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On-board Downlink Prioritization Balancing Science Utility and Data Diversity

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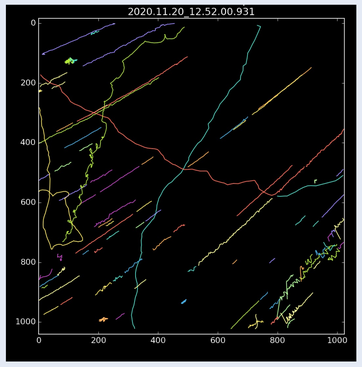
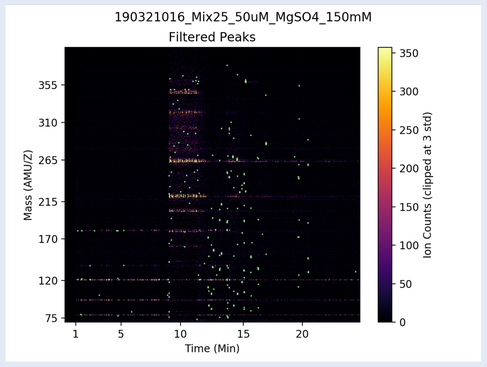
We demonstrate the benefits of a downlink prioritization system that uses content-based utility and diversity estimates.

OWLS: Ocean Worlds Life Surveyor

- Searches for life in water samples at the cellular and molecular levels using **holographic microscopy** and **mass spectrometry**
- Designed for missions to ocean worlds like **Europa** or **Enceladus**, and terrestrial applications as a field instrument
- **HELM** and **ACME** are autonomous science algorithms to detect and classify particle tracks and mass spectrum peaks to reduce **downlink data volume** by orders of magnitude and estimate **science utility** for downlink prioritization



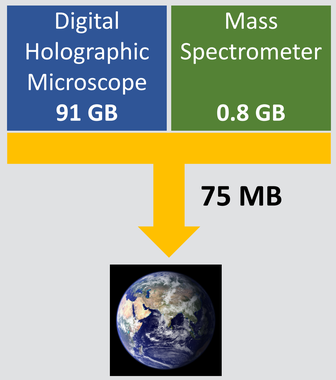
HELM detects particle tracks in holographic microscope videos



ACME detects peaks in mass spectrometer observations

Data Volume Limitations

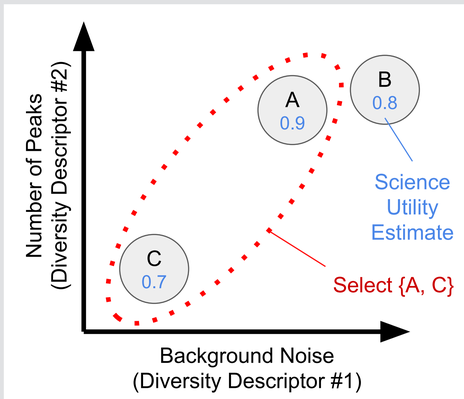
- Transmitting data from the outer solar system is energy intensive, which **limits downlink volume** [1]
- Evidence of life might be **rare** within collected data, and downlinking all samples is infeasible [2]
- **Solution:** Missions can analyze data onboard the spacecraft to determine **science utility** and downlink accordingly, while ensuring sample **diversity**



JEWEL

(Joint Examination for Water-based Extant Life)

- Incorporates both a "science utility estimate" and a "diversity descriptor" to select products
- Using the "**maximum marginal relevance**" algorithm [3], iteratively select the data product with highest utility, discounted by the Gaussian similarity of each candidate with the most similar product already selected

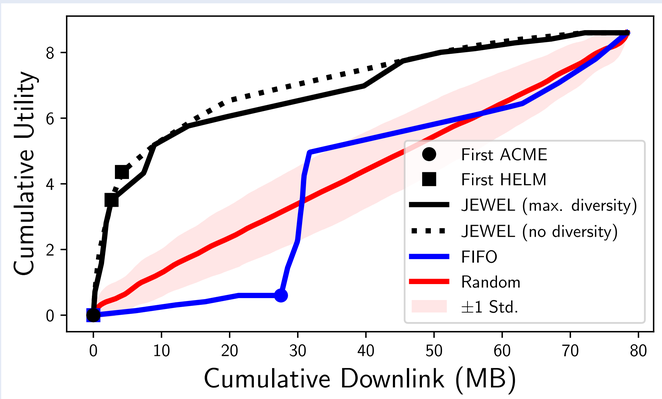


Experiments

- Compare JEWEL-based prioritization to baseline approaches: Random and FIFO (first-in, first-out)
- Dataset includes 12 samples processed by HELM and 7 samples processed by ACME
- Diversity trade-off parameter set to both 0 (ignores diversity) and 1 (utility fully discounted by similarity)
- 1,000 trails for Random strategy

Results

- As data is downlink in prioritized order, JEWEL achieves the highest utility faster than other strategies
- The highest-utility observations come in the middle of the downlink for FIFO, and are distributed evenly across the downlink for the Random strategy
- The first HELM observation is prioritized earlier in the downlink when diversity is taken into account



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References: [1] Deutsch, L. and Townes S. *JPL White Paper* 2019, [2] Nadeau, J. et al. *Advances in Physics: X* 2017, [3] Carbonell, J. and Goldstein, J. *ACM* 1998.