A preliminary analysis of the Shangri-La Bolide on 2017 Oct 4

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At 12:07 UT (8:07 pm China Standard Time) on 2017 Oct 4, a bright bolide was widely observed in the Shangri-La region of the Province of Yunnan, China (Figure 1). The event was well observed by the general public as it took place on the night of the Mid Autumn Festival, which is associated with moon gazing. Sonic booms and ground shaking were reported in an area of about a thousand square kilometers northwest of Shangri-La City. Data from U.S. government sensors suggests that the impact energy of the event was approximately 0.54 kt TNT equivalent, with the terminus of the bolide positioned at 28.1°N, 99.4°E. This is the largest observed bolide event over land since the bolide event that took place in Mauritania on 2016 Jun 27 (1.2 kt).

The International Meteor Organization and the American Meteor Society operate fireball report programs that collect world-wide observations of fireballs and bolides (https://www.im.net/observations/fireballs/fireballs/ and https://www.amsmeteors.org/fireballs/, see Hankey et al., 2014; Hankey and Perlerin 2015). However, very few (2) reports of the Shangri-La event have been archived in either database. Here we collect various accounts from Weibo users, forum posts, and media reports, tabulated in Table 1.

Figure 2 shows that moderate ground shaking was limited to an area about 30 km x 30 km aroundHongpo Village, ~40 km northwest of Shangri-La City (labeled as Dêqên/迪庆藏族自治州 in the figure). Curiously, reports from Hongpo Village did not indicate ground shaking. It is not clear whether this was the case or the information was simply omitted. According to the local government agency, no significant property damage or loss has so far been reported (http://news.chinaxiaokang.com/duijiazhengdong/2017/1006/260312.html, in Chinese. Retrieved 2017 Dec 19).

We also collected footage from 3 dashboard cameras for which the shooting locations are precisely known: two from freeways

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near the cities of Lijiang and Dali in Yunnan, approximately 100 km and 300 km to the northwest (Figure 3). Initial analysis shows that the trajectory and motion of the bolide broadly agree with the U.S. government sensor data. The Rawu footage included the full moon in the field of view, which appeared to be much less bright than the bolide at its peak brightness (Figure 3, frame b).

The event was also detected seismically and infrasonically. China Earthquake Administration has reported positive detection by two seismic stations, Zhongdian (27.824°N, 99.707°E) and Gongshan (27.740°N, 98.665°E), registered at a Richter scale of 2.1 (http://news.xinhuanet.com/tech/2017-10/06/c_1121765328.html, in Chinese. Retrieved 2017 Dec 19). The CTBTO Kunming station and an infrasound array deployed in western Yunnan also de-

Table 1. Compilation of the visual and video accounts of the Shangri-La bolide. Some accounts are extracted from the post by WenJie Liu⁹

| Site                          | Coordinate           | Concurrent boom? | Delayed boom? | Shaking? | Source         | Note                                                                 |
|-------------------------------|----------------------|------------------|---------------|----------|----------------|----------------------------------------------------------------------|
| Balagezong National Park       | 28.285°N, 99.432°E   | √                | √             | √        | Media report   | “Passing overhead and heading E, red”                                |
| Baoshan City                  | 25.1°N, 99.2°E       |                  |               |          | Media report   | Multiple accounts                                                    |
| Benzilan (奔子栏)              | 28.24°N, 99.30°E     | √                | √             | √        | Witness report | “Sonic boom and shaking like a landslide is taking place”           |
| Dali City (大理)               | 25.6°N, 100.3°E      |                  |               |          | Media report   | Multiple accounts                                                    |
| Dali City (大理)               | 25.535°N, 100.330°E |                  |               |          | Dashcam        | G56 freeway facing NW                                                |
| Hongpo Village (红坡村)        | 27.81°N, 99.81°E     | √                | √             | √        | Media report   |                                                                      |
| Lijiang City (丽江)            | 25.964°N, 100.157°E |                  |               |          | Dashcam        | G5611 freeway facing NW                                              |
| Niding Village (尼丁村)        | 28.19°N, 99.24°E     | √                | √             | √        | Liu’s post     | House shaking, like a gas explosion                                 |
| Nixi Township (尼西县城)        | 28.1°N, 99.5°E       | √                | √             | √        | Media report   | “Pigs run out of barn”                                              |
| Nuijiang City (怒江)           | 25.8°N, 98.9°E       |                  |               |          | Media report   | Multiple accounts                                                    |
| Rawu, Tibet (然乌)             | 29.317°N, 96.990°E   |                  |               |          | Dashcam        | S201 highway facing E                                                |
| Shusong Village (书松村)        | 28.27°N, 99.19°E     | √                | √             | √        | Liu’s post     |                                                                      |
| Tangman Village (汤满村)        | 28.02°N, 99.49°E     | √                | √             | √        | Media report   |                                                                      |
| Xiaruo Township (霞若乡)        | 27.80°N, 99.30°E     | √                | √             | √        | Liu’s post     |                                                                      |
| Xingfu Village (幸福村)        | 28.14°N, 99.43°E     | √                | √             | √        | Liu’s post     |                                                                      |
| Shangri-La City (Zhongdian/中甸) | 27.8°N, 99.7°E     |                  |               |          | Witness report |                                                                      |

⁹http://bbs.tianya.cn/post-travel-821029-1.shtml, in Chinese. Retrieved 2017 Dec 19.

Figure 3. Footage of the dashboard camera provided by KaiXin Tan, who was then traveling on an eastbound vehicle on Highway S201 near Rawu, Tibet. The clock of the camera was not calibrated and the timings on the lower-right corner are likely inaccurate.
tected the event (Wei Su, private communication). Both datasets are not yet publicly available.

After the termination of ablation, meteorites decelerate to a speed of a few km·s⁻¹ and will typically spend a few minutes airborne before reaching the ground (Cephecha et al., 1998). Atmospheric sounding data obtained by the nearby Xichang Station in Sichuan, ~250 km to the east (Available from an archive maintained by the Department of Atmospheric Science at the University of Wyoming, http://weather.uwyo.edu/upperair/sounding.html, retrieved 2018 Jan. 4), revealed that the local atmosphere was dominated by westerly wind, largely parallel to the travel direction of the bolide. Therefore, we expect that any surviving meteorites would show little transverse motion. We estimate the possible strewn field to be ~100 km northeast of the bolide terminus near the Yunnan–Sichuan border (Figure 4). This is in line with independent calculation carried out by R. Matson (R. Matson, private communication).

![Figure 4. Estimated strewn field of the Shangri-La meteorites.](image)

We also attempted to use the Doppler weather radar data to look for micrometeorites in the atmosphere. However the predicted region is not covered by the Chinese weather radar network; the closest Doppler radar (at Lijiang) is about 200 km to the south with an effective observing range of 150 km.

It was reported that “several hundreds of” meteorite hunters had arrived on the scene to search for meteorites (http://news.sina.com.cn/o/2017-10-10/doc-ifymcmcm9945166.shtml, in Chinese. Retrieved 2018 Jan 3). Many chose to search northwest of Shangri-La City where most of the shock wave reports surfaced. Both this region and our estimated strewn field are very mountainous, but the latter is more so and is sparsely populated. At the time of this writing, the searches have ceased (http://news.sina.com.cn/s/wh/2017-10-22/doc-ifymyxyw4058501.shtml, in Chinese. Retrieved 2018 Jan 3) and there is no credible report of successful recovery of any Shangri-La meteorite.

Unlike the U.S. and Europe, China has yet to establish a dedicated government-level body that oversees research of near-Earth objects. Bolides that are energetic enough to be recorded by U.S. government sensors occur in China about once per year, the most recent being the 2014 Xilin Gol event and the 2015 Gansu event. The Xilin Gol event, which occurred in the early morning of 2014 Nov 5 over the Gobi desert ~300 km north of Beijing, was of similar magnitude to the Shangri-La event and attracted similarly wide public attention. It was believed that multi-kilogram meteorites from the Xilin Gol event had reached the ground. Efforts (mostly led by amateurs) were launched to recover these meteorites but no successful recovery has been reported so far.

Globally, meteorite-dropping events are quite frequent. Using the event rate derived by Halliday et al. (1984) we estimate that events with >1 kg meteorite fall occur over Chinese territory approximately once per week on average. Amateur astronomers in several parts of China have recently begun to build video camera networks, hoping to better determine the trajectories of future meteorite-dropping events. As of early 2018, camera networks in Beijing, Shandong, Guangdong, northern Xinjiang, and northwestern Tibet are operational (Ye, 2018).

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