Collaborative observations to search 1968-081E fragments

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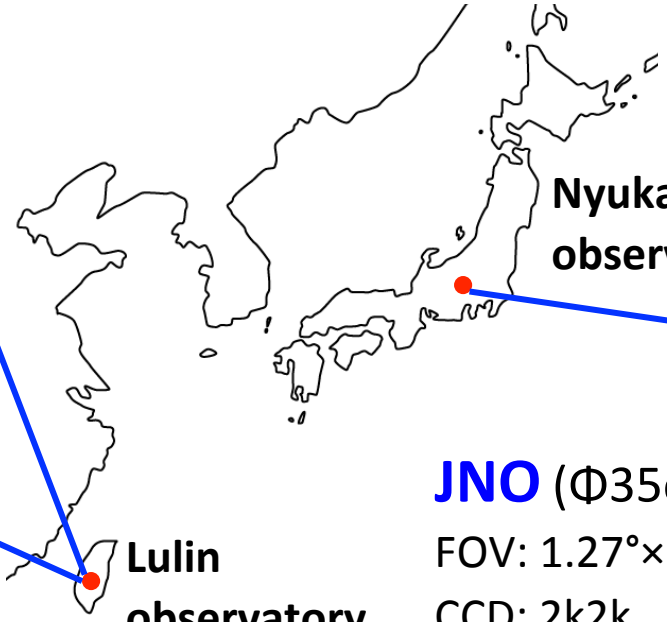
Overview of the collaborative observations

LOT (Φ1m)
FOV: 26.4'×13.2'
CCD: 4k2k

TAOS (Φ50cm)
FOV: 1.74°×1.78°
CCD: 2k2k

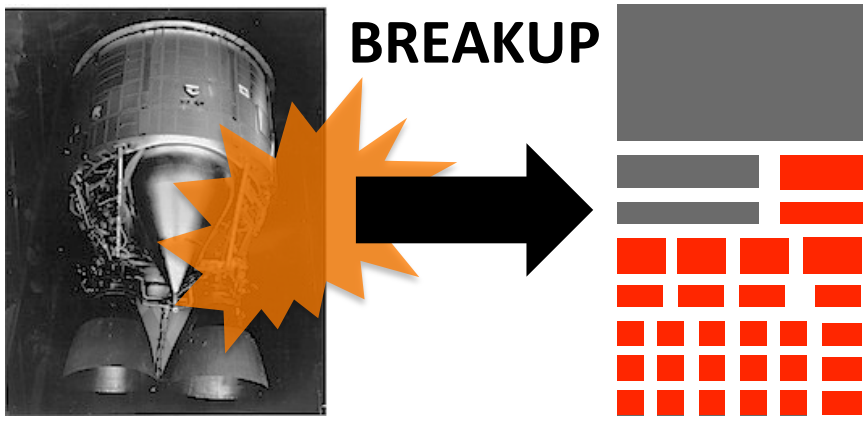


JNO (Φ35cm)
FOV: 1.27°×1.27°
CCD: 2k2k

Search target	1968-081E (Titan IIIC Transtage) fragments
Observation period	20 – 22 Oct. 2011 (3 nights)
Observation mode	Survey (6 hours / night)

40 uncataloged objects are detected to be identified with the 1968-081E fragments

Breakup fragments



Transtage (ref. U.S. Air Force website)

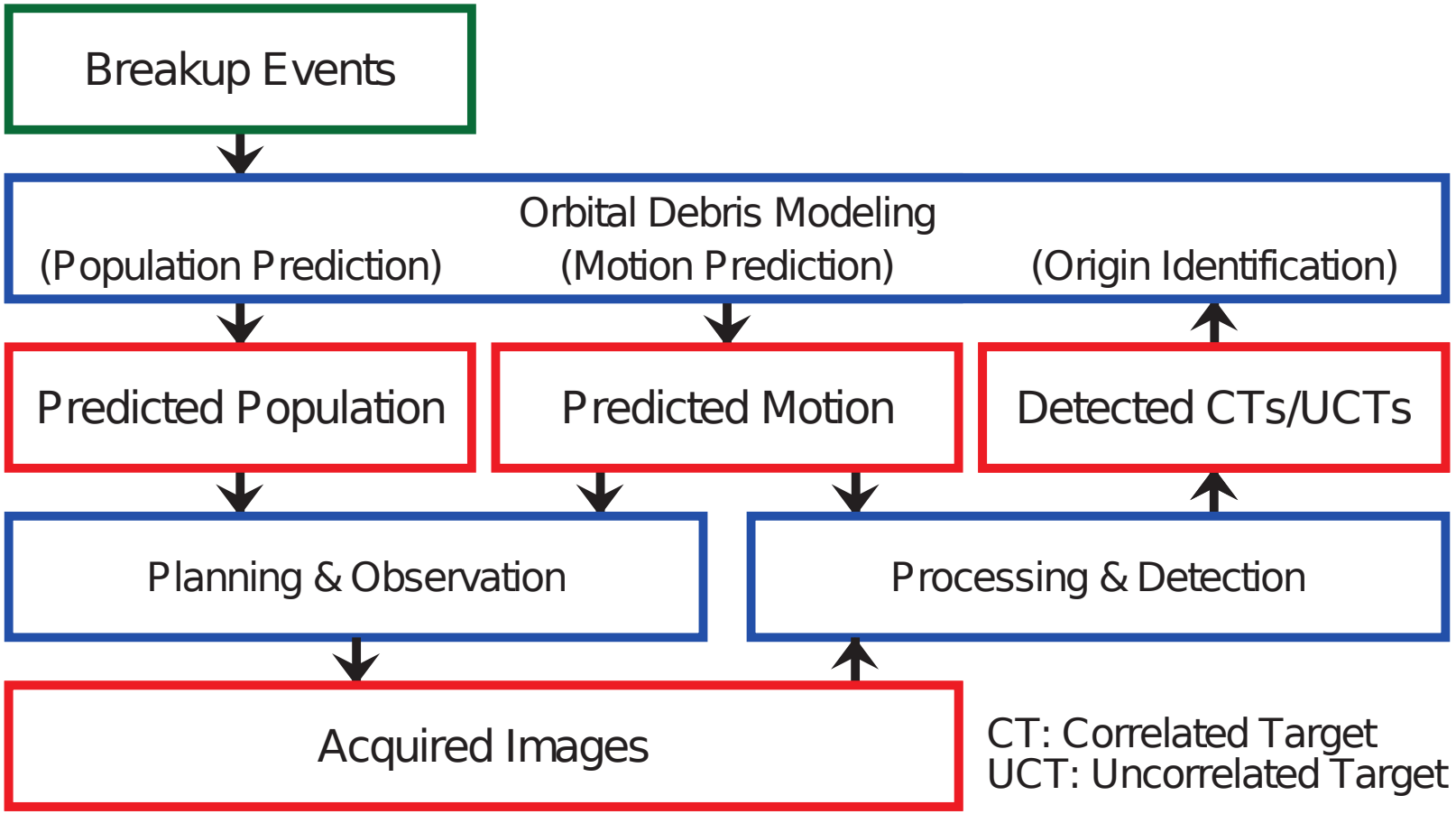
Properties of breakup fragments

Small size (**<1m**) = **Faint objects**

Large part **remains lost** = **Uncertainties in states**

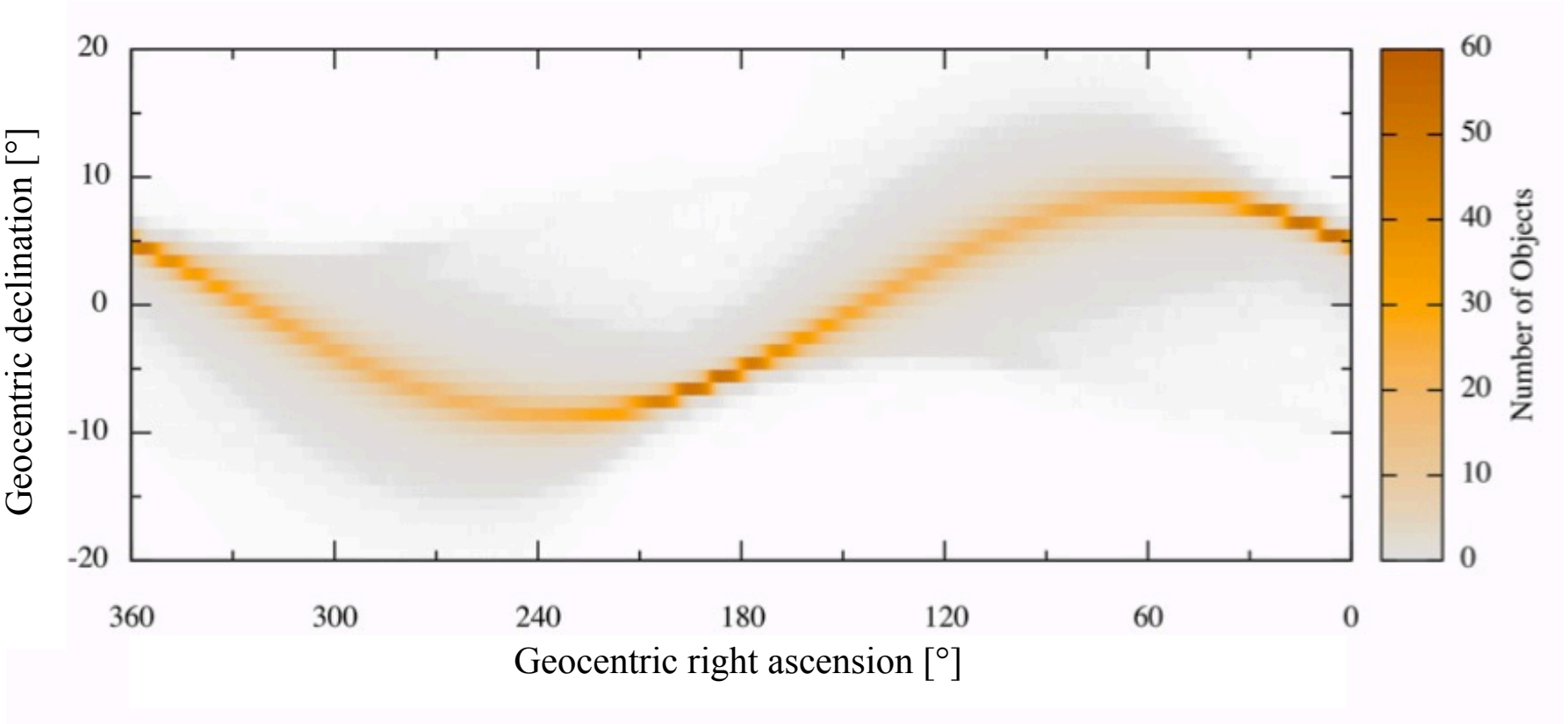
Necessity of predictive analyses

The search strategy



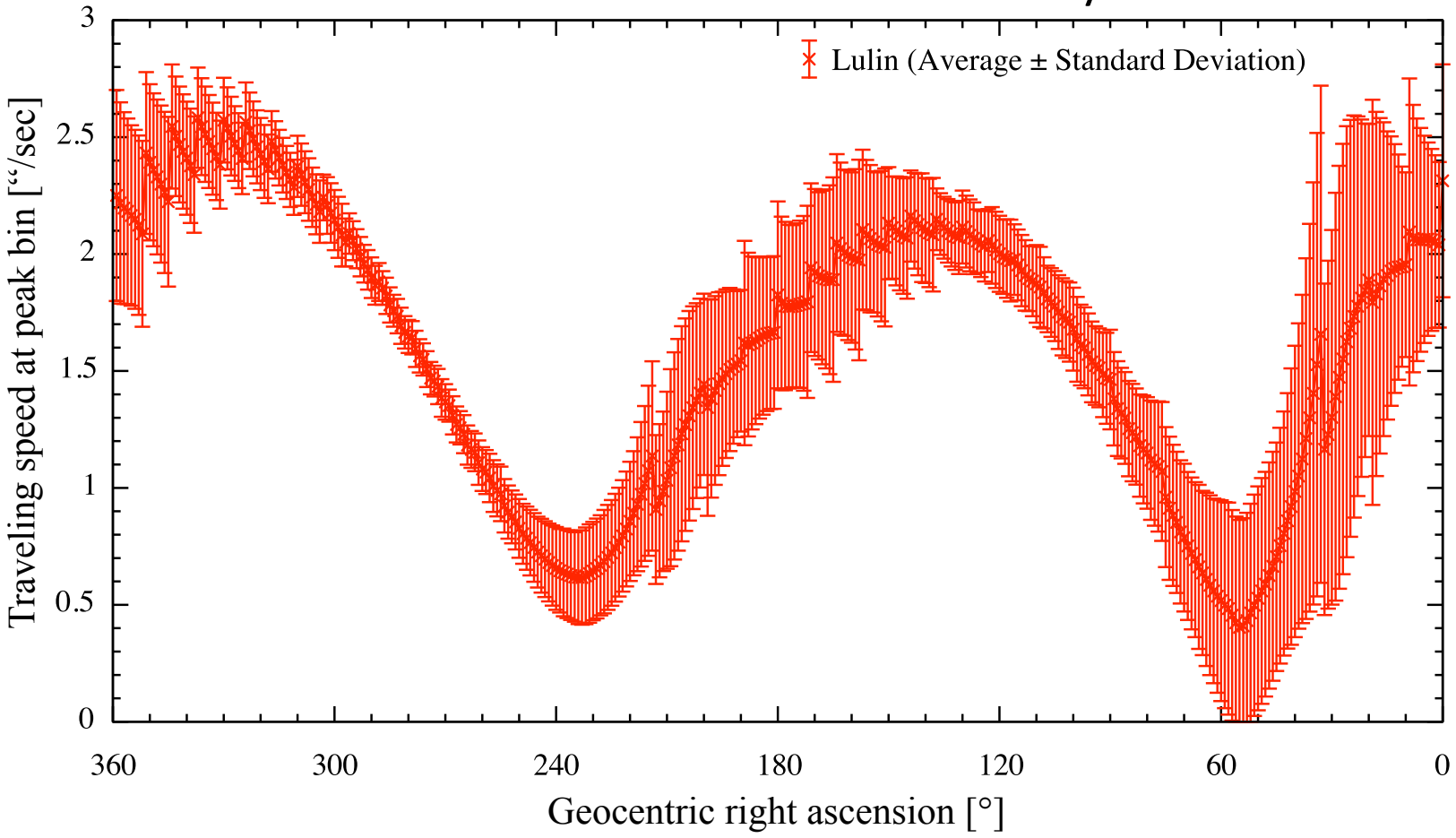
Observation planning (1)

Predicted population of 1968-081E fragments
as 6 hours time-integrated distribution (Bin size = 1°×1°)

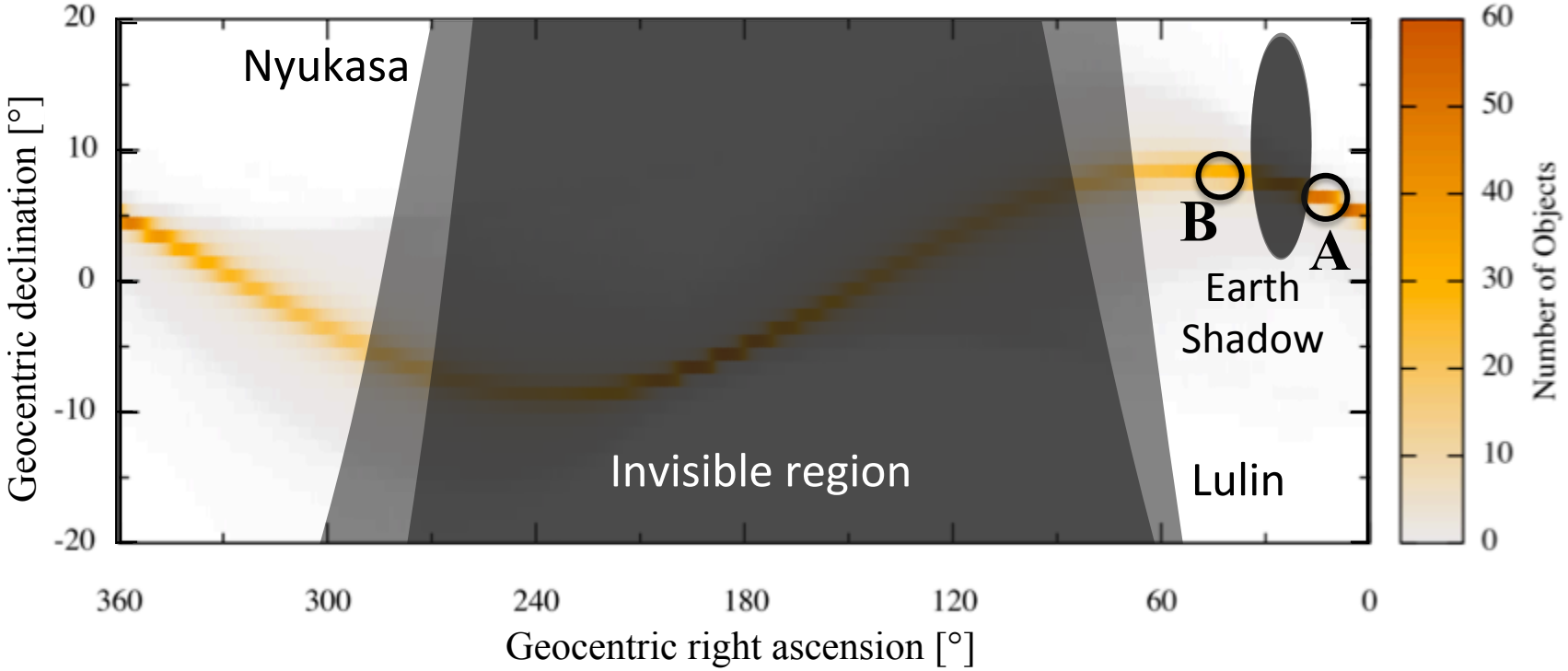


Observation planning (2)

Traveling speed of 1968-081E fragments in the peak population bins seen from the Lulin Observatory



Observation planning (3)



Sensor Name	Population (6 hrs.) [#]		Traveling speed [“/sec]	
	A	B	A	B
TAOS	56.47 ± 1.09	39.95 ± 1.80	2.01 ± 0.55	0.87 ± 0.61
LOT	27.56 ± 2.04	14.82 ± 1.77	1.96 ± 0.43	0.74 ± 0.42
JNO	53.16 ± 1.32	33.21 ± 2.01	1.94 ± 0.49	0.80 ± 0.53

Origin identification (1)

- Demonstrating the origin identification by estimating the orbits as circular ones

Separation angle (φ) between 2 observed points (α_1, δ_1) and (α_2, δ_2)

$$\varphi = \cos^{-1}\left\{\sin\delta_1 \sin\delta_2 + \cos\delta_1 \cos\delta_2 \cos\left(\alpha_2 - \alpha_1\right)\right\}$$

Mean motion (n) is approximated from φ and observation interval (Δt) between the 2 observations

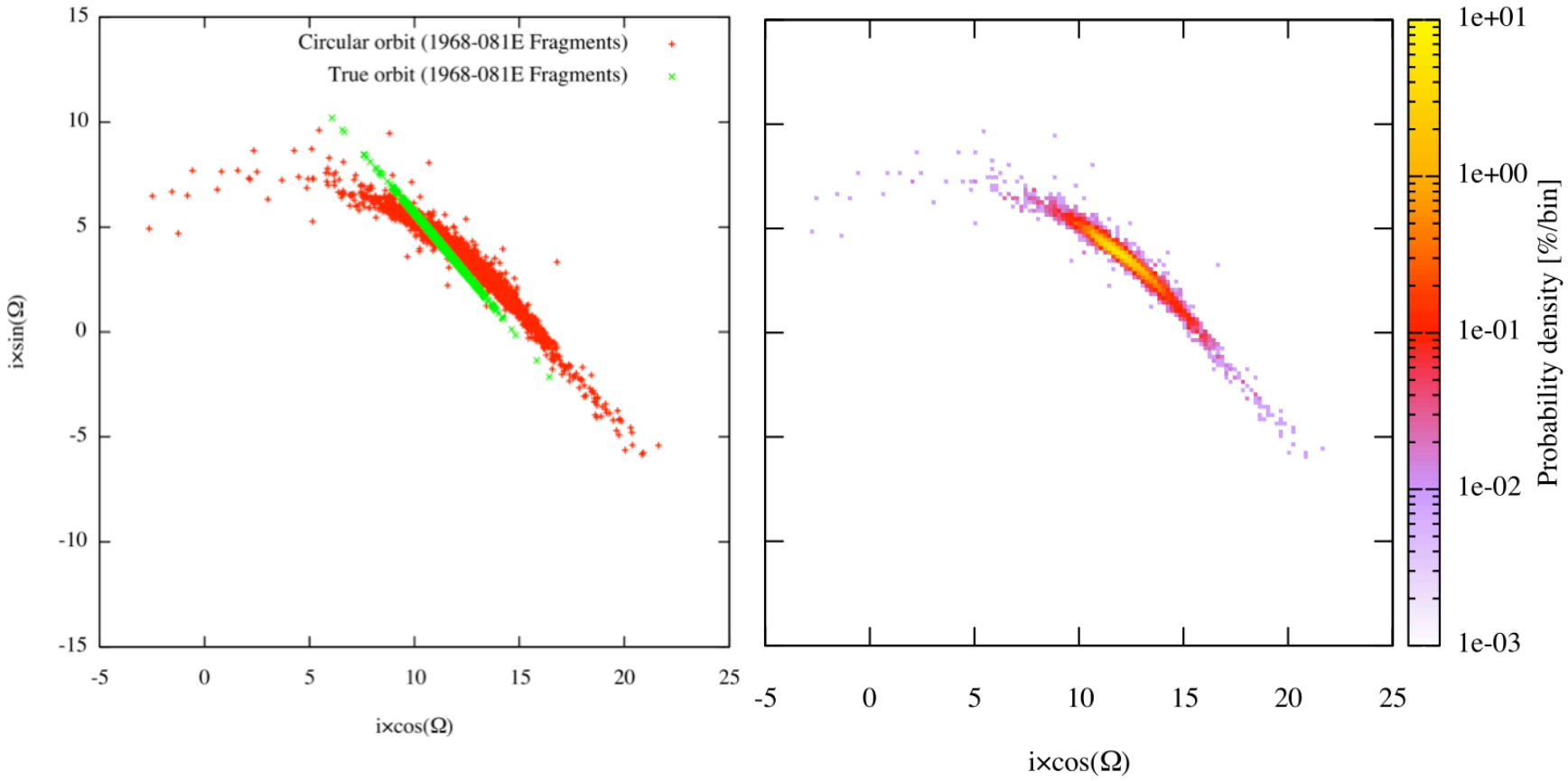
$$n \cong \frac{\varphi}{\Delta t}$$

Semi-major axis (a), inclination (i), and right ascension of ascending node (Ω) can be recovered from φ and n

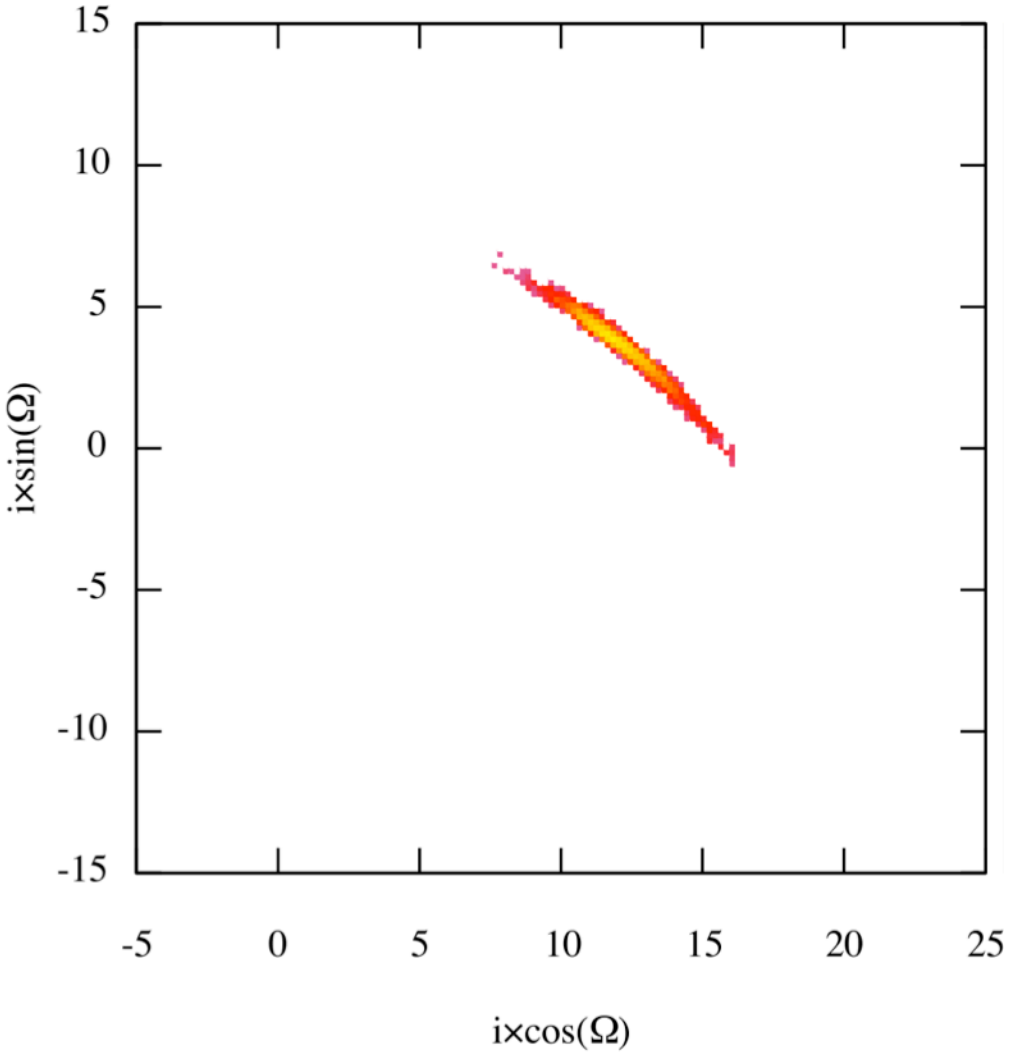
Correlations in the $i\cos(\Omega)$-$i\sin(\Omega)$ plane (Hanada et al., 2005)

Origin identification (2)

- 1968-081E fragments (generated by the breakup model) in the *i*cos(*Ω*)–*i*sin(*Ω*) plane at the breakup epoch

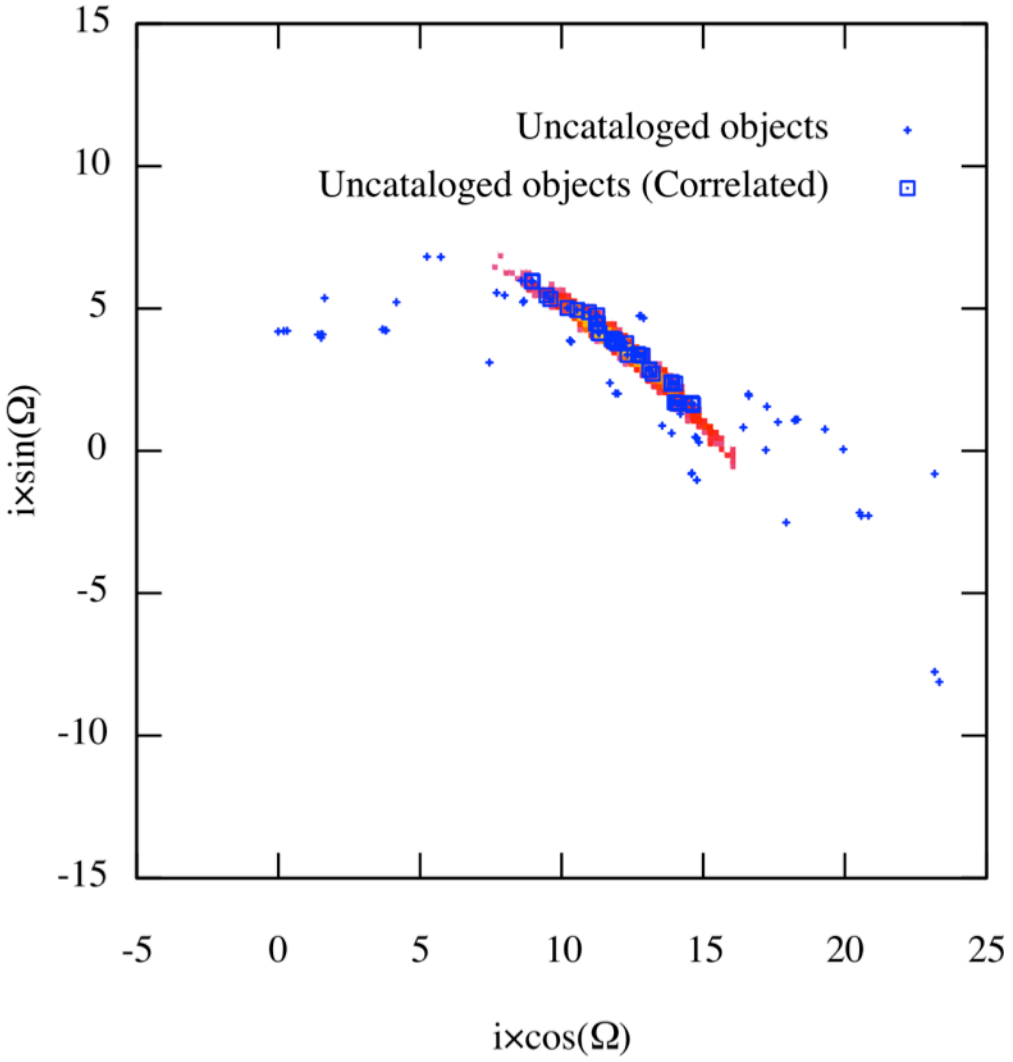


Origin identification (3)



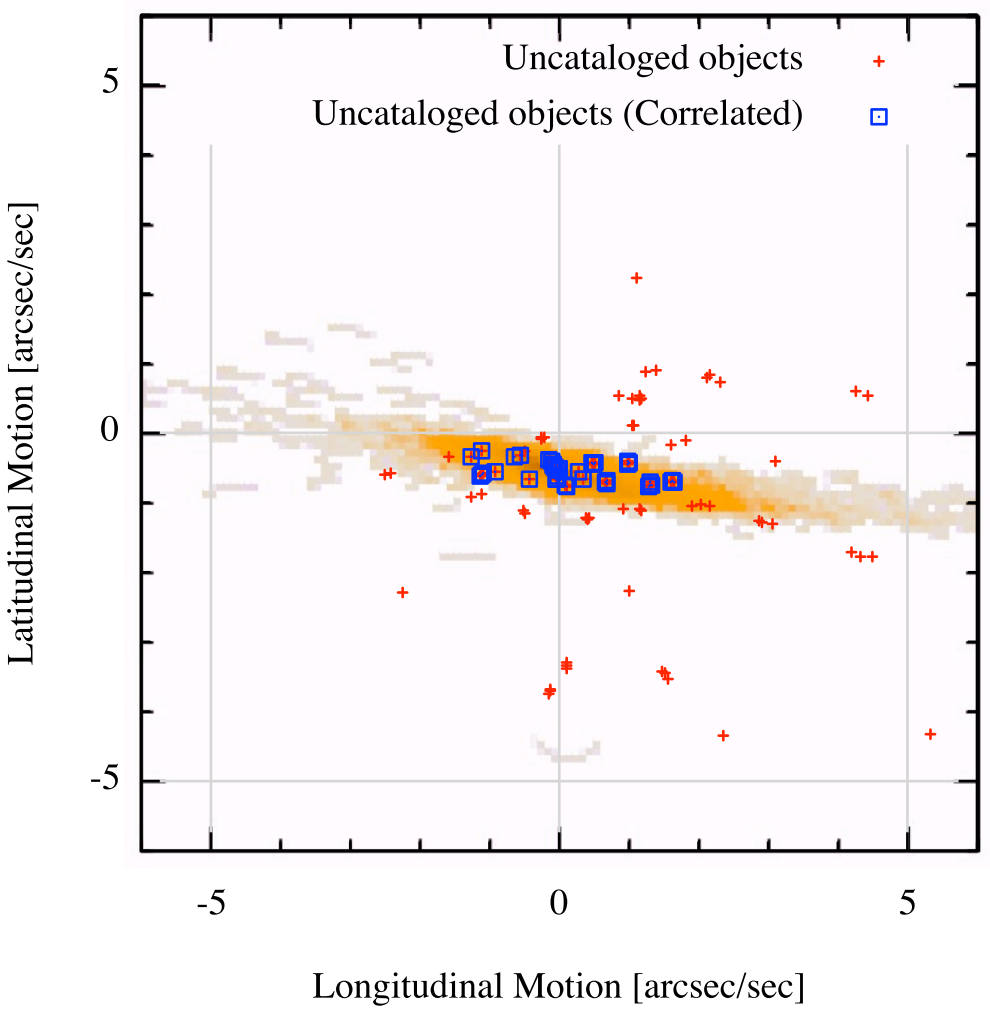
Probability distribution of 1968-081E fragments, applied a threshold

Origin identification (3)



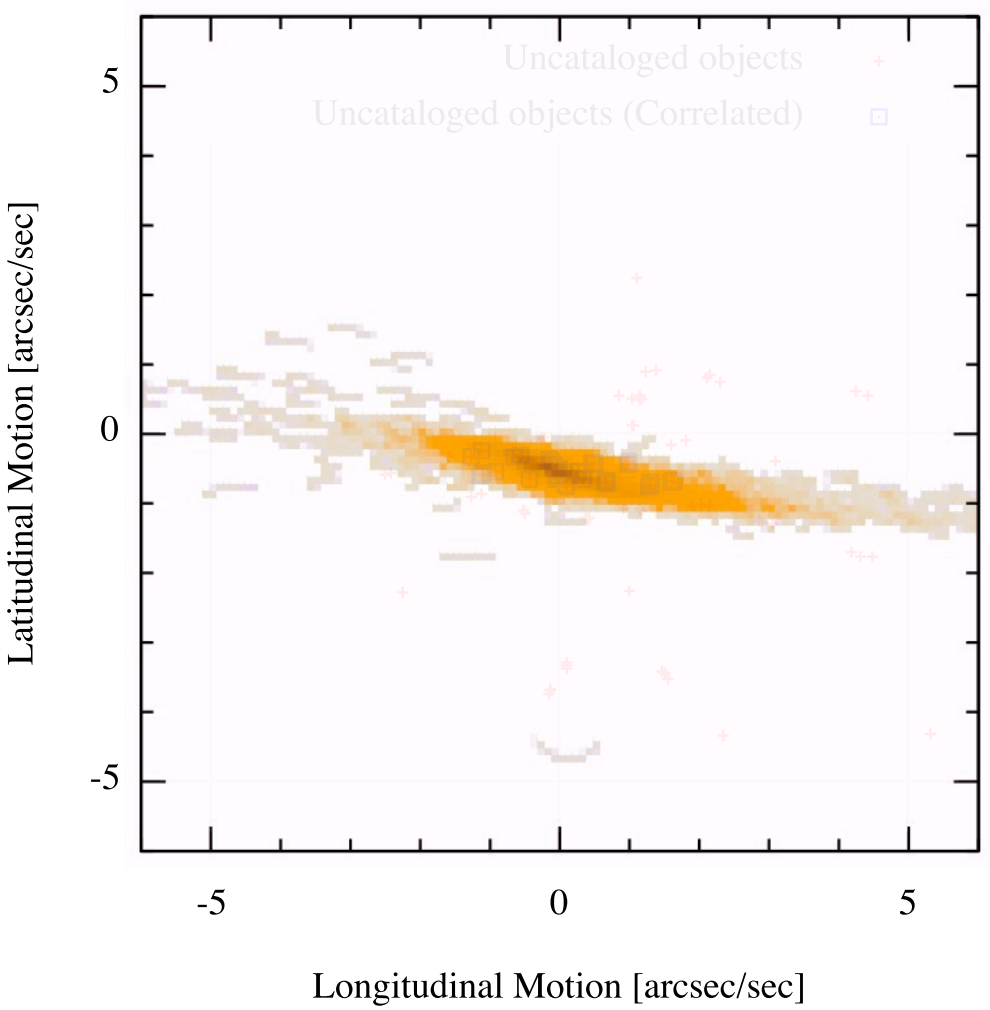
40 UCTs are correlated with the 1968-081E fragments in total

Validation of observation planning



- Traveling speed of correlated objects
  - 0.94 ± 0.41 “/sec
- Prediction results
  - 0.87 ± 0.61 “/sec
- Qualitative features of measured motions and predicted ones are in good correspondence

Validation of observation planning



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Conclusions

- Collaborative observations with the search strategy successfully demonstrated the detections of 1968-081E fragments
  - Observation planning with a consideration of traveling speed of the fragments in a sensor's FOV
  - Origin identification of UCTs by the circular obit estimation
- 40 objects were correlated with 1968-081E fragments, which will be evaluated to characterize the breakup event… stay tuned!

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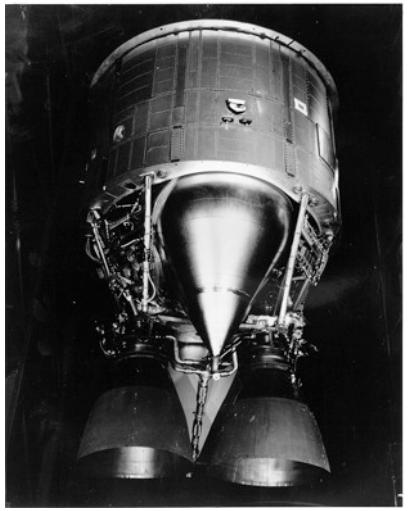
BACKUP SLIDES

Historical breakup events in GEO

- Ekran II (1977-092A)
  - Breakup epoch: 1978.6.23
  - Explosion breakup (battery malfunction)
  - 4 cataloged fragments
- **Titan IIIC Transtage (1968-081E)**
  - Breakup epoch: 1992.2.21
  - Explosion breakup (remnant fuel)
  - **23** fragments have been observed in near breakup epoch (*Pensa, et al., 1996*)
  - **8** cataloged fragments
- And ≥ **9** suspected (unconfirmed) events



Transtage (ref. U.S. Air Force website)

Research objective

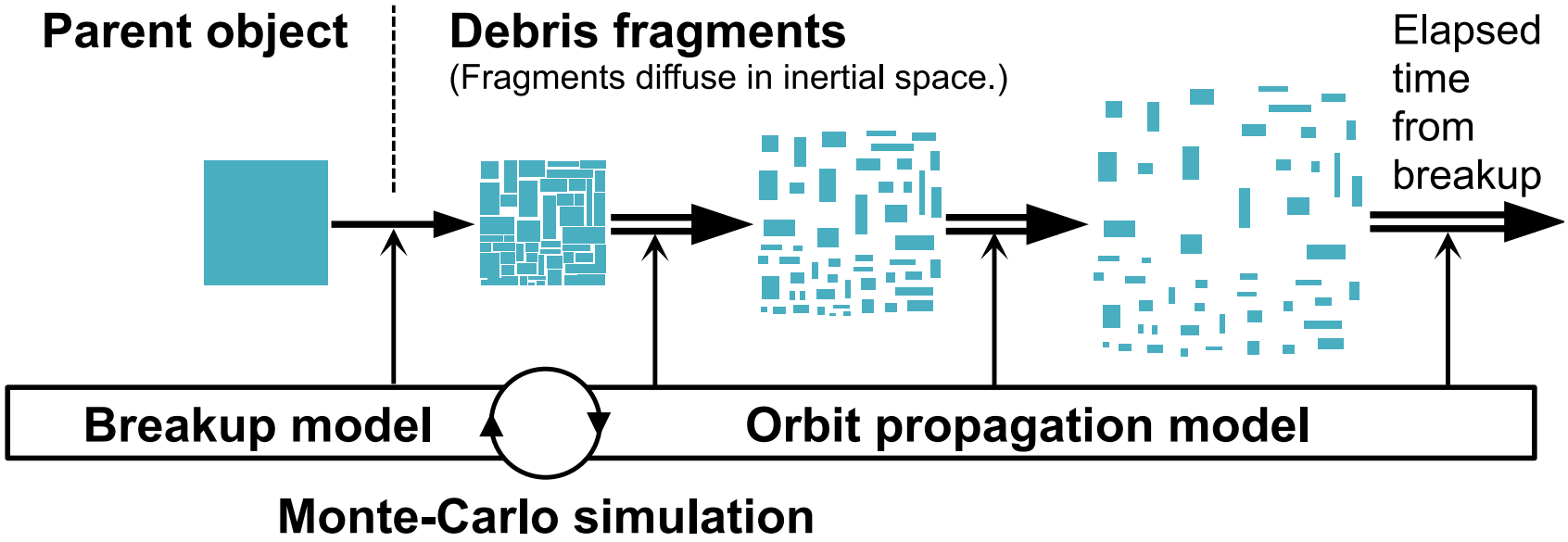
Final goal aims to contribute to **Space Situational Awareness**

1. Investigation of orbital debris generation process
   - **Model** predictions vs. **Observation** results
2. Evaluation of orbital debris environment
   - Better definition of the current situation **for secure space activities**

This study;

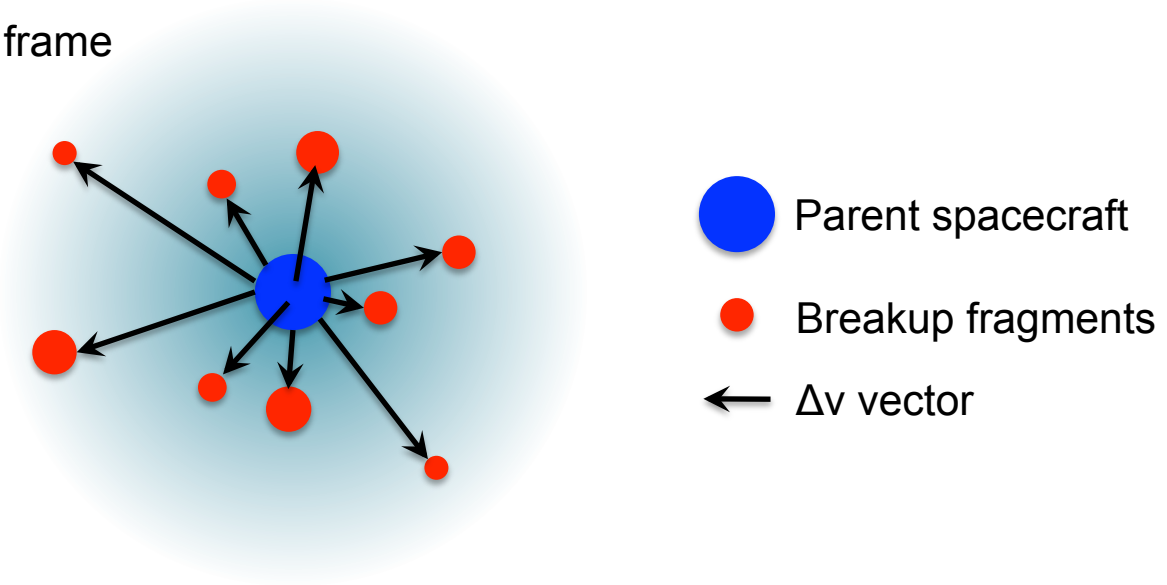
- Establishment of **effective search strategy** applicable for **breakup fragments** **in the geostationary region** by means of optical observations

Modeling of breakup fragments

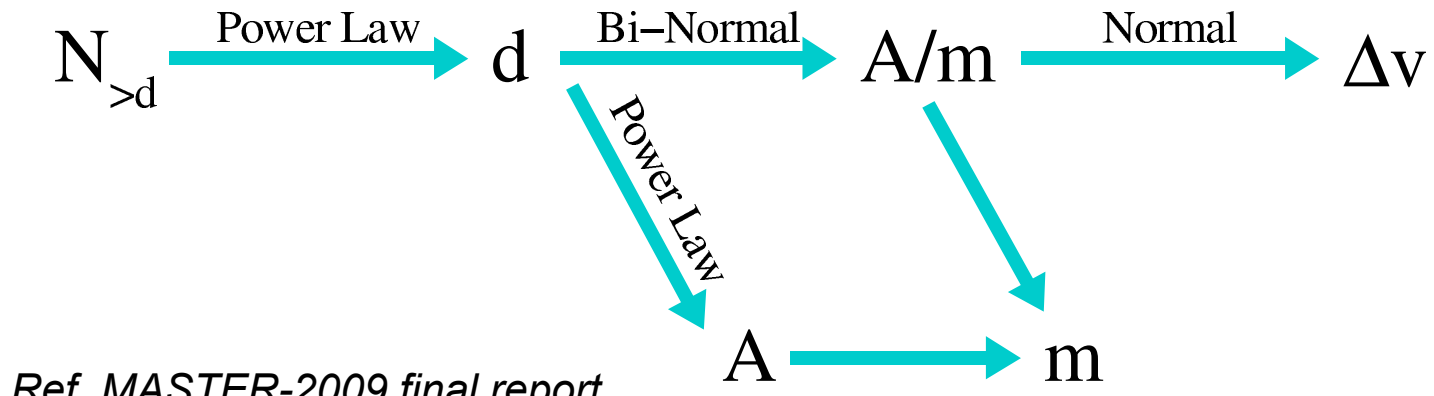


Breakup model

Parent spacecraft fixed frame



The NASA standard breakup model



Ref. MASTER-2009 final report

The search strategy (previous)