Deliverable

H2020 COMPET-05-2015 project
"Small Bodies: Near And Far (SBNAF)"

Topic: COMPET-05-2015 - Scientific exploitation of astrophysics, comets, and planetary data
Project Title: Small Bodies Near and Far (SBNAF)
Proposal No: 687378 - SBNAF - RIA
Duration: Apr 1, 2016 - Mar 31, 2019

WP	WP3 Lightcurve inversion technique
Del.No	D3.6
Title	Joint multi-data inversion models
Lead Beneficiary	UAM
Type	Websites, patents filling, etc.
Dissemination Level	Public
Est. Del. Date	31 Mar 2019
Version	1.0
Date	31 Mar 2019
Lead Author	Bartczak, P.,UAM (przebar@amu.edu.pl)

WP3 Lightcurve Inversion techniques
Objectives: WP3 has the main objective to join various types of data for full physical models of benchmark asteroids and to develop the web service with a database in order to provide the models to the community.
Deliverable 3.6: Joint multi-data inversion models
Objectives: , ISAM (Inter-active Service for Asteroid Models) service upgrade.

# Description of deliverable

1   ISAM service

The service ISAM was developed in LAMP (Linux, Apache, MySQL, PHP) technology. It works on a Debian GNU / Linux 6.0 operating system. The management of the www sites is done with Apache ver.2, while the site is based on the PHP 5.0 language and HTML forms with the addition of JavaScript. The PHP code works with the programmes written in C++ language. The C++ codes use the "z-buffer" algorithm to plot the asteroid orientation and return "png" type images. In both modifying the images and creating animations and the three-dimensional (3D) effects, the functions "convert" and "composite" from the Image Magick package are used. Data on the asteroid models and their orbital parameters are stored in the MySQL database.

For a selected model the service's functions make it possible to:

- generate exact sky projections necessary for size determination from stellar occultation observations,

- create synthetic lightcurves,

- animate model's rotation while simultaneously simulating its lightcurve,

- create 3D images in various stereoscopic techniques.

The ISAM service contains 3122 models for 1618 asteroids.

Aside from its scientific utility, ISAM service is a great tool for popularising science.
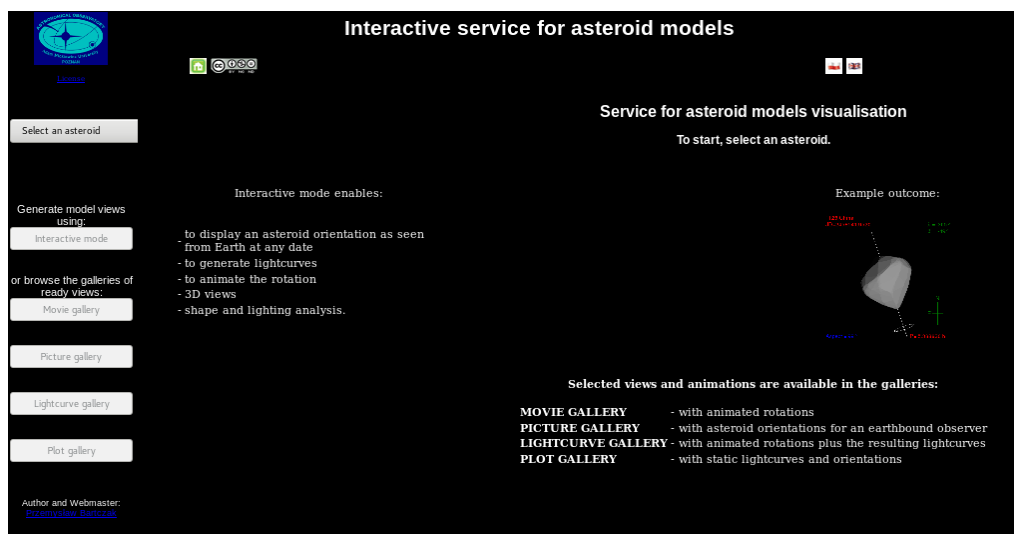
2 ISAM service upgrade

The possibility of presenting additional data to the ISAM website has been added:

2.1 Triangle mesh

Added link to download the data on the shape of asteroids:

The shape of the asteroid saved in a format OBJ containing additional physical parameters information in the header of the file:

```
#target: 6
#method: Inversion Techniques (KOALA model)
#period[h]: 7.27446719
#lambda: 345.9
#beta: 51.7
#gamma: 0
#jd_gamma0: 2434569
#number_of_vertices: 258
#number_of_facets: 512

v 0 0 90.506302
v 17.379325 0 87.371766
v 0 18.316009 92.080794
v -17.506598 0 88.011611
v -0 -17.53026 88.130567
v 33.30997 0 80.417382
v 24.962794 24.962794 85.22831
v 0 37.611165 90.801384
v -26.170257 26.170257 89.350847
v -33.68527 0 81.323436
v -23.529441 -23.529441 80.334536
v -0 -35.30716 85.239024
v 24.205185 -24.205185 82.641672
v 48.408473 0 72.4484
v 43.870117 25.328424 75.813331
v 26.959653 46.695489 80.695945
v 0 56.448631 84.481346
v -28.556493 49.461296 85.475623
v -46.518611 26.857533 80.390276
v -48.788107 0 73.016562
v -40.687163 -23.490745 70.312767
v -25.062073 -43.408784 75.016086
```

File OBJ is availabe for all models of asteroids in ISAM service and contain the necessary information for running typical codes to predict lightcurves and also to do thermophysical studies.

2.2   Asteroid occultations
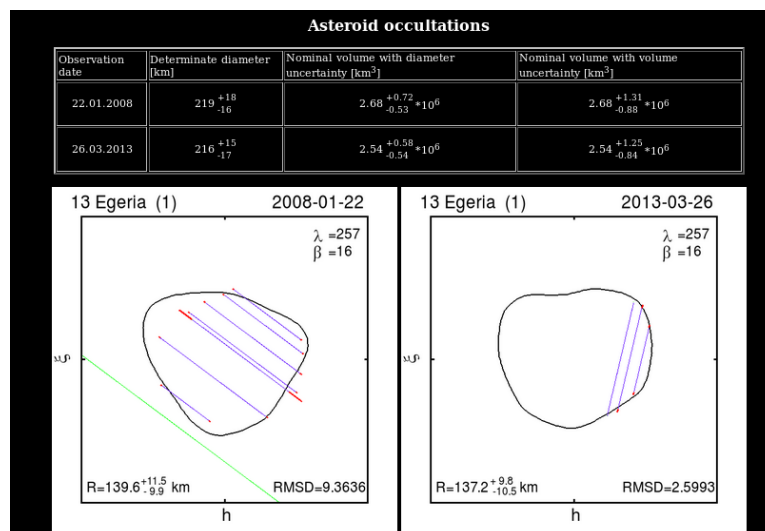
Added link to download the data on asteroid occultations:
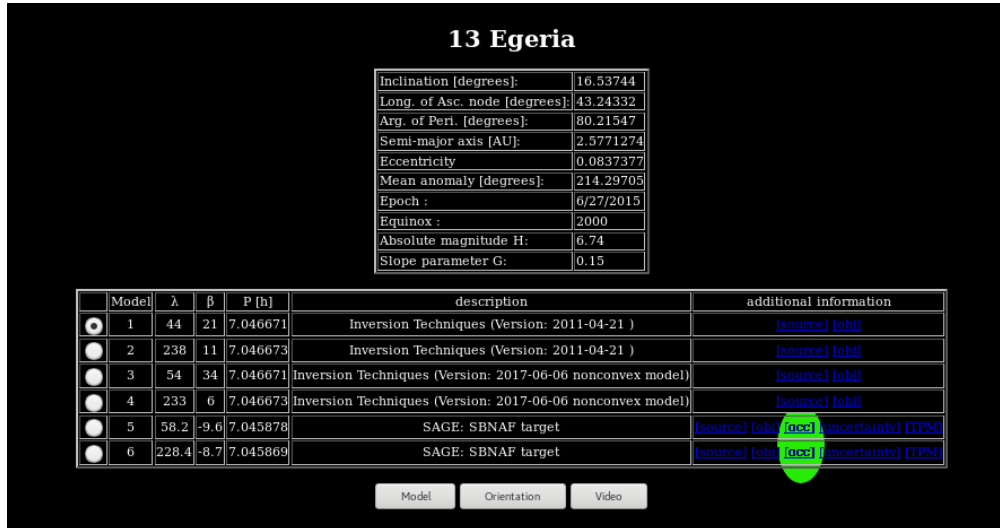
The subpage contains:

- information about the size and volume determined with uncertainty:

  - observation date,
  - determinate equivalent diameter with uncertainty,
  - nominal volume respect only diameter uncertainty,
  - nominal volume respect diameter and volume uncertainty.

- pictures with size determination results.

2.3   Uncertainty of physical parameters

Added link to download the data on uncentainty of physical parameters:

13 Egeria

Inclination [degrees]:	16.53744
Long. of Asc. node [degrees]:	43.24332
Arg. of Peri. [degrees]:	80.21547
Semi-major axis [AU]:	2.5771274
Eccentricity	0.0837377
Mean anomaly [degrees]:	214.29705
Epoch :	6/27/2015
Equinox :	2000
Absolute magnitude H:	6.74
Slope parameter G:	0.15

	Model	λ	β	P [h]	description	additional information
●	1	44	21	7.046671	Inversion Techniques (Version: 2011-04-21)	[source] [obj]
○	2	238	11	7.046673	Inversion Techniques (Version: 2011-04-21)	[source] [obj]
○	3	54	34	7.046671	Inversion Techniques (Version: 2017-06-06 nonconvex model)	[source] [obj]
○	4	233	6	7.046673	Inversion Techniques (Version: 2017-06-06 nonconvex model)	[source] [obj]
○	5	58.2	-9.6	7.045878	SAGE: SBNAF target	[source] [obj] [spc] [uncertainty] [Text]
○	6	228.4	-8.7	7.045869	SAGE: SBNAF target	[source] [obj] [spc] [uncertainty] [Text]

Model   Orientation   Video

The subpage constains informations about uncertainty of physical parameters:

- volume (normalizing the maximum length of the vertex to unit),

- rotation period,

- initial rotation angle,

- orientation of spin axis.

14 Egeria

model 5

Model uncertainty

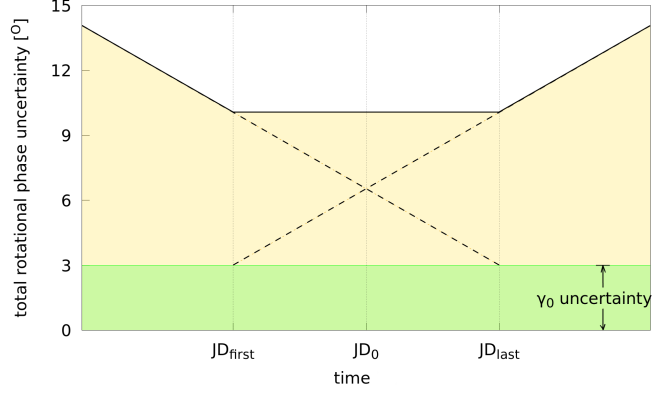| Physical parameter of model	Value and uncertainty	
Volume (R_{max}=1)	$2.03081958_{-33\%}^{+49\%}$	
Period	$7.045876_{-0.000010}^{+0.000008}$	h
Rotation phase γ	62_{-14}^{+12}	deg
Epoch	2447890.369635	JD
ΔT	17730.683	day
Pole solution	(λ) 58.2_{-10}^{+5} (β) -9.6_{-10}^{+22}	deg

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Figure 1: The plot of total rotation phase uncertainty. In this example $\Delta T_{obs} = 38.5$ years, the uncertainty of rotation phase for reference epoch JD_0 is $u(\gamma_0) = 3°$ and the period uncertainty $u(P) = 1.5 \times 10^{-6}\ h$.

The rotation phase on the given date t is calculated from the formula

$$\gamma = \gamma_0 + \frac{2\pi}{P'}\Delta t$$

and uncertainty of rotational phase:

$$u(\gamma) = \frac{2\pi}{(P')^2}\left[a + b + max(-a + b, 0)\right] + u(\gamma_0),$$
$$a = |u(P')\Delta t|,$$
$$b = \frac{1}{2}u(P')\Delta T_{obs}$$

where:

P' is a rotational period in day $P' = P[h]/24$,

γ is a rotational phase,

γ_0 is a rotational phase for reference epoch JD_0,

$\Delta T_{obs} = JD_{last} - JD_{first}$ is an observations' time span,

$\Delta t = t - JD_0$ is a distance in time from the reference epoch,

$u(x)$ denotes uncertainty of x.

The max function returns larger of the two arguments.

An example plot of this function is shown in Fig. 1.

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2.4 Thermophysical model

Added link to download the data on thermophysical model of asteroid:

The subpage include summary of TPM results:

- the number of IR data modelled,

- TLC (Yes/No) refers to the presence of at least one thermal light curve with eigth or more points sampling the rotation period,

- the minimum reduced chi-squared,

- the best-fitting diameter (D) and corresponding 1σ statistical error bars,

- the chi-squared obtained for a spherical model with the same spin properties.
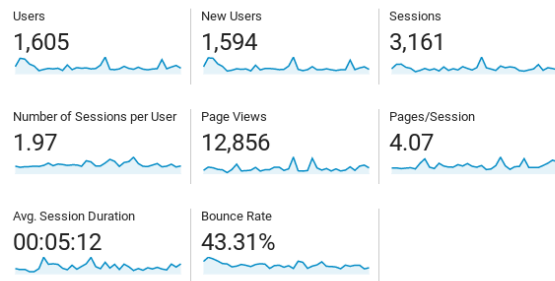
3 Asteroid with additional information

The ISAM service contains information on 29 asteroid models with additional parameters determined.

asteroid	uncertainty	occultations	thermophysical
(3) Juno	YES	YES	YES
(9) Metis	YES	YES	NO
(13) Egeria	YES	YES	YES
(13) Egeria	YES	YES	YES
(14) Irene	YES	YES	YES
(14) Irene	YES	YES	YES
(20) Massalia	YES	YES	YES
(20) Massalia	YES	YES	YES
(64) Angelina	YES	YES	YES
(64) Angelina	YES	YES	YES
(68) Leto	YES	YES	YES
(68) Leto	YES	YES	YES
(89) Julia	YES	YES	YES
(145) Adeona	YES	YES	YES
(145) Adeona	YES	YES	YES
(297) Caecilia	YES	NO	YES
(297) Caecilia	YES	NO	YES
(308) Polyxo	YES	YES	YES
(308) Polyxo	YES	YES	YES
(381) Myrrha	YES	YES	YES
(433) Eros	YES	NO	NO
(441) Bathilde	YES	YES	YES
(441) Bathilde	YES	YES	YES
(654) Zelinda	YES	NO	YES
(654) Zelinda	YES	NO	YES
(704) Interamnia	YES	YES	YES
(704) Interamnia	YES	YES	YES
(721) Tabora	YES	NO	YES
(721) Tabora	YES	NO	YES

4 Statistics of using the ISAM service

The source of all statistical data is Google Analytics.
Statistics form 1 April 2016 to 31 March 2019.

4.1 Users and sessions

Users	New Users	Sessions
1,605	1,594	3,161

Number of Sessions per User	Page Views	Pages/Session
1.97	12,856	4.07

Avg. Session Duration	Bounce Rate
00:05:12	43.31%
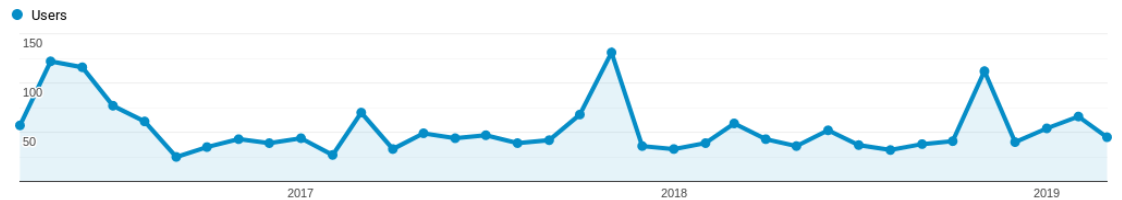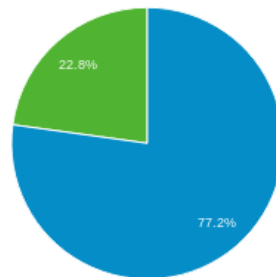
	Language	Users	% Users	
1.	en-us	425		40.40%
2.	ja-jp	127		12.07%
3.	pl	114		10.84%
4.	pl-pl	48		4.56%
5.	en-gb	43		4.09%
6.	de	28		2.66%
7.	es-es	26		2.47%
8.	fr	25		2.38%
9.	es	22		2.09%
10.	zh-cn	16		1.52%

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4.2 Connections to the ISAM service (World)
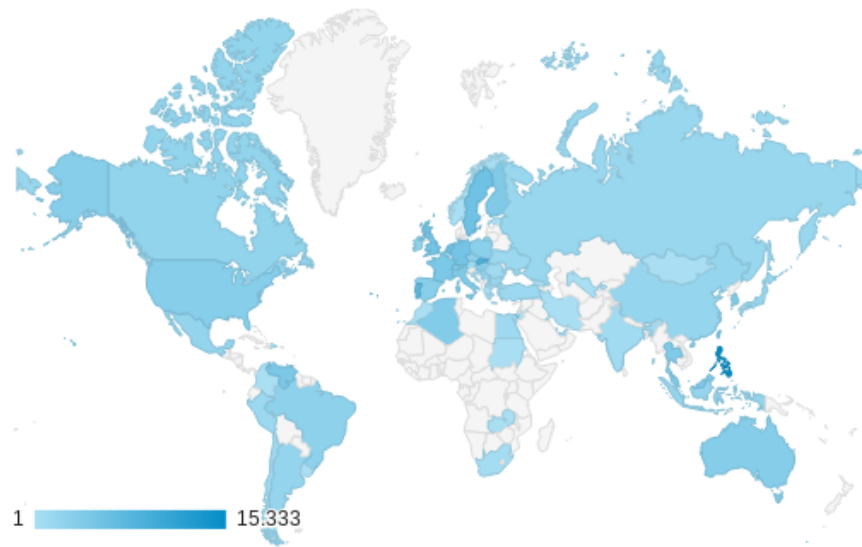
Continent	New Users ⌄ ↓	New Users
	1,599 % of Total: 100.31% (1,594)	1,599 % of Total: 100.31% (1,594)
1. ■ Europe	821	51.34%
2. ■ Americas	357	22.33%
3. ■ Asia	327	20.45%
4. ■ Oceania	34	2.13%
5. ■ Africa	32	2.00%
6. ■ (not set)	28	1.75%

Top 10 countries:

Country	New Users	New Users	contribution to total: New Users
	1,600 % of Total: 100.31% (1,595)	1,600 % of Total: 100.31% (1,595)	
1. 🇺🇸 United States	292	18.25%	
2. 🇬🇧 United Kingdom	246	15.38%	
3. 🇵🇱 Poland	212	13.25%	
4. 🇯🇵 Japan	195	12.19%	
5. 🇩🇪 Germany	99	6.19%	
6. 🇪🇸 Spain	63	3.94%	
7. 🇮🇹 Italy	37	2.31%	
8. 🇦🇺 Australia	34	2.12%	
9. 🇫🇷 France	32	2.00%	
10. 🇲🇾 Malaysia	29	1.81%	
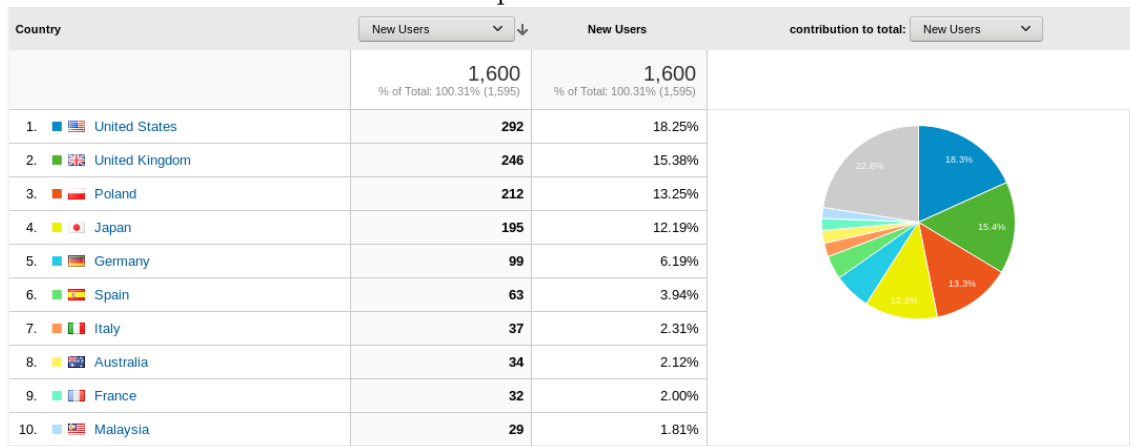
Top 10 cities:

City	Users	% Users
1. Poznan	120	10.86%
2. Ota	115	10.41%
3. Madison	92	8.33%
4. (not set)	49	4.43%
5. Garching	45	4.07%
6. Cardiff	35	3.17%
7. Warsaw	22	1.99%
8. Kedah	16	1.45%
9. Wroclaw	15	1.36%
10. Kuala Lumpur	14	1.27%

4.3   Connections to the ISAM service (Europe)

Sub Continent	New Users	New Users
	821 % of Total: 51.51% (1,594)	821 % of Total: 51.51% (1,594)
1. ■ Southern Europe	110	13.40%
2. ■ Eastern Europe	278	33.86%
3. ■ Northern Europe	264	32.16%
4. ■ Western Europe	169	20.58%
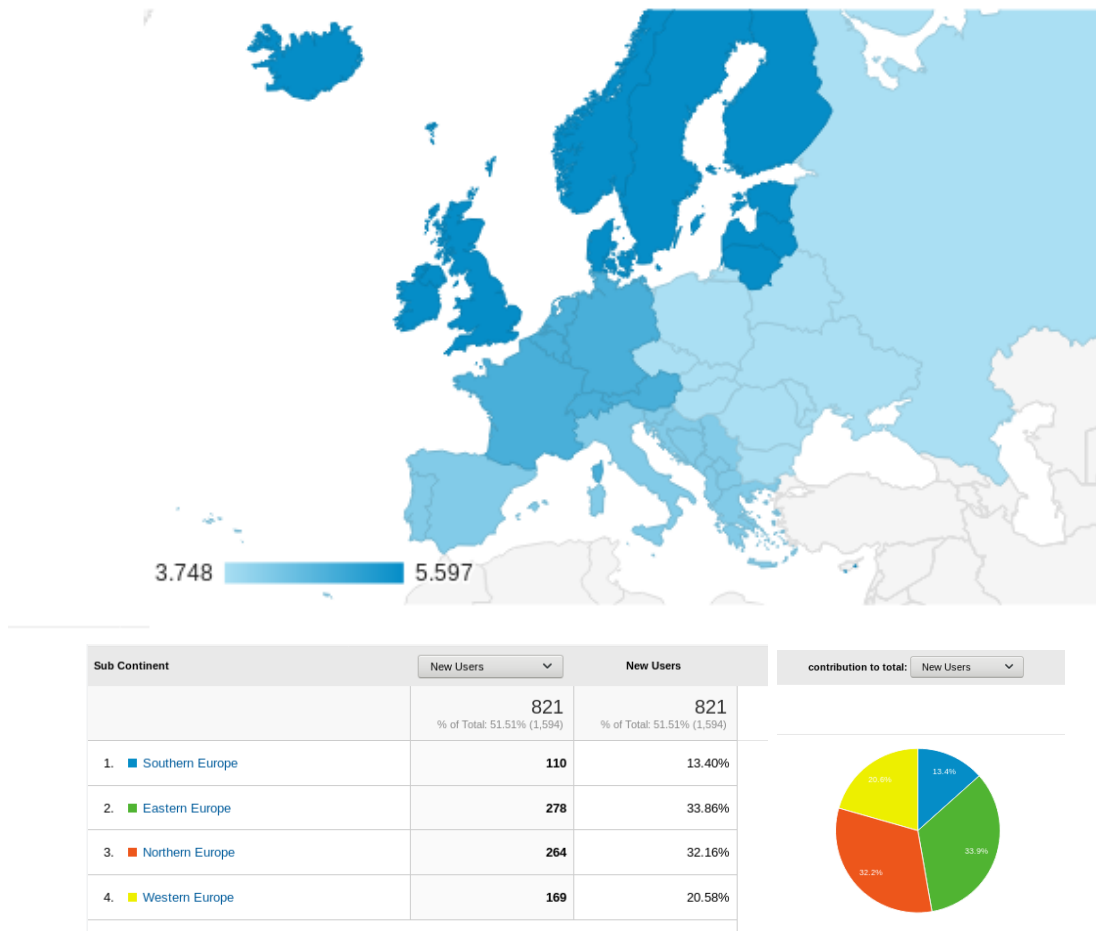
Top 10 countries:

	Country	New Users	New Users
		821 % of Total: 51.51% (1,594)	821 % of Total: 51.51% (1,594)
1.	United Kingdom	246	29.96%
2.	Poland	212	25.82%
3.	Germany	99	12.06%
4.	Spain	62	7.55%
5.	Italy	37	4.51%
6.	France	32	3.90%
7.	Czechia	20	2.44%
8.	Belgium	17	2.07%
9.	Russia	15	1.83%
10.	Switzerland	12	1.46%

5 Future: Near and Far

Maintenance of the ISAM website is paid by Adam Mickiewicz University which guarantees continuous access to the website. With the development of inversion techniques, the website will be adapted to the challenges. The website is and will be open to sharing created models from various observation techniques. All contact details (technical, scientific) are available on the home page of the website.