



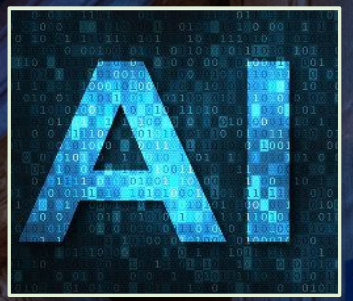

Unistellar eVscope Network and its Potential for Occultation

FRANCK MARCHIS @AllPlanets

Contributors: Emmanuel Arbouch, Thomas Bellier, Emmanuel Bertin, Martin Costa, Christian Everett, Arnaud Malvache

Senior Planetary Astronomer at the SETI Institute
Chief Scientific Officer at Unistellar
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UNISTELLAR

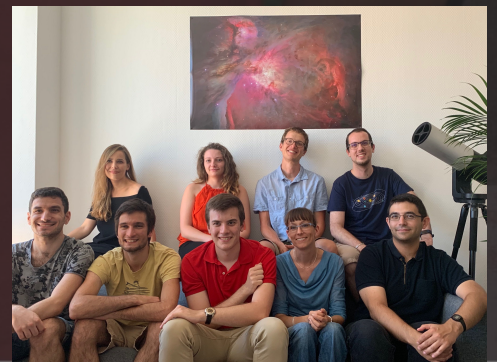
SETI INSTITUTE

What is Unistellar?

UNISTELLAR

Unistellar (HQ in Marseille, France & Offices in San Francisco, CA) is an electronic and software company that designs & makes the first IoT consumer telescope…

…and generates sky-related data



Customer Expectations

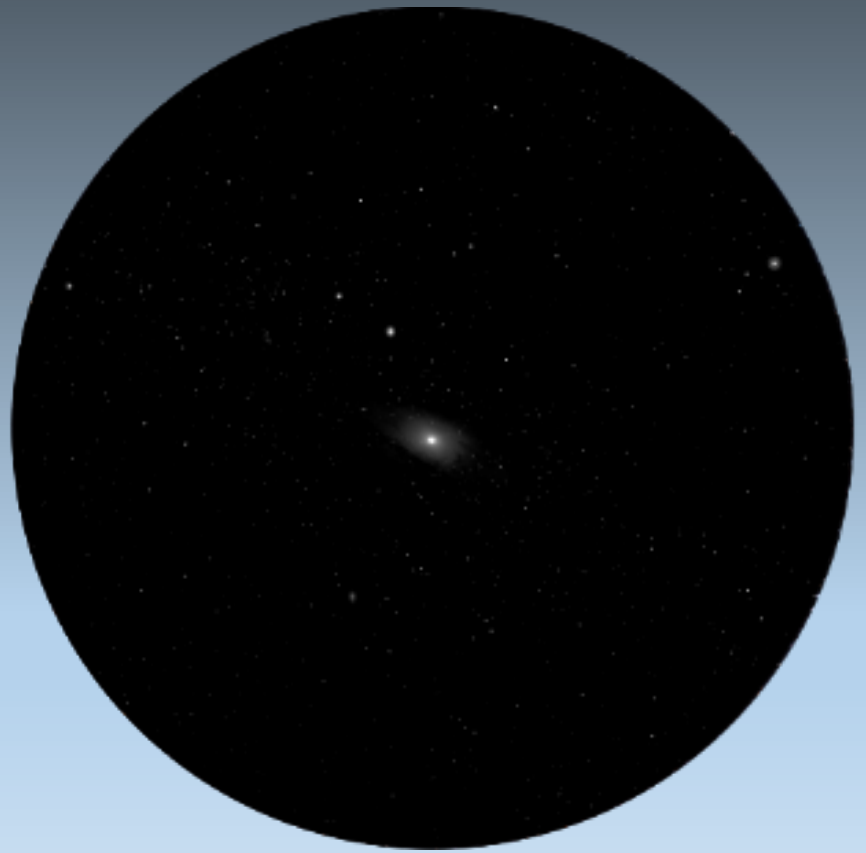
Visual wonder
Beautiful and colorful objects

Ease of use
Turnkey experience

Use it Everywhere
Especially From Home

Infotainment
Engaging, with learning, sharing

Current Customer Experience



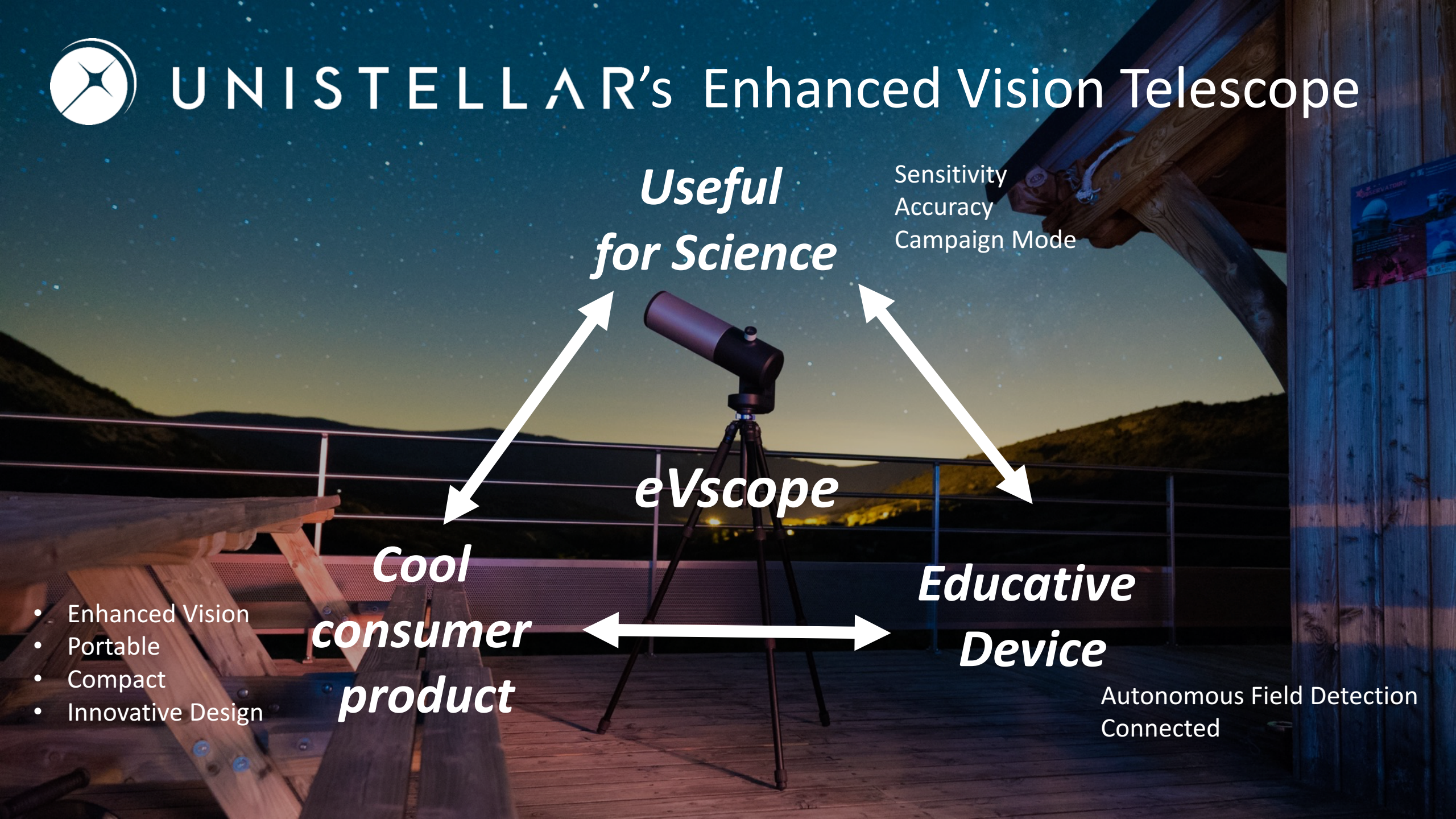
Lack of visual power
Faint and gray object

Overall complexity
Long and painful to use

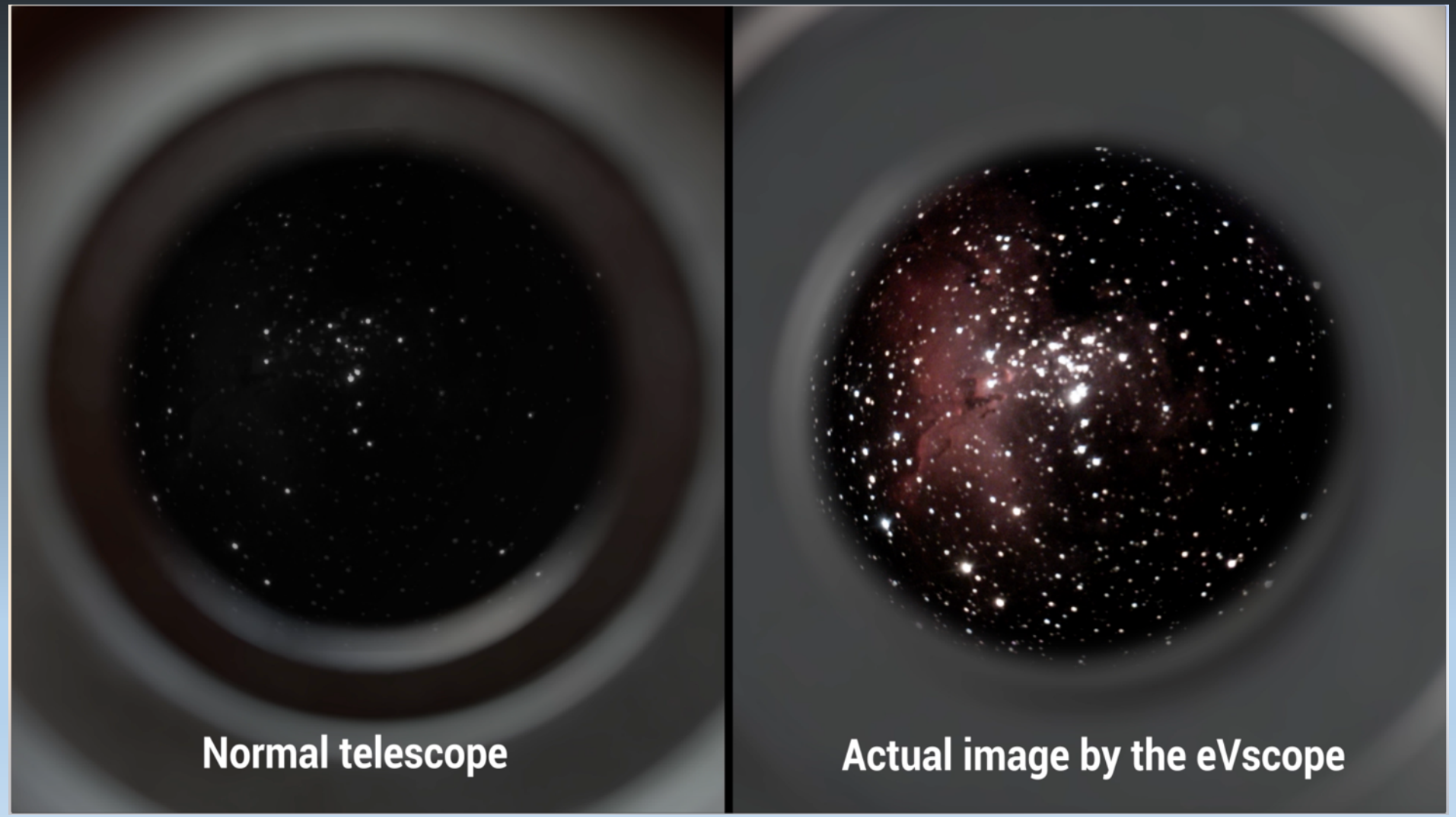
Unreachable From Cities
Light Pollution

Not connected
Less Engaging / Not Participative.

UNISTELLAR's Enhanced Vision Telescope

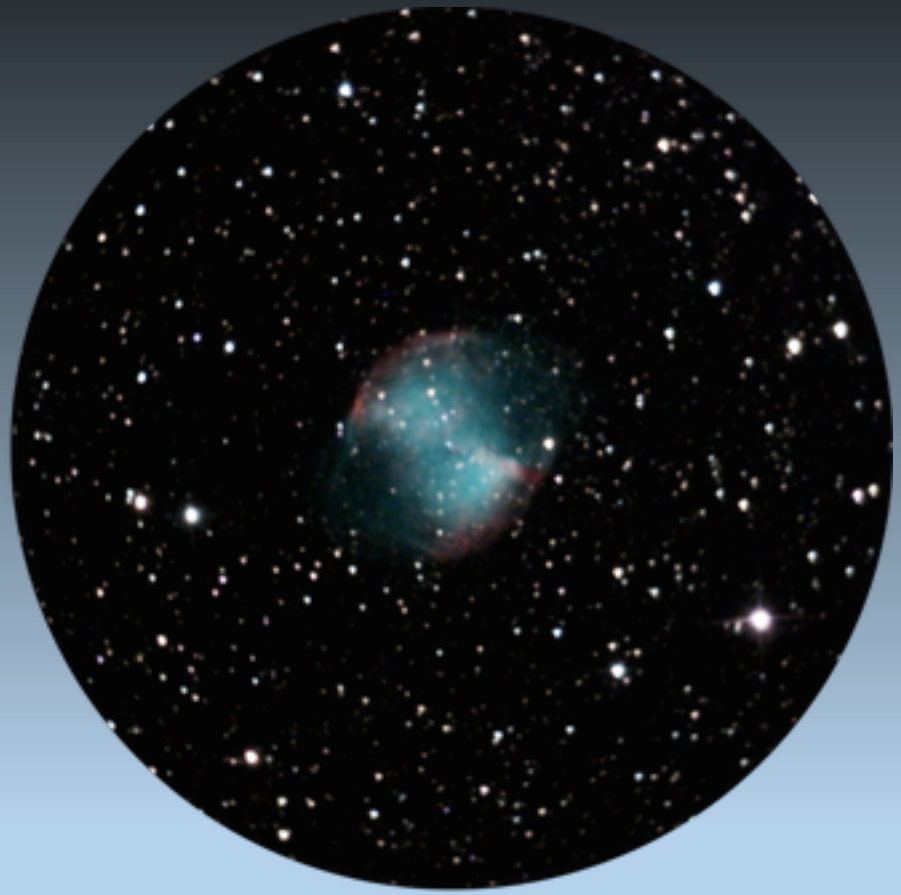


What can you see?



What can you see?

M51



M27

What can you see?

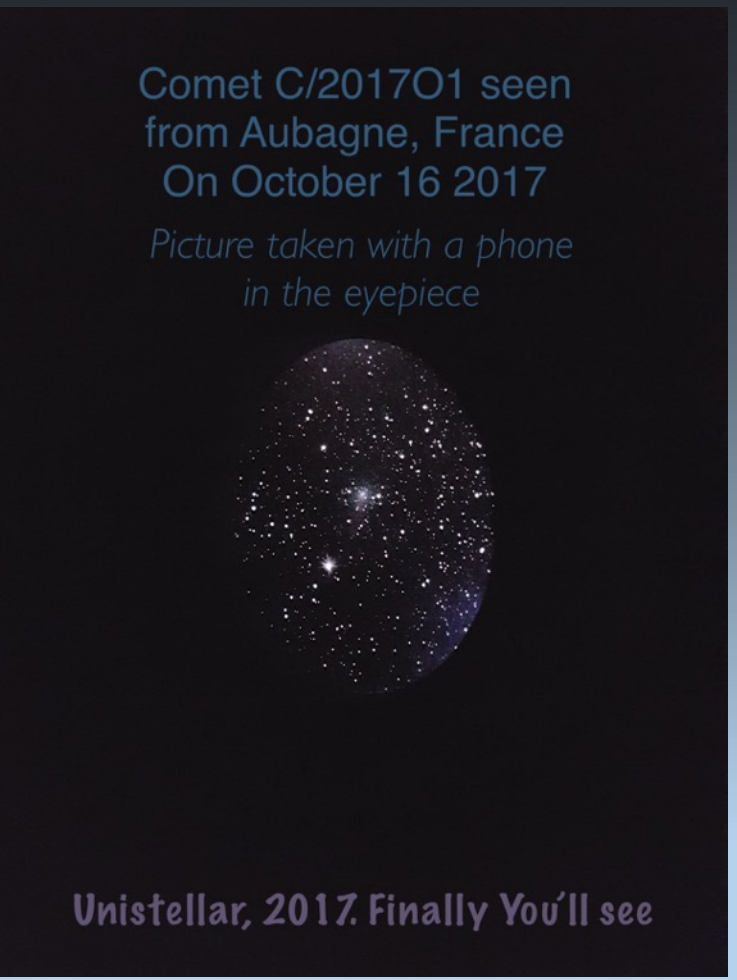
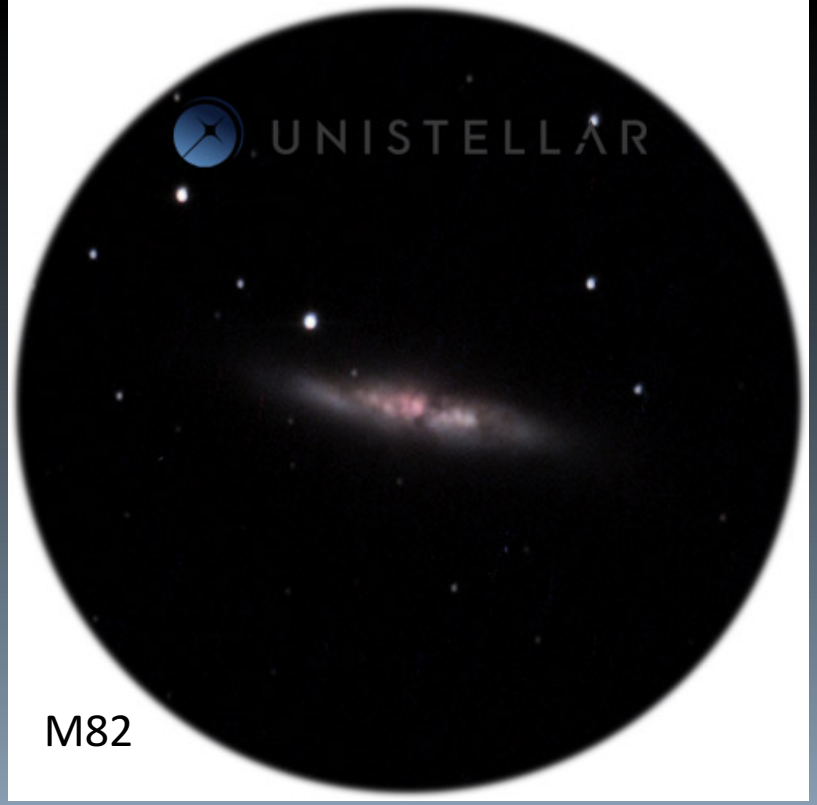
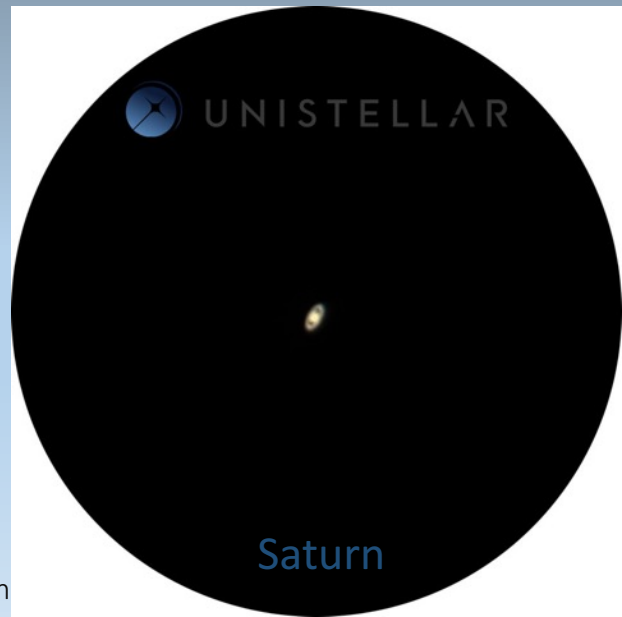


Image taken in the eyepiece with a phone

M17



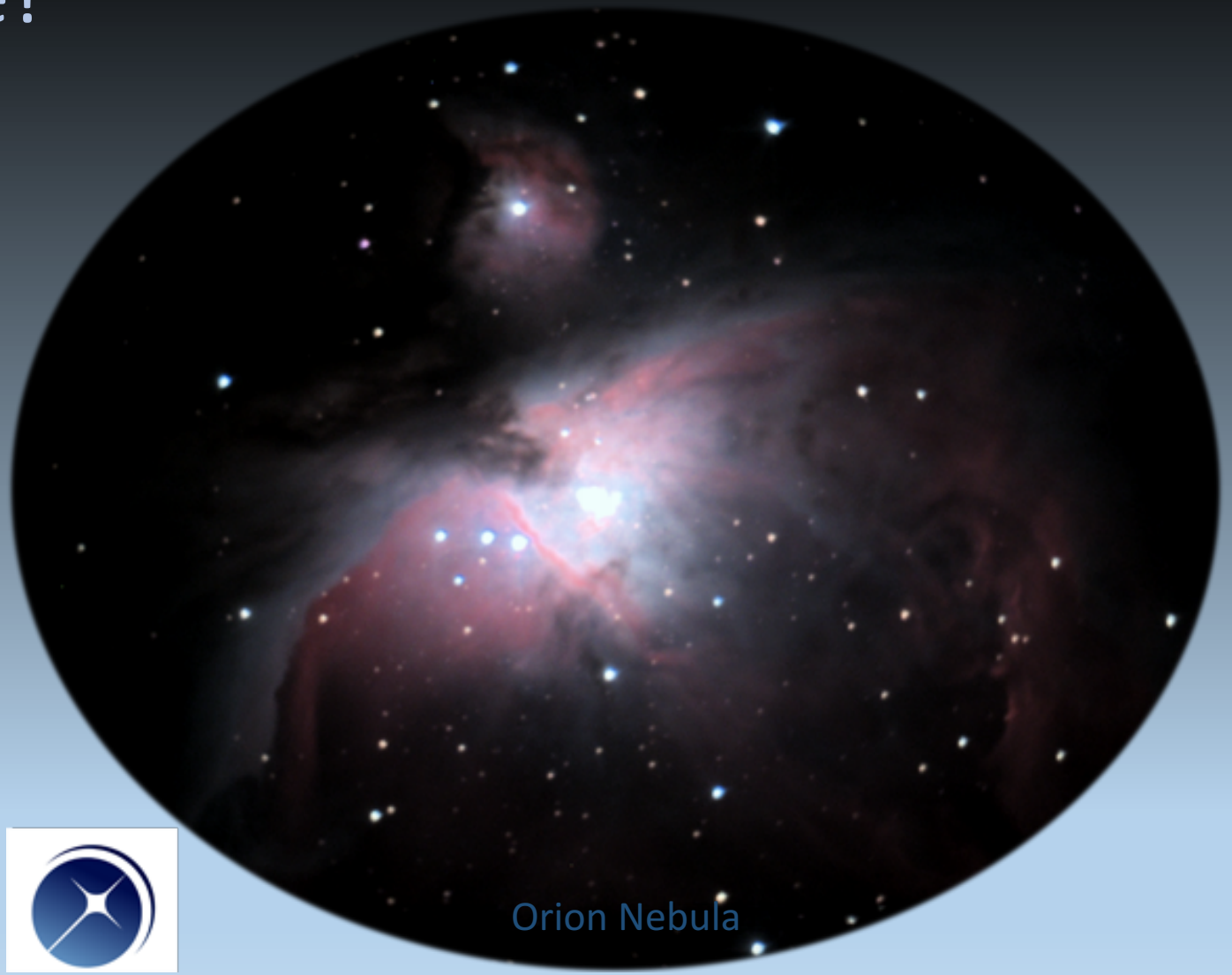
M82



Saturn

What can you see?

Galaxy NGC891



Orion Nebula

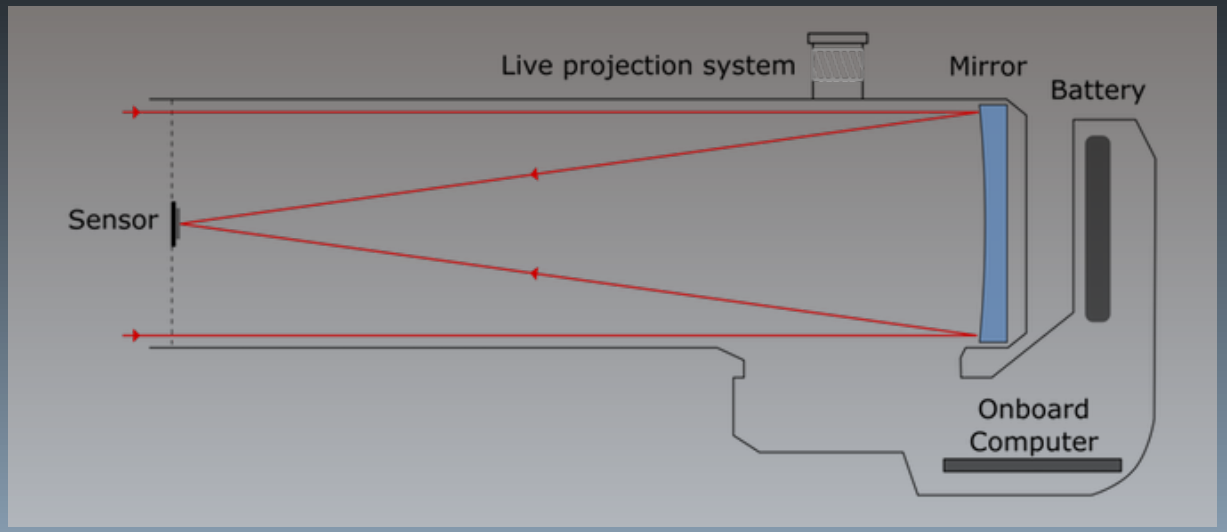
The Technology

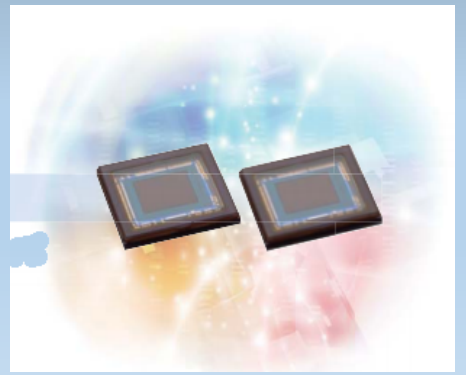
HARDWARE

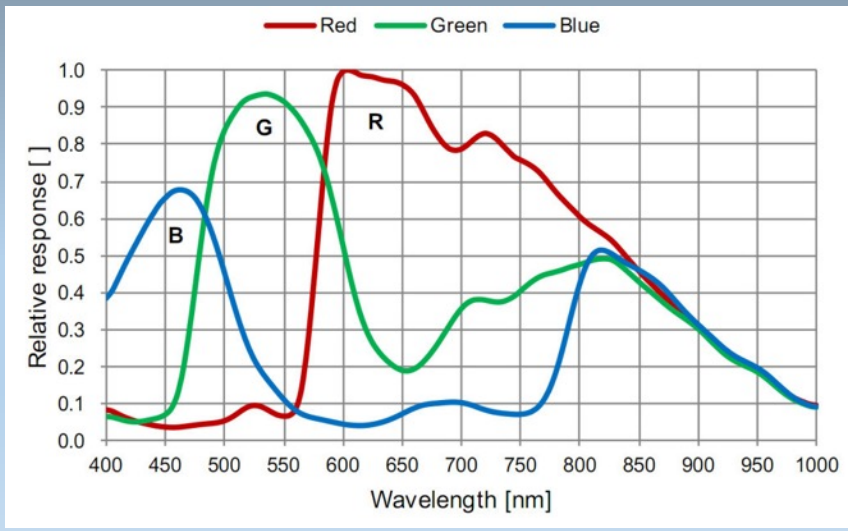
- Magnification: 50/100/150x (numerically adjustable)
- Max magnitude: up to 16 in standard night sky
- Mirror Diameter: 4.5 inches
- Focal length: 450mm
- Focal ratio: 4
- Motorized alt-az mount
- Weight: 15.4lbs (7kg) including tripod

ELECTRONICS

- Sensor model: SONY IMX224
- Read Noise: < 1e-
- Display: Micro-OLED (1,000,000:1 contrast ratio)
- Battery Life: up to 10 hours
- 6 axis Compass/accelerometer
- Wireless connectivity: Wifi or Bluetooth for smartphone or computer control and GPS access.







UNISTELLAR

Enhanced Vision for Exploration, Learning and Citizen Science.

The Technology

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SMARTS

- Autonomous Field Detection
- Fully automated star alignment procedure.
- Automated Pointing
- Automated Celestial Tracking with Feedback
- Field derotation
- Intelligent Image Processing
- Intelligent Sensor Settings
- Light Pollution Reduction

Autonomous Field Detection
Patented algorithm to identify the FOV based on real time data acquired with the telescope.

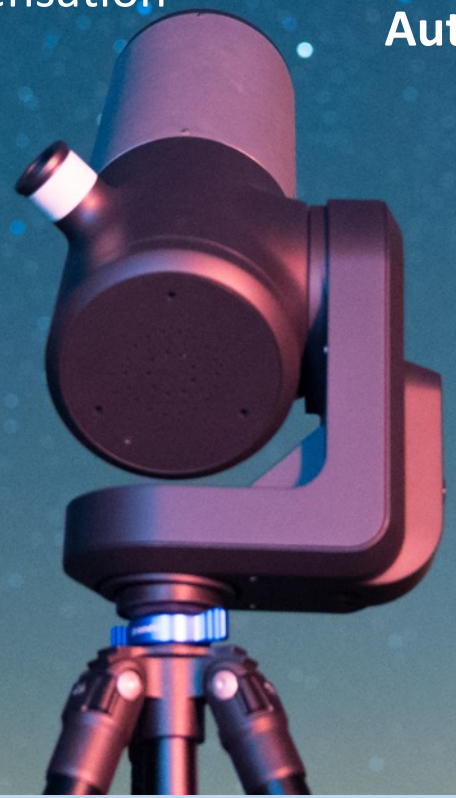
Database will include:
- 110 Messier Objects
- 7840 NGC targets
- About ~4,000 asteroids (V<15.5)

eVscope: making astronomy fun and popular

Enhanced Vision technology
Beautiful images
Light pollution compensation

Autonomous Field Detection
Educative and Interactive

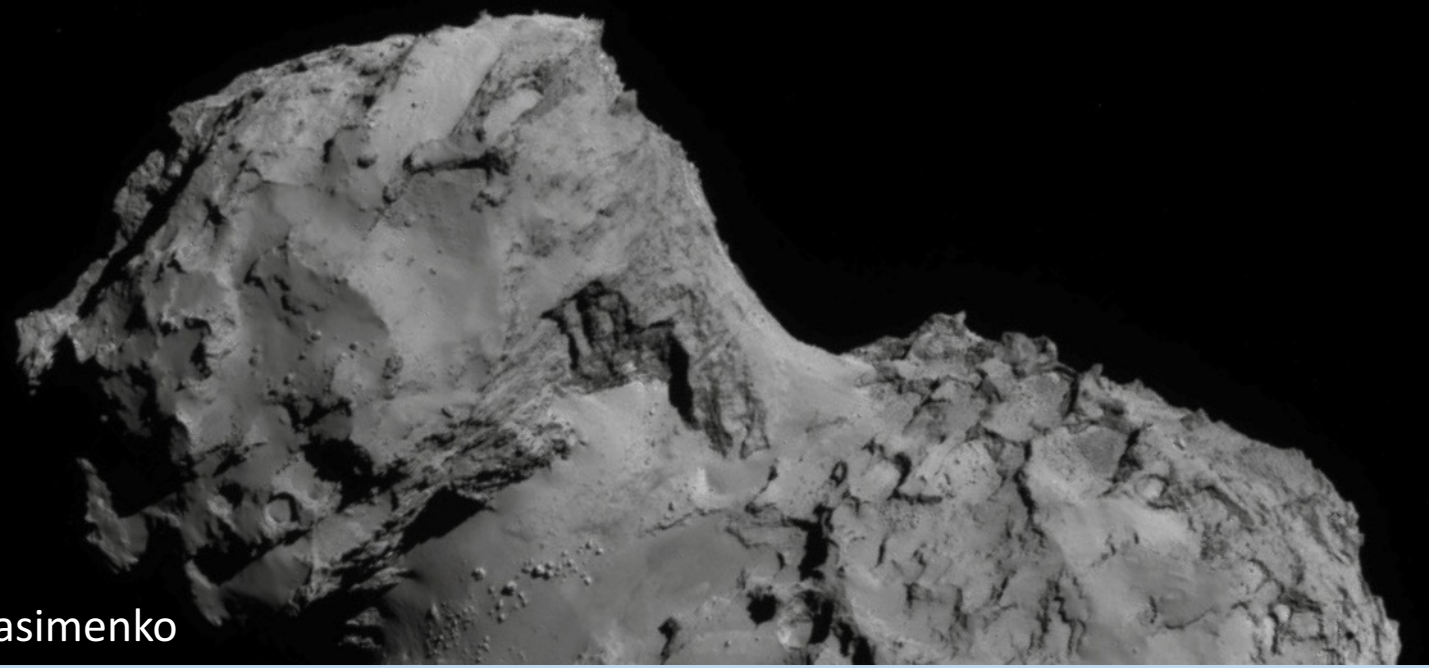
Portable and autonomous
Fits in an urban backpack



Connected
Science campaign
Data Sharing

Astronomy is a Citizen Science

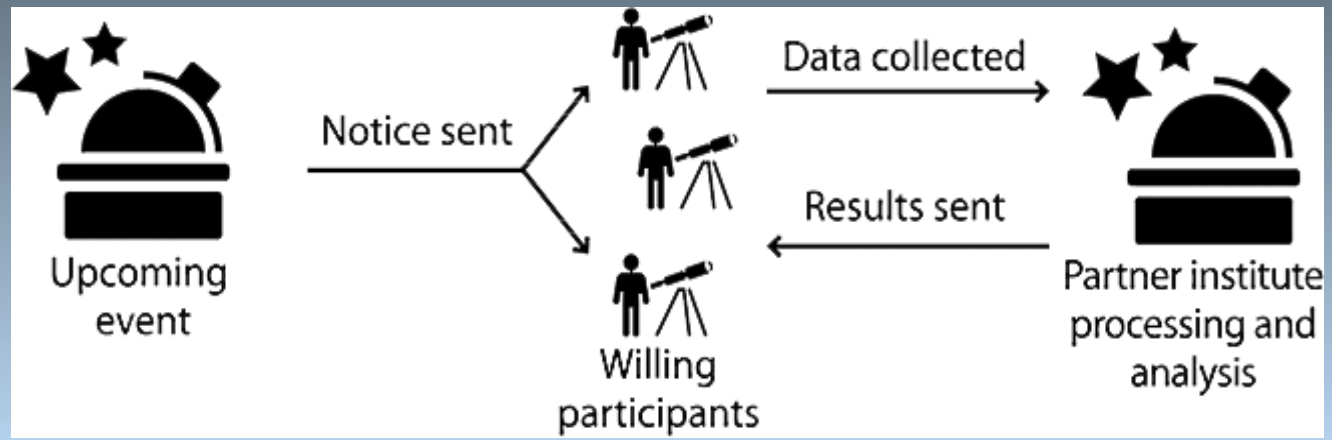
Amateur Astronomers have discovered comets and asteroids for decades.



67P/Churyumov–Gerasimenko

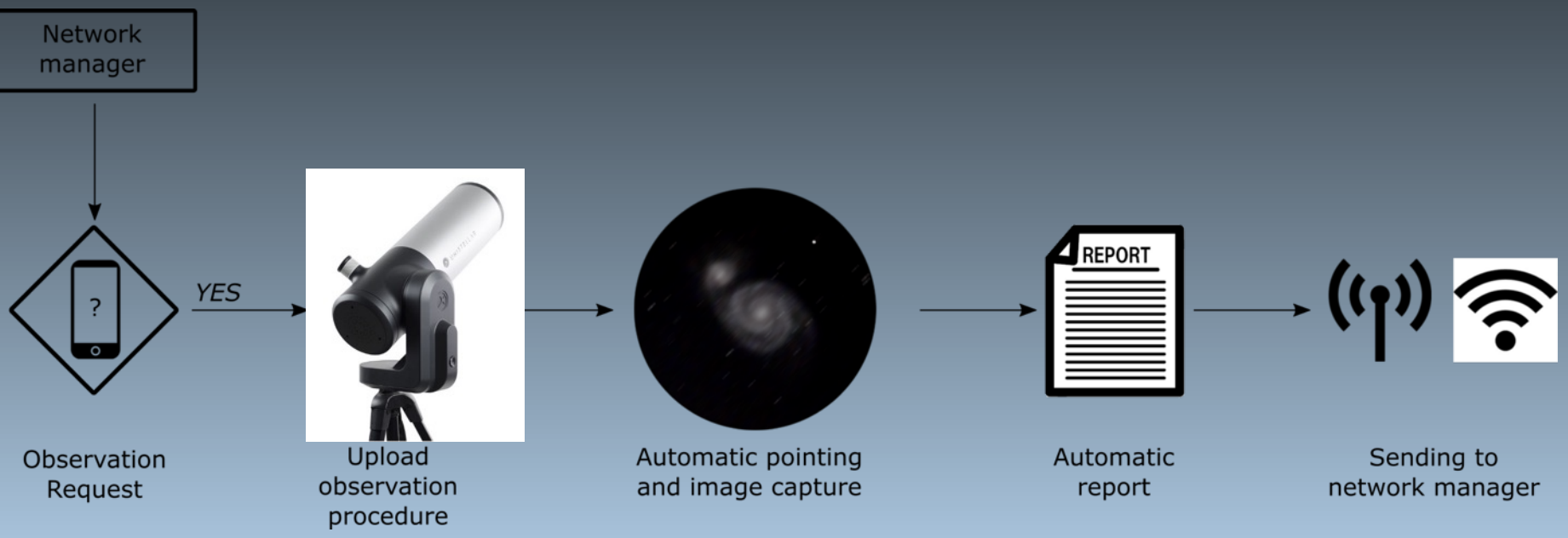
From Consumer to Citizen Scientist

Partnership

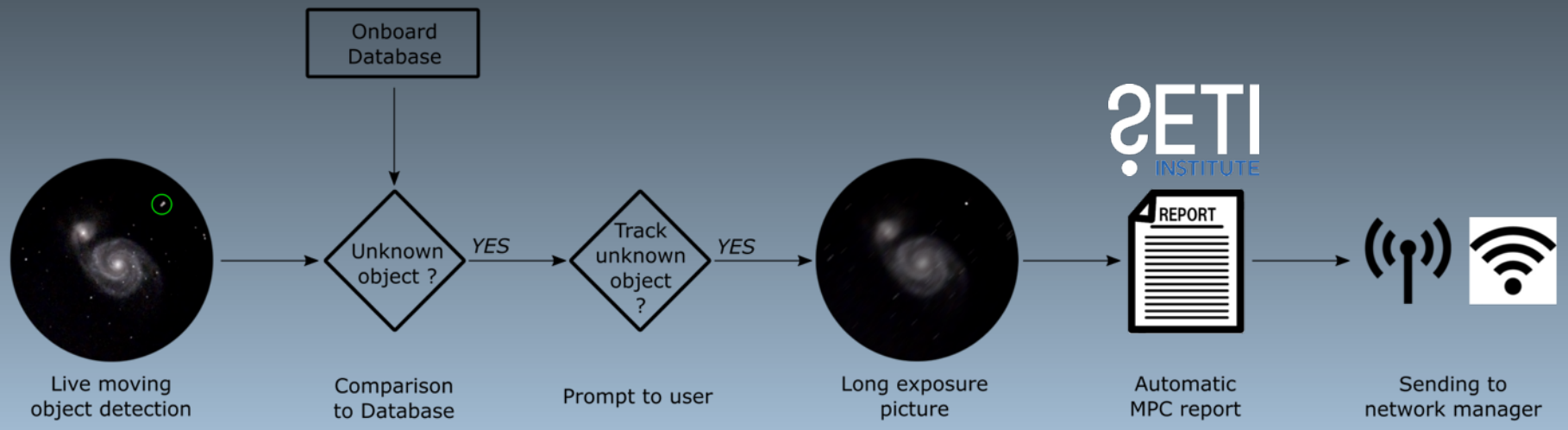


Occultation, Planetary Defense, Exoplanet, Supernovae, Transients....

Operating modes:
Mode 1 – Requested Observations



Operating modes:
Mode 2 – Event Detection



Science & EPO

- Franck Marchis (at least 50% FTE)
- Emmanuel Arbouch (80% FTE)
- SETI research Assistant: Christian Everett (<25% FTE)
- Daniel Peluso (~30% FTE)
- Emmanuel Bertin (Astronomer at IAP)
- Arnaud Malvache (President & CTO at Unistellar)

AT SETI Institute

- Pamela Hartman (Director of Education at the SETI Institute)
- Rebecca McDonald (Director of Communication at the SETI Institute)
- Simon Steel (Director of Outreach at the SETI Institute)

What kind of Science

- **Planetary Defense**

"to detect the possibility and warn of potential asteroid or comet impacts with Earth, and then either prevent them or mitigate their possible effects"

- Early and quick detection of PHAs reported in MPC/ESA
- Orbits of NEAs, Impact zone of PHAs.

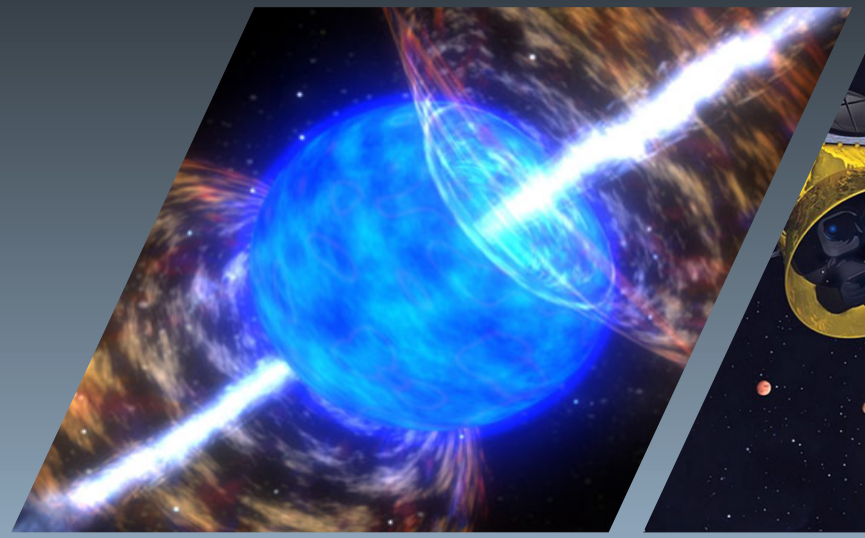
- **Asteroid study**

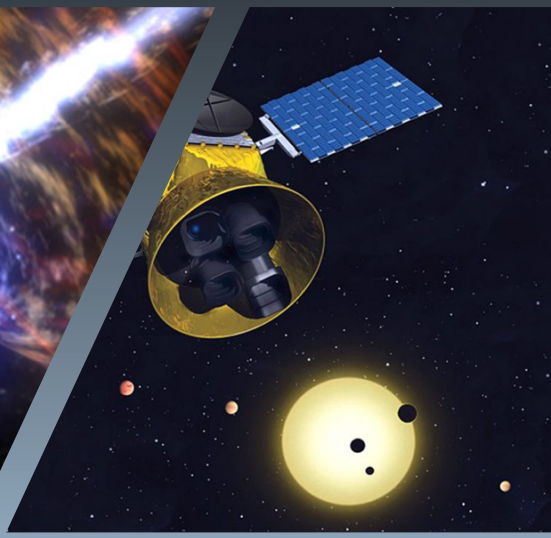
More than 750,000 orbits of asteroids are known today, we don't anything about them.

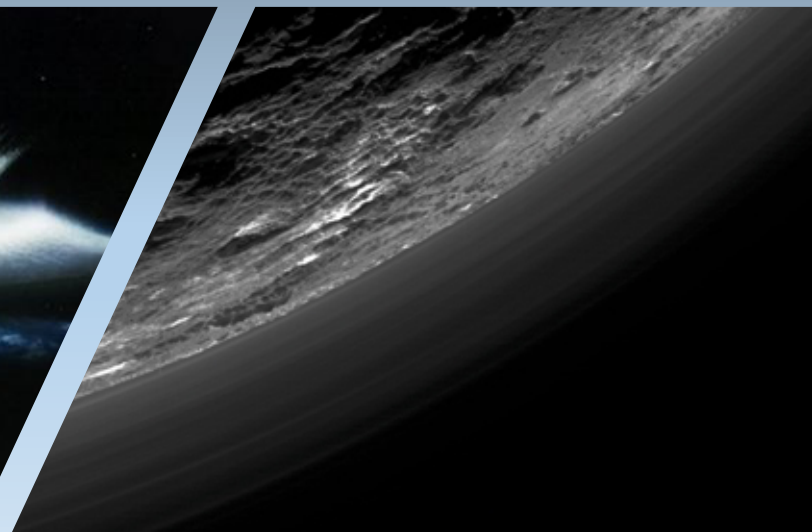
- Shape, Size, and multiplicity by occultation

- **Exoplanet Studies**
- Follow-ups of TESS, and soon Plato discoveries
- Characterization of the orbits, TTV, rings & moons

- **Transient events**
  - Localization of gravitational wave events
  - Afterglow of Gamma-ray bursts
  - ET civilizations (Laser SETI)

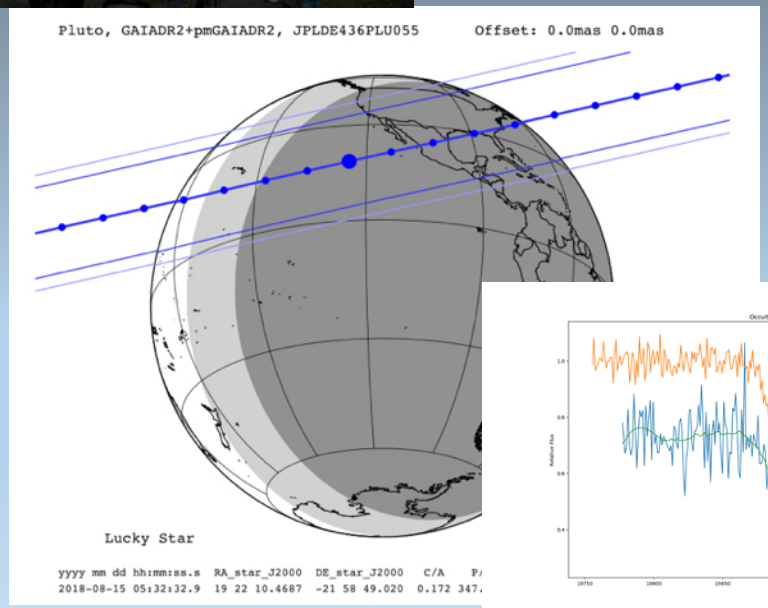


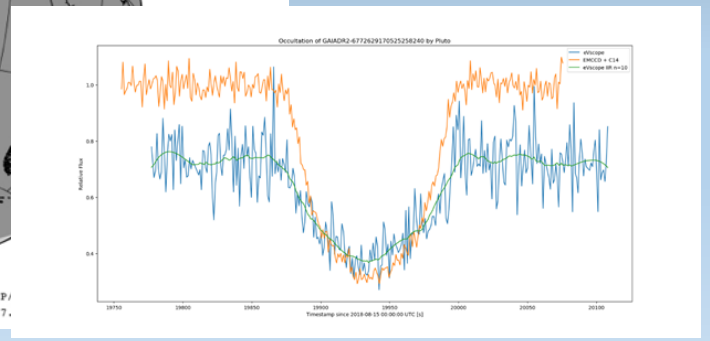




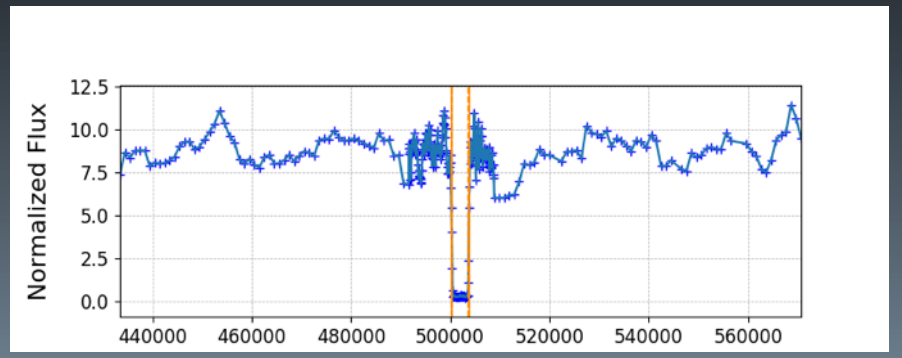
Occultation events with the First eVscope

August 15 2018
Pluto occulted a 13-mag star

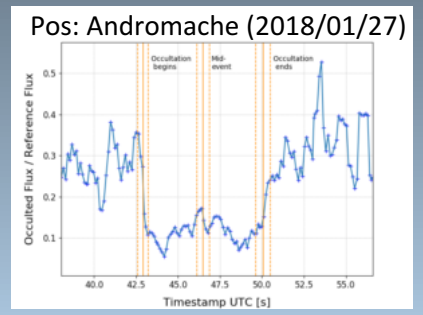




September 16 2018
(80) Sappho occulted a 7.5-mag star



With our First Prototype



Promising First Results!

Goals:

- Astrometric position (Mass of Asteroids)
- Size and shape of asteroid
- Detection of an atmosphere
- Detection of rings and moons

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Enhanced Vision for Exploration, Learning and Citizen Science.

The Industrialized version of the eVscope

Manufacturing

Urban astronomy

Soon a large network around the world

Testing internally
Beta-testing

Science?

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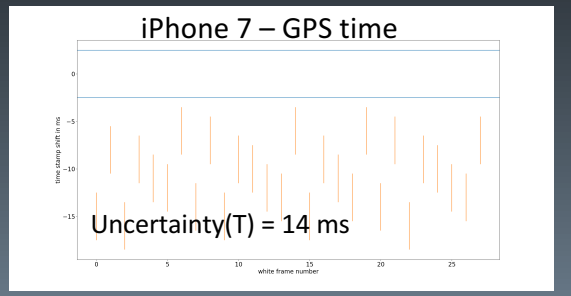
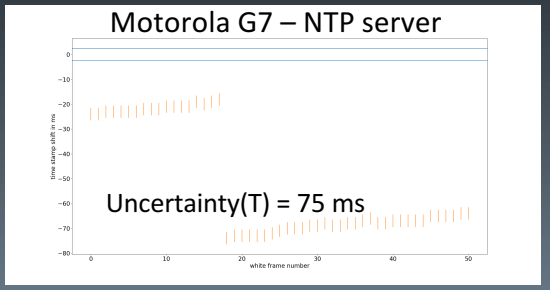
Enhanced Vision for Exploration, Learning and Citizen Science.

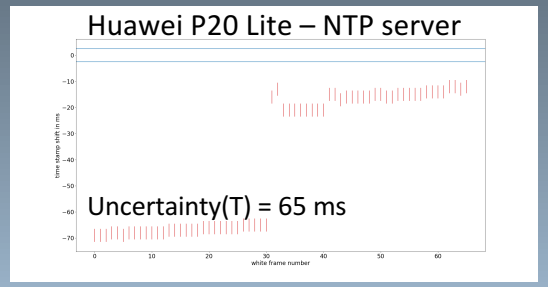
Timing Accuracy Testing

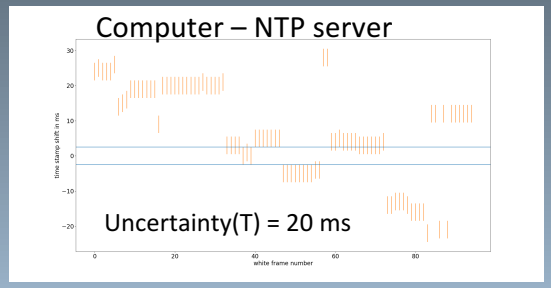
Q: What is the accuracy in the time of the frame provided by the eVscope?

A high tech experiment





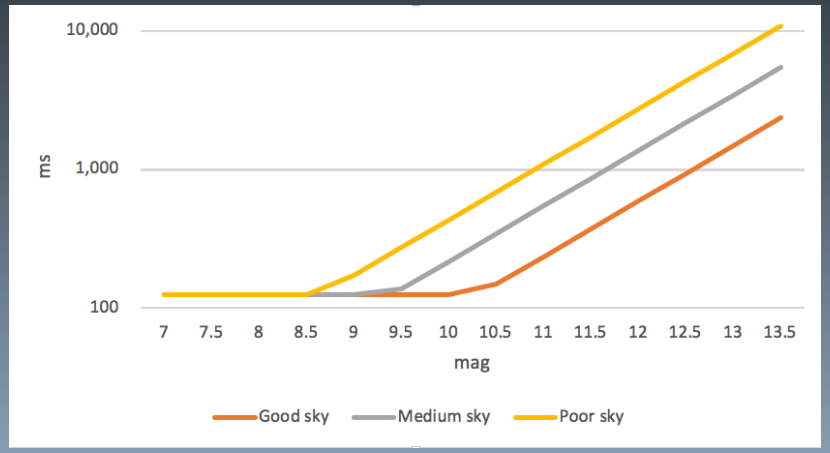




- Drift of the eVscope computer only 4 ms per hour
- Use of the Chronoflash (Prado et al. 2019) – flash of 5 ms (accuracy of the flash 1ms source: TENUM)
- Method
  - Time in the eVscope is synchronized using NTP servers (on Android phone or computer) and GPS (iPhone)
  - Record 100 frames with 5 ms exposure time and 125 ms cadence (max currently available)
  - Compare Time stamp of those frames vs flash timing
- Best time accuracy for iPhone (14 ms), worst case for Xiaomi A2 lite (150 ms).
- Conclusion: **<100 ms time accuracy** if a 4G connection is available on most phones

More Occultations with the eVscope

Goal: More observers, more collaborations, more outreach



Sensitivity limit of 1 eVscope

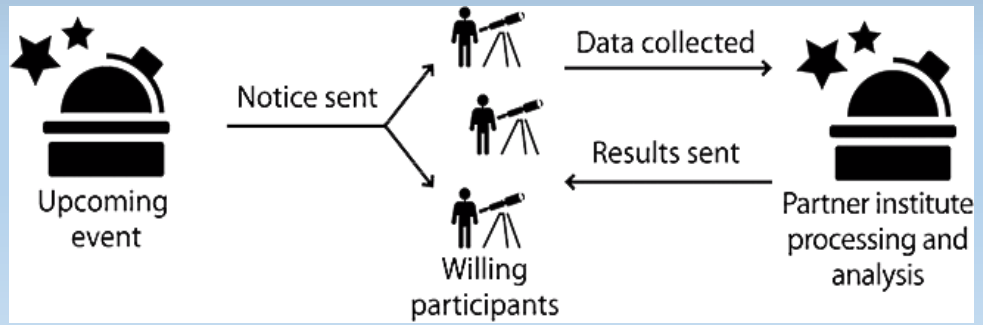
Good sampling (more than 10 points for 1s occultation) for V<[11.2,12.2] (depending of sky condition)

44 events per night

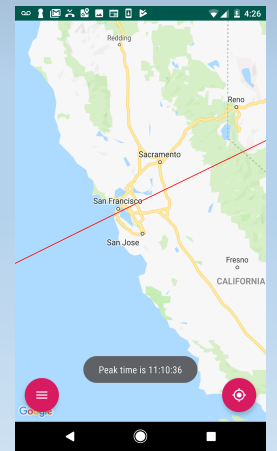
2019: Mag < 11.2 V Number of Events at Duration Minimums						
Date	t > 5 s	5 - 4 s	4 - 3 s	3 - 2 s	2 - 1 s	1 s > t
1-May	5	3	5	8	19	148
1-Aug	1	1	4	12	28	157
1-Nov	2	3	3	8	28	177

2019: Mag < 12.2 V Number of Events at Duration Minimums						
Date	t > 5 s	5 - 4 s	4 - 3 s	3 - 2 s	2 - 1 s	1 s > t
1-May	12	4	12	18	51	340
1-Aug	4	1	7	22	52	367
1-Nov	8	5	9	15	56	415

Number of events



An App

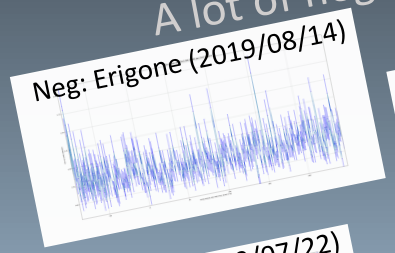


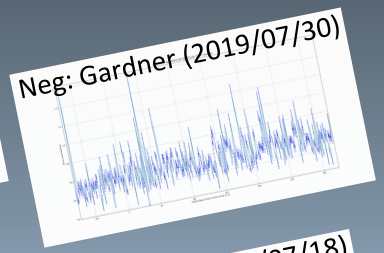
Summer 2019 – More Occultation

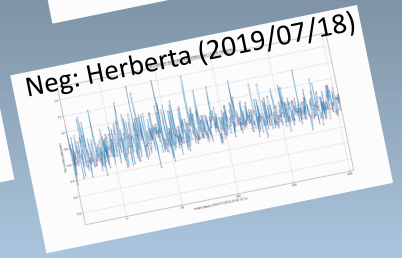
Goals:

- Testing the eVscope in real conditions for Occultation
- Validate the pipeline to extract the photometry

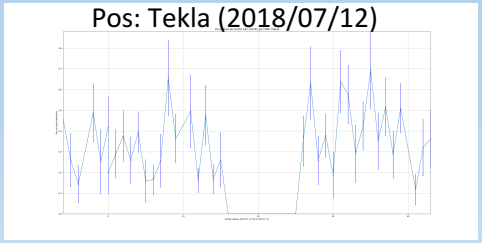
A lot of negative chords





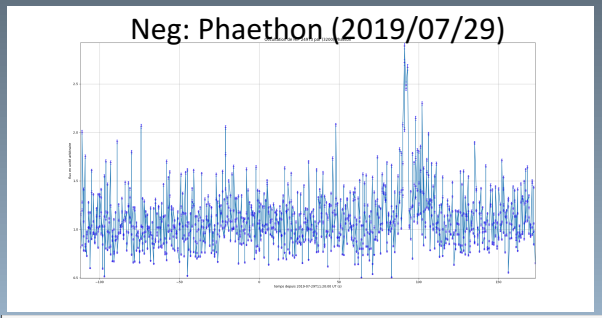


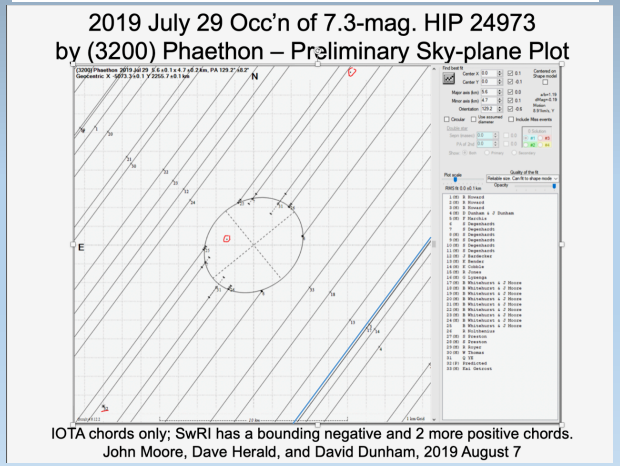
One Positive



Thanks T. Bellier (intern and observer)

In California as well

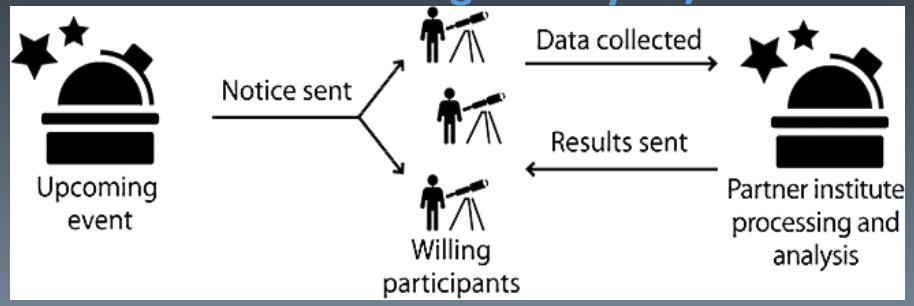


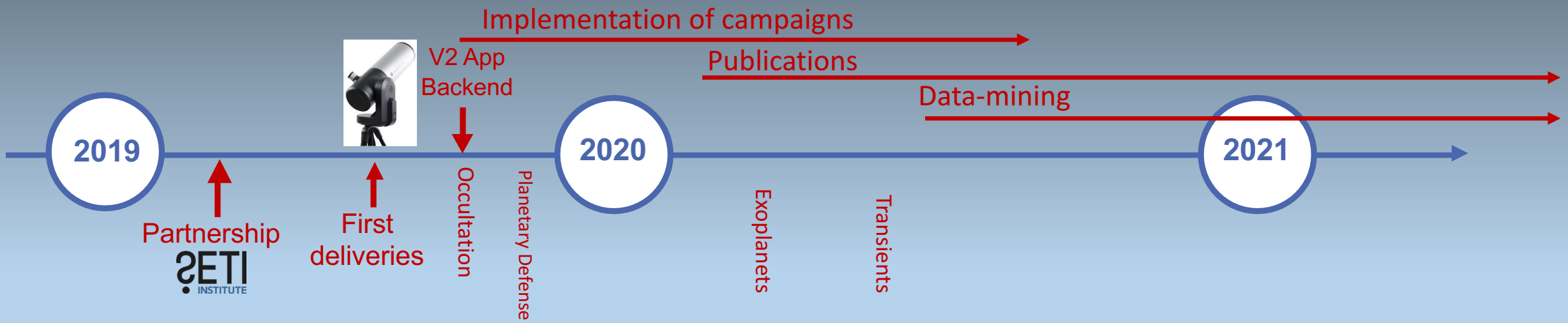


All those observations were reported to PlanetOccult

Next Steps in Science

To develop the largest network of telescopes in the world capable of watching the sky 24/7





- Grow the group
- Funding: NASA/NSF/ESA/Private Foundations

In Conclusion

- The eVscope: a smart, powerful, and easy-to-use device for novices & experts, schools and universities
- Occultation: first science case implemented in the eVscope
- Feasibility demonstration in Summer 2019
- Alerts, backend and automatic data processing to be implemented in 2019B
- More observers, more collaborations, more outreach to support of NASA/JAXA/ESA Missions (stay tuned…) and large campaigns in collaboration with IOTA/EURASTER

UNISTELLAR

The largest network of telescopes in the world to watch the sky 24/7

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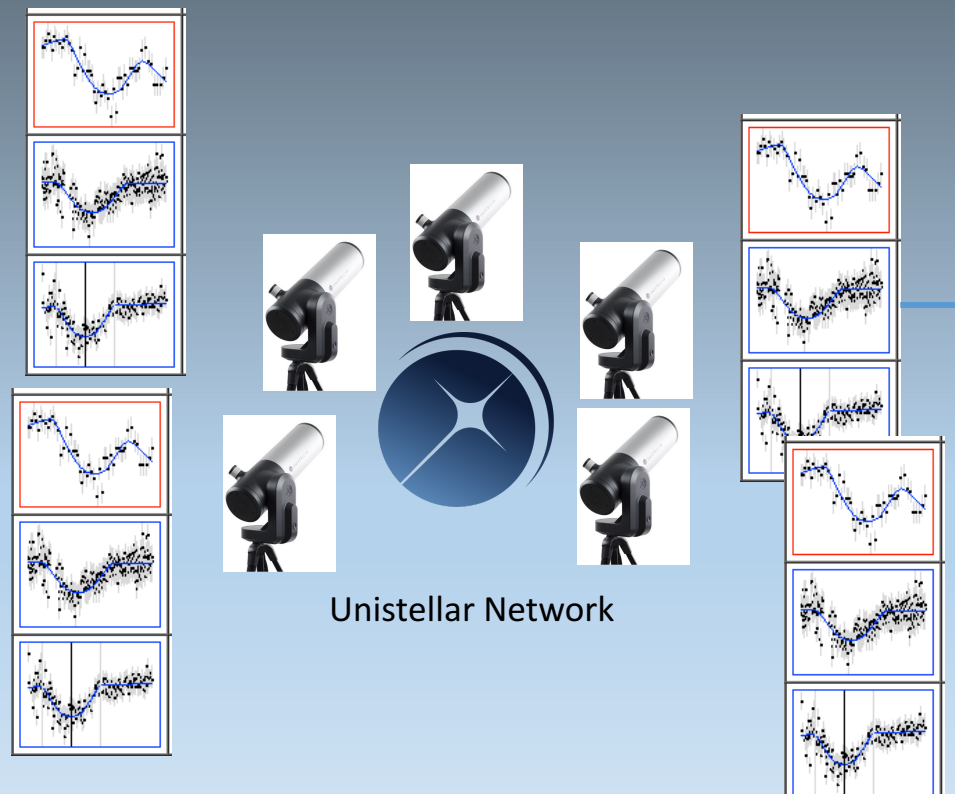
Properties of the Network

One eVscope:

FOV = 37 x 28 arcmin
Pixel size = 3.75µm
magMax = mag 18 in 5- 10 min of stacking
astrometric accuracy < 0.3 px (0.5 arcsec), TBC
photometric accuracy <0.02 mag @ mag 12.4



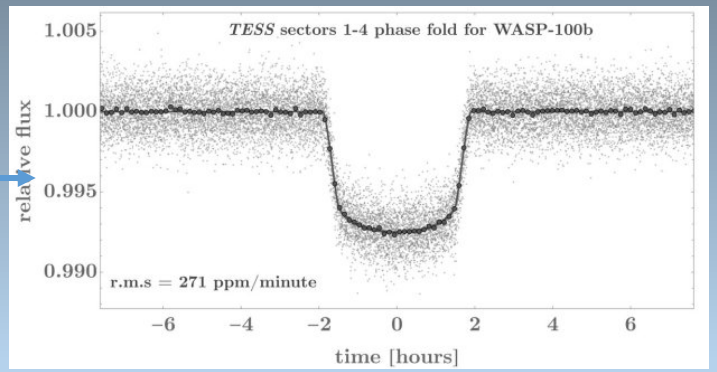
Unistellar Network

UNISTELLAR PIPELINE

Multiple eVscopes:

Limit in magnitude:??
Astrometric accuracy:" ??"
Photometric accuracy: ???

E. Arbouch these



UNISTELLAR

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