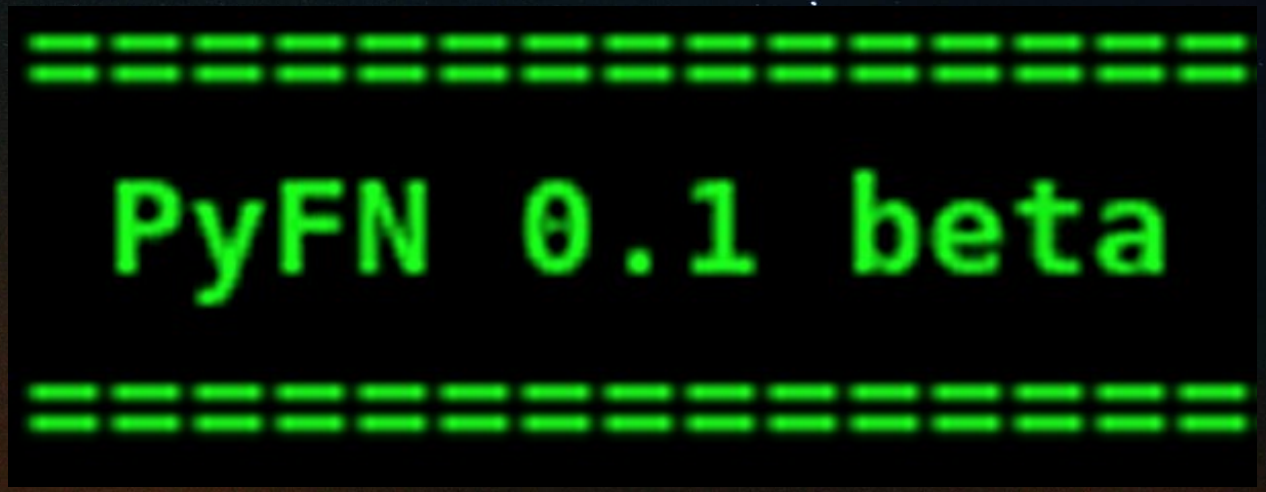
# PyFN

MULTIPURPOSE METEOR SOFTWARE

Przemysław Żołądek
POLISH FIREBALL NETWORK




PRACOWNIA KOMET I METEORÓW
00-716 Warszawa ul. Bartycka 18

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# IMOGENA – currently used software

IMOGENA – a software suite which is able to calculate astrometry, photometry, trajectories and orbits

Created in 2005-2007

- User friendly interface
- Easy to use (but require some knowledge)
- Modular

- Meteors are individually calculated, it's time consuming

# New software requirements

- There is ~10^5 meteors in the PFN database. It's impossible to calculate it manually

- New software should be partially automated. Should work with large amount of data

- User will be able to control calculations and will reject low quality results

- Critical procedures should be created with trustworthy libraries like i.e. CSPICE

# PyFN overview

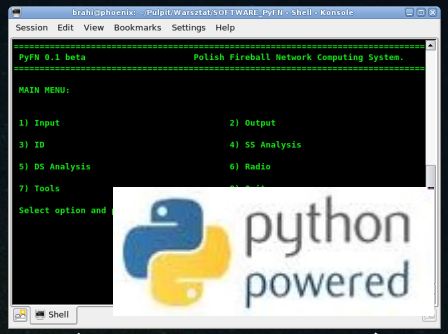
Multi Instrument Input

Video data

AstroRecord

Visual reports

Radio




Processing, linking, calculations

-Orbital databases
-Trajectory databases

Individual meteors
- with trajectory
-with orbit
-with radio data
-with visual data

Video Flux

Radio Flux

ZHR analysis

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# Libraries and modules

```
 1  #! /usr/bin/env python
 2  import os
 3  import sys
 4  import string
 5  import datetime
 6  import time
 7  import array
 8  import scipy
 9  import pylab
10  import math
11  import numpy as np
12  import pyfnspice
13  import sidereal
```

http://numpy.scipy.org

NumPy is the fundamental package needed for scientific computing with Python. It contains among other things:

a powerful N-dimensional array object

sophisticated (broadcasting) functions

tools for integrating C/C++ and Fortran code

useful linear algebra, Fourier transform, and random number capabilities.

# Libraries and modules

```
 1  #! /usr/bin/env python
 2  import os
 3  import sys
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 5  import datetime
 6  import time
 7  import array
 8  import scipy
 9  import pylab
10  import math
11  import numpy as np
12  import pyfnspice
13  import sidereal
```

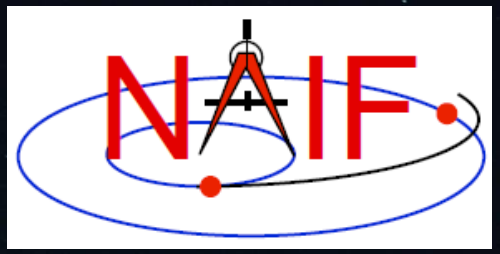
http://www.scipy.org/

SciPy (pronounced "Sigh Pie") is open-source software for mathematics, science, and engineering. It is also the name of a very popular conference on scientific programming with Python. The SciPy library depends on NumPy, which provides convenient and fast N-dimensional array manipulation. The SciPy library is built to work with NumPy arrays, and provides many user-friendly and efficient numerical routines such as routines for numerical integration and optimization

# Libraries and modules

```
1  #! /usr/bin/env python
2  import os
3  import sys
4  import string
5  import datetime
6  import time
7  import array
8  import scipy
9  import pylab
10 import math
11 import numpy as np
12 import pyfnspice
13 import sidereal
```

http://www.scipy.org/




**SPICE**

The SPICE system includes a large suite of software, mostly in the form of subroutines that customers incorporate in their own application programs to read SPICE files and to compute derived observation geometry, such as altitude, latitude/longitude, and lighting angles.

Only few routines were wrapped in this module

# Libraries and modules

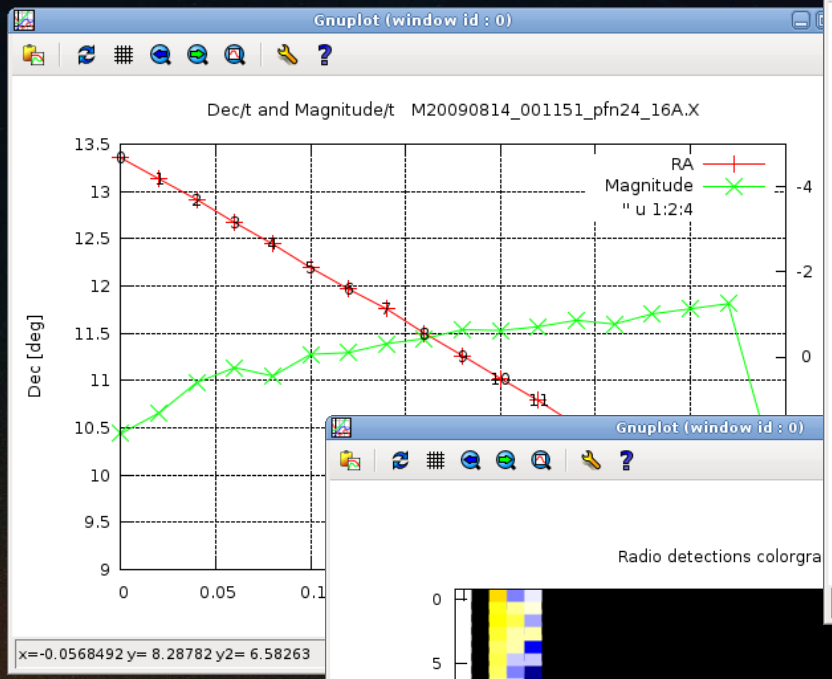
```
 1  #! /usr/bin/env python
 2  import os
 3  import sys
 4  import string
 5  import datetime
 6  import time
 7  import array
 8  import scipy
 9  import pylab
10  import math
11  import numpy as np
12  import pyfnspice
13  import sidereal
```

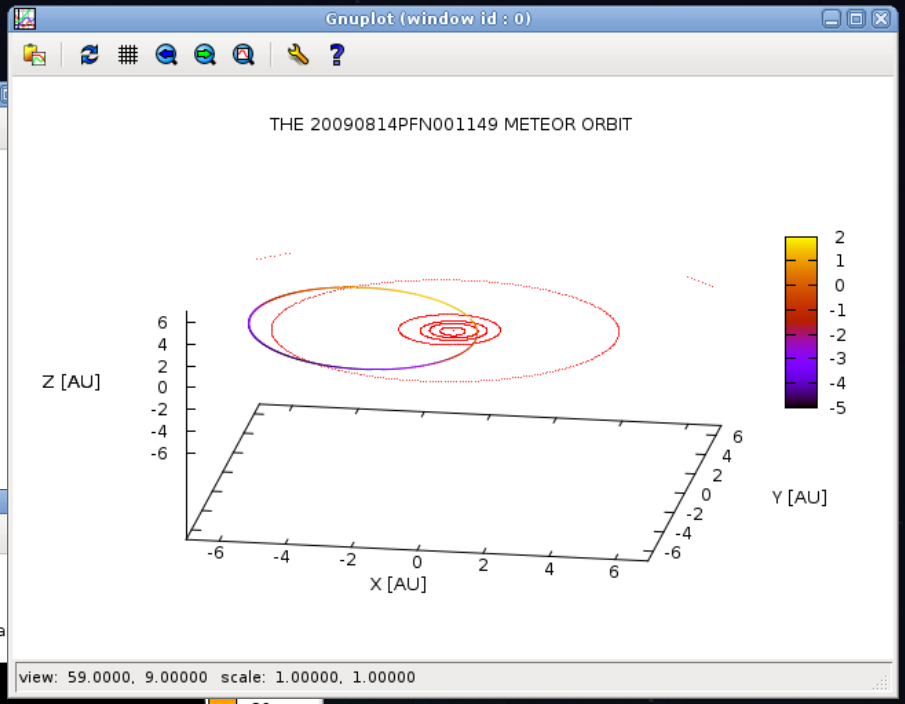
http://www.scipy.org/

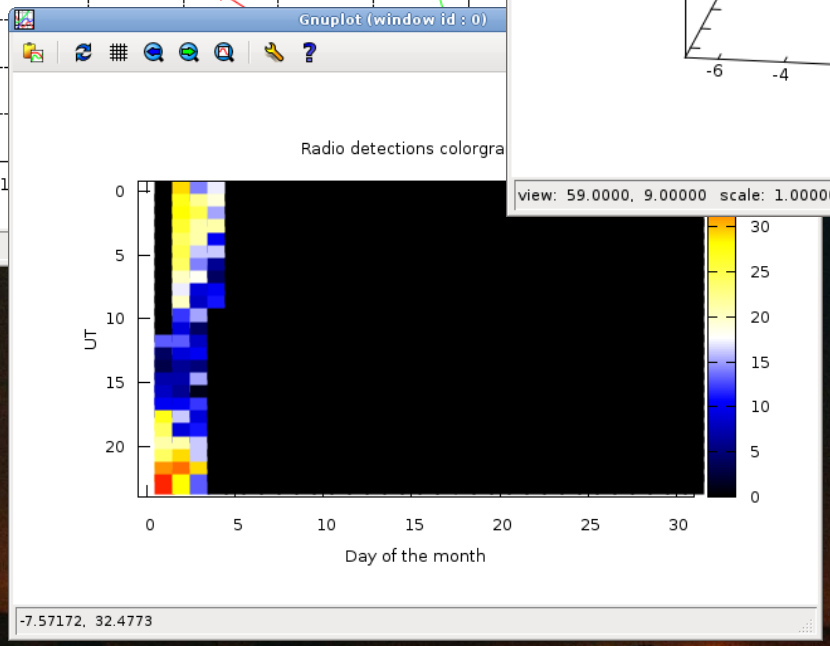
**Sidereal.py**

Python module used to simple calculations (Alt Az → Ra dec conversion, sidereal time calculation etc.)

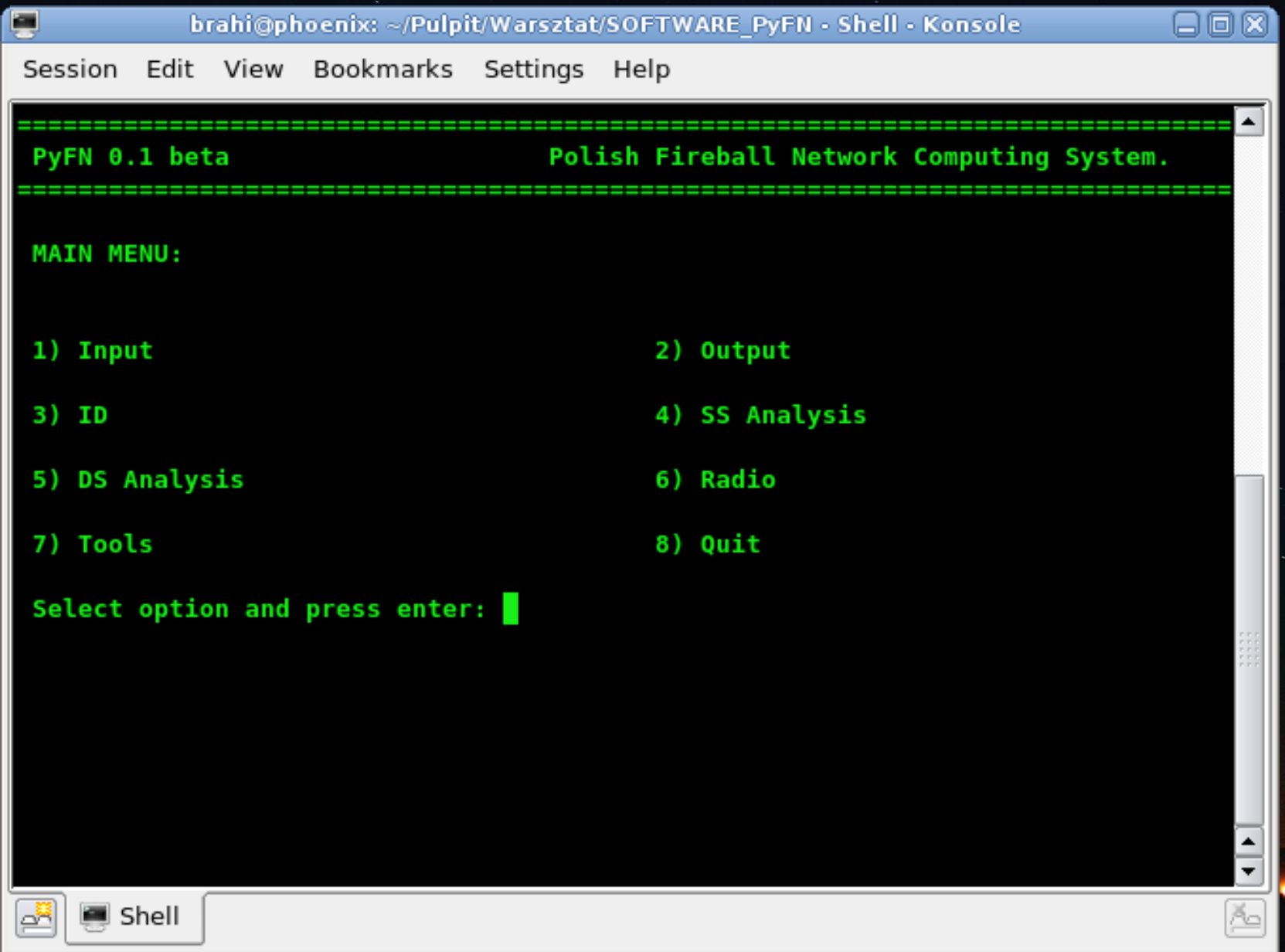
# Gnuplot


Gnuplot (window id : 0)
Dec/t and Magnitude/t M20090814_001151_pfn24_16A.X
RA
Magnitude
" u 1:2:4
Dec [deg]
x=-0.0568492 y= 8.28782 y2= 6.58263

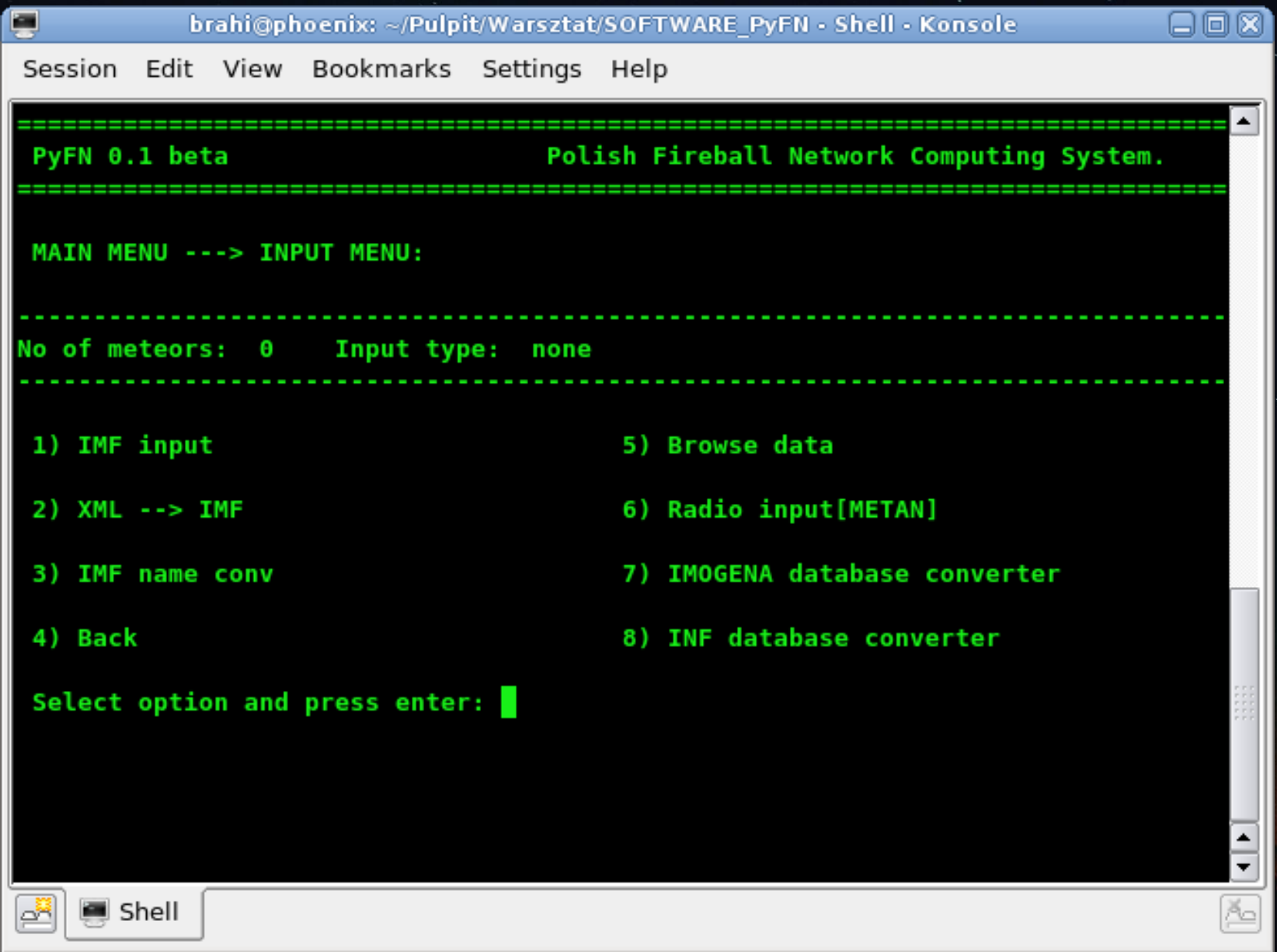

Gnuplot (window id : 0)
THE 20090814PFN001149 METEOR ORBIT
Z [AU]
Y [AU]
X [AU]
view: 59.0000, 9.00000 scale: 1.00000, 1.00000


Gnuplot (window id : 0)
Radio detections colorgra
UT
Day of the month
-7.57172, 32.4773

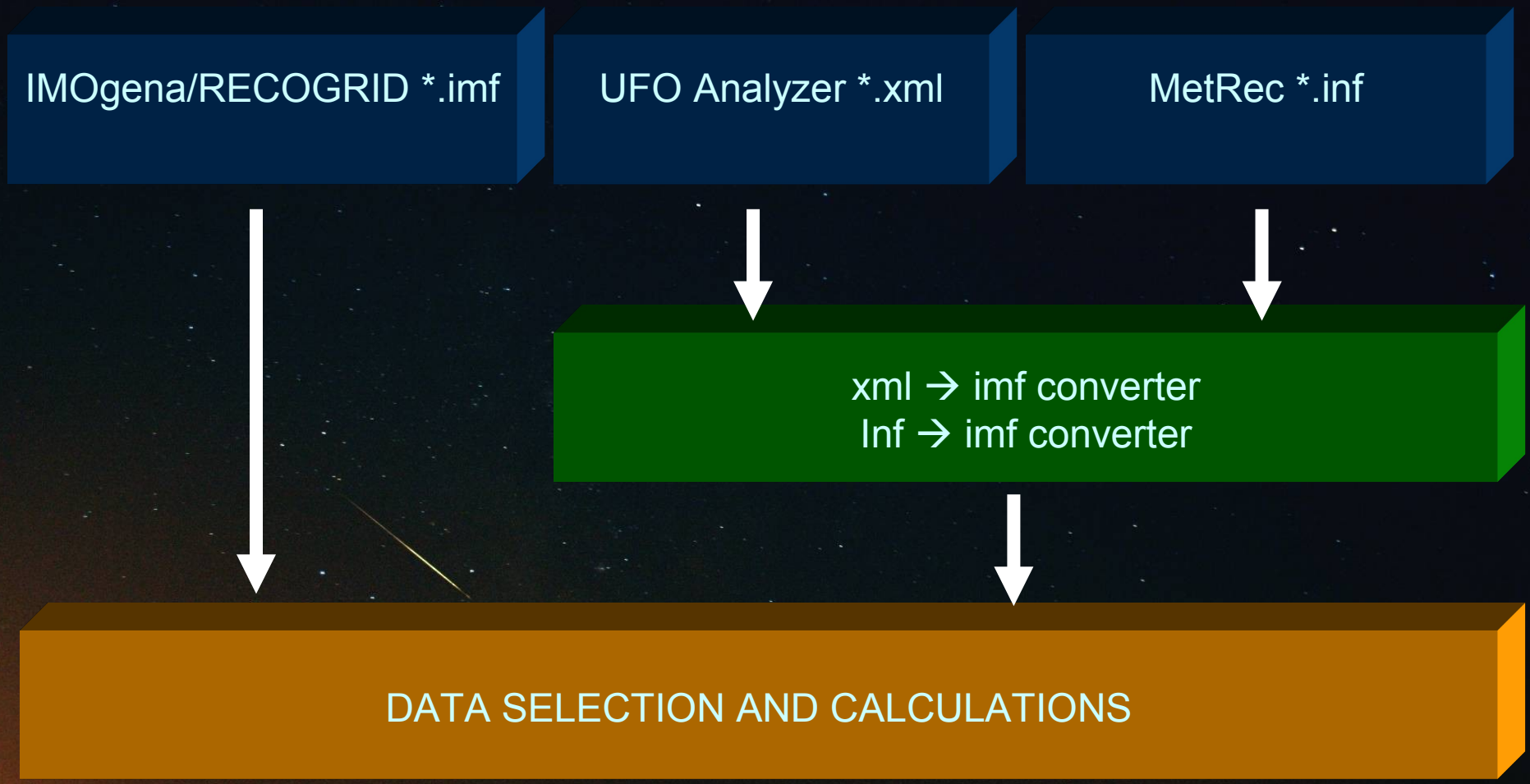
# PyFN main menu



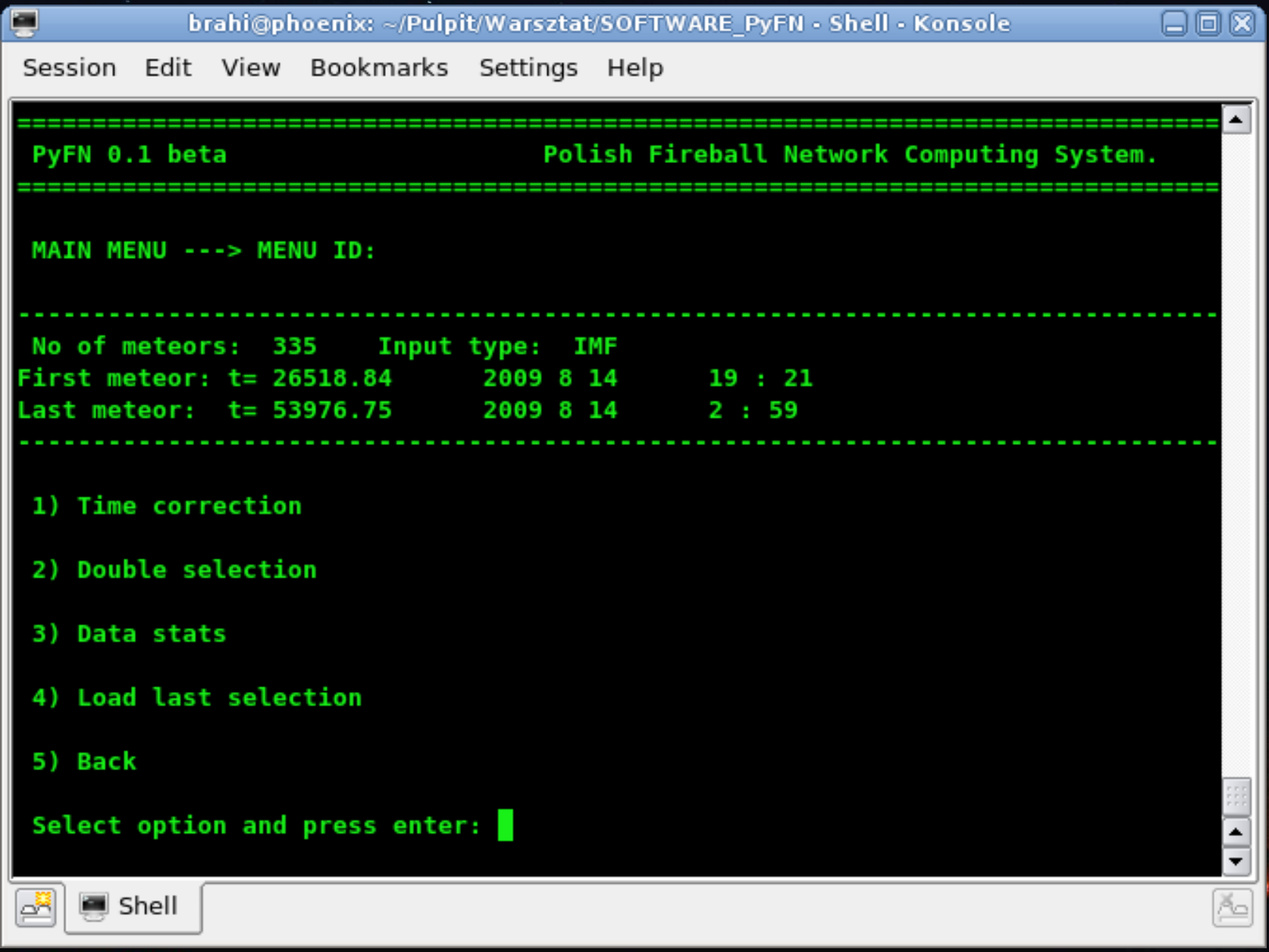
# PyFN input menu



# Video data input files



# Multistation meteor identification



brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

Session Edit View Bookmarks Settings Help

```
==========================================================================
 PyFN 0.1 beta                    Polish Fireball Network Computing System.
==========================================================================

 MAIN MENU ---> MENU ID:

--------------------------------------------------------------------------
 No of meteors:  335    Input type:  IMF
First meteor: t= 26518.84      2009 8 14      19 : 21
Last meteor:  t= 53976.75      2009 8 14      2 : 59
--------------------------------------------------------------------------

 1) Time correction

 2) Double selection

 3) Data stats

 4) Load last selection

 5) Back

 Select option and press enter:
```

Shell

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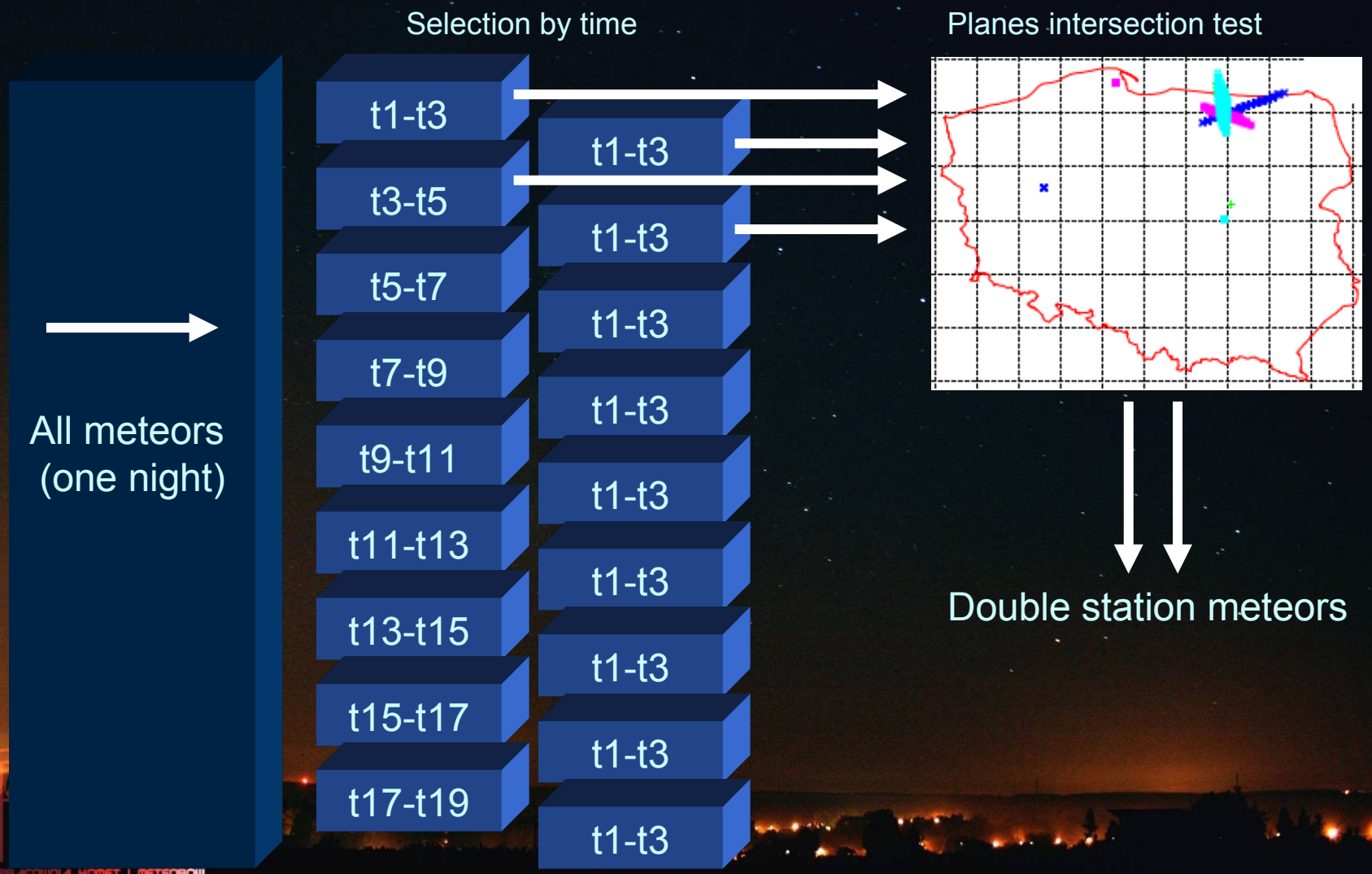
# Multistation meteor identification



# Double station meteor list

brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

Session Edit View Bookmarks Settings Help

```
326  ------------  ['M20090814_224506_PFN05_PAV11']
327  ------------  ['M20090814_224558_PFN05_PAV05']
328  ------------  ['M20090814_225600_PFN34_PHOT1']
329  ------------  ['M20090814_225600_PFN34_PHOT1', 'M20090814_225632_PFN32_PAV35']
330  ------------  ['M20090814_225632_PFN32_PAV35']
331  ------------  ['M20090814_225656_PFN05_PAV05']
332  ------------  ['M20090814_230605_34003_EA.XM', 'M20090814_230606_PFN05_PAV11']
333  ------------  ['M20090814_231014_34003_MFA.X', 'M20090814_231015_PFN05_PAV24']
334  ------------  ['M20090814_231300_PFN34_PHOT1']
335  ------------  ['M20090814_231300_PFN34_PHOT1', 'M20090814_231307_PFN06_PAV06', 'M20090814_231310_PFN32_PAV35']
336  ------------  ['M20090814_231307_PFN06_PAV06', 'M20090814_231423_PFN32_PAV35']
337  ------------  ['M20090814_231423_PFN32_PAV35']
338  ------------  ['M20090814_231936_PFN05_PAV11']
339  ------------  ['M20090814_231936_PFN05_PAV11', 'M20090814_232018_PFN30_P34_A']
340  ------------  ['M20090814_232018_PFN30_P34_A']
341  ------------  ['M20090814_232114_AGO-01_W1A.']
342  ------------  ['M20090814_232716_AGO-01_W1A.']
343  ------------  ['M20090814_233023_34003_MFA.X', 'M20090814_233024_PFN05_PAV24']
344  ------------  ['M20090814_233024_PFN05_PAV24']
345  ------------  ['M20090814_233204_PFN32_PAV35']
346  ------------  ['M20090814_233810_AGO-01_W1A.']
347  ------------  ['M20090814_233920_AGO-01_W1A.']
348  ------------  ['M20090814_234113_AGO-01_W1A.']
349  ------------  ['M20090814_234119_PFN32_PAV35']
350  ------------  ['M20090814_234300_PFN34_PHOT1', 'M20090814_234350_PFN32_PAV35', 'M20090814_234351_PFN32_PAV35']
351  ------------  ['M20090814_234300_PFN34_PHOT1', 'M20090814_234350_PFN32_PAV35', 'M20090814_234351_PFN32_PAV35', 'M20090814_234430_PFN30_P33_A']
352  ------------  ['M20090814_234351_PFN32_PAV35']
353  ------------  ['M20090814_234430_PFN30_P33_A']
354  ------------  ['M20090814_234840_AGO-01_W1A.']
355  ------------  ['M20090814_234954_34003_EA.XM']
356  ------------  ['M20090814_234954_34003_EA.XM', 'M20090814_235037_PFN30_P34_A']
357  ------------  ['M20090814_235037_PFN30_P34_A']
358  ------------  ['M20090814_235353_AGO-01_W1A.']
359  ------------  ['M20090814_235608_AGO-01_W1A.']
360  ------------  ['M20090814_235627_AGO-01_W1A.']
361  ------------  ['M20090814_235707_pfn24_16A.X']
362  ------------  ['M20090814_235957_PFN30_P34_A']

ok - accept, r - remove, m - merge, enter option and press enter:
```

Shell

# Meteor identified on four cameras

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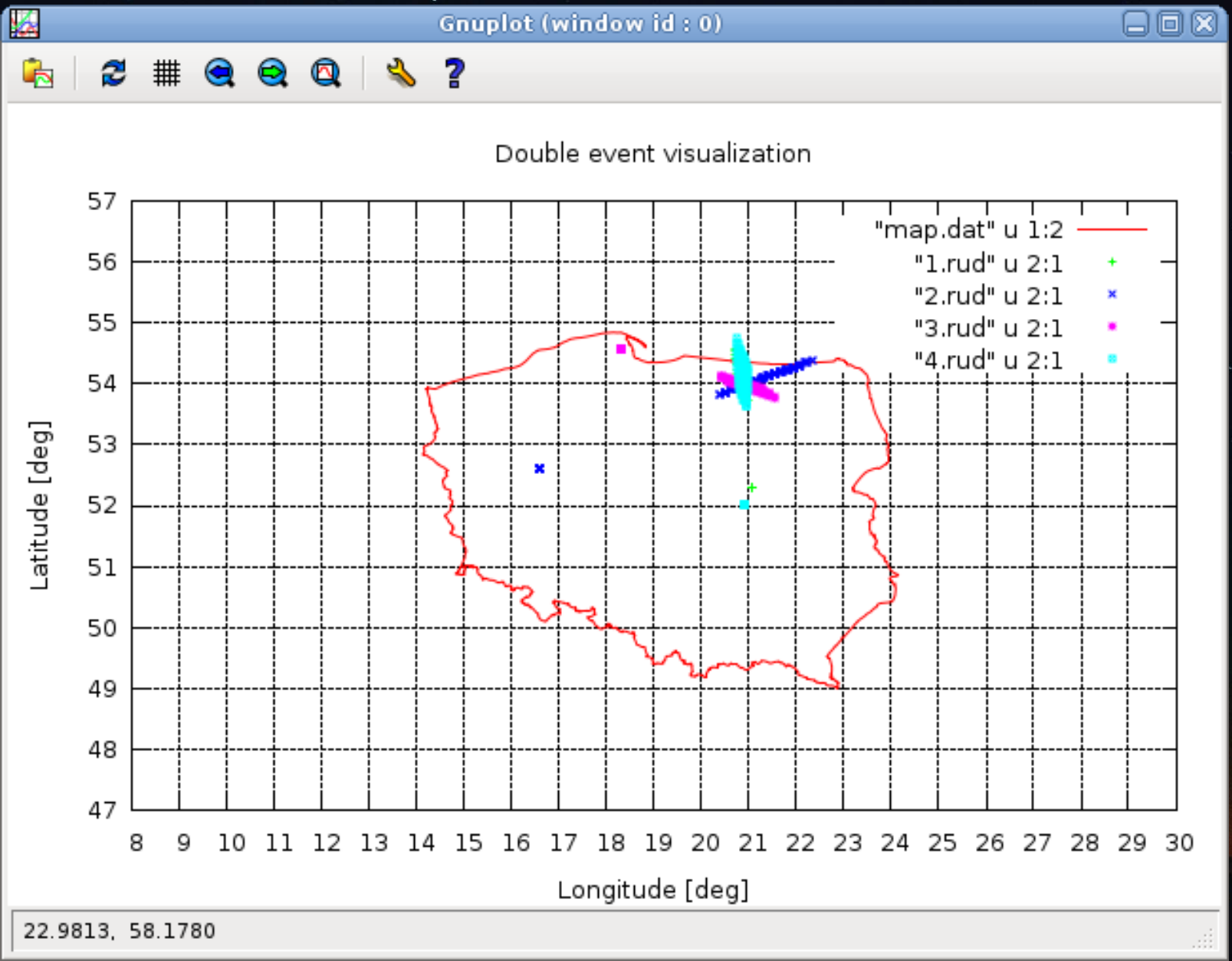
Session Edit View Bookmarks Settings Help

```
================================================================================
 PyFN 0.1 beta                    Polish Fireball Network Computing System.
================================================================================

 MAIN MENU ---> MENU ID ---> DOUBLE STATION ANALYSIS ---> TRAJECTORY/ORBIT:

--------------------------------------------------------------------------------

DS meteor:   ['M20090814_001146_PFN23_PAV13', 'M20090814_001147_34003_EA.XM', 'M20090814_001151_pfn24_16A.X', 'M20090814_001152_PFN03_PAV03']
_____________________

 No. 1    meteor designation:  M20090814_001146_PFN23_PAV13
 Date and time:            2009 - 8 - 14      0 : 11 : 46.78  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 46.78  UT
 Duration:  0.4 [s]   Length:  5.0 [deg]   Points:  11    Vel:  12.5 [deg/s]
 Solar longitude:  141.22761 [deg]  Enabled:  True   Status:  Raw Data

 No. 2    meteor designation:  M20090814_001147_34003_EA.XM
 Date and time:            2009 - 8 - 14      0 : 11 : 47.48  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 47.48  UT
 Duration:  0.18 [s]   Length:  1.3 [deg]   Points:  10    Vel:  7.0 [deg/s]
 Solar longitude:  141.22762 [deg]  Enabled:  True   Status:  Raw Data

 No. 3    meteor designation:  M20090814_001151_pfn24_16A.X
 Date and time:            2009 - 8 - 14      0 : 11 : 51.44  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 51.44  UT
 Duration:  0.34 [s]   Length:  4.1 [deg]   Points:  18    Vel:  12.0 [deg/s]
 Solar longitude:  141.22766 [deg]  Enabled:  True   Status:  Raw Data

 No. 4    meteor designation:  M20090814_001152_PFN03_PAV03
 Date and time:            2009 - 8 - 14      0 : 11 : 52.78  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 52.78  UT
 Duration:  0.48 [s]   Length:  5.4 [deg]   Points:  13    Vel:  11.3 [deg/s]
 Solar longitude:  141.22768 [deg]  Enabled:  True   Status:  Raw Data


 mr - draw RA and magnitude,  md - draw Dec and magnitude,  pt - check frame timing, d - disable meteor
 e - enable meteor, dp - delete meteor point,  inter - correct UFO interlace error, tic - time correction
 bin2 - 2-points binning, disp - display meteor data,  calc - proceed to calculations, ok - accept/proceed next
 draw - draw double event on the map, tim - apply mean time
 Enter option   >:
```

Shell

# Meteor identified on four cameras



# Calculations (2 stations)

## Method described by Zdenek Ceplecha

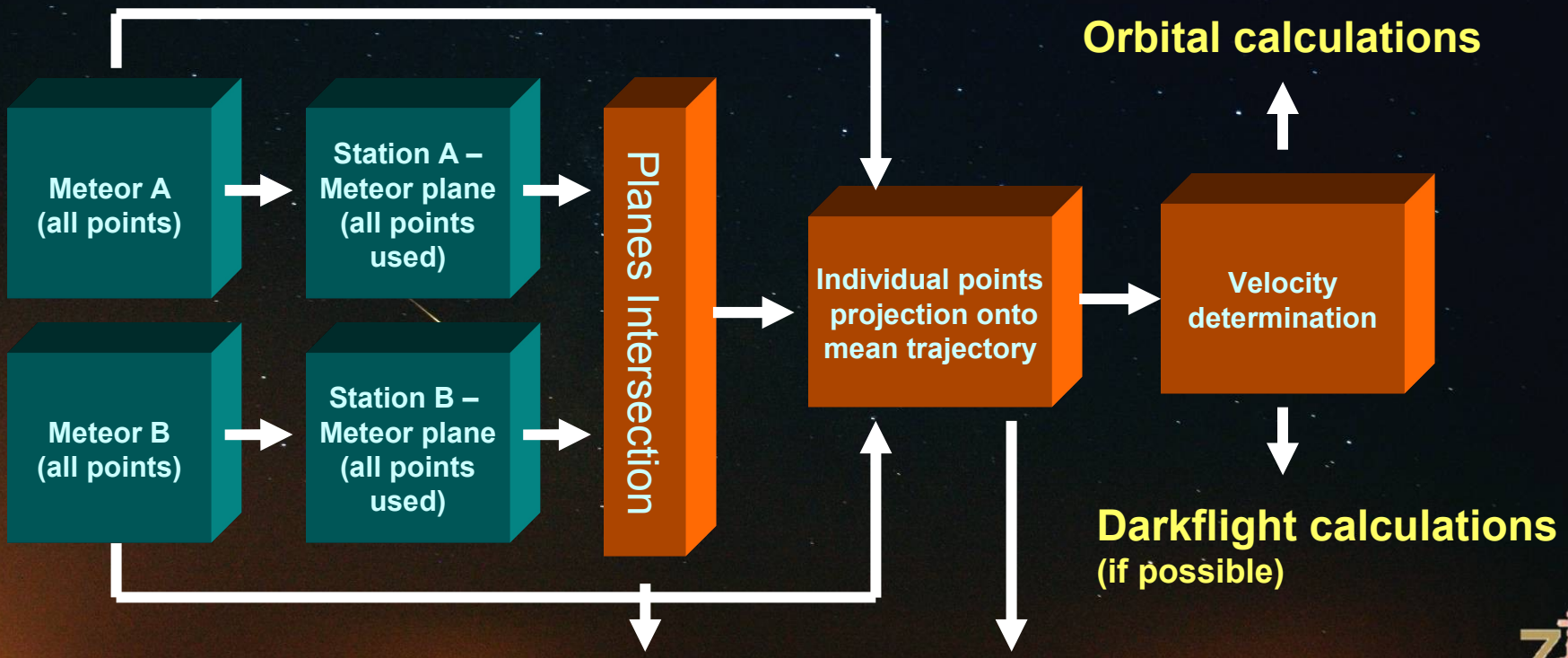
*Title:* ***Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks***

*Authors: Ceplecha, Zdenek*

*Affiliation: AA(Ceskoslovenska Akademie Ved, Astronomicky Ustav, Ondrejov, Czechoslovakia)*

*Publication: Astronomical Institutes of Czechoslovakia, Bulletin (ISSN 0004-6248), vol. 38, July 1987, p. 222-234.*

*Publication Date: 07/1987*

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# Calculations (n-stations)

## Method described by Zdenek Ceplecha

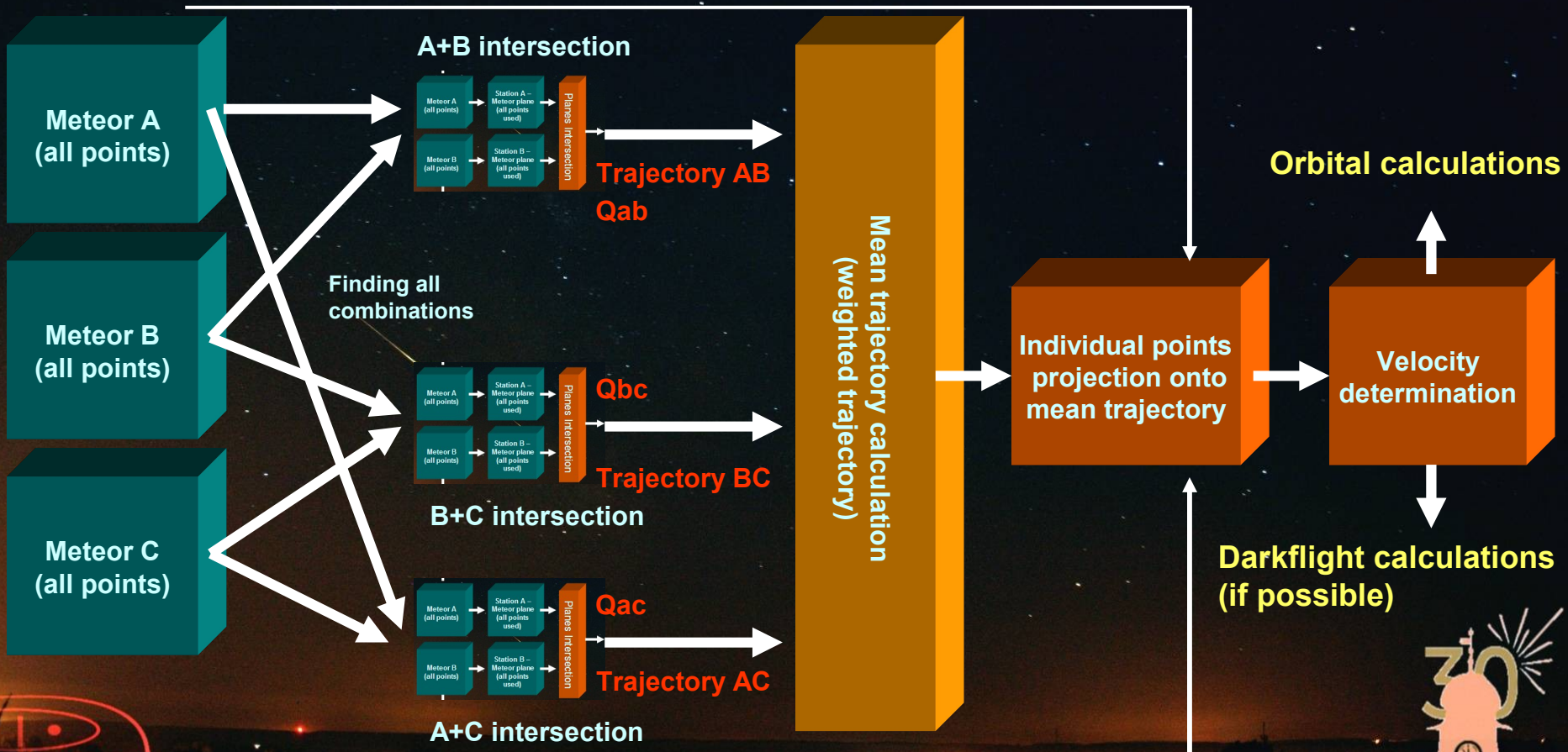
*Title:* ***Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks***

*Authors: Ceplecha, Zdenek*

*Affiliation: AA(Ceskoslovenska Akademie Ved, Astronomicky Ustav, Ondrejov, Czechoslovakia)*

*Publication: Astronomical Institutes of Czechoslovakia, Bulletin (ISSN 0004-6248), vol. 38, July 1987, p. 222-234.*

*Publication Date: 07/1987*

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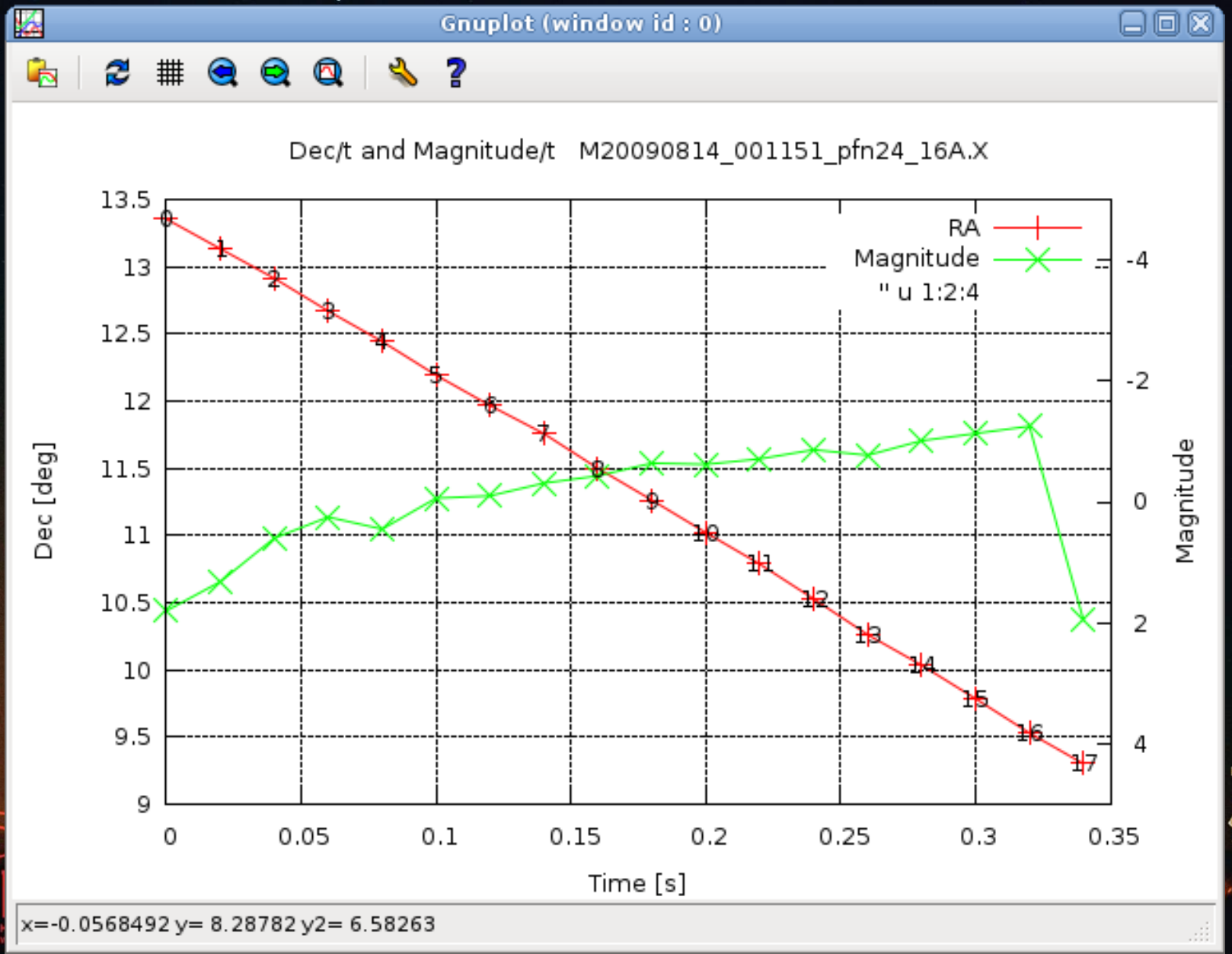
# Test of the input quality



# Trajectory calculations

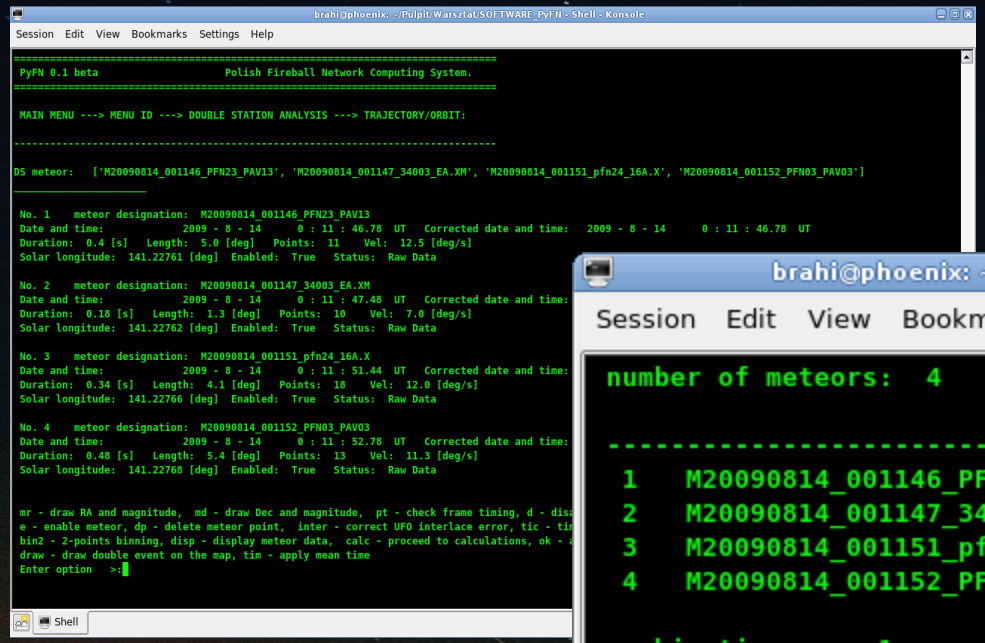
brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

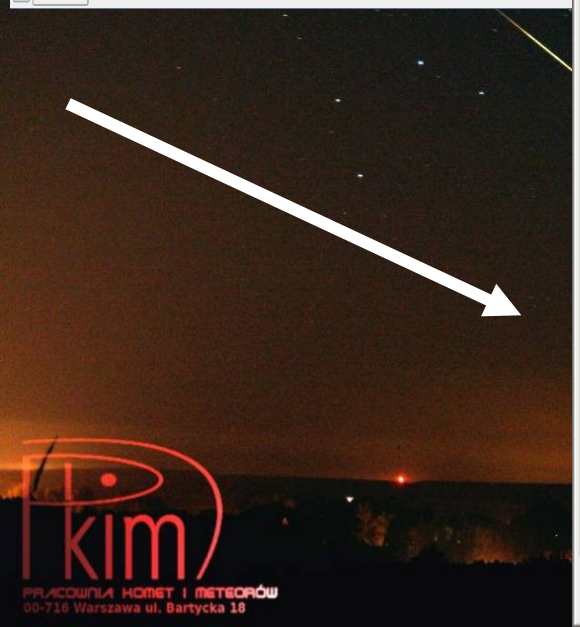
Session Edit View Bookmarks Settings Help

```
================================================================================
 PyFN 0.1 beta                    Polish Fireball Network Computing System.
================================================================================

 MAIN MENU ---> MENU ID ---> DOUBLE STATION ANALYSIS ---> TRAJECTORY/ORBIT:

--------------------------------------------------------------------------------

DS meteor:   ['M20090814_001146_PFN23_PAV13', 'M20090814_001147_34003_EA.XM', 'M20090814_001151_pfn24_16A.X', 'M20090814_001152_PFN03_PAV03']
_____________________

 No. 1    meteor designation:  M20090814_001146_PFN23_PAV13
 Date and time:            2009 - 8 - 14      0 : 11 : 46.78  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 46.78  UT
 Duration:  0.4 [s]   Length:  5.0 [deg]   Points:  11    Vel:  12.5 [deg/s]
 Solar longitude:  141.22761 [deg]  Enabled:  True   Status:  Raw Data

 No. 2    meteor designation:  M20090814_001147_34003_EA.XM
 Date and time:            2009 - 8 - 14      0 : 11 : 47.48  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 47.48  UT
 Duration:  0.18 [s]   Length:  1.3 [deg]   Points:  10    Vel:  7.0 [deg/s]
 Solar longitude:  141.22762 [deg]  Enabled:  True   Status:  Raw Data

 No. 3    meteor designation:  M20090814_001151_pfn24_16A.X
 Date and time:            2009 - 8 - 14      0 : 11 : 51.44  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 51.44  UT
 Duration:  0.34 [s]   Length:  4.1 [deg]   Points:  18    Vel:  12.0 [deg/s]
 Solar longitude:  141.22766 [deg]  Enabled:  True   Status:  Raw Data

 No. 4    meteor designation:  M20090814_001152_PFN03_PAV03
 Date and time:            2009 - 8 - 14      0 : 11 : 52.78  UT   Corrected date and time:   2009 - 8 - 14      0 : 11 : 52.78  UT
 Duration:  0.48 [s]   Length:  5.4 [deg]   Points:  13    Vel:  11.3 [deg/s]
 Solar longitude:  141.22768 [deg]  Enabled:  True   Status:  Raw Data


 mr - draw RA and magnitude,  md - draw Dec and magnitude,  pt - check frame timing, d - disable meteor
 e - enable meteor, dp - delete meteor point,  inter - correct UFO interlace error, tic - time correction
 bin2 - 2-points binning, disp - display meteor data,  calc - proceed to calculations, ok - accept/proceed next
 draw - draw double event on the map, tim - apply mean time
 Enter option   >:
```

Shell

# Trajectory calculations



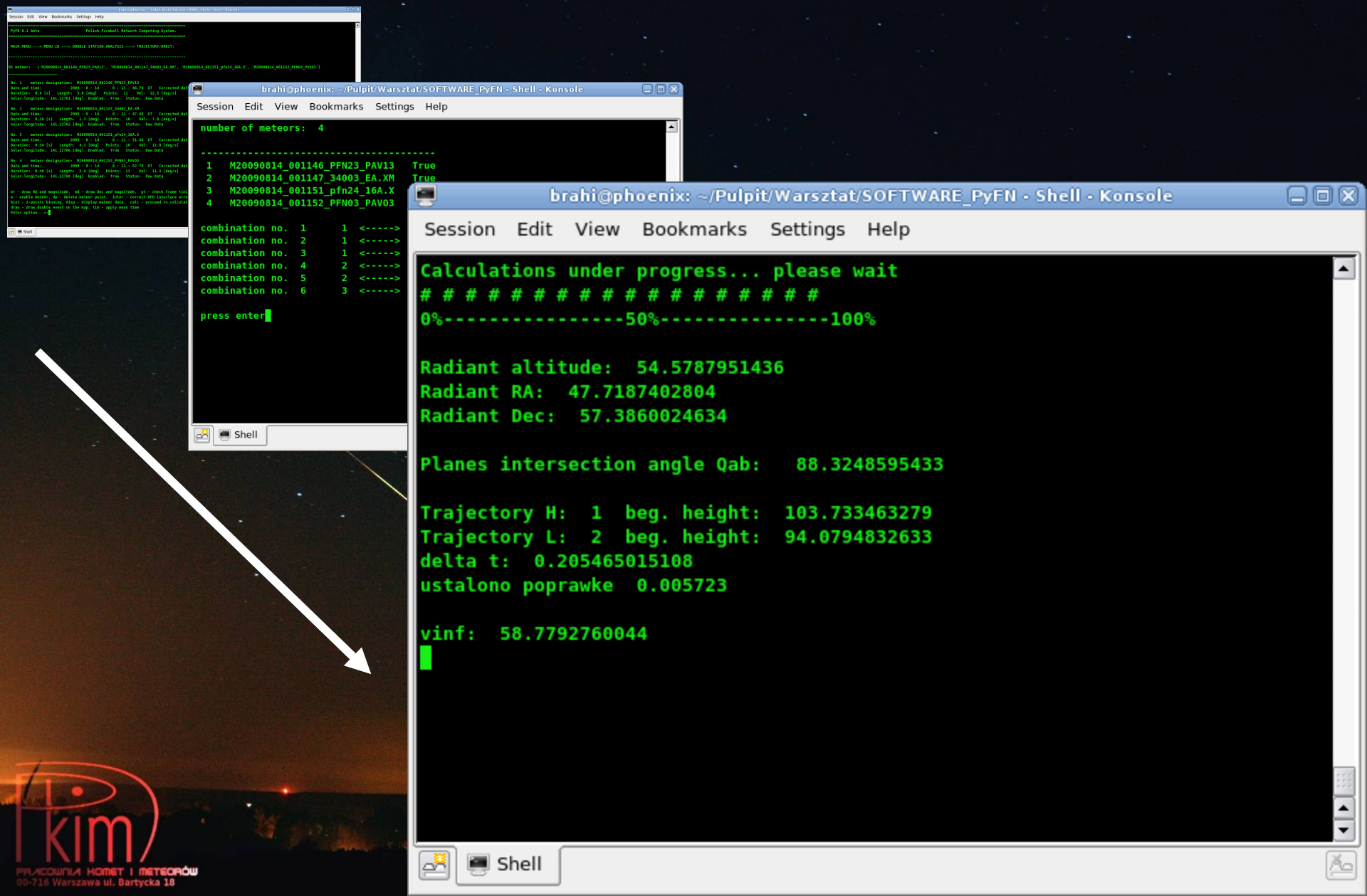

brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

Session Edit View Bookmarks Settings Help

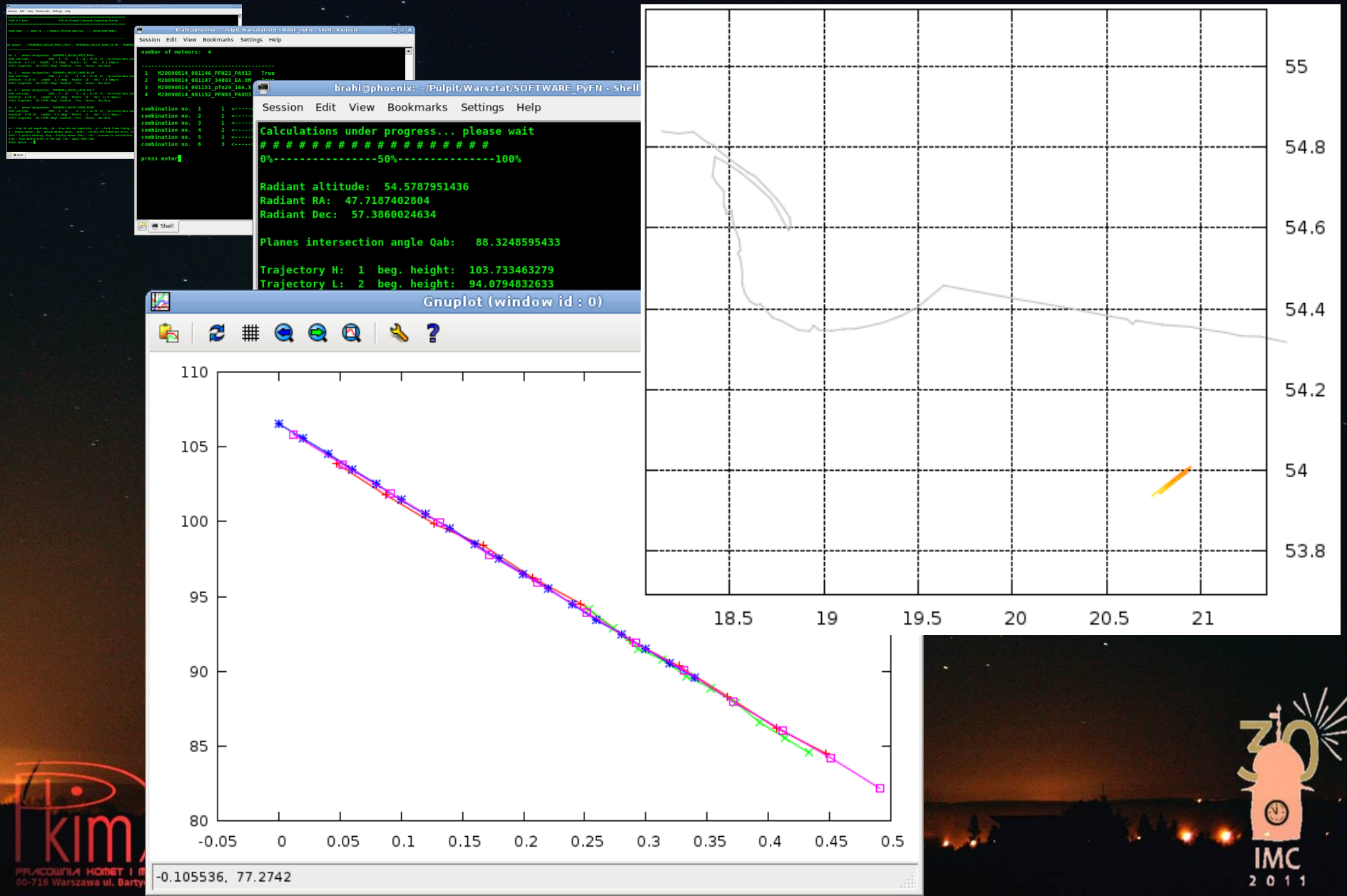
```
number of meteors:  4

----------------------------------------
 1   M20090814_001146_PFN23_PAV13   True
 2   M20090814_001147_34003_EA.XM   True
 3   M20090814_001151_pfn24_16A.X   True
 4   M20090814_001152_PFN03_PAVO3   True

combination no.  1      1  <-----> 2
combination no.  2      1  <-----> 3
combination no.  3      1  <-----> 4
combination no.  4      2  <-----> 3
combination no.  5      2  <-----> 4
combination no.  6      3  <-----> 4

press enter
```

Shell

# Trajectory calculations



# Trajectory calculations - results



# Orbital calculations

## Method described by Zdenek Ceplecha + CSPICE routine *oscelt.c*

*Title:* ***Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks***

*Authors: Ceplecha, Zdenek*

*Affiliation: AA(Ceskoslovenska Akademie Ved, Astronomicky Ustav, Ondrejov, Czechoslovakia)*

*Publication: Astronomical Institutes of Czechoslovakia, Bulletin (ISSN 0004-6248), vol. 38, July 1987, p. 222-234.*

*Publication Date: 07/1987*

- Radiant α
- Radiant δ
- Vinf
- LST

$\alpha \rightarrow \alpha_{geo}$
$\delta \rightarrow \delta_{geo}$
Vinf → Vgeo

Geocentric radiant

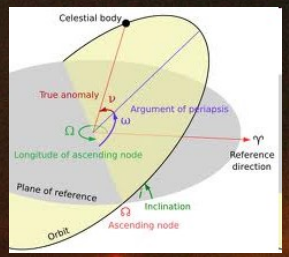
$\alpha_{geo} \rightarrow L_{hel}$
$\delta_{geo} \rightarrow B_{hel}$
Vinf → Vhel

Heliocentric radiant

Conversion to heliocentric state vector

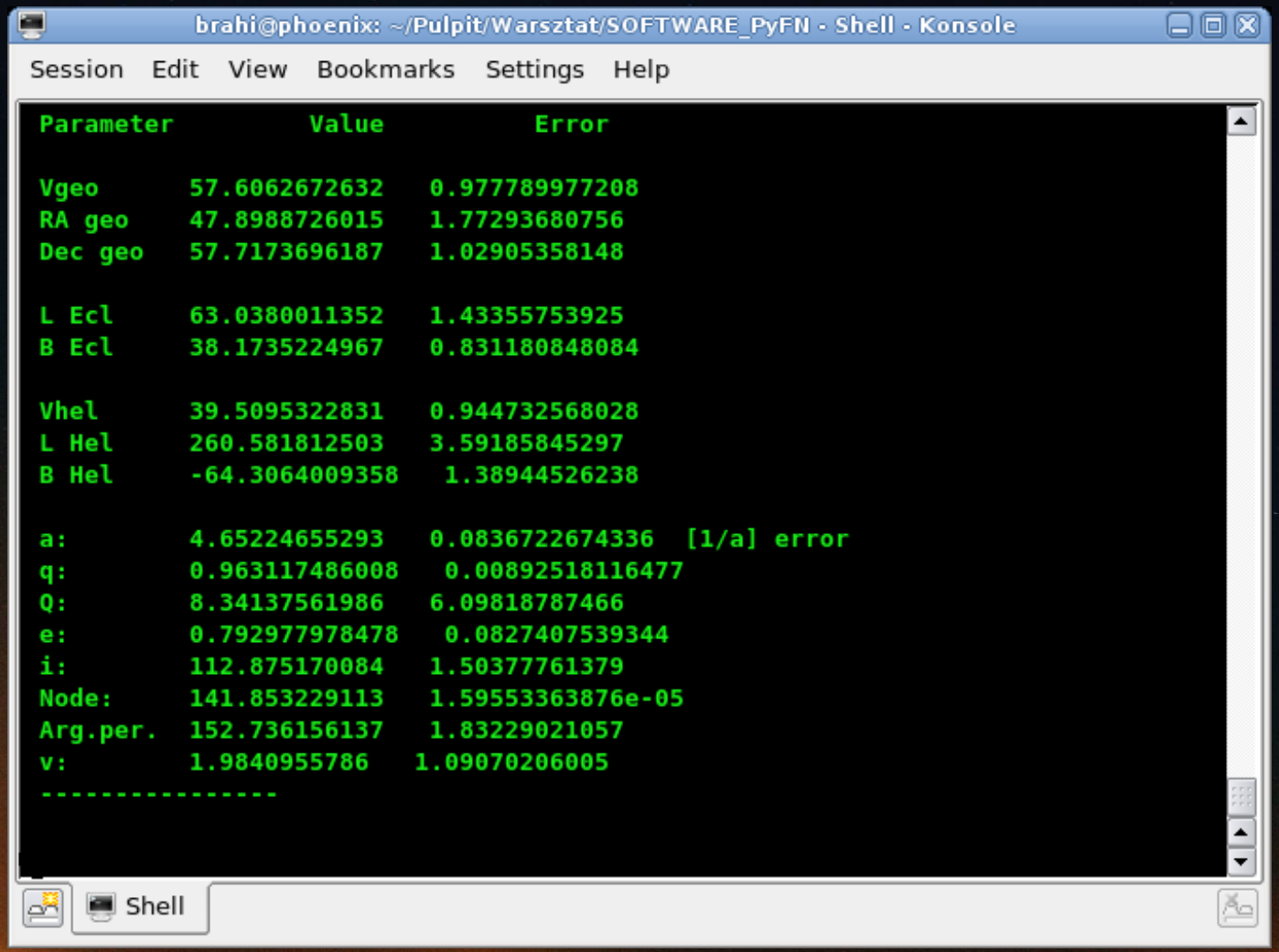
X, Y, Z, dX, dY, dZ

CSPICE oscelt.c vector to orbital Elements conversion




L , B hel – heliocentric longitude and latitude

# Orbital calculations - results



# Orbital calculations - results

brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

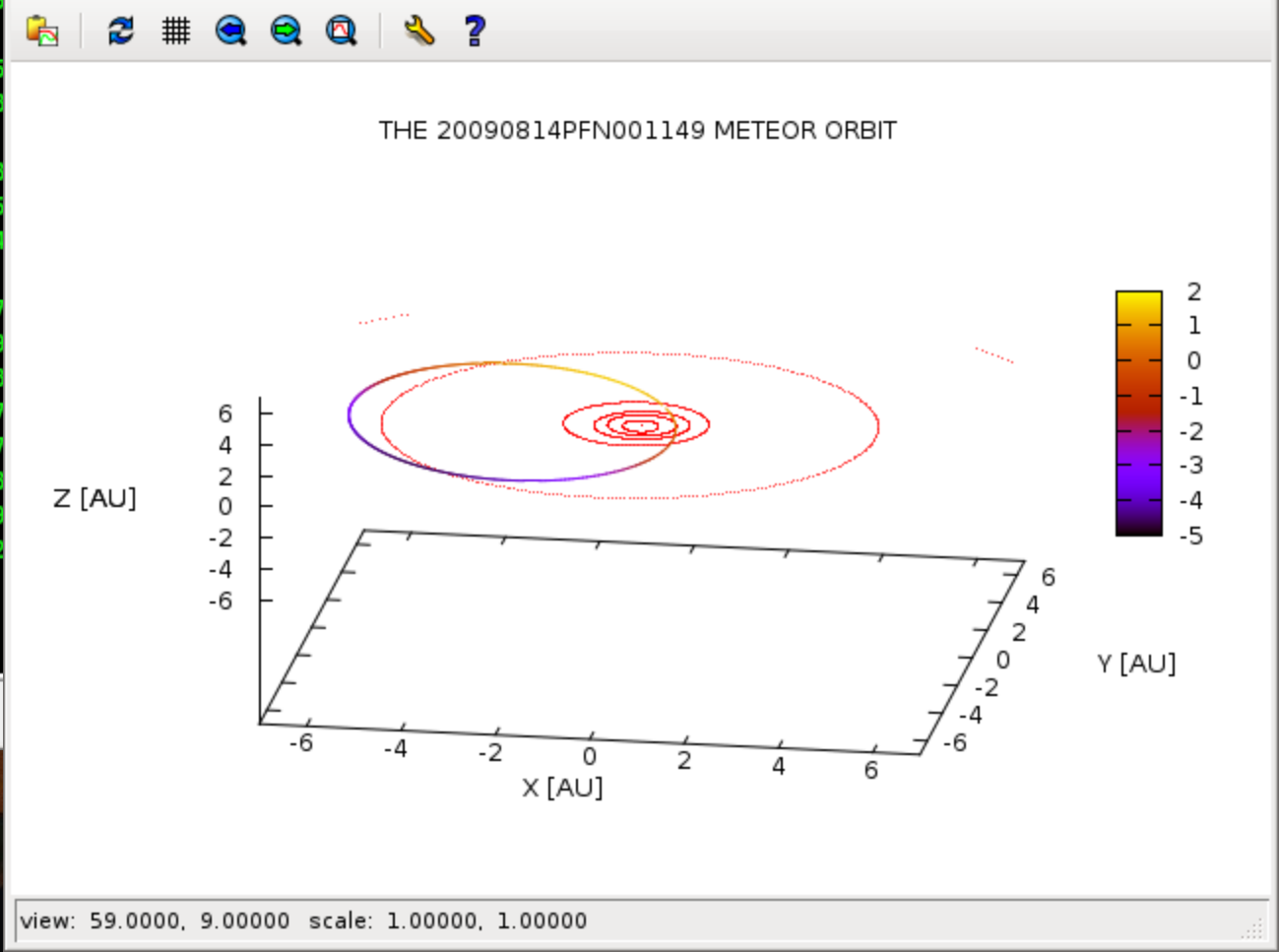
Session Edit View Bookmarks Settings Help

| Parameter | Value | Error |
|---|---|---|
| Vgeo | 57.6062672632 | 0.977789977208 |
| RA geo | 47.8988726015 | 1.77293 |
| Dec geo | 57.7173696187 | 1.02905 |
| L Ecl | 63.0380011352 | 1.43355 |
| B Ecl | 38.1735224967 | 0.83118 |
| Vhel | 39.5095322831 | 0.94473 |
| L Hel | 260.581812503 | 3.59185 |
| B Hel | -64.3064009358 | 1.3894 |
| a: | 4.65224655293 | 0.08367 |
| q: | 0.963117486008 | 0.0089 |
| Q: | 8.34137561986 | 6.09818 |
| e: | 0.792977978478 | 0.0827 |
| i: | 112.875170084 | 1.50377 |
| Node: | 141.853229113 | 1.59553 |
| Arg.per. | 152.736156137 | 1.83229 |
| v: | 1.9840955786 | 1.090702 |

---

Shell

Gnuplot (window id : 0)




kim
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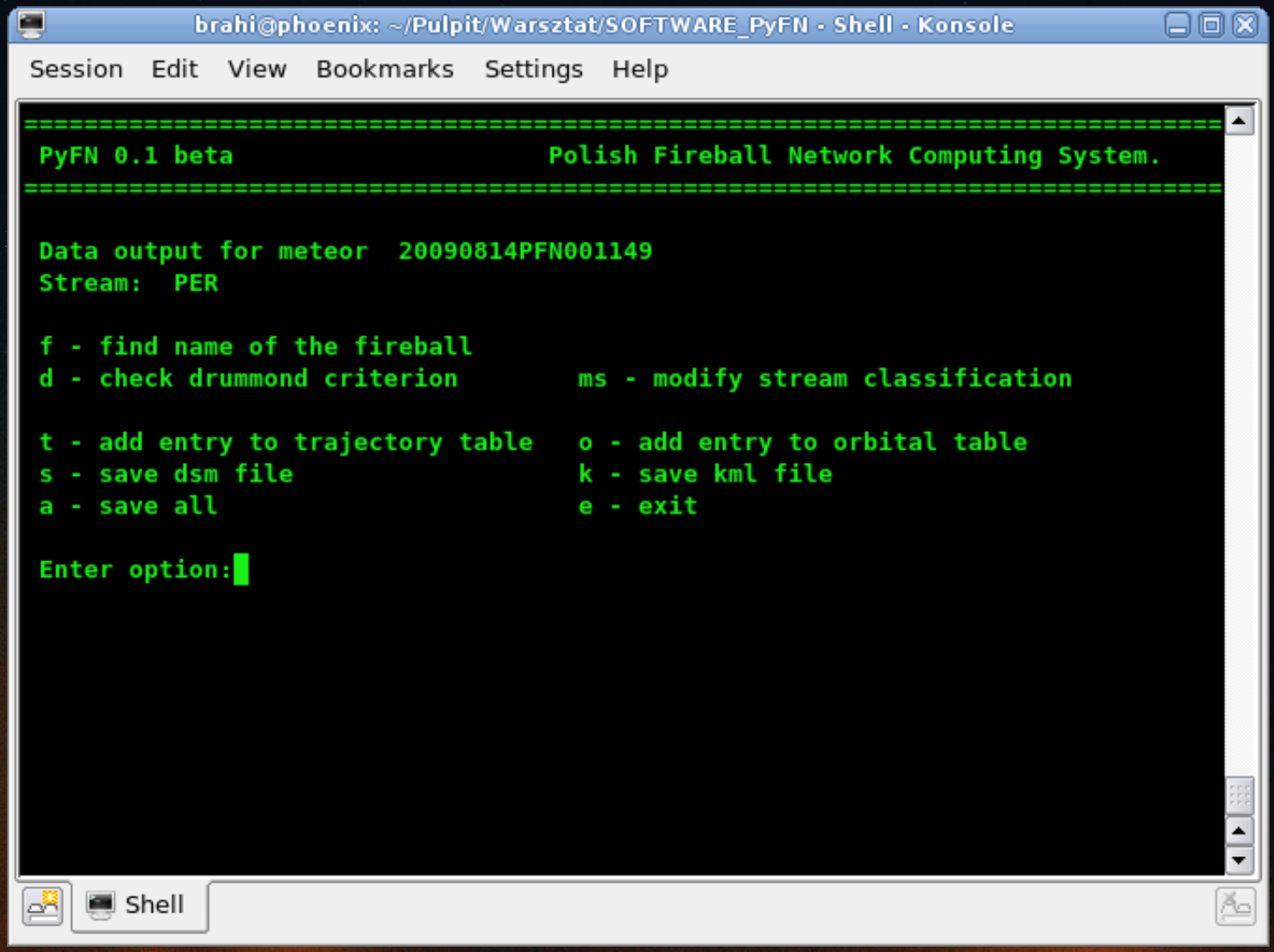
# Output

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IMC 2011

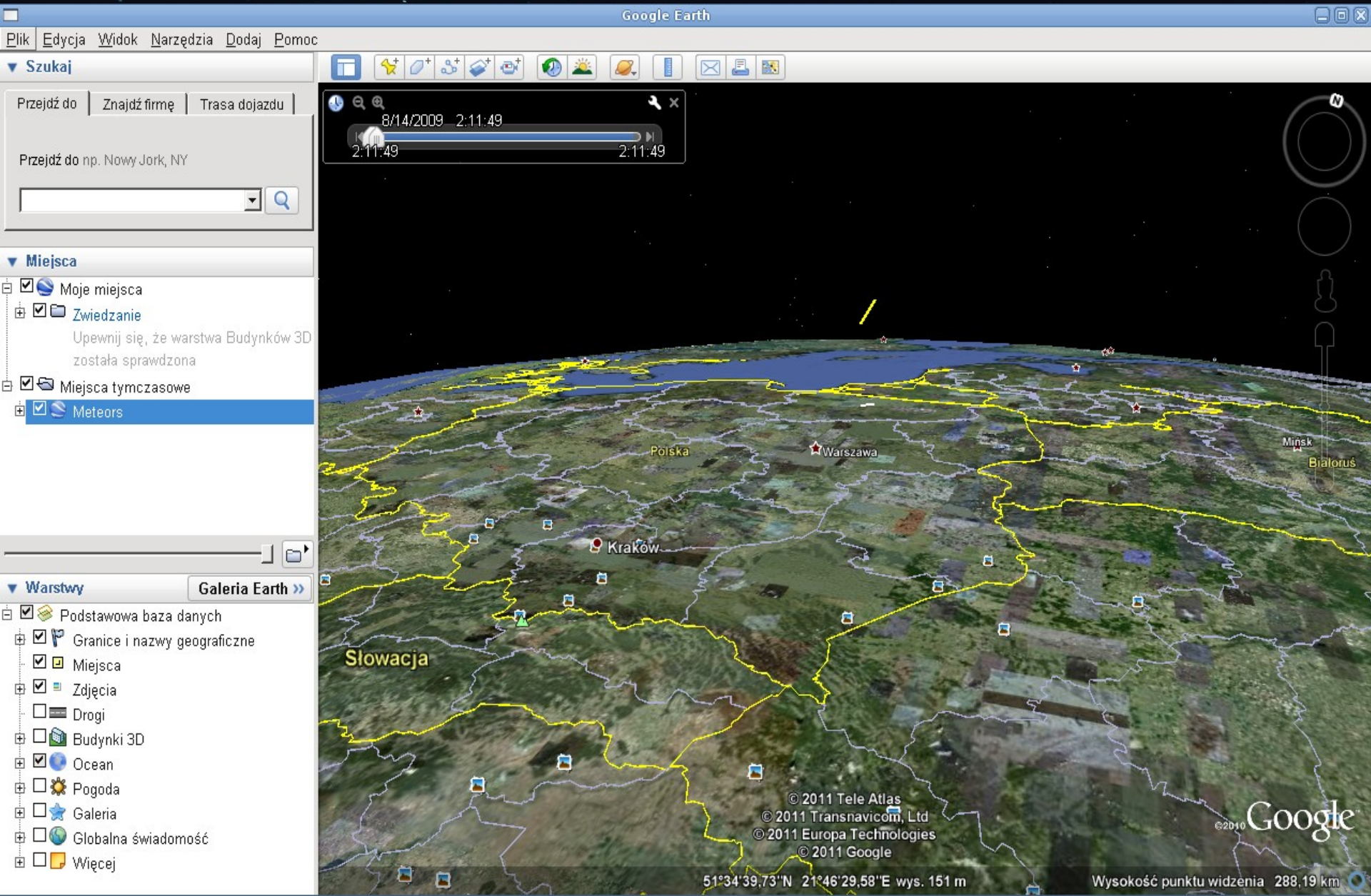
# D’ criterion test

brahi@phoenix: ~/Pulpit/Warsztat/SOFTWARE_PyFN - Shell - Konsole

Session Edit View Bookmarks Settings Help

```
 0.0838342650732   PER_00812016   0.939   0.93   114.6   148.0   140.605
 0.0691704498816   PER_00812038   0.953   0.909   112.5   151.0   140.635
 0.0361676010707   PER_00812042   0.944   0.84   113.1   148.3   140.637
 0.0723669994592   PER_00812048   0.931   0.9   112.3   146.0   140.653
 0.0963480794982   PER_00812049   0.948   0.96   112.9   150.4   140.656
 0.063908500473   PER_01812006   0.955   0.895   110.4   151.4   140.197
 0.0870105284923   PER_01812011   0.949   0.94   111.3   150.4   140.201
 0.0961683414311   PER_01812014   0.941   0.956   112.01   148.8   140.204
 0.0765852540236   PER_01812015   0.943   0.919   113.2   148.9   140.206
 0.0410529788989   PER_01812028   0.946   0.852   113.99   149.0   140.241
 0.0530484200862   PER_01812033   0.941   0.86   109.4   147.8   140.243
 0.0985908337087   PER_01815076   0.953   0.95   106.2   151.6   143.178
 0.0741693479072   PER_01815110   0.966   0.91   116.9   154.7   143.214
 0.0629116200877   PER_01815152   0.937   0.88   114.6   147.1   143.28
 0.0919095165704   PER_01816013   0.937   0.93   117.5   147.8   144.031
 0.0645861509778   PER_01816045   0.956   0.891   108.6   151.8   144.122


DMS (2456 entries):
----------------------------------------
 0.0862699409985   Per 97509   0.958   0.94   114.44   152.67   139.6834
 0.087233533259   Per 97510   0.958   0.941   115.23   152.61   139.6902
 0.0230512170714   Per 97515   0.957   0.789   116.37   150.84   139.696
 0.0740894200041   Per 97519   0.94   0.911   112.73   147.95   139.6999
 0.0650678751337   Per 97525   0.948   0.898   114.44   149.76   139.71
 0.0780246031242   Per 97530   0.963   0.913   118.36   153.73   139.7148
 0.0497573074312   Per 97533   0.945   0.73   111.55   147.2   139.7197
 0.084667942878   Per 97541   0.925   0.919   112.4   144.84   139.7256
 0.070711372799   Per 97542   0.914   0.863   110.73   141.99   139.7266
 0.0296812991146   Per 97543   0.956   0.834   112.25   151.02   139.7268
 0.0719926675061   Per 97545   0.903   0.756   114.06   138.34   139.7375
 0.0345352655297   Per 97551   0.941   0.824   111.72   147.33   139.7499
 0.0743389775101   Per 97555   0.902   0.815   108.75   139.1   139.7588
 0.0053806692724   Per 23570[illegible]
 0.0891258318609   Per 1997084   0.93724   0.94013   112.78367   147.71499   140.42504
 0.0944513043375   Per? 1997204   0.9011   0.9066   112.0782   140.1085   139.6841
 0.0398291881659   Per? 1997226   0.942   0.8325   116.509   147.7027   139.7408
```

Shell

# KML output (Google Earth)