(step 0: retrieve data)

http://archive.stsci.edu/hst/search.php

Proposal IDs:

`12679,12879,13101,13334,13335,13344,13678,13686,13928,14062,14206`

Filters/Gratings:

`F160W*`

Got 248 entries returned.

query_result.csv

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(1) Select the Cepheids in our sample and convert the calendar dates to Julian dates.

(2) If the same object was observed several times within two hours, take them as only one epoch. Derive the phase of each epoch.

(3) Calculate three types of sigma:

- (3.1.1) Uncertainty from the model:

The model reads

$$m_t = M + L \cdot [A_0 + \sum_{i=1}^{7} A_i \cos(2\pi i(\phi_t + \psi) + \Phi_i)] + \sigma_t \epsilon$$

which yields

$$\sigma_1 = \frac{\partial m}{\partial M} \cdot \sigma_M + \frac{\partial m}{\partial L} \cdot \sigma_L + \frac{\partial m}{\partial \psi} \cdot \sigma_\psi$$

$$= \sigma_M + \sigma_L \cdot |[A_0 + \sum_{i=1}^{7} A_i \cos(2\pi i(\phi_t + \psi) + \Phi_i)]| + L \cdot \sigma_\psi \cdot |\sum_{i=1}^{7} A_i \sin(2\pi i(\phi_t + \psi) + \Phi_i) \cdot 2\pi i|$$

- (3.1.2) Uncertainty from model fit residuals (since template is not the true light curve)

$\sigma_2 = \sigma$ where σ is the model-measurement scatter from [Table 4 of Inno+ (2015)](), or maybe better, take σ as the standard deviation of our model fit residuals, since we fit the model for individual Cepheids and have some freedom in the template to reduce σ.

- (3.1.3) Uncertainty from the uncertainty of the period

$$\sigma_3 = \frac{\partial m}{\partial \phi} \cdot \frac{\partial \phi}{\partial P} \cdot \sigma_P$$

$$= L \cdot |\sum_{i=1}^{7} A_i \sin(2\pi i(\phi_t + \psi) + \Phi_i) \cdot 2\pi i \cdot \frac{N_{cyc}}{P}| \cdot \sigma_P$$

Where N_{cyc} is the number of cycles between HST and ground-based observatiosn, and it can be negative if the HST observation is prior to the ground-based observation.

(3.2.1) If there is only one HST observation, then $\sigma = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2}$.

(3.2.2) If there are multiple HST observations:

$$\sigma_{1,total} = \sigma_M + \frac{\sigma_L}{N} \cdot |\sum_{j=1}^{N} \{A_0 + \sum_{i=1}^{7} A_i \cos(2\pi i(\phi_{t,j} + \psi) + \Phi_i)\}| + \frac{L \cdot \sigma_\psi}{N} \cdot |\sum_{j=1}^{N} \{\sum_{i=1}^{7} A_i \sin(2\pi i(\phi_{t,j} + \psi) + \Phi_i) \cdot 2\pi i\}|$$

The $\sigma_{1,total}$ denotes the total model uncertainty. It does not go down with the square root of number of observations N, but the differences in phase might beat the last two terms down.

$$\sigma_{2,total} = \frac{\sigma_2}{\sqrt{N}}$$

This assumes that the model residuals of ground-based measurements are the same as that of HST-based measurements. This is true if the residuals of the model fit of true light curves are relatively large. If not, $\sigma_{2,total}$ would over estimate the residual uncertainty.

$$\sigma_{3,total} = \frac{L}{N} \cdot |\sum_{j=1}^{N} \sum_{i=1}^{7} \{A_i \sin(2\pi i(\phi_{t,j} + \psi) + \Phi_i) \cdot 2\pi i \cdot \frac{N_{cyc}}{P}\}| \cdot \sigma_P$$

Similar to $\sigma_{1,total}$, $\sigma_{3,total}$ does not go down with N substantially. It decrease only when the HST observations distribute both before and after the ground-based observations.

Finally, the total phase correction uncertainty of multiple HST observations should be

$$\sigma = \sqrt{\sigma_{1,total}^2 + \sigma_{2,total}^2 + \sigma_{3,total}^2}$$

Results

```
#     id     sigma.1   sigma.2   sigma.3 sigma.total  mag.corr
    adpup   0.03144   0.02413   0.00035   0.03963    -0.14656
    aqcar   0.00745   0.00782   0.00000   0.01080    -0.03681
    aqpup   0.01110   0.01294   0.00022   0.01705     0.00957
    betad   0.03286   0.03251   0.00000   0.04622    -0.13521
    bnpup   0.06742   0.04923   0.00007   0.08348    -0.05277
    crcar   0.00987   0.01672   0.00000   0.01942     0.03029
    drvel   0.02510   0.02501   0.00017   0.03543     0.03932
    hwcar   0.00576   0.00580   0.00000   0.00818    -0.00794
    kkcen   0.00838   0.01874   0.00006   0.02053    -0.13490
    kncen   0.01871   0.01356   0.00012   0.02311    -0.04146
    lcarl   0.03923   0.03513   0.00035   0.05266    -0.10137
    rysco   0.00959   0.00966   0.00000   0.01361    -0.03411
    ryvel   0.01398   0.01742   0.00009   0.02234    -0.01858
    s-nor   0.02993   0.03157   0.00000   0.04350     0.03132
    sscma   0.01817   0.01313   0.00056   0.02243    -0.00256
    svvel   0.01919   0.01125   0.00000   0.02225     0.11542
    synor   0.01760   0.01638   0.00000   0.02404     0.02580
    t-mon   0.03821   0.02592   0.00000   0.04618     0.14277
    u-car   0.01656   0.01493   0.00035   0.02230     0.18328
    uumus   0.00838   0.00575   0.00041   0.01017    -0.07461
    vjara   0.00864   0.01437   0.00000   0.01676     0.09615
    vjcen   0.02584   0.02908   0.00004   0.03890     0.08094
    vwcen   0.00991   0.01248   0.00002   0.01594    -0.18063
    vycar   0.01417   0.00936   0.00082   0.01700     0.04012
    vzpup   0.03728   0.02650   0.00110   0.04575    -0.26534
    w-sgr   0.02044   0.03140   0.00000   0.03747    -0.00706
    wxpup   0.01431   0.01205   0.00025   0.01871     0.08612
    wzsgr   0.00513   0.00362   0.00024   0.00629    -0.01021
    x-pup   0.02486   0.01564   0.00119   0.02940    -0.03171
    xxcar   0.02473   0.02645   0.00019   0.03621     0.00050
    xycar   0.00868   0.00667   0.00000   0.01095    -0.03409
    xzcar   0.01006   0.00880   0.00012   0.01336     0.04828
    yzcar   0.02715   0.01639   0.00005   0.03171    -0.07605
    yzsgr   0.00824   0.02115   0.00001   0.02270     0.04179
```

(4) Update the table in the draft paper

```
\begin{deluxetable*}{lrrrrrrrrc}
\tabletypesize{\scriptsize}
\tablecaption{Light Curve Parameters \label{tbl:par}}
\tablewidth{0pt}
\tablehead{
\multicolumn{1}{c}{Object} & \multicolumn{1}{c}{$P$} & \multicolumn{1}{c}{$\sigma_P$} & \mult
icolumn{1}{c}{$t_0$} & \multicolumn{1}{c}{$M$} & \multicolumn{1}{c}{$\sigma_M$} & \multicolum
n{1}{c}{$L$} & \multicolumn{1}{c}{$\sigma_L$}  & \multicolumn{1}{c}{$\psi$} & \multicolumn{1}
{c}{$\sigma_{\it \psi}$} & \multicolumn{1}{c}{$\sigma_\mathrm{corr}$} \\
\multicolumn{1}{c}{} & \multicolumn{1}{c}{(d)} & \multicolumn{1}{c}{([1])} & \multicolumn{1}{
c}{(d)} & \multicolumn{1}{c}{(mag)} & \multicolumn{3}{c}{($10^{-4}$mag)} & \multicolumn{2}{c}
{([2])} & \multicolumn{1}{c}{($10^{-4}$mag)}}
\startdata
\input{tables/pars.tex}
\enddata
\tablecomments{[1]: units of $10^{-6}$~d; [2]: units of $10^{-4}{\rm rad}/2\pi$.}
\end{deluxetable*}
```

```
W~Sgr       &   7.585536 &      1768 &  7187 &   2.886 &      97 &    2902 &     365 &    677
5 &     153 &     375 \\
WX~Pup      &   8.935991 &       422 &  6967 &   6.690 &      48 &    2571 &     224 &    330
8 &      83 &     187 \\
HW~Car      &   9.199488 &        39 &  6759 &   6.753 &      35 &    1501 &     234 &    659
7 &     113 &      82 \\
V339~Cen    &   9.466540 &        76 &  6961 &   5.809 &     108 &    2649 &     329 &    682
0 &     194 &     389 \\
YZ~Sgr      &   9.553551 &       290 &  6900 &   4.941 &      44 &    2558 &     116 &    597
7 &      71 &     227 \\
S~Nor       &   9.754615 &       122 &  7416 &   4.384 &     170 &    2292 &     446 &    482
5 &     243 &     435 \\
CR~Car      &   9.758552 &       119 &  7179 &   8.211 &      43 &    2079 &     121 &    905
1 &      95 &     194 \\
AQ~Car      &   9.769427 &       119 &  6762 &   6.704 &      44 &    2023 &     138 &     23
4 &     169 &     108 \\
$\beta$~Dor &   9.842865 &      3365 &  6910 &   1.974 &     116 &    2661 &     337 &    102
9 &     194 &     462 \\
DR~Vel      &  11.199240 &        86 &  6996 &   5.983 &      94 &    2759 &     258 &    290
4 &     147 &     354 \\
UU~Mus      &  11.636093 &       156 &  7038 &   6.959 &      27 &    3109 &      91 &    112
4 &      31 &     102 \\
KK~Cen      &  12.182794 &       135 &  7042 &   8.106 &      30 &    2714 &      80 &    451
0 &      58 &     205 \\
SS~CMa      &  12.353912 &       571 &  6958 &   6.836 &     106 &    2463 &     374 &    812
7 &     150 &     224 \\
XY~Car      &  12.436119 &        23 &  6735 &   6.425 &      60 &    3104 &     174 &    122
1 &      74 &     110 \\
SY~Nor      &  12.645111 &        94 &  7181 &   6.009 &      76 &    3163 &     265 &    378
9 &      79 &     240 \\
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AD~Pup      &  13.597026 &       414 &  6957 &   7.320 &      96 &    3258 &     281 &    290
2 &     150 &     396 \\
BN~Pup      &  13.672693 &        42 &  6971 &   7.080 &     196 &    3654 &     481 &    228
8 &     231 &     835 \\
```