‘Oumuamua, our Solar System’s first (known) interstellar visitor

Karen Meech
Institute for Astronomy
SBAG - January 17, 2018
The Discovery 2017

- **10/19** – Discovered by PS1 → P10Ee5V
- **10/18** – Prediscovery images found in PS1 data
  - Follow up ESA ground station – data rejected, large eccentricity
  - Classified as an Earth-orbit crossing asteroid
- **10/20** – Catalina Sky Survey data → classified as short-period comet
- **10/22** – CFHT observations: orbit is hyperbolic: $e = 1.188$
- **10/24** – The Minor Planet Center posted a name: C/2017 U1
- **10/26** – MPEC 2017-U183 – name: A/2017 U1
Jupiter's orbit

A/2017 U1 path

Comet orbit

Mercury

Venus

Mars

Uranus

Earth

Sun

Jupiter

Saturn

Neptune

1837 – Passed inside 1000 au
Jan 17, 2017 – inside 5.2 au
Aug 10, 2017 – inside 1.0 au
Sep 9, 2017 – perihelion q = 0.255 au
Oct 10, 2017 – outside 1.0 au
Oct 14, 2017 – close Earth approach ∆ = 0.162 au

May 3, 2018 outside 5.2 au
Jun 2022 – 30 au
Feb 2024 – 39 au
Dec 2025 – 50 au
Jul 2038 – 121 au
2196 – 1000 au
What do we want to know?

- Size & Shape
- Rotation state
- Comet or asteroid?
- Composition
  - Surface colors
  - Mineral / ice composition
  - Isotopic composition
- Orbit
  - Origin
  - Age
  - Implications


- Avg $102 \pm 4$ m, $800 \times 80 \times 80$ m
- Period $7.34 \pm 0.06$ hr . . . (complex rot)
- No activity
- Composition
  - Red reflectivity, $23 \pm 2 \% / 100$ nm
  - Organics, minerals, Fe grains, metal
- Orbit
  - Not from our SS
  - $v_\infty$ similar to solar neighborhood – young system
  - Many more ISOs than expected
# The Timeline

<table>
<thead>
<tr>
<th>Sun</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
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</thead>
<tbody>
<tr>
<td>← Sep 9 Perihelion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14- Close Earth, CSS Precovery</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18-PS1 Precovery</td>
<td>19-PS1 Discovery</td>
<td>20-Astrometry</td>
<td>21-Astrometry</td>
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<tr>
<td>22- Hyperbolic orbit confirmed</td>
<td>23-DD prop VLT, GS; VLT Approve</td>
<td>24- GS prop approved; MPEC orbit announce</td>
<td>25-VLT Obs, HST prop submit, UKIRT DD award; ★</td>
<td>26- VLT, GS obs; HST Approve; PR ★</td>
<td>27- GS, CFHT, UKIRT, Keck obs</td>
<td>28- UKIRT obs ☆</td>
</tr>
<tr>
<td>29 – Hawaiian name</td>
<td>30- ★</td>
<td>31- Nature paper submit</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>6-Ref. Rpt. IAU Name OK</td>
<td>7</td>
<td>8-Resubmit paper</td>
<td>9</td>
<td>10-Paper in production</td>
<td>11</td>
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</tbody>
</table>

- Name: **P10EeV5 → C/2017 U1 → A/2017 U1**
  - Ka‘iu Kimura (navigator), Larry Kimura (Hawaiian linguistics)

- Proposal of ‘Oumuamua
  - ‘Ou = to reach out for, mua = first, in advance of (duplication emphasis)
  - Scout or distant messenger sent from our distant beginnings to reach out to us or build connections with us

Effective obs window

- Propagation of C/2017 U1 → A/2017 U1

Ka‘iu Kimura (navigator), Larry Kimura (Hawaiian linguistics)

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A brief visit from a red and extremely elongated interstellar asteroid

First observed interstellar object to pass by Earth given Hawaiian name

By Timothy Hurley

Following a speedy yet far-reaching analysis, University of Hawaii astronomers Monday unveiled a description of their discovery last month of the first interstellar object seen passing through our solar system.

The assessment?

"This thing is quite strange," said Karen Meech of UH’s Institute for Astronomy and lead author of the study, which appeared Monday in the journal Nature.

The rapidly rotating interstellar asteroid — about 2.625 feet long, or roughly seven football fields or more — has an unusual appearance and orbit.

**INTERSTELLAR ASTEROID**

<table>
<thead>
<tr>
<th>Name</th>
<th>Discovered</th>
<th>Origins</th>
<th>Age</th>
<th>Status</th>
<th>Telescope</th>
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</thead>
<tbody>
<tr>
<td>'Oumuamua</td>
<td>Oct. 19</td>
<td>Beyond our solar system</td>
<td>Millions of years</td>
<td>Passing through</td>
<td>Pan-STARRS 1</td>
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</tbody>
</table>

Approximate length: **2,625 feet** (800 meters)

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**HART board delays $18M increase for rail contractor**

Most of the higher costs are due to a heavier workload, a rail official says
<table>
<thead>
<tr>
<th>PI</th>
<th>Telescope</th>
<th>Allocation</th>
<th>Date Obs</th>
<th>Science</th>
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</thead>
<tbody>
<tr>
<td>Hainaut/Meech</td>
<td>VLT 8m</td>
<td>3.5 hr</td>
<td>10/25, 10/26</td>
<td>Rotation, shape, color</td>
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<tr>
<td>Fitzsimmons</td>
<td>WHT</td>
<td>&lt; 1 hr</td>
<td>10/25, 10/28</td>
<td>Spectrum</td>
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<tr>
<td>Masiero</td>
<td>Palomar 5m</td>
<td>3 hr</td>
<td>10/25</td>
<td>Spectrum</td>
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<tr>
<td>Ye</td>
<td>Palomar 5m</td>
<td>&lt; 1 hr</td>
<td>10/26</td>
<td>Spectrum</td>
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<tr>
<td>Meech</td>
<td>Gemini 8m</td>
<td>3.5 hr</td>
<td>10/26, 10/27</td>
<td>Rotation, shape, color</td>
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<tr>
<td>Snodgrass</td>
<td>VLT 8m</td>
<td>4 hr</td>
<td>10/27</td>
<td>Spectrum</td>
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<tr>
<td>Guzik</td>
<td>Gemini 8m</td>
<td>9.7 hr</td>
<td>10/27</td>
<td>Rotation</td>
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<tr>
<td>Chambers</td>
<td>UKIRT 3.8 m</td>
<td>9 hr</td>
<td>10/27, 10/28</td>
<td>Color - IR</td>
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<tr>
<td>Magnier</td>
<td>Keck 10 m</td>
<td>3 hr</td>
<td>10/27</td>
<td>Rotation, color</td>
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<tr>
<td>Wainscoat</td>
<td>CFHT 3.6 m</td>
<td>8 hr</td>
<td>10/27, 11/20, 11/21</td>
<td>Rotation, astrometry</td>
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<td>Jewitt</td>
<td>NOT 2.5 m</td>
<td>2.3 hr</td>
<td>10/25, 10/30</td>
<td>Rotation, color</td>
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<tr>
<td>Jewitt</td>
<td>WIYN 3.5m</td>
<td>4.5 hr</td>
<td>10/28</td>
<td>Rotation</td>
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<tr>
<td>Bannister</td>
<td>Gemini 8m</td>
<td>2 hr</td>
<td>10/29</td>
<td>Colors</td>
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<tr>
<td>Bolin</td>
<td>APO 3.5m</td>
<td>4 hr</td>
<td>10/29</td>
<td>Rotation</td>
</tr>
<tr>
<td>Knight</td>
<td>DCT 4 m</td>
<td>2.8 hr</td>
<td>10/30</td>
<td>Rotation</td>
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<tr>
<td>Meech</td>
<td>HST 1.8 m</td>
<td>9 orbits</td>
<td>11/21, 11/22, Dec, Jan</td>
<td>Astrometry</td>
</tr>
<tr>
<td>Sheppard</td>
<td>Magellan 6.5m</td>
<td>3 hr</td>
<td>11/21, 11/22</td>
<td>Rotation</td>
</tr>
<tr>
<td>Trilling</td>
<td>Spitzer</td>
<td>32.6 hr</td>
<td>11/21</td>
<td>Albedo, size</td>
</tr>
</tbody>
</table>
AstroPh papers posted

- **Oct. 31** – Mamajek – ISO kinematics
- **Nov. 1** – Marcos – pole, pericenter....
- **Nov. 2** – Masiero – spectrum
- **Nov. 2** – Knight – partial light curve
- **Nov. 3** – Trilling – implications
- **Nov. 3** – Gaidos – origin location
- **Nov. 7** – Laughlin – consequences
- **Nov. 7** – Ye – color, activity search
- **Nov. 12** – Cyncynates – dark matter?
- **Nov. 14** – Hein – ISO mission
- **Nov. 14** – Zwart – ISO origin
- **Nov. 14** – Bolin – rotation
- **Nov. 15** – Jewitt – characterization
- **Nov. 16** – Bannister – colors
- **Nov. 22** – Schneider – is U1 interstellar?
- **Nov. 22** – Ferrin – 1I might be a comet?
- **Nov. 23** – Feng – Origin local assoc.
- **Nov. 27** – Raymond - Implications
- **Nov. 28** – Zuluaga – Origin - Methods
- **Nov. 30** – Fraser – Rotation – tumbling
- **Dec 1** – Drahus – 1I is tumbling
- **Dec 12** – Domokos – explain shape
- **Dec 13** – Jackson – ejection from binary
- **Dec 17** – Wright – not a SS object
- **Dec 18** – Cuk – tidal fragment from binary
- **Dec 18** – Fitzsimmons – spectra & thermal
- **Dec 19** – Gaidos – characterizing 1I
- **Dec 19** – Hansen – ejection from post MS *
- **Dec 21** – Zhang – backtracking the orbit
- **Jan 9** – Do – Number density of ISO
- **Jan 10** – Enriquez – Breakthrough Listen
- **Jan 13** – Rafikov – Disruption by WD
- **TBD** – Belton – Excited spin state of 1I
Average size & Activity

• **Brightness is related to size (and how reflective)**
  – Combine all the 8-m telescope data
  – Average radius \(102 \pm 4\) m

• **Dust Limits**
  – Compare shape of stars to `Oumuamua: Maximum amount of dust is about \(1/2\) kg
  – Agrees with sublimation model analysis

• **Icy or rocky?**
  – The surface at closest approach to sun reaches \(600\)°
  – Heat from likely to penetrate only \(\sim 1\) m
  – \(1\) billion years exposure to cosmic rays should not remove all ice if it exists near surface
Surface Composition

- It is “red” like comets.
- Organic compounds (kerogen), pyroxene, metallic iron, iron oxides
- Weathering or original composition?
Surface Composition

Spectra from many groups

- Surface reflectivity is red
- Palomar 10/25 – 30% / 100 nm
- WHT 10/25 – 16% / 100 nm
- Palomar 10/26 – 10±6 % / 100 nm
- Gemini 10/28 (Bannister) – 22±15 % / 100 nm
- Fitzsimmons 17±2.3 % / 100 nm (WHT)
- Fitzsimmons 9.3±0.6 % / 100 nm (VLT)
How fast does it spin?

What was done

- Fit for color and rotation
- Light curve range, $\Delta m = 2.5$ mag
- Axis ratio $> 10:1$

Results

- Rotation period $7.34\pm0.06$ hr
- Broad maxima, sharp minima
- Must have some strength
‘Oumuamua’s shape
Rotation

P = 8.14 hr, a:b = (6.9±3.4) : 1

P > 5 hr, a:b = > 3:1

"ordinary"

P = 8.26 hr, a:b = > 6:1
Some issues: Rotation
Where did it come from?

- **Initial direction from the direction of Vega**
  - Could this be coming from the Vega debris disk? - no

- **Can it be a comet from our Solar System – perturbed by Planet X?**
  - To be undiscovered planet needs to be near galactic plane (U1’s radiant has galactic latitude of -16°)
  - The radiant of the recently proposed planet X is not close to U1’s

<table>
<thead>
<tr>
<th>Lead Author</th>
<th>Galactic $v_\infty(U, V, W)$ km/s</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meech</td>
<td>-11.2, -22.4, -7.6</td>
<td>Similar to stars in solar neighborhood, from a younger system?</td>
</tr>
<tr>
<td>Mamajek (31 Oct)</td>
<td>-11.3, -22.4, -7.6</td>
<td>Not from $\alpha$ Cen Oort cloud</td>
</tr>
<tr>
<td>Gaidos (3 Nov)</td>
<td>-11.3, -22.4, -7.6</td>
<td>Possible origin in proto planetary disk from Carina/Columba association</td>
</tr>
<tr>
<td>Zwart (13 Nov)</td>
<td></td>
<td>Passed by 5 stars with somewhat close encounters</td>
</tr>
<tr>
<td>Feng (27 Nov)</td>
<td>-11.4, -22.4, -7.7</td>
<td>Integrate orbit back 100 Myr – 109 stars with “close” encounters; young</td>
</tr>
</tbody>
</table>
Interstellar Object Density

• **Goal**
  - ISO # density upper limit given lack of detection of any ISOs in 19 yrs of survey
  - Generated random (direction, v) ISO population
  - Simulated the detection of synthetic ISOs using PS1, Mt. Lemmon, and Catalina sky surveys

• **Results**
  - 90% CL – no comet activity \(2.4 \times 10^{-2} \text{ au}^{-3}\)
  - 90% CL – with comet activity \(2.4 \times 10^{-4} \text{ au}^{-3}\)
  - `Oumuamua is asteroidal – using the higher density implies at any one moment there is \(~1\) object of similar size inside 1 au

A Mission to/from ‘Oumuamua?

- **Initiative for Interstellar Studies – Project Lyra** (10/30; Hein)
  - Launch in 2027, mission duration 15 years
  - Need to reach hyperbolic excess velocity of 37.4 km/s
  - Current technology limits to flyby – not rendezvous
  - Encounter distance between 100-200 AU – requires RTGs

- **The Breakthrough Listen Experiment**
  - Wed Dec 13 using the GBT
  - From 1-12 GHz
  - No signal detected
Why is this important?

• Rare opportunity to study a sample of another solar system
  – Is the planet formation process similar everywhere?
  – Is the composition of small bodies the same everywhere?
• How much of this material is out there?
  – Because of the high velocity $\rightarrow$ hazardous
• Many groups have tried to assess 1I/2017 U1’s star of origin