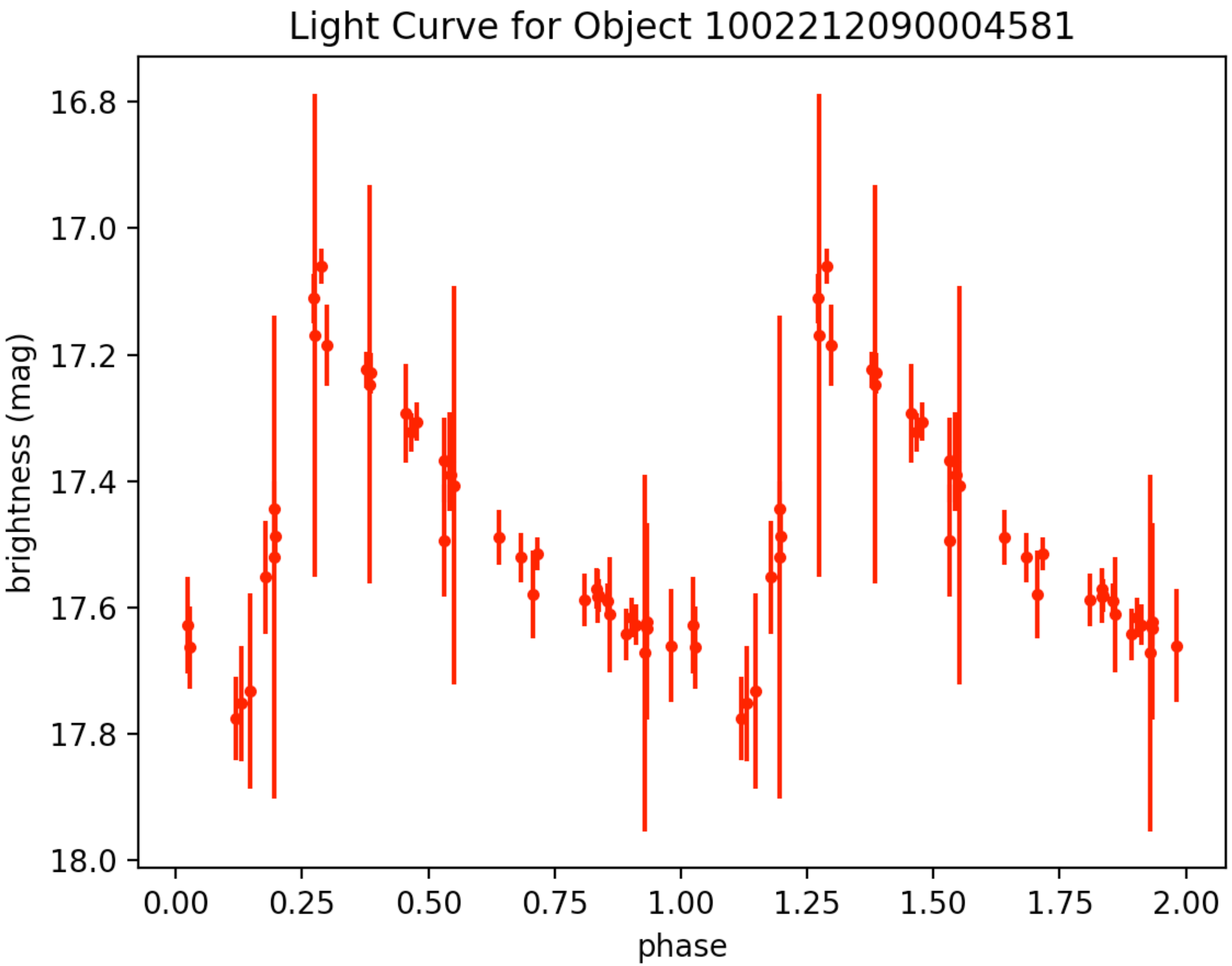
lyrae35.tbl – 20 57 59.1 -00 12 33 – period: 0.266690206522229 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



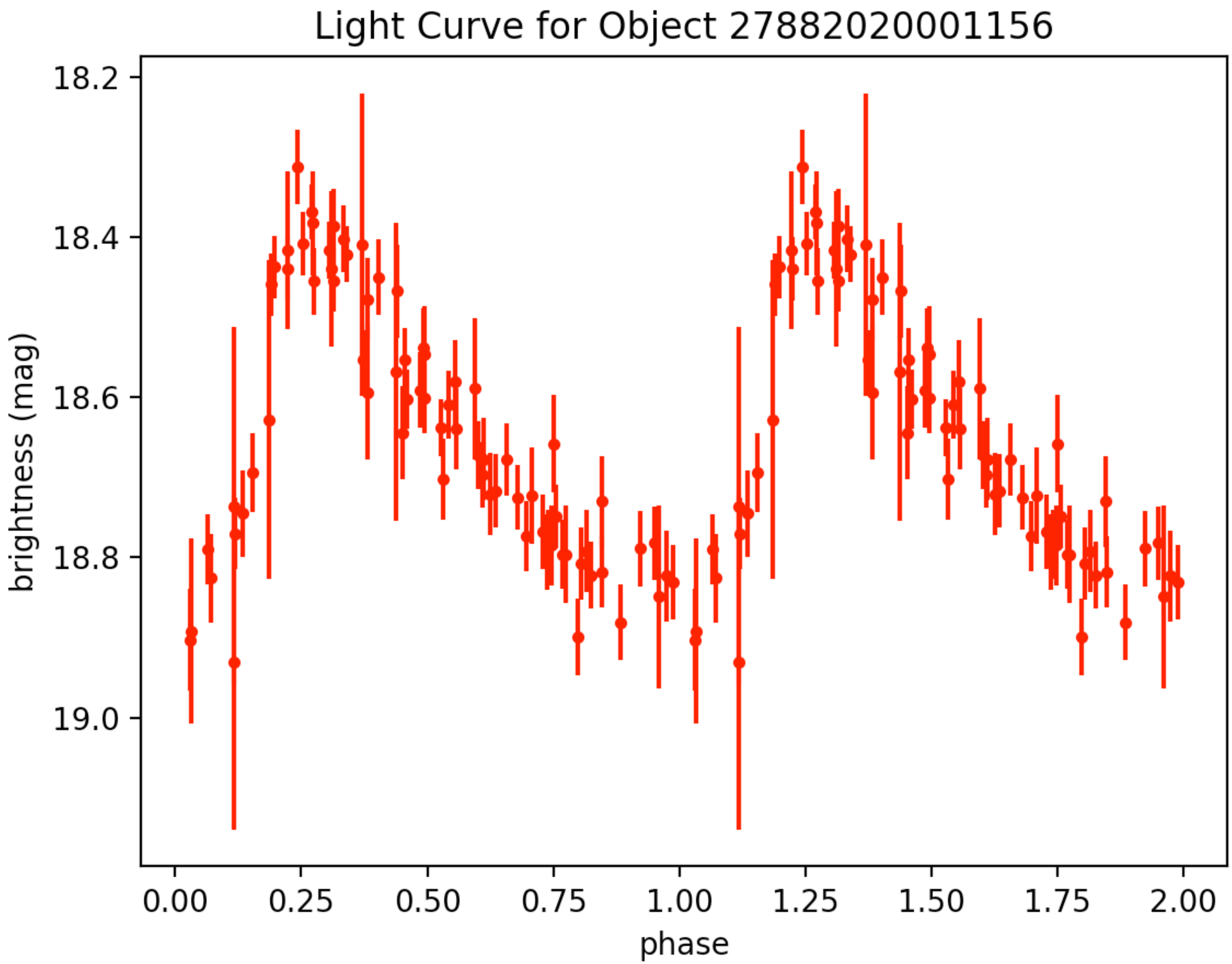
lyrae37.tbl – 20 58 52.3 -00 55 36 – period: 0.32951393728624845 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



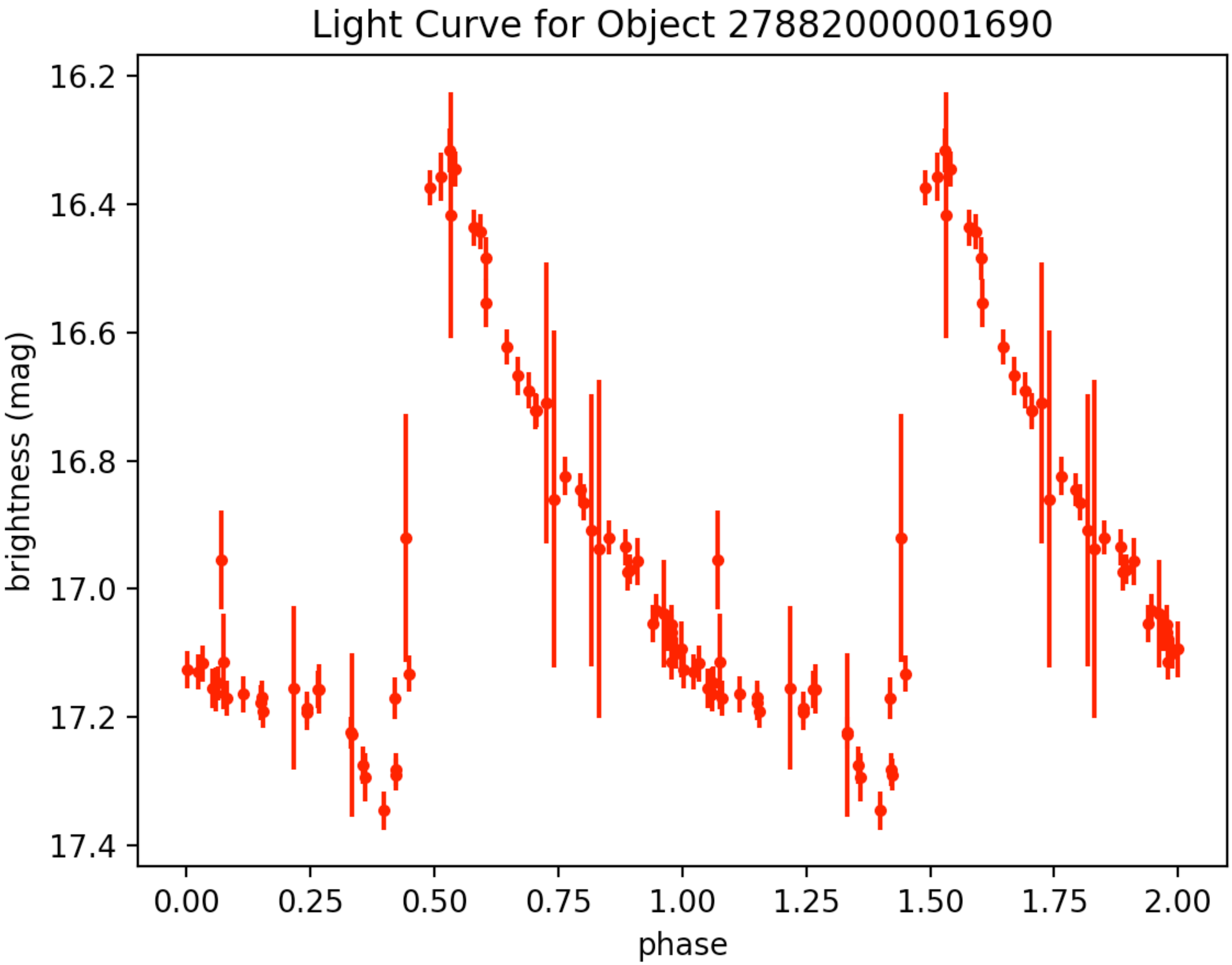
lyrae1.tbl - 20:42:47.8 00:03:52 - period: 0.561844783636383 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



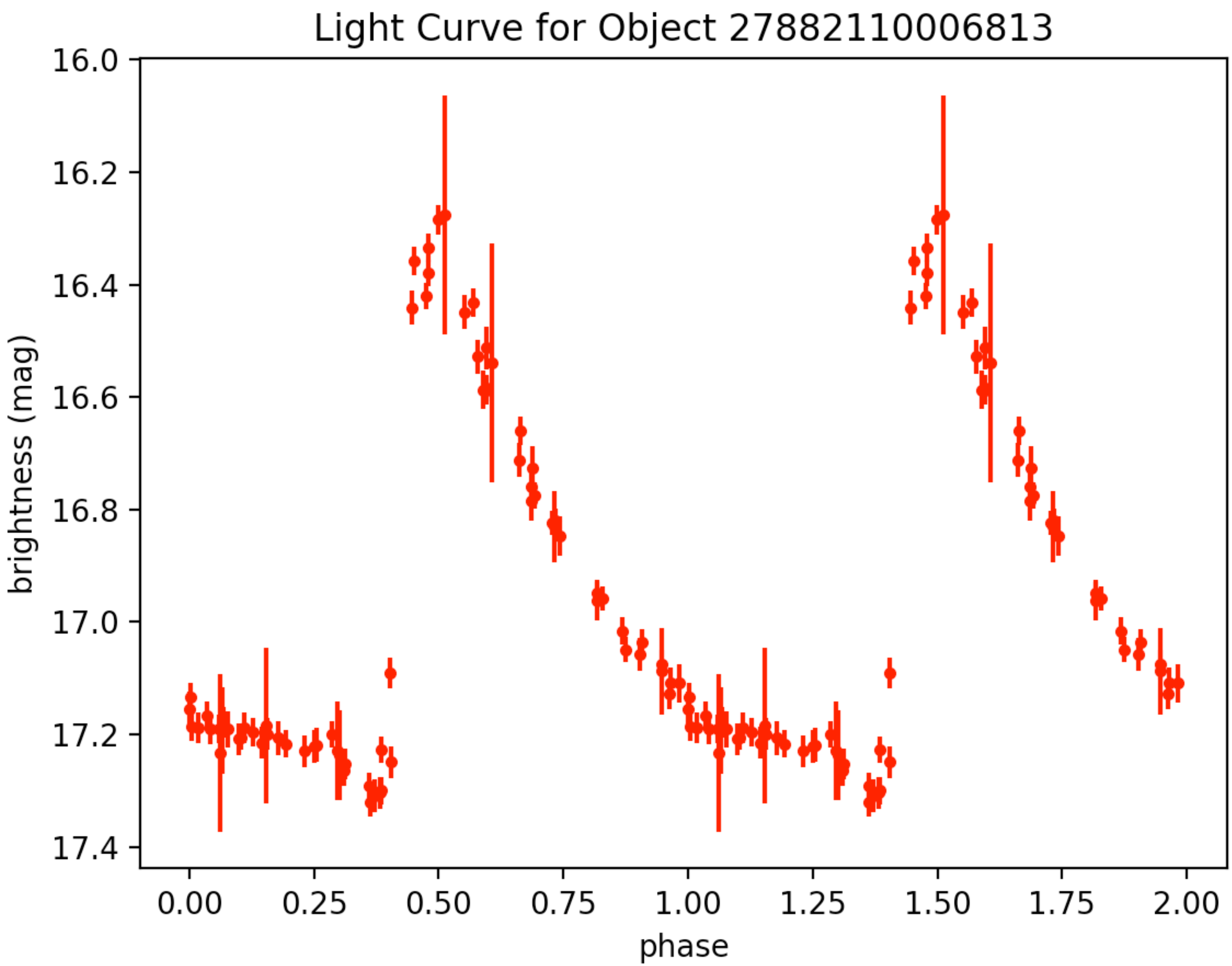
lyrae13.tbl – 20 52 41.8 +01 10 33 – period: 0.6333033991926649 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



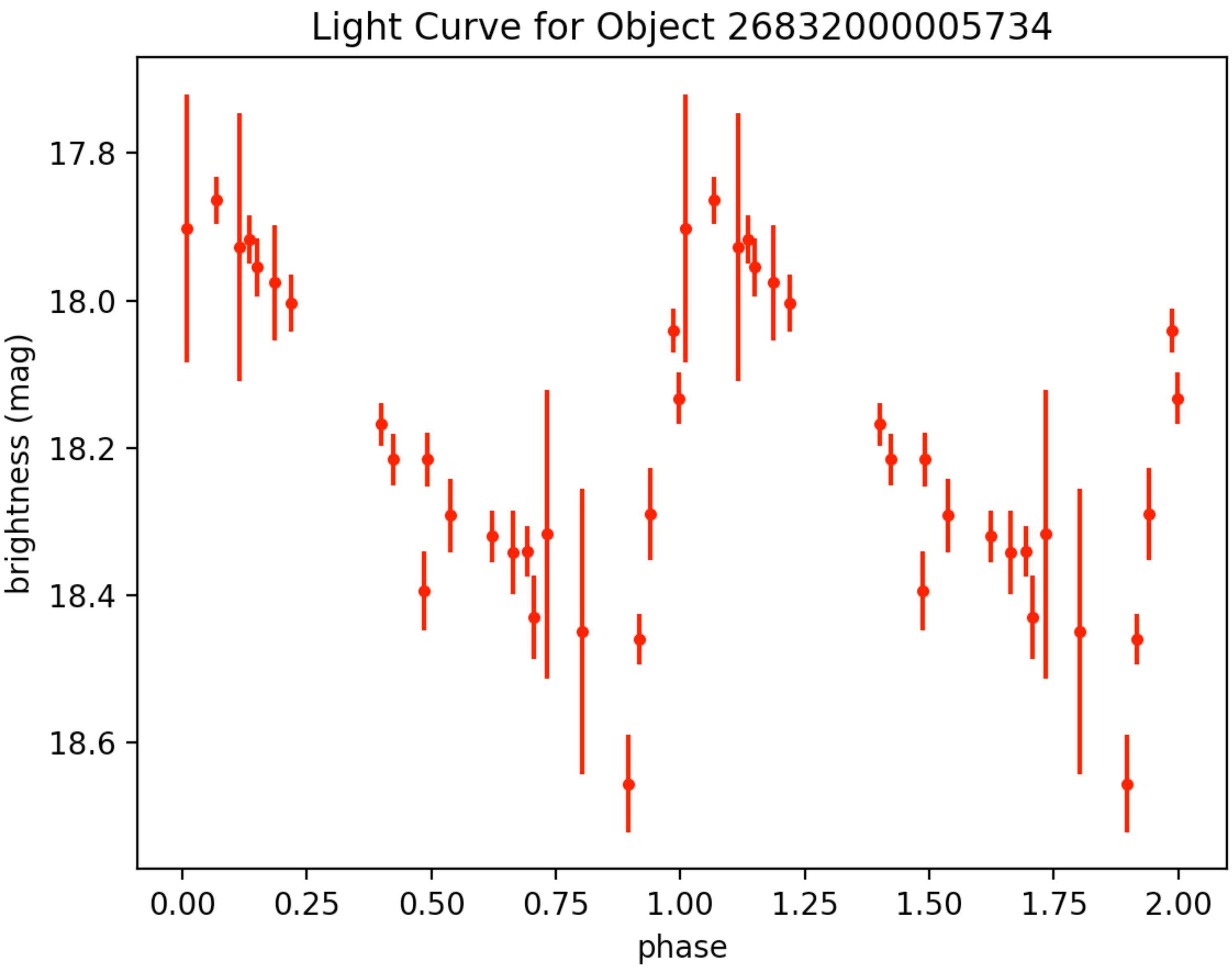
lyrae12.tbl – 20 50 01.9 +01 12 50 – period: 0.47739464735573495 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



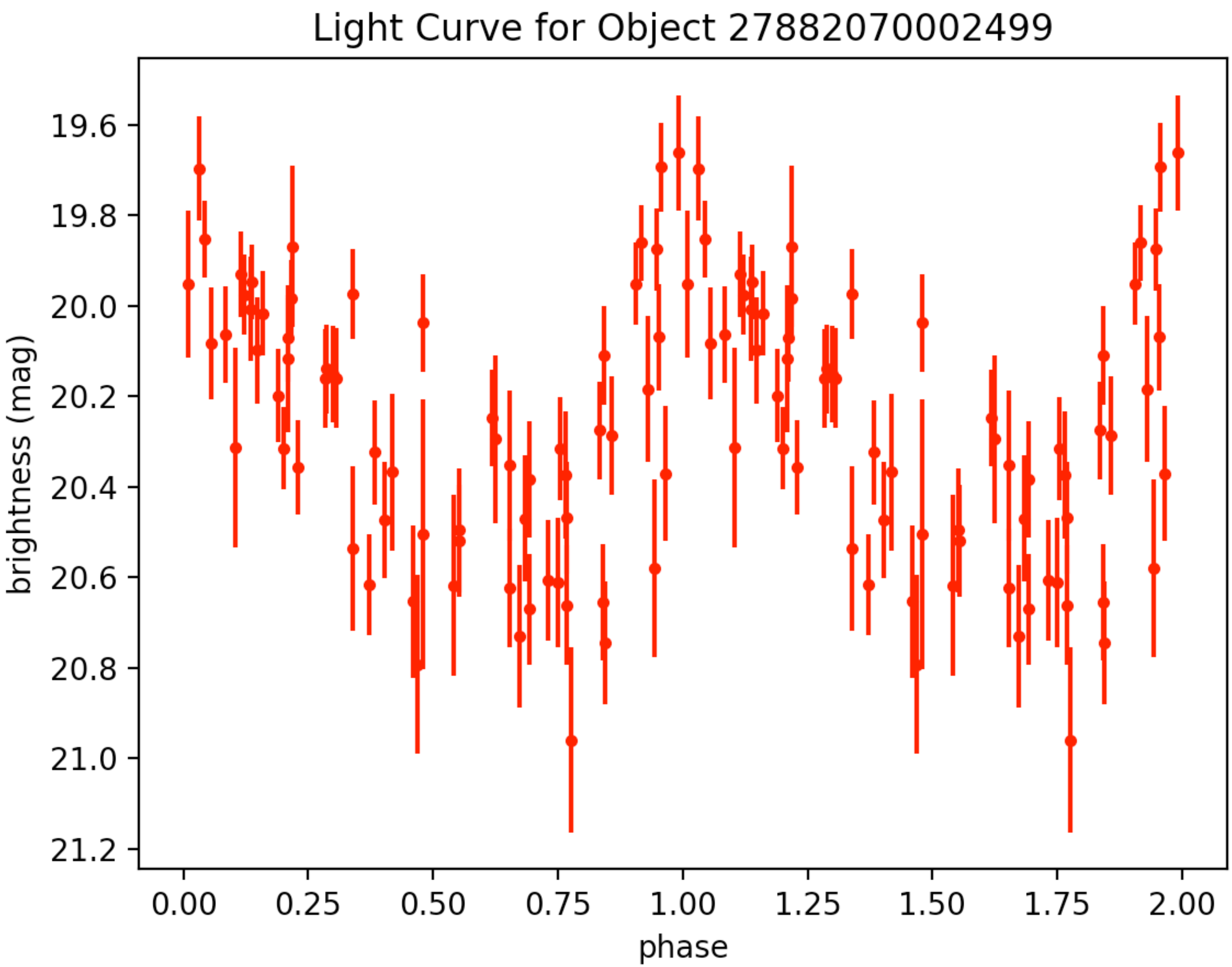
lyrae4.tbl – 21 00 08.7 +00 27 02 – period: 0.4661441811921079 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



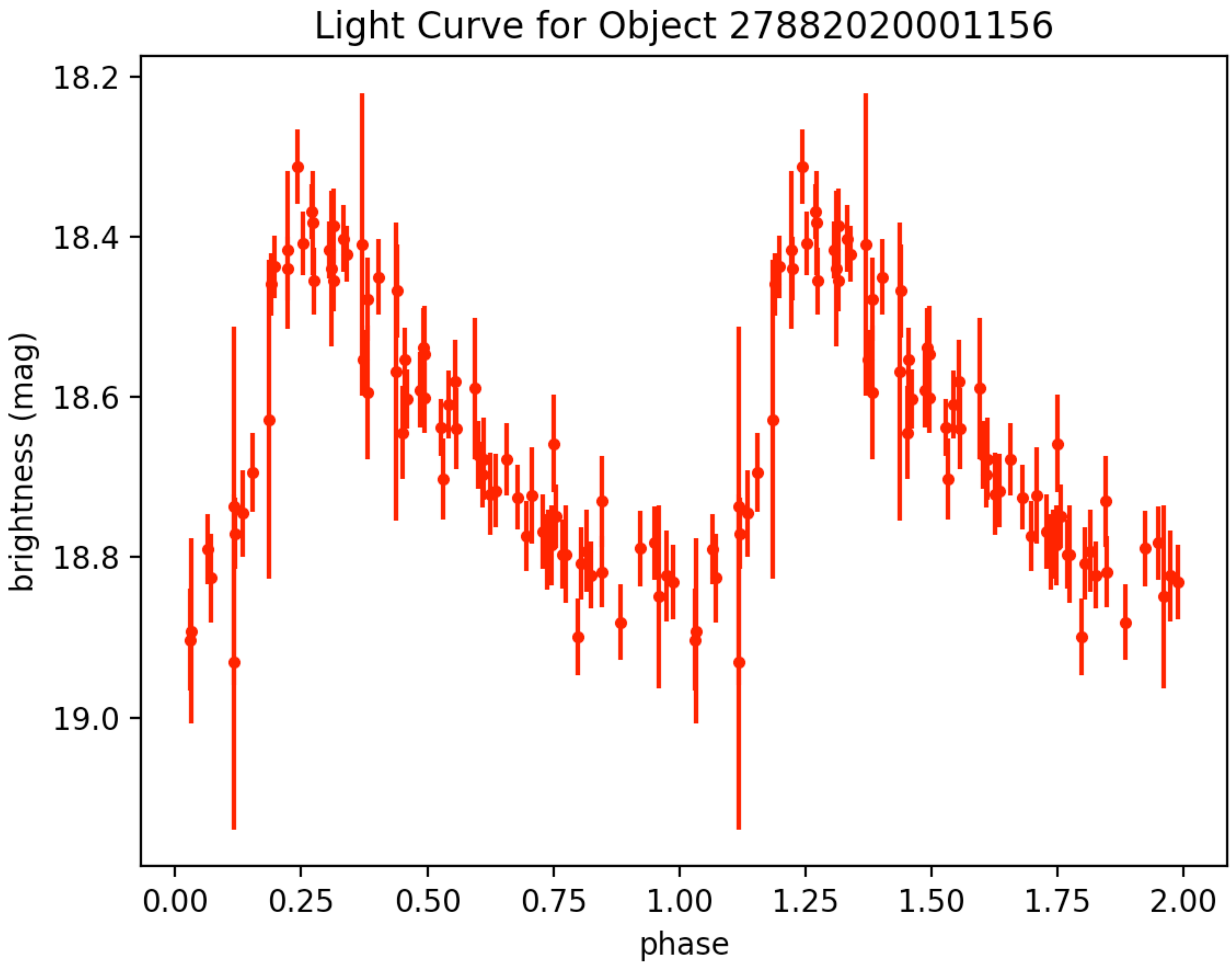
lyrae19.tbl – 20 50 00.9 -00 42 24 – period: 0.627194789767442 5 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



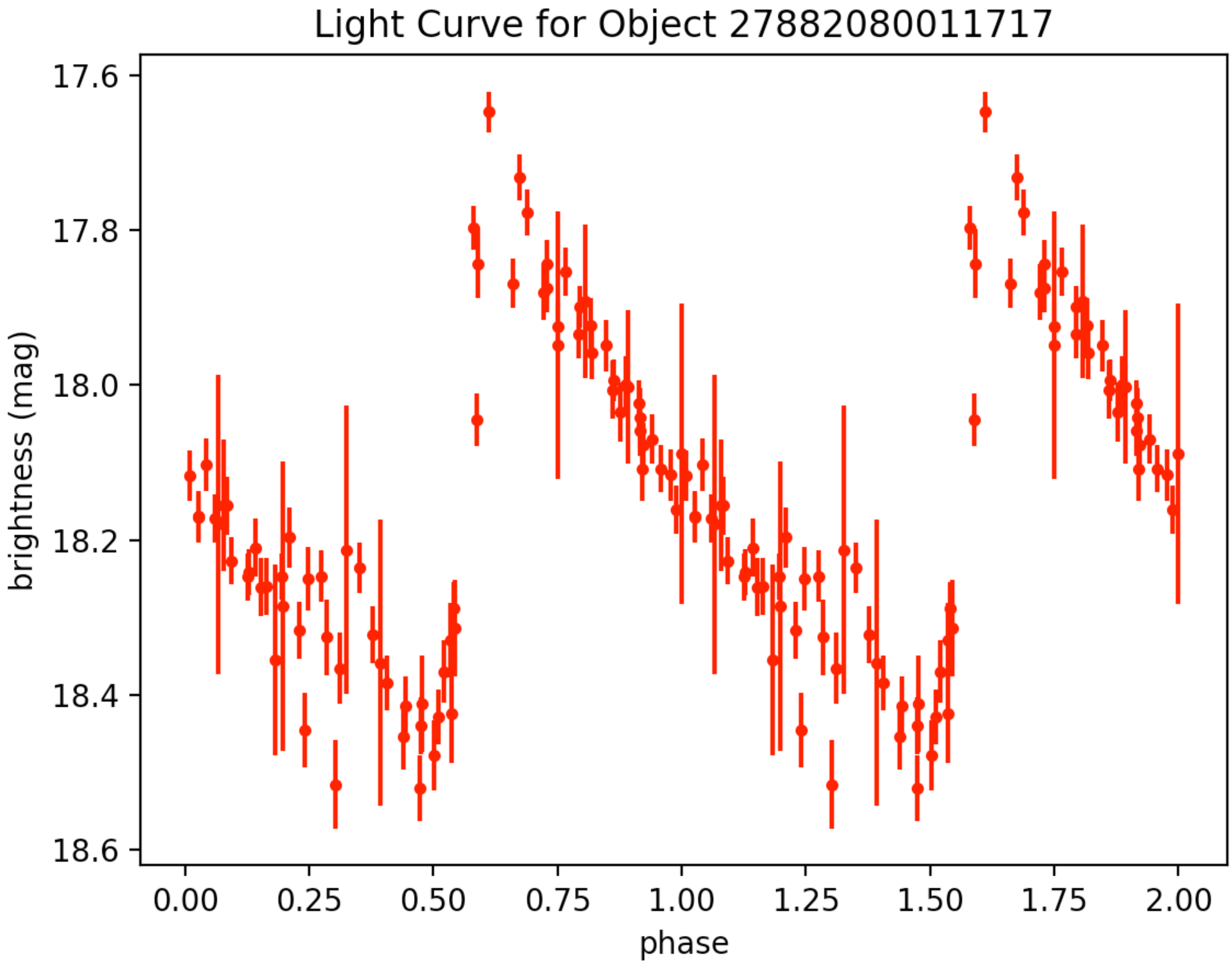
lyrae23.tbl – 20 52 21.1 +00 08 01 – period: 0.5592960029351854 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



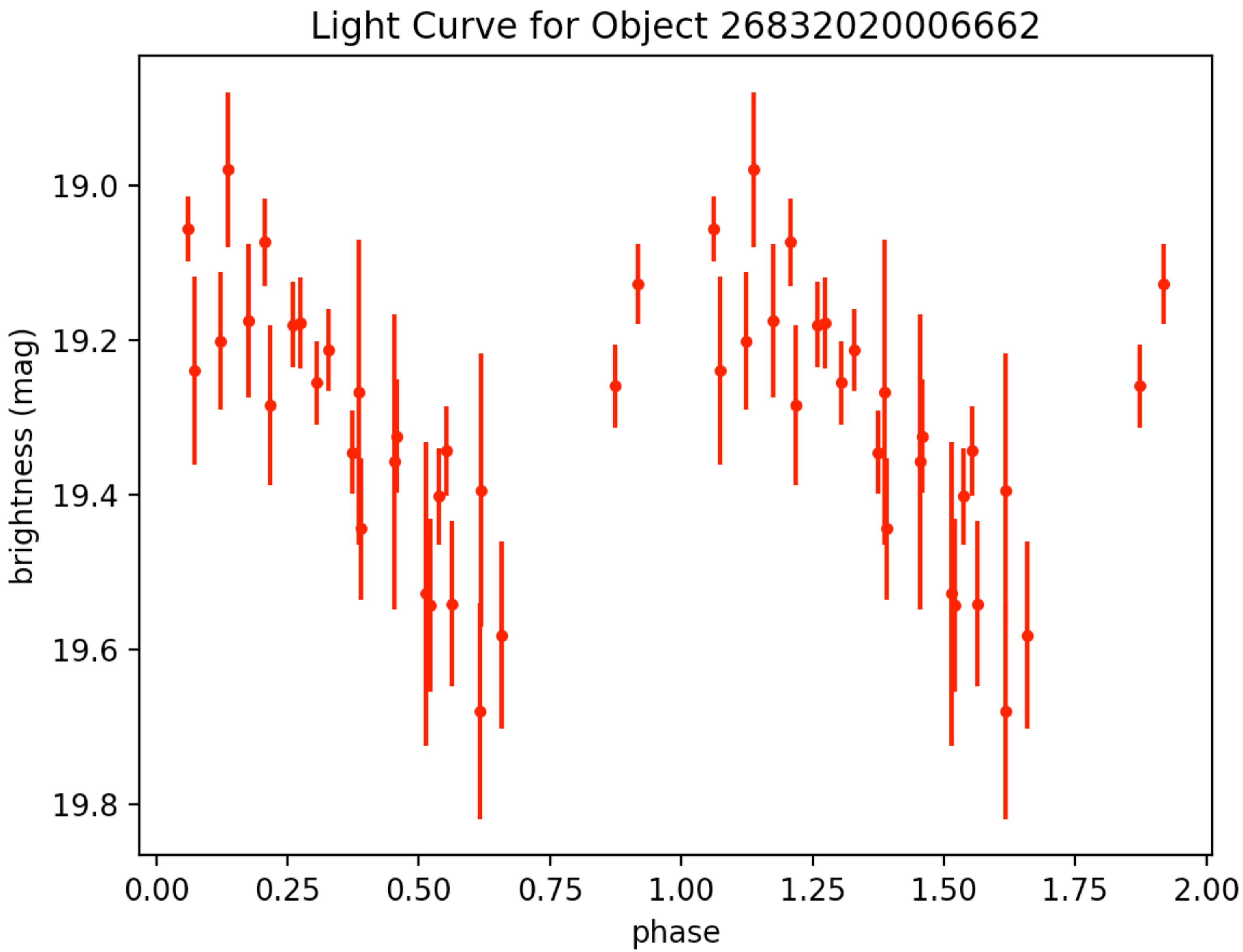
lyrae24.tbl – 20 52 41.8 +01 10 33 – period: 0.6333033991926649 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



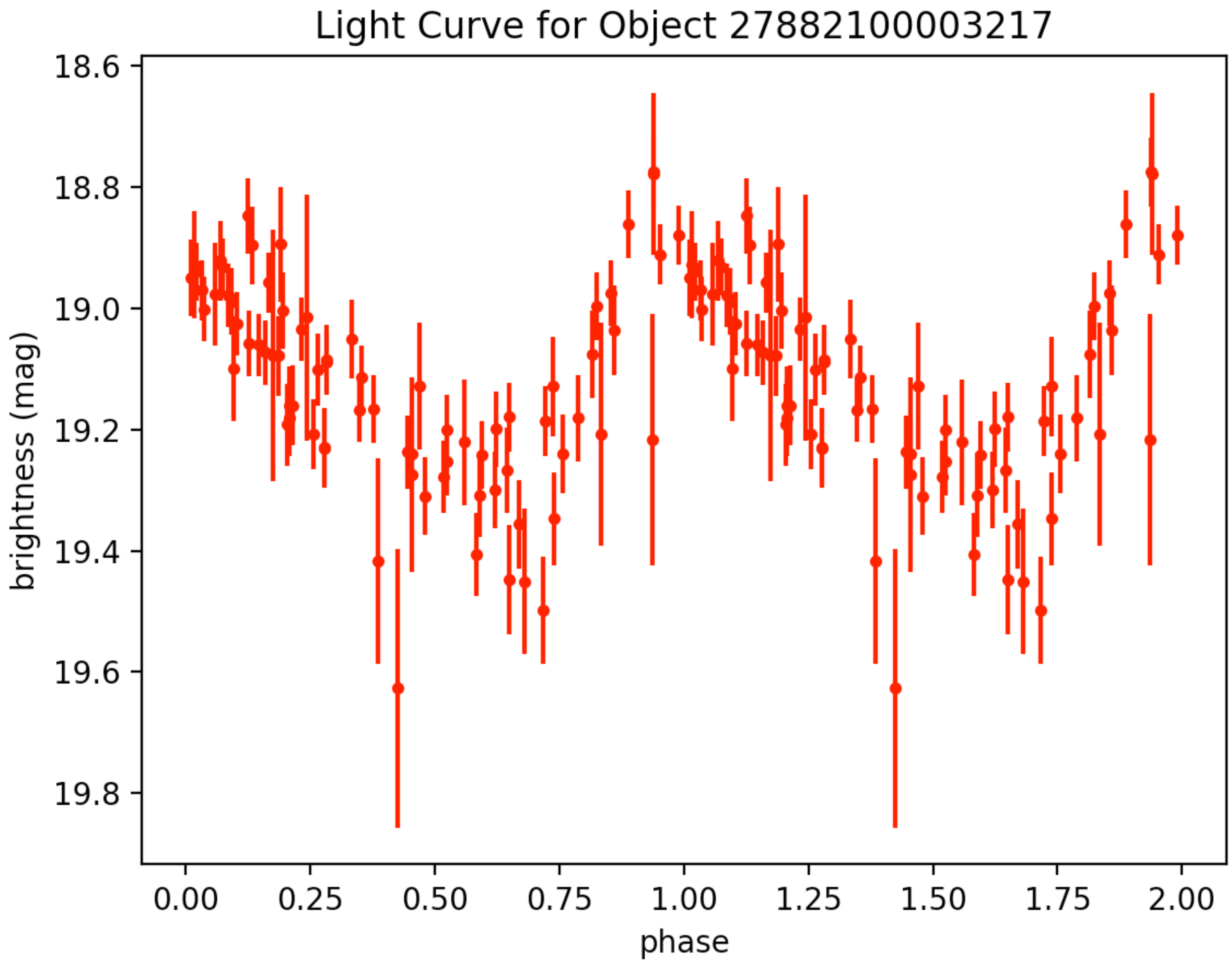
lyrae26.tbl – 20 52 42.7 +00 46 31 – period: 0.6434066581007793 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



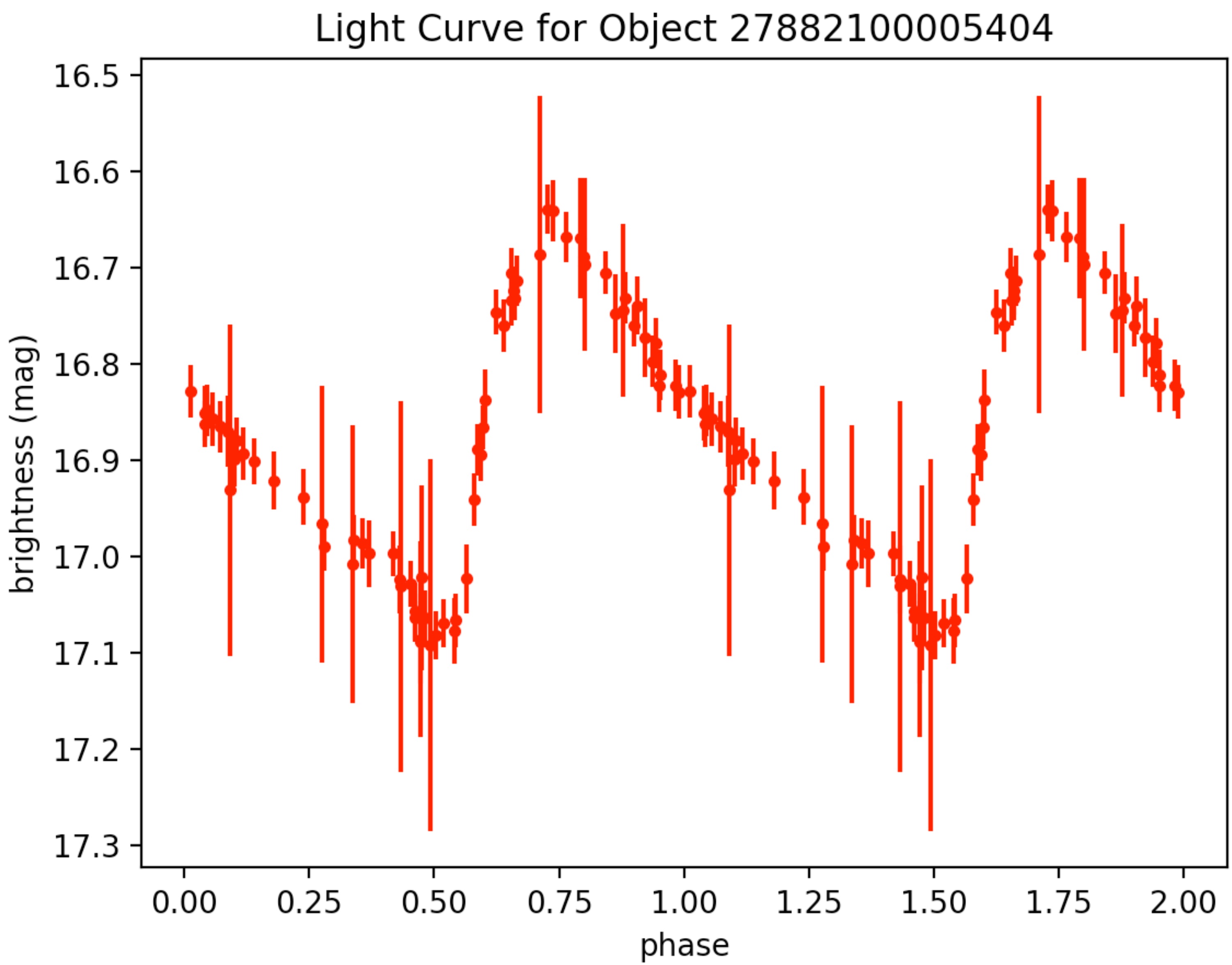
lyrae29.tbl – 20 54 11.7 -00 32 28 – period: 0.6424224981498232 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



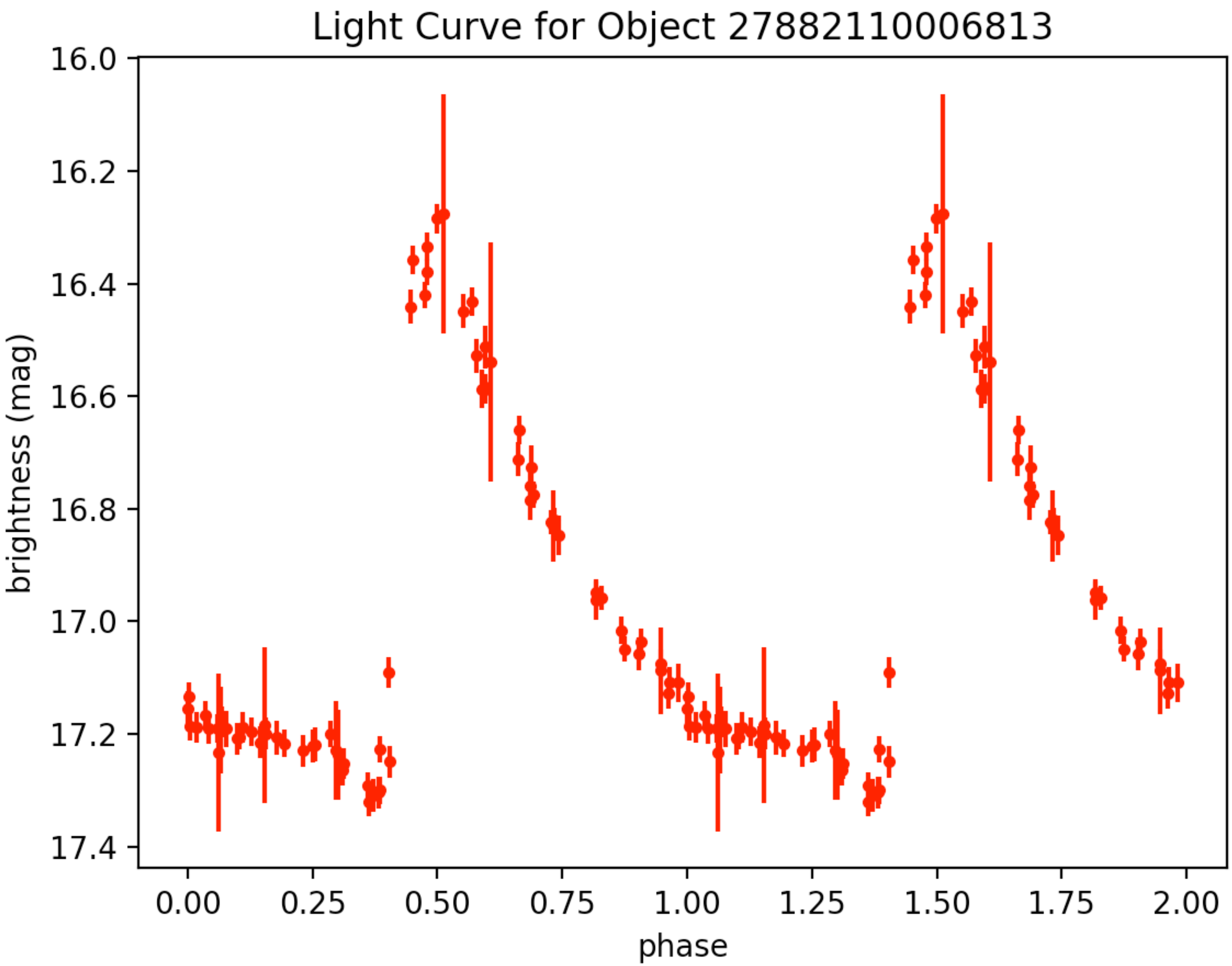
lyrae33.tbl – 20 57 32.9 +00 11 52 – period: 0.6278003820793125 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes



lyrae36.tbl – 20 58 28.8 +00 21 12 – period: 0.723389572049963 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

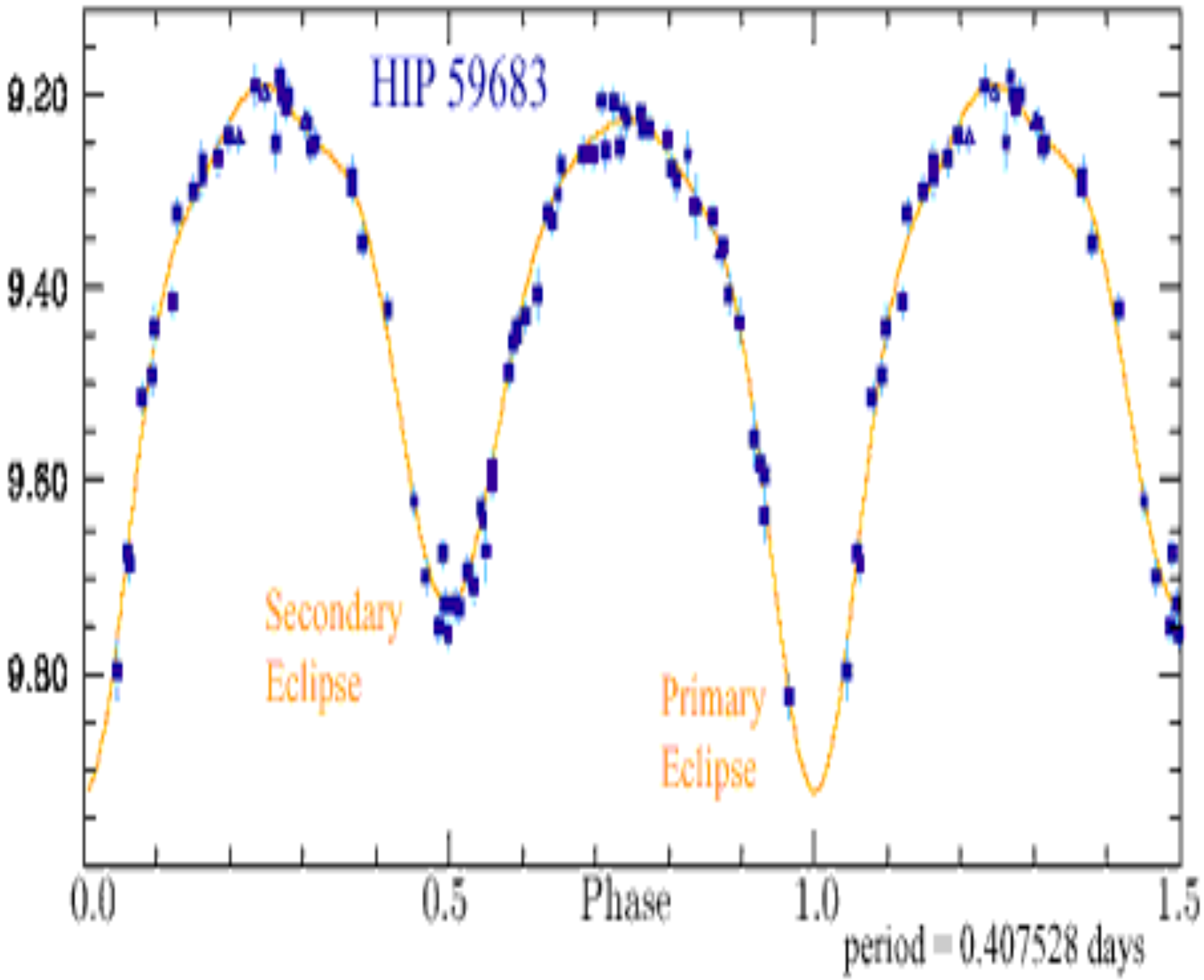


lyrae40.tbl – 21 00 08.7 +00 27 02 – period: 0.4661441811921079 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/398/1757/lyraes

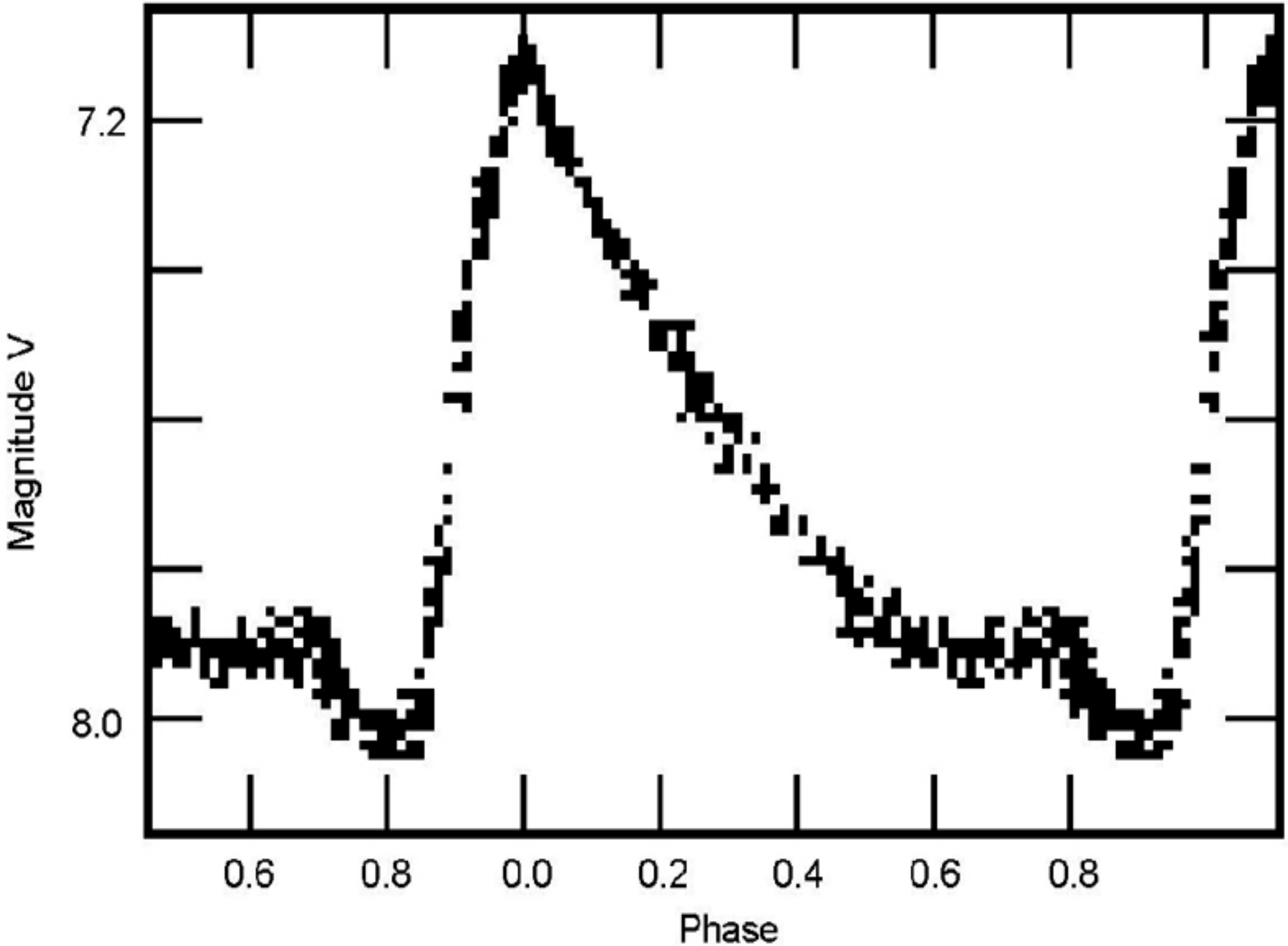


Light Curves and .’s

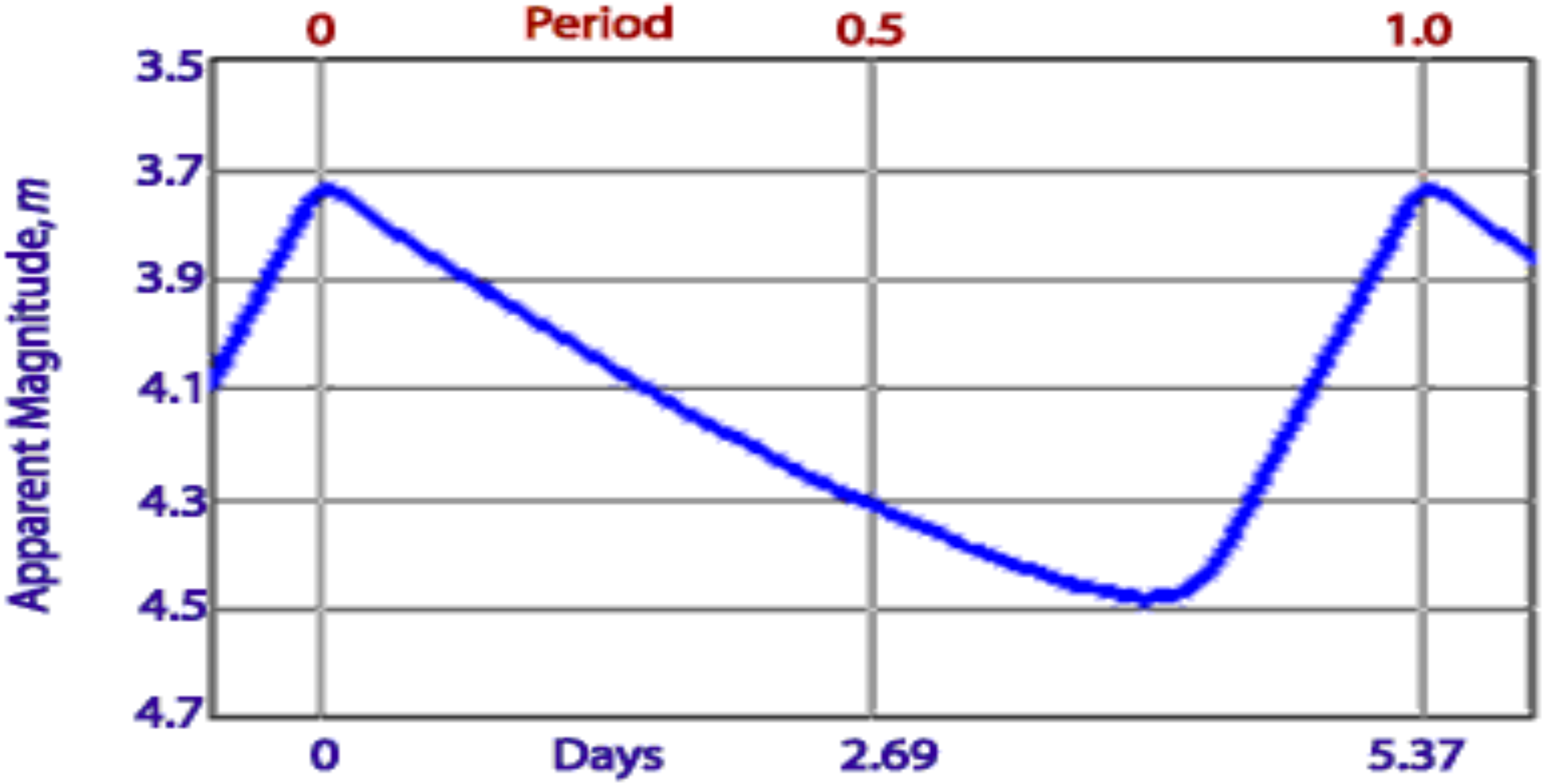
- The following are the light curves of various variable stars and the corresponding expected period range.
  - For the zooniverse project we will be showing these (the PTF messier-actual-data version) to our users (and superusers!)



“The periods of **eclipsing variables** are generally in the range of 0.25 to ten days because, as mentioned above, most eclipsing variables are likely to be close binaries. But some eclipsing variables -- especially those containing giant or supergiant components -- have periods as long as several decades” (Percy textbook).



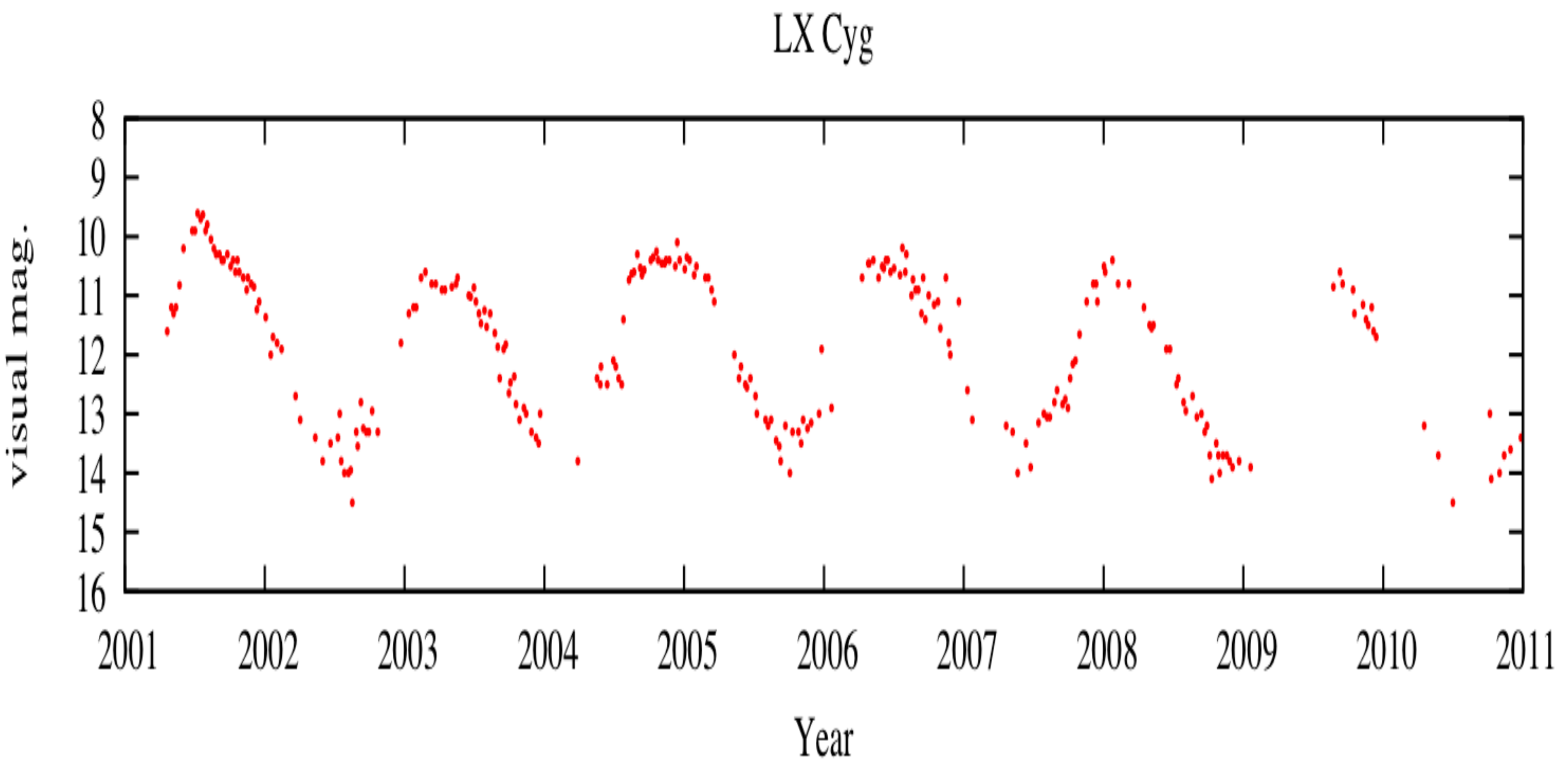
RR Lyrae periods 0.1 - 1 day ; sinusoidal (RRc): mean period = 0.33 days with approximate range of 0.267 - 0.38 days ; asymmetric (RRab): mean period = 0.69 days with approximate range of 0.466 - 0.72 days



Light Curve for δ Cephei

Cepheid Variables are the most important type of variable because it has been discovered that their periods of variability are related to their absolute luminosity. This makes them invaluable as a contributer to astronomical distance measurement. The periods are very regular and range from 1 to 100 days (Hyperphysics).

Cepheids with periods as short as 0.8 day (fundamental mode) and 0.5 day (first overtone) have recently been found in the dwarf irregular galaxies of the Local Group -- including the Magellanic Clouds -- thanks to large-scale photometric surveys -> poses problem (b/c similar shape to RRab)



Mira variables: pulsating red giants ; light curve roughly sinusoidal with slightly varying amplitude as shown above ; stable periods of 100 – 1000 days, with most between 150 and 450 days

Proceeding…

- So we have golden examples of RRL ab and RRL c, but not yet type d.
- Need to continue with new classes of sources (e.g., Mira variables, Cepheids, Eclipsing Binaries)
- Include amplitude as summary stat
- Need to create zooniverse project
  - Can initialize project and begin working on tutorial, for example

Week 5

- Employ cesium to also spit out amplitude
  - See if reflective of what ‘eye-balling’ light curve yields
  - Summary stats -> (amplitude, period, notion of ‘fuzziness’)

lyrae (type)	by 'hand'	cesium freq1_amplitude1	cesium amplitude
gold/avg (c)			
lyrae8.tbl (c)	0.19	0.173612	0.5725
lyrae3.tbl (c)	0.19	0.175292	0.329
lyrae21.tbl (c)	0.16	0.174313	0.278
lyrae34.tbl (c)	0.18	0.17272	0.2005
lyrae27.tbl (c)	0.14	0.155065	0.178
lyrae39.tbl (c)	0.135	0.149759	0.1555
gold/avg (ab)			
lyrae32.tbl (ab)	0.425	0.282298	0.5625
lyrae9.tbl (ab)	0.475	0.347032	0.607
RRL9DiffOID	0.475	0.347032	0.607
lyrae10.tbl (ab)	0.515	0.348594	0.5275
RRL10DiffOID	0.5	0.348594	0.5275
lyrae20.tbl (ab)	0.485	0.316273	0.534
lyrae1.tbl (ab)	0.3	0.237879	0.5315
RRL1DiffOID	0.384	0.237879	0.5315
lyrae7.tbl (ab)	0.42	0.296446	0.541
RRL7DiffOID	0.35	0.296446	0.541
non-gold/avg			
lyrae35.tbl (c)	0.215	0.16538	0.252
RRL35DiffOID (sparse)	0.11	0.16538	0.252
lyrae37.tbl (c)	0.2175	0.162072	0.225
lyrae4.tbl (goldAB)	0.5	0.36683	0.604
lyrae6.tbl (avgAB)	0.5	0.325443	0.558

General Findings / Take-aways:

amplitude = ~ 1/2(bottom points location - top points location) (*)

I trust the 'by hand' the most b/c this is exactly (*)

cesium_amplitude too high (zero counter-examples) and freq1_amplitude1 is too low (13/17 times [there are 17 unique oid's])

cesium freq1_amplitude1 very good for gold/avg RRc => use freq1_amplitude1 as amplitude summary statistic for RRc

Not as straight-forward for RRab b/c asymmetric whereas RRab is sinusoidal/symmetric

cesium freq1_amplitude1 is low for all RRab but...

1/2(amplitude + freq1_amplitude1) gives a very good estimate for RRab!

=> use 1/2(amplitude + freq1_amplitude1) as amplitude summary statistic for RRab

Miras

-> periods of 100 – 1000 days, with most between 150 and 450 days

Search resulted in 2895 objects.

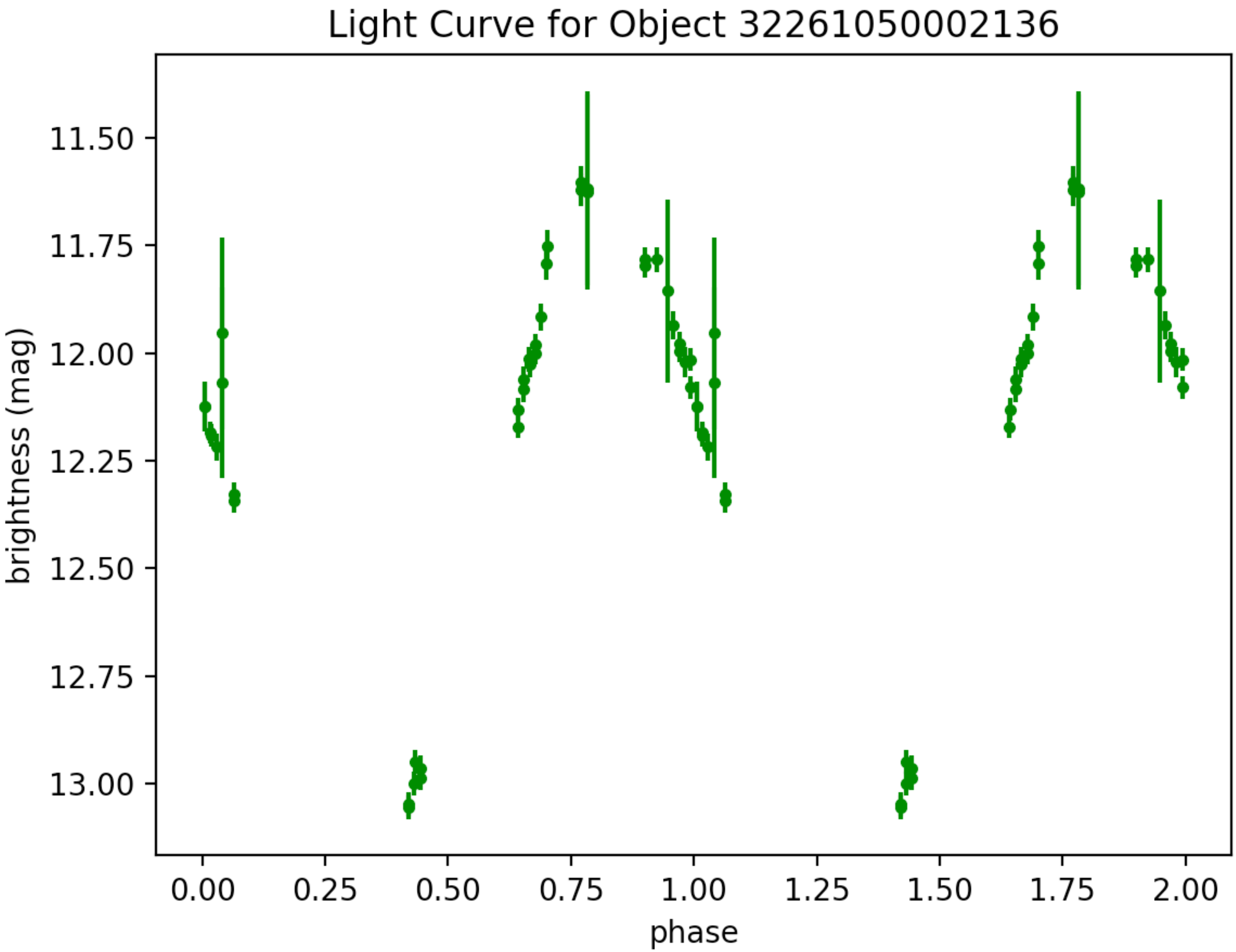
Back to: ACVS » Star list (Click on the star ID to get detailed info-page)

Showing 25 starting from 1.
Show: All 50 20 10 next 25

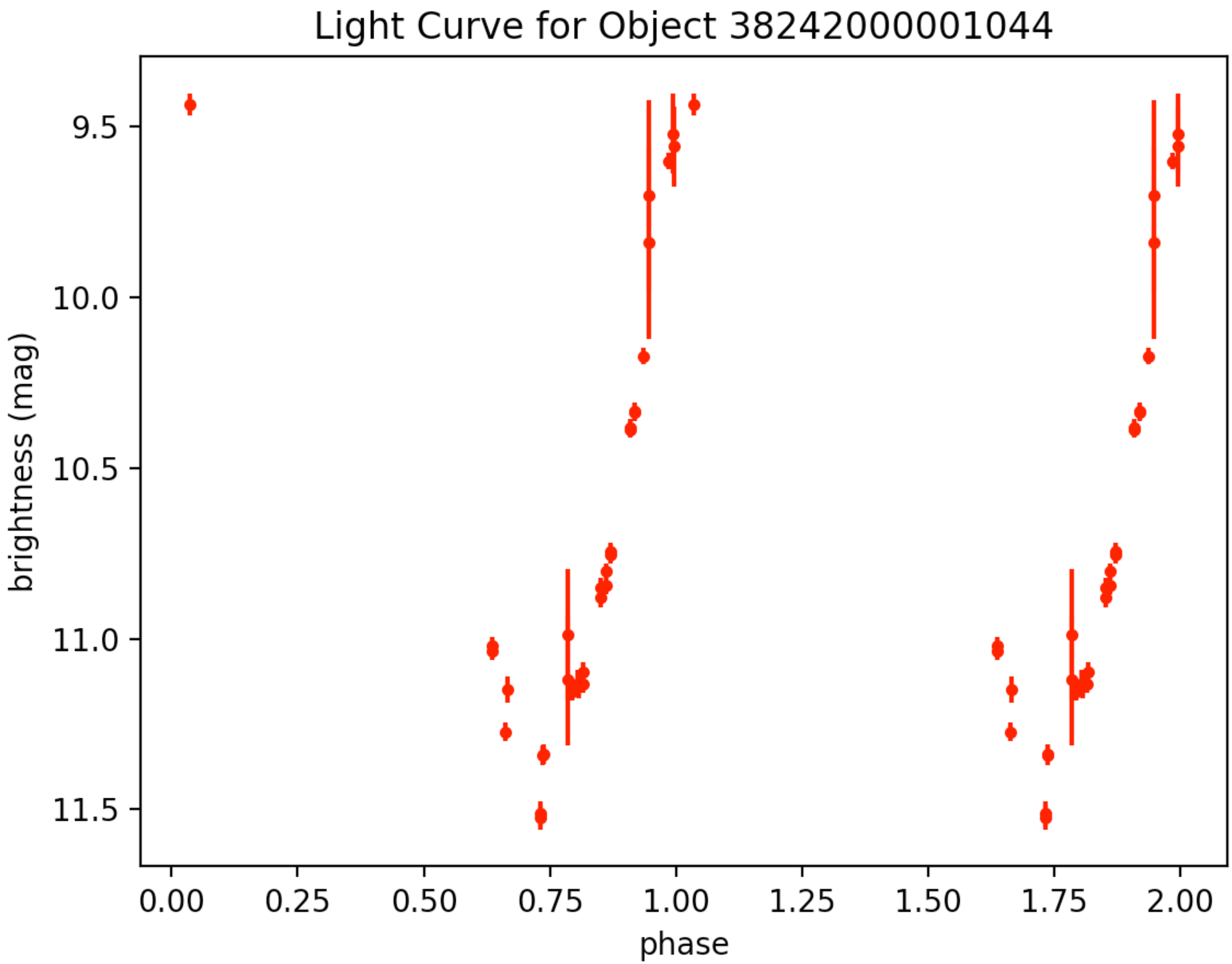
ID ↓	RA (2000)	DEC (2000)	Period [days]	T_0	V [mag]	V Amp [mag]	Class	Other ID	Other Class
000006+2553.2	00:00:06	25:53:12	313.9633	0	8.564	4.054	MIRA	Z~Peg	M
000017+2636.4	00:00:17	26:36:24	381.6981	0	10.828	2.292	MIRA	AH~Peg	SRB
000208-1440.5	00:02:08	-14:40:30	352	2911.5	8.35	5.27	MIRA	W~Cet	-
000736-2529.5	00:07:36	-25:29:30	321	2639.9	13.29	2.06	MIRA	PCC93~2	-
000837-3913.2	00:08:37	-39:13:12	304	2550.5	9.26	5.41	MIRA	V~Scl	-
000842-8611.3	00:08:42	-86:11:18	340	2895.3	11.35	2.35	MIRA	RU~Oct	-
001522-3202.7	00:15:22	-32:02:42	425	4452.5	6.72	5.42	MIRA	S~Scl	-
001654-3013.8	00:16:54	-30:13:48	171	2282.4	11.44	3.21	MIRA	TT~Scl	-
002223+2659.8	00:22:23	26:59:48	599	4600.2	10.65	3.38	MIRA	T~And	M
002231-1832.7	00:22:31	-18:32:42	197	2467.4	12.37	2.47	MIRA	-	-
002308-6140.3	00:23:08	-61:40:18	246	2286.7	8.83	5.2	MIRA	S~Tuc	-
002404-0919.7	00:24:04	-09:19:42	320	2489.3	8.46	5.4	MIRA	S~Cet	-
002912-3754.5	00:29:12	-37:54:30	214	2249.5	9.06	4.49	MIRA/DCEP-FU	T~Scl	-
003026-4624.6	00:30:26	-46:24:36	259	2365.8	10.55	3.78	MIRA	T~Phe	-
003223+2601.7	00:32:23	26:01:42	619	4072	8.76	3.54	MIRA	TU~And	M
003419-4300.1	00:34:19	-43:00:06	144	2165.2	10.81	2.05	MIRA	NSV00207	|SR:

But didn't lead to any good mira light curves in ptf… (see questions) mira1.tbl – 01 22 58.3 +12 52 06 – **period: 85.2587603376247**

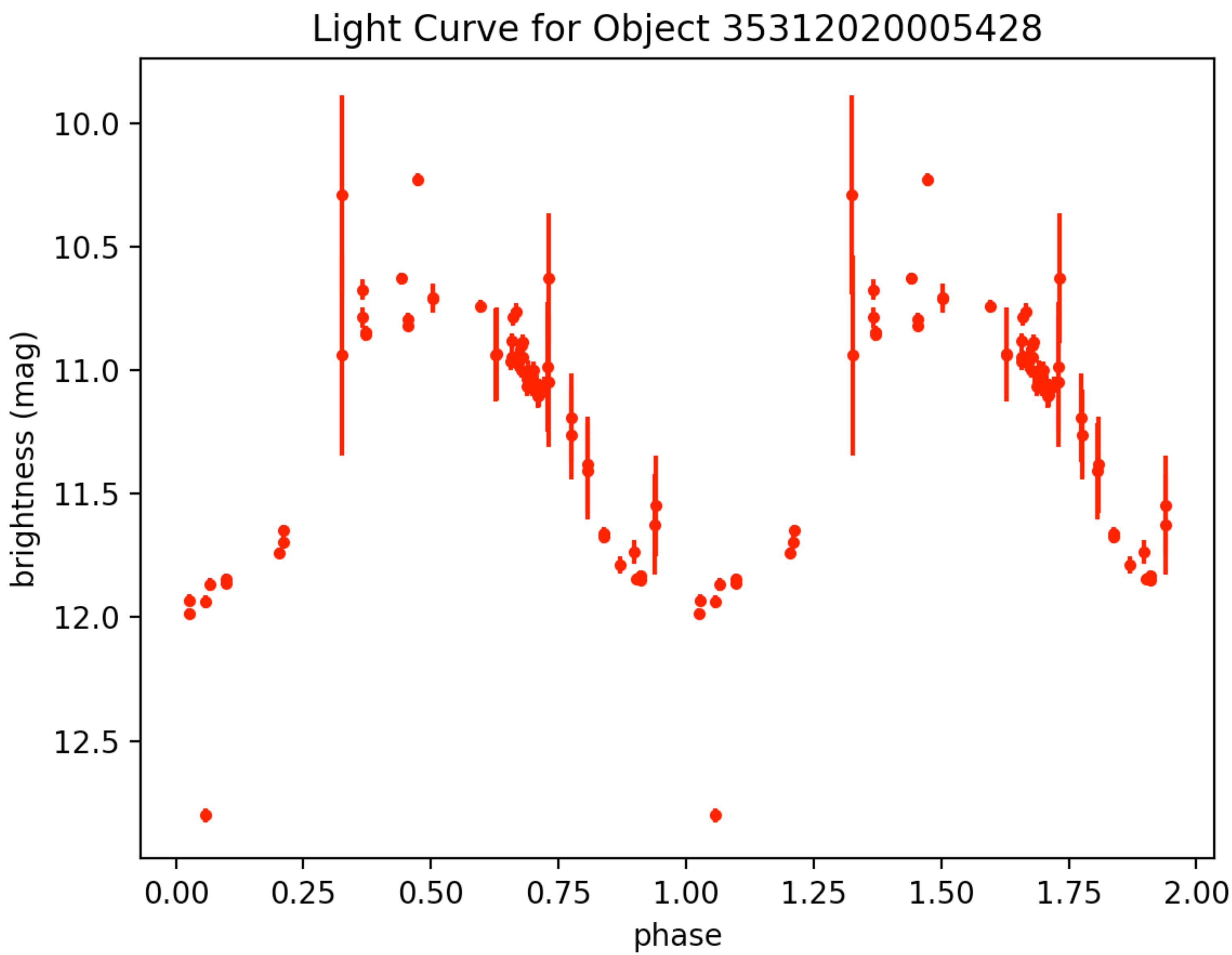
LPV with light curve representative of miras but if period is correct, it can't be



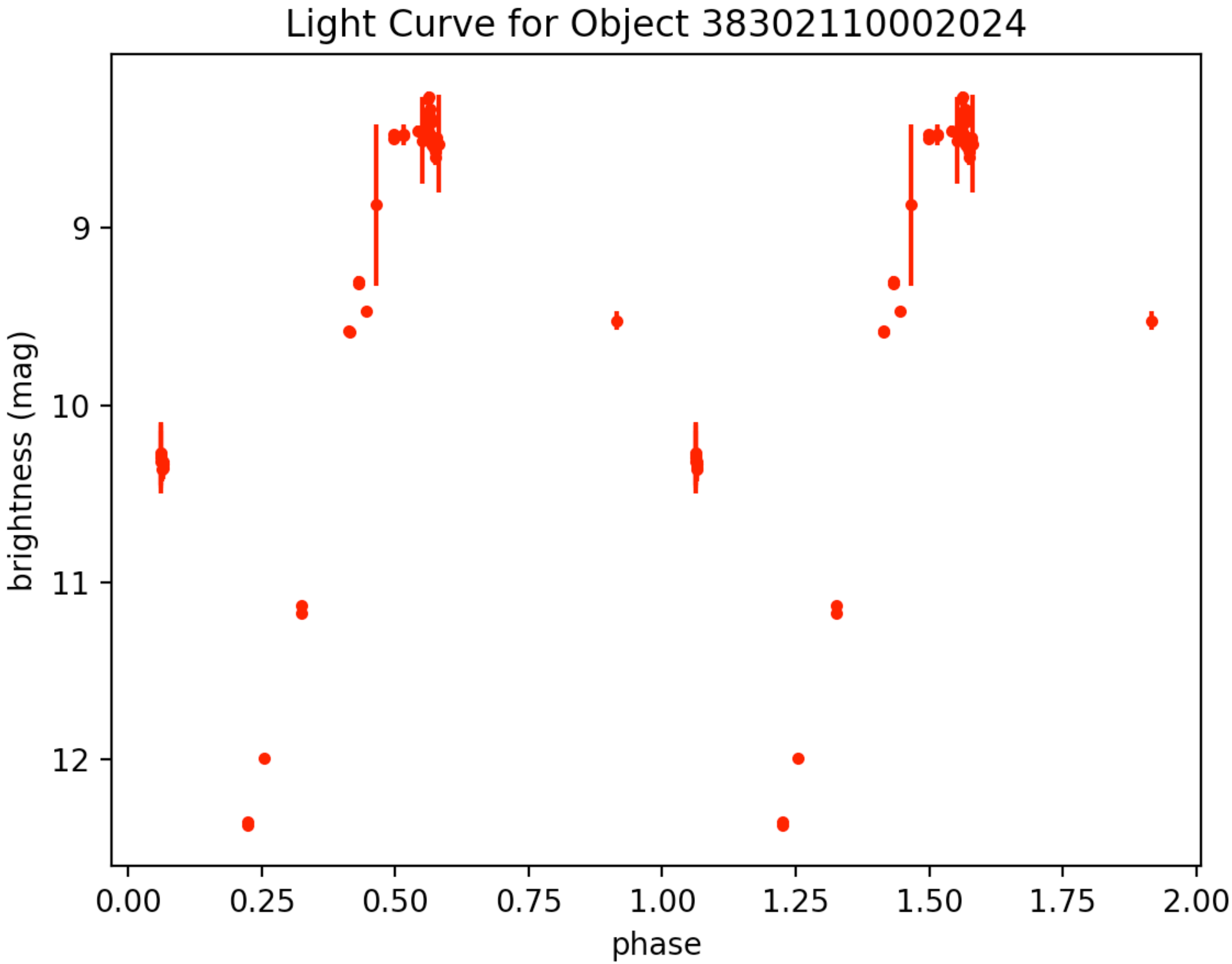
mira6.tbl – 00 32 22.6 +26 01 44 – period: 313.4796238244514 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/ApJS/227/6&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



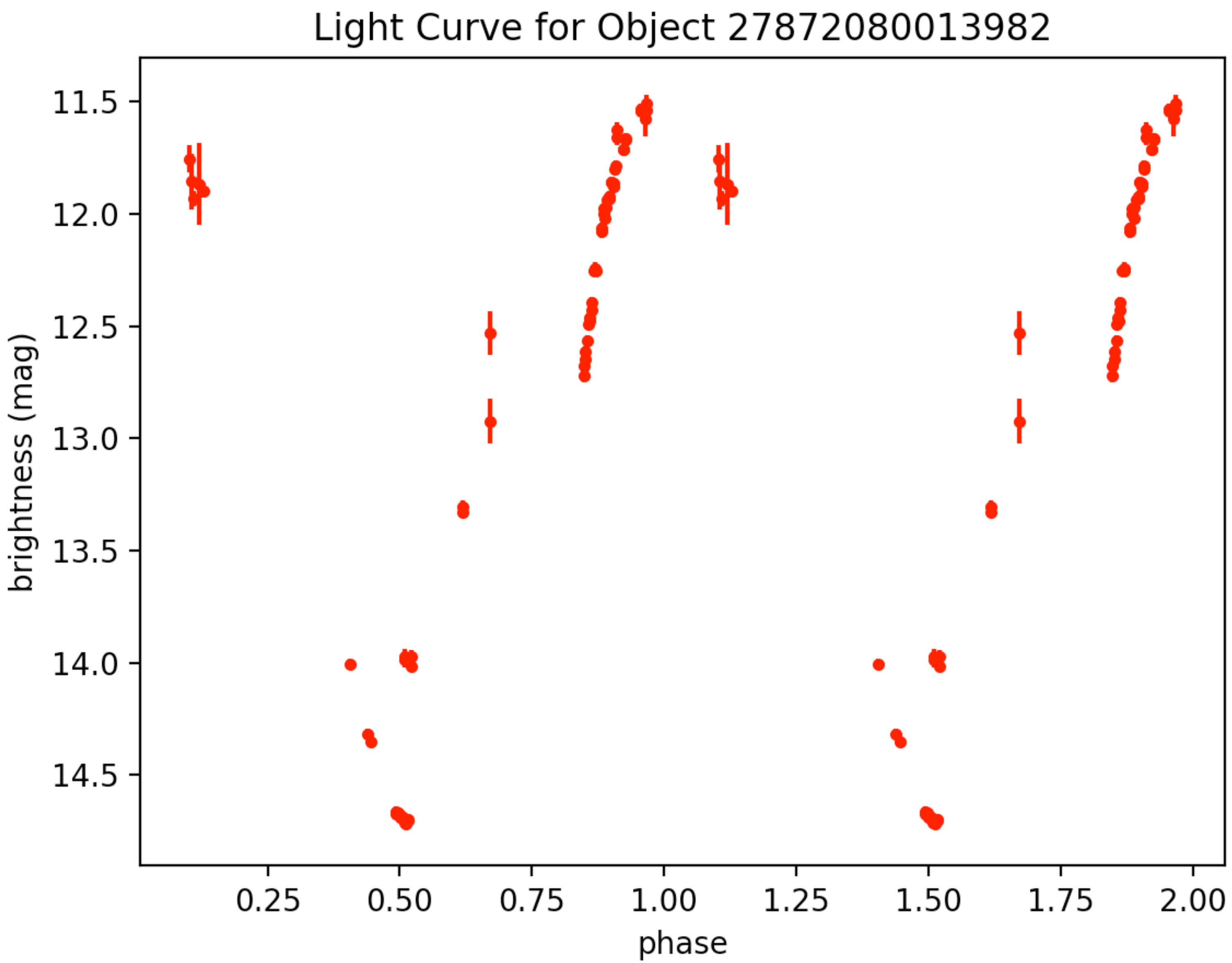
mira8.tbl – 01 03 57.5 +20 11 46 – **period: 96.24639076034649** – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/ApJS/227/6&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



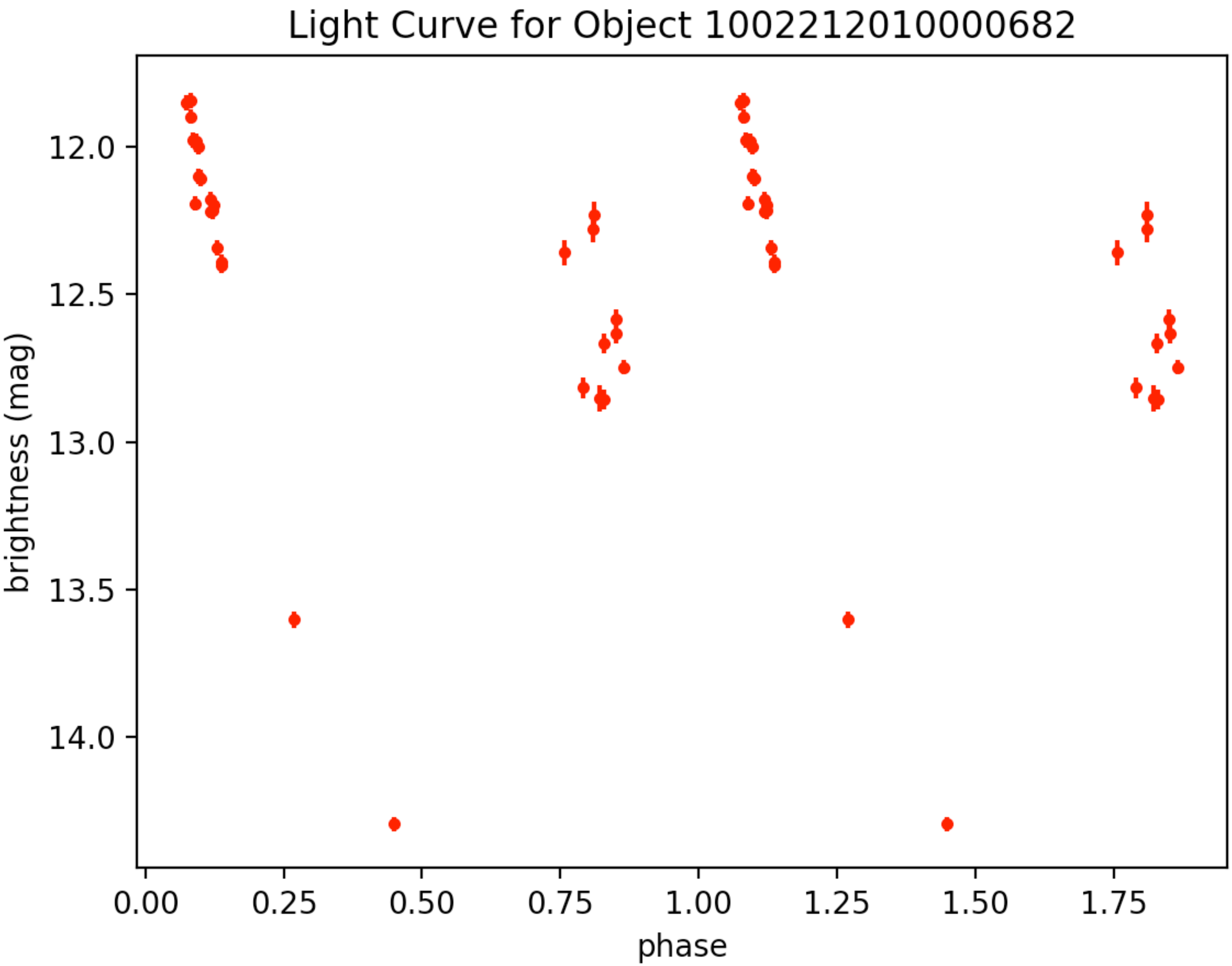
mira10.tbl – 02 16 07.1 +25 03 24 – period: 335.2329869259135 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/ApJS/227/6&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



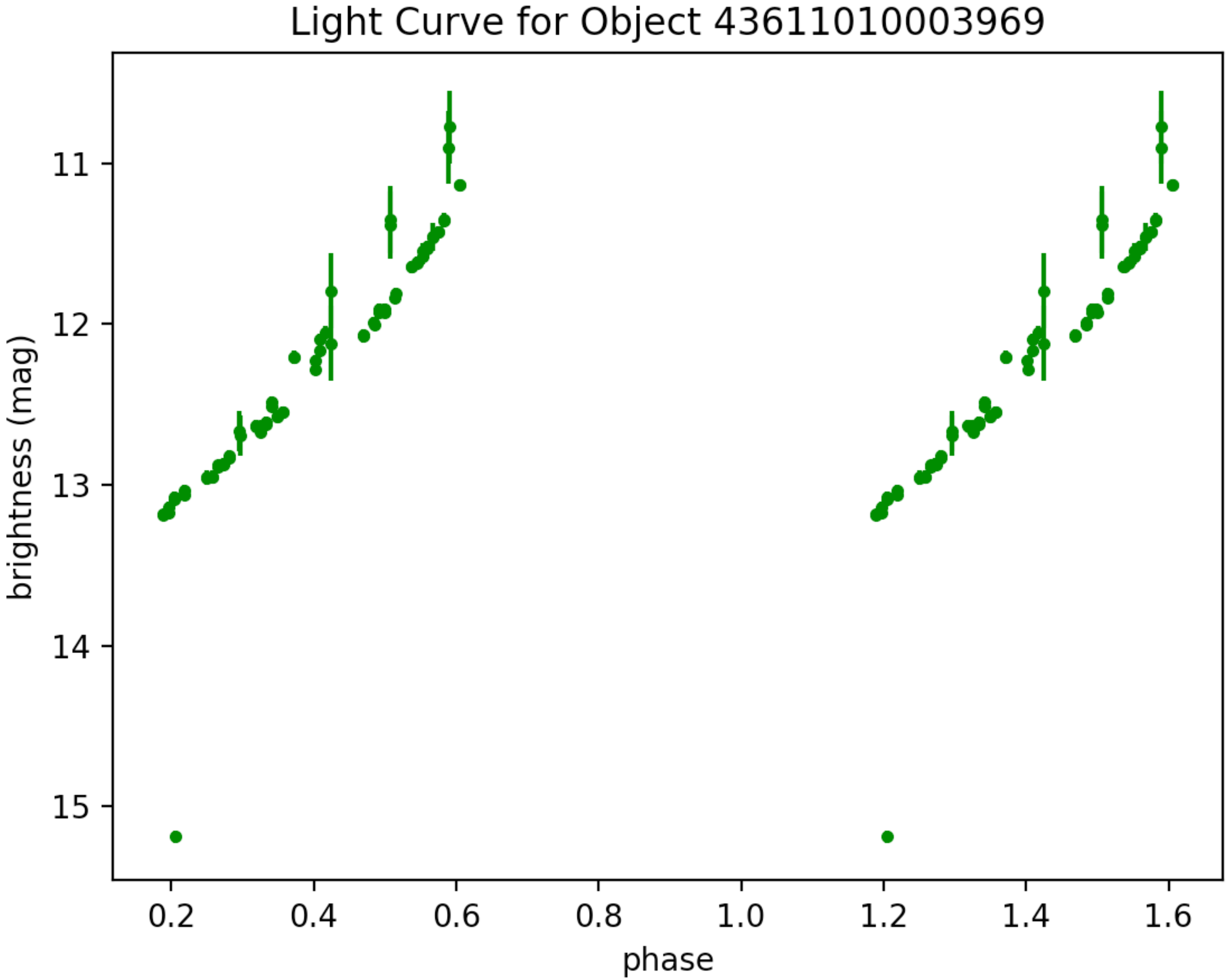
mira18.tbl – 20 39 00.76 +00 55 57.9 – period: 267.379679144385 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/other/NewA/17.504&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



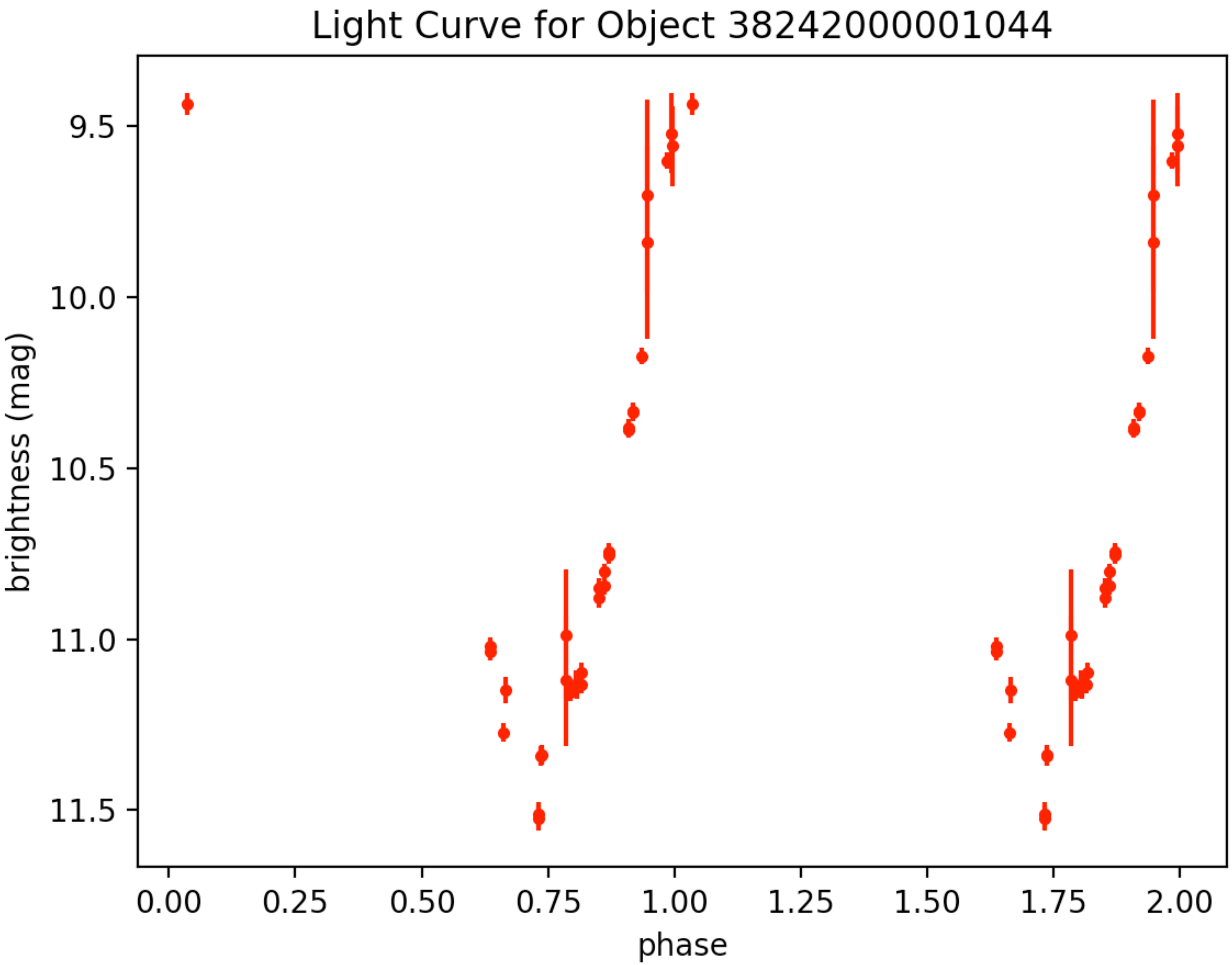
mira18.tbl – 20 39 00.76 +00 55 57.9 – period: 267.379679144385 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/other/NewA/17.504&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



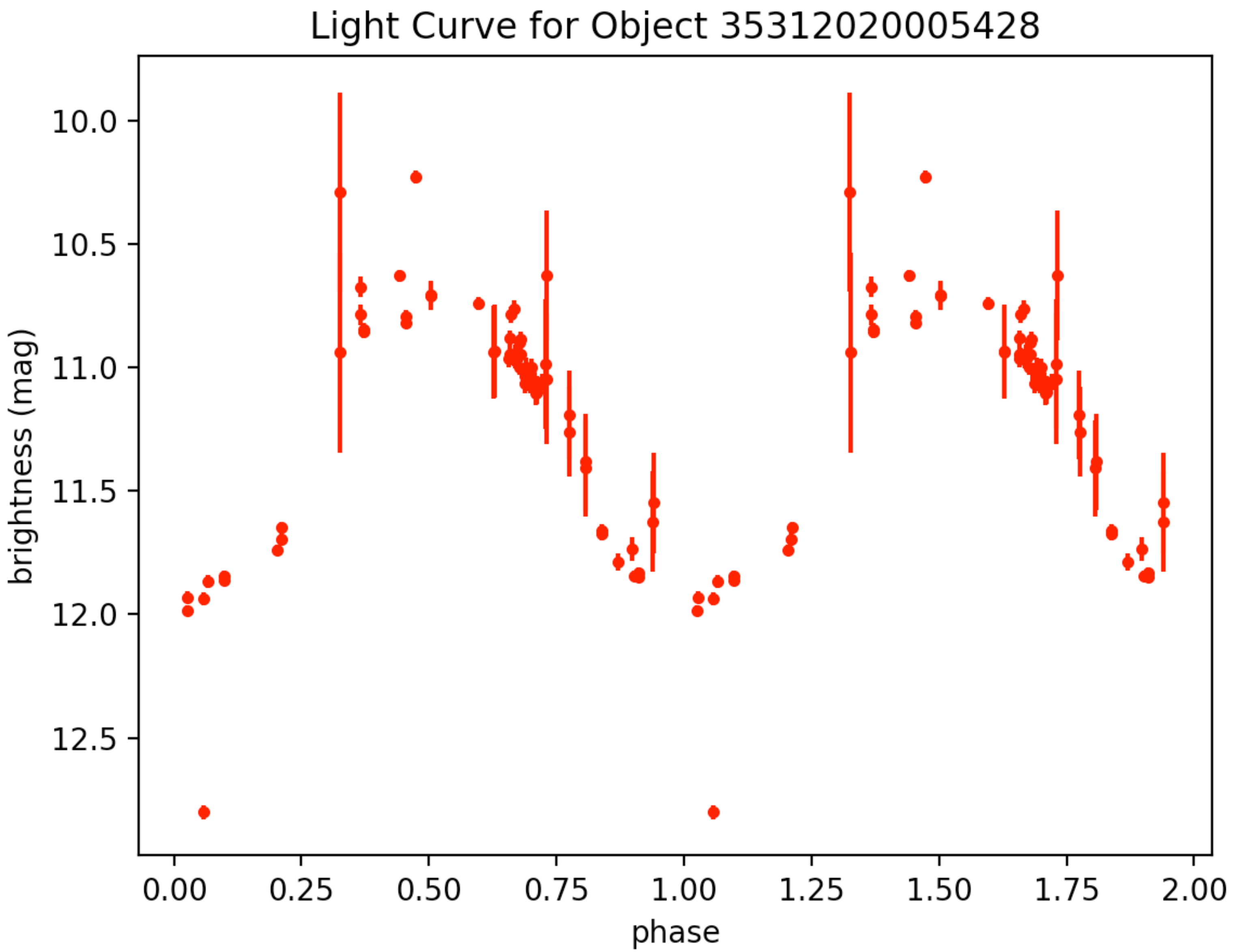
mira24.tbl – 00 04 20.07 +40 06 35.8 – period: 132.27513227513228 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/BaltA/9/646&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



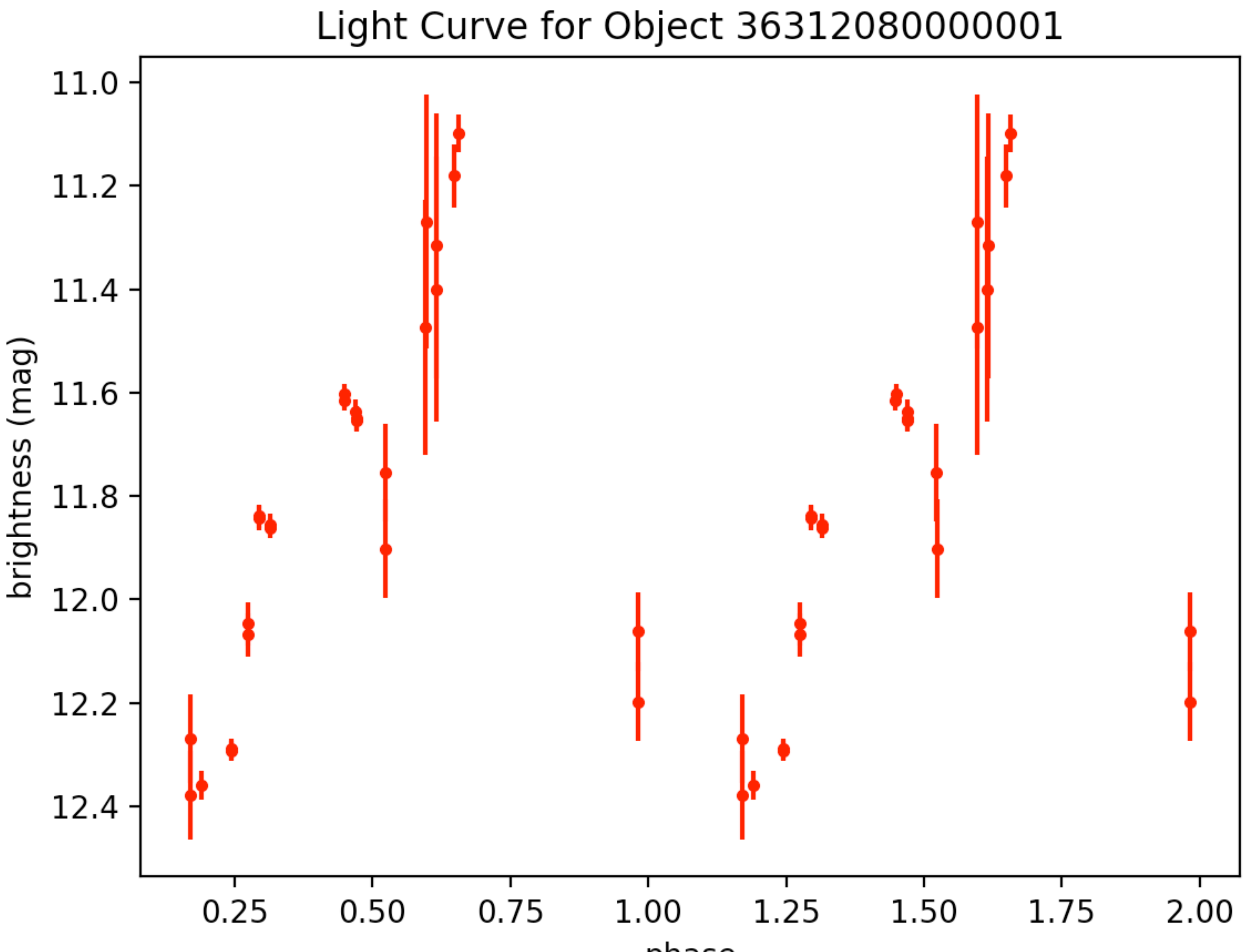
mira25.tbl – 00 32 22.73 +26 01 46.0 – period: 313.4796238244514 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/BaltA/9/646&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



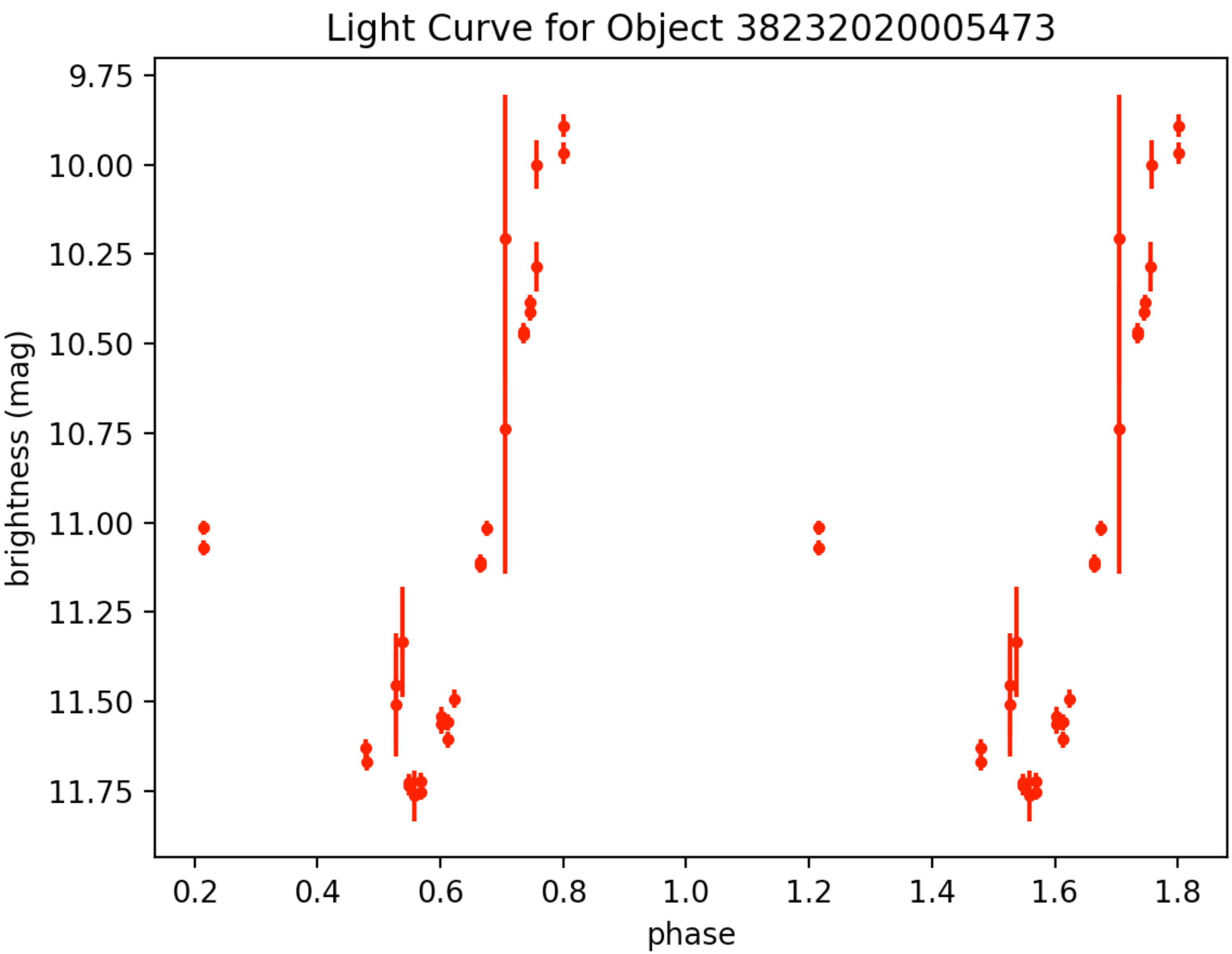
mira30.tbl – 01 03 57.5 +20 11 46 010357+2011.7 – **period: 96.24639076034649** – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/ApJS/227/6



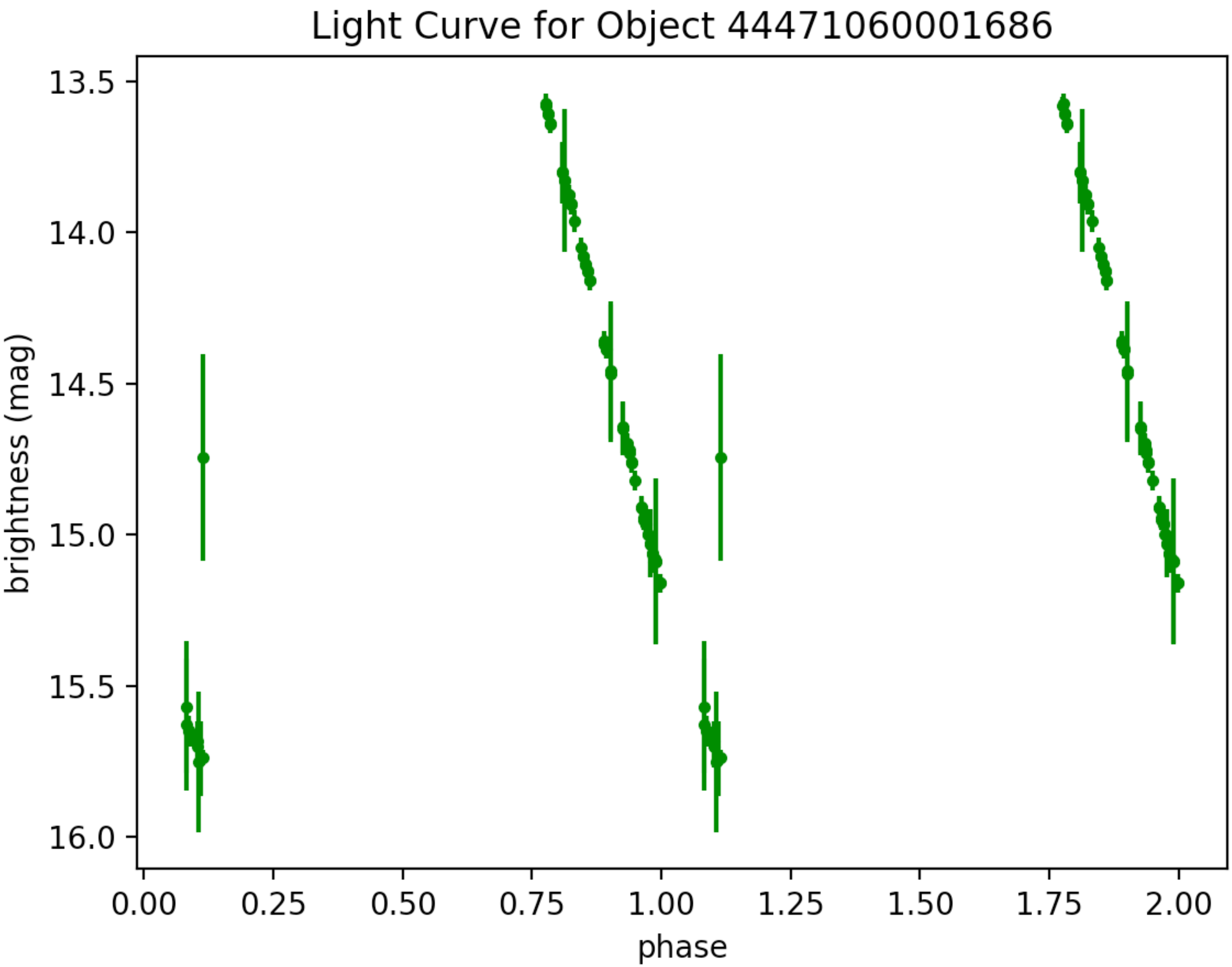
mira30.tbl (same guy, diff. oid) – 01 03 57.5 +20 11 46 010357+2011.7 – **period: 96.24639076034649** – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/ApJS/227/6



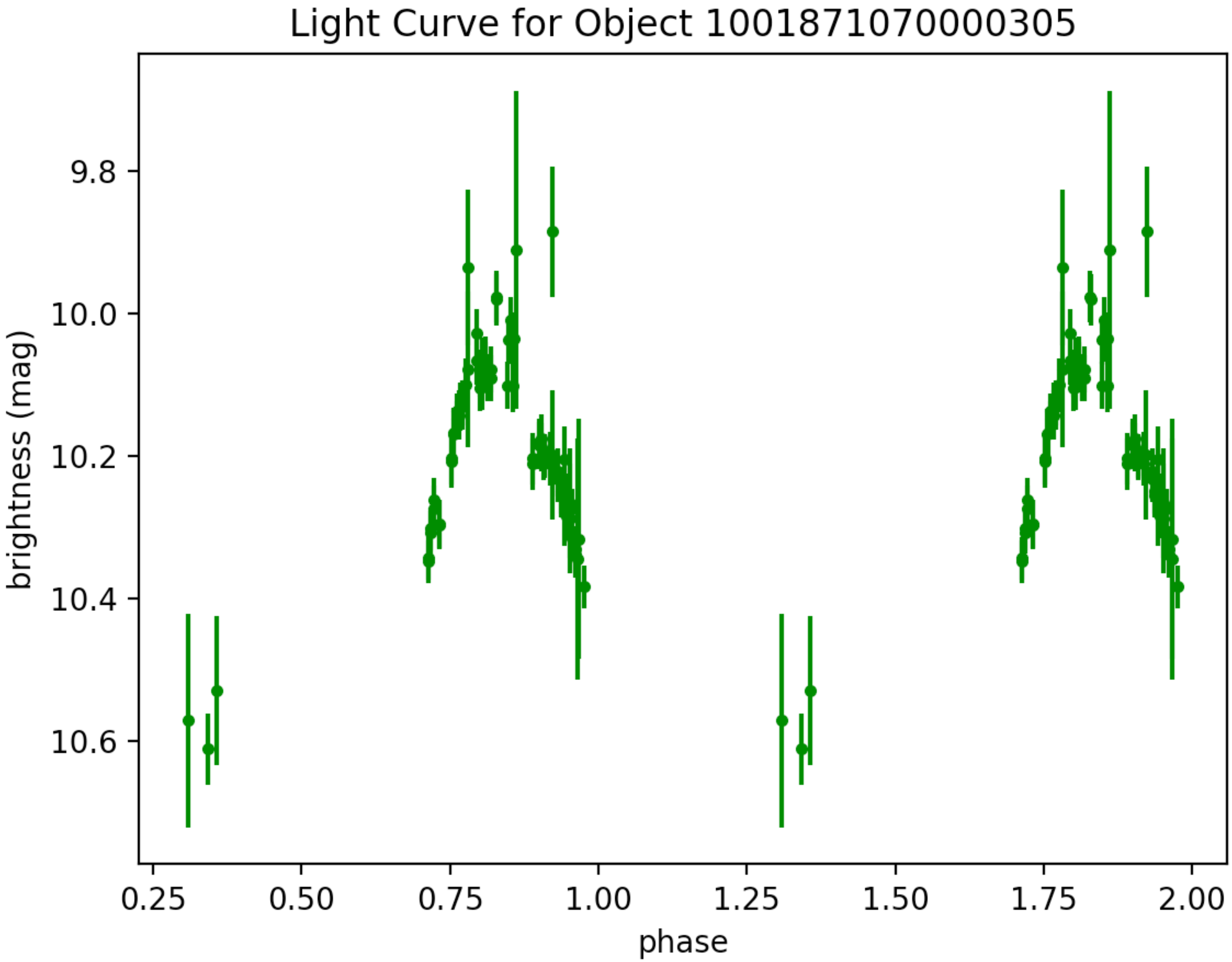
mira31.tbl – 00 22 23.1 +26 59 46 – period: 292.39766081871346 – Found at http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/ApJS/227/6



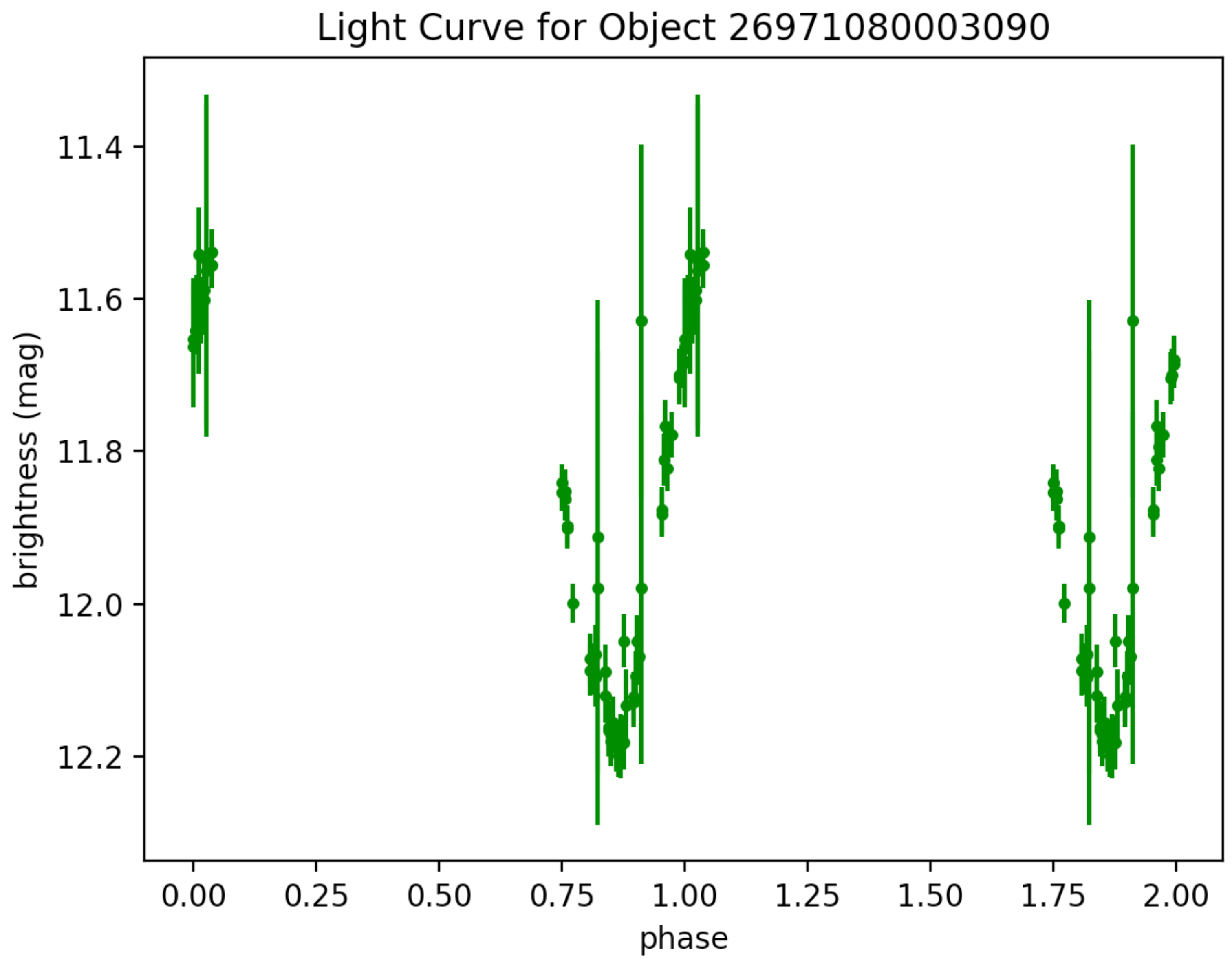
mira38.tbl – 01 15 29.8 +40 43 09 – period: 247.64735017335315 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/317/460/stars&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



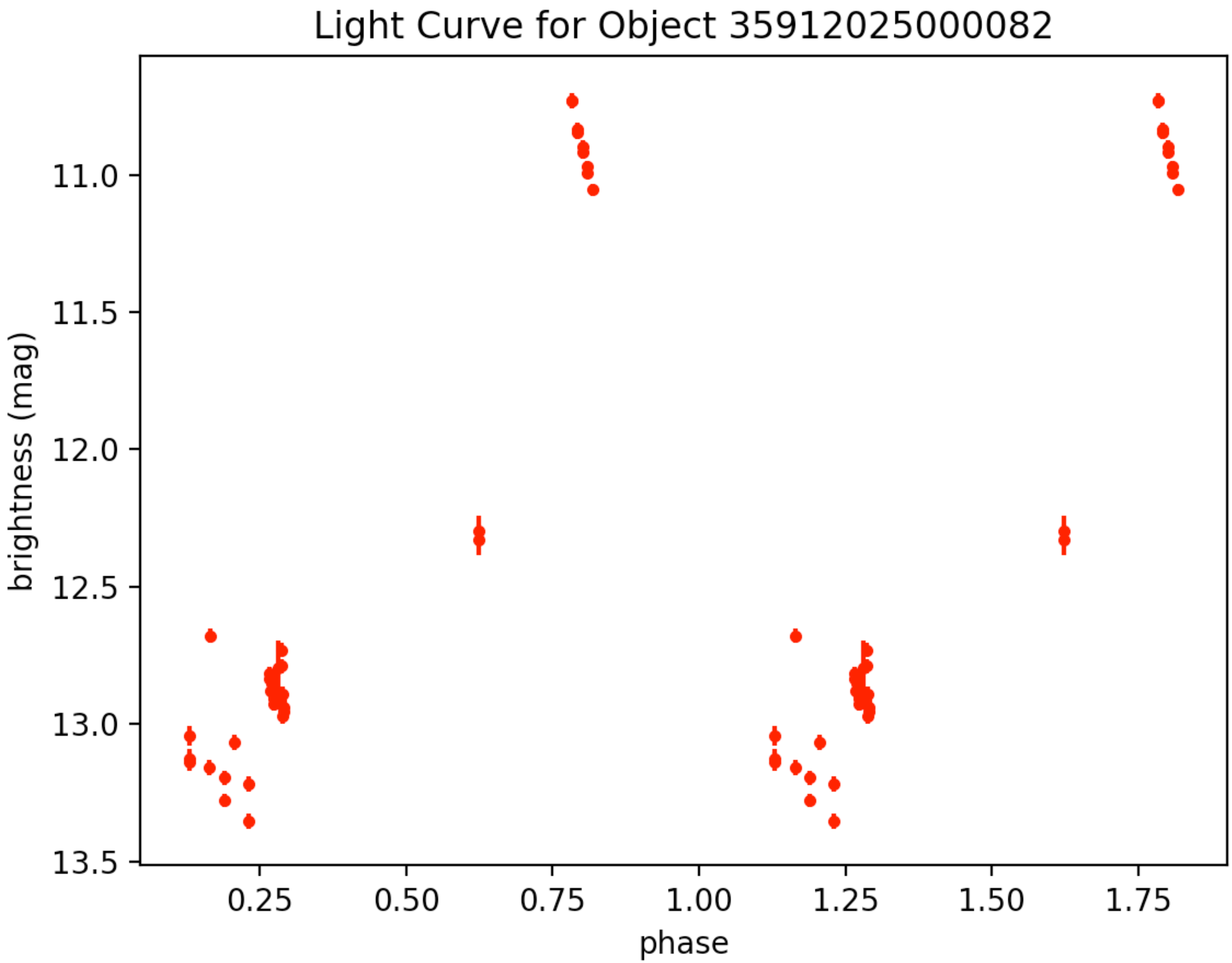
mira40.tbl – 23 14 44.2 +40 47 39 – period: 209.4240837696335 – Found at: http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/317/460/stars&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



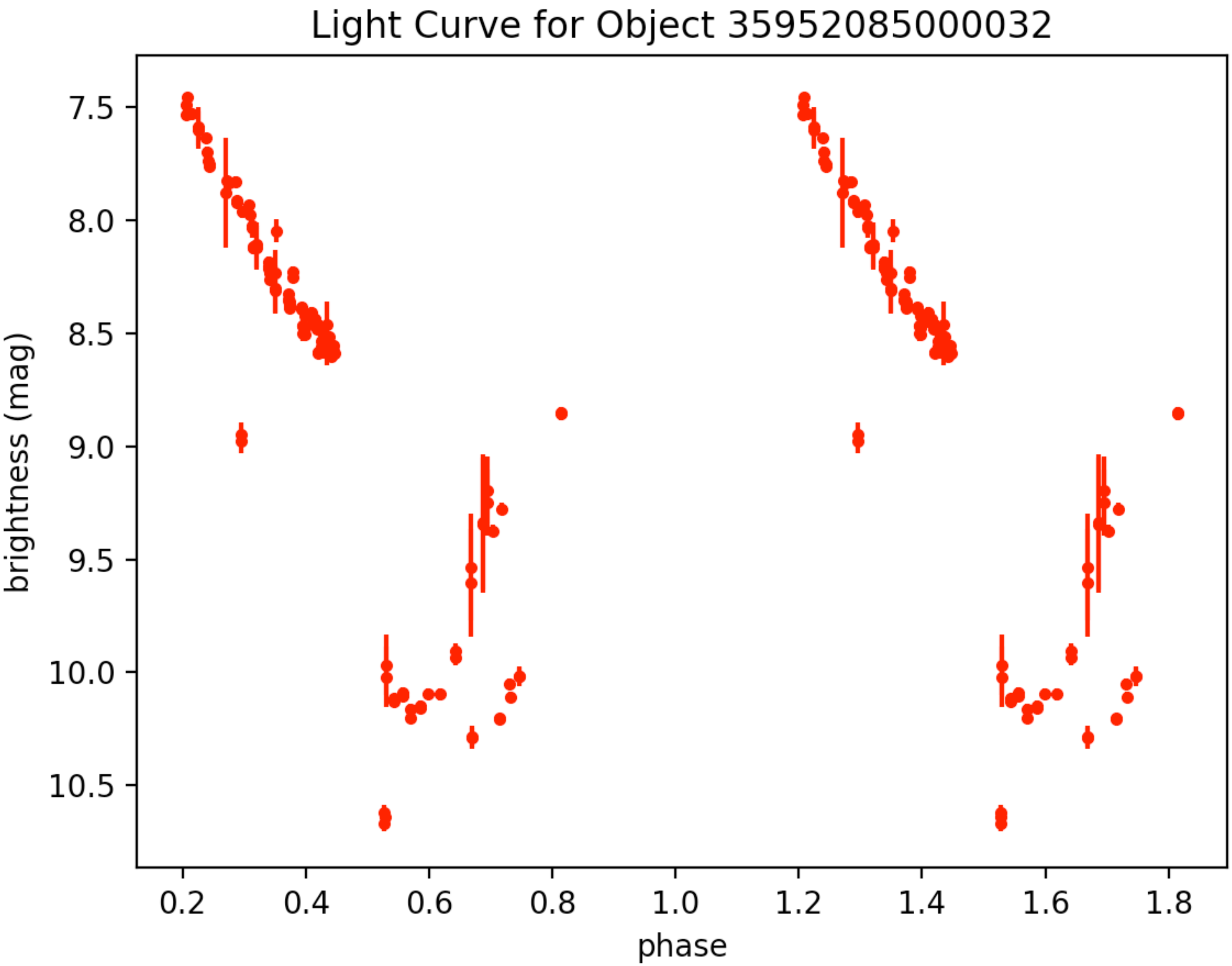
mira42.tbl – 00 05 06.0 +00 43 48 – period: 191.755 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=II/264



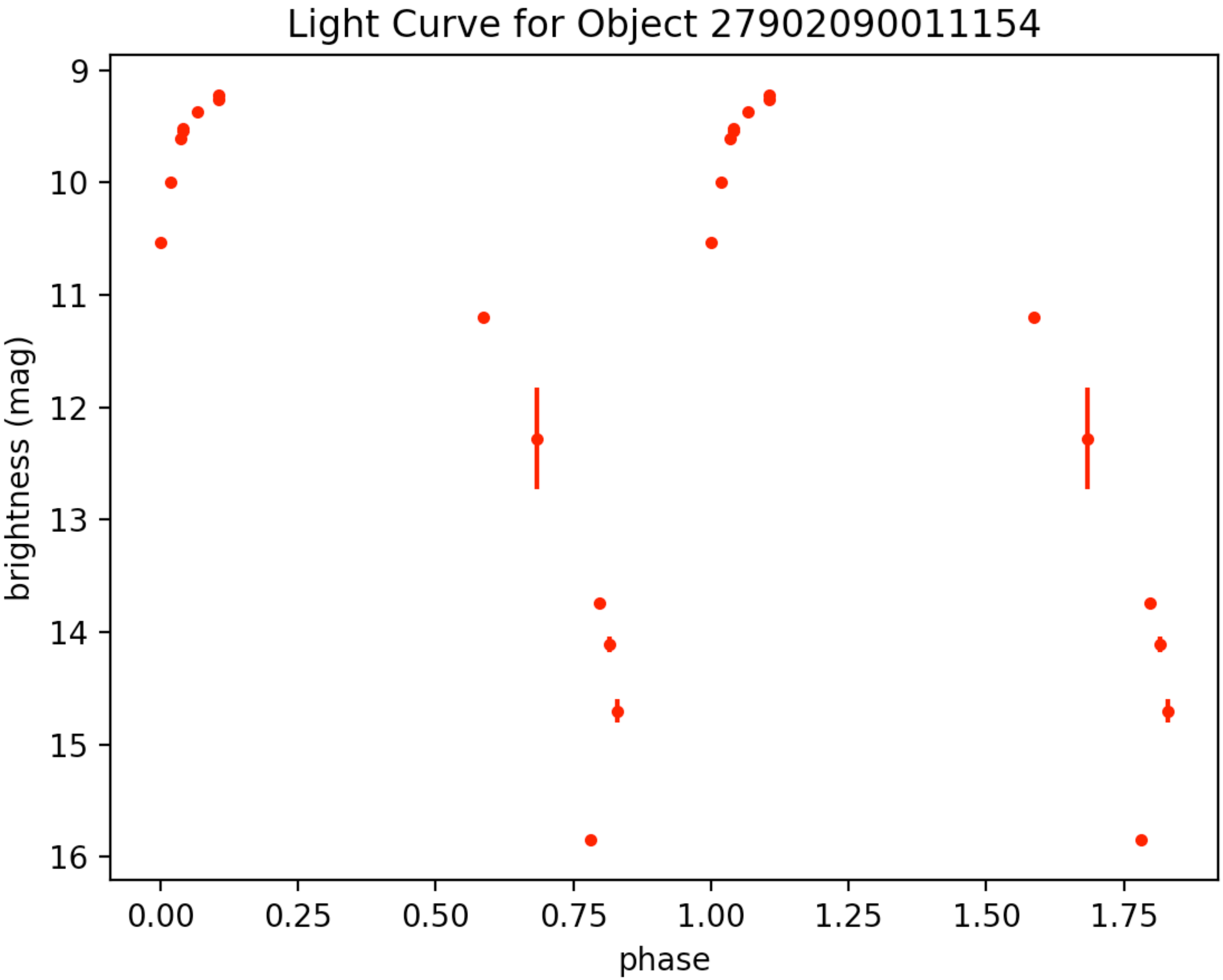
mira49.tbl – 15 27 47.3 +19 33 48 – period: 584.1121495327103 – http://iopscience.iop.org/article/10.1086/338647/pdf



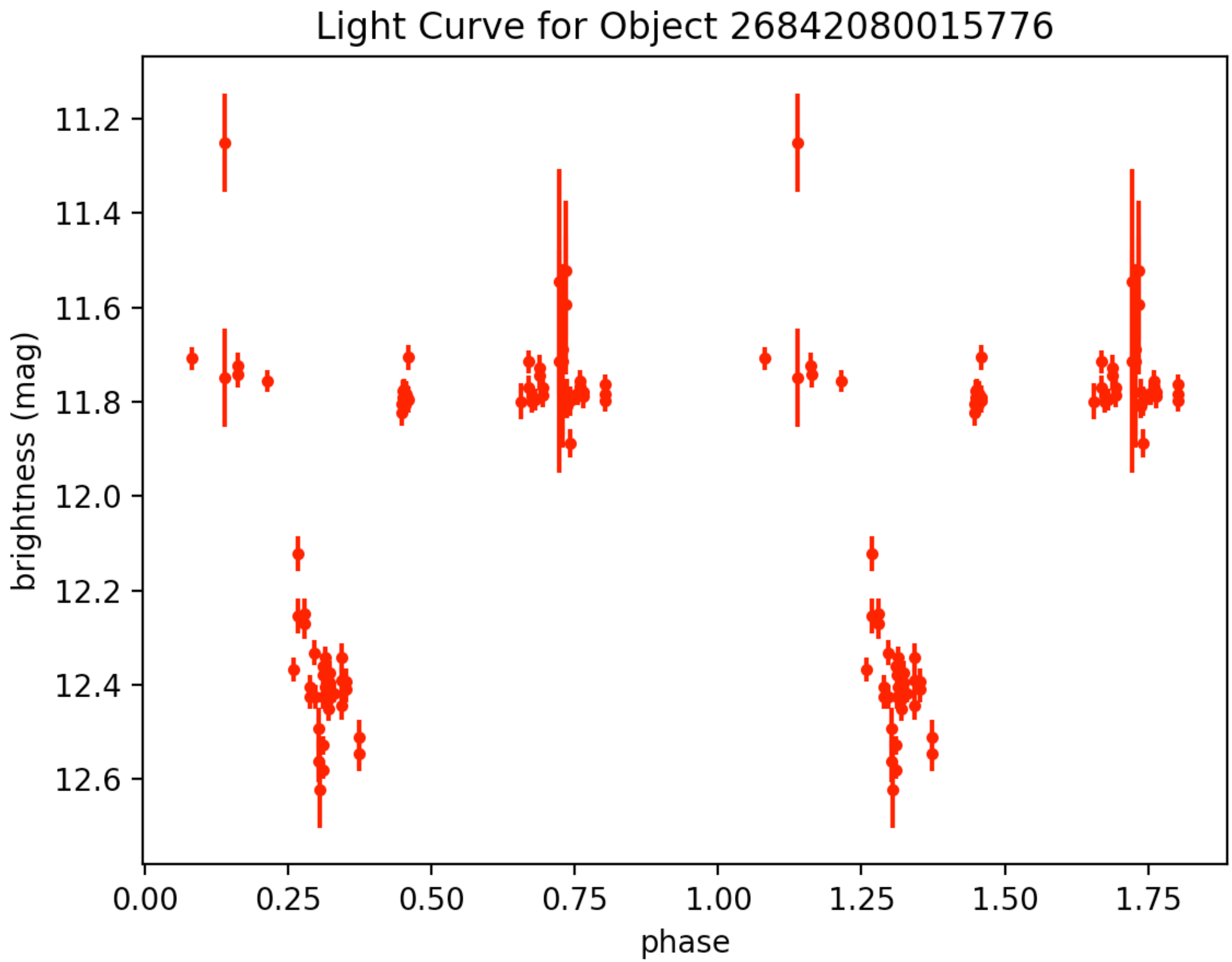
mira50.tbl – 16 25 47.47 +18 53 32.9 – period: 375.234521575985 – http://iopscience.iop.org/article/10.1086/338647/pdf



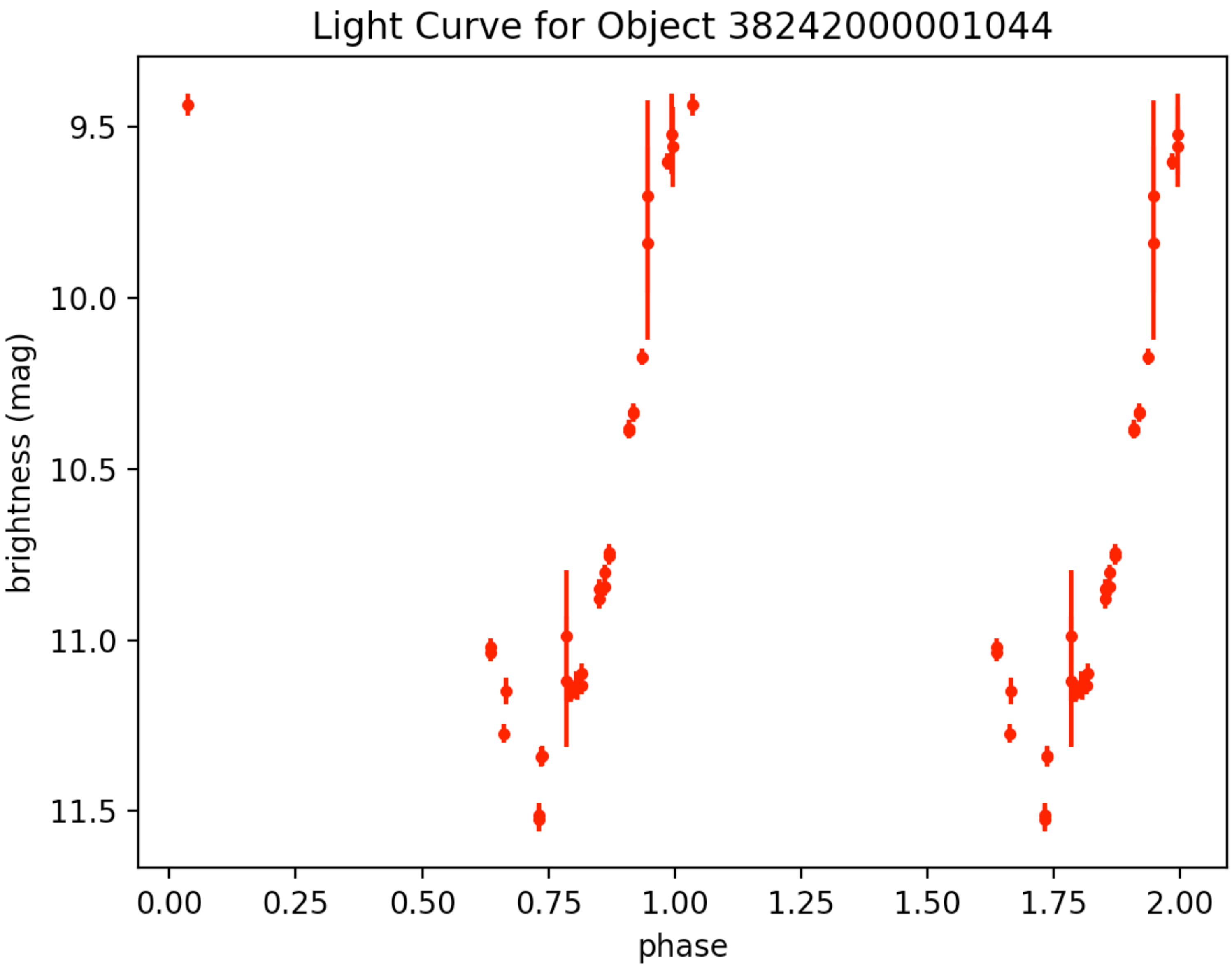
mira63.tbl – 320.77419055 +00.83782056 – period: 226.75736961451247 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/A+A/384/925&-to=3



mira64.tbl – 316.71325944 -01.36506611 – period: 869.5652173913044 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/A+A/384/925&-to=3



mira68.tbl – 8.09472019 +26.02943021 – period: 313.4796238244514 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/A+A/384/925&-to=3



Miras are tough…

- Mira variables ARE harder than RRL (though this will be true for everything, RRL are the best studied variables in astronomy over the past 30 yr). There is also a special reason Mira variables are hard for PTF: Mira variables are intrinsically very bright. Most of the Mira variables in the Galaxy will be so bright that they cause the PTF detectors to saturate. So many Miras are missed by PTF. For now we are going to keep the dataset homogeneous and only work with PTF data, though we may decide to adjust that in the future.
- Nervous about using sources that are very bright because PTF saturates around 13.5 or 14 mag.
- Options to adjust
  - Southern PTF (see questions)
  - See next slide

Again: finding golden/average miras is more challenging than RR Lyraes.

To be a mira technically speaking: peak to peak amplitude (twice from cesium) for miras has to be greater than 2.5 magnitudes in V band (filter a little more red than g filter)

If we can't find sufficiently 'good' ones, here is an alternative:

http://www.astronet.ru/db/varstars/msg/eid/PZP-14-0009

See L.Curve & Data!

Questions

- ? when multiple oid's ?
- How do frequencies add? (RRd combo of fundamental and first overtone)
  - add like f = f1 + f2 or reciprocals?
- Plan for what to work on for the next 10 days
  - next couple of things

Questions

- Why didn't variable star catalogue -> any miras? Even the non negative second numbers…
  – I know –numbers are bad, but some positive lead to no sources found as well
  – It found 18 02 29.44 -30 24 14.1 ?
  – looking at a lot of data => going to see a lot of weird things - will eventually start to notice patterns
  – Pattern for what missed ptf?
- Two types of RA and DEC – how to convert?
  – 23.04642 30.54967 -> what? (this is a mira)
  – the following link works for converting! - http://www.astrouw.edu.pl/~jskowron/ra-dec/?q=+23.04642+30.54967
  – the link the flexible converter not working for me

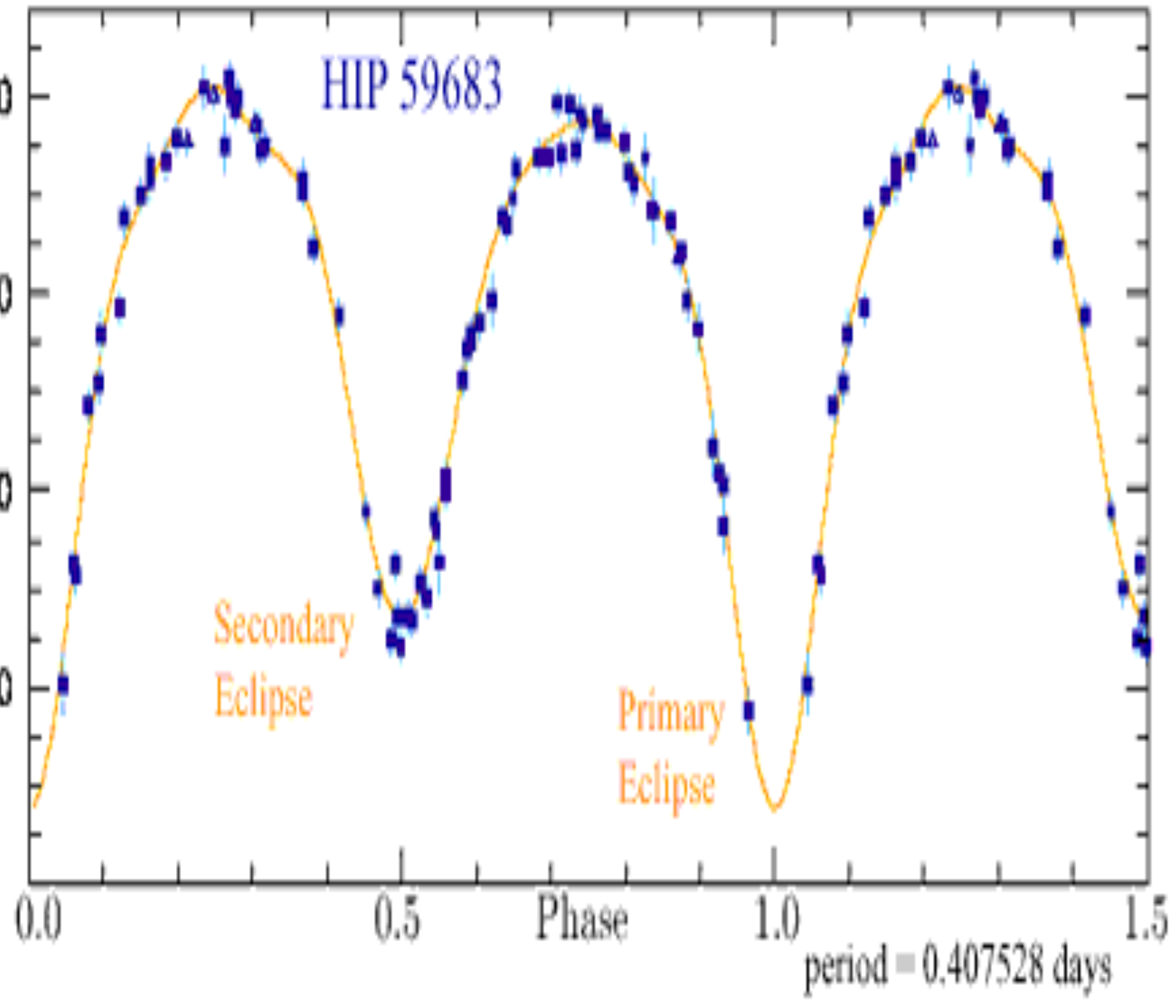
Week 6

Quick remark about amplitude…

lyrae (type)	by 'hand'	cesium freq1_amplitude1	cesium amplitude
gold/avg (c)			
lyrae8.tbl (c)	0.19	0.173612	0.5725
lyrae3.tbl (c)	0.19	0.175292	0.329
lyrae21.tbl (c)	0.16	0.174313	0.278
lyrae34.tbl (c)	0.18	0.17272	0.2005
lyrae27.tbl (c)	0.14	0.155065	0.178
lyrae39.tbl (c)	0.135	0.149759	0.1555
gold/avg (ab)			
lyrae32.tbl (ab)	0.425	0.282298	0.5625
lyrae9.tbl (ab)	0.475	0.347032	0.607
RRL9DiffOID	0.475	0.347032	0.607
lyrae10.tbl (ab)	0.515	0.348594	0.5275
RRL10DiffOID	0.5	0.348594	0.5275
lyrae20.tbl (ab)	0.485	0.316273	0.534
lyrae1.tbl (ab)	0.3	0.237879	0.5315
RRL1DiffOID	0.384	0.237879	0.5315
lyrae7.tbl (ab)	0.42	0.296446	0.541
RRL7DiffOID	0.35	0.296446	0.541
non-gold/avg			
lyrae35.tbl (c)	0.215	0.16538	0.252
RRL35DiffOID (sparse)	0.11	0.16538	0.252
lyrae37.tbl (c)	0.2175	0.162072	0.225
lyrae4.tbl (goldAB)	0.5	0.36683	0.604
lyrae6.tbl (avgAB)	0.5	0.325443	0.558

Amplitude

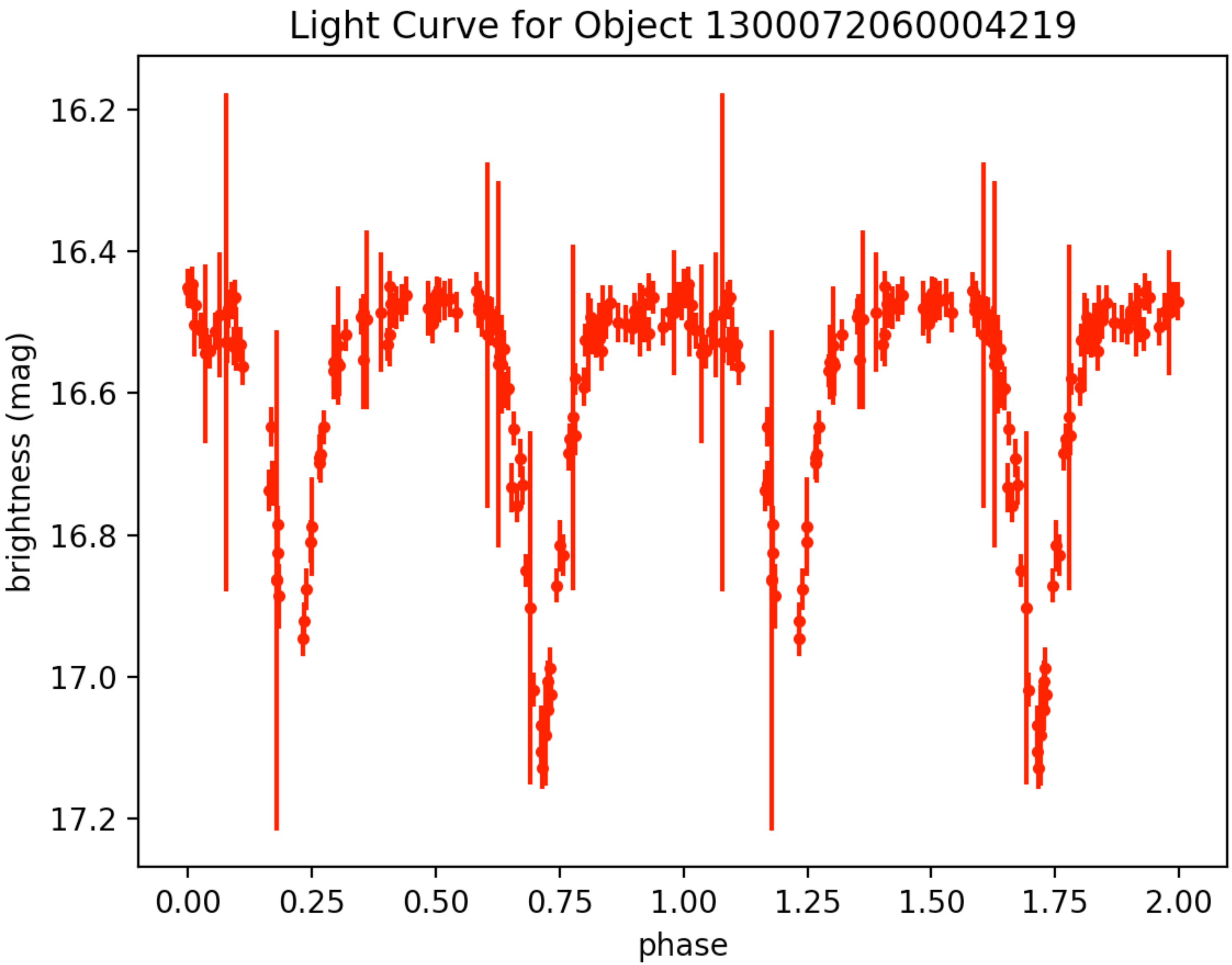
- If source is periodic and symmetric, freq1_amplitude1 is good
- If periodic and asymmetric (e.g. RRab), ½(freq1_amplitude1 + amplitude) is good
- But **we are** also **attempting to classify non-periodic light curves and we don't know up front if the source is periodic**
  - **Can have zooniverse user 'eye-ball' and report an approximate value**



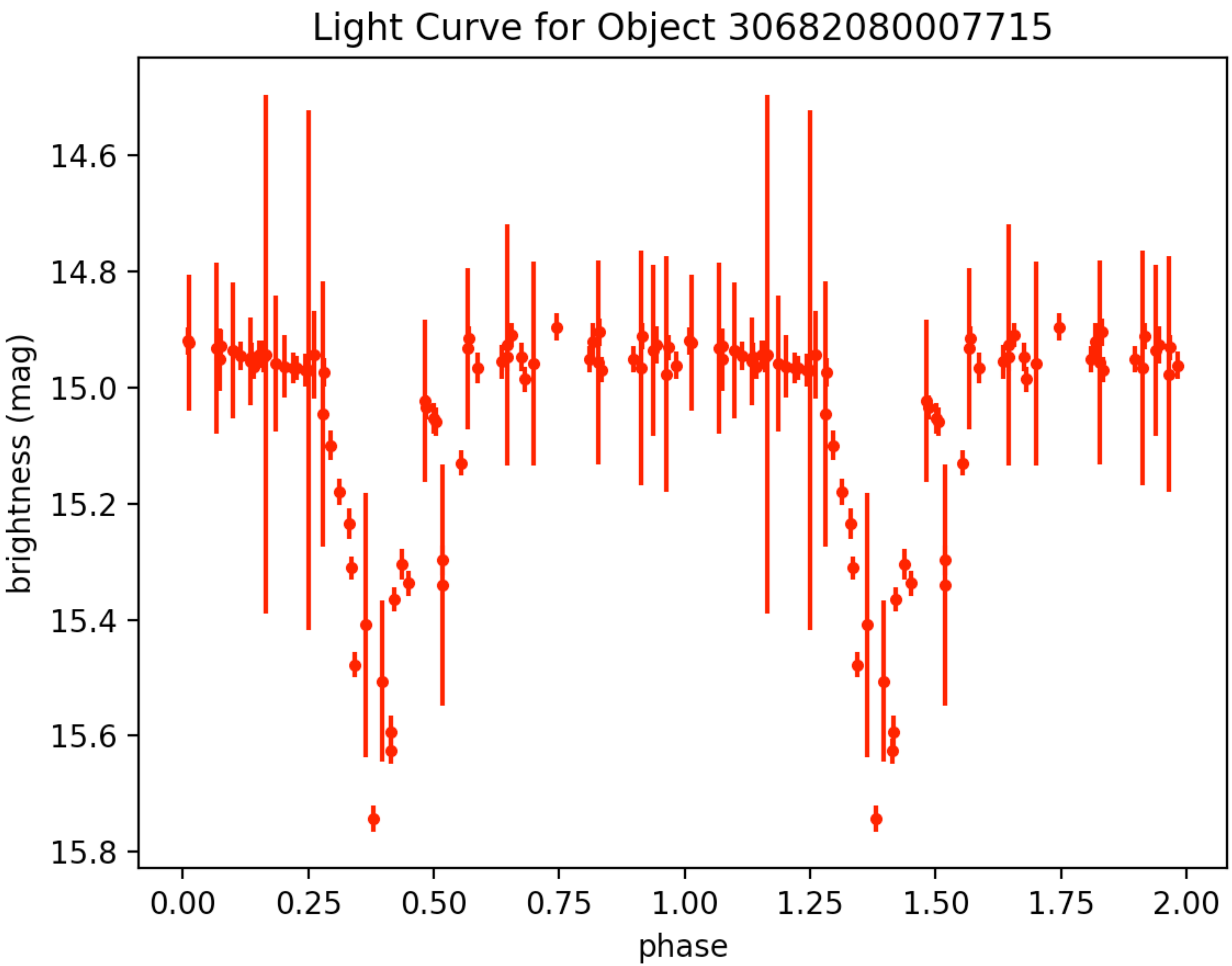
"The periods of **eclipsing variables** are generally in the range of 0.25 to ten days because, as mentioned above, most eclipsing variables are likely to be close binaries. But some eclipsing variables -- especially those containing giant or supergiant components -- have periods as long as several decades" (Percy textbook).

Best EB LCs…

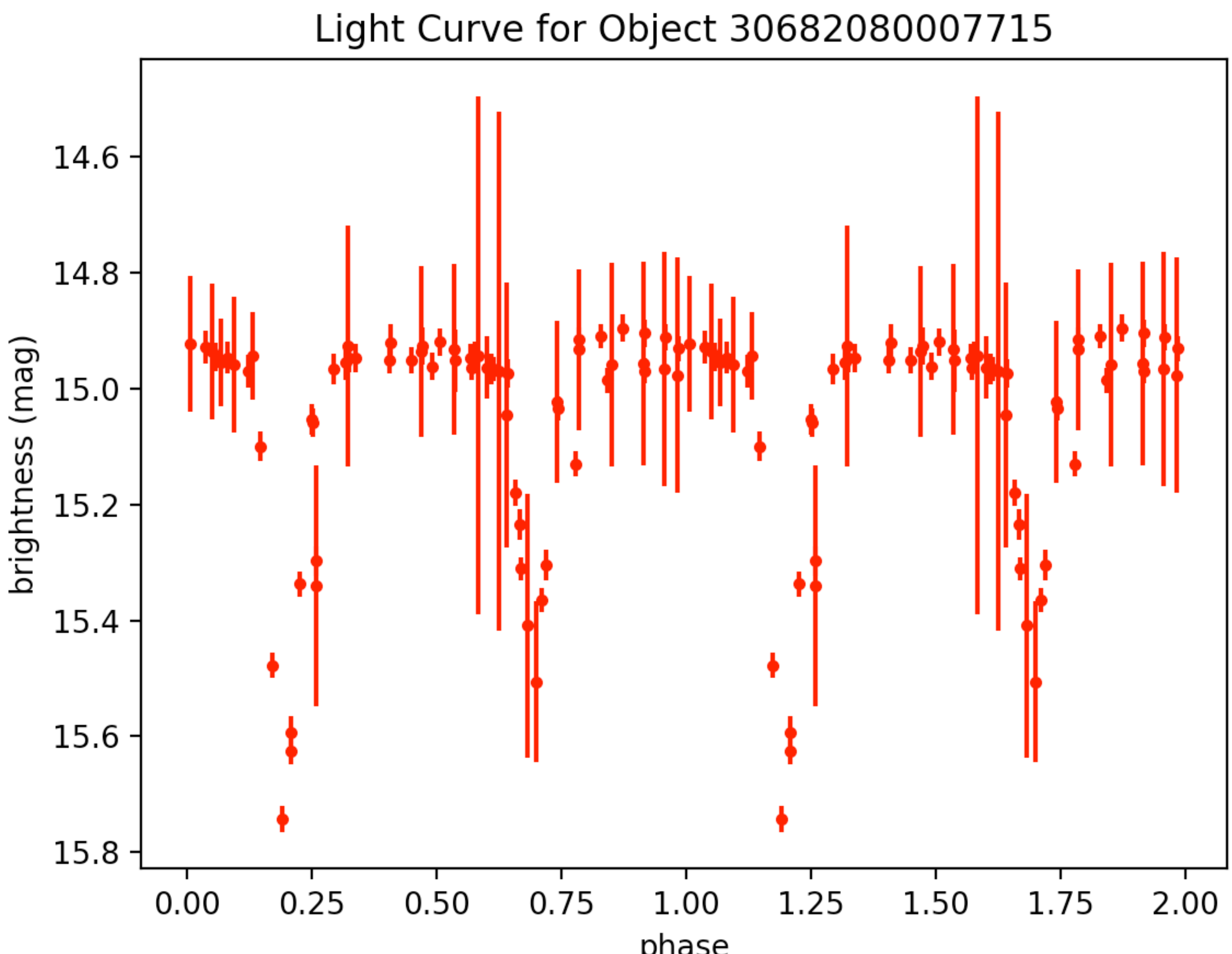
eb152.tbl – 14 29 38.946 +05 46 21.44 – period: 0.3432616031003388 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows] – with T'=2T – use for poster



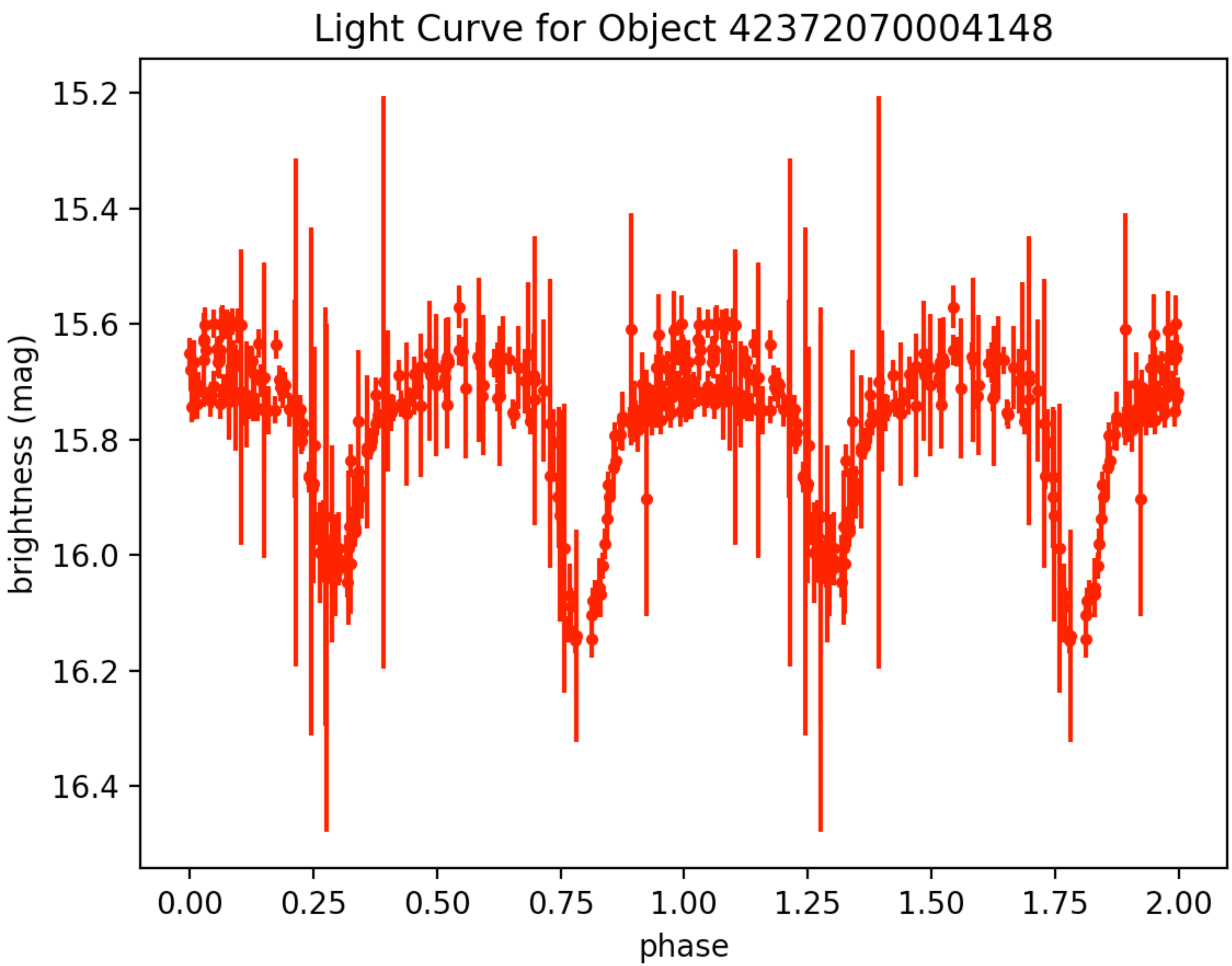
eb142.tbl – 12 53 45.732 +07 45 36.69 – period: 0.3443305628496246 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



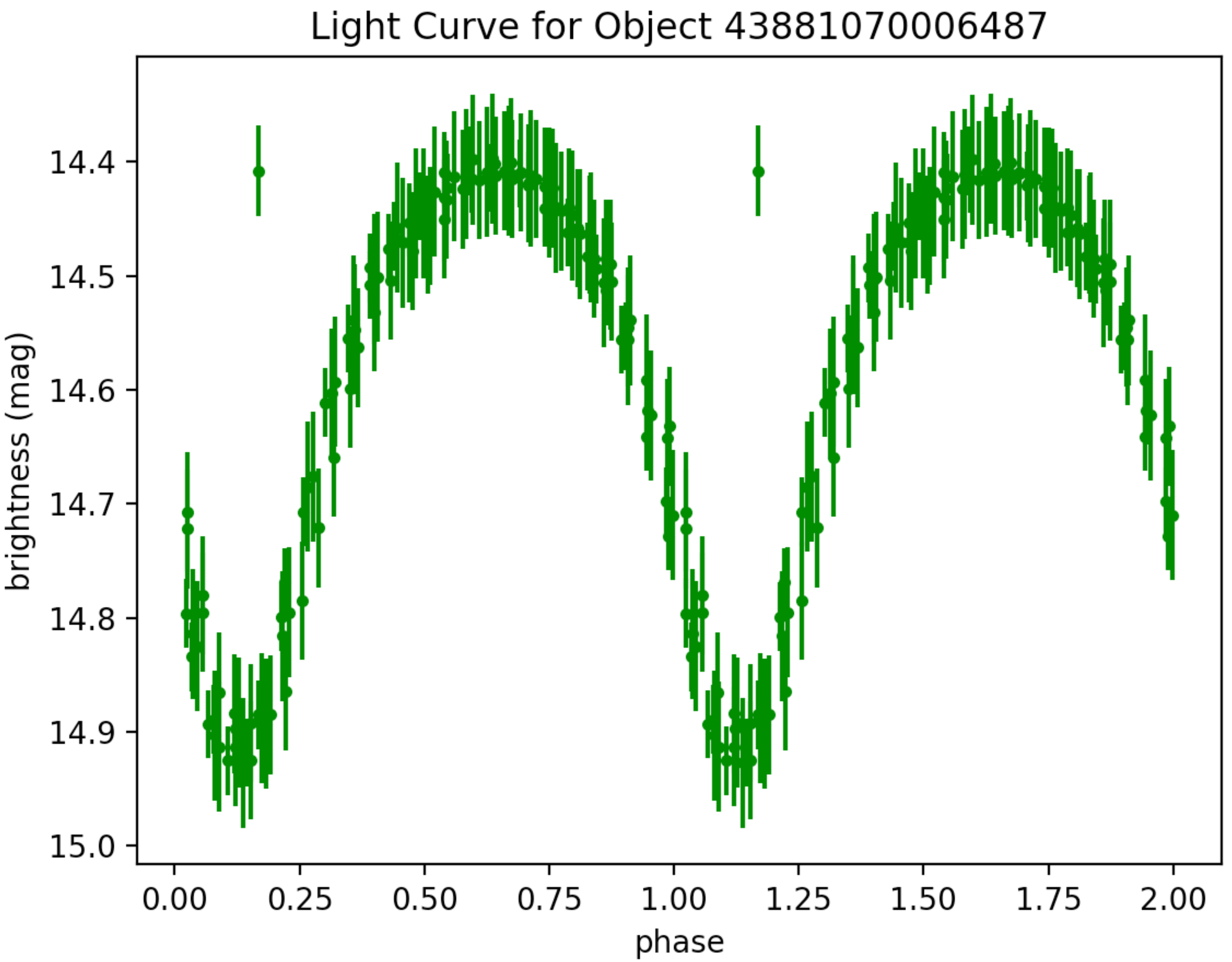
eb142.tbl – 12 53 45.732 +07 45 36.69 – period: 0.6886611256992492 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



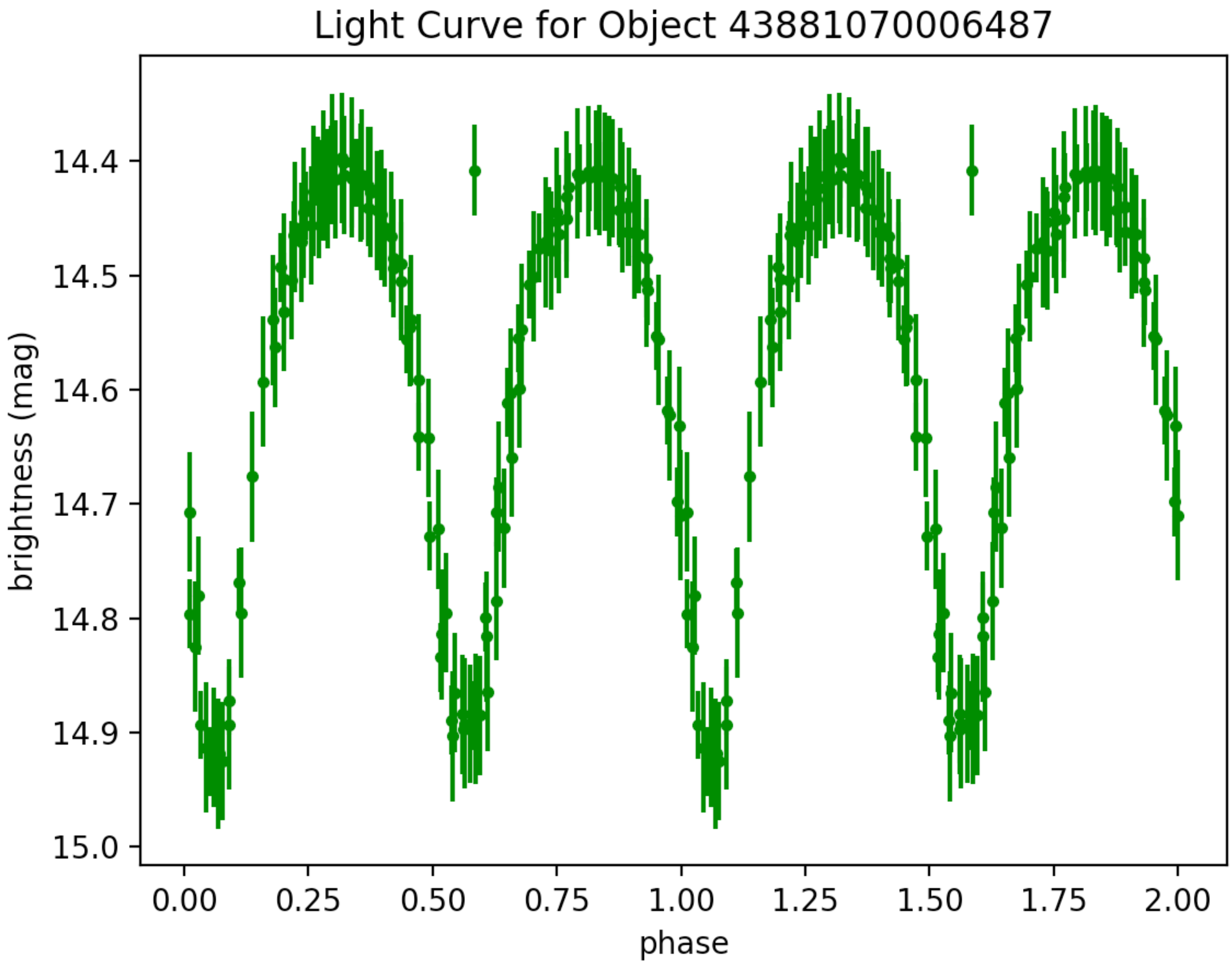
eb145.tbl – 13 03 12.100 +34 16 47.53 – period: 0.9702577198555481 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



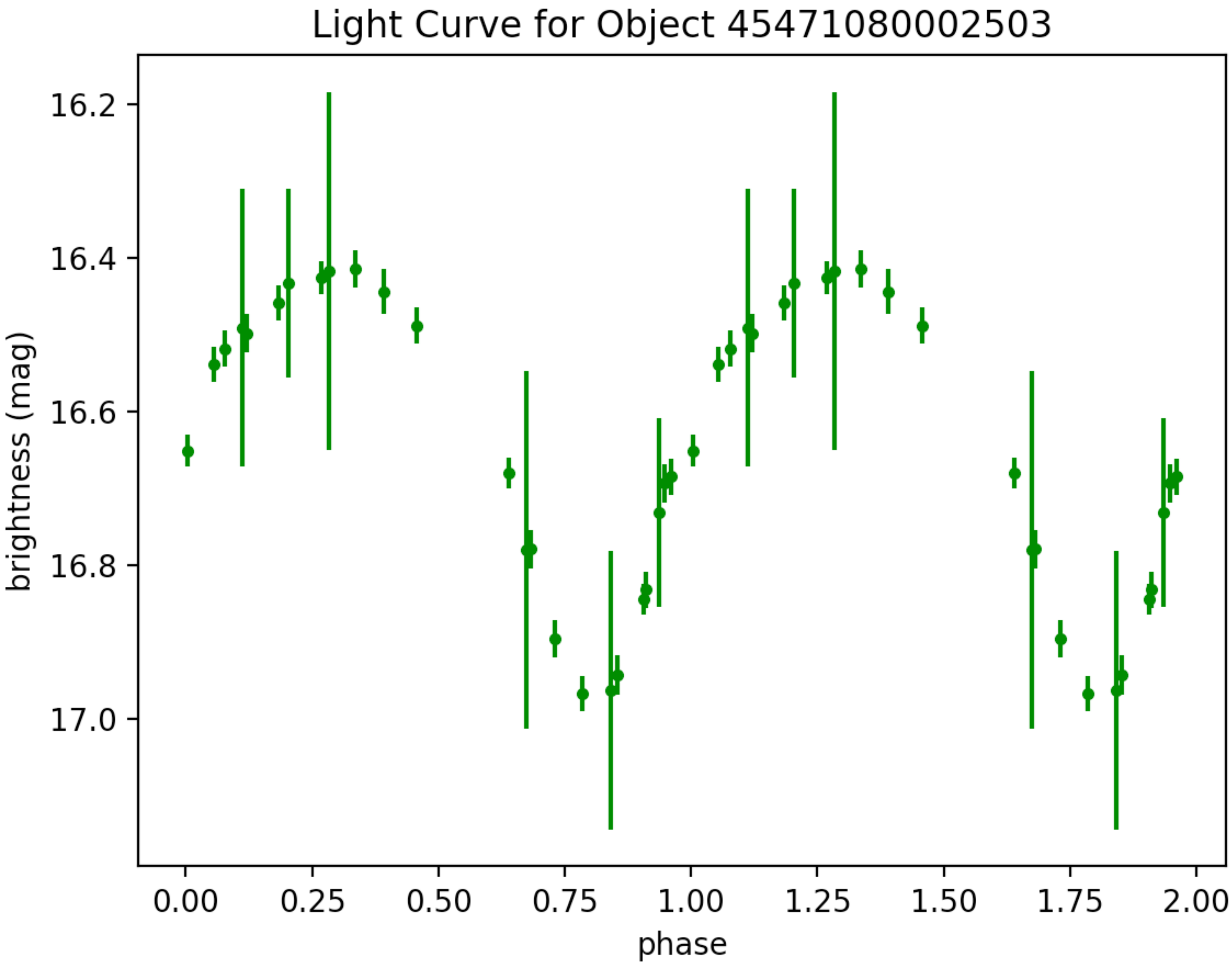
eb110.tbl – 119.858231 +39.112766 – period: 0.2138885995451445 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101



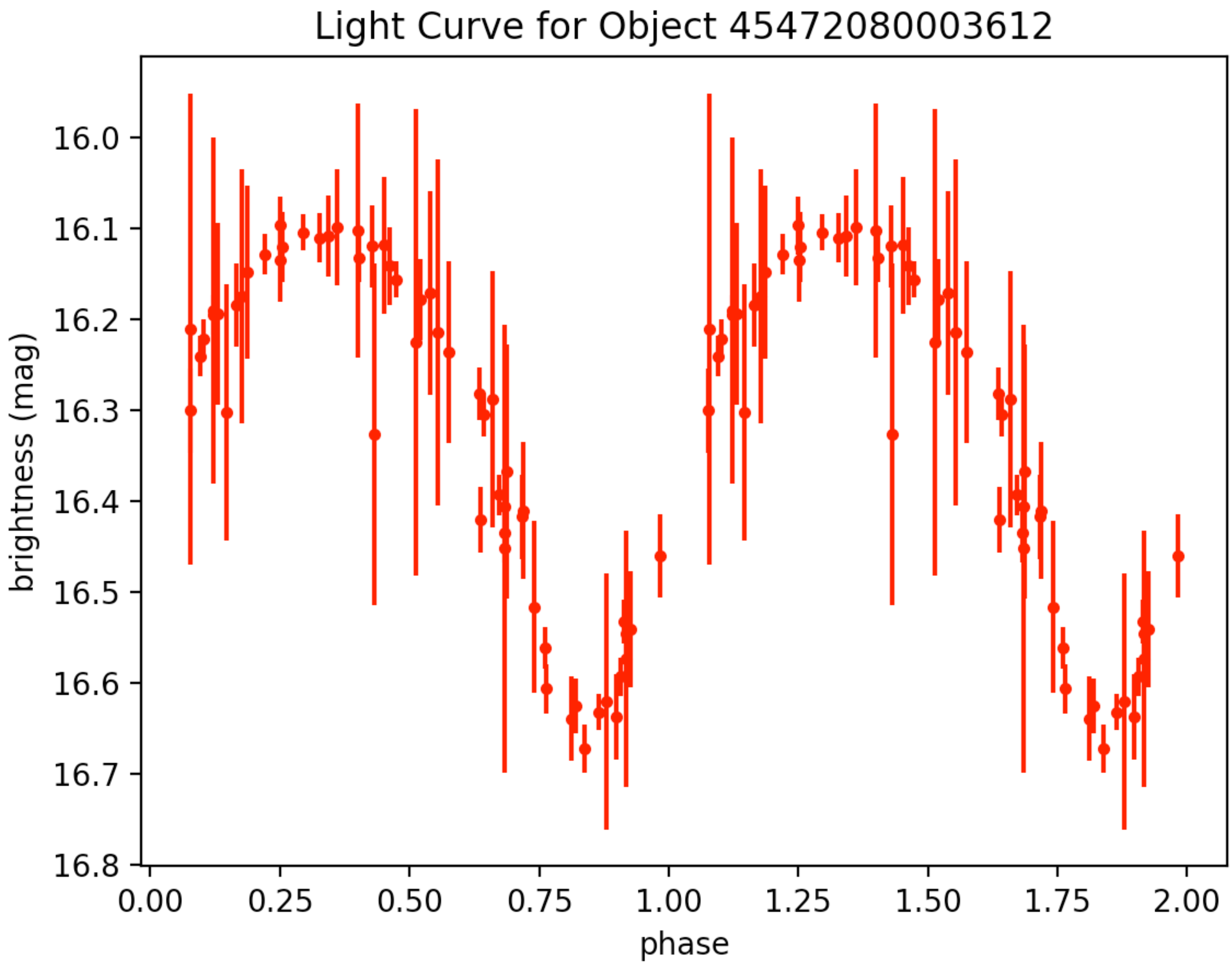
eb110.tbl – 119.858231 +39.112766 – period: 0.427777199090289 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101 – with T’ = 2T



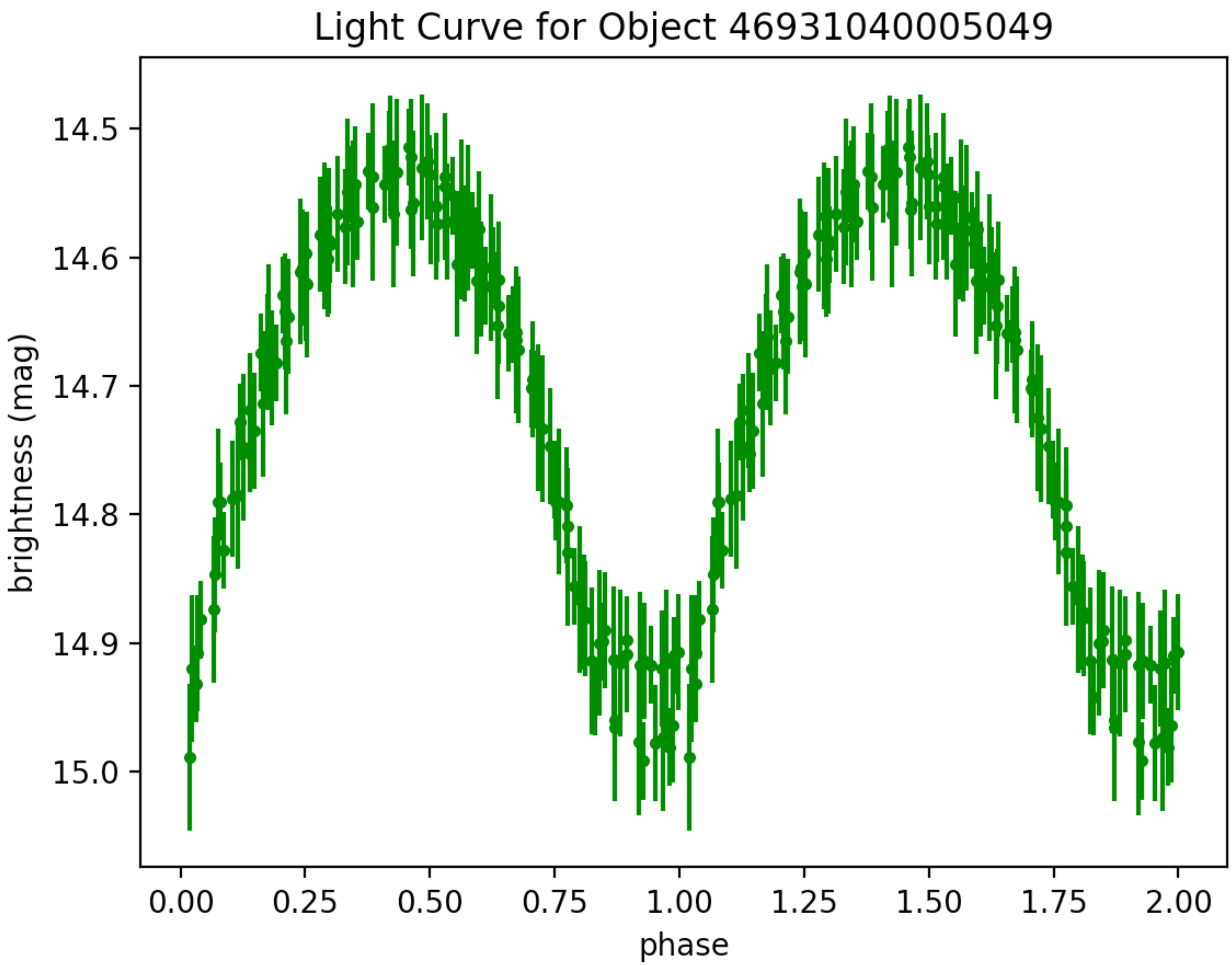
eb124.tbl – 120.541634 +43.337402 – period: 0.16472483539870822 –
http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101



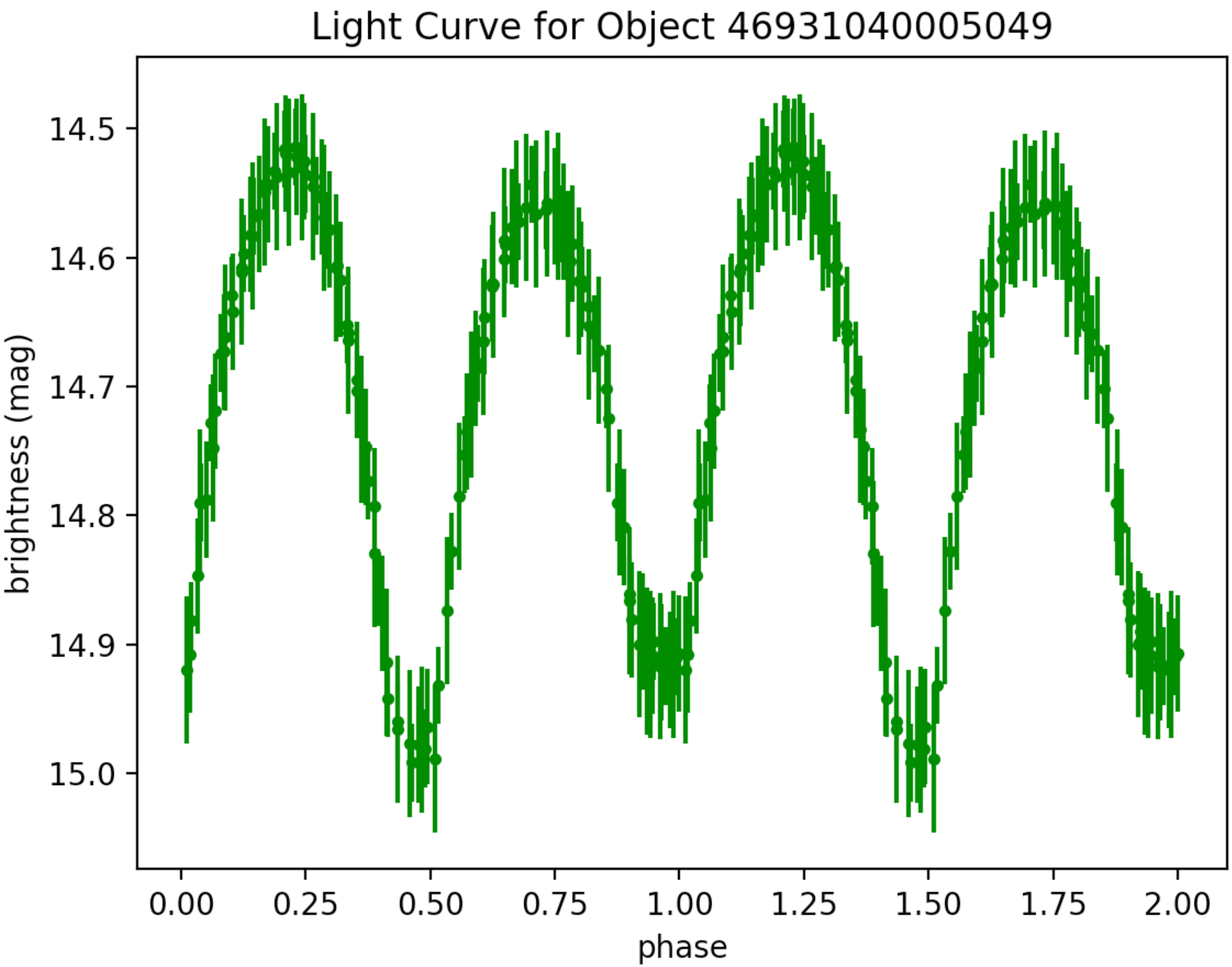
eb124.tbl – 120.541634 +43.337402 – period: 0.16472483539870822 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101



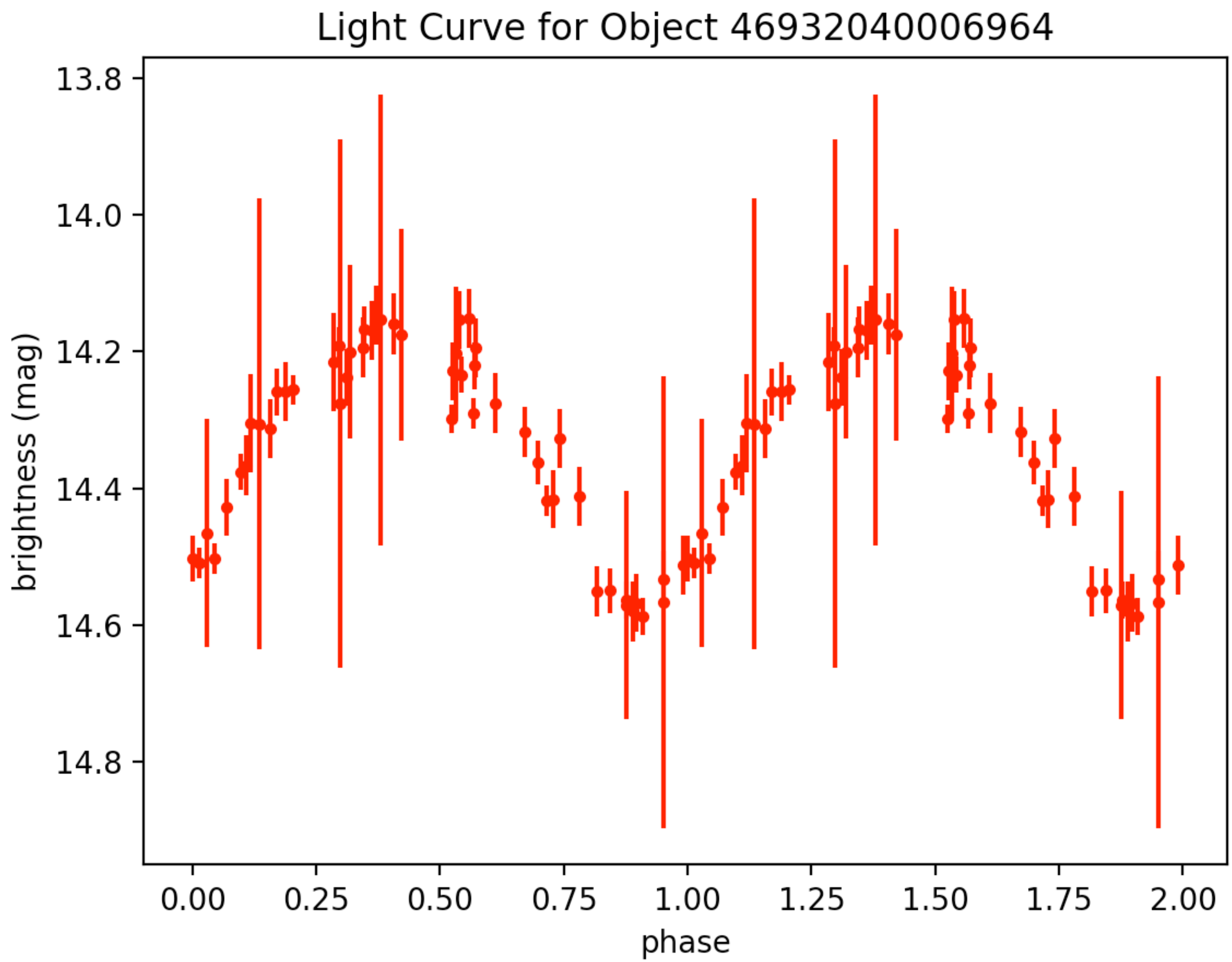
eb106.tbl – 117.369339 +49.340282 – period: 0.20141408802923563 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101



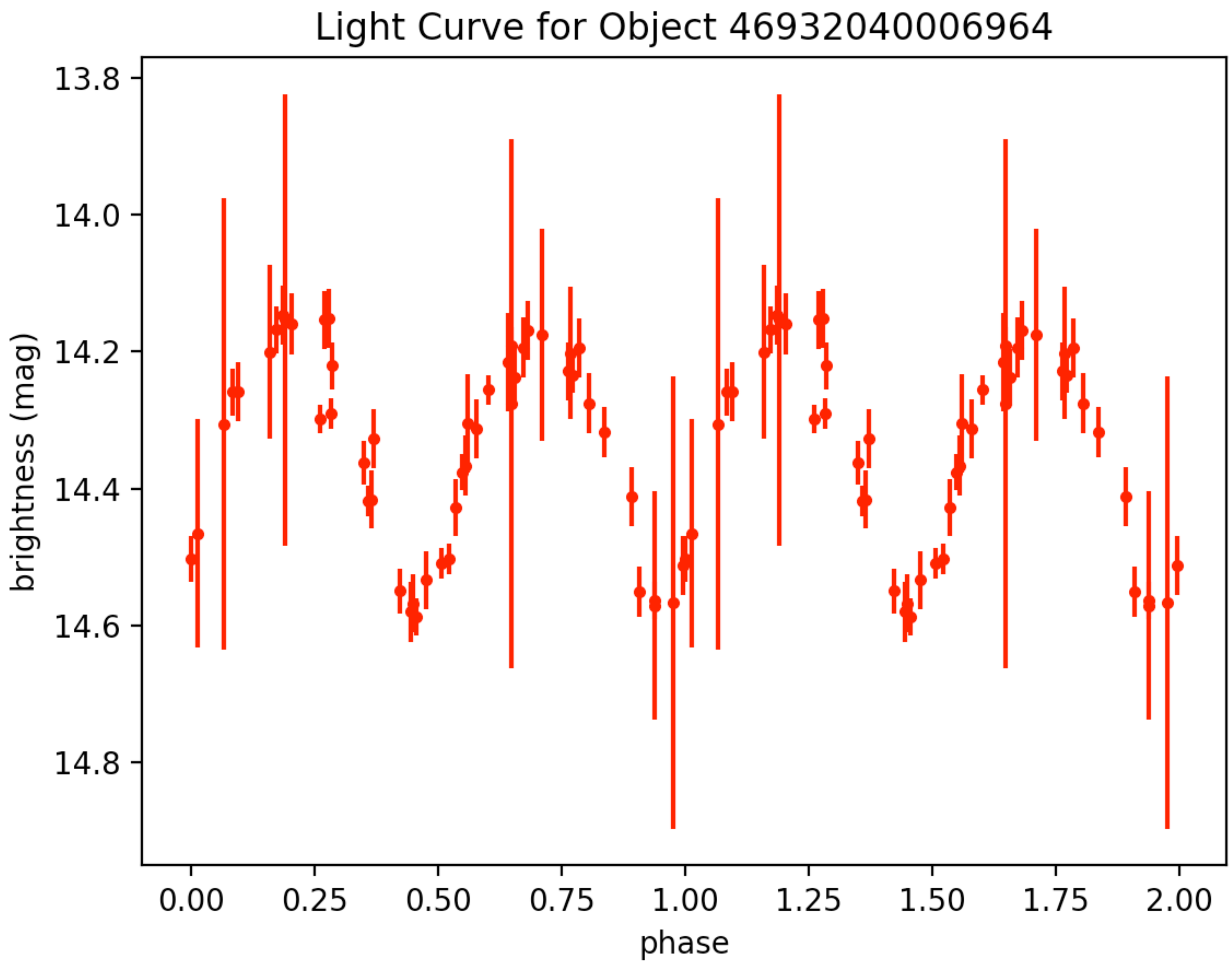
eb106.tbl – 117.369339 +49.340282 – period: 0.40282817605 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101 – with T' = 2T



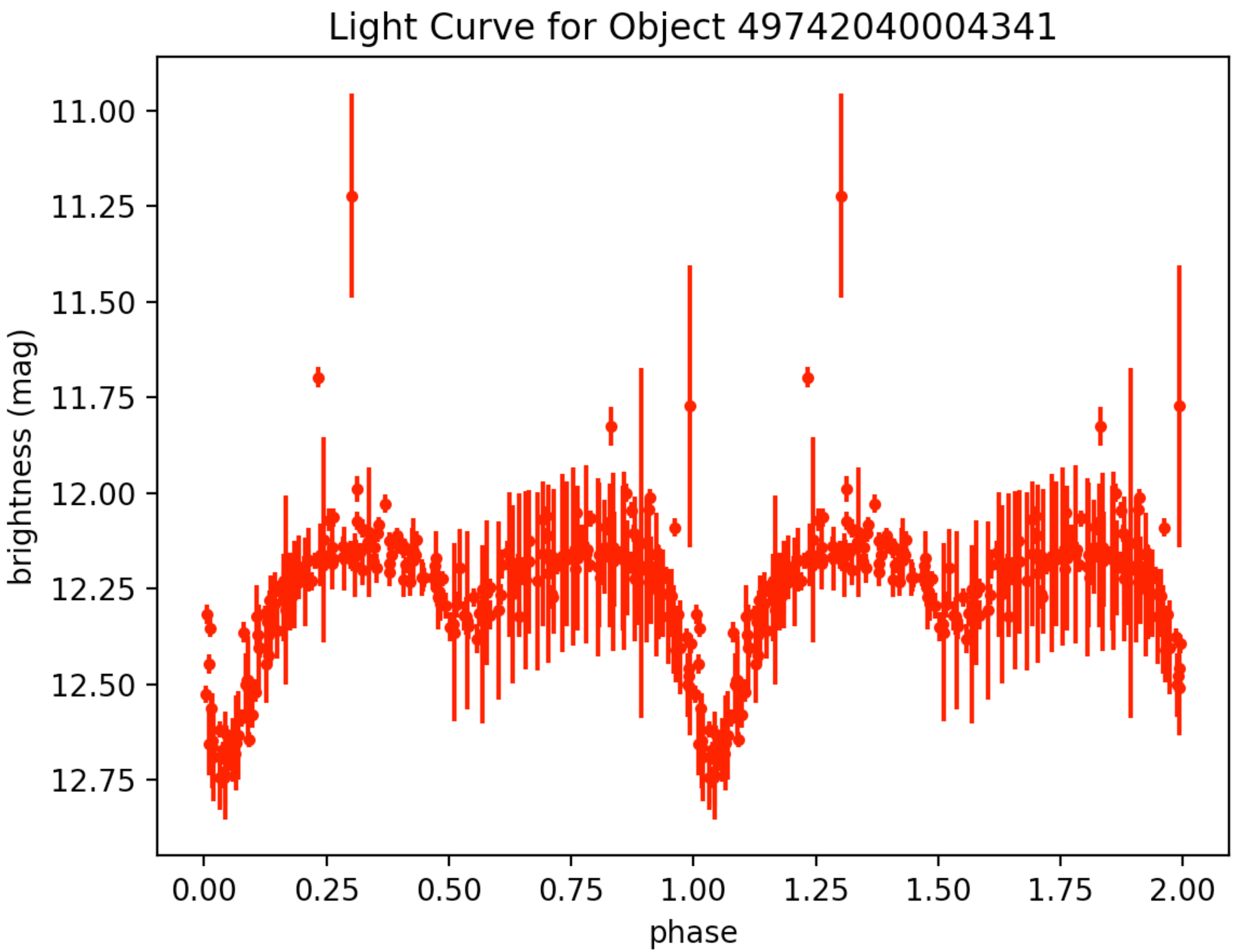
eb106.tbl – 117.369339 +49.340282 – period: 0.20141408802923563 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101



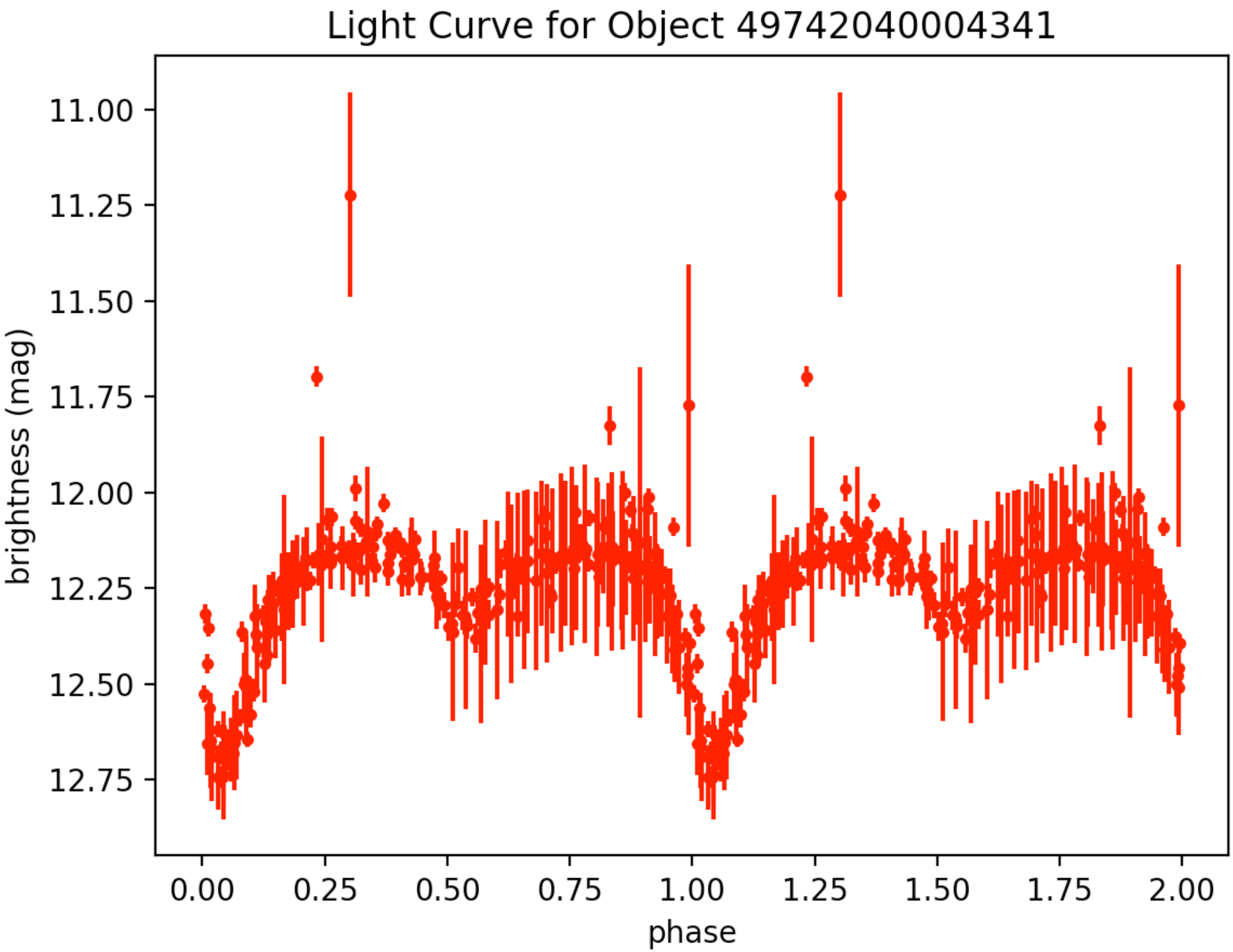
eb106.tbl – 117.369339 +49.340282 – period: 0.40282817605 – http://vizier.u-strasbg.fr/viz-bin/VizieR?-source=J/AJ/146/101 – with T' = 2T



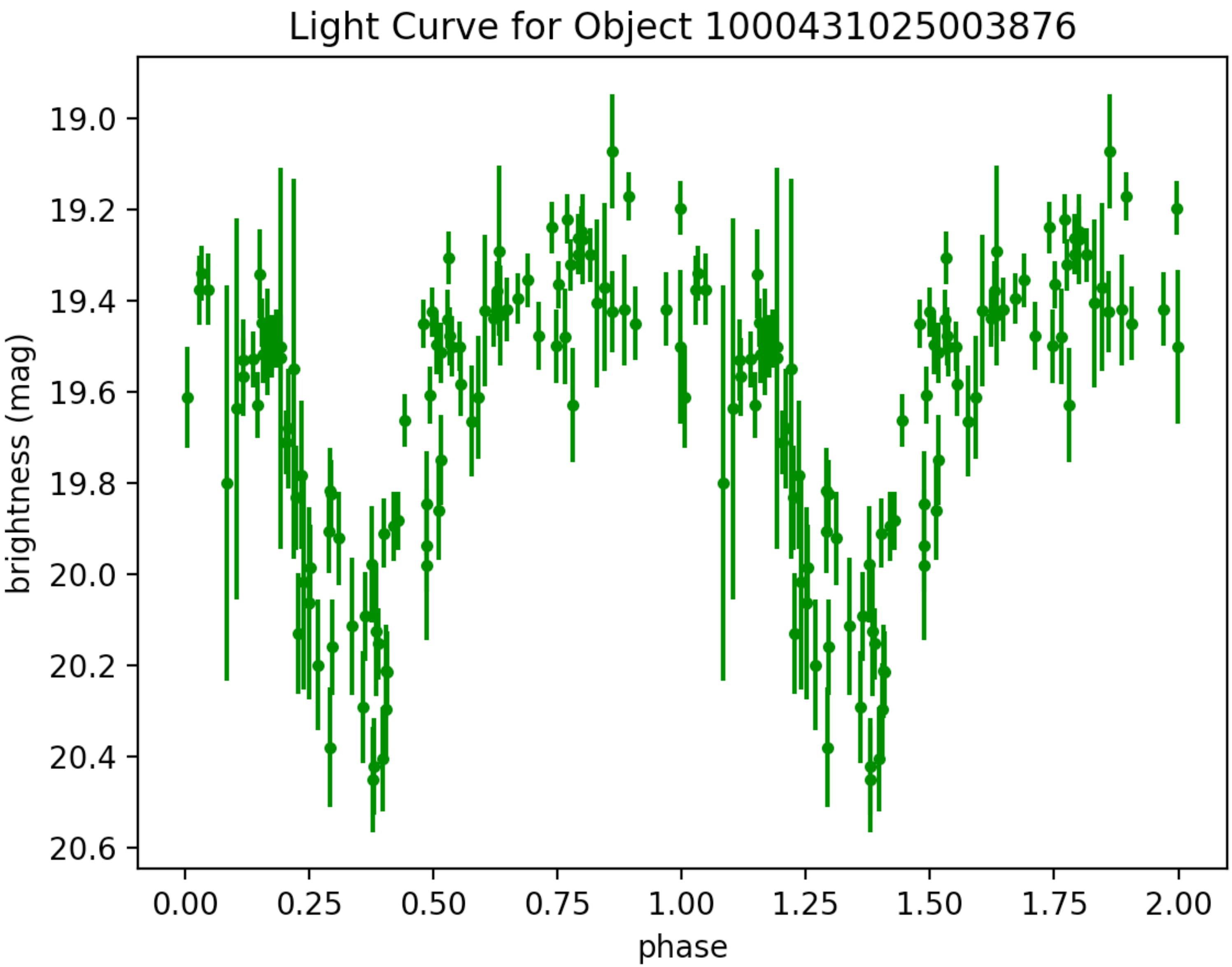
eb100.tbl – 17 35 32.388 +57 48 09.36 – period: 0.5876766556026741 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3



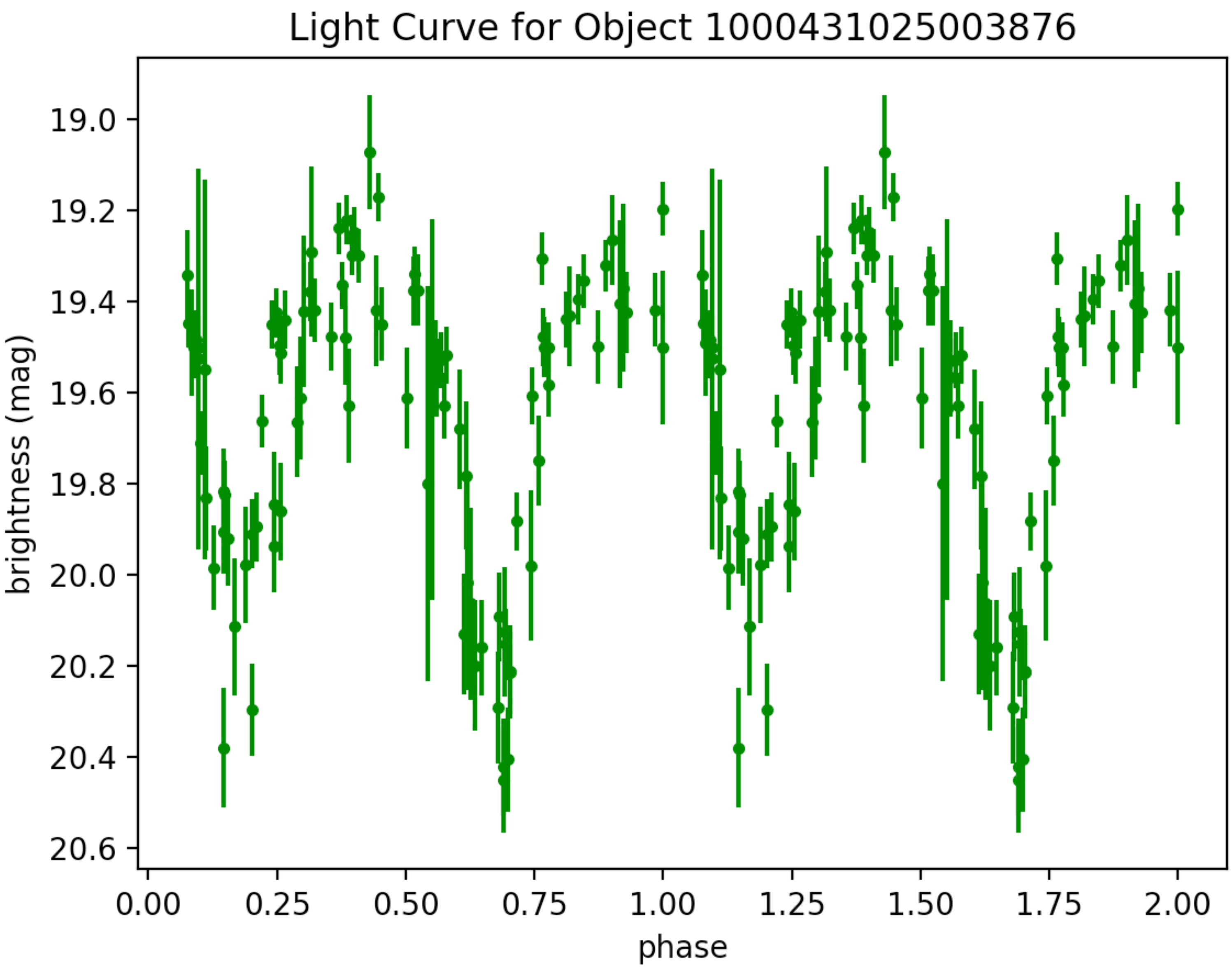
eb100.tbl – 17 35 32.388 +57 48 09.36 – period: 1.17535331121 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3 – with T’ = 2T



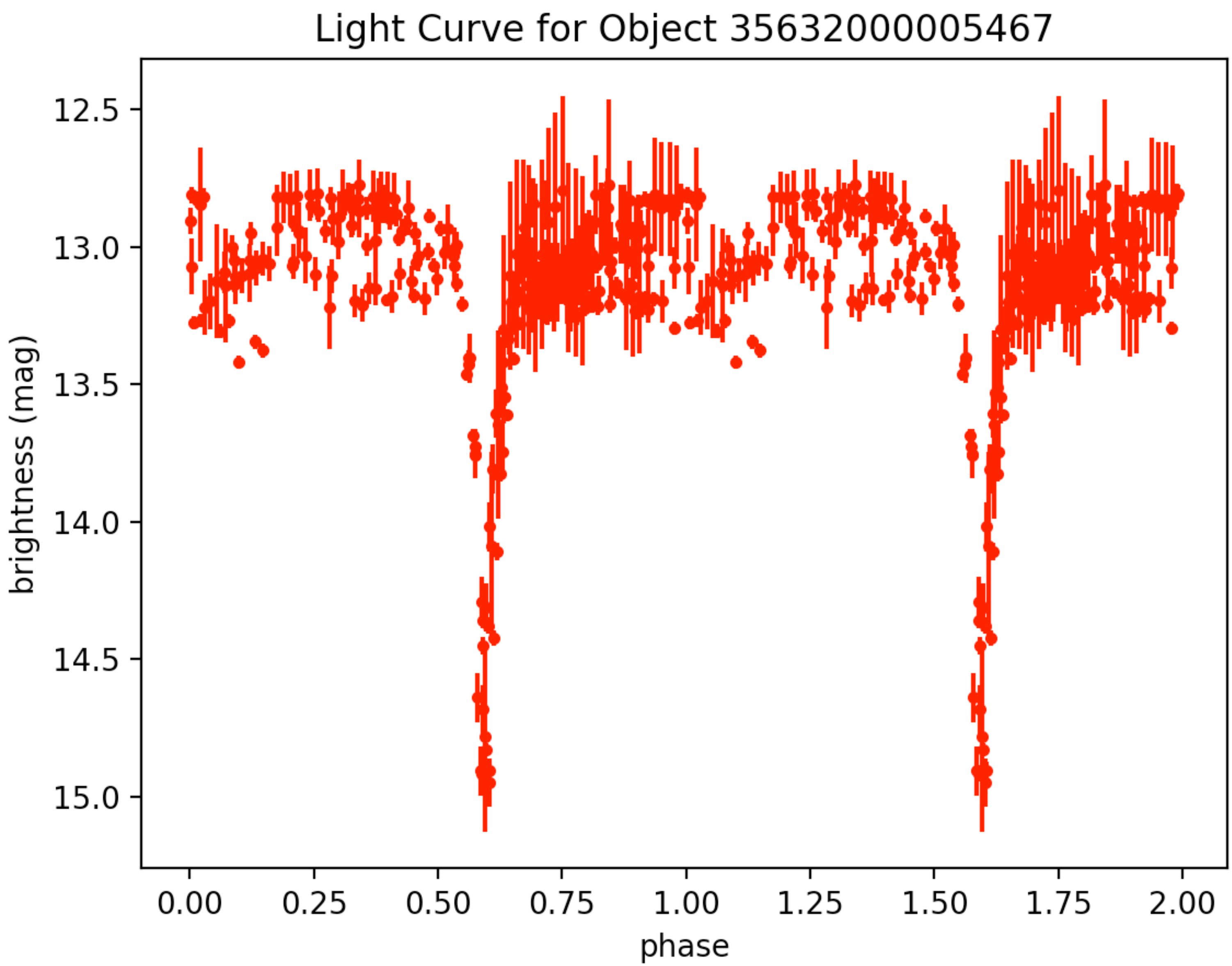
eb1.tbl – 00 44 29.272 +41 23 01.45 – period: 1.5844571095382733 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/362/1006&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – contact binary –> plot with T'=2T



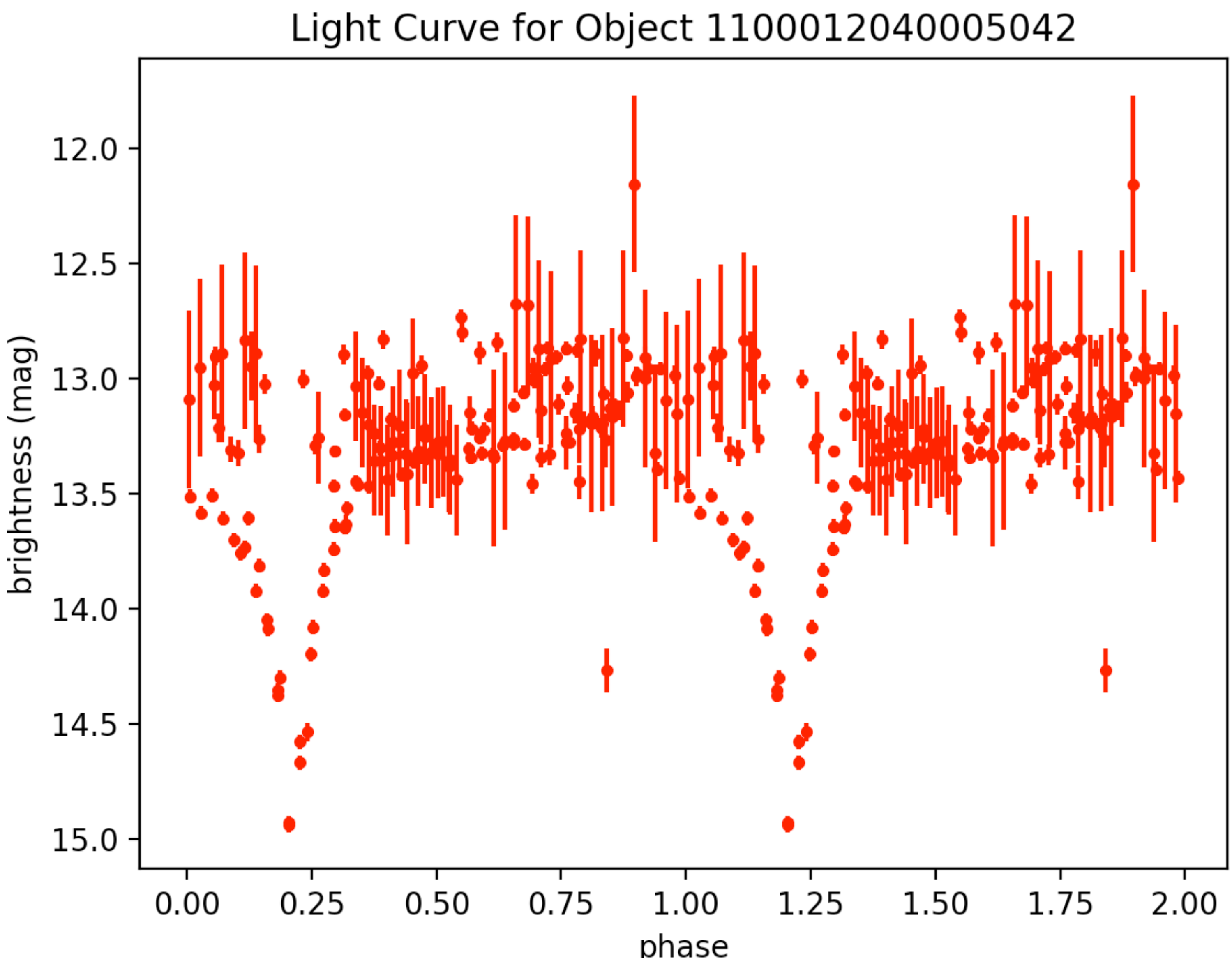
eb1.tbl – 00 44 29.272 +41 23 01.45 – period: 3.16891421908 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/362/1006&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – contact binary –> plotted with T'=2T



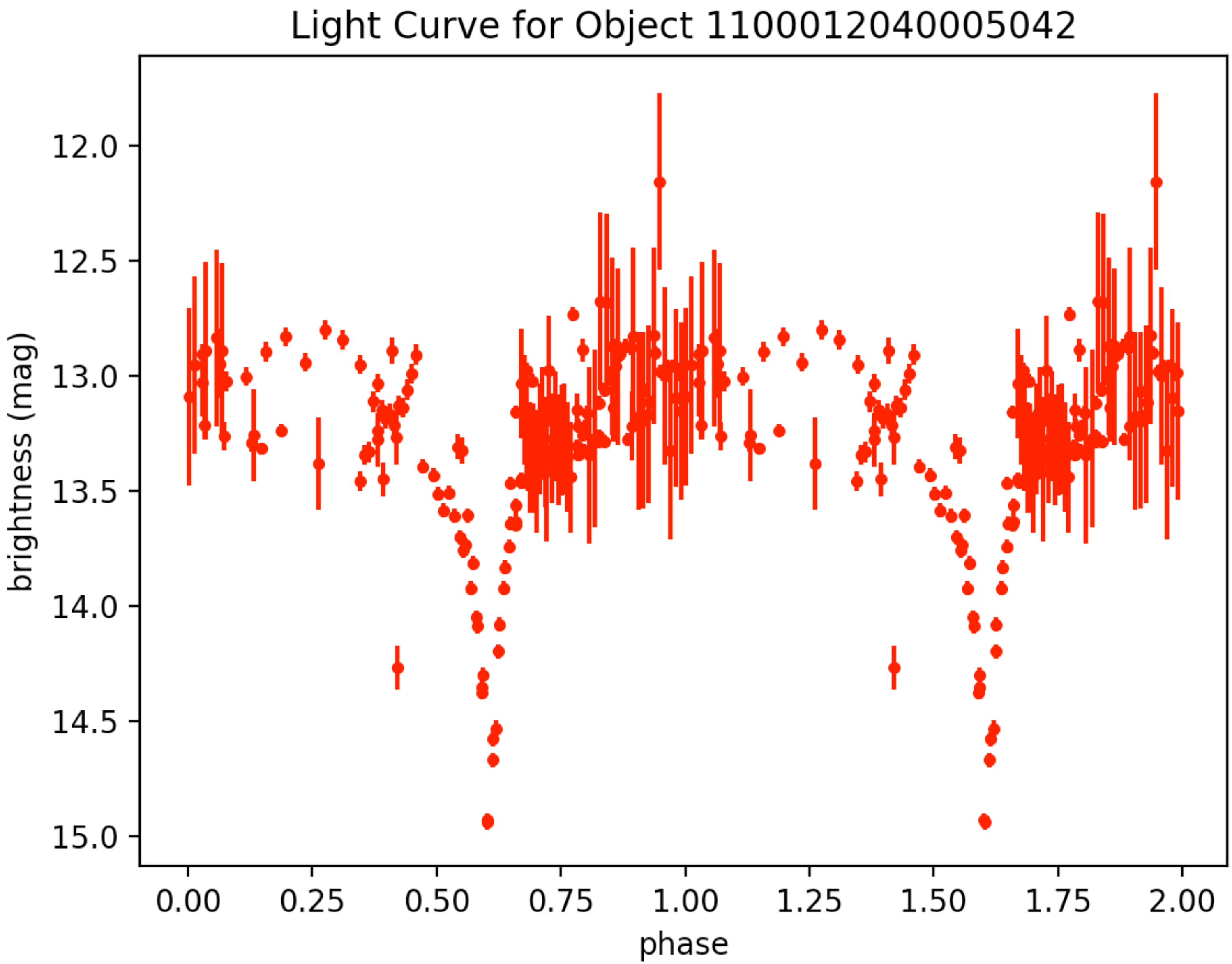
eb96.tbl – 8:39:54.6 +19:49:18 – period: 1.09296246931 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – with T'=2T



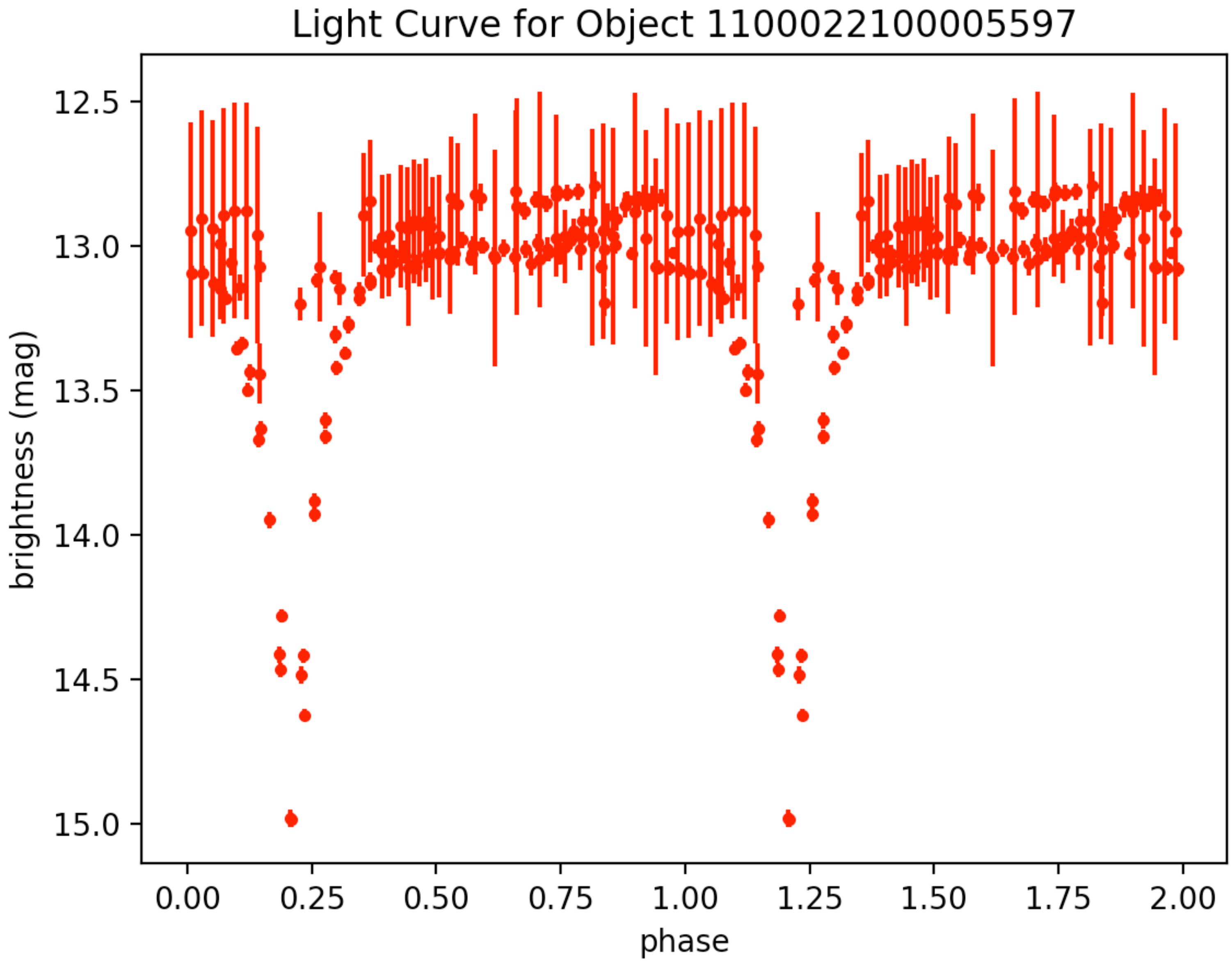
eb96.tbl – 8:39:54.6 +19:49:18 – period: 0.5464812346541238 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – same thing -> try plotting T’ = 2T



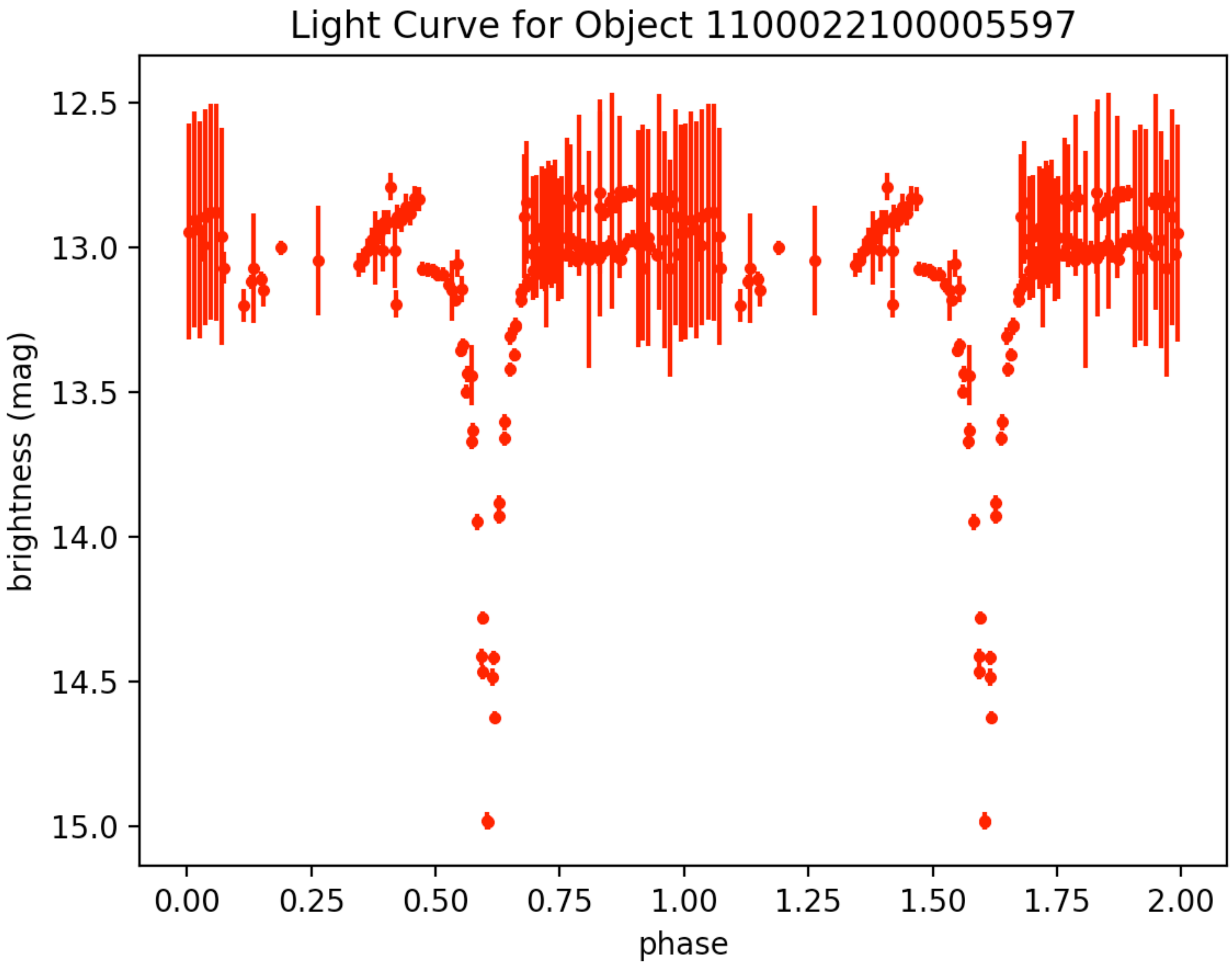
eb96.tbl – 8:39:54.6 +19:49:18 – period: 1.09296246931 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – with T’ = 2T



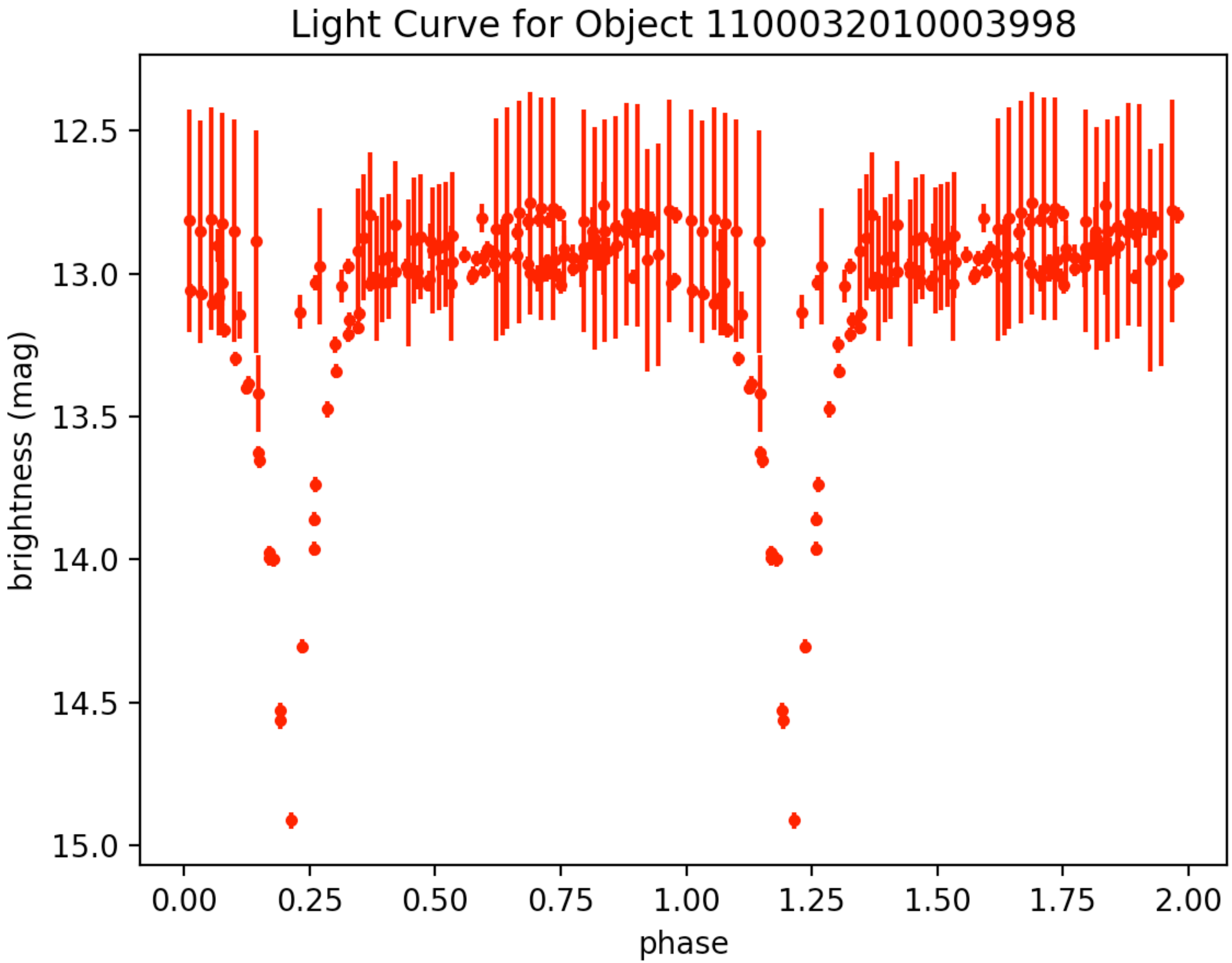
eb96.tbl – 8:39:54.6 +19:49:18 – period: 0.5464812346541238 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – same thing -> try plotting T' = 2T



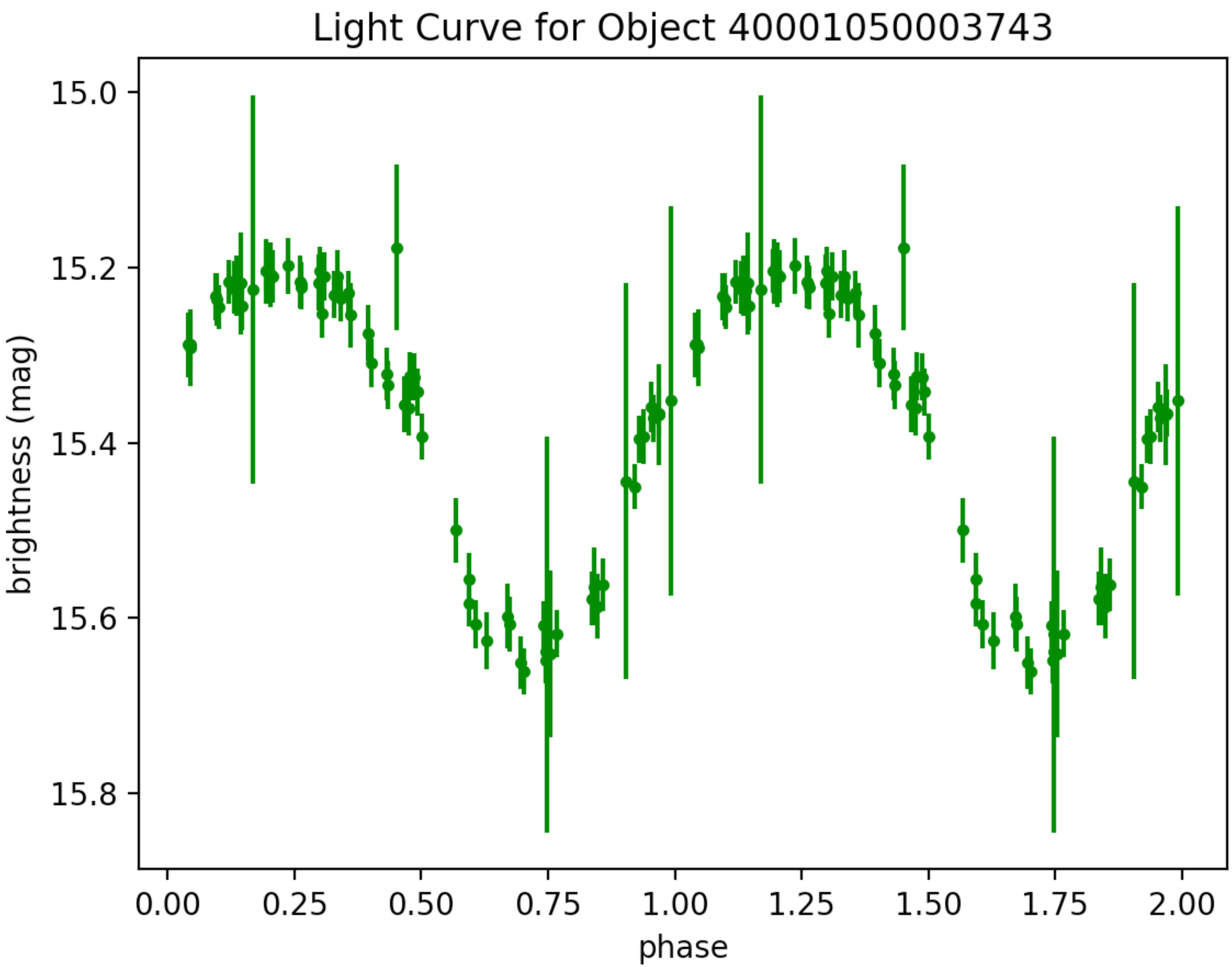
eb96.tbl – 8:39:54.6 +19:49:18 – period: 1.09296246931 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – with T' = 2T



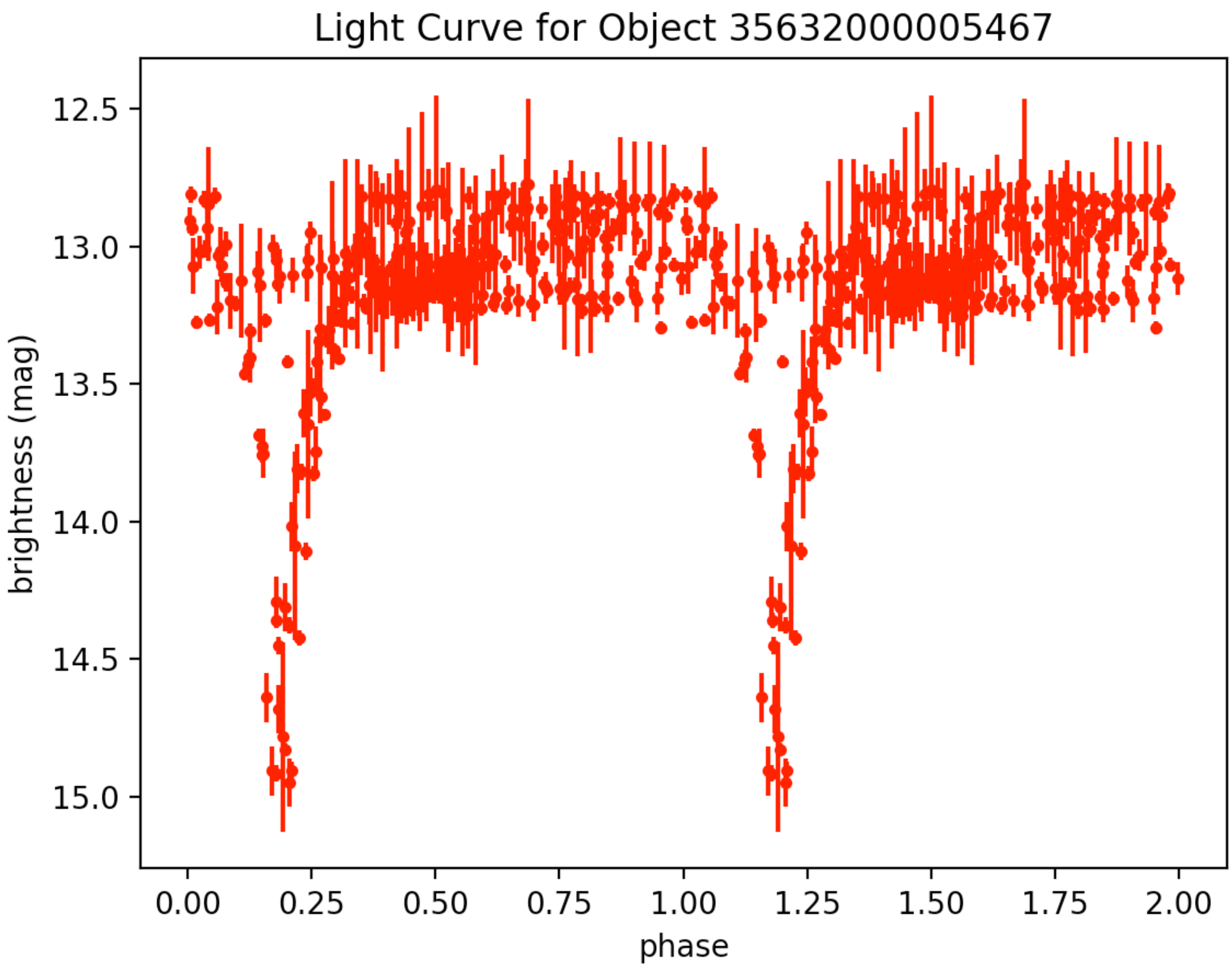
eb96.tbl – 8:39:54.6 +19:49:18 – period: 0.5464812346541238 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – same thing -> try plotting T' = 2T



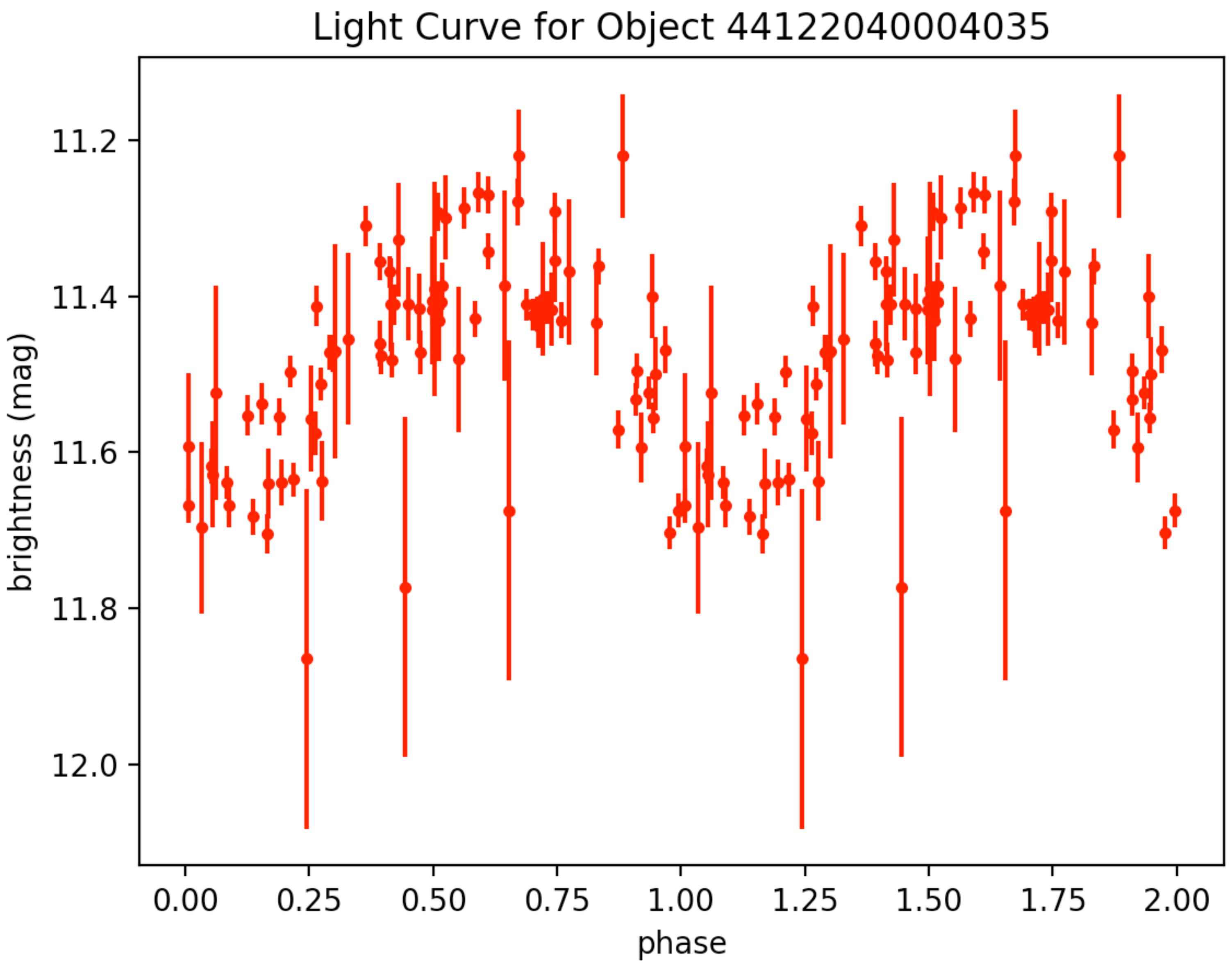
eb10.tbl – 21:39:43 28:22:39 – period: 0.17631450840958496 – http://www.sciencedirect.com/science/article/pii/S1384107616301828?via%3Dihub – contact binary (chance it could be RRc)



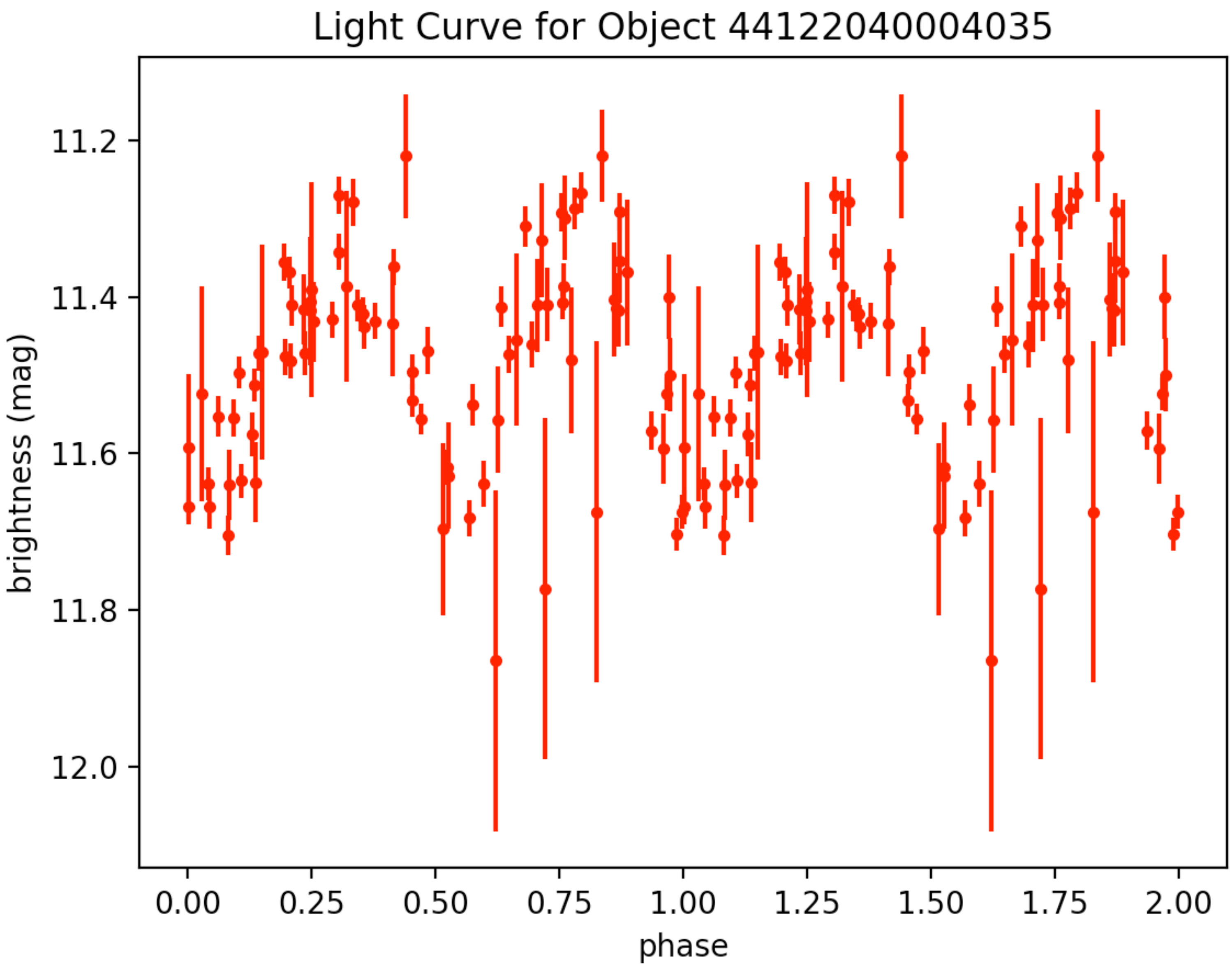
eb96.tbl – 8:39:54.6 +19:49:18 – period: 0.5464812346541238 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – period is probably wrong b/c there shouldn't be points above eclipse



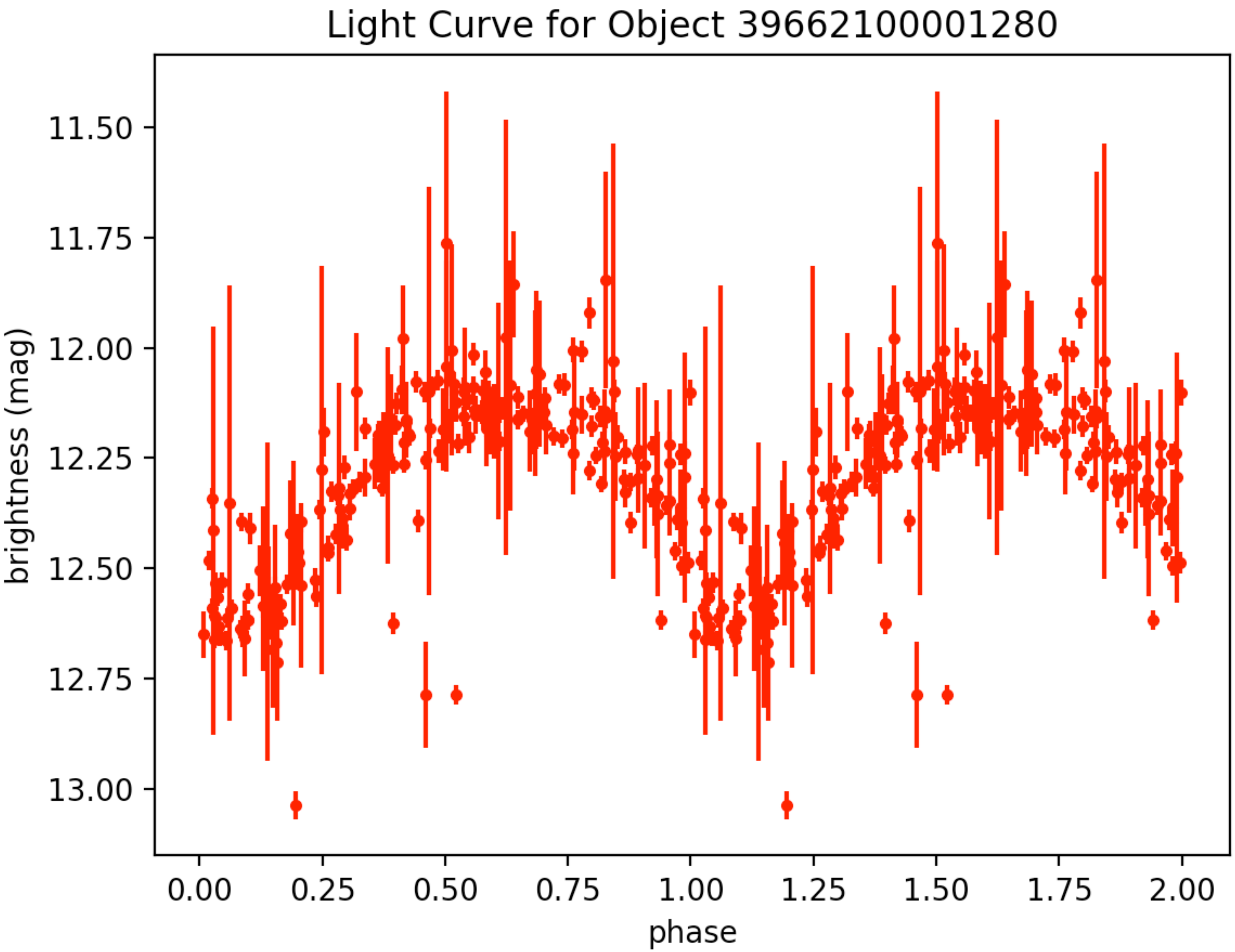
eb70.tbl – 15:8:9.2 +39:58:12.3 – period: 0.14863507665928397 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Boo – plot at twice the period -> should look nicer



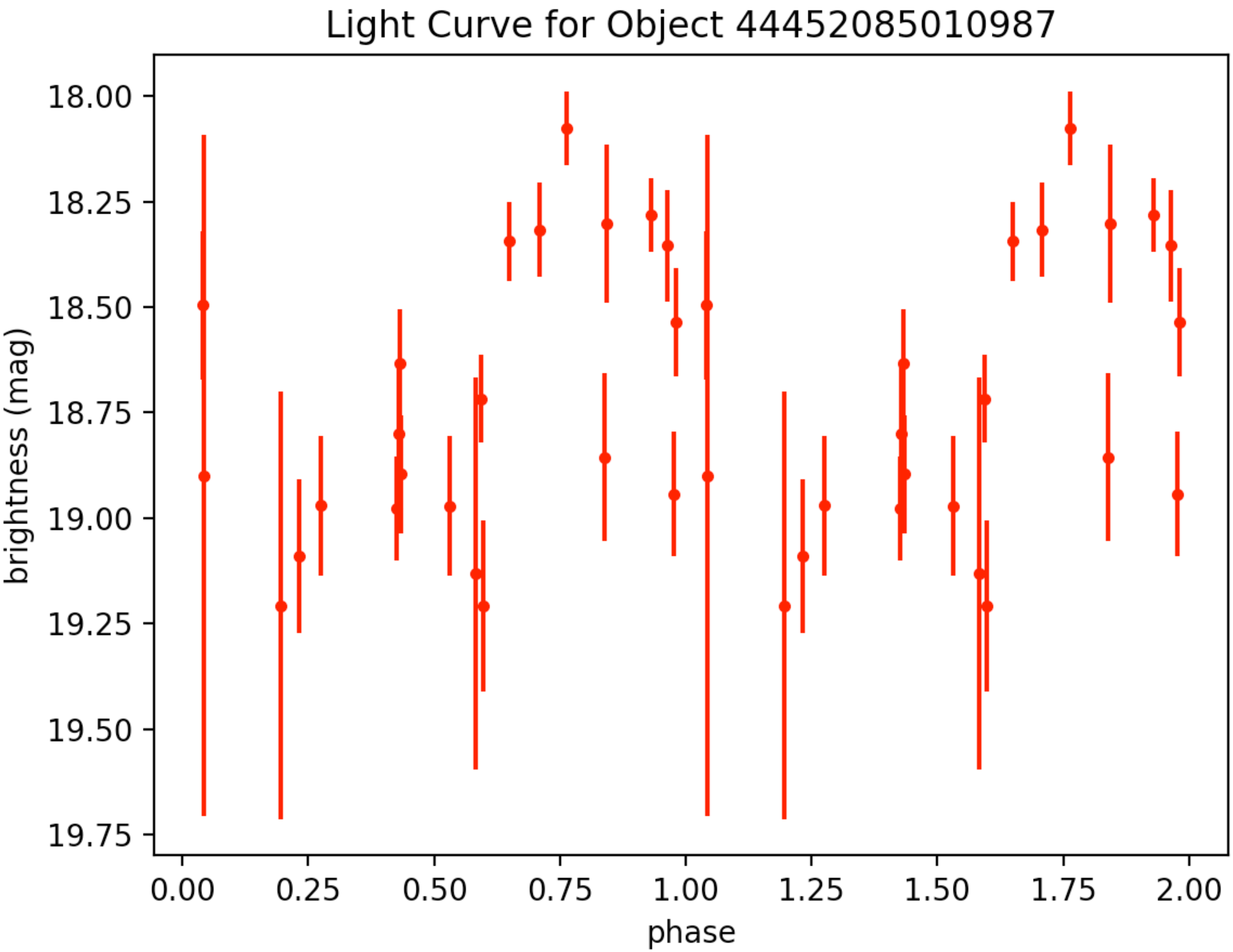
eb70.tbl – 15:8:9.2 +39:58:12.3 – period: 0.29727015331 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Boo – plotted with twice the period



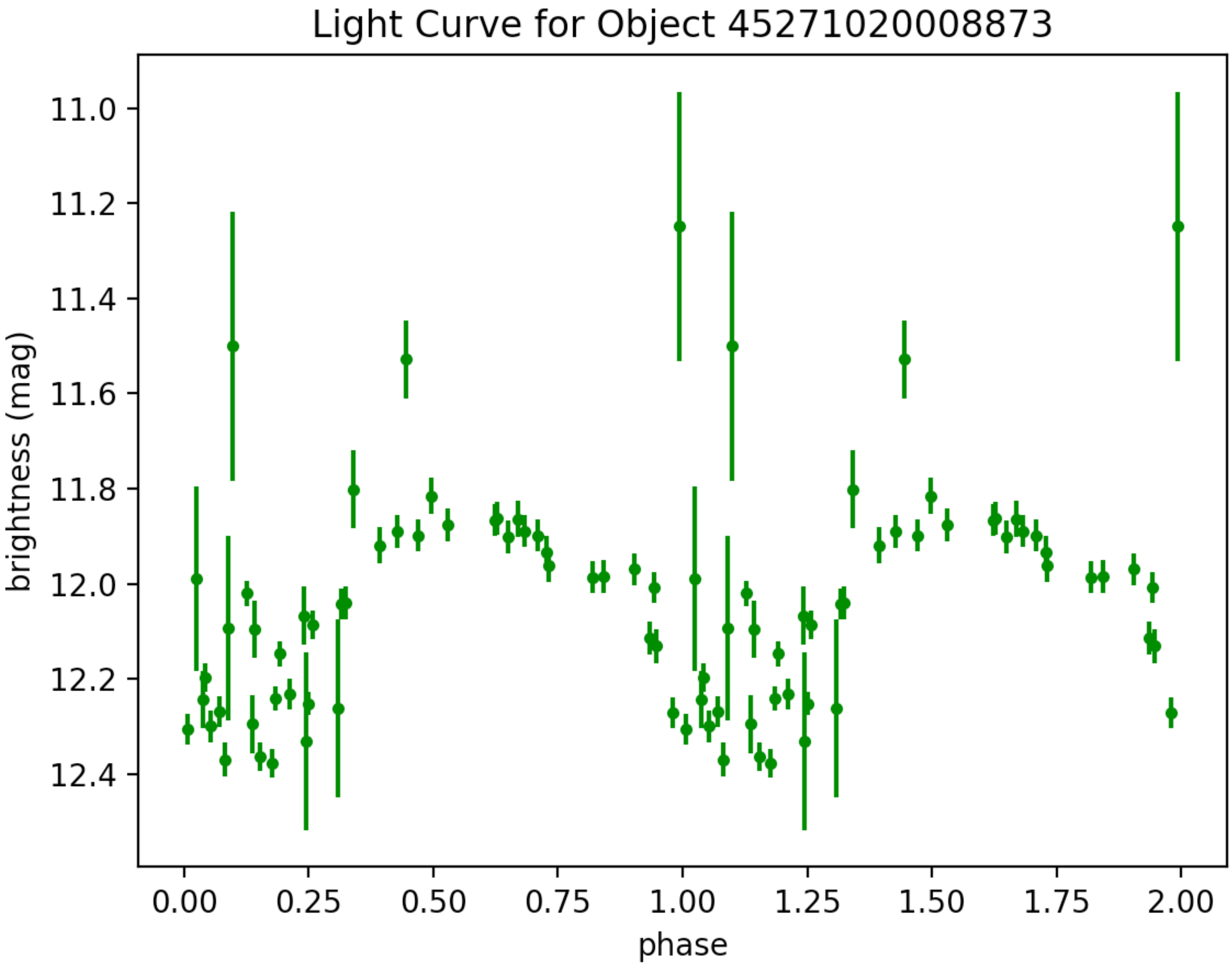
eb15.tbl – 12:51:21.37 27:13:46.7 – period: 0.13334190277295155 – http://www.sciencedirect.com/science/article/pii/S1384107616301828?via%3Dihub – looks like contact binary, saturation might be an issue



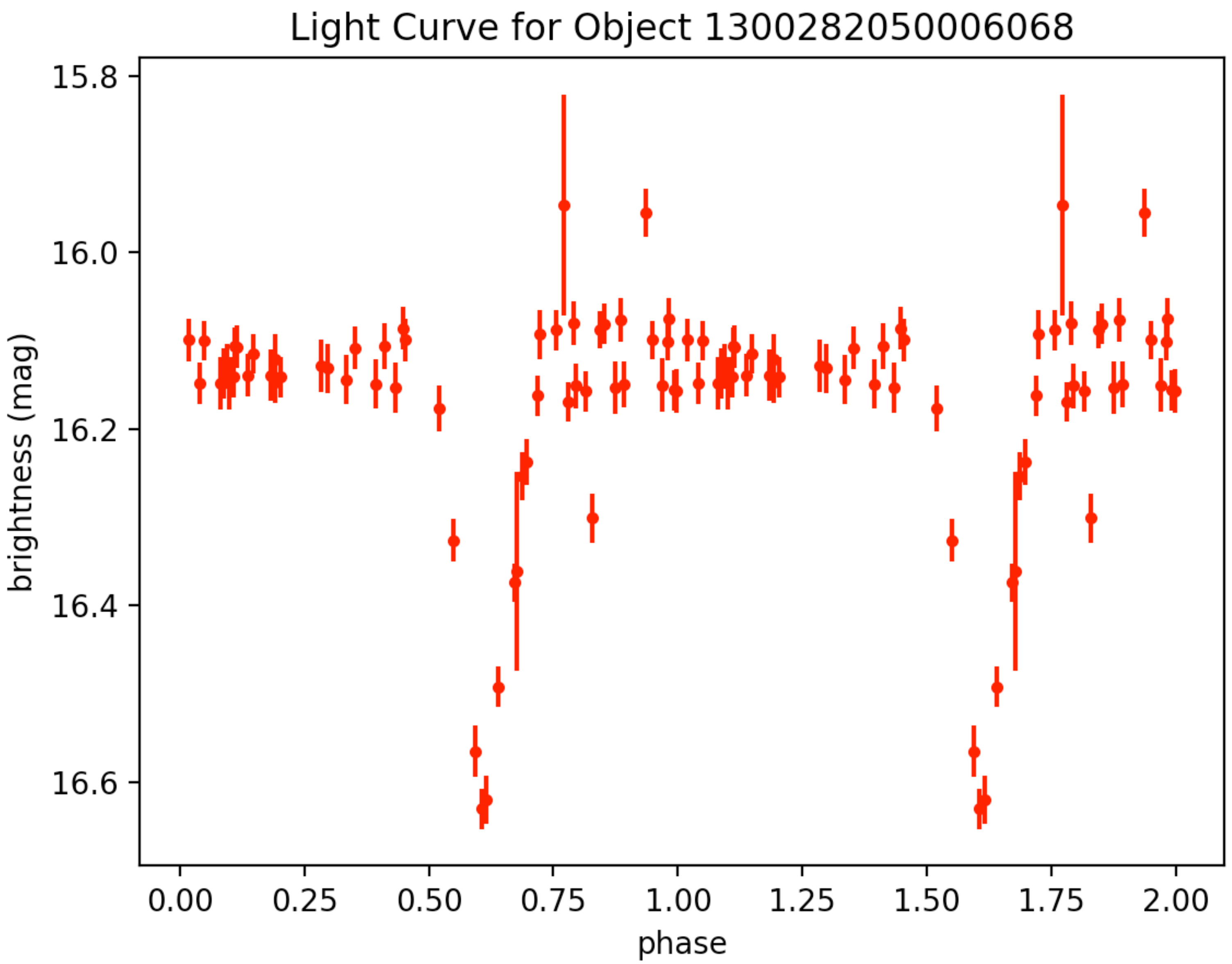
eb2.tbl – 00 44 48.675 +41 29 15.56 – period: 0.2606250988746469 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=J/MNRAS/362/1006&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – contact binary – BAD!



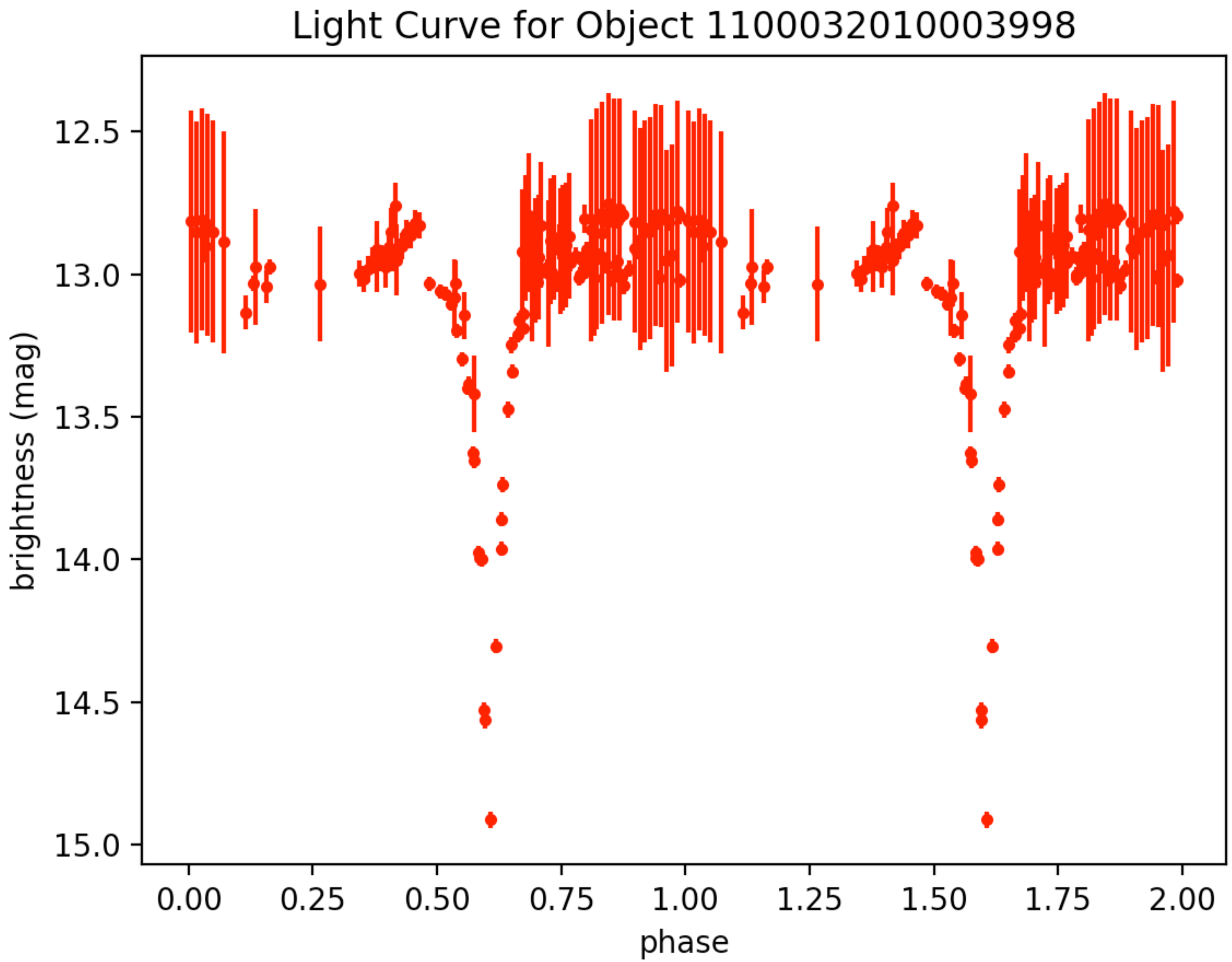
eb11.tbl – 01:42:29.33 44:45:42.4 – period: 0.25336256461695505 – http://www.sciencedirect.com/science/article/pii/S1384107616301828?via%3Dihub – contact binary – saturation issues!



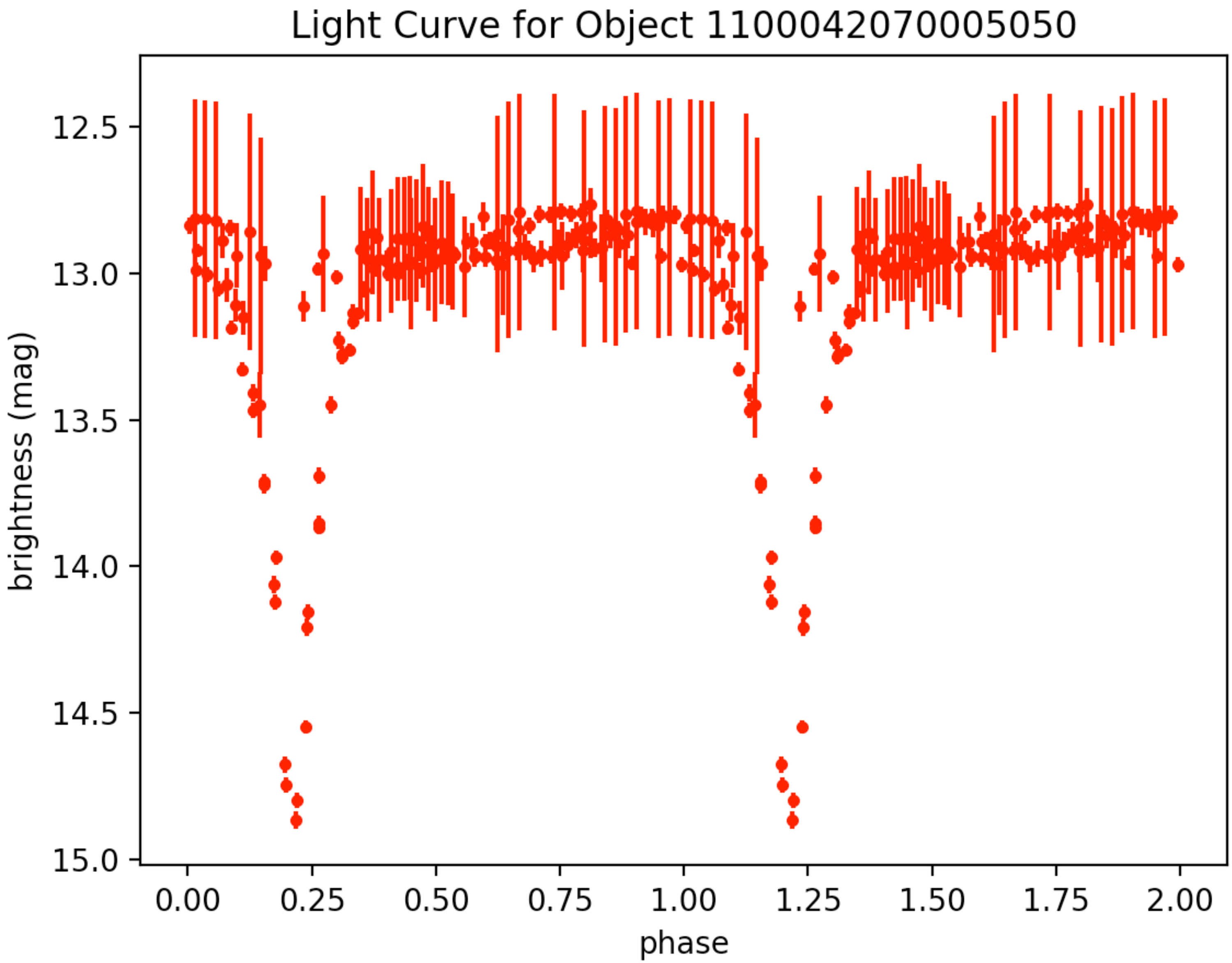
eb158.tbl – 15 09 24.767 +13 46 00.83 – period: 0.3090320806202892 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



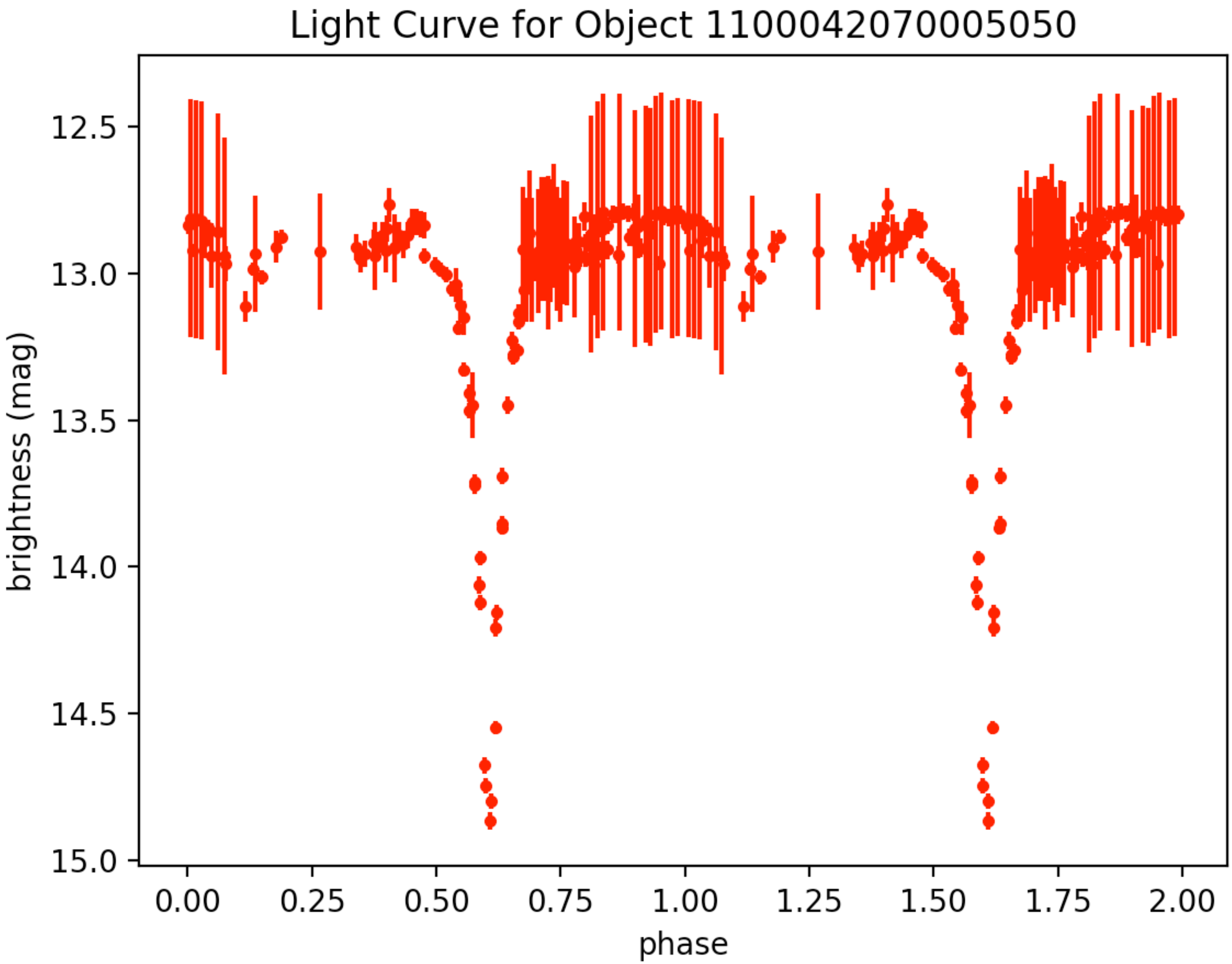
eb96.tbl – 8:39:54.6 +19:49:18 – period: 1.09296246931 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – plotted with T' = 2T



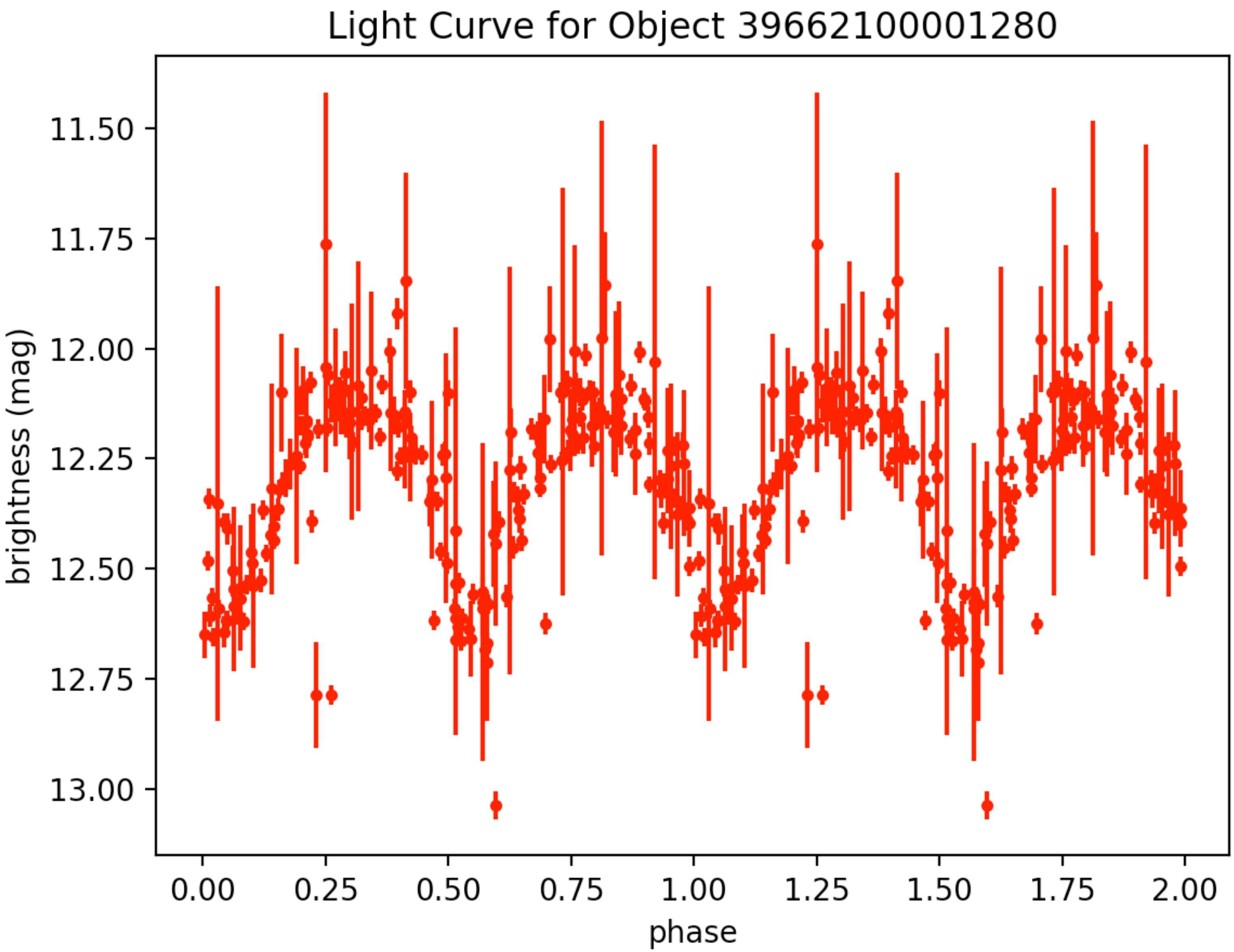
eb96.tbl – 8:39:54.6 +19:49:18 – period: 0.5464812346541238 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – same thing -> try plotting T' = 2T



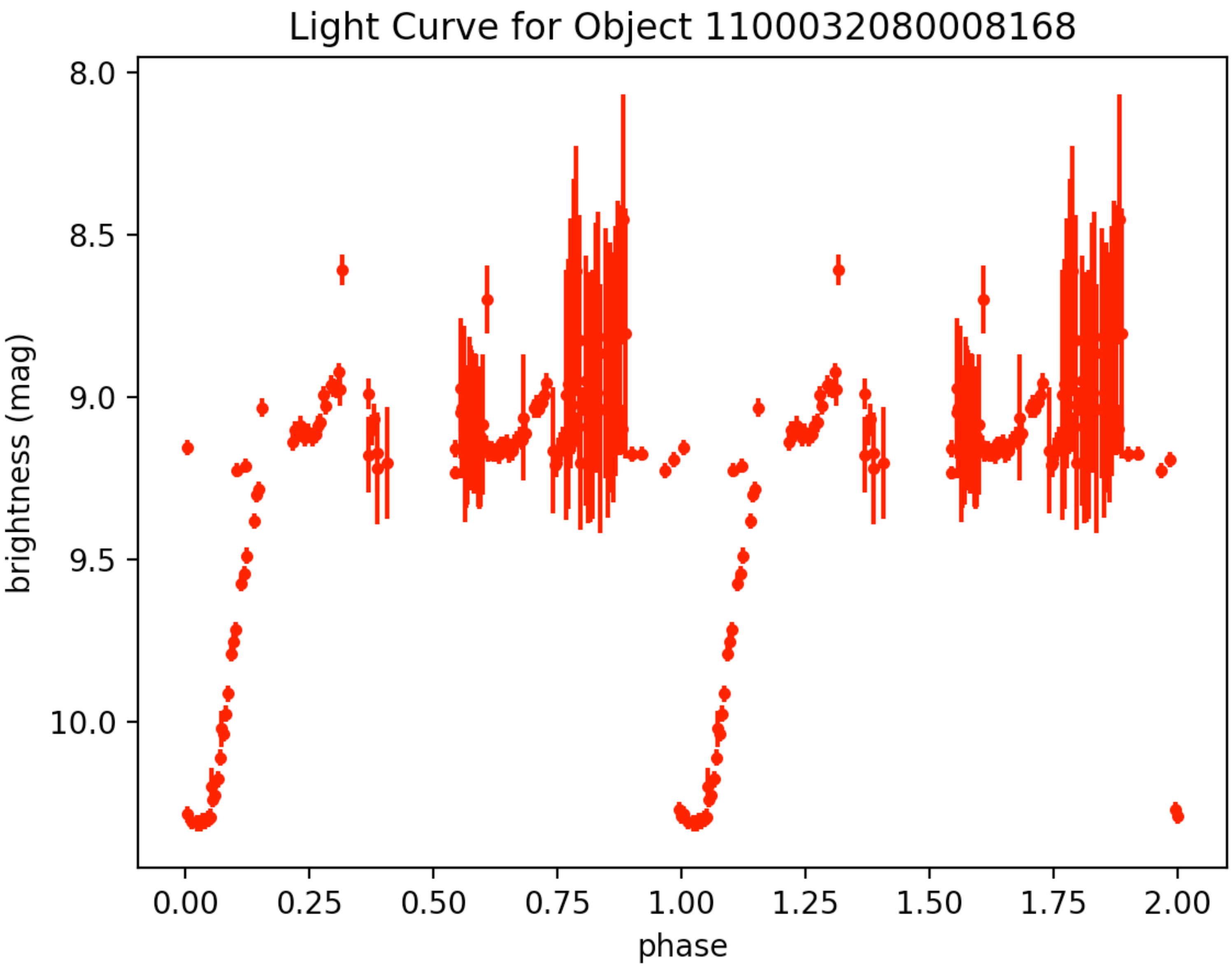
eb96.tbl – 8:39:54.6 +19:49:18 – period: 1.09296246931 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – with T’ = 2T



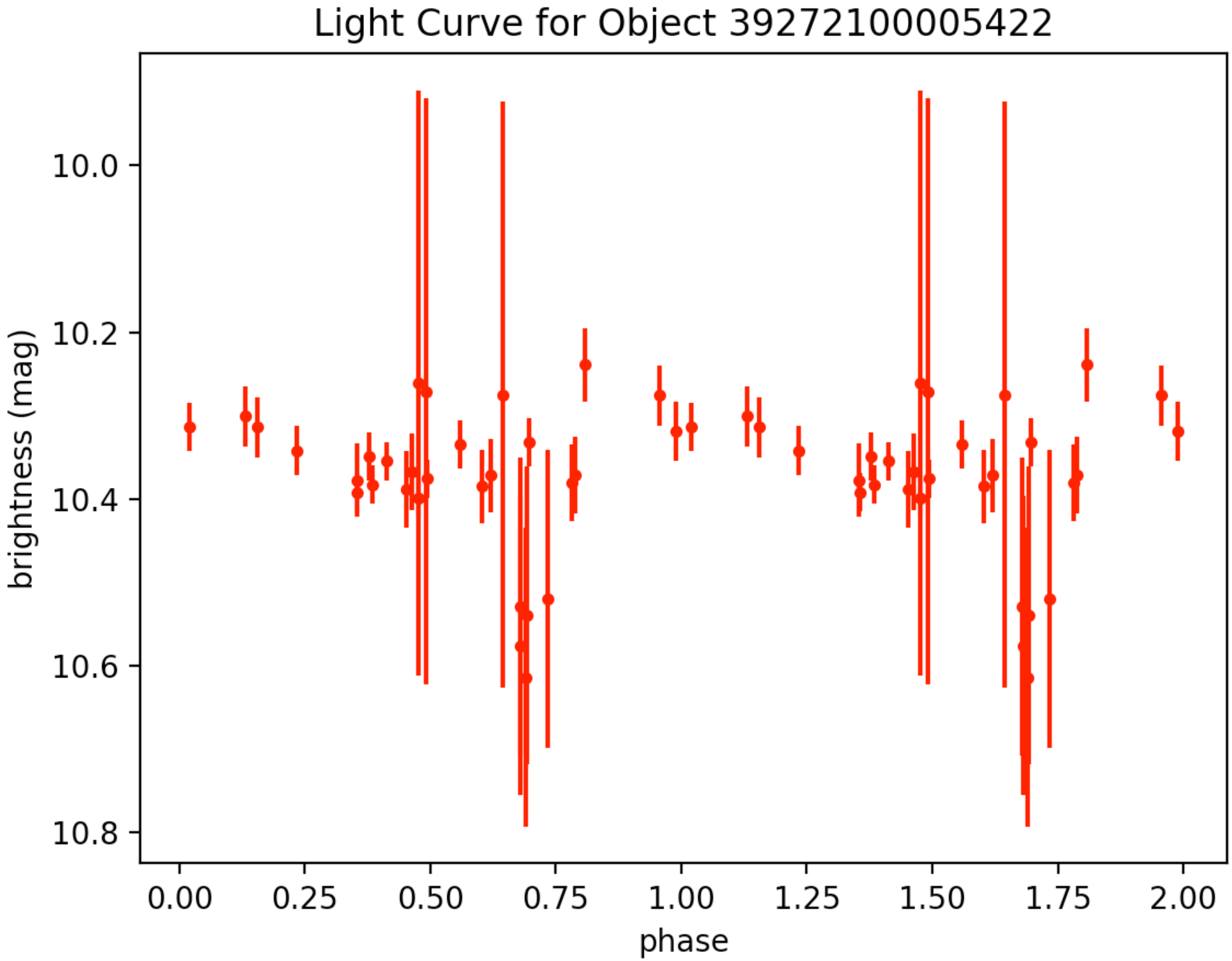
eb15.tbl – 12:51:21.37 27:13:46.7 – period: 0.26668380554 – http://www.sciencedirect.com/science/article/pii/S1384107616301828?via%3Dihub – looks like contact binary, saturation might be an issue – plotted with T'=2T



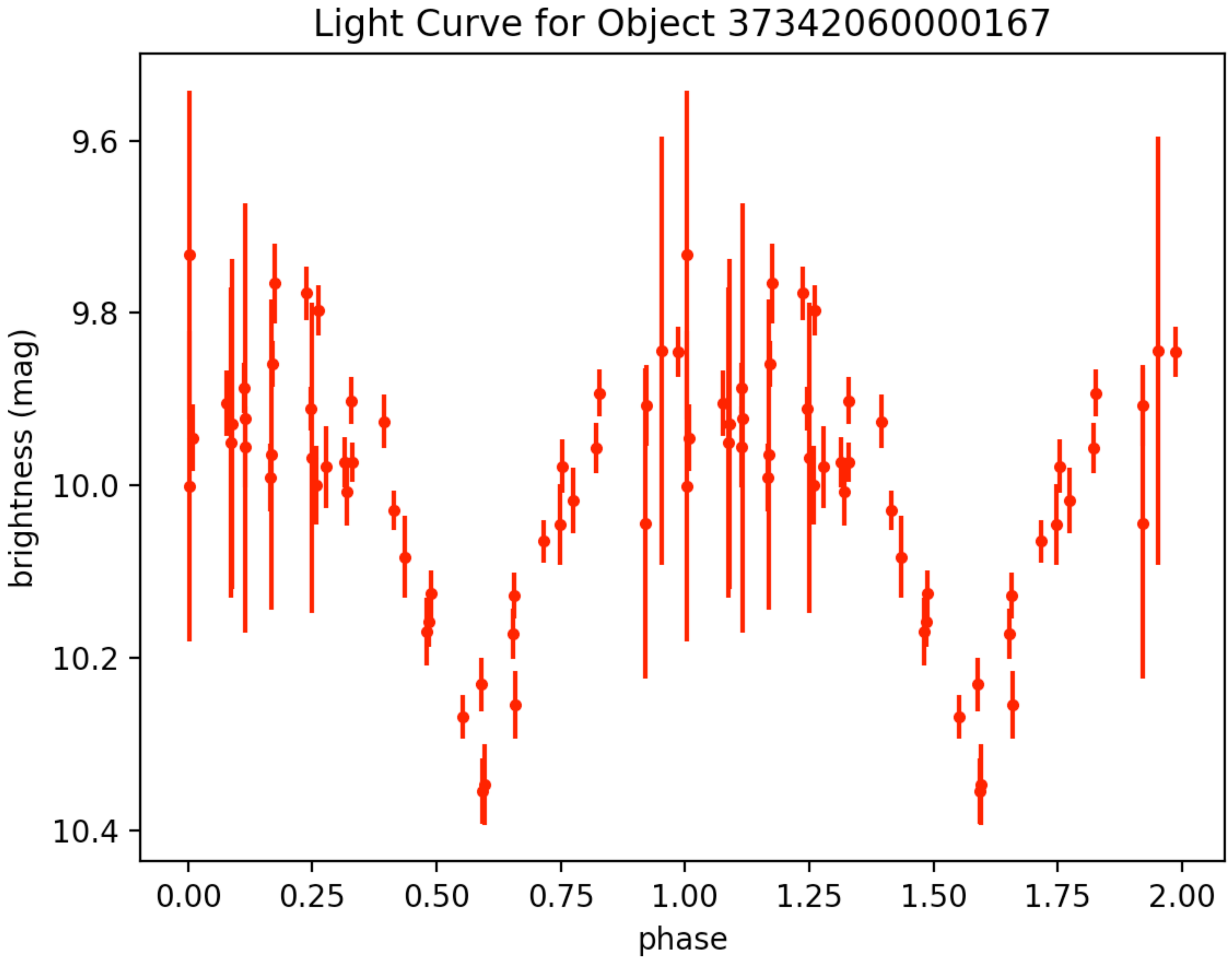
eb95.tbl – 8:43:56.15 +19:2:3 – period: 2.37141590129 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cnc – sat issue but looks like eb (ratty)



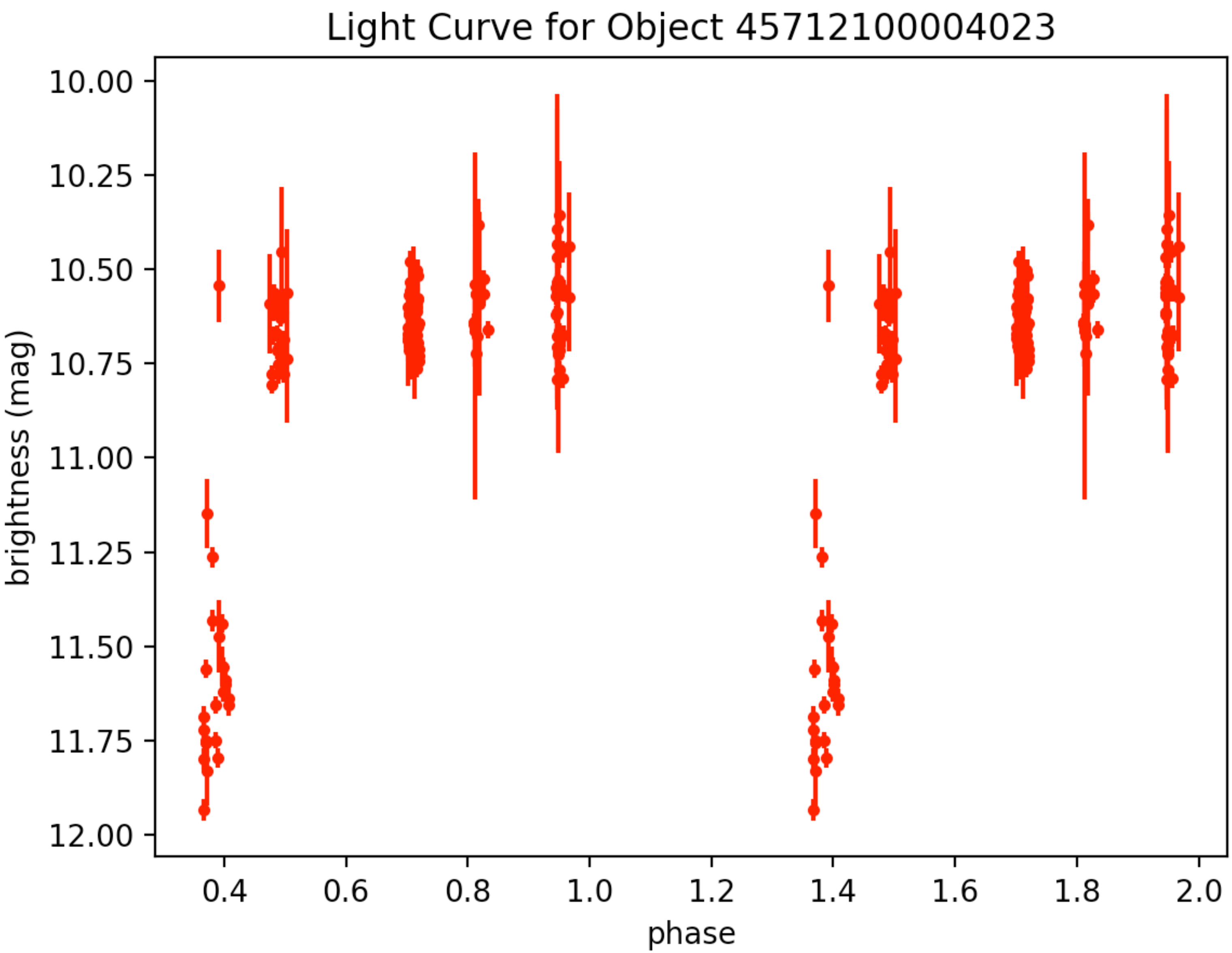
eb57.tbl – 2:46:14.1 +27:52:39 – period: 0.042339087229400836 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Ari – bad!



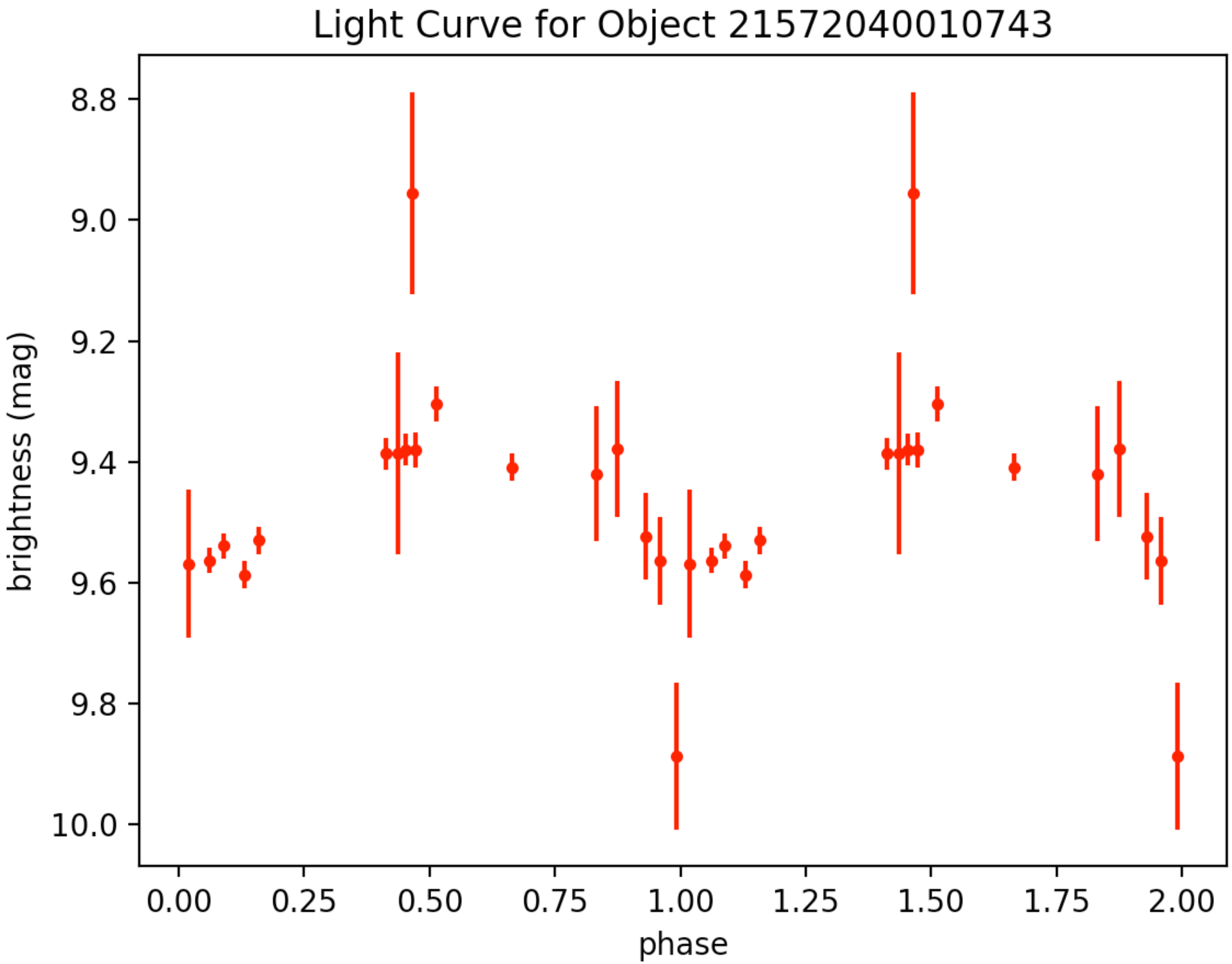
eb58.tbl – 2:15:20.8 +22:34:11 – period: 0.5131992275325227 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Ari – saturation issue!



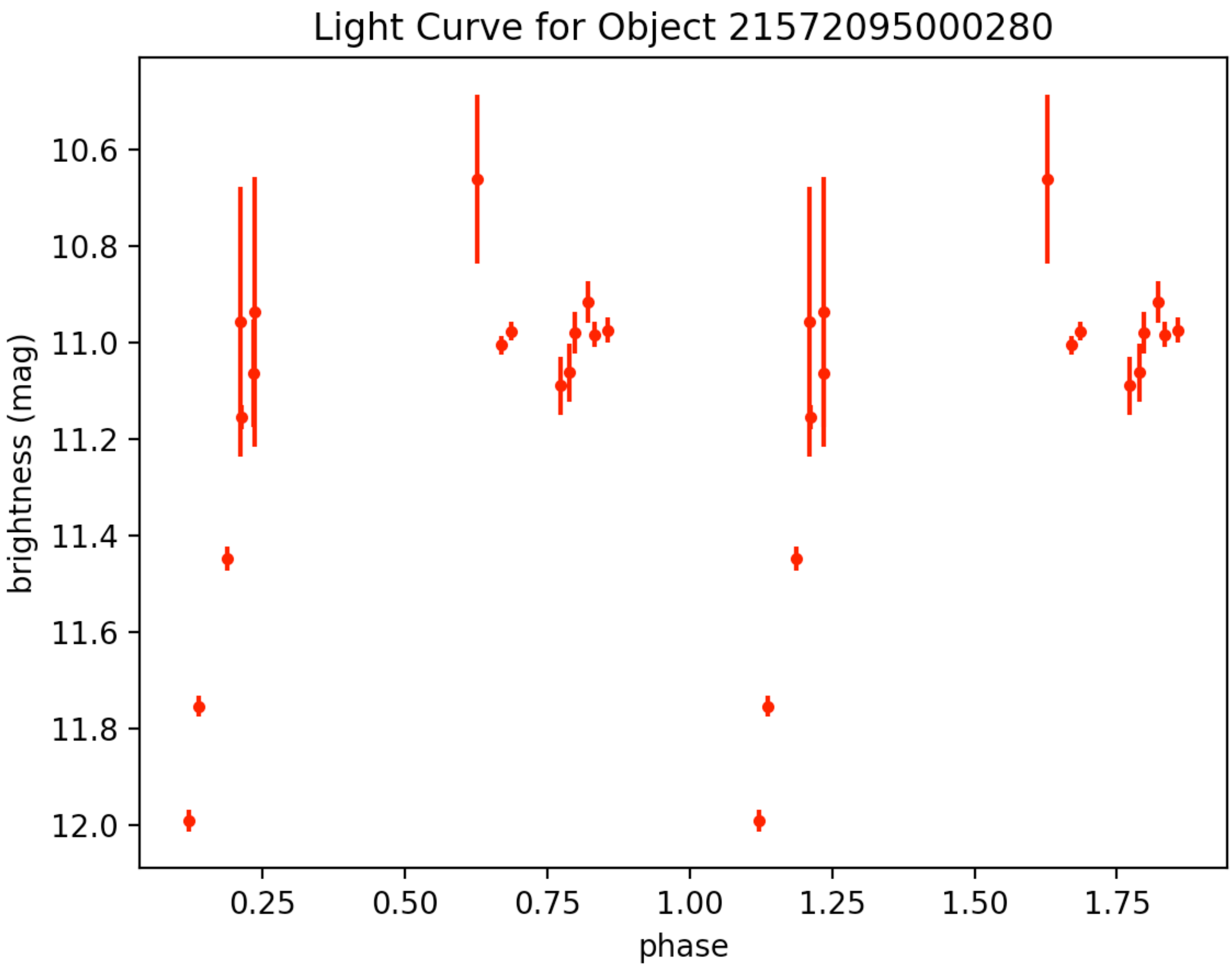
eb81.tbl – 15:43:0.25 +43:15:55.1 – period: 3164.556962025317 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Boo – confident period is wrong => disregard



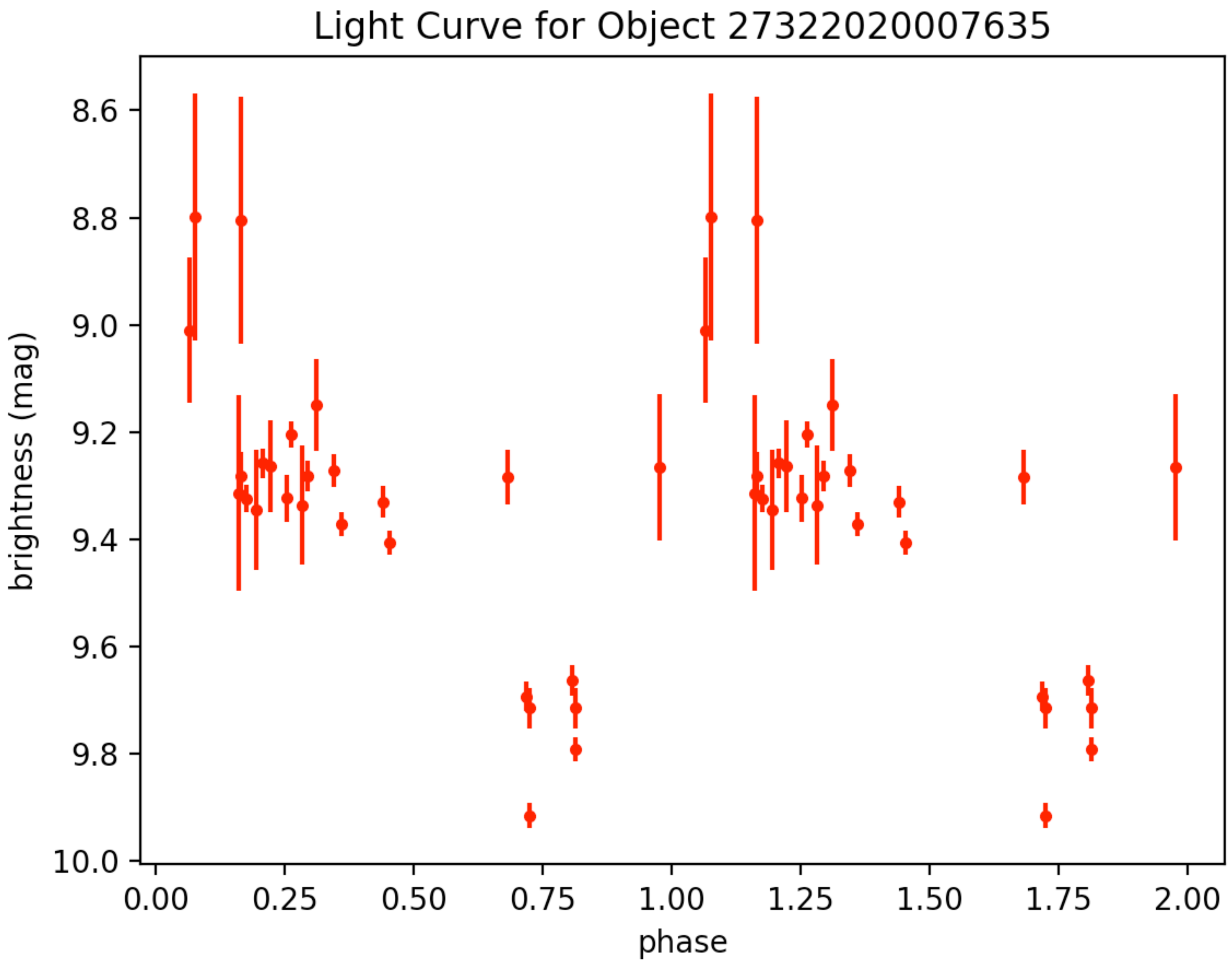
eb85.tbl – 20:27:8.49 -11:32:50.5 – period: 1.0750226023502145 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cap – bad!



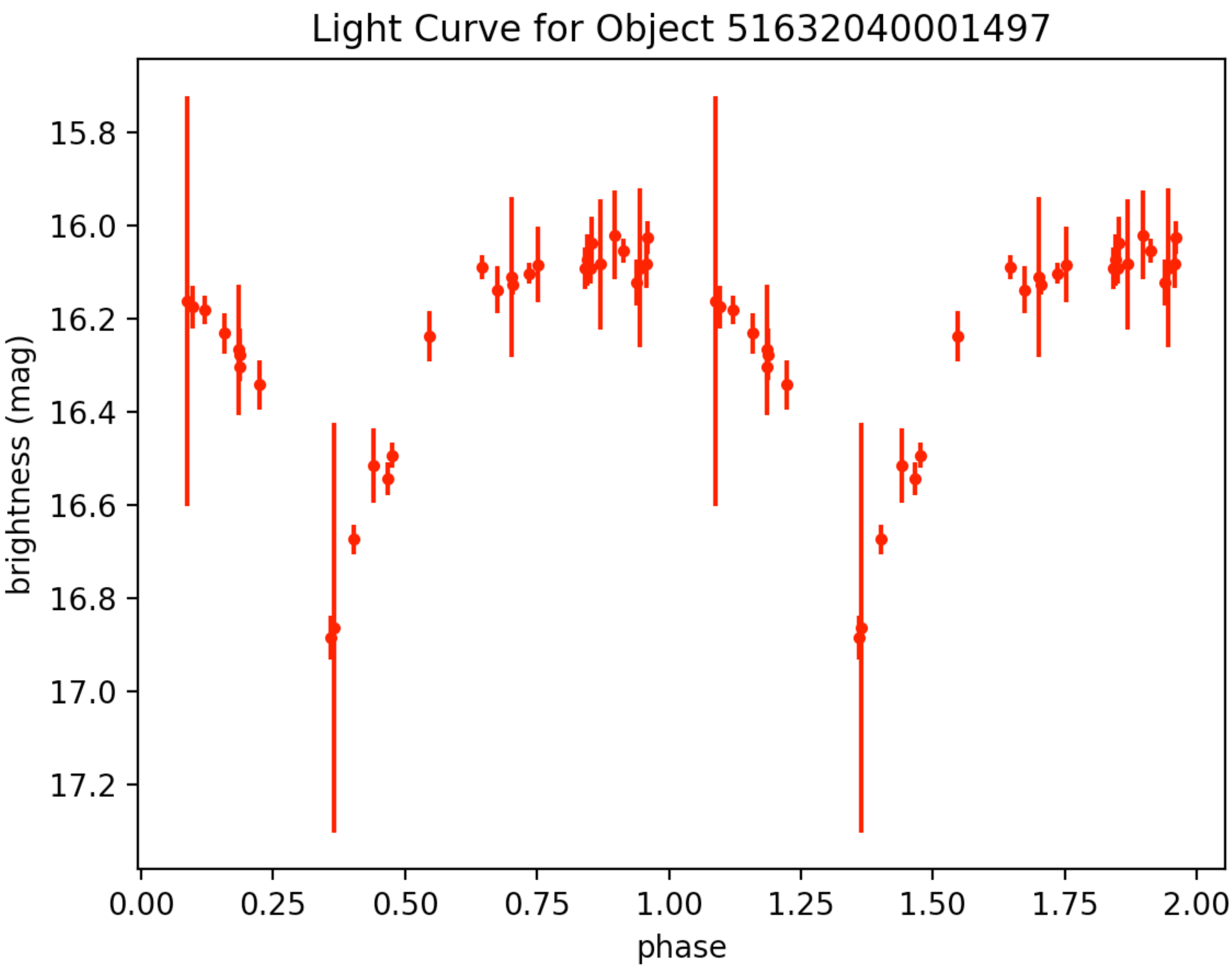
eb88.tbl – 20:24:29.7 -12:57:55 – period: 1.822110951980088 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cap – bad!



eb94.tbl – 8:6:38.6 +1:55:46 – period: 0.5474247769928314 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=CMi – bad!



eb148.tbl – 13 18 19.519 +66 39 28.71 – period: 0.327893148803813 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



KIC	Period (days)	RA(°) (J2000)	Dec(°) (J2000)
1573836	3.557093	291.5025	37.1775
2010607	18.632296	290.5056	37.4590
2444348	103.206989	291.6687	37.7041
2697935	21.513359	287.4679	37.9666
2720096	26.674680	292.9791	37.9109
3230227	7.047106	290.1126	38.3999
3240976	15.238869	292.9291	38.3280
3547874	19.692172	292.2829	38.6657
3729724	16.418755	285.6555	38.8505
3734660	19.942137	287.6238	38.8554
3749404	20.306385	292.0795	38.8371
3764714	6.633276	295.7400	38.8623
3766353	2.666965	296.0538	38.8943
3850086	19.114247	291.3975	38.9647
3862171	6.996461	294.4970	38.9801
3869825	4.800656	296.1339	38.9990
3965556	6.556770	294.3909	39.0767
4142768	27.991603	287.2629	39.2600
4150136	9.478402	289.6193	39.2939
4247092	21.056416	286.8797	39.3784
4248941	8.644598	287.6032	39.3977
4253860	155.061112	289.2337	39.3865
4359851	13.542328	290.0829	39.4008
4372379	4.535171	293.5203	39.4478
4377638	2.821875	294.7438	39.4994
4450976	12.044869	287.3733	39.5261
4459068	24.955995	290.0244	39.5634
4470124	11.438984	293.1966	39.5072
4545729	18.383520	286.4008	39.6984
4649305	22.651138	290.1033	39.7816
4659476	58.996374	293.1102	39.7564
4669402	8.496468	295.5339	39.7623
4761060	3.361391	295.5471	39.8618
4847343	11.416917	294.9517	39.9294
4847369	12.350014	294.9584	39.9046
4936180	4.640922	295.1137	40.0712
4949187	11.977392	297.9250	40.0884
4949194	41.263202	297.9279	40.0549
5006817	94.811969	290.4560	40.1457
5017127	20.006404	293.5486	40.1117
5034333	6.932280	297.4004	40.1495
5039392	236.727941	298.4009	40.1722
5090937	8.800693	289.2657	40.2555

use ga if want to use l and b?

Tried online converters….

Shouldn't need to => just plug in as is to PTF (it can handle both coords)

Binary Classification / Types

- **roche lobe**: used to describe a distinctively shaped region surrounding a star in a binary system. This teardrop-shaped space defines the region in which material is bound to the star by gravity. Any material outside the Roche-lobe of a star may, depending on its initial location, energy and momentum, either escape the system completely, orbit both stars, or fall onto the binary companion.

- In **detached binaries**, both components are well within their Roche lobes.
- In **semi-detached binaries** (SD in the GCVS4), one component fills its Roche lobe; the other is well within its Roche lobe. The former star is distorted, and is prob- ably losing mass through the inner Lagrangian point; the latter star is almost spherical (figure 5.4).
- In **contact binaries** (K in the GCVS4), both components fill their Roche lobes, and are essentially in contact.

Period Ranges for EBs:

— the farther apart the eclipsing binaries (i.e. the more detached it is, the longer the period) => detached binaries have the longest periods, then semi-detached, then contact binaries — cut-offs?

The periods of eclipsing variables are generally in the range of 0.25 to ten days because, as mentioned above, most eclipsing variables are likely to be close binaries.

contact binaries period: 0 - ~10

semi-detached period: ~8 - ~16

detached periods: ~20 - infinity

how good is this? what modifications would make more robust?

Detached binary: There is no physical contact between the both stars. None has filled it's Roche lobe and they are both spherical in shape (unless one or both of them rotate really fast).

Semi-detached binary: One of the stars has filled its Roche lobe and has a shape which resembles an egg - due to the gravitational distortion of a very close neutron star or a black hole, which also rips gas from the surface of the distorted star. The gas often has a too high angular momentum while moving towards the compact object that the gas slowly forms an accretion disc.

Contact binary: In this case, both stars will have filled their Roche lobe, and may have become slightly egg-shaped. In this case the stars are relatively close to each other.

=> the shape of the light curve will be the telling difference?

I think in general detached binaries will have the longest periods, but semi-detached and contact binaries overlap?

Look at light curve character not period.

Distinguished by LC

Can tell what's going on EB type based off LC!

the size of the star relative to orbit determines period (not the type of EB)

two stars orbiting - they can evolve and become giants that both fill roche lobe so what started out as detached becomes semi-detached when the first giant fills roche lobe and can become contact binaries if they both fill roche lobe

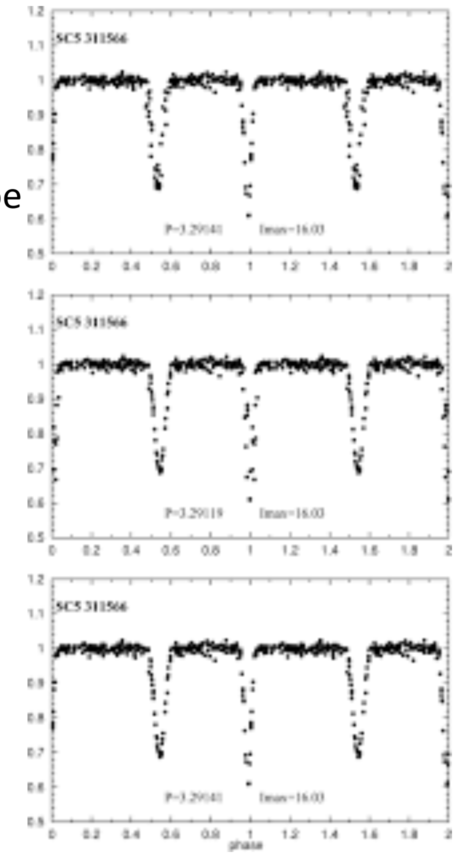
even as this evolution is happening, the orbit stays approx. the same b/c the mass is pretty much invariant

detached => sharp dip in light curve

semi-detached => onset is more gradual, rounded between eclipses

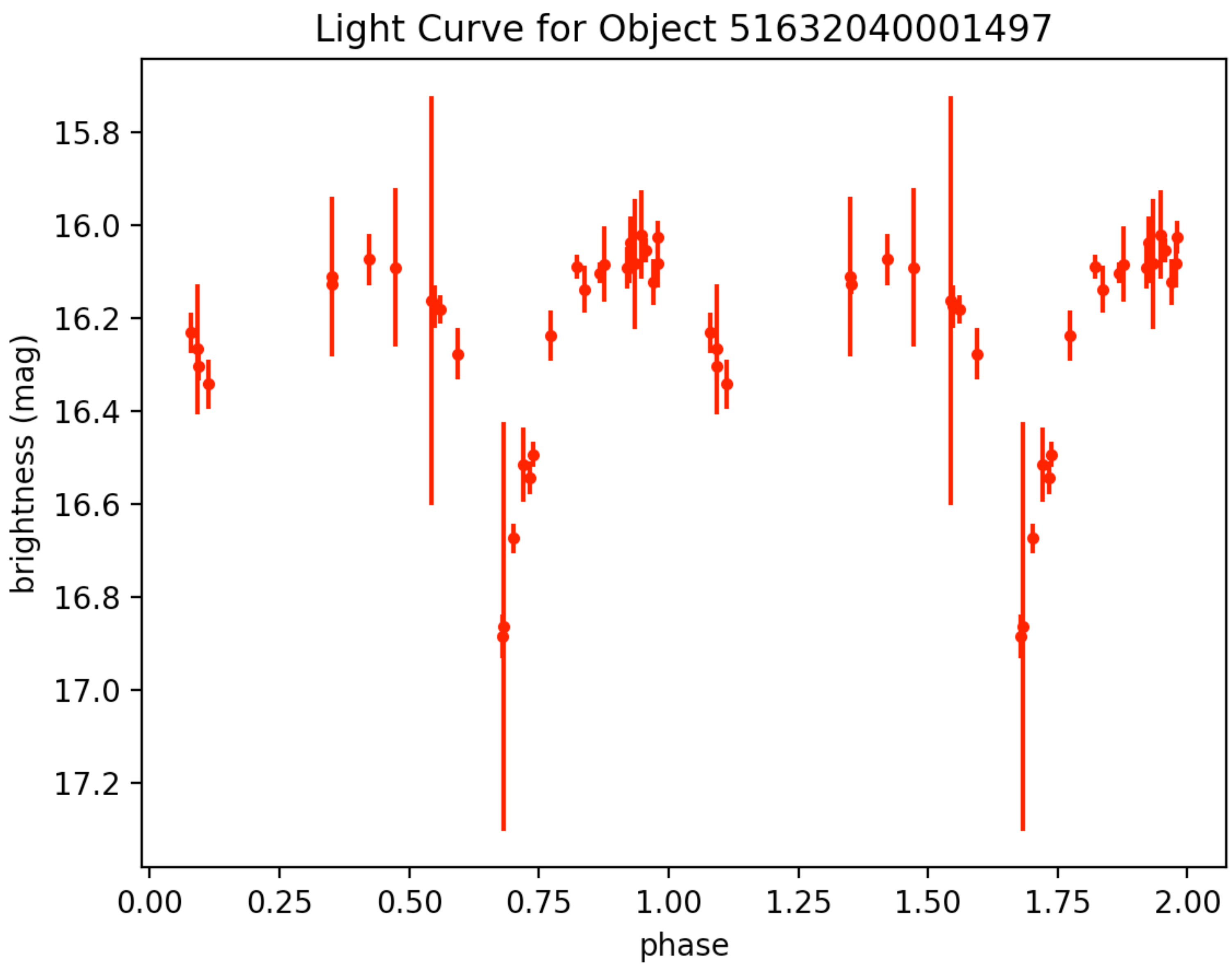
contact binaries => look sinusoidal - you don't have the flat part outside of eclipse b/c they are 'touching'

To the right: detached binary light curves

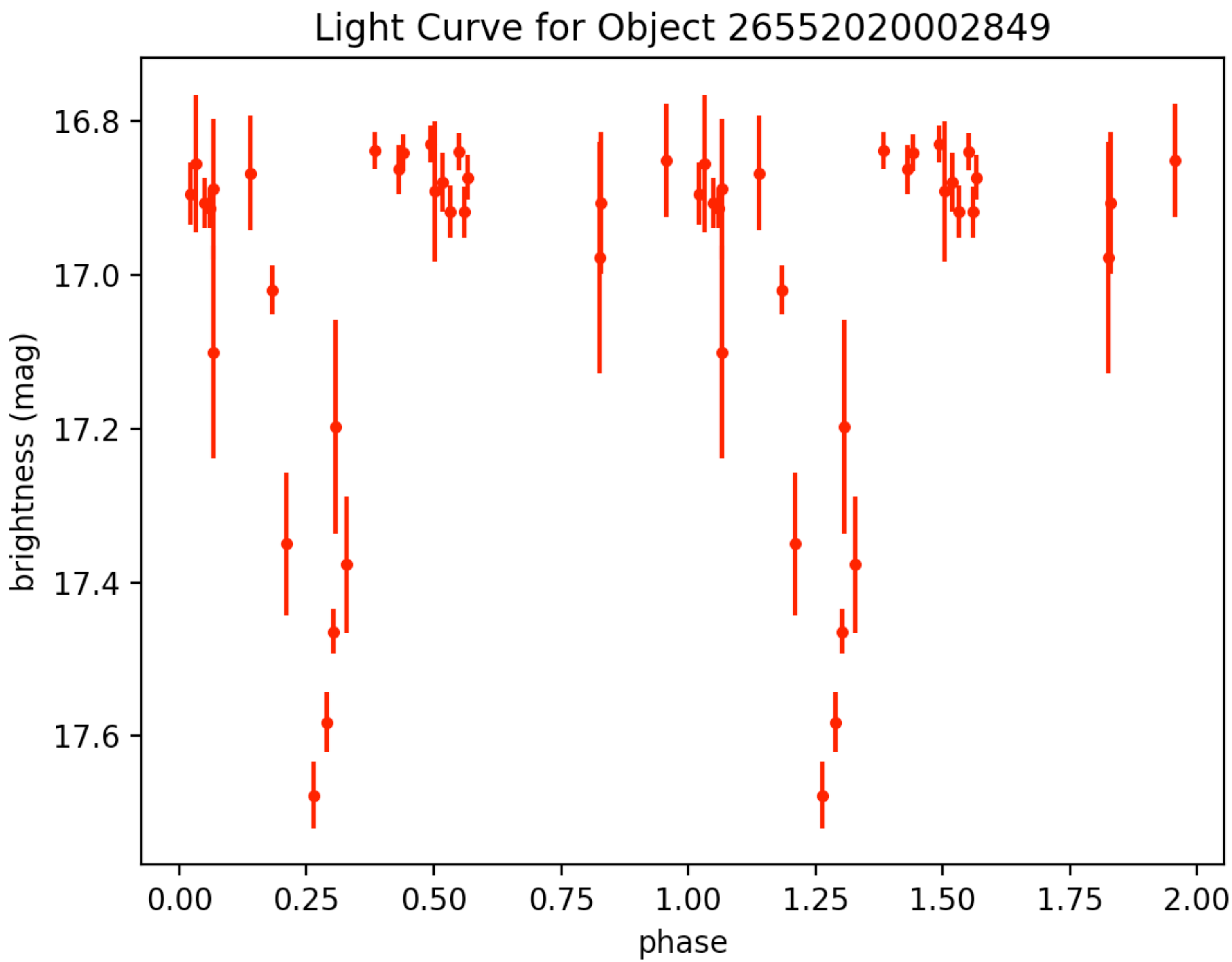


Let’s find more good EB LCs…

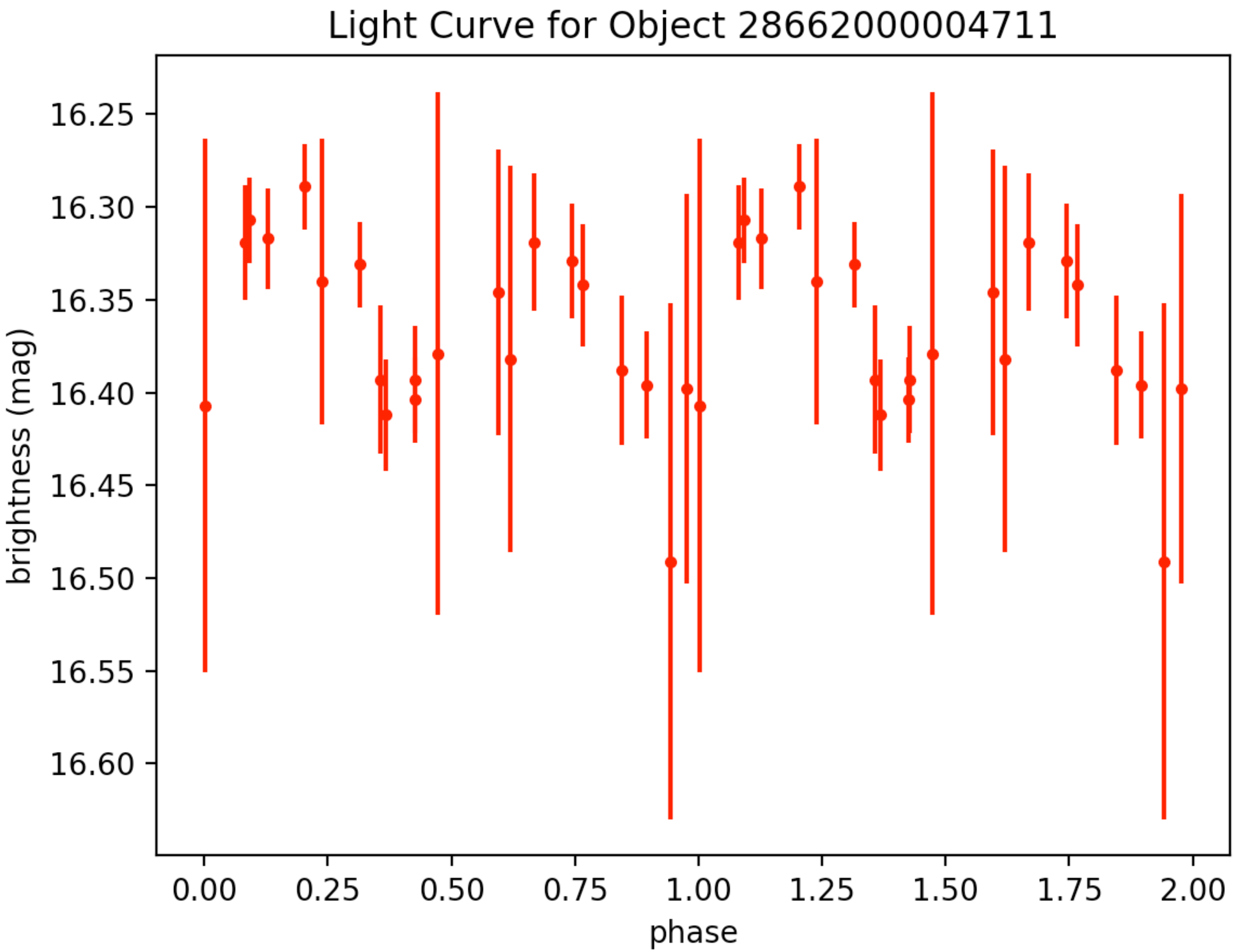
eb148.tbl – 13 18 19.519 +66 39 28.71 – period: 0.327893148803813 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows] – with T'=2T



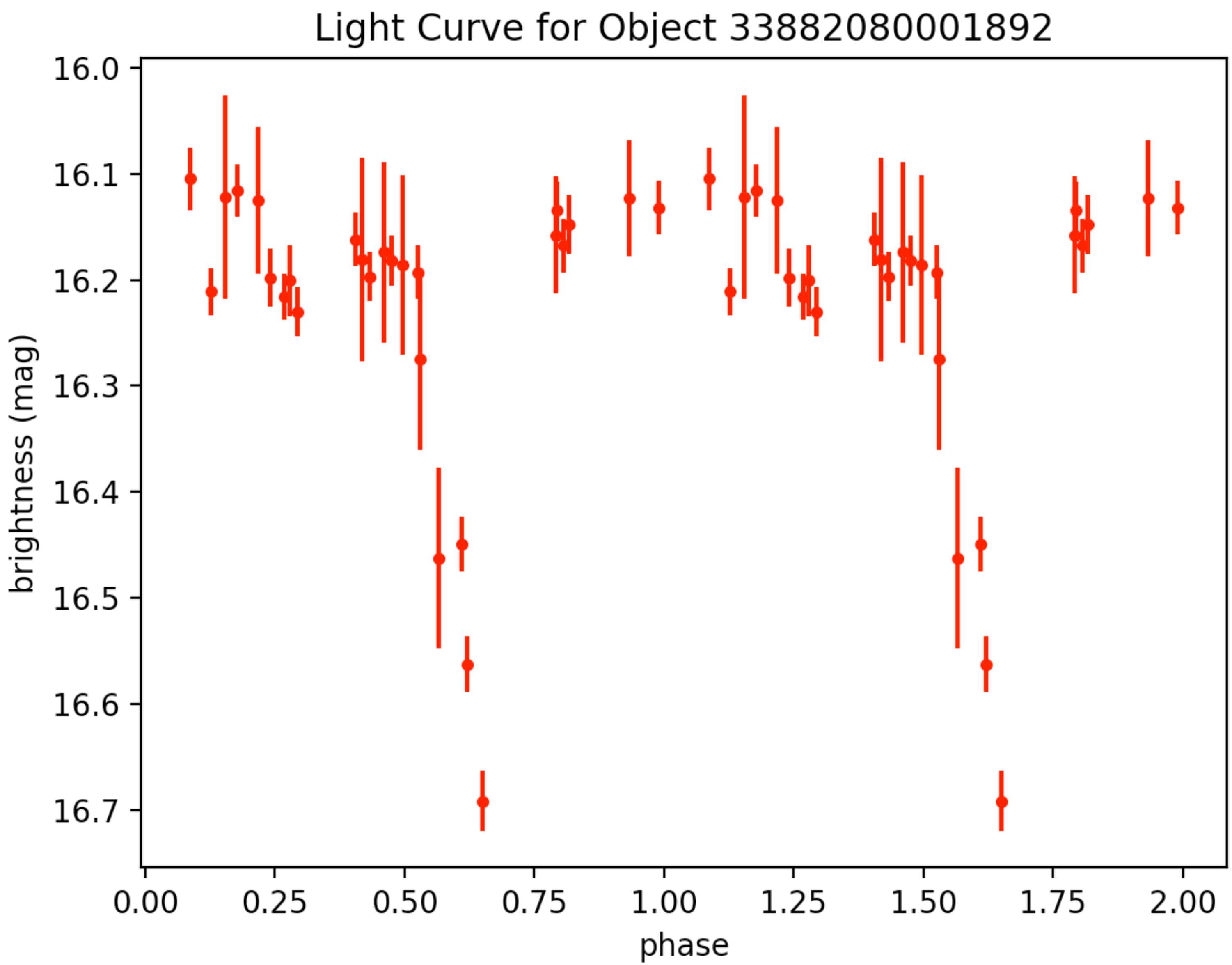
eb151.tbl – 14 30 12.451 -00 37 45.08 – period: 0.20028542676167807 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows] – with T'=2T



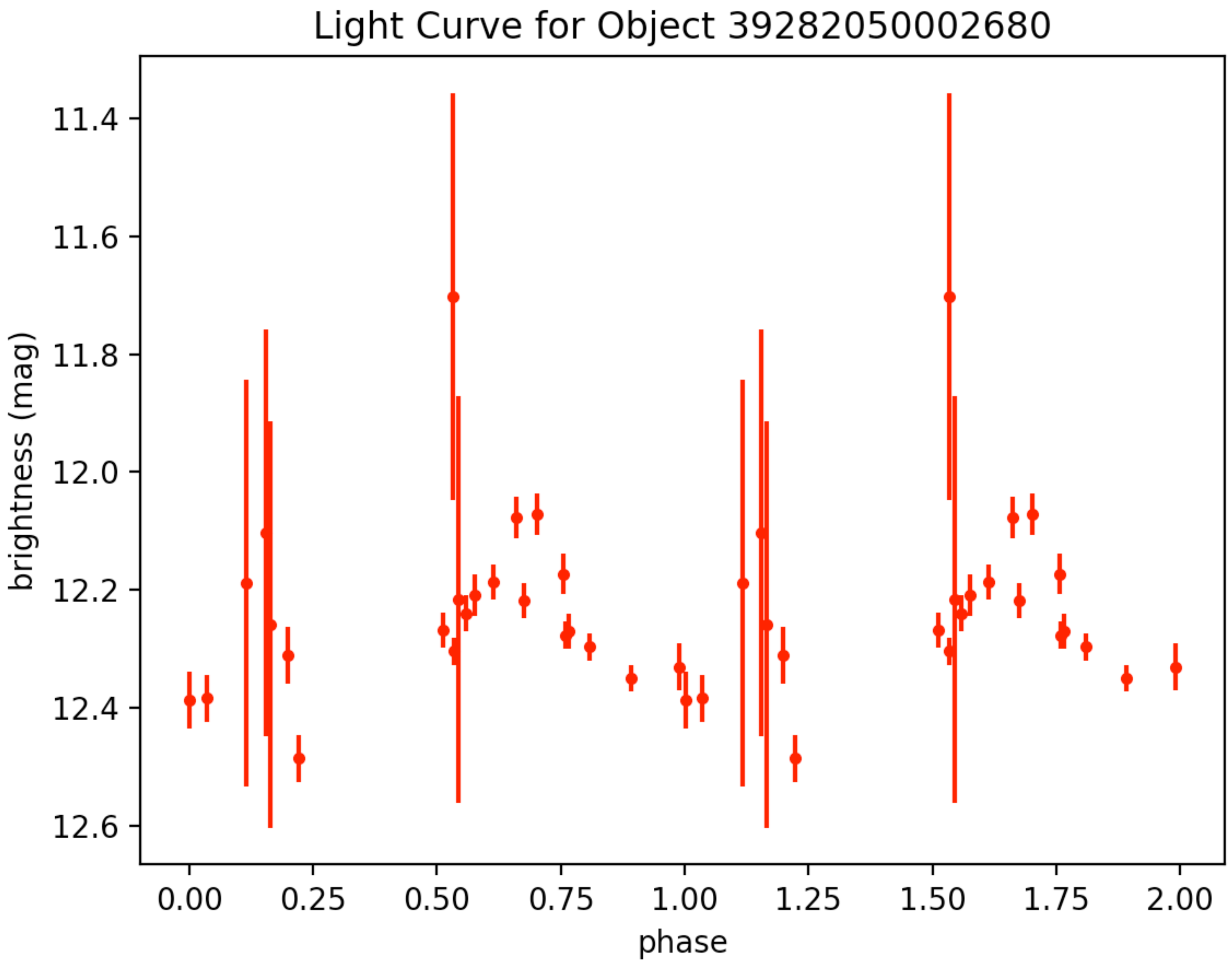
eb153.tbl – 14 38 38.591 +04 10 57.57 – period: 0.1029746651946095 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows] – with T'=2T



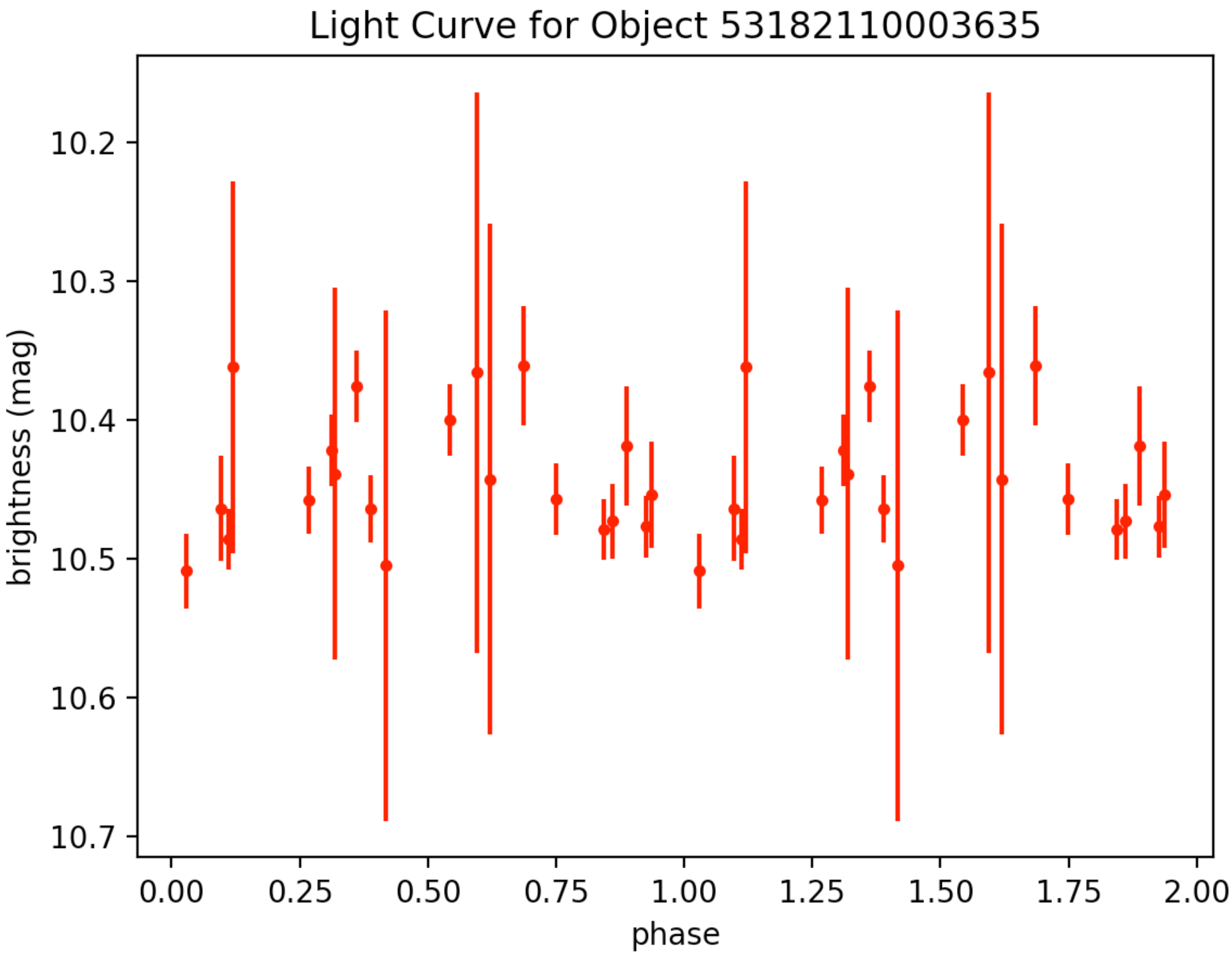
eb158.tbl – 15 09 24.767 +13 46 00.83 – period: 0.3090320806202892 – http://vizier.cfa.harvard.edu/viz-bin/VizieR?-source=J/MNRAS/453/3474 (Binary properties from MECI, including 1558 LC from ASAS, 350 LC from NSVS, and 230 LC from LINEAR [2138 rows]



eb63.tbl – 3:5:51.8 +28:34:4 – period: 0.03582776504 –
http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Ari – bad!



eb83.tbl – 4:5:57.6 +76:53:12 – period: 0.06056084184415031 – http://var2.astro.cz/EN/brno/eclipsing_binaries.php?f=list&cons=Cam – disregard!



Questions

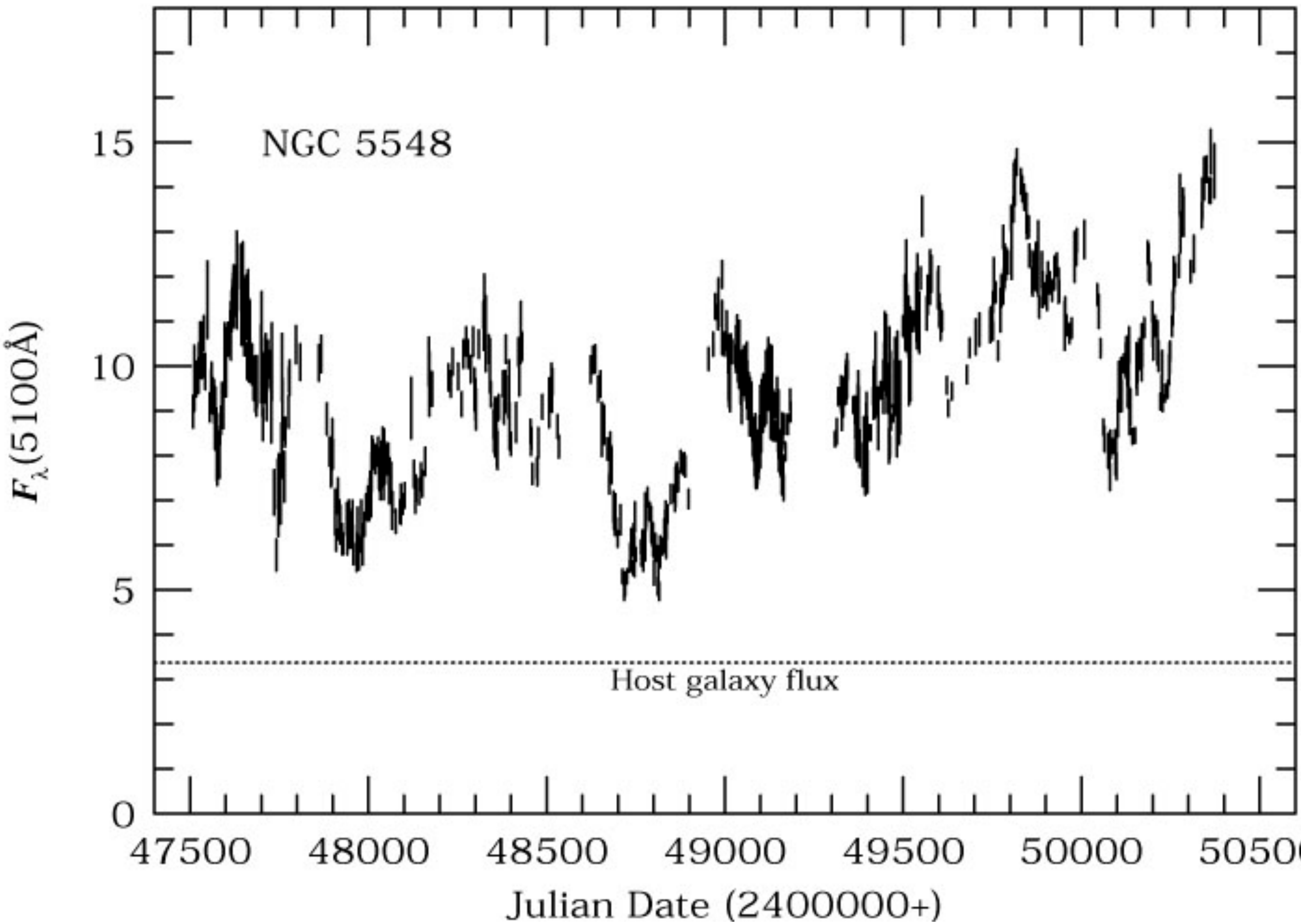
— range 0.25 - 10 days good for EBs?

— picture for the three types of EBs that adam and I found at meeting - I couldn't find again doing a quick google search

— EB LC one dip? Is this possible and if so how?

Week 7

Quasars (AGN)



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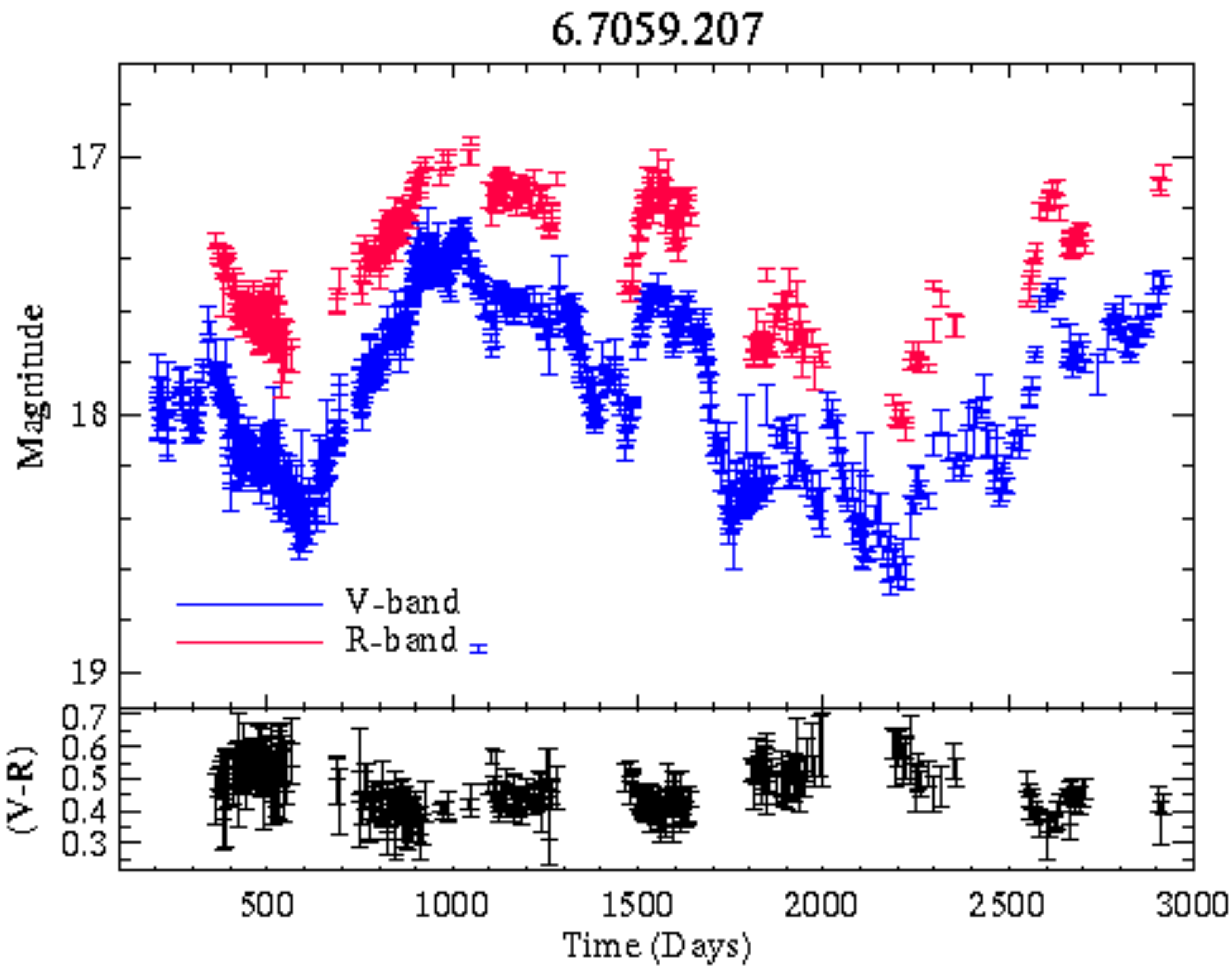
Host galaxy flux
47500
48000
48500
49000
49500
50000
5050(
Julian Date (2400000+)

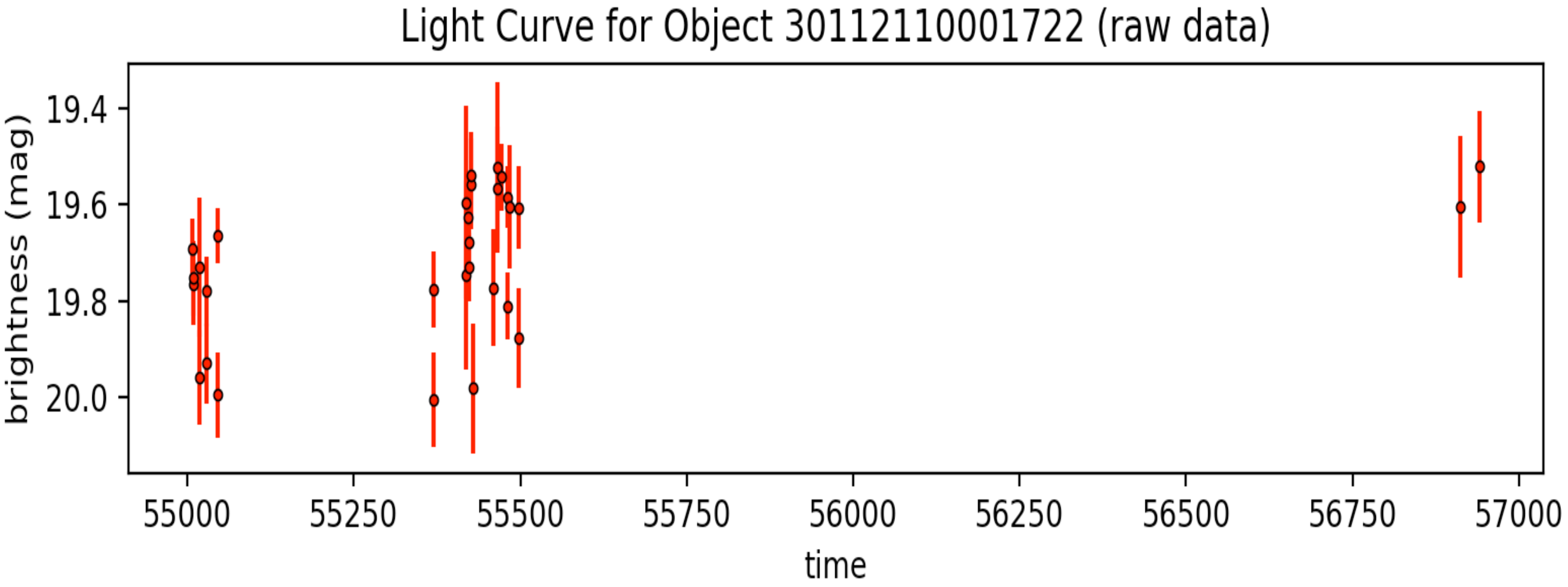
Quasars (AGN)


6.7059.207
Magnitude
17
18
19
V-band
R-band
(V-R)
0.7
0.6
0.5
0.4
0.3
500
1000
1500
2000
2500
3000
Time (Days)

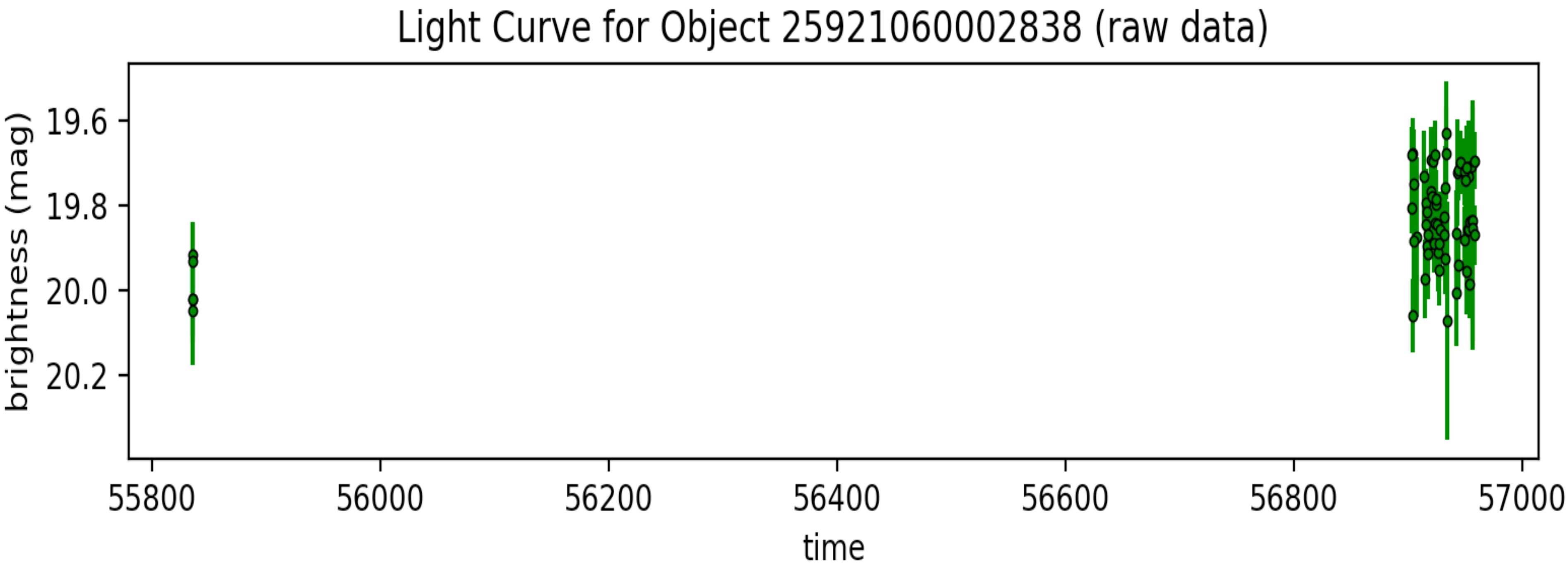
Quasar Question

- Quasars live only in galaxies with supermassive black holes — black holes that contain billions of times the mass of the sun. Although light cannot escape from the black hole itself, some signals can break free around its edges. **How? Why?**
  - While some dust and gas fall into the black hole, other particles are accelerated away from it at near the speed of light. The particles stream away from the black hole in jets above and below it, transported by one of the most powerful particle accelerators in the universe.
  - **By what mechanism are things emitted from black hole? If it gets within its roche lobe, so to speak, it is a goner, but if is just outside -> gravitational slingshot?**
  - When a galaxy, star or gas is absorbed into a quasar in such a way, the result is a massive collision of matter that causes a gigantic explosive output of radiation energy and light. This great burst of energy results in a flare, which is a distinct characteristic of quasars. => collision (not gravitational slingshot)
  - magnetic environment forms twin jets of material – AGN => the mechanism is magnetic fields/environment?

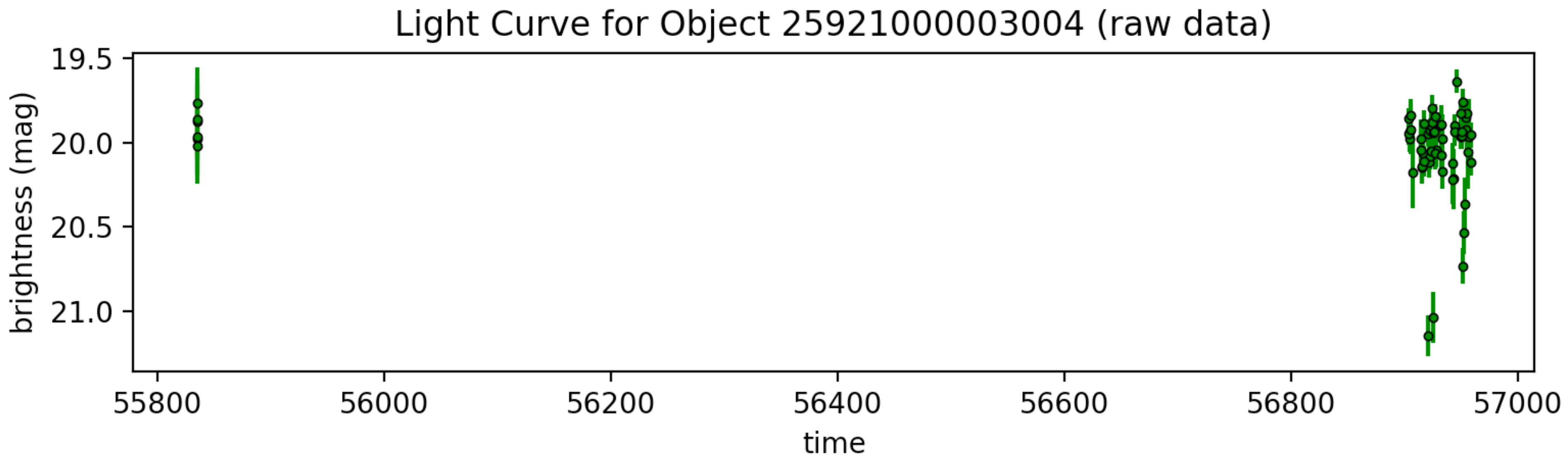
quasar1.tbl – 00 00 00.972 +04 49 47.21 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – AVG

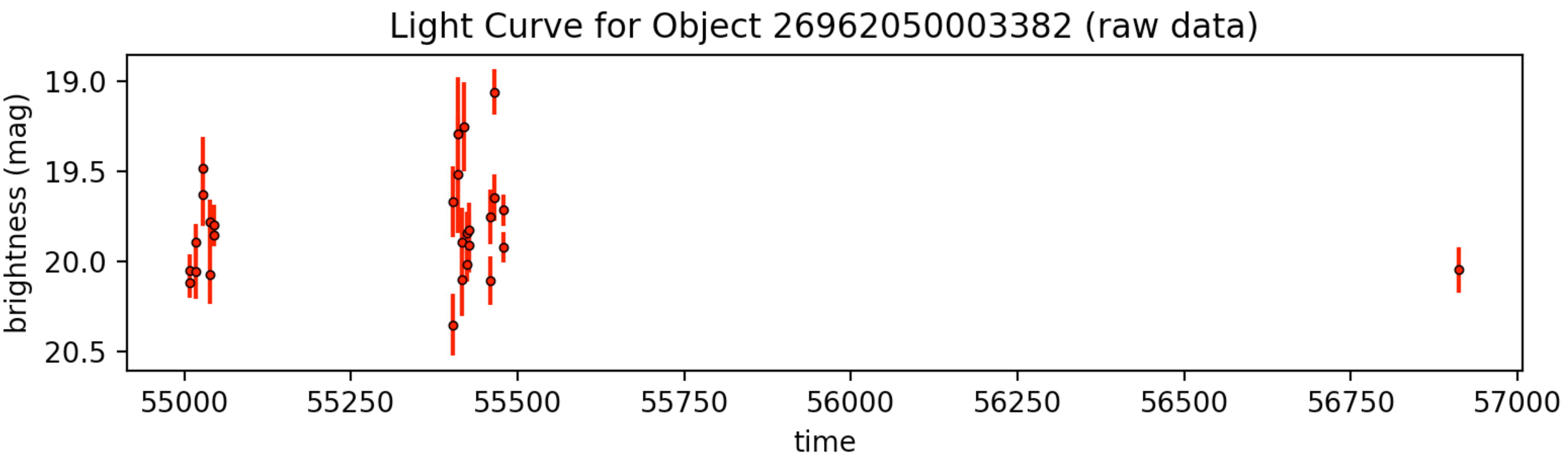


quasar3.tbl – 00 00 01.381 -01 19 30.05 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – BAD

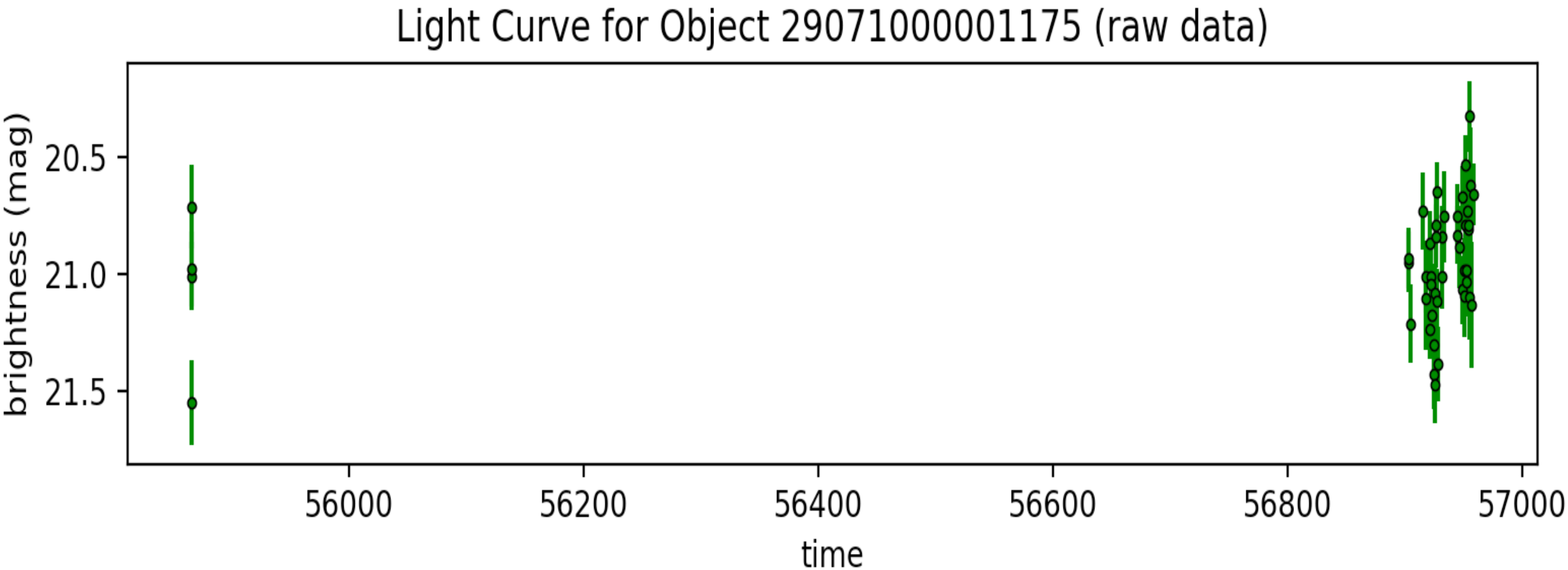


quasar4.tbl – 00 00 01.936 -00 14 27.51 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – OKAY

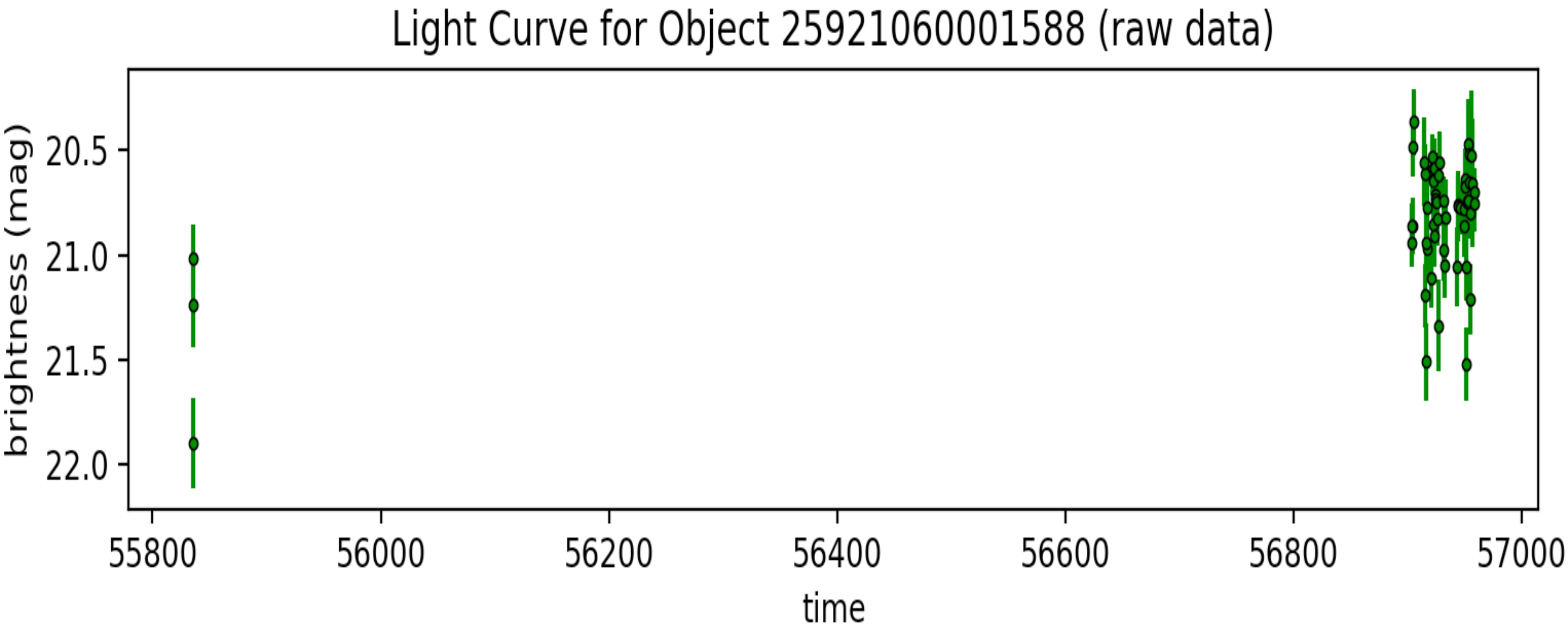




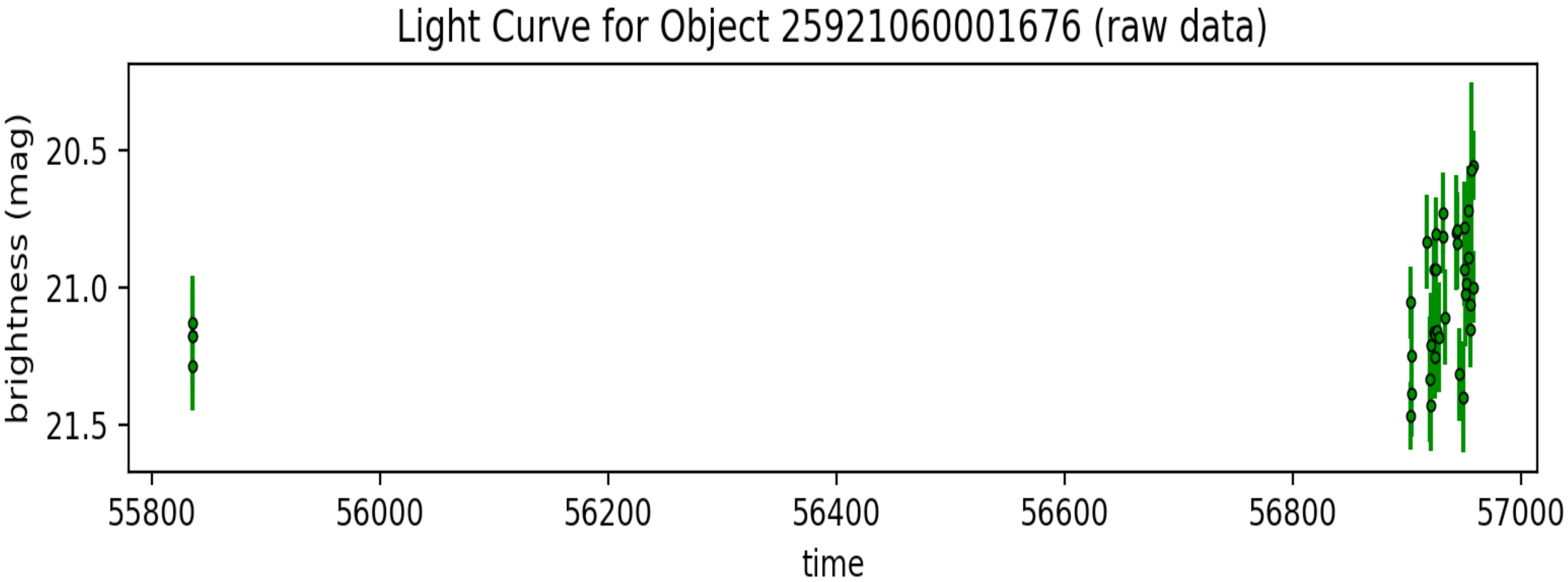
quasar10.tbl – 00 00 07.060 +06 03 33.87 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – BAD



quasar13.tbl – 00 00 11.164 -01 44 34.16 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – bad (but if got rid of white space…)



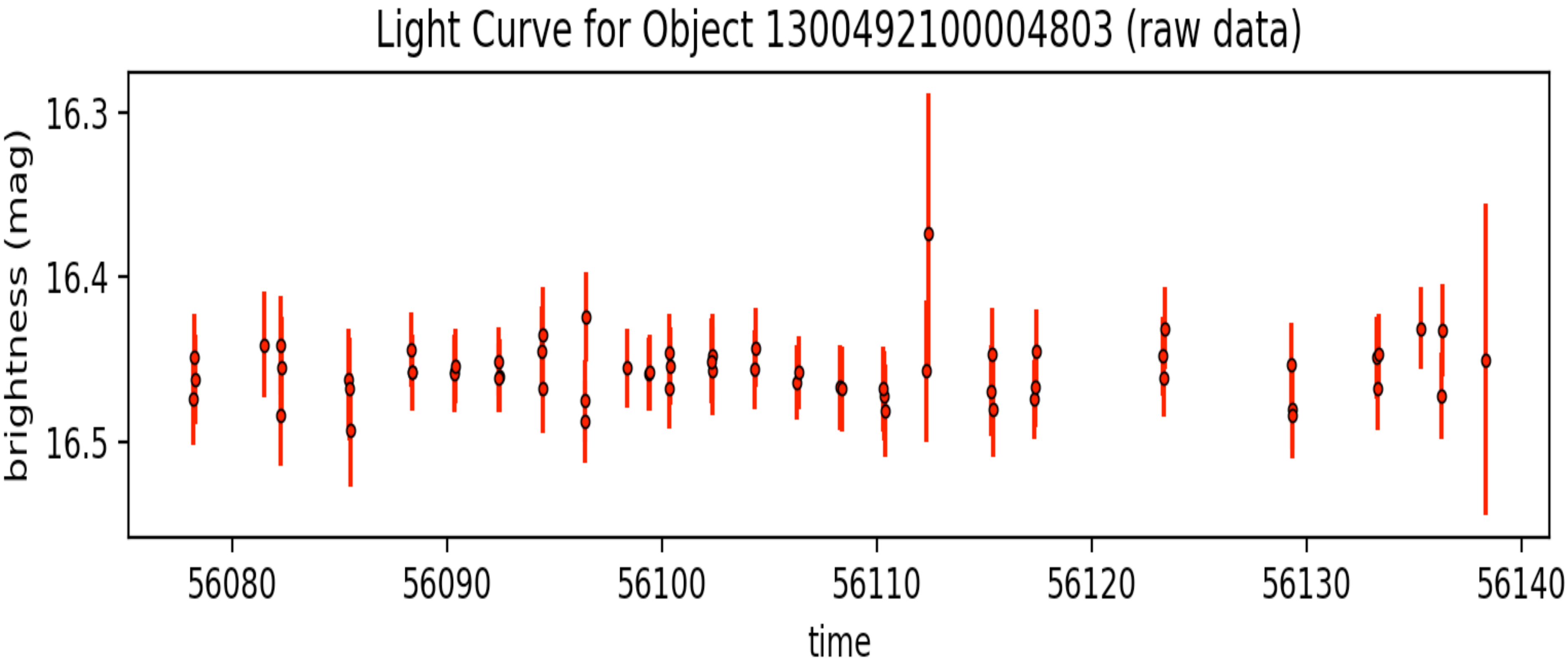
quasar15.tbl – 00 00 12.600 -01 42 16.73 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – bad (but if got rid of white space)



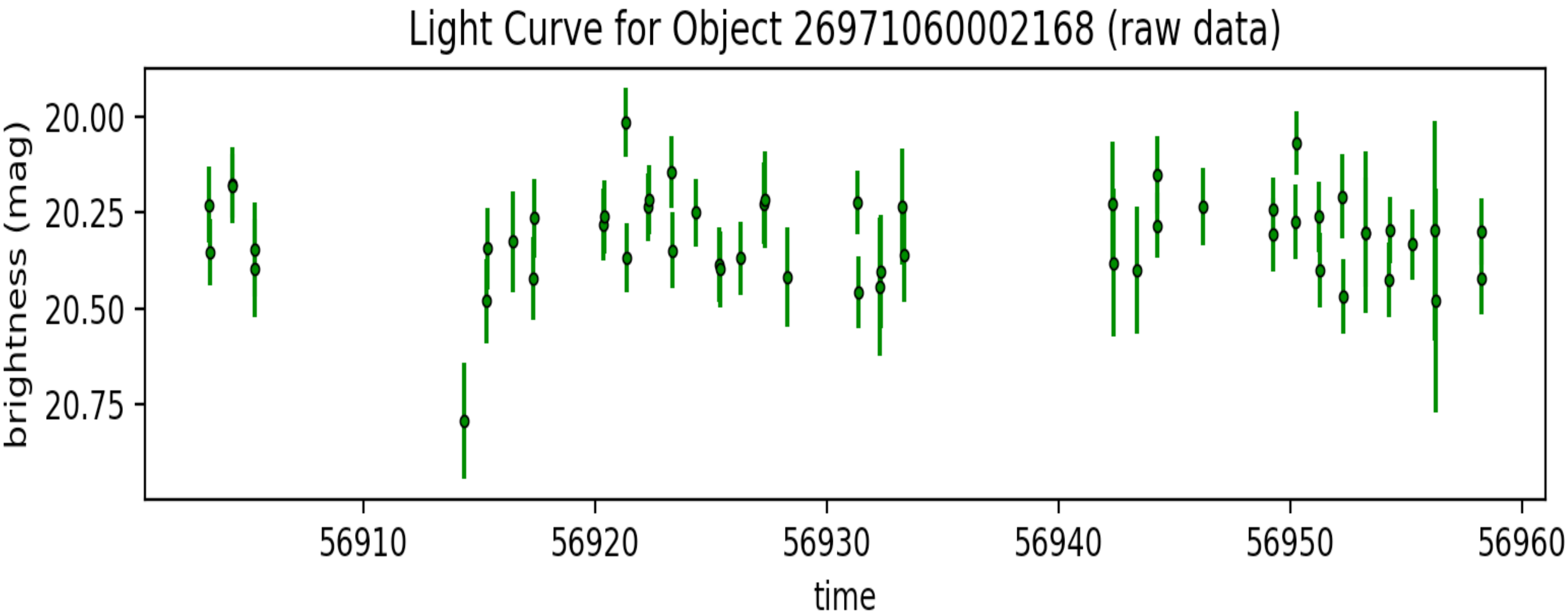
Week 8

Best Quasars…

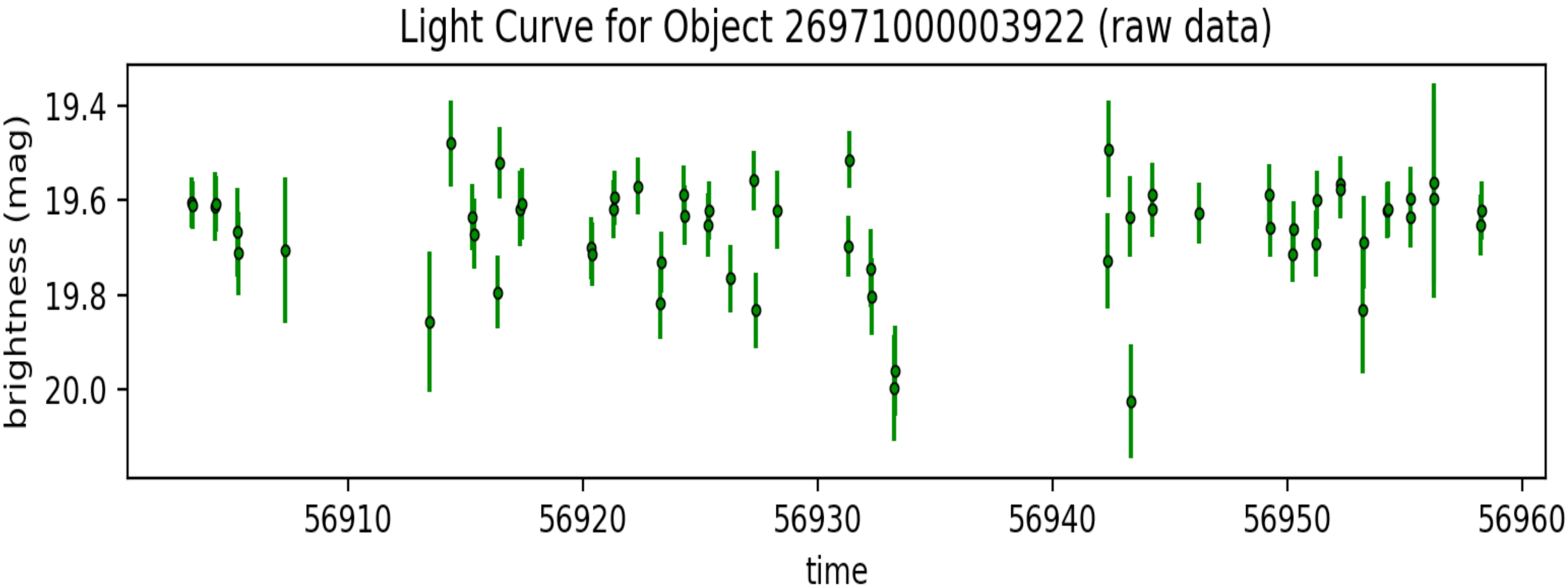
quasar60.tbl – 16 07 44.826 +18 46 48.26 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – GREAT



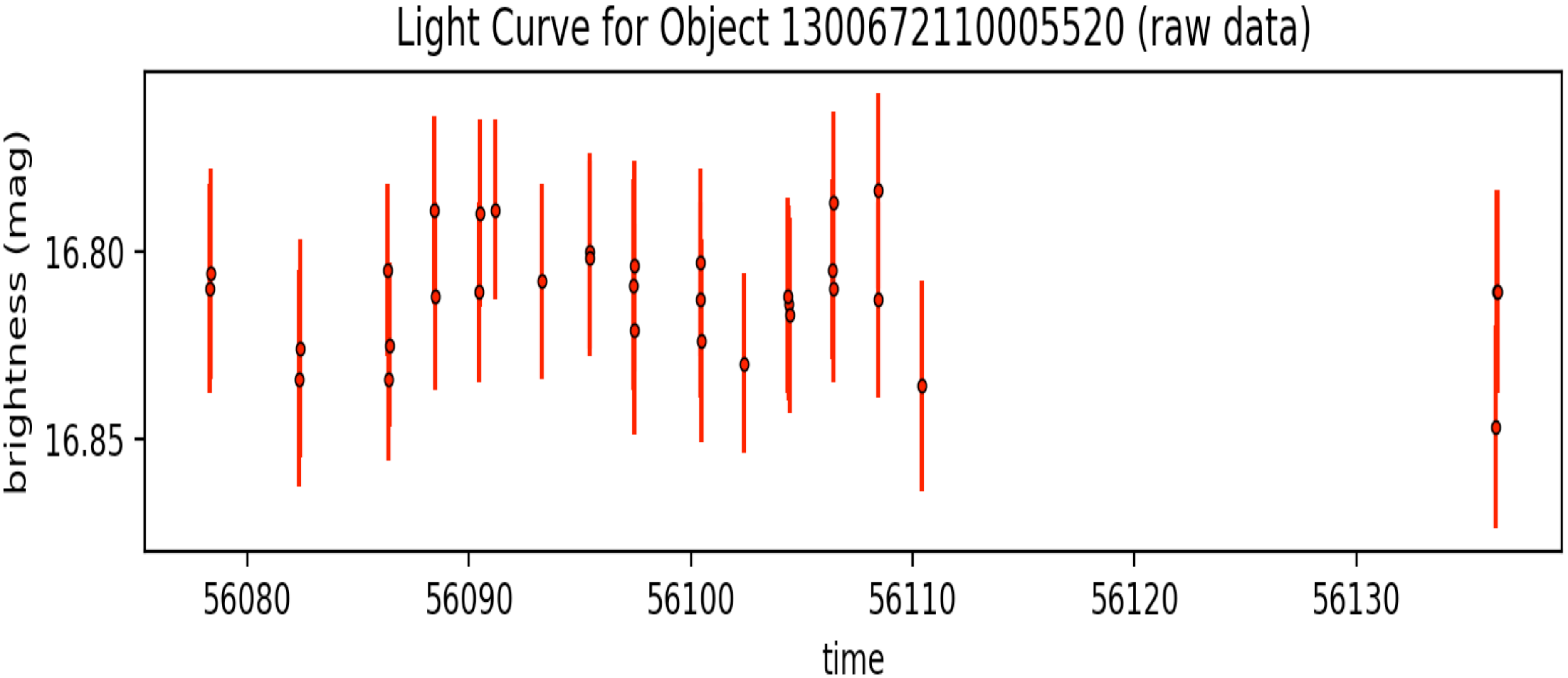
quasar11.tbl – 00 00 07.589 +00 29 43.27 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – great (mimics getting rid of white space)



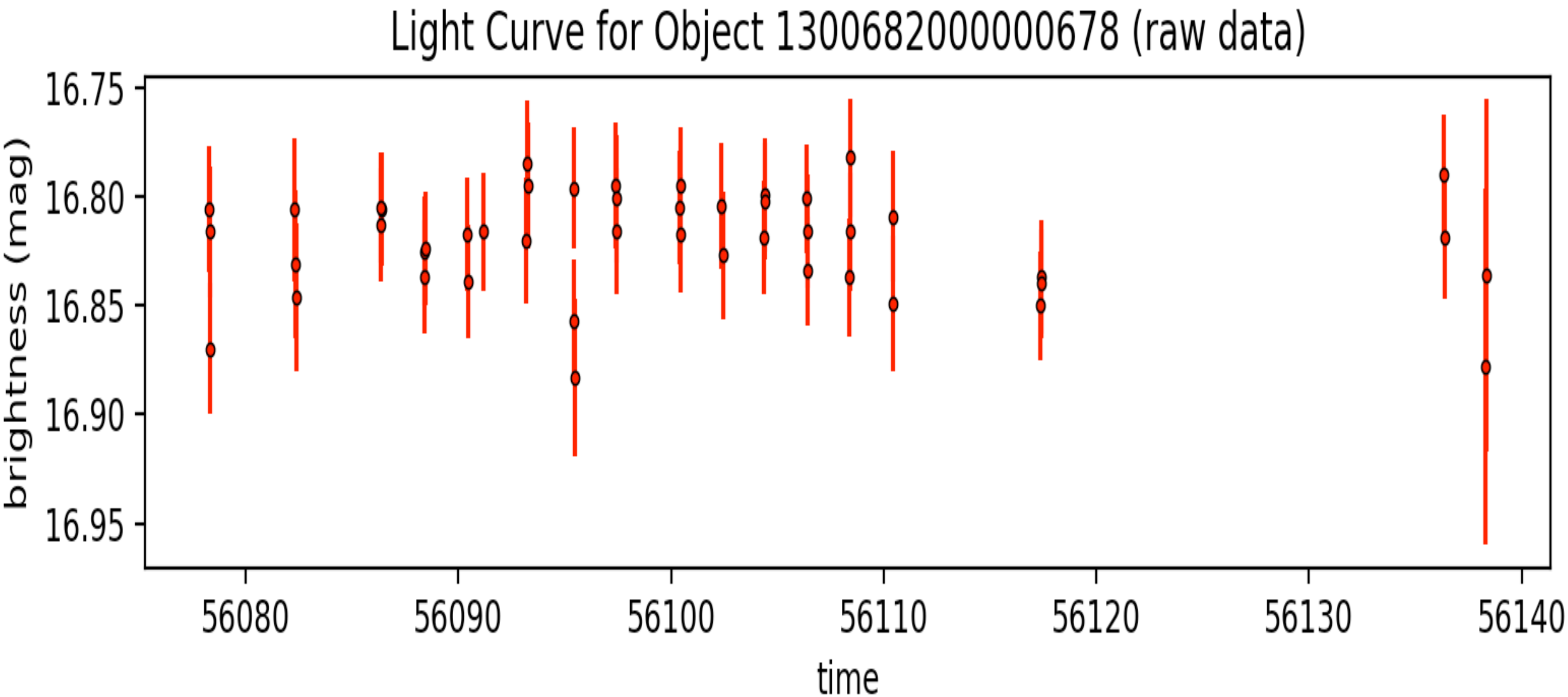
quasar12.tbl – 00 00 09.278 +02 06 21.99 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa – more random (not quite as good as last one)



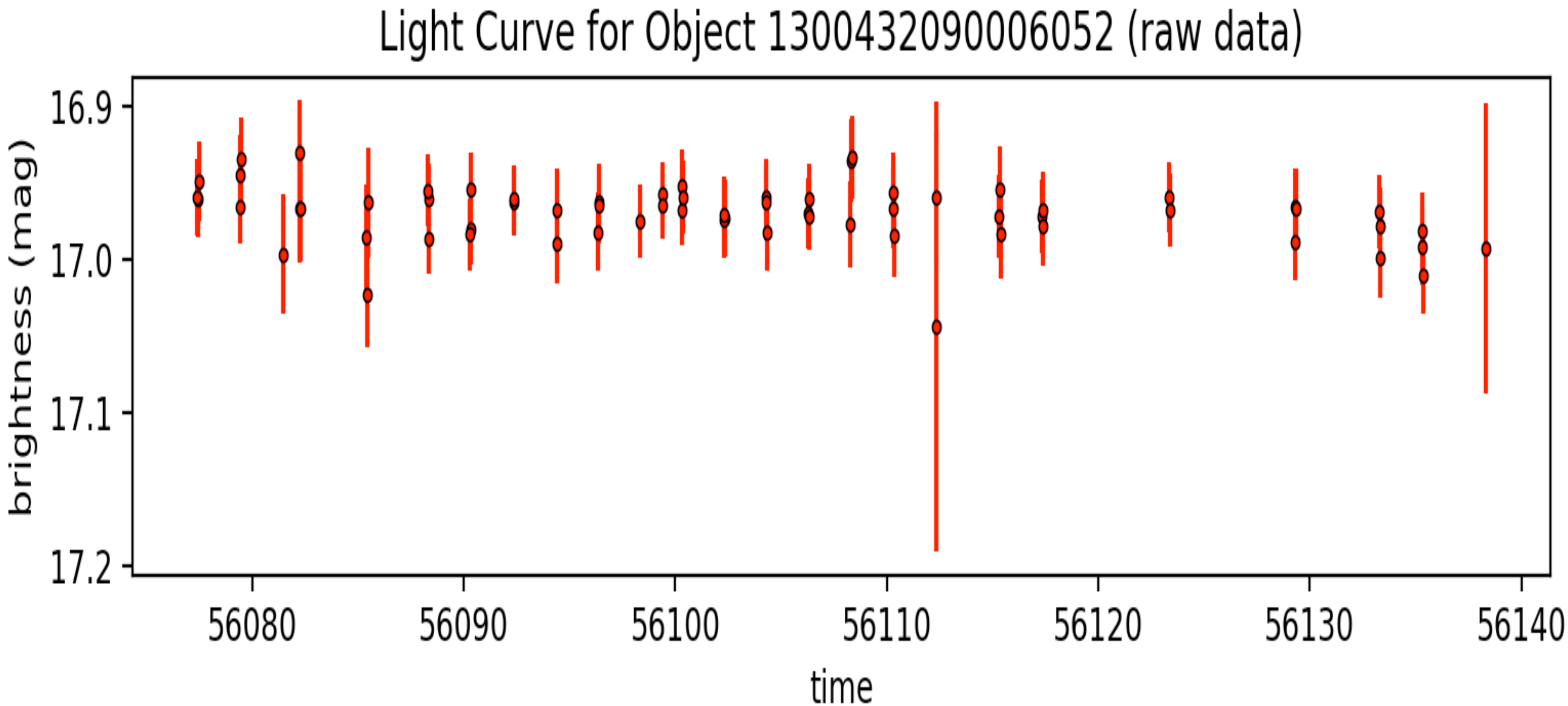
quasar74.tbl – 16 19 02.497 +30 30 51.62 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



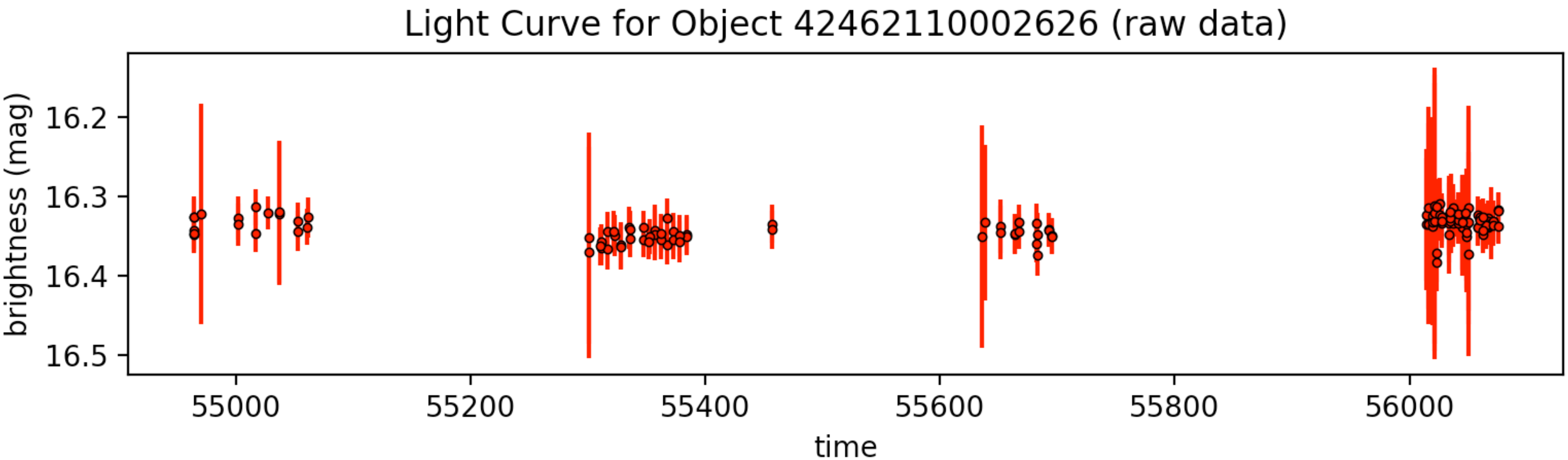
quasar74.tbl – 16 19 02.497 +30 30 51.62 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

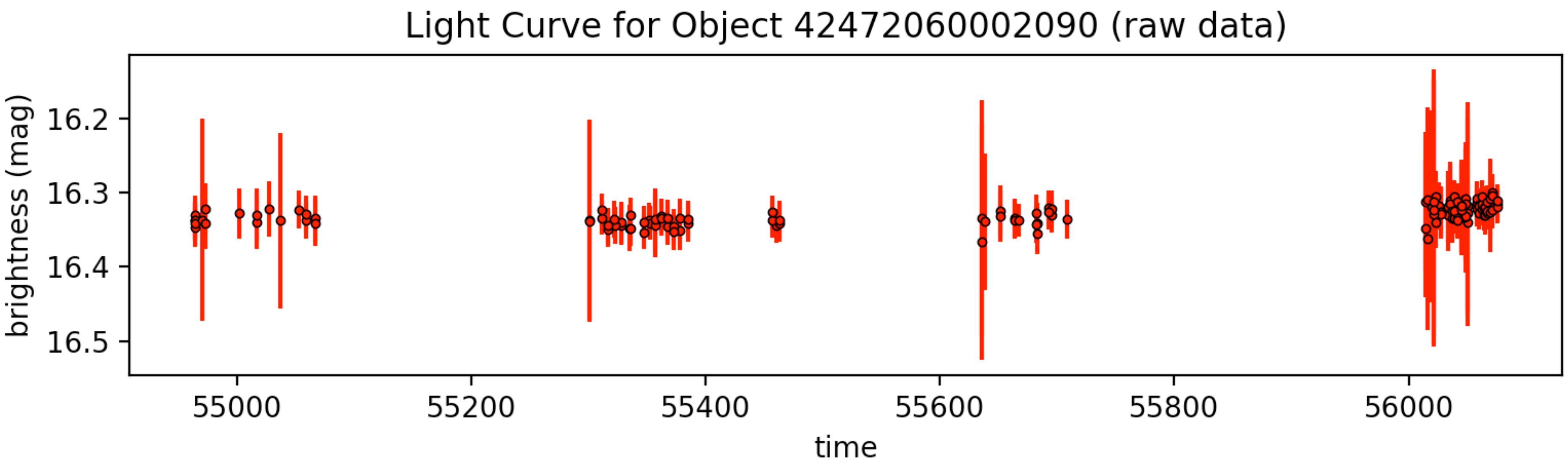


quasar76.tbl – 16 04 41.472 +16 45 38.34 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



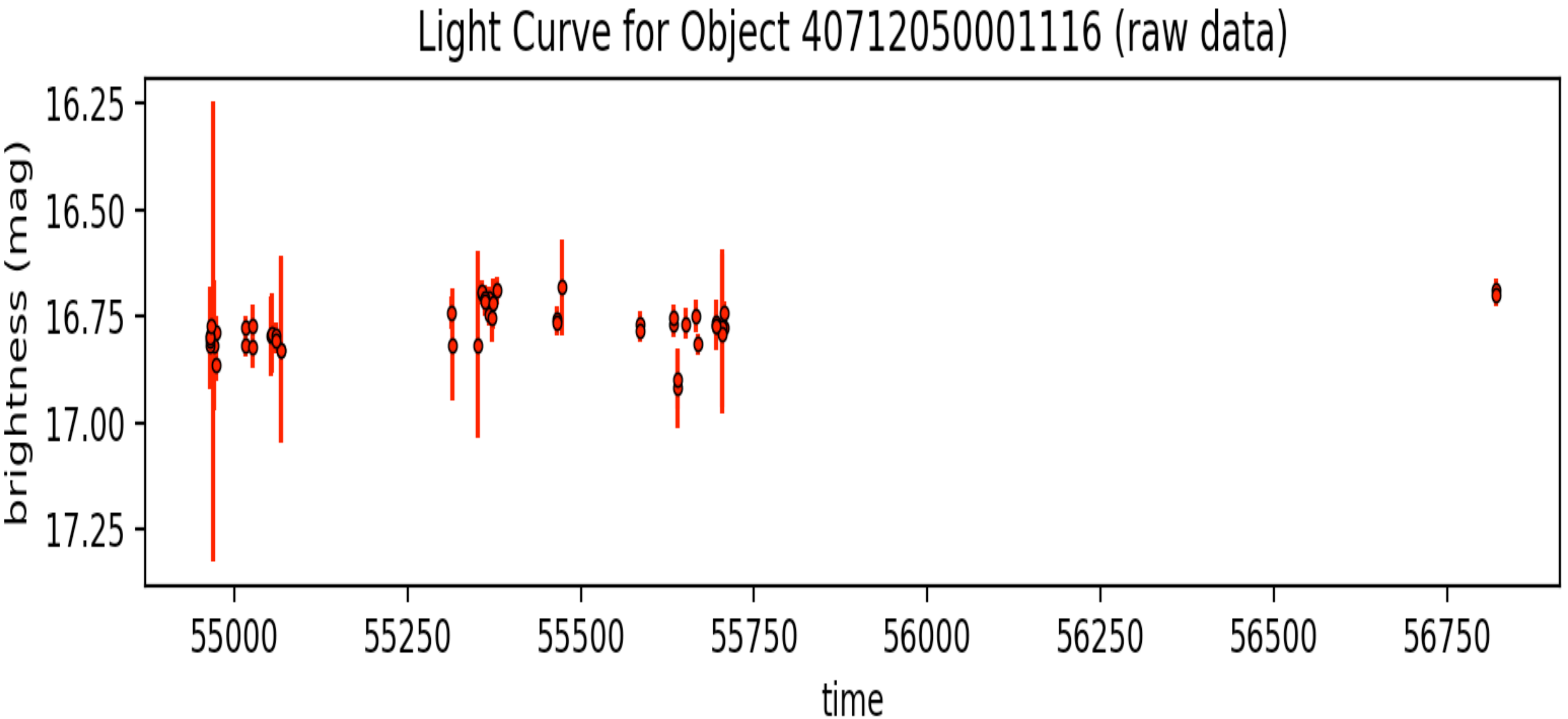
quasar51.tbl – 15 43 29.473 +33 59 08.71 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



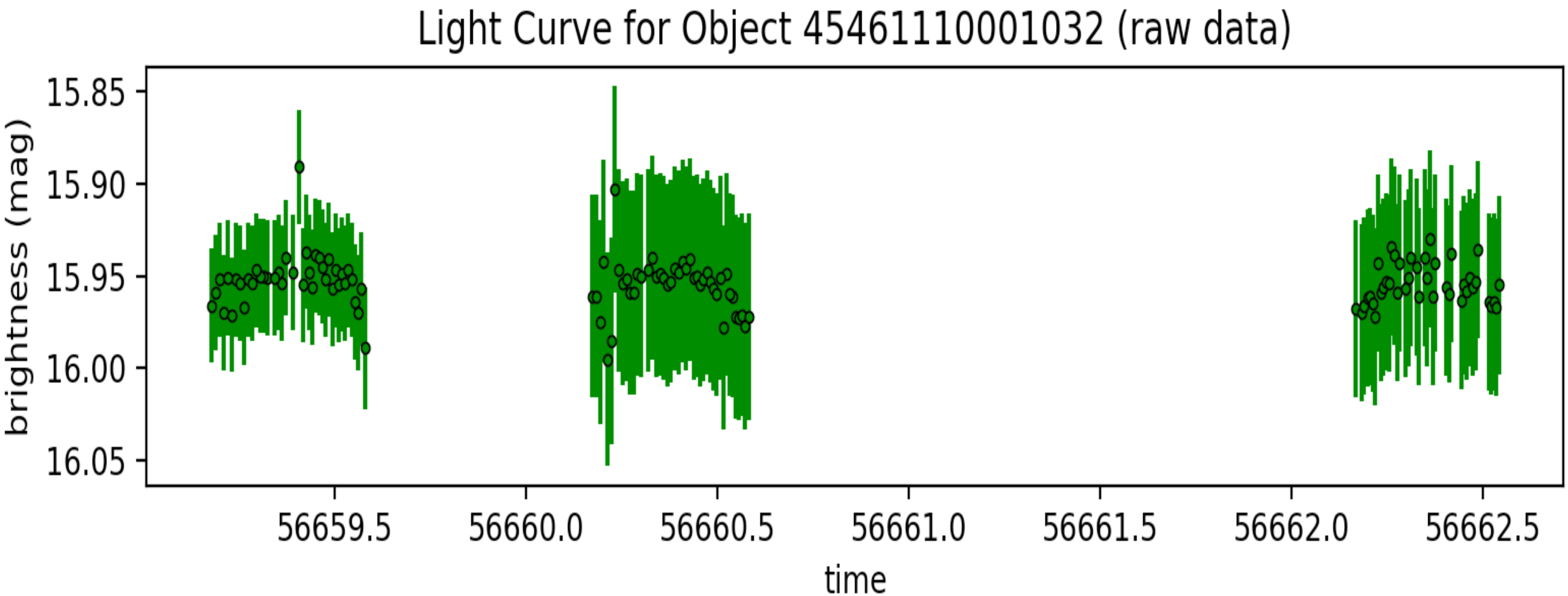


Others…

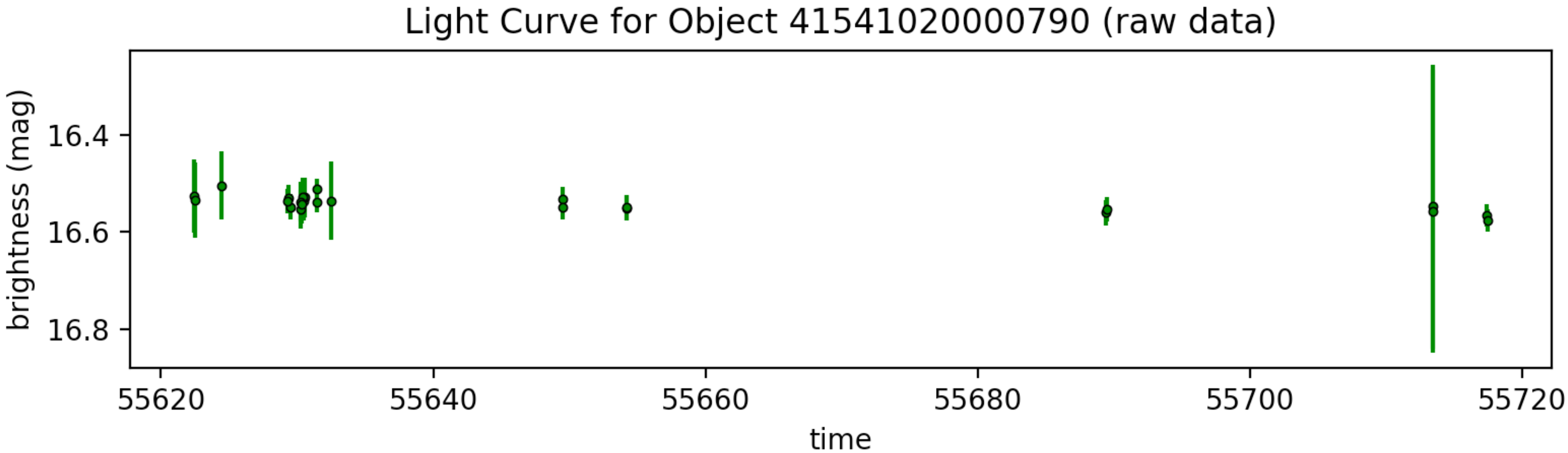
quasar74.tbl – 16 19 02.497 +30 30 51.62 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

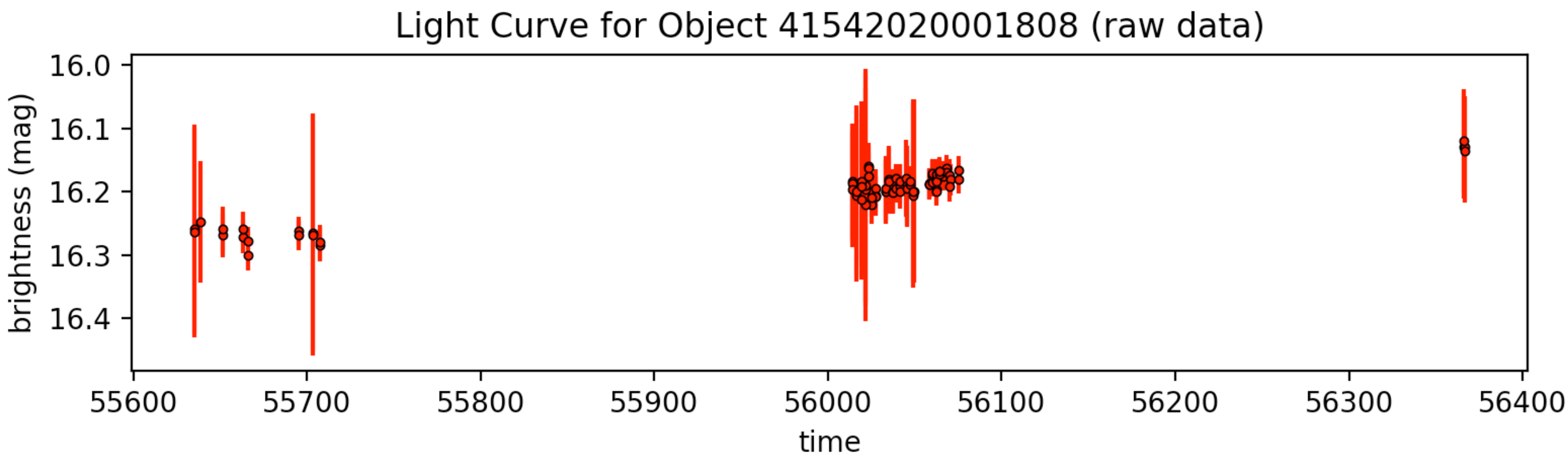


quasar30.tbl – 13 33 35.785 +16 49 03.96 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

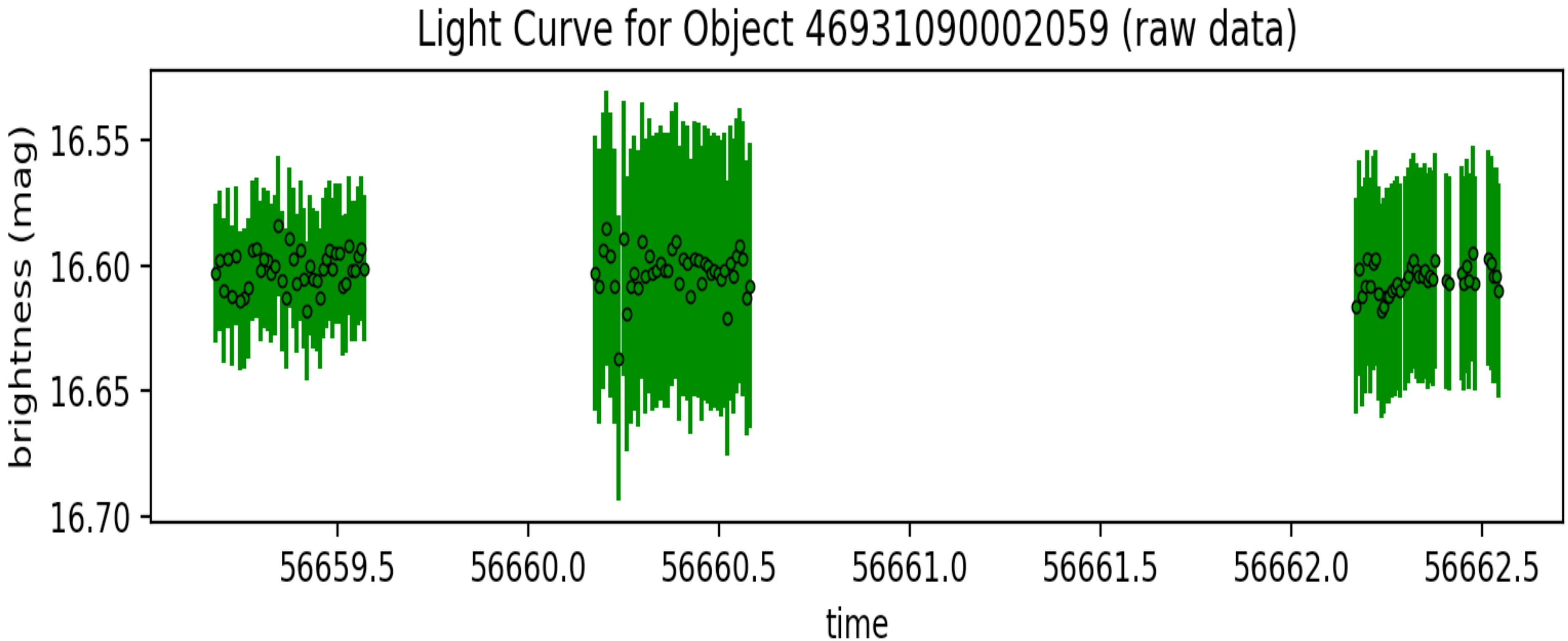


quasar36.tbl – 14 23 26.054 +32 52 20.37 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

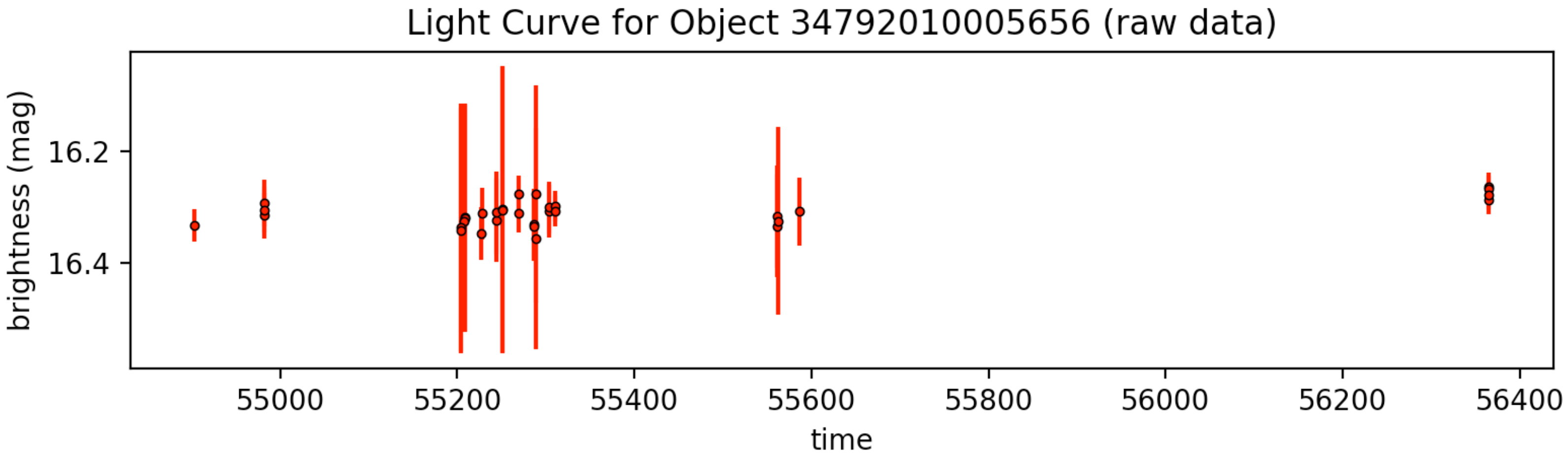


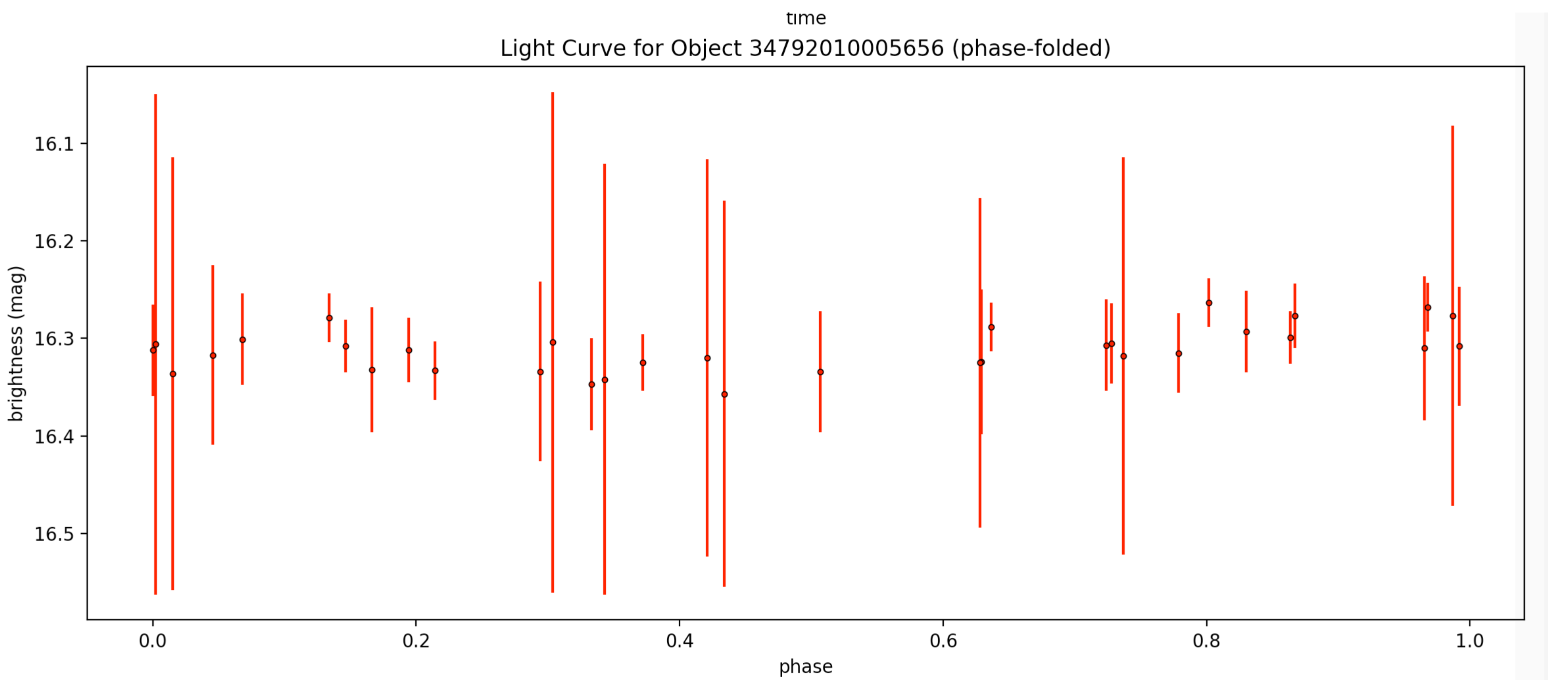


quasar38.tbl – 07 45 21.785 +47 34 36.44 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa

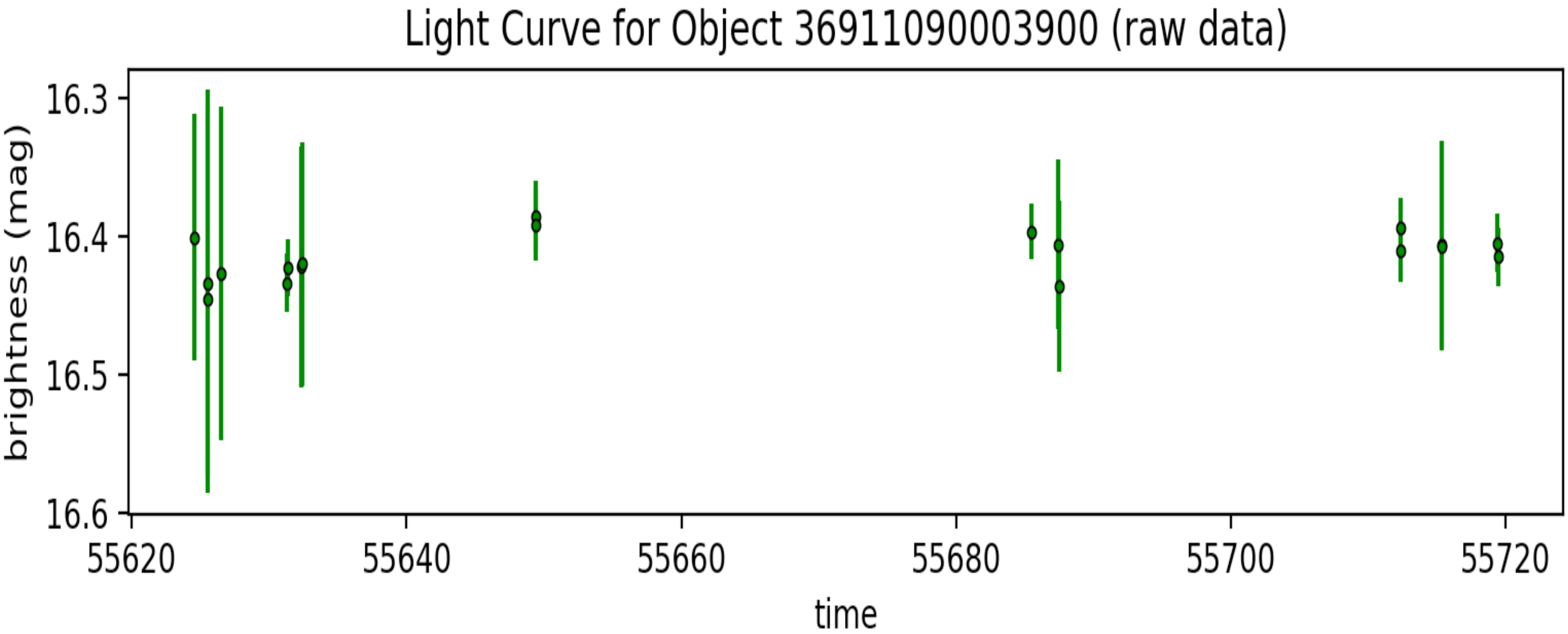


quasar50.tbl – 12 38 20.198 +17 50 39.15 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa





quasar53.tbl – 15 49 43.330 +21 14 03.39 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



quasar53.tbl – 15 49 43.330 +21 14 03.39 –
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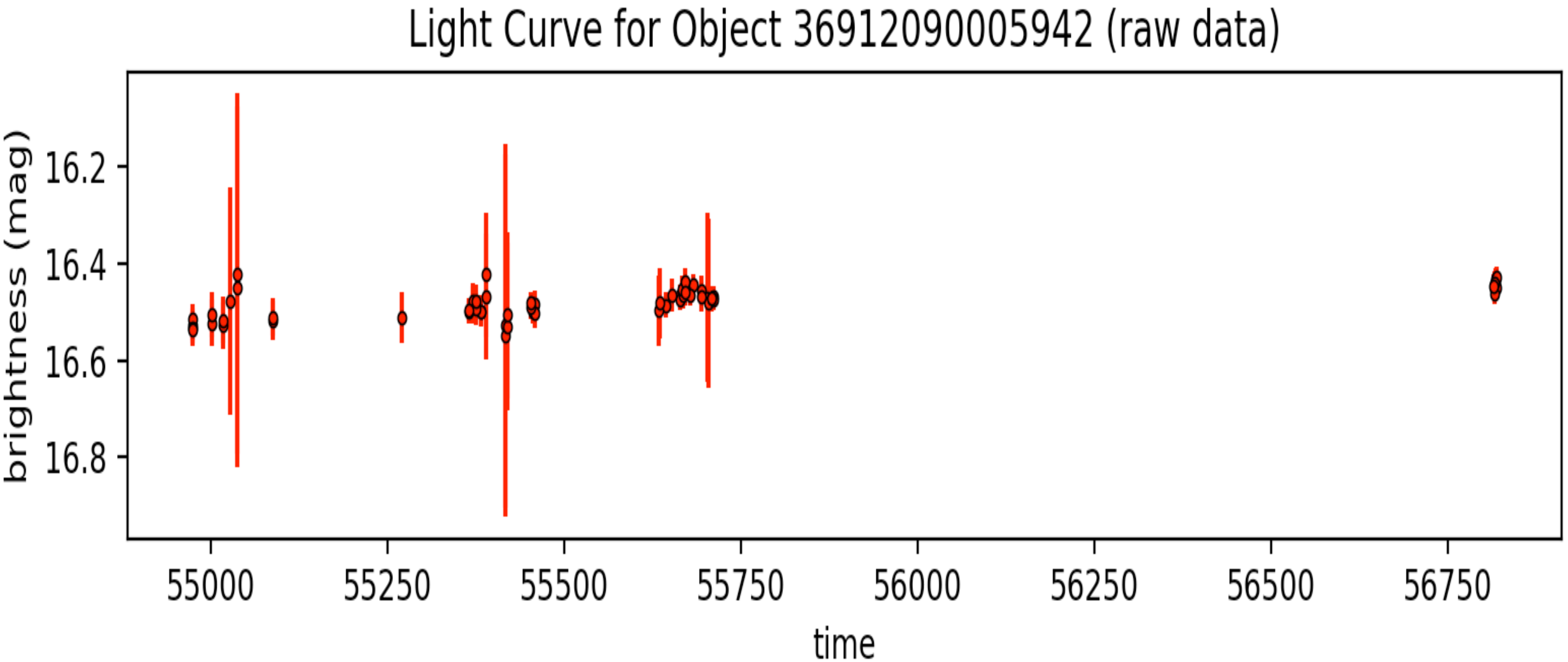

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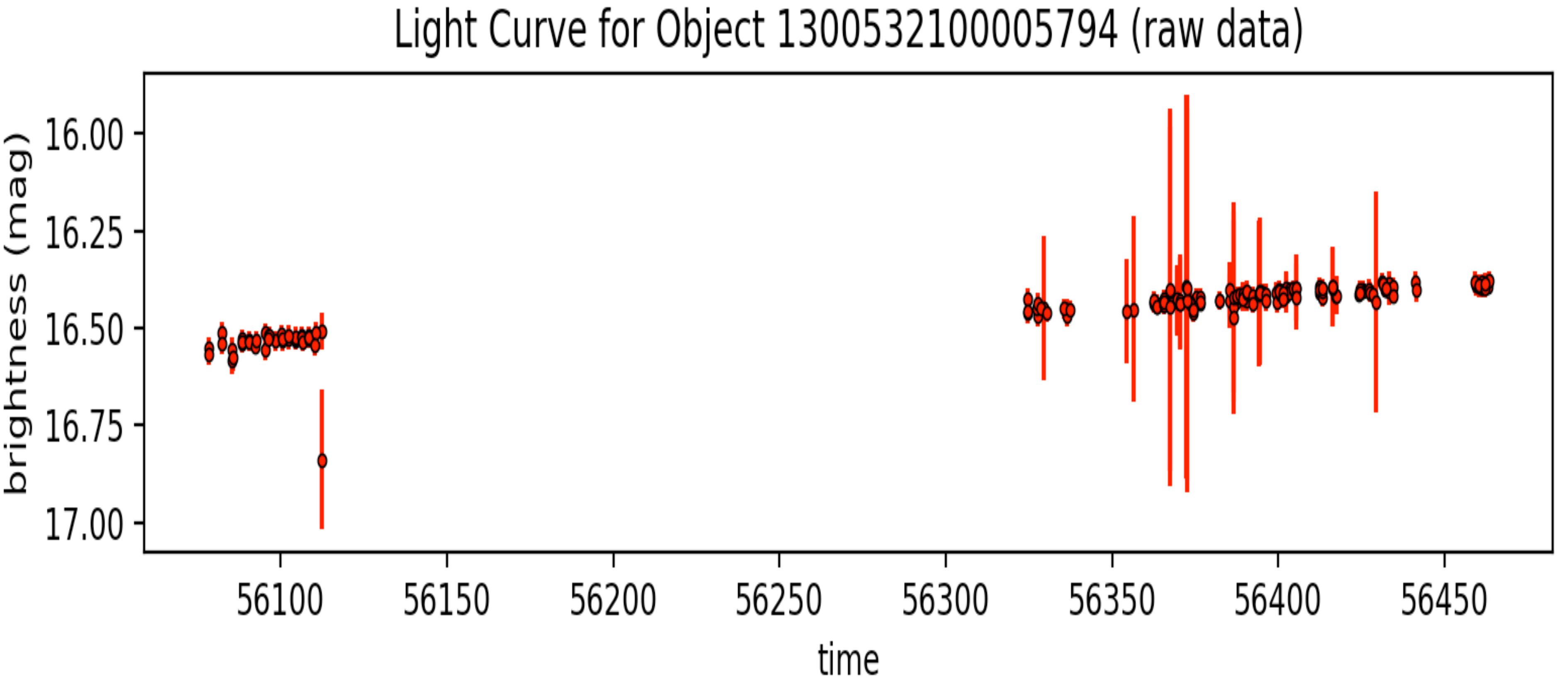
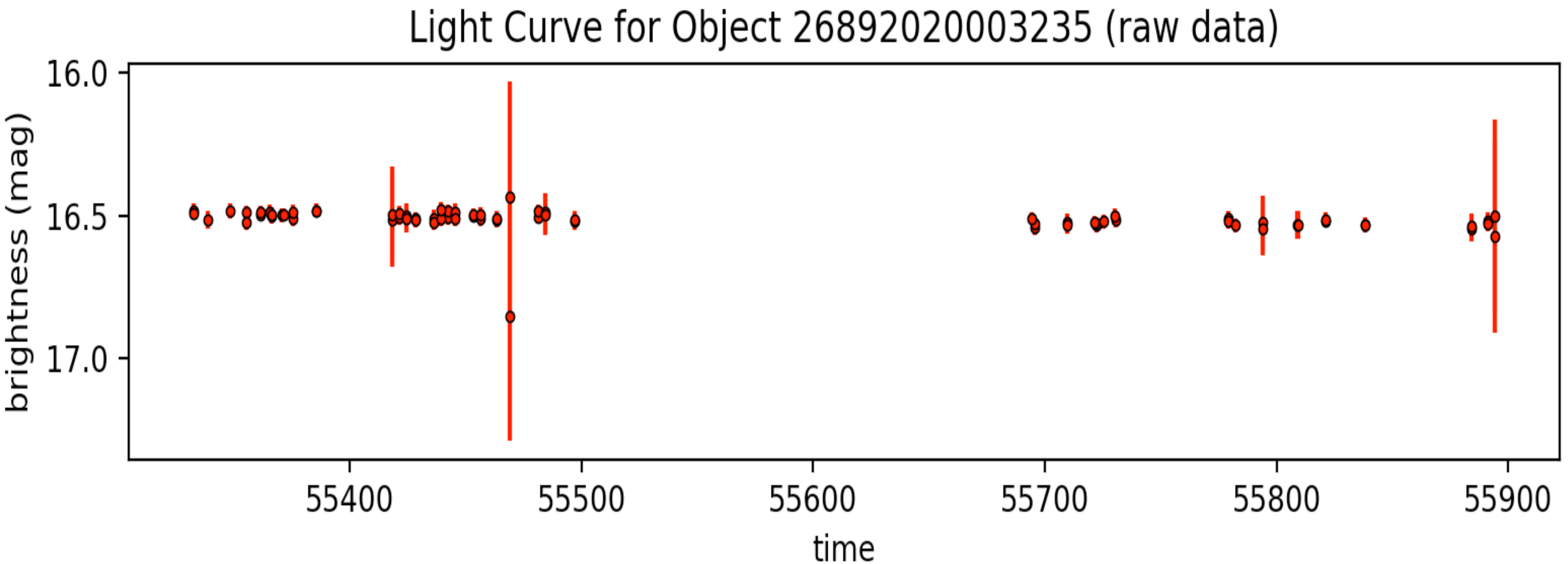
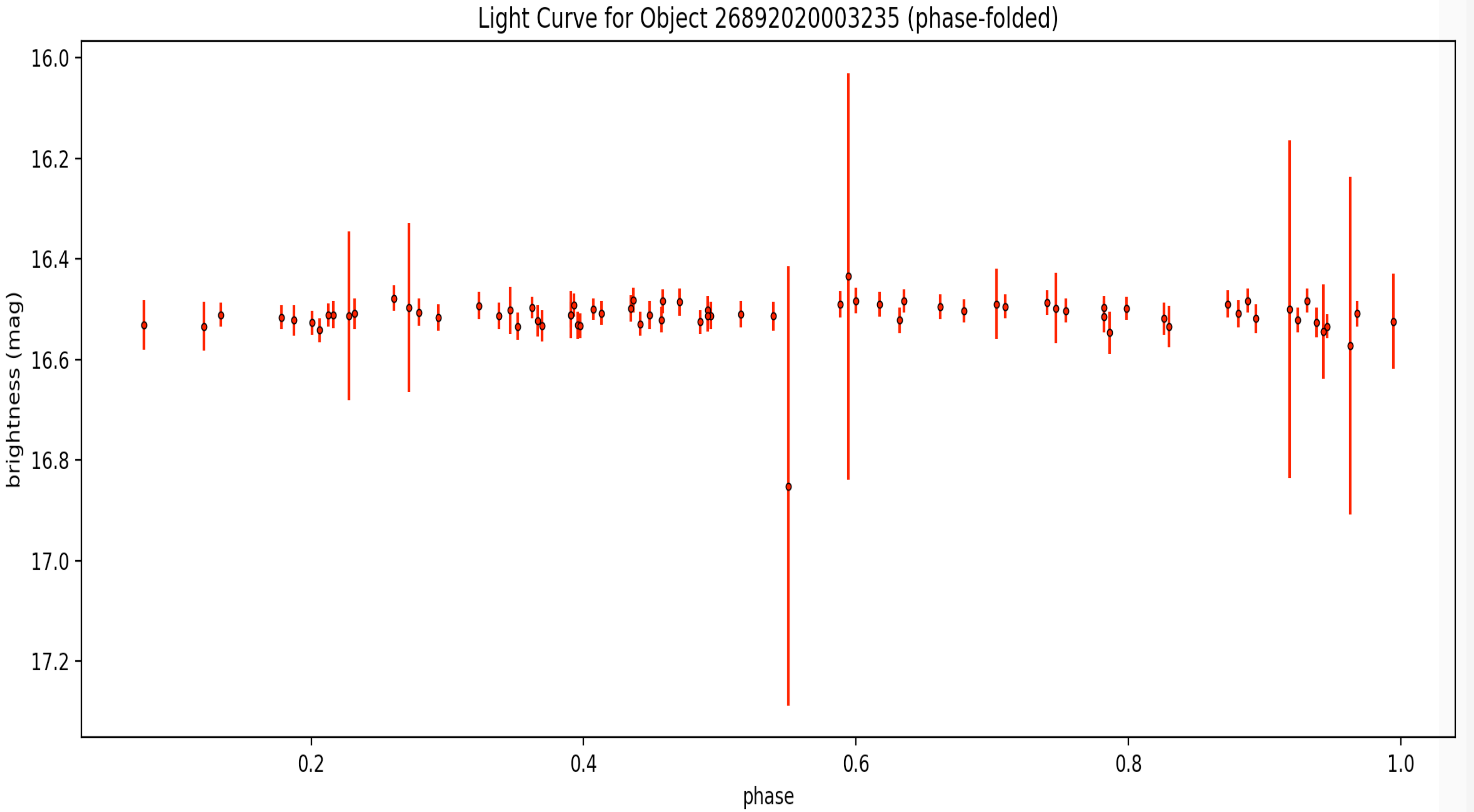


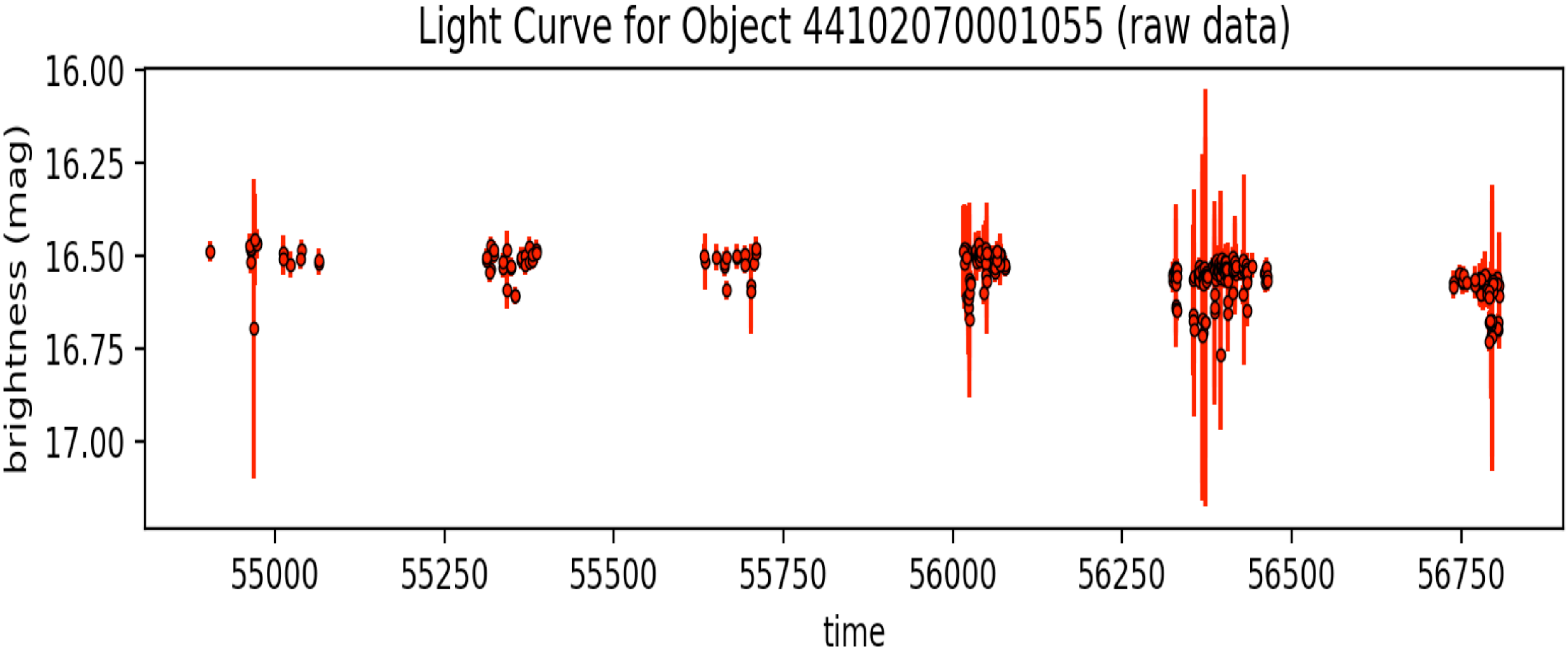
quasar62.tbl – 22 15 11.934 -00 45 50.02 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



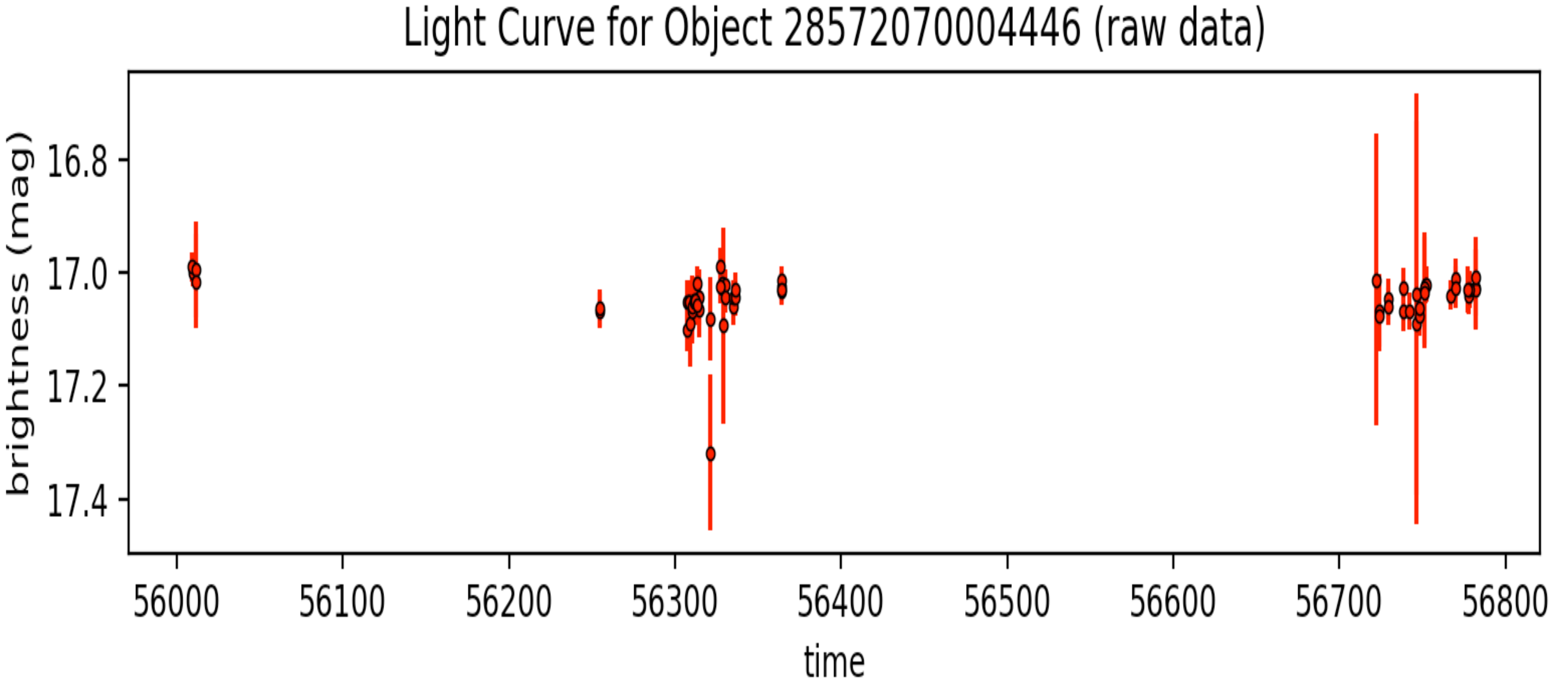
quasar62.tbl – 22 15 11.934 -00 45 50.02 – http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



quasar70.tbl – 14 25 01.461 +38 21 00.53 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



quasar73.tbl – 12 36 38.282 +03 02 50.36 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa



quasar76.tbl – 16 04 41.472 +16 45 38.34 –
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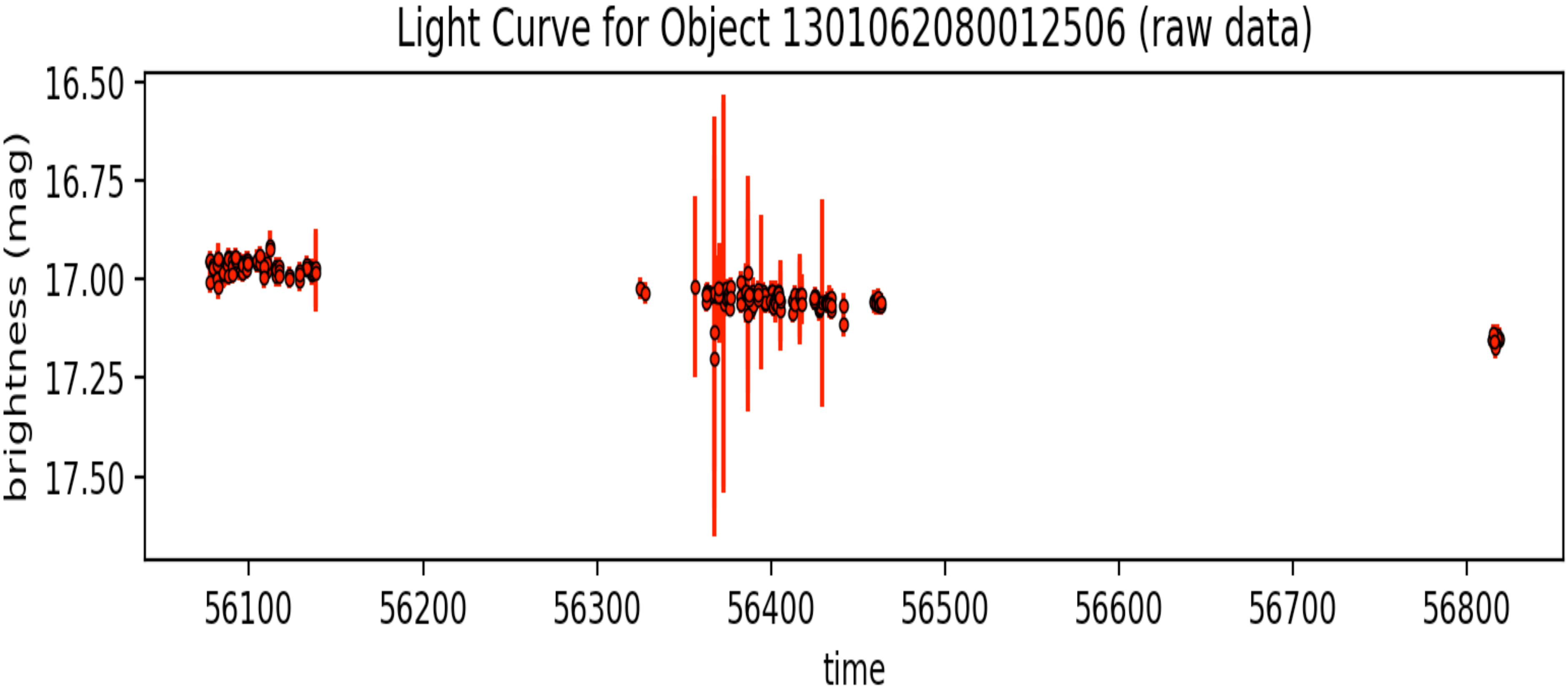

quasar80.tbl – 13 07 53.478 +11 58 03.34 –
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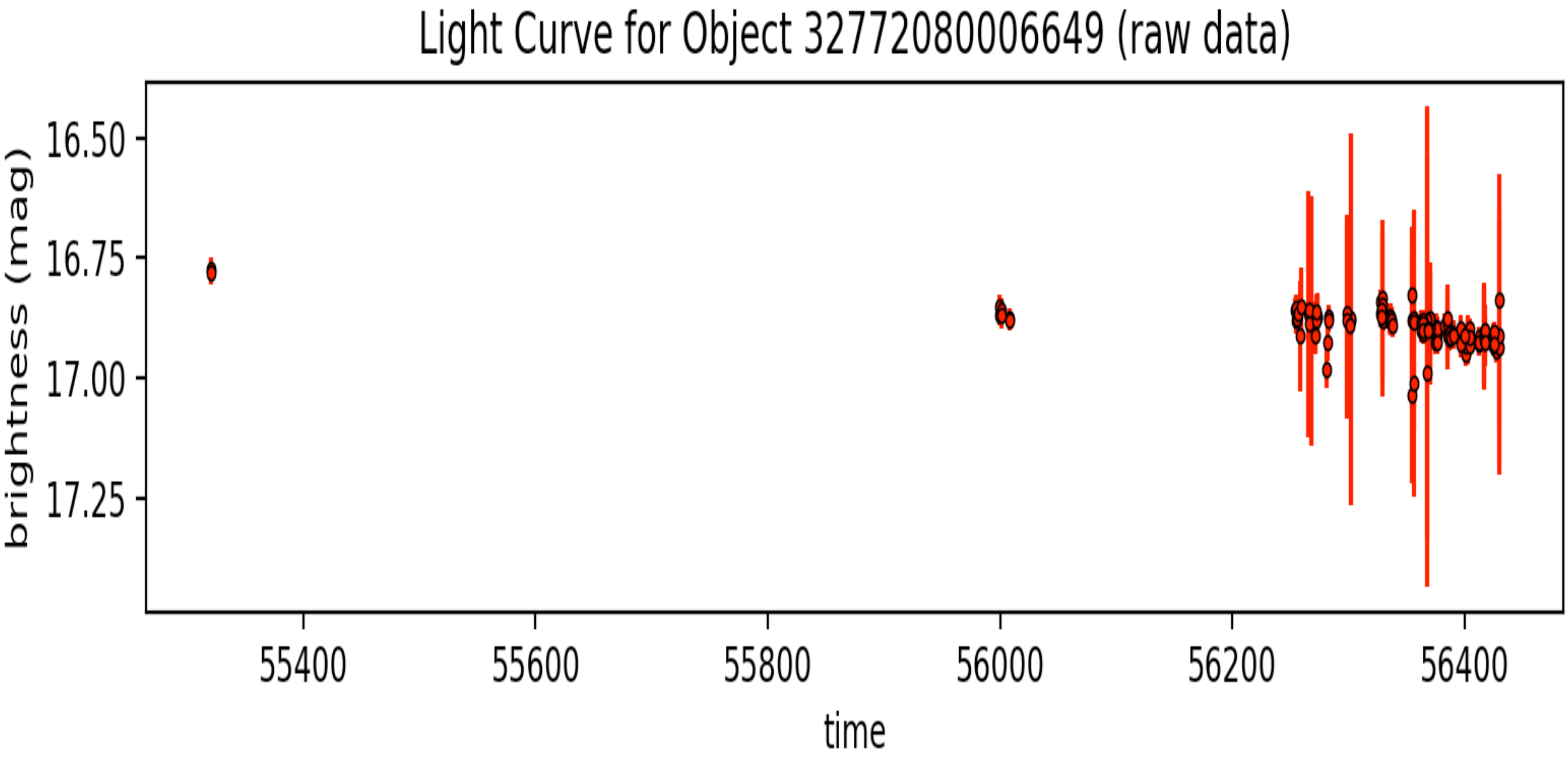

quasar80.tbl – 13 07 53.478 +11 58 03.34 –
http://vizier.cfa.harvard.edu/viz-bin/VizieR-3?-source=VII/270/dr10q&-out.max=50&-out.form=HTML%20Table&-out.add=_r&-out.add=_RAJ,_DEJ&-sort=_r&-oc.form=sexa