Using Deep Learning neural networks to predict the interior composition of exoplanets

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**Motivation**
- Very few observable parameters for exoplanets
- Solutions for interior structures are often degenerate
- Many interior models need to be run to find all possible solutions
- What observables do we need to break the degeneracies?
- Can we use machine learning to predict a planet's interior?

**Neural Network**
- Deep learning neural network with 3 hidden layers
- Up to four inputs:
  - Planet mass $M$
  - Planet radius $R$
  - Fluid Love number $k_2$
  - Fe/Si ratio of planet
- Predictions / Outputs:
  - Mass fraction of each planetary layer

**Training data**
- Monte-Carlo sampling
- 200,000 planets with random mass fractions for each layer
- Mass between $0$ and $25 M_{\oplus}$
- 50% of planets are created with an atmosphere
- Data distribution:
  - 50% training
  - 25% validation
  - 25% error estimation

**Training Results**
Each subplot shows the mass fraction predicted by the neural network over the actual mass fraction from the validation data. Points on the red diagonal line are accurately predicted. Points are colored corresponding to the $k_2$ of the planet. Low values of $k_2$ correspond to extended atmospheres.

**Interior model**
- Planet layers:
  - Iron core
  - Silicate mantle
  - Ice
  - H/He atmosphere (solar-like)
- Mass fractions constrained by model input
- Model output:
  - Planet radius
  - Fluid Love number $k_2$
  - Fe/Si ratio of planet

**Predictions for Solar System planets**

**Conclusion**
- Our neural network predicts the full interior composition based on just a few inputs
- By changing the input parameters we can very quickly check how well these characterize the interior composition
- Outlook:
  - Error estimation using a second neural network
  - Testing more possible observables (e.g. Mg/Si ratio, Metallicity of the atmosphere...)

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**References**