Bayesian Inference of Asteroid Physical Properties: Application to Impact Scenarios

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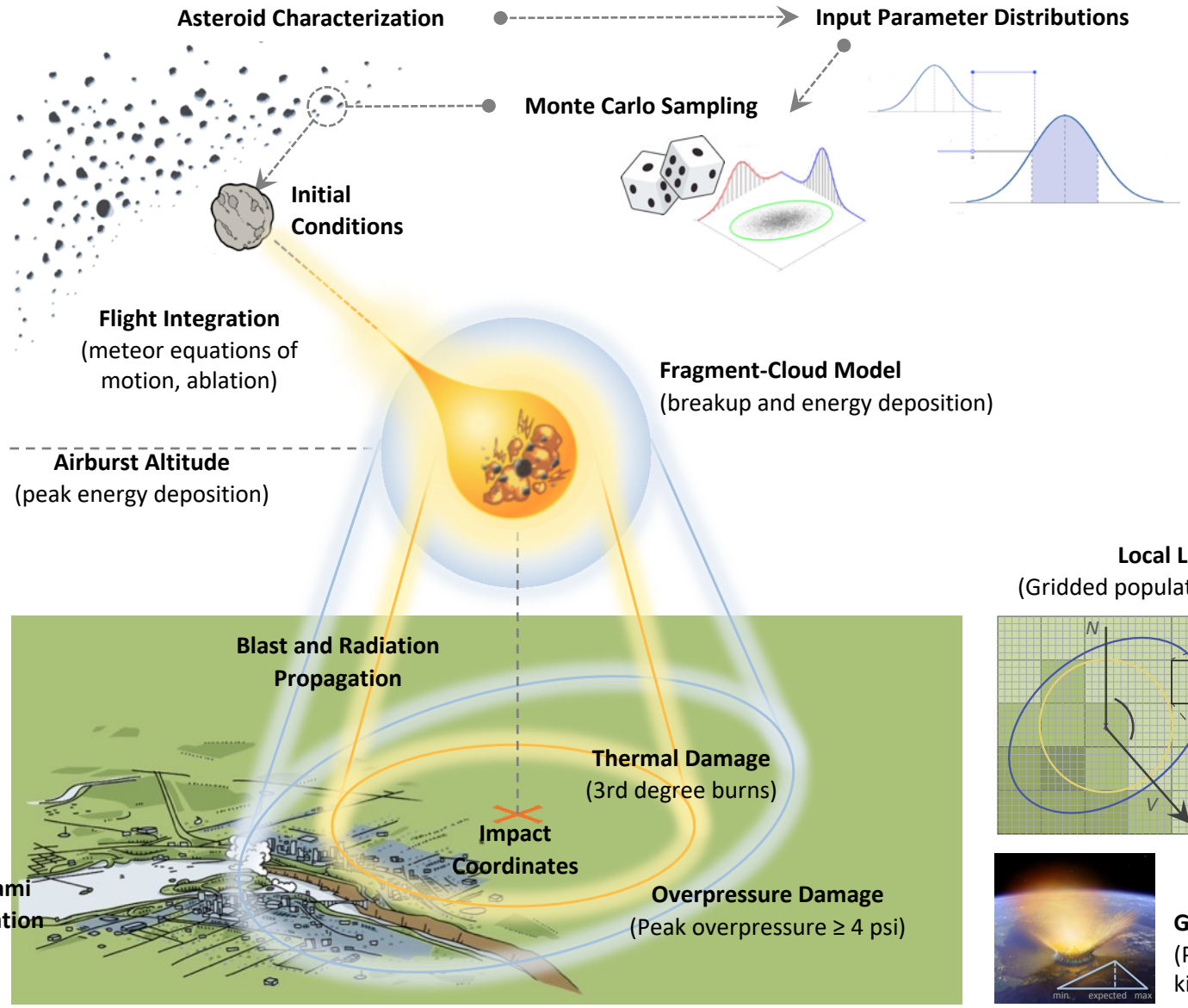
Probabilistic Asteroid Impact Risk Model



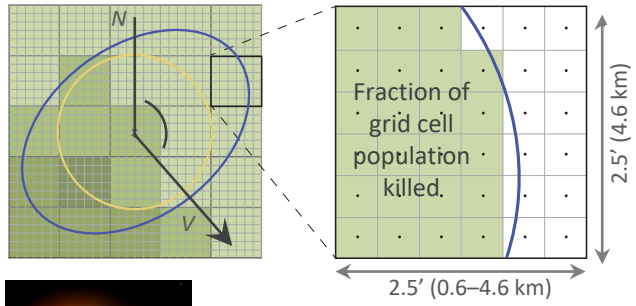
PHA Measurements

- H-magnitude
- Albedo
- Orbital trajectory
- Asteroid class
- Composition

Impact Parameters

- Diameter
- Density
- Strength
- Porosity
- Luminous efficiency
- Velocity
- Entry angle
- Azimuth angle
- Impact coordinates

Local Land Impact Casualties
(Gridded population within largest damage area)



Global Effects Casualties
(Percentage world population killed by climatic effects)

Mathias 2017

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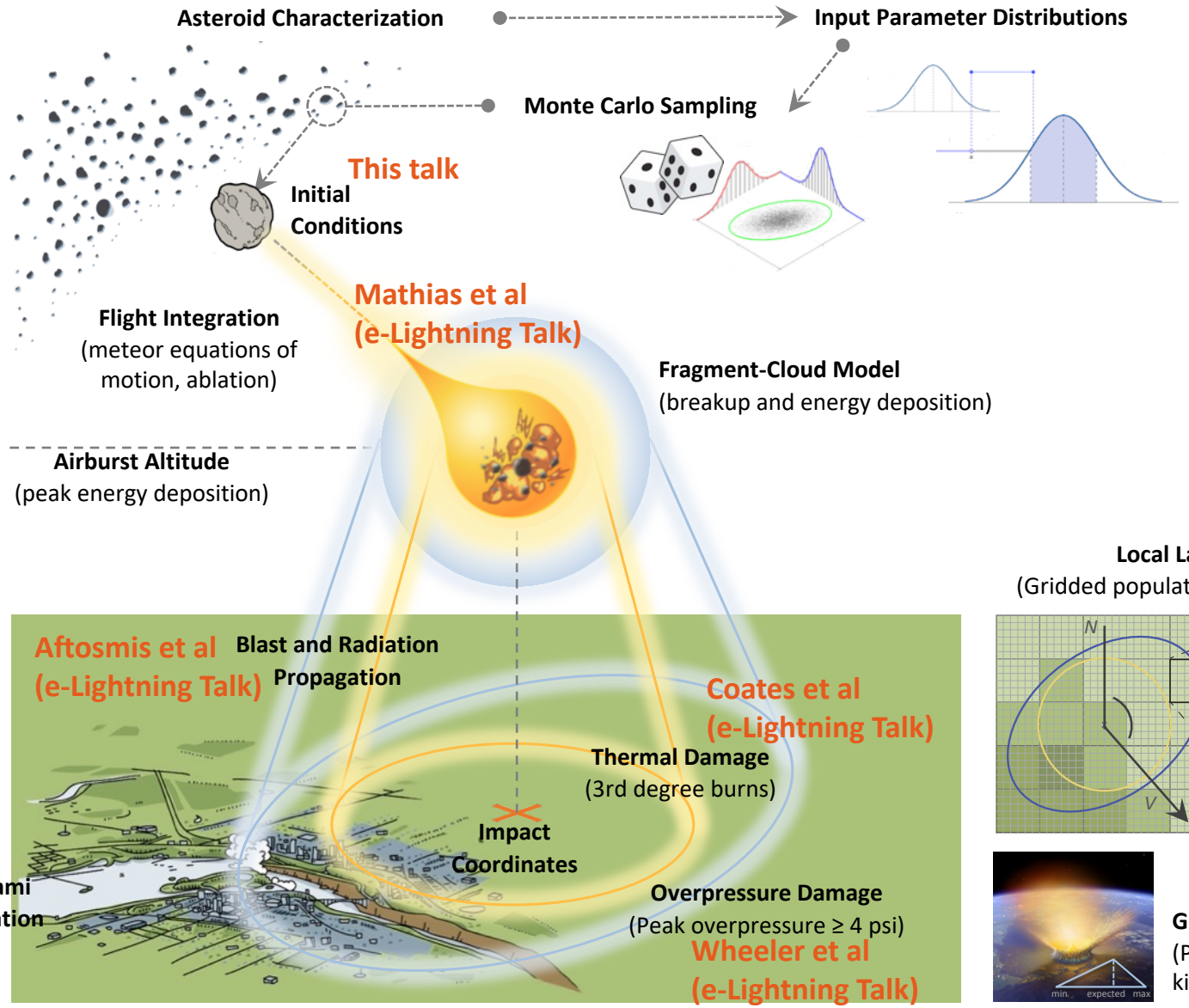

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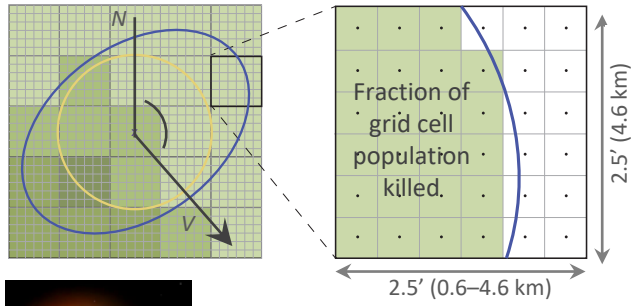

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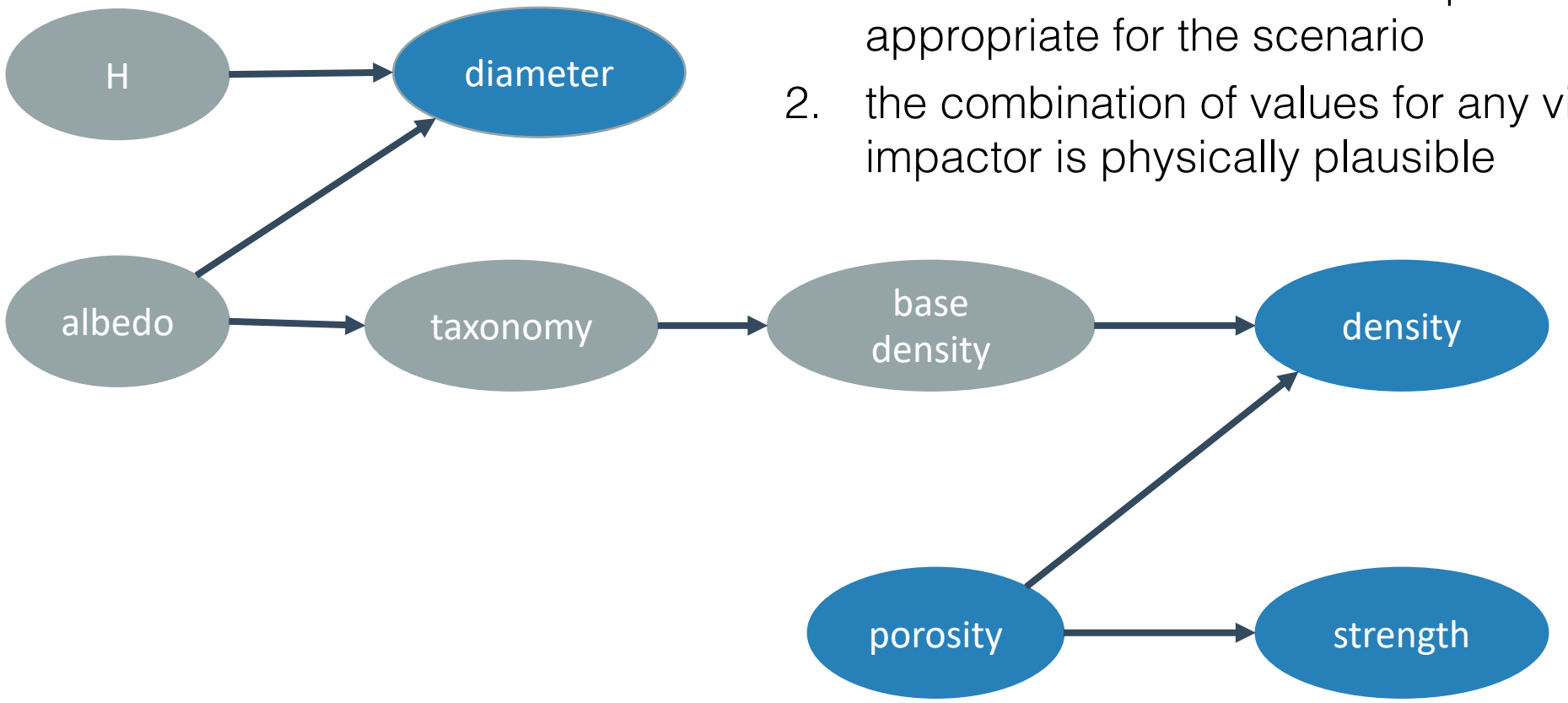
Asteroid Physical Property Risk Model Inputs

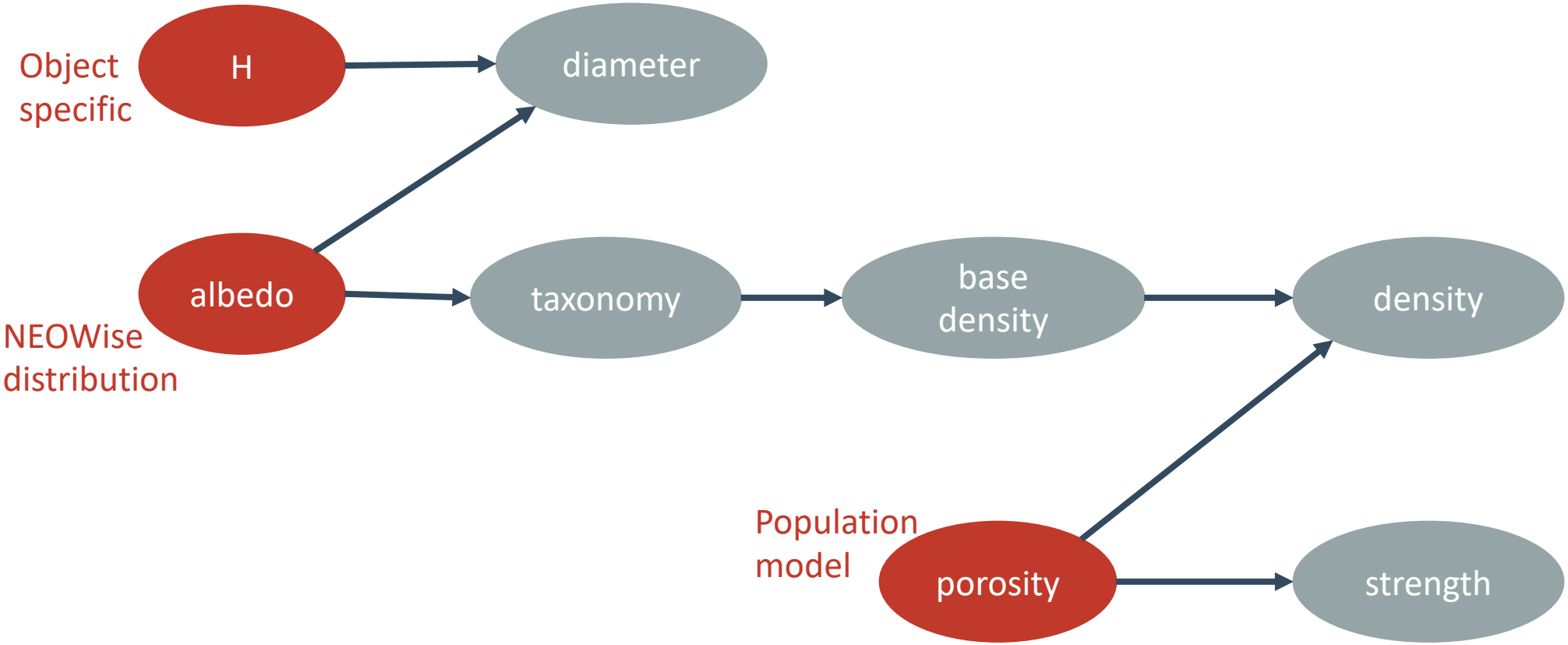
Asteroid Physical Property Inference Network



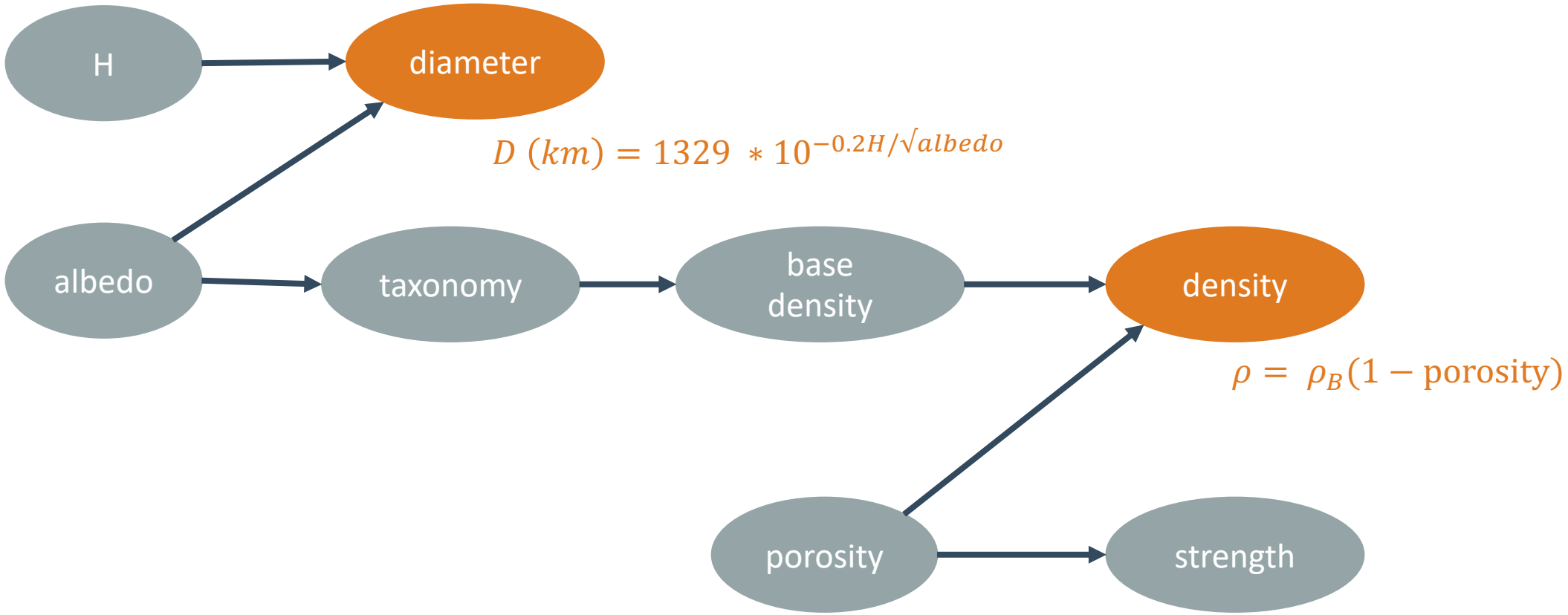
Goal: generate virtual impactors such that

1. the distribution of values are plausible and appropriate for the scenario
2. the combination of values for any virtual impactor is physically plausible

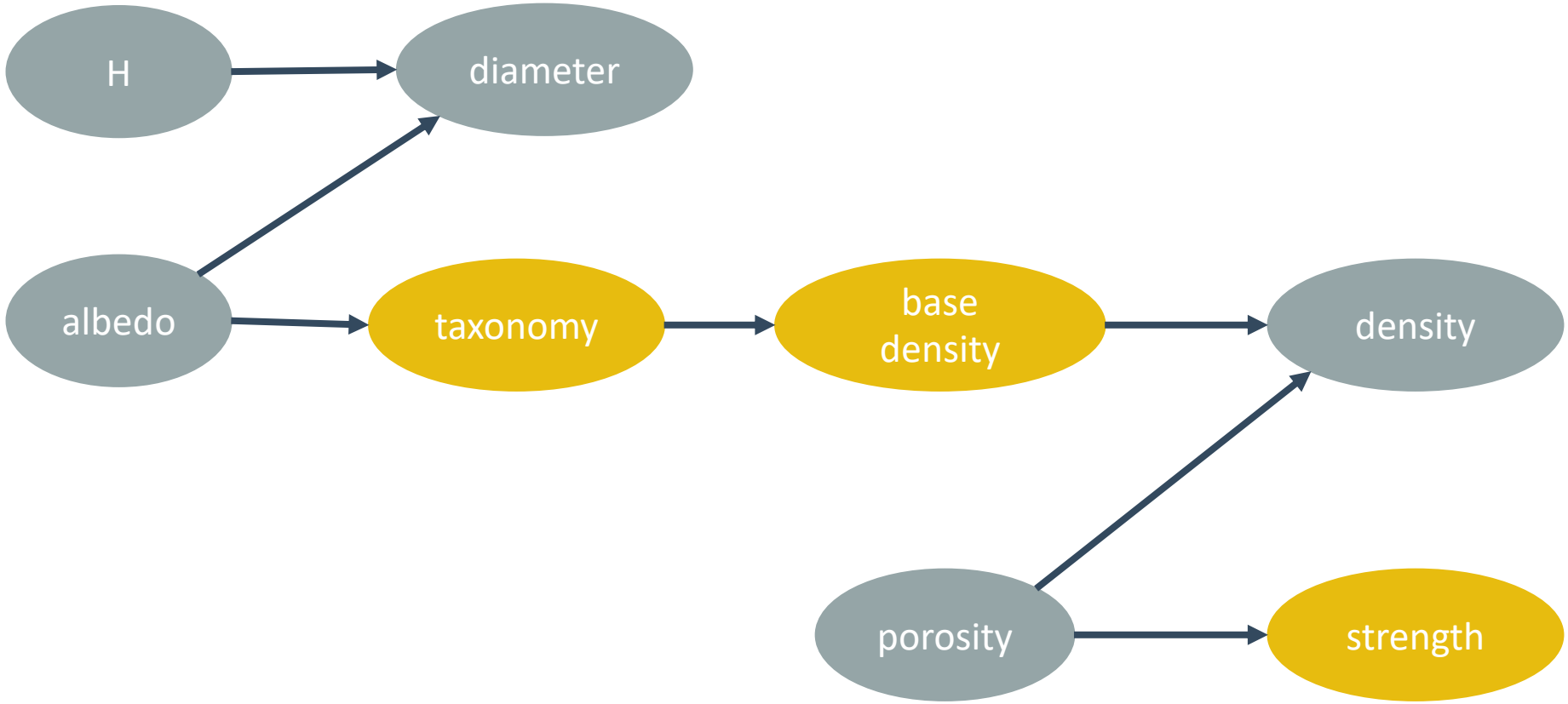
Data Derived Properties



Calculated Properties



Inferred Properties



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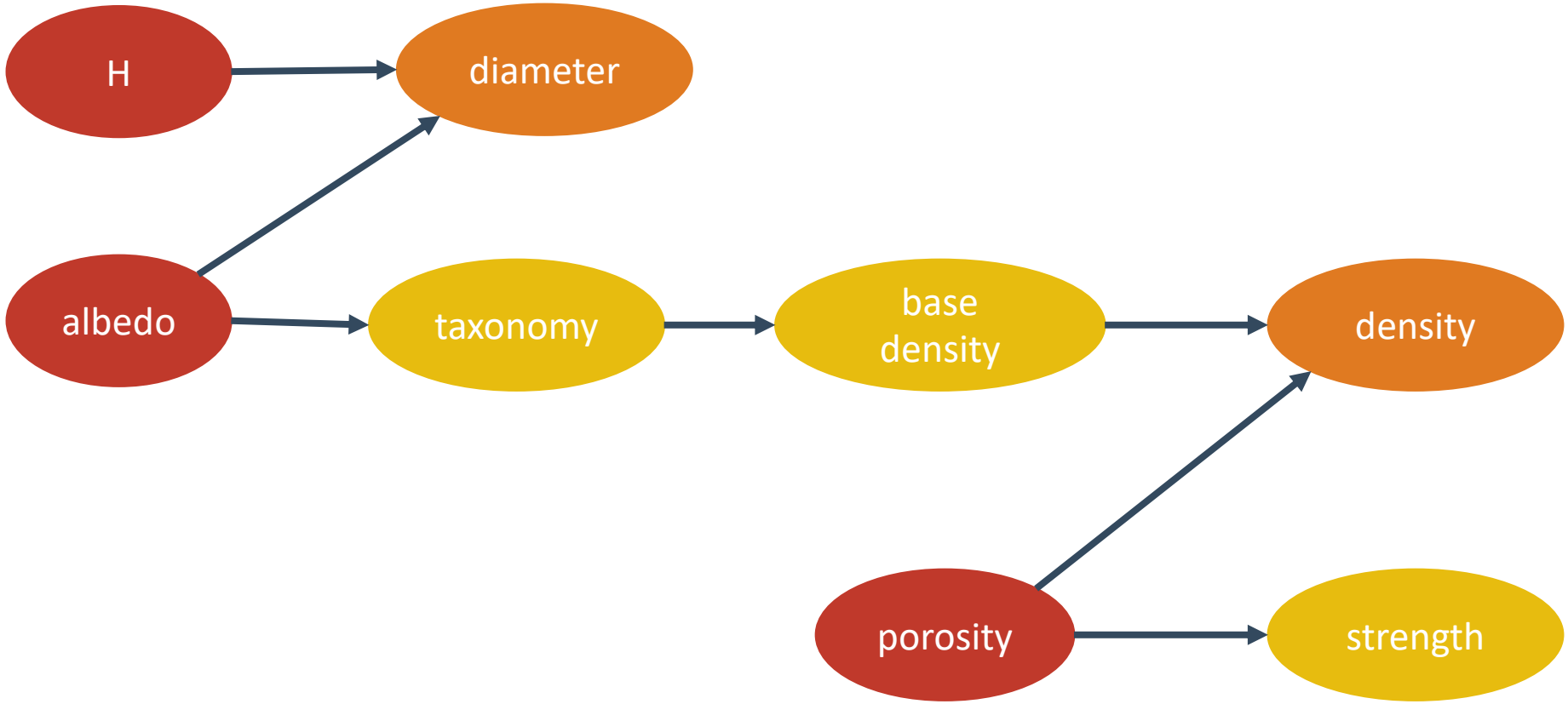
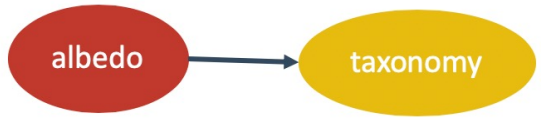
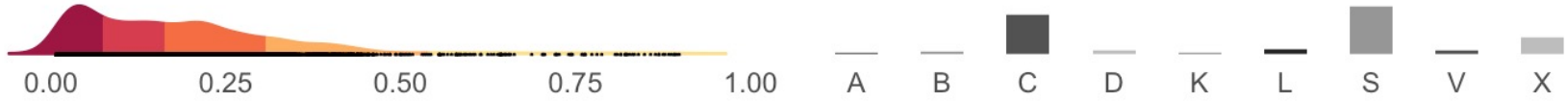


Taxonomy



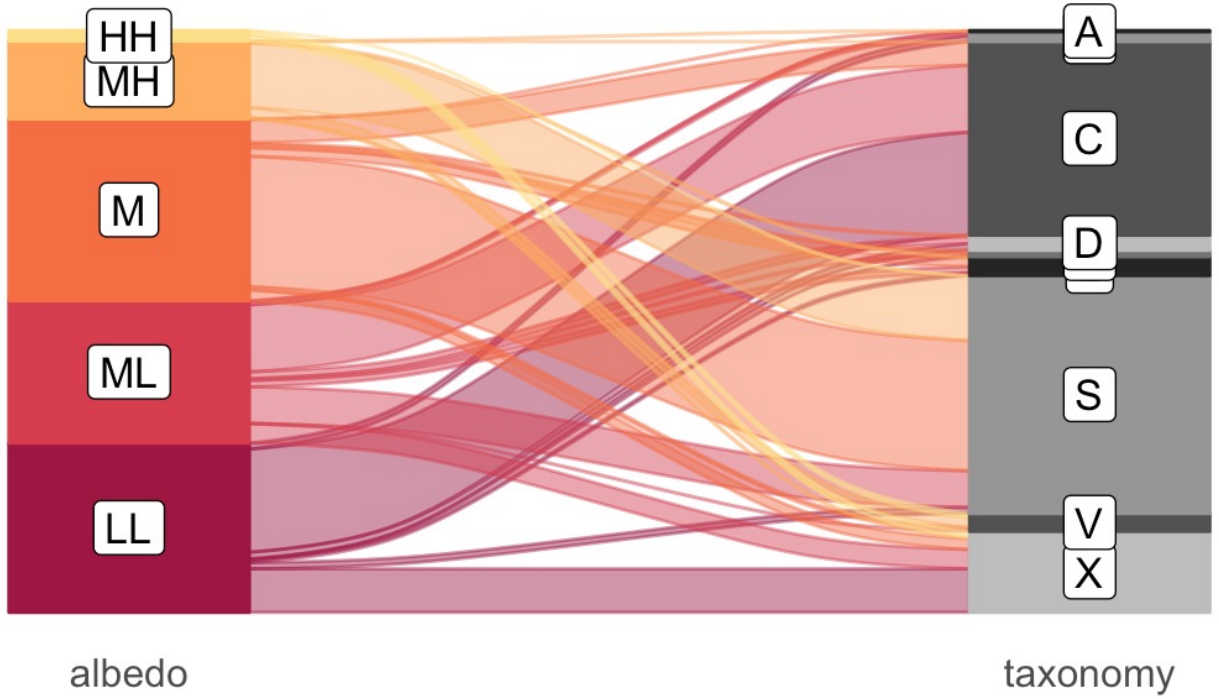


Taxonomy is inferred from albedo via Bayes Theorem

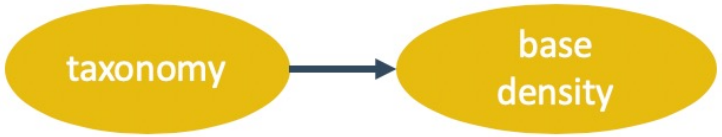
$$P(taxonomy|p_v) \sim P(p_v|taxonomy) * P(taxonomy)$$

albedo distribution for a specific taxonomy

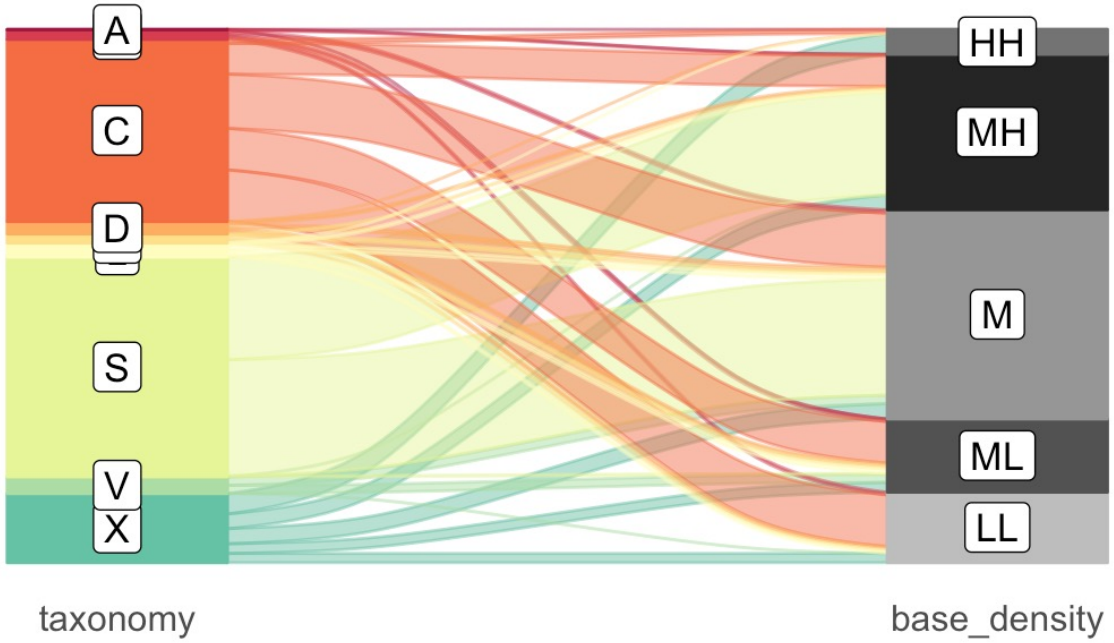
frequency of taxonomy in the population



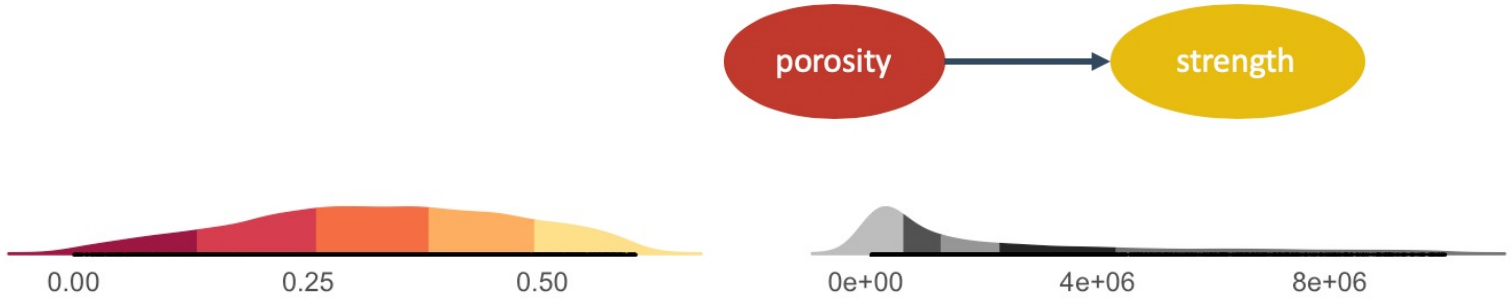
Base Density



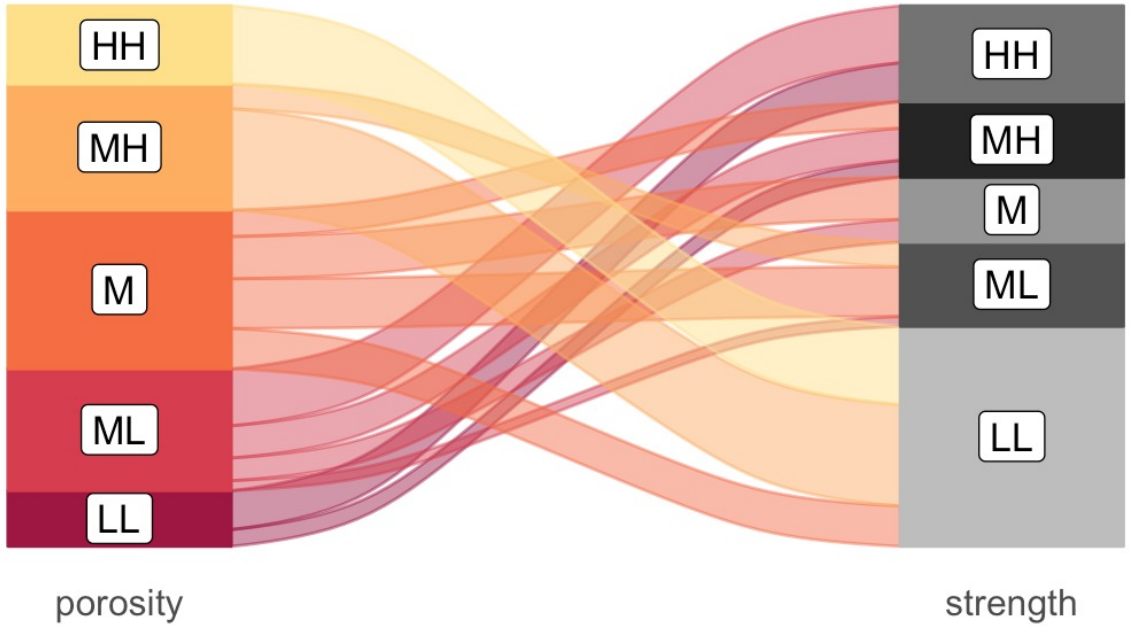
- A literature derived mapping was used to associate each taxonomy with related meteorites.
- Density measurements of meteorites were used to derive base density distributions for the associated taxonomy.
- Base densities were randomly selected from these distributions.



Aerodynamic Strength



- Strength values are selected from a uniform distribution in log space
- Virtual impactors in the lowest porosity quartile are randomly assigned a strength from the strongest quartile
- Other quartiles are mapped similarly



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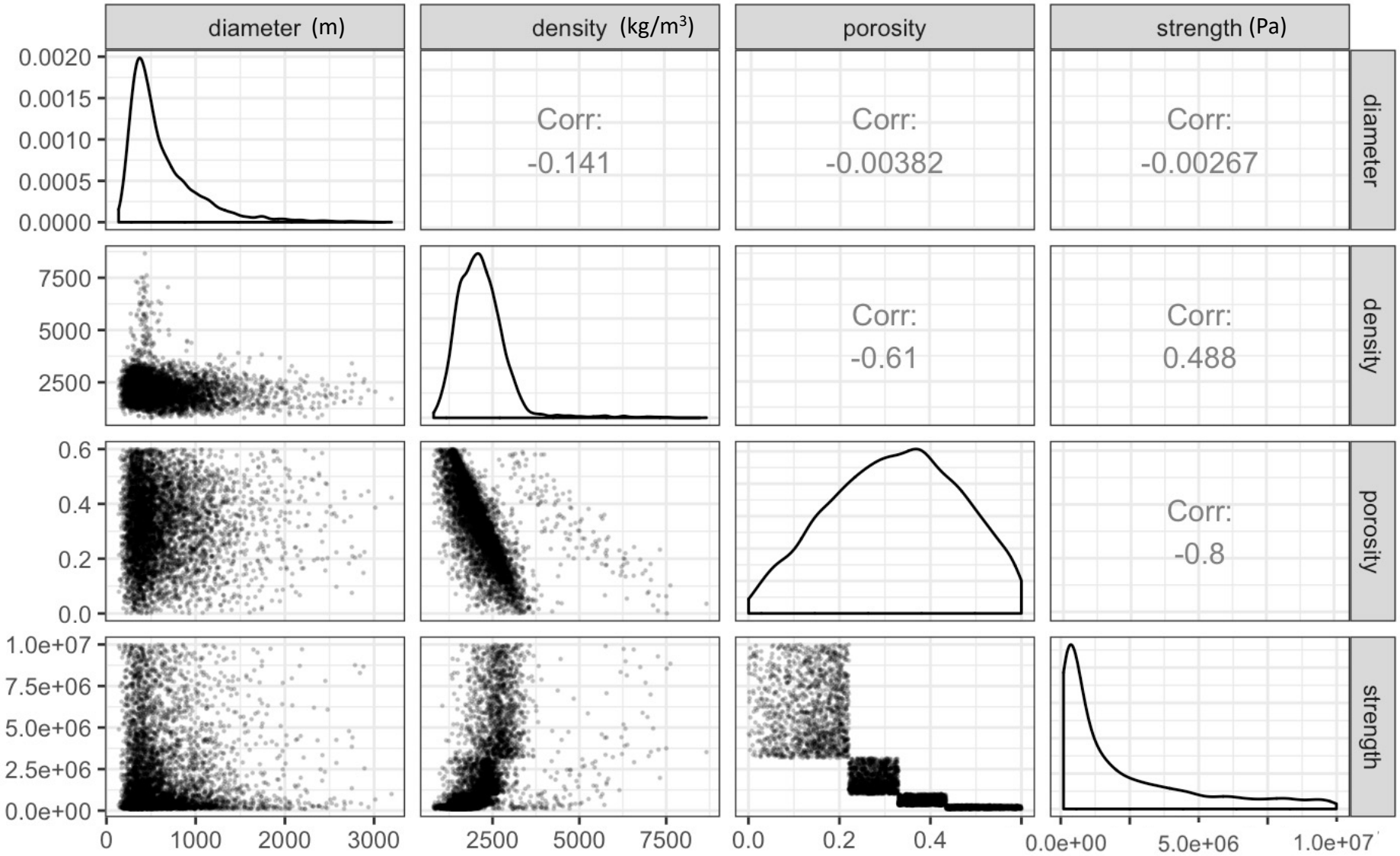
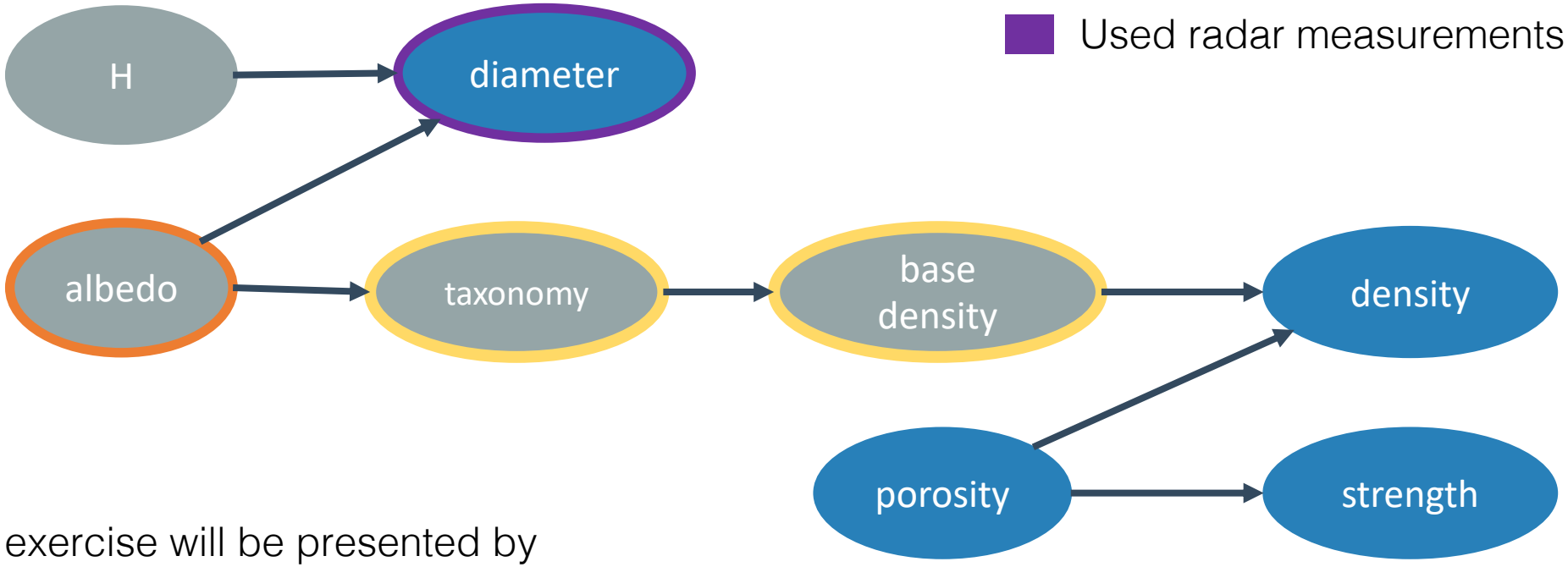


Characterization results can be incorporated into the inference network

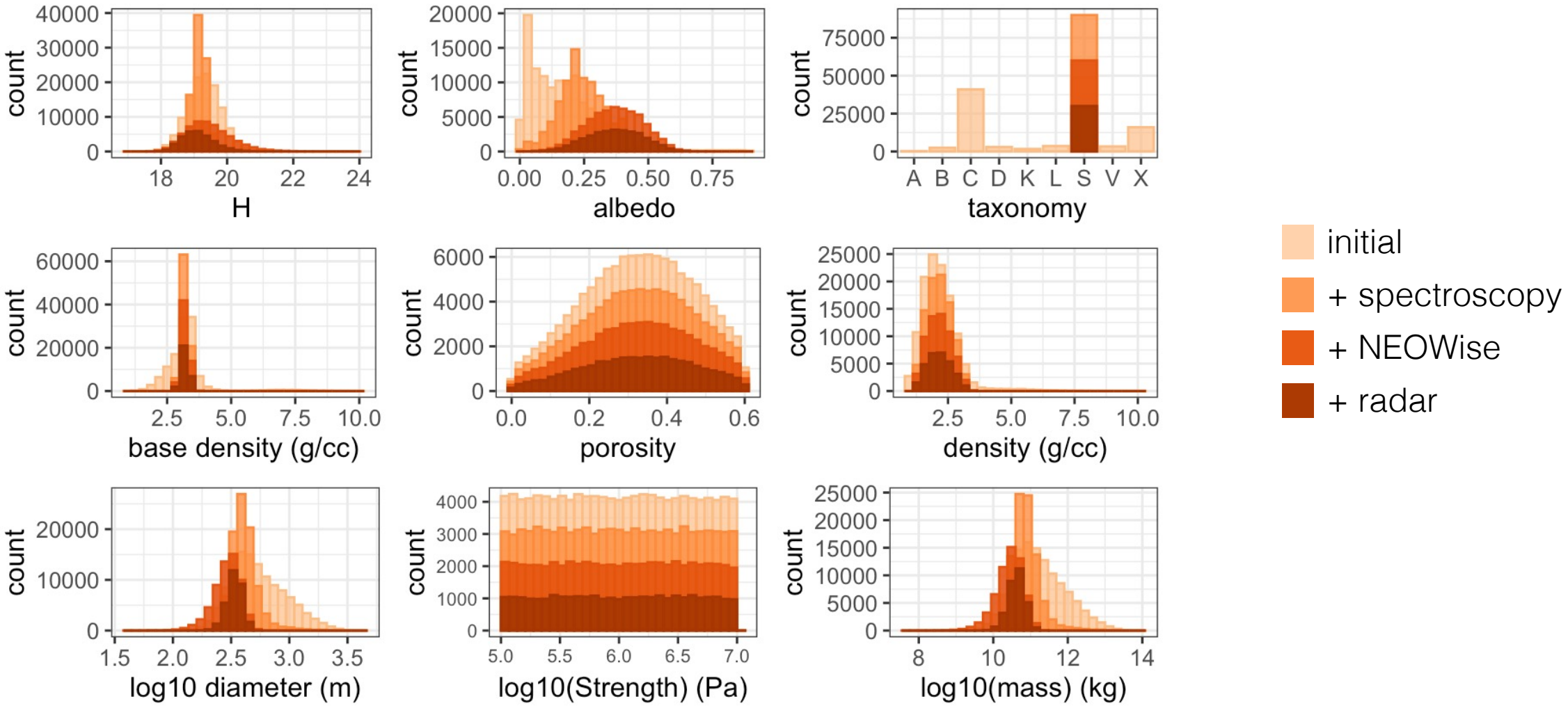
Apophis Exercise Example:

- Used spectroscopy results
- Used NEOWise measurements
- Used radar measurements

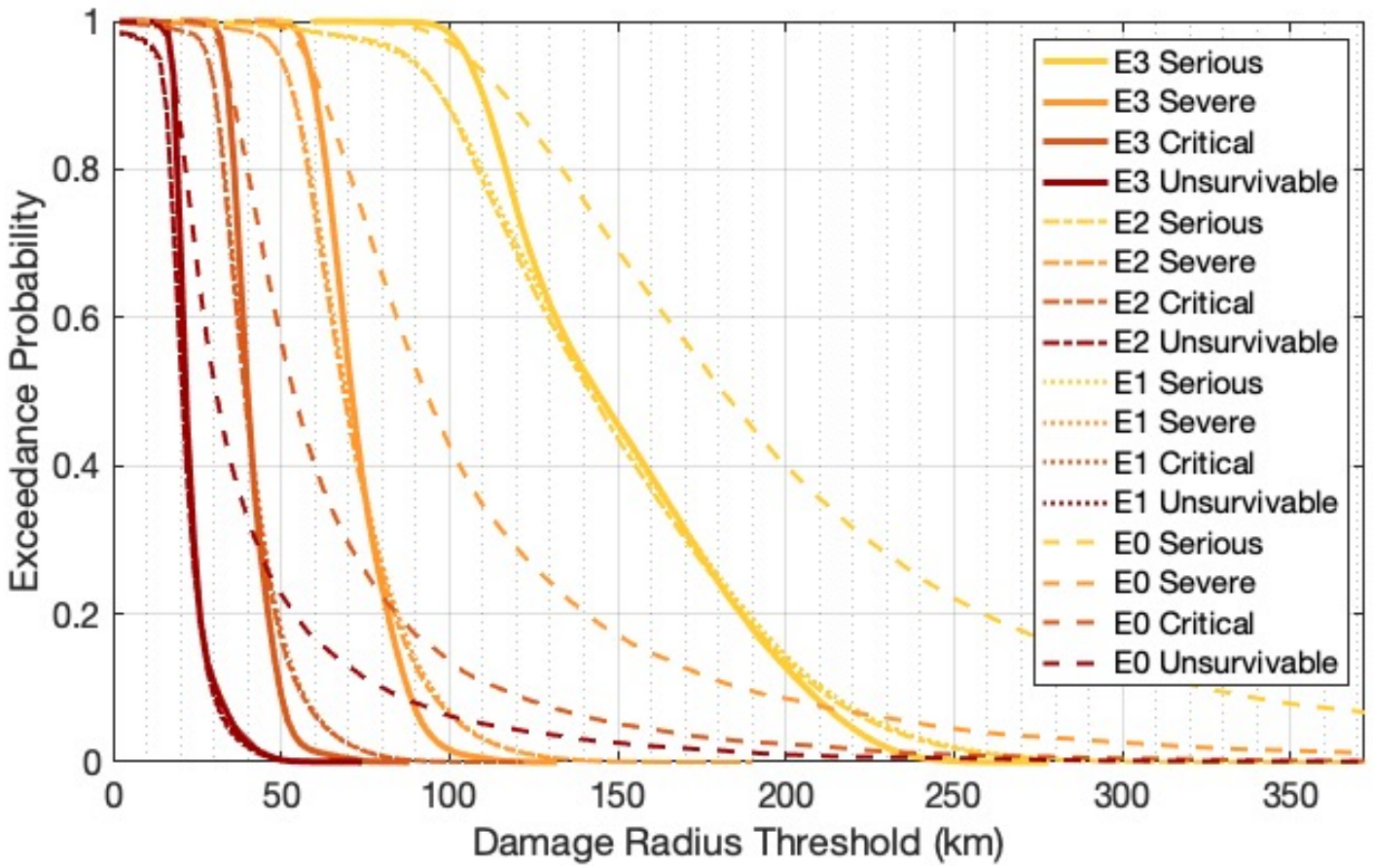


Apophis exercise will be presented by Kelley et al in session 13

Property distributions incorporate characterization observations



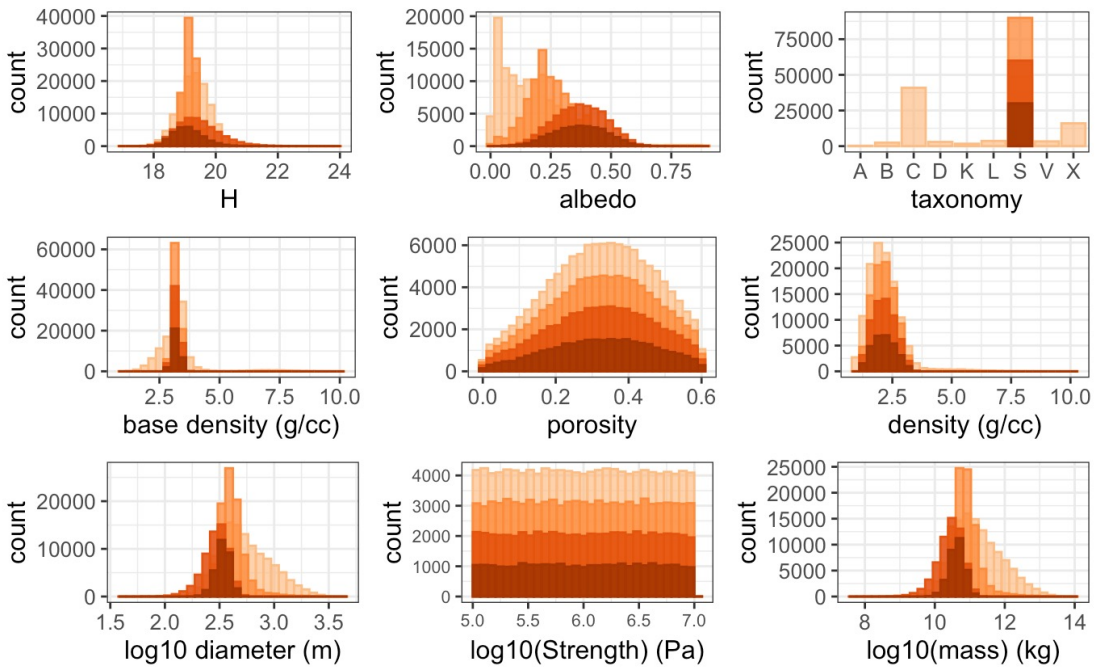
Local Damage Regions for different property sets

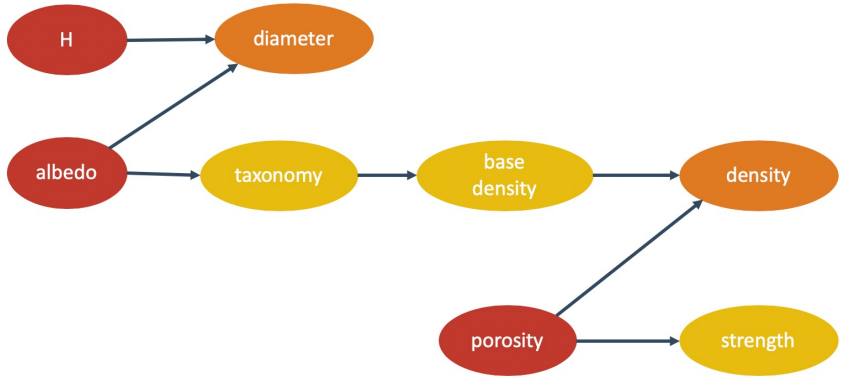


E0: initial
E1: + NEOWise
E2: + spectroscopy
E3: + radar

Physical Property Inference in Planetary Defense Scenarios

- Inference network simulates virtual impactors such that the distribution of their physical properties and the combination of these values for any impactor are physically plausible.
- The inference network has been used to support a variety of planetary defense exercises. (e.g. PDC, Apophis campaign)
- Future work includes improving inference nodes and improving ability to incorporate observational results.





Meteorite Property References

Densities

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Britt and Consolmagno 2004; LPSC
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Hogan et al 2015; Icarus
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Asteroid Property References

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Carry 2012; PS&S

Asteroid to Meteorite Association References

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DeMeo et al 2015; Asteroids IV
de Leon et al 2012; Icarus
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