BOLIDE AIRBURST CHAINS ON EARTH AND VENUS: TIDAL BREAKUP FROM A PREVIOUS ENCOUNTER? Mark Boslough[1,2], Peter H. Schultz[3], R. Scott Harris[4], [1]Verification and Analysis, XCP-8, Los Alamos National Laboratory, Los Alamos, New Mexico, 87545, [2]Dept. of Earth and Planetary Sciences, University of New Mexico, MSC O3-2040 Albuquerque, NM 87131-0001, mbeb@unm.edu [3]Dept. of Earth, Environmental, and Planetary Sciences, Brown University; P.O. Box 1846, Providence, Rhode Island 02912, [4]Dept. of Space Sciences, Fernbank Science Center; 156 Heaton Park Drive, Atlanta, Georgia 30307.

Abstract: The Pica Glass in Chile [1] (Fig. 1), and the Phoebe Regio splotch chain on Venus [2] (Fig. 2) share attributes and may have a common explanation. We suggest that they were caused by a series of bolide airbursts from fragments of a body that disrupted during an earlier close pass of their respective planet. When an asteroid or comet has a sufficiently close encounter with a planet, the resulting tidal disruption generates a family of fragments with orbital elements that share a node crossing on or near the orbit of that planet, but with a range of speeds and other orbital elements. A subset of the fragments can wind up in resonance with their planet and strike it on a subsequent encounter. If they are in a short period resonance (on the order of a few the planet's years), then some fragments will not have had time to separate by more than the planet's diameter. Perturbations in an object's velocity along its direction of motion increases its displacement with time at a much higher rate than perpendicular perturbations, so the resulting swarm would spread along their path before colliding with the planet, resulting in a chain of craters, splotches, and/or airburst glass fields.

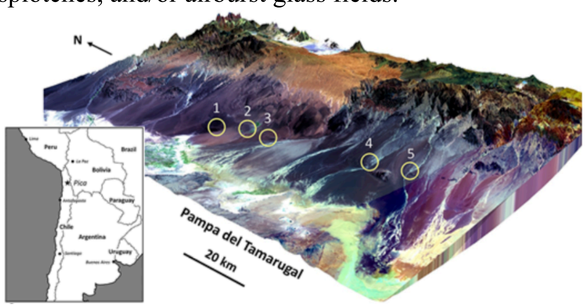

Figure 1: Pica Glass chain, Atacama Desert, Chile [1].

Airburst physics: When a small body strikes a planet with an atmosphere, it loses its kinetic energy and mass through drag and ablation, generating a trail of high temperature meteoritic vapor mixed with air. The hot wake continues to descend much more rapidly than it can expand radially and becomes an incandescent vapor jet that either transfers all its momentum to the atmosphere or strikes the surface of the planet. If it stagnates before it reaches the surface, it becomes buoyant and recedes upward with little effect on the ground other than its thermal radiation and mechanical damage from the non-radiating low-temperature air shock. We have called this a "Type 1", "Tunguska type", "non-contact", or "fire-in-the-sky" airburst [3,4]. If it reaches the surface, it is held in contact with the ground by its own inertia and expands radially until buoyancy takes over and causes it to recede upward. Because of the high-temperature, high-opacity meteoritic vapor in direct contact with the ground, it melts and ablates surface material through a combination of radiation and convection. This is a "Type 2", "Libyan Desert Glass type", "contact", "touchdown", or "fire-on-the-ground" airburst [3,4,5]. The type of airburst depends on the meteoritic body's mass, velocity, density, strength, entry angle and other attributes. Airbursts of either type can also accompany crater-forming events.

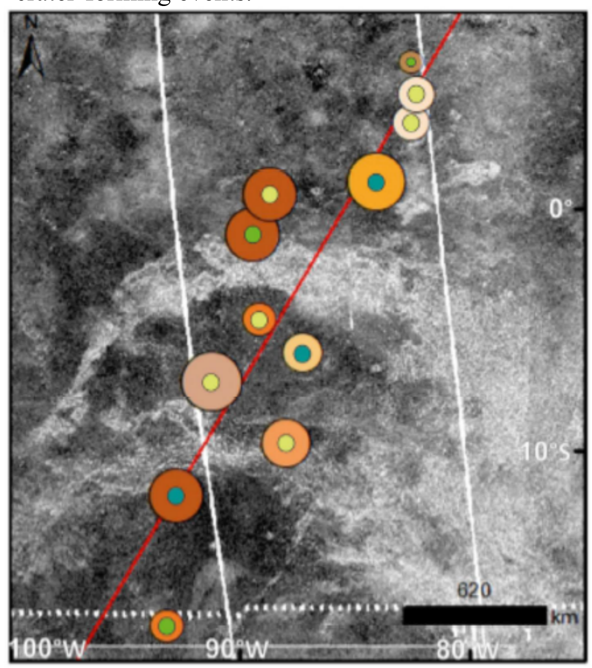

Figure 2: Phoebe Regio splotch chain, Venus [2].

Pica Glass chain: Pica Glass requires rapid heating and quenching of surface materials. We suggested [5] the that multiple contact airburst fireballs from the cascading fragmentation of a comet that broke up upon low-angle entry into the atmosphere could explain the spatial distribution of the five Pica glass locations in a nearly straight line. However, subsequent fieldwork led to the discovery of more glass locations with lateral distributions that are too wide for this scenario. This would require disruption much earlier to give fragments enough time to spread in the lateral direction in addition to their longitudinal distribution.

Phoebe Regio splotch chain: We argue that this chain may have formed by precisely the same mechanism, but with much larger objects with sufficient mass to penetrate the denser Venusian atmosphere and strike the surface, in some cases, to form craters in addition to generating airburst glass and shock damage. Because of the strong power-law size frequency distribution of NEOs and other inner-solar-system objects, such an event has much lower probability than the same event on Earth, so the expected recurrence interval would be much longer. The estimated age of the splotch chain on Venus is less than 35 Ma, whereas the Pica Glass is less than 11.5 ka old. Both events are improbable, but not necessarily on the time scale over which they formed.

Misconceptions: Many misconceptions about airbursts and orbital dynamics have crept into the scientific literature, much of it driven by proponents of the Younger Dryas impact hypothesis (YDIH) and its ancillary claims that airbursts are so frequent that they have been responsible for the destruction of human settlements in the past. These papers have also conflated the air temperatures behind the blast wave at the surface with temperatures of the hot jet of meteoritic vapor that is responsible for melting surface materials (e.g. Libyan Desert Glass) [3]. These misunderstandings have led to the retraction of two of the papers (Tall el-Hammam in Jordan and Hopewell in Ohio). A third one [6] went even further, speculating that an airburst destroyed Abu Hureyra in Syria, and was part of a "cosmic impact event" that "occurred ~12,800 years ago, resulting in multi-continental airbursts, possibly caused by the debris stream from a short-period comet." Such a debris stream, if caused by a fragmentation event, would generate a narrow chain of impact or airburst features like the Phoebe Regio Splotch Chain or the Pica Glass Chain (which formed at least a few hundred years after the end of the Younger Dryas and has no link to it).

A less serious, but still significant misconception, expressed in the Phoebe Regio paper [2] is that "Given the angle of the Phoebe Regio splotch chain (60° from the Venusian equator and 3.4° inclination of the Venusian orbit to the plane of the ecliptic), then the stream of incoming bolide fragments must be significantly out of the plane of the ecliptic." The fragments are in fact lined up along their path around the sun, but in Venus's reference frame they are flying in an echelon formation, so the locus of their impact points on a planet does not represent the intersection with their orbital plane. Thus, the roughly N-S trend of both the Phoebe Regio and Pica Glass chains do not require a high inclination orbit for the fragmented body. As an example, the 2024 PDC25 tabletop exercise had a N-S trending risk corridor from a NEO in a low (11°) inclination orbit (Fig. 3).

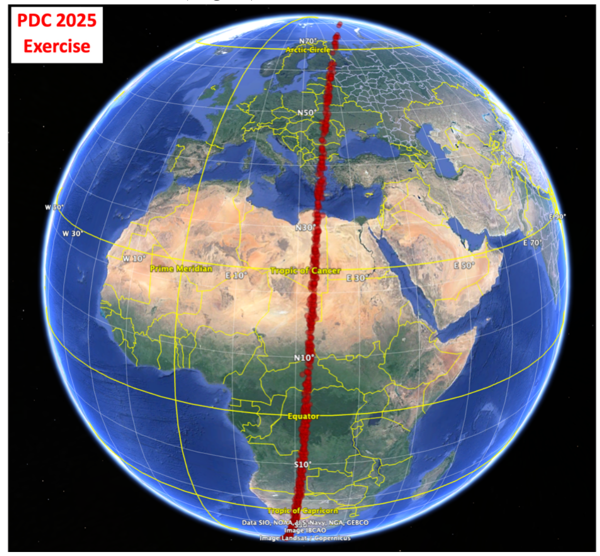

Figure 3: Risk corridor from hypothetical impact [7].

Conclusions and further work: Both the Pica Glass and the Phoebe Regio chains are consistent with formation by airbursts or impacts from fragments of parent bodies that were disrupted by a previous close encounter with Earth and Venus, respectively. We believe that orbital dynamics and hydrocode airburst models can be used to develop specific scenarios that are consistent with these chains and determine if they are sufficiently likely to have taken place on the timescale of their ages. We further suggest that such a mechanism could have also generated long and sparse crater chains on the moon that may not yet have been recognized and recommend efforts to identify them.

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