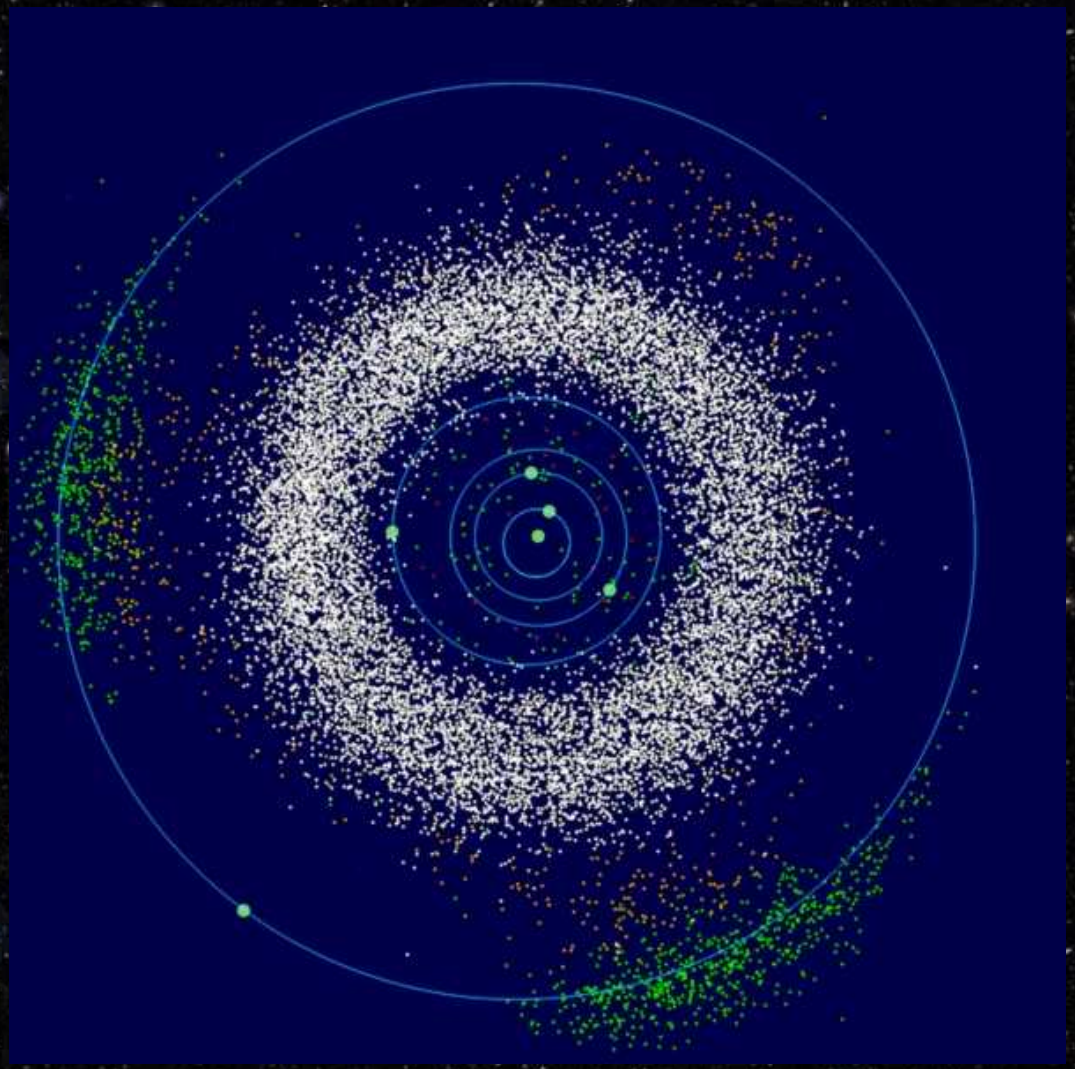
My successful EURONEAR collaboration with students and amateur astronomers

Ovidiu Vaduvescu
and the EURONEAR team

IMC2012
International Meteor Conference

La Palma, Canary Islands
20-23 Sep 2012

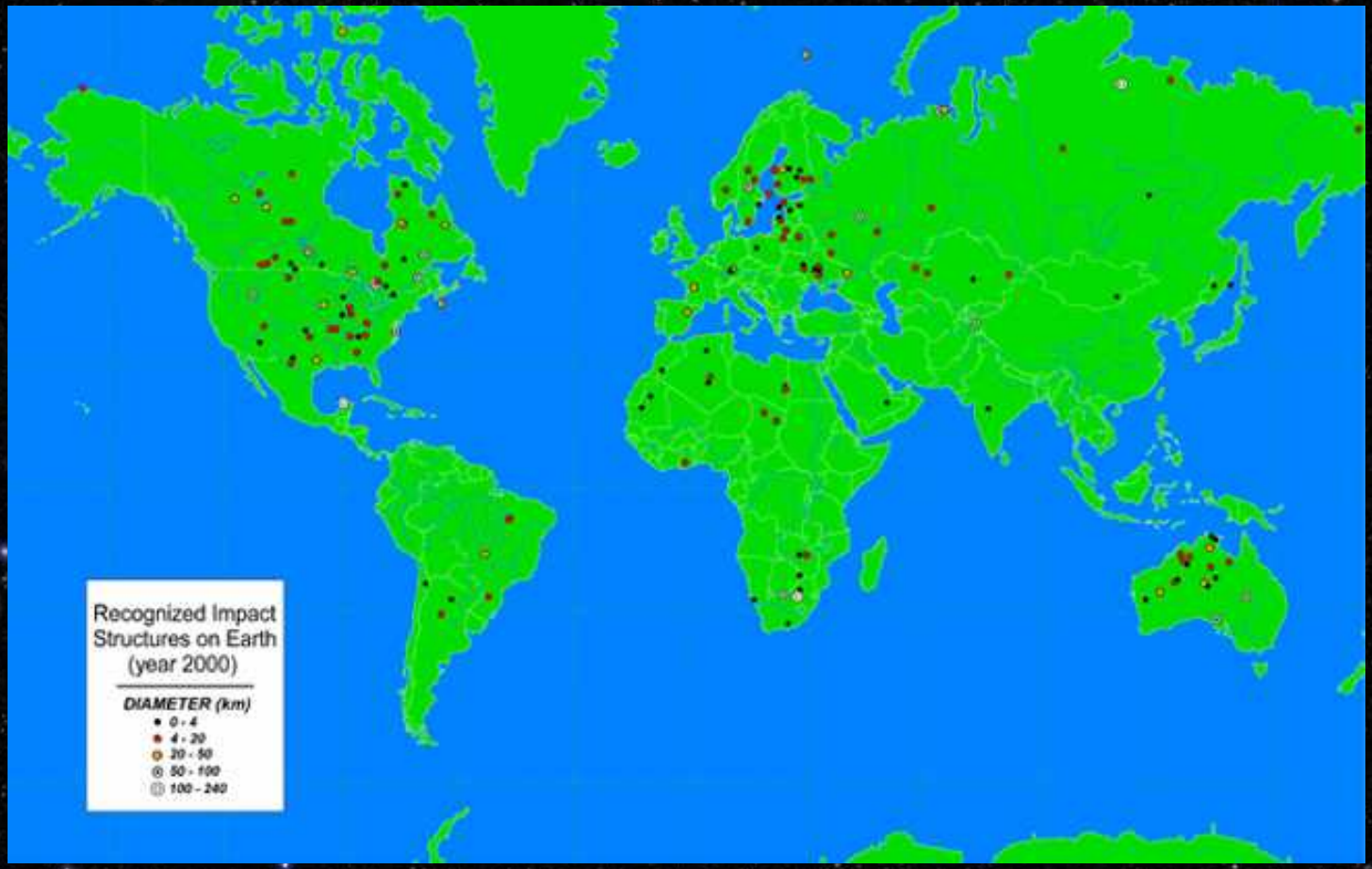
Introduction



1801:
G. Piazzi
discovers
(1) Ceres

Sep 2012:
580.000+
known asteroids!
(Bowell, 2012)

Why Near Earth Asteroids?



Earth Impact Database: 160 known craters!
(University of New Brunswick, Canada)

Barringer Meteor Crater, Arizona US
About 50,000 yrs ago

1.2 Km crater
Asteroid ~ 50m diam
E ~ 150x Hyroshima

Carangas, Peru
15th Sep 2007

10m crater
3m meteorite 10T

Few Definitions

MBA = Main Belt Asteroid:
orbits in the main ring between Mars and Jupiter
More than 580,000 MBAs known today (Bowell, 2012);

NEA = Near Earth Asteroid:
Perihelion distance: **q < 1.3 AU** and
aphelion distance**: Q > 0.98 AU** (Morbidelli et. al., 2002)
More than 9,000 known NEAs today (JPL/NASA, 2012);

PHA = Potentially Hazardous Asteroid:
NEAs with **MOID < 0.05 AU** and **H < 22**
(Bowell and Muinonen, 1994)
More than 1,300 PHAs known today (JPL/NASA, 2012);

VI = Virtual Impactor (**~100 objects** – NEODyS, 2011):
PHAs with non-zero future Earth impact probability, acc. To actual orbital uncertainty (Milani and Gronchi, 2009).

Context: the SPACEGUARD project

> Stated in 1994 as an international project and funded mainly by NASA since 1997;

> The original goal: to discover 90% of the entire NEA population > 1km within one decade (1997-2007);

> 5 major U.S. surveys (CSS, LINEAR, Spacewatch, LONEOS, NEAT) using automated 1m class telescopes almost fulfilled this goal;

> Europe's contribution: <1 % in discoveries, few initiatives, no dedicated telescope!

What is EURONEAR?

> EURONEAR = EUROpean Near Earth Asteroid Research

> A project to establish an European coordinated network to contribute at NEAs research: astronomers, students, amateurs from different places via the Internet;

> A project to follow-up, recover and discover NEAs
The Dream: 2 automated telescopes in both hemispheres;

> A project aimed also to education and public outreach;

> Born in May 2006 at IMCCE Paris (Ovidiu Vaduvescu, Mirel Birlan, Francois Colas, Alin Nedelcu).

EURONEAR - Scientific Goals

> Observe NEAs in an optimized fashion;
> Data reduction in an automated pipeline and results reported promptly to Minor Planet Center (MPC).

> Astrometry and orbital improvement:

1) Securing the orbits of newly discovered objects;
2) Follow-up and recovery of NEAs and PHAs in most need of data;
3) Data mining of imaging archives available online;
4) Additionally, EURONEAR is expected to discover many new MBAs and some NEAs.

> Photometry, spectroscopy and polarimetry;

Results: Data mining of imaging archives

Four NEA data-mining projects and papers in collaboration mostly with students and amateurs:

1. EURONEAR: Data mining of asteroids and NEAs:
   > Introducing PRECOVERY server.
   > Application on the Astronomical Observatory Bucharest Plate Archive
   13,000 plates 0.4m refractor, 1930-2005
   > AN, Vaduvescu et. al. 2009, with 2 students and amateurs

2. CFHT Legacy Survey Archive (CFTHLS) MegaCam survey
   > 25,000 MegaCam mosaic CCD images 3.6m, 2003-2009
   > 143 NEAs and PHAs found and reported from 508 images
   > AN, Vaduvescu et. al. 2011, incl 6 students and amateurs)

Results: Data mining of imaging archives (2)

3. Mining the ESO WFI and INT WFC archives. Mega-Precovery.

> 330,000 mosaic CCD images taken with ESO/MPG 2.2m WFI and the ING/INT 2.5m WFC 1998-2009
> 152 NEAs and PHAs found in 761 images reported to MPC
> prolonged orbits for 18 precovered objects and 10 new opposition recoveries

> Introducing Mega-Precovery server and Mega-Archive: 28 instrument archives (ESO, NOAO, etc) including 2.5 million images to query for known NEAs and other asteroids via Mega-Precovery

> AN accepted, Vaduvescu et al. 2012, 13 students/amateurs)

Results: Data mining of imaging archives (3)

4. Data Mining the SuprimeCam Archive for NEAs

> 50,000 SuprimeCam mosaic CCD images taken with Subaru 8.3m telescope (1999-2010)
> 500 known NEAs to be searched for on 2100 candidate images
> Additionally, scanning some 1000 selected SuprimeCam fields for new NEAs to improve the NEA statistics at the faint end
> Poster presented at ACM2012 Japan
> To become a paper 2013, with 14 students and amateurs, including SARM and Valentin Grigore.

Results: Observing runs and EURONEAR Network

Observing NEAs from 5 countries with 15 telescopes:

> Cerro Tololo, Chile - Blanco 4m (June 2011);
> Isaac Newton Group, La Palma - WHT 4.2m (2011);
> Isaac Newton Group, La Palma - INT 2.5m (2009-present);
> La Silla, Chile - ESO/MPG 2.2m with WFI camera (Mar 2008);
> TLS Tautenburg, Germany - Schmidt 2m with CCD (2012);
> Las Campanas Observatory, Chile - Swope 1m (3 runs 2008);
> Cerro Tololo, Chile - Yale 1m telescope (May 2008);
> La Silla Observatory, Chile - ESO 1m (Aug 2007);
> Cerro Armazones Observatory, Chile - 0.84m (Nov 2007);
> Haute Provence Observatory, France - 1.2m (2007-2012);
> Pic du Midi Observatory, France - T1m 1m (2006-2012);
> Argelander Institute for Astronomy, Bonn, Germany - 0.5m (2011-2012);
> Galati Public Outreach Observatory, Romania - 0.40m (2011 - present);
> Bucharest Urseanu public outreach Observatory, Romania –
0.25m and 0.30m telescopes (started 2006).

Results: Observing runs and network (2)

Six papers including 20+ EURONEAR observing runs:

5-6. Observing NEAs with a small telescope
> Big surveys overview, planning observations, data reduction, catalogs, etc
> Application with York University 0.6m telescope (Toronto)
> RoAJ papers, Vaduvescu 2004 and 2005;

7. EURONEAR First Results
> Two runs 1m telescopes, (Pic T1m and OHP 1.2m)
> 17 observed NEAs, planning tools, reduction pipeline,
> astrometry, O-C calculator, etc
> PSS, Vaduvescu et al. 2008

Results: Observing runs and network (3)

8. Paper presenting 162 NEAs observed during regular runs
   > 55 nights total (1500 reported positions)
   > Using 8 class 1-2m telescopes (INT 2.5m, ESO 2.2m, OHP 1.2m, Swope 1m, CTIO 1m, Pic 1m, ESO 1m, OCA 0.85m)
   > A&A, Birlan et al. 2010, including 9 students and amateurs!

9. Recovery, follow-up and discovery of NEAs and MBAs using 3 large field 1-2m telescopes (Swope 1m, ESO 2.2m & INT 2.5m)
   > 100 NEAs, 558 known MBAs, 628 unknown objects (including 58/500 MBA discoveries and 4-16 NEA candidates)
   > Some MBA and NEA observable statistics using 1-2m scopes
   > PSS, Vaduvescu et al. 2011, including 13 students and amateurs from Romania + SARM!

Results: Observing runs and network (4)

10. More than 740 NEAs observed presently (Sep 2012) by the EURONEAR network (Aug 2012)

> To include 10 new runs taken with 9 telescopes: Blanco 4m MOSAIC-2, WHT 4.2m, INT 2.5m WFC, TLS Tautenburg 2m and OHP 1.2m, Pic T1m and 3 educational/amateur scopes Bonn 0.5m, Galati 0.4m and Urseanu Bucharest 0.3m.

> To become a paper soon and including 24 co-authors students and amateurs from Romania, Chile, UK, Germany, France and Iran;

11. More than 50 MPC and MPEC publications including our NEA and MBA reports;

12. About 15 communications in conferences including students/amateurs.

Results: Other topics and papers related to EURONEAR

1. Asteroid Pairs - Formation by rotational fission (Pravec, P. et al. 2010, Nature)

2. Binary asteroids: Distribution of orbit poles of small, inner main-belt binaries (Pravec, P. et al. 2011, Icarus)

3. Main Belt Comets: (596) Scheila in outburst: A probable collision event in the Main Asteroid Belt (Moreno et al. 2011, ApJ)

4. Comets: Spectroscopic observations of new Oort cloud comet 2006 VZ13 and four other comets (Gilbert, et al, 2011, MNRAS)

Results: Asteroid discoveries and naming

1. About 500 new MBAs from which 58 official based on the ESO/MPG 2.2m 3-night run in 2008 reduced by students and amateurs;

2. First Romanian discoverers of asteroids (2008) lead by two Romanian astronomers from Diaspora in a team of 9 mostly students and amateurs;

3. About 1000 new MBAs from which cca 100 to become official based on the INT opposition 3-night mini-survey run in 2012 reduced by 5 students and amateurs;

4. First 3 asteroids discovered by Romanians recently named after passed away Romanian astronomers and public outreach amateurs: (263516) Alexescu, (257005) ArpadPal and (320790) Anestin;

Few memories… Pic du Midi 2006

First EURONEAR run with Francois Colas

Few memories... Haute Provence 2007

OHP EURONEAR run using the old Newtonian 1.2m telescope

Few memories... Las Campanas 2008

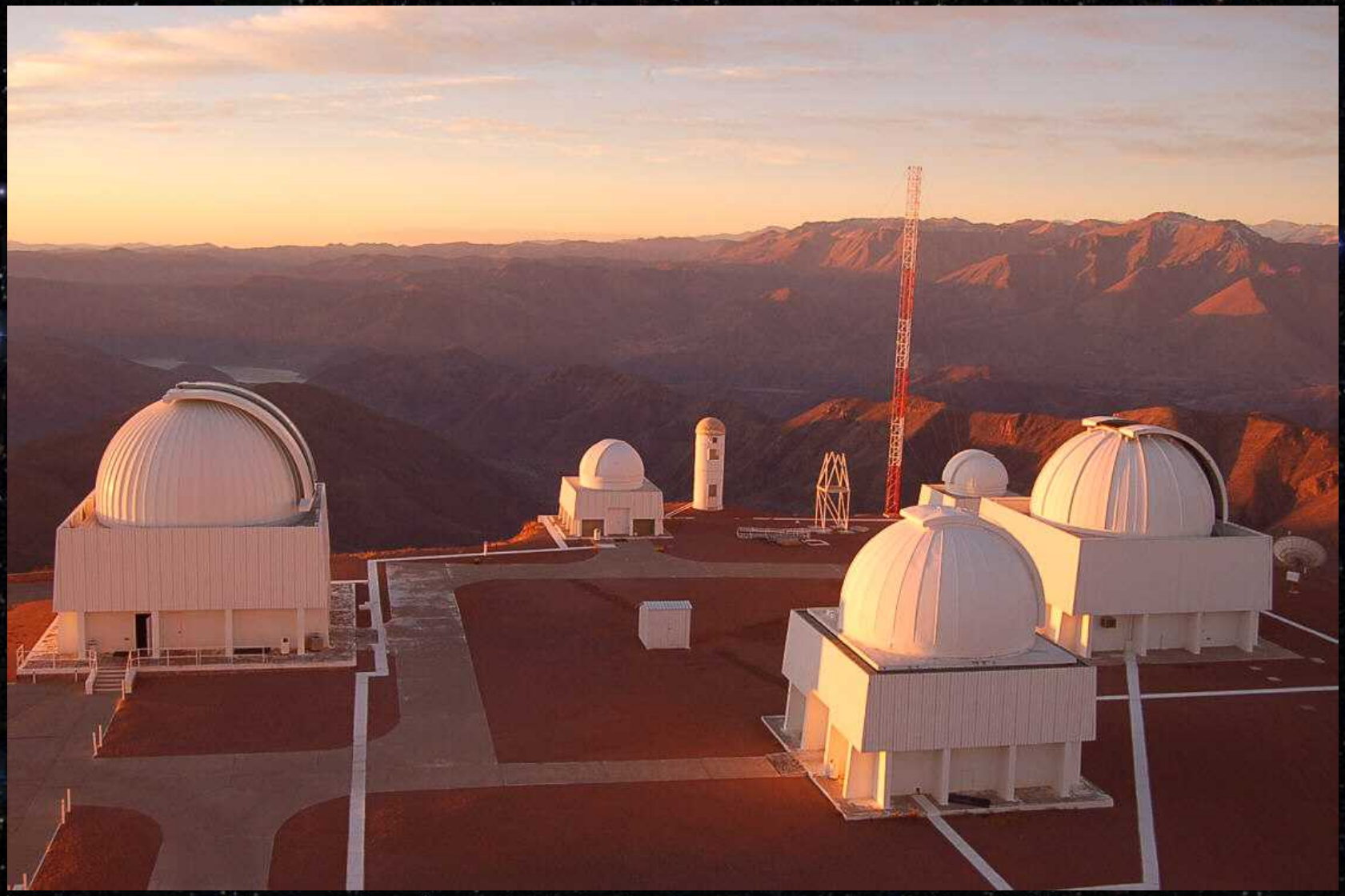
Alex Tudorica, the first Romanian student observing in Chile!

Few memories… Cerro Tololo 2006

Few memories... Cerro Tololo 2008

Besides Alex Tudorica, observing with Yale 1m telescope

Few memories… Cerro Tololo 2007



Few memories… Tololo Sunset

Few memories… Atacama Dessert 2008

Few memories… Cerro Armazones 2008

The small 40cm and 85cm domes just bellow the E-ELT site

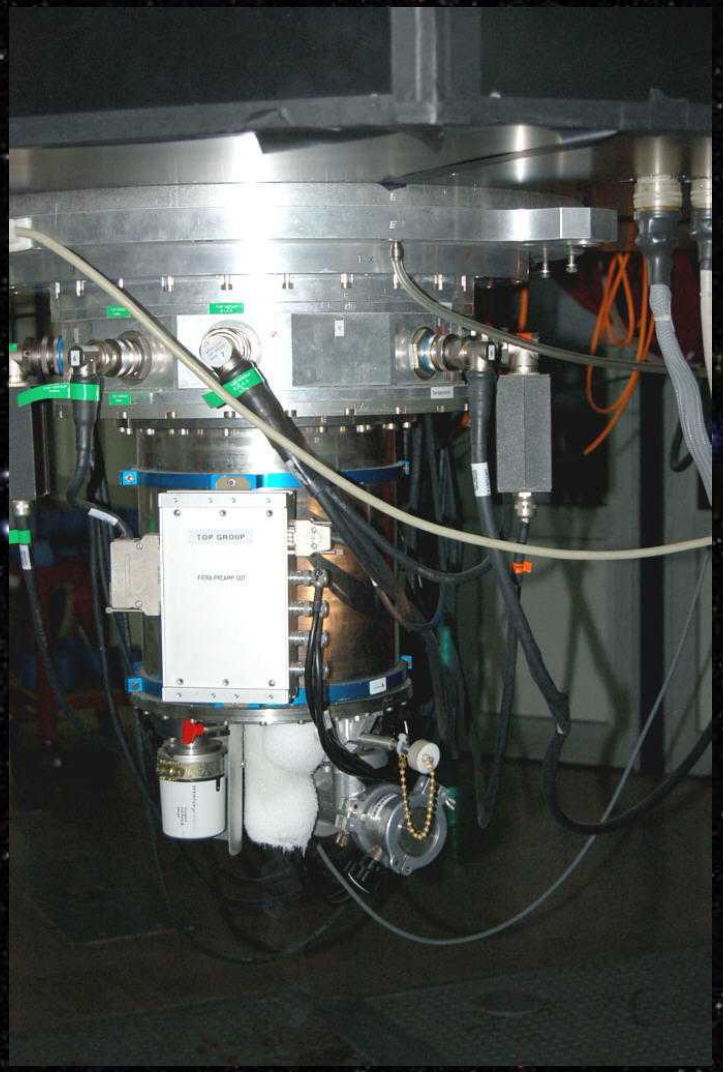
Few memories… La Silla, 2006

Few memories… La Silla Sunset

Few memories… La Silla Sunset

Few memories... La Silla 2008

ESO/MPG 2.2m with Mirel Birlan and the WFI camera



Few memories… Bucharest 2008

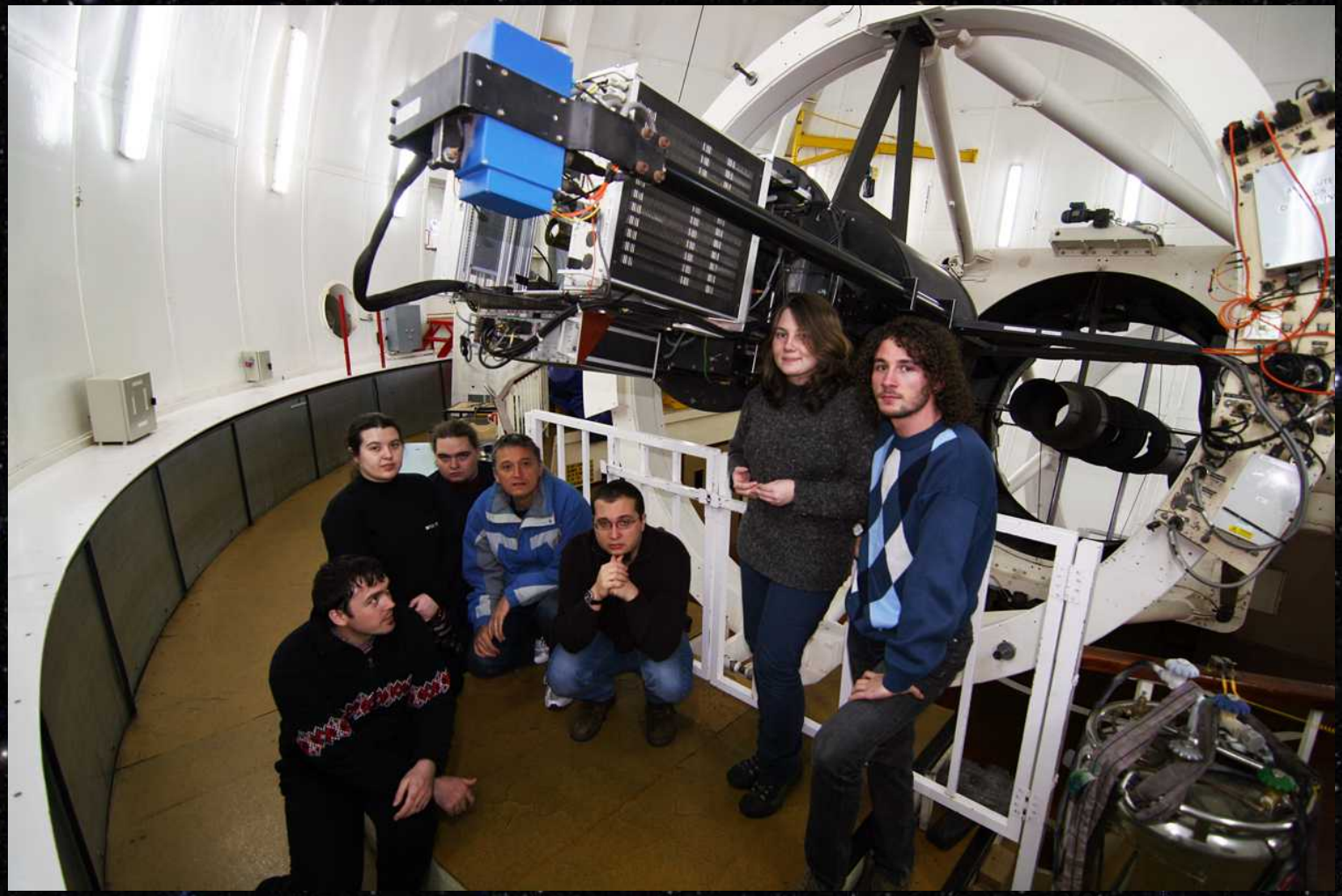
First Romanians to discover asteroids using ESO/MPG

Few memories... La Palma 2009

First Romanian students observing with the INT 2.5m

Few memories... La Palma 2012

6 Romanian and German students near the WFC PF of INT



Few memories... La Palma 2012

Romanian and German students under the INT

Few memories… La Palma 2012

Mily Way and meteor above Roque de Los Muchachos

Analysis and measurements

Dedicated software for image processing and field correction:

> THELI (Erben, Schrimer, Dietrich et al, 2005):

- Applied if needed to correct the field and improve very much the astrometry;
- Needed especially for large field and/pr PF cameras (INT WFC, OCA 0.85m, etc);

> SDFRED for Subaru SuprimeCam (Ouchi, Yagi, 2002, 2004);
> Our own IRAF pipeline for image reduction some tasks;

> FIND_ORB (Gray, 2012), ORBFIT (Millani et al, 2012) for orbits

Analysis and measurements

Astrometrica (Raab, 2012):

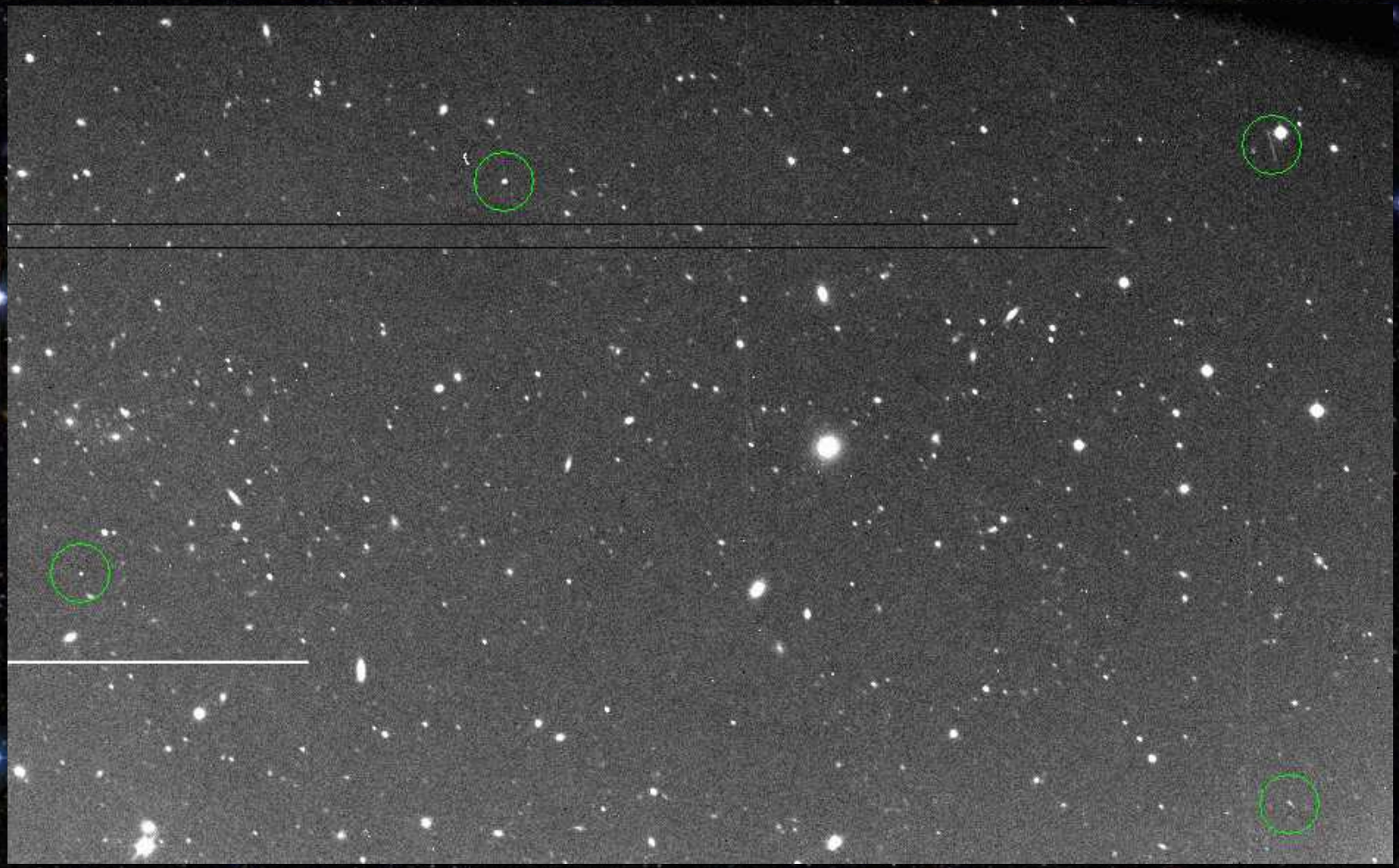
> To identify fields and resolve astrometry and photometry;
> Easy to learn and use for students and amateurs;
> Detect and measure known objects – MPC database;

> Blink all fields, measure and report:
- the target NEA;
- all known objects identified by software;
- all unknown moving objects, give acronyms;

> All known and unknown objects reported to MPC (astrometry and photometry).

Data Reduction

Visual blink with Astrometrica



Results: Improved Astrometry

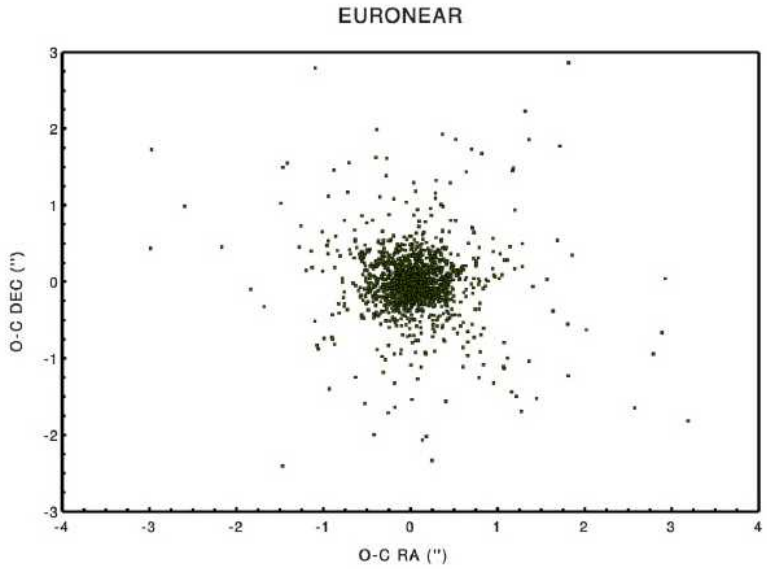


Fig. 2. (o-c) residuals for 1538 positions of 162 NEAs observed in the EURONEAR network. Most of the points are confined within 1″, probing the observational capabilities for all facilities and the accurate data reduction.

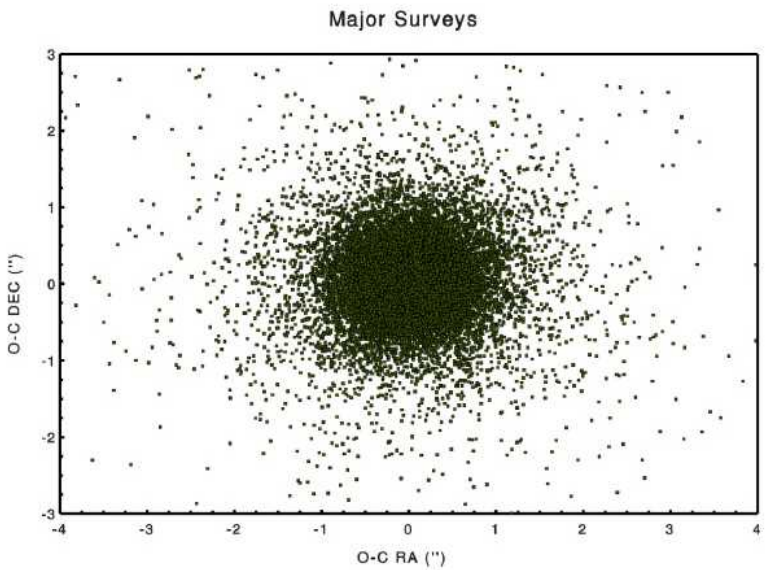


Fig. 3. Over 23 000 (o-c) residuals related with observations performed by all other surveys which observed in the past the same asteroids with EURONEAR. Comparing this plot with the one of Fig. 2, one can observe that EURONEAR observations appear better confined around zero, and this fact is also supported by statistics.

Residuals = O-C (Observed minus Calculated)
Smaller O-Cs => Improved orbits (Birlan et al, 2010)
EURONEAR FWHM 0.4” versus 0.6” major surveys

Results: Prolonged orbital arcs at both ends

Table A1 Five special classes including 58 NEA and PHA asteroids data mined in the CFHTLS. Besides the asteroid name we give its MPC classification, the number of CFHTLS observations, the orbital arc and the number of covered oppositions before and after adding our data, and some comments showing how our work improved the orbits.

Asteroid	Classification	Obs.	Arc	Opp.	Comments
		Extended Arcs at First Opposition (Precoveries):			
2008 ED69	NEA very desirable	6	9m/4y	2/3	Arc prolonged by 3 yrs
2005 CJ	PHA very desirable	3	5/8m	2	Arc prolonged by 3 mths
2006 PA1	PHA very desirable	1	4y	3	Arc prolonged by one mth
2008 OX2	PHA	4	2y	2	Arc prolonged by 1.5 mths
2003 WO151	NEA very desirable	3	2y	2	Arc prolonged by 1.5 mths
2005 LW	NEA very desirable	2	4/5y	3/4	Arc prolonged by 8 mths
2005 OW	NEA extremely desirable	3	4/5m	1	Short arc prolonged by 1 mth
2005 QN11	NEA extremely desirable	3	4/5m	1	Short arc prolonged by 1 mth
2005 QS10	NEA very desirable	3	4y	2	Arc prolonged by 1.5 mths
2005 SS4	NEA very desirable	4	3y	3	Arc prolonged by 2 weeks
2004 BE86	NEA very desirable	4	5y	2	Arc prolonged by one mth
2007 RM133	NEA	8	3y	2	Arc prolonged by one week
2008 SQ1	NEA	5	5y	2	Arc prolonged by one mth
2008 AF4	PHA very desirable	1	4m/6y	2/3	We only at 2nd opp, Goldstone radar target
2007 FS35	NEA very desirable	4	3m/8y	2/3	We only at 2nd opp
2008 CR118	PHA	1	8m/5y	2/3	We only at 2nd opp
2006 SV19	NEA	3	6y	3/4	We only at 2nd opp, numbered (212546)
2006 SU49	PHA very desirable	3	7y	3/4	We only at 2nd opp
2005 RN33	NEA very desirable	6	4y	2	We first at 2nd opp
2008 XE3	NEA	4	4y	2	We 2nd set at 1st opp
2005 UU3	NEA very desirable	4	2y	2	We 2nd set, only just 4 hrs after discovery
		Extended Arcs at Last Opposition (Recoveries):			
1998 VD35	PHA desirable	1	2/7y	3/4	Arc prolonged by 5 yrs, numbered (20425)
1993 BX3	PHA desirable	6	11/13y	3/4	Arc prolonged by 5 yrs, numbered (65717)
1999 GS6	PHA desirable	3	7/8y	4/5	Arc prolonged by 1 yr, numbered (152754)
2005 RR6	PHA very desirable	4	2y	2	Arc prolonged by 2 weeks
2005 WA1	PHA extremely desirable	3	1/7m	1	Initial 3 week arc prolonged by 6 mths
2003 TG2	NEA for survey recovery	3	18/24d	1	Very small arc prolonged by one week, old object
2004 XG29	NEA extremely desirable	1	25/35d	1	Very small arc prolonged by 10 days
1998 XA5	NEA very desirable	3	4/8y	3/4	Arc prolonged by 4 yrs
2002 TY57	NEA very desirable	1	3/5y	2/3	Arc prolonged by 2 yrs
2002 AA	NEA very desirable	6	5y	3	Arc prolonged by 1 week
2007 DL8	NEA very desirable	4	2y	2	Arc prolonged by 2 mths

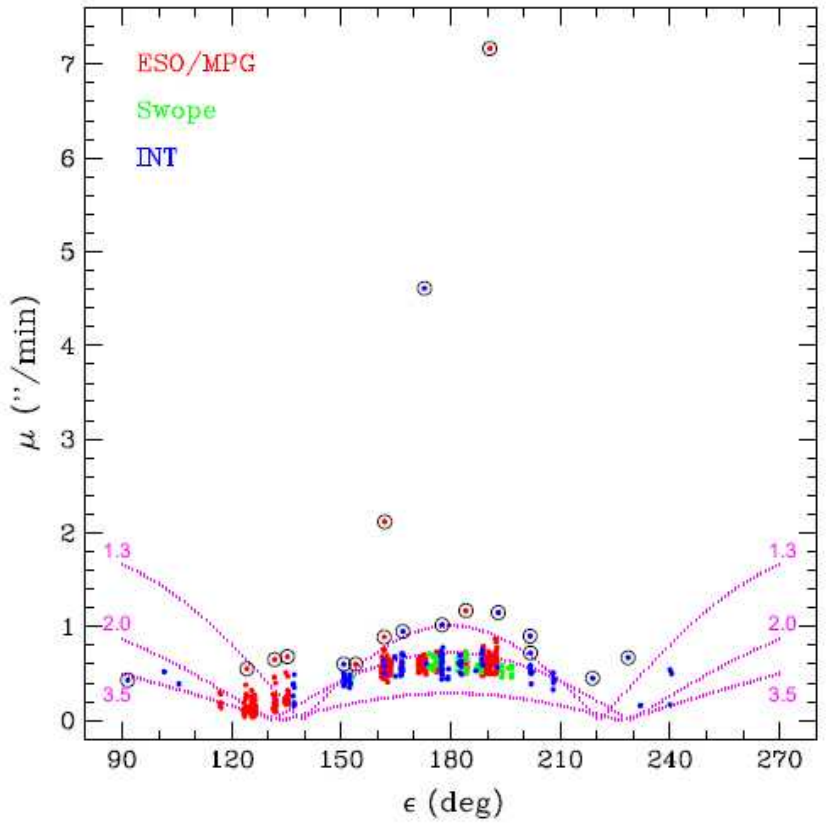


Fig. 5. Basic orbital model using the asteroid observed proper motion μ and the solar elongation ε. We plot all unknown objects observed at ESO/MPG (red), Swope (green) and INT (blue). The three overlaid dotted magenta curves correspond to asteroids orbiting between a=2.0 and a=3.5 AU (Main Belt) and a=1.3 (Near Earth Objects limit). The model allows us to easily flag NEO candidates in a survey. We mark with circles our NEO candidates and we include their properties in Table 4. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Results:

Simple orbital model to distinguish between MBAs and NEA candidates based on proper motion and Solar elongation

(Vaduvescu et al, 2011)

Results:
1-2m survey statistics in magnitude distribution

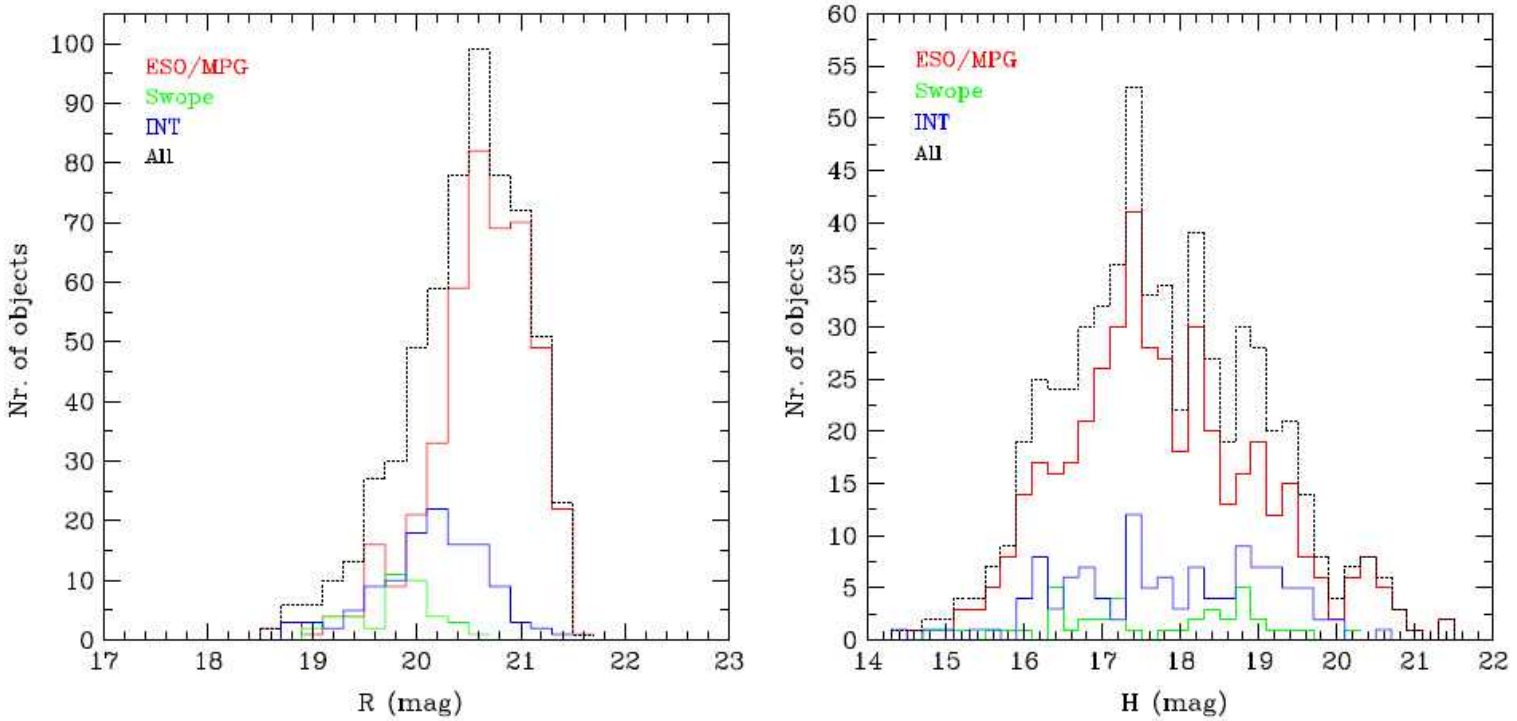


Fig. 9. Histograms showing number of unknown objects as function of observed apparent *R* magnitude (left) and calculated absolute magnitude *H* (right) for the ESO/MPG dataset (red), Swope (green), INT (blue) and the total number of objects (black dots). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Results:
1-2m survey statistics in orbital distribution

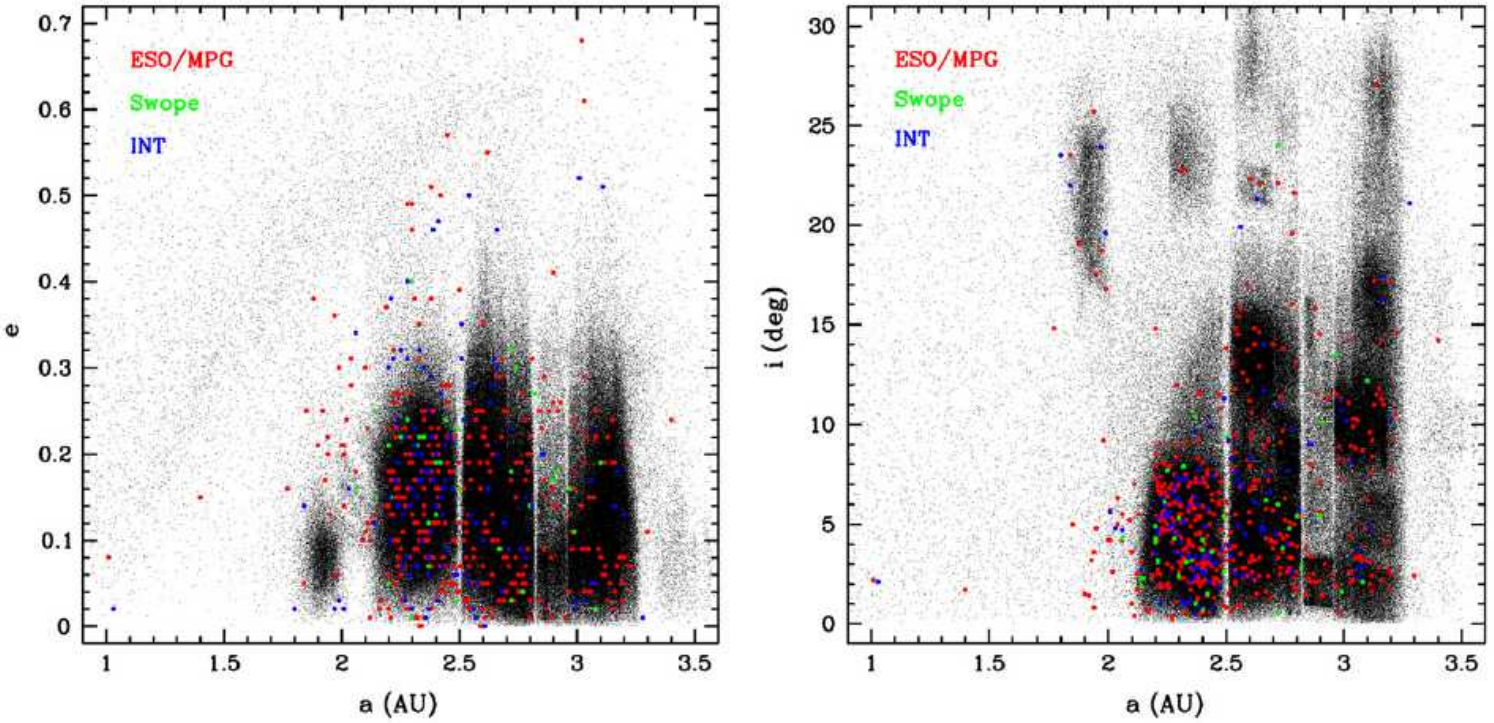


Fig. 7. Orbital distributions of 628 unknown objects observed at ESO/MPG (red points), Swope (green) and INT (blue) compared with the entire known asteroid population (ASTORB - 541,260 fine black points). Although our preliminary orbits were derived using mostly short arcs, the distributions are consistent with the known MBA population, showing the usefulness of the FIND_ORB orbital fit in *a*, *e* and *i*. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Results:

Mega-Archive includes currently 2.5 million images

Table A3 28 instrument archives available in August 2012 in the *Mega-Archive* used by *Mega-Precovery* adding together about 2.5 million images. We list the telescope, instrument, number of images (thousands rounded), archive start and end date, field of view (in arcmin), number of CCDs (for mosaics) and estimated V limiting magnitude suitable to detect NEAs.

Telescope	Instrument	Nr. images	Start Date	End Date	FOV′	CCDs	V
			ESO Instruments:				
VLT 8.2m	FORS1	36,000	23-01-1999	26-03-2009	6.8×6.8	2	26
VLT 8.2m	FORS2	111,000	30-10-1999	25-02-2012	6.8×6.8	2	26
VLT 8.2m	HAWKI	69,000	01-08-2007	24-02-2012	7.5×7.5	4	26
VLT 8.2m	ISAAC	199,000	01-03-1999	25-02-2012	2.5×2.5	1	26
VLT 8.2m	NACO	275,000	02-12-2001	29-02-2012	1.0×1.0	1	26
VLT 8.2m	VIMOS	66,000	30-10-2002	28-02-2012	12.8×16.0	4	26
VLT 8.2m	VISIR	67,000	11-05-2004	26-02-2012	0.5×0.5	1	26
VISTA 4.1m	VIRCAM	230,000	16-10-2009	22-06-2011	46.3×46.3	16	25
VST 2.6m	OmegaCam	19,000	01-04-2011	15-03-2012	58.4×58.4	32	24
NTT 3.5m	EMMI	18,000	17-03-2004	01-04-2008	9.1×9.1	2	25
NTT 3.5m	SOFI	126,000	30-03-2006	15-02-2012	4.9×4.9	1	25
NTT 3.5m	SUSI2	17,000	02-04-2004	29-12-2008	5.5×5.5	2	25
ESO 3.6m	EFOSC2	47,000	03-07-2004	16-03-2012	4.1×4.1	1	25
ESO 3.6m	TIMMI2	64,000	08-05-2004	28-06-2006	1.6×1.2	1	25
ESO/MPG 2.2m	WFC	124,000	20-06-1998	25-02-2012	33.6×32.7	8	23
			AURA NVO Instruments:				
KPNO 4m	MOSAIC	33,000	01-09-2004	27-06-2012	36×36	8	25
KPNO 4m	NEWFIRM	130,000	30-06-2007	10-07-2012	28×28	4	25
WIYN 3.5m	Mini Mosaic	6,000	17-03-2009	19-07-2012	10×10	2	25
WIYN 3.5m	WHIRC	89,000	04-04-2009	11-04-2012	3.3×3.3	1	25
WIYN 0.9m	MOSAIC	9,000	27-05-2009	03-05-2012	59×59	8	21
CTIO 4m	MOSAIC-2	67,000	11-08-2004	20-02-2012	37.0×37.5	8	25
CTIO 4m	NEWFIRM	74,000	18-05-2010	17-10-2011	28×28	4	25
CTIO 0.9m	Cass Img	228,000	27-03-2009	24-07-2012	13.5×13.5	1	21
SOAR 4m	OSIRIS	60,000	17-03-2009	20-07-2012	3.3×3.3	2	25
			Other Instruments:				
CFHT 3.6m	CFHTLS	25,000	22-03-2003	02-02-2009	57.6×56.4	36	25
INT 2.5m	WFC	230,000	20-06-1998	10-07-2009	34.1×34.5	4	23
Subaru 8.3m	SuprimeCam	60,000	05-01-1999	31-12-2010	35.1×27.6	10	26
AAT 3.9m	WFC	5,000	21-08-2000	05-02-2006	31.4×31.4	8	25

Selected collaborators related to IMO

> Mirel Birlan, IMCCE Paris;

> Francois Colas, IMCCE Paris;

> Jerome Berthier, IMCCE Paris;

> Alex Tudorica, Univ. Bucharest, SARM & Bonn University;

> Ruxandra Toma, Univ. Bucharest, SARM, Bonn University & Armagh Observatory;

> David Asher, Armagh Observatory;

> Valentin Grigore, SARM;

> Etc…

Conclusions and Future Work?

My dreams….

> To upgrade two retired 1m telescope (ESO 1m in the South and JKT 1m in the North) did not succeed (FP7 application);

> To unite Europe in a common European NEO survey also did not succeed :(so the Americans continue to be the leaders followed by two European amateur & public outreach projects (La Sagra Spain and Crni Vrh Slovenia);

But I had many successful collaboration with the amateurs….

> Some 25 amateurs and students, mostly from my natal Romania, but also from other countries (Chile, France, Germany, UK, Spain, etc);

> During the last 5 years, I published some 10 papers related to EURONEAR work and others related to it, lead by other PIs;

> Through EURONEAR, we did lots of education and public outreach ☺

Conclusions and Future Work?

> I will probably give up EURONEAR in case we could not get funding or partnership for a 2m class telescope dedicated to asteroids;

> Any IMO workers interested in collaboration in linking NEAs to meteors, please let me know.

References:

http://euronear.imcce.fr

THANK YOU!

WE HOPE YOU LIKED LA PALMA

AND THIS IMC!