TMT Solar System Science

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TMT Solar System ISDT Members

Liu, Junjun	Caltech
Yang, Bin	Yunnan
Puthiyaveettil, Shalima	IIA, Bangalore
Terai, Tsuyoshi	NAOJ
Urakawa, Seitaro	Japan Spaceguard
Otarola, Angel	TMT
Wong, Mike	UC Berkeley
Greathouse, Thomas	Southwest
Li, Jian-Yang	Planetary Science
Marchis, Franck	SETI Institute

- Conveners:
  - Tomohiko Sekiguchi (Hokkaido University of Education, Japan)
  - Feng Tian (Tsinghua University, China)

Presentations at 2014 TMT Forum

- K. J. Meech (IfA, University of Hawai'i)
  - Solar System Small Body Science with TMT
- Michael H. Wong (UCB)
  - Giant planet atmospheres at high spatial resolution

TMT SS Detailed Science Cases

- Small Bodies
  - Asteroid satellites
  - Outer belt asteroids
  - KBOs
  - Centaurs
  - Comets: in particular MBCs
- Giant Planets
  - Waves and vortices
  - Impacts
  - Internal Heat
- Solid Planets
  - Climate change on Titan
  - Probe the atmosphere of Mars through limb sounding
  - Volcanic Activities on Io

TMT for SS Giant Planets

7. How do the giant planets serve as laboratories to understand Earth, the solar system, and extrasolar planetary systems?

9. Can understanding the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres and climates lead to a better understanding of climate change on Earth?

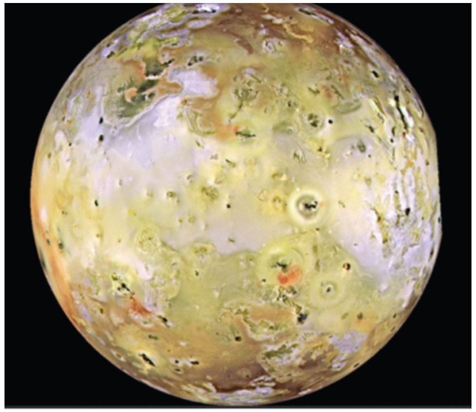
- Key Planetary Science Decadal Goals – small bodies
  - Understanding how habitable worlds are created
  - What were the initial stages, conditions and processes of solar system formation?
  - What governed the accretion, supply of H_2O & inner planet chemistry?
  - From where did Earth get its water?
- A rapidly changing landscape
  - Dynamical models are starting to reproduce structure, but not chemistry
  - Disk chemical models predict chemical gradients, but many models & don't fold in dynamics

Titan

- Titan lakes = cold-trapped methane accumulated in the polar regions.

- Titan is entering a different season: Clouds will form within about two (Earth) years and lake levels will rise over the next fifteen years

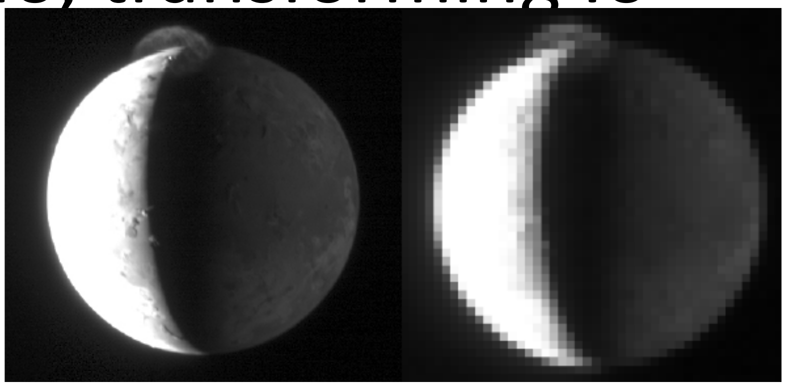
- TMT can reveal the spatial distribution and temporal variation of methane clouds during the exciting climate change on Titan with high spatial and spectral resolution – a link to climate change on the Earth.



Io

- SO2 has molecular bands at 7, 8 and 19 μm.
- At these wavelengths, Io can just barely be resolved on an 8 meter telescope without AO.

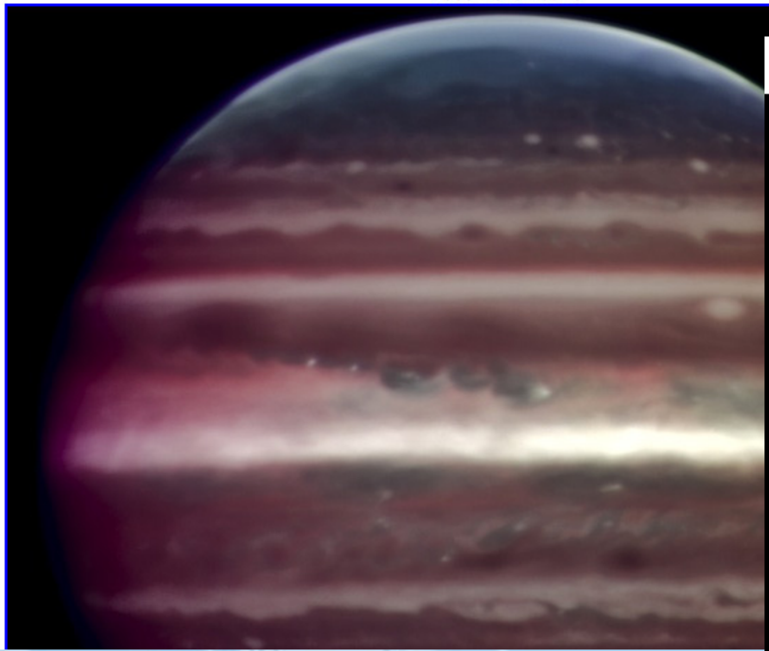
- MICHI on the TMT will be able to measure the spatial variation of SO2 on Io, transforming Io science.



Astronomy Picture of the Day

Discover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2008 November 6



NATIONAL GEOGRAPHI

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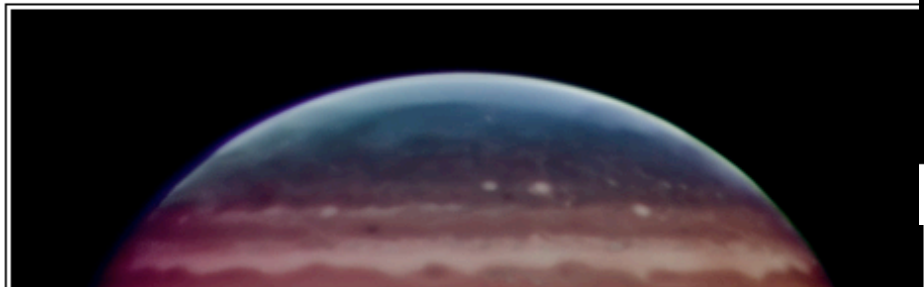
NEW JUPITER IMAGE: Sharpest View Ever From Earth



back scatter

Adapting adaptive optics

For the past 20 years, adaptive optics techniques have provided ground-based astronomers with space-quality images. With rapid, real-time analysis of the time-varying spread of light from a star or other point source (termed a guide star), a computer-controlled deformable mirror corrects for the distortion introduced by atmospheric turbulence and restores crisp detail to images. But the corrections are effective only for light arriving from essentially the same direction, and that limits the field of view to only about 15 arcseconds. An international team led by Franck Marchis of the University of California, Berkeley, [OK?] has recently demonstrated one technique to overcome that limitation: the Multi-Conjugate Adaptive Optics Demonstrator, or MAD.

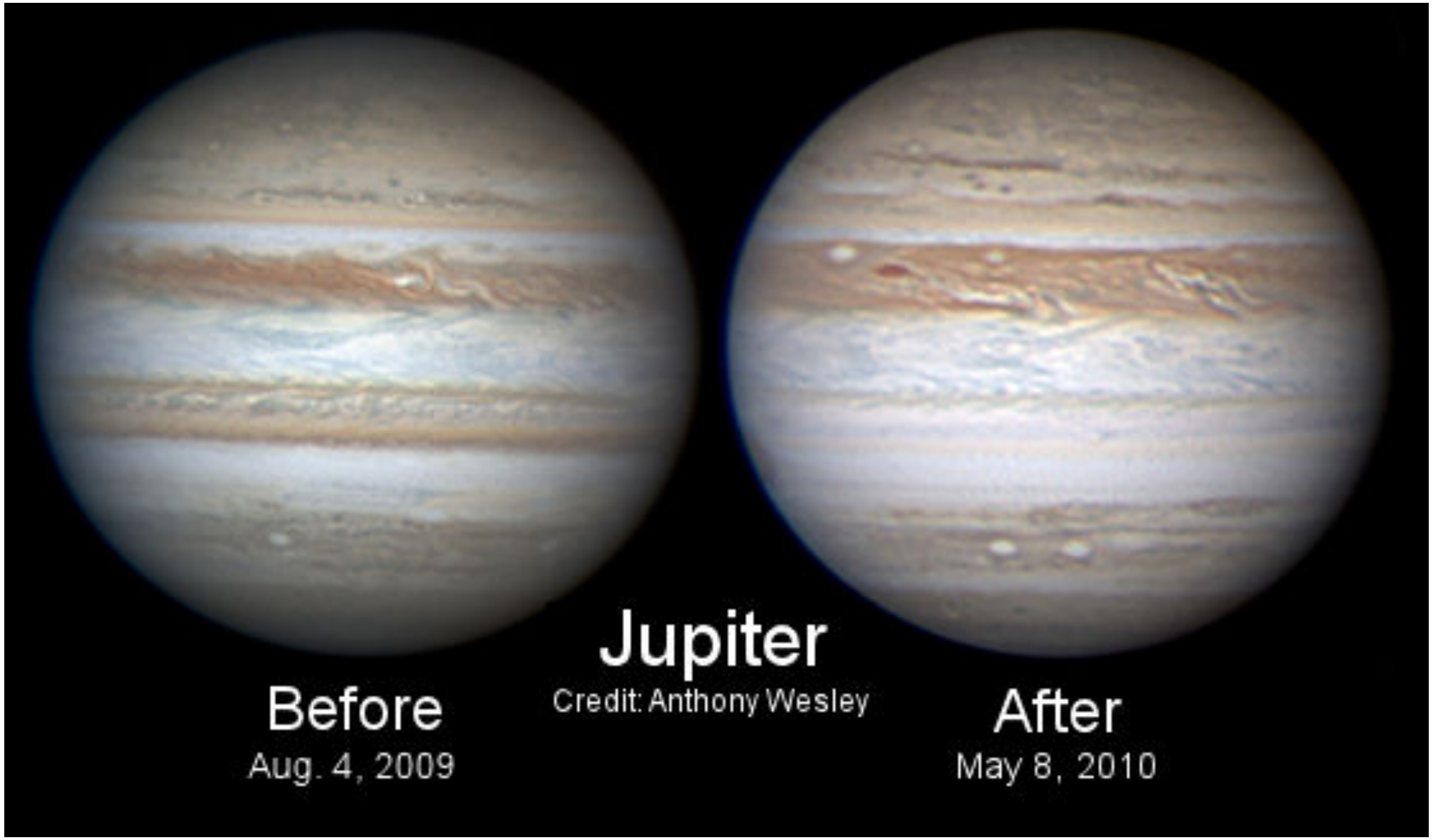
MAD uses multiple guide stars and two deformable mirrors to correct for phase distortions over a broader range of angles; the resulting field of view is 30 times larger. Shown here is a false-color IR image of Jupiter obtained with MAD at the European Southern Observatory's Very Large Telescope in August. The moons Io and Europa, on either side of Jupiter at the time, served as guide stars. The corrected angular resolution was less than a tenth of an arcsecond—details about 300 km across could be resolved. In the observed region of the IR, absorption by hydrogen and methane is strong. The image thus maps the distribution of the planet's high-altitude haze. A comparison with images taken three years ago by the *Hubble Space Telescope* reveals significant changes in the haze distribution; the researchers attribute those changes to a planet-wide upheaval last year. Michael Wong presented the team's results at the October meeting of the American Astronomical Society's Division for Planetary Science in Ithaca, New York. (Image courtesy of ESO/F. Marchis, M. Wong, E. Marchetti, O. Amico, and S. Tordo.)

To submit candidate images for Back Scatter, visit http://www.physicstoday.org/backscatter.html.

NATIONAL

Jupiter: Global upheaval

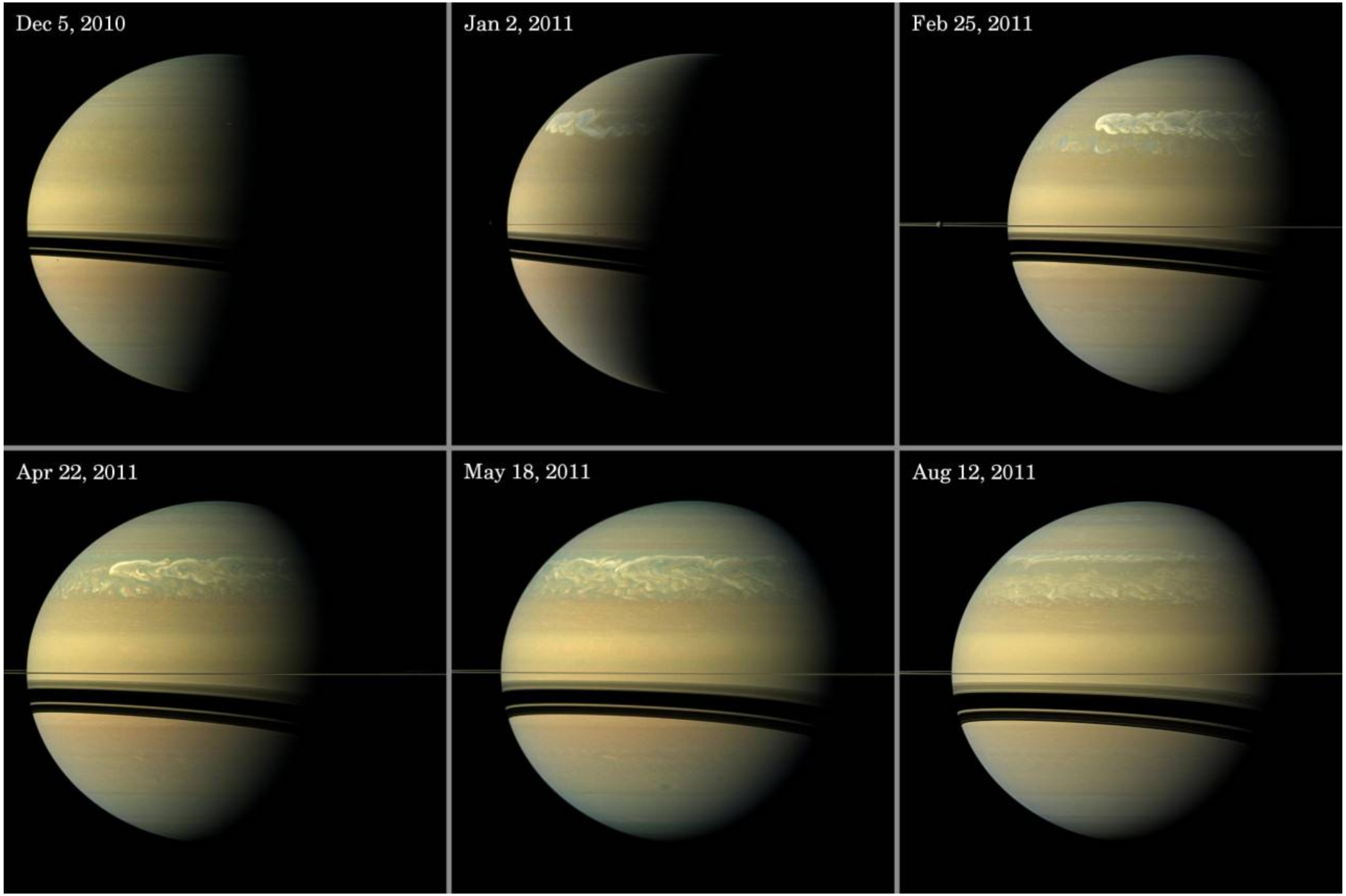
From J. Liu



- Jupiter's visible cloud structure undergo a sudden upheaval where belts and zone change color (e.g., Rogers 1995).
- Measurements of the temperature and composition fields, and the opacity and vertical distribution of cloud provide direct clues to particulate cloud chemistry and atmospheric dynamics accompanying the color change.

Saturn: Giant storm

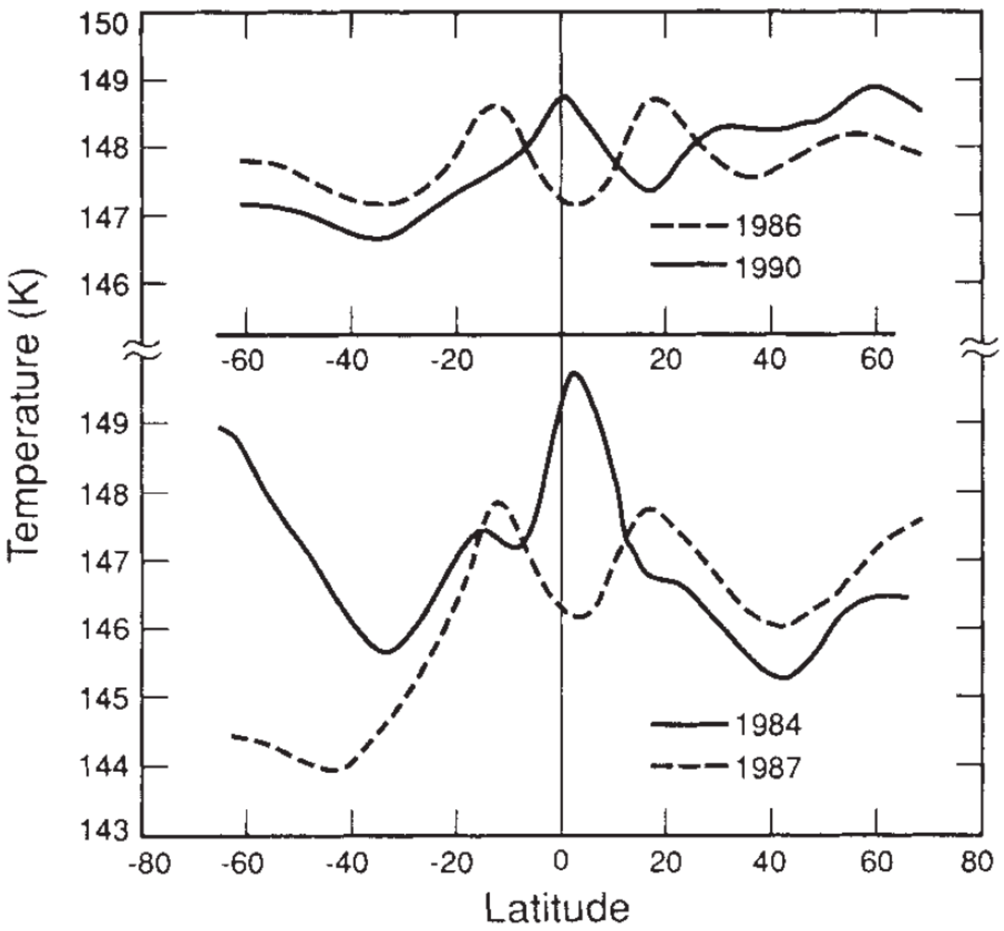
From J. Liu



- TMT can be used to monitor the onset, develop and decay of the large scale convective storm.

Jupiter: Low frequency variability

From J. Liu

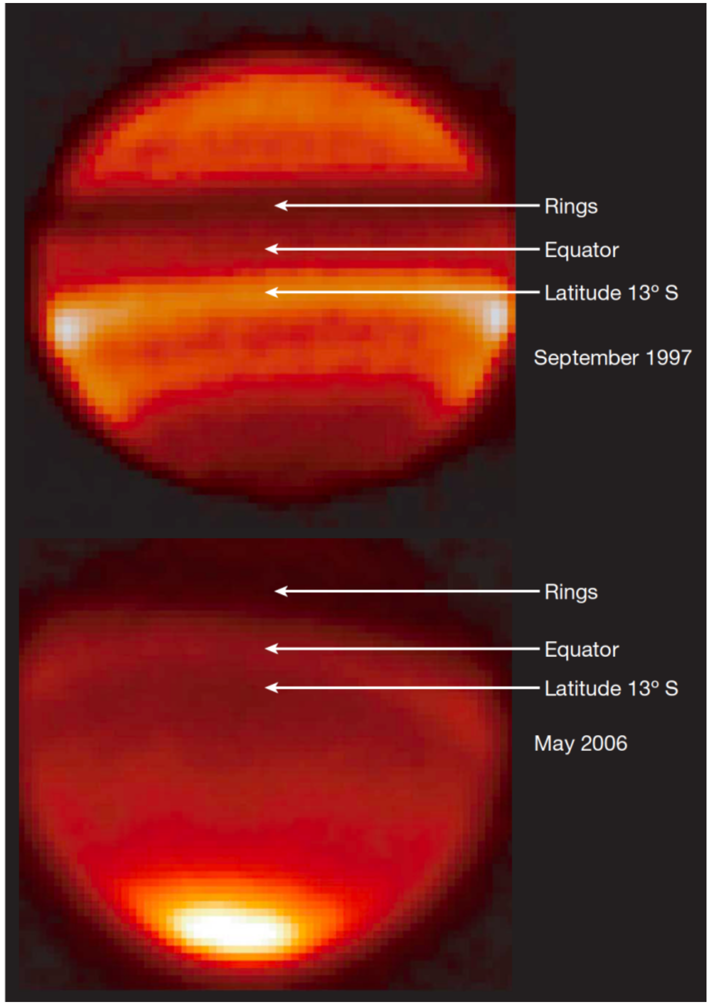


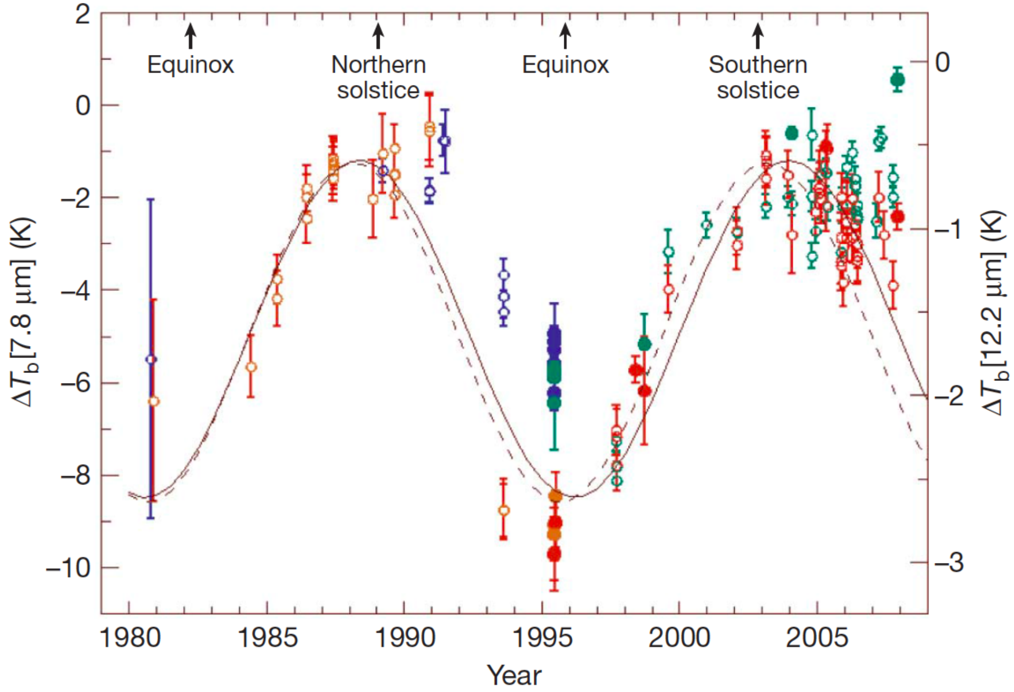
Observed equatorial temperature oscillation on Jupiter (Leovy et al., 1991)

- Jupiter's stratosphere undergoes "quasi-quadrennial" oscillation (QQO) with period of 4 ~ 5 years. It is similar with the QBO in Earth's atmospheres.
- How is the low-frequency variability generated? What determines its characteristic time scale?
- Is the global upheaval related to the different phases of QQO?

Saturn: Low frequency variability

From J. Liu



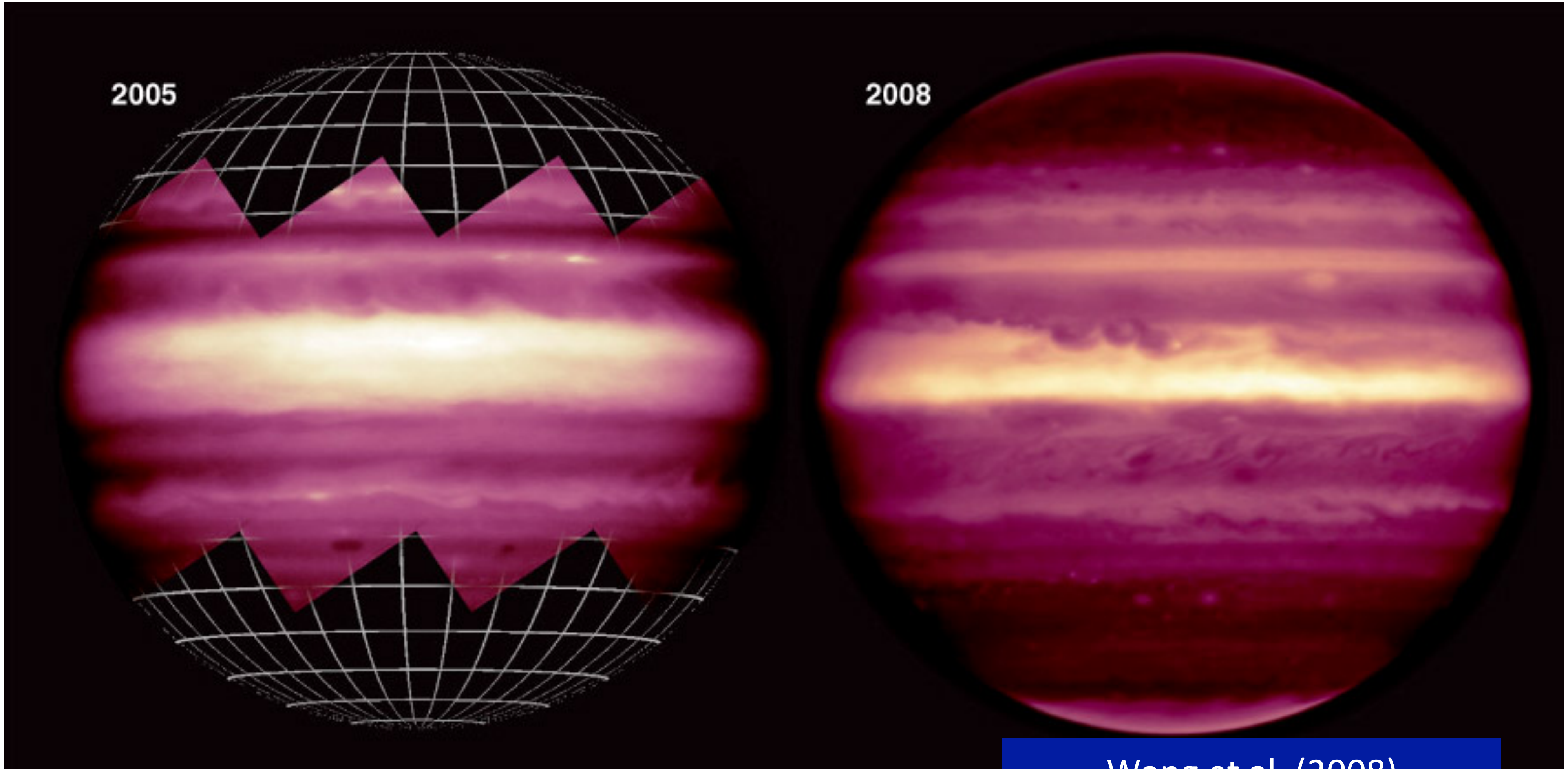


- Saturn's stratosphere undergoes "quasi-semiannual" oscillation with period of 14 ~15 years. It is likely related to Saturn's seasonal variation. But how?

NASA (IRTF), Orton et al. 2008

Equatorial haze shift

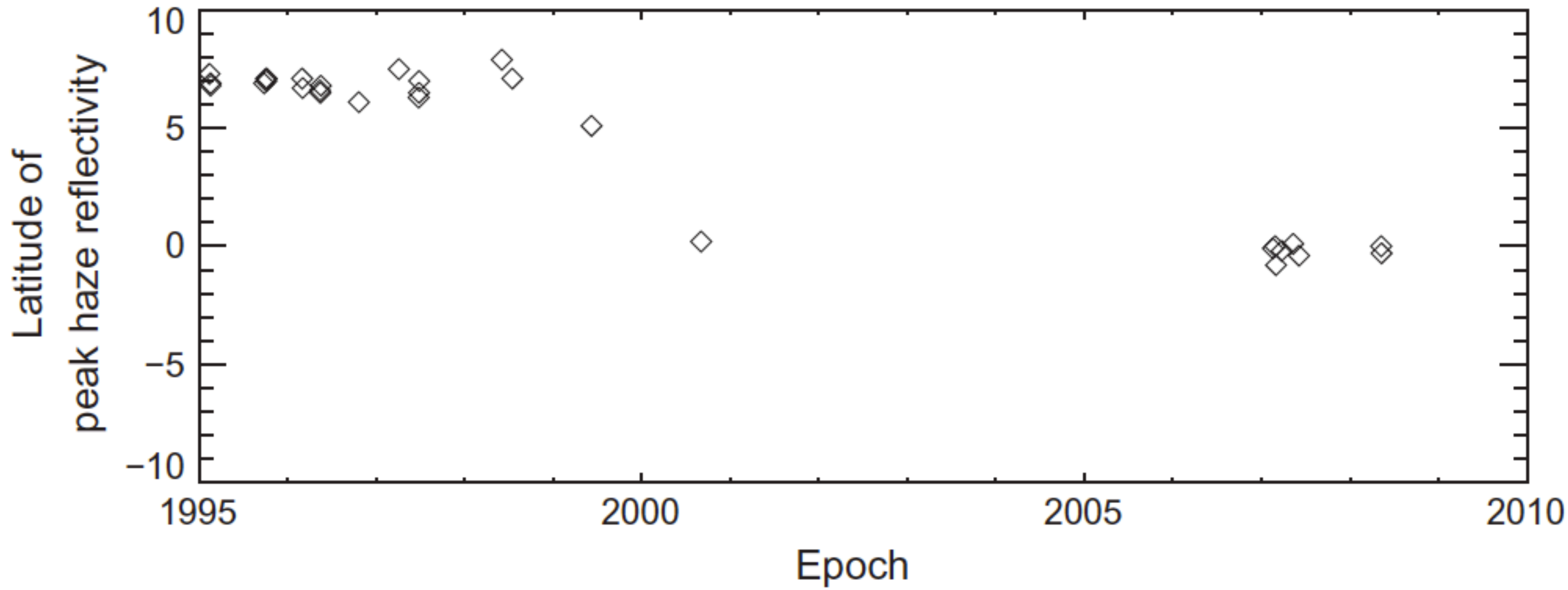
From M. Wong



Wong et al. (2008)
arxiv.org/abs/0810.3703

Haze variability

From M. Wong



Lii et al. (2010)

HST/WFPC2 data: value of coherent reusable datasets

Specific giant planet atmosphere objectives

From M. Wong

CIRCULATION

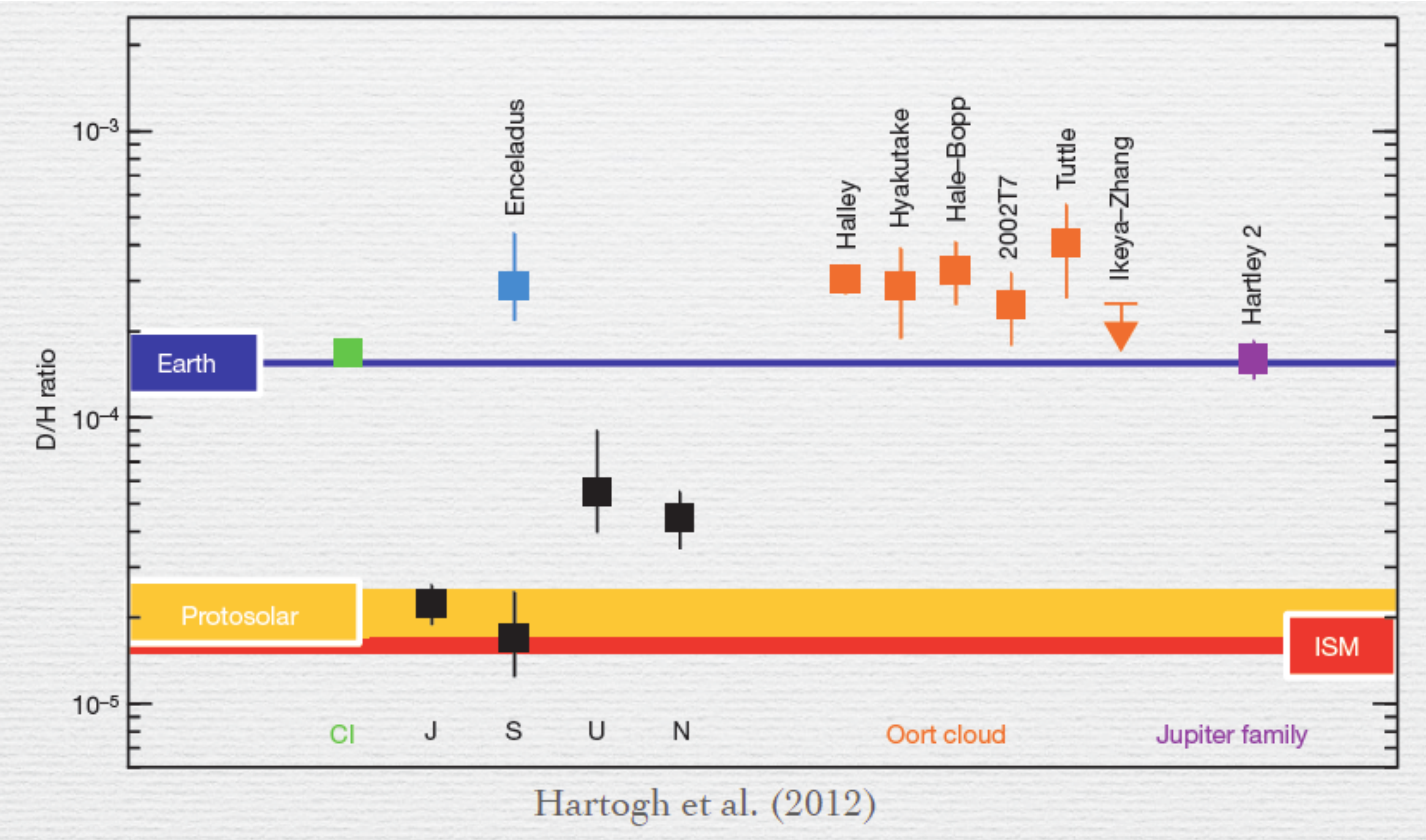
- Determine the distributions of dynamical tracers, and how they change
- Relate the histories of thermal evolution of the giant planets to the array of diverse exoplanets
- Identify chemical and physical processes that affect dynamical tracers

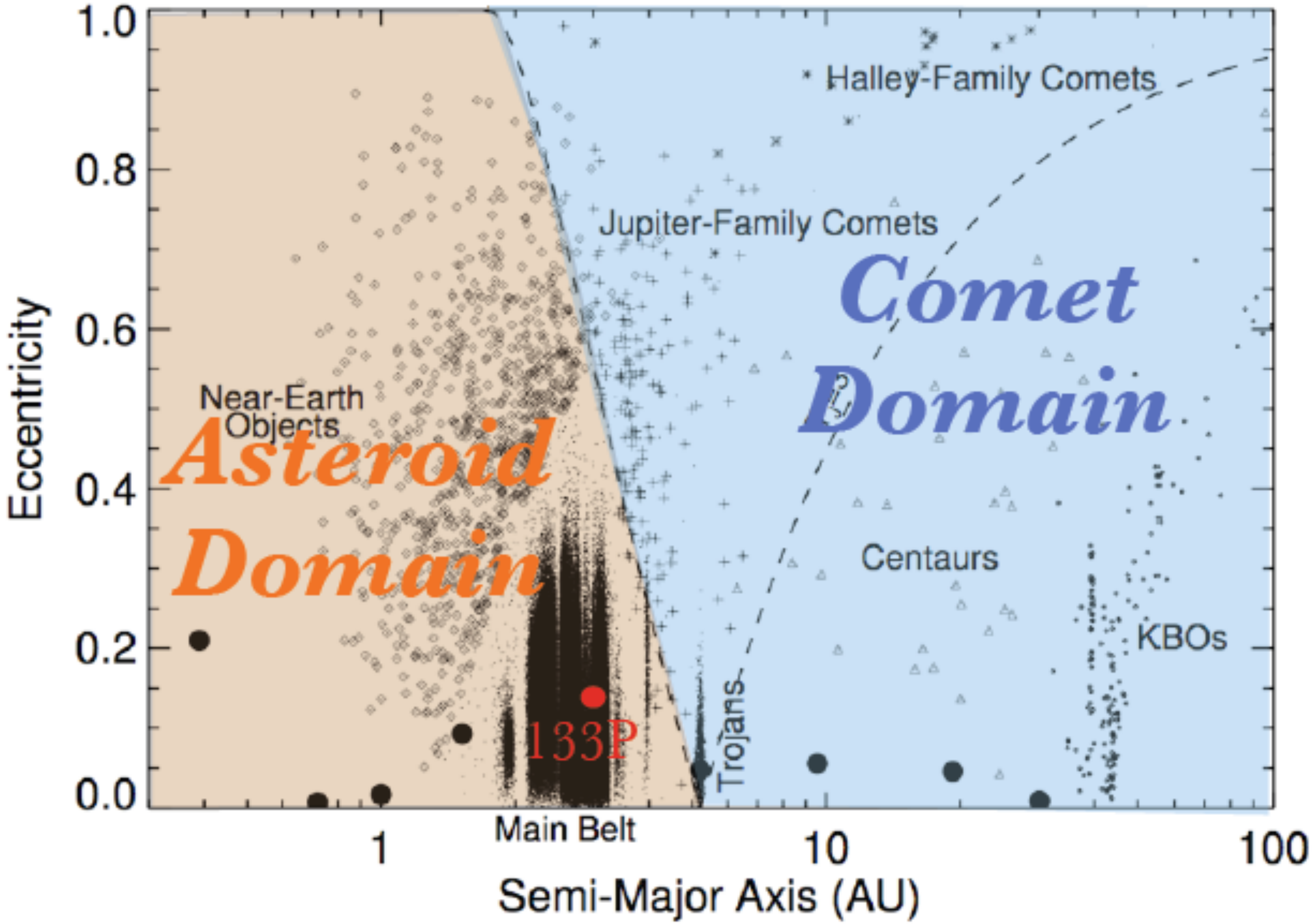
VARIABILITY

- Study dynamic processes over a wide range of timescales
- David Silva: we need coherent reusable datasets
- Key programs can satisfy this goal

We do not know where Earth's Ocean is from....

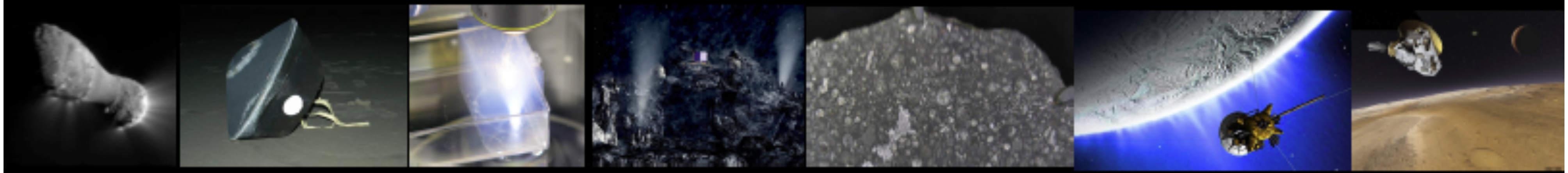
From B. Yang




Halley-Family Comets
Jupiter-Family Comets
Comet Domain
Near-Earth Objects
Asteroid Domain
Centaurs
KBOs
133P
Trojans
Main Belt
Eccentricity
Semi-Major Axis (AU)
1.0
0.8
0.6
0.4
0.2
0.0
1
10
100

From B. Yang

MBCs – An Unsampled Volatile Reservoir



- We have detailed information from
  - JF comets (EPOXI, Stardust,… Rosetta)
  - Inner asteroid belt / NEOs (meteorites)
  - Icy outer moons (Cassini)
  - Kuiper belt (New Horizons)
- Sample a new H2O reservoir: MBCs
  - Measurement of isotopic fingerprints
  - Testing dynamical models
  - Testing disk chemistry models

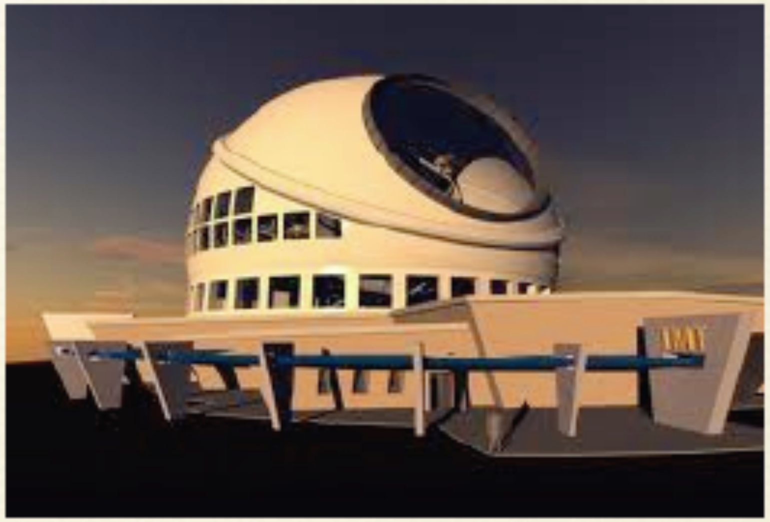
From K.J. Meech

MBCs Via TMT

From B. Yang

- Search for direct evidence of H2O ice
- Search for direct evidence of sublimating gas
- Search for faint cometary activity
- Study surface/gas composition from UV to NIR

IRiS
InfraRed Imaging Spectrograph



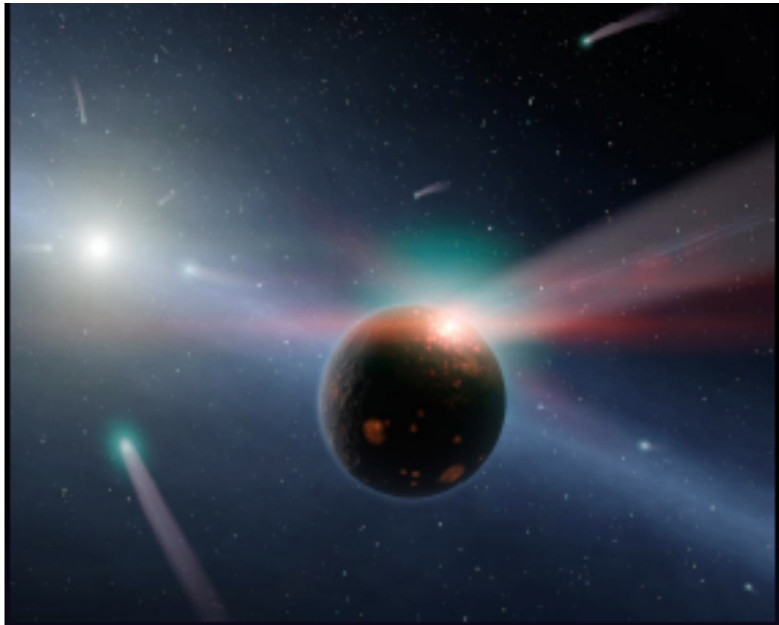
TMT for Comet Composition

- Enable observations of fainter comets
  - More JFCs
  - OCs at larger heliocentric distances
- Enable new measurements
  - D/H for more comets, especially JFCs
  - Other isotopes, such as ^{16}O/
  - Nuclear spin temperature (ortho/para)

From J. Li

Images from Google Image Search

What's left for TMT?



A paradigm shift is underway – there may be water everywhere in the outer belt, and this may profoundly change our understanding of the formation and location of habitable worlds. . . .

The key is mapping distribution of volatiles & isotopes in small bodies & disks

Understanding how habitable worlds form in our SS has implication for habitability in extra solar planetary systems

From K.J. Meech

Critical Instruments for SS small body science

From K. J. Meech

1. High resolution optical spectrograph — for getting isotope ratios in comets (R ~ 60,000-80,000)

- 2. High resolution near IR spectrograph - for parent organic volatiles (R ~ 20,000)

Special Software Requirements for SS Small Bodies

From K. J. Meech

- 1. ensure capability for non-sidereal GUIDING (not just tracking).
  - Rates < 1 arc sec/hr (typical of KBOs) to several 100 arc sec / hr for NEO

- 2. The Adaptive Optics system needs to be able to handle moving targets too.

- 3. For moving objects there is a need to fully integrate with national archives of orbital elements - so that standard names can be entered and other things can be done automatically - a software requirement.

Questions?