Optimizing the ALMA Research Proposal Process with Machine Learning

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Agenda

- About ALMA
- Project Aim
- Project Significance
- Data Discussion
- Methods
- Summary and Findings
- Limitations and Assumptions
- Future Work

ALMA Observatory

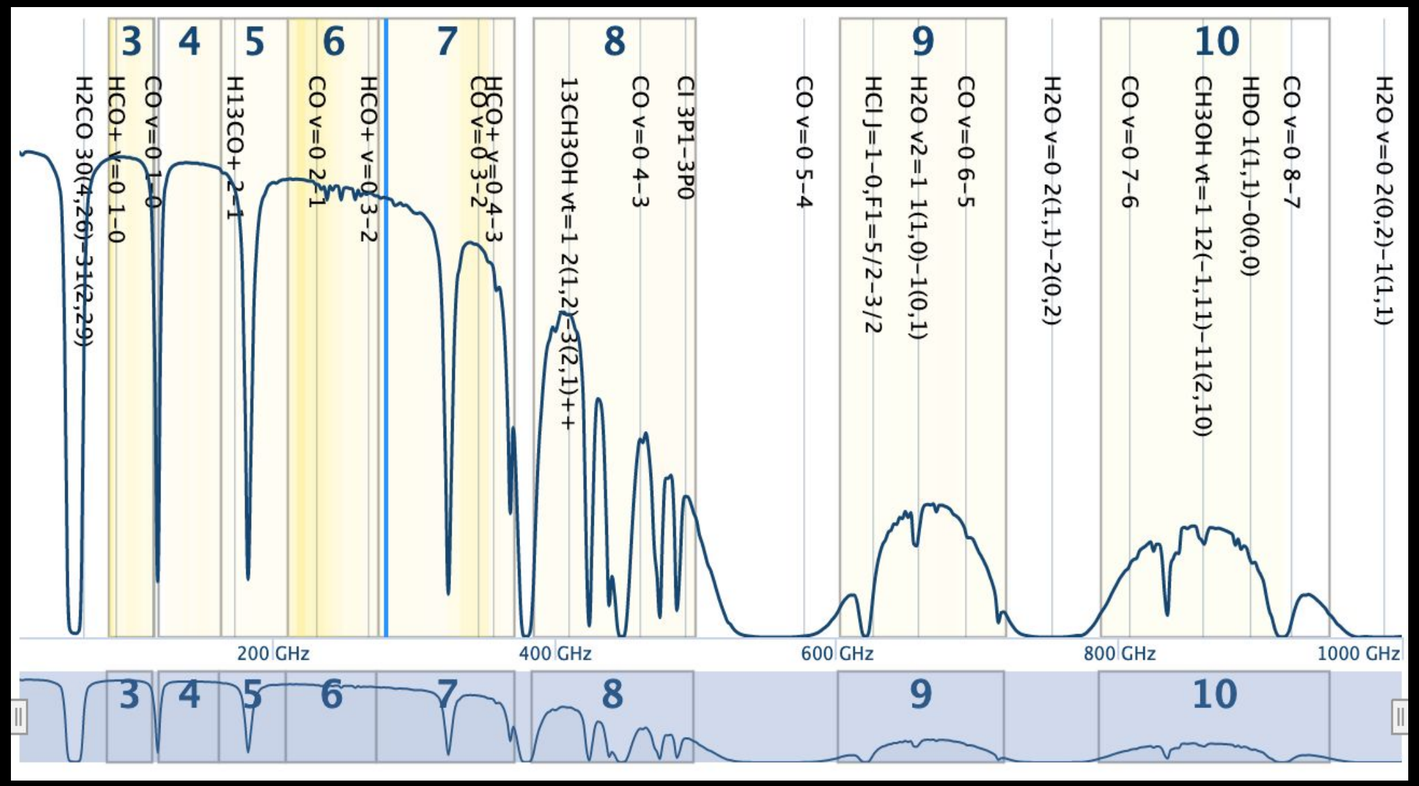
- The ALMA Observatory is located in the Atacama Desert in northern Chile
- The state-of-the-art radio telescope array consists of 66 high-precision antennas that observe electromagnetic radiation outside of visible light

Project Significance

- ALMA is open to anyone for use, based on a proposal process
- Reduce the time and effort required for researchers to prepare proposals.
- Our work will help the astronomy community by simplifying the technical aspects of proposal writing, leading to more precise and effective observations

Data Discussion

- Two types of projects:
  - Line and Continuum
- Line projects require specific measurement setup



Line Measurements

Target Variable

Project Title and Abstract

Predictor Variable

4,586

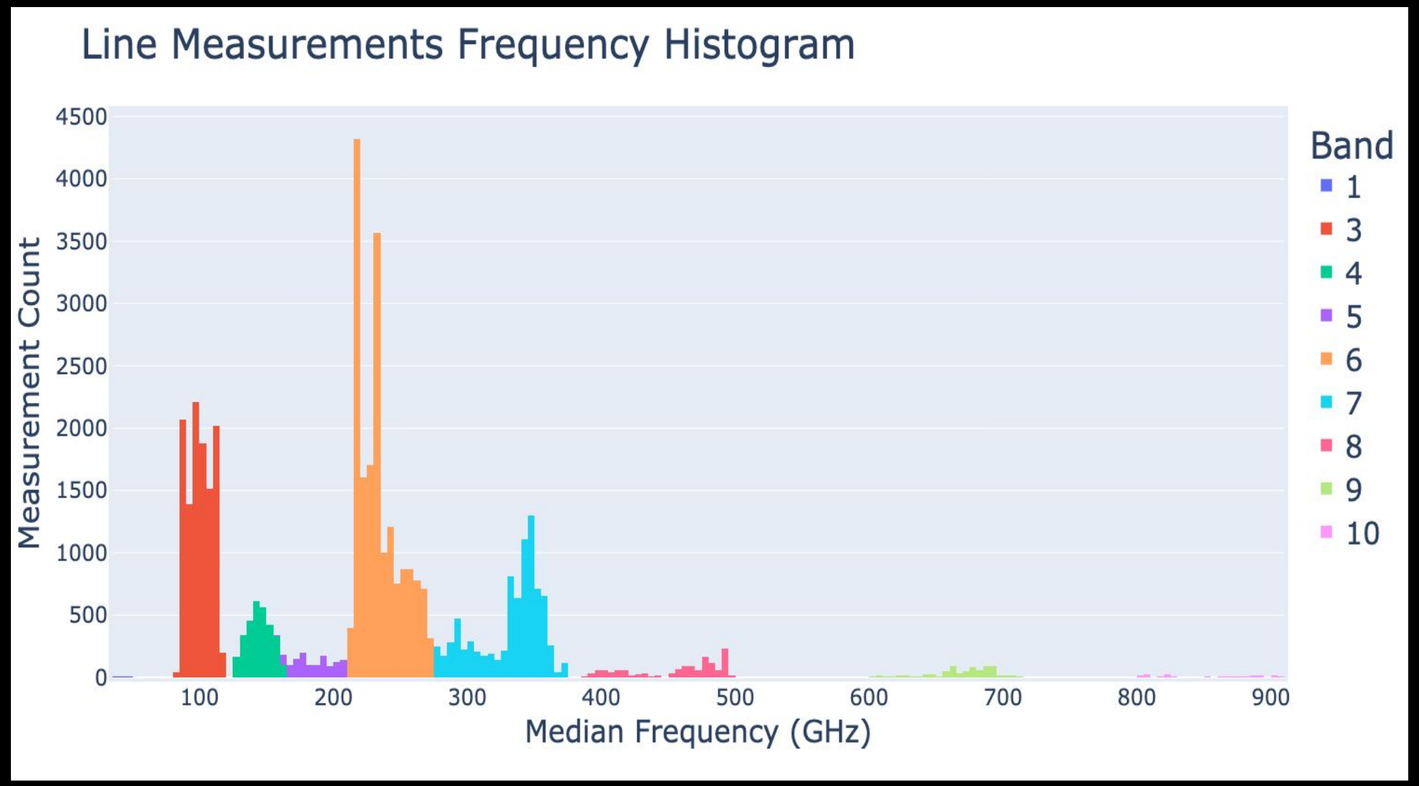
Previous Projects

67,439

Total Measurements

Data Discussion Cont.

- Distribution of measurements across bands show that the vast majority exist in band 3 and 6 and in the lower frequency ranges



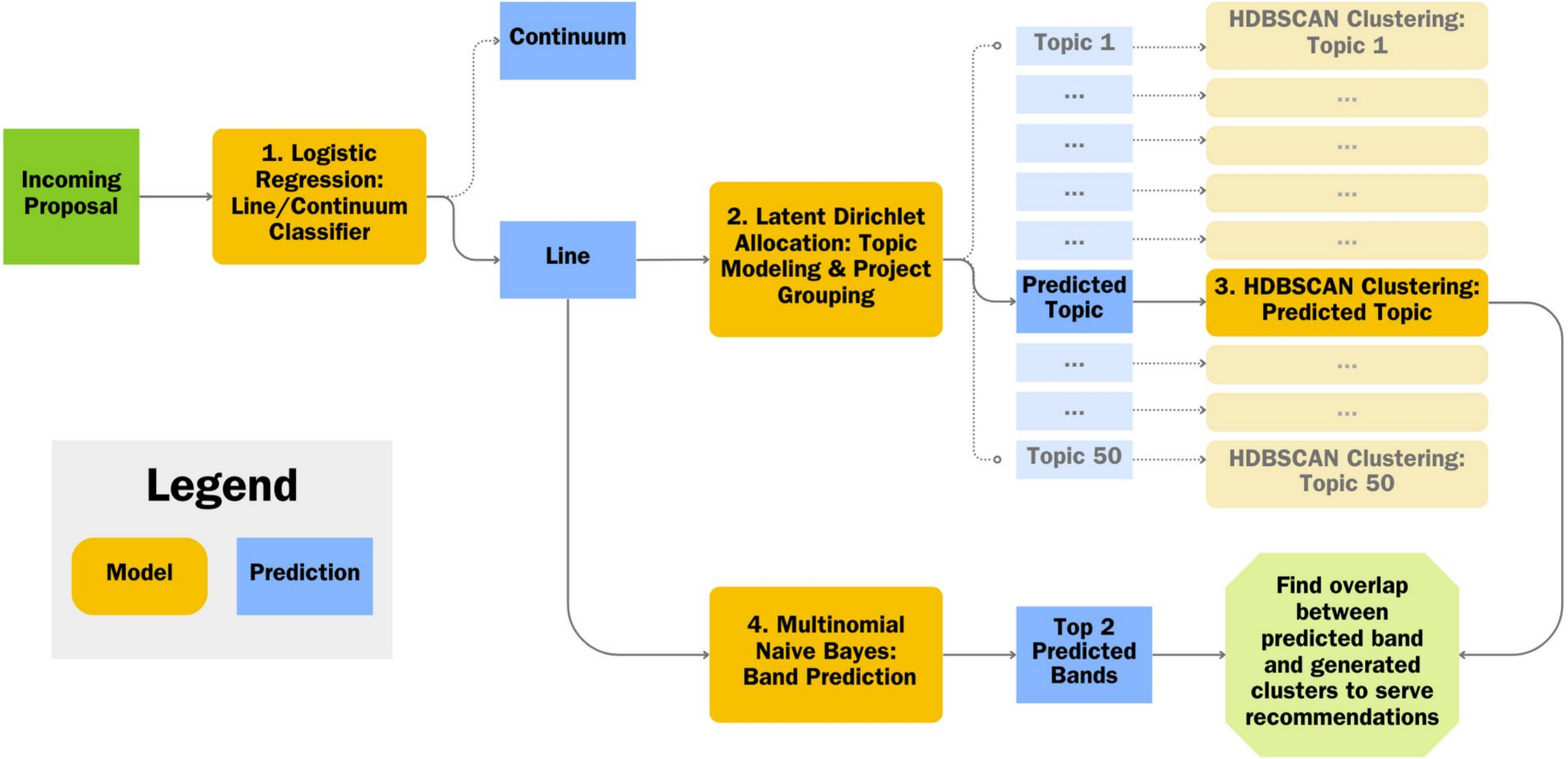
3,628
Line Projects

75%
Have fewer than 13 measurements

450
Outlier projects have more than 26 measurements

82%
Have measurements in only one band

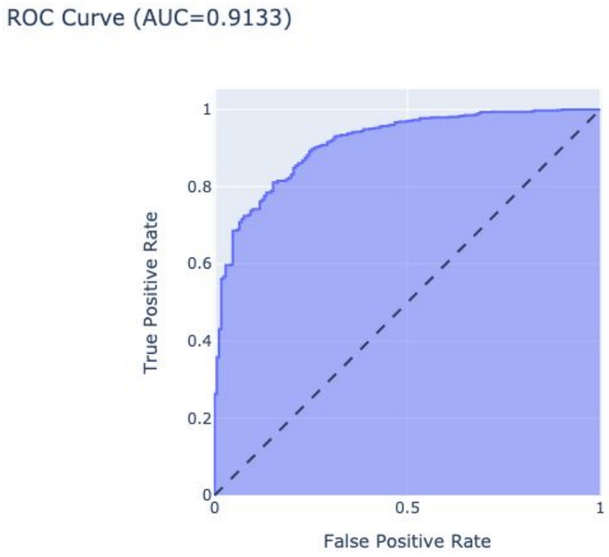
Model Prediction Pipeline



Project Classification: Logistic Regression

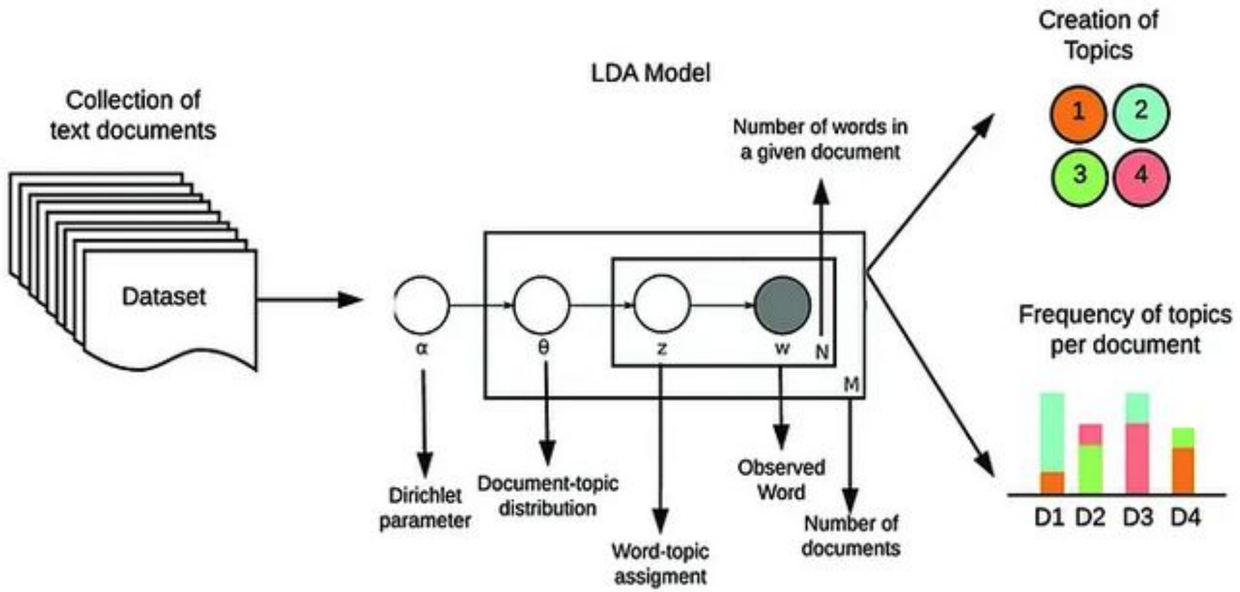
- Vectorize title and abstract using TF-IDF
- Vector used as features to classify a project as either line or continuum
- Only projects with line observations are of interest to us
- Accuracy of 90.02%
- Correctly predicted line 96.41% of the time
- Correctly predicted continuum 59.42% of the time

	Predicted Continuum	Predicted Line
True Continuum	104	71
True Line	26	699



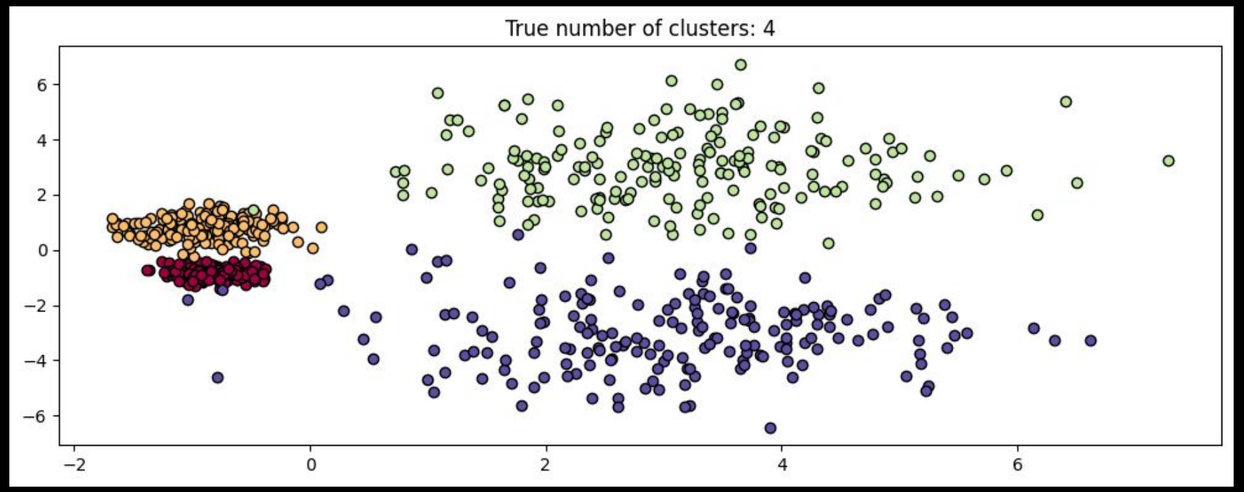
02 Project Grouping: LDA

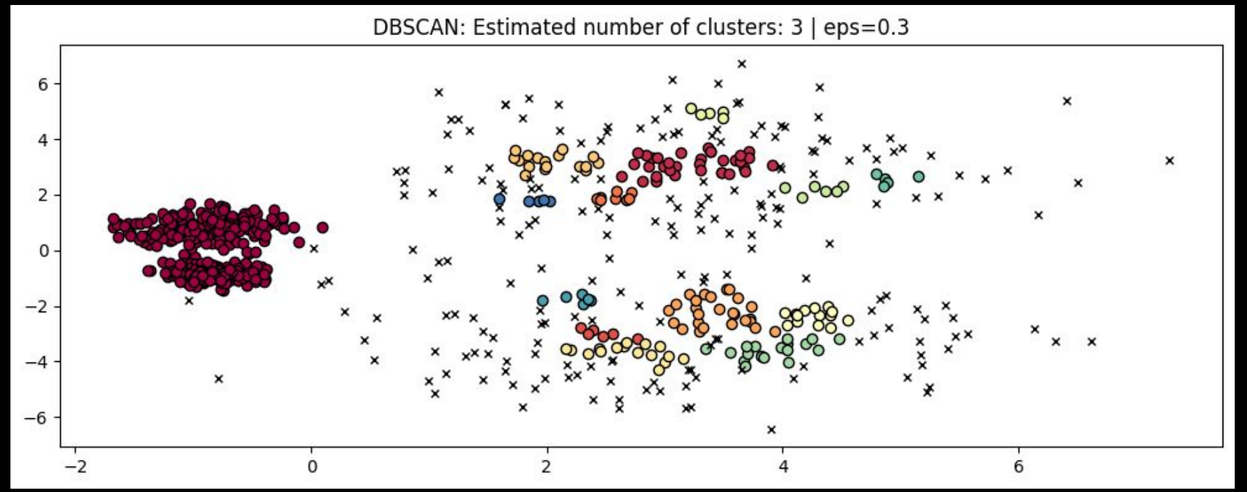
- Generate 50 topics
- Group projects into topics generated by LDA
- Projects are assigned to their “max topic”
- Topic 25 most heavily weighted words: *bar, gmcs, molecular, spiral, galaxy*
- Topic 37 most heavily weighted words: *mass, chemical, chain, protostars, wccc*

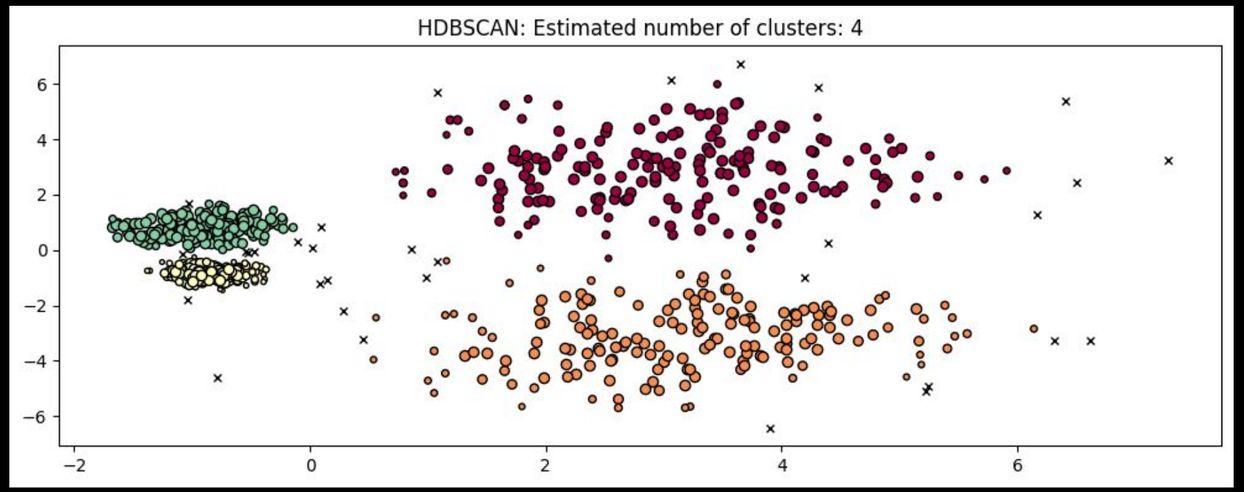


Measurement Clustering: HDBSCAN

- Cluster measurements for projects within each LDA topic
- Accounts for different densities in measurement distribution
  - Keeps clusters representative of overall measurement distribution
- Ensure clusters are not too large
- Average noise 14.59 ± 0.05%
- Score clusters with count of measurements and projects


True number of clusters: 4


DBSCAN: Estimated number of clusters: 3 | eps=0.3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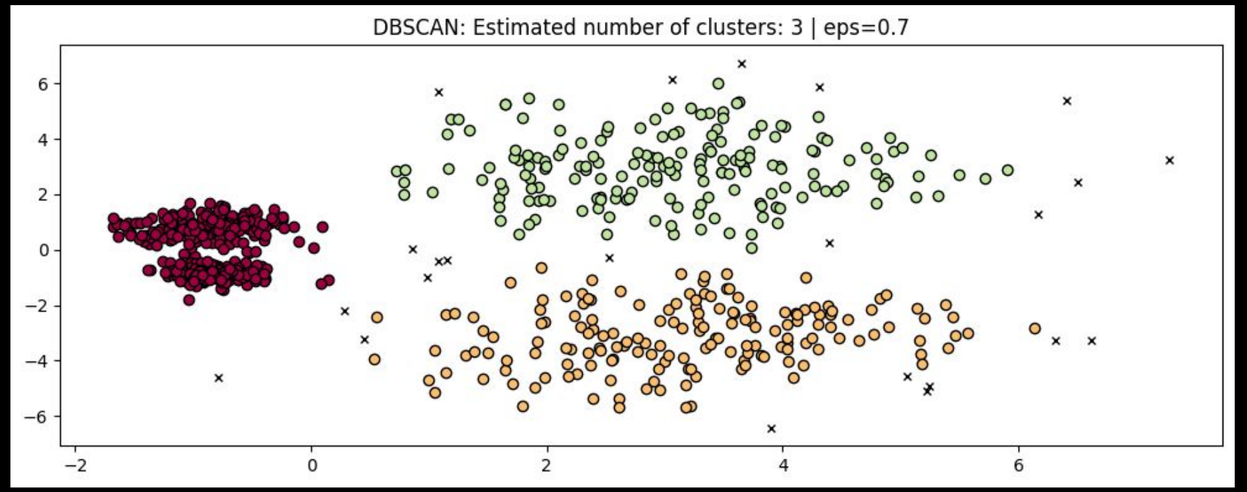
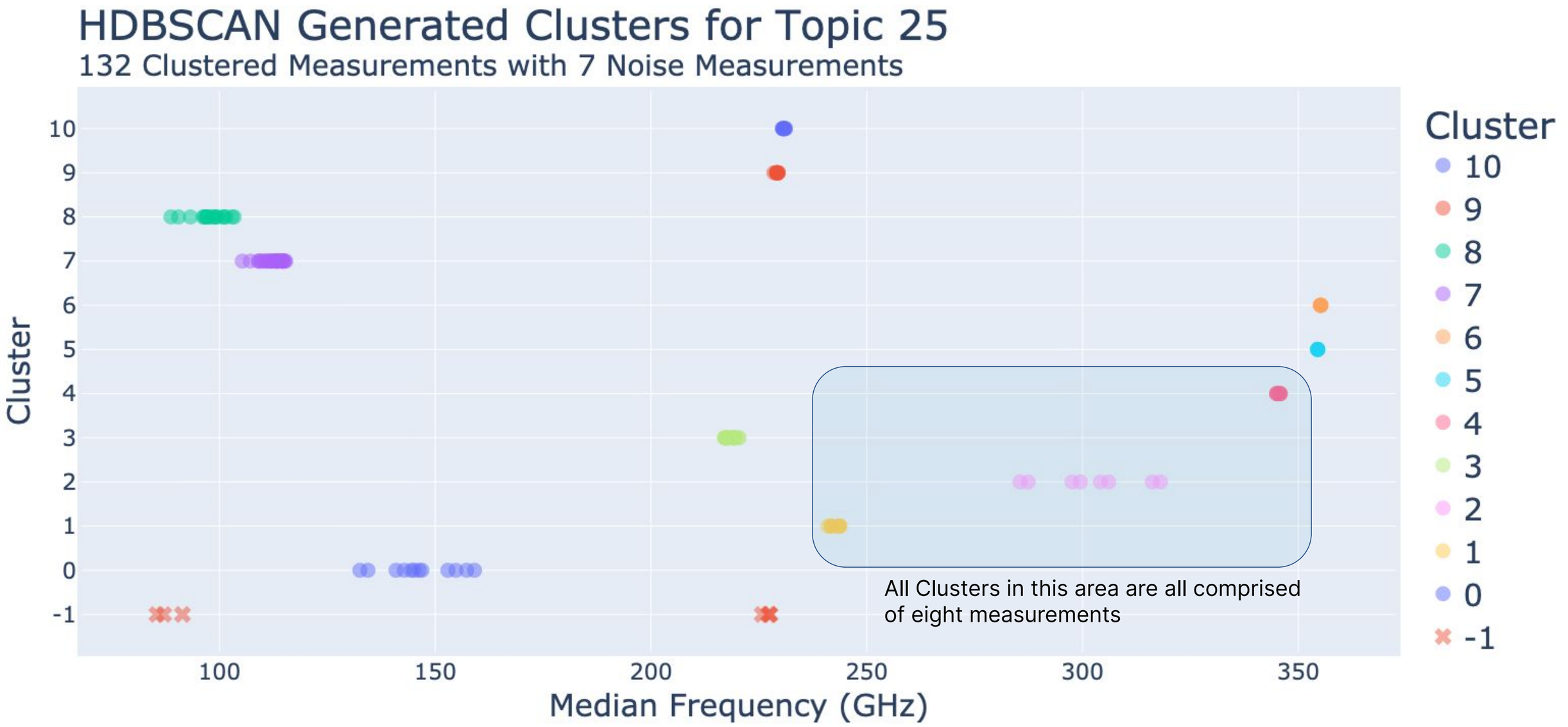
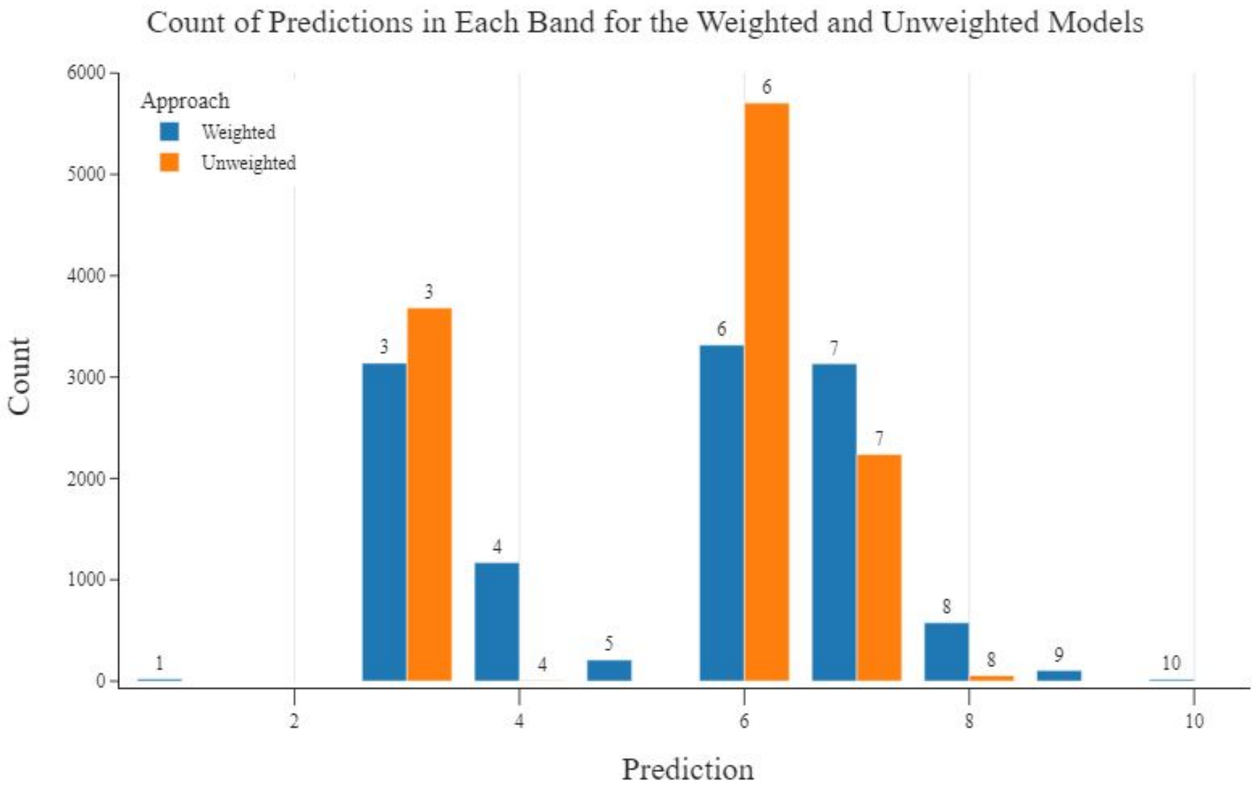

DBSCAN: Estimated number of clusters: 3 | eps=0.7


HDBSCAN Generated Clusters for Topic 25
132 Clustered Measurements with 7 Noise Measurements
Cluster
10
9
8
7
6
5
4
3
2
1
0
-1
100
150
200
250
300
350
Median Frequency (GHz)
All Clusters in this area are all comprised of eight measurements

Band Prediction: Multinomial Naive Bayes

- **Text Preprocessing:**
  - Remove stop words
  - Lemmatize text
    TF-IDF Vectorization
- **Unweighted Model:**
  - Fit the data according to the percent of instances of each band
- **Weighted Model:**
  - Specify prior probabilities to improve accuracy for less common bands

Unweighted Results	Weighted Results
73.55%	69.70%



05 Combined Method

- Combine HDBSCAN and Band Classification (weighted) to filter HDBSCAN's predictions with Band Classification predictions
- Yields more precise results, predicting fewer and narrower "areas of interest"

Combined Method	
Predicts >= 1 "Area of Interest" for Projects	Measurements Captured per Project
67.17%	44.72%

Project Code	***HDBSCAN* Prediction**	***Band Classification* (*weighted*) Prediction**	***Combined (unweighted)* Prediction**
2017.1.00786.S	Band: [Frequency Range] 3: [89.105 101.005] 3: [109.775 115.160] 6: [213.095 220.395] 6: [227.095 231.490] 7: [355.090 357.225] 7: [344.980 345.180] 7: [345.785 345.815]	Bands: 6 7	Band: [Frequency Range] 6: [213.095 220.395] 6: [227.095 231.490] 7: [355.090 357.225] 7: [344.980 345.180] 7: [345.785 345.815]

Limitations & Assumptions

Limitation

Difficulty measuring success

Limitation

Did not have full research papers to train on

Assumption

All “areas of interest” already exist in the data

Assumption

LDA topics are salient and discriminant

Assumption

Optimal weights were calculated

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Conclusions

- Combined (weighted) process is useful to both
  - Researchers submitting projects to ALMA
  - Proposal reviewers
- Provides valuable insights
  - Understanding of project proposals
  - Recommendations for proposed projects

Thank You

Special thanks to:
Our mentor, Antonios Mamalakis
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Citations

LDA Graphic:

M. Bakrey, "All About Latent Dirichlet Allocation (LDA) in NLP," Medium, 01-Nov-2020. [Online]. Available: https://mohamedbakrey094.medium.com/all-about-latent-dirichlet-allocation-lda-in-nlp-6cfa7825034e. [Accessed: 26-April-2024].

HDBSCAN Example Graph Code:

"HDBSCAN clustering with sklearn," Scikit-learn, [Online]. Available: https://scikit-learn.org/stable/auto_examples/cluster/plot_hdbscan.html#sphx-glr-auto-examples-cluster-plot-hdbscan-py. [Accessed: 26-April-2024].