Current and Future Prospcts for Small-Body Science at the University of Hawaii's Institute for Astronomy

Karen Meech, Interim Director

Decadal Survey on Planetary Science and Astrobiology:
Panel on Small Solar System Bodies

March 31, 2021

MKO Matters & New Maunakea Lease

- Bob McLaren has retired (served as interim Jan 2018-Jan 2021)

- Karen Meech (IfA Faculty) is serving as interim

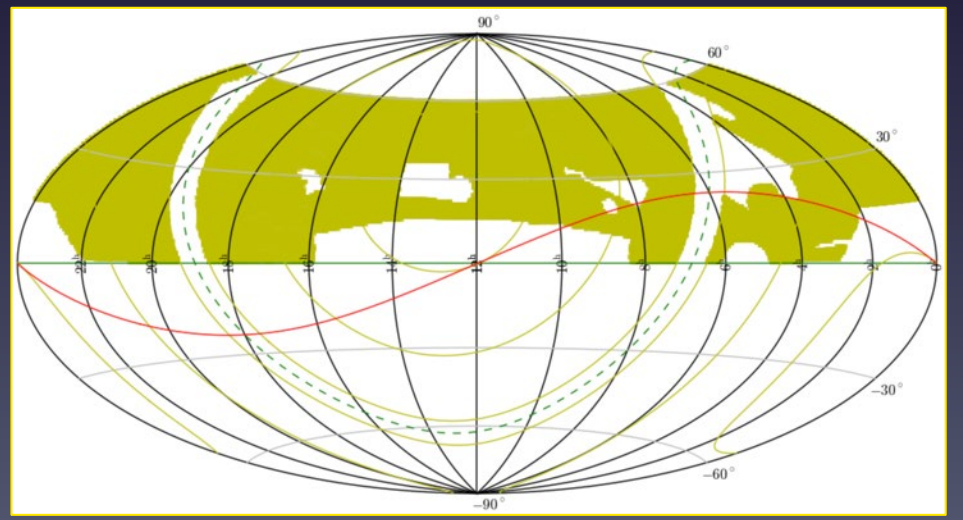
- Current UH lease for MK Science Reserve expires in 2033
- Work ongoing on updated Master Plan for 2020-2040 & updated Comprehensive Mgmt Plan
- EIS for new Master Lease is paused pending completion of planning projects
- State House committee recently advanced resolutions calling for formation of a working group to consider new approaches to Maunakea management
- UH will participate in the working group if/as requested, but anticipates major challenges in developing and implementing a new structure in time to ensure a future for astronomy
- UH will continue work on the current structure

UKIRT Transition to full IfA Operation

UKIRT Surveys

- UKIDSS (K-band) and Large Area Survey (LAS)
  - All sky visible from Hawaii, N limit δ=+60°
  - Upon completion – 4000 sq deg to K=18.4
- UH Survey
  - UHS-J 12,700 sq deg – median 5σ point source sensitivity is 19.6
  - UHS-K will complete UKIDSS K band to 12,700 sq deg
  - UHS-H planned for same coverage (started)

- Relocated UKIRT remote observing operations and offices from EAO to IfA Hilo
- Virtualized data reduction, data transfer, web services
- Created UHSDR1 public data archive mirror at IfA Hilo
- Archive could enable searching for pre-discoveries of moving objects



Roboticizing the UH 2.2m

Robo-AO 2 – NSF MRI award (C. Baranec AST 1712014, Shappee, AST-1920392)

- Goal: produce world-class science on medium-sized telescopes
- Prototyped at Palomar 1.5m

Moving to a 3 instrument automated facility

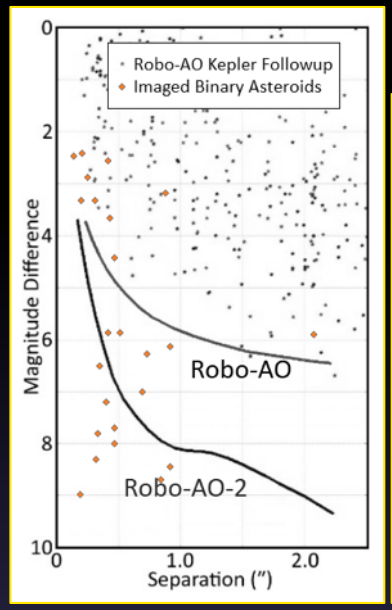
- Wide field imaging for orbit recovery (Tholen, Wainscoat)
- Visible IFS for rapid classification (Meech)
- Near-HST resolution vis/IR imaging (Robo AO 2) (Meech)

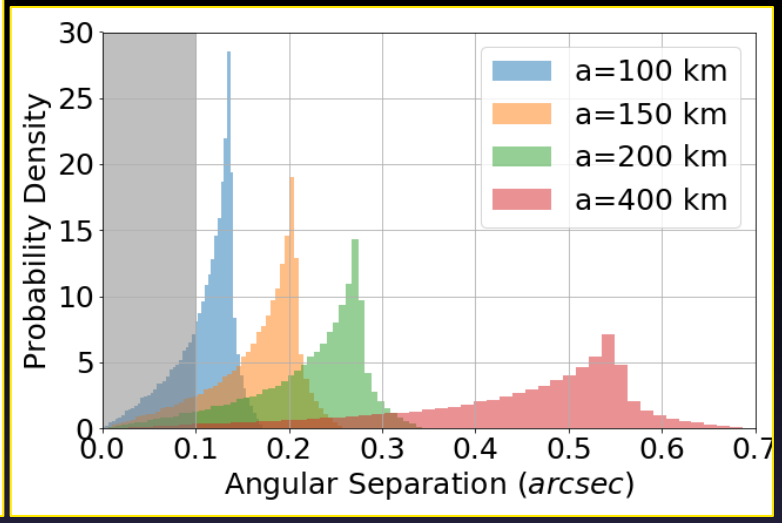
Science case – James Ou dissertation

- Mass distribution of main belt families
- Survey several 1000 MBA for companions with Robo AO2
- Monitor binary asteroid orbits to get mass

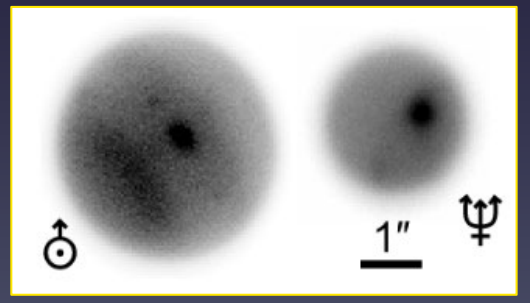
Status

- AO system to be installed later this year





Robo-AO improvement at UH2.2m

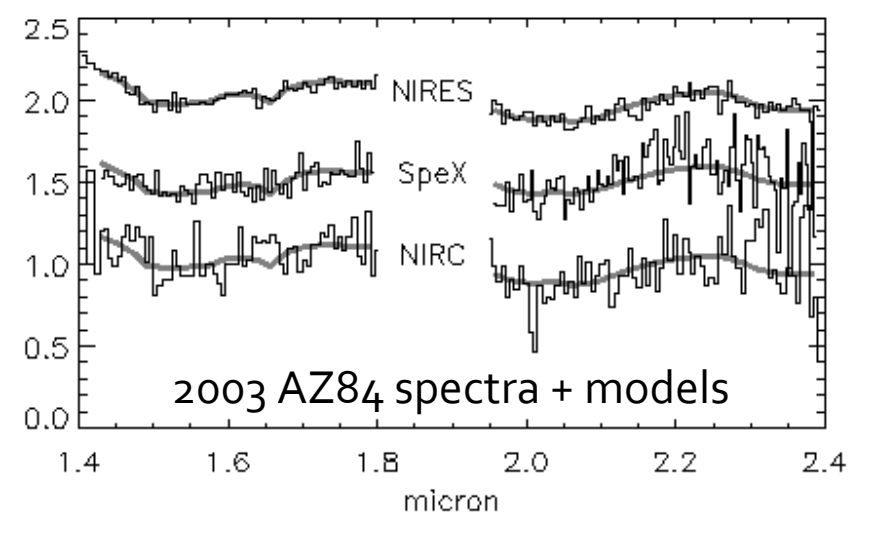


Details on giant planets with Robo AO2

UH2.2m daycrew with the Robo-AO-2 laser projector

Keck & NIRES

- Exploring surface & coma ice in small bodies
  - NIRES on Keck 2 only instrument sensitive enough for most comets
  - Excellent detail for KBO surface ices
  - Keane & Young collaboration

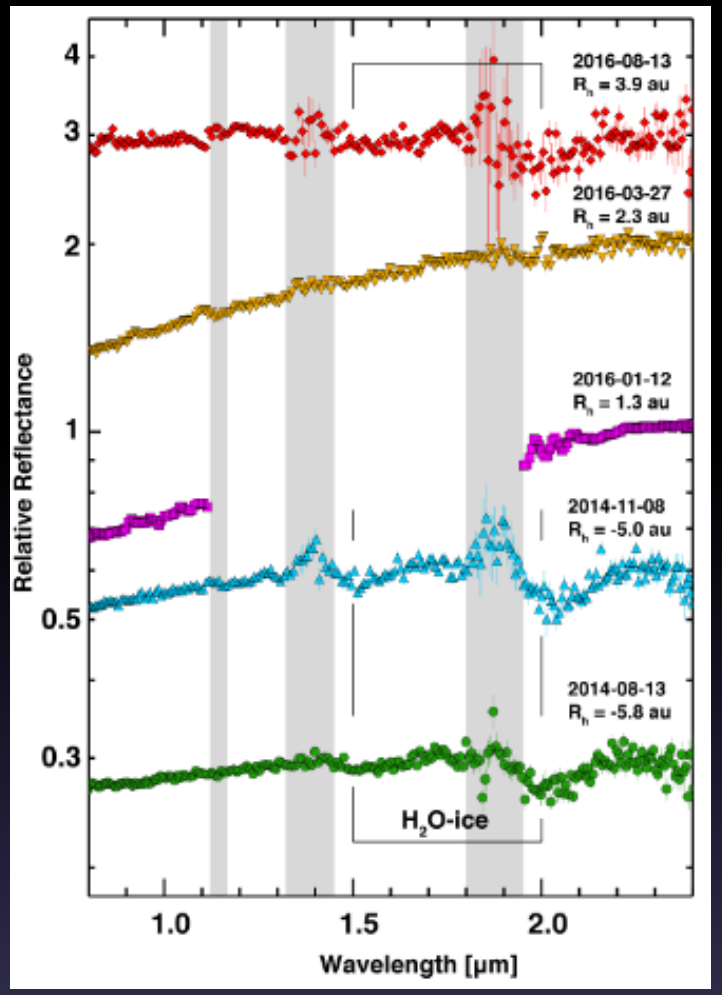


Simulated NIRES data , 55 min

SpeX, 600 min

NIRC (Keck 1), 216 min

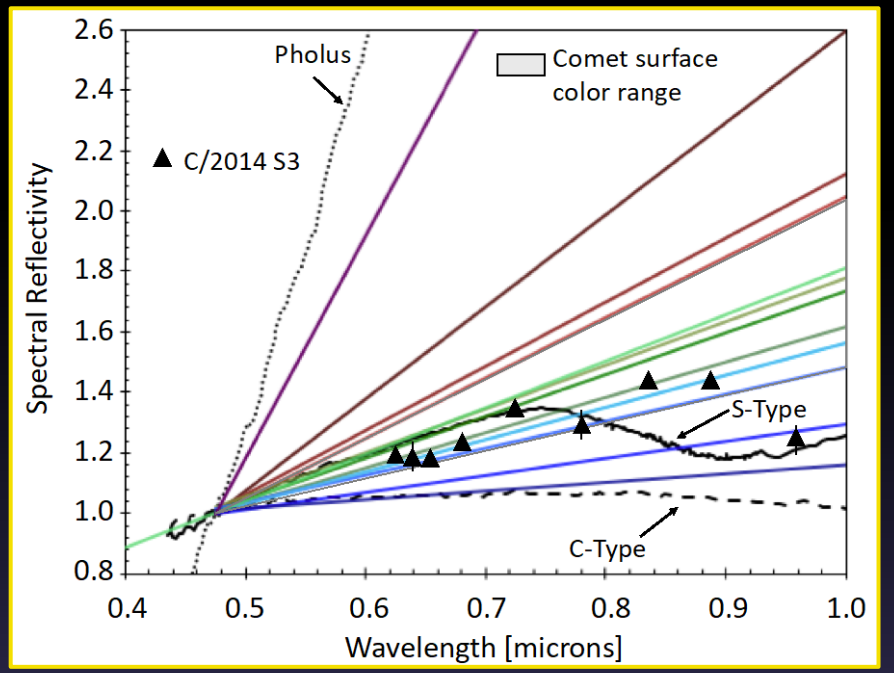
Fig. from L. Young



C/2013 US10 coma ice evolution
- IRTF (Protopapa et al. 2018)

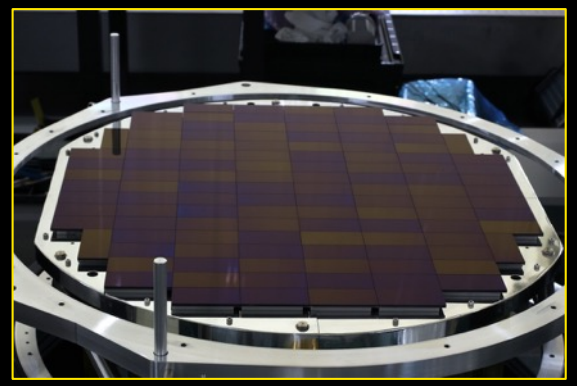
Gemini & SCORPIO

- Observe ~100 Manxes as tests of dynamical models
  - Discovery by PanSTARRS (predominantly) and Catalina surveys
  - Immediate follow up on CFHT: astrometry, brightness for Gemini
  - Gemini 8m: Spectral Reflectivity
- Many Observational Challenges
  - Fade fast, scheduling on Gemini, rotation
- SCORPIO (at critical design stage)
  - 8 channel imager & spectrograph
  - Simultaneously observe grizYJHK in 3x3' FOV



Part of PhD thesis (E. Bufanda)

Subaru and HypersuprimeCam

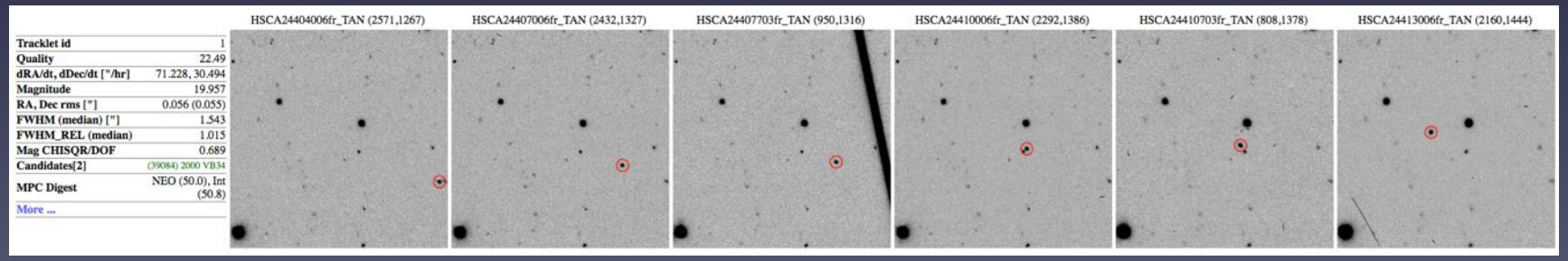


1.5 deg FOV

Small body projects

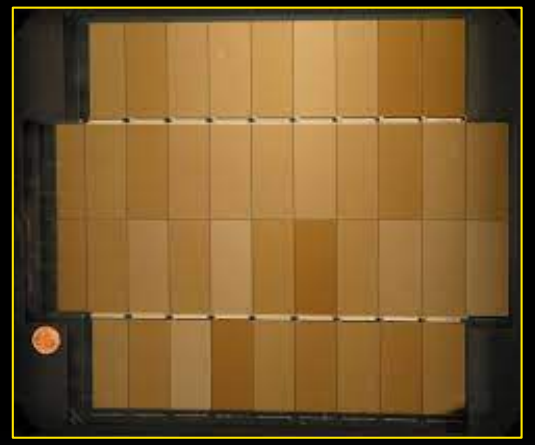
- Searching for planet 9 (Sheppard, Tholen, Trujillo)
  - Farfarout – The solar system's most distant planetoid
  - 2018 AG37 - Diameter ~ 400 km
- Small Aphelion Survey for PHAs inside Earth's orbit (Wainscoat, Kleyna)
  - Observe 1 hr at sunrise / sunset
  - Download data in real time, WCS-fit, calibrate, extract detections (mini-MOPS pipeline)
  - Remove static objects and link moving detections, set aside known solar system objects
  - Find objects with high NEO digest scores, submit to MPC & JPL scout before next night

Issues: very oversubscribed . . . .



CFHT and MegaCam

1.0 deg FOV, 40 2048 x 4612 CCDs



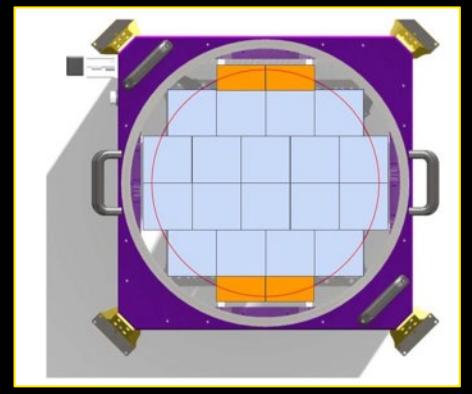
Critical Follow up for many small body projects

- Small Aphelion Survey for PHAs inside Earth's orbit (Wainscoat, Kleyna)
- Manxes (Meech, Bufanda)
- NEO followup (Wainscoat)
- Unusual PanSTARRS Discoveries (Meech, Wainscoat, Kleyna, Keane et al)

MSE – Maunakea Spectroscopic Explorer

- 11.25 m
- Multiobject spectrograph – wide field surveys

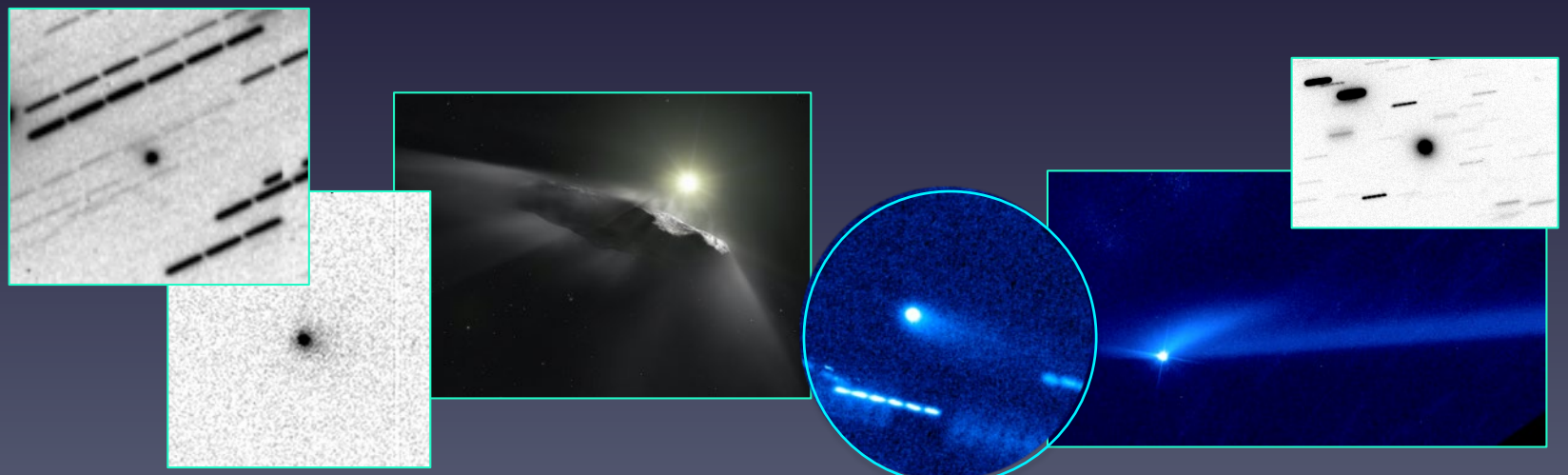
Pan-STARRS

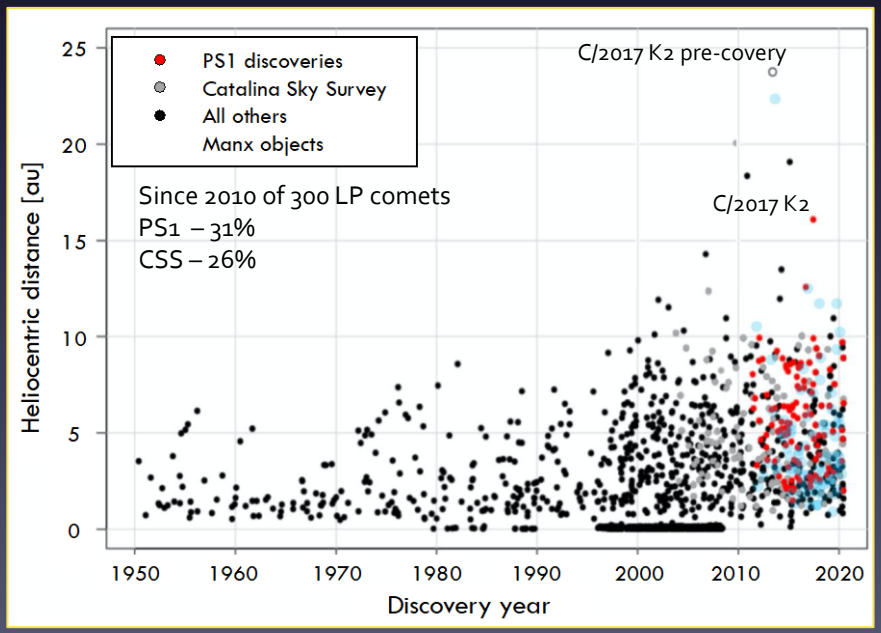


- NEO Survey funded effort to find PHAs
- Discovery Highlights
  - Excellent astrometry -> discover nearby objects from curvature of motion (2020 SO; old Centaur rocket)
  - Many exciting small bodies

Desired enhancements: New focal plane - Increases survey power by 2x

- Eliminates false positives and correlated RN
- Improved fill factor from faster read
- Improved QE
- Eliminating cell gaps -> substantial increase in efficiency for fast moving NEOs
- Longer exposure times – deeper for slower movers
- Better match for LSST





ATLAS Update

- NEO survey specializing in "death plunge" objects on final Earth-impacting trajectory
- Impactors detected: 2018 LA and 2019 MO
- ATLAS 1 & 2 (Maunaloa & Haleakalā) operating robotically since 2016
- ATLAS 3 & 4 (Sutherland, S. Africa & El Sauce, Chile) ~6 mo COVID-19 delay, expect installation mid-2021. All major components completed.
- Funded through 2025

System Specifications

Each telescope 30 deg^2 (5.4 × 5.4), ~3.5″ PSF

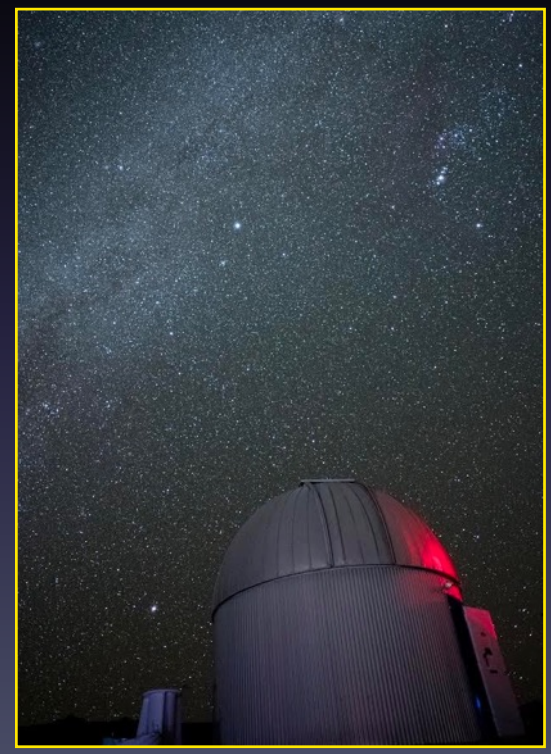
f/2 Schmidt, 110 Mpix STA1600 detector, 1.9″ pixels

Gaia astrometry, Refcat2 (Pan-STARRS+) photometry

30,000 deg^2/night with 4 visits, m=19.5

10^8 obs/night, 0.5 TB/night

Tonry *et al.* 2018 PASP (arXiv:1802.00879)



ATLAS Maunaloa (Shinsuke Abe)

Recent Publications

NEO Population, Velocity Bias, and Impact Risk from an ATLAS Analysis, Heinze *et al.* 2020

A Two-Stage Deep Learning Detection Classifier for the ATLAS Asteroid Survey, Rabeendran & Denneau 2021

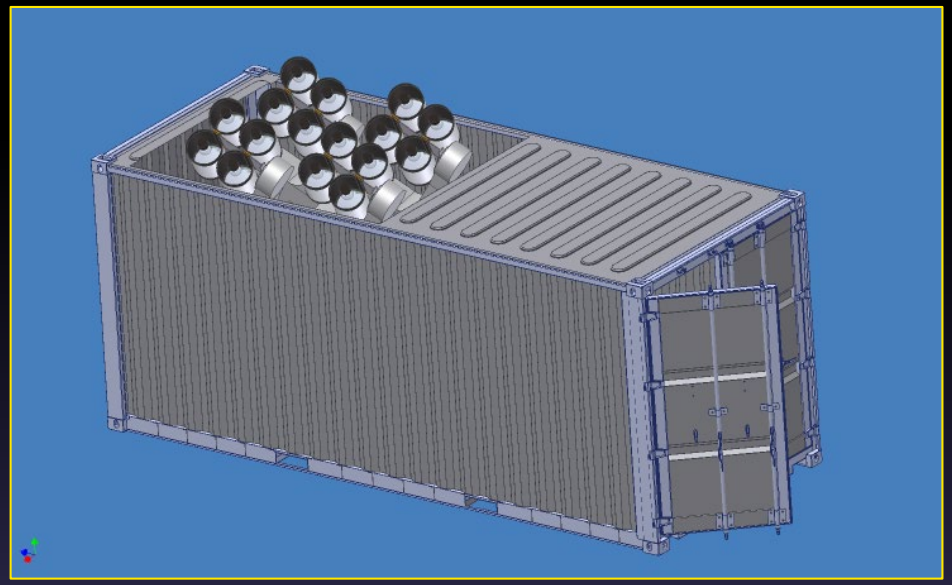
Comparison of the physical properties of the L4 and L5 Trojan asteroids from ATLAS data, McNiell *et al.* 2021

Asteroid models reconstructed from ATLAS photometry, Durech *et al.* 2020

Asteroid phase curves from ATLAS dual-band photometry, Mahlke *et al.* 2020

Increasing the Sky Survey Capability

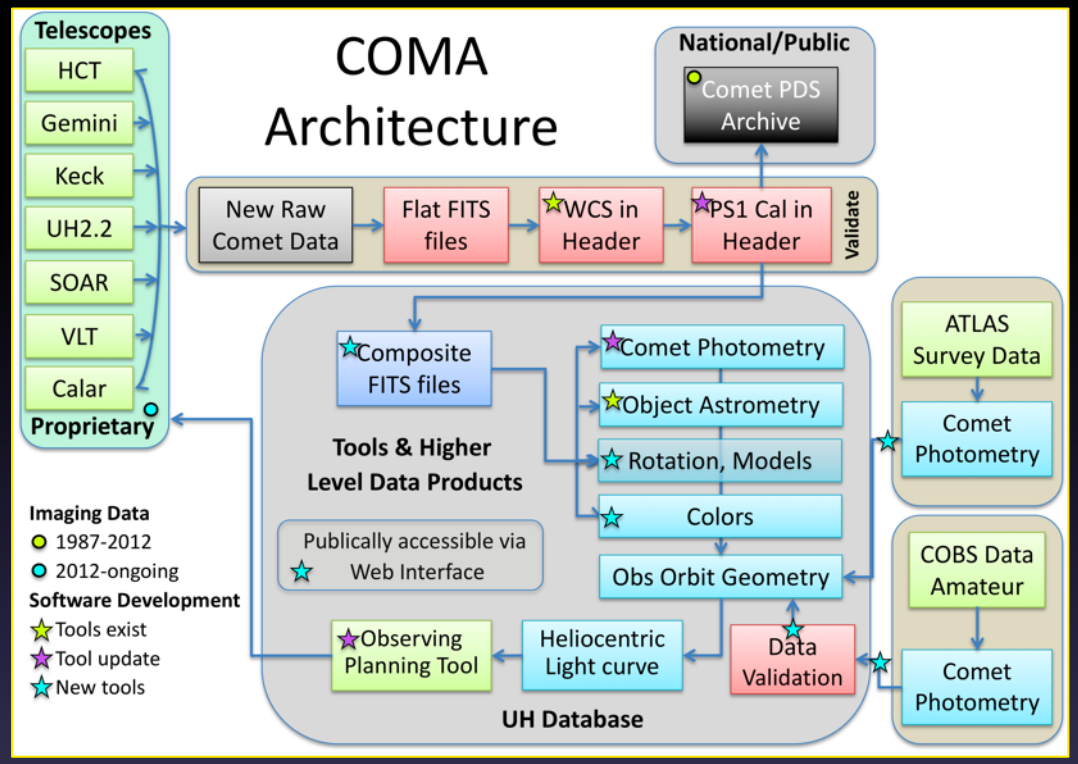
- Current & Future Surveys
  - Pan-STARRS, Catalina, ZTF, ATLAS, ASAS-SN, LSST . . .
  - LSST is great for depth, terrible for time cadence
- Increasing survey capacity
  - Stacking simultaneous exposures → depth



- Tonry Concept
  - 16 RASA-11 telescopes with QHY600 cameras on 4 planewave mounts
  - Limiting mag ~ 19 in 30 sec over 30 sq deg FOV
  - Cost $400k
  - Fully robotic, can run on solar & starlink

COMA: Cometary Observation Metadata Archive

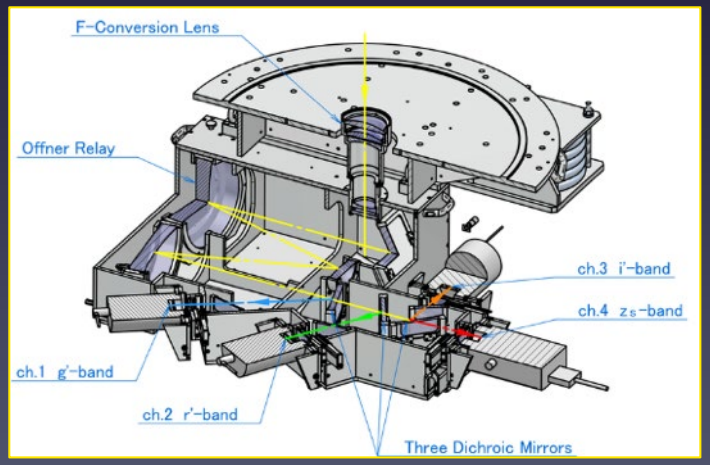
- Database driven 30 yr archive of targeted small body data & higher level products
- This could be used for archival searches from all Hawaii surveys
- Collaborating with UH Data science for cutting edge interface tools and data visualization



Meech, Dodds, Leigh, Kleyna et al.

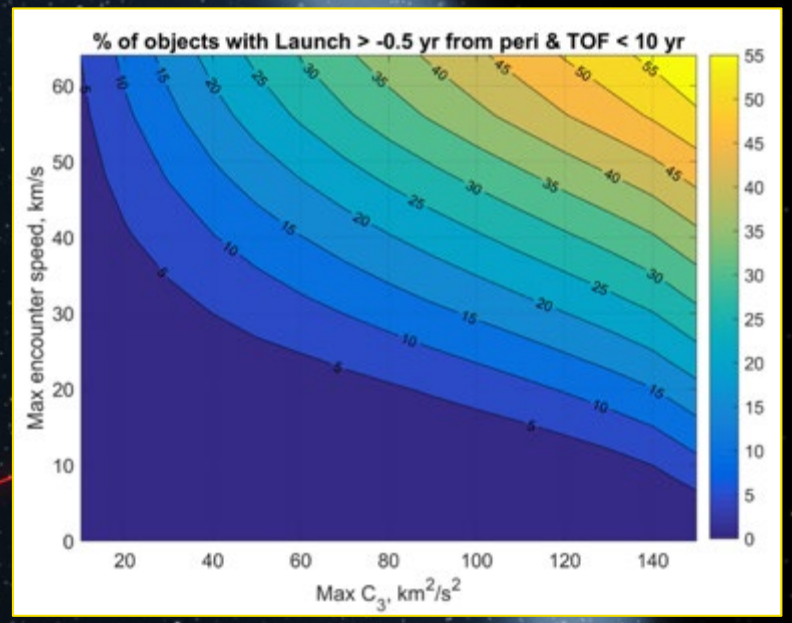
Las Cumbres Observatory

- Network of 0.4m and 2m telescopes for Education & Outreach
  - Can be used by grad students
  - Undergrad research
  - HISTAR high school science fair projects
- MuSCAT3 on FTN
  - Simultaneous observations in griz bands

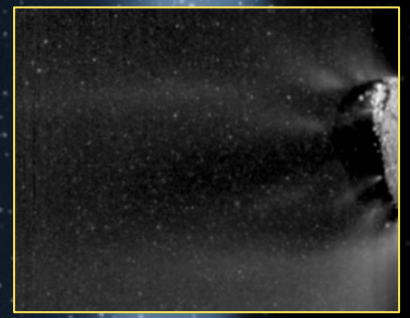


IfA Access Supports new Class of Small Body Missions

- Transformative science from LPOs
  - Unheated objects best preserve the early solar system environment
  - Critical constraints for planet building in our and other solar systems
  - Want to know detailed chemical & physical properties
- Mission challenges
  - LSST (first light 2022) may detect LPOs ~ 10 yr pre-perihelion
  - All inclinations – more challenging for rendezvous
  - LPCs are driven by CO, CO_2 → large debris
  - Small objects: characterization requires very large aperture from Earth,
  - Surveys, and database access allow longer lead times and opportunity for characterization



Credit: D. Landau, JPL



Launch E	Enc Velocity	% reachable	Comment
High	High (< 64 km/s)	90	
Low	High	20	
High	Low (< 4 km/s)	2-5	Long travel time

Mahalo!