W. M. KECK OBSERVATORY (WMKO)

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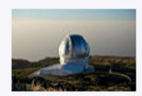
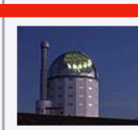
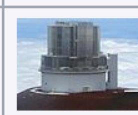
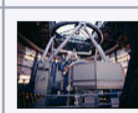
2018/11/23

Outline

- Basic information about WMKO
- Scientific results
- Summary

Largest Optical Telescopes

Reflecting telescopes

Name	Image	Effective aperture	Mirror type	Nationality / Sponsors	Site	Built
Gran Telescopio Canarias (GTC)		10.4 m (409 in)	Segmented, 36	Spain (90%), Mexico, USA	Roque de los Muchachos Obs., Canary Islands, Spain	2006/9
Hobby–Eberly Telescope (HET) 11 m × 9.8 m mirror		10 m (394 in) [1]	Segmented, 91	USA, Germany	McDonald Observatory, Texas, USA	1997
Keck 1		10 m (394 in)	Segmented, 36	USA	Mauna Kea Observatories, Hawaii, USA	1993
Keck 2		10 m (394 in)	Segmented, 36	USA	Mauna Kea Observatories, Hawaii, USA	1996
Southern African Large Telescope (SALT) 11 m × 9.8 m mirror[2]		9.2 m (362 in)	Segmented, 91	South Africa, USA, UK, Germany, Poland, New Zealand	South African Astronomical Obs., Northern Cape, South Africa	2005
Large Binocular Telescope (LBT) Phased-array optics for combined 11.9 m[3]		8.4 m (331 in) × 2	Multiple mirror, 2	USA, Italy, Germany	Mount Graham International Observatory, Arizona, USA	2004
Subaru (JNLT)		8.2 m (323 in)	Single	Japan	Mauna Kea Observatories, Hawaii, USA	1999
VLT UT1 — Antu		8.2 m (323 in)	Single	ESO Countries, Chile	Paranal Observatory, Antofagasta Region, Chile	1998
VLT UT2 — Kueyen		8.2 m (323 in)	Single	ESO Countries, Chile	Paranal Observatory, Antofagasta Region, Chile	1999

Information

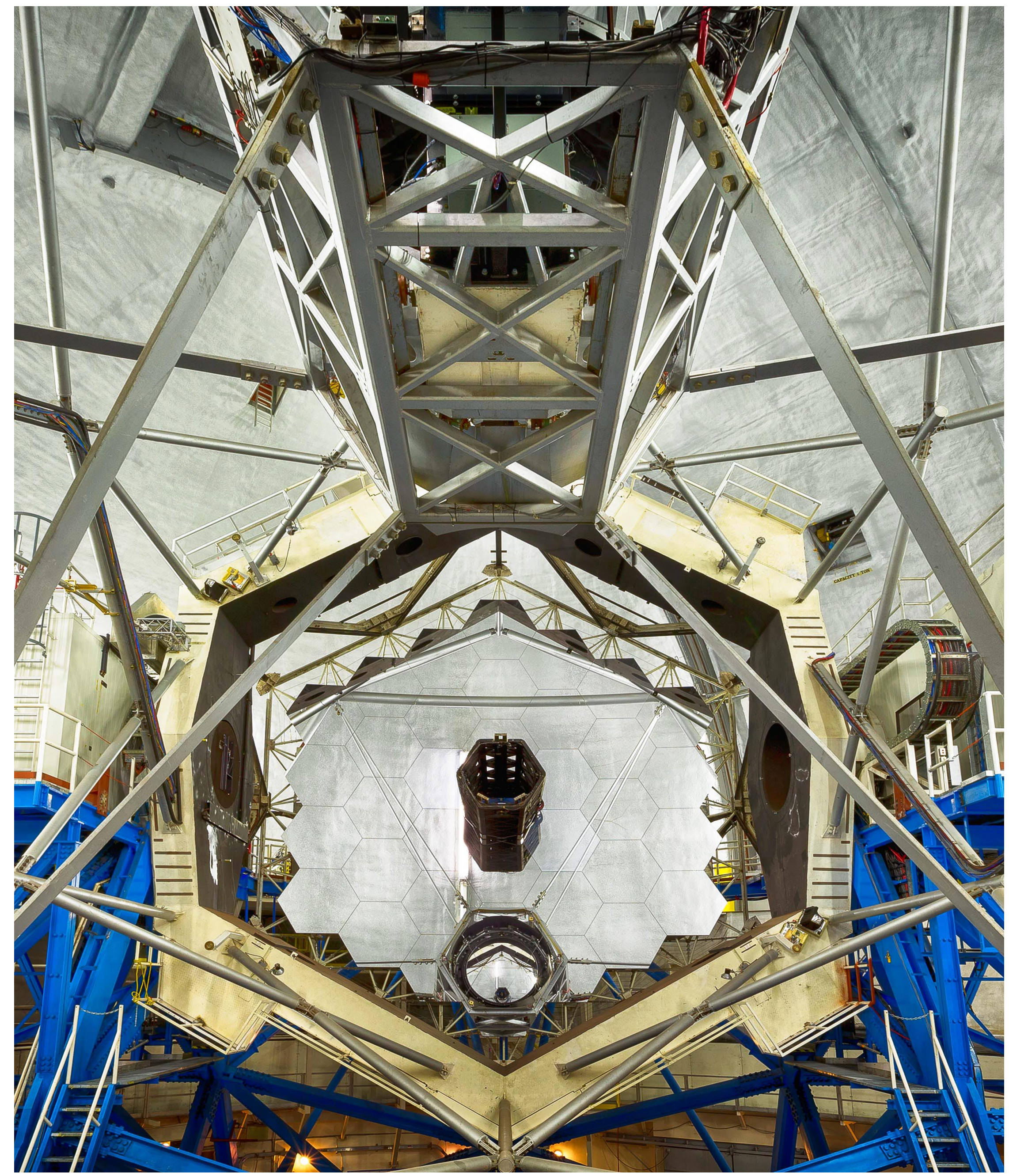
- Location: Mauna Kea Observatories, Hawai’i
- Mirror diameters: 10 m
- Angular resolution: 0.04 to 0.4 arcseconds
- Instrument wavelength: optical to near-infrared

Mauna Kea Observatories

- Altitude: 4,205 m (4,145 m for WMKO)
- Temperature: 2.2C
- Wind: 11.3km/h
- Humidity: RH=8%
- Seeing: 0.43”
- Dry, Cold, Sunny

Information

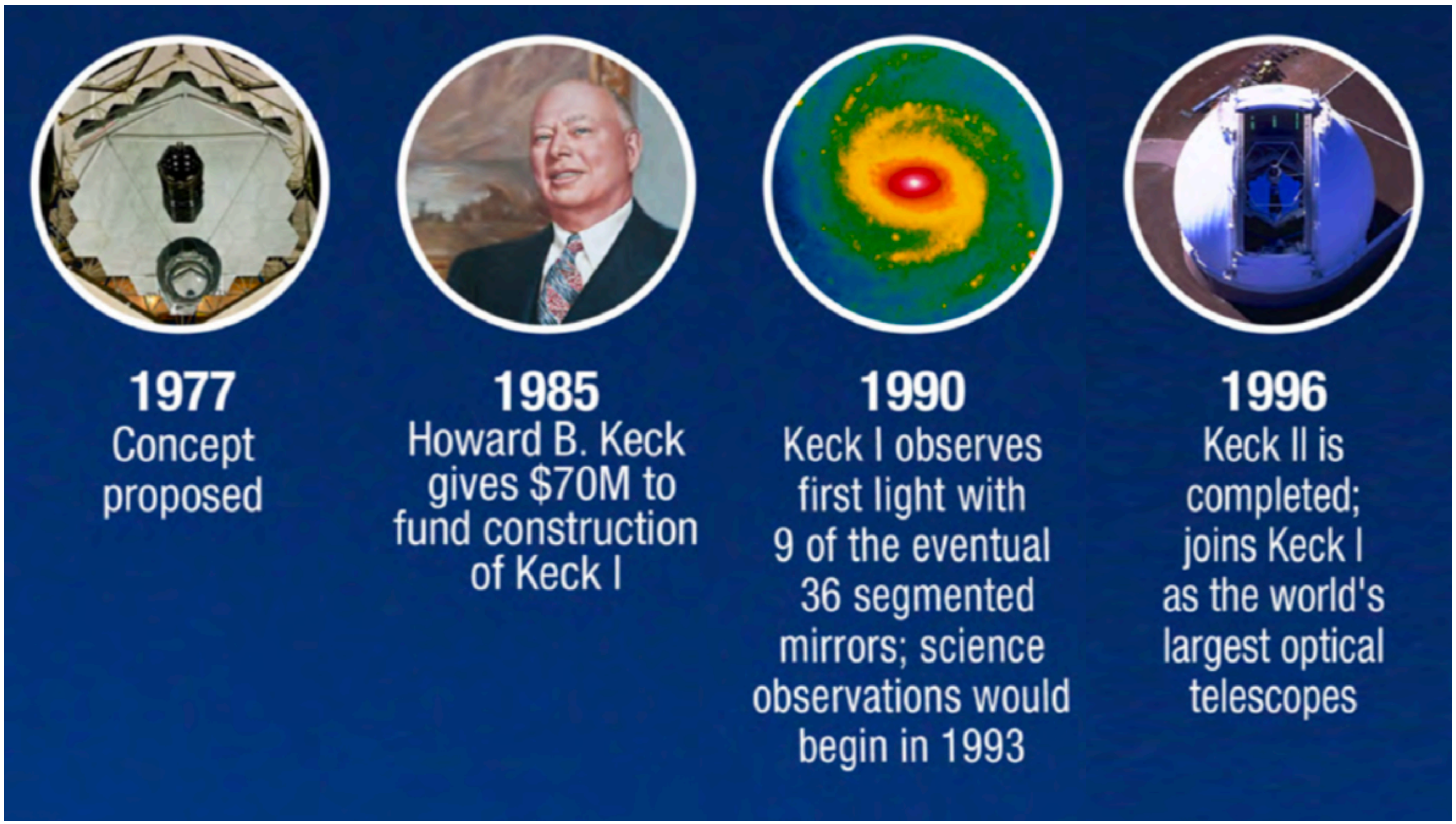
- The primary mirrors is composed of 36 hexagonal segments
- Each segment is 1.8 meters wide, 7.5 centimeters thick
- Total collecting area is 75.76 m^2
- The total weight of the telescope is more than 300 tons



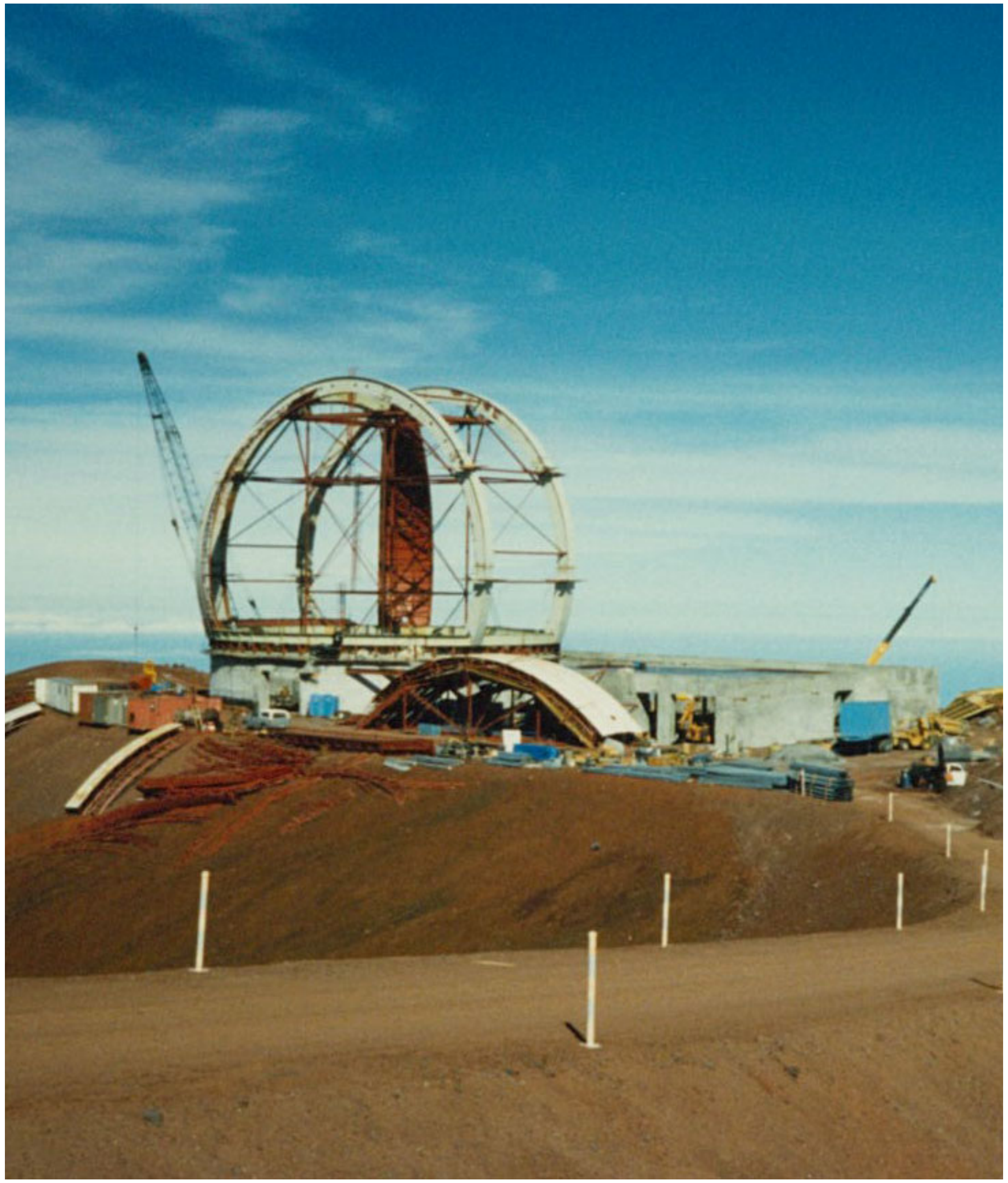
Concept

- In 1977, to build a telescope that doubles the size of the largest telescope in the world(5m-Hale), The University of California form a five-member committee to design it.
- A 10-meter telescope, using a single reflecting mirror, would cost a billion dollars.
- Nelson came up with the idea of segmented mirror, they spent a long time to design it and finally succeeded.

Construction Process



Keck I in 1980s



Adaptive Optics(AO)

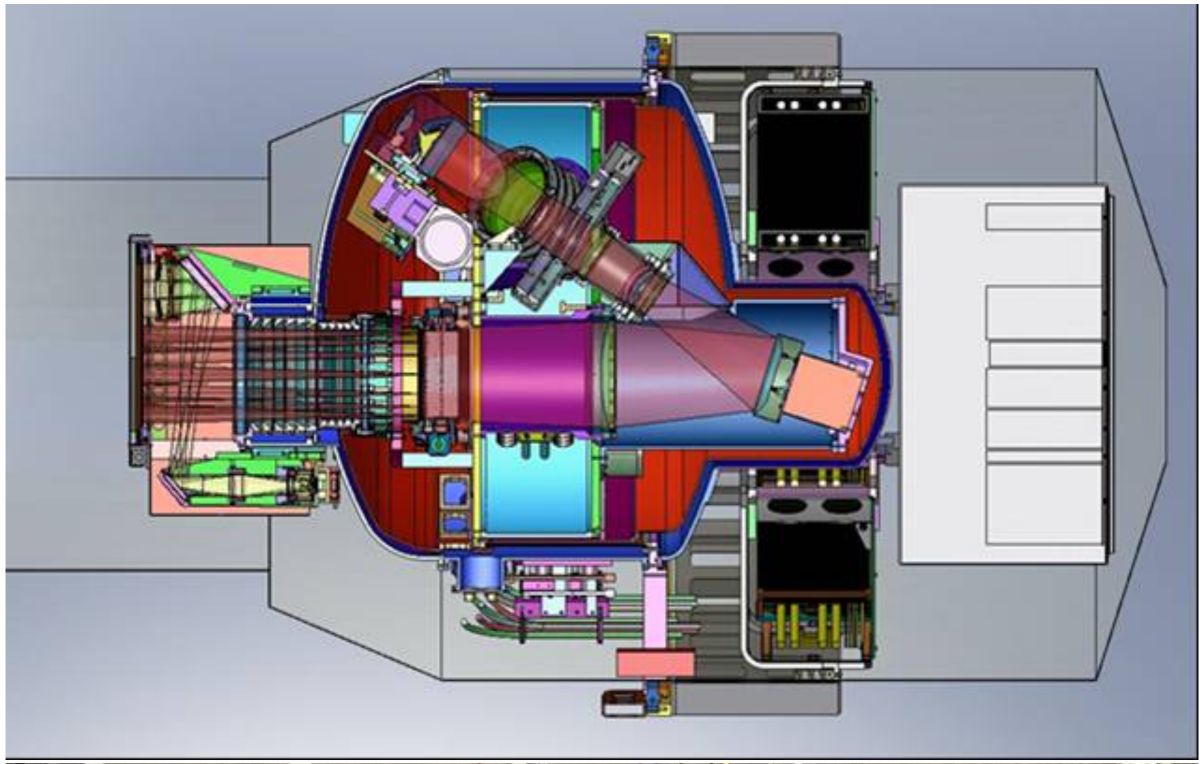
- AO measures and then corrects the atmospheric turbulence using a deformable mirror that changes shape 2,000 times per second
- AO relies on the light of a star that was both bright and close to the target
- 1999: the first large telescope installing an AO system(Keck II)
- 2004: the first laser guide star AO system
- Angular resolution with AO ~0.05” for 8-10 m telescope (Diffraction limit)

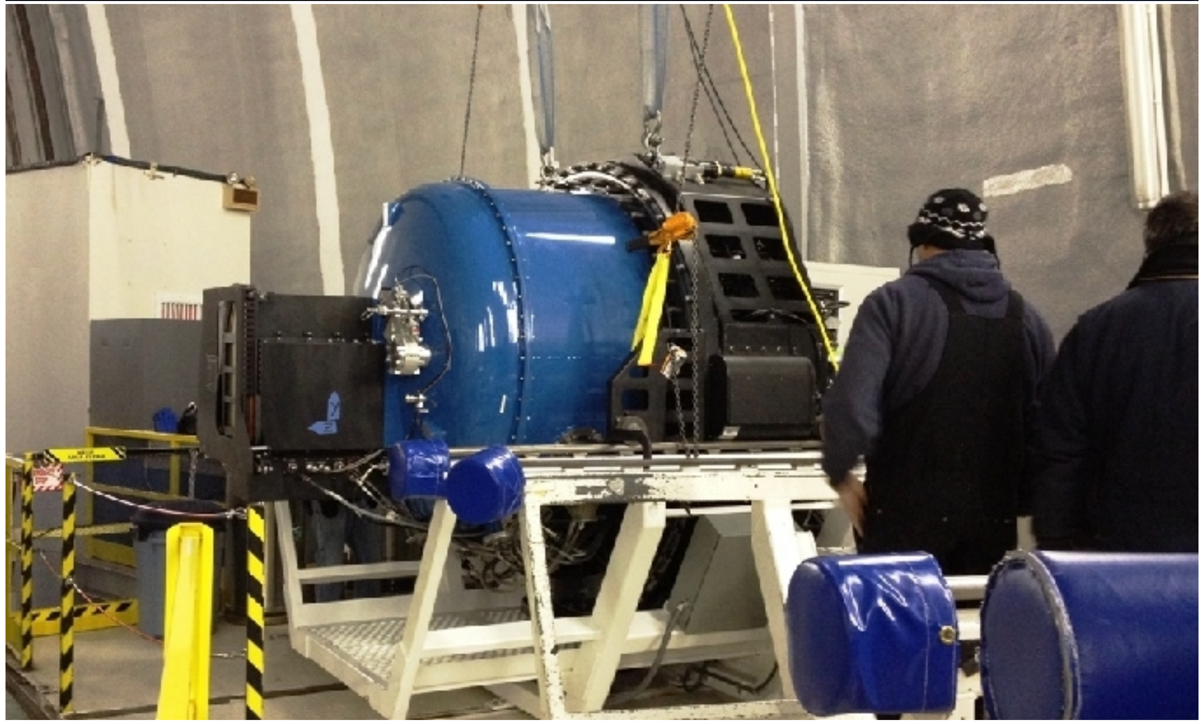
Instruments

- **VISIBLE BAND** (0.3-1.0 Micron): DEIMOS, ESI, HIRES, KCWI, LRIS…
- **NEAR-INFRARED** (1-5 Micron): MOSFIRE, NIRC-2, NIRSPEC, OSIRIS…

MOSFIRE

- The Multi-Object **Spectrograph** for **Infrared** Exploration
- Filed of view: 6.1’x6.1’
- Installed in 2012
- It can select up to 46 individual objects and then record their infrared spectrum simultaneously.



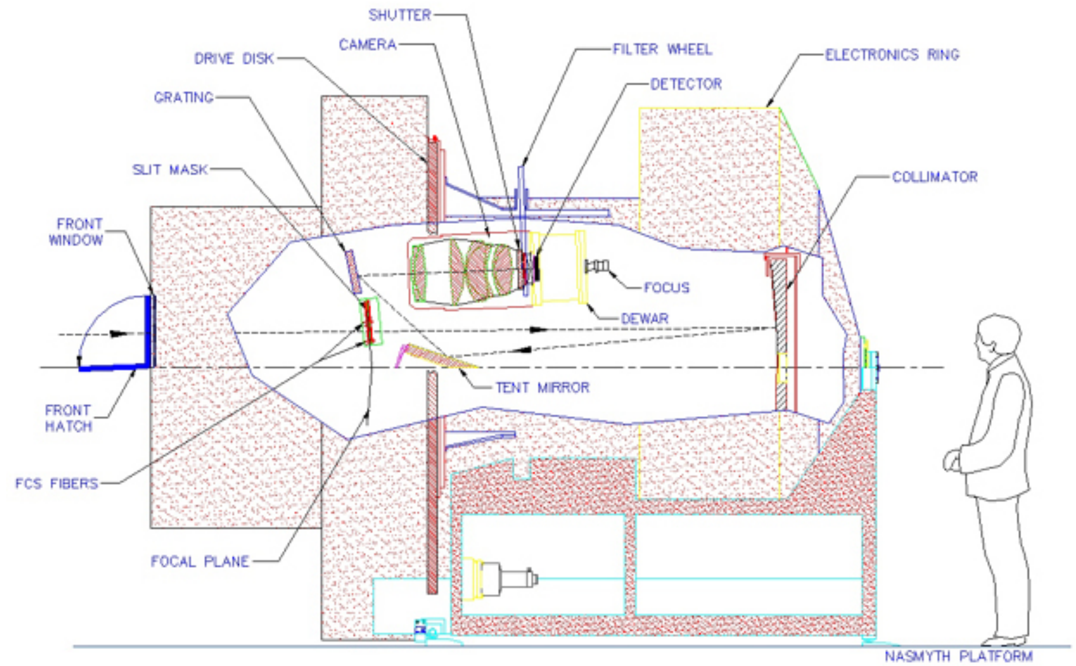


KCWI

- The Keck Cosmic Web Imager
- Installed in 2017
- Filed of view: 20” x (8.3”, 16.5”, or 33”)
- **Visible band (350-1050 nm), integral field spectrograph**
- Focusing on the connection between galaxies and the gas in their dark matter halos, stellar relics, star clusters and lensed galaxies

DEIMOS

- Deep Imaging Multi-Object **Spectrograph**
- Installed in 2002
- An **optical**, faint-object, multi-slit imaging spectrograph
- Slit length spanning 16.6’
- Gather spectra from more than 100+ galaxies or 1000+ stars in a single exposure



Why Infrared?

- About half of the Keck Observatory instruments analyze near-infrared light.

- Why not stay entirely in the optical band?

Advantages

- Infrared is a “well-traveled” energy—to see the most distant objects in the Universe cause their light is redshifted.

- Infrared is a thermal energy—to detect cool objects, including dim stars, brown dwarfs, and planets.

- Infrared is a “stealth” energy—to see clear across the dust.

To see Further, Cooler, Clearer!

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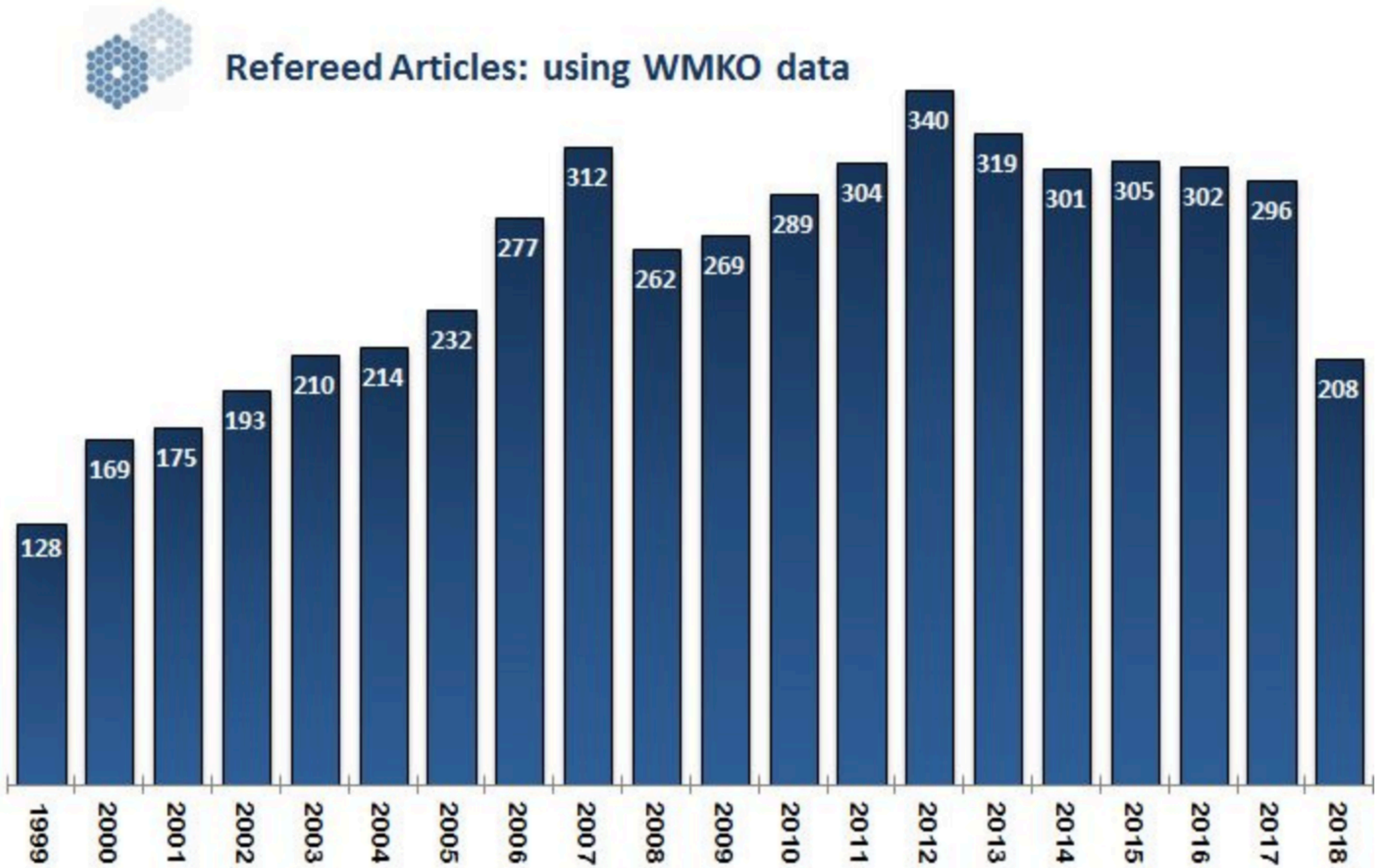
Papers


Refereed Articles: using WMKO data
128
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Key Science

- Understanding the Formation and Evolution of Today's Galaxies since z=3
- Measuring Dark Matter in our Galaxy and Beyond
- Testing the Theory of General Relativity in the Galactic Center
- Understanding the Formation of Planetary Systems around Nearby Stars
- Exploring the Origins of Our Solar System

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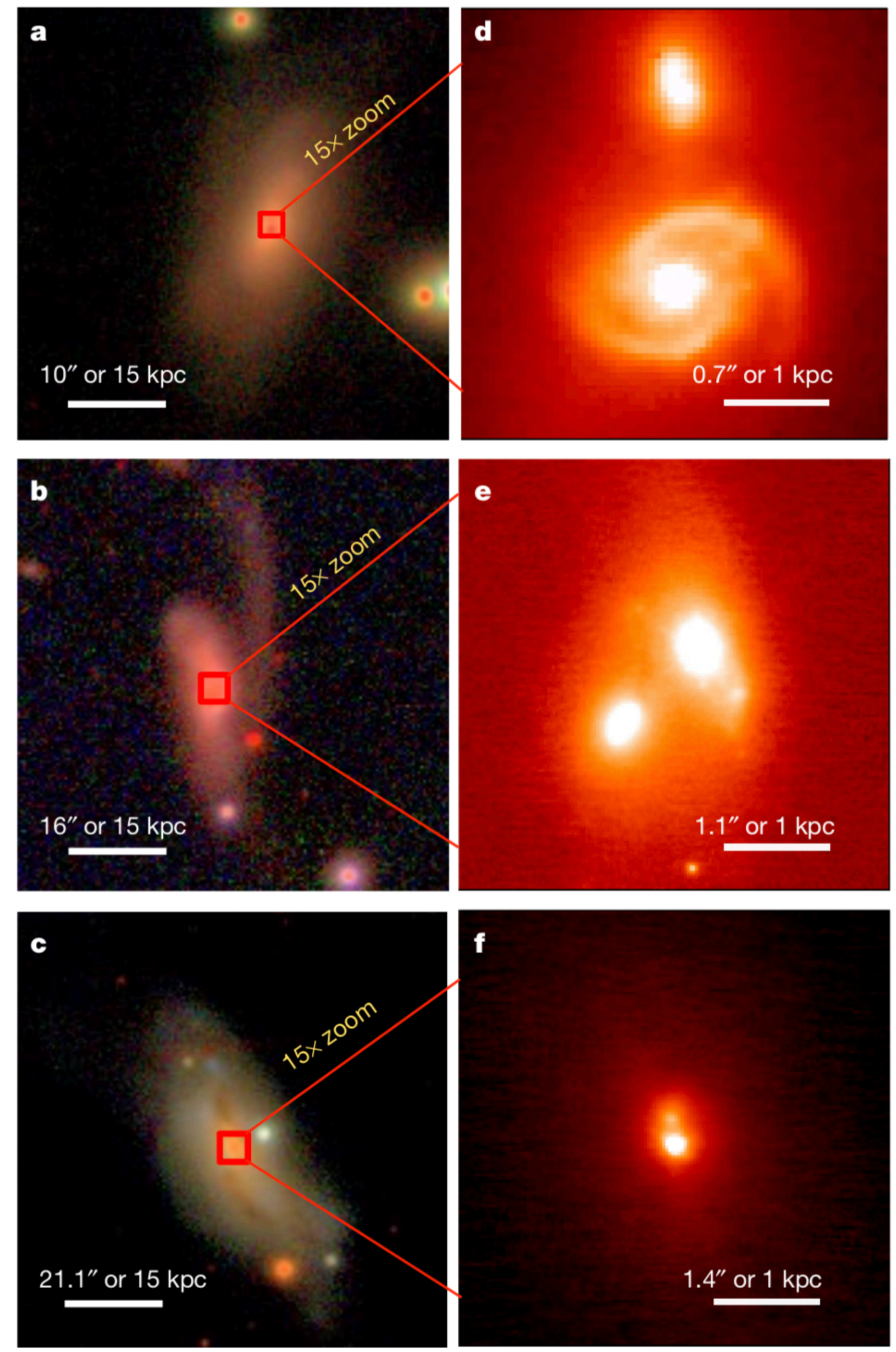
Linking Late-Stage Galaxy Merging and fueling SMBH

- Obscured luminous Super Massive Black Holes (Swift Observatory, X-ray) show a significant excess of late-stage double nuclear mergers (**KECK**), compared to inactive galaxy sample
- Galaxy mergers are critical in fueling the growth of supermassive black holes



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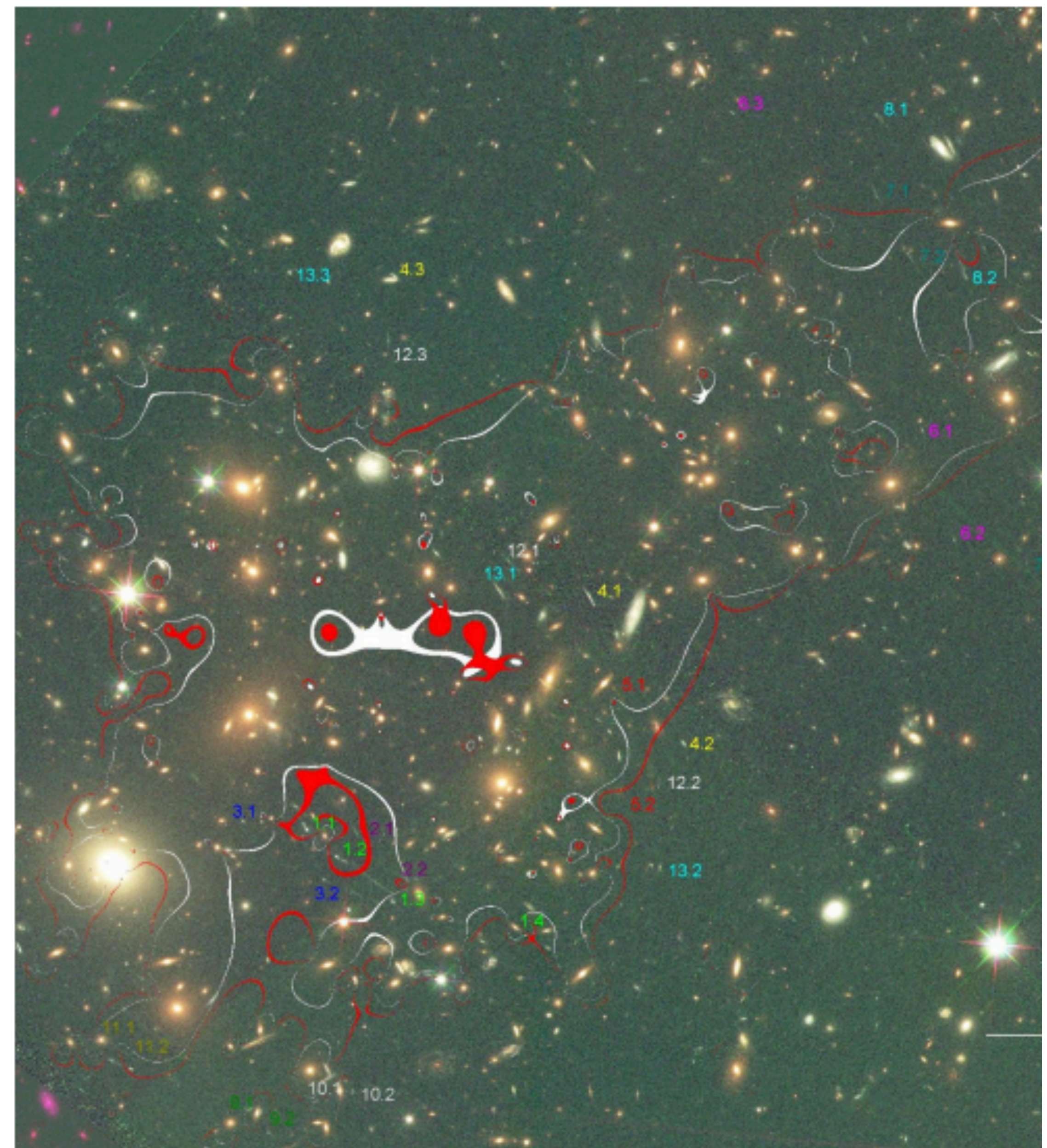
MACS J0717 and Gravitational lens

- MACS J0717 is a unique cluster in that it is itself of smash-up of four galaxy clusters, representing a massive early-universe collision
- It is massive and creates a gravitational lens
- Scientists used the HST and another 2 telescopes to capture a 2D map of this area.



2D to 3D

- Scientists turned to Keck DEIMOS for spectrographic measurements of the objects' distance and speed.
- Make the 2D map into 3D, distinguish the background galaxies.
- According to the feature of weak lensing coherent shape distortion, Scientists reveal the cosmic web of galaxies strung along the yet-to-be-seen dark matter filaments.

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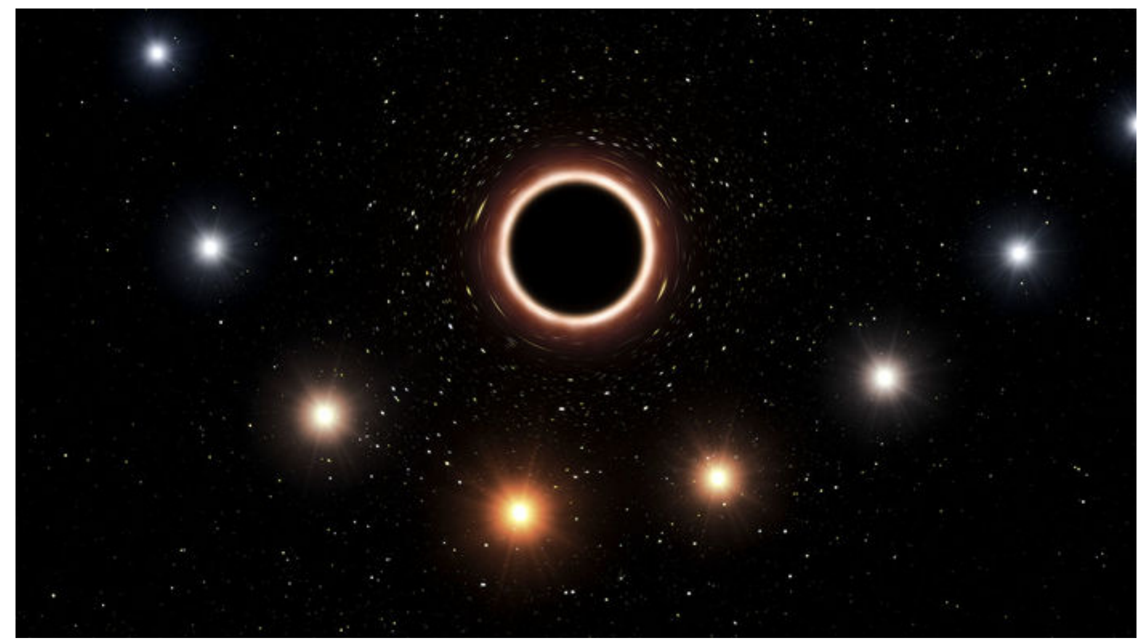
Gravitational Redshift of S2

- The highly elliptical, 16-year-period orbit of the star S2 around the Galactic centre massive black hole
- Near pericentre at 120 AU
- The first time to detect gravitational redshift so directly



- Five 2000-2003 slit-spectra from the AO imagers and spectrometers NIRC2 at Keck

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Summary

- Largest ground-based (10m)
- Adaptive optics(AO)
- Optical/near-infrared
- Imaging/spectroscopy

Observational Highlights

1999: First exoplanetary transit prediction (star HD 209458)

2005: Tripling what was understood to be Andromeda's size by plotting the motion of stars along the galaxy's edge

2007: First planetary disk detected, seen around Mira, a dying star system

2010: Quiescent volcanic activity discovered on Io, the innermost moon of Jupiter

2014: Keck observes merging galaxies in unprecedented detail

2016: Keck spots the most distant galaxy to date

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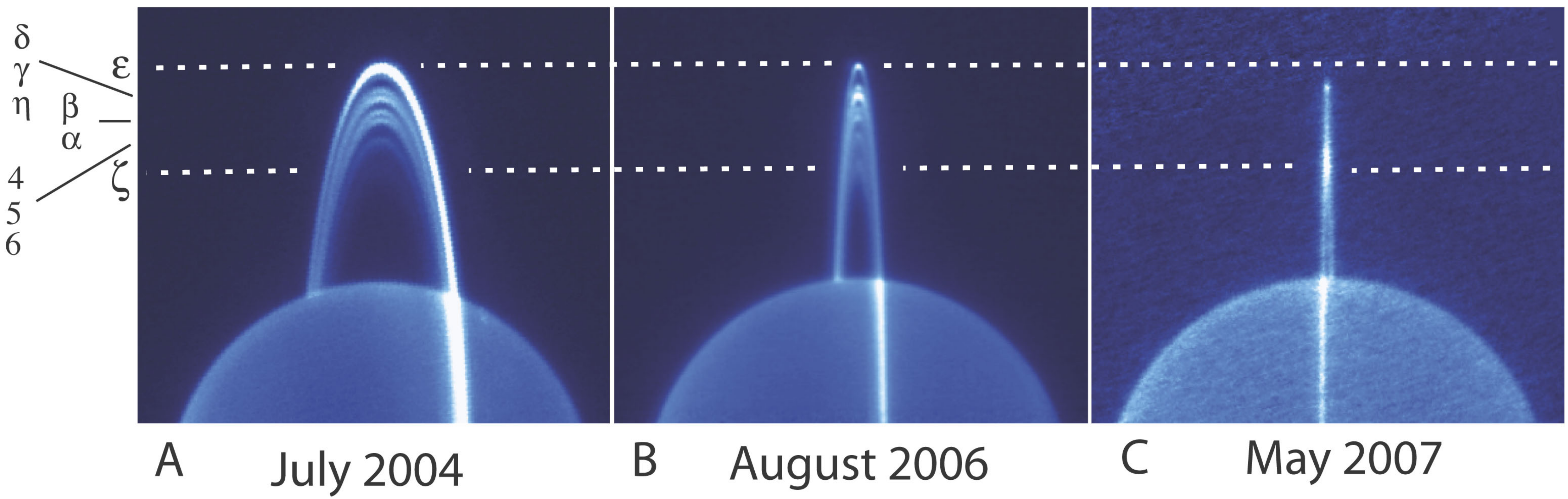
Uranus and its rings



- Optically thick rings like ε disappear due to inter-particle shadowing during the crossing, while optically thin rings like ζ brighten
- The states of the rings evolve rapidly instead of steady

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Volatiles in the Solar System

- Volatiles: H_2O, C_2H_6, HCN, CO, CH_3OH, H_2CO, C_2H_2, and CH_4
- Jupiter-family comet Tempel 1
- The volatile ices in Tempel 1 and in most Oort cloud comets originated in a common region of the protoplanetary disk.

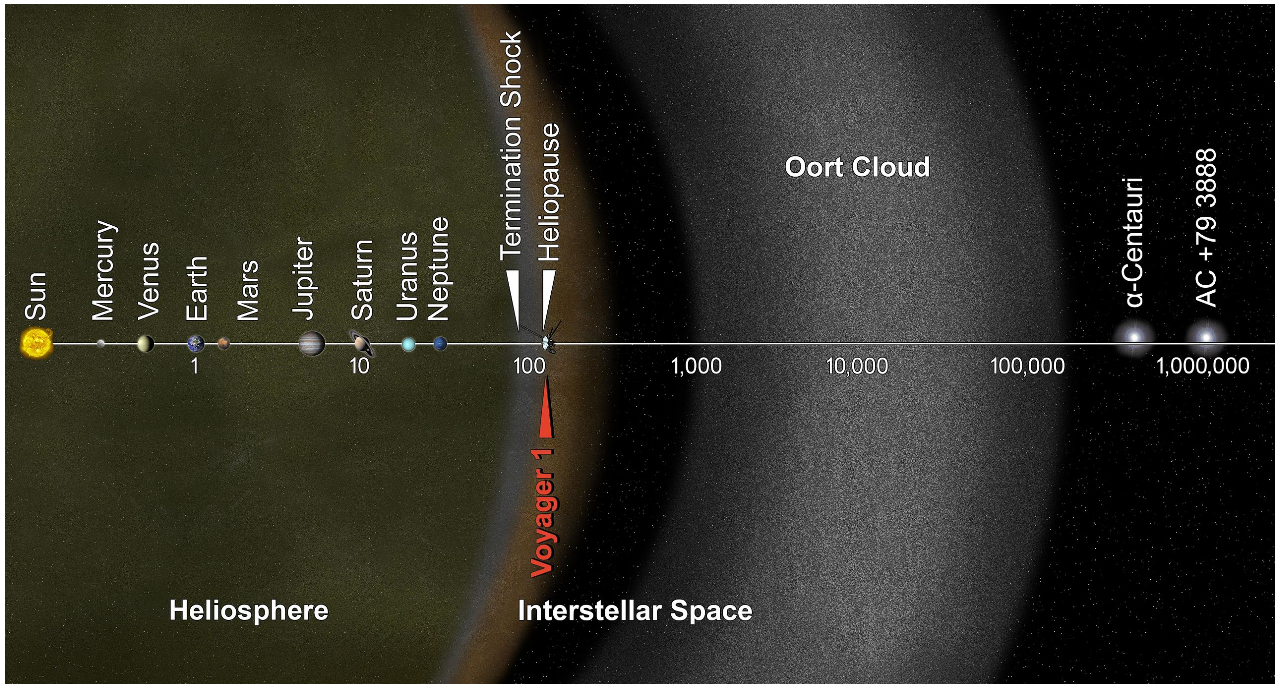
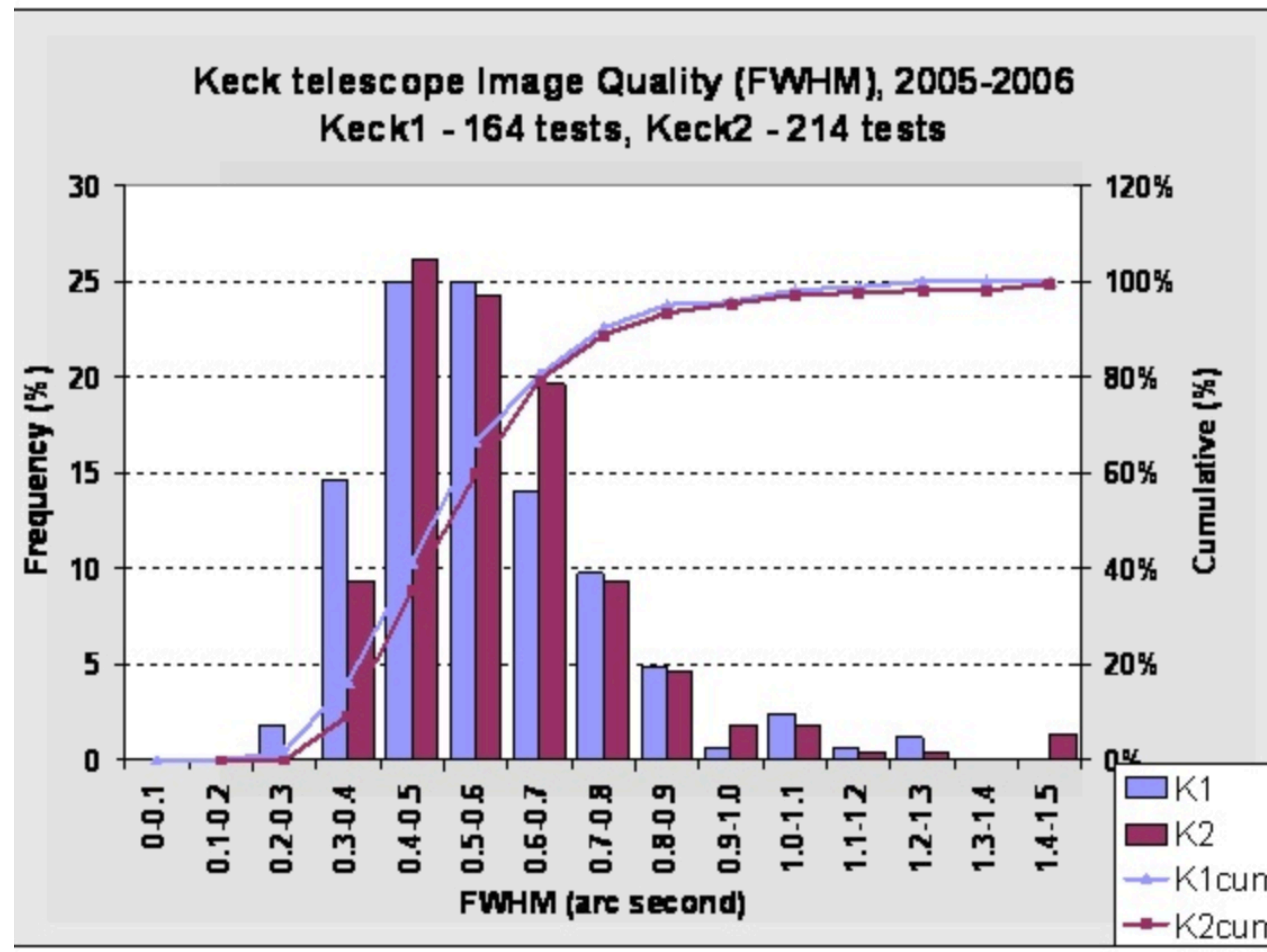


Image Quality

- Non-AO test in 2005&2006
- Median FWHM: 0.5”
- The percentage of tests with FWHM less then 0.7”: 80%



Reference

- [1] The Value of the Keck Observatory to NASA and Its Scientific Community. Rachel Akeson, Tom Greene
- [2]The Keck Observatory Portal to the Universe. Hilton Lewis, Anne Kinney, etc.
- [3]W. M. Keck Observatory's Next Generation Adaptive Optics Facility. Peter Wizinowich
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- [5]The Dark Side of the Rings of Uranus. Imke de Pater, H. B. Hammel, Mark R. Showalter, Marcos A. van Dam
- [6]Water Vapor and Hydrogen in the Terrestrial Planet Form- ing Region of a Protoplanetary Disk. J.A. Eisner
- [7]Strong-Lensing Analysis of a Complete Sample of 12 MACS Clusters at z > 0.5: Mass Models and Einstein Radii. Adi Zitrin, Tom Broadhurst, Rennan Barkana, Yoel Rephaeli, Narciso Ben´ıtez
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- [9]Parent Volatiles in Comet 9P/Tempel 1: Before and After Impact. Michael J. Mumma, Michael A. DiSanti, Karen Magee-Sauer
- [10]http://www.keckobservatory.org
- [11]https://en.wikipedia.org/wiki/W._M._Keck_Observatory