

# CENTAURUS

## Exploring Centaurs and More, Messengers from the Era of Planet Formation

Kelsi N. Singer (1), S. Alan Stern (1), Daniel Stern (2), Anne Verbiscer (3), Cathy Olkin (1), and the Centaurus Science Team. (1) Southwest Research Inst., Colorado, USA, [ksinger@boulder.swri.edu](mailto:ksinger@boulder.swri.edu); (2) Jet Propulsion Laboratory, Pasadena, CA, USA. (3) University of Virginia, Charlottesville, VA, USA.

**Centaurus is a non-nuclear Discovery mission proposed to make the first reconnaissance of Centaurs—escaped Kuiper Belt Objects (KBOs)—via a series of flybys.**

### Centaur Targets

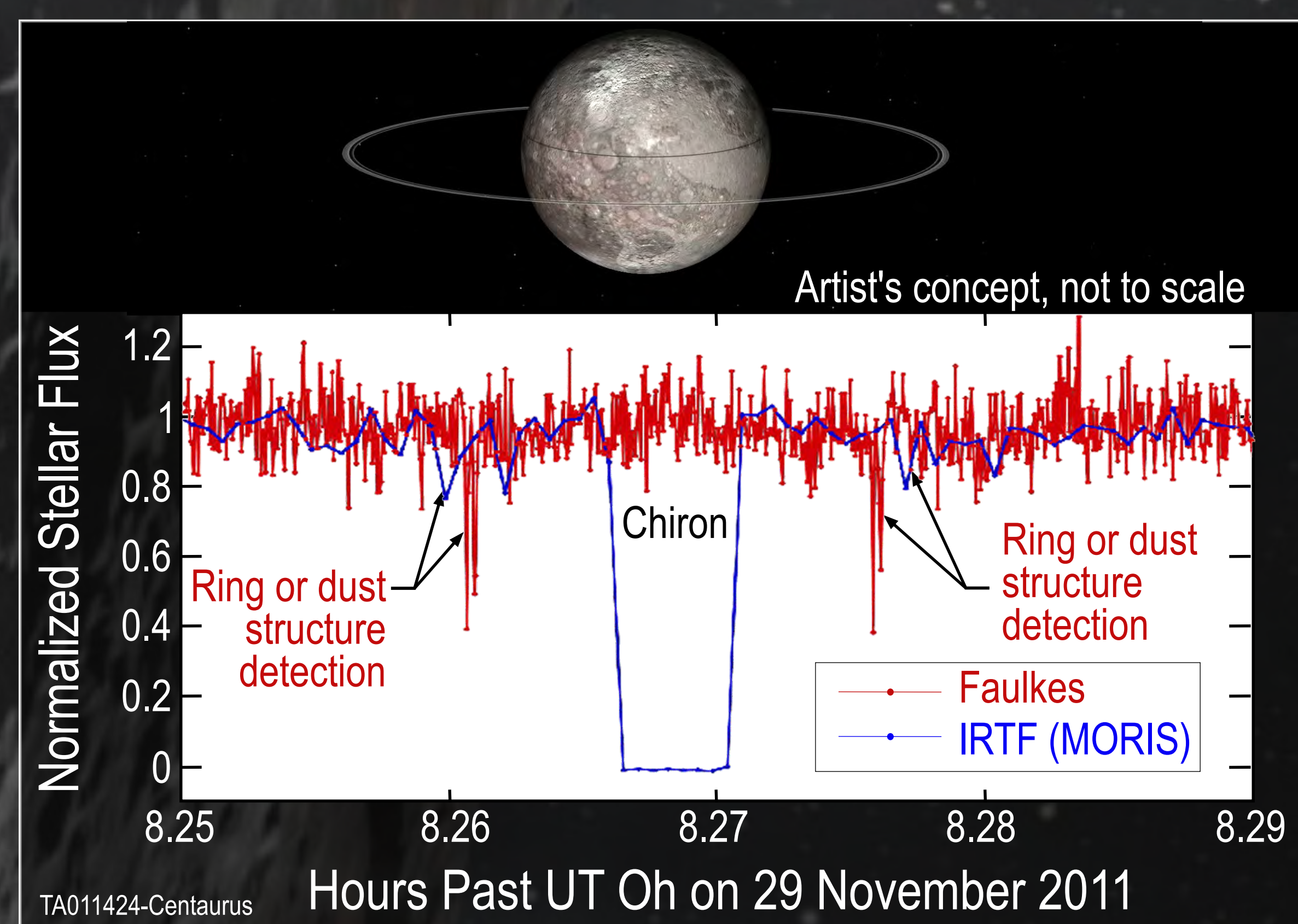
*Centaurus* targets include two scientifically amazing Centaurs:

- Chiron
- Schwassmann-Wachmann-1 (SW1)

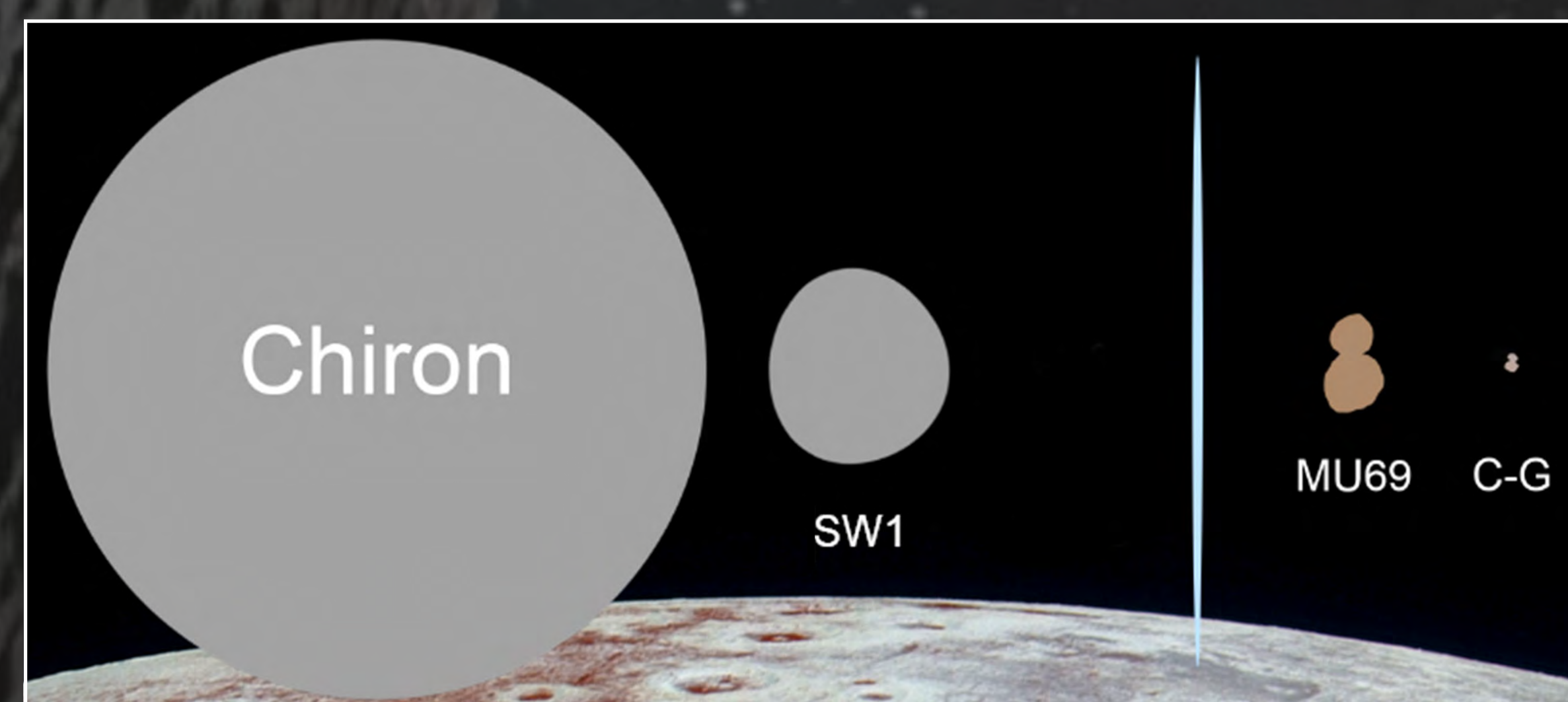
→ both are large Centaurs with evidence for rings and/or other dust structures above their surfaces and varying styles of coma activity.

Target	Diameter	Perihelion Distance	Key Attributes
Chiron	~220 km	8.4 AU	<ul style="list-style-type: none"><li>• Evidence for rings or dust structures [1, 13-15]</li><li>• Frequently shows a coma [9-12]</li><li>• 2<sup>nd</sup> largest Centaur</li><li>• ~2000× as voluminous (and presumably about as much more massive) as 2014 MU69</li></ul>
SW1	~50 km	5.7 AU	<ul style="list-style-type: none"><li>• Most persistent and active coma of any known Centaur [e.g., 5]</li><li>• Displays one (or more) large coma dust structures [6-8]</li><li>• It is an order of magnitude more massive than 2014 MU69, which New Horizons explored.</li></ul>

- Crucially, the ~50 and ~220 km diameters of these Centaurs place them in the unexplored, almost two order of magnitude wide size gap between MU69 and Pluto.
- No such heliocentrically formed bodies have ever been explored, a significant limitation to understanding the origin and evolution of Kuiper Belt worlds and also planet and planetesimal formation in the outer solar system in general.



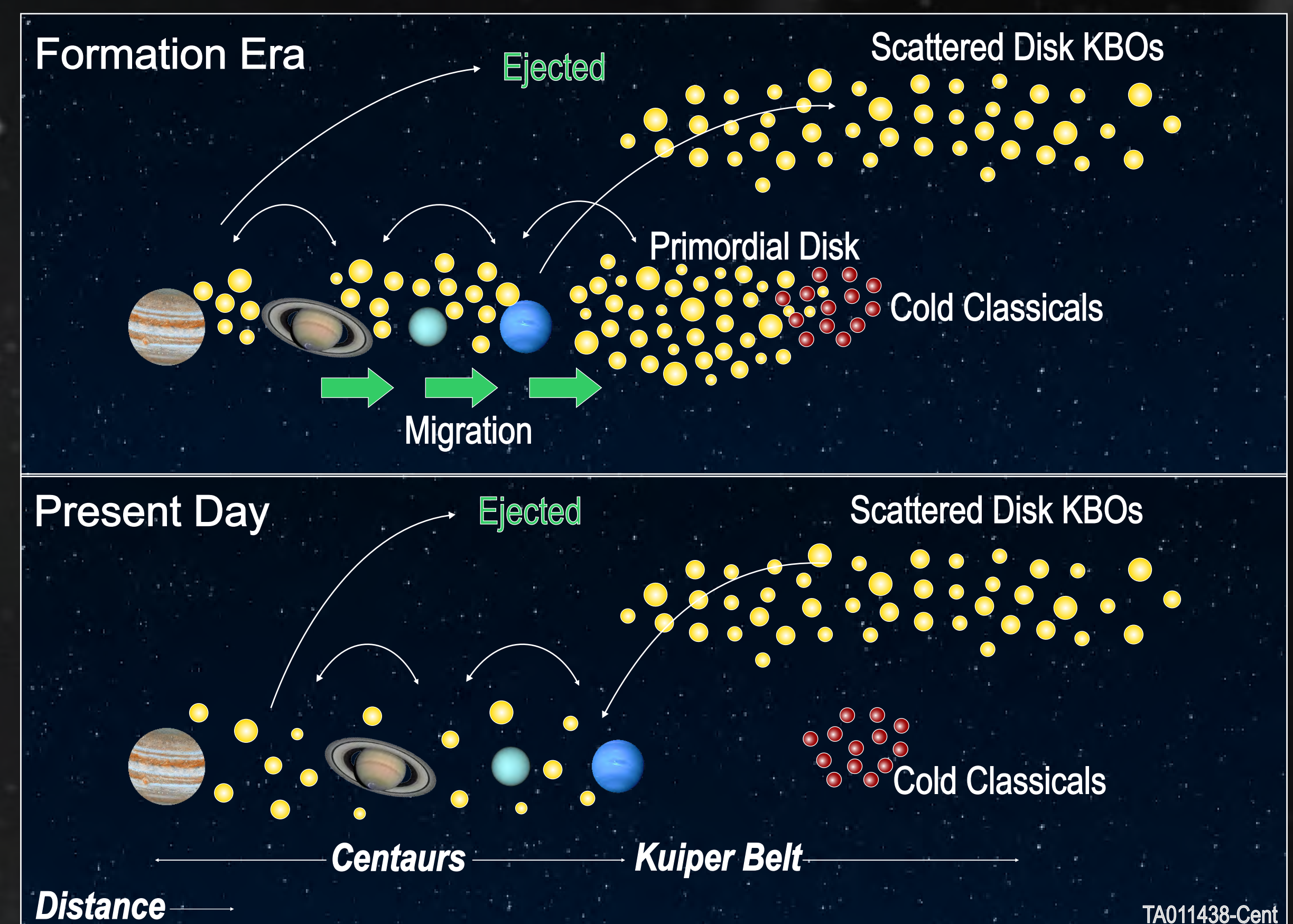
**Figure 1:** Chiron has displayed evidence for orbiting rings or other dust structures in multiple stellar occultations. Here is a 2011 stellar occultation showing evidence of symmetric, hence likely ring, opacity structures with significant optical depths (upper figure artwork by Dan Durda, lower figure modified from [1]).



**Figure 2:** The *Centaurus* targets Chiron and SW1 fill in a crucial size/mass gap between smaller bodies like MU69 and dwarf planets like Pluto (shown at the bottom for scale). Figure by Dan Durda.

### What are Centaurs?

- The Kuiper Belt consists of myriad of well-preserved planetesimals (i.e., intermediate-sized bodies up to 100s of km in diameter) and a population of larger objects called dwarf planets.
- Centaurs are escapees from the Kuiper Belt's Scattered Disk [2]—an ancient, unexplored KBO population of less evolved objects than Pluto, and with different origins [3] than the Cold Classical KBO 2014 MU<sub>69</sub> that New Horizons explored.



**Figure 3:** Simplified schematic of Centaur creation 4+ Gyr ago (top) and present-day dynamics (bottom) showing transport from SD KBOs to orbits between Neptune and Jupiter. For simplicity, Centaur losses to Jupiter Family Comets (JFCs) and KB resonant populations are not shown. The relative numbers of various populations are not quantitatively represented here.

- But unlike Scattered Disk bodies, which orbit beyond Neptune, Centaurs are more accessible, temporarily (i.e.,  $10^{5-7}$  yr) orbiting far closer, among the giant planets [e.g. 2, 4].
- After their short dynamical lives as *Centaurs*, these objects are either ejected back out to more distant parts of the solar system, or they are kicked inward to become Jupiter family comets.

### Centaurus Mission Facts

- *Centaurus* is a joint SwRI-JPL proposal; Lockheed-Martin is the spacecraft provider. APL and NASA Goddard are also involved.
- *Centaurus* has deep roots in both the 2003 and 2013 Decadal Surveys, addressing multiple Priority Questions and all three DS13 themes.
- The *Centaurus* PI and deputy PI are Alan Stern and Kelsi Singer from Southwest Research Institute (SwRI).
- *Centaurus* includes a payload of imagers and spectrometers to study the surfaces and atmospheres/comae of its flyby targets.
- *Centaurus* can launch in any year from 2026 to 2029.

### Key Points

- The core of the *Centaurus* Discovery mission is the inaugural exploration of Centaurs. By exploring these KBO ejectees at closer range, *Centaurus* becomes the next chapter in KBO exploration—and expands the types of explored KBOs (resonant and cold classicals) to include Scattered Disk Objects.
- *Centaurus* thus accomplishes KBO exploration on a Discovery budget and without the need to use precious nuclear resources for the next stage in KB exploration.
- By exploring these Centaurs while also exploring other primitive bodies, *Centaurus* will reveal crucial new insights into:

- Planetesimal and dwarf planet formation and evolution
- The source of distant cometary activity,
- The nature of rings around solid bodies,
- And Kuiper Belt formation.

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