Predicting the surface exposure time of asteroids using the space weathering features in reflectance spectra: small data machine learning.

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Abstract

Take away message

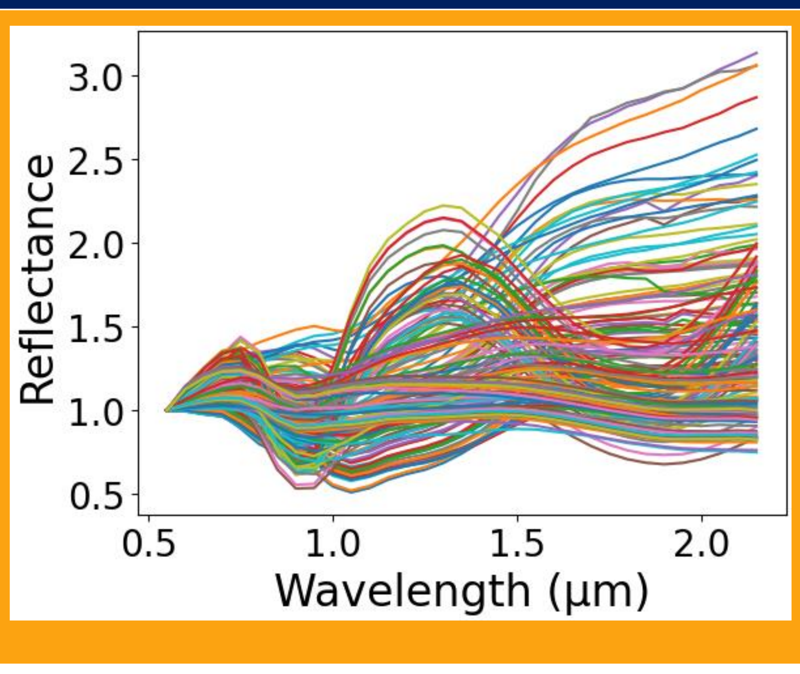
- ➢ Use of machine learning models to estimate the **surface exposure time of S-complex asteroids affected by space weathering (SW)**.
- ➢ Ensemble model combining Convolutional Neural Network (CNN) and decision tree algorithms outperforms the standalone CNN model in predicting exposure times and models enhance the overall prediction capability, **even with a small dataset**.
- ➢ For 90% of the spectra, **the model deviates by no more than a factor of 2.95 (either higher or lower) from the actual values, within the range of 1-10^3 and 10^7-10^9 years.**

Background

The surfaces of airless planetary bodies exposed to the interplanetary environment experience SW. Over time, the SW process distorts certain reflectance spectral features such as spectral slope, albedo, or absorption band depths and widths. Extensive laboratory experiments studied the evolution of these spectral parameters under simulated SW conditions. However, despite these efforts, the **precise relationship between SW duration and the alteration of reflectance spectra remains not fully understood**.

GOAL: to develop and apply **machine-learning models** to **estimate the surface exposure time of S-complex asteroids as a function of space weathering agents and dose**.

Methodology



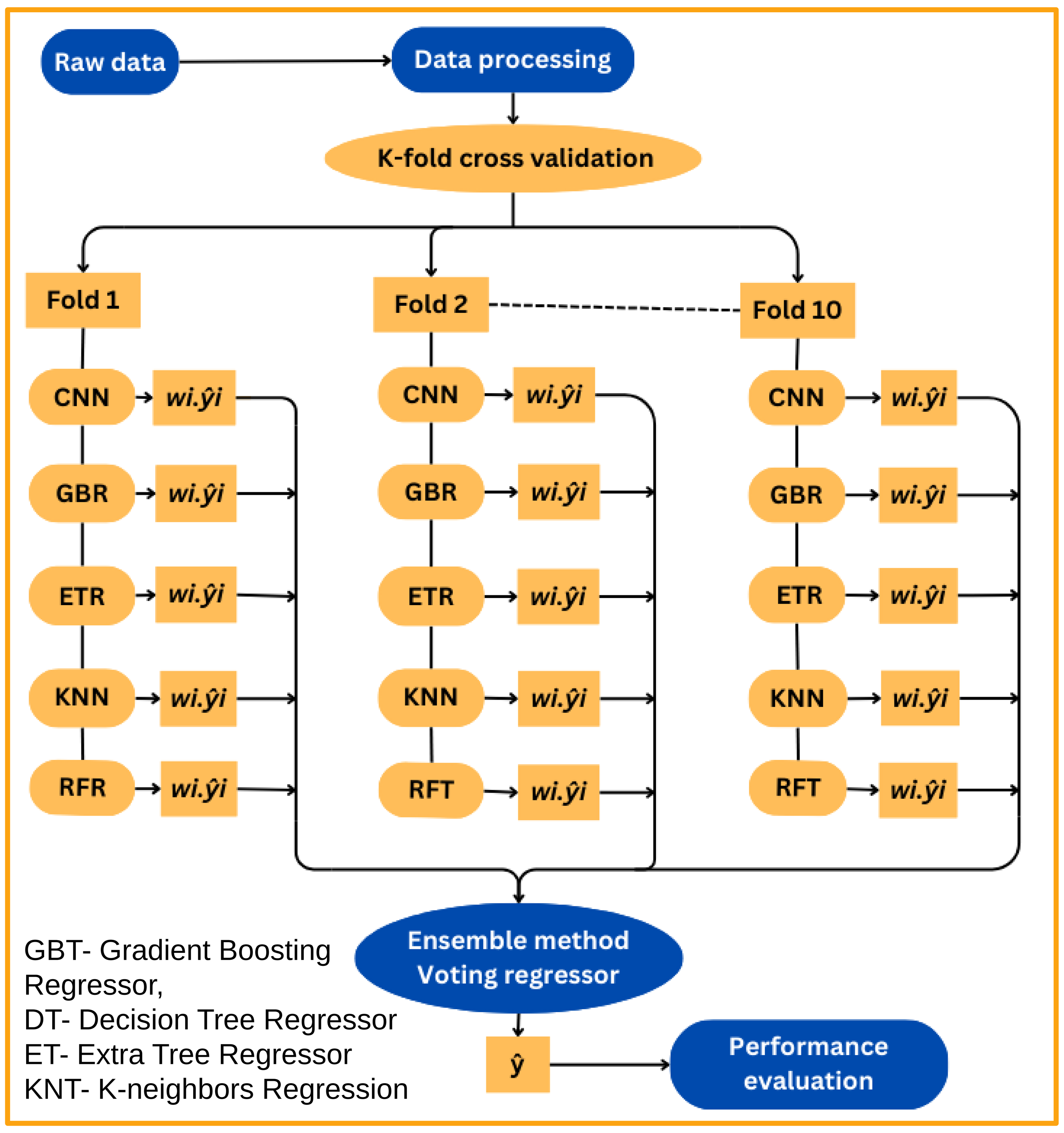
Raw data

Independent variable

- ➢ Reflectance spectra of **H^+ and laser irradiated**
  - 71 – olivine
  - 34 – pyroxene
  - 10 – olivine-pyroxene mixtures
  - 54 – meteorite
- ➢ Irradiation dose

Dependent variable

- Exposure time (1 – 10^3 and 10^7– 10^9 years)
- **Data for 10^3-10^7 years → not available**



Exposure time calculation

- ➢ Using the experimental parameters
- ➢ Exposure time was calculated,
  - ❑ for ion irradiation → as in Chrbolková et al., 2021.
  - ❑ for laser irradiation → as in Zhang et al., 2022.

Results

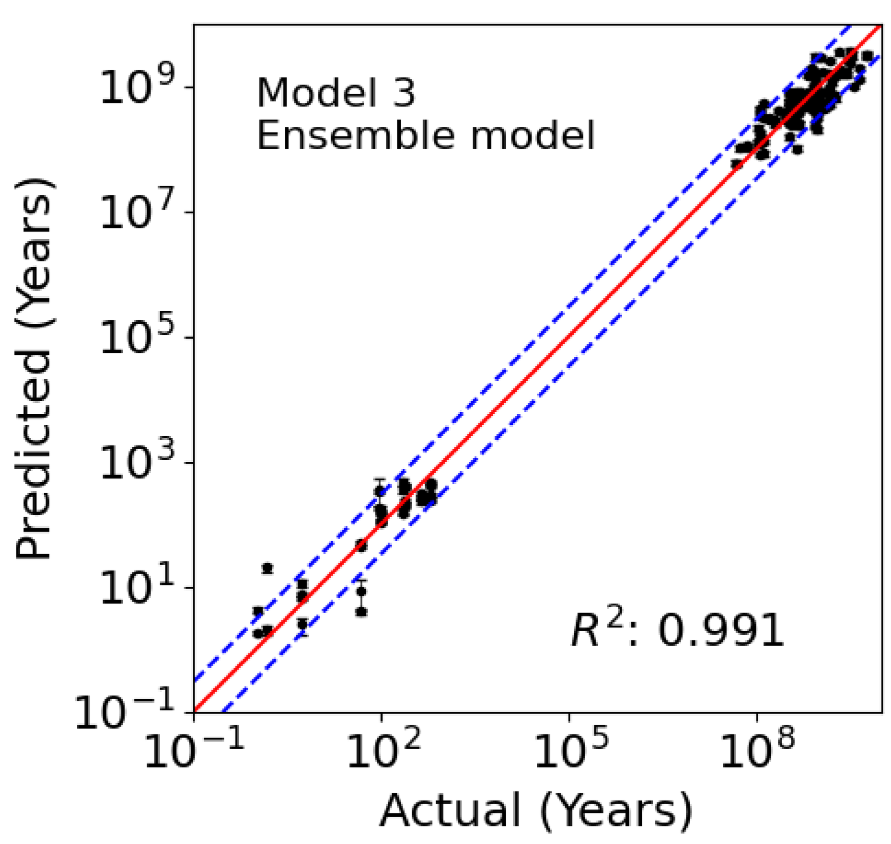


Figure 1. Scatter plots of **the true and predicted exposure time** of the test data.

The red color diagonal line delimits the ideal predictions. The bule dash line gives the 3-factor accuracy.

From model 1 to model 3, enhancement in prediction accuracy, and reduction in standard deviation.

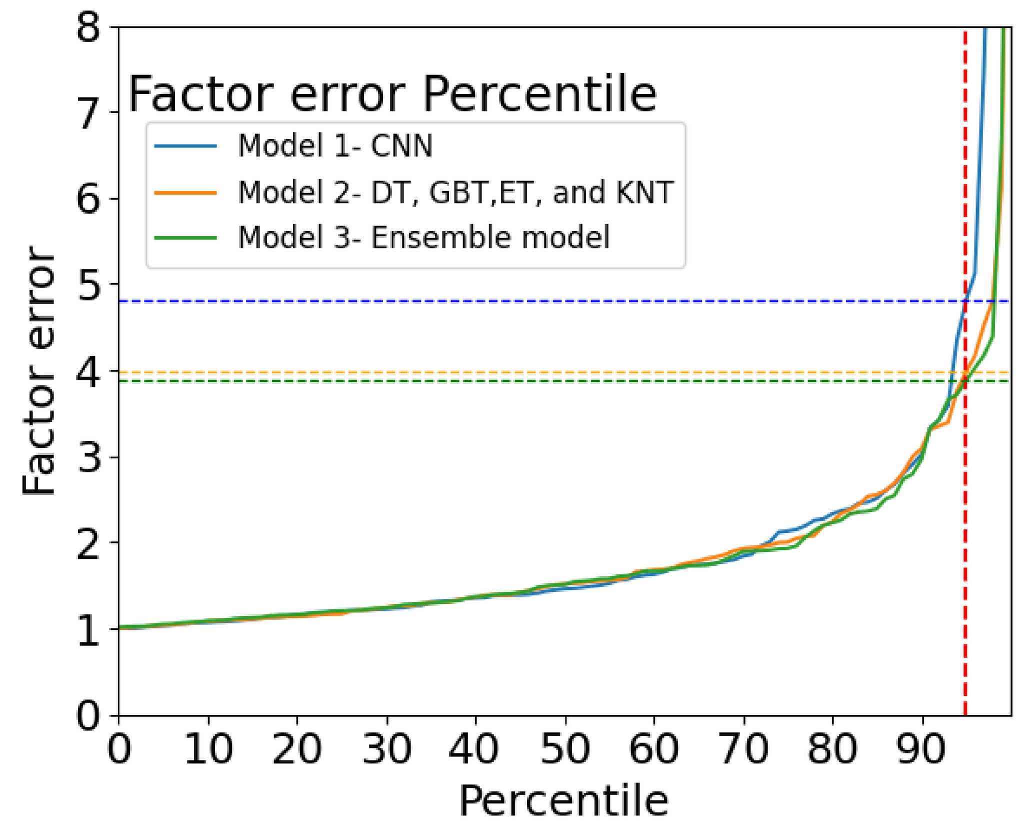
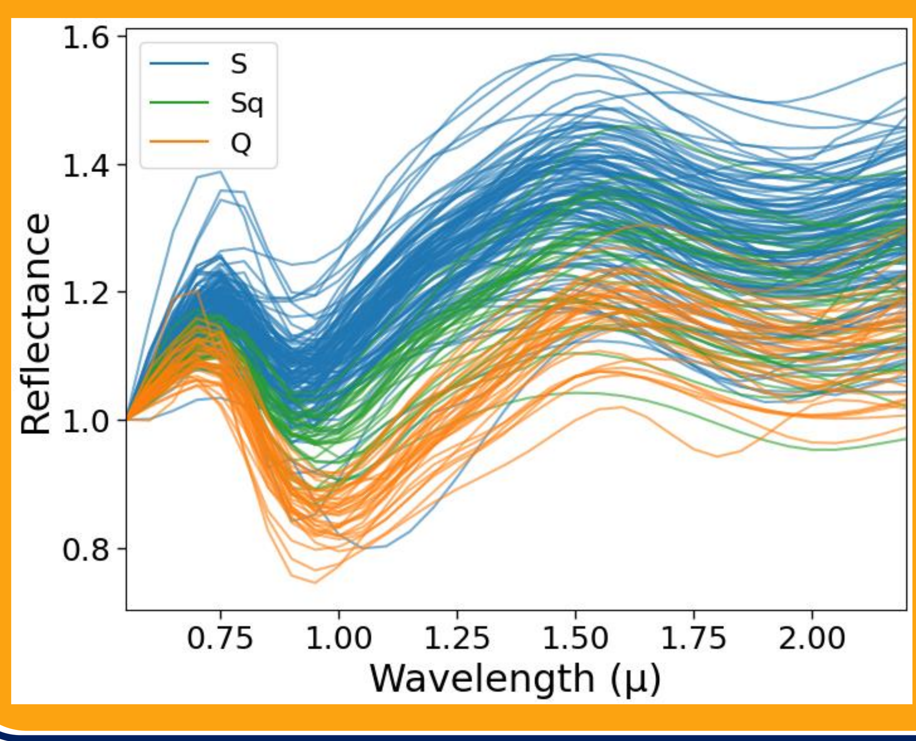
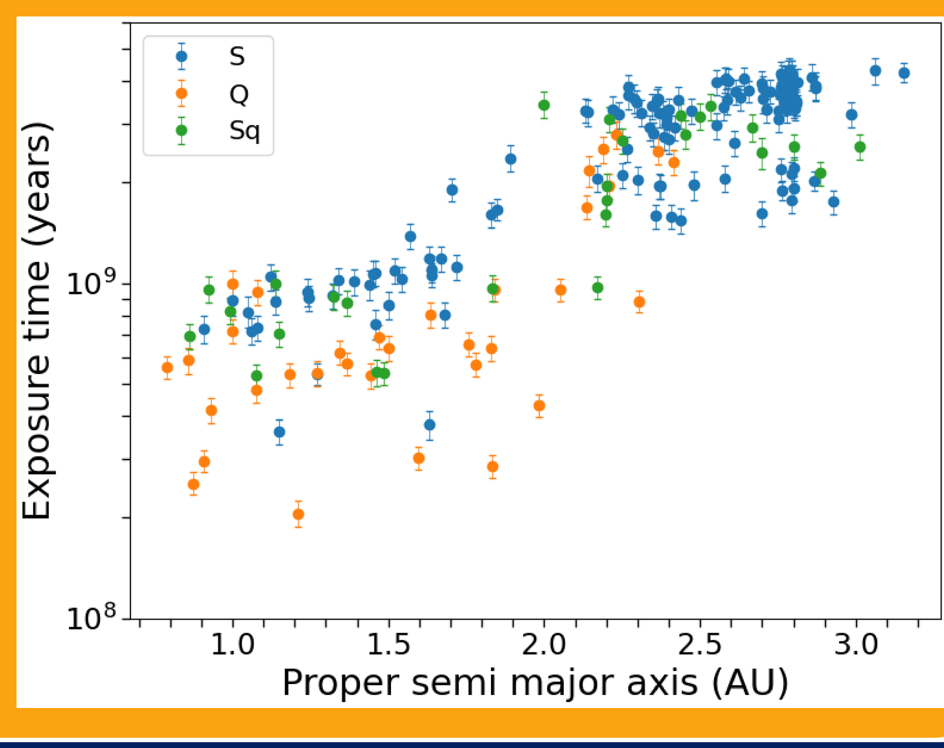


Figure 2. Quantiles of the **factor errors of the actual and predicted values** of exposure time in years. **95% of the predicted values** estimate time with an **accuracy factor of**,

Model 1 → 4.80
Model 2 → 3.97
Model 3 → 3.87

Predictions for Q-, Sq- and S- type asteroids.





Discussion and conclusion

- ➢ **Ensemble mode**l combining CNN model and tree algorithms, even with a small data set can,
  - ▪ **reduces factor error** and **improves standard deviation**, thus **increasing the reliability of predictions**.
  - ▪ **yields more dependable prediction** compared to a standalone CNN model.
- ➢ For 90% of the spectra, the model deviates by no more than a factor of 2.95 (either higher or lower) from the actual values, within the range of 1-10^3 and 10^7-10^9 years.

Acknowledgment

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My work

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