Major fragmentation of Atlas 5 Centaur upper stage 2014-055B (SSN #40209)

Vladimir Agapov

IAA Space Debris Committee meeting

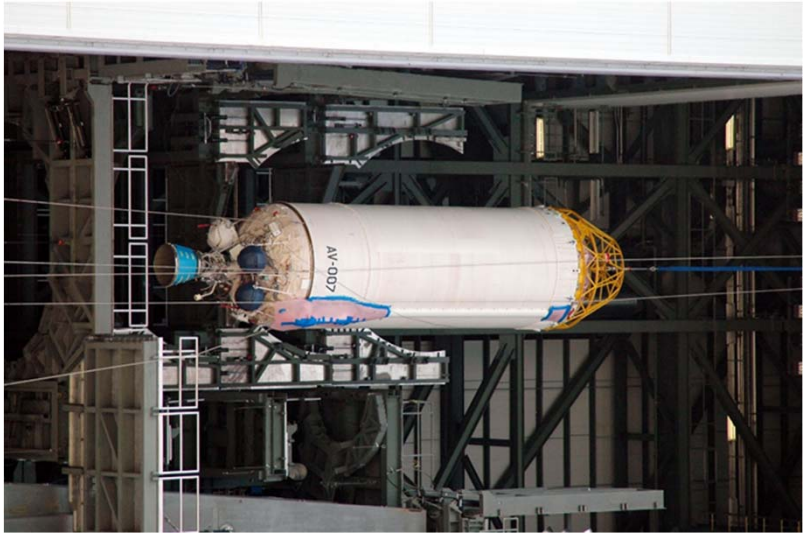
Bremen, 29 Sep 2018

Outline

- Atlas 5 Centaur overview
- 30 Aug 2018 anomaly in orbital motion of the Centaur (2014-055B)
- Detection of new debris and their association with the 2014-055B
- Characterization of detected debris associated with the fragmentation of the 2014-055B
- Conclusion

Atlas 5 Centaur 2014-055B

- Launch on Sep 17, 2014 0010 UTC to place CLIO (USA-257) satellite in GTO, the launch declared as successful
- Atlas V (AV-049) in configuration V401 was used
- No official orbital information for Centaur upper stage was provided to the date at SpaceTrack



Centaur with a single RL-10A-4-2 engine
Length 12.68 m
Diameter 3.05 m
Dry mass 2243 kg

2014-055B routine observations

- Performed by telescopes of ASPOS OKP, Astronomical Scientific Center and ISON on a regular basis (nearly every night) in a follow-up mode
- Last observation prior to the detection of an anomaly in orbital motion – Aug 30 at 2020 UT
- OD fit span which included the last observation was equal to 59.8 days, 950 measured positions from 31 telescopes were used for the OD
- Orbital parameters derived from the OD (J2000 frame, WGS84 ellipsoid):
  nodal period – 779.91 min
  inclination – 22.24°
  RAAN – 47.836°
  argument of perigee – 54.637°
  apogee – 35180.7 km
  perigee – 8202.7 km

2014-055B orbital motion anomaly detection

- First observation that lead to the detection an anomaly in orbital motion – Aug 30 at 2346 UT (i.e. 3 hours 26 min after the prior observation)

- Large residuals of new measurements with respect to the propagated orbit from the last OD revealed:
  -392 arcsec along track (equivalent to -14.2 sec of time) – compare to expected 0.3 arcsec calculated from the last OD covariance
  -221 arcsec cross-track

- Additional observations were used to determine new orbit and estimate time when anomaly in the orbital motion have occurred

2014-055B orbital motion anomaly assessment

- Following estimations obtained for the equivalent impulse:

  Time: Aug 30, 2018 at 22:03:49 UT

  Place: latitude 8.504 E, longitude 22.189 S, altitude 29017 km

  dV: 9.3 m/s with components dVr +5.7 m/s, dVt -6.1 m/s, dVz -4.0 m/s

- Following estimations obtained for orbital parameters changes:
  Semimajor axis: -89.93 km
  Inclination: -0.0002° (due to argument of latitude was equal 270.3 deg!)
  RAAN: +0.231°
  Argument of perigee: +0.174°
  Apogee radius: -100.8 km
  Perigee radius: -71.9 km

Search for possible fragments of 2014-055B

- Numerous bright (of 15th magnitude or brighter) fragments were detected on tracks similar to the 2014-055B during the routine observations of Centaur at 2346 UTC on Aug 30, 2018
- Dedicated search scenario was developed immediately
- Two dozens of new debris-like objects were detected on the pass at 0118-0121 UTC on Aug 31
- Starting Aug 31 dedicated surveys were performed by different sensors

Detected debris of fragmentation of 2014-055B

- As of Sep 25, 2018 there were 440 fragments with well established orbits in the ASPOS OKP database
- 51 additional fragments in the ‘analyst’ category requires additional observations to be collected in order to declare their orbits as well established
- All determined trajectories propagated back to the estimated event time interval
- If to define GTO as a class of orbits having T≥300 min, ecc ≥ 0.25 and incl≤35° then 491 detected fragments of 2014-055B will correspond to 25% instantaneous increase of population of objects tracked at GTO !

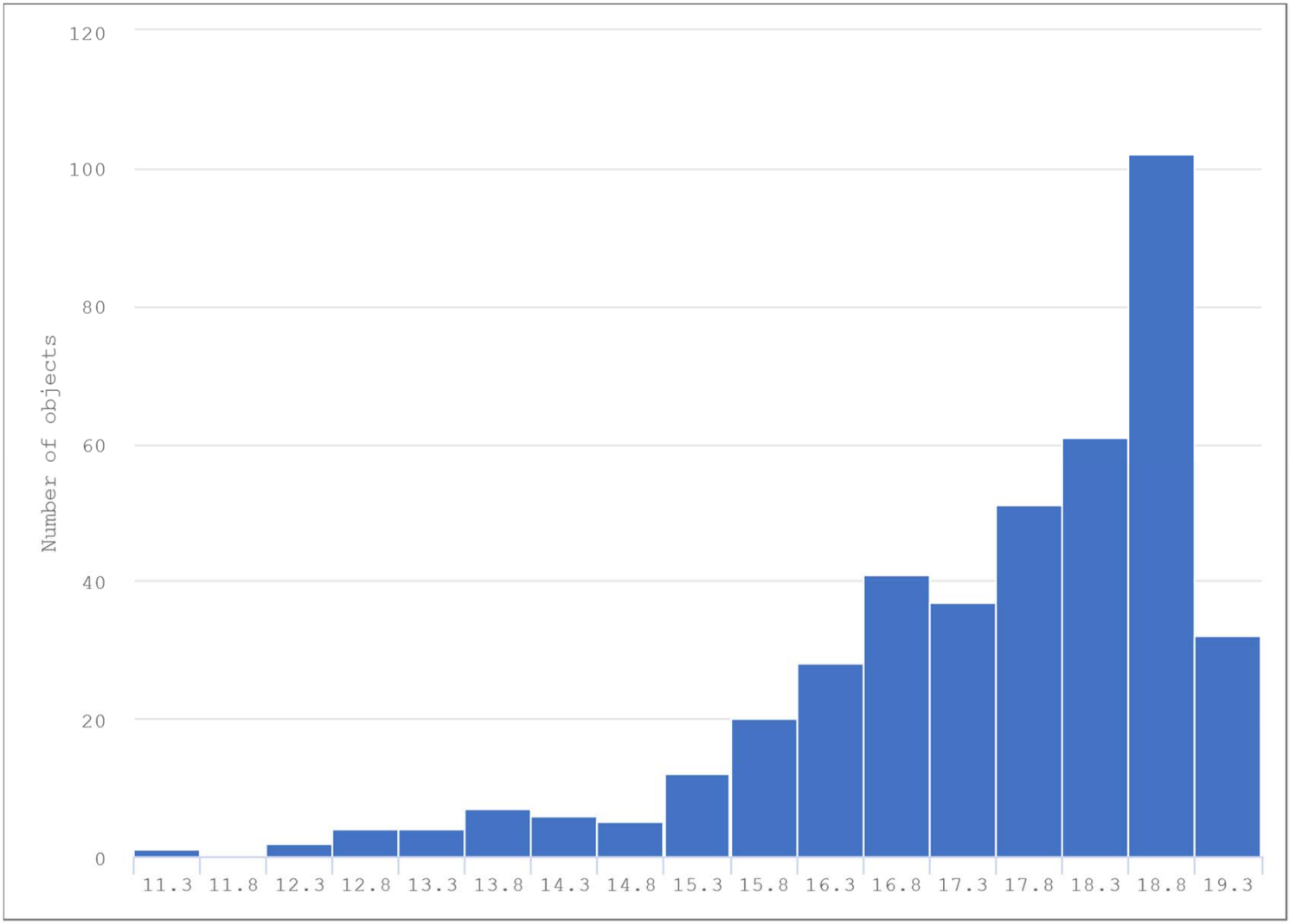
Characterization of the 2014-055B fragments

- 262 of 491 the identified fragmentation debris have average area-to-mass ratio less or equal to 1 sq.m/kg, all others – more than 1 sq.m/kg (largest value is 69 sq.m/kg)

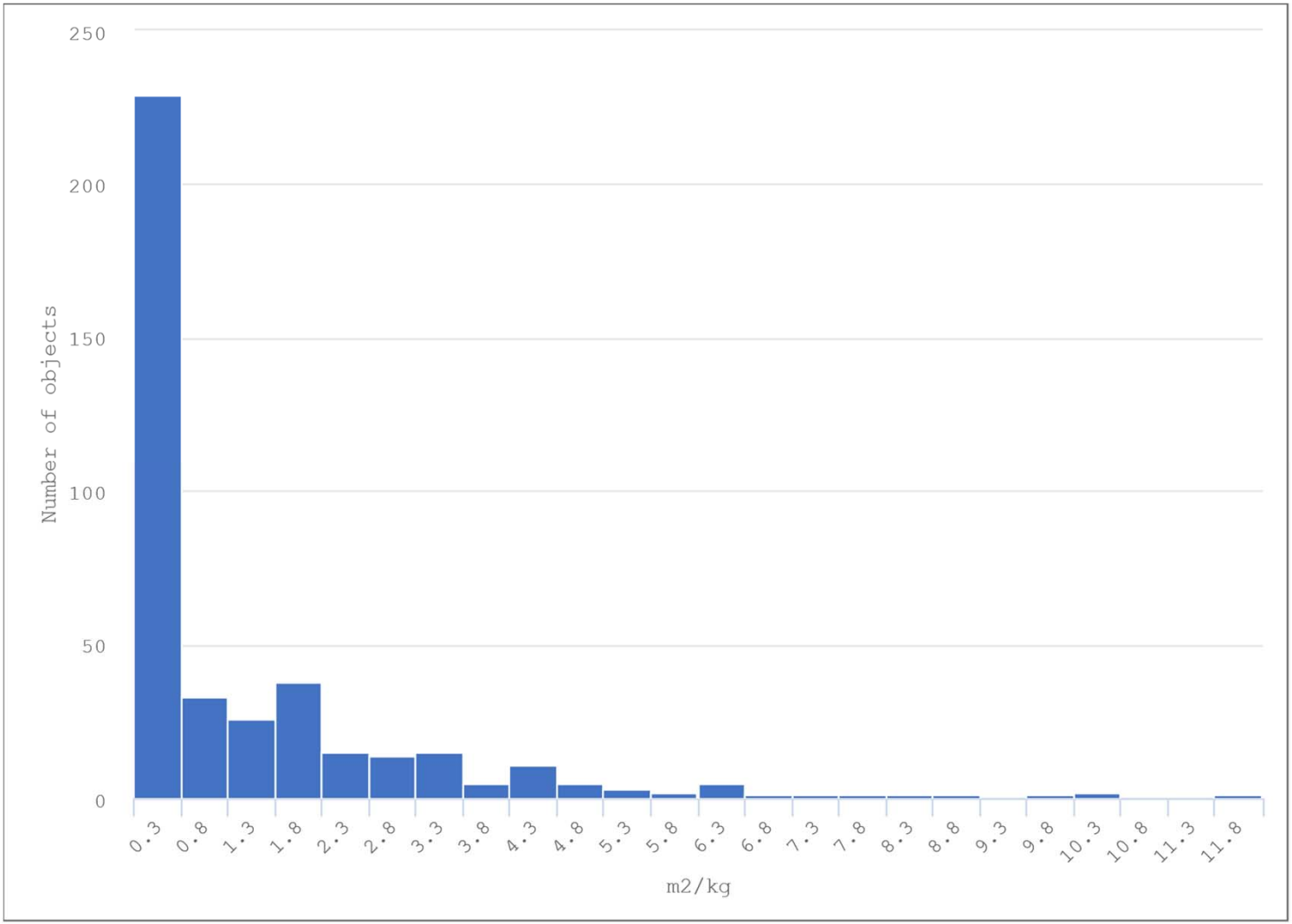
- Standard magnitude (observed visual magnitude adjusted to 40000 km range and 0 deg phase angle for the diffuse sphere model) is dispersed between 12.3 and 19.3

- Surprisingly there are many quite large objects – 36 with average reflecting surface area more than 1 sq.m and 135 with estimated mass of more 1 kg (diffuse sphere model and albedo 0.15 assumed)

Standard magnitude distribution for identified fragments of the 2014-055B



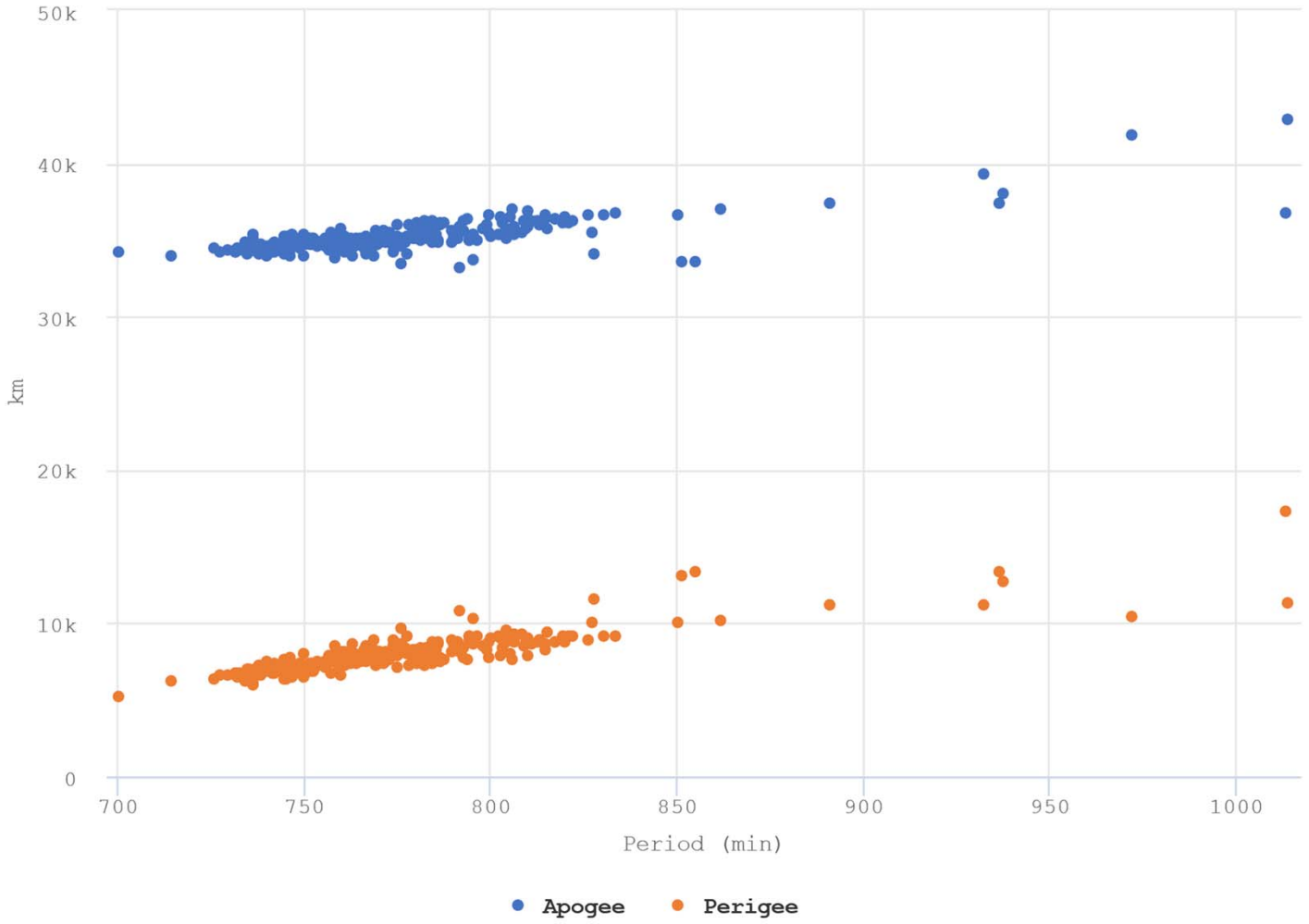
Area-to-mass distribution for identified fragments of 2014-055B



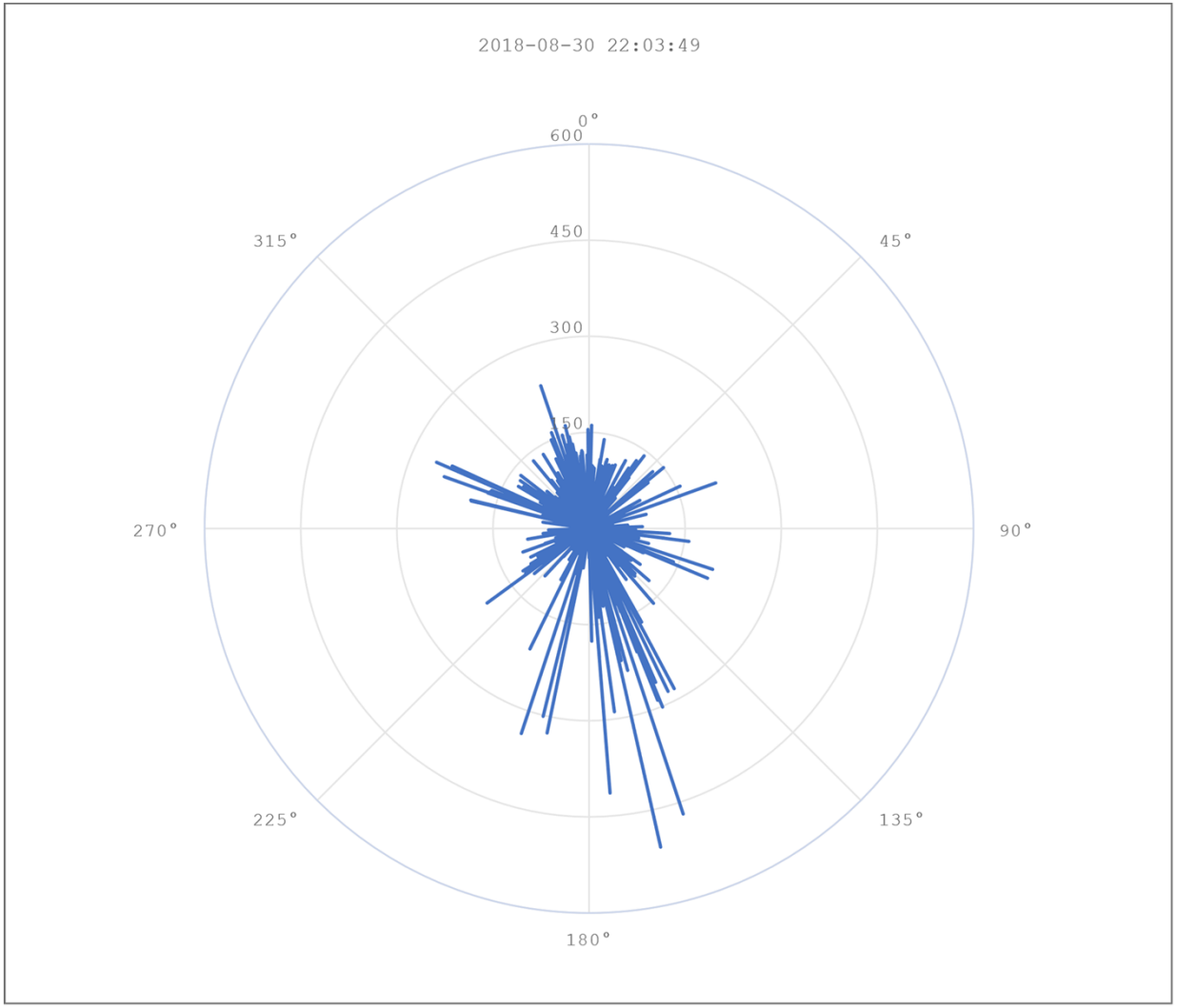
Characterization of the 2014-055B fragments

- Orbital period of the identified debris dispersed between 700 and 1047 min
- Inclination at the moment of fragmentation was dispersed between 22.23 and 22.37 deg (due to argument of latitude at the moment of fragmentation was equal to 270.3°!)
- RAAN at the moment of fragmentation was dispersed between 37 and 62 deg

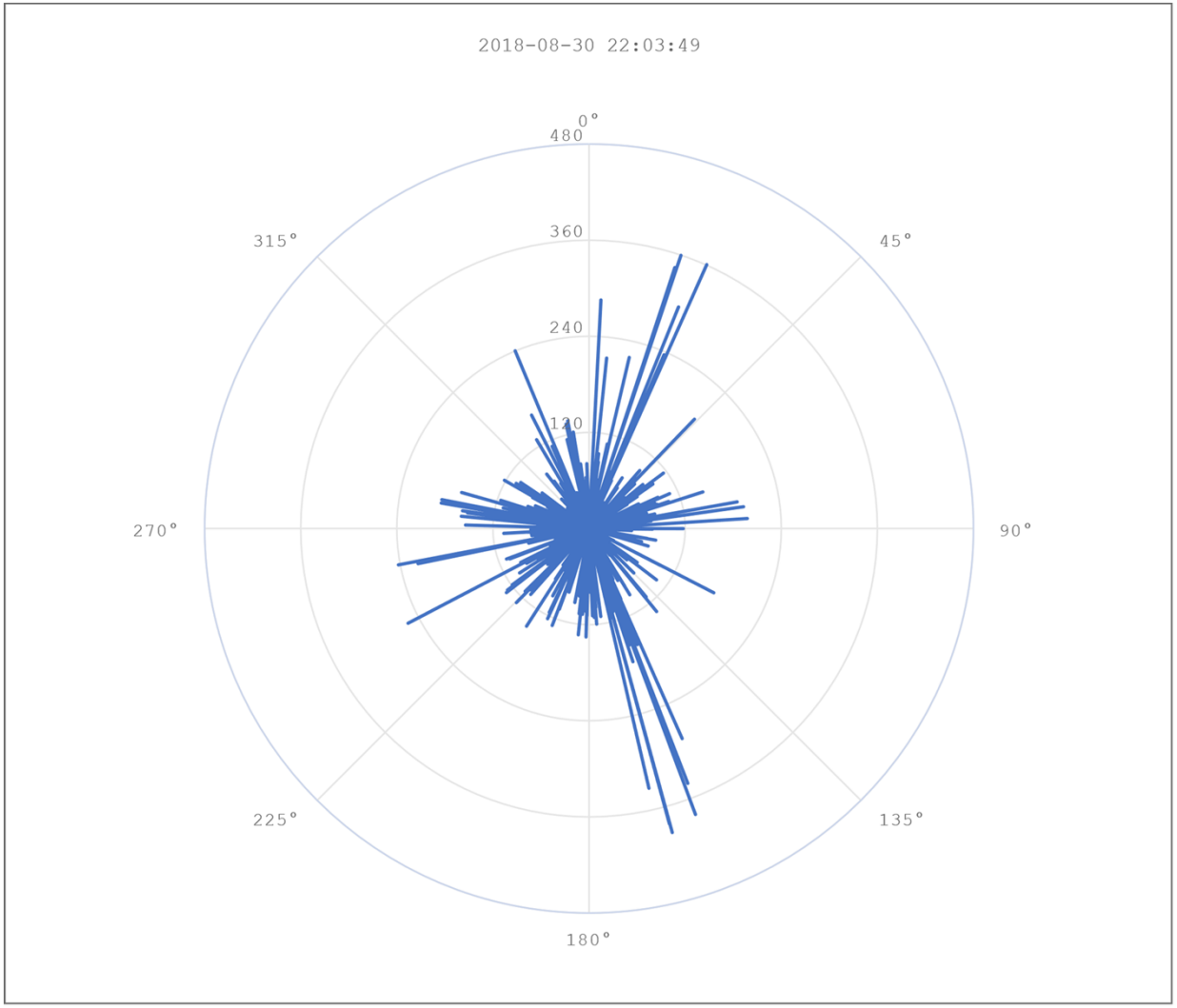
Gabbard diagram based on orbits propagated at 22:03:49 UT on Aug 30, 2018



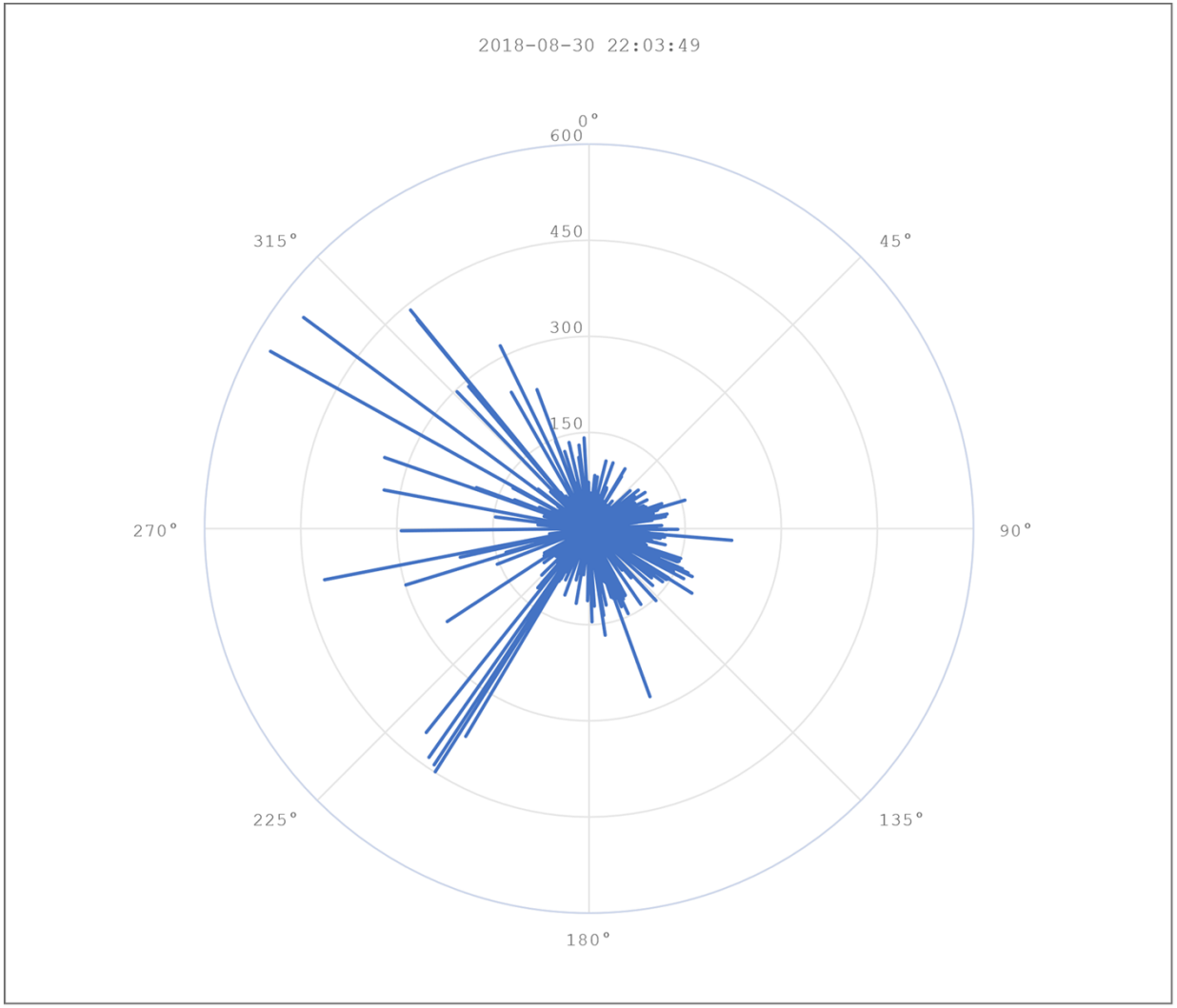
dV distribution (in-track – cross-track)



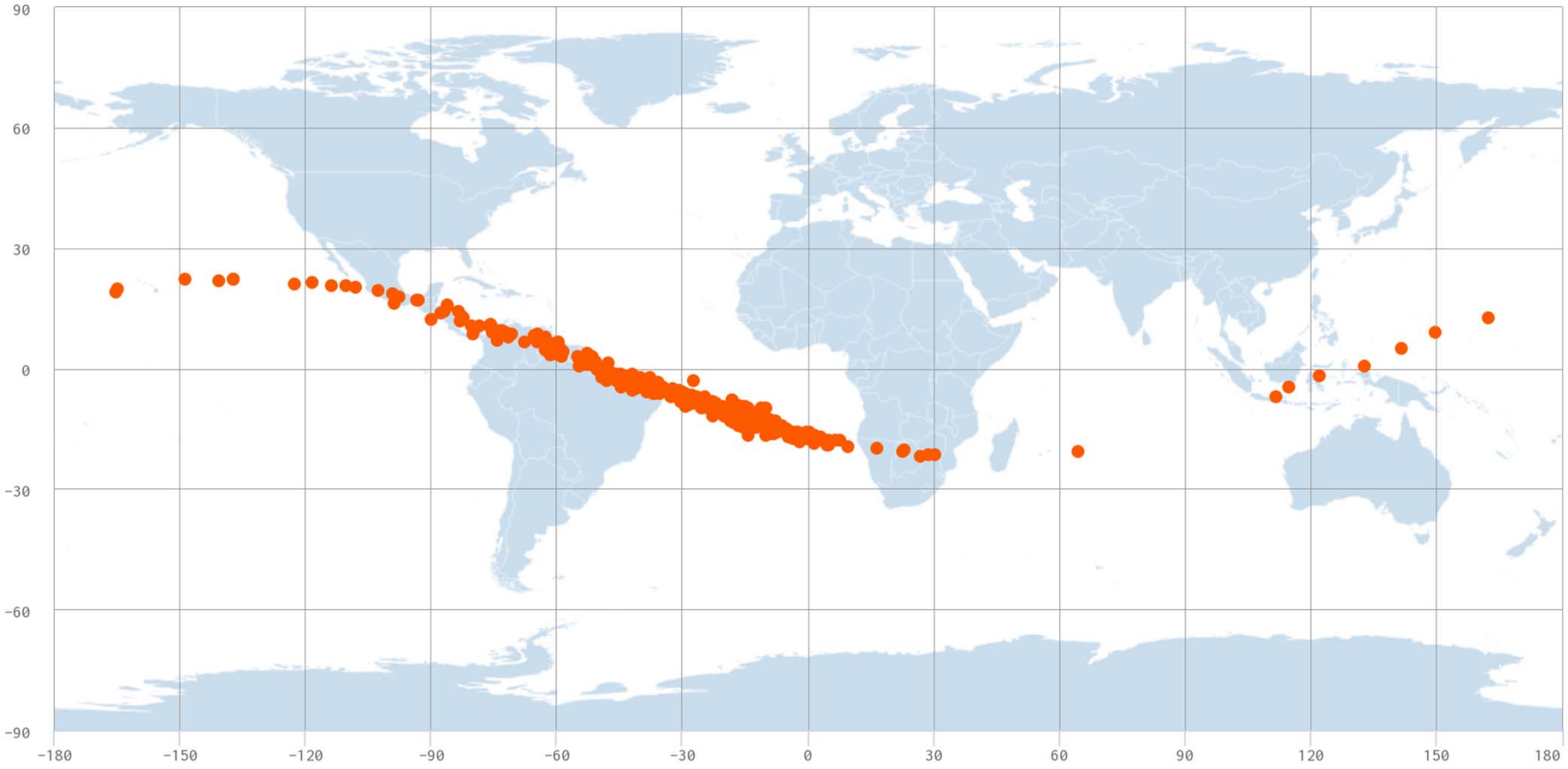
dV distribution (radial – cross-track)



dV distribution (radial – in-track)



Evolution of the fragmentation cloud (projected for 48 hours with the 0.1 days step)



Conclusion

- Centaur 2014-055B in GTO have experienced major fragmentation on Aug 30, 2018
- This is the first known fragmentation of the Atlas V Centaur upper stages
- 491 fragmentation debris were detected and tracked -> 25% increase of population of tracked objects in GTO!
- Majority of discovered debris are quite faint and pretty fast simultaneously therefore larger aperture telescopes (preferably 0.5-0.7 m and more) are required for their regular observation and detection/follow-up of new objects associated with this event
- Identified debris of the fragmentation dispersed in HEO orbits with perigees altitudes in range 5270-17850 km and apogee heights in range 32825-43240 km thus crossing operational altitudes of all GNSS (will start crossing GEO operational altitude within 2 years)
- The event requires more detailed study (space debris models reviewing, associated collision risks assessment etc.) -> topic for special attention of the IADC?

Thank you for your attention!