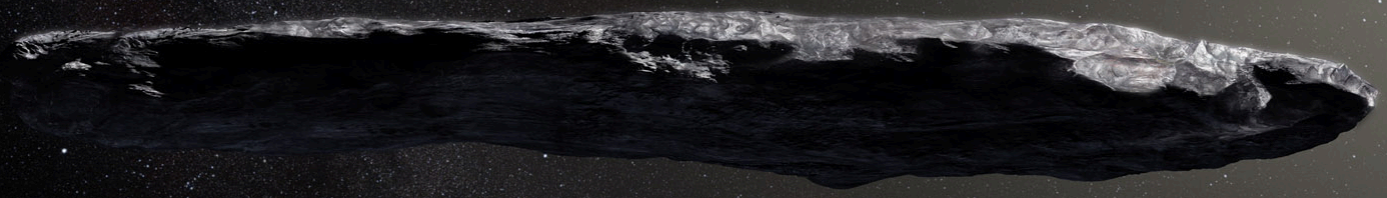
‘Oumuamua, our Solar System’s first (known) interstellar visitor



Karen Meech

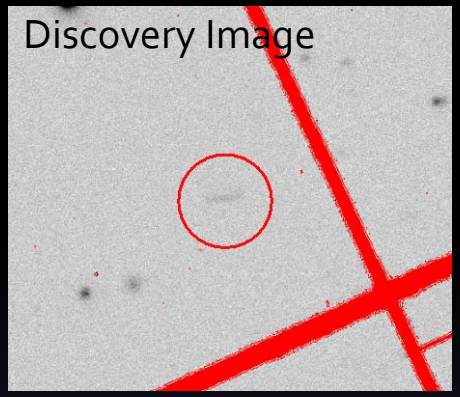
Institute for Astronomy

SBAG - January 17, 2018

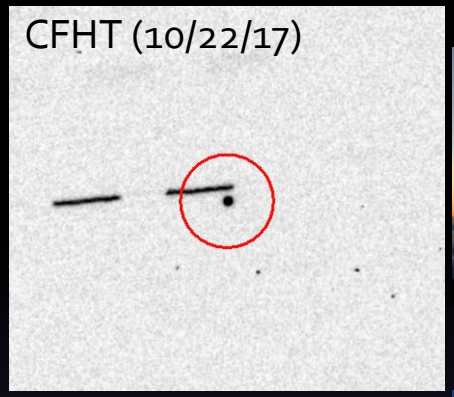
R. Weryk

M. Micheli, R. Wainscoat

The Discovery 2017



Tracked on stars



Tracked on object

PanSTARRS1 (1.8m)

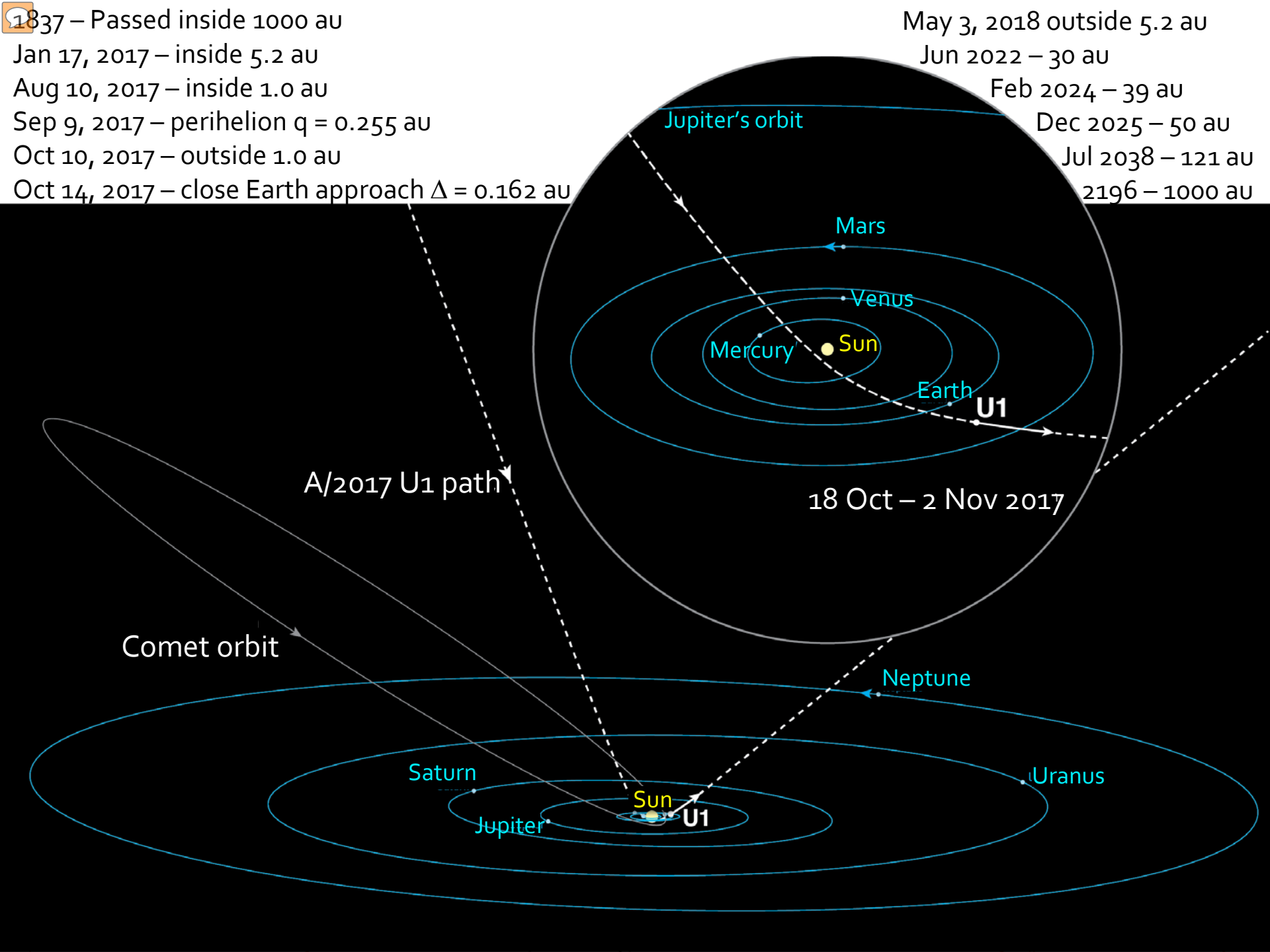
ESA Ground (1m)

CFHT (3.6m)

- 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

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 Δ = 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



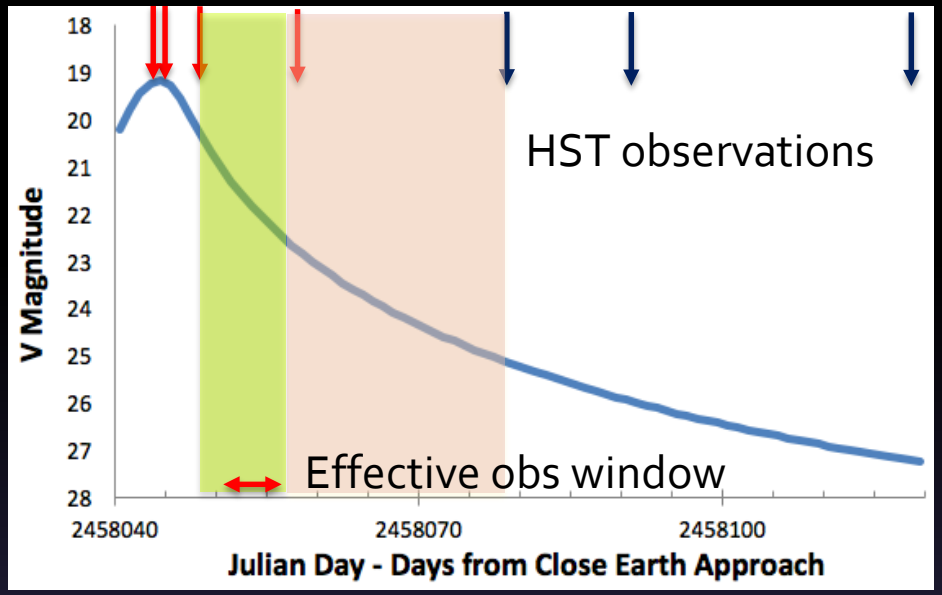
What do we want to know?

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

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

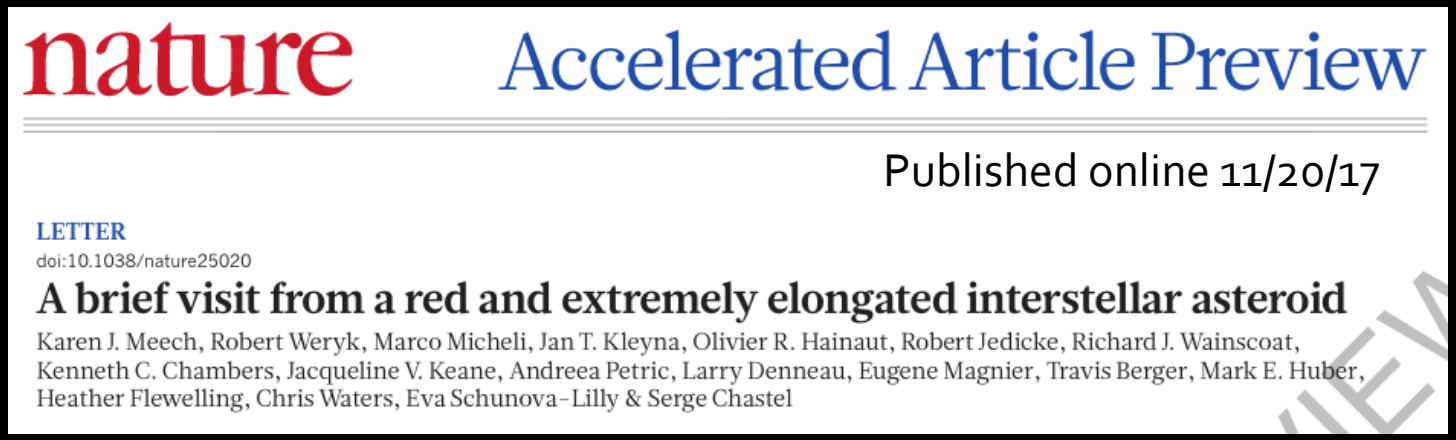
Meech et al (2017). *Nature 552*, 378 – doi:10.1038/nature25020

The Timeline



- 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

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



nature

Accelerated Article Preview

Published online 11/20/17

LETTER

doi:10.1038/nature25020

A brief visit from a red and extremely elongated interstellar asteroid

Karen J. Meech, Robert Weryk, Marco Micheli, Jan T. Kleyna, Olivier R. Hainaut, Robert Jedicke, Richard J. Wainscoat, Kenneth C. Chambers, Jacqueline V. Keane, Andreea Petric, Larry Denneau, Eugene Magnier, Travis Berger, Mark E. Huber, Heather Flewelling, Chris Waters, Eva Schunova-Lilly & Serge Chastel

R.it Scienze

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'Oumuamua, il primo asteroide interstellare mai osservato

SPACE.com

NEWS TECH SPACEFLIGHT SCIENCE & ASTRONOMY SEARCH

Space.com › Science & Astronomy

Wow! 1st Interstellar Asteroid Is a Spinning Space Cigar

By Ian O'Neill, Space.com Contributor | November 20, 2017 03:29pm ET

ABC

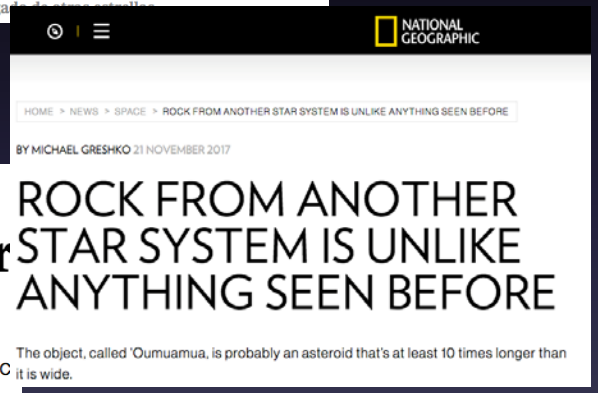
Buscar en ABC

ESPAÑA INTERNACIONAL ECONOMÍA OPINIÓN DEPORTES CONOCER MOTOR FAMILIA GENTE SUMMUM CULTURA & OCIO SERVICIOS EDICIONES MADRID

Publicidad

Adiós al primer visitante interestelar de la Historia

• Los astrónomos logran nuevos detalles de Oumamua, el asteroide llega



NATIONAL GEOGRAPHIC

HOME > NEWS > SPACE > ROCK FROM ANOTHER STAR SYSTEM IS UNLIKE ANYTHING SEEN BEFORE

BY MICHAEL GRESHKO 21 NOVEMBER 2017

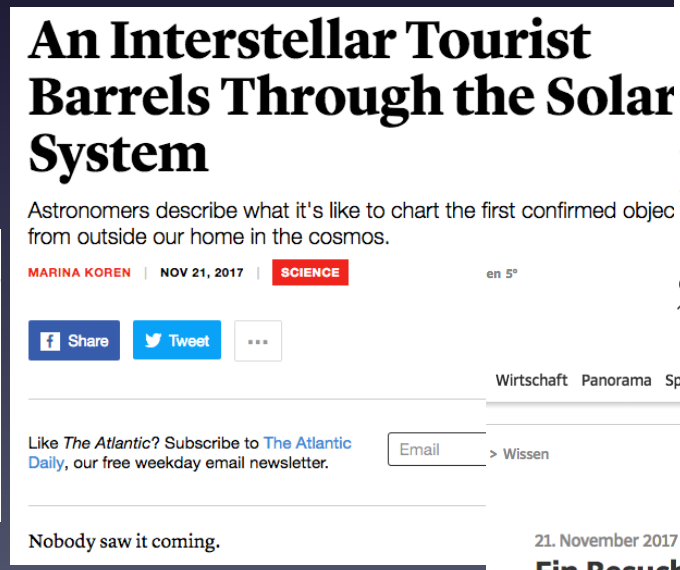
ROCK FROM ANOTHER STAR SYSTEM IS UNLIKE ANYTHING SEEN BEFORE

The object, called 'Oumuamua, is probably an asteroid that's at least 10 times longer than it is wide.

Science & Environment

Bizarre shape of interstellar asteroid

By Paul Rincon
Science editor, BBC News website



An Interstellar Tourist Barrels Through the Solar System

Astronomers describe what it's like to chart the first confirmed objec from outside our home in the cosmos.

MARINA KOREN | NOV 21, 2017 | SCIENCE

en 5°

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Nobody saw it coming.

The New York Times | https://nyti.ms/2jOQSSg

SCIENCE

An Interstellar Visitor Both Familiar and Alien

Leer en español

Dennis Overbye

OUT THERE NOV. 22, 2017

Süddeutsche Zeitung

SZ.de Zeitung Magazin

Wirtschaft Panorama Sport München Bayern Kultur Gesellschaft Wissen Digital Karriere Reise

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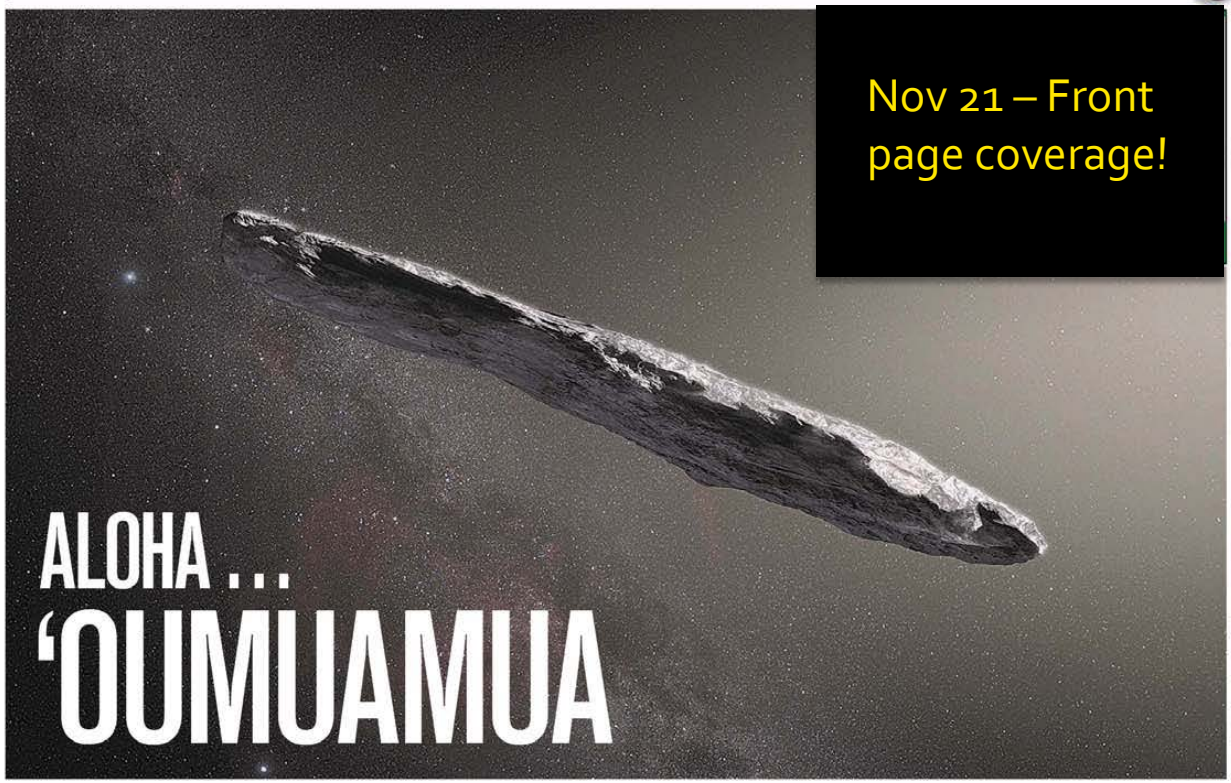
21. November 2017 12:25 Wissenschaft

Ein Besucher aus dem All verblüfft Astronomen

TUESDAY 11/21/17 STARADVERTISER.COM >> $1 Oahu, $1.25 neighbor islands >> Partly sunny. High 83, low 69 >> A12

Nov 21 – Front page coverage!



COURTESY UNIVERSITY OF HAWAII AT MANOA'S INSTITUTE FOR ASTRONOMY

ALOHA … 'OUMUAMUA

First observed interstellar object to pass by Earth given Hawaiian name

The Pulse of Paradise
Honolulu Star Advertiser

By Timothy Hurley
thurley@staradvertiser.com

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

INTERSTELLAR ASTEROID

The recently identified interstellar asteroid is described as likely a dark red, long, metallic or rocky object. It is now headed out of our solar system:

• **Name:** 'Oumuamua • **Discovered:** Oct. 19 • **Origins:** Beyond our solar system
• **Age:** Millions of years • **Status:** Passing through • **Telescope:** Pan-STARRS 1

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

HART board delays $18M increase for rail contractor

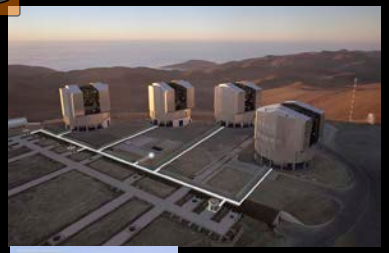
Most of the higher costs are due to a heavier workload, a rail official says

World Resources ~ 100 hrs

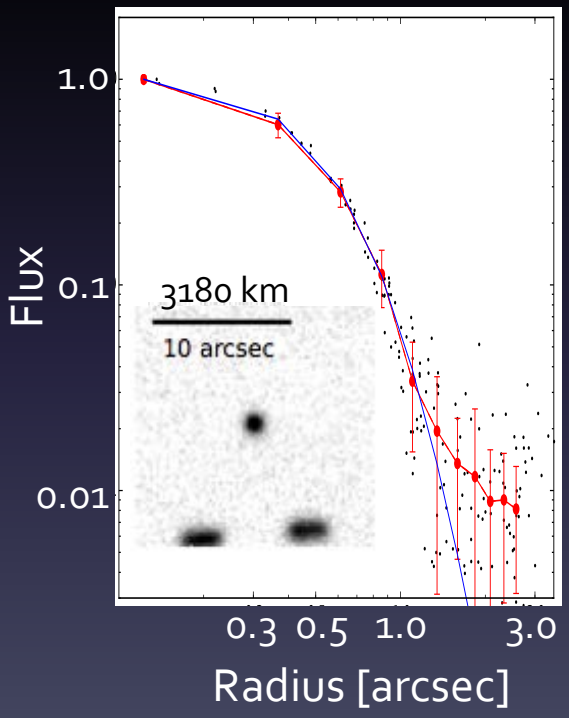
PI	Telescope	Allocation	Date Obs	Science
Hainaut/Meech	VLT 8m	3.5 hr	10/25, 10/26	Rotation, shape, color
Fitzsimmons	WHT	< 1 hr	10/25, 10/28	Spectrum
Masiero	Palomar 5m	3 hr	10/25	Spectrum
Ye	Palomar 5m	< 1 hr	10/26	Spectrum
Meech	Gemini 8m	3.5 hr	10/26, 10/27	Rotation, shape, color
Snodgrass	VLT 8m	4 hr	10/27	Spectrum
Guzik	Gemini 8m	9.7 hr	10/27	Rotation
Chambers	UKIRT 3.8 m	9 hr	10/27, 10/28	Color - IR
Magnier	Keck 10 m	3 hr	10/27	Rotation, color
Wainscoat	CFHT 3.6 m	8 hr	10/27, 11/20, 11/21	Rotation, astrometry
Jewitt	NOT 2.5 m	2.3 hr	10/25, 10/30	Rotation, color
Jewitt	WIYN 3.5m	4.5 hr	10/28	Rotation
Bannister	Gemini 8 m	2 hr	10/29	Colors
Bolin	APO 3.5m	4 hr	10/29	Rotation
Knight	DCT 4 m	2.8 hr	10/30	Rotation
Meech	HST 1.8 m	9 orbits	11/21, 11/22, Dec, Jan	Astrometry
Sheppard	Magellan 6.5m	3 hr	11/21, 11/22	Rotation
Trilling	Spitzer	32.6 hr	11/21	Albedo, size

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

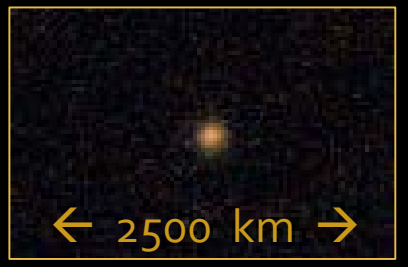


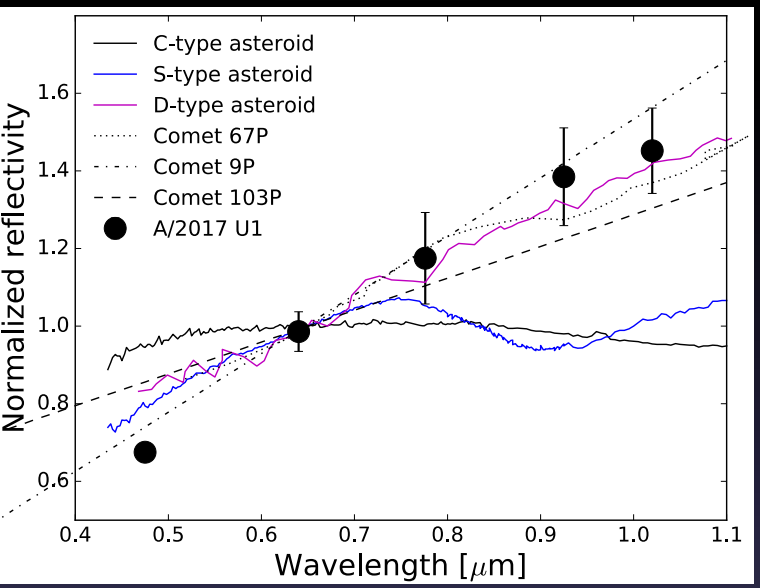
Average size & Activity

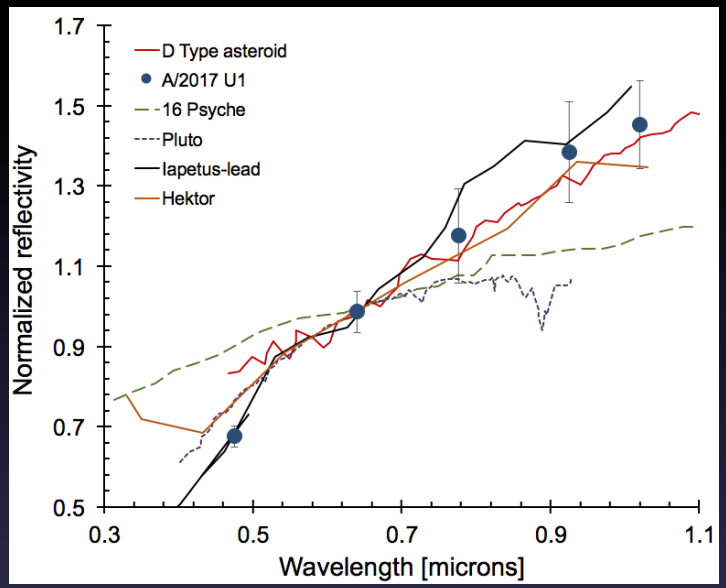


- Brightness is related to size (and how reflective)
  - Combine all the 8-m telescope data
  - Average radius 102±4 m
- Dust Limits
  - Compare shape of stars to `Oumuamua: Maximum amount of dust is about 1/2 kg
  - Agrees with sublimation model analysis
- Icy or rocky?
  - The surface at closest approach to sun reaches 600°
  - Heat from likely to penetrate only ~1 m
  - 1 billion years exposure to cosmic rays should not remove all ice if it exists near surface

Surface Composition



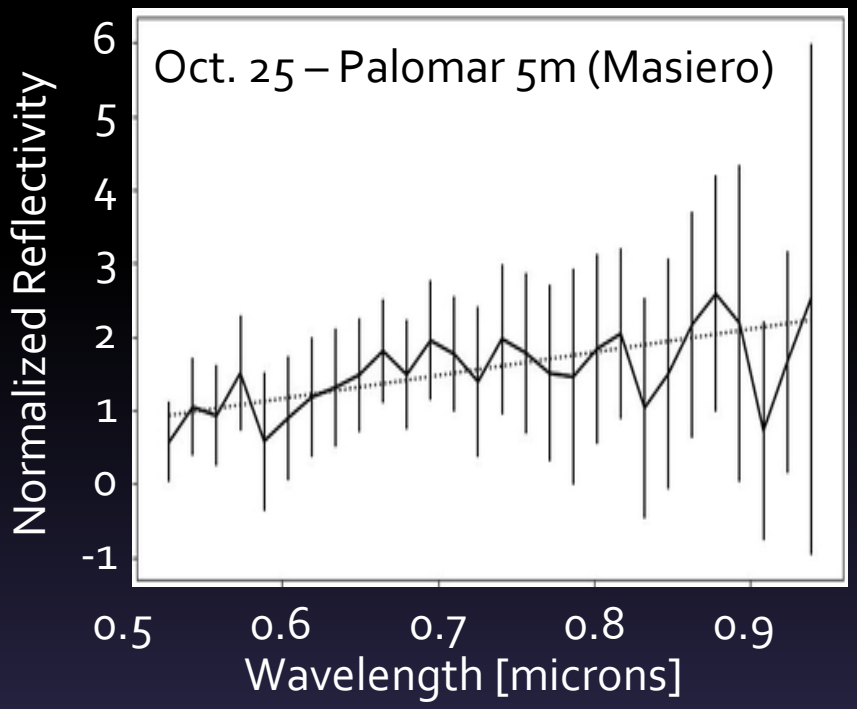


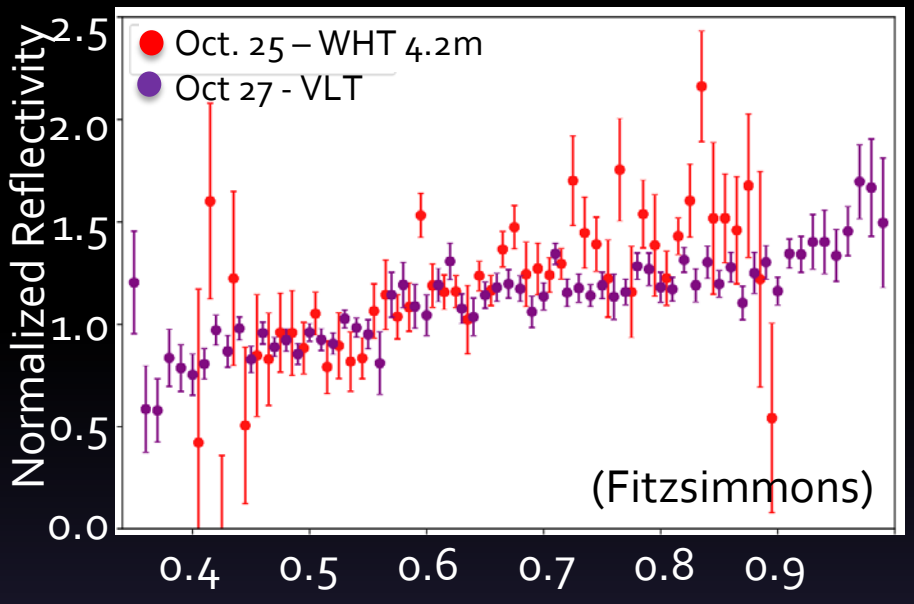


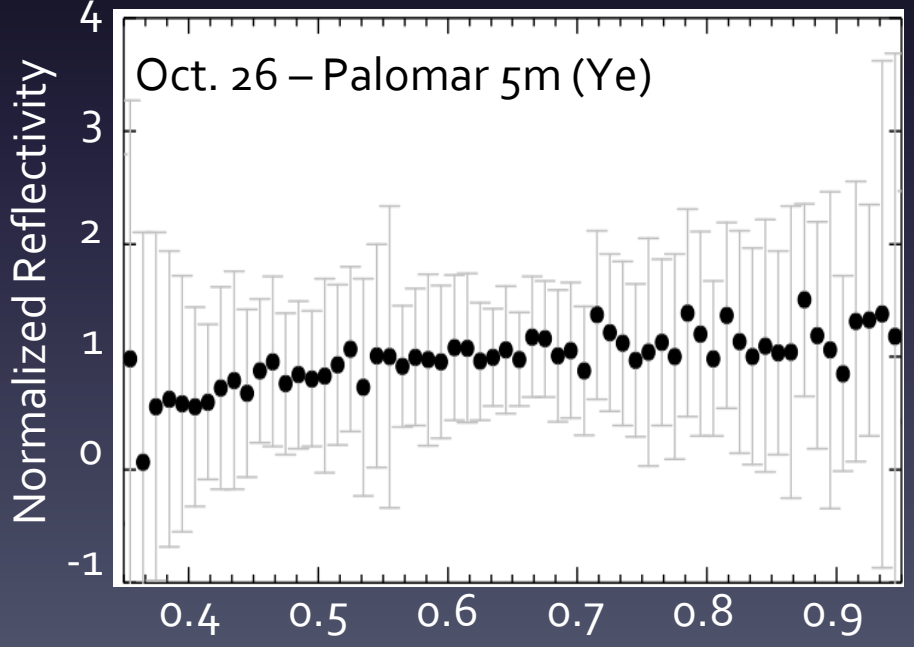
- It is "red" like comets. . . .
- Organic compounds (kerogen), pyroxene, metallic iron, iron oxides

- Weathering or original composition?

Surface Composition



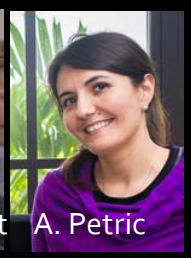


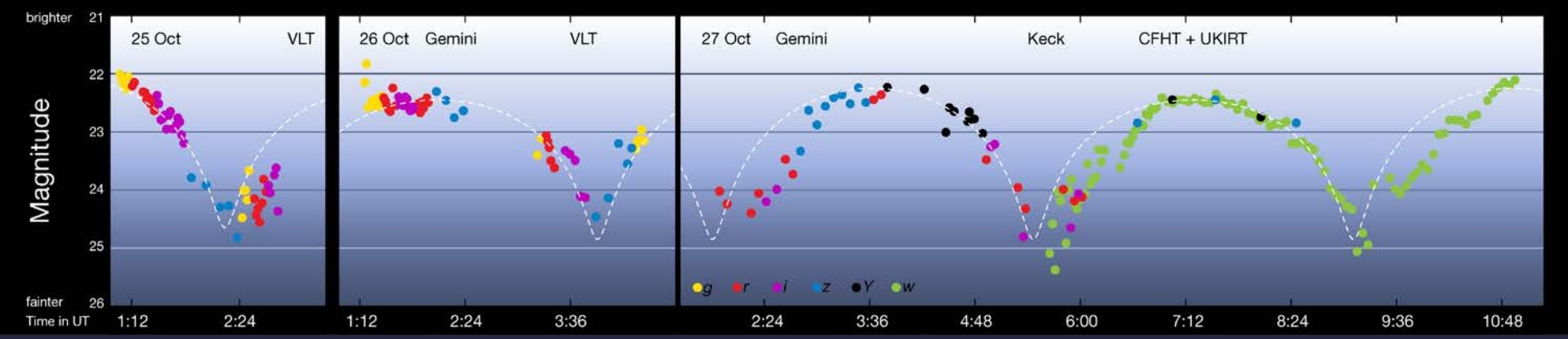


Spectra from many groups

- 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±0.06 hr
- Broad maxima, sharp minima
- Must have some strength

‘Oumuamua’s shape

ESO/M. Kornmesser

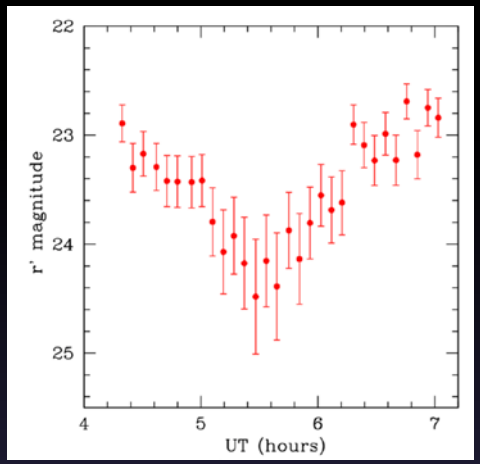
Rotation

Submitted to The Astrophysical Journal
2017 November 2

The rotation period and shape of the hyperbolic asteroid A/2017 U1 from its lightcurve

Matthew M. Knight[1], Silvia Protopapa[1], Michael S.P. Kelley[1], Tony L. Farnham[1], James M. Bauer[1], Dennis Bodewits[1], Lori M. Feaga[1], Jessica M. Sunshine[1]

[1]University of Maryland, 1113 Physical Sciences Complex, Building 415, College Park, Maryland 20742-2421, USA; mmk8a@astro.umd.edu



P > 5hr,

a:b = > 3: 1

Draft version November 15, 2017
Typeset using LaTeX twocolumn style in AASTeX61

APO TIME RESOLVED COLOR PHOTOMETRY OF HIGHLY-ELONGATED INTERSTELLAR OBJECT 1I/'OUMUAMUA

Bryce T. Bolin,[1,2,3] Harold A. Weaver,[4] Yanga R. Fernandez,[5] Carey M. Lisse,[4] Daniela Huppenkothen,[1] R. Lynne Jones,[1] Mario Jurić,[1] Joachim Moeyens,[1,6] Charles A. Schambeau,[5] Colin. T. Slater,[1] Željko Ivezić,[1] and Andrew J. Connolly[1]

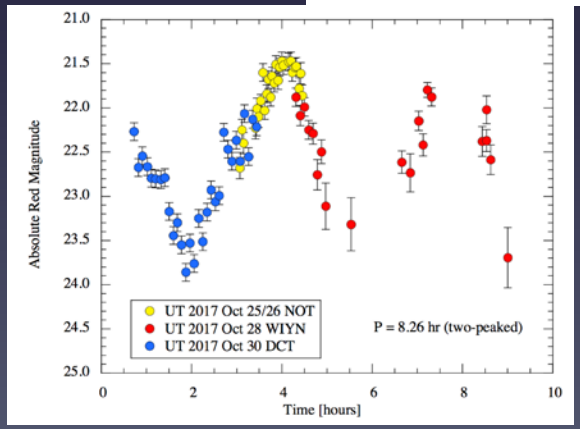
[1]*Department of Astronomy, University of Washington, 3910 15th Ave NE, Seattle, WA 98195*
[2]*B612 Asteroid Institute and DIRAC Institute Postdoctoral Fellow*
[3]*Laboratoire Lagrange, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Blvd. de l'Observatoire, CS 34229, 06304 Nice cedex 4, France*
[4]*Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723*
[5]*Department of Physics, University of Central Florida, Orlando, FL 32816, USA*
[6]*LSSTC Data Science Fellow*

(Received -; Revised -; Accepted -)
Submitted to AJ

P = 8.14 hr, a:b = (6.9±3.4) : 1

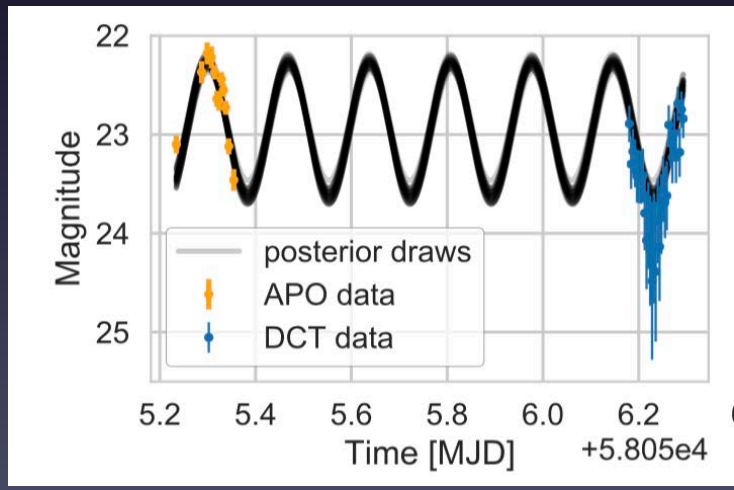
Interstellar Interloper 1I/2017 U1: Observations from the NOT and WIYN Telescopes

David Jewitt[1,2], Jane Luu[3,4], Jayadev Rajagopal[5], Ralf Kotulla[6], Susan Ridgway[5], Wilson Liu[5] and Thomas Augusteijn[7]

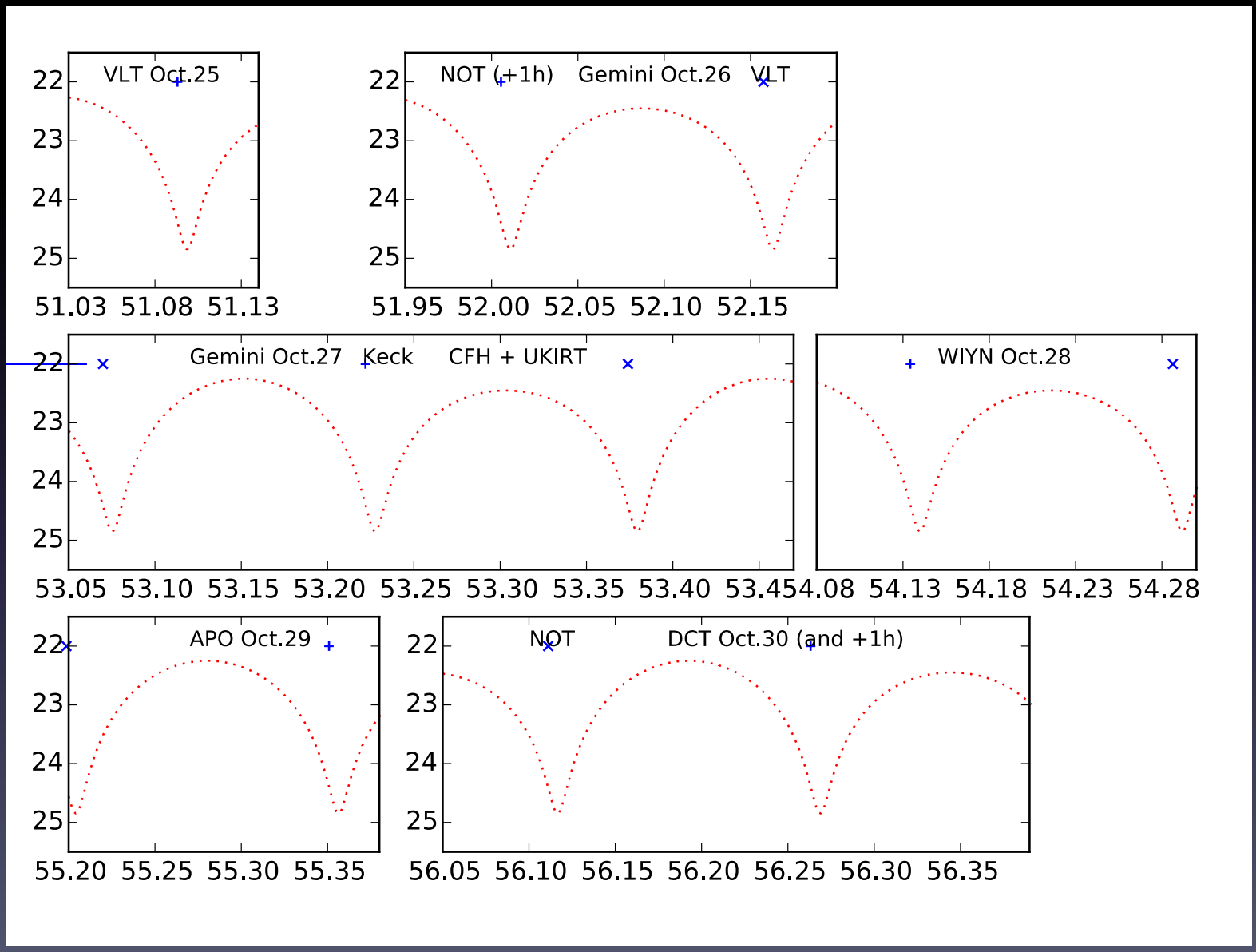


P = 8.26 hr, a:b = > 6 : 1

"ordinary"



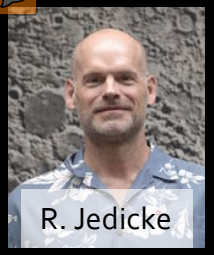
Some issues: Rotation



Where did it come from?

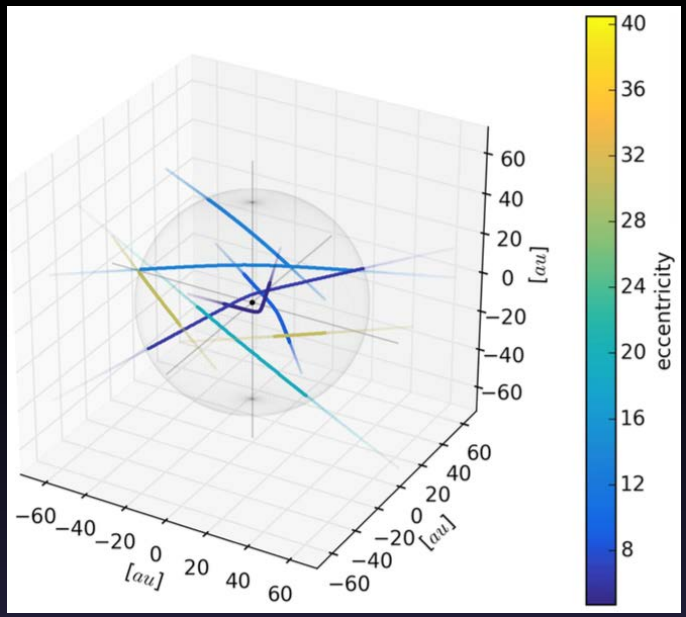
- Initial direction from the direction of Vega
  - Could this be coming from the Vega debris disk? - no
- Can it be a comet from our Solar System – perturbed by Planet X?
  - To be undiscovered planet needs to be near galactic plane (U1's radiant has galactic latitude of -16°)
  - The radiant of the recently proposed planet X is not close to U1's

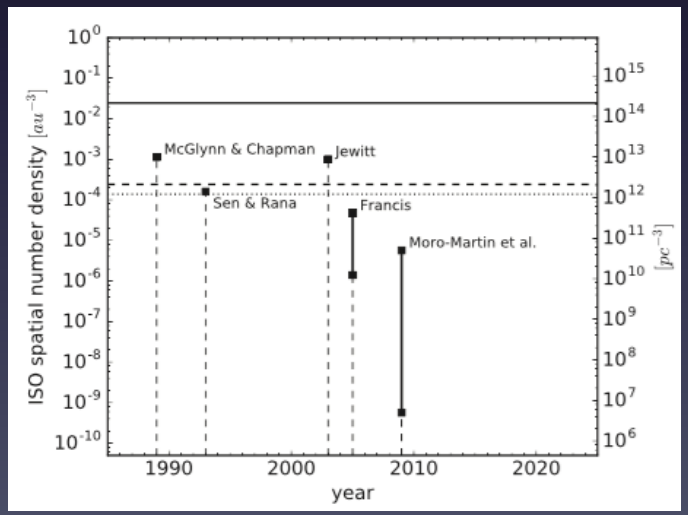
Lead Author	Galactic $v_\infty(U, V, W)$ km/s	Comments
Meech	-11.2, -22.4, -7.6	Similar to stars in solar neighborhood, from a younger system?
Mamajek (31 Oct)	-11.3, -22.4 -7.6	Not from α Cen Oort cloud
Gaidos (3 Nov)	-11.3, -22.4, -7.6	Possible origin in proto planetary disk from Carina/Columba association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



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



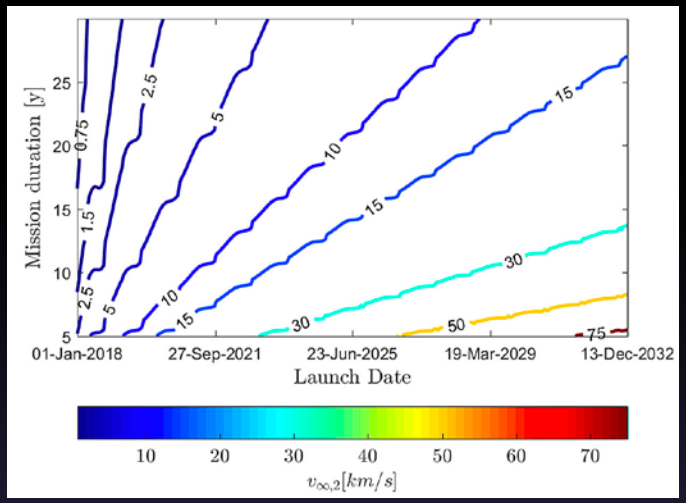


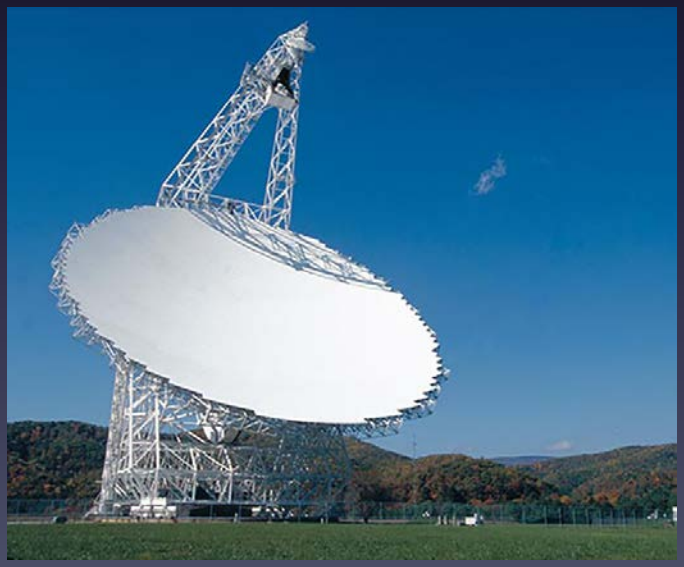
- Results
  - 90% CL – no comet activity 2.4 x 10^{-2} au^{-3}
  - 90% CL – with comet activity 2.4 x 10^{-4} au^{-3}
  - 'Oumuamua is asteroidal – using the higher density implies at any one moment there is ~1 object of similar size inside 1 au

Engelhardt, Jedicke et al (2017), AJ 153, 133.

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 → hazardous
- Many groups have tried to assess 1I/2017 U1's star of origin