Final Presentation

Synthetic Generation of a NEO Population

ESRIN,
November 18th, 2014

DLR

Observatoire de la CÔTE d'AZUR

Institute of Aerospace Systems

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Motivation

- NEOs could potentially hit our planet
- Depending on their size an impact can produce considerable damage.
- Impacts of large objects are rare, but probability increases with smaller sizes.

https://tallbloke.wordpress.com/2013/03/05/andrew-cooper-were-the-recent-asteroid-flyby-and-russian-meteor-strike-events-linked/

© Michael Farmer Peru, 2007

- Currently about 11,600 NEOs are known
- 460 NEOs are currently in the risk list

➔ About 4% of the known NEO environment

Overview

1. Introduction

2. The new synthetic NEO population model:

   The way the new NEO model was derived
   and the current status or work

3. **N**ear **E**arth **O**bject **P**opulation **O**bservation **P**rogram (NEOPOP):

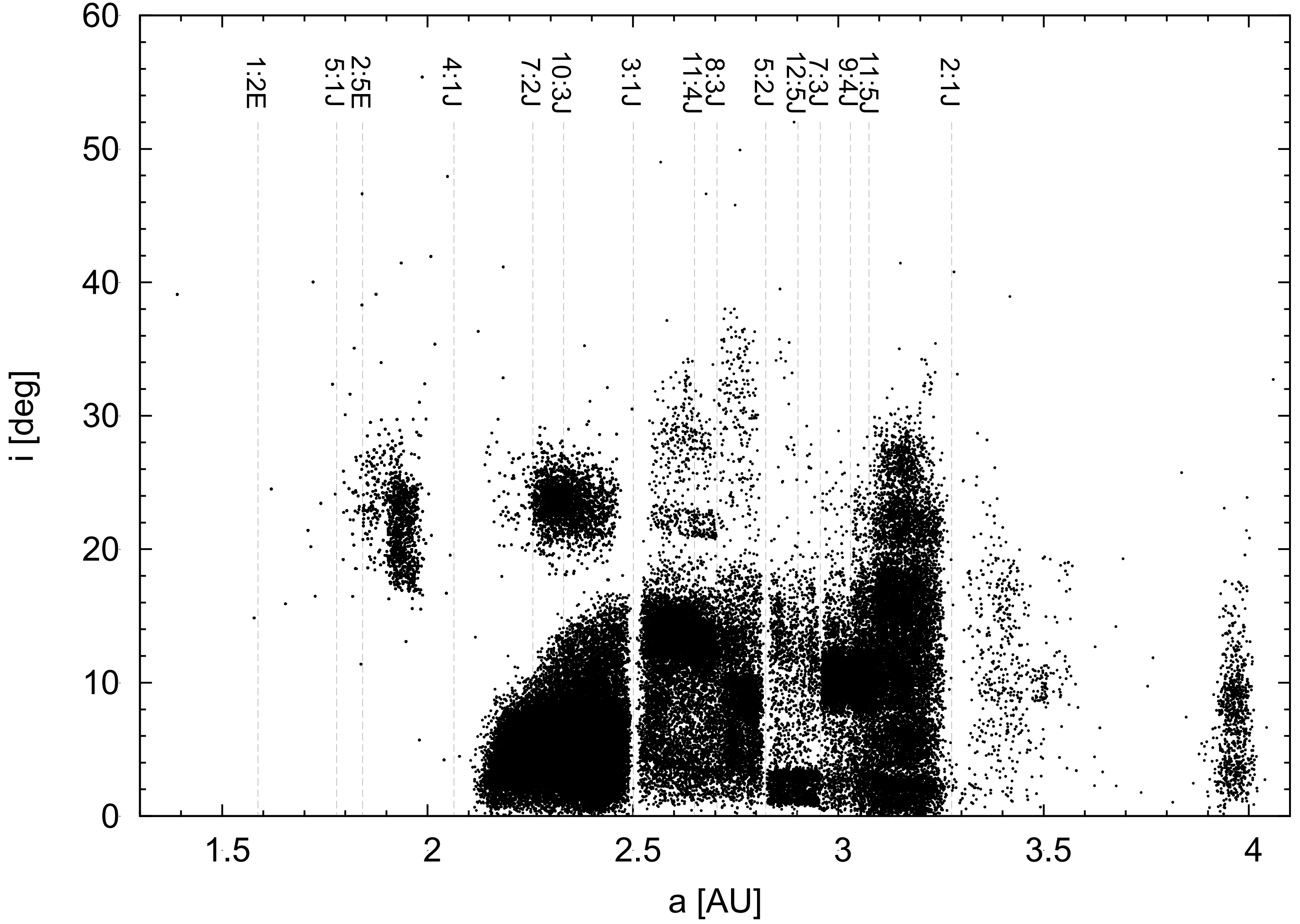
   Although more included the focus will be
   on the Observation Simulation

4. Demonstration of the two parts of NEOPOP:

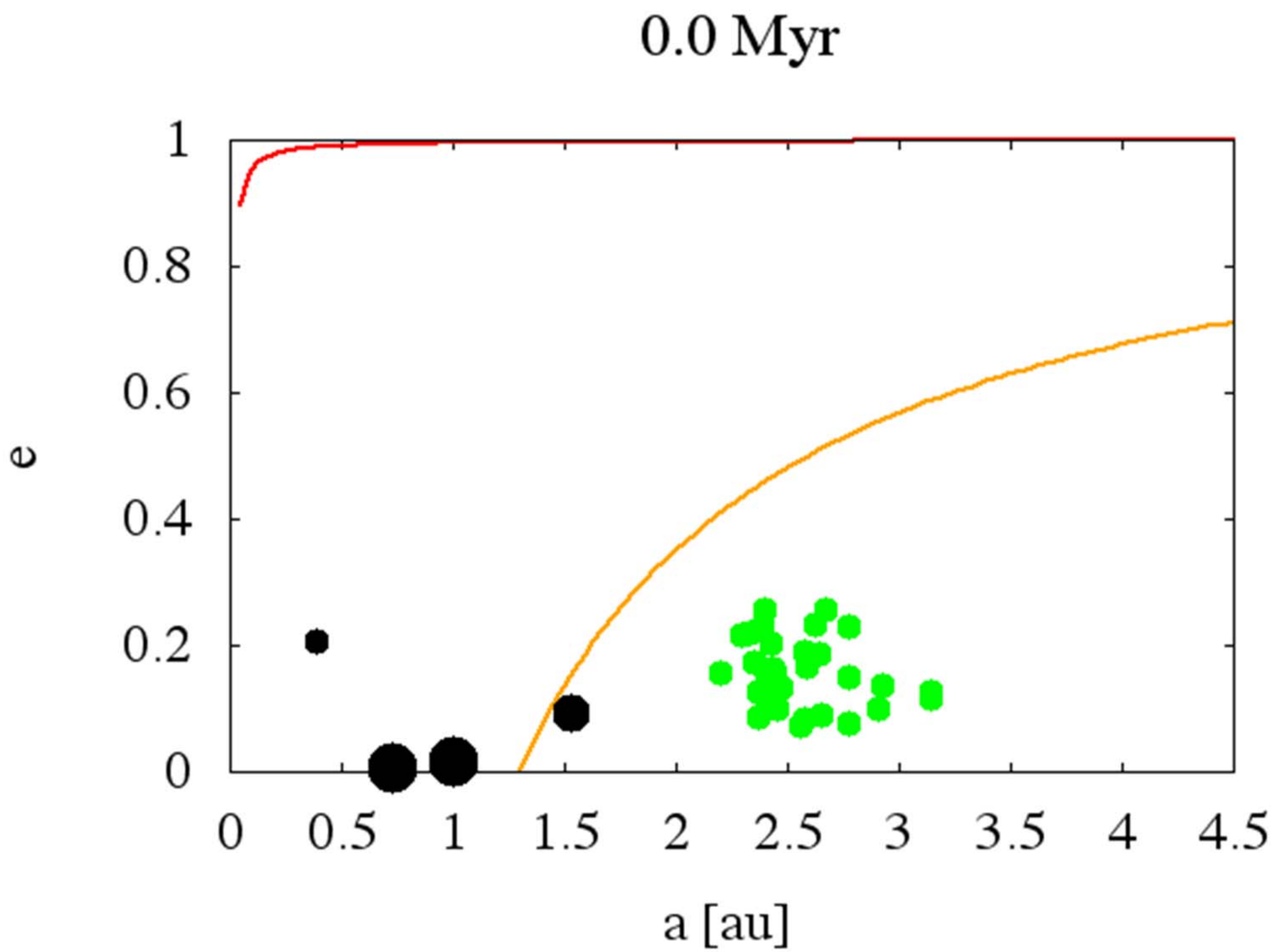
   Population Generator
   Observation Simulator

5. Conclusion & Discussion

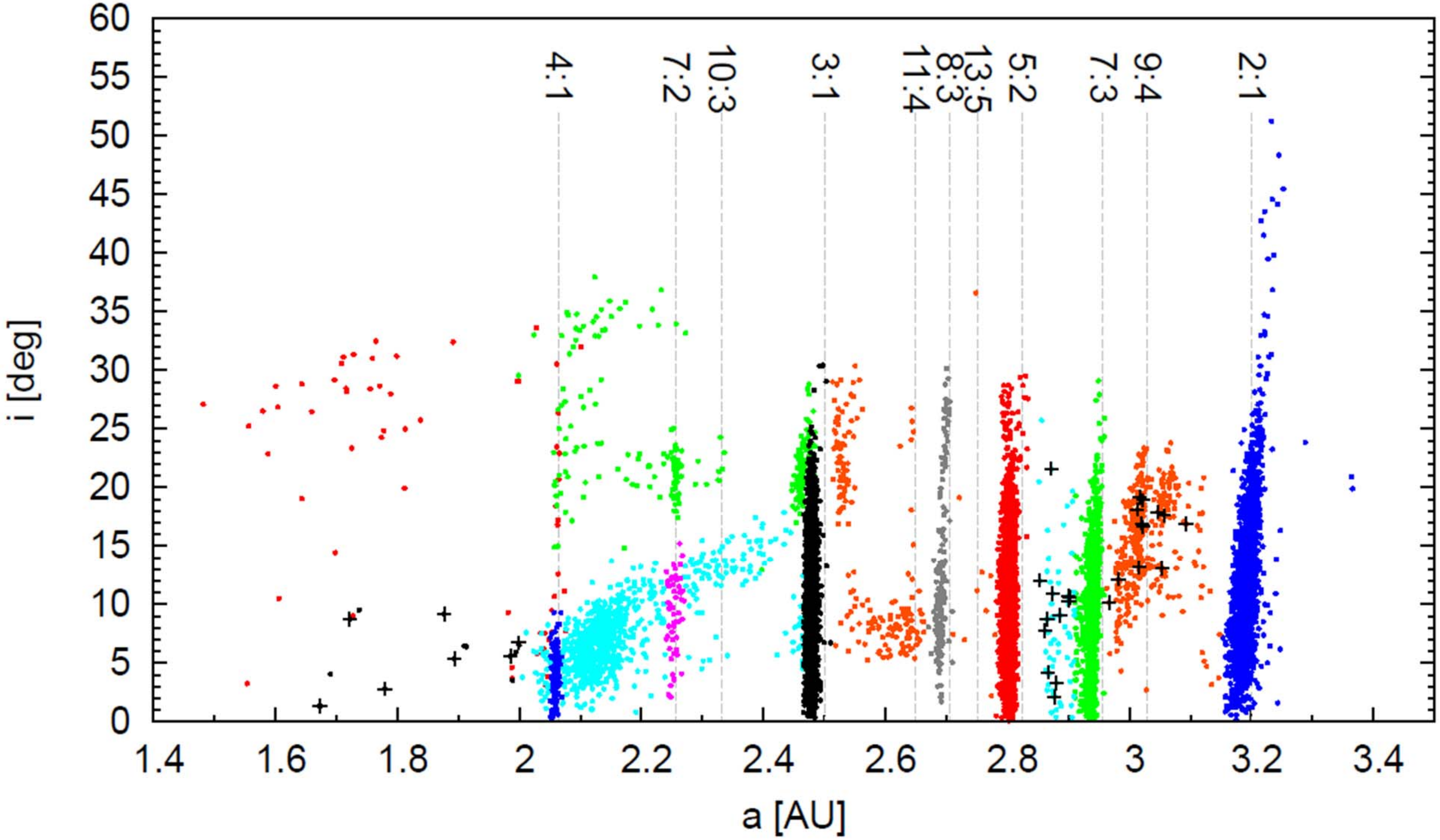
NEOs come predominantly from the main asteroid belt: Initial conditions for residence integrations from known MBOs



Escape routes from the main belt

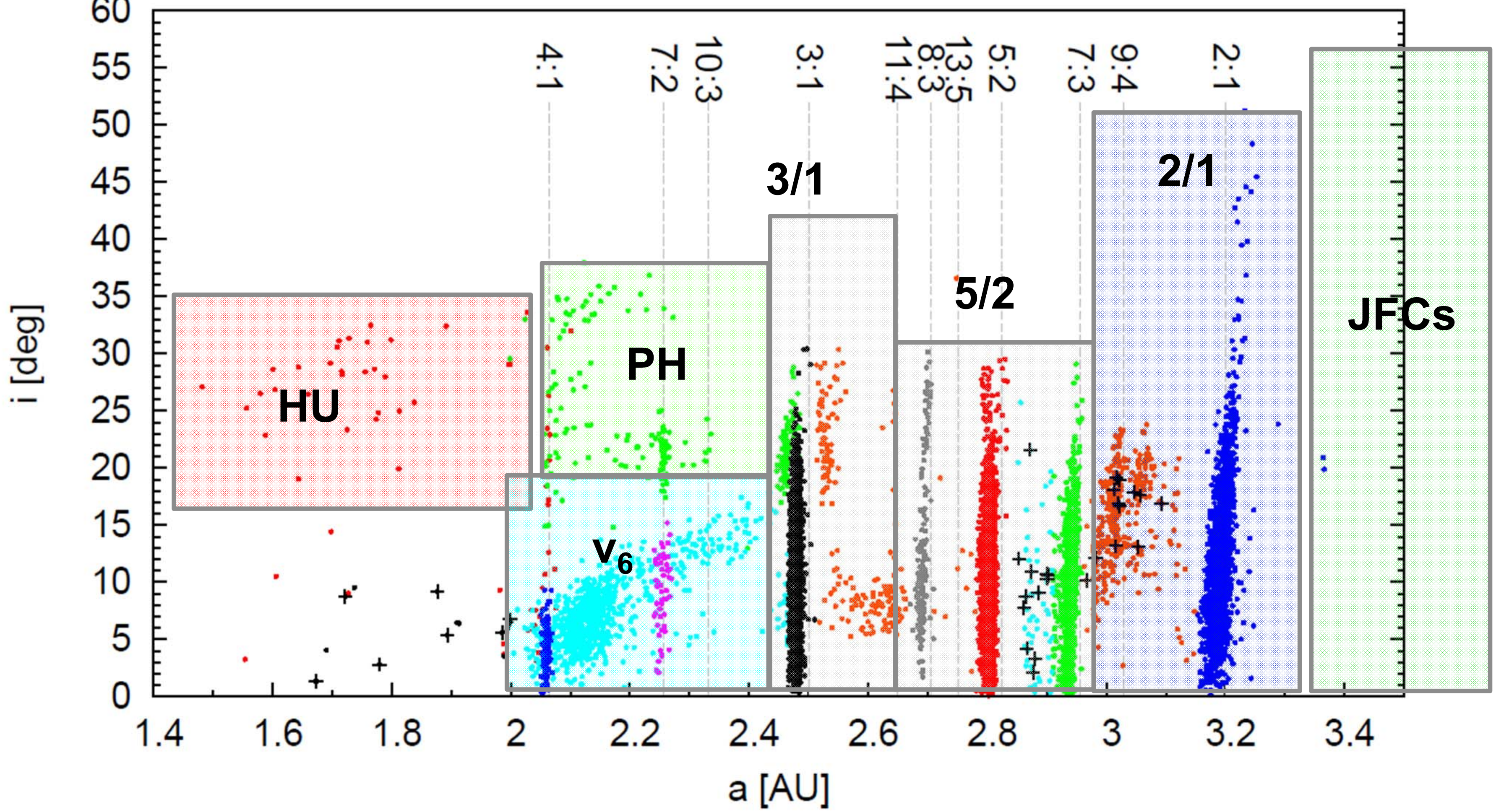


The new NEO Model
Orbits of asteroids at the moment they enter the NEO region



The new NEO Model
Orbits of asteroids at the moment they enter the NEO region

Grouped as 7 independent sources



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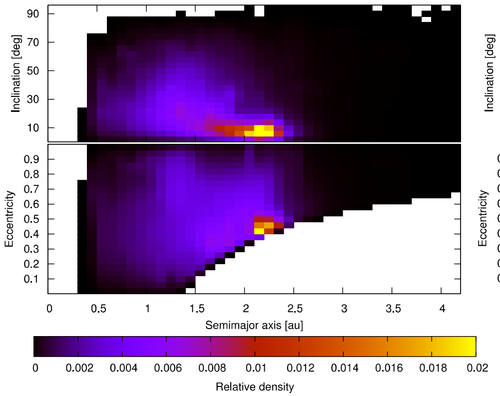
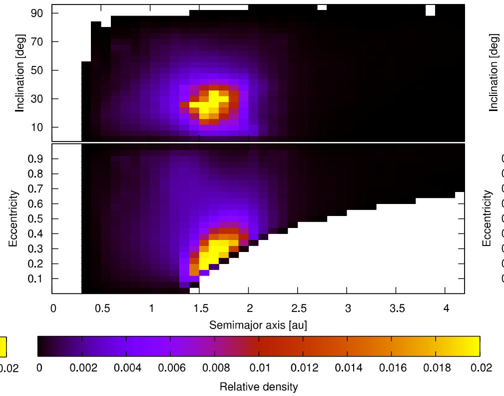
The new NEO Model
NEO orbital distribution from each source

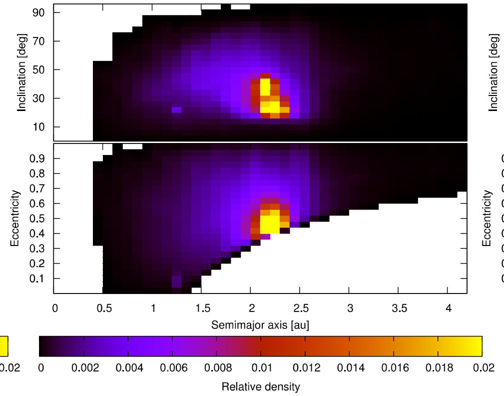
nu6



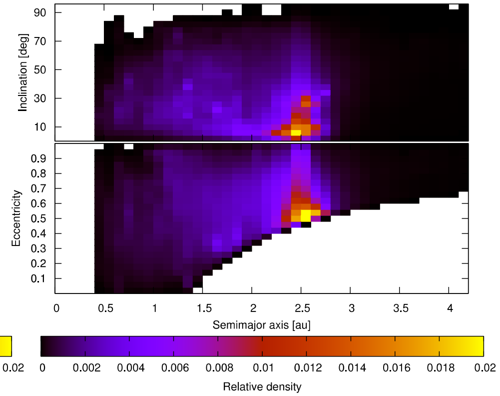
Hungaria



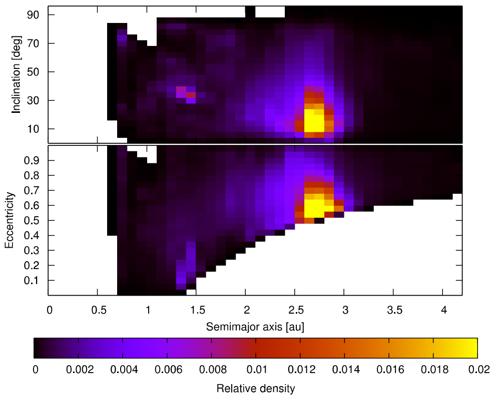
Phocaea



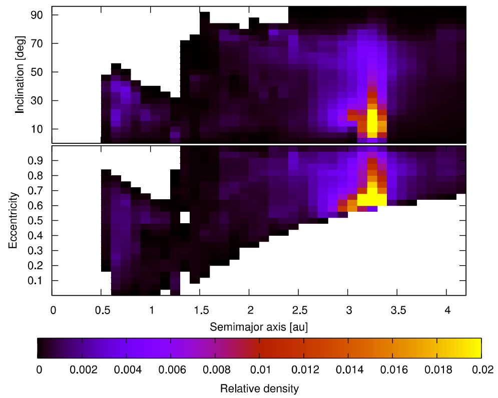
3:1J



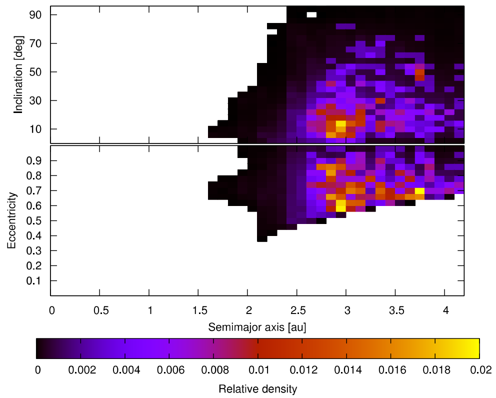
5:2J complex



2:1J complex



JFC



The model equation

Objects detected by a survey

Source ratios (to be determined)

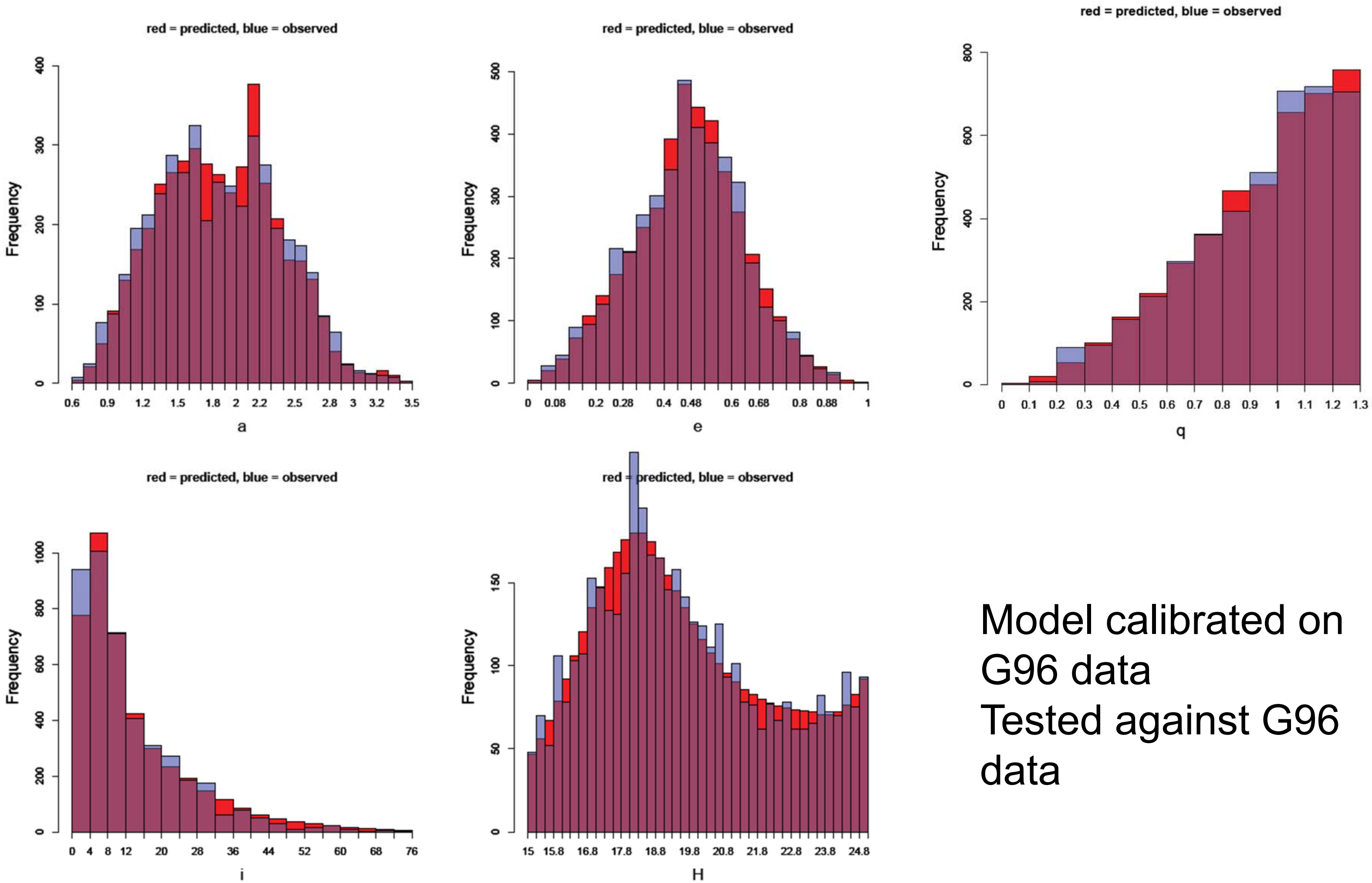
$$n(a,e,i,H) = \varepsilon(a,e,i,H)\sum_{i=1}^{N_S} f_i N_i(H) R_i(a,e,i)$$

Survey efficiency function (bias)

NEO orbital distribution from source (from numerical integrations)

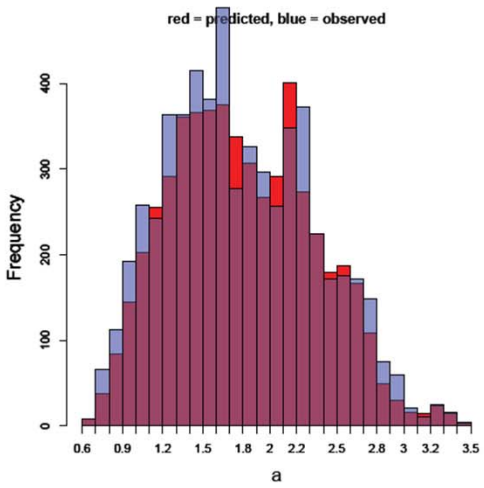
Source H-distribution (to be determined)

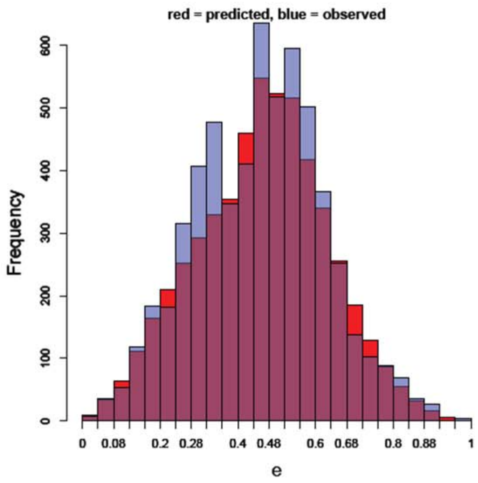
The new NEO Model
Model fit (G96 data)

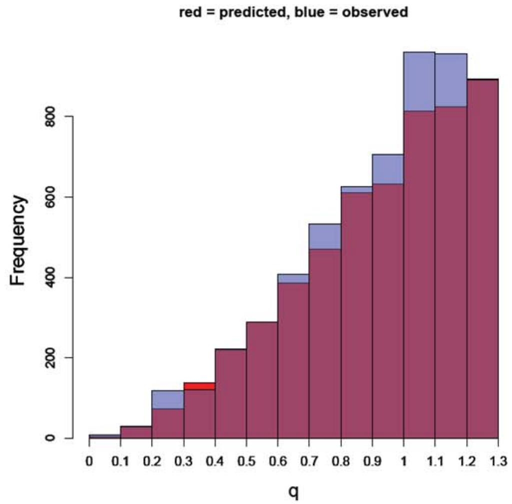


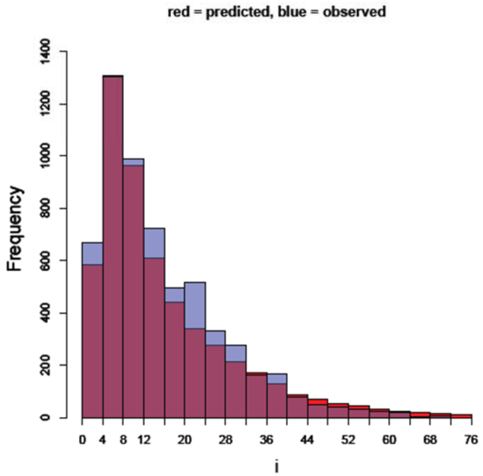
Model calibrated on G96 data
Tested against G96 data

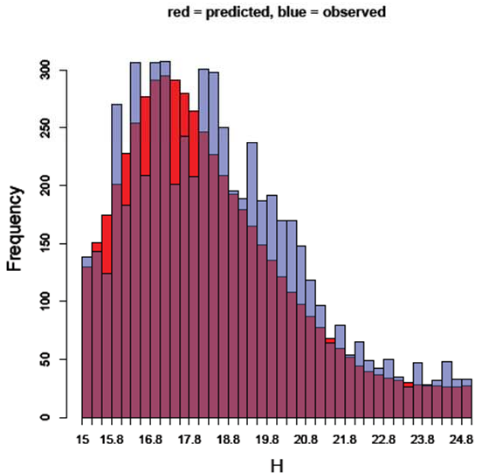
The new NEO Model
Model test (703 data)





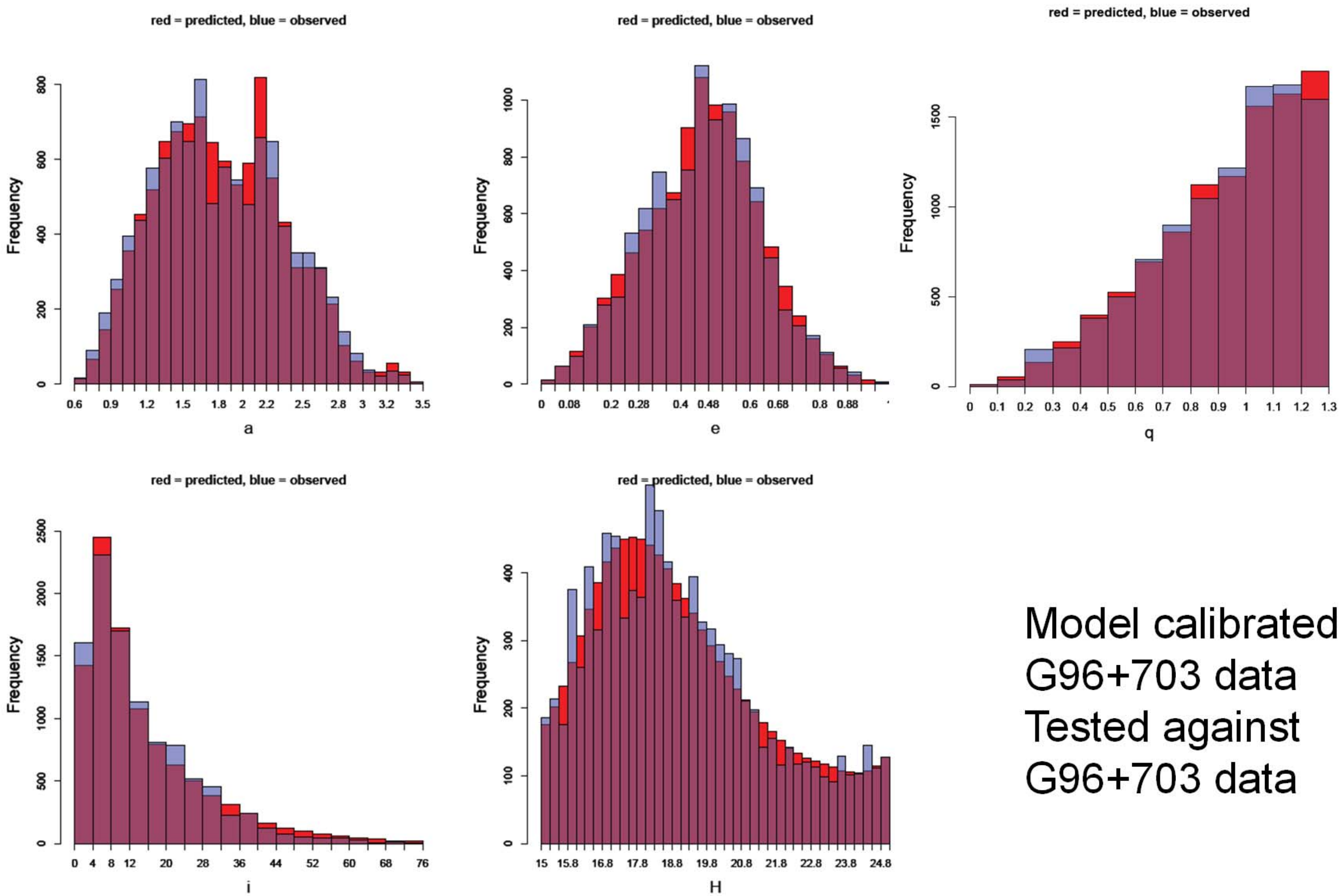






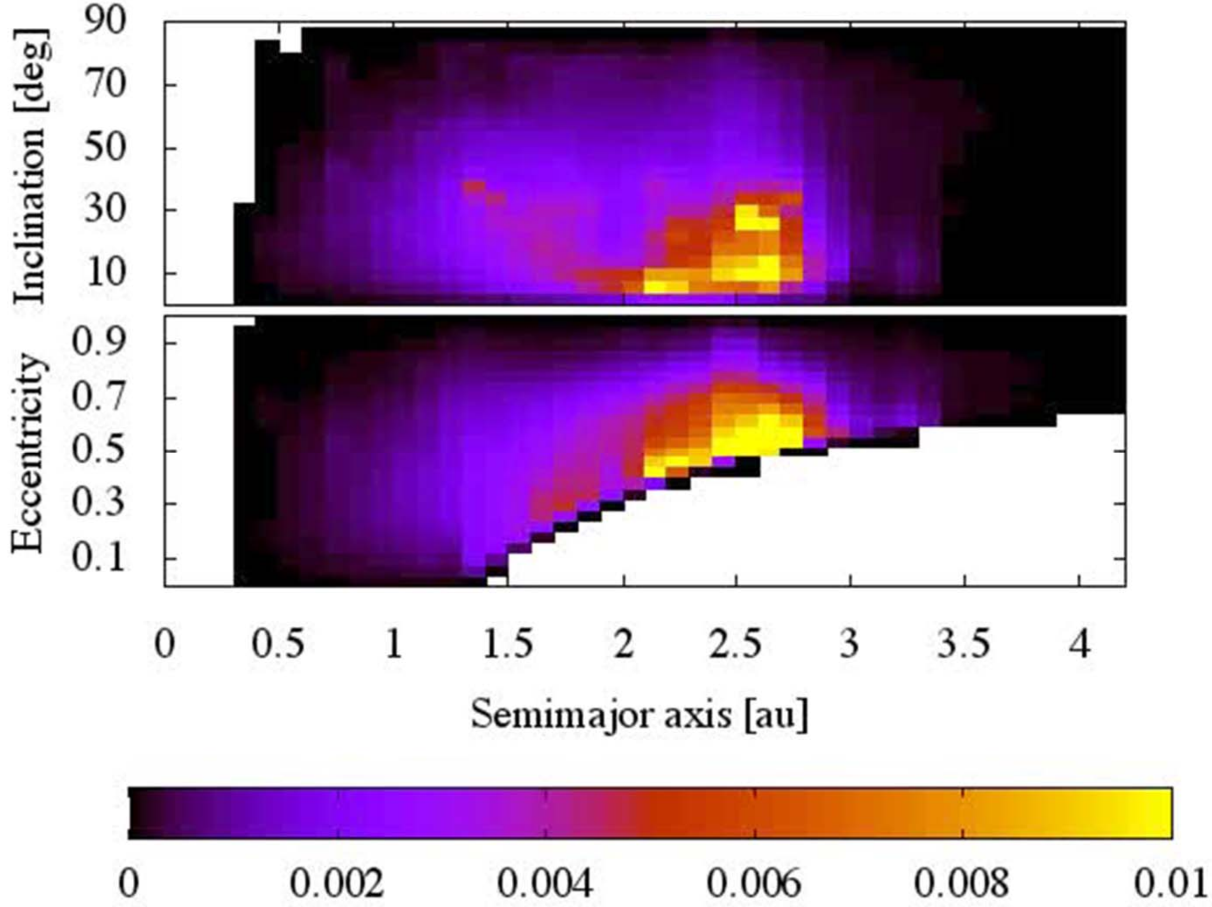
Model calibrated on G96 data
Tested against 703 data

The new NEO Model
Final 7 source model: calibrated to both G96 and 703

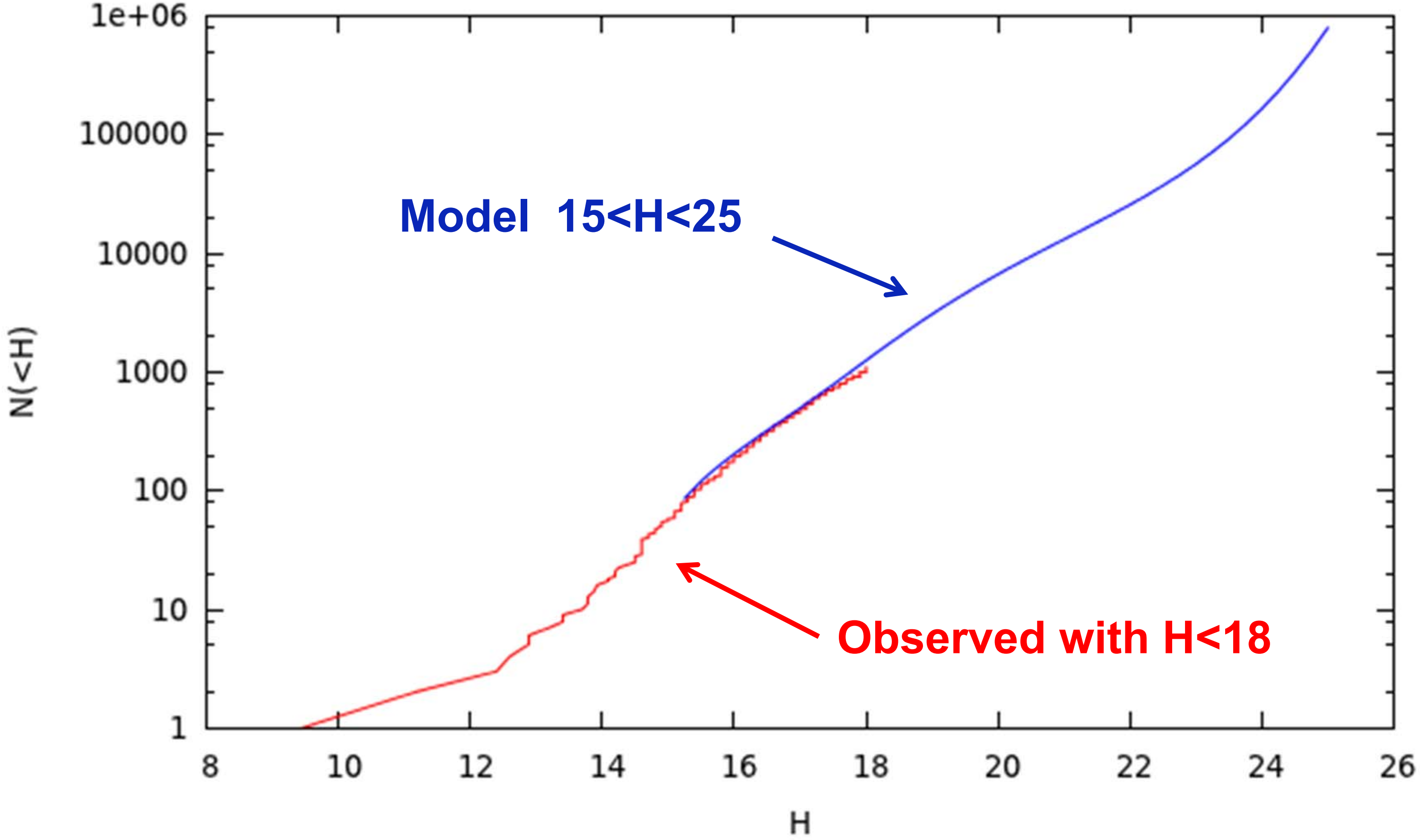


Model calibrated on
G96+703 data
Tested against
G96+703 data

The final model: orbital distribution



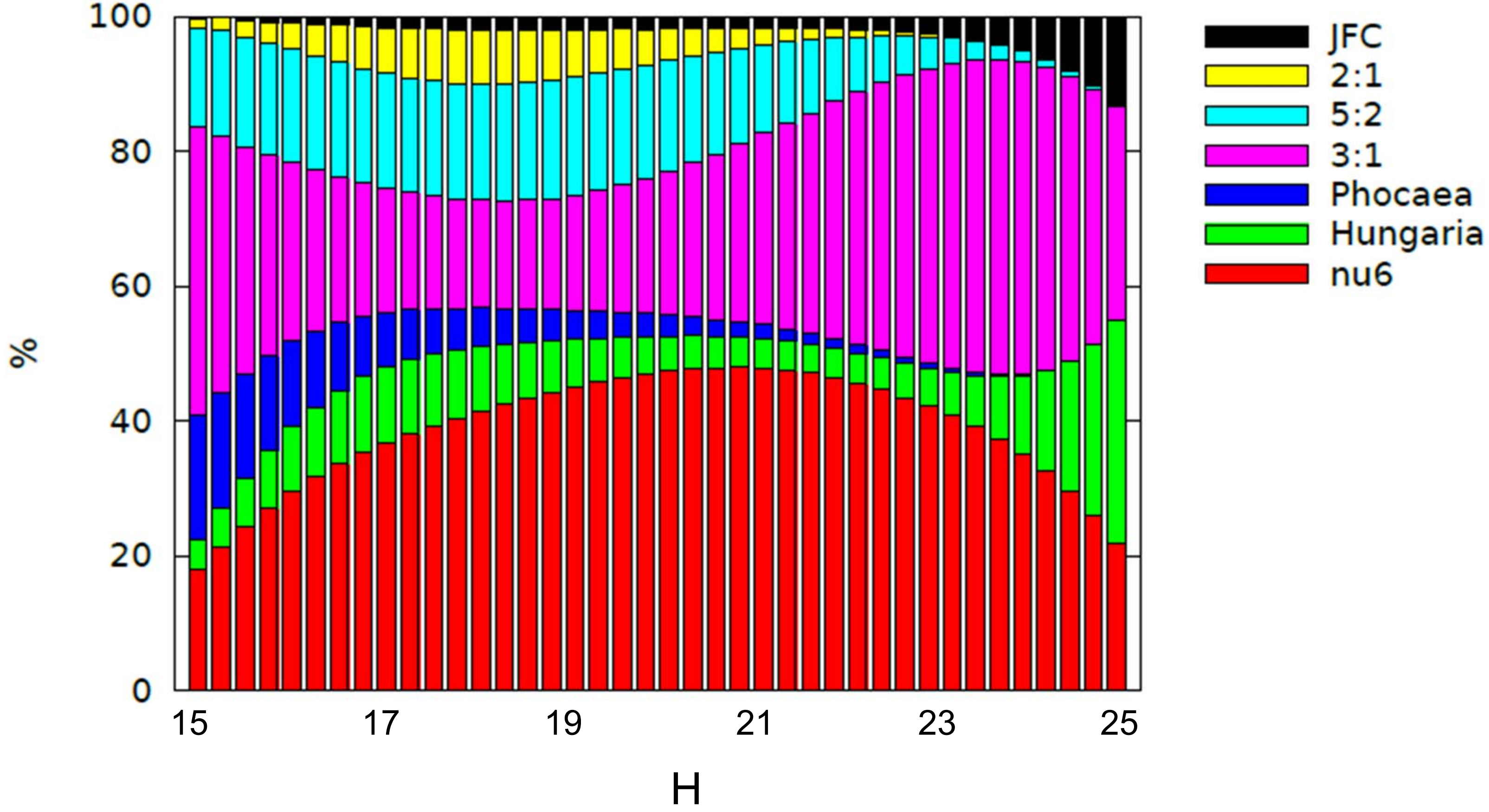
The final model: H - distribution



Population estimates for D>1km (H<17.5)

Stuart & Binzel (2004):	1090 ± 180
Mainzer et al. (2011):	981 ± 19
Harris (2012, unpublished):	976 ± 30
OUR MODEL:	987 ± 100

The new NEO Model
Final 7 source model: source ratios as a function of H



The new NEO Model
NEO albedo model: methods

We define three albedo categories:

Category 1: p_v smaller or equal than 0.1 - flat distribution in the 0.02-0.1 range
Category 2: p_v larger than 0.1 and smaller or equal than 0.3 – flat distribution
Category 3 p_v larger than 0.3 –exponential distribution: decay by 2.6 every 0.1in p_v

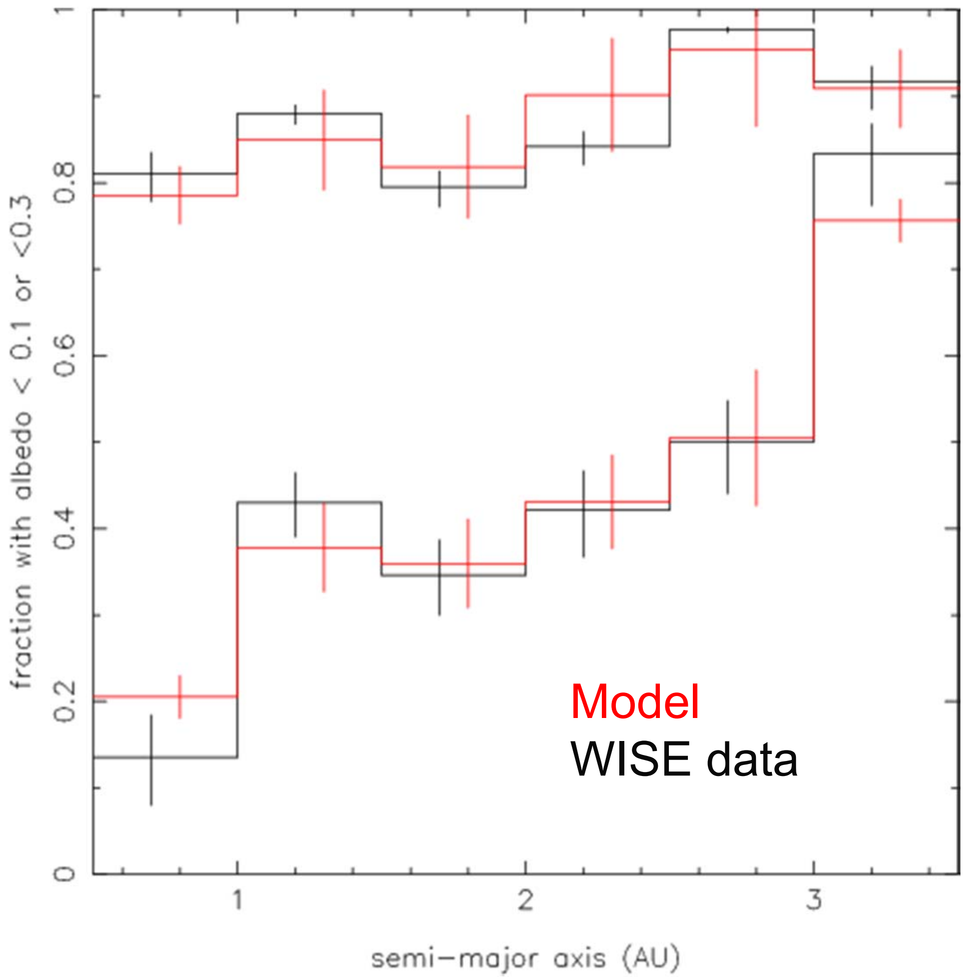
We use 328 NEOs with WISE-measured albedos (H>15 and W3<10). For each object we compute the albedo category. We also compute the probability that the object would have been observed if it had been in either albedo category: B(1), B(2), B(3)

Each survey *s* is caracterized by two parameters: the fraction of objects in cat. 1, 2: $p_s(1)$, $p_s(2)$. Note: $p_s(3)=1- p_s(1) - p_s(2)$. In JFC source we impose $p_s(1)=1$.
We fit for the parameters $p_s(1)$, $p_s(2)$ (s=1,..6) by maximizing the function

$\text{Ł}=\sum_n \text{Log}(\mathcal{P}_n)$, where *n* is the index of the NEO and

$\mathcal{P}_n=\sum_s P_s(n)(B_n(c_n)p_s(c_n))/(B_n(1)p_s(1)+B_n(2)p_s(2)+B_n(3)p_s(3))$,
$P_s(n)$ being the probability that the asteroid *n* comes from source *s*.

The new NEO Model
NEO albedo model: results & comparison with WISE data



NEOPOP
Introduction / Overview

NEOPOP – Near Earth Object Population Observation Program

NEOPOP is written in Fortran as Command-Line Tool (CLT).

CLT consists of four modules in two components:

- Population Generator
  - ➔ Population Generation
  - ➔ Population Analysis
- Observation Generator
  - ➔ **Observation Simulation**
  - ➔ Observation Analysis

Graphical User Interface (GUI) uses the CLT.

NEOPOP
Population Generator

Population Generation:

fictitious model
old model
new model
external population

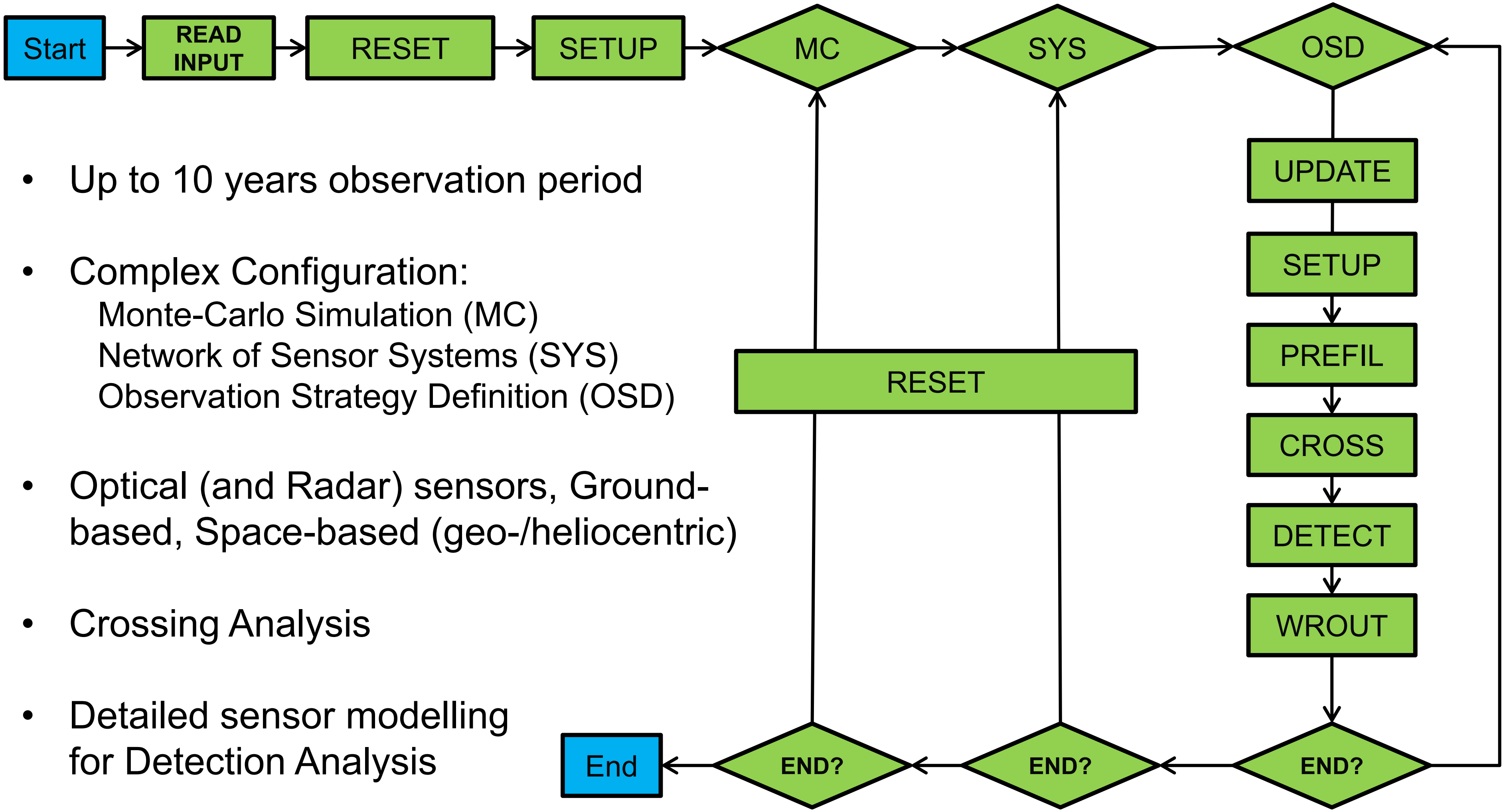
⇩

Population file (MPC,DYS, DES)
Physical properties file

Population Analysis:

- makes use of given or generated population
- user-defined analysis and filtering
  - Groups & Sources
  - Orbital and Object parameters
  - Relative distance
  - Close-Approach Analysis
- Results generated for 2D/3D/scatter/solar plots

NEOPOP
Observation Simulation: Top-Level Data-Flow



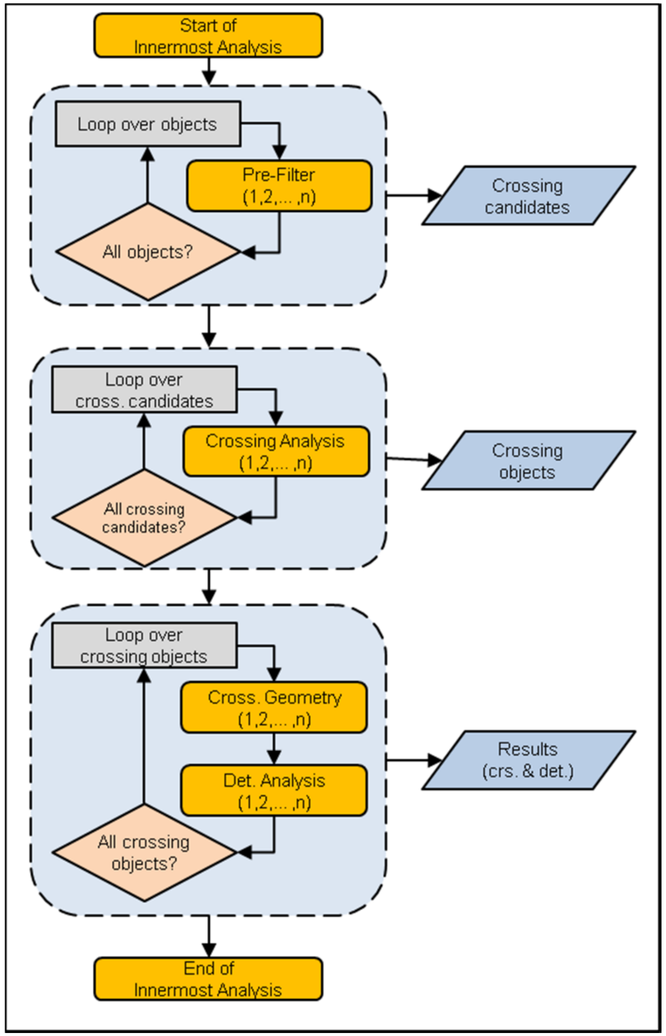
- Up to 10 years observation period
- Complex Configuration:
  Monte-Carlo Simulation (MC)
  Network of Sensor Systems (SYS)
  Observation Strategy Definition (OSD)
- Optical (and Radar) sensors, Ground-based, Space-based (geo-/heliocentric)
- Crossing Analysis
- Detailed sensor modelling for Detection Analysis

NEOPOP
Observation Simulation: The Three Innermost Loops

Stepwise decrease of initial object population:

- Pre-Filter: *To skip objects not being able to cross the field of view*
- Crossing Analysis: *To identify objects that are crossing the field of view*
- Detection Analysis: *To identify objects that can be detected by the defined sensor system*

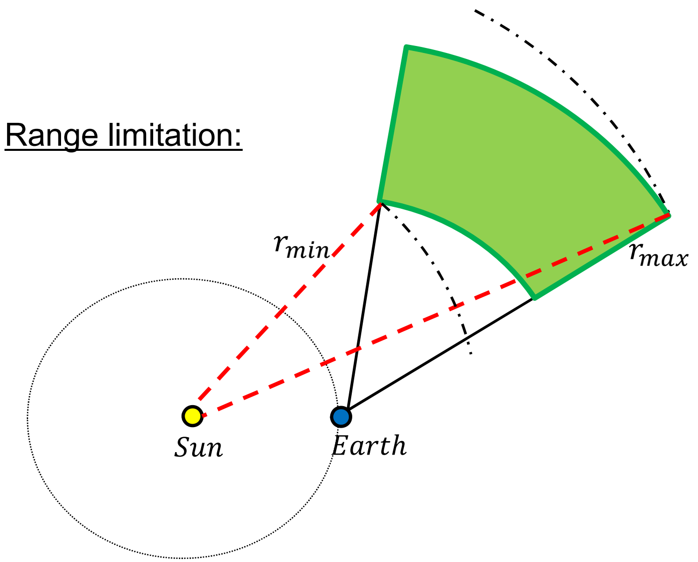
➔ All three parts are implemented in a way for being parallelized in the future.



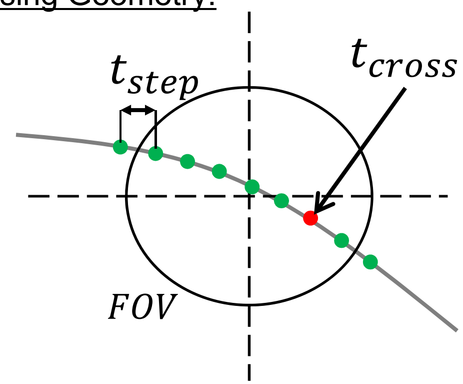
NEOPOP
Deriving the Crossing Geometry

- Only the objects, which have successfully passed the Crossing Analysis, are analyzed for their crossing of the circular FOV.
- The task is to approximate the objects path within the FOV by a set of snapshots. Linear movement is assumed between two nearby steps.
- For each time step t_{step} the time and related coordinates of the sensor and object are stored.

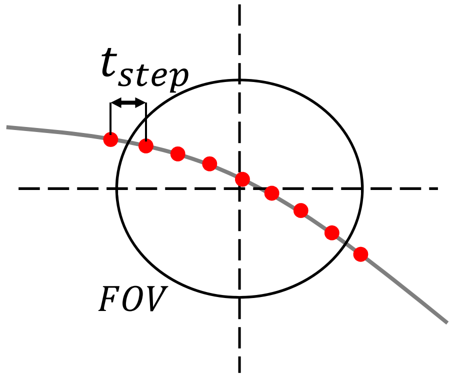
Range limitation:



Crossing Geometry:

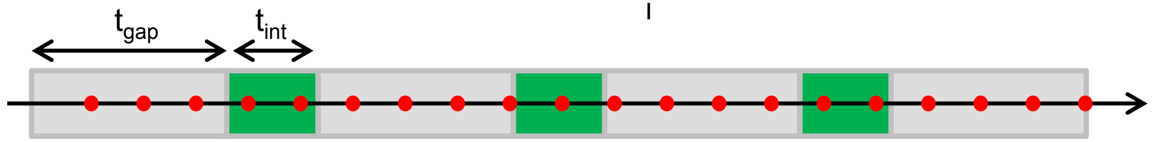


NEOPOP
Data for CCD Exposure



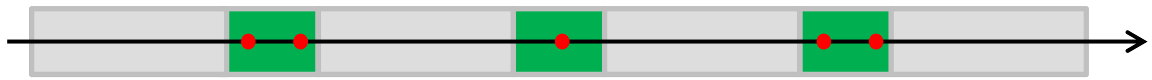
Consideration of integration and gap times:

- Crossing Geometry is taken



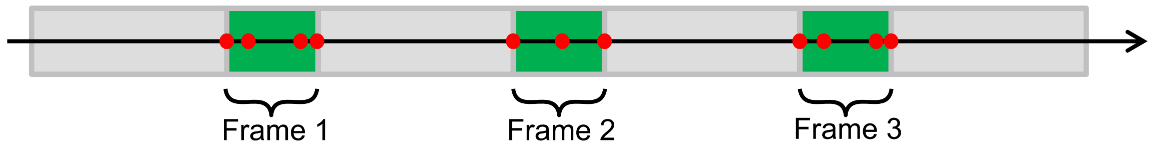
- Steps in integration time are used directly

Take valid point of crossing geometry:



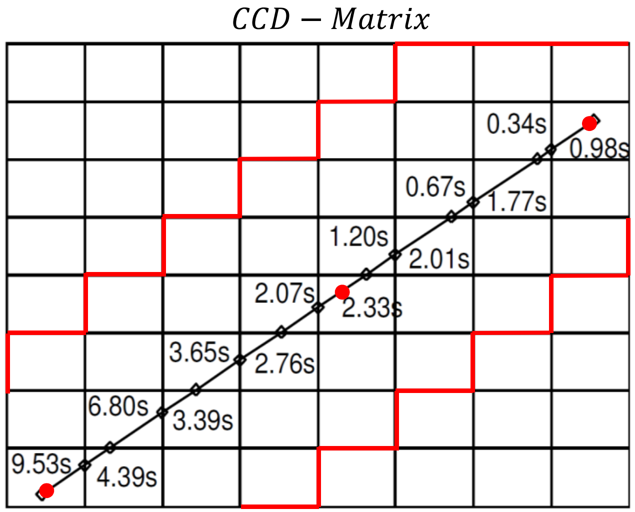
- Start and end point of object is being interpolated

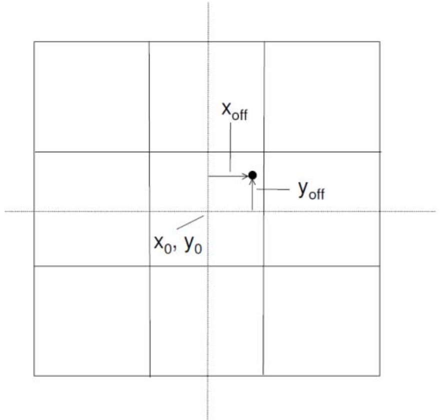
Interpolation / Extrapolation:

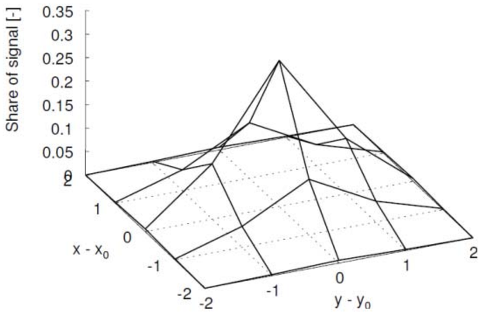


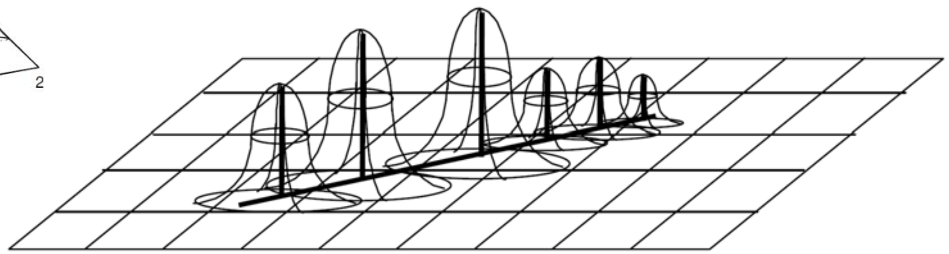
NEOPOP
CCD – Signal Modelling

Based on the …
… trace of the object
… the pixel dwell times are calculated and
… the signal is computed for the center
 and the surrounding pixels (apply PSF)









NEOPOP
Optical Performance Model

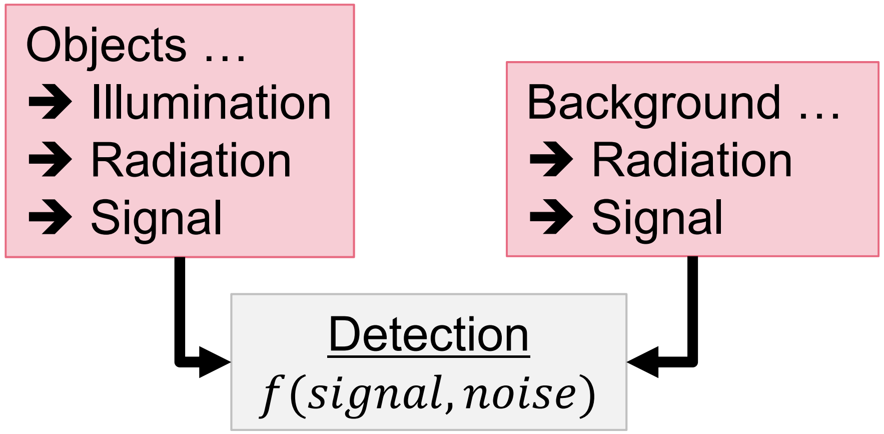
Background Sources

Visible light:

- Stars up to user-defined magnitude
- Planets
- Faint starts above user-defined mag.
- Galaxies
- Zodiacal light
- Airglow
- Atmospherically scattered Moon- & Sunlight

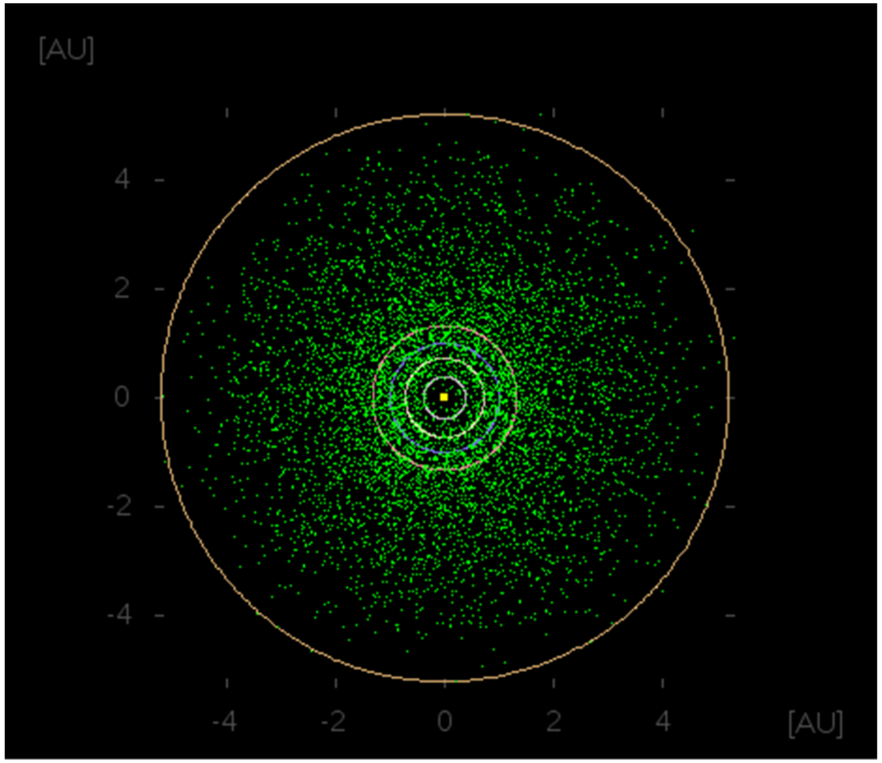
Infrared light:

- Stars up to user-defined magnitude
- Planets
- Faint starts above user-defined mag.
- Galaxies
- Zodiacal light
- Interstellar Medium
- Extragalactic Background



NEOPOP
Further Features

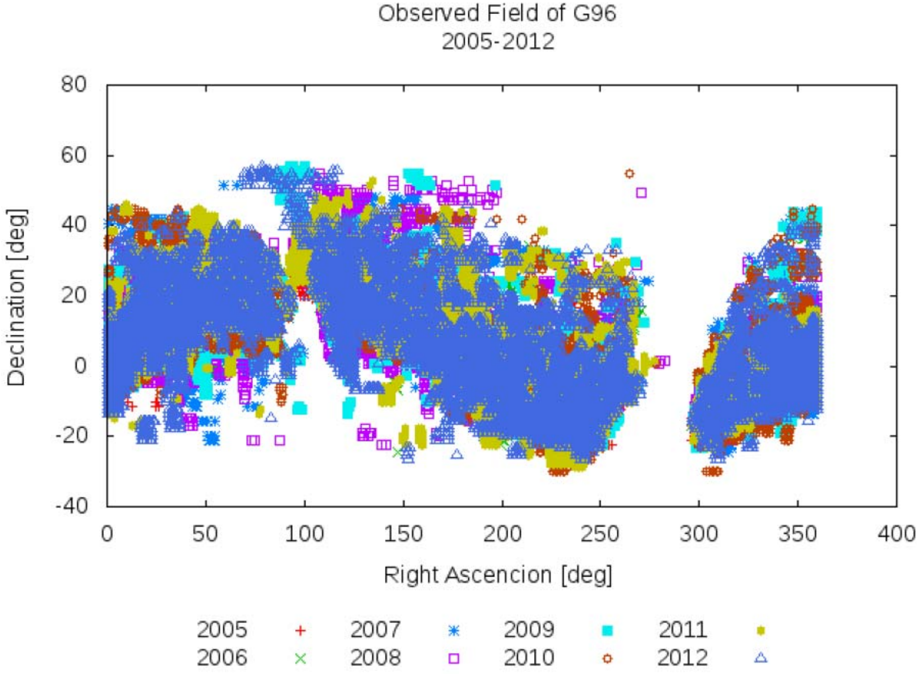
- Simple Radar sensor model
- Measurement data generation (incl. bias, noise and drift errors)
- Output files contain large set of parameters: Crossing and detected objects, magnitude, SNR etc.
- Output provided per sensor system as well as for overall sensor network
- Skyplots show the objects' positions in the sky for a given time and location.
- Solar system overview plots show object positions, crossings and detections



NEOPOP
Verification by CSS-Campaign Simulation (1/5)

CSS Campaigns of G96:

CSS data (G96&703) from 2005 to 2012 has been used.

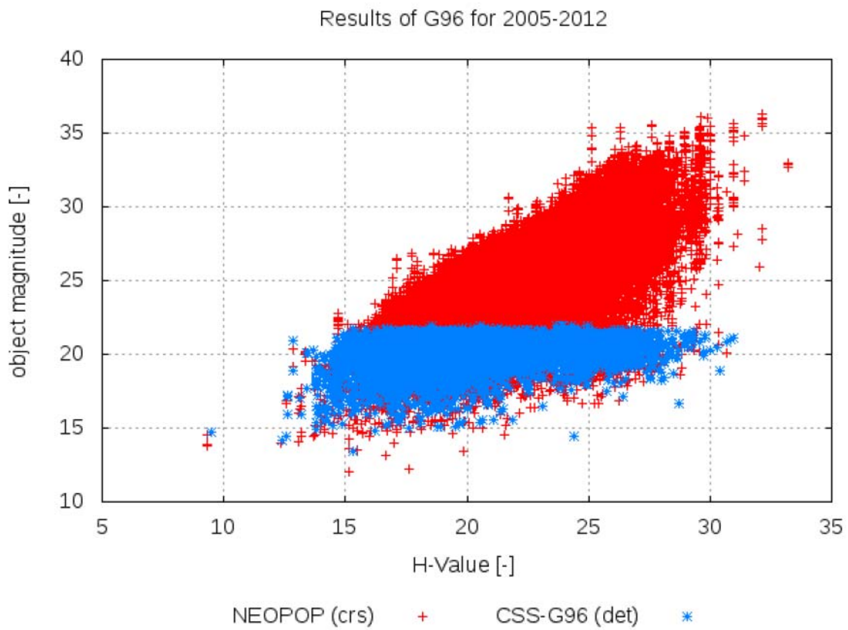


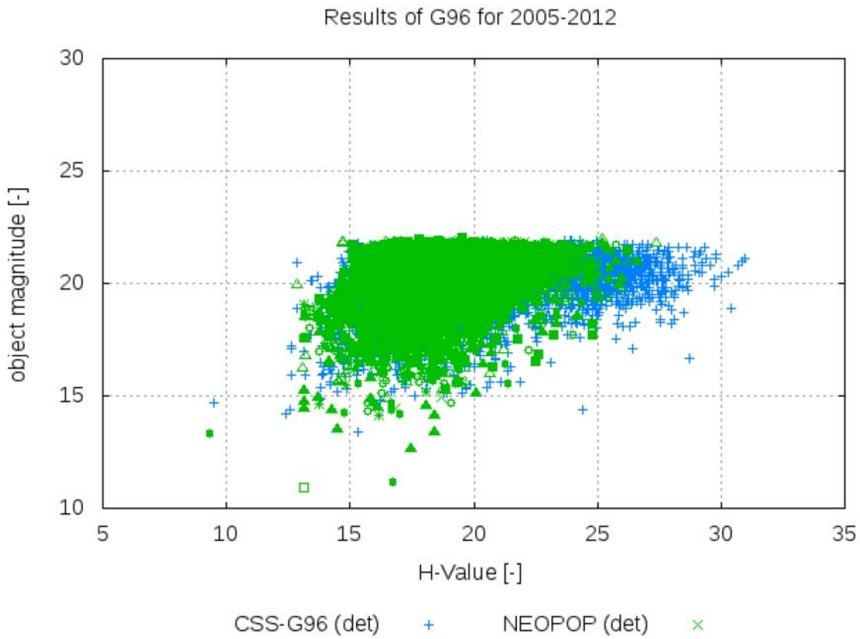
http://www.lpl.arizona.edu/css/css_facilities.html

Parameters used for the simulation:

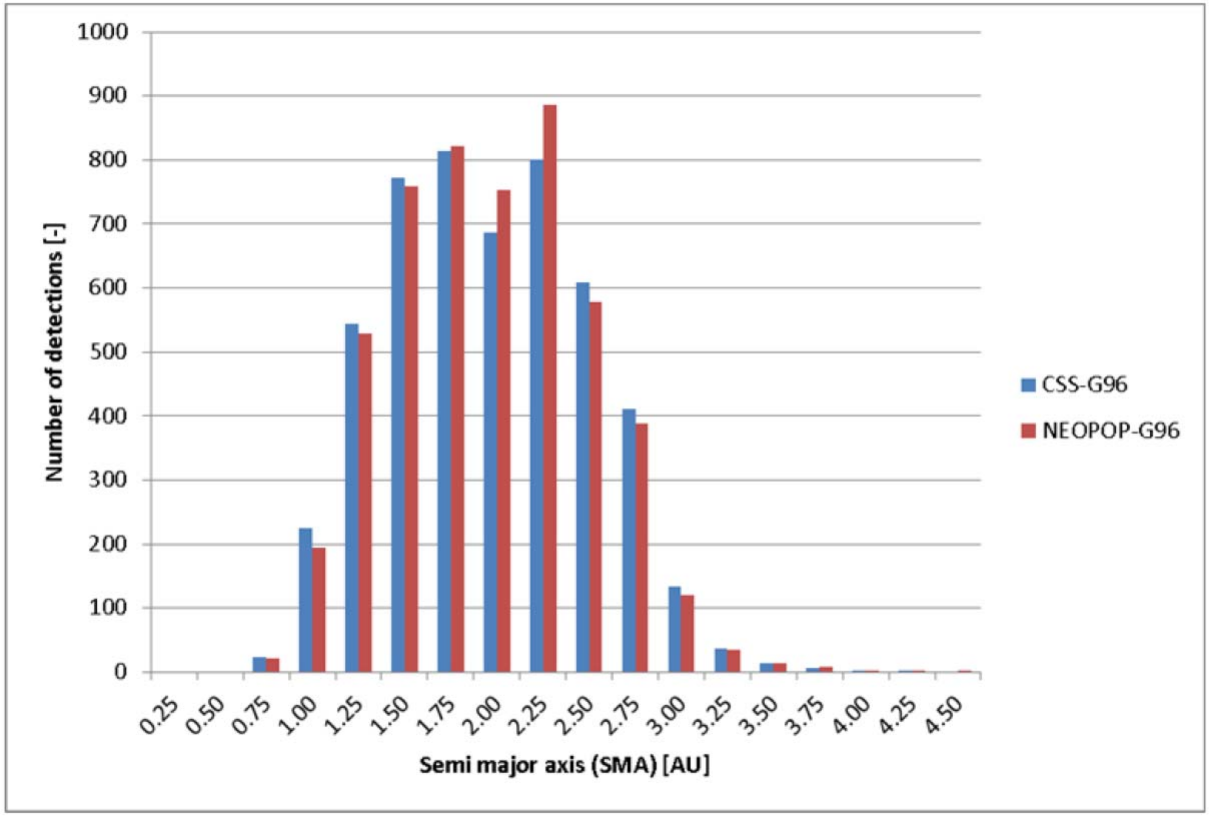
Parameter	Value
FOV	1°
Integration Time	30s
Gap Time	30s
FOV per Pixel	0.973“

NEOPOP
Verification by CSS-Campaign Simulation (2/5)

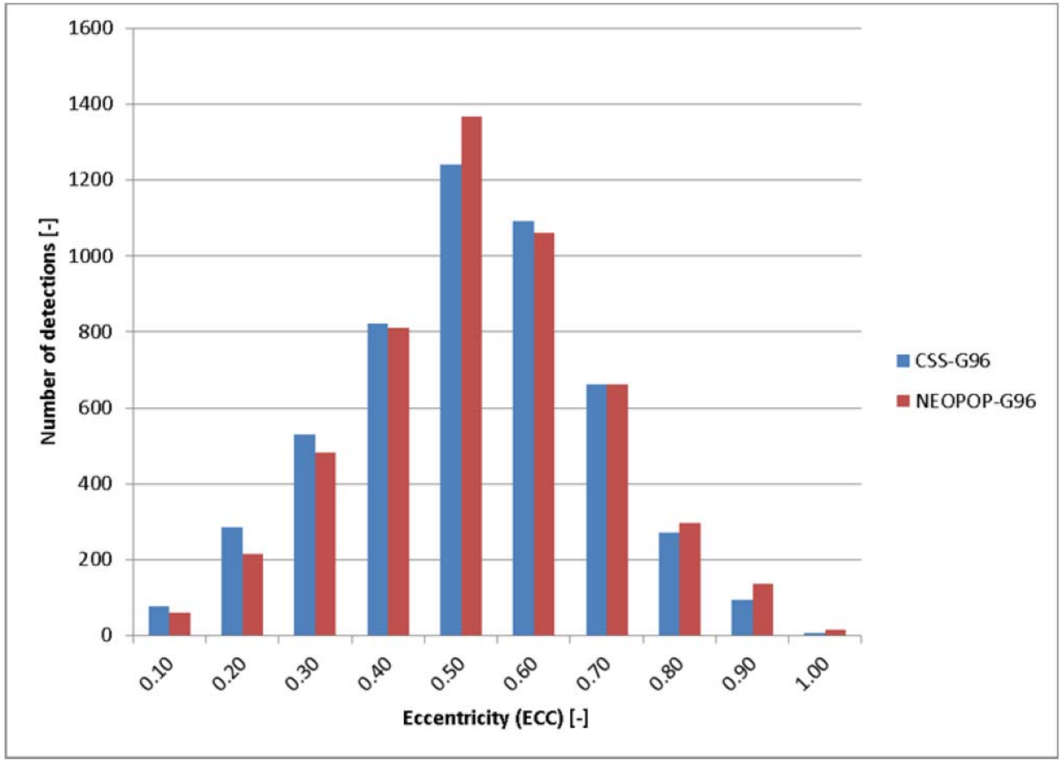




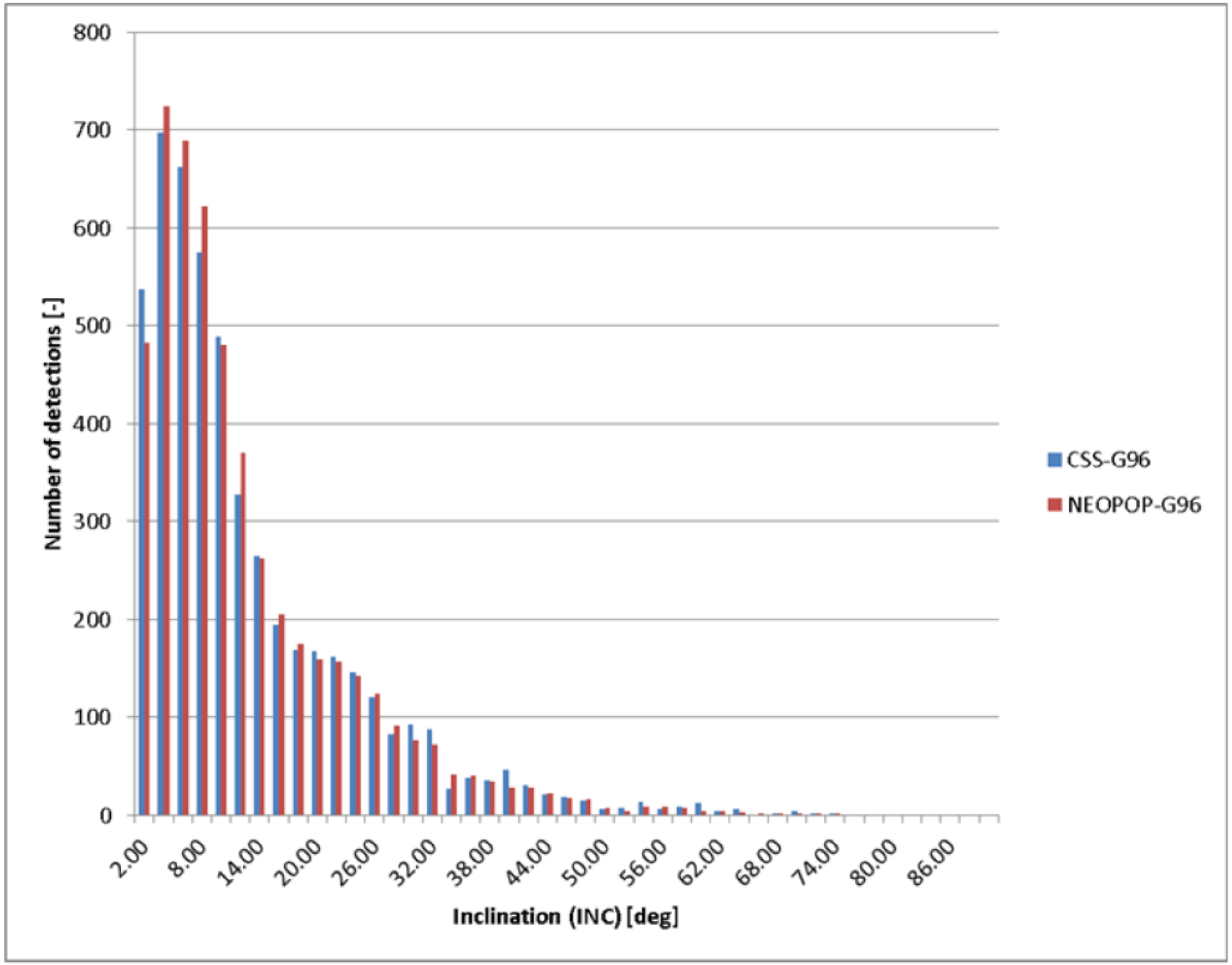
NEOPOP
Verification by CSS-Campaign Simulation (3/5)



NEOPOP
Verification by CSS-Campaign Simulation (4/5)



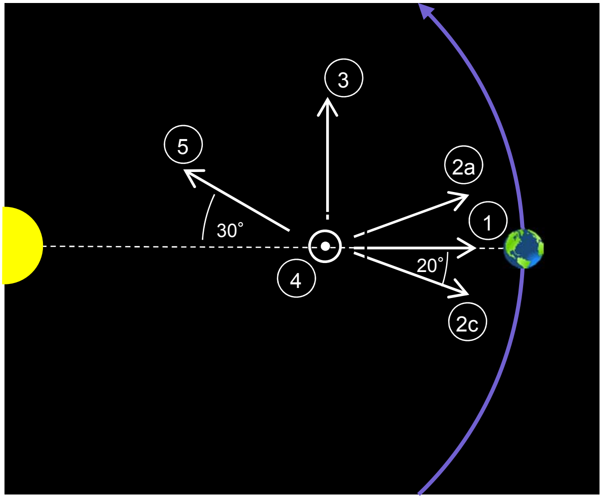
NEOPOP
Verification by CSS-Campaign Simulation (5/5)



NEOPOP
NEOPOP Application: Simulation of Observations from L1

Objective:
- Identify the viability of a NEO-detector on a L1 Space Weather mission
- Compare different potential instruments and setups
- Instrument constraint: max. mass of 3 kg

Setup:
- Observer virtually "in" L1
- Simulation over 14 days
- 3 different instruments, 8 different viewing directions
- Longer simulation (1 year, to obtain statistically more significant results) still to be done

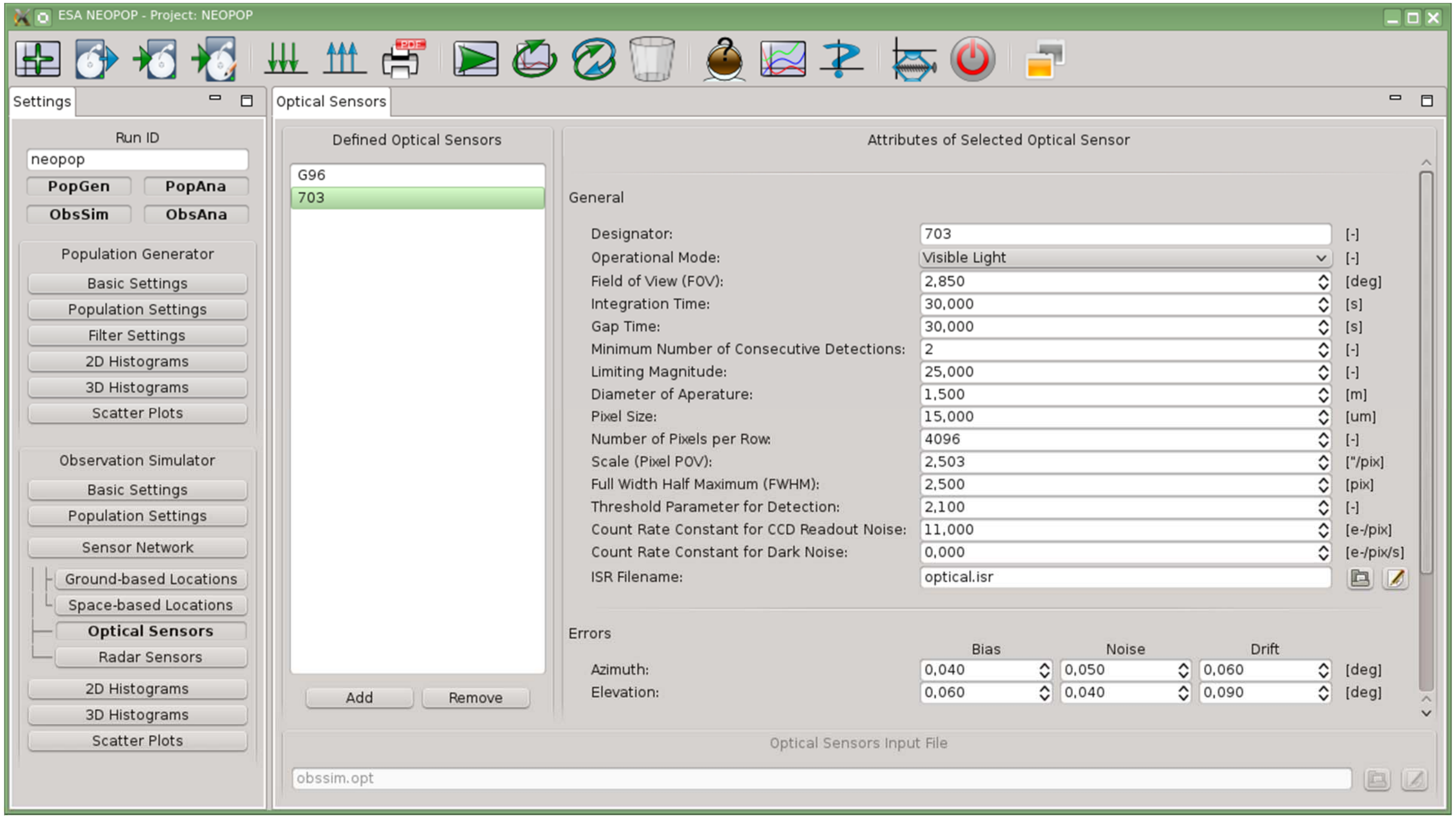


Sensor LOS orientations from L1

Results (all NEO detections):

	FoV [deg^2]	Lim. mag.		1	2 a/b/c/d	3	4	5	Probability object is newly discovered
Sensor 1	5x5	16		0	0/1/1/0	0	0	0	0 % / > 70 %
Sensor 2	22x22	14		0	1/0/1/0	0	0	0	> 92 % / > 76 %
Sensor 3	140x140	9		0	0/0/0/0	0	0	0	

NEOPOP Demonstration



Conclusion & Discussion
Conclusion

Near-**E**arth **O**bject **P**opulation **O**bservation **P**rogram (NEOPOP)

- Generation of NEO populations

➢ Uses new NEO Model, calibrated to recent observation data

- Simulation of NEO population observations

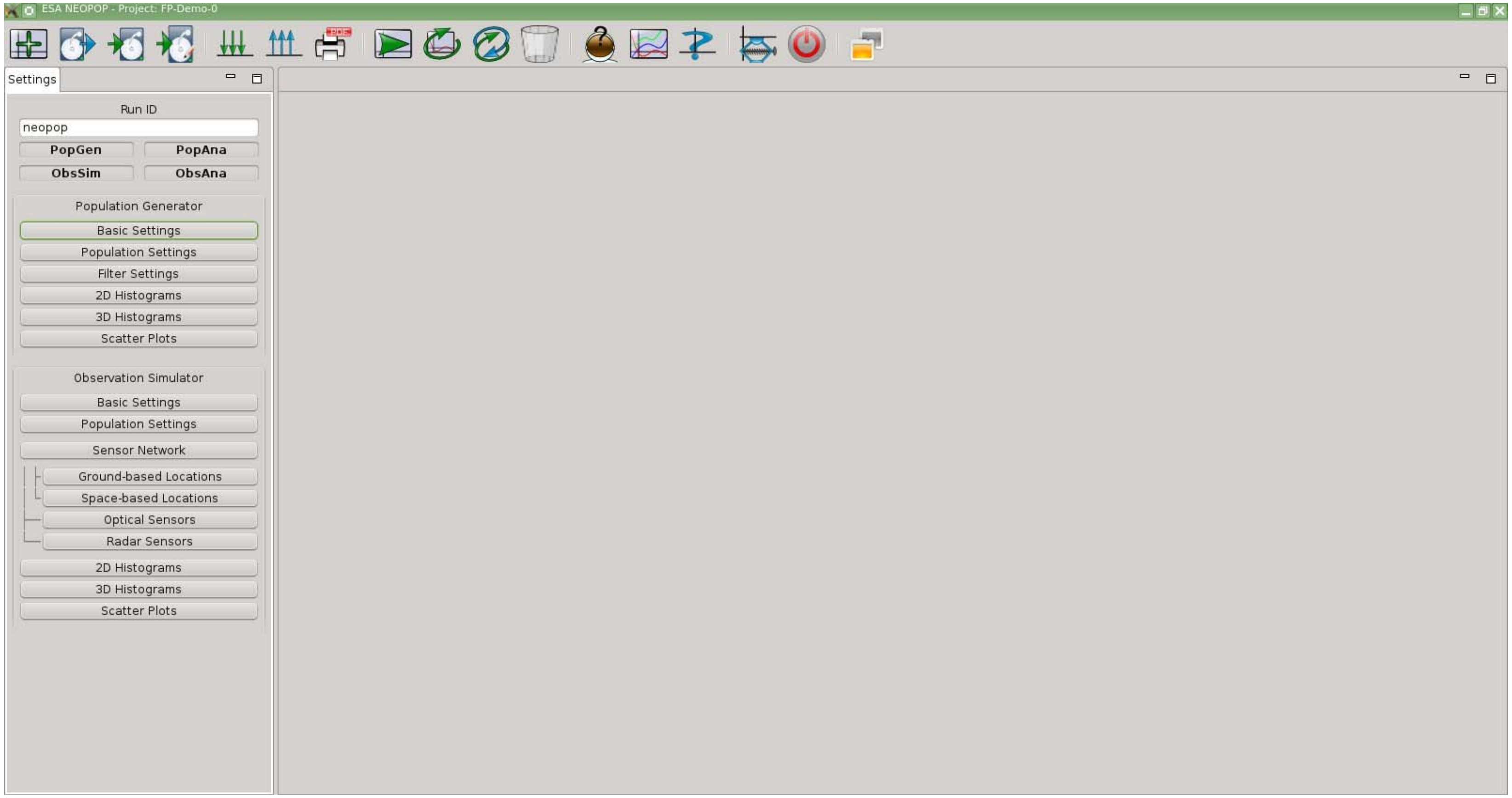
➢ Uses new Optical Sensor model, taking various background sources into account

Discussion

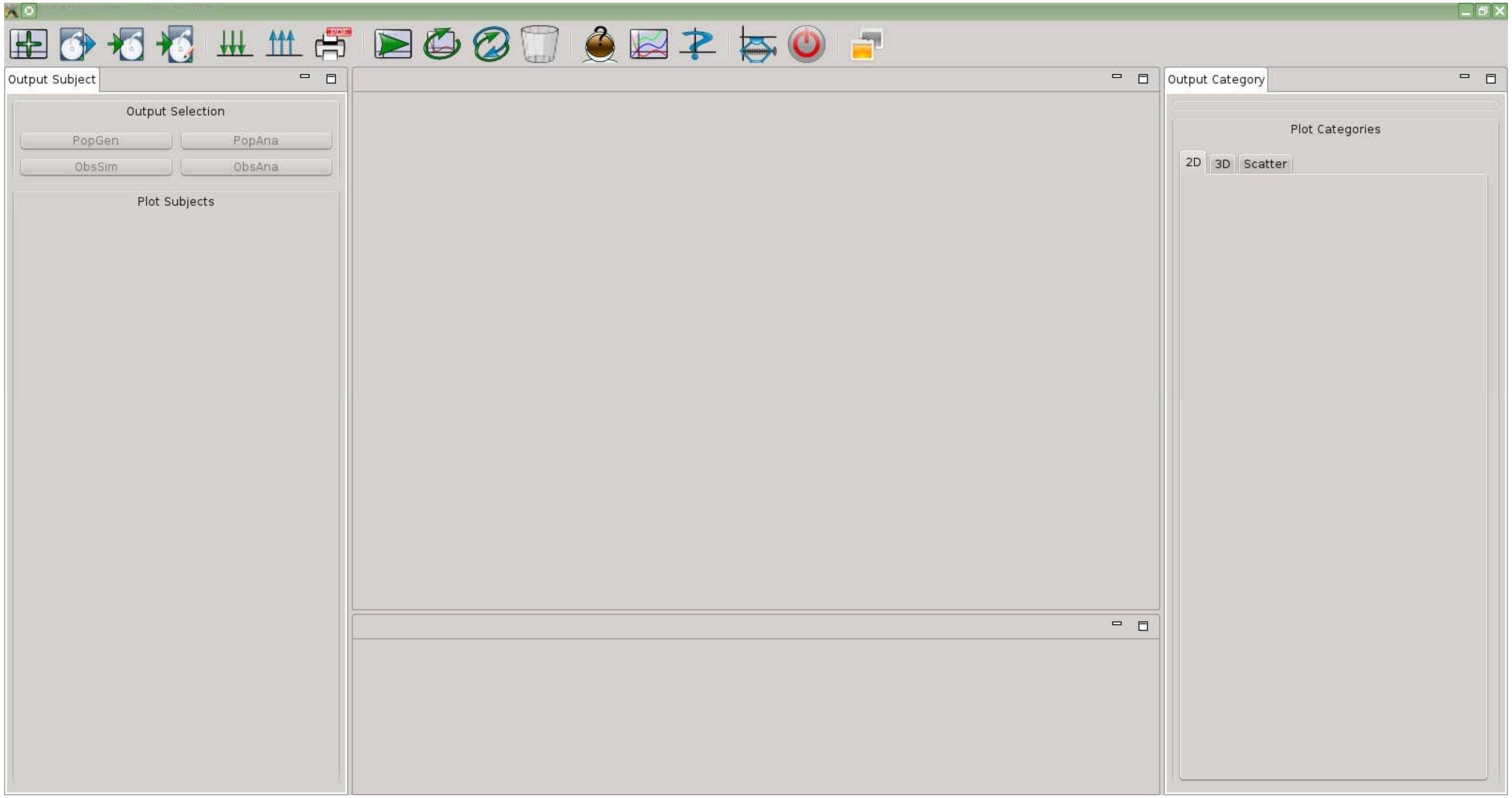
Thank you very much for your attention!

Questions?

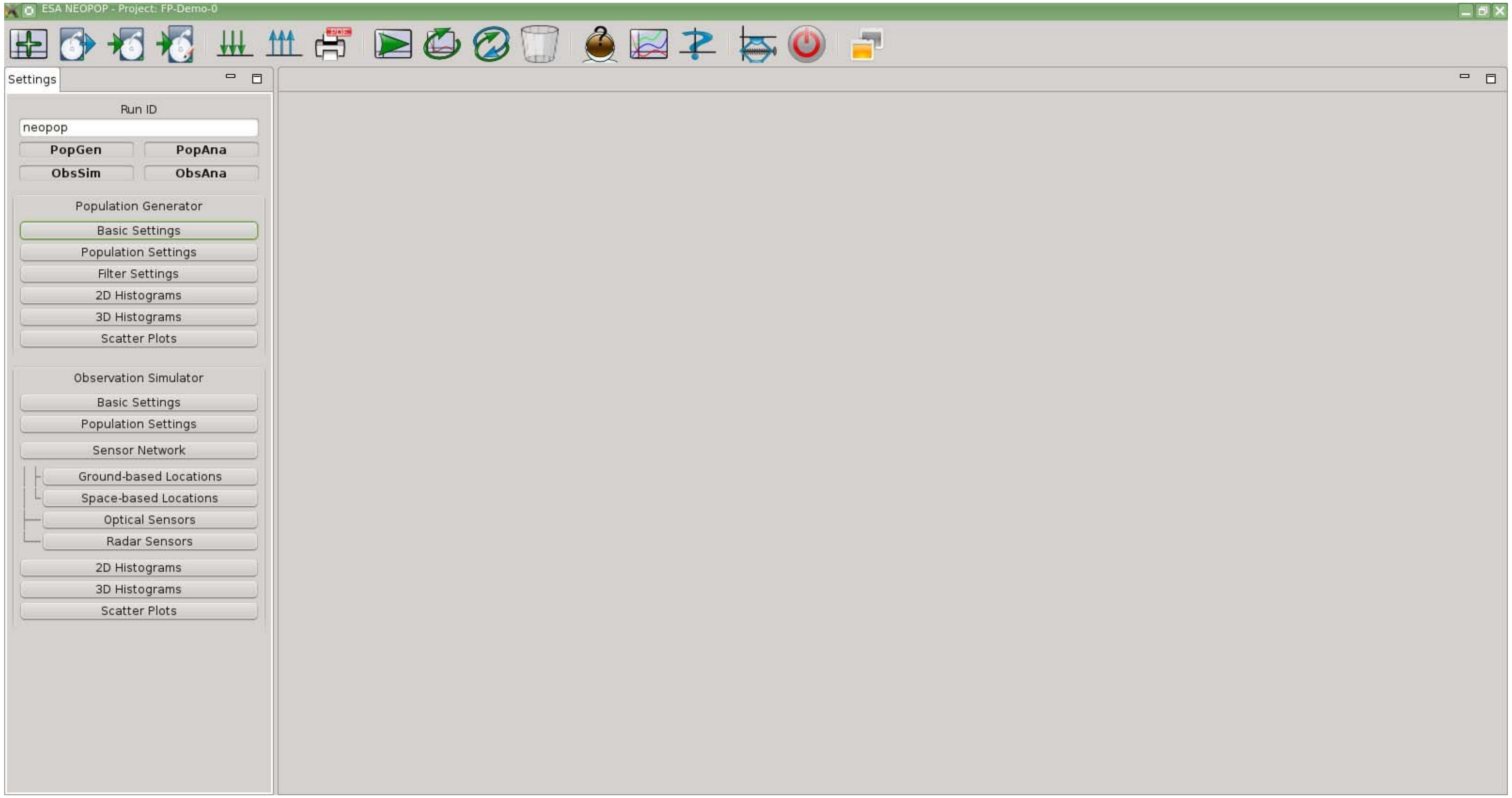
NEOPOP Demonstration
Backup 0



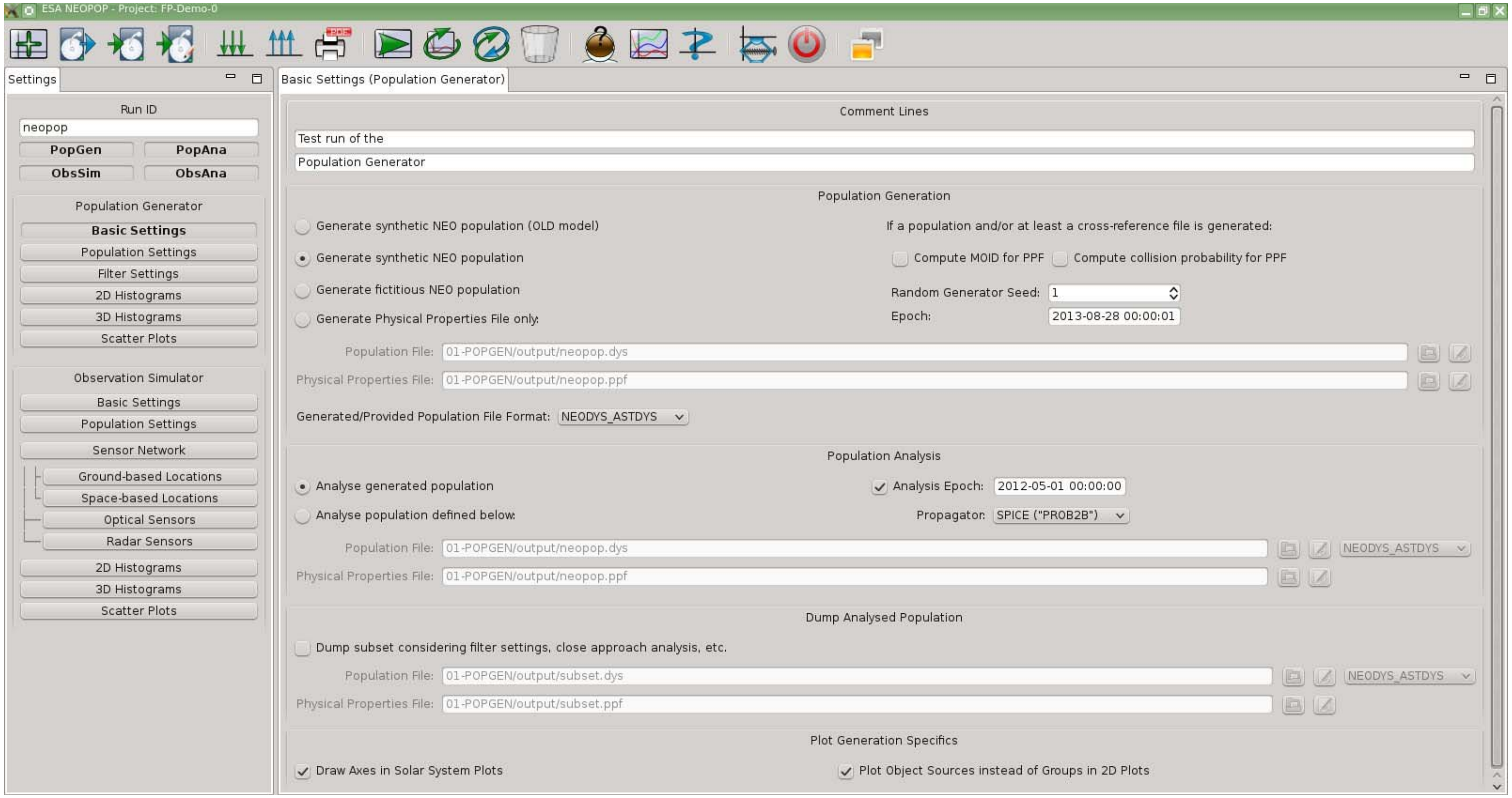
NEOPOP Demonstration
Backup 1



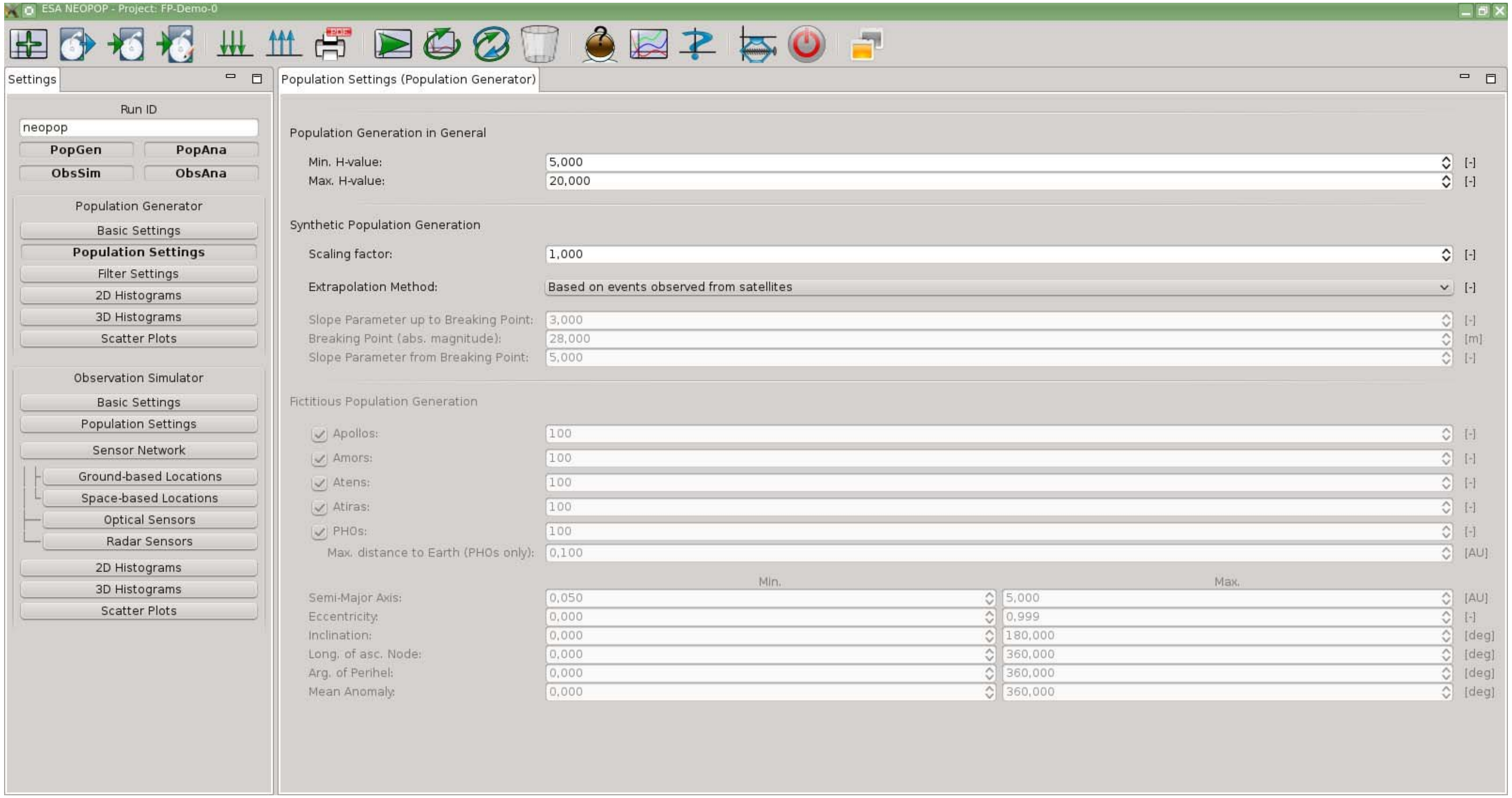
NEOPOP Demonstration
Backup 2



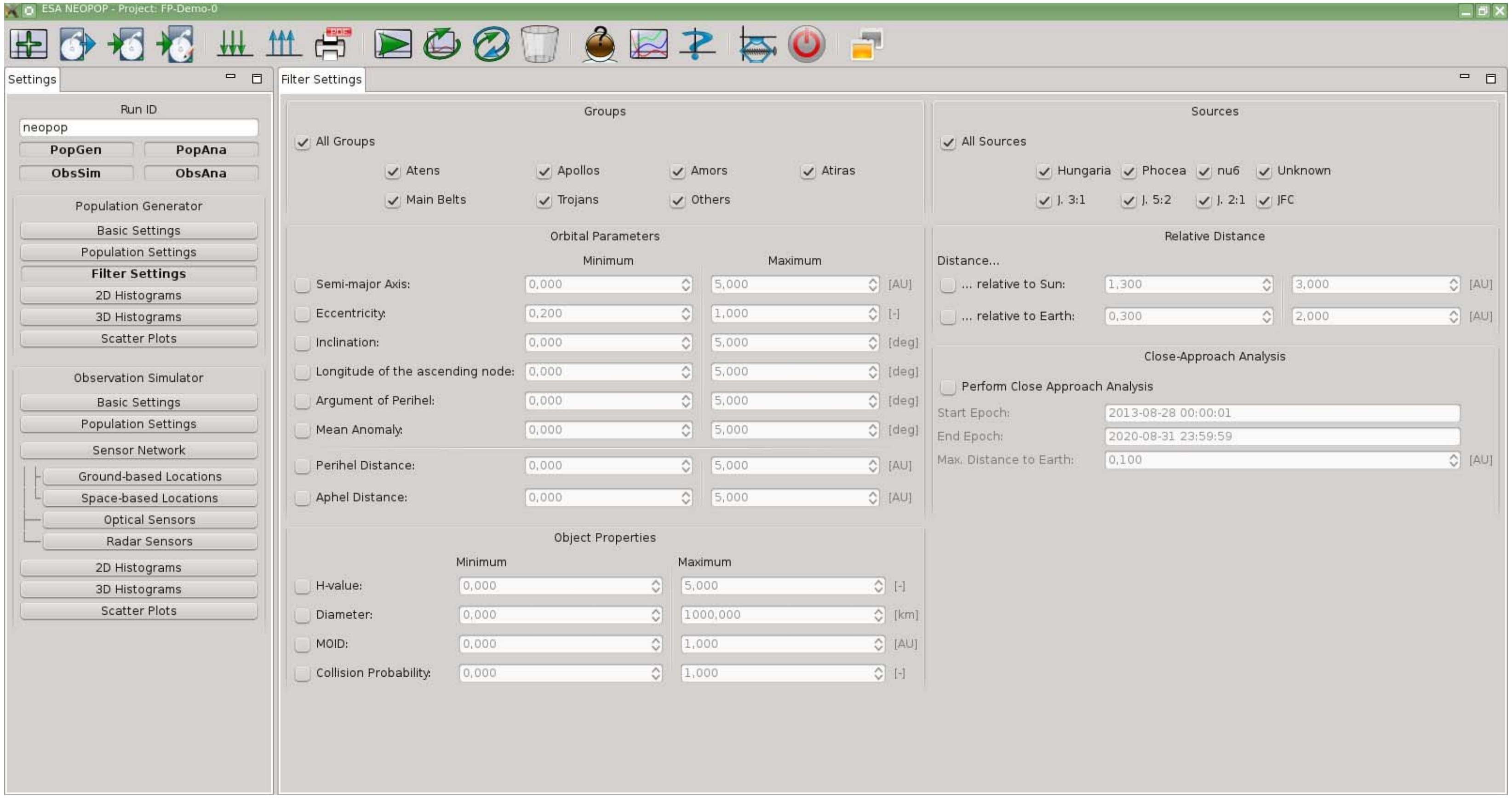
NEOPOP Demonstration
Backup 3



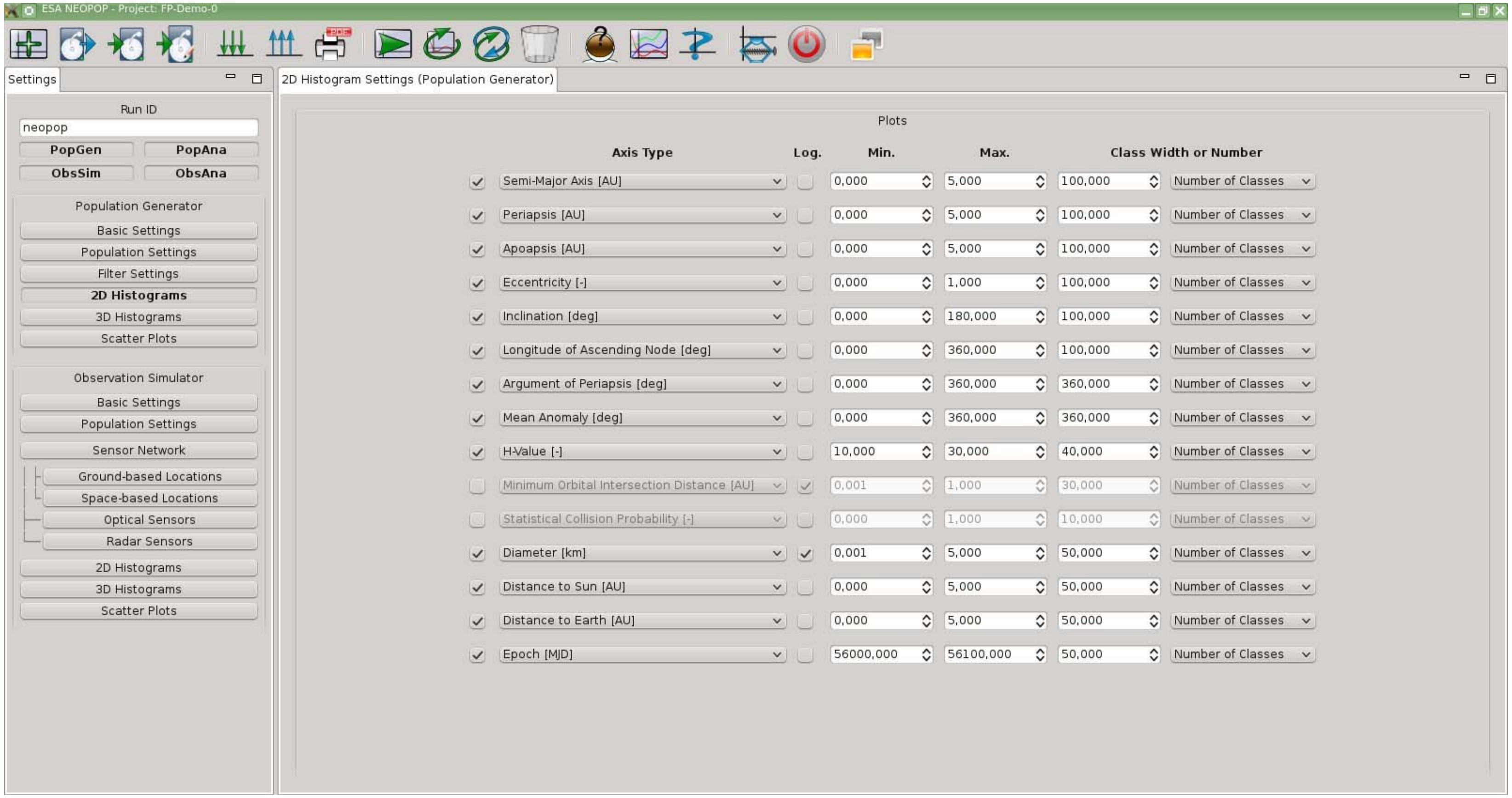
NEOPOP Demonstration
Backup 4



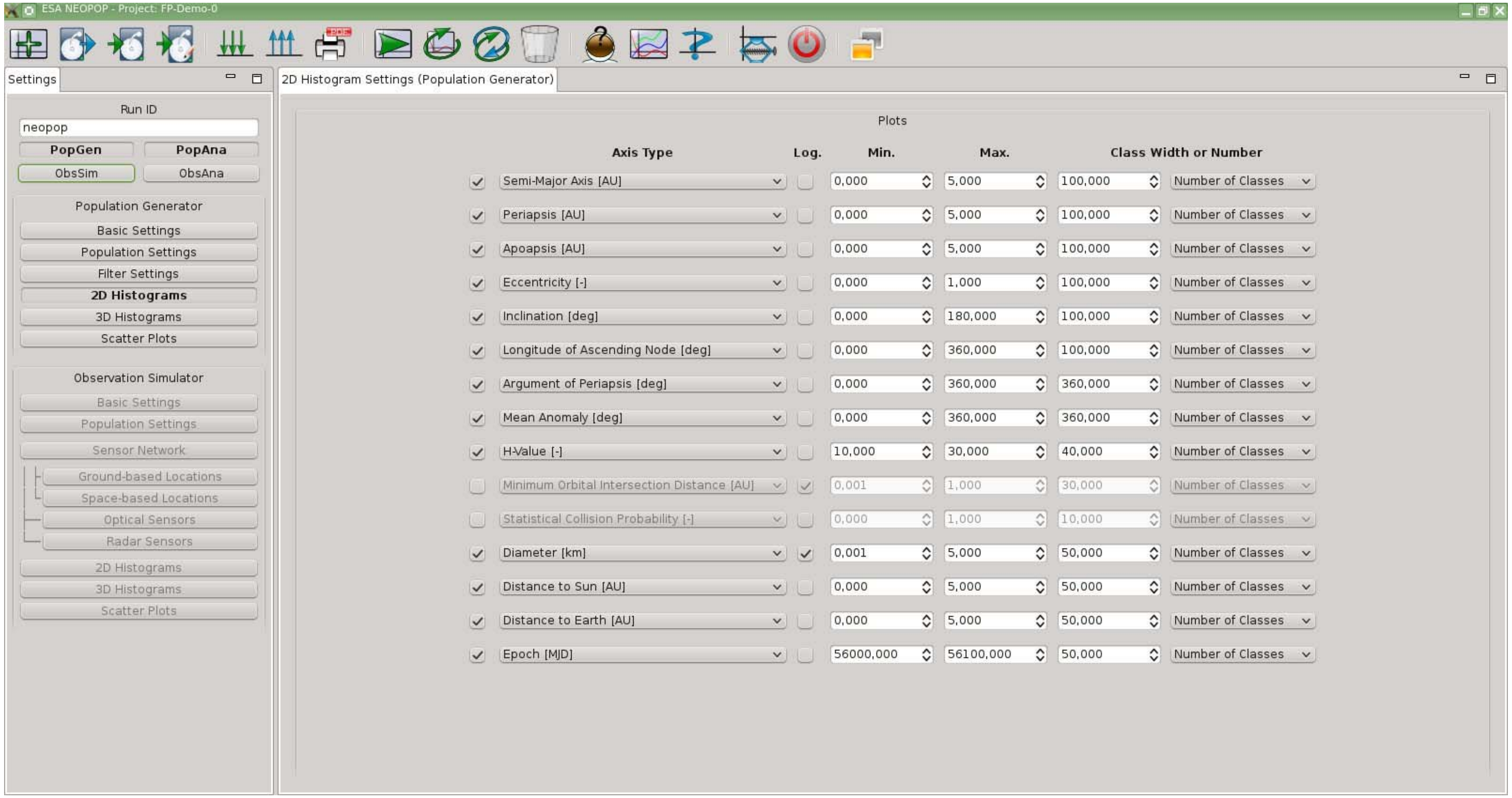
NEOPOP Demonstration Backup
Backup 5



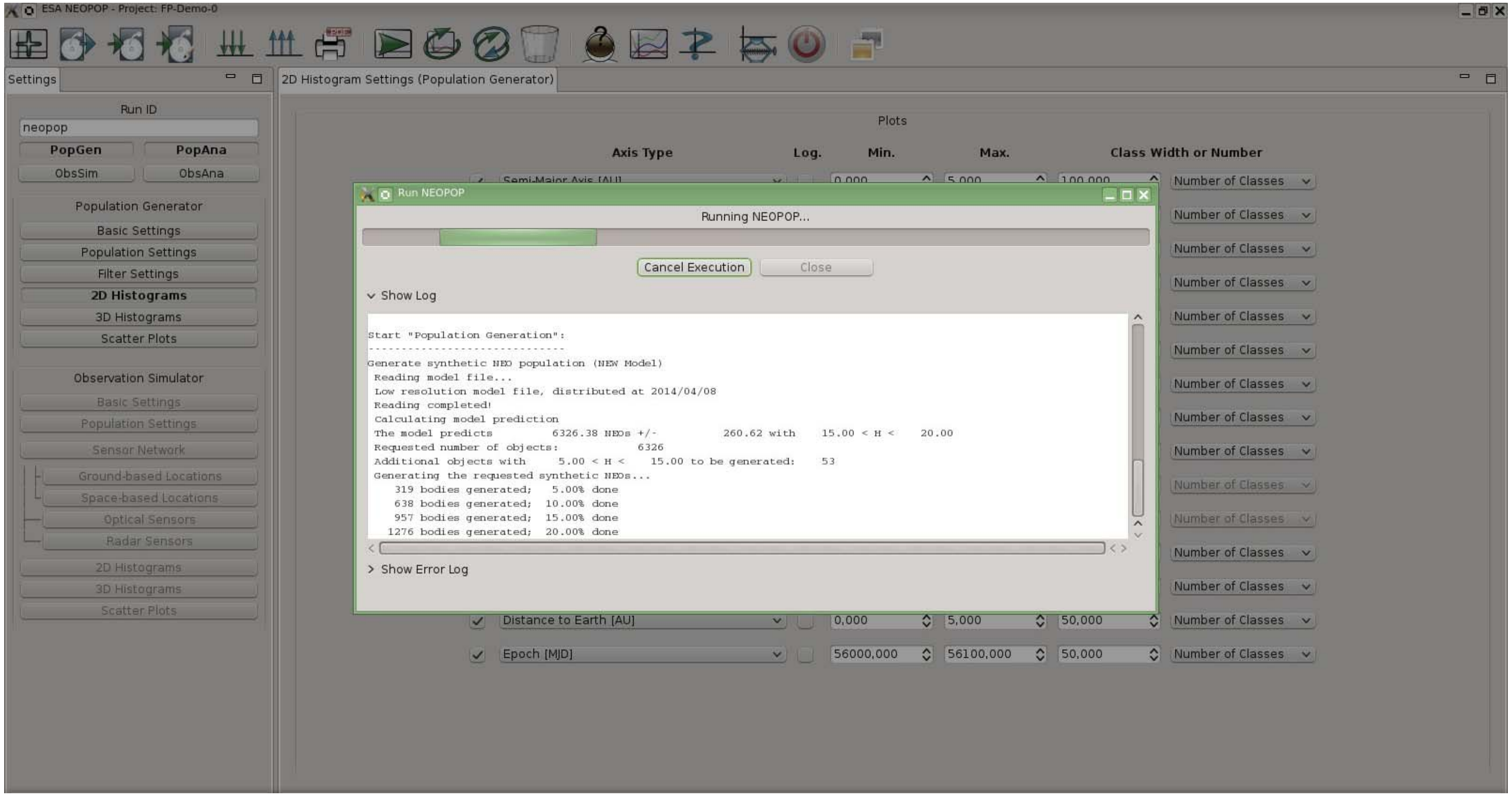
NEOPOP Demonstration
Backup 6



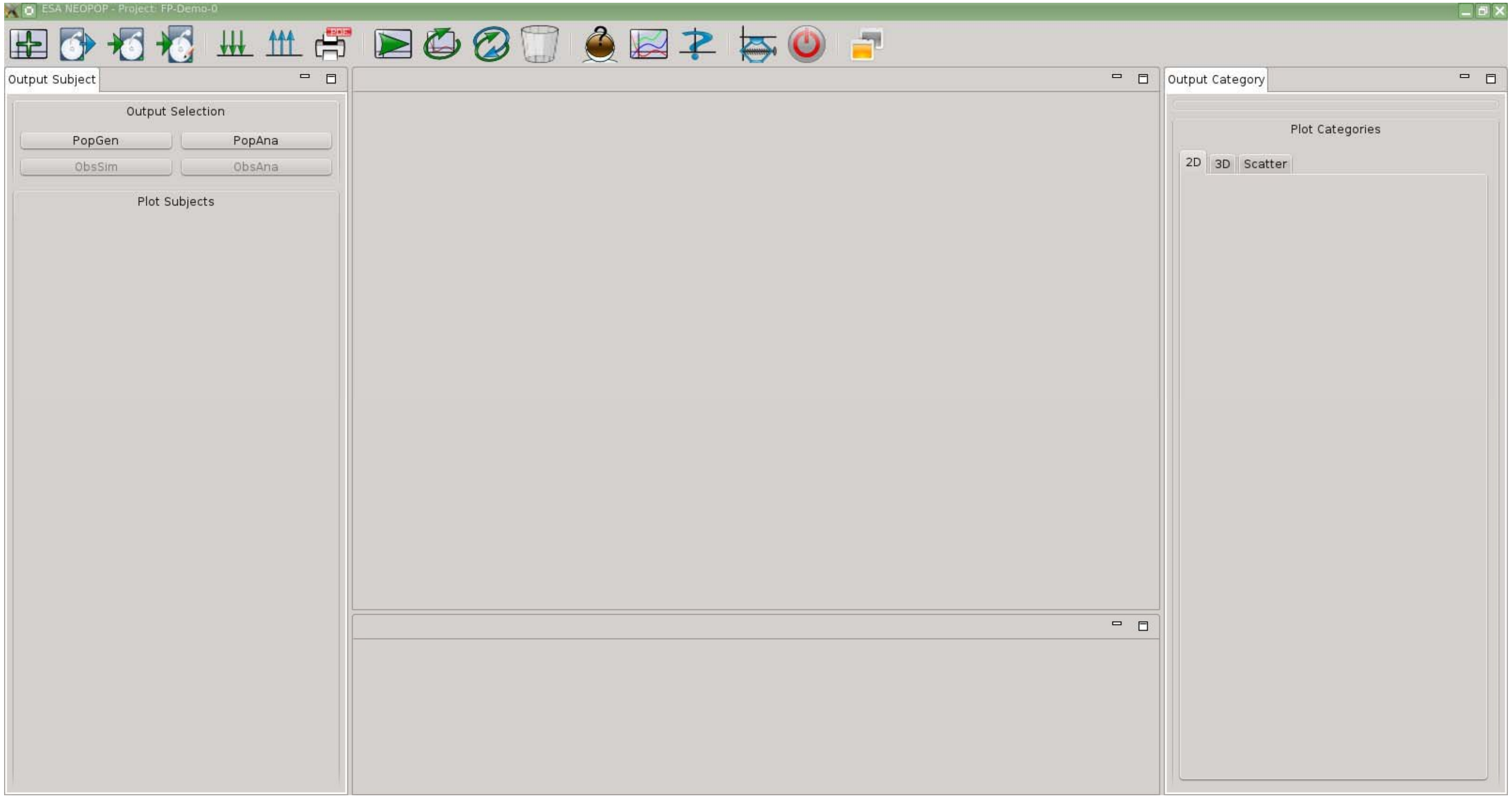
NEOPOP Demonstration
Backup 7



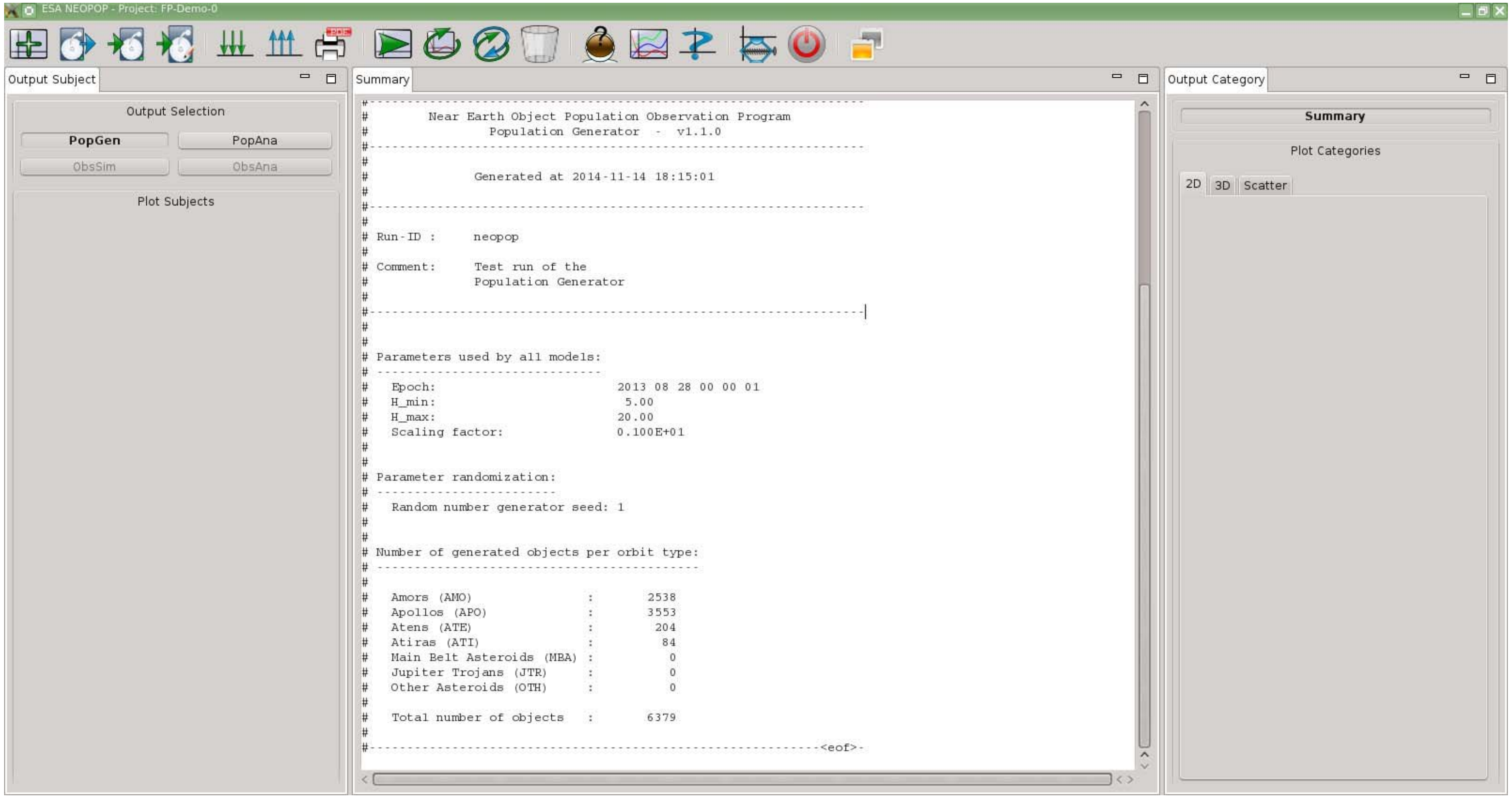
NEOPOP Demonstration
Backup 8



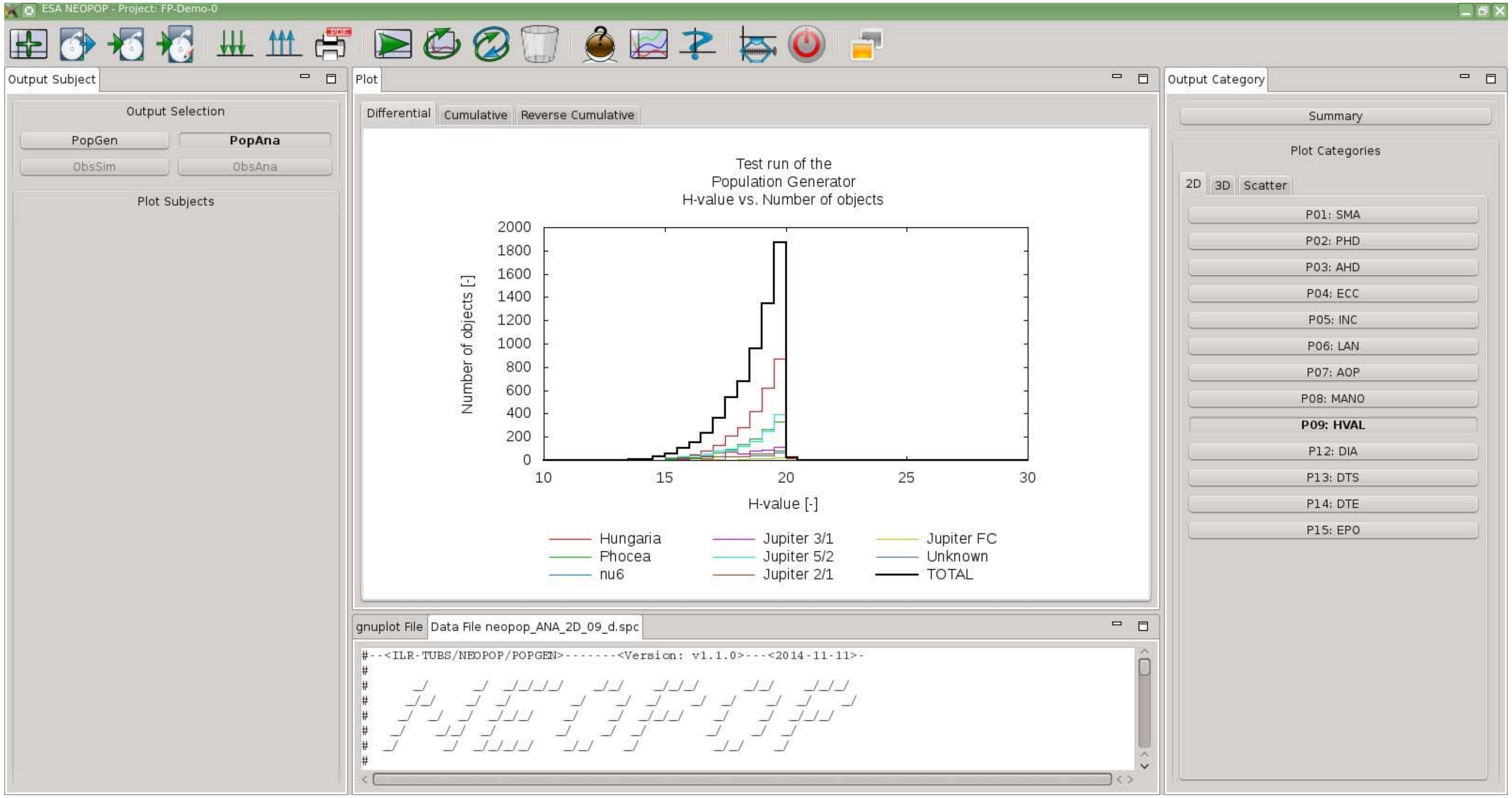
NEOPOP Demonstration
Backup 9



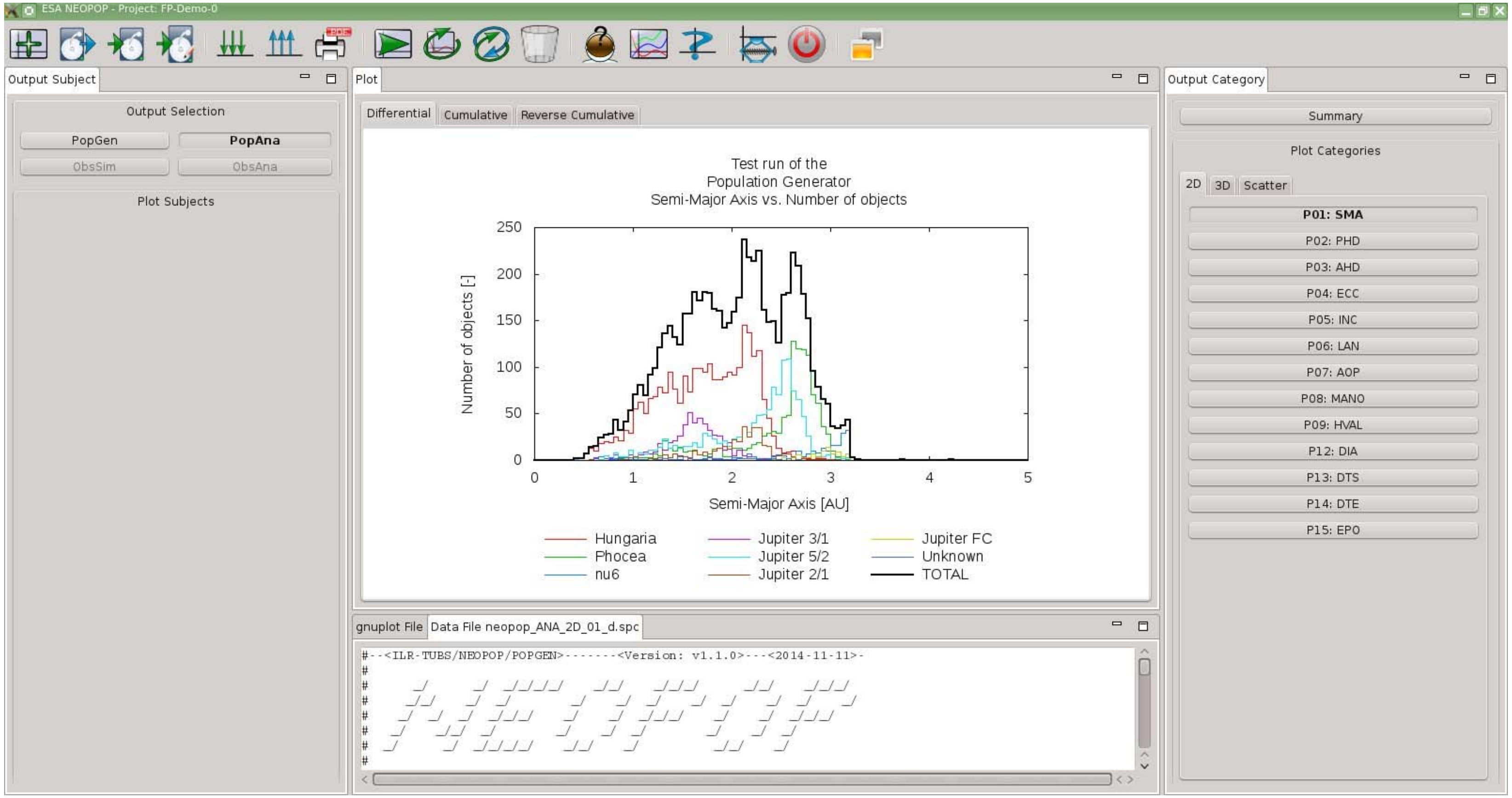
NEOPOP Demonstration
Backup 10



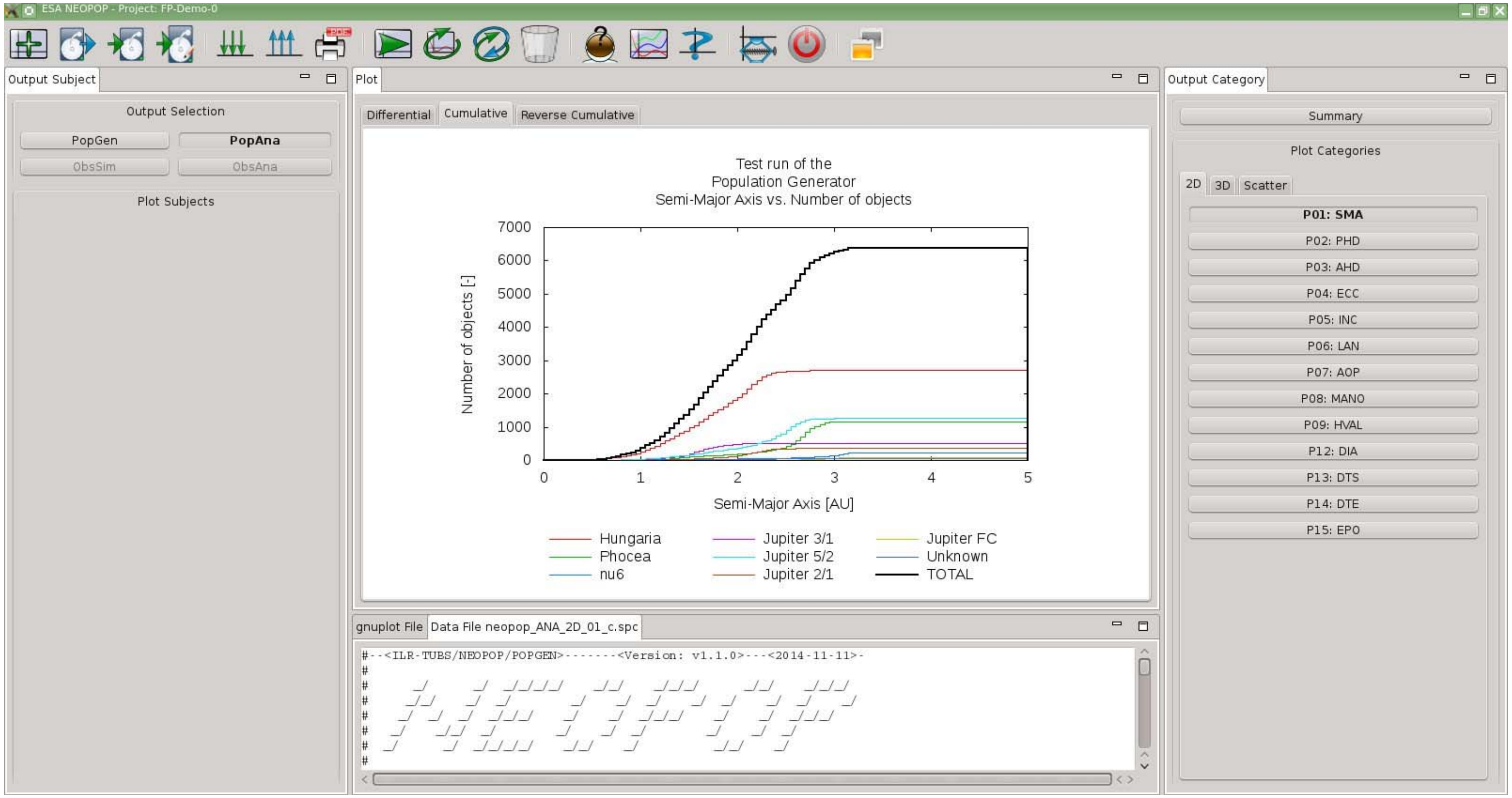
NEOPOP Demonstration
Backup 11



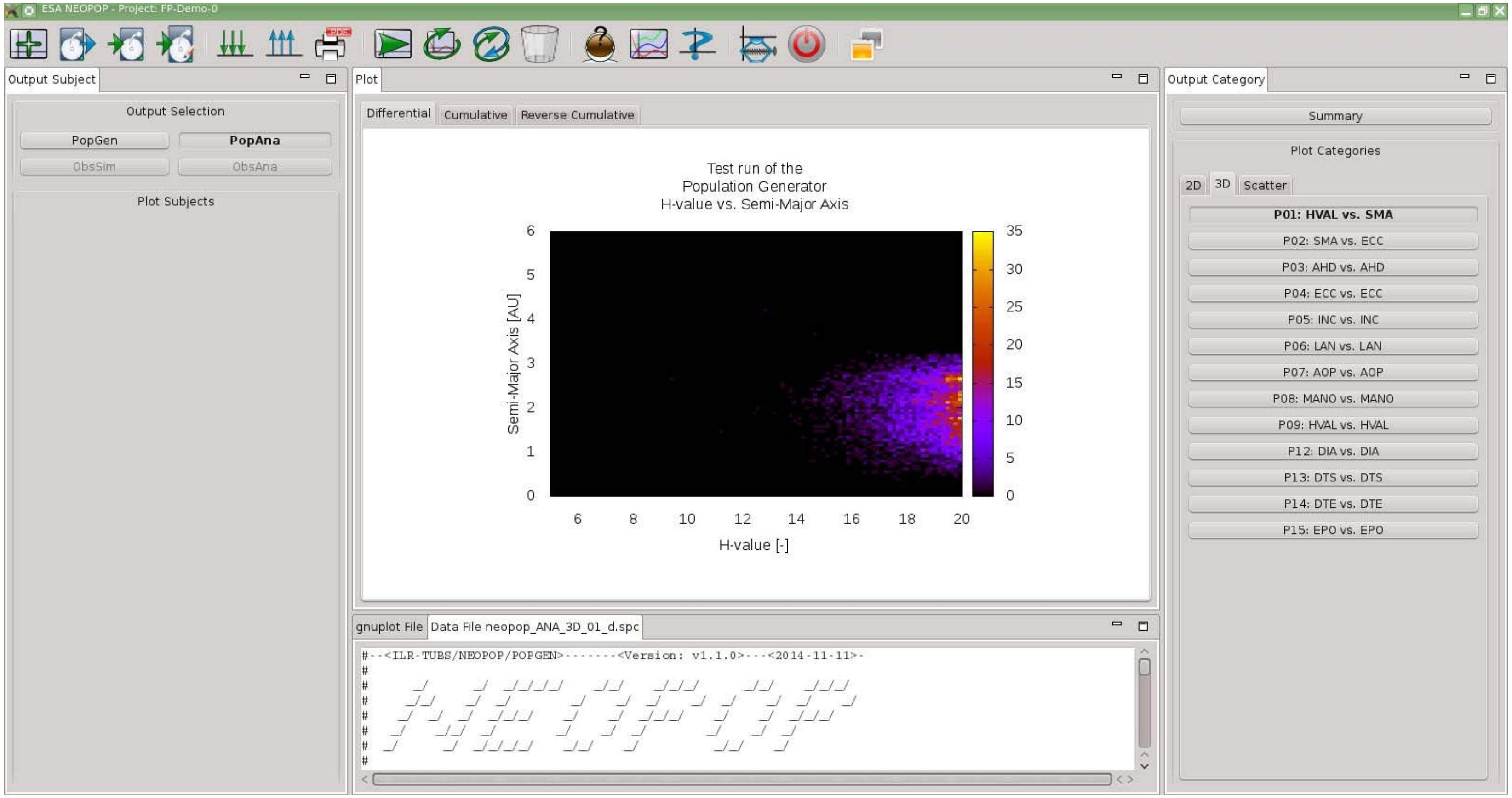
NEOPOP Demonstration
Backup 12



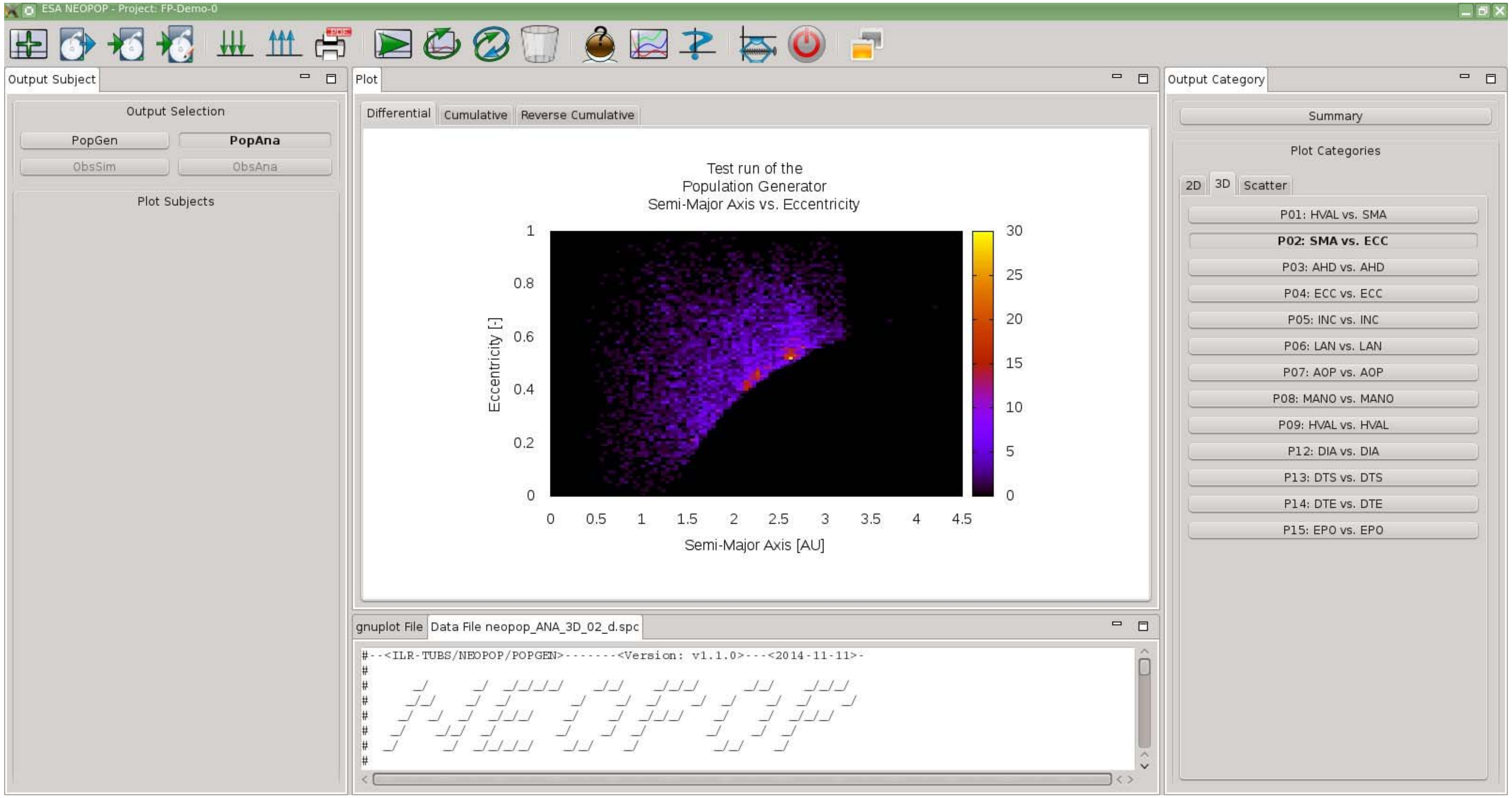
NEOPOP Demonstration
Backup 13



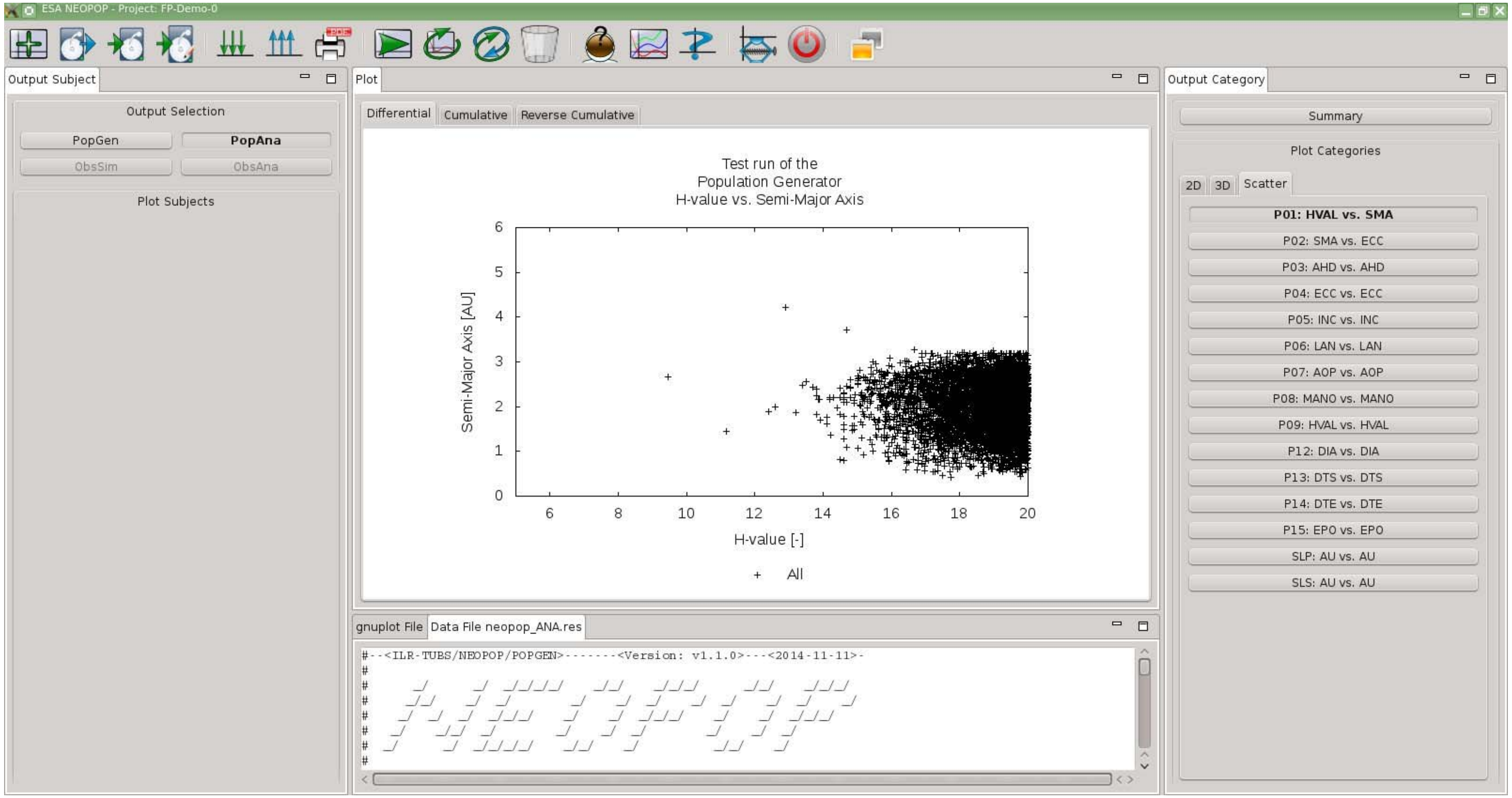
NEOPOP Demonstration
Backup 14



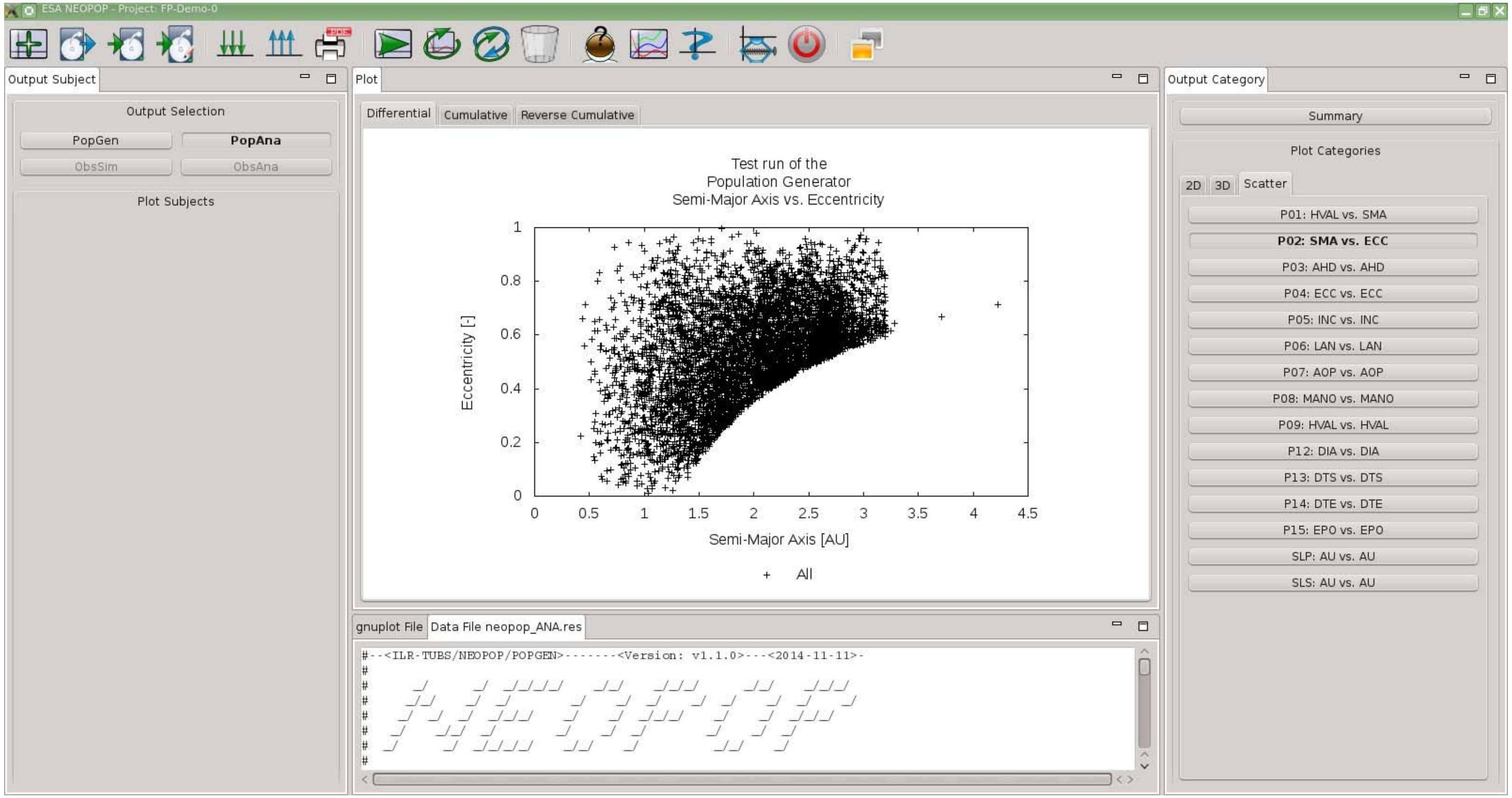
NEOPOP Demonstration
Backup 15



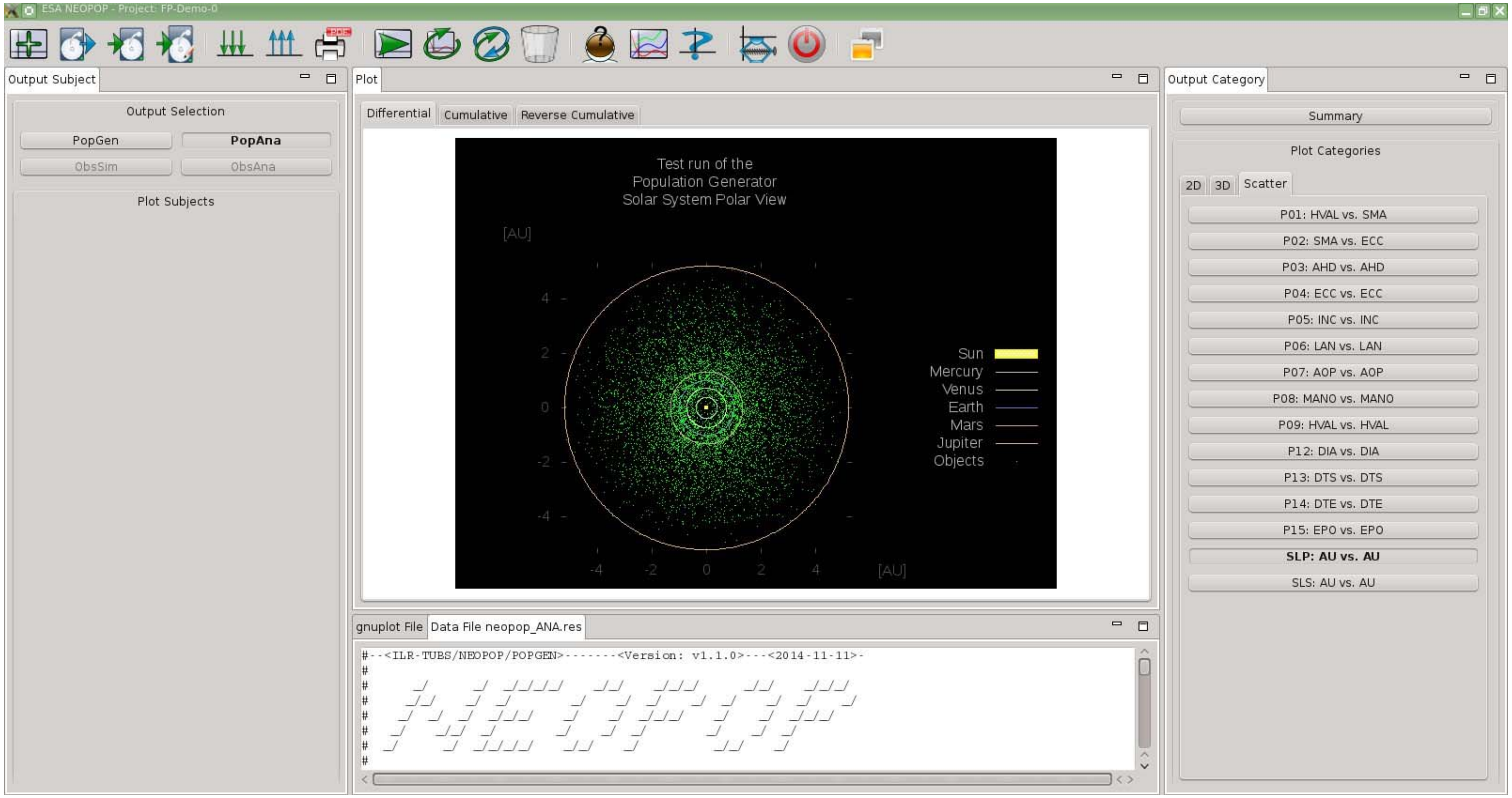
NEOPOP Demonstration
Backup 16



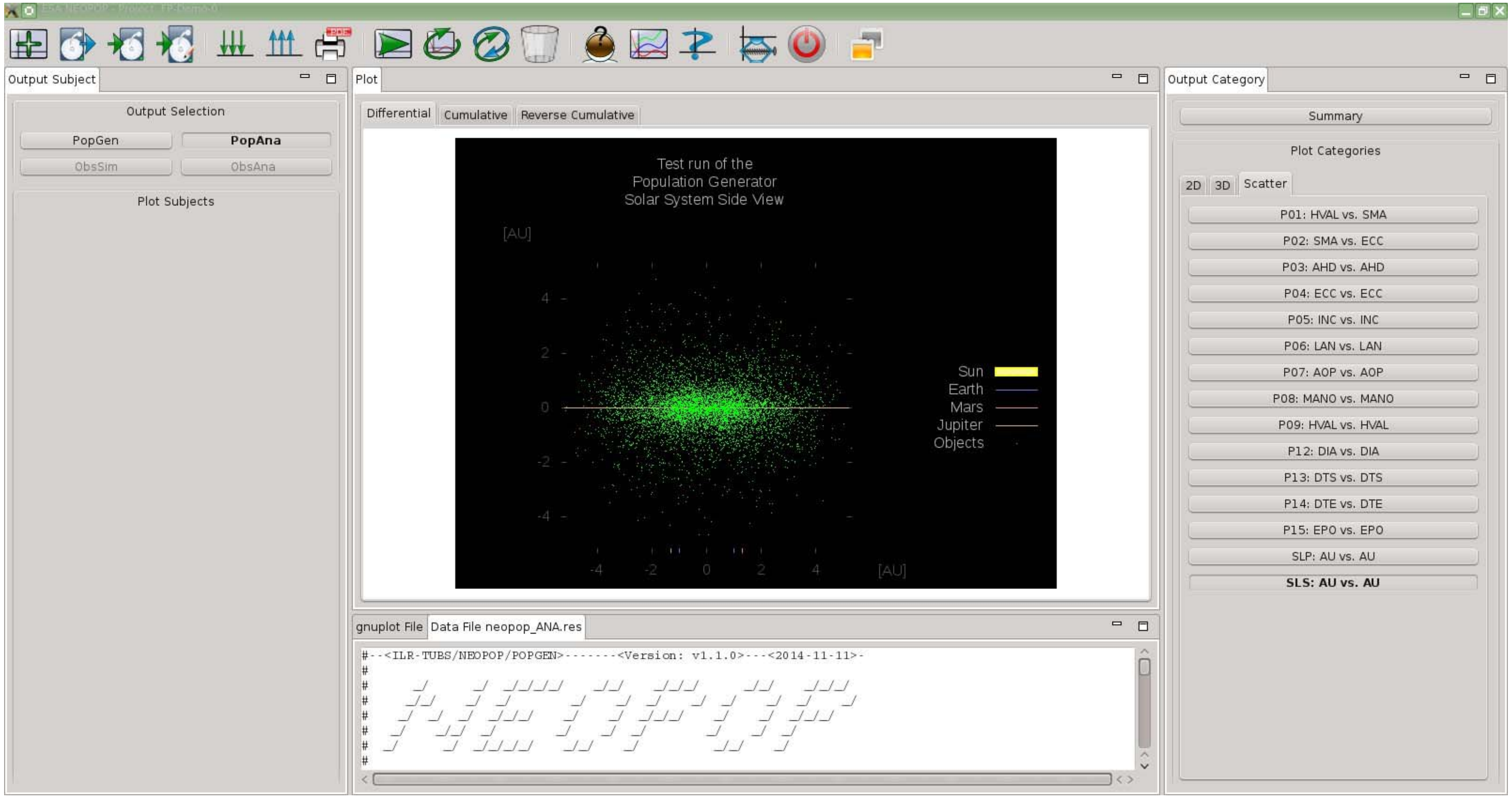
NEOPOP Demonstration
Backup 17



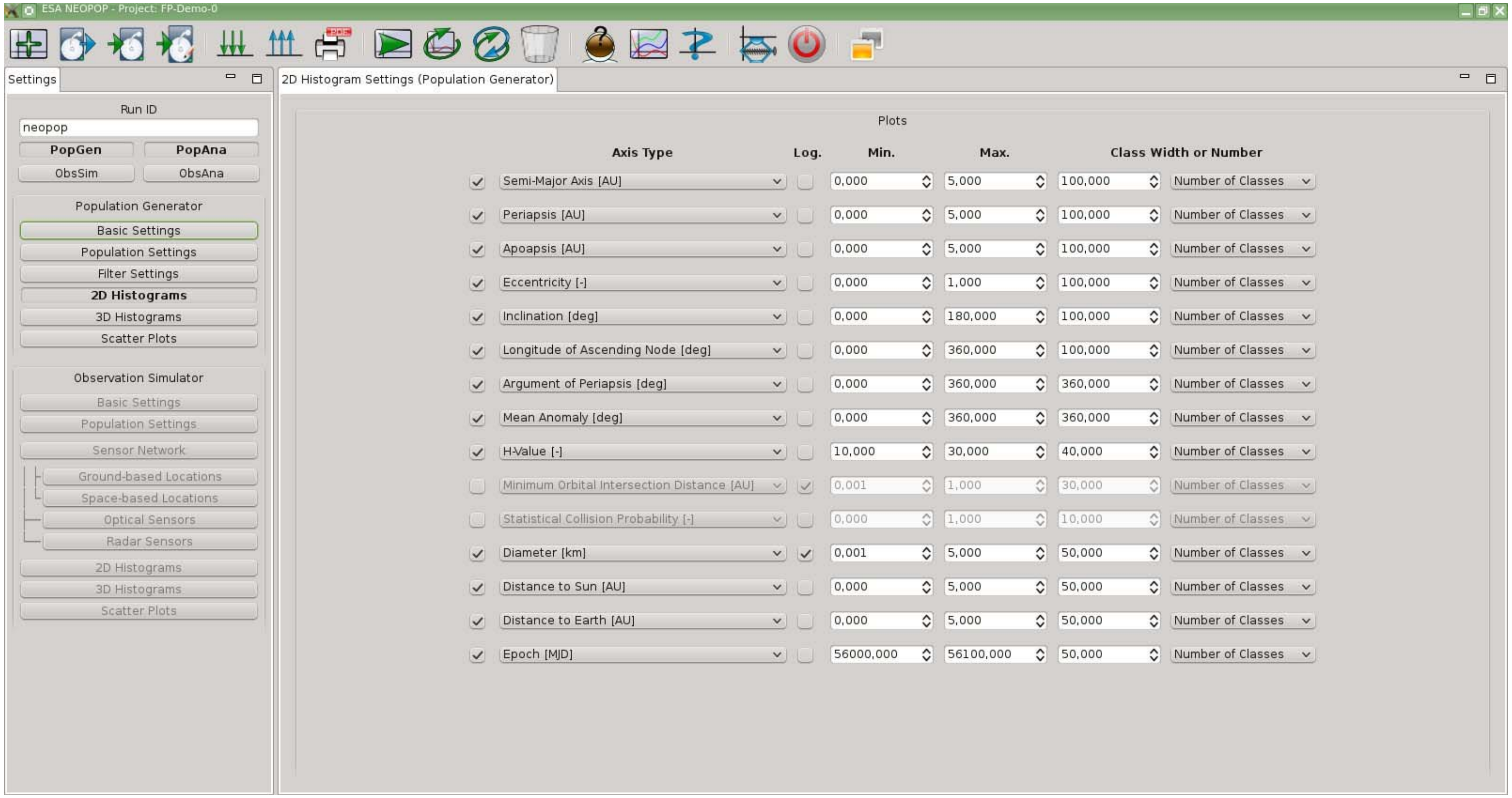
NEOPOP Demonstration
Backup 18



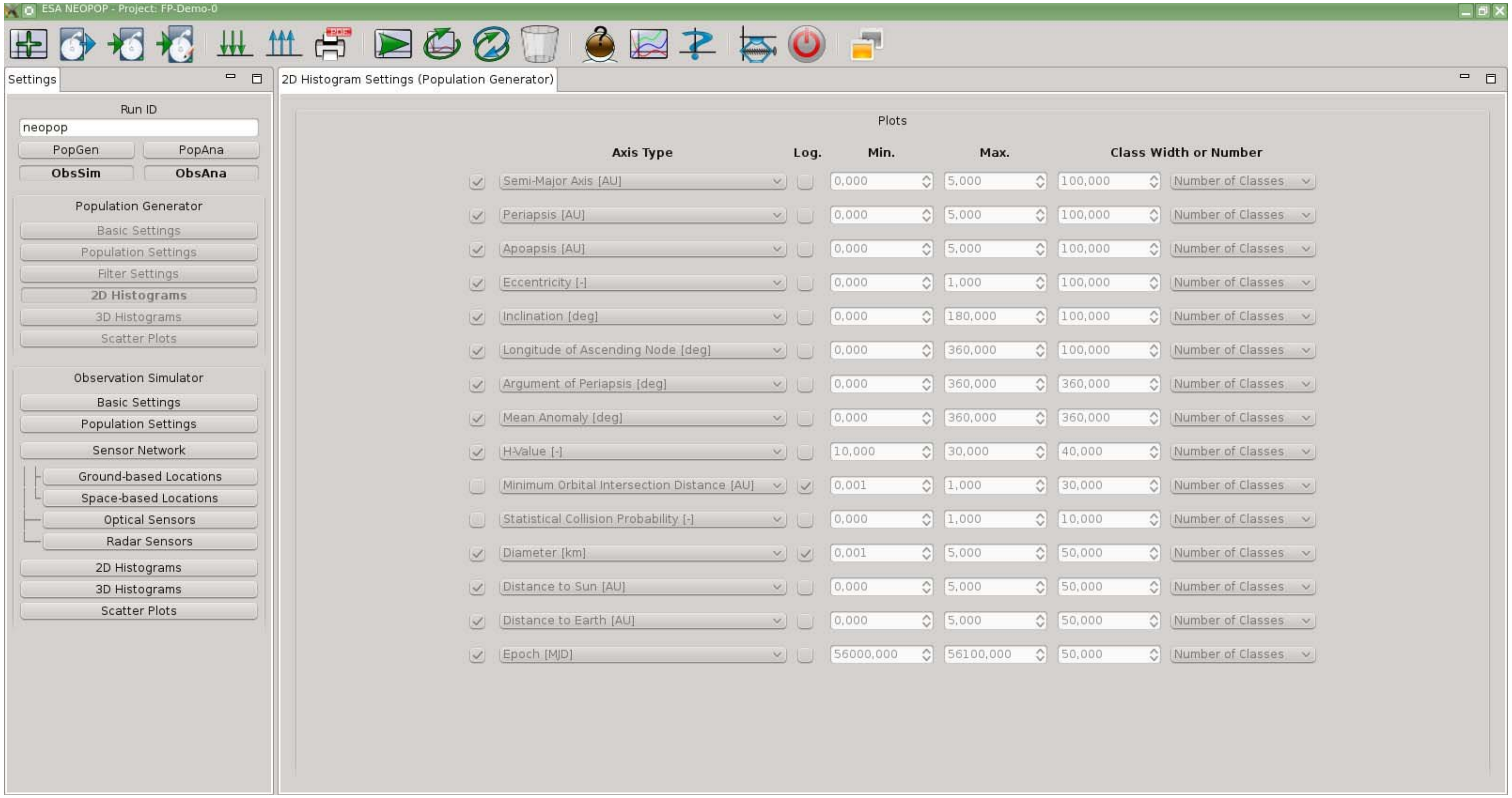
NEOPOP Demonstration
Backup 19



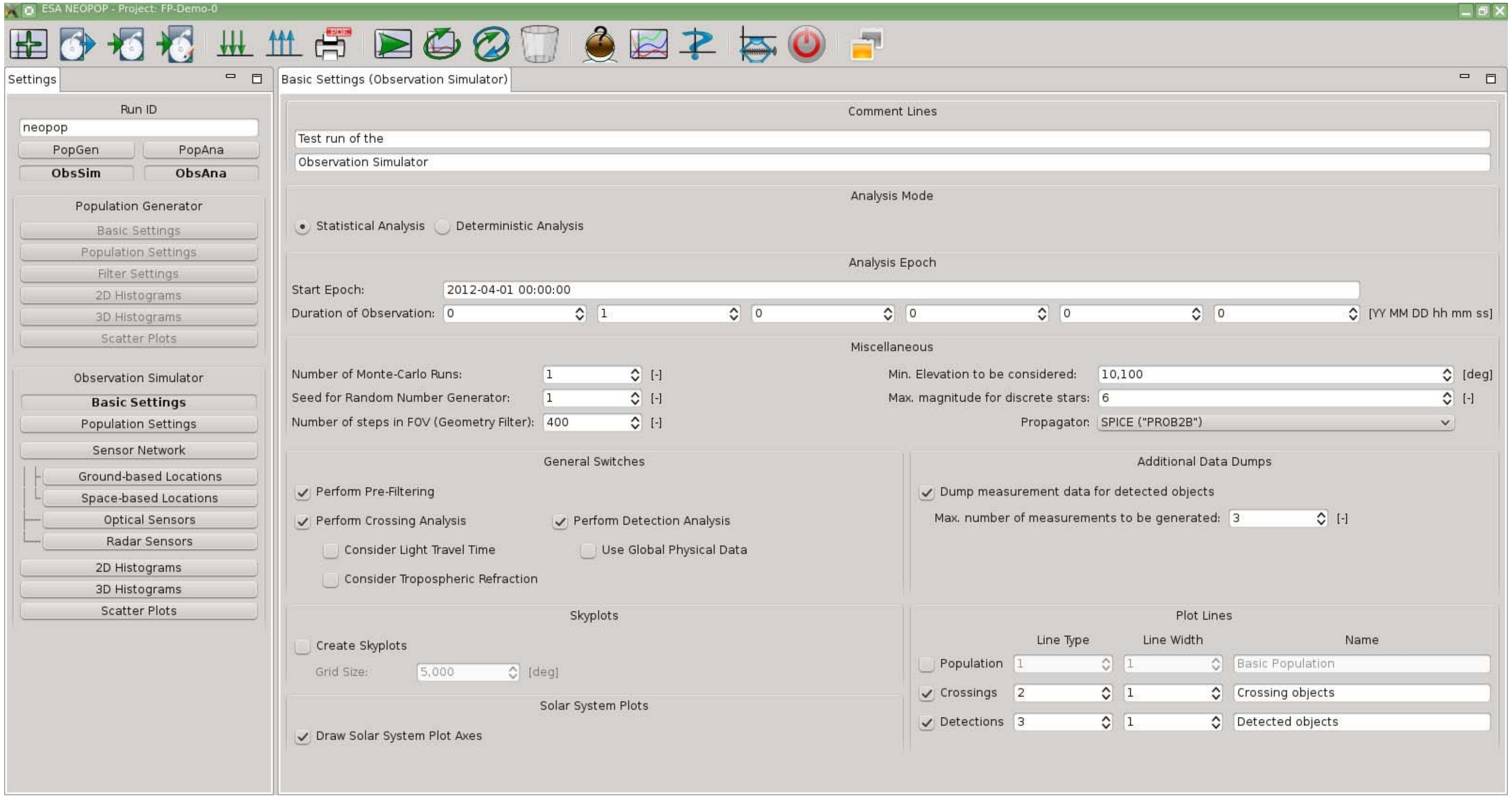
NEOPOP Demonstration
Backup 20



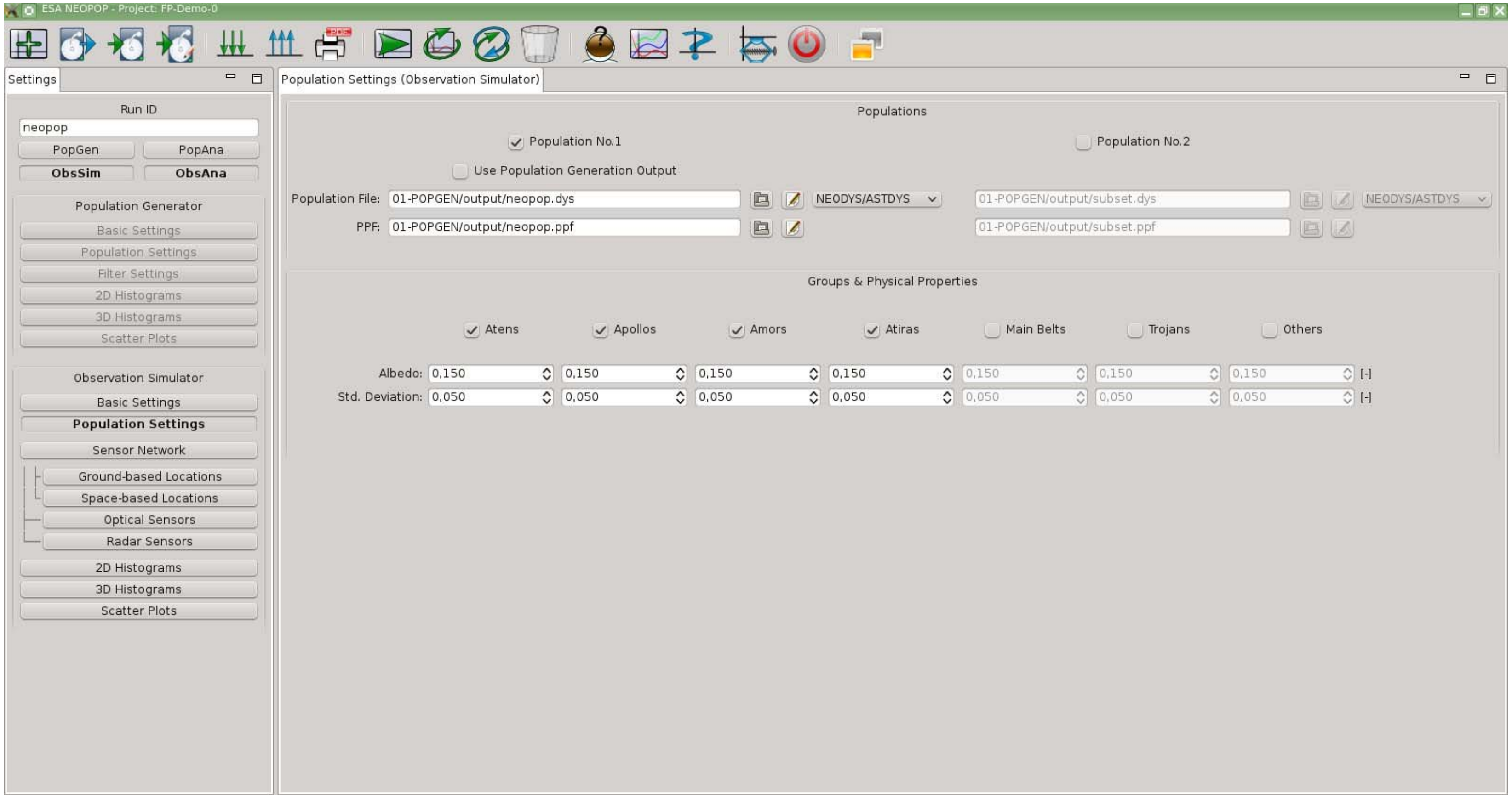
NEOPOP Demonstration
Backup 21



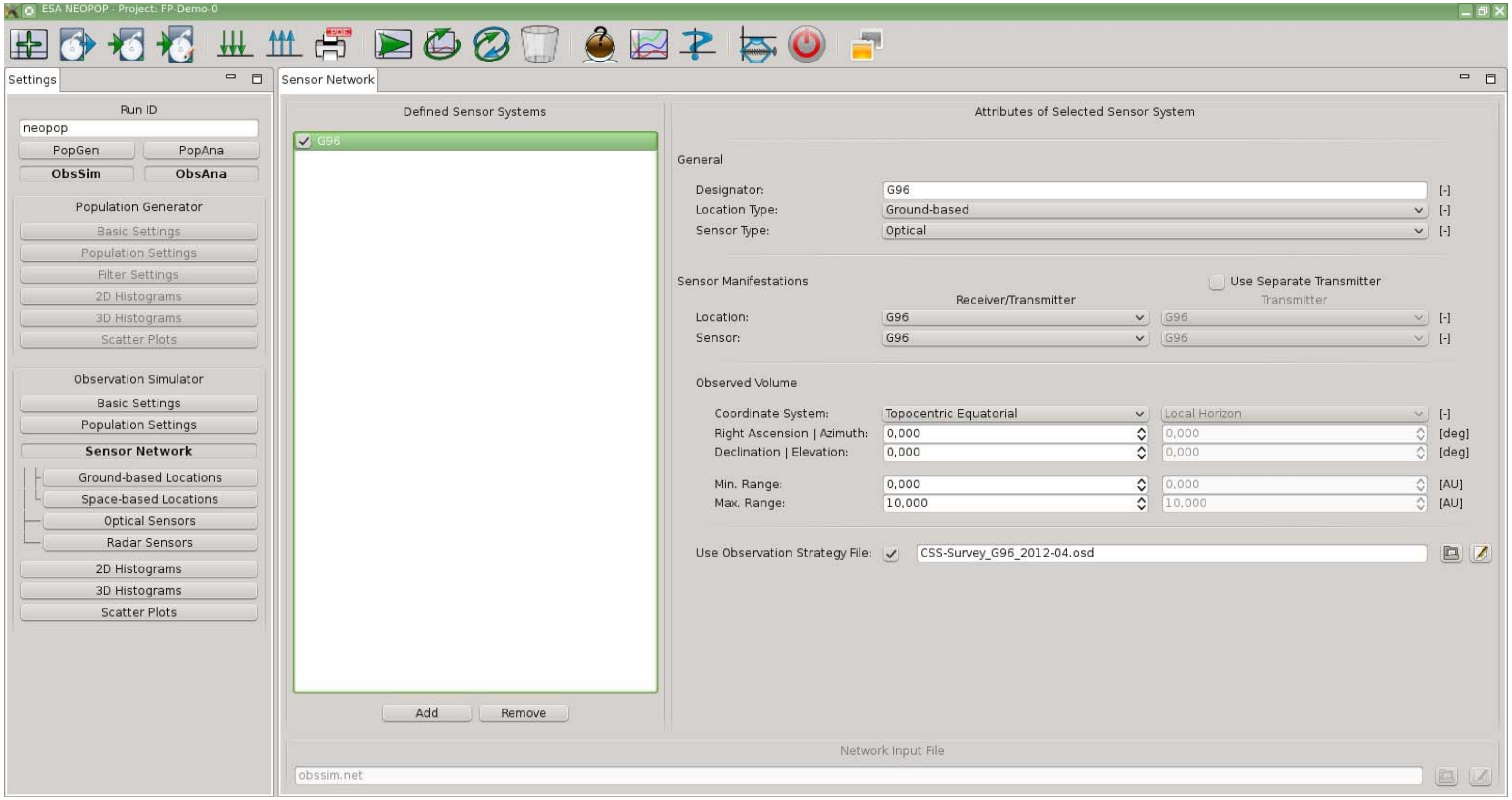
NEOPOP Demonstration
Backup 22



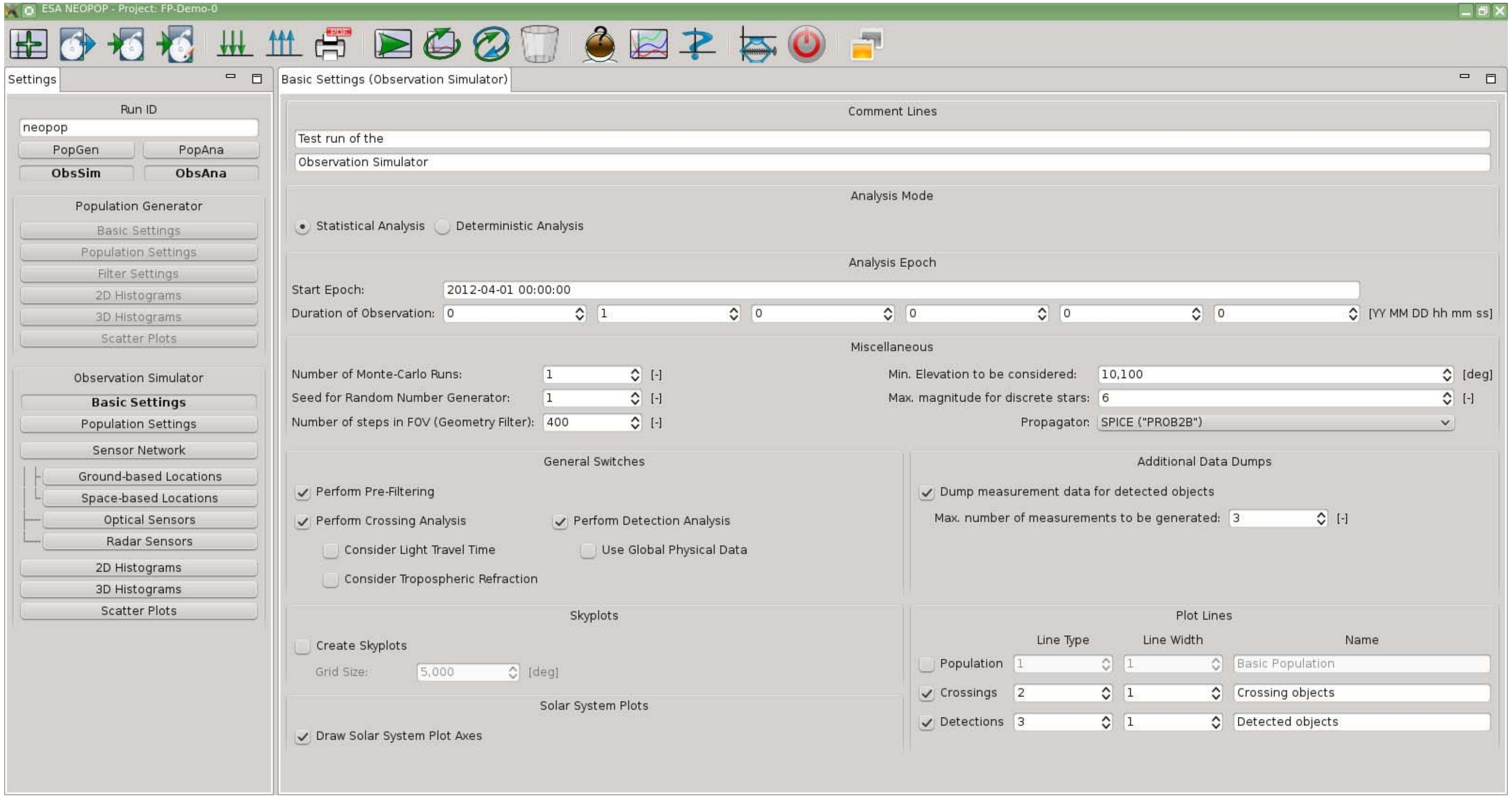
NEOPOP Demonstration
Backup 23



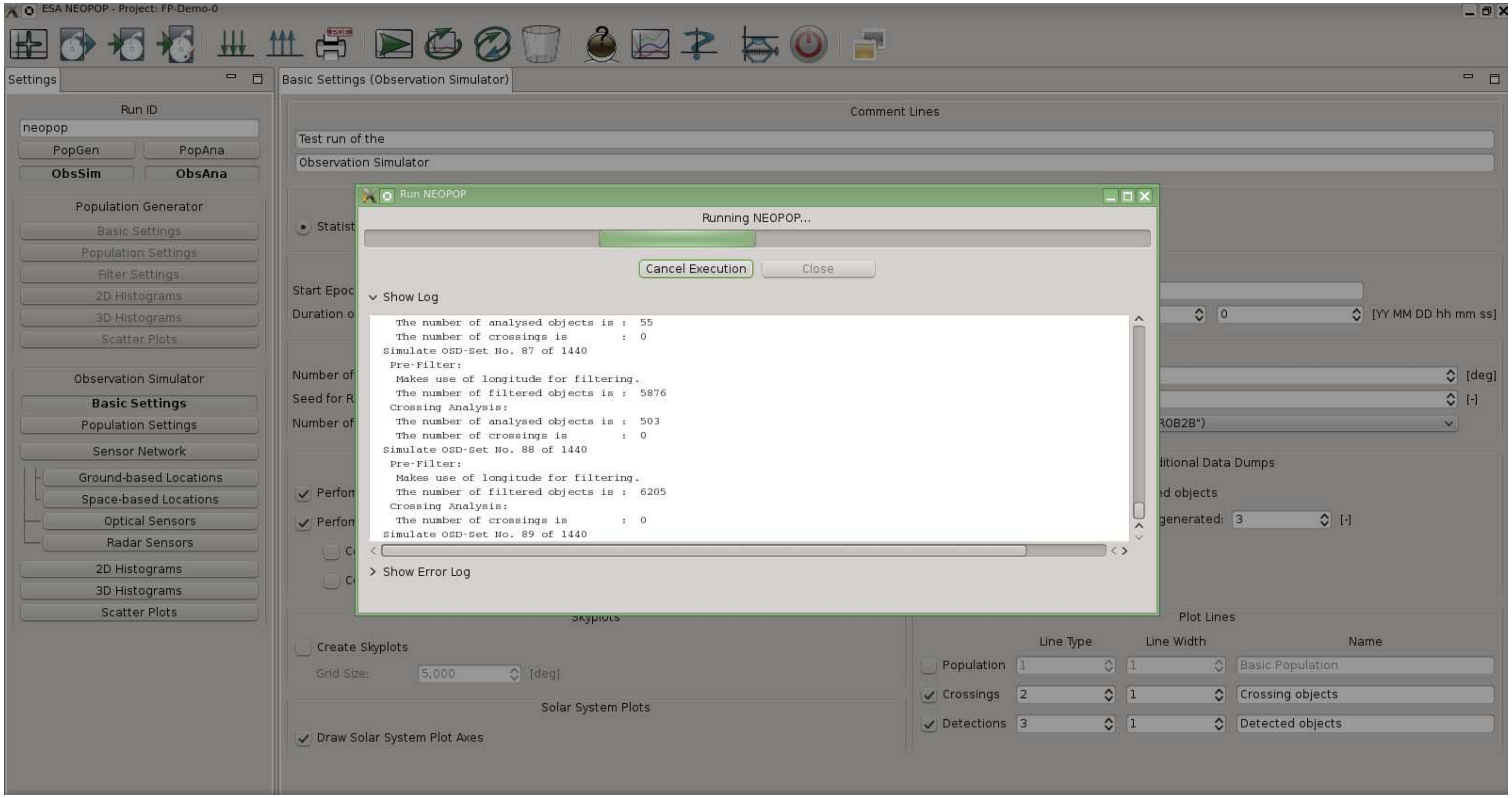
NEOPOP Demonstration
Backup 24



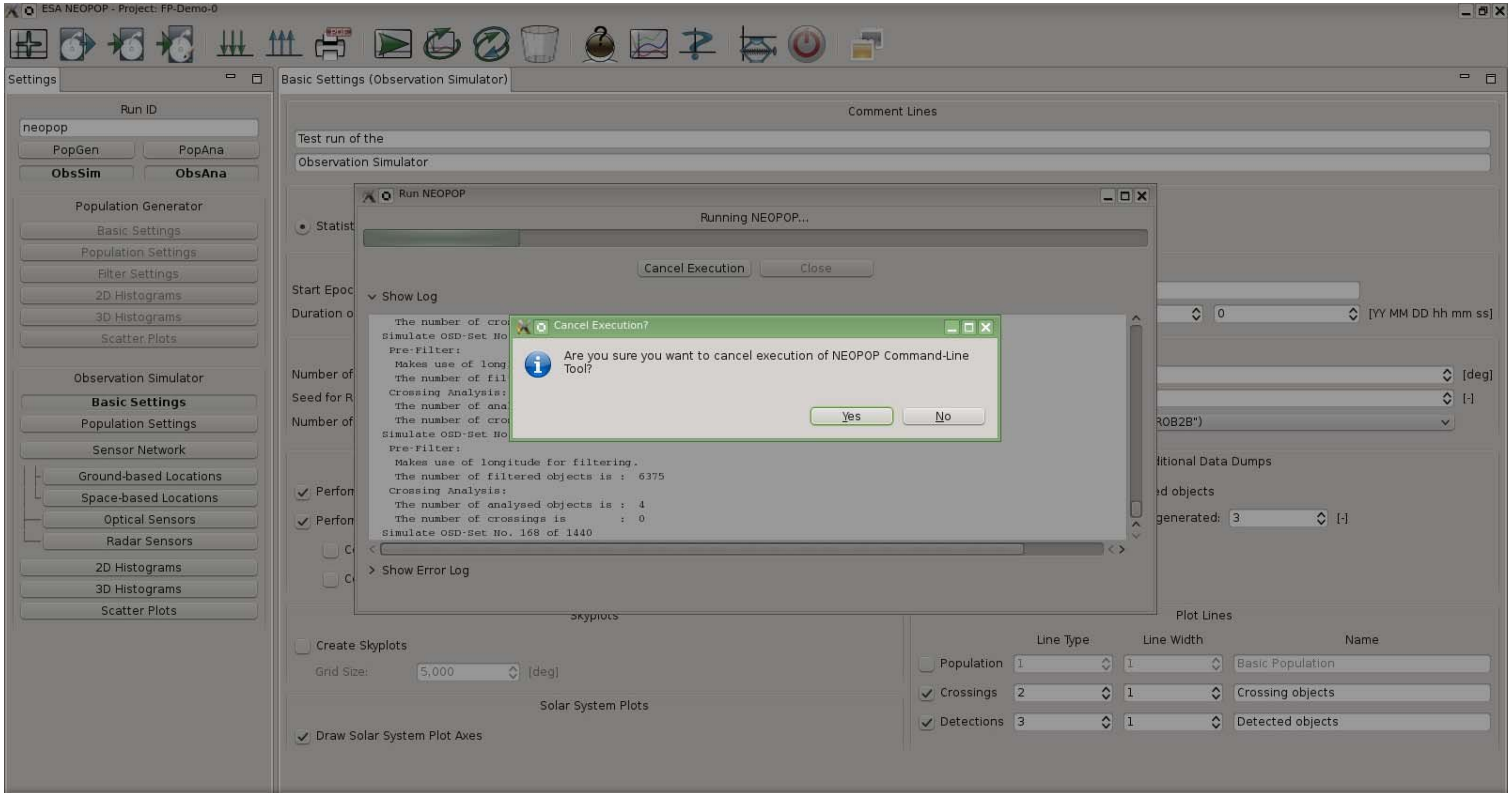
NEOPOP Demonstration
Backup 25



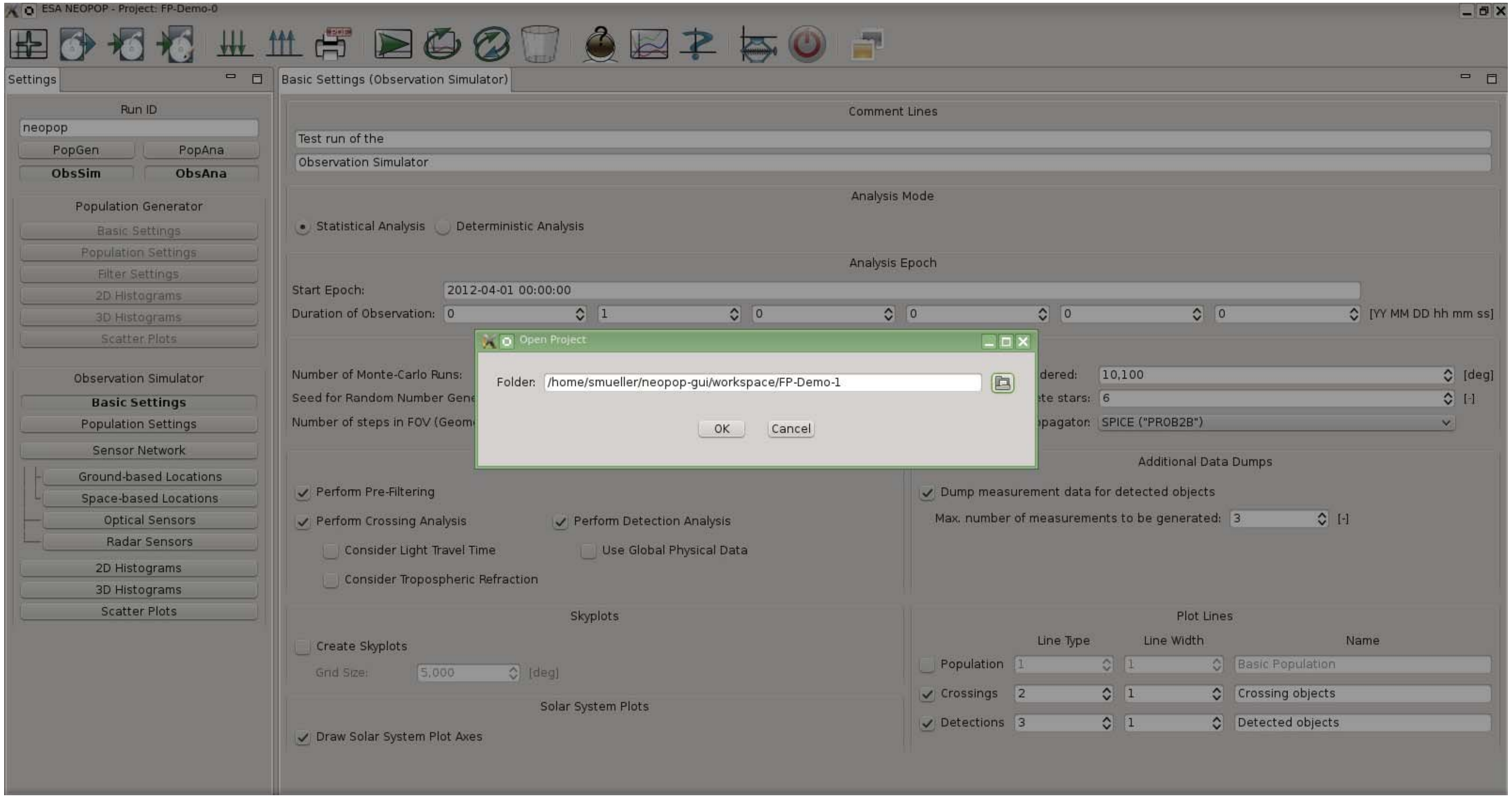
NEOPOP Demonstration
Backup 26



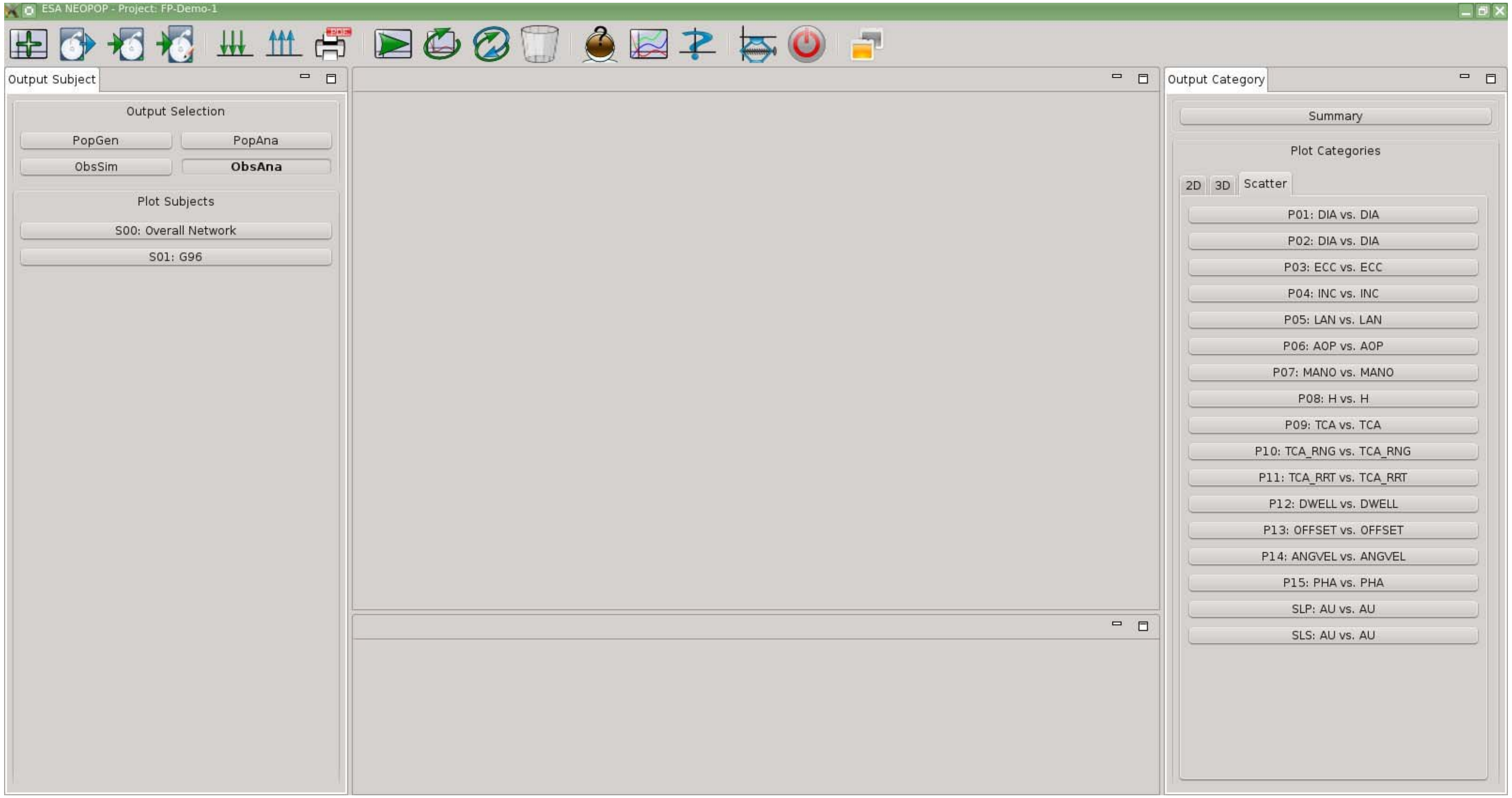
NEOPOP Demonstration
Backup 27



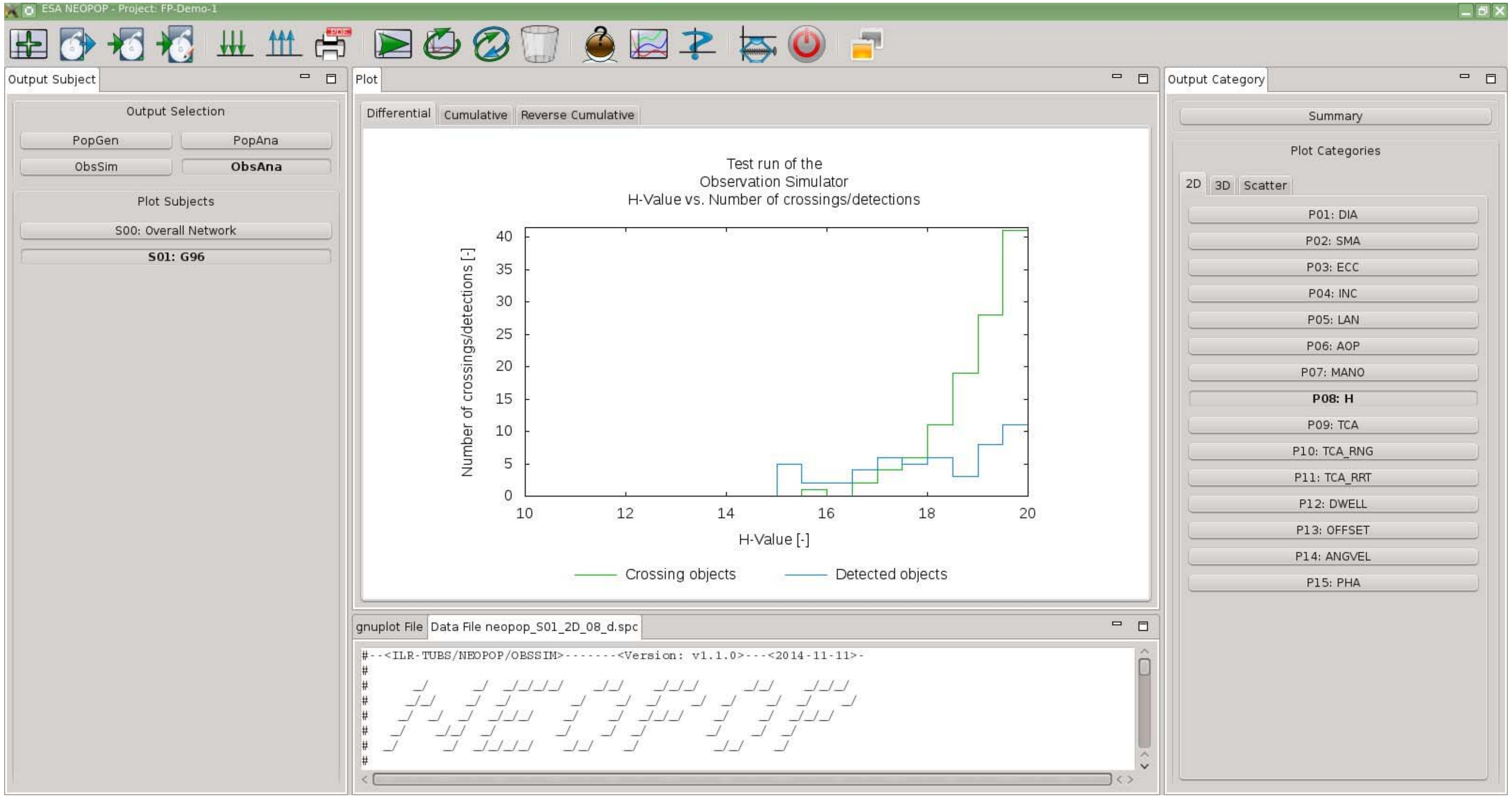
NEOPOP Demonstration
Backup 28



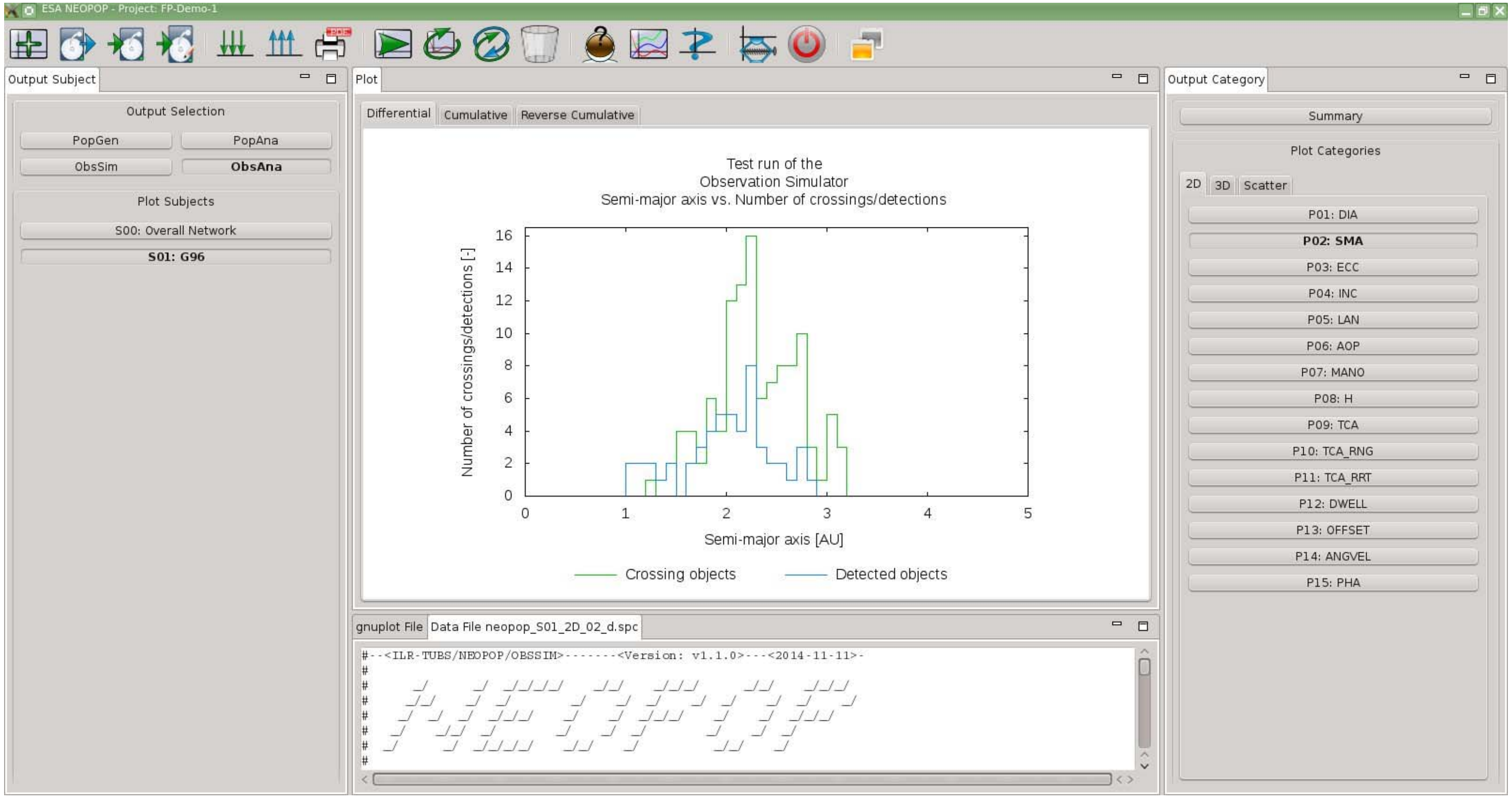
NEOPOP Demonstration
Backup 29



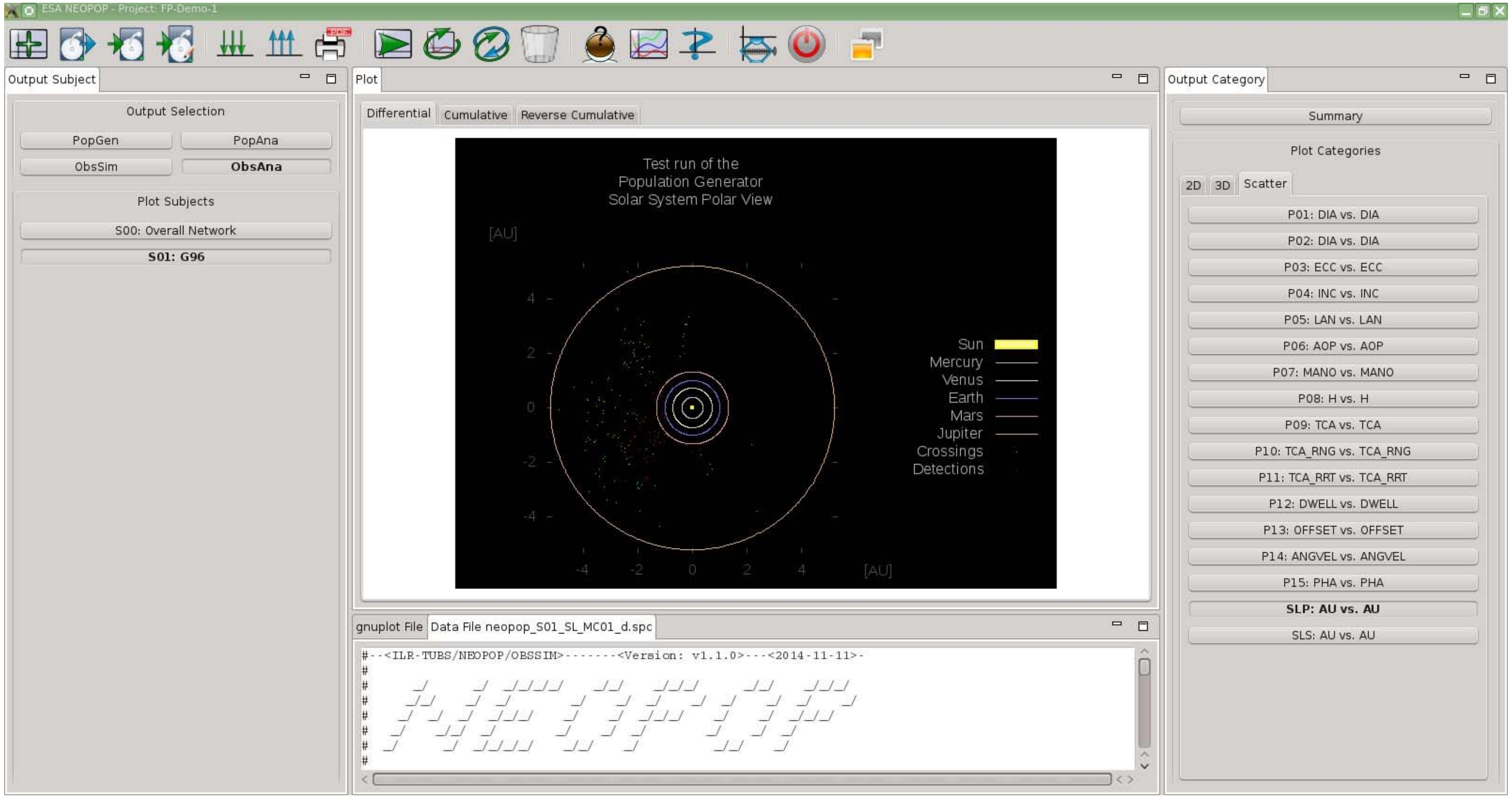
NEOPOP Demonstration
Backup 30



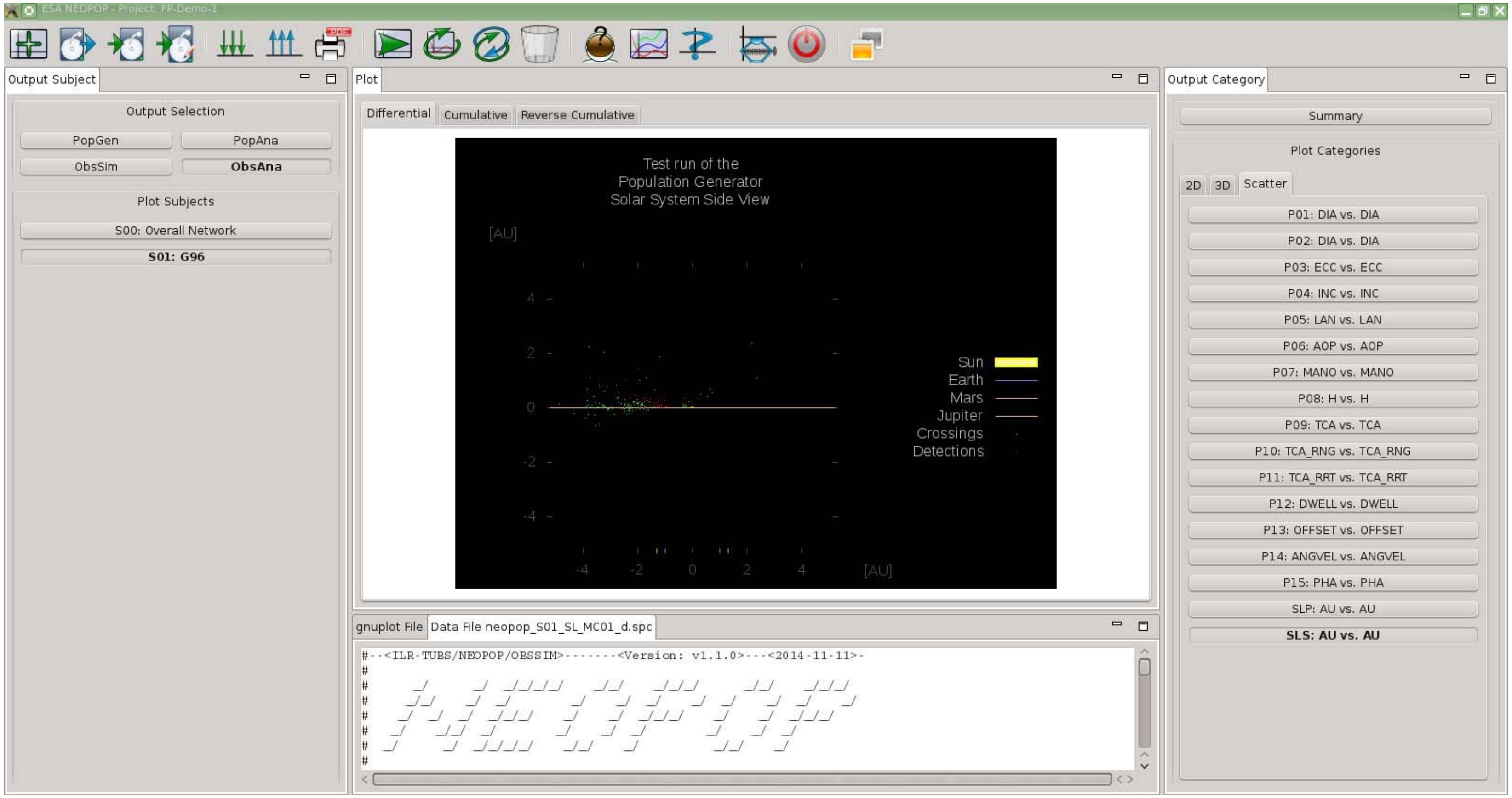
NEOPOP Demonstration
Backup 31



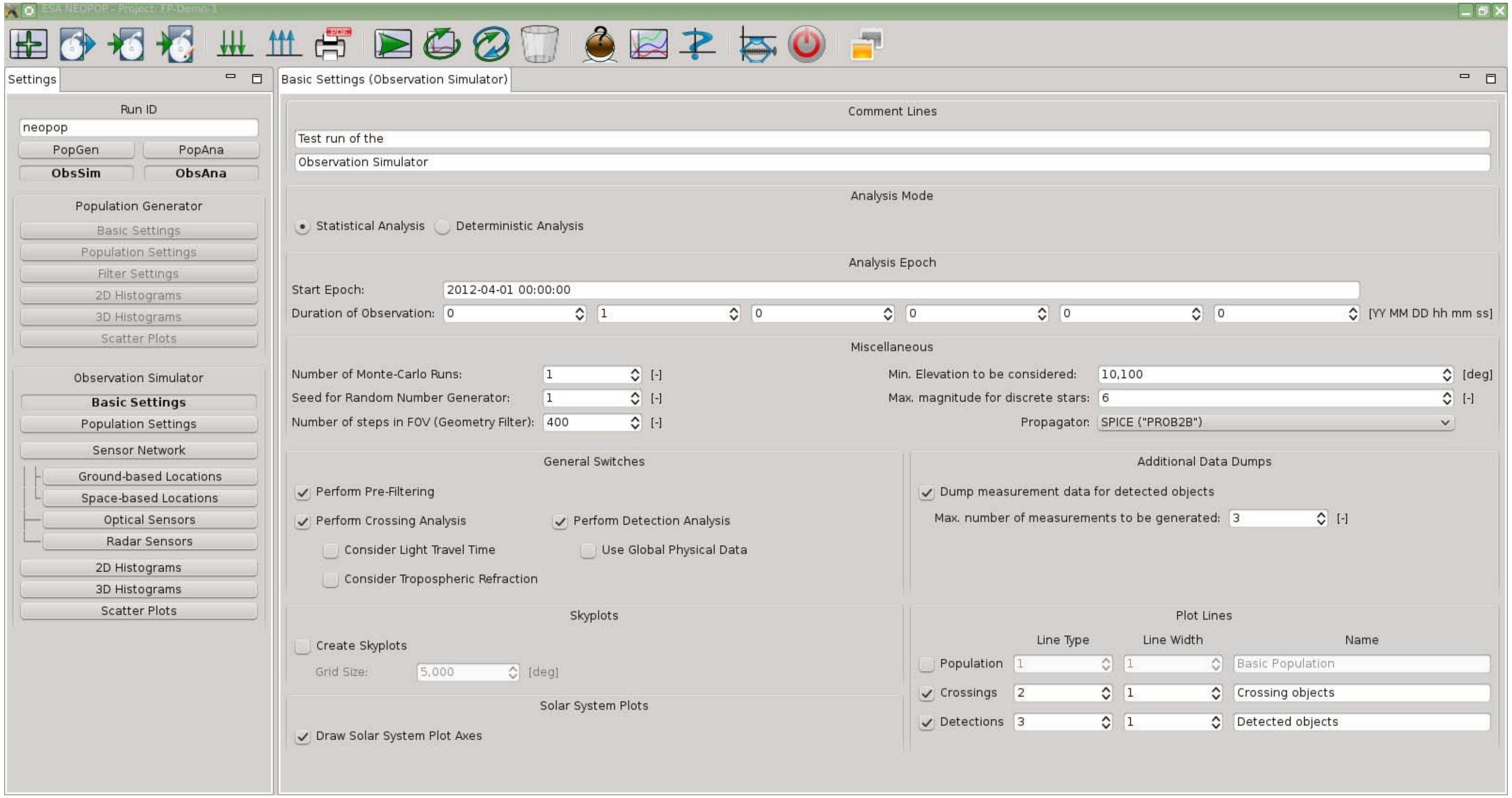
NEOPOP Demonstration
Backup 32



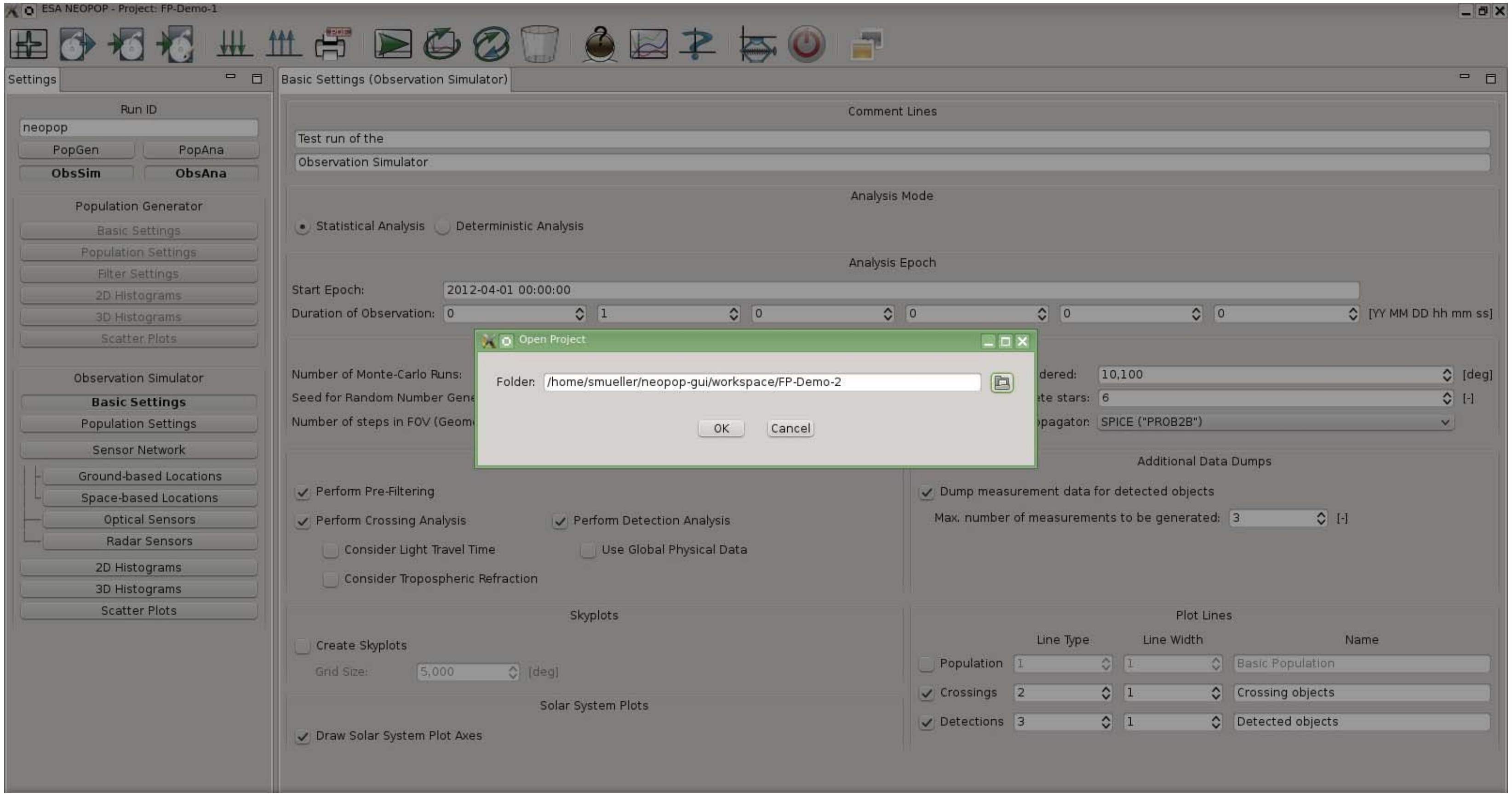
NEOPOP Demonstration
Backup 33



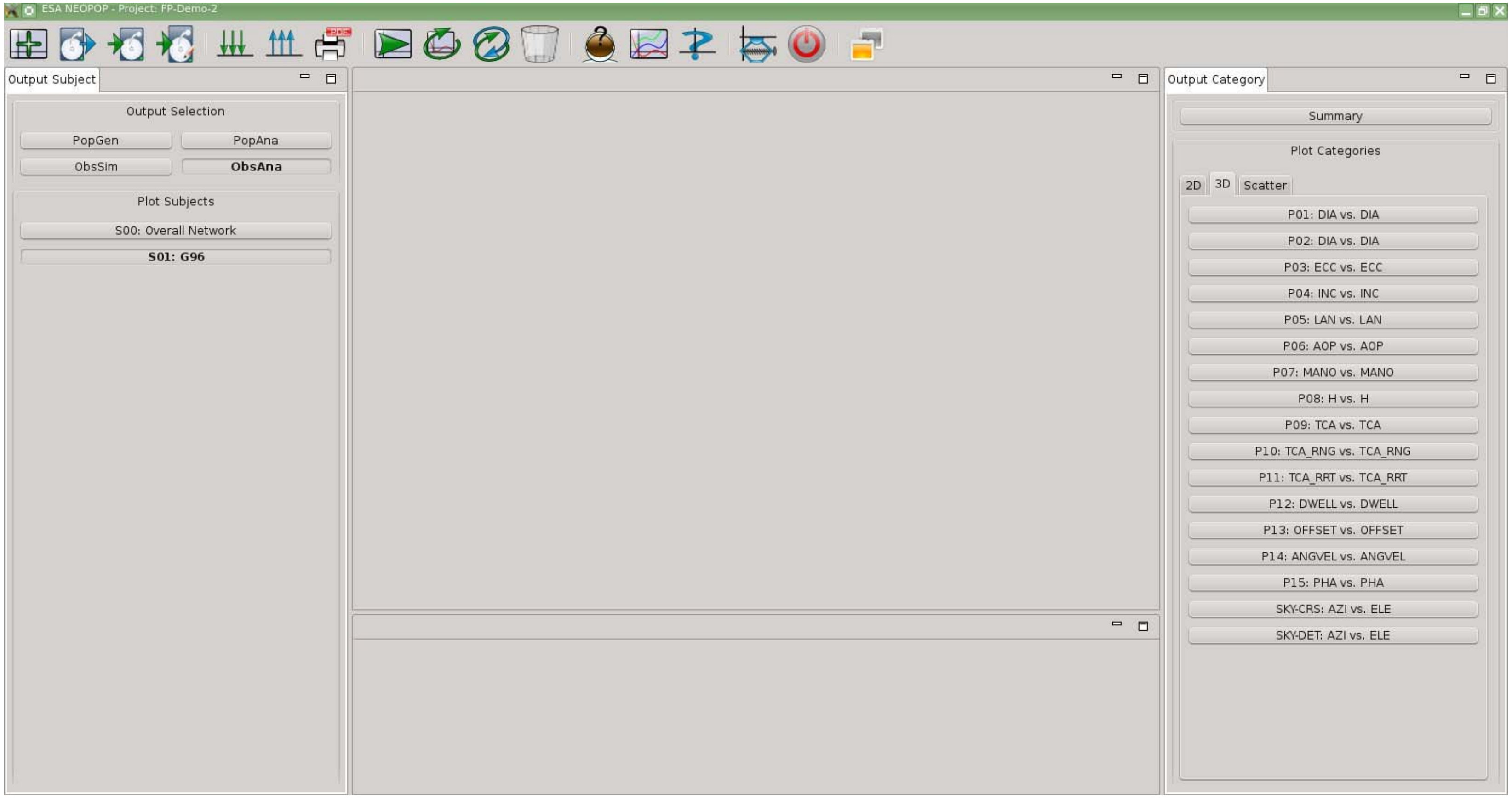
NEOPOP Demonstration
Backup 34



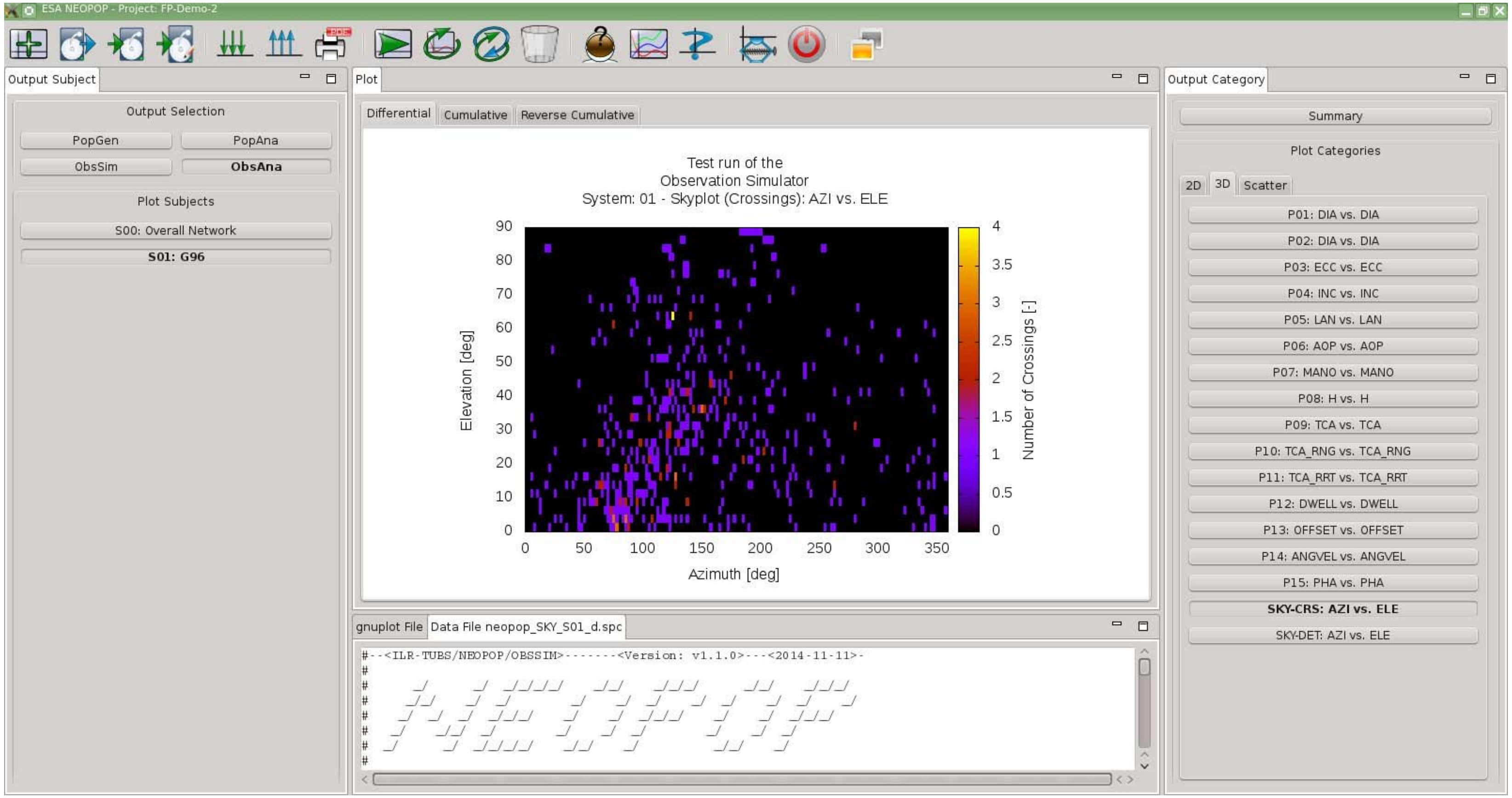
NEOPOP Demonstration
Backup 35



NEOPOP Demonstration
Backup 36



NEOPOP Demonstration
Backup 37



NEOPOP Demonstration
Backup 38