NEO absolute magnitudes with H, G_1, G_2 photometric function

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Background

- The lightcurve-corrected photometric observations of asteroids at different phase angles are used to predict the *H*-parameter, the absolute magnitude of an asteroid at backscattering
- The absolute magnitude links to asteroid size estimation via

$$\log_{10} D = 3.1236 - 0.2\, H - 0.5 \log_{10} p_V$$

  where *D* is the asteroids' diameter and p_V the albedo
- Errors in estimating *H* will propagate to errors in *D*
- The *HG* photometric function was adopted in 1985 by IAU
  - One parameter *G* controlling the shape of the reduced magnitude curve as a function of the phase angle
  - For cases with low number of data points, especially close to opposition, version where *G* is fixed to 0.15 is often used.

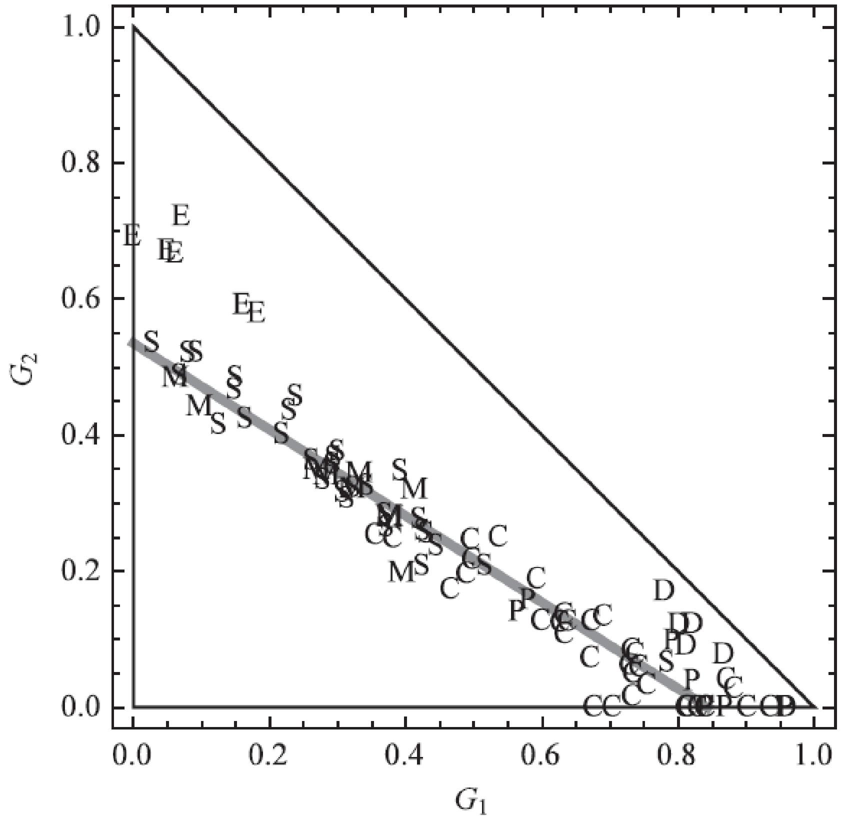
...background

- In 2012 IAU adopted the *HG1G2* function for fitting magnitude-phase relation
  - Improved flexibility close to opposition with three base functions instead of two as in *HG*-function
  - Base functions defined as splines
  - One more parameter
  - Systematic use in, e.g., Minor Planet Center not done (?)
- Due to increased demands towards data, also a two-parameter version(s) of *HG1G2*, namely the *HG12* (and *HG12**) were introduced

...background

- Linear connection between *G1* and *G2* was seen, except not holding well the E and D-types
- Connection parametrized as single parameter *G12*

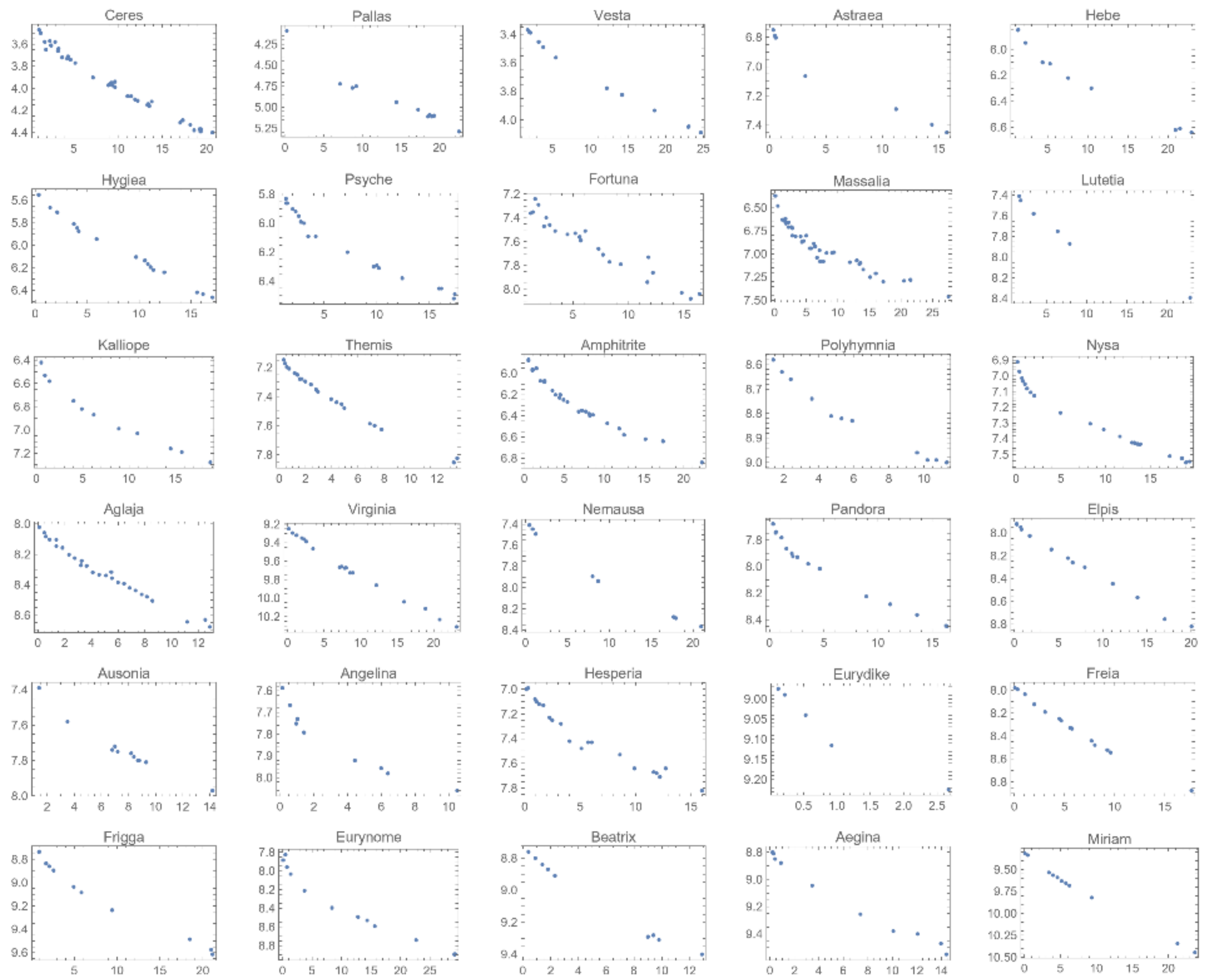
- Main question: what function should one use in predicting absolute magnitude *H*?



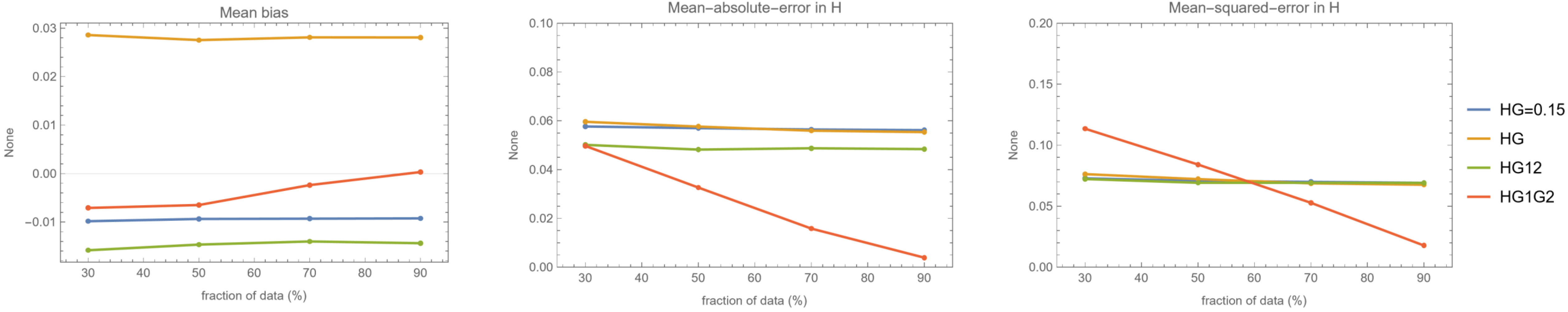
From Penttilä et al. (2016), Planetary and Space Science123

Simulation study

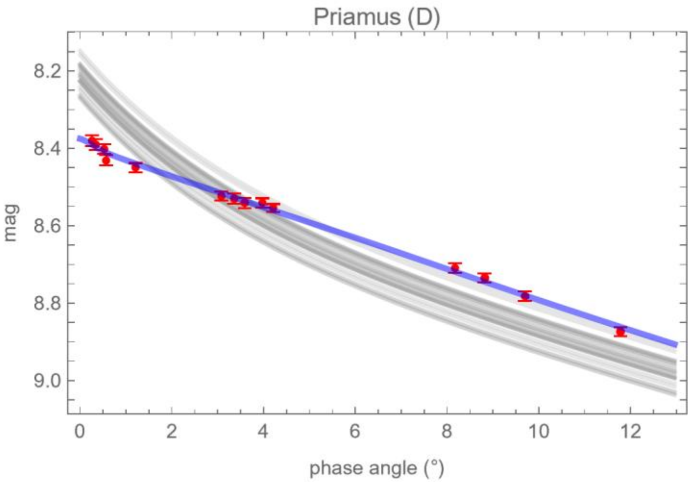
- Let's take the well-curated photometric data of 93 asteroids that was used in deriving the *HG1G2* system and do a simulation test
  - Predict the absolute magnitude *H* with the *HG1G2* function
  - Randomly, drop parts of data and fit using different functions, see the prediction error in *H*
  - Test done leaving 30, 50, 70, or 90 % of observations per asteroid

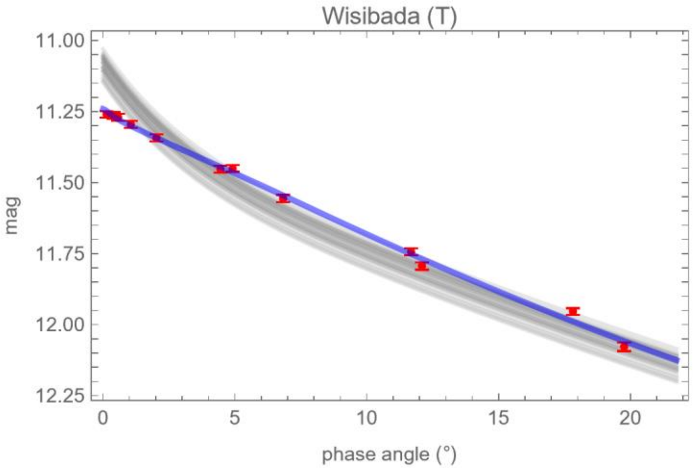


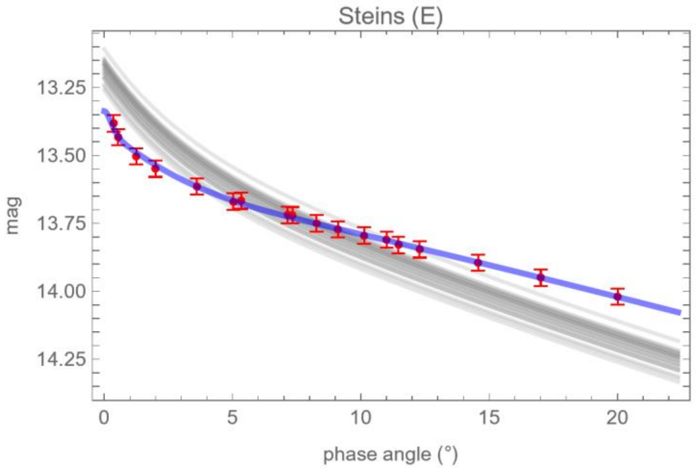
Bias and error in general



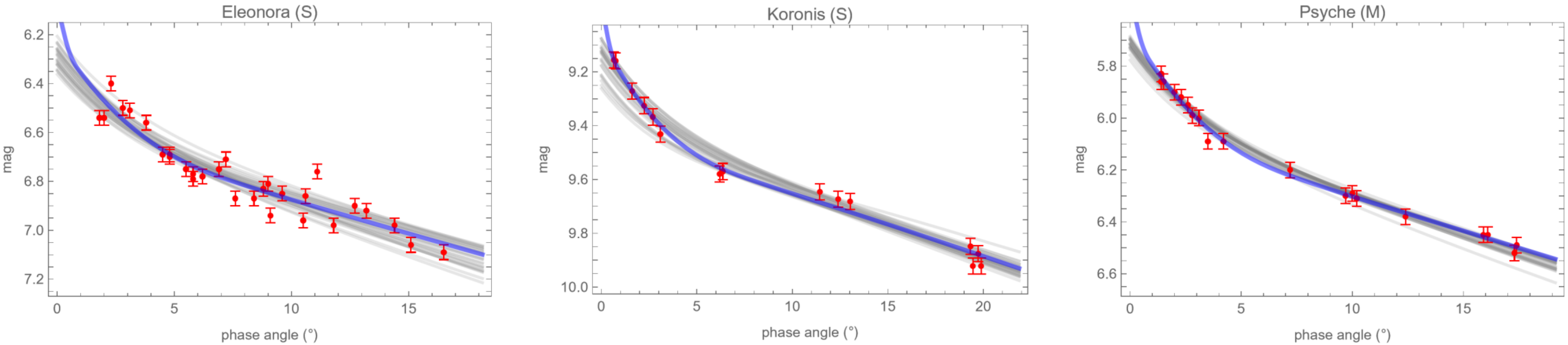
Worst-case predictions, *HG* with fixed *G*=0.15



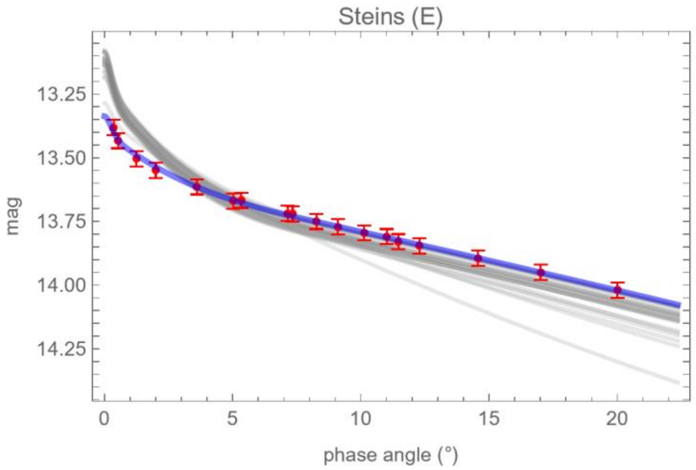


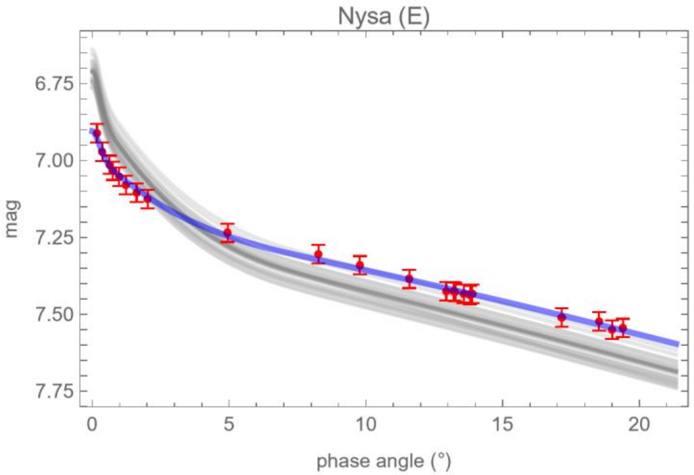


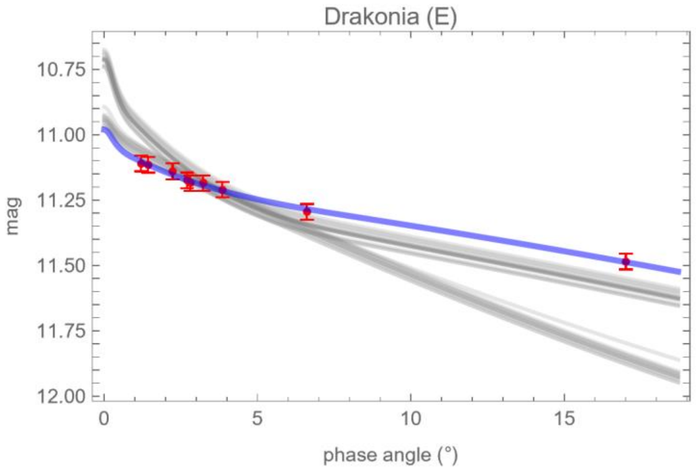
Worst-case predictions, *HG*



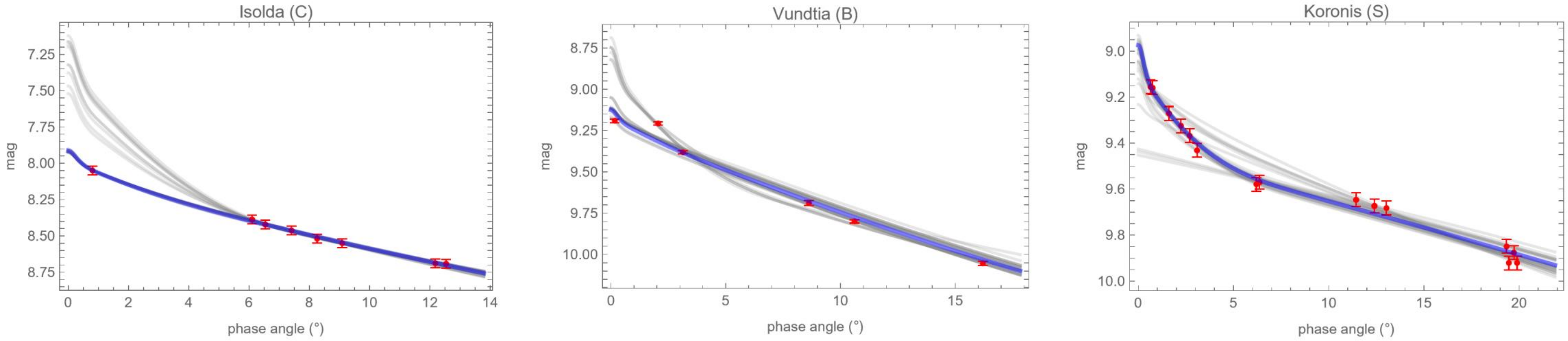
Worst-case predictions, *HG12*



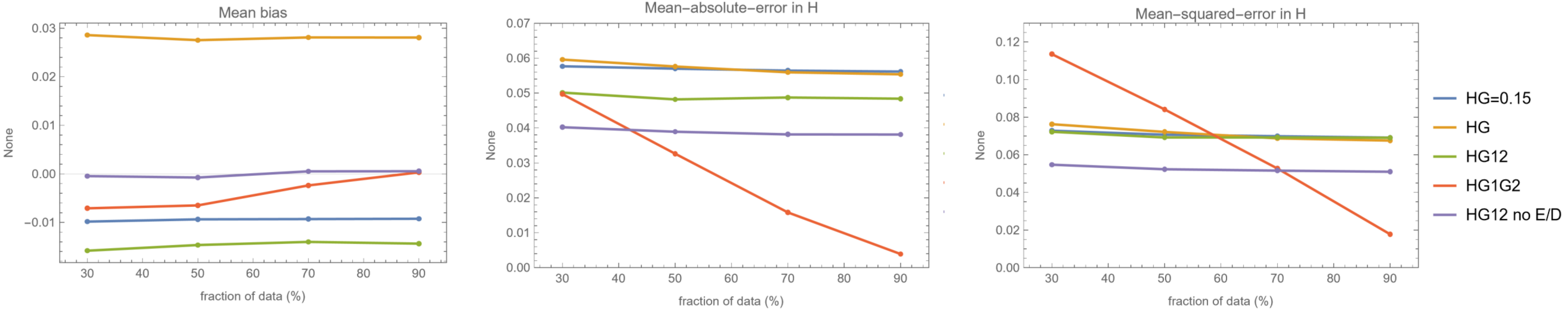




Worst-case predictions, *HG1G2*



Bias and error in general, with HG12 without E and D types



Solution

- My take on the proposed solution has two methods:
  1. Test *HG1G2*-based systems with different number of parameters, select the best for the data based on BIC or similar model selection parameter
     - See https://psr.it.helsinki.fi/HG1G2/

Online calculator for H,G_1,G_2 photometric system

Version 2022.09

You can download the example file with (44) Nysa observations for testing this tool. The linear, unconstrained version implements the IAU-adopted system from Muinonen et al. (2010), and the nonlinear, constrained version the extension from Penttilä et al. (2016). For local copies of the articles, see http://wiki.helsinki.fi/display/PSR/HG1G2+tools. Please cite if you publish results using this tool.

Inputs

Choose File 44_Nysa.dat

Name: unknown

Angles in ◉ degrees ○ radians

Input ready

23 values read for target 'unknown'

angle(°)	magnitude	error
0.17	6.911	0.03
0.36	6.972	0.03
0.63	7.014	0.03
0.75	7.033	0.03
0.98	7.052	0.03
1.23	7.08	0.03
1.62	7.105	0.03
2.02	7.126	0.03
4.95	7.235	0.03
8.27	7.304	0.03
9.78	7.341	0.03
11.59	7.385	0.03
12.94	7.425	0.03
13.2	7.426	0.03
13.27	7.427	0.03
13.58	7.433	0.03
13.81	7.437	0.03
13.89	7.434	0.03
17.16	7.511	0.03
18.52	7.524	0.03
19	7.551	0.03
19.4	7.545	0.03
21.47	7.599	0.03

Compute

○ Linear, unconstrained fit

◉ Nonlinear, constrained fit

Compute fit

H,G_1,G_2 and H,G_{12} **nonlinear** and **constrained** fits are done in magnitude values. One-parameter *H* fits always in magnitude values.

The recommended model, according to BIC-value of the fit, is the three-parameter (H,G_1,G_2) model:

H	G_1	G_2	k (°)$^{-1}$	wRMS	BIC
6.9044	0.04988	0.6716	-0.01161	0.05001	-128.4

The one-dimensional models suggest that the target 'unknown' is best explained as **E**-type.

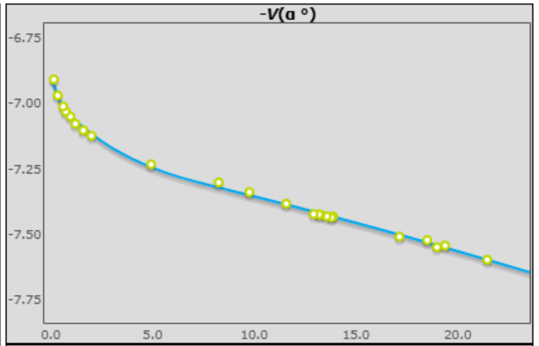
All models in BIC-recommended order:

type	H	G_1	G_2	k (°)$^{-1}$	wRMS	ΔBIC
◉ H,G_1,G_2	6.9044	0.04988	0.6716	-0.01161	0.05001	0.000
○ $H(E)$	6.9036	0.1505	0.6005	-0.01468	0.08380	17.48
○ H,G_{12}	6.6947	0.000	0.5324	-0.01000	0.5364	106.0
○ $H(S/M)$	6.7201	0.2588	0.3721	-0.01957	0.6128	109.0
○ $H(D)$	6.8797	0.9617	0.01645	-0.03294	0.6530	111.9
○ $H(P)$	6.8142	0.8343	0.04887	-0.03204	0.7354	117.4
○ $H(C)$	6.7670	0.8228	0.01938	-0.03280	0.8569	124.4

Plot, errors, report

Errors for selected model

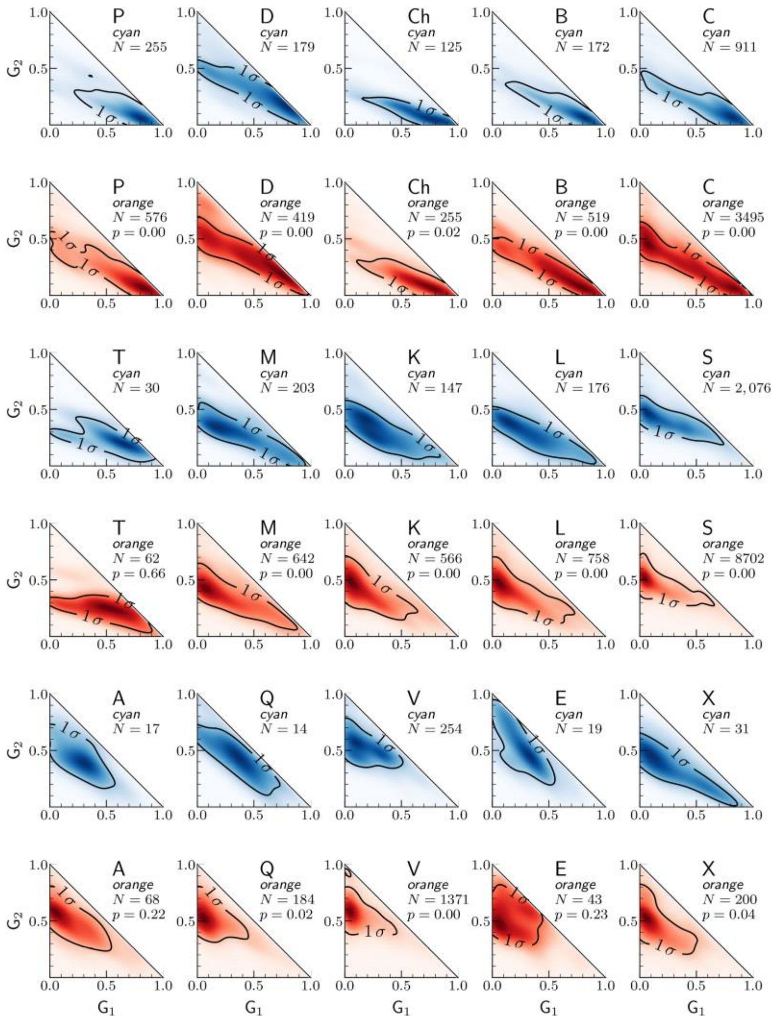
Give fit report



Fit error log window

Solution

1. Have the known distribution of *G1*,*G2* values as *a priori* distribution for MCMC fit of the *HG1G2* function
   - Note: talk by student of M. Devogele (?) at ACM 2023



From Mahlke et al. (2021), Icarus 354