

Predicting the limits of the ELT

Defensio

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Outline

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- Data storage
- Cluster
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- Milky Way Potential
- Cone of vision
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- Source Detection

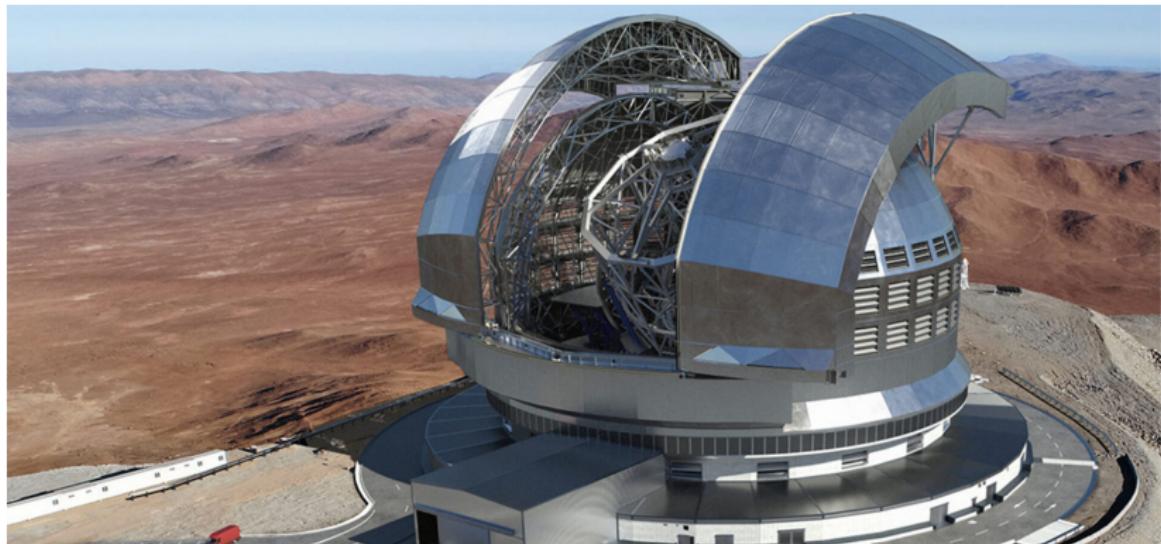
Goals

Primary objective

Estimate reliability limit for future IMF studies in the galactic centre using the ELT!

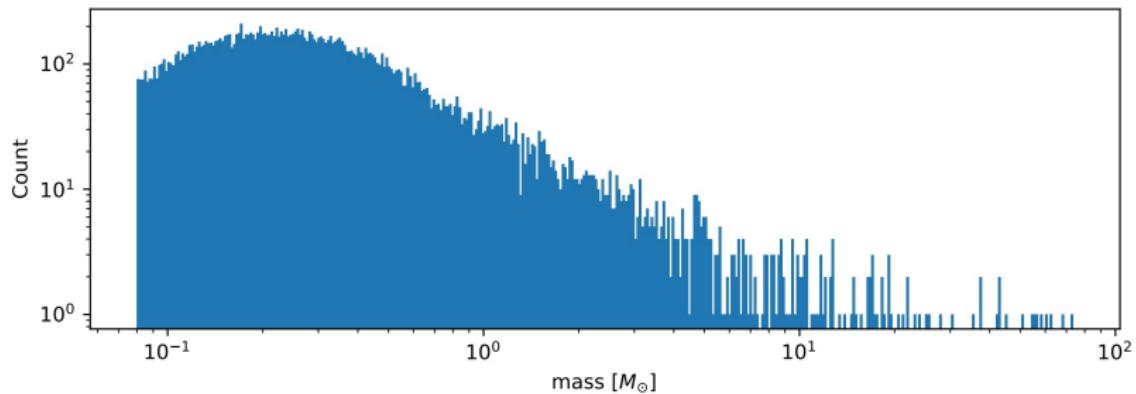
... what?

ELT

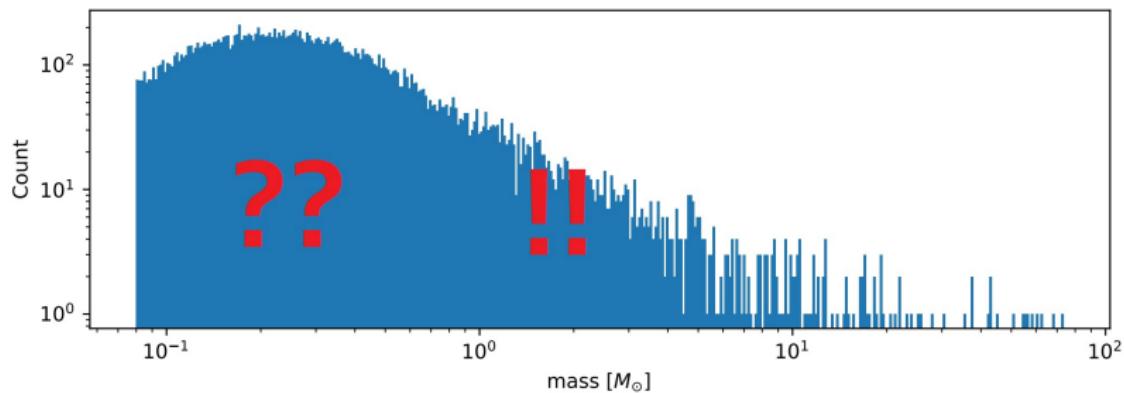


<https://cdn.eso.org/images/banner1920/telescope-dome-landing.jpg>

IMF



Reliability Limit

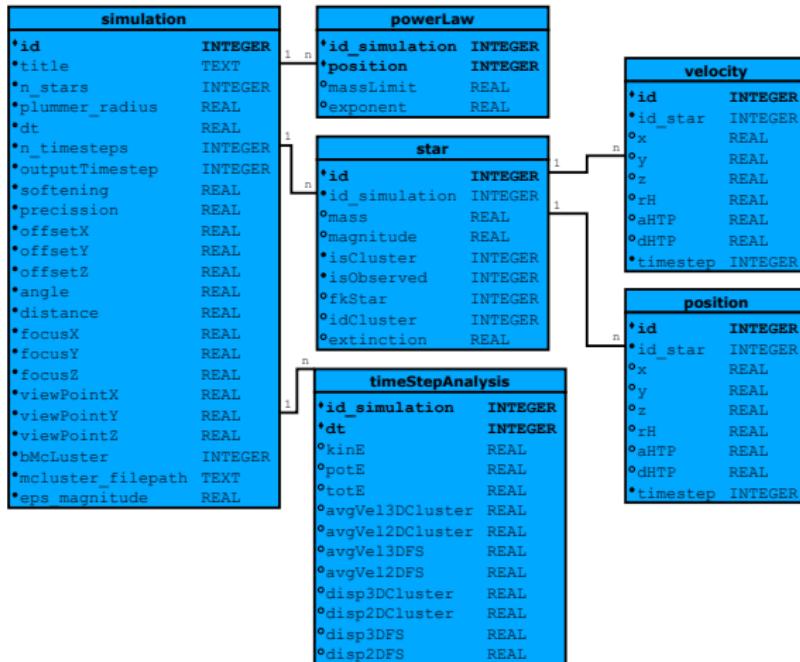


Motivation

- Universal IMF?
- estimate number of lower-mass stars
- understand star formation process
- N-body simulation with $N \gg 1$
- Clustering of time-dependent data

Action Plan

1. Simulate stars
2. Observe stars
3. Analyze
4. Measure performance



Parameters

McLuster by Andreas Kuepper with Kroupa, P. & Baumgardt, H.

- Plummer density profile
- virial equilibrium
- Kroupa IMF $0.08 M_{\odot}$ to $100 M_{\odot}$
- Metallicity in range 0.5 - 2 solar
- No binaries
- N 1.3k - 40.4k

1. Issue with large N

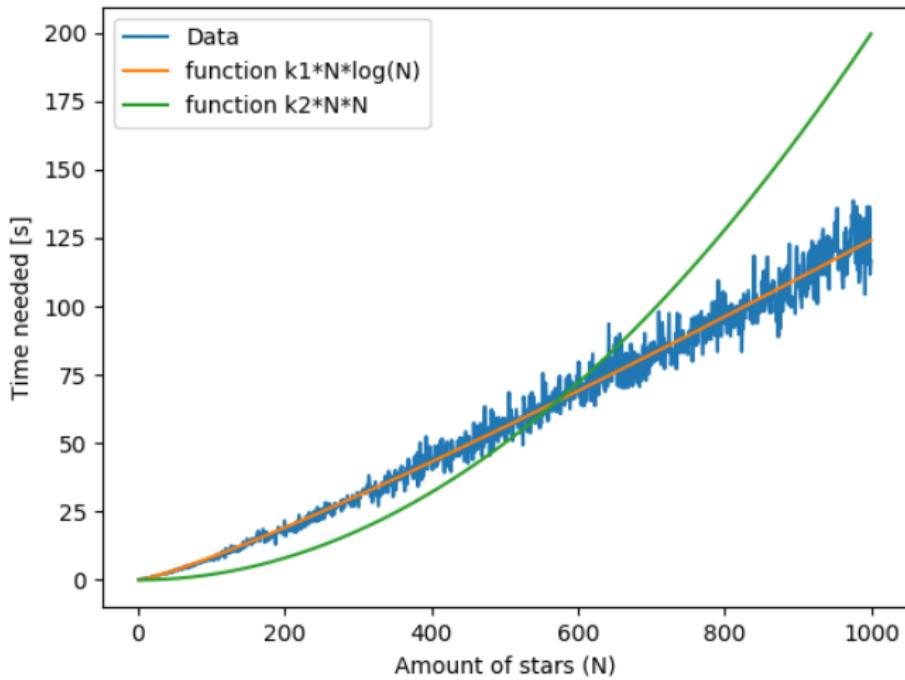
Direct summation $O(N^2)$

Barnes-Hut Algorithm $O(N \log(N))$

- approximate with macro particles
- $\frac{width}{distance} < \theta_{max}$

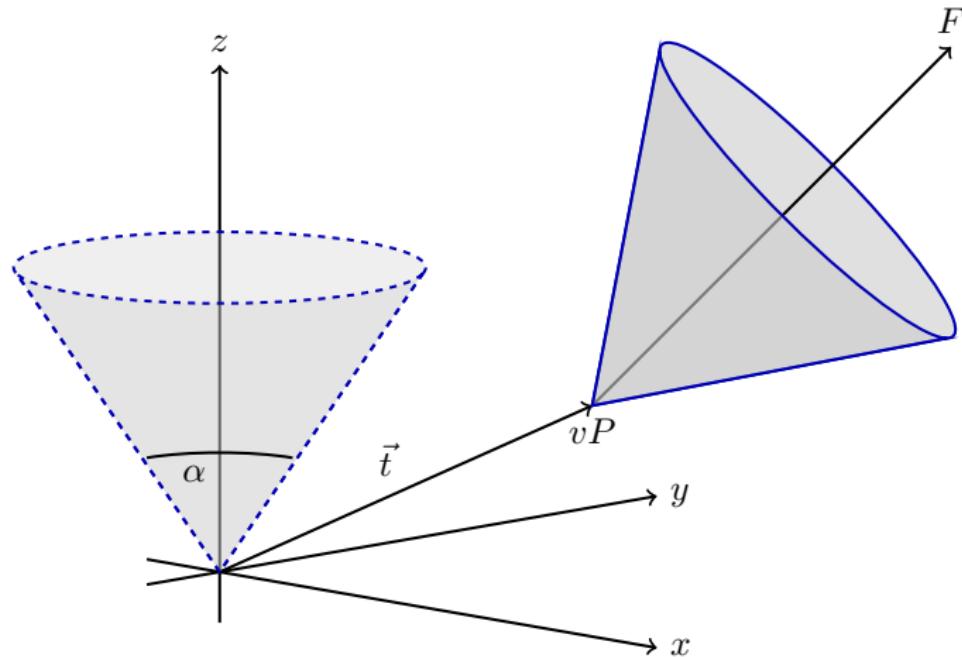


<http://arborjs.org/docs/img/example-space.png>



Multi-component axis-symmetric potential

- components
 - Black hole: Keplerian potential
 - Disk: Miyamoto Nagai potential
 - Bulge: Hernquist potential
 - Dark matter halo: Navarro–Frenk–White potential
- needed for
 - Force from analytic derivatives
 - Initial conditions for field stars



Initialize mass (1)

Total mass inside code

$$M = \int_{-R}^R \int_{-\sqrt{R^2 - x^2}}^{\sqrt{R^2 - x^2}} \int_{\frac{h}{R}r}^h \rho \left(\mathbf{T} \cdot \begin{pmatrix} x \\ y \\ z \end{pmatrix} \right) dz dy dx$$

R cone base radius

T transformation matrix

h cone height

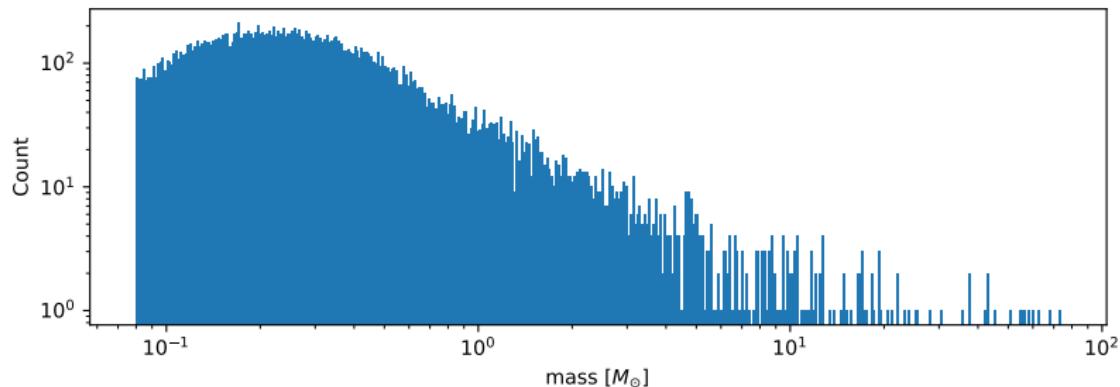
Integration

- GSL: GNU Scientific Library
- Gauss-Kronrod quadrature

Initialize mass (2)

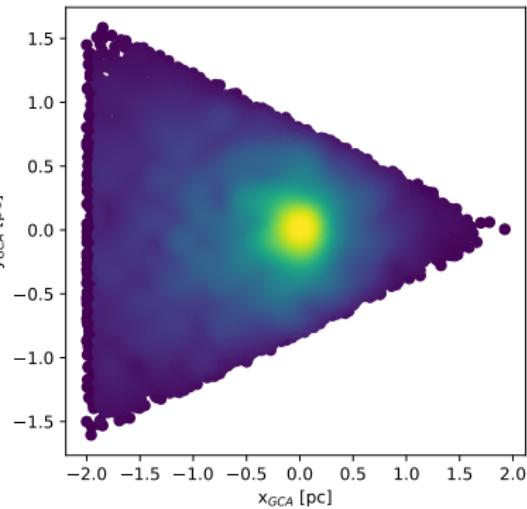
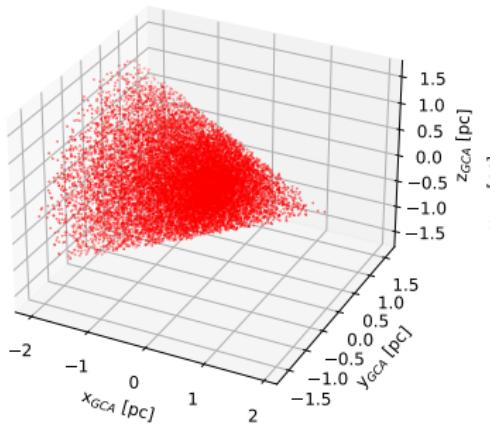
Sample mass functions

- rejection sampling
- inverse transformation sampling



Positions

1. uniform distribution
2. transformation
3. rejection sampling

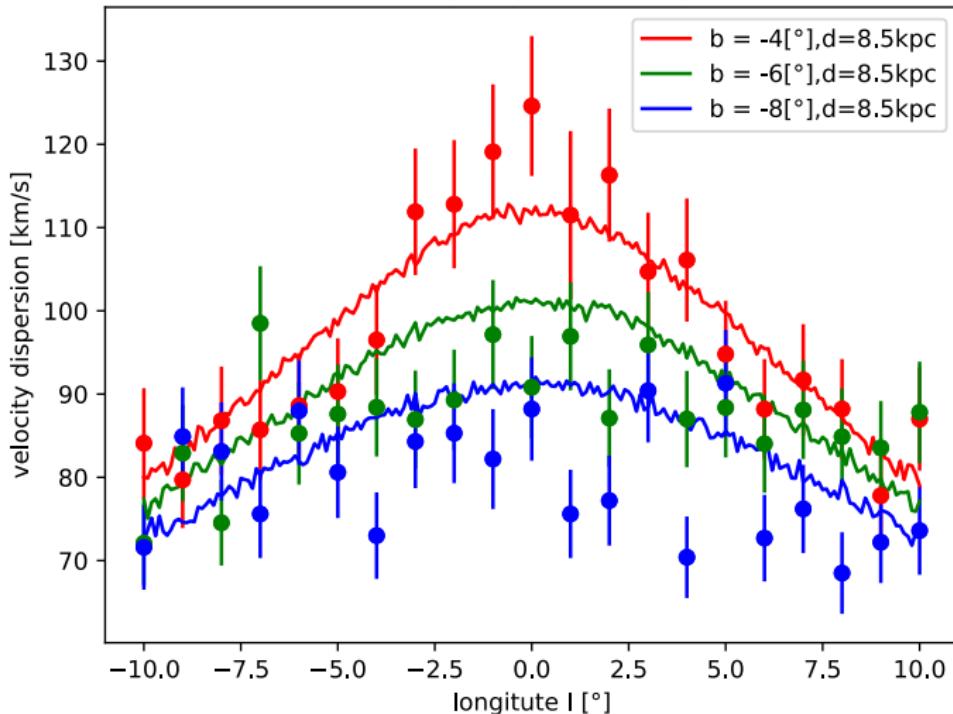


Velocities

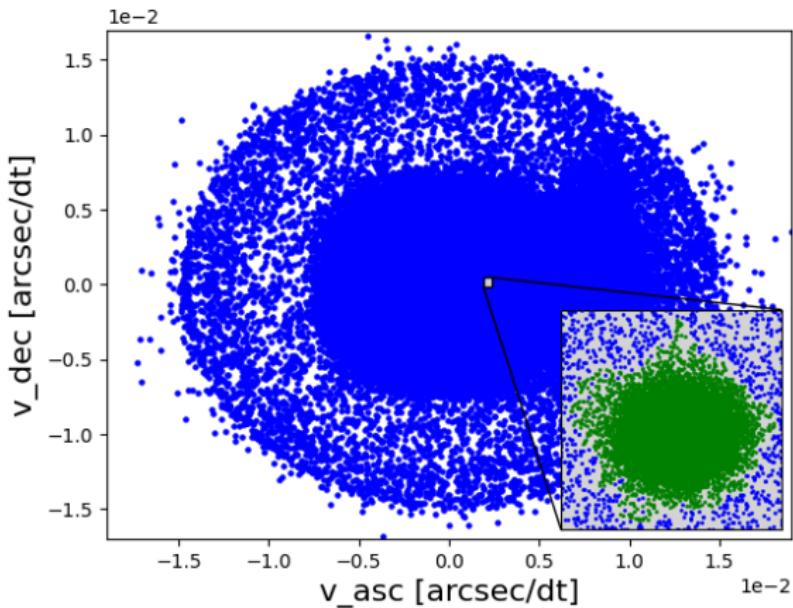
Solve Jeans equations

- Disk
 - Epicyclic Approximation
 - average & dispersion
 - Sampled from Gaussian distributions
- Bulge
 - $\sigma_r^2 = \frac{1}{\rho} \int_r^\infty \rho \frac{\partial \Phi}{\partial r} dr$
 - Lookup table
 - isotropic
 - limited by escape speed

velocity dispersion bulge



1. Integrate equations of motion
 - Euler
 - Velocity Verlet
2. Write to Database every x timesteps
3. Test total Energy



Coordinate Systems

GalPot by Paul McMillan

GCA Galactocentric Cartesian

LSR Local Standard of Rest

HCA Heliocentric Cartesian

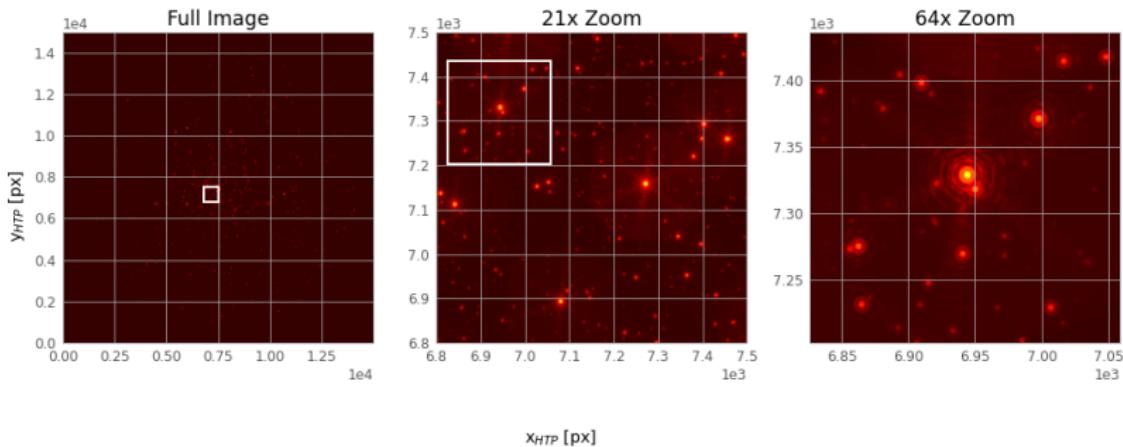
HTP Heliocentric Telescope Polar

ScopeSim by Kieran Leschinski

Spectra

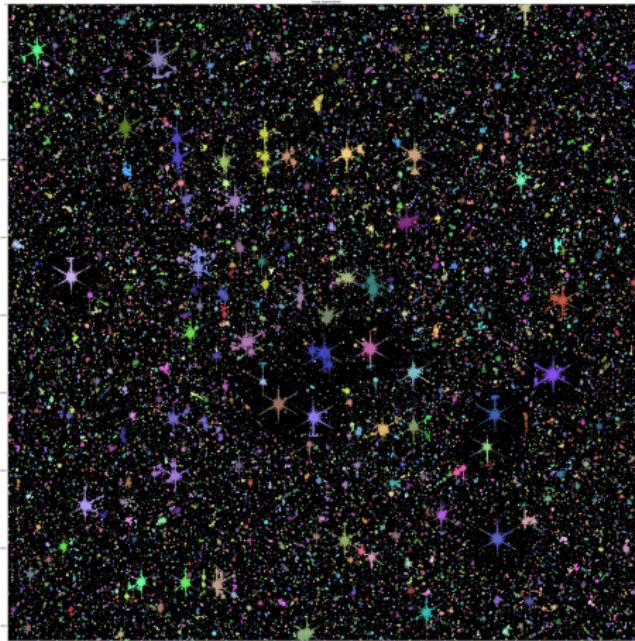
- Spectral type
- Pickles catalogue
- Apparent magnitude
- Extinction
- Weight of spectrum

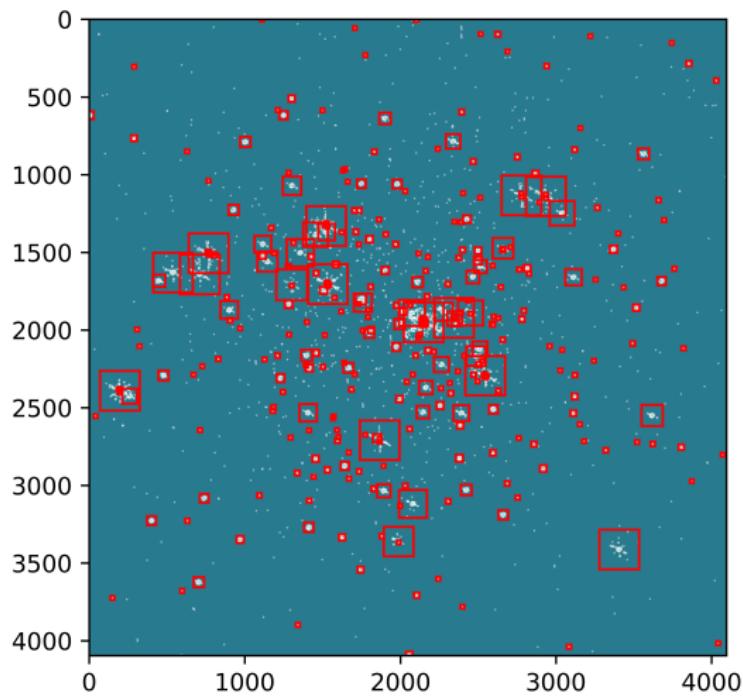
Output FITS files

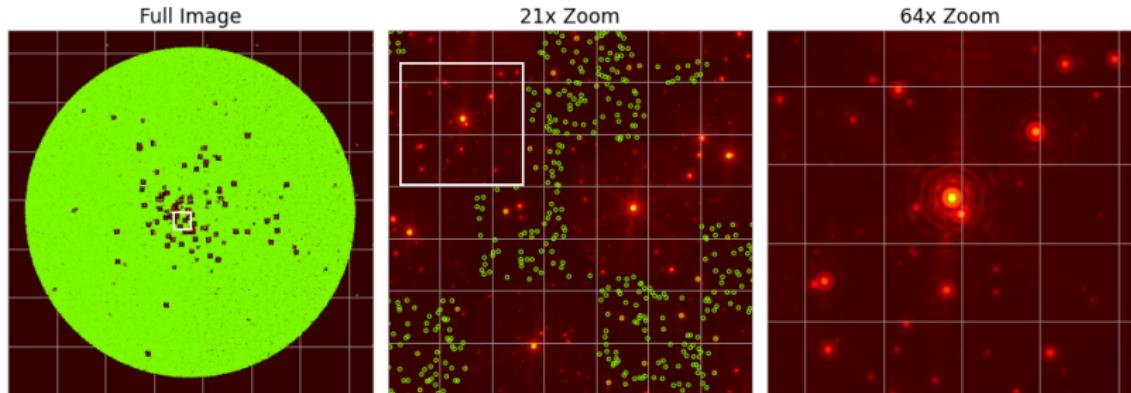


Photutils by Larry Bradley et al.

- DAOStarFinder
 - Threshold
 - 2D Gaussian kernel
 - Roundness
 - Mask
- Image Segmentation
 - Connected pixels
 - Threshold
 - Source Deblending







mlpack by Ryan Curtin et al.

- Map observed stars
 - Range search
- Velocity approximation
 - Nearest-neighbors search
 - max magnitude difference
 - compare with mapping

DBSCAN Algorithm

Density-based spatial clustering of applications with noise

Pros:

- noise
- amount of clusters

F1 Score

$$F_1 = 2 \frac{P \cdot R}{P + R} = \frac{TP}{TP + 0.5(FP + UP + FN)}$$

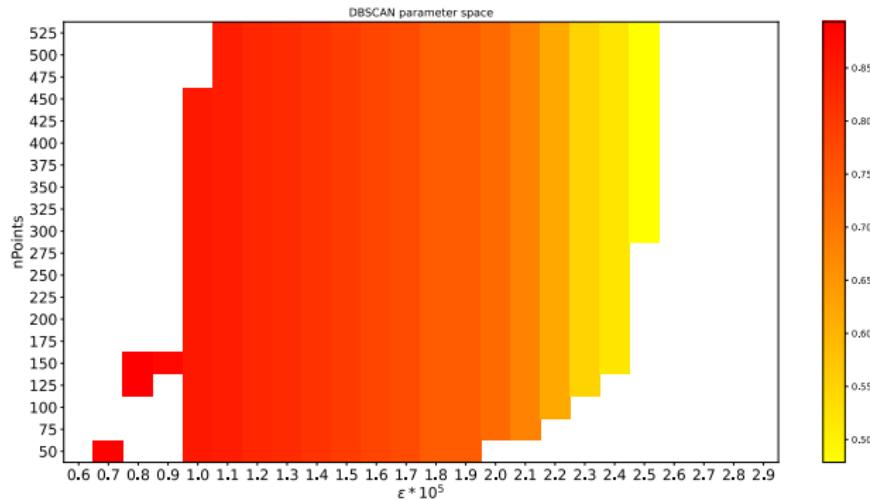
TP correctly classified as cluster star

FP wrongly classified as cluster star

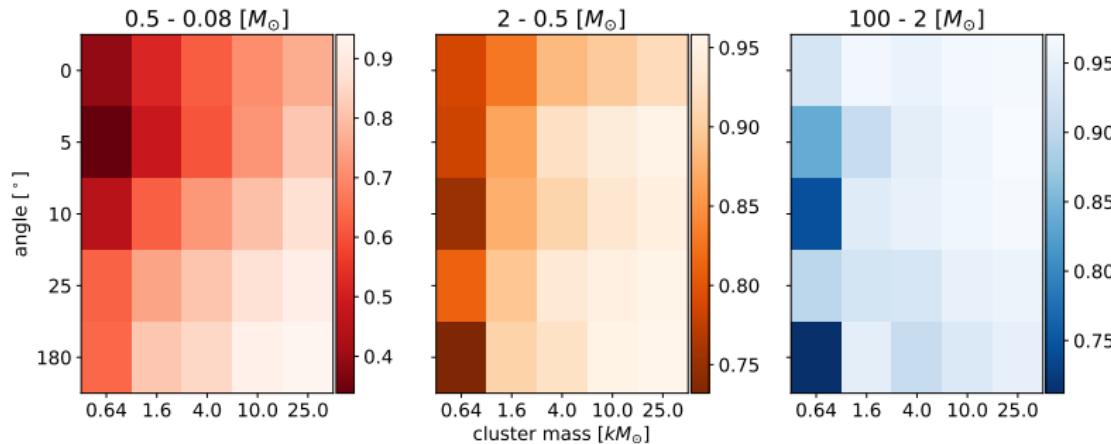
UP not mapped star classified as cluster star

FN wrongly classified as field star

Parameter optimization



Results: F1



Star M _☉	Cluster kM _☉	% Found	F1 Score
<0.5	0.64	41	0.39
<0.5	1.60	40	0.52
<0.5	4.00	40	0.62
<0.5	10.00	35	0.71
<0.5	25.00	28	0.76
0.5 - 2	0.64	81	0.79
0.5 - 2	1.60	80	0.83
0.5 - 2	4.00	76	0.88
0.5 - 2	10.00	63	0.90
0.5 - 2	25.00	54	0.92

