# **Technical Report: *Sambandha* Multi-messenger Correlator**

## **Overview**

This submission presents a sophisticated multi-messenger astronomical event correlation system - **Sambandha** that efficiently matches events across different detection modalities (**gravitational waves**, **gamma-ray bursts**, **neutrinos**, etc.) using advanced **spatial-temporal indexing** and **adaptive scoring algorithms.**

**vercel link :** [**https://space-landing1.vercel.app/**](https://space-landing1.vercel.app/)

**python server git repo :** [**https://github.com/madanVedansh21/kd-tree\_-ctrl-hack**](https://github.com/madanVedansh21/kd-tree_-ctrl-hack)

**web server git repo :** [**https://github.com/madanVedansh21/space-landing**](https://github.com/madanVedansh21/space-landing)

## **Key Technical Innovations**

### **Scalable Data Processing Architecture**

* **Intelligent Column Detection:** Automatically maps variable **CSV formats** to standardized schema using flexible column name matching
* **Robust Data Cleaning:** Handles missing data gracefully with **timezone-aware temporal processing** and comprehensive data validation
* **Dynamic Schema Adaptation**: Supports diverse input formats while maintaining consistent internal representation

### **High-Performance Matching Engine**

* **KD-Tree Spatial Indexing**: Implements efficient spherical coordinate matching using **3D Cartesian conversion** and **chord distance calculations**
* **Binary Search Temporal Queries**: Utilizes sorted time arrays for O(log N) temporal candidate selection
* **Dual-Stage Filtering**: Combines spatial and temporal pruning to **minimize computational complexity from O(N²) to near-linear scaling**

### **Adaptive Correlation Scoring**

* **Multi-Component Analysis**: Evaluates temporal, spatial, and signal significance components with exponential decay functions
* **Dynamic Weight Normalization**: Automatically adjusts scoring weights based on available data components. Formula used:**normalized\_weight[component] = weight[component] / sum(weights[available\_components])**
* **Reliability Assessment**: Incorporates data completeness into confidence calculations
* **Missing Data Estimation**: Provides intelligent fallback calculations when primary metrics are unavailable

### **Advanced Astrophysical Modeling**

* **Angular Separation Calculations**: Precise spherical geometry computations with error circle overlap detection
* **Signal Strength Normalization: Z-score** based significance assessment across heterogeneous datasets
* **Position Error Estimation:** Dataset-specific error modeling for incomplete positional data

## **Performance Characteristics**

* Efficient cross-dataset correlation discovery
* Scalable to large astronomical survey datasets
* Configurable temporal and spatial search windows
* Comprehensive output with schema-compliant CSV export
* Detailed statistical analysis and quality metrics