4SITE: The 4MOST survey of Stars In Their Environments

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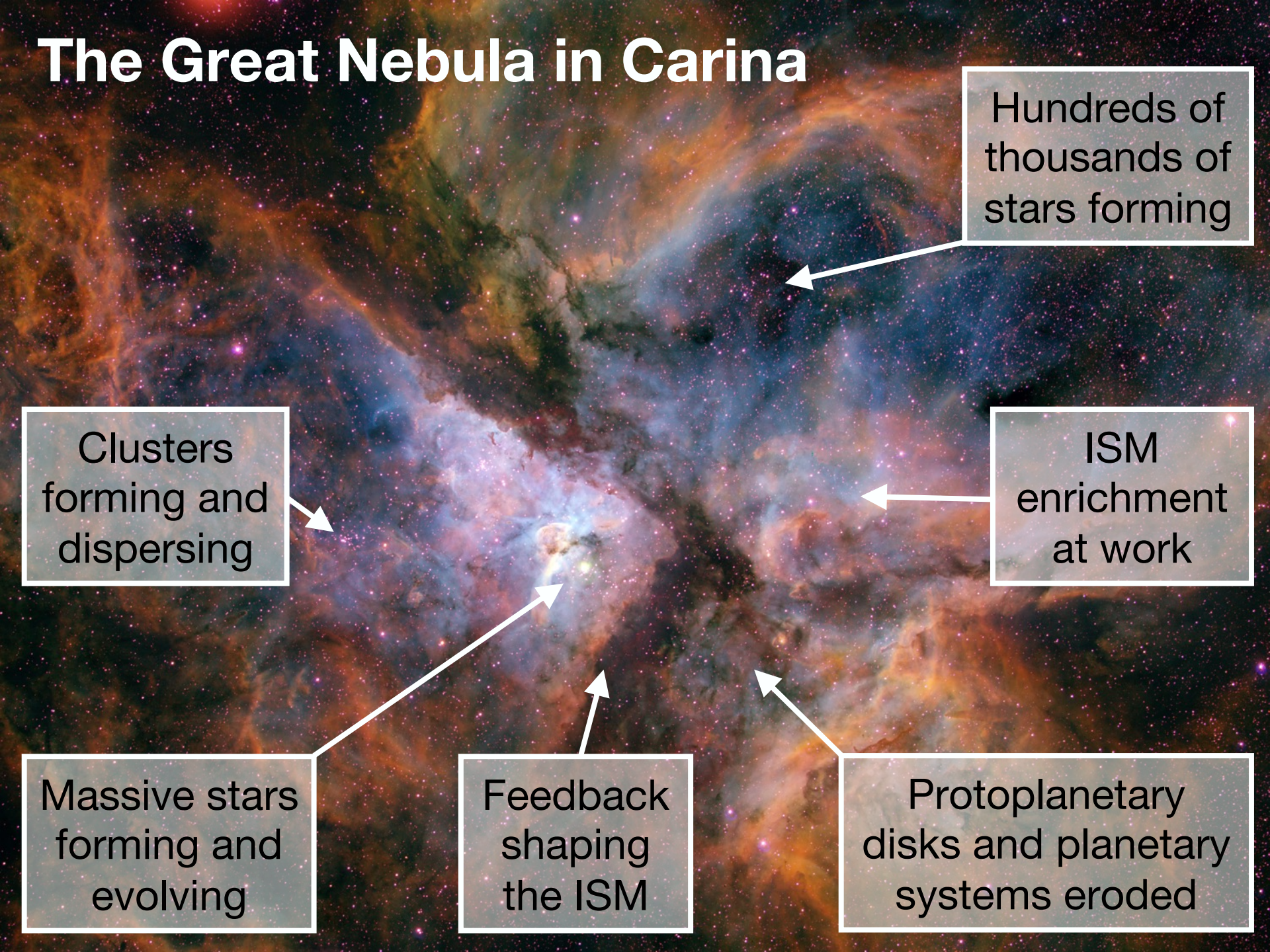

The Great Nebula in Carina
Hundreds of thousands of stars forming
Clusters forming and dispersing
ISM enrichment at work
Massive stars forming and evolving
Feedback shaping the ISM
Protoplanetary disks and planetary systems eroded

4SITE Key Science Goals

1. How does the evolution of massive stars depend on their rotation, over-shoot, mass-loss and binarity?

2. How does environment affect the properties and lifetimes of protoplanetary disks, accretion rates and timescales and how common are stars in different environments?

3. How are the properties, energetics, abundances and dynamics of HII regions affected by nearby massive stars, and how do they influence the wider ISM?

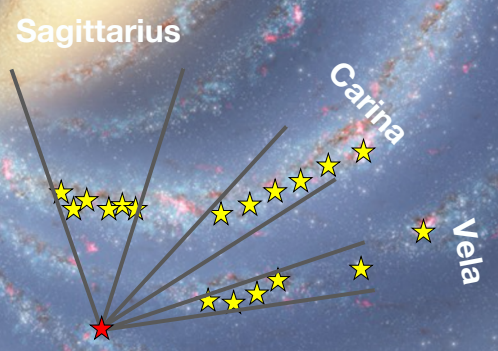
4. How do massive star forming complexes form, evolve and disperse, how does this affect their constituent clusters and HII regions, and how does this compare to Galactic scale models of star formation?

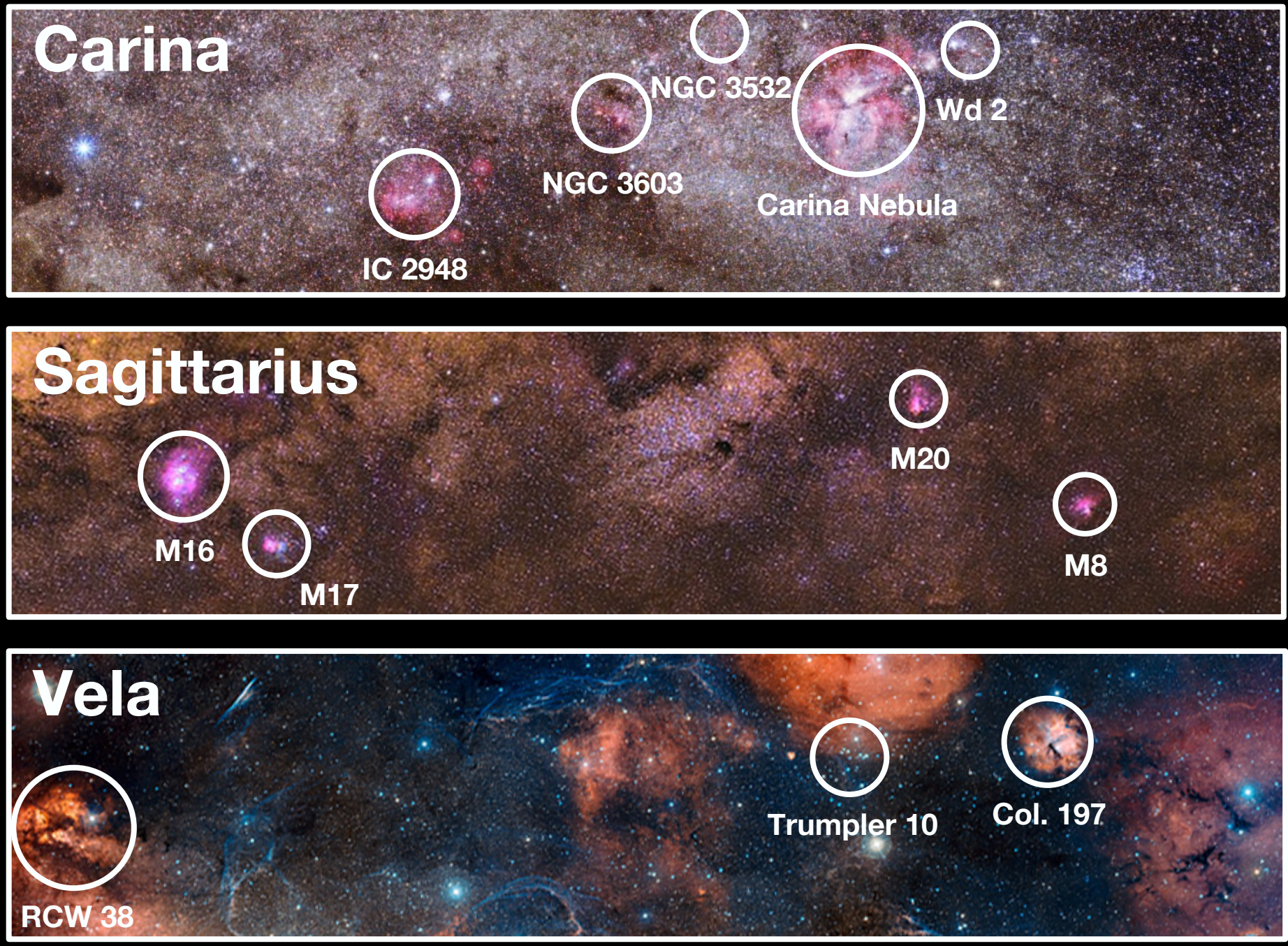
Galactic Distribution of Targets

Massive star-forming complexes trace spiral arms.

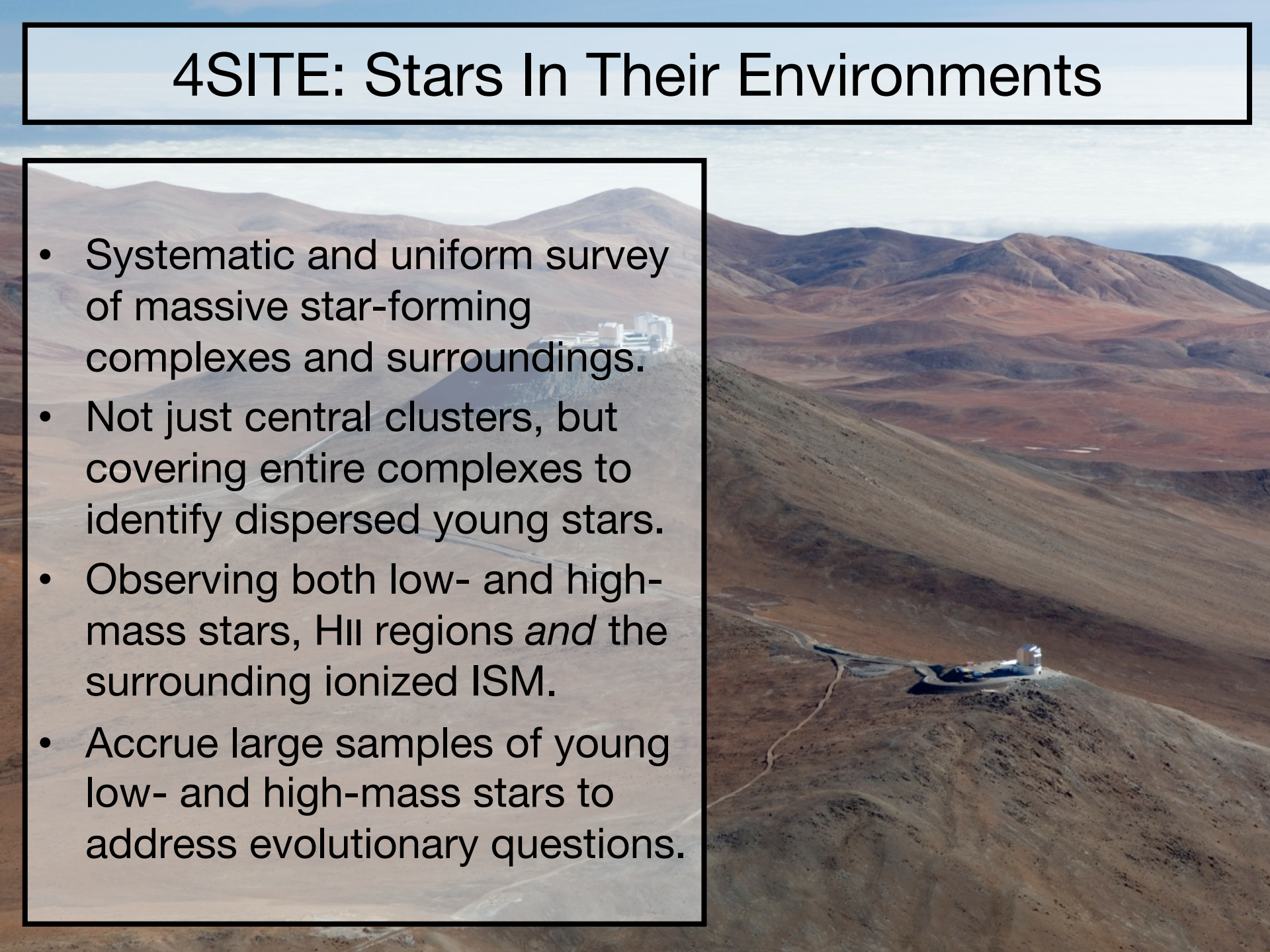
This allows us to observe large swathes of these in three sightlines:

- Sagittarius
- Carina
- Vela




Carina
NGC 3532
Wd 2
NGC 3603
Carina Nebula
IC 2948
Sagittarius
M20
M16
M17
M8
Vela
Trumpler 10
Col. 197
RCW 38

4SITE: Stars In Their Environments



- Systematic and uniform survey of massive star-forming complexes and surroundings.
- Not just central clusters, but covering entire complexes to identify dispersed young stars.
- Observing both low- and high-mass stars, HII regions *and* the surrounding ionized ISM.
- Accrue large samples of young low- and high-mass stars to address evolutionary questions.

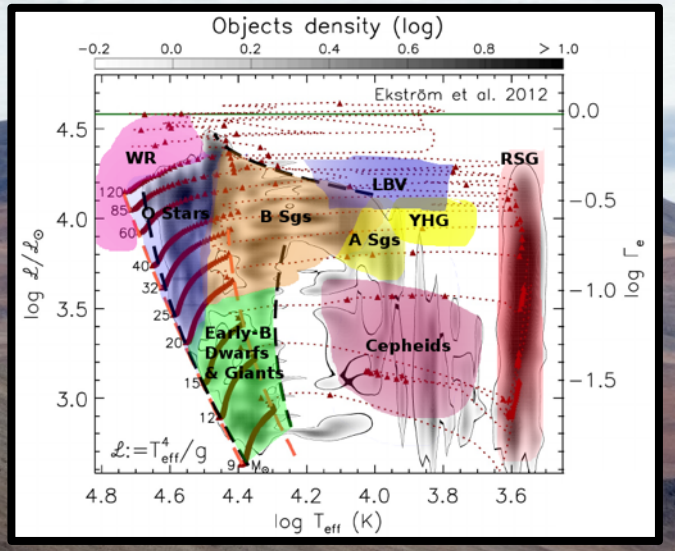
Survey Goals & Method: High-Mass Stars

Science drivers:

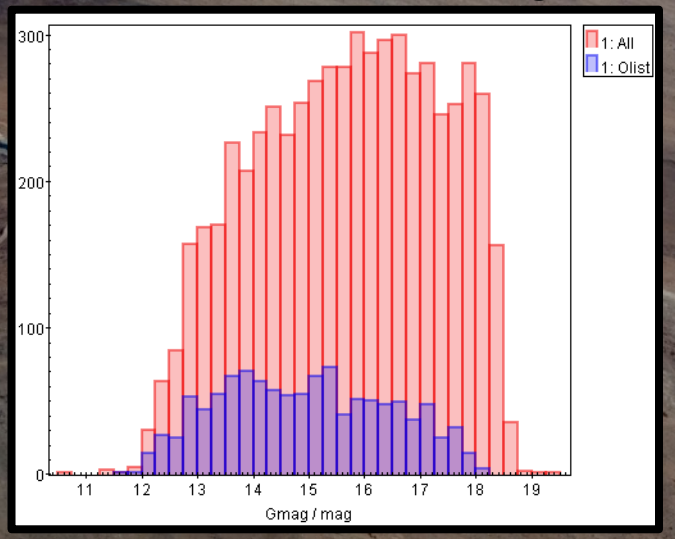
- Understand the evolution of high-mass stars
- What is the role of properties such as rotation and mass-loss in high-mass stellar evolution?
- How does binarity influence the production of SNe and the ejection of runaway stars?

Method:

- Obtain LR spectra of ~45,000 OB stars to achieve high coverage of HR diagram and variation of parameters (rotation, mass-loss, etc) – targets both in *and* behind massive star-forming complexes.
- Main sample ($15 < G < 16.5$) at SNR > 100 per Å:
  - Stellar params: T_{eff} (±5-10%), log *g* (±0.15-0.3 dex), *v* sin *i* (±25-50 km/s), RV (±2 km/s)
- Bright sample ($G \lesssim 15$) at SNR > 200 per Å also:
  - Abundances for He, C, N, O, Si, Mg (±0.15-0.3 dex)
  - Identify spectroscopic binaries
- Faint sample ($G \gtrsim 16.5$) at SNR ~ 50 per Å:
  - Measure T_{eff} to ±10-20% to confirm candidates.



Credit: Gonzalo Holgado



Credit: Janet Drew

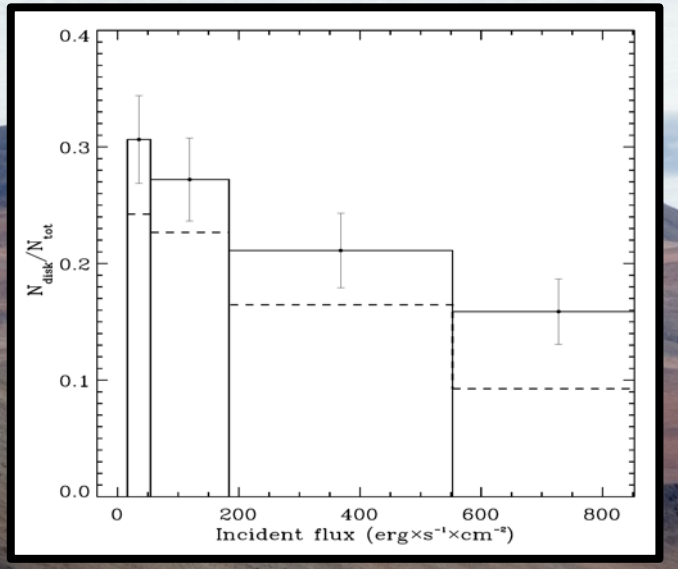
Survey Goals & Method: Low-Mass Stars

Science drivers:

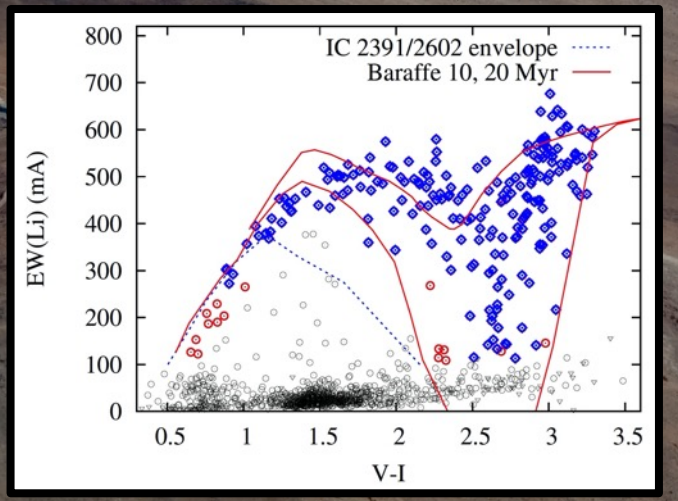
- Trace the spatial distribution of young stars by age and determine the demographics of star formation by environment (stellar density & UV radiation field).
- Measure disk lifetimes, accretion timescales and rates as a function of environment and stellar mass.

Method:

- Need sufficient number of confirmed YSOs in different environments and at different stellar masses to study how disk and accretion properties vary as a function of environment.
- Obtain LR spectra of ~100,000 candidate YSOs)
- Spectra at SNR > 30 per Å (G=15-19) for measuring:
  - T_{eff} (±100 K)
  - Li 6708 Å EW (±100 mÅ)
  - RV (±1 km/s)
  - EW(Hα), FWZI(Hα), [S II] 6716/6731 Å
- Brightest sample (G < 18, ~72,000) observed at SNR=50 per Å to get log *g* (±0.5 dex) for ages.



Credit: Guarcello+ (2009)



Credit: Jeffries+ (2014)

Survey Goals & Method: Nebulae & ISM

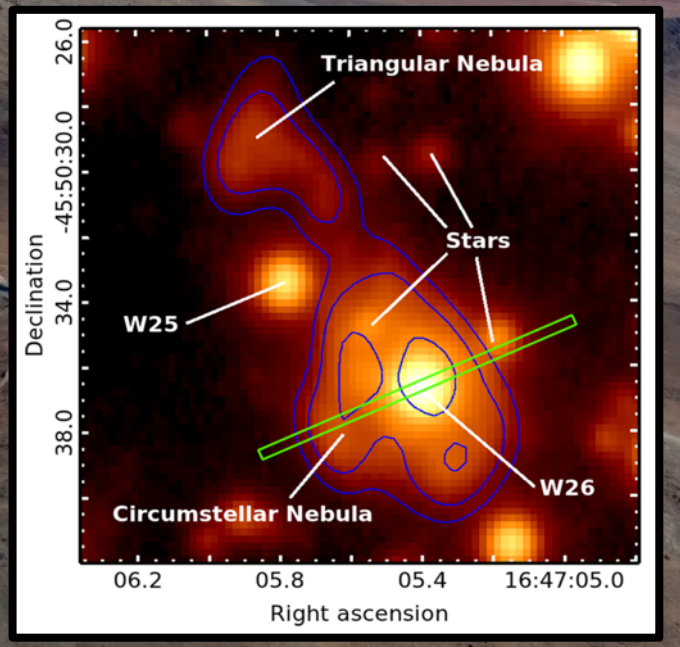
Science drivers:

- Trace HII region energetics and photoevaporation rates of pillar-like structures, connecting all to nearby ionizing sources.
- Connect HII region dynamics to the wider ISM to understand how they shape Galactic-scale ISM.
- Study nebular abundances to reveal ISM mixing, dust-grain depletion and chemical enrichment.

Method:

- Need a high spatial sampling of the ionized ISM in different environments to study it's properties and energetics, and for background subtraction.
- ~400,000 LR spectra (SNR~50) to measure:
  - Electron temperature (from [NII], [SIII], [OIII] to ±500 K)
  - Electron density (from [SII] to ±150-500 cm^{-3})
  - Excitation characteristics (e.g., [OII]/[OIII])
  - Abundances
- ~40,000 HR spectra (SNR~50) to get RV to 1 km/s
- Will provide a legacy dataset of unprecedented size

Credit: VPHAS+ / ESO



Credit: Wright+ 2014

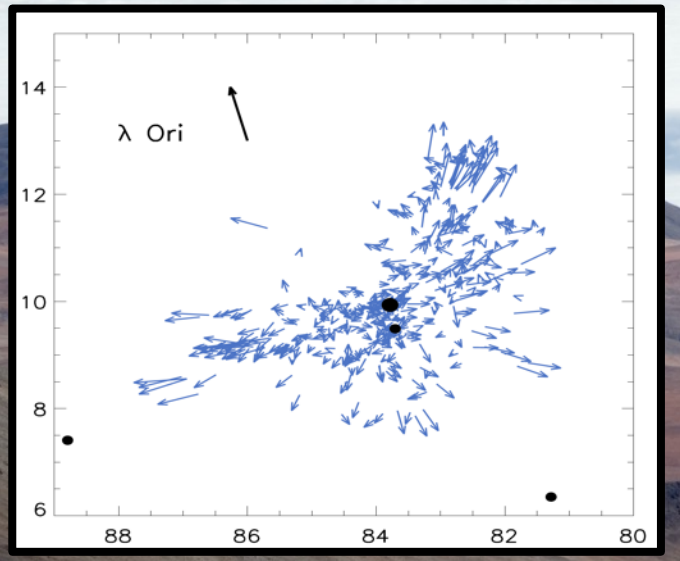
Survey Goals & Method: Ecosystems

Science drivers:

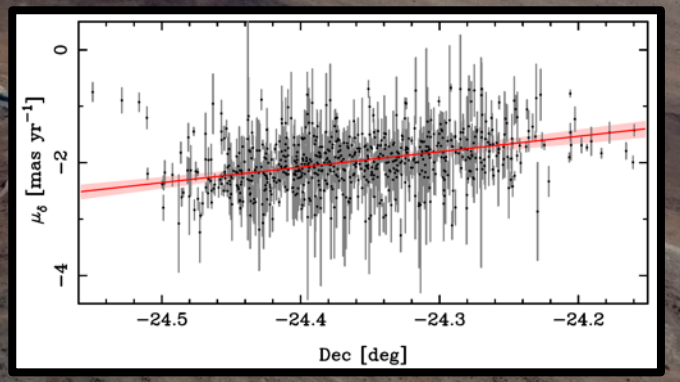
- Identify clusters, associations and field stars across these complexes using 6D spatial and kinematic information and stellar ages.
- Study the large-scale kinematics and star formation histories of these complexes to compare to Galactic-scale star formation models.
- Measure 3D kinematics and study how/why groups are dispersing, relating to local gas dynamics and energetics of nearby OB stars.

Method:

- Use confirmed low- and high-mass young stars to study spatial distributions as a function of age (require sufficient numbers of stars in each cluster / association to measure dynamical properties).
- Measure stellar RVs and combine with Gaia PMs for 3D stellar kinematics.
- Compare stellar and gas RVs to study relation between the two.



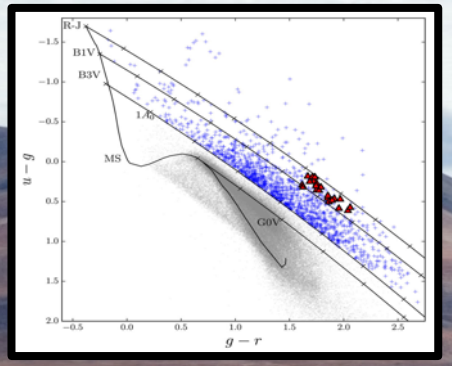
Credit: Kounkel+ (2018)



Credit: Wright+ (2019)

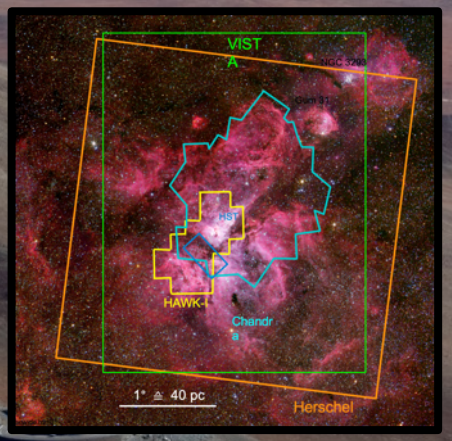
Target Selection

High-mass stars: ~45,000 targets selected from existing catalogues and Gaia, VPHAS+ and 2MASS photometry (proven high success rate ~97%, Mohr-Smith+ 2017, Drew+ 2018, 2019).



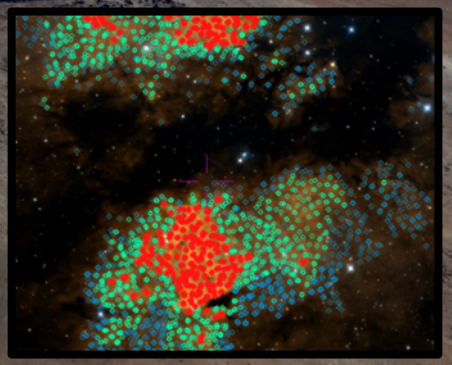
Mohr-Smith+ 2015

Low-mass stars: ~100,000 targets selected from both existing catalogues (e.g., Preibisch+ 2011) and with a Bayes classifier that combines photometry, astrometry and variability information.



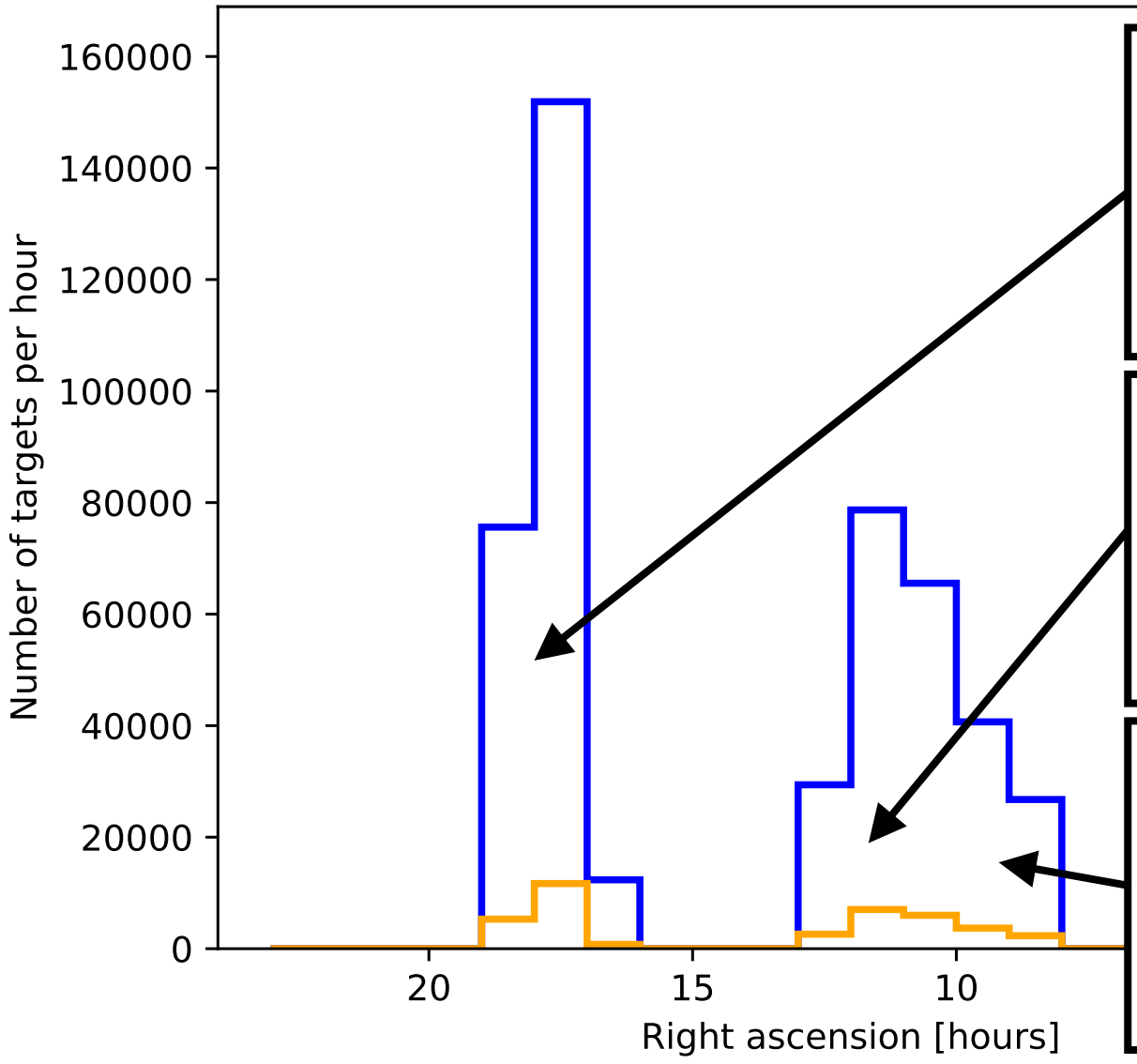
Thomas Preibisch

Nebulae: ~435,000 targets selected from VPHAS+ Hα images spanning entire Galactic Plane (automated method already developed for WEAVE northern Galactic Plane survey).



Janet Drew

Target Distribution



Sagittarius (16-19h):

- Area ~ 320 deg^2
- Density: LR ~ 250 - 1500 deg^{-2}
  HR ~ 10 - 150 deg^{-2}
- Number: LR ~ 265,000
  HR ~ 15,000

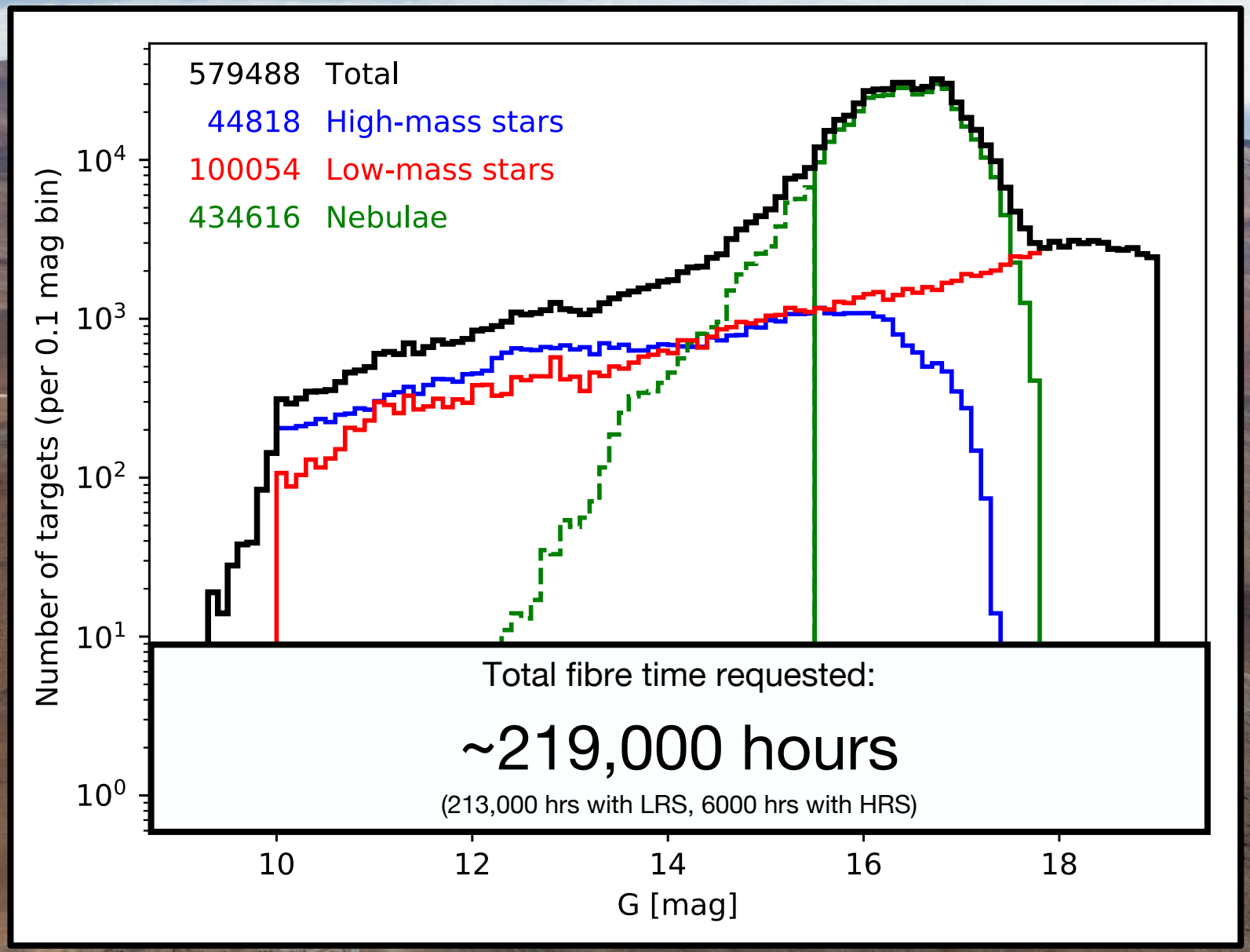
Carina (10-12h):

- Area ~ 200 deg^2
- Density: LR ~ 250 - 5000 deg^{-2}
  HR ~ 10 - 50 deg^{-2}
- Number: LR ~ 200,000
  HR ~ 10,000

Vela (8-10h):

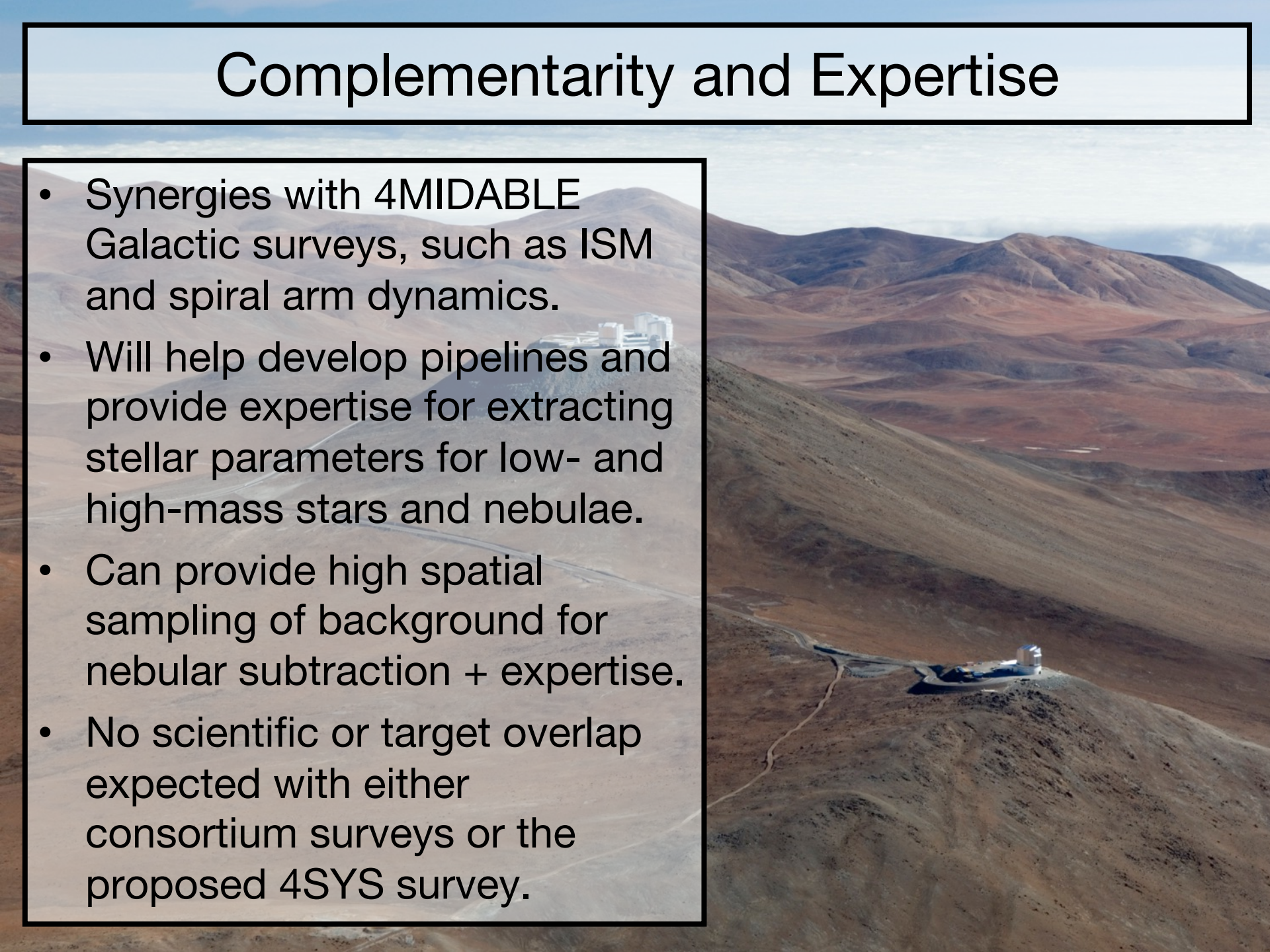
- Area ~ 144 deg^2
- Density: LR ~ 250 - 750 deg^{-2}
  HR ~ 10 - 30 deg^{-2}
- Number: LR ~ 80,000
  HR ~ 5,000

Target Distribution



Complementarity and Expertise

- Synergies with 4MIDABLE Galactic surveys, such as ISM and spiral arm dynamics.
- Will help develop pipelines and provide expertise for extracting stellar parameters for low- and high-mass stars and nebulae.
- Can provide high spatial sampling of background for nebular subtraction + expertise.
- No scientific or target overlap expected with either consortium surveys or the proposed 4SYS survey.



The 4SITE team: Who we are

Experts in low- and high-mass stellar evolution, star clusters and OB associations, stellar and nebula dynamics.

Considerable expertise with stellar and nebula photometry, spectroscopy, and astrometry, as well as with large surveys.

Experience and expertise from multiple surveys:

- Gaia-ESO Survey
- IPHAS and VPHAS+ Photometric Galactic Plane Surveys
- WEAVE / SCIP Northern Galactic Plane Survey
- VLT/FLAMES Tarantula Survey
- Galactic O-Star Spectroscopic Survey
- IACOB and OWN spectroscopic surveys

4SITE Summary

We are proposing a 4MOST survey of massive star-forming complexes targeting both low- and high-mass stars, HII regions, and the surrounding ionized ISM.

This will provide large-scale samples to study:

- Low- and high-mass star formation and evolution
- The properties, energetics and dynamics of the ionized ISM
- Structure and kinematics of clusters and associations
- Dependence of mass accretion rates and disk dispersal timescales on environment
- How massive star feedback shapes the ISM

This will be the first ever detailed, systematic and uniform survey of massive star-forming complexes. Can **only** be done with 4MOST due to the abundance of these regions in the south and the wide-field spectroscopic view that 4MOST provides.