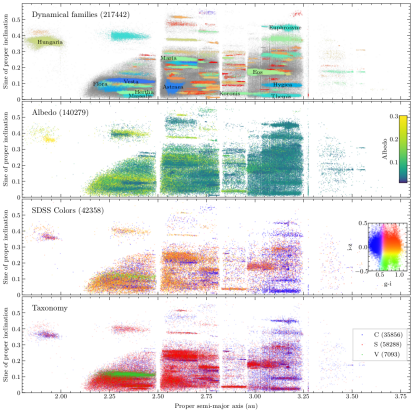
SsODNet
Solar system Open Database Network

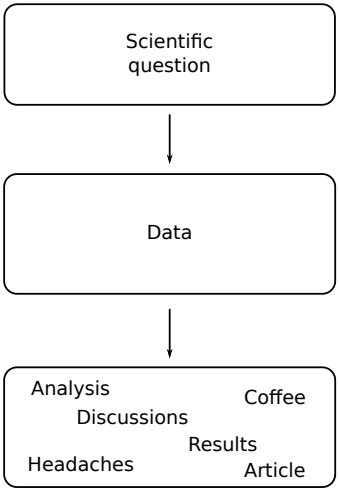


B. Carry[1], J. Berthier[2], M. Mahlke[3] & J. Normand[2]

[1]Lagrange, OCA, Nice
[2]IMCCE, Paris Observatory
[2]IAS, Orsay

▷ Web form: `https://ssp.imcce.fr`
▷ python client: `https://rocks.readthedocs.io`
▷ APIs: `https://ssp.imcce.fr/webservices`

A typical research project



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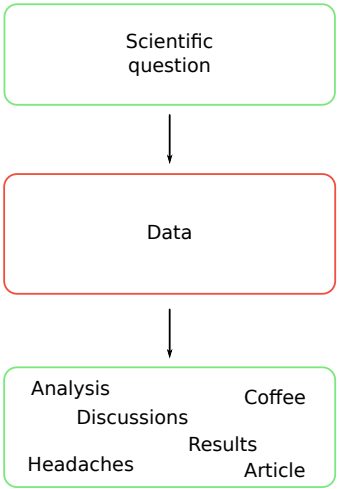

Repetitive (and tedious) tasks!

- Planning and conduction of observations
- Gathering ancillary data for the analysis
  - Complementary information diameter, fall/find, ...
  - Context for research another population
- Repetitive low-level analysis

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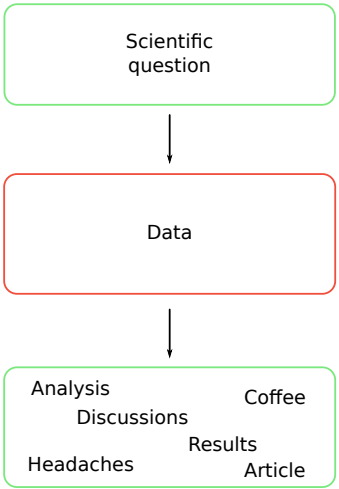

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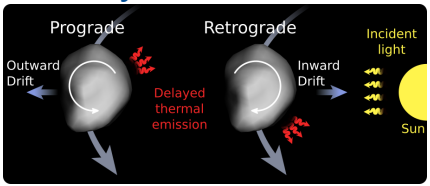
Example: Mass from Yarkovsky

Yarkovsky effect



Inspired by Bottke2001

Main evolutionary process

- Delayed thermal emission
- Semi-major axis drift $\frac{da}{dt} \approx 10^{-4}$au/My
- ▷ Diffuses orbital structures Families

Detection in Gaia DR2! Spoto+2018

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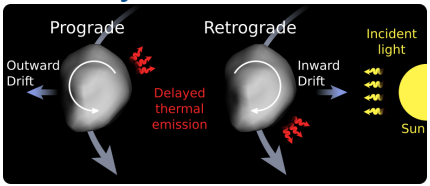

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Detection in Gaia DR2! Spoto+2018

$$\frac{da}{dt} = \frac{(1-A)}{9n}\frac{\pi D^2}{mc}\frac{S_\odot}{\Delta^2}\left[W_n \sin^2\gamma - 2W_\omega \cos\gamma\right]$$

$$W_\nu \approx -\frac{0.5\,\Theta_\nu}{1+\Theta_\nu+0.5\Theta_\nu^2}$$

$$\Theta_\nu = \frac{\Gamma\sqrt{\nu}}{\epsilon\sigma_B T_\star^3} \quad \text{with } \nu = n \text{ or } \nu = \omega$$

$$T_\star^4 = \frac{(1-A)S_\odot}{\eta\sigma_B\epsilon\Delta^2}$$

n the mean motion, ω the asteroid rotation (rad/s), D the diameter (m), A the Bond albedo, m the mass (kg), Γ the thermal inertia (J m^{-2} s$^{-1/2}$ K^{-1}), γ the obliquity (rad), Δ the heliocentric distance (ua), $S_\odot$ the Solar constant at 1 au (W m^{-2}), $T_\star$ the subsolar temperature (K) (c lightspeed, ϵ emissivity, σ_B Stefan-Boltzman constant, η beaming).

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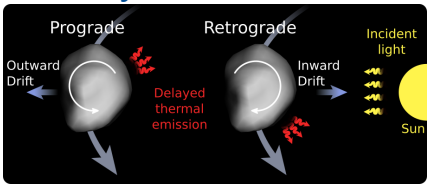

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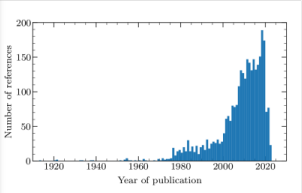
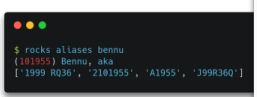
SsODNet in a nutshell

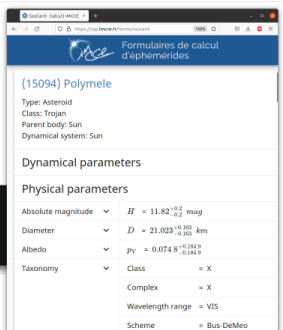
- **A massive source of information**
  - **5.6** million designations
  - **1.4** million SSOs
  - **208** million properties
  - **3377** compiled articles

- **With dedicated APIs**
  - `quaero` Name resolution
  - `datacloud` All the data
  - `ssoCard` Best estimates only
  - `BFT` All `ssoCards` at once

- **Open access to everyone**
  - ▷ Web form `https://ssp.imcce.fr`
  - ▷ `rocks` python client `https://rocks.readthedocs.io`
  - ▷ APIs: json/text/votable `https://ssp.imcce.fr/webservices`

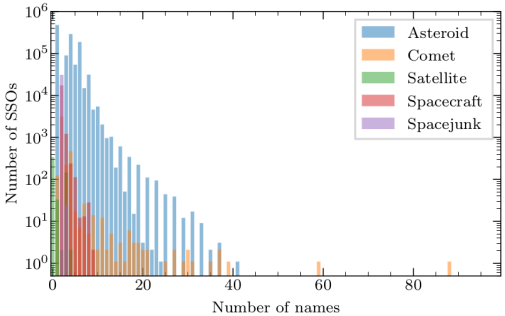






quaero: name resolver

- **Translates identification**
  - From **any** alias
  - To current designation
  - With all others aliases
- **Usages**
  - Resolver Alias to sky coordinates
  - Fuzzy search
  - Auto-completion in Web forms
- **Performances**
  - **5.7** millions of designations
  - **1.4** million of SSOs
  - 10k-100k identifications in 2-3s



Example: Moshup
= 66391
= 1999 KW4
= 2066391
= J99K04W

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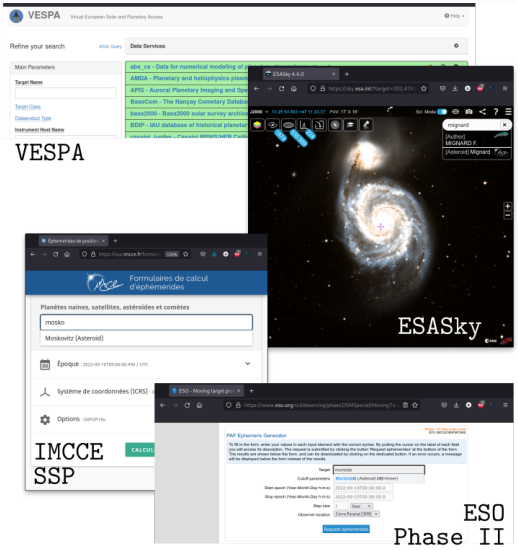

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```
$ rocks aliases bennu
(101955) Bennu, aka
['1999 RQ36', '2101955', 'A1955', 'J99R36Q']
```

- **Usages**
  - Resolver Alias to sky coordinates
  - Fuzzy search
  - Auto-completion in Web forms

```
>>> import rocks

>>> ids = [1159, '1938 SW', 'rYugU']

>>> num_name = rocks.identify(ids)

>>> for nn in num_name:
...     print(nn[1], nn[0])

1159 Granada
1495 Helsinki
162173 Ryugu
```

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datacloud: compilation of properties

- **Massive data compilation**
  - Most data **were not** available
  - Dynamics
    Osculating & proper elements, MOIDs,
    Pairs & families, Source regions, Yarkovsky
  - Physics
    Diameter, spin, mass, density
  - Surface
    Colors, albedo, phase function,
    Thermal inertia & taxonomy
  - ▷ **208** millions parameters
- **Philosophy**
  - Identification
  - Parameter & Uncertainty
  - Method
  - Bibliography
  - Ancillary information

dataset	#	#SSO
Colors	5 M	430 k
Density	57	32
Diameter	261 k	149 k
Families	593 k	268 k
Masses	3 k	463
MOID	1 M	1 M
Pairs	342	238
Phase	303 k	202 k
Prop. element	800 k	800 k
Source region	34 k	34 k
Spin	85 k	47 k
Taxonomy	284 k	170 k
Thermal inertia	4 k	2 k
Yarkovsky	870	601

Number of entries for each resource

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```
$ rocks masses ceres
```

(1) Ceres

	mass	err_mass_up	err_mass_down	method	shortbib
1	9.3483e+20	5.967e+19	-5.967e+19	DEFLECT	Goffin1991
2	9.55e+20	4.38e+19	-4.38e+19	DEFLECT	Williams+1992
3	9.54e+20	1.69e+19	-1.69e+19	DEFLECT	Sitarski+1992
4	9.94e+20	3.98e+19	-3.98e+19	DEFLECT	Viateau+1995
5	9.19e+20	1.41e+19	-1.41e+19	DEFLECT	Sitarski+1995
6	8.27e+20	3.78e+19	-3.78e+19	DEFLECT	Kuzmanoski+1996
7	9.29e+20	1.79e+19	-1.79e+19	DEFLECT	Carpino+1996
8	9.52e+20	7.76e+18	-7.76e+18	DEFLECT	Viateau+1997b
9	9.47e+20	4.57e+18	-4.57e+18	DEFLECT	Viateau+1998
10	8.73e+20	7.96e+18	-7.96e+18	DEFLECT	Hilton+1999
11	9.35e+20	7.96e+18	-7.96e+18	DEFLECT	Michalak+2000
12	9.35e+20	5.97e+19	-5.97e+19	DEFLECT	Goffin+2001
13	9.57e+20	1.99e+18	-1.99e+18	DEFLECT	Pitjeva+2001
14	9.45e+20	3.98e+18	-3.98e+18	DEFLECT	Pitjeva+2004
15	9.45e+20	4.18e+18	-4.18e+18	EPHEM	Pitjeva+2005
16	9.35e+20	5.57e+18	-5.57e+18	DEFLECT	Konopliv+2006
17	9.42e+20	5.17e+18	-5.17e+18	DEFLECT	Kova+2007
18	9.46e+20	7.96e+17	-7.96e+17	EPHEM	Fienga+2008
19	9.45e+20	5.97e+18	-5.97e+18	DEFLECT	Baer+2008a
20	9.32e+20	9.32e+19	-9.32e+19	EPHEM	Folkner+2009
21	9.39e+20	5.97e+18	-5.97e+18	EPHEM	Pitjeva+2010
22	9.46e+20	1.43e+18	-1.43e+18	DEFLECT	Baer+2011
23	9.52e+20	4.63e+18	-4.63e+18	DEFLECT	Zielenbach+2011
24	9.46366e+20	5.5692e+18	-5.5692e+18	EPHEM	Fienga+2011
25	9.4e+20	3.1e+18	-3.1e+18	DEFLECT	Zielenbach+2011
26	9.42e+20	2.65e+18	-2.65e+18	DEFLECT	Zielenbach+2011
27	9.42e+20	2.68e+18	-2.68e+18	DEFLECT	Zielenbach+2011
28	9.31e+20	6.46e+18	-6.46e+18	EPHEM	Konopliv+2011
29	9.04e+20	1.39e+19	-1.39e+19	DEFLECT	Kova+2012
30	9.29e+20	3.68e+18	-3.68e+18	EPHEM	Fienga+2013
31	9.41e+20	5.69e+18	-5.69e+18	EPHEM	Kuchynka+2013
32	9.39e+20	1.57e+18	-1.57e+18	EPHEM	Pitjeva+2013
33	9.40797e+20	0.0	0.0	EPHEM	Folkner+2014
34	9.44e+20	5.97e+17	-5.97e+17	DEFLECT	Goffin+2014
35	9.29e+20	3.84e+18	-3.84e+18	EPHEM	Fienga+2014
36	9.384e+20	1e+17	-1e+17	SPACE	Russell+2016
37	9.394e+20	1.312e+18	-1.312e+18	EPHEM	Baer+2017
38	9.38e+20	2.21e+18	-2.21e+18	EPHEM	Viswanathan+2017
39	9.38348e+20	2.28689e+18	-2.28689e+18	EPHEM	Fienga+2019
40	9.39e+20	2.31e+18	-2.31e+18	EPHEM	Fienga+2020

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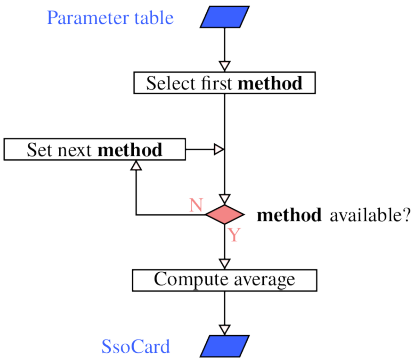
Green: preferred entry

ssoCard: best estimates

- **Best estimates?**
  - Decision trees for each parameter
  - Based on methods
  - With a weighted average
  - ▷ Stored in `ssoCards`
- **Added values**
  - Tisserand's parameter
  - Recompute albedo
  - Compute density
  - *etc.*
- **Usage & performance**
  - Request `ssoCard` via API/`rocks`
  - 30 ms per request 11 ms from cache
  - Full traceability with bibliography
    `https://ssp.imcce.fr/data/ssodnet.bib`



E.g., for masses: Space mission
↳ Binary system
↳ Deflection & ephemerides
↳ Yarkovsky estimate

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```
>>> import rocks
>>> ssocard = rocks.Rock(17919)
>>> ssocard.number, ssocard.name
(17919, 'Licandro')

>>> ssocard.diameter.value
3.064

>>> ssocard.diameter.error.min_, ssocard.diameter.error.max_
(-0.039, 0.039)

>>> ssocard.diameter.method
[Method(doi='10.1006/icar.1999.6248',
        name='Near-Earth Asteroid Thermal Model',
        year=1999,
        title='Physical Characteristics ...',
        bibcode='1999Icar..142..464H',
        shortbib='Harris1999')]

>>> ssocard.diameter.bibref
[Bibref(doi='10.3847/PSJ/ac3232',
        year=2022,
        title='Analysis of Four-band WISE ...',
        bibcode='2022PSJ.....3...30M',
        shortbib='Myhrvold+2022'),
 Bibref(doi='10.1088/0004-637X/741/2/68',
        year=2011,
        title='Main Belt Asteroids with WISE/NEOWISE ...',
        bibcode='2011ApJ...741...68M',
       shortbib='Masiero+2011'),
 Bibref(doi='10.1088/2041-8205/759/1/L8',
        year=2012,
        title='Preliminary analysis of WISE/NEOWISE ...',
        bibcode='2012ApJ...759L...8M',
        shortbib='Masiero+2012')
]
```

BFT: all ssoCards at once

- **It's a BIG table**
  - 1.4M SSOs × 766 fields
  - Filled at 15.9%
- **Usages**
  - Data curation
  - ▷ Data exploration
  - ▷ Statistical studies
- **Access**
  - Compressed eCSV 3.4 Gb uncompressed

`https://ssp.imcce.fr/data/ssoBFT-latest_Asteroid.ecsv.bz2`

  - Apache parquet 488 Mb

`https://ssp.imcce.fr/data/ssoBFT-latest_Asteroid.parquet`

  - ▷ Easy to use: TOPCAT, python, ...

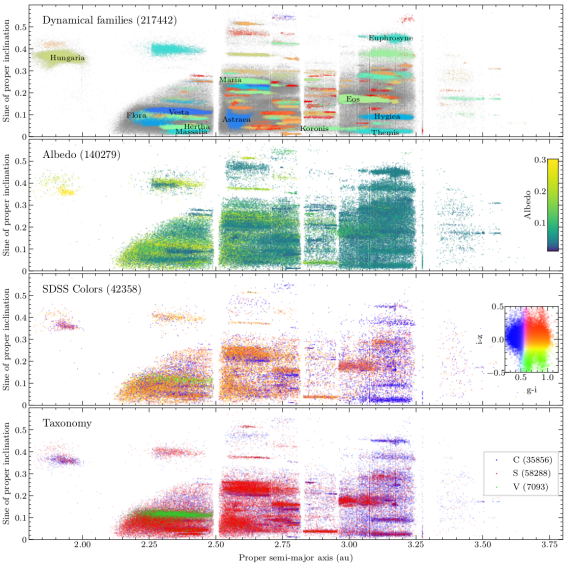
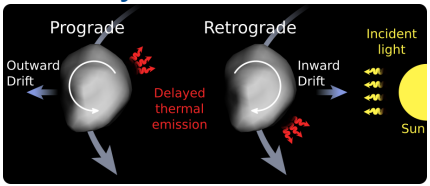


Illustration of SsODNet capacities

Yarkovsky effect



Inspired by Bottke2001

$$\frac{da}{dt} = \frac{(1-A)}{9n}\frac{\pi D^2}{mc}\frac{S_\odot}{\Delta^2}\left[W_n \sin^2\gamma - 2W_\omega \cos\gamma\right]$$

Detection in Gaia DR2 Spoto+2018

Detection in Gaia DR3! Dziadura+2023

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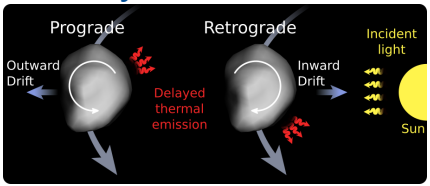
Yarkovsky effect



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Detection in Gaia DR2 Spoto+2018

Detection in Gaia DR3! Dziadura+2023

```python
import rocks

targets = ["Anteros", "Bacchus", "2002 WP", "2000 BD19", ...]

ssos = rocks.rocks(targets)

for i in range(len(targets)):

    data.loc[i, "num"] = ssos[i].number
    data.loc[i, "name"] = ssos[i].name

    data.loc[i, "diameter"] = ssos[i].diameter.value
    data.loc[i, "albedo"] = ssos[i].albedo.value

    ...
```

Extremely easy access to information

- Dedicated `rocks` `python` client
- Density for 49 small asteroids!

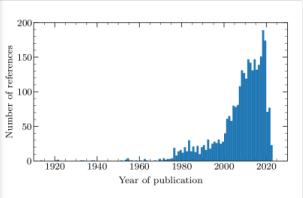
Dziadura+2023

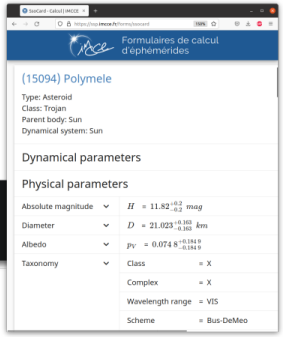
SsODNet in a nutshell

- **A massive source of information**
  - **5.6** million designations
  - **1.4** million SSOs
  - **208** million properties
  - **3377** compiled articles

- **With dedicated APIs**
  - `quaero` Name resolution
  - `datacloud` All the data
  - `ssoCard` Best estimates only
  - `BFT` All `ssoCards` at once

- **Open access to everyone**
  - ▷ Web form `https://ssp.imcce.fr`
  - ▷ `rocks` python client `https://rocks.readthedocs.io`
  - ▷ APIs: json/text/votable `https://ssp.imcce.fr/webservices`





What's next?

- **Data compilation**
  - Continuous addition of data
  - ▷ Any feedback welcome!
- **Expand the set of parameters**
  - Polarimetry, activity, ...
  - ▷ Any suggestion welcome!
- ▶ **Aiming at completeness**

- **Types of SSO**
  - Comets, planets & satellites
  - ▷ Set of parameters? Decision trees?
- **User interface**
  - Advanced data queries
  - ▷ What do **you** need/want?
- ▶ **Structural improvements**

`SsODNet` is a service for & by the community

`SsODNet` is ready for large data releases (LSST, Gaia, Euclid, ...)