ITC09 Fundamental Data Analysis in Lunar and Planetary Explorations

演習課題2

・swingby.cを改造してはやぶさの軌道を打ち上げ（2003年5月9日）からイトカワ到着（2005年9月12日）まで計算できるツールcruise.cを作れ

- イトカワの軌道，地球の軌道と地球-はやぶさ間の距離の時間変化も計算すること

・使用するカーネル

- はやぶさの軌道情報: kernels/HAYABUSA/spk/hayabusa_cruise.bsp
- イトカワの軌道情報: kernels/Itokawa/spk/sb_25143_140.bsp

・座標系

- J2000（原点/観測者は太陽”SUN"）

・位置関係を客観視するための計算の場合は光行差などの補正は不要

・spkに含まれている軌道情報の時間範囲を確認の上，計算時間を決定すること

- spkに情報がない時刻を計算しようとするとエラーとなる
- briefコマンド（cspiceに含まれている）でspkの中身を確認できる

hayabusa_cruise.bspの時間範囲: 2003 MAY 09 00:01:04.185 ~ 2005 SEP 12 00:01:04.182

```
(base) wlan-napt-002:SPICE_tutorial shiranui$ ../cspice/exe/brief ./kernels/HAYABUSA/spk/hayabusa_cruise.bsp

BRIEF -- Version 4.0.0, September 8, 2010 -- Toolkit Version N0066


Summary for: ./kernels/HAYABUSA/spk/hayabusa_cruise.bsp

Body: HAYABUSA (-130)
      Start of Interval (ET)              End of Interval (ET)
      ----------------------------        ----------------------------
      2003 MAY 09 00:01:04.185            2005 SEP 12 00:01:04.182

(base) wlan-napt-002:SPICE_tutorial shiranui$ _
```

sb_25143_140.bspの時間範囲: 2002 NOV 01 00:00:00:000 ~ 2006 AUG 08 00:00:00:000

```
(base) wlan-napt-002:SPICE_tutorial shiranui$ ../cspice/exe/brief ./kernels/Itokawa/spk/sb_25143_140.bsp

BRIEF -- Version 4.0.0, September 8, 2010 -- Toolkit Version N0066


Summary for: ./kernels/Itokawa/spk/sb_25143_140.bsp

Body: ITOKAWA (2025143)
      Start of Interval (ET)              End of Interval (ET)
      ----------------------------        ----------------------------
      2002 NOV 01 00:00:00.000            2006 AUG 08 00:00:00.000

(base) wlan-napt-002:SPICE_tutorial shiranui$ _
```

<cruise.cの内容>

```
#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include "SpiceUsr.h"

#define  STRLEN 100

int main(int argc, char *argv[]) {

  SpiceDouble            et;
  SpiceDouble            start_et;
  SpiceChar              utc[STRLEN];

  SpiceDouble hayabusa_pos_J2k[3];
  SpiceDouble itokawa_pos_J2k[3];
  SpiceDouble earth_pos_J2k[3];
  SpiceDouble lt_hayabusa, lt_itokawa, lt_earth;

  //Define start time
  SpiceChar   time[STRLEN]="2003-05-09T00:00:00";

  if (argc < 2) {
    printf("Usage: %s kernel ...\n",argv[0]);
    exit(-1);
  }

  //Read kernels
  while (argc > 1) {
    furnsh_c (argv[1]);
    fprintf(stderr,"%s is loaded.\n",argv[1]);
    --argc;
    ++argv;
  }

  //Convert UTC time string to et
  str2et_c ( time, &start_et );

  //Output index text
  printf ("#hayabusa_pos_X\tY\tZ\titokawa_pos_X\tY\tZ\tearth_pos_X\tY\tZ\thayabusa_distance\n");

  //Compute from the start time with 1 hour interval
  for(et=start_et;et< start_et+24*3600*857-3600;et=et+3600){

    //Convert et to UTC time string
    et2utc_c ( et, "ISOC", 0, STRLEN, utc );
    printf("%s\t",utc);

    spkpos_c ( "MUSES-C", et, "J2000", "NONE", "SUN", hayabusa_pos_J2k, &lt_hayabusa);
    spkpos_c ( "ITOKAWA", et, "J2000", "NONE", "SUN", itokawa_pos_J2k, &lt_itokawa);
    spkpos_c ( "EARTH", et, "J2000", "NONE", "SUN", earth_pos_J2k, &lt_earth);

    printf ( "%9.4f\t%9.4f\t%9.4f\t%9.4f\t%9.4f\t%9.4f\t%9.4f\t%9.4f\t%9.4f\n",
          hayabusa_pos_J2k[0], hayabusa_pos_J2k[1], hayabusa_pos_J2k[2],
          itokawa_pos_J2k[0], itokawa_pos_J2k[1], itokawa_pos_J2k[2],
          earth_pos_J2k[0], earth_pos_J2k[1], earth_pos_J2k[2],
          lt_hayabusa);
  }
  return 0;
}
```

<得られた出力(cruise.txt)>

左から順にHayabusaの位置(X, Y, Z), Itokawaの位置(X, Y, Z), 地球の位置(X, Y, Z), 地球-はやぶさ間の距離

SPICE_tutorial — less ./cruise.txt — 237×17

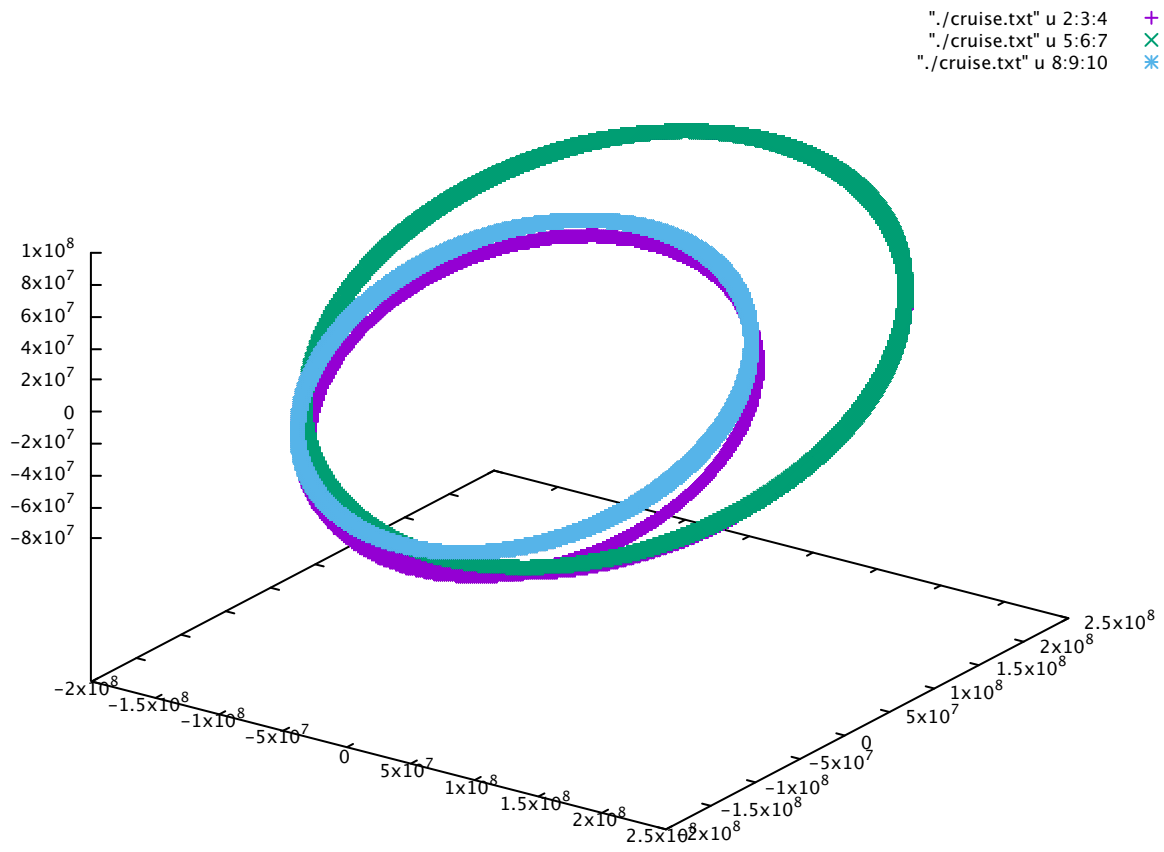
#hayabusa_pos_X Y	Z	itokawa_pos_X	Y	Z	earth_pos_X	Y	Z	hayabusa_distance			
2003-05-09T00:00:00	-101156759.9450	-102862865.3937	-44595964.8078	227013738.3155	46796384.8467	13754662.0501	-101156759.9151	-102862865.4288	-44595964.7959	503.6957
2003-05-09T01:00:00	-101089712.0973	-102936529.3137	-44633397.4685	227014869.0251	46867869.7039	13786460.3771	-101078832.5389	-102929092.2829	-44624678.0048	503.7502
2003-05-09T02:00:00	-101022664.2496	-103010193.2338	-44670830.1293	227015968.5519	46939348.1227	13818256.8101	-101000854.9609	-102995267.4495	-44653368.7636	503.8051
2003-05-09T03:00:00	-100955616.4019	-103083857.1538	-44708262.7900	227017036.9026	47010820.0949	13850051.3452	-100922827.2248	-103061390.8992	-44682037.0594	503.8601
2003-05-09T04:00:00	-100888568.5542	-103157521.0739	-44745695.4508	227018074.0841	47082285.6120	13881843.9785	-100844749.3742	-103127462.6029	-44710682.8794	503.9154
2003-05-09T05:00:00	-100821520.7065	-103231184.9939	-44783128.1115	227019080.1033	47153744.6657	13913634.7061	-100766621.4529	-103193482.5312	-44739306.2106	503.9709
2003-05-09T06:00:00	-100754472.8588	-103304848.9140	-44820560.7722	227020054.9670	47225197.2475	13945423.5240	-100688443.5046	-103259450.6549	-44767907.0403	504.0267
2003-05-09T07:00:00	-100687425.0111	-103378512.8341	-44857993.4330	227020998.6822	47296643.3493	13977210.4283	-100610215.5731	-103325366.9451	-44796485.3558	504.0827
2003-05-09T08:00:00	-100620377.1634	-103452176.7541	-44895426.0937	227021911.2555	47368082.9626	14008995.4150	-100531937.7020	-103391231.3726	-44825041.1442	504.1390
2003-05-09T09:00:00	-100553329.3157	-103525840.6742	-44932858.7545	227022792.6940	47439516.0790	14040778.4803	-100453609.9351	-103457043.9085	-44853574.3929	504.1955
2003-05-09T10:00:00	-100486281.4680	-103599504.5942	-44970291.4152	227023643.0044	47510942.6903	14072559.6201	-100375232.3162	-103522804.5238	-44882085.0892	504.2522
2003-05-09T11:00:00	-100419233.6203	-103673168.5143	-45007724.0759	227024462.1936	47582362.7881	14104338.8307	-100296804.8889	-103588513.1896	-44910573.2204	504.3092
2003-05-09T12:00:00	-100352185.7726	-103746832.4343	-45045156.7367	227025250.2685	47653776.3640	14136116.1080	-100218327.6972	-103654169.8772	-44939038.7739	504.3665
2003-05-09T13:00:00	-100285137.9249	-103820496.3544	-45082589.3974	227026007.2359	47725183.4098	14167891.4481	-100139800.7846	-103719774.5577	-44967481.7371	504.4240
2003-05-09T14:00:00	-100218090.0772	-103894160.2745	-45120022.0582	227026733.1026	47796583.9171	14199664.8471	-100061224.1950	-103785327.2026	-44995902.0974	504.4817

./cruise.txt

<gnuplotによるプロット>

```
gnuplot> splot "./cruise.txt" u 2:3:4, "./cruise.txt" u 5:6:7, "./cruise.txt" u 8:9:10
gnuplot> plot "./cruise.txt" u 2:3, "./cruise.txt" u 5:6, "./cruise.txt" u 8:9
gnuplot>
```

- splotによる三次元プロット

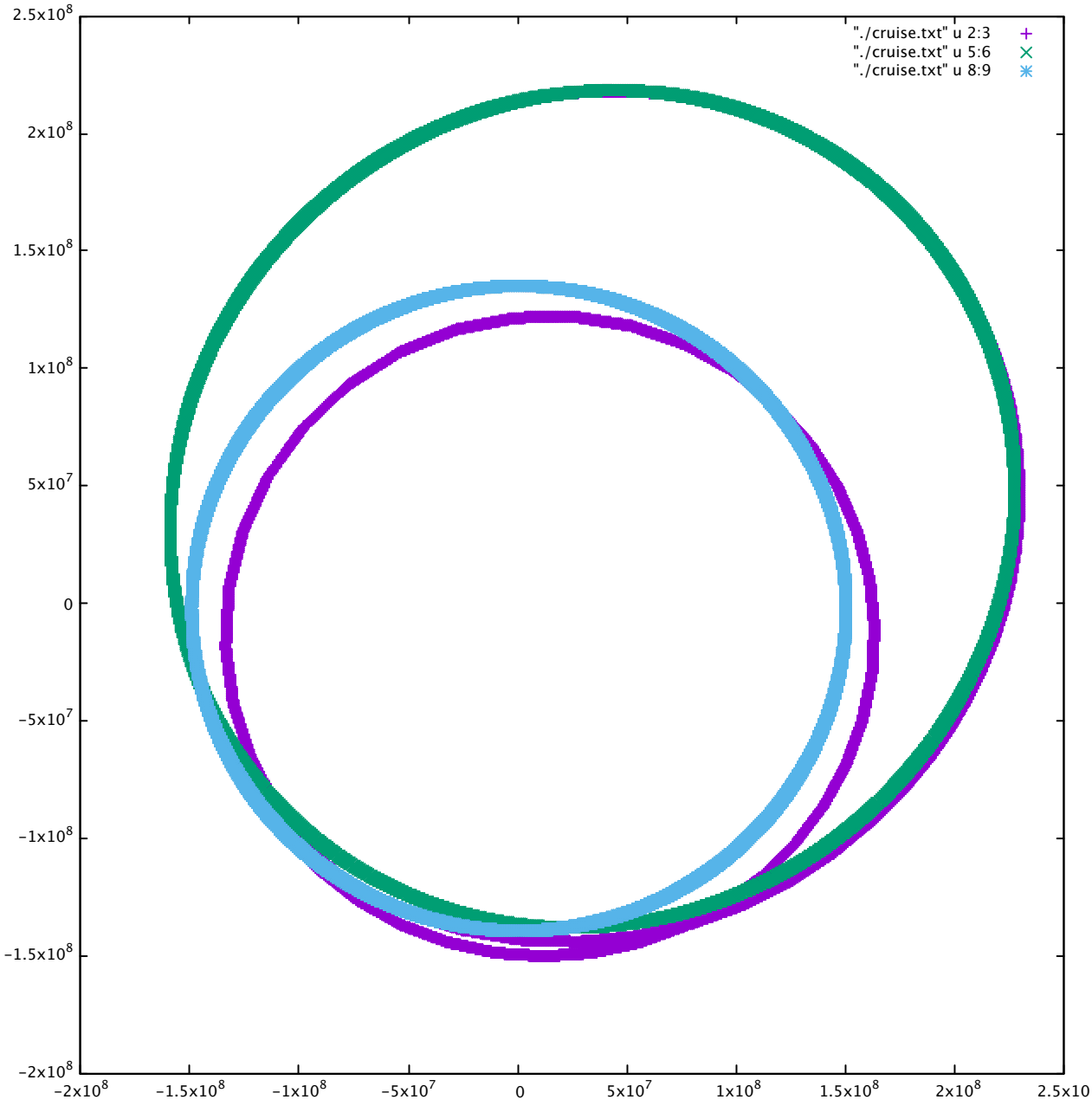


紫(u 2:3:4 - Hayabusaの軌道)

緑(u 5:6:7 - Itokawaの軌道)

青(u 8:9:10 - 地球の軌道)

- plotによる二次元プロット（Z軸を無視）



紫(u 2:3 - Hayabusaの軌道)

緑(u 5:6 - Itokawaの軌道)

青(u 8:9 - 地球の軌道)