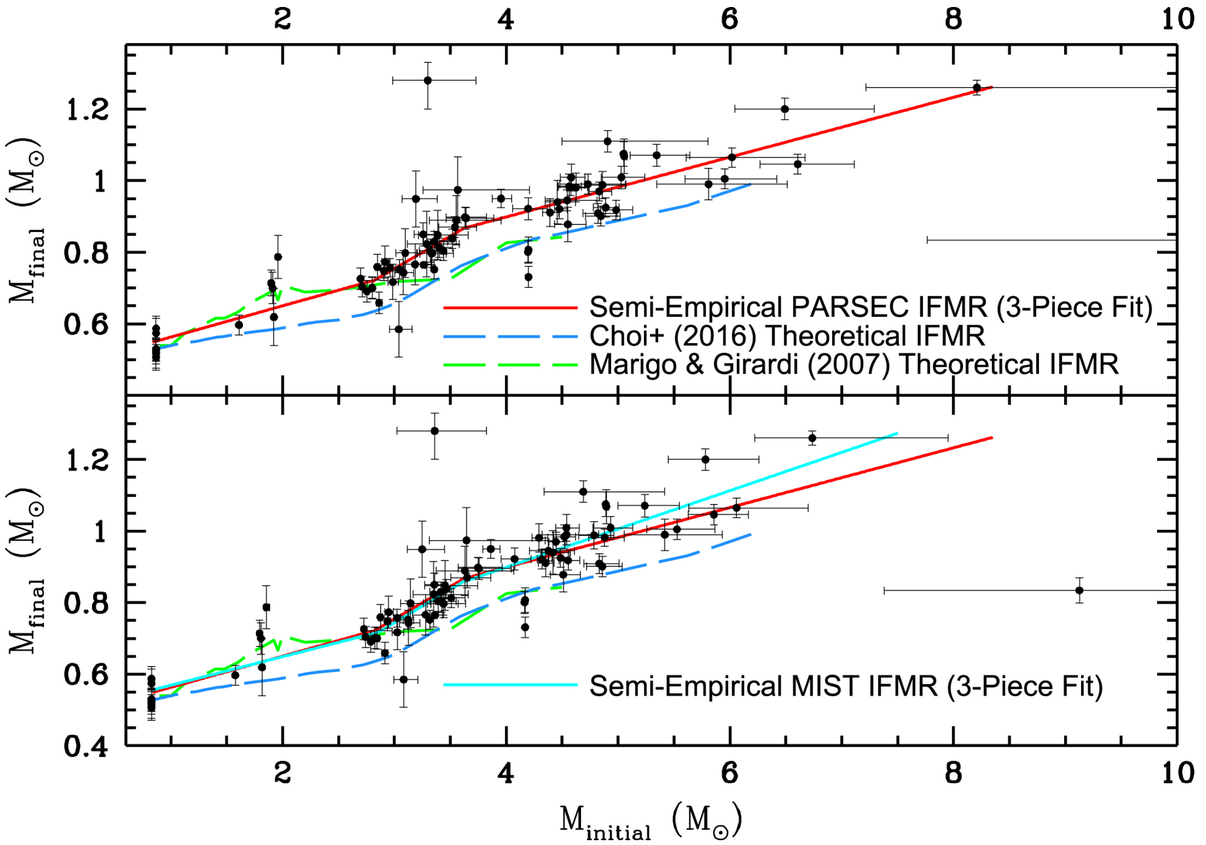
Constraining the Initial-Final Mass Relation of White Dwarf Stars

D A Crake, R G Mann & N C Hambly

The Initial-Final Mass Relation

- Acts as a ground truth for evaluating stellar evolution models.
- Current version have 79 examples from 13 star clusters.
- We aim to drastically increase the census of White Dwarfs and produce a scalable pipeline for future telescopes.



J D Cummings et al. (2019)

Pipeline Architecture

- Final Mass is an observable value. [Fusillo et al. (2021)]

Initial mass requires:

- The removal of spurious sources.
- **Identifying stellar clusters with clustering algorithms.**
- Total age of identified clusters must be obtained.
- Using WD cooldown models provides WD lifetime.
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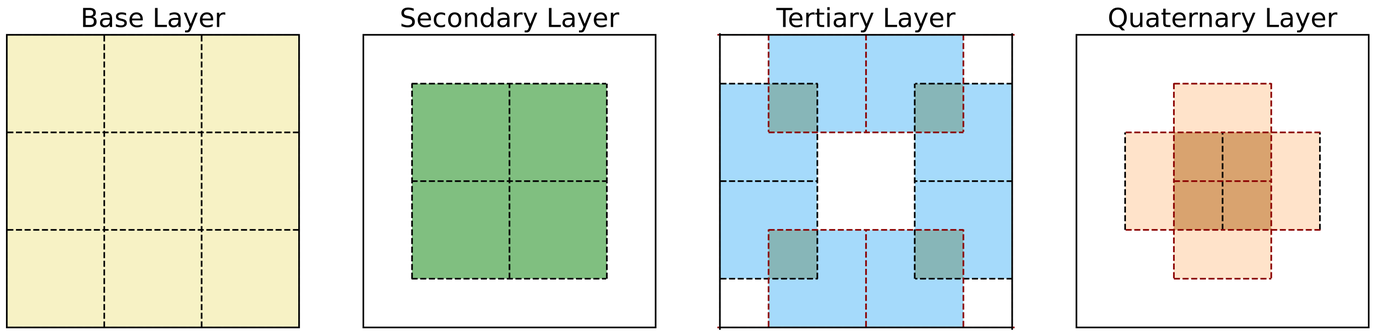
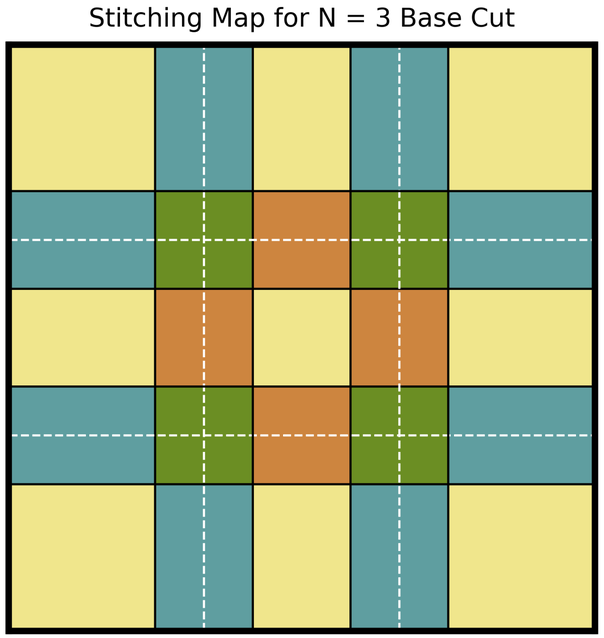
Identifying Stellar Clusters

Credit: NASA

- Our target stellar clusters and co-moving groups form from a single cloud collapse history.
- The clustering phase of our work is influenced by the work within Kounkel & Covey (2019).
- The clustering algorithm selected is HDBSCAN, which has significant computational requirements at scale.
- This work aims to remain scalable and repeatable, thus human input must be minimised.

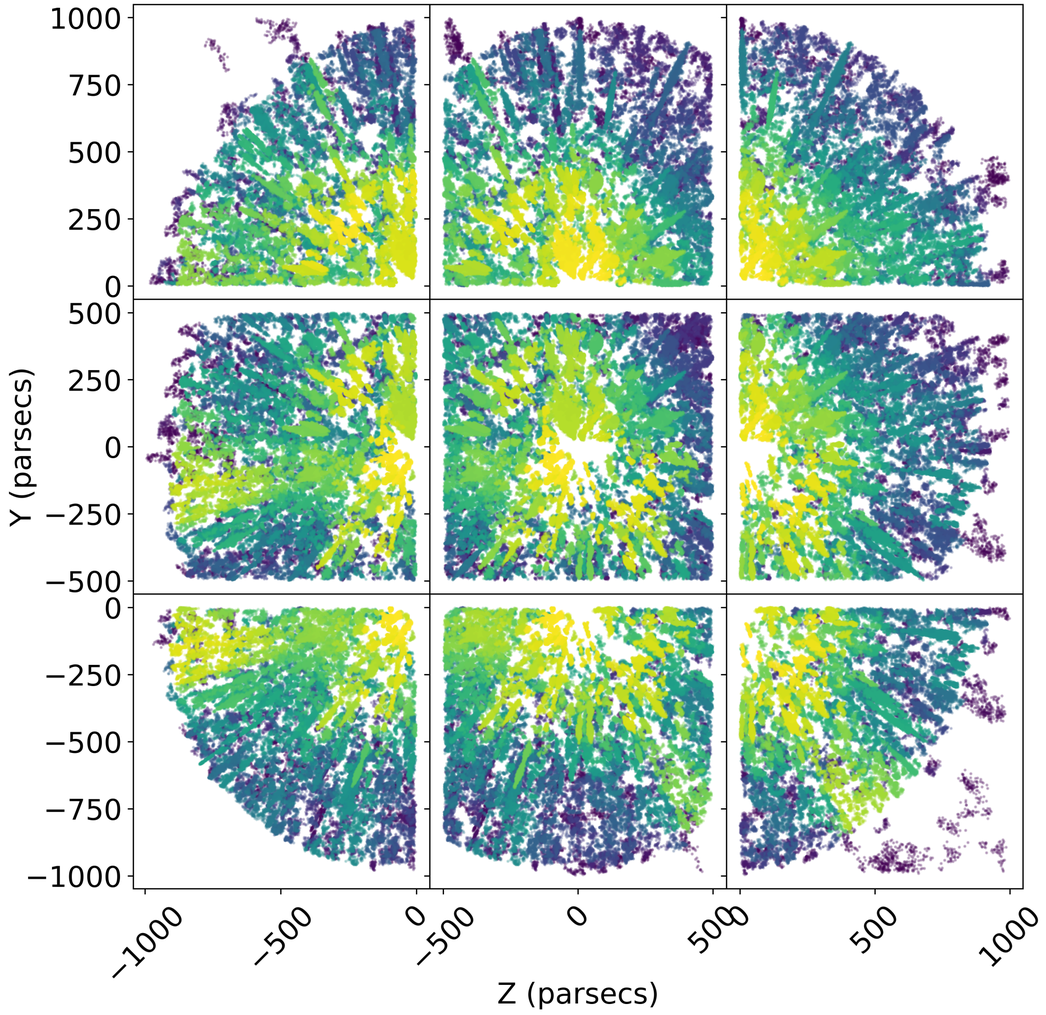
Introducing: HEADSS





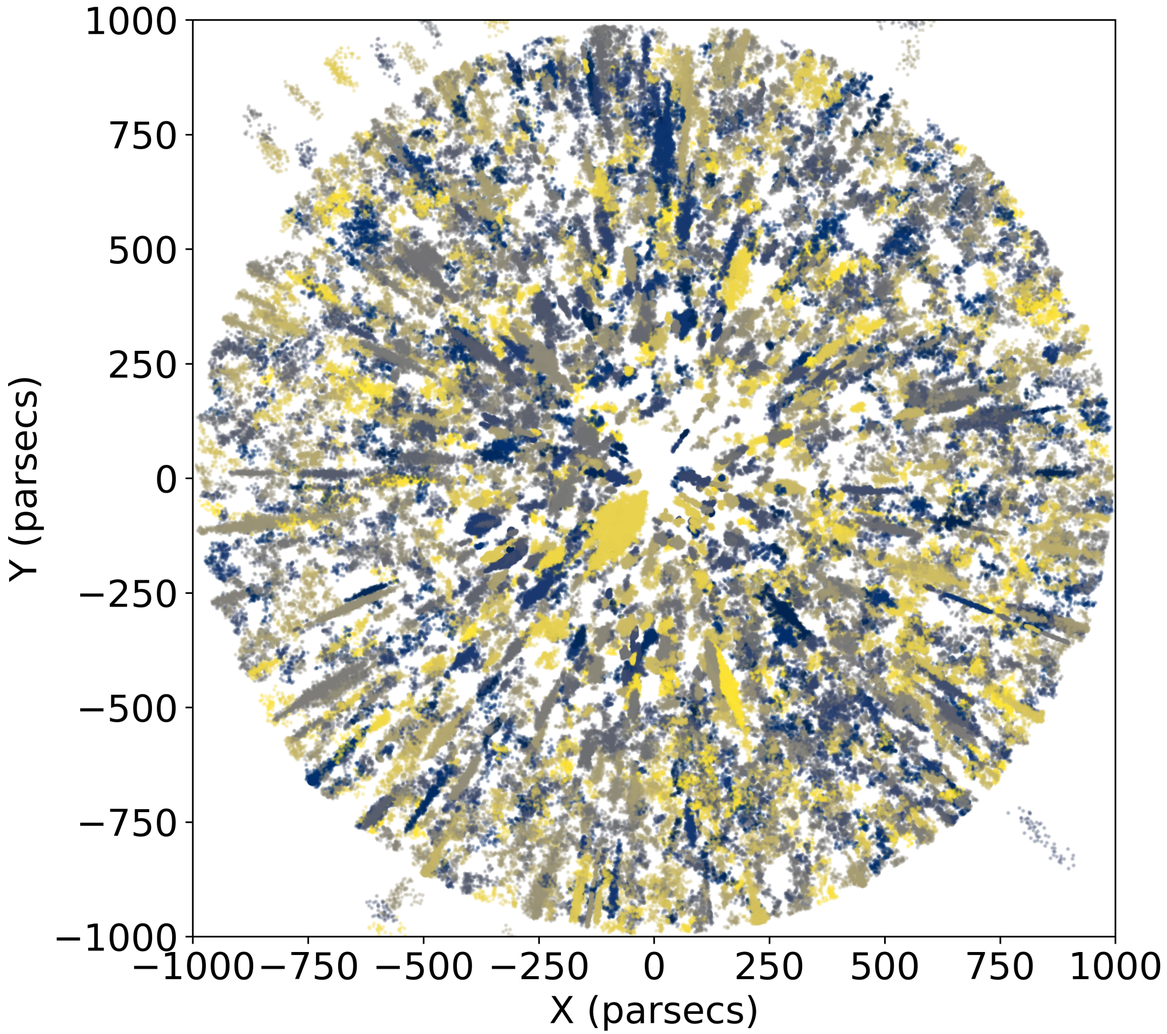
- HiErArchical Data Splitting and Stitching (HEADSS) is a scalable solution to big data clustering.
- This is an original package that distributes big data clustering with smaller node requirements.
- Removed edge effects through overlapping regions and merging large clusters.

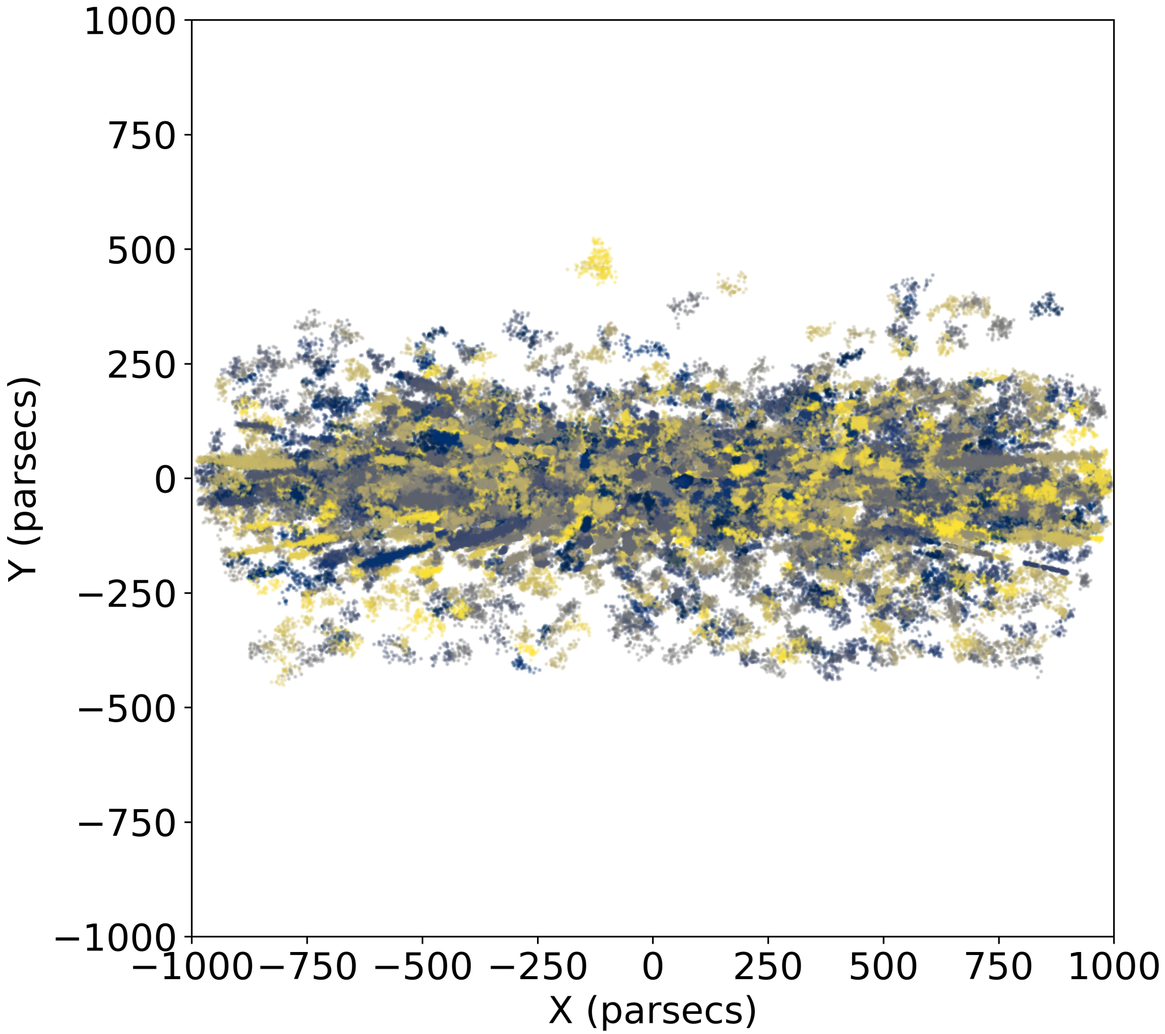
Clustering Results - HEADSS



- Slicing a 2D sample of the data reveals the regions.
- Using the HEADSS stitching capabilities optimally merges the regions.
- After stitching we identify ~3000 candidate stellar clusters and co-moving groups.

Stitched Results





Removing Unsuitable Clusters

- Kounkel & Covey (2019) estimate 5-10% of clusters are contamination.
- To identify these, we study the clusters in Colour - Magnitude space.
- Hough Transformations identify the edges of known population features.

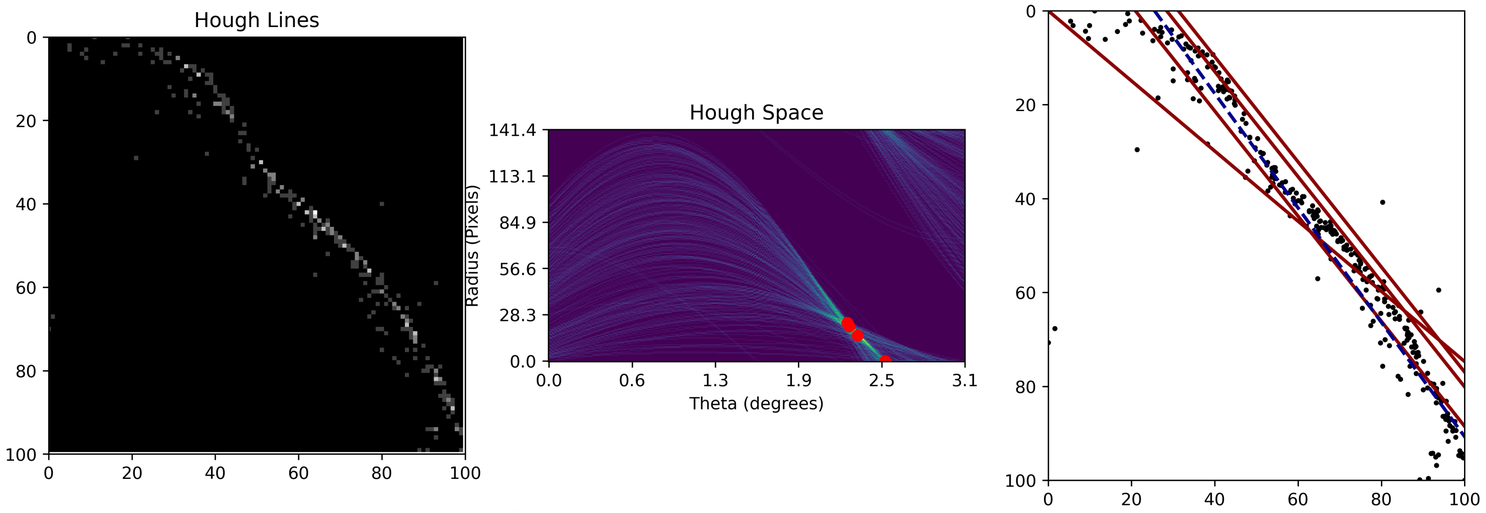
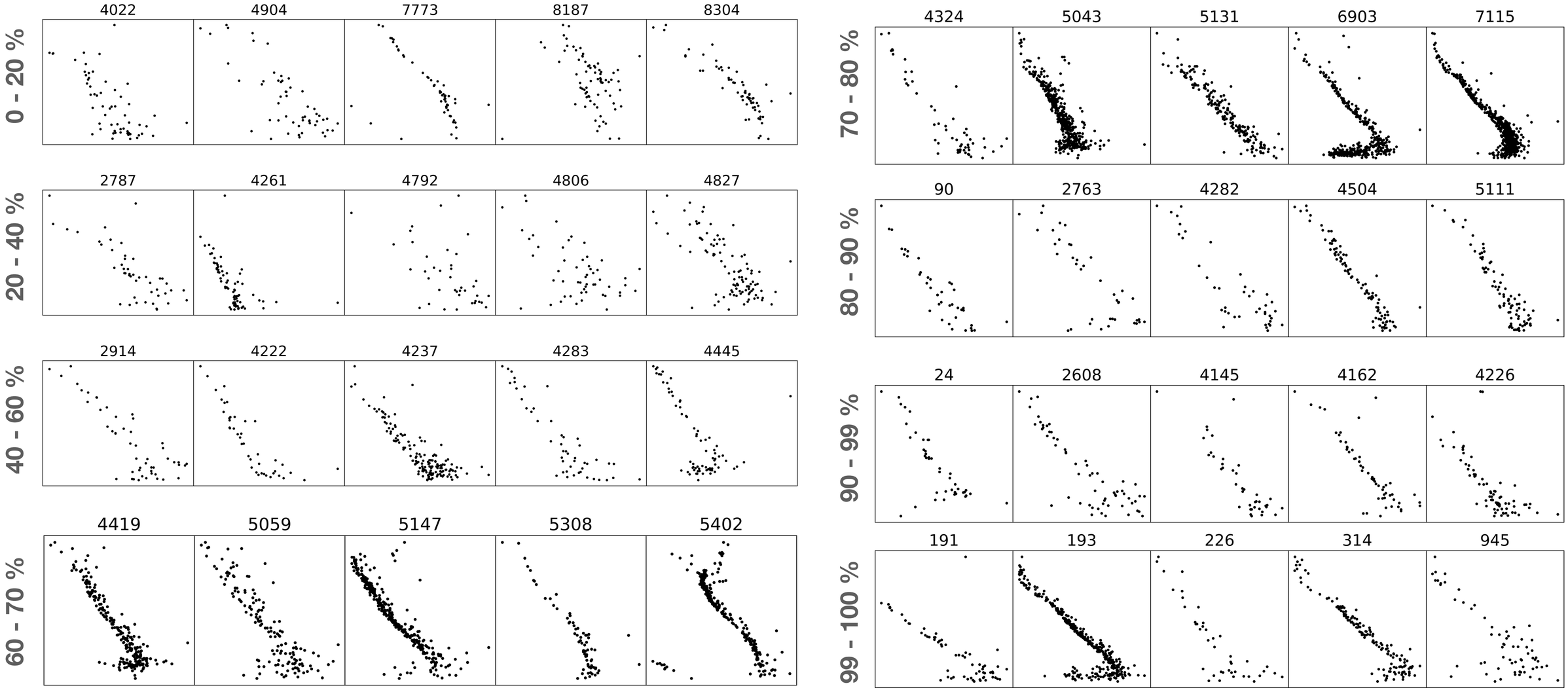


Fig: Example stellar cluster in Colour - Magnitude space (left), Hough space (Middle), finally, colour - magnitude space with identified hough lines displayed (right)

Active Learning Results



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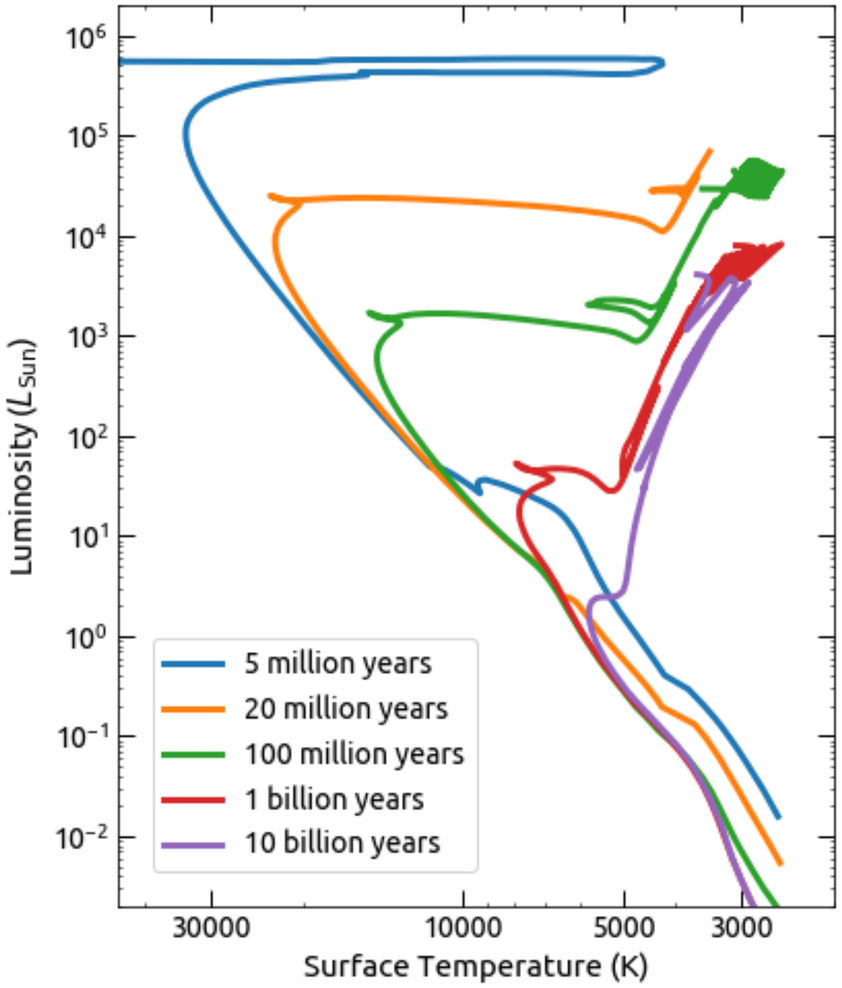
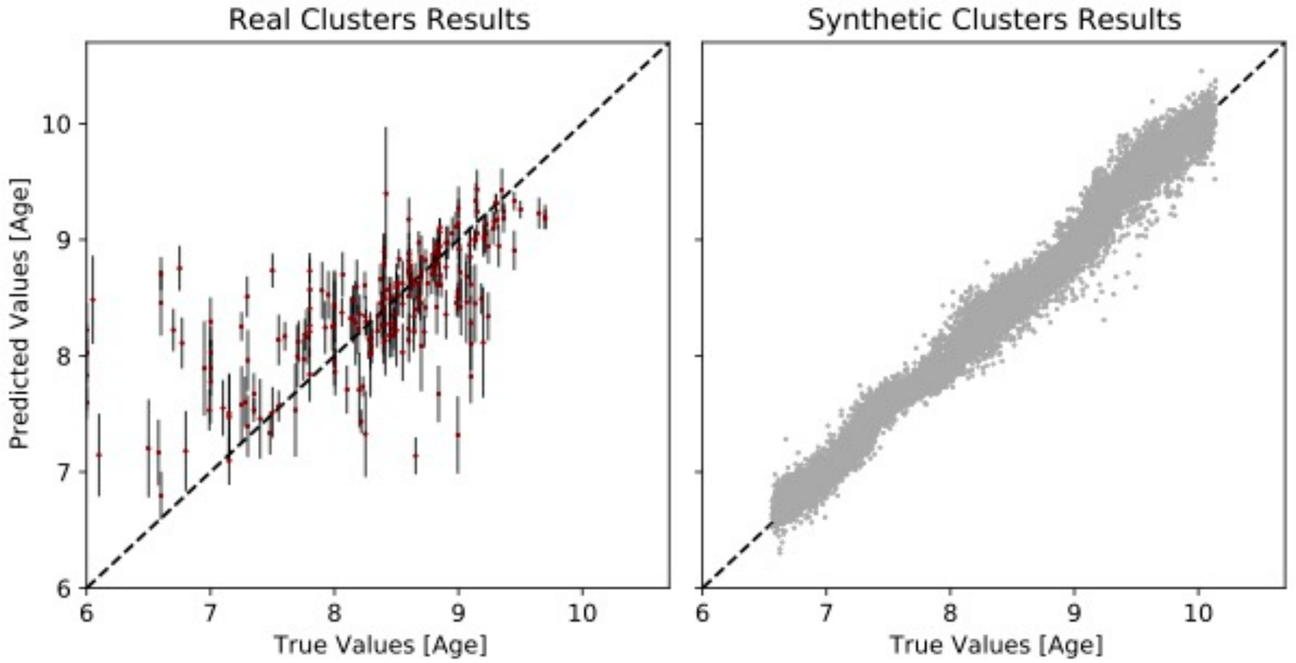
Ageing Clusters



- The lifetime and magnitude of a star is related to it's mass.
- Using this relation it is possible to age clusters by identifying the Main Sequence turn off mass.
- Typically, this is done through Bayesian fitting of isochrones, however this is computationally heavy.
- In this project we have developed a Neural Network to estimate the cluster ages.

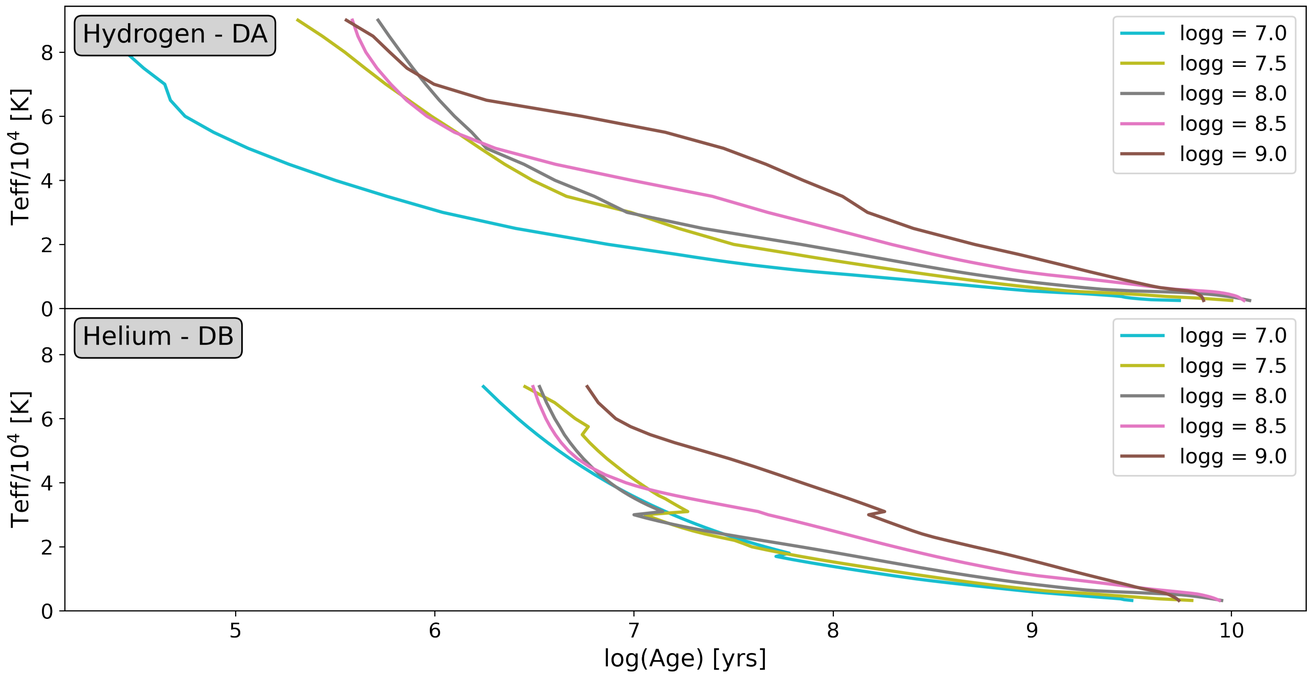
Ageing Clusters - Results

- The clusters are sampled causing larger scatter in the results.
- Less accuracy for younger clusters due to sparse stellar population of high mass stars.
- The earliest WD stars will have progenitor masses $\sim 8M_{\odot}$, thus clusters less than ~7.5 dex will not contain any WD stars.



All ages are in Dex.

White Dwarf Cooldown Models



- Cooldown models provided by: Bergeron et al.*
- Complications through unusual events such as Crystallisation interfere with cooldown curves.
- Small surface area allowing them to radiate over vast timeframes.
- There is currently a debate about whether or not White Dwarfs are truly inert bodies.

*** Models available: https://www.astro.umontreal.ca/~bergeron/CoolingModels/**

The IFMR..

Conclusion

- We have (almost) developed a scalable approach to creating the Initial-Final Mass Relation of White Dwarf stars.
- Introduced a scalable and repeatable method for clustering large datasets on limited resources through HEADSS.
- Eagerly await the final IFMR results in the coming weeks…

Thank you for listening.

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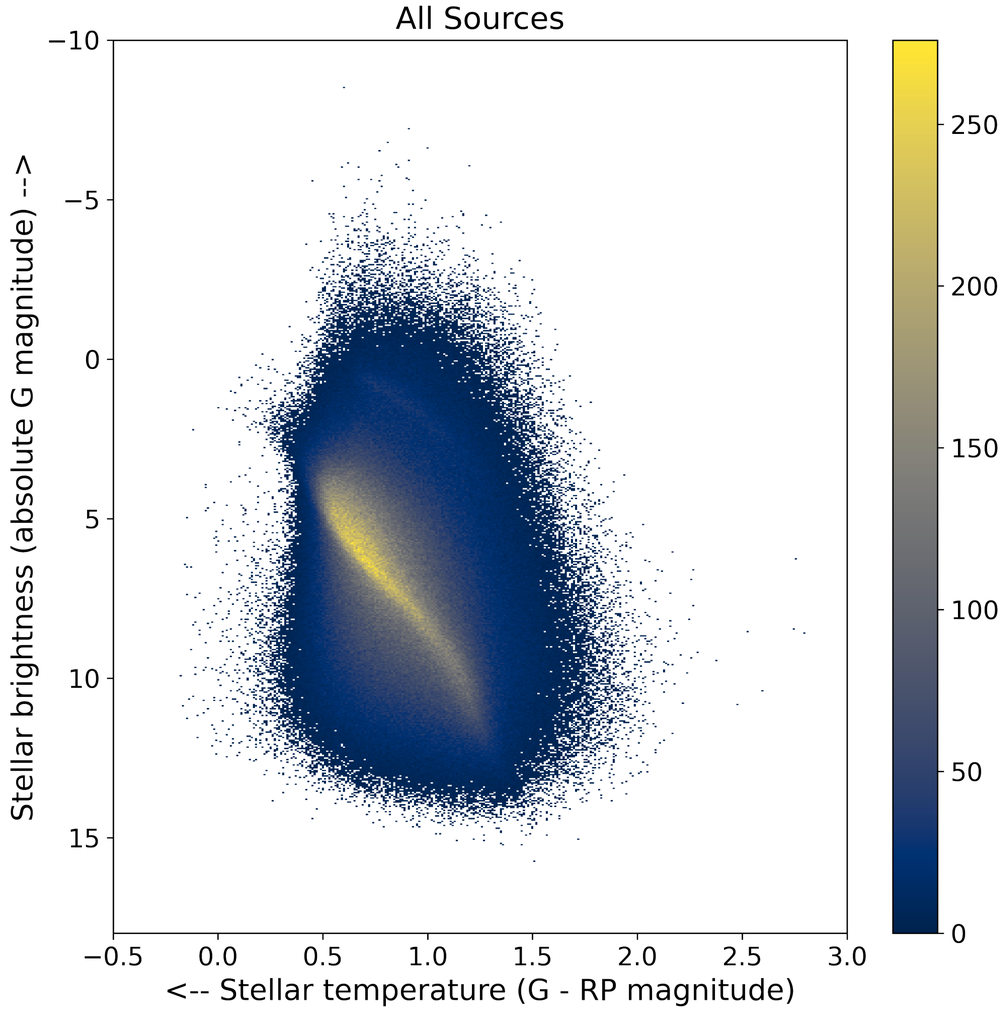
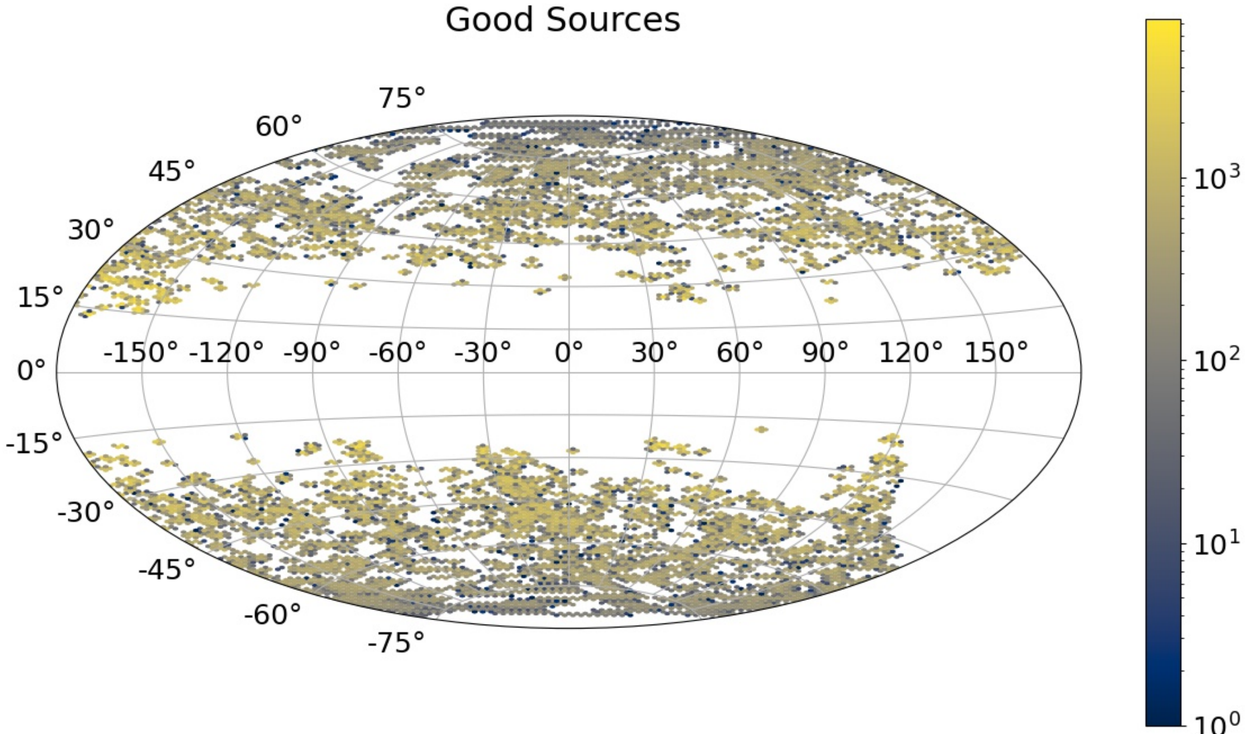
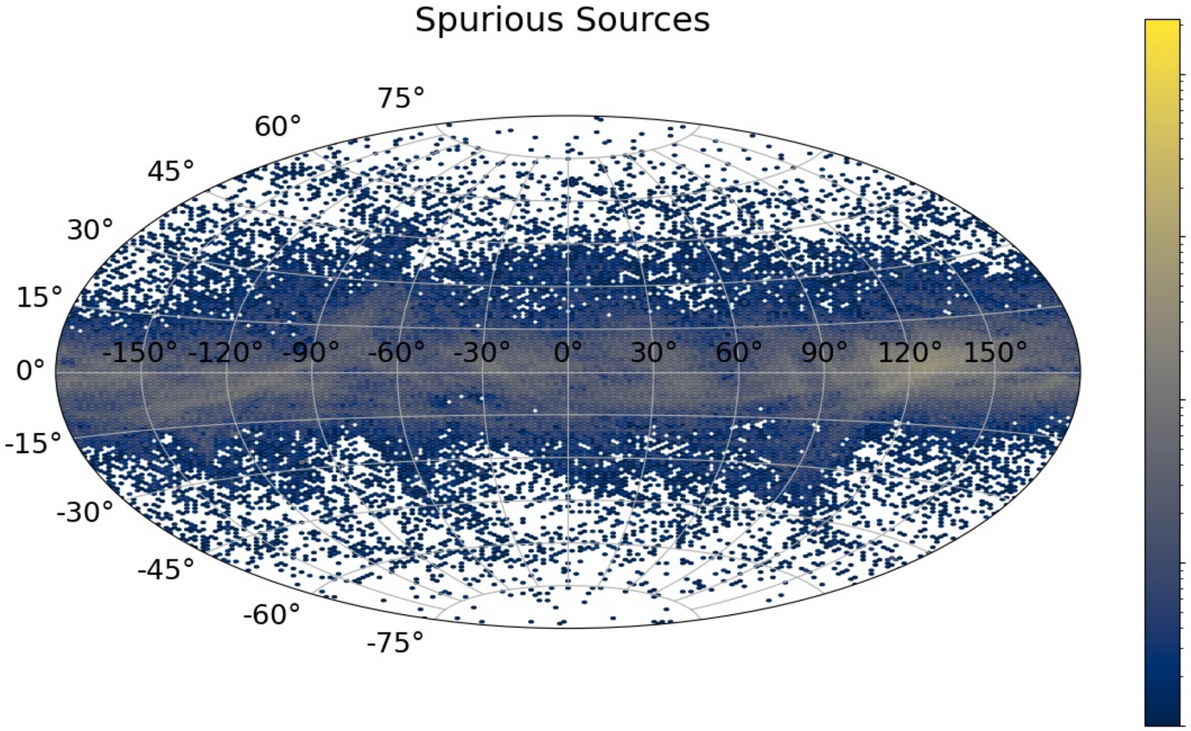
Removing Spurious Sources



- Need to remove spurious astrometric sources to accurately cluster the sources.
- Initial spurious sources are defined as: parallax over error < -4.5.
- A ML model is trained using the above as a training set of spurious sources.

Spacial Distribution of QC Training Data





- Good data is defined as data from HEALpix pixels that contain no bad data points.
- Bad data points is defined as any source with significantly negative values: parallax_over_error < -4.5.

Removing Spurious Sources

- Our model analyses objects within 3kpc
- Due to their lack of brightness, we find no examples of the WD population beyond 1kpc.
- After our model is applied, the expected structure in the HR diagram returns.
- In contrast, spurious sources show no physical structure.