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Landesamt für Besoldung
und Versorgung

INAF
ISTITUTO NAZIONALE
DI ASTROFISICA

Flying the Nest

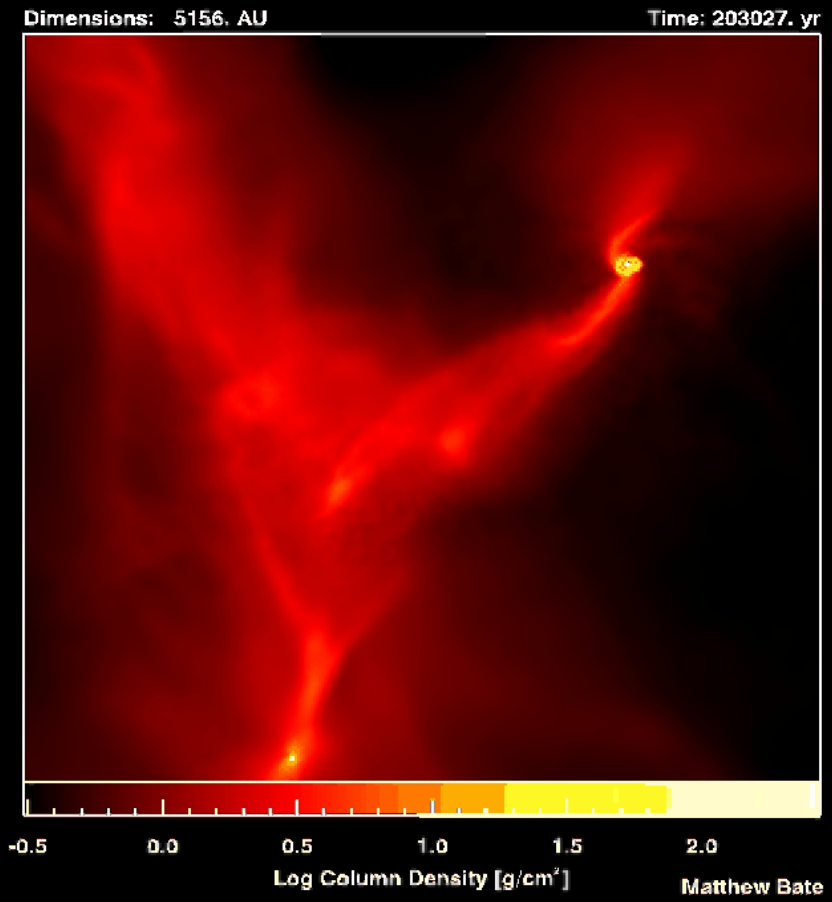
Using 4MOST to explore the origins of nearby young runaway stars

Alex Binks (IAAT), Beate Stelzer (IAAT) & Germano Sacco (INAF-OAA)

Astronomische Gesellschaft 2026: Star Formation splinter
ESO Garching, Germany
Friday 11 September, 2026

Image: Orion A Giant Molecular Cloud. Credit: ESA/Webb, NASA & CSA, T. Megeath, M. Zamani (ESA/Webb) Acknowledgement: M. H. Özsaraç

Simulations predict runaways



- Molecular cloud, 50$M_\odot$, size ~ 0.4pc.
- (nearly all) stars born in clusters.
- B-fields → filaments → cores.
- Protostar and disk formation.
- Many class I/II/III stars ejected.

What causes runaway stars?

Bate et al. 2009; http://www.astro.ex.ac.uk/people/mbate/

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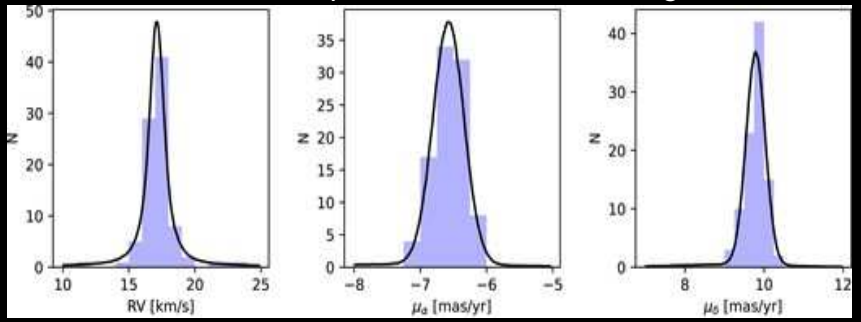
How do stars “fly the nest”?

Single/binary interaction with a tightly bound binary system

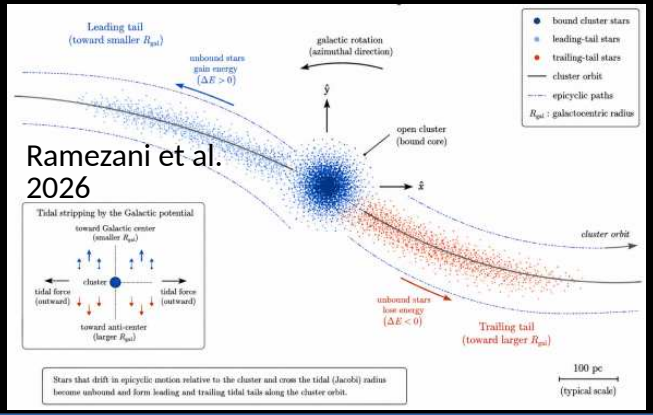
Andreas Irrgang;
www.sternwarte.uni-erlangen.de/~irrgang/animations/runaways

Extreme tail of cluster velocity distribution

~20 Myr Gamma Vel cluster, Wright et al. 2024



The nest flies: gas expulsion & tidal tails



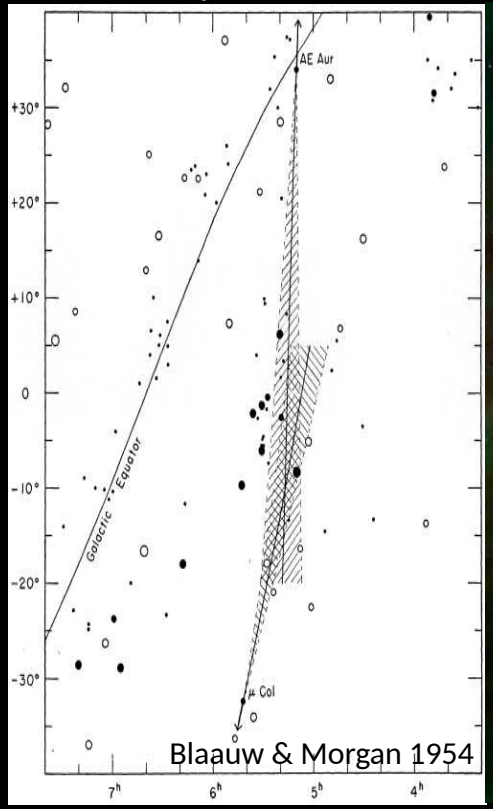
Ramezani et al. 2026

Companion ejected from SN blast wave

Andreas Irrgang;
www.sternwarte.uni-erlangen.de/~irrgang/animations/runaways

Pre-Gaia: High-mass runaways

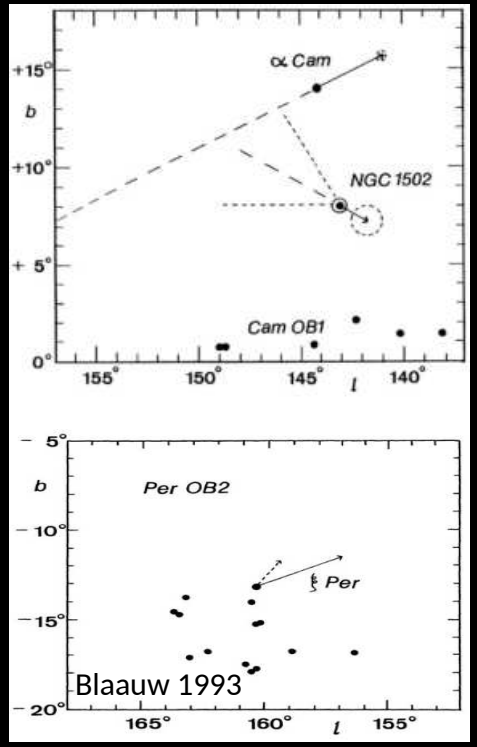
Orion ONC OBs:
AE Aur & μ Col



Blaauw & Morgan 1954

ρ Ophiuchus (160 pc)
ζ Oph (Blaauw+1961)


Image credit: X-ray: NASA/CXC/Dublin Inst. Advanced Studies/S. Green et al.; Infrared: NASA/JPL/Spitzer



Blaauw 1993

- Several dozen high-mass runaways: OB stars.
- Proper motion surveys.
- Pre-Gaia:
  No low-mass stars.

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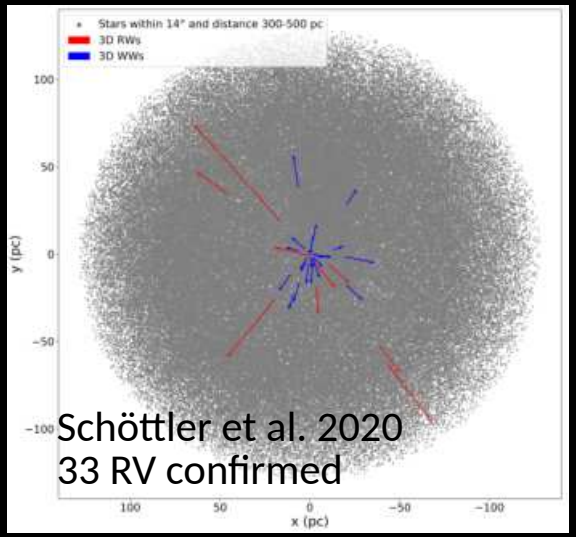
Runaway stars: Gaia-era

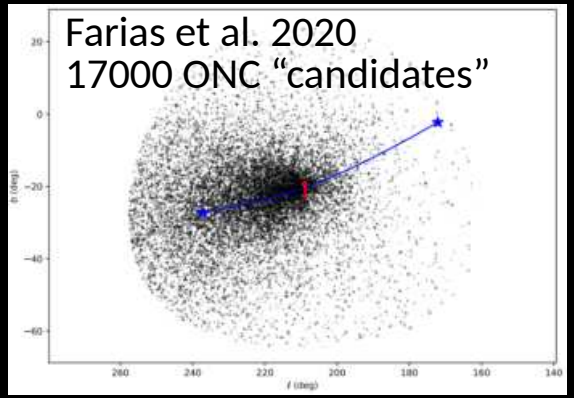
Orion Nebular Cluster

~$10^{3\text{-}4}$ candidate **FGK stars** (need follow up spec)

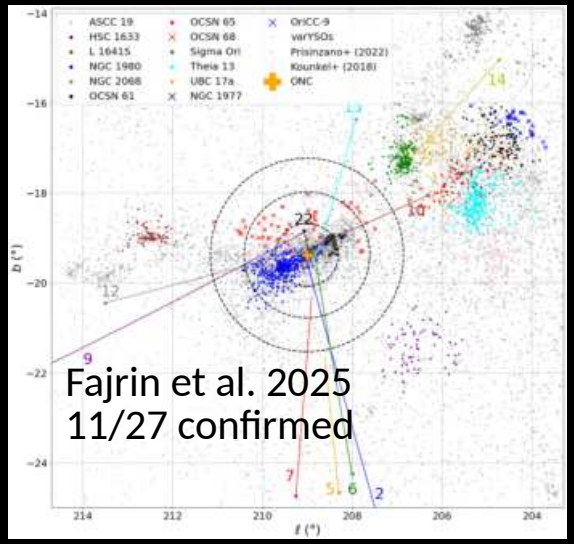
Cluster ages & SF efficiency



Schöttler et al. 2020
33 RV confirmed



Farias et al. 2020
17000 ONC “candidates”



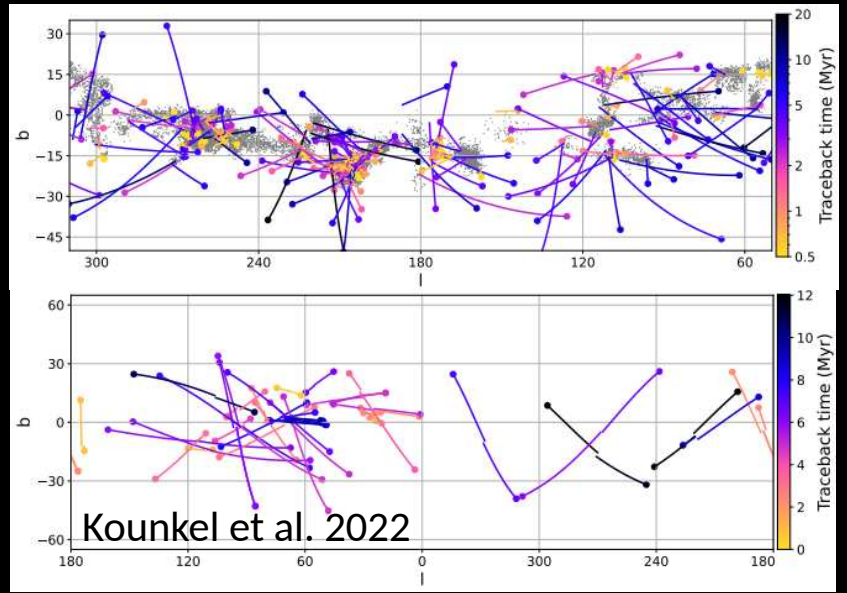
Fajrin et al. 2025
11/27 confirmed

All-sky search for runaways

2D traceback → need spec. follow up

546 “isochronally” young stars, d<500 pc

42 diametric pairs (bottom plot).



Kounkel et al. 2022

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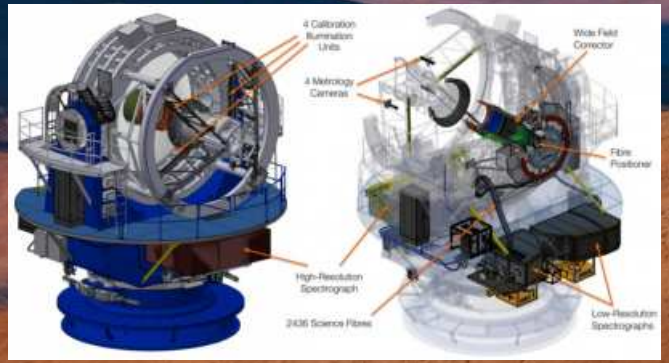
The 4MOST mission

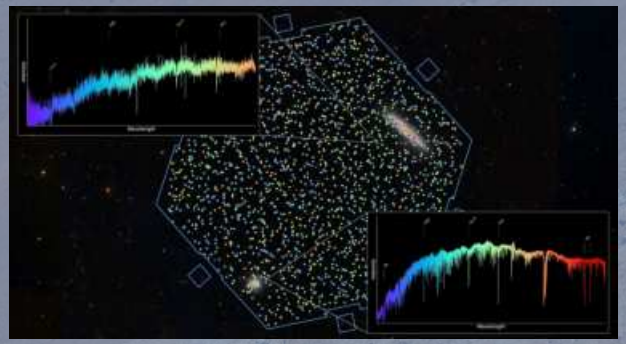
- 5 year ESO spectroscopic mission: 4-m VISTA telescope.
- 2436 fibres in 4.2° FOV hexagonal array, full optical range
  1624 fibres @ Low-Res, R~5k
  812 fibres @ High-Res, R>18.5k
- RV precision ~ 1.0 km/s, [X/Fe]~0.15 dex
- 15 community service programs, 30% observing time.

https://www.4most.eu/cms/facility/overview



Major dates

Oct 18, 2025 → first light
Q2-3, 2026 → tests, verification
Oct 15, 2026 → programs begin!
Jan 1 2029 → DR1 (public)
Jan 1 2033 → DR4 (final)



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4MOST Survey of Young Stars

4SYS: P.I. Germano Sacco + 50 Co-Is (incl. Alex Binks & Beate Stelzer)

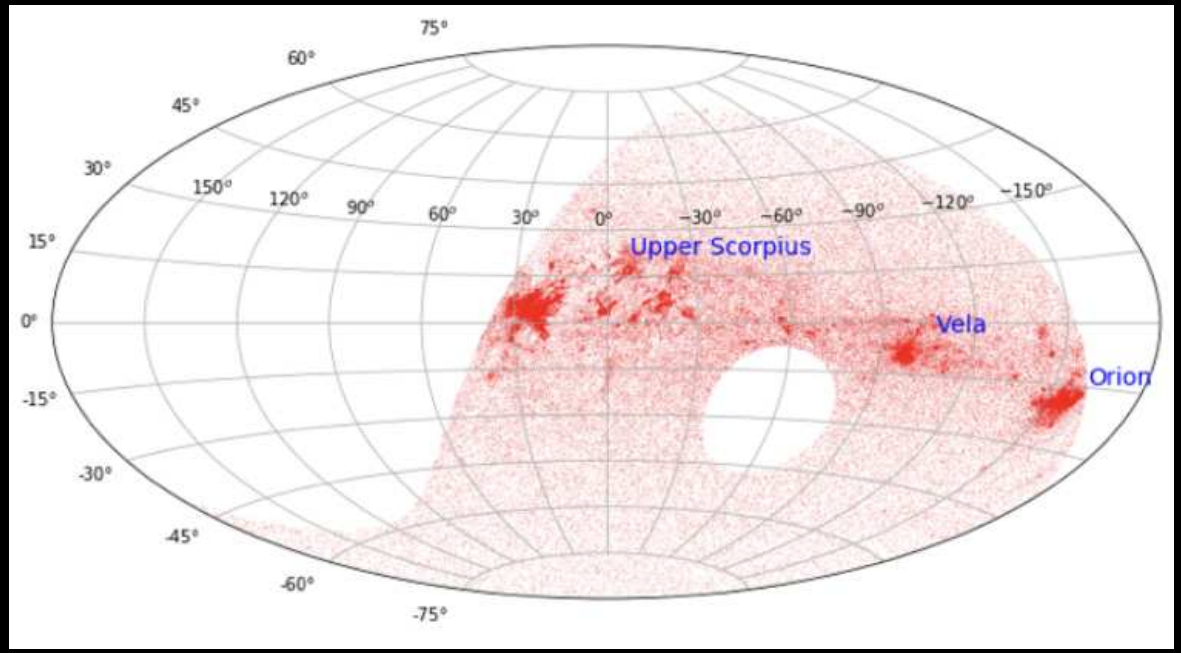
Observational Goals

- First *kinematically-unbiased* survey of GKM-type young stars within 500 pc.
- Young stars in *any* environment!
- ~50k young stars, many new!
- High precision 3D kinematics and ages.

Scientific Goals

- Where are the young nearby stars?
- PMS evolution: missing ingredients?
- Ejection mechanisms?
- Traceback young field stars?
- Galactic star formation rate/efficiency?

4SYS: target sample



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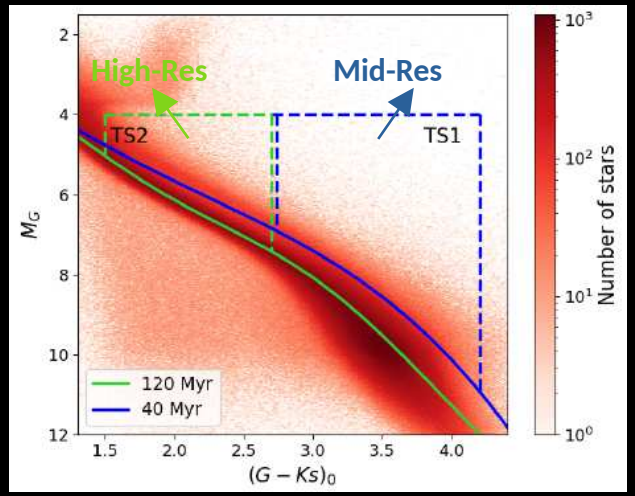
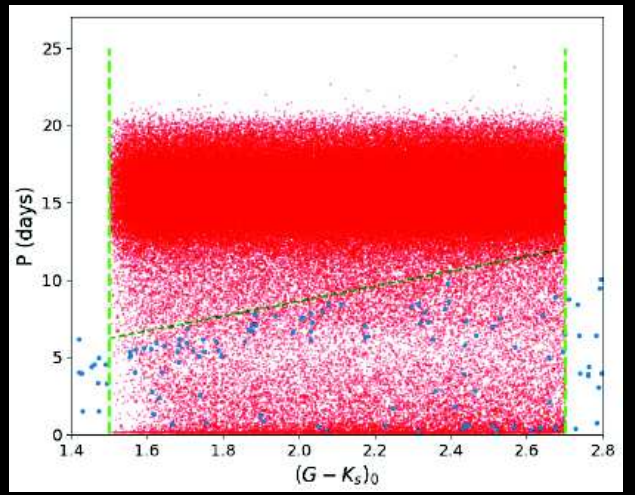
4SYS: target sample

- **Parent sample:**
  - **(d < 500pc)** → covers SFRs out to Orion.
  - **(10.5 < *G* < 18.0)** → SNR requirements in <1 hour
  - **(-70 < δ° < +5)** → within 4MOST observing limits
- Photometry: Gaia DR2 (*G*), 2MASS/VHS (K_S)
- Extinction/reddening corrections: 3D dust maps.



Class	Res'n	#	SpTs	Criteria	Measurements
TS1	Mid	100k	K7-M5	CMD < 40 Myr	3D kinematics, Li (< 20 Myr)



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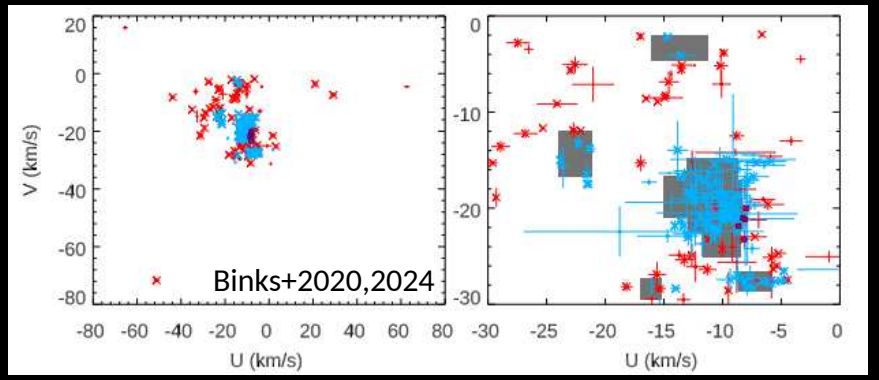
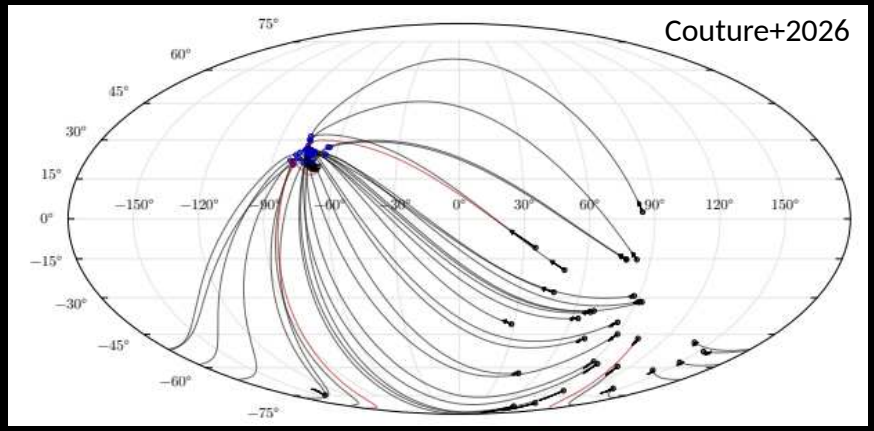
Young nearby stars

(1) Origins of young stars in nearby moving groups.



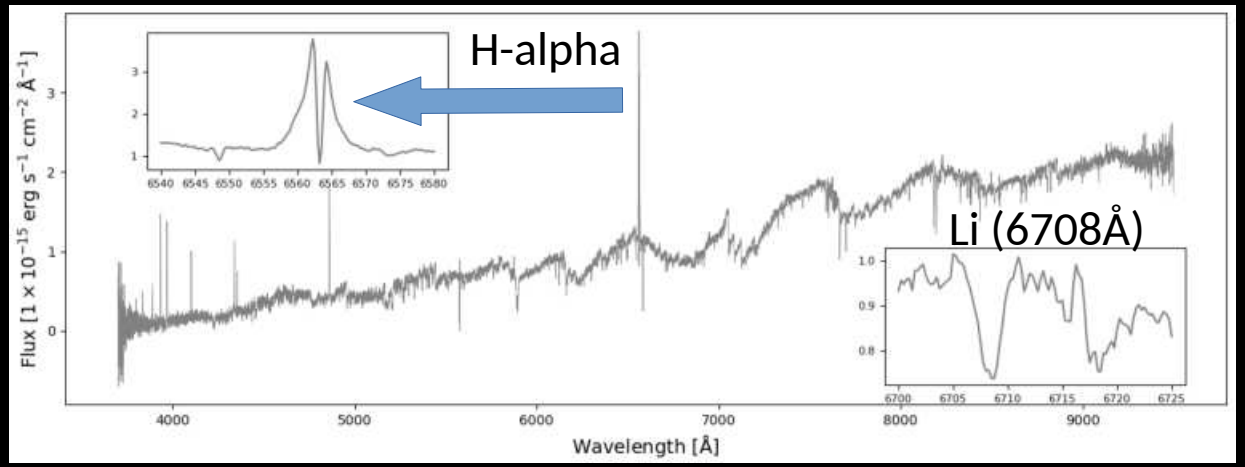
(2) Runaways from known SFRs and open clusters.



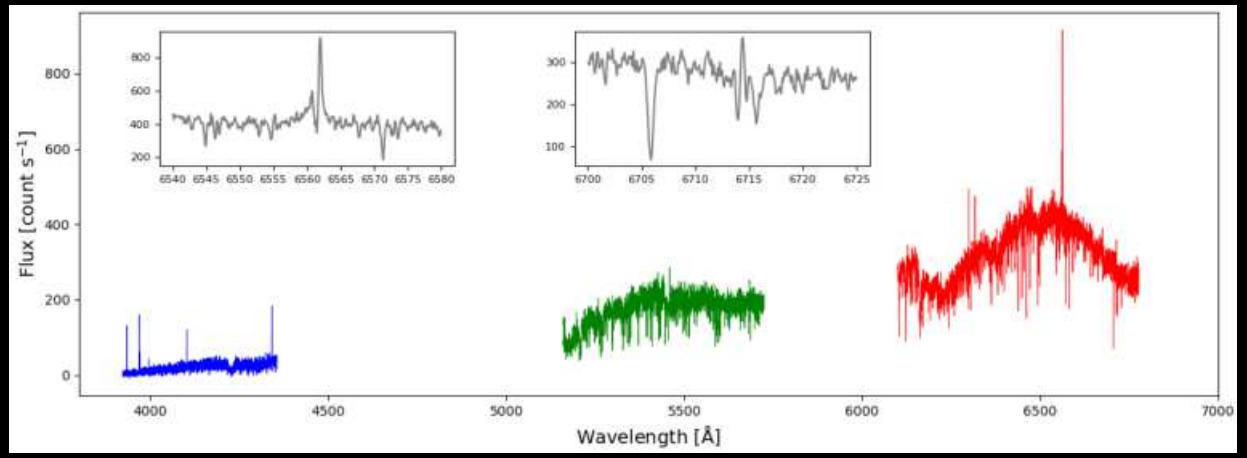
(3) Traceback: *young* field.

Verification: Vela SFR

Low-resolution spectrum



High-resolution spectrum



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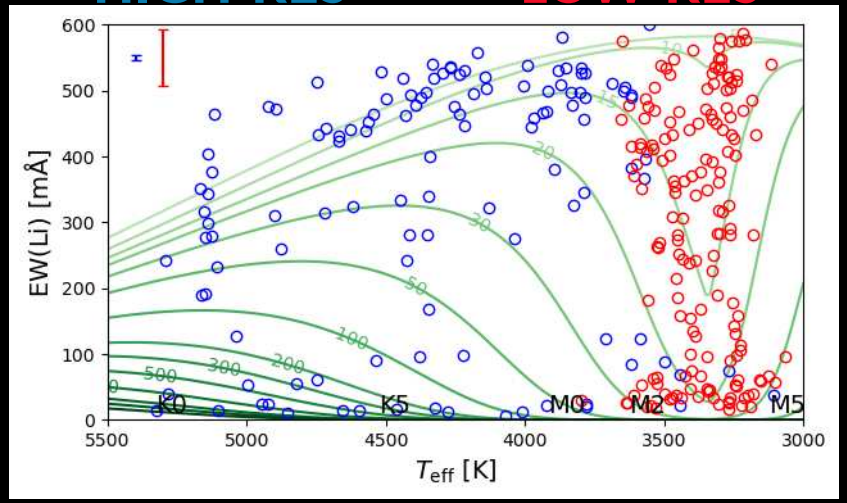
Verification: Vela SFR

Lithium measurements

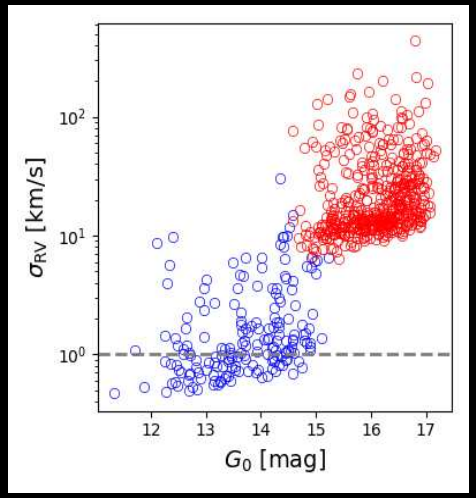
- EW(Li) measured from spectra.
- Majority of **K-stars** < 100 Myr.
- ~half of **early/mid M-stars** are young.

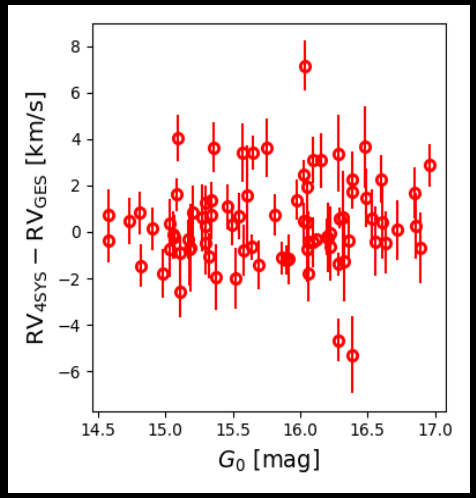
HIGH-RES **LOW-RES**



Radial velocities

- Most **High-Res** RVs: errors ~ 1.0 km/s.
- Pipeline poorly calibrated for **Low-Res** stars.
- In-house analysis gives better results!





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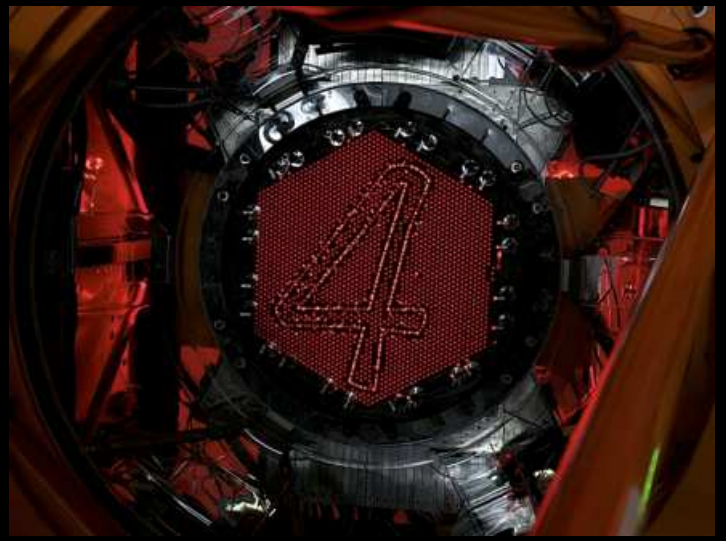
5 years of 4MOST data

- 4MOST performed excellent in tests.
- Science Program Operations: October 2026
- Warranty period: 2 years
- Data added every 2 – 3 months.

Are you ready for 240 million fibre hours of high-res data?



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Summary

- **Gaia** → Runaway star "candidates" → *spectroscopy needed!*
- **4MOST** → 5-yr mission, ~2.4k multi-fibre high-res spectrograph.
- **4SYS** → kinematically-unbiased young-star survey, d<500 pc.
- **Goals** → find young stars in *any* environment
  → locate & traceback runaways
  → constrain Galactic SF-rate

Thanks for listening!

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