

Predicting the limits of the ELT

Defensio

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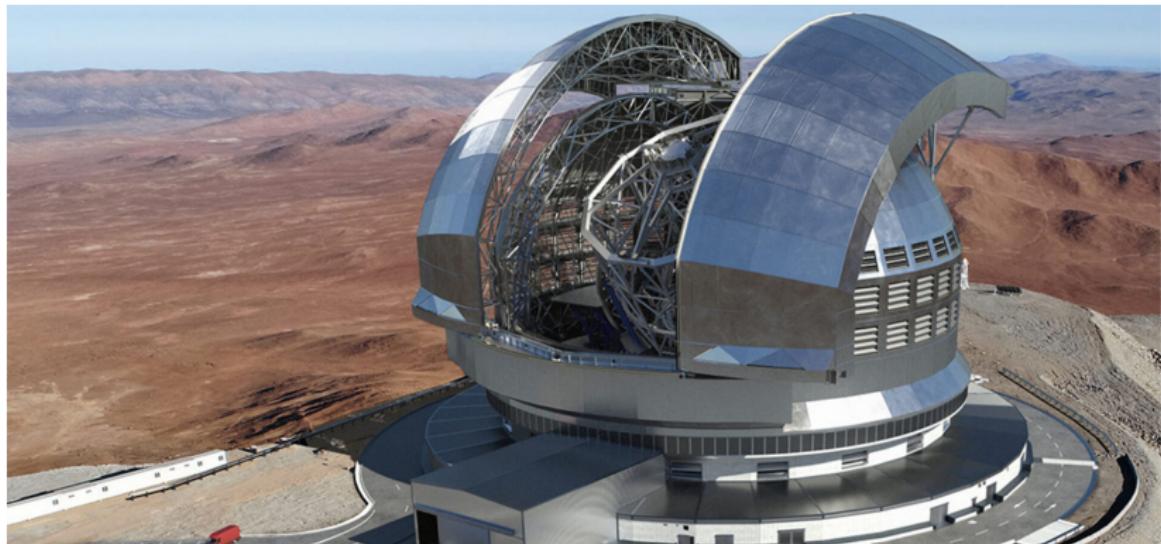
Outline

- 1 Introduction
- 2 Simulation
- 3 Observation
- 4 Analysis

Primary objective

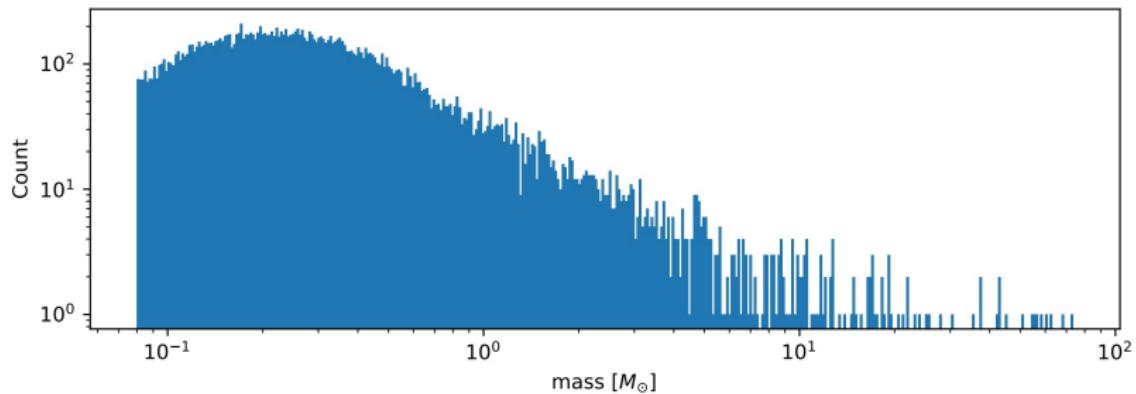
Estimate reliability limit for future IMF studies in the galactic centre using the ELT!

ELT

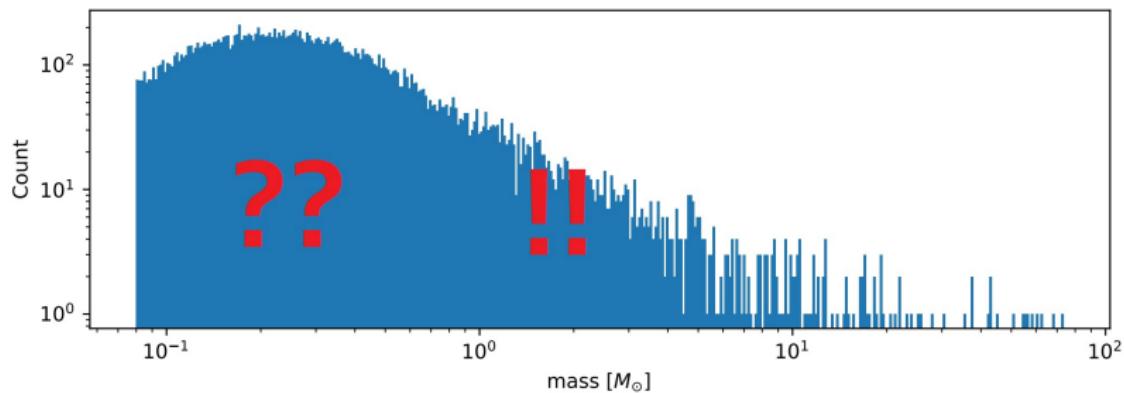


<https://cdn.eso.org/images/banner1920/telescope-dome-landing.jpg>

IMF



Reliability Limit

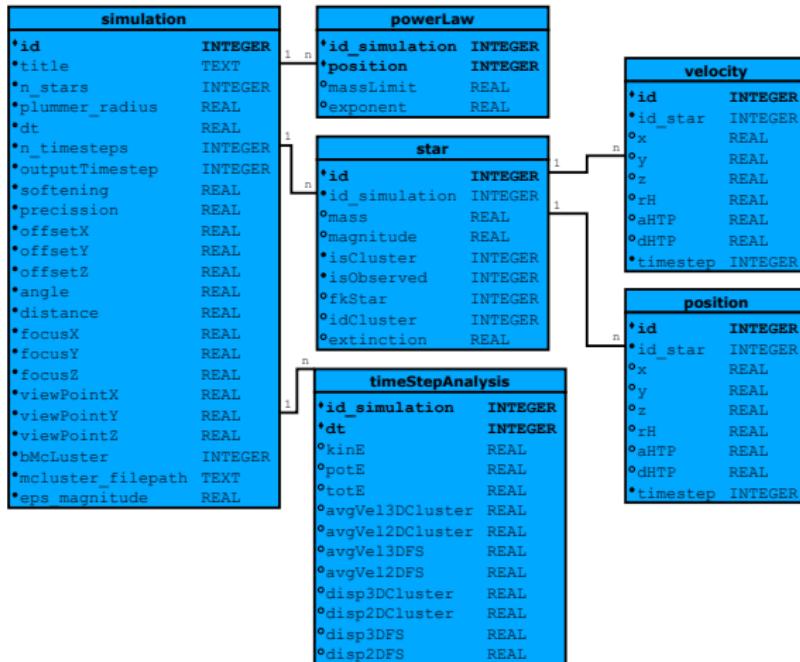


Motivation

- 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 $100 M_{\odot}$
- N 1.3k - 40.4k

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Time integration

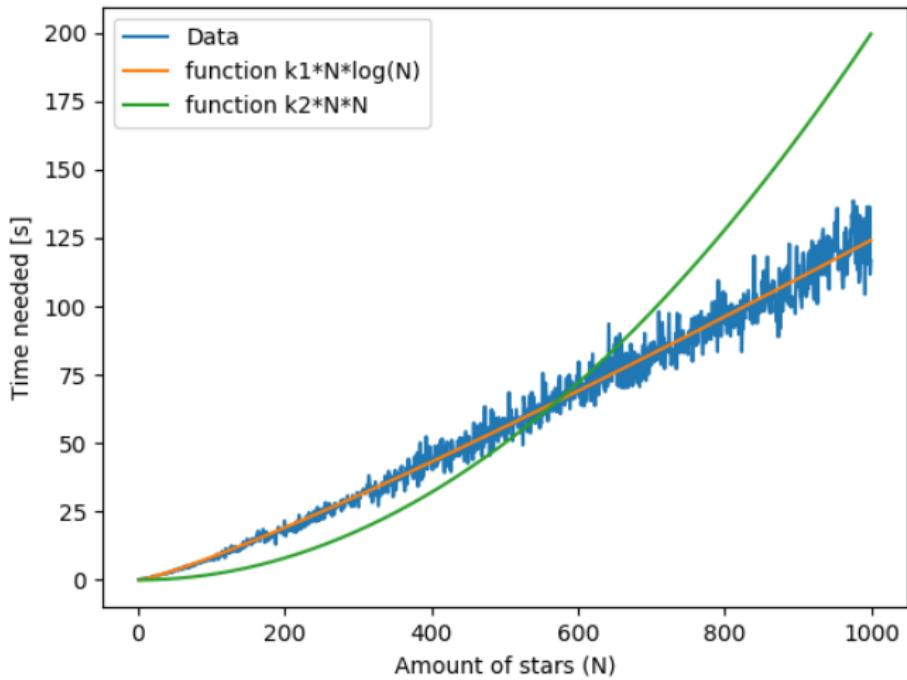
- Direct summation $O(N^2)$
- Barnes-Hut Algorithm $O(N \log(N))$
 - approximate with macro particles
 - $\frac{\text{width}}{\text{distance}} < \theta_{\max}$
- Softening

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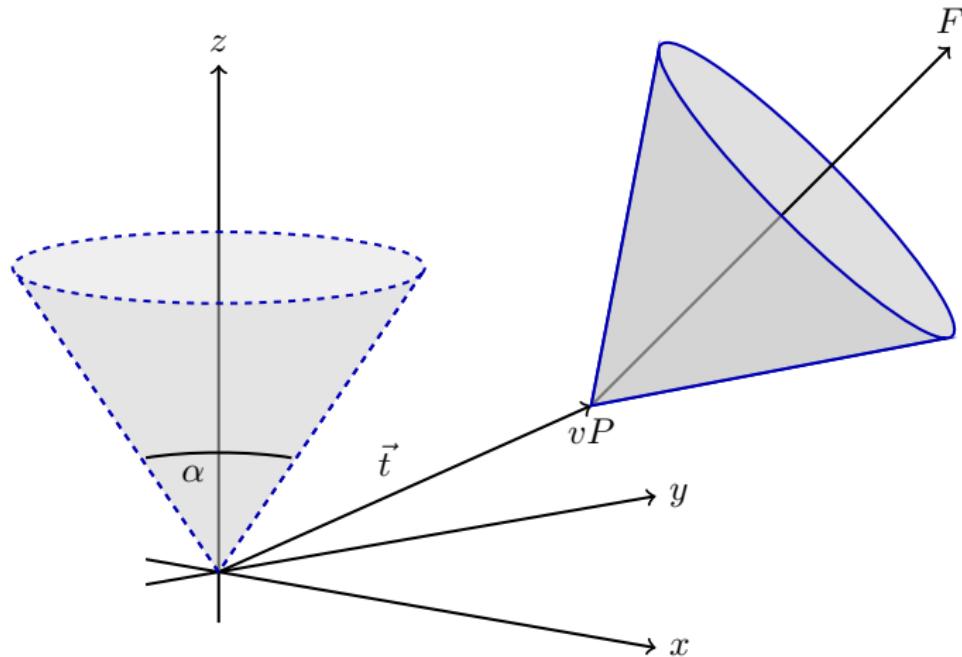
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Multi-component axis-symmetric potential $\Phi(R, z)$

- components
 - Black hole: Keplerian potential $\Phi_{bh}(r)$
 - Disk: Miyamoto Nagai potential $\Phi_{disk}(R, z)$
 - Bulge: Hernquist potential $\Phi_{bulge}(r)$
 - Dark matter halo: Navarro–Frenk–White potential $\Phi_{halo}(r)$
- 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

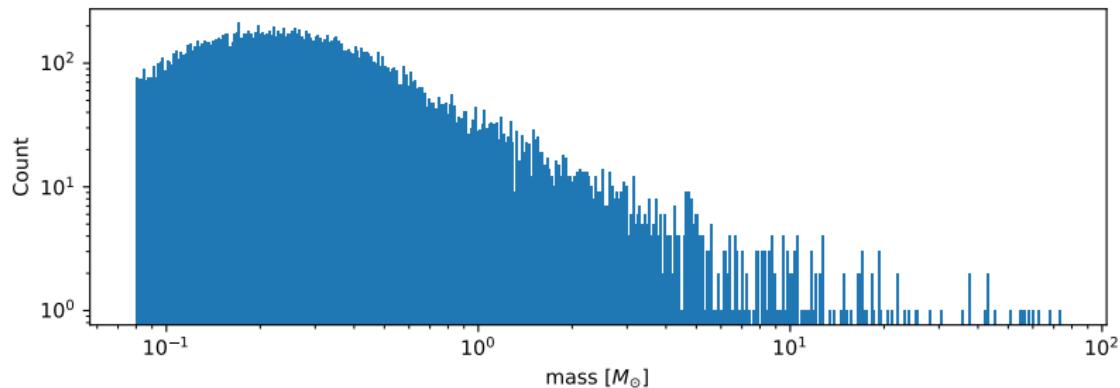
Integration

- GSL: GNU Scientific Library
- Gauss-Kronrod quadrature

Initialize mass (2)

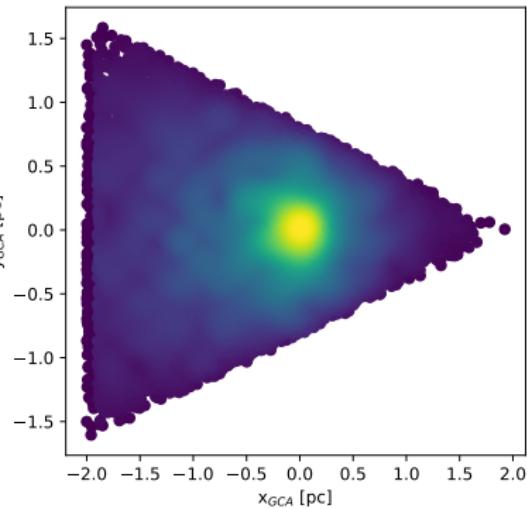
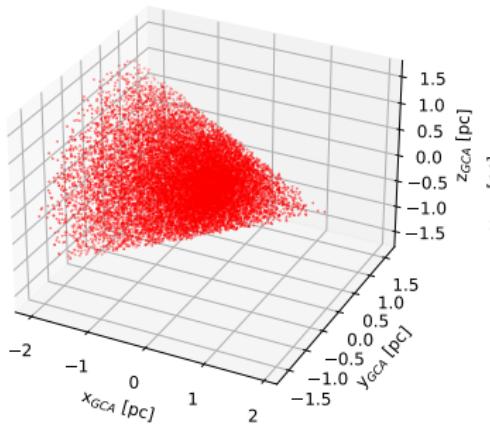
Sample mass functions

- rejection sampling
- inverse transformation sampling



Positions

1. uniform distribution
2. transformation
3. rejection sampling

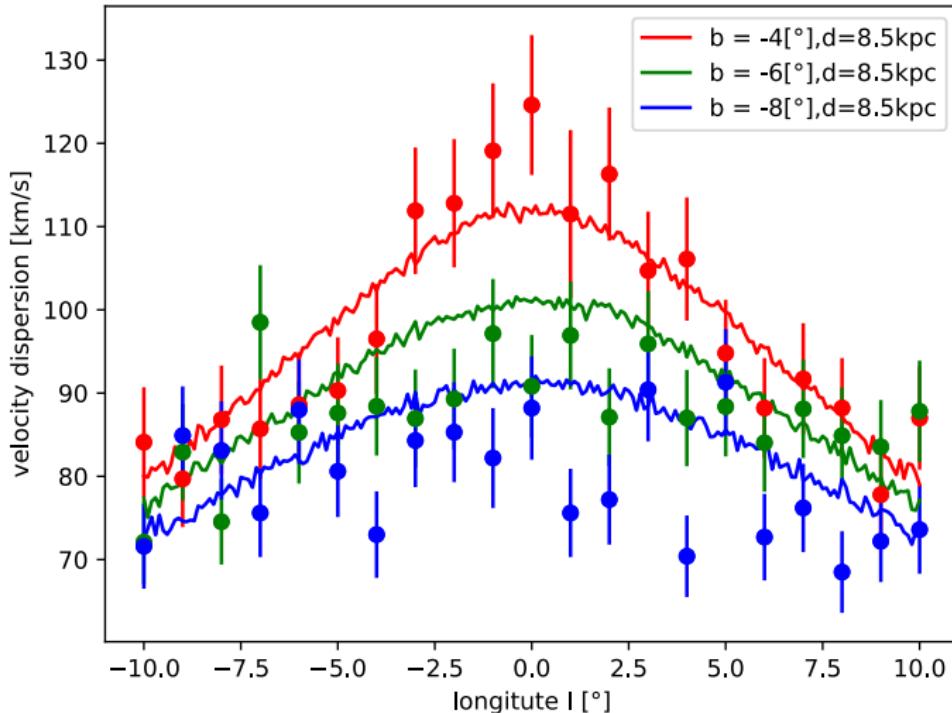


Velocities

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

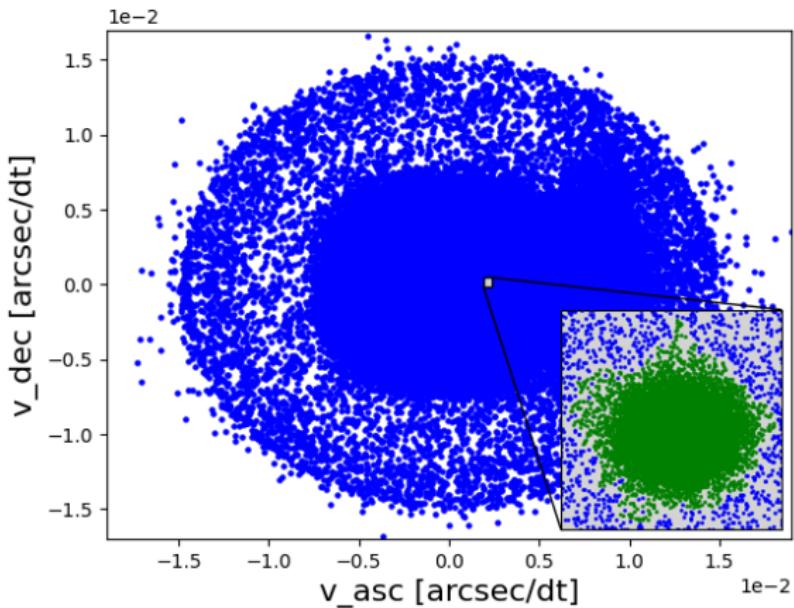


1. Integrate equations of motion
2. Write to Database every x timesteps
3. Test total Energy
4. Boundary conditions?

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Coordinate Systems

GalPot by Paul McMillan

GCA Galactocentric Cartesian

LSR Local Standard of Rest

HCA Heliocentric Cartesian

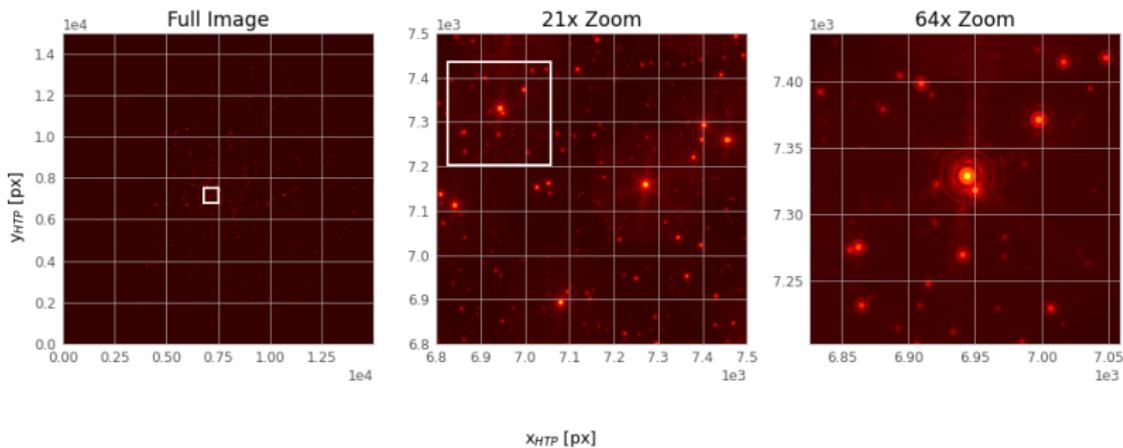
HTP Heliocentric Telescope Polar

ScopeSim by Kieran Leschinski

Spectra

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

Output FITS files

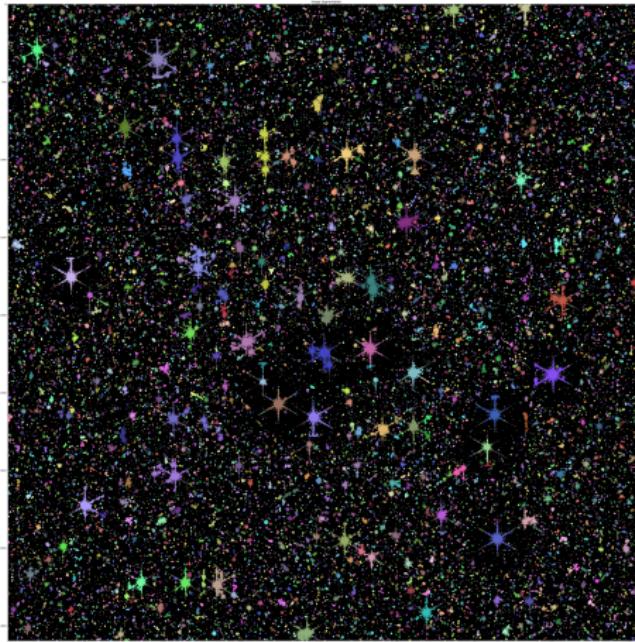


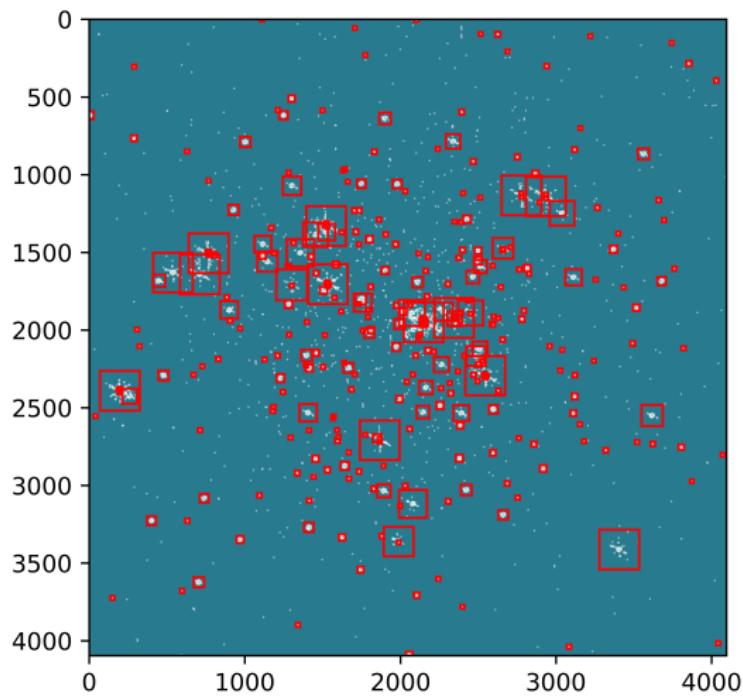
Photutils by Larry Bradley et al.

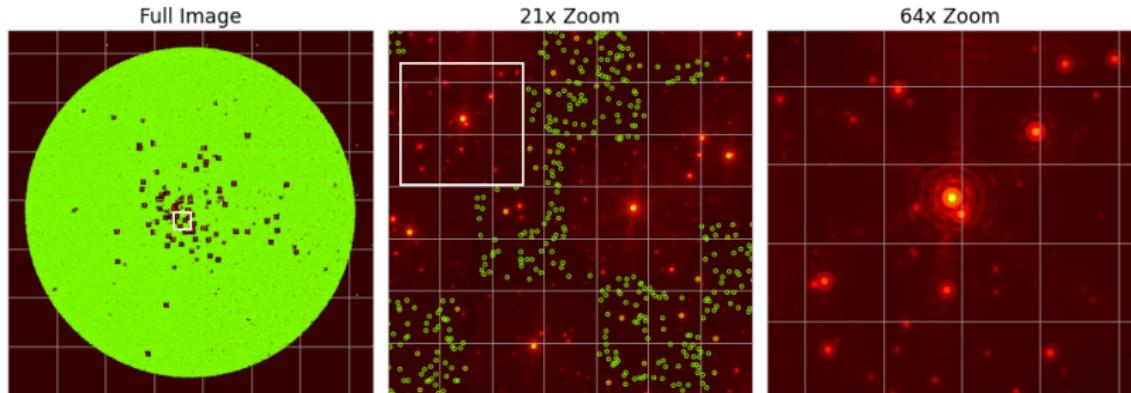
- DAOStarFinder
 - Threshold
 - Roundness
 - Mask
- Image Segmentation
 - Connected pixels
 - Threshold
 - Source Deblending

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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

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

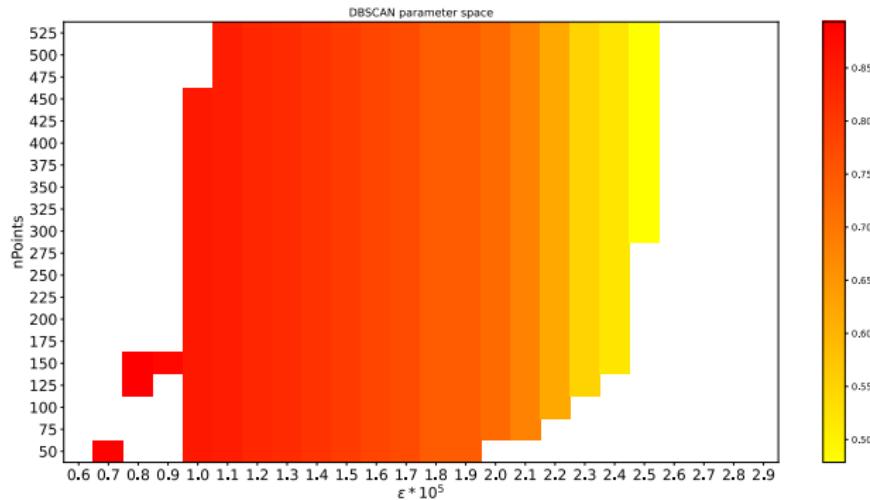
TP correctly classified as cluster star

FP wrongly classified as cluster star

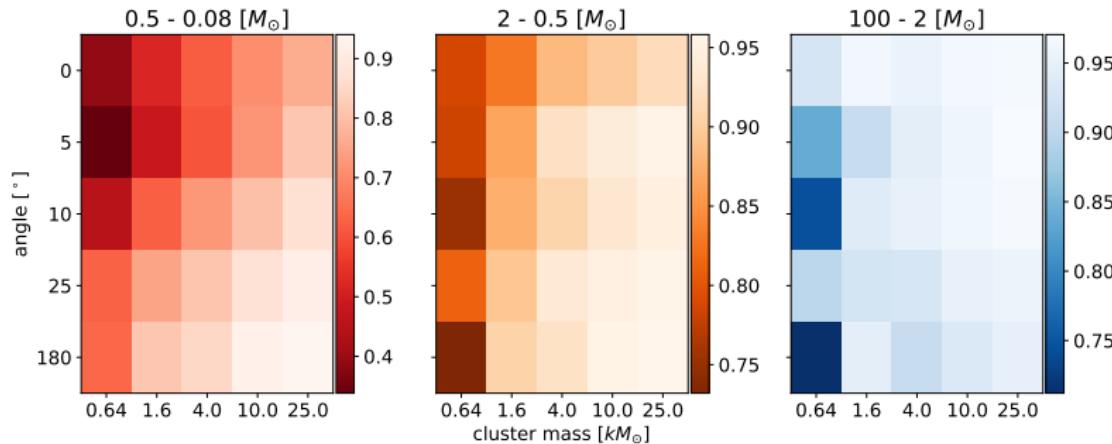
UP not mapped star classified as cluster star

FN wrongly classified as field star

Parameter optimization

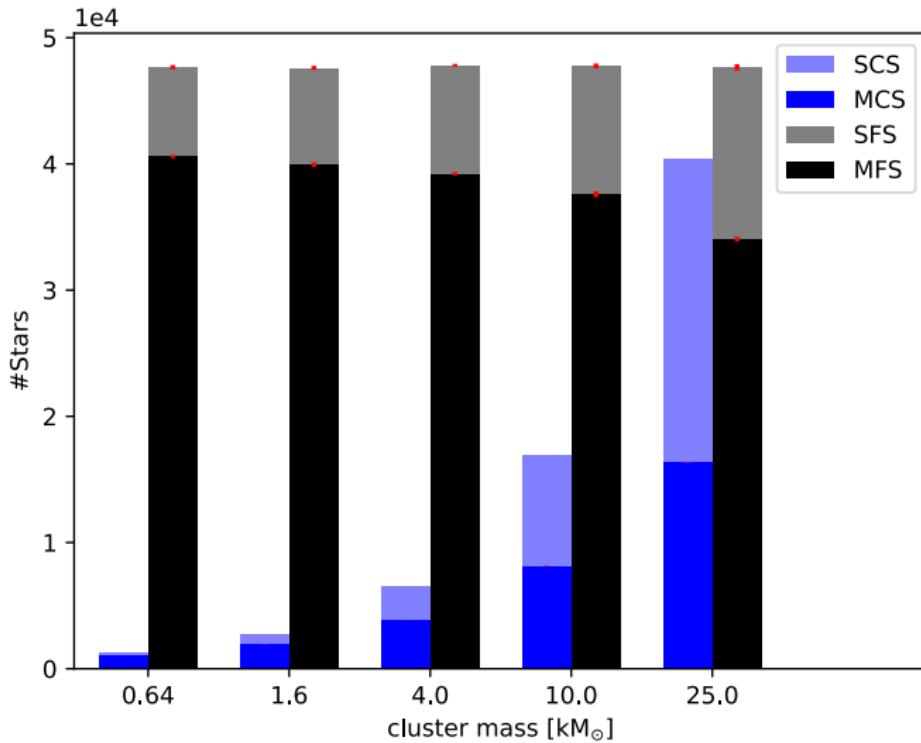


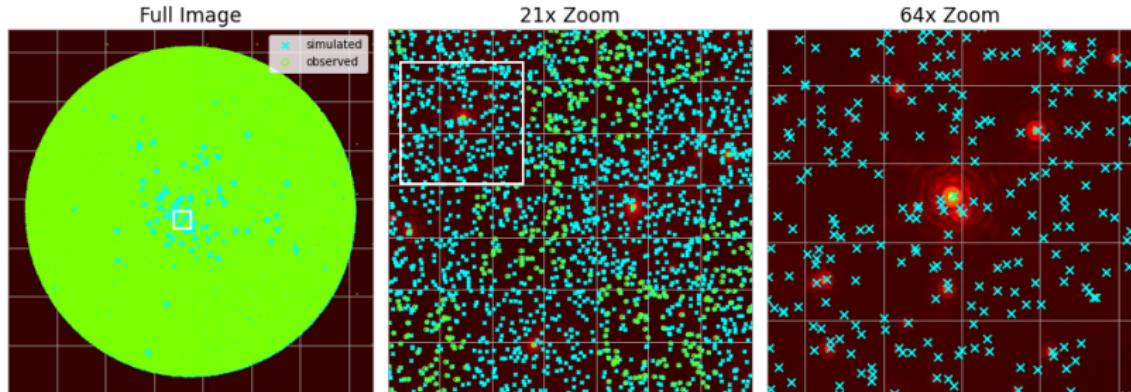
Results: F1



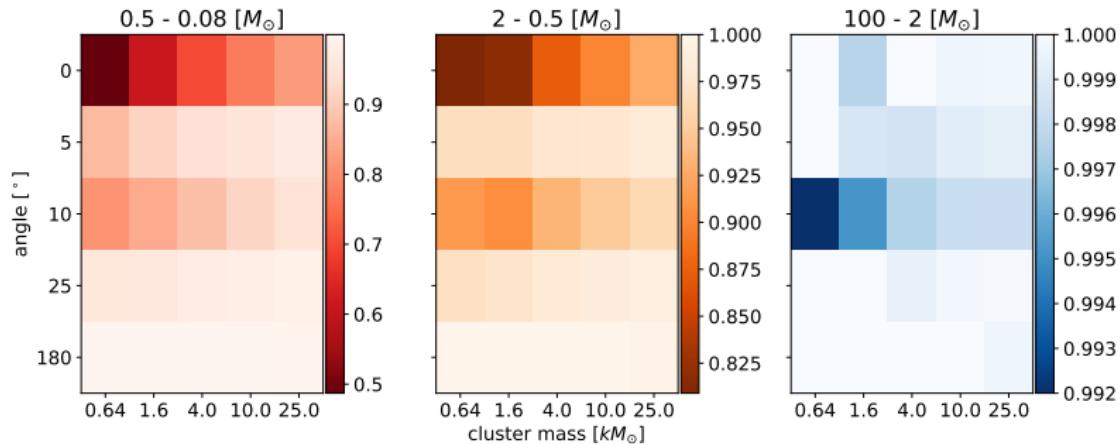
Star M _☉	Cluster kM _☉	% Found	F1 Score
<0.5	0.64	41	0.39
<0.5	1.60	40	0.52
<0.5	4.00	40	0.62
<0.5	10.00	35	0.71
<0.5	25.00	28	0.76
0.5 - 2	0.64	81	0.79
0.5 - 2	1.60	80	0.83
0.5 - 2	4.00	76	0.88
0.5 - 2	10.00	63	0.90
0.5 - 2	25.00	54	0.92

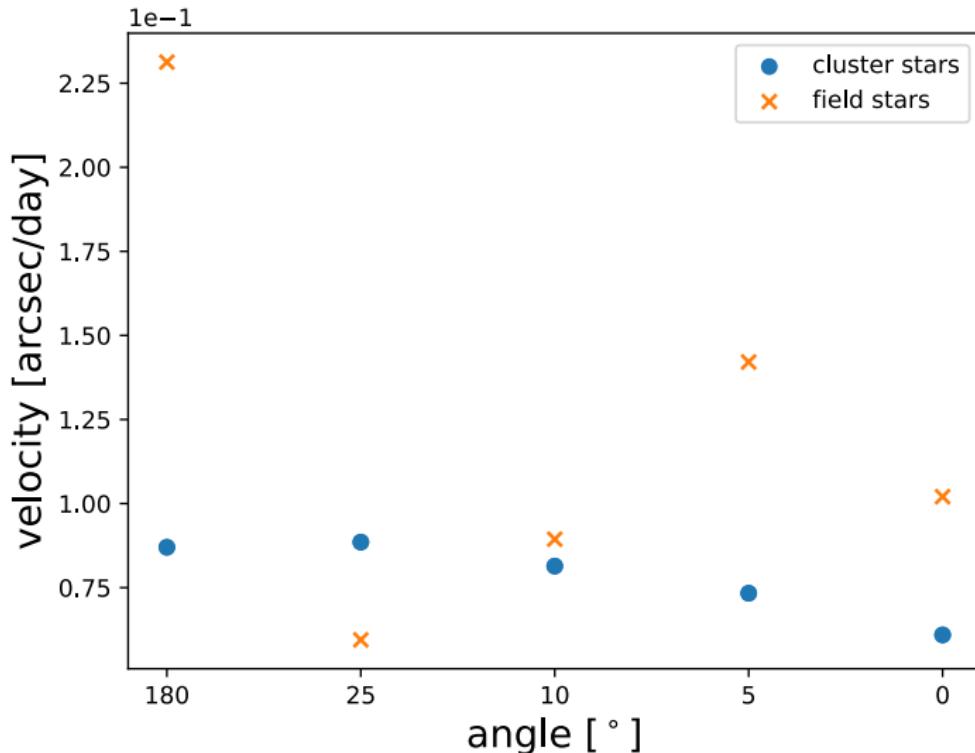
Thanks for your attention!





Precision





general remarks on performance

- Pass and loop by reference
- Multithreading (OpenMP)
- Choice of language
- Define (mathematical) constants
- C++ : `emplace_back` VS `push_back`