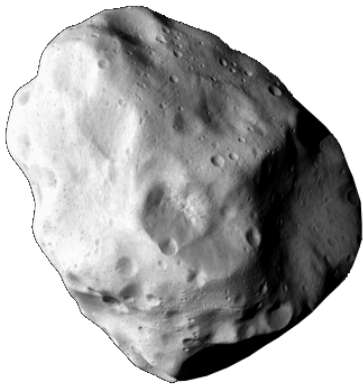


A NEEDLE IN A HAYSTACK: ASTEROIDS IN LARGE SURVEYS



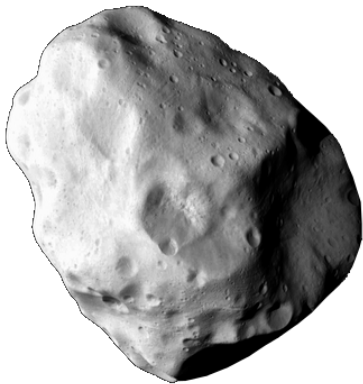
Benoit Carry, Lagrange/OCA

Solar System Objects



ESA/Rosetta

Solar System Objects

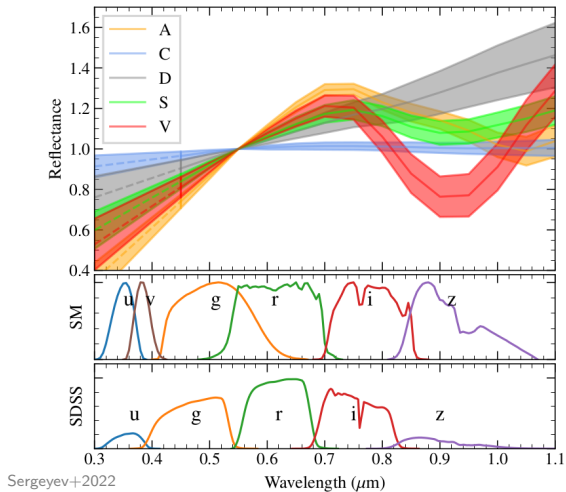


ESA/Rosetta

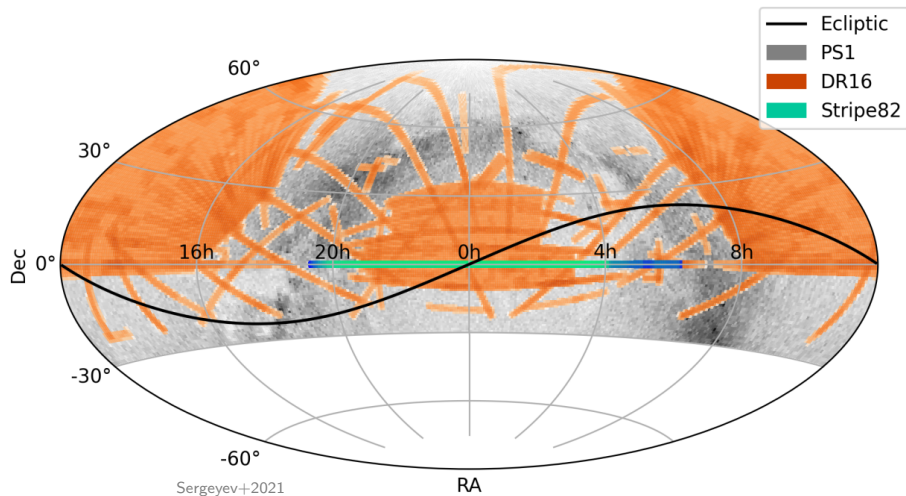


ESO/INAF-VST/OmegaCAM

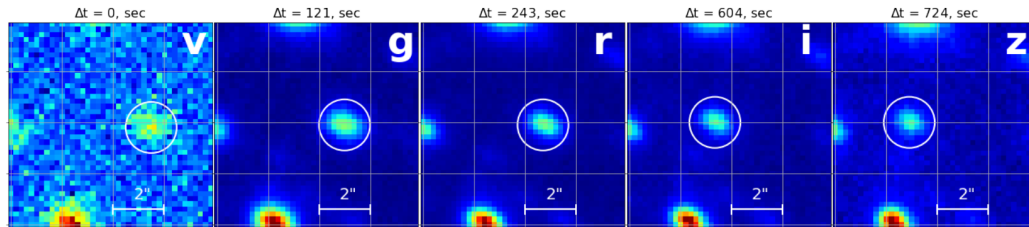
Solar System Objects in surveys



Solar System Objects in surveys



Solar System Objects in surveys



Sergeyev+2021

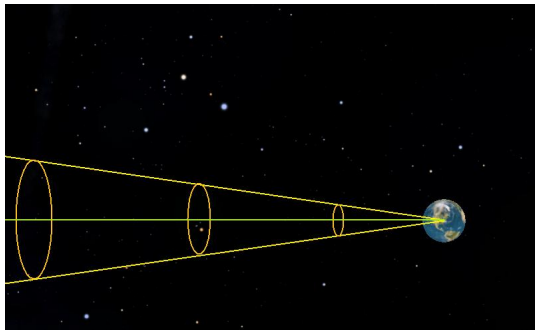
Identification of Solar System Objects

- **Where are the asteroids?**



ESO/INAF-VST/OmegaCAM

Identification of Solar System Objects



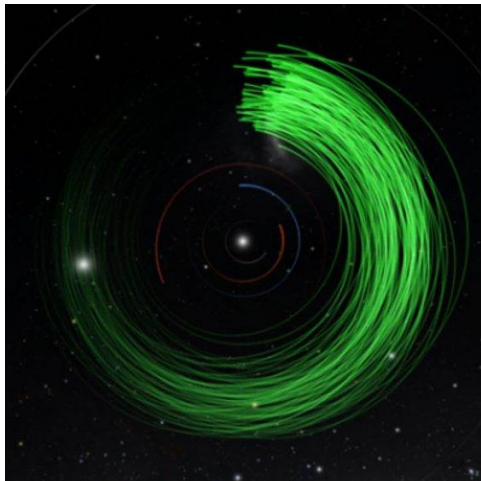
Worldwide Telescope User Manual

- **Where are the asteroids?**

- **Cone-search**

- All sources in one FOV
- **At a specific time!**

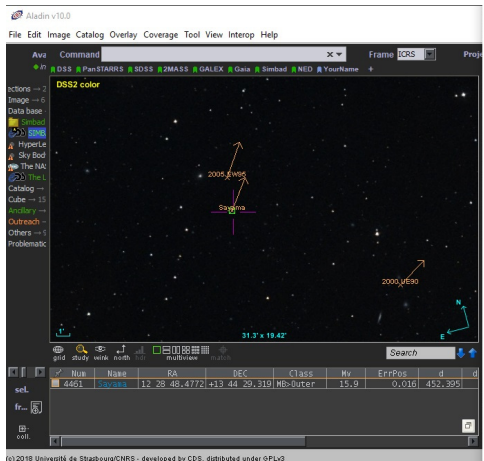
Identification of Solar System Objects



J. Moeyens

- **Where are the asteroids?**
- **Cone-search**
 - All sources in one FOV
 - **At a specific time!**
- **Solar-system Cone-search**
 - All known objects (1.3M)
 - Compute ephemerides
 - Crossmatch with FOV

Identification of Solar System Objects



Ciel de nuit en Vercors

• Where are the asteroids?

• Cone-search

- All sources in one FOV
- **At a specific time!**

• Solar-system Cone-search

- All known objects (1.3M)
- Compute ephemerides
- Crossmatch with FOV

• SkyBoT

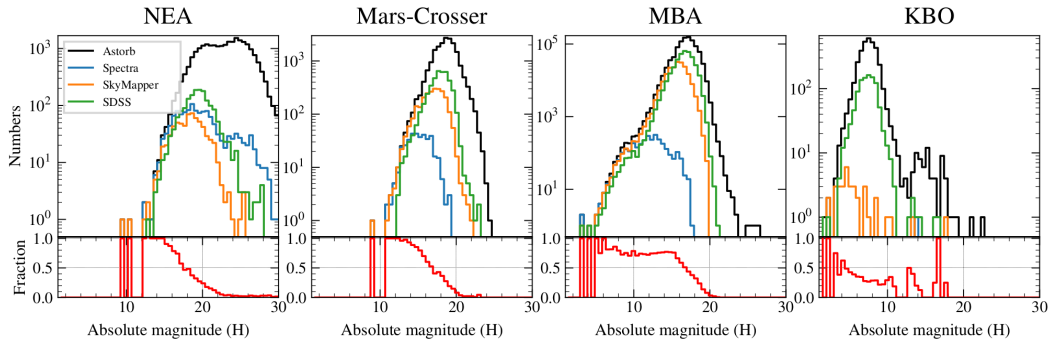
- VO ConeSearch for SSO!
- **Pre-**Compute ephemerides

Berthier+2006, +2016

Merci VO & SkyBoT

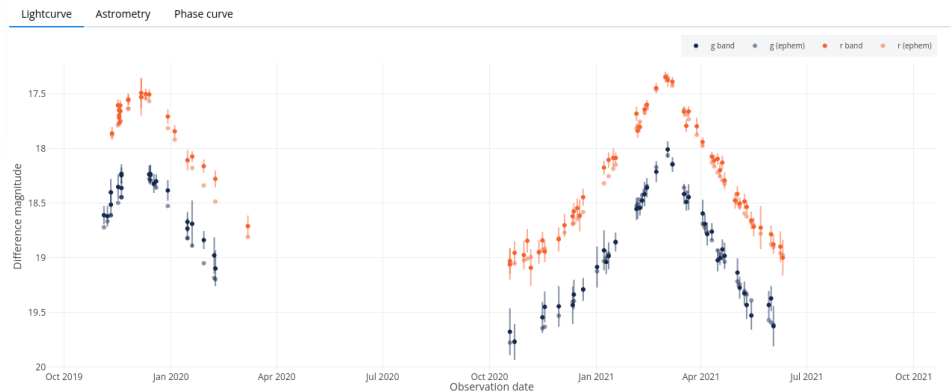
We produced 96% of available colors of SSOs in two articles

based on data released 13 years before



Sergeyev+2021, +2022

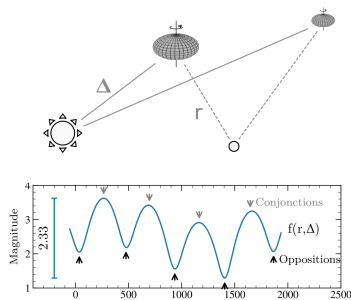
Solar System Objects Photometry



FINK borker of alert for LSST, data from ZTF

Solar System Objects Photometry: model

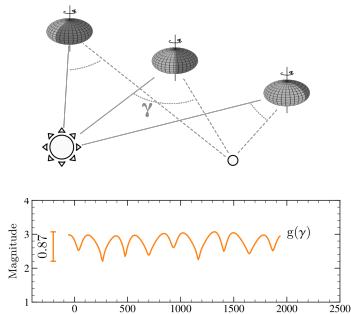
• Distance



○ HG Bowell1989

$$H = m - f(r, \Delta)$$

• Phase

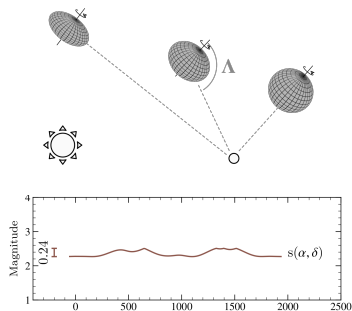


○ HG Bowell1989

○ HG₁G₂ Muinonen+2010

$$H = m - f(r, \Delta) - g(\gamma)$$

• Aspect



○ sHG₁G₂ Carry+2024

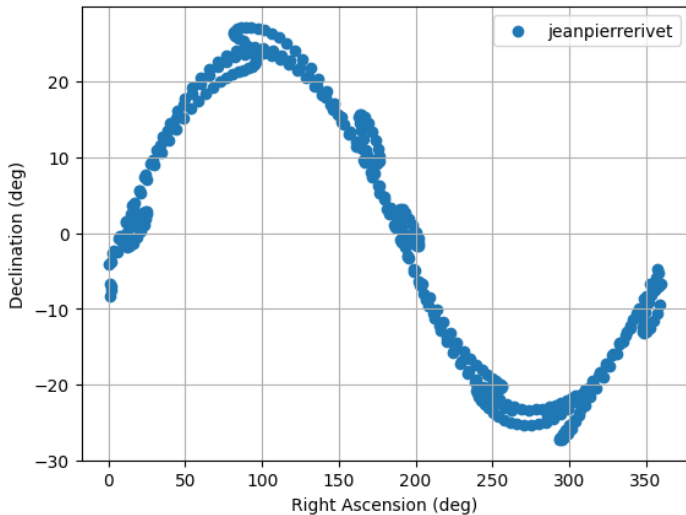
$$H = m - f(r, \Delta) - g(\gamma) - s(\alpha, \delta)$$

== Merci VO & Miriade ==

```
1 import requests
2
3 url = "https://ssp.imcce.fr/webservices/miriade/api/ephemcc.php?"
4
5 params = {
6     "-name": 'jeanpierrerivet',
7     "-ep": '2024-01-01T00:00:00',
8     "-nbd": 365,
9     "-step": '10d',
10    "-mime": "json",
11 }
12 r = requests.post(url, params=params, timeout=2000)
```

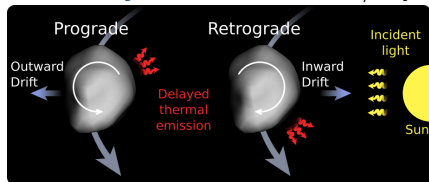
Python

Merci VO & Miriade



Properties of Solar System Objects

Yarkovsky effect $\propto 10^{-4}$ au/My



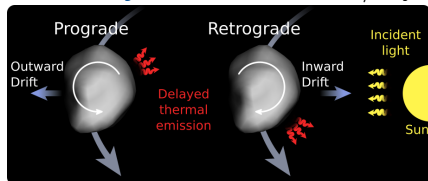
Inspired by Bottke2001

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

Detection in Gaia DR2 Spoto+2018

Properties of Solar System Objects

Yarkovsky effect $\propto 10^{-4}$ au/My



Inspired by Bottke2001

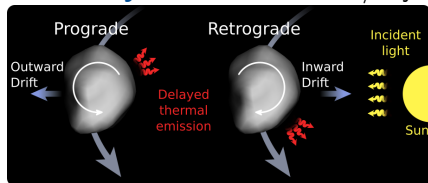
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Detection in Gaia DR2 Spoto+2018

Detection in Gaia DR3! Dziadura+2023

Merci VO & SsODNet

Yarkovsky effect $\propto 10^{-4}$ au/My



Inspired by Bottke2001

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

Detection in Gaia DR2 Spoto+2018

Detection in Gaia DR3! Dziadura+2023

```
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 NEOs! 74%!

Dziadura+2023

Some remarks on VO & planetary sciences

- **We are a community not (yet) used to big data**
 - Used to deal with 10s or 100s (maybe 1000s) of objects
 - Watch out! NEOSurveyor, LSST, ...
- **VO is amazing but yes, many tools are not designed for SSOs**
 - Many protocols are not time-dependent
 - TAP is pretty universal
 - Some VO services exist! VOSSP (SkyBoT, Miriade, SsODNet), MP3C, EPN, ...
 - Some non-VO services exist! JPL API, MPC API, ..., wrappers in astroquery! sbpy!
- **Building services for us by ourselves**
 - Services are (generally) not decided top-down
 - Best (most useful) services are bottom-up IMHO
 - If you have a nice solution to [a problem], consider releasing it! Open science