Navigating the Night SkyPart 1 Meridian: The great circle passing through the celestial poles(zenith) and the nadir of an observer's location. Zenith: Imaginary point directly above a particular location on celestial sphere. Equinox: The moment(date) that the plane of Earth's equator passes through the center of Sun's disk. Summer Solstice: (For Northern Hemisphere) The time when North Pole inclined most toward the Sun. Winter Solstice: (For Northern Hemisphere) The time when the North Pole is tilted most away from the Sun. Airmass: The path length for light from a celestial source to pass through the atmosphere. Nadir: The direction diametrically opposite to the Zenith. (Rest questions on the paper)Part 2: Planning Observation Partner's name: Darren Hunt The object type: Globular Cluster The catalog: GLOBCLUST - Milky Way Globular Clusters Catalog

In [1]:
```
import numpy as np
import pandas as pd

import astropy.units as u
from astropy.time import Time
from astropy.coordinates import SkyCoord, EarthLocation
import pytz

from astroplan import Observer, FixedTarget

import warnings
warnings.filterwarnings('ignore', category=Warning)
```

In [2]:
```
mro = Observer.at_site('mro')
mro
```

Out[2]:
```
<Observer: name='mro',
    location (lon, lat, el)=(-120.7278 deg, 46.9528 deg, 1198.0000
0000122 m),
    timezone=<UTC>>
```

In [3]:
```
mro.timezone = pytz.timezone('US/Pacific')
```

In [4]:
```
mro
```

Out[4]:
```
<Observer: name='mro',
    location (lon, lat, el)=(-120.7278 deg, 46.9528 deg, 1198.0000
0000122 m),
    timezone=<DstTzInfo 'US/Pacific' LMT-1 day, 16:07:00 STD>>
```

In [5]:
```
StartTime = Time("2018-08-01 00:00:00")
EndTime = Time("2018-08-15 00:00:00")
```

In [6]:
```
astro_set = mro.twilight_evening_astronomical(StartTime, which='nea
rest')
astro_rise = mro.twilight_morning_astronomical(EndTime, which='prev
ious')
```

In [7]:
```
target_table = pd.read_csv('GLOBCLUST-1.csv')
table_values = target_table.as_matrix()
targets = [FixedTarget(coord=SkyCoord(ra = RA*u.hourangle, dec = DE
C*u.deg), name=Name)
           for Name, RA, DEC in table_values]
targets
```

Out[7]:
```
[<FixedTarget "NGC 104" at SkyCoord (ICRS): (ra, dec) in deg (6.02
3625, -72.08128)>,
 <FixedTarget "NGC 288" at SkyCoord (ICRS): (ra, dec) in deg (13.1
884995, -26.58261)>,
 <FixedTarget "NGC 362" at SkyCoord (ICRS): (ra, dec) in deg (15.8
09415, -70.84878)>,
 <FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30
.737505, -3.252778)>,
 <FixedTarget "NGC 1261" at SkyCoord (ICRS): (ra, dec) in deg (48.
067545, -55.21622)>,
 <FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.333
505, 79.58106)>,
 <FixedTarget "AM 1" at SkyCoord (ICRS): (ra, dec) in deg (58.7595
9, -49.61528)>,
 <FixedTarget "Eridanus" at SkyCoord (ICRS): (ra, dec) in deg (66.
185415, -21.18694)>,
 <FixedTarget "Pal 2" at SkyCoord (ICRS): (ra, dec) in deg (71.524
62, 31.3815)>,
 <FixedTarget "NGC 1851" at SkyCoord (ICRS): (ra, dec) in deg (78.
528165, -40.04656)>,
 <FixedTarget "NGC 1904" at SkyCoord (ICRS): (ra, dec) in deg (81.
04959, -24.52472)>,
 <FixedTarget "NGC 2298" at SkyCoord (ICRS): (ra, dec) in deg (102
.247545, -36.00531)>,
 <FixedTarget "NGC 2419" at SkyCoord (ICRS): (ra, dec) in deg (114
.53529, 38.88244)>,
 <FixedTarget "Ko 2" at SkyCoord (ICRS): (ra, dec) in deg (119.570
835, 26.255)>,
 <FixedTarget "Pyxis" at SkyCoord (ICRS): (ra, dec) in deg (136.99
083, -37.22139)>,
 <FixedTarget "NGC 2808" at SkyCoord (ICRS): (ra, dec) in deg (138
.012915, -64.8635)>,
 <FixedTarget "E 3" at SkyCoord (ICRS): (ra, dec) in deg (140.2377
9, -77.28189)>,
 <FixedTarget "Pal 3" at SkyCoord (ICRS): (ra, dec) in deg (151.38
285, 0.07166667)>,
 <FixedTarget "NGC 3201" at SkyCoord (ICRS): (ra, dec) in deg (154
.4034, -46.41247)>,
 <FixedTarget "Pal 4" at SkyCoord (ICRS): (ra, dec) in deg (172.32
, 28.97358)>,
 <FixedTarget "Ko 1" at SkyCoord (ICRS): (ra, dec) in deg (179.827
05, 12.26)>,
 <FixedTarget "NGC 4147" at SkyCoord (ICRS): (ra, dec) in deg (182
.5263, 18.54264)>,
 <FixedTarget "NGC 4372" at SkyCoord (ICRS): (ra, dec) in deg (186
.4392, -72.659)>,
```

```
 <FixedTarget "Rup 106" at SkyCoord (ICRS): (ra, dec) in deg (189.
6675, -51.15028)>,
 <FixedTarget "NGC 4590" at SkyCoord (ICRS): (ra, dec) in deg (189
.86655, -26.74406)>,
 <FixedTarget "NGC 4833" at SkyCoord (ICRS): (ra, dec) in deg (194
.8914, -70.8765)>,
 <FixedTarget "NGC 5024" at SkyCoord (ICRS): (ra, dec) in deg (198
.23025, 18.16817)>]
```

In [8]:
```
from astroplan import AltitudeConstraint, AirmassConstraint, AtNigh
tConstraint
from astroplan import observability_table
```

In [9]:
```
observing_range = [astro_set, astro_rise]
constraints = [AirmassConstraint(2)]
observing_table = observability_table(constraints, mro, targets, ti
me_range=observing_range)

print(observing_table)
```

```
target name ever observable always observable fraction of time obs
ervable
----------- -------------- ---------------- --------------------
-------
    NGC 104           False             False
0.0
    NGC 288           False             False
0.0
    NGC 362           False             False
0.0
  Whiting 1            True             False          0.207874015
7480315
   NGC 1261           False             False
0.0
      Pal 1            True              True
1.0
       AM 1           False             False
0.0
   Eridanus           False             False
0.0
      Pal 2            True             False          0.426771653
5433071
   NGC 1851           False             False
0.0
        ...             ...               ...
...
       E 3           False             False
0.0
      Pal 3            True             False           0.23149606
2992126
   NGC 3201           False             False
0.0
      Pal 4            True             False          0.412598425
1968504
       Ko 1            True             False         0.3212598425
1968503
   NGC 4147            True             False         0.3559055118
1102364
   NGC 4372           False             False
0.0
    Rup 106           False             False
0.0
   NGC 4590           False             False
0.0
   NGC 4833           False             False
0.0
   NGC 5024            True             False          0.354330708
6614173
Length = 27 rows
```

In [10]:
```
for i, my_object in enumerate(targets):

    if observing_table['ever observable'][i]:
        print(my_object)
```

```
<FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30.
737505, -3.252778)>
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
<FixedTarget "Pal 2" at SkyCoord (ICRS): (ra, dec) in deg (71.5246
2, 31.3815)>
<FixedTarget "NGC 2419" at SkyCoord (ICRS): (ra, dec) in deg (114.
53529, 38.88244)>
<FixedTarget "Ko 2" at SkyCoord (ICRS): (ra, dec) in deg (119.5708
35, 26.255)>
<FixedTarget "Pal 3" at SkyCoord (ICRS): (ra, dec) in deg (151.382
85, 0.07166667)>
<FixedTarget "Pal 4" at SkyCoord (ICRS): (ra, dec) in deg (172.32,
28.97358)>
<FixedTarget "Ko 1" at SkyCoord (ICRS): (ra, dec) in deg (179.8270
5, 12.26)>
<FixedTarget "NGC 4147" at SkyCoord (ICRS): (ra, dec) in deg (182.
5263, 18.54264)>
<FixedTarget "NGC 5024" at SkyCoord (ICRS): (ra, dec) in deg (198.
23025, 18.16817)>
```

Air mass could be a constraint for observing. Objects that turn out to be True are observable. These are the objects that are observable for the whole two weeks.

In [11]:
```
StartTime1 = Time("2018-08-08 00:00:00")
EndTime1 = Time("2018-08-09 00:00:00")

astro_set1 = mro.twilight_evening_astronomical(StartTime1, which='n
earest')
astro_rise1 = mro.twilight_morning_astronomical(EndTime1, which='pr
evious')

observing_range1 = [astro_set1, astro_rise1]
constraints = [AirmassConstraint(2)]
observing_table1 = observability_table(constraints, mro, targets, t
ime_range=observing_range1)

for i, my_object in enumerate(targets):

    if observing_table1['ever observable'][i]:
        print(my_object)
```

```
<FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30.
737505, -3.252778)>
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
<FixedTarget "Pal 2" at SkyCoord (ICRS): (ra, dec) in deg (71.5246
2, 31.3815)>
```

These are the objects that are observable at August 8th, which is at the middle of the two weeks. This result could be more representative.

In [13]:
```
StartTime2 = Time("2018-08-01 00:00:00")
EndTime2 = Time("2018-08-02 00:00:00")

astro_set2 = mro.twilight_evening_astronomical(StartTime2, which='n
earest')
astro_rise2 = mro.twilight_morning_astronomical(EndTime2, which='pr
evious')

observing_range2 = [astro_set2, astro_rise2]
constraints = [AirmassConstraint(2)]
observing_table2 = observability_table(constraints, mro, targets, t
ime_range=observing_range2)

for i, my_object2 in enumerate(targets):

    if observing_table2['ever observable'][i]:
        print(my_object2)
```

```
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
```

These are the objects that are observable at August 1st, which is at the the beginning of the two weeks. Just a reference.

In [14]:
```
StartTime3 = Time("2018-08-14 00:00:00")
EndTime3 = Time("2018-08-15 00:00:00")

astro_set3 = mro.twilight_evening_astronomical(StartTime3, which='n
earest')
astro_rise3 = mro.twilight_morning_astronomical(EndTime3, which='pr
evious')

observing_range3 = [astro_set3, astro_rise3]
constraints = [AirmassConstraint(2)]
observing_table3 = observability_table(constraints, mro, targets, t
ime_range=observing_range3)

for i, my_object3 in enumerate(targets):

    if observing_table3['ever observable'][i]:
        print(my_object3)
```

```
<FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30.
737505, -3.252778)>
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
<FixedTarget "Pal 2" at SkyCoord (ICRS): (ra, dec) in deg (71.5246
2, 31.3815)>
```

These are the objects that are observable at August 14th, which is at the the end of the two weeks. Just a reference.

In [26]:
```
phase1 = mro.moon_phase(EndTime2)
phase2 = mro.moon_phase(EndTime1)
phase3 = mro.moon_phase(EndTime3)
print("The Moon phase is {0:.3f} so it is about Waning Gibbous.".fo
rmat(phase1))
print("The Moon phase is {0:.3f} so it is about Waning Crescent.".f
ormat(phase2))
print("The Moon phase is {0:.3f} so it is about Waxing Crescent.".f
ormat(phase3))
```

```
The Moon phase is 0.996 rad so it is about Waning Gibbous.
The Moon phase is 2.544 rad so it is about Waning Crescent.
The Moon phase is 2.280 rad so it is about Waxing Crescent.
```

In [16]:
```
from astroplan import MoonSeparationConstraint
```

In [17]:
```
constraints.append(MoonSeparationConstraint(35*u.deg))
observing_table_moon = observability_table(constraints, mro, target
s, time_range=observing_range1)
for i, my_object in enumerate(targets):

    if observing_table_moon['ever observable'][i]:
        print(my_object)
```

```
<FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30.
737505, -3.252778)>
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
```

In [18]:
```
print(observing_table_moon)
```

```
target name ever observable always observable fraction of time obs
ervable
----------- -------------- ---------------- --------------------
-------
    NGC 104           False             False
0.0
    NGC 288           False             False
0.0
    NGC 362           False             False
0.0
  Whiting 1            True             False         0.0909090909
0909091
   NGC 1261           False             False
0.0
      Pal 1            True              True
1.0
       AM 1           False             False
0.0
   Eridanus           False             False
0.0
      Pal 2           False             False
0.0
   NGC 1851           False             False
0.0
        ...             ...               ...
...
        E 3           False             False
0.0
      Pal 3           False             False
0.0
   NGC 3201           False             False
0.0
      Pal 4           False             False
0.0
       Ko 1           False             False
0.0
   NGC 4147           False             False
0.0
   NGC 4372           False             False
0.0
    Rup 106           False             False
0.0
   NGC 4590           False             False
0.0
   NGC 4833           False             False
0.0
   NGC 5024           False             False
0.0
Length = 27 rows
```

The Moon will interfere the observation of Pal 2, which is not observable after I add moon constraint (May able to observe part of the Pal 2 but not the whole object). However, the Moon will not interfere with the observation of Whiting 1 and Pal 1.

In [19]:
```
StartTime_Later = Time("2018-09-08 00:00:00")
EndTime_Later = Time("2018-09-09 00:00:00")

astro_set_later = mro.twilight_evening_astronomical(StartTime_Later
, which='nearest')
astro_rise_later = mro.twilight_morning_astronomical(EndTime_Later,
which='previous')

observing_range_later = [astro_set_later, astro_rise_later]
constraints = [AirmassConstraint(2)]
constraints.append(MoonSeparationConstraint(35*u.deg))
observing_table_later = observability_table(constraints, mro, targe
ts, time_range=observing_range_later)

for i, my_object_later in enumerate(targets):

    if observing_table_later['ever observable'][i]:
        print(my_object_later)
```

```
<FixedTarget "Whiting 1" at SkyCoord (ICRS): (ra, dec) in deg (30.
737505, -3.252778)>
<FixedTarget "Pal 1" at SkyCoord (ICRS): (ra, dec) in deg (53.3335
05, 79.58106)>
<FixedTarget "Pal 2" at SkyCoord (ICRS): (ra, dec) in deg (71.5246
2, 31.3815)>
<FixedTarget "NGC 2419" at SkyCoord (ICRS): (ra, dec) in deg (114.
53529, 38.88244)>
```

In [21]:
```
print(observing_table1)
```

```
target name ever observable always observable fraction of time obs
ervable
----------- -------------- ----------------- --------------------
-------
    NGC 104           False             False
0.0
    NGC 288           False             False
0.0
    NGC 362           False             False
0.0
  Whiting 1            True             False         0.0909090909
0909091
   NGC 1261           False             False
0.0
      Pal 1            True              True
1.0
       AM 1           False             False
0.0
   Eridanus           False             False
0.0
      Pal 2            True             False         0.0909090909
0909091
   NGC 1851           False             False
0.0
        ...             ...               ...
...
        E 3           False             False
0.0
      Pal 3           False             False
0.0
   NGC 3201           False             False
0.0
      Pal 4           False             False
0.0
       Ko 1           False             False
0.0
   NGC 4147           False             False
0.0
   NGC 4372           False             False
0.0
    Rup 106           False             False
0.0
   NGC 4590           False             False
0.0
   NGC 4833           False             False
0.0
   NGC 5024           False             False
0.0
Length = 27 rows
```

In [20]:
```
print(observing_table_later)
```

```
target name ever observable always observable fraction of time obs
ervable
----------- -------------- ----------------- --------------------
-------
    NGC 104           False             False
0.0
    NGC 288           False             False
0.0
    NGC 362           False             False
0.0
  Whiting 1            True             False
0.4
   NGC 1261           False             False
0.0
      Pal 1            True              True
1.0
       AM 1           False             False
0.0
   Eridanus           False             False
0.0
      Pal 2            True             False
0.4
   NGC 1851           False             False
0.0
        ...             ...               ...
...
        E 3           False             False
0.0
      Pal 3           False             False
0.0
   NGC 3201           False             False
0.0
      Pal 4           False             False
0.0
       Ko 1           False             False
0.0
   NGC 4147           False             False
0.0
   NGC 4372           False             False
0.0
    Rup 106           False             False
0.0
   NGC 4590           False             False
0.0
   NGC 4833           False             False
0.0
   NGC 5024           False             False
0.0
Length = 27 rows
```

Better, because the fraction of time observable for Whiting 1 and Pal 2 increases.