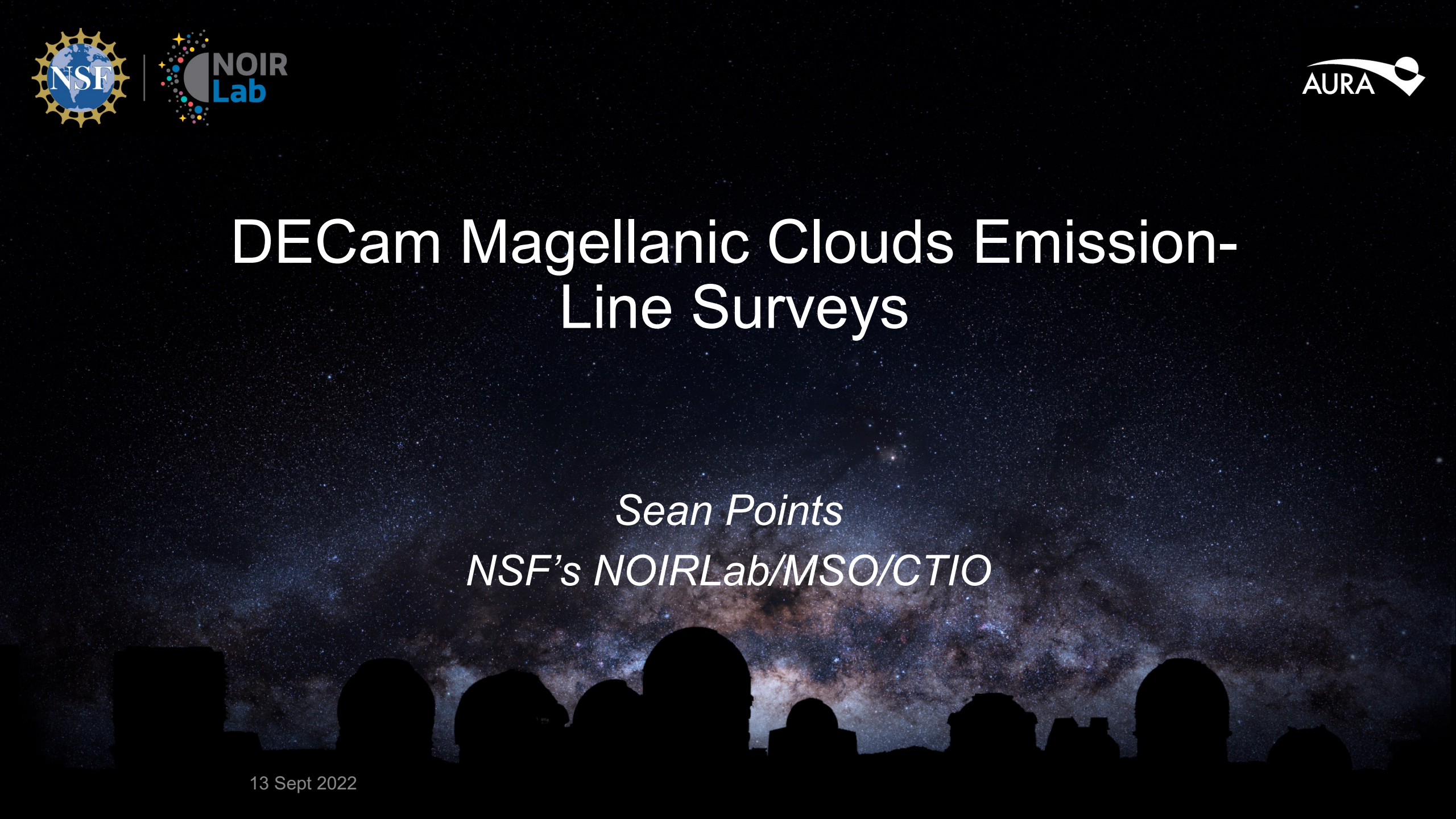


DECam Magellanic Clouds Emission-Line Surveys

Sean Points

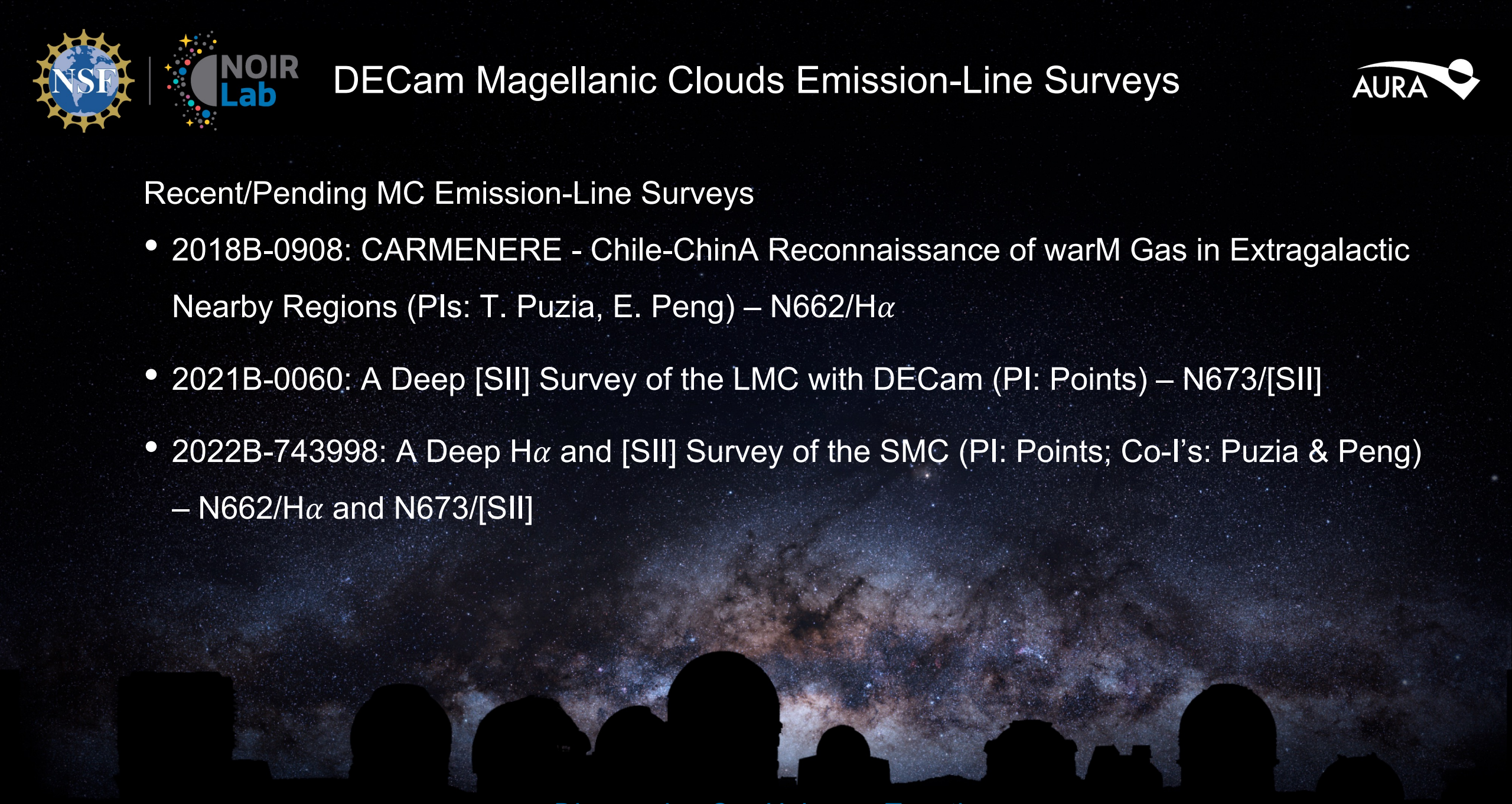
NSF's NOIRLab/MSO/CTIO

13 Sept 2022

DECam Magellanic Clouds Emission-Line Surveys

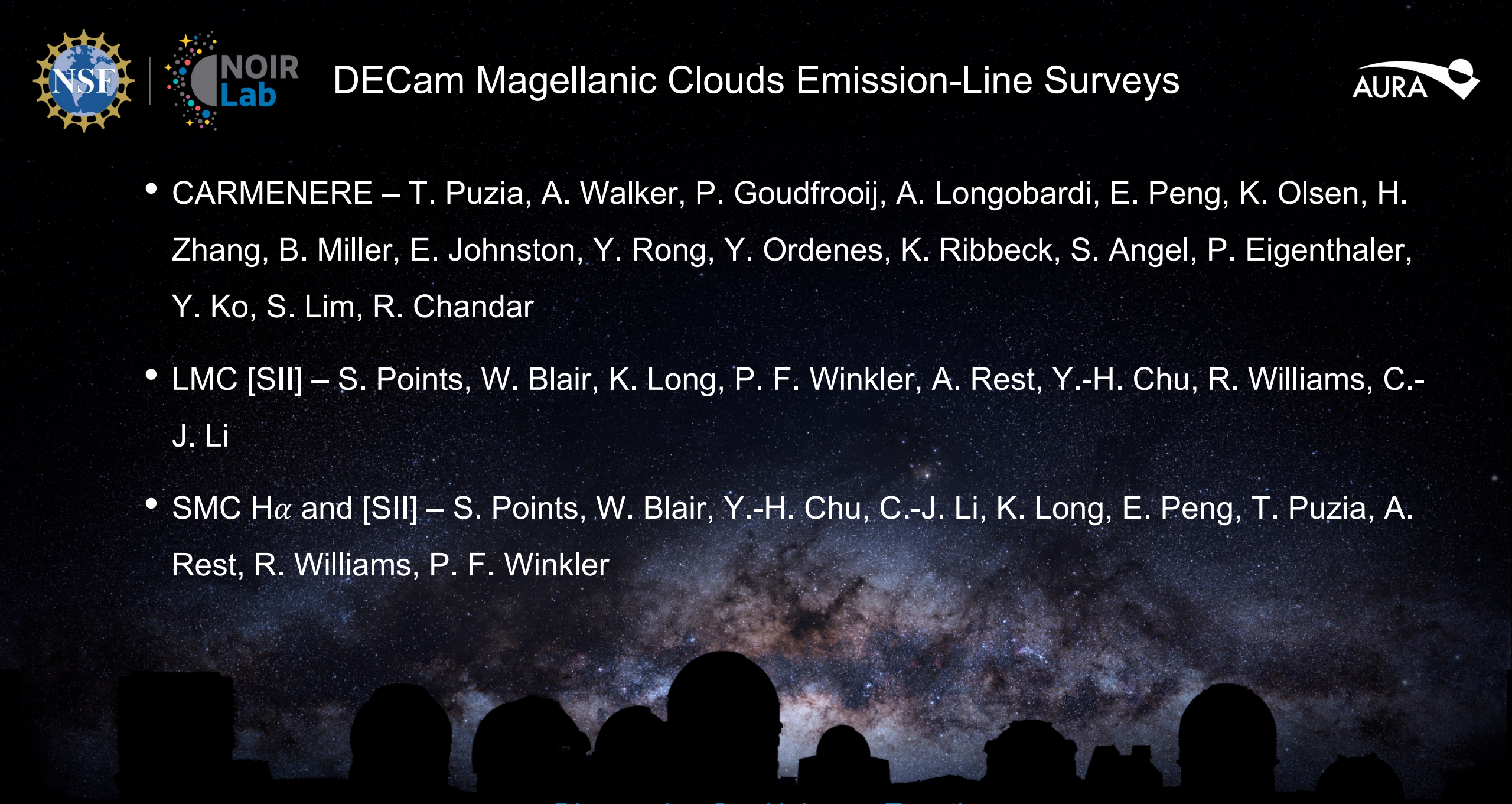
Recent/Pending MC Emission-Line Surveys

- 2018B-0908: CARMENERE - Chile-ChinA Reconnaissance of warM Gas in Extragalactic Nearby Regions (PIs: T. Puzia, E. Peng) – N662/Hα
- 2021B-0060: A Deep [SII] Survey of the LMC with DECam (PI: Points) – N673/[SII]
- 2022B-743998: A Deep Hα and [SII] Survey of the SMC (PI: Points; Co-I's: Puzia & Peng) – N662/Hα and N673/[SII]



DECam Magellanic Clouds Emission-Line Surveys

- CARMENERE – T. Puzia, A. Walker, P. Goudfrooij, A. Longobardi, E. Peng, K. Olsen, H. Zhang, B. Miller, E. Johnston, Y. Rong, Y. Ordenes, K. Ribbeck, S. Angel, P. Eigenthaler, Y. Ko, S. Lim, R. Chandar
- LMC [SII] – S. Points, W. Blair, K. Long, P. F. Winkler, A. Rest, Y.-H. Chu, R. Williams, C.-J. Li
- SMC Hα and [SII] – S. Points, W. Blair, Y.-H. Chu, C.-J. Li, K. Long, E. Peng, T. Puzia, A. Rest, R. Williams, P. F. Winkler



DECam Magellanic Clouds Emission-Line Surveys

Why the Magellanic Clouds?

- Nearby
  - LMC: 49.59 ± 0.09 kpc (Pietrzyński et al. 2019)
  - SMC: 62.44 ± 0.47 kpc (Graczyk et al. 2020)
- Low inclination angle
  - LMC: 36° (Olsen & Salyk 2002)
  - SMC: 64° (Subramanian & Subramaniam 2015)
- Low foreground extinction
  - LMC: A_V = 0.43 – 0.55 mag (Zaritsky et al. 2004)
  - SMC: A_V = 0.18 – 0.46 mag (Zaritsky et al. 2002)

⟹ Can study interstellar structures (e.g., SNRs) at high-spatial resolution with little confusion along the line-of-sight in addition to the underlying stellar population

DECam Magellanic Clouds Emission-Line Surveys

Why the Magellanic Clouds?

- CO (2.6 mm; J 1 → 0) – Wong et al. (2009)
- HI (21 cm) – Kim et al. (2003)
- Radio continuum (6-cm & 3cm) – Dickel et al. (2006)
- Spitzer Mid-IR/Far-IR (24-160 μm [MIPS] and 3.6-8.0 [IRAC]): SAGE LMC – Meixner et al. (2006)
- Spitzer Mid-IR/Far-IR (24-160 μm [MIPS] and 3.6-8.0 [IRAC]): SAGE SMC – Gordon et al. (2011)
- Optical broad band
  - Zaritsky et al. ([UBVI]: SMC - 2002, LMC - 2004)
  - Nidever et al. ([*ugriz*] SMASH; 2017)
- MCELS – Smith et al. (1999)
  - [OIII], Hα, [SII], green continuum, red continuum
- X-ray
  - ROSAT (0.1 – 2.4 keV) – Haberl & Pietsch (1999)
  - XMM (0.1 – 15 keV) – Haberl (2014)
  - eROSITA (0.2 – 8.0 keV) – Sasaki et al. (2021)

⟹ Physical conditions and energetics of multi-phase ISM

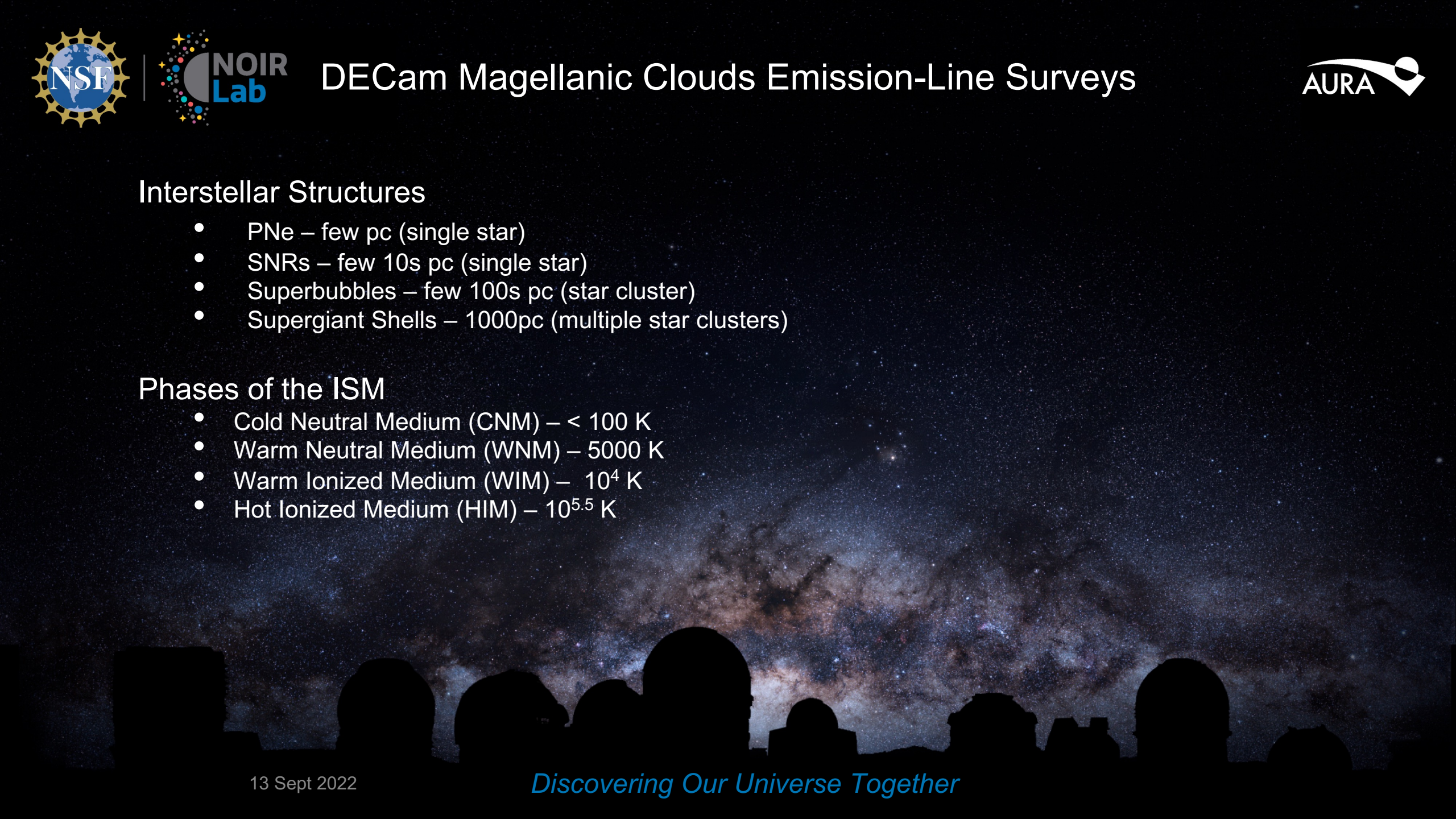
DECam Magellanic Clouds Emission-Line Surveys

Interstellar Structures

- PNe – few pc (single star)
- SNRs – few 10s pc (single star)
- Superbubbles – few 100s pc (star cluster)
- Supergiant Shells – 1000pc (multiple star clusters)

Phases of the ISM

- Cold Neutral Medium (CNM) – < 100 K
- Warm Neutral Medium (WNM) – 5000 K
- Warm Ionized Medium (WIM) – 10^4 K
- Hot Ionized Medium (HIM) – $10^{5.5}$ K



DECam Magellanic Clouds Emission-Line Surveys

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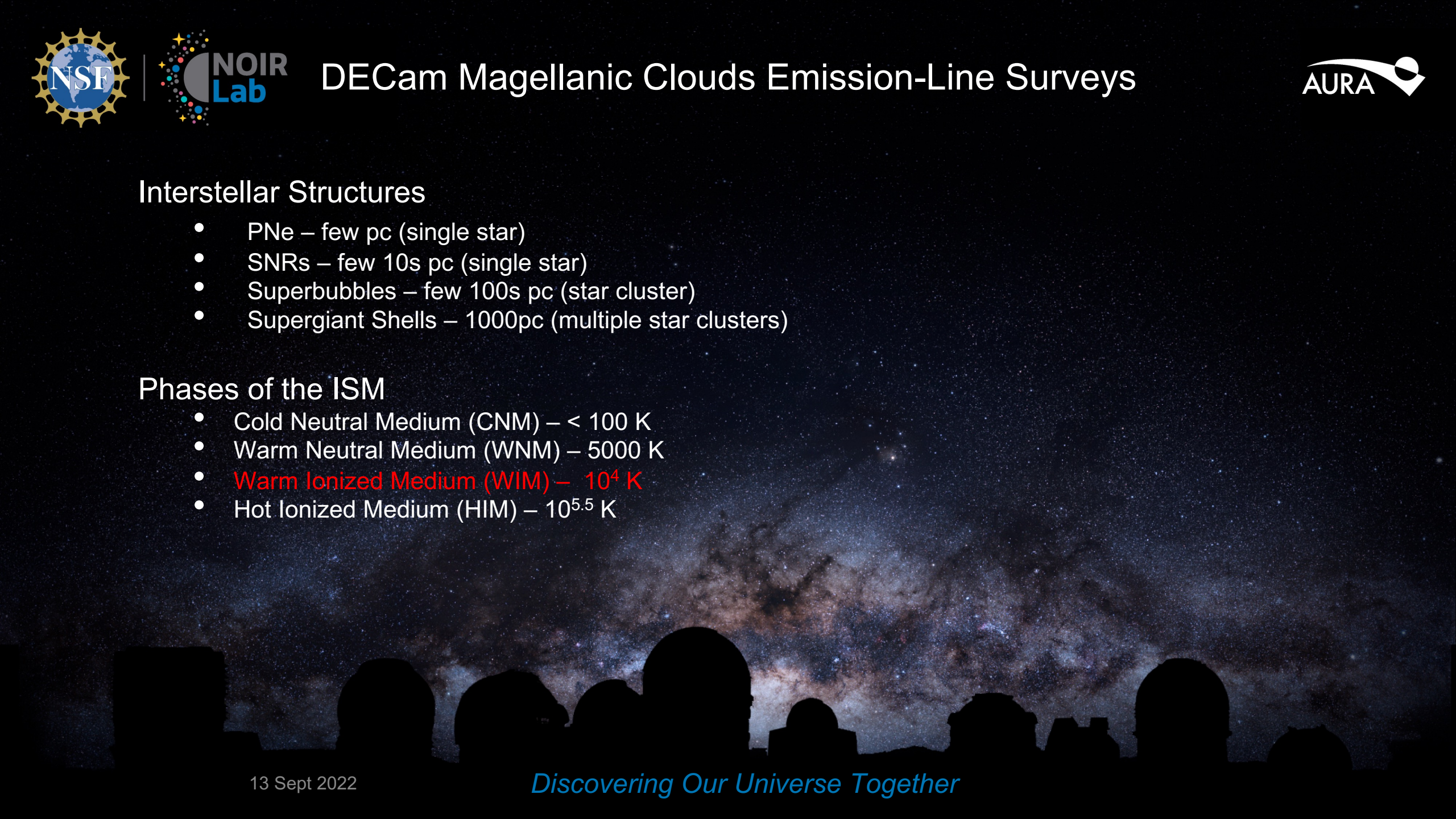


DECam Magellanic Clouds Emission-Line Surveys

Previous Optical Narrow-Band Surveys

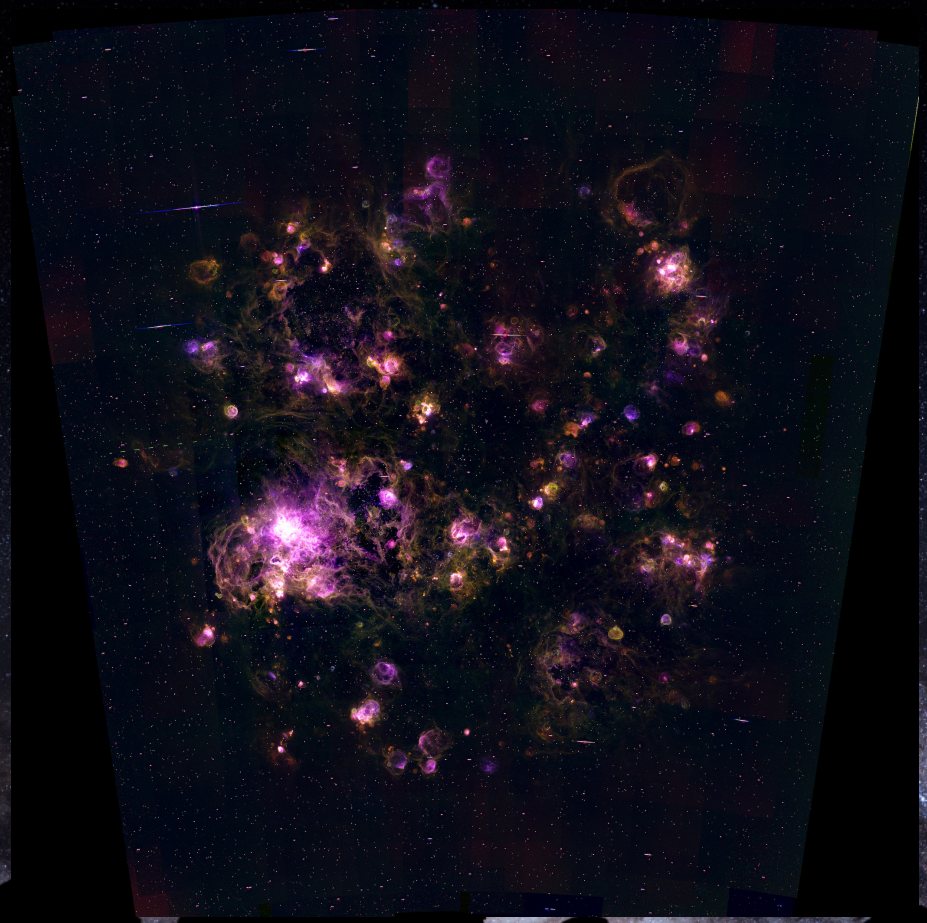
- Henize (1956, ApJS, 2, 315)
  - 221 (415) Emission-line nebulae in LMC (LHA 120-N ###)
  - 90 (117) Emission-line nebulae in SMC (LHA 115-N ###)
- DEM - Davies, Elliott, Meaburn (1976, MmRAS, 81)
  - 329 (358) Emission-line nebulae in LMC (DEM L ###)
  - 167 (168) Emission-line nebulae in SMC (DEM S ###)
- MCELS – Magellanic Cloud Emission-Line Survey (Smith et al. 1999)
  - 401 Emission-line nebulae in LMC (Pellegrini et al. 2012; MCELS-L###)
  - 214 Emission-line nebulae in SMC (Pellegrini et al. 2012; MCELS-S###)

⟹ MCELS 1st global MC survey using CCDs in multiple narrow-band filters ([OIII], Hα, [SII] and continuum)

DECam Magellanic Clouds Emission-Line Surveys

MCELS

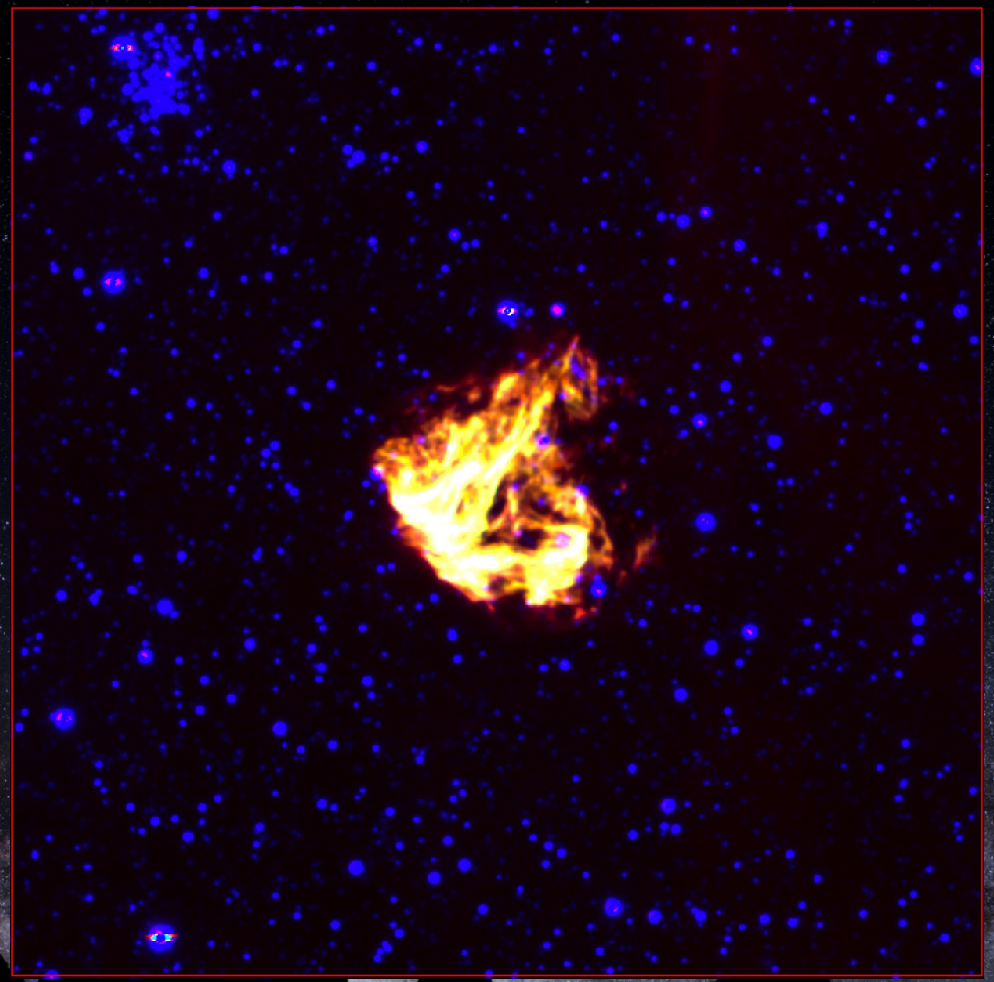
- Covers 8° x 8° LMC
- 5 Filters
  - [OIII] 5012/30
  - Green 5130/155
  - Hα 6568/28
  - [SII] 6729/50
  - Red 6850/100



DECam Magellanic Clouds Emission-Line Surveys

Why DECam?

- **Resolution: 0.27” pixel^{-1} vs 2.3” pixel^{-1}**
- **Depth: few x10^{-18} erg s^{-1} cm^{-2} vs ~10^{-17} erg s^{-1} cm^{-2}**

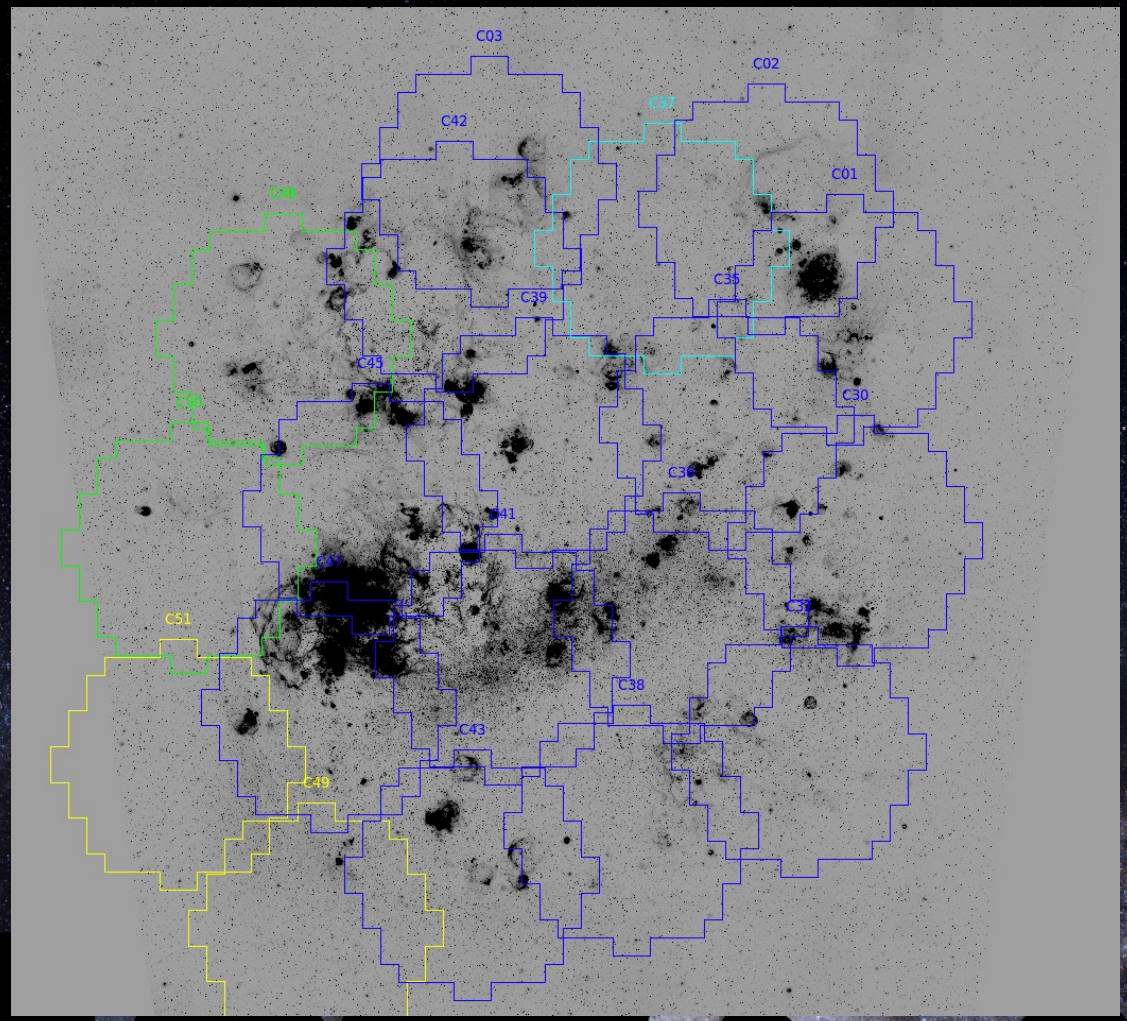


DECam Magellanic Clouds Emission-Line Surveys

Survey Observing

- CARMENERE (Hα – N662)
  - 17 fields
  - 6 x 30 sec (Hα)
  - 6 x 800 sec (Hα)
- LMC [SII] (N673, *r*)
  - 19 fields
  - 6 x 2 x 30 sec [SII]
  - 6 x 2 x 800 sec [SII]
  - 6 x 8 sec [*r*]
  - 6 x 60 sec [*r*]
- SMC – Hα, [SII], *r*
  - 5 fields
  - Use exposure times from LMC surveys

DECam Magellanic Clouds Emission-Line Surveys



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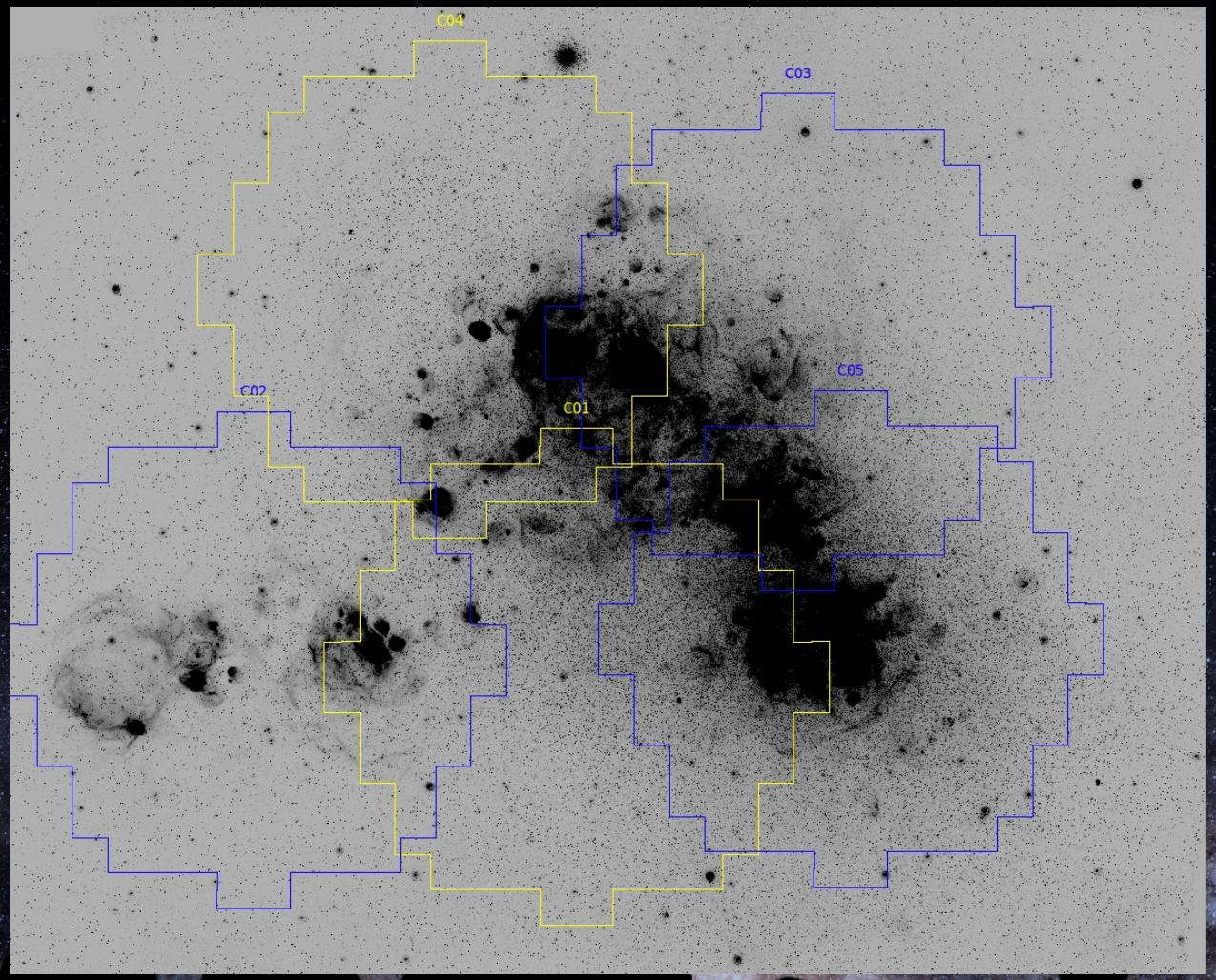
Discovering Our Universe Together

DECam Magellanic Clouds Emission-Line Surveys



Discovering Our Universe Together

DECam Magellanic Clouds Emission-Line Surveys

Data Reduction

- Start with 1 field to test methods
- Use DECam Community Pipeline (Valdes & Gruendl 2014)
- Split each field into individual detectors (e.g., IRAF mscred.mscsplit)
- Normalize data to 1 sec exposures
- Sky-subtraction
- Combine individual detectors from each dither to fill in chip-gaps
- Continuum-subtraction
  - Create “line-free” continuum image
  - Scale “line-free” continuum image to narrow-band images
- Mosaic
- Flux-calibrate

DECam Magellanic Clouds Emission-Line Surveys

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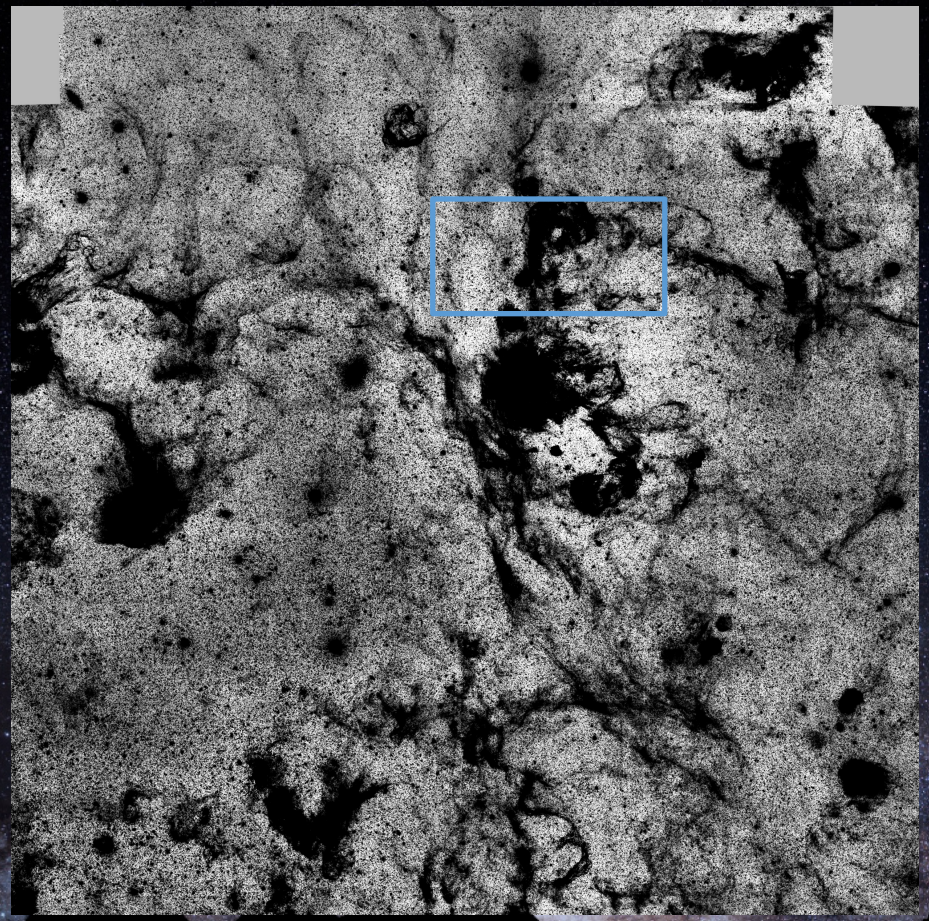
DECam Magellanic Clouds Emission-Line Surveys

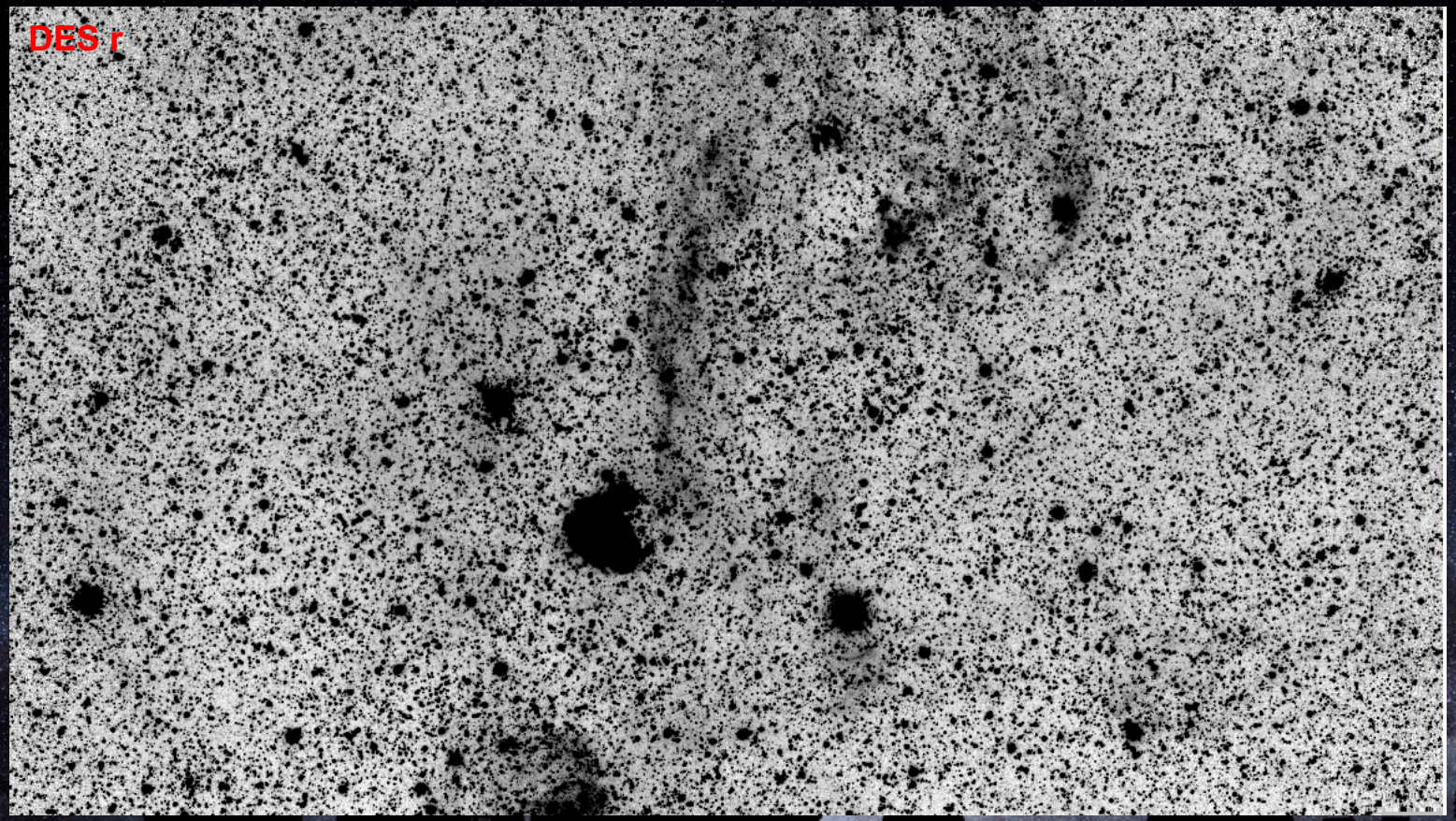
Sky-subtraction:

- Difficult



DECam Magellanic Clouds Emission-Line Surveys

Create “line-free” continuum image



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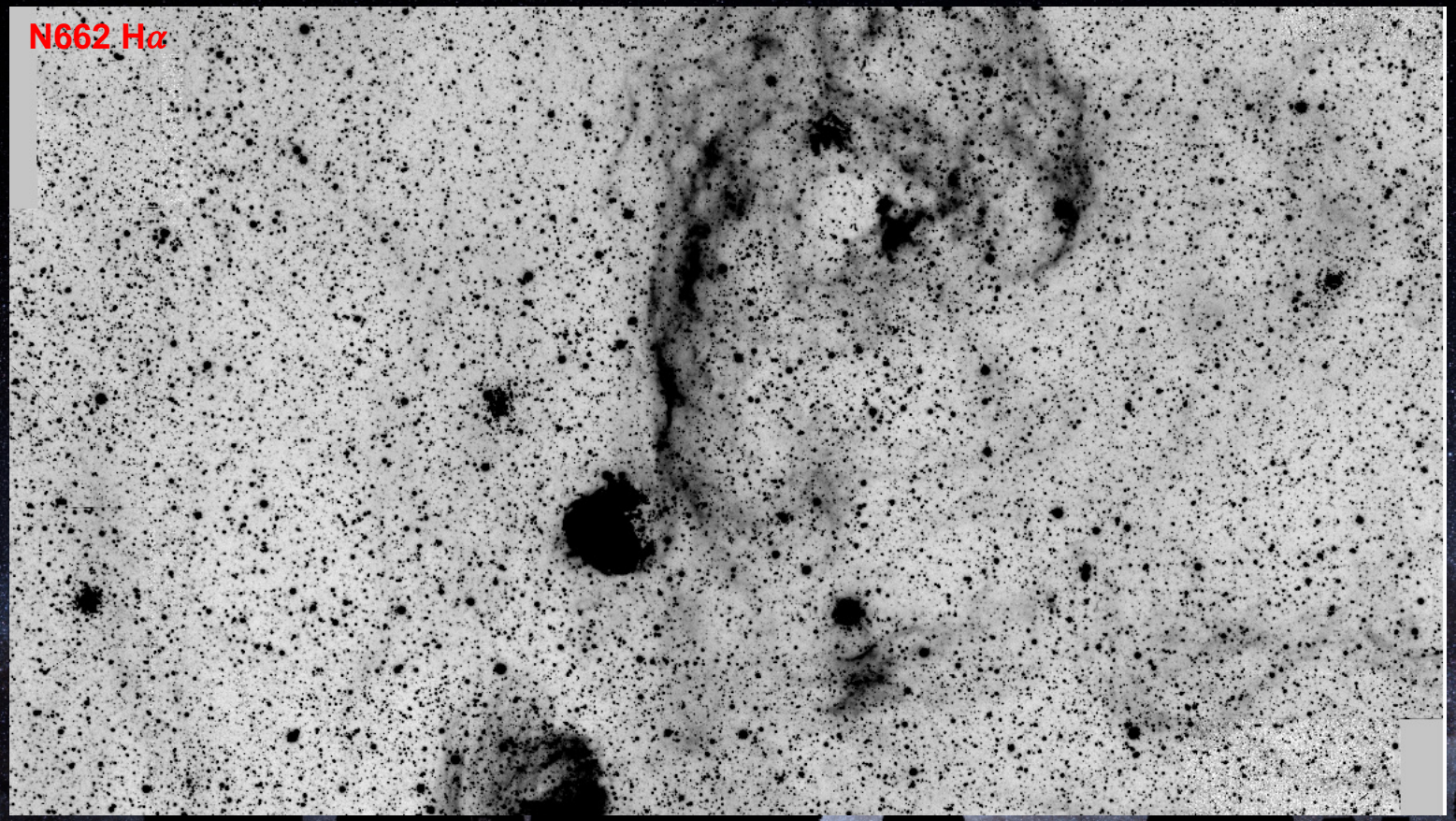
DECam Magellanic Clouds Emission-Line Surveys

Create “line-free” continuum image



DECam Magellanic Clouds Emission-Line Surveys

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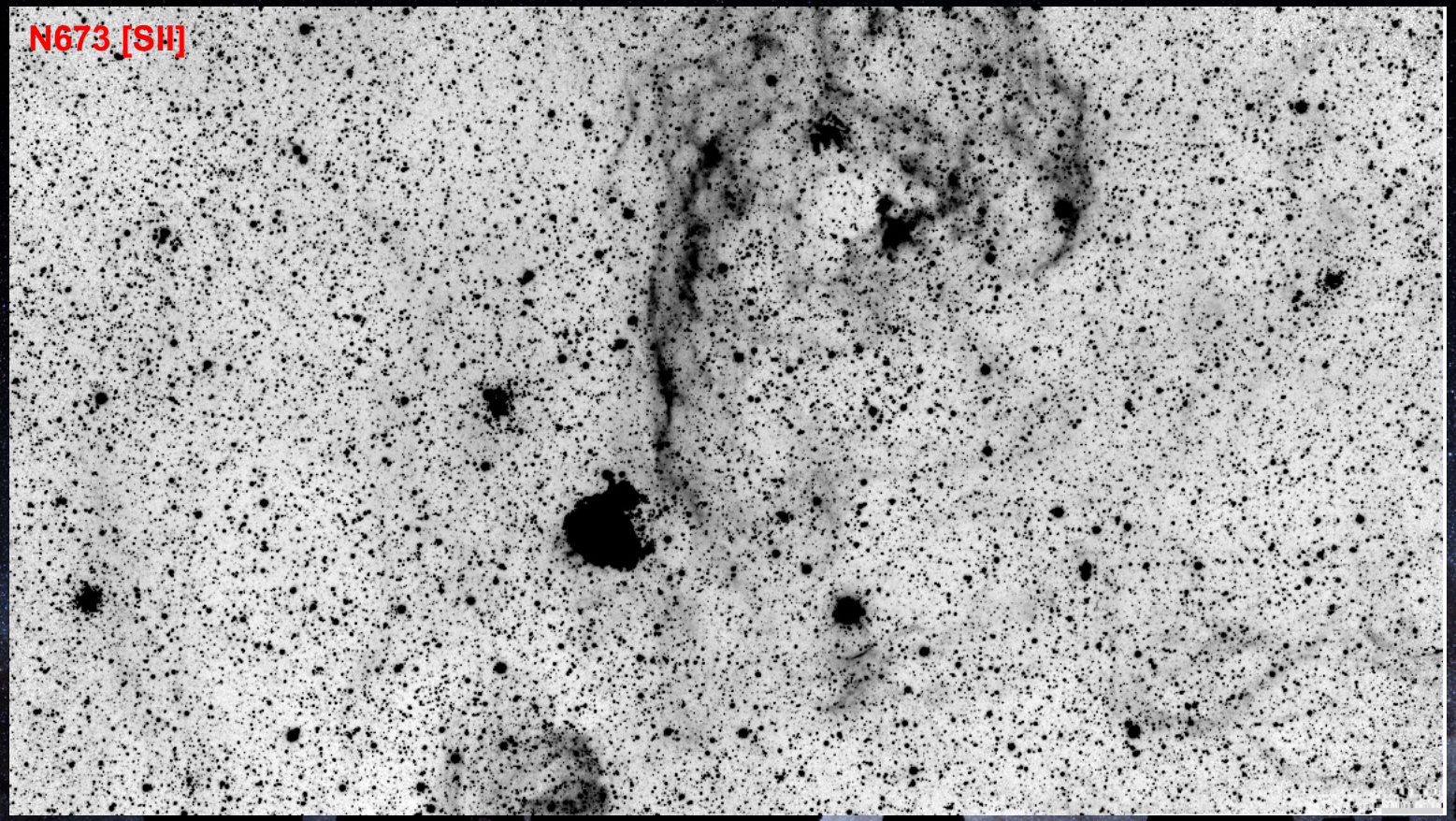

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DECam Magellanic Clouds Emission-Line Surveys

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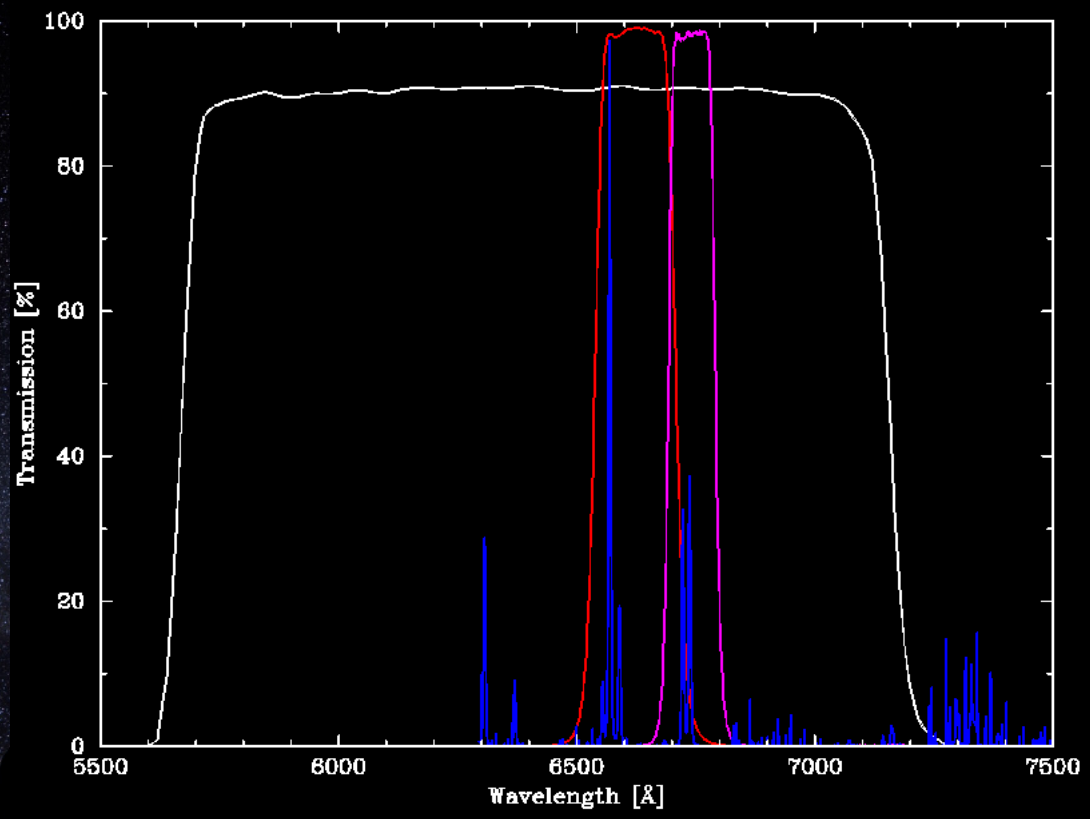

DECam Magellanic Clouds Emission-Line Surveys

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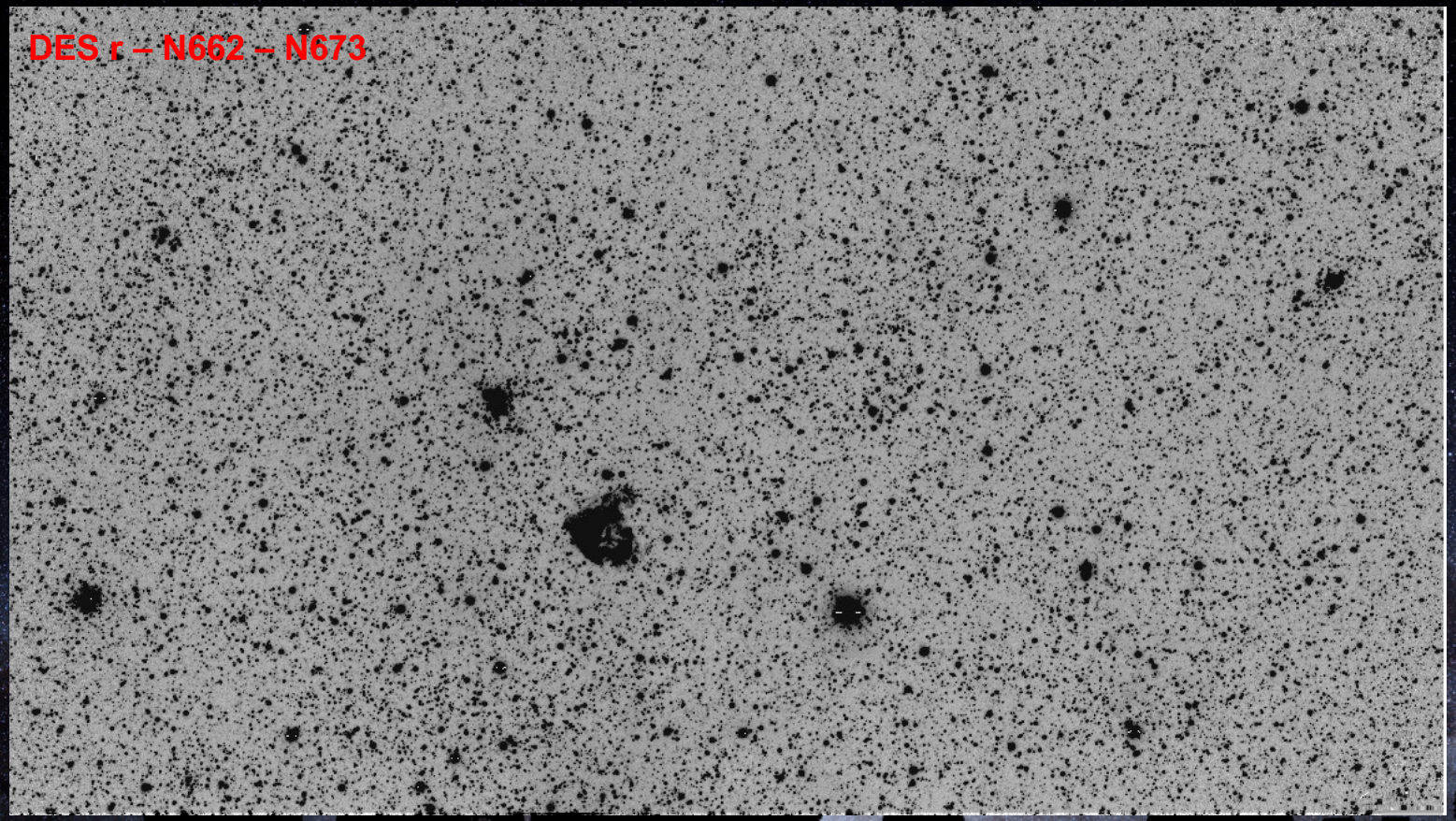


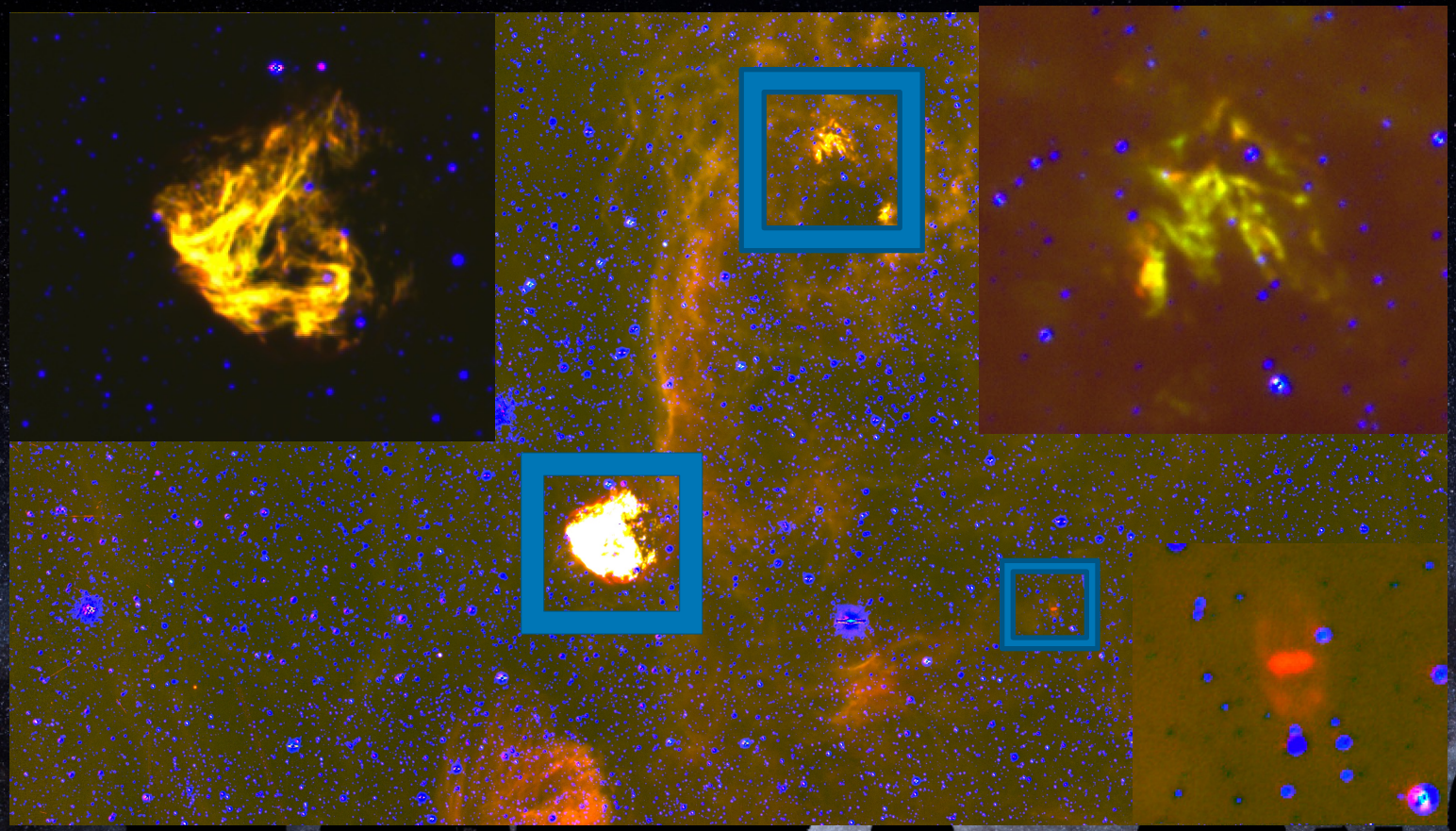
Discovering Our Universe Together

DECam Magellanic Clouds Emission-Line Surveys

Combine

DECam Magellanic Clouds Emission-Line Surveys

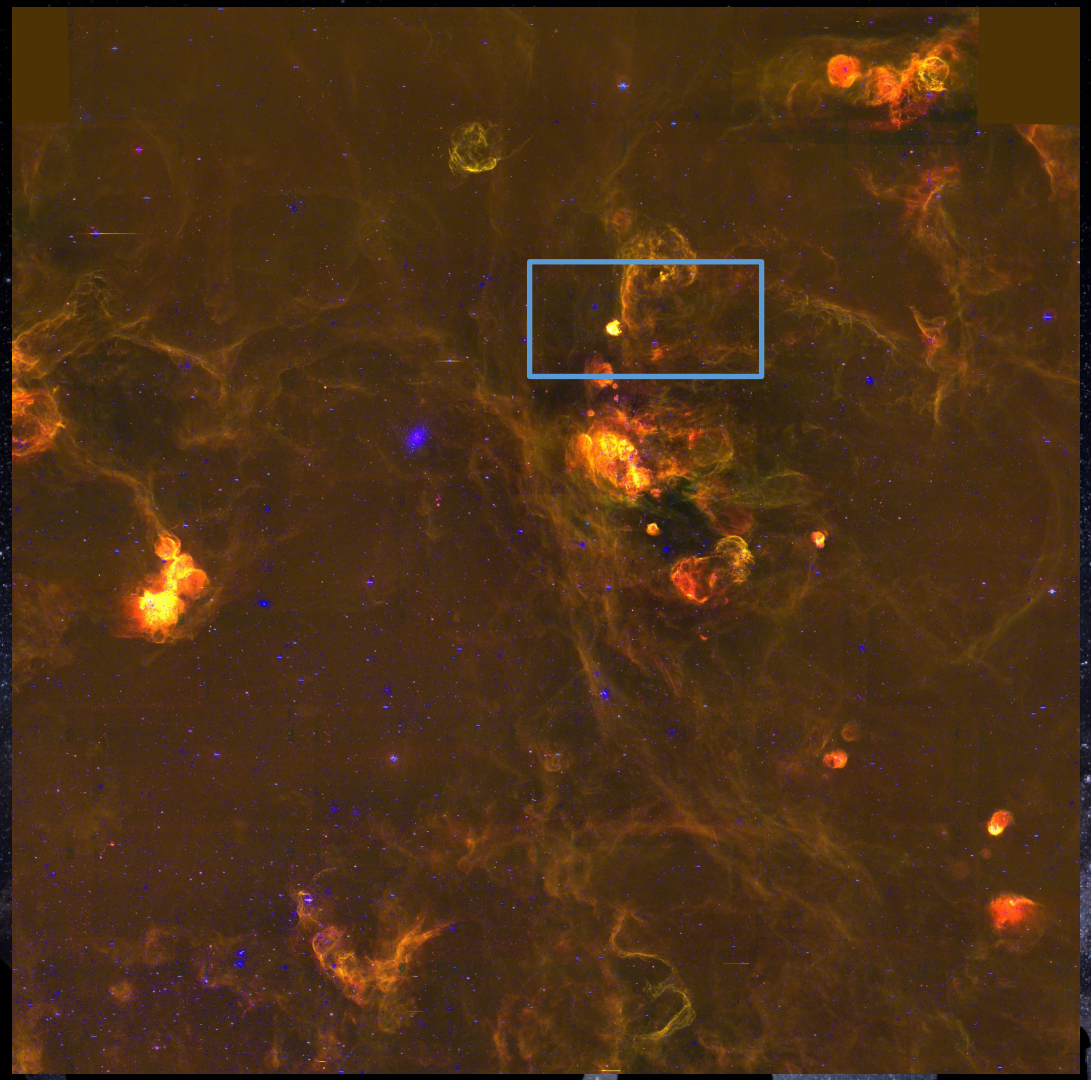
Combine – Continuum-subtracted



DECam Magellanic Clouds Emission-Line Surveys

Mosaic

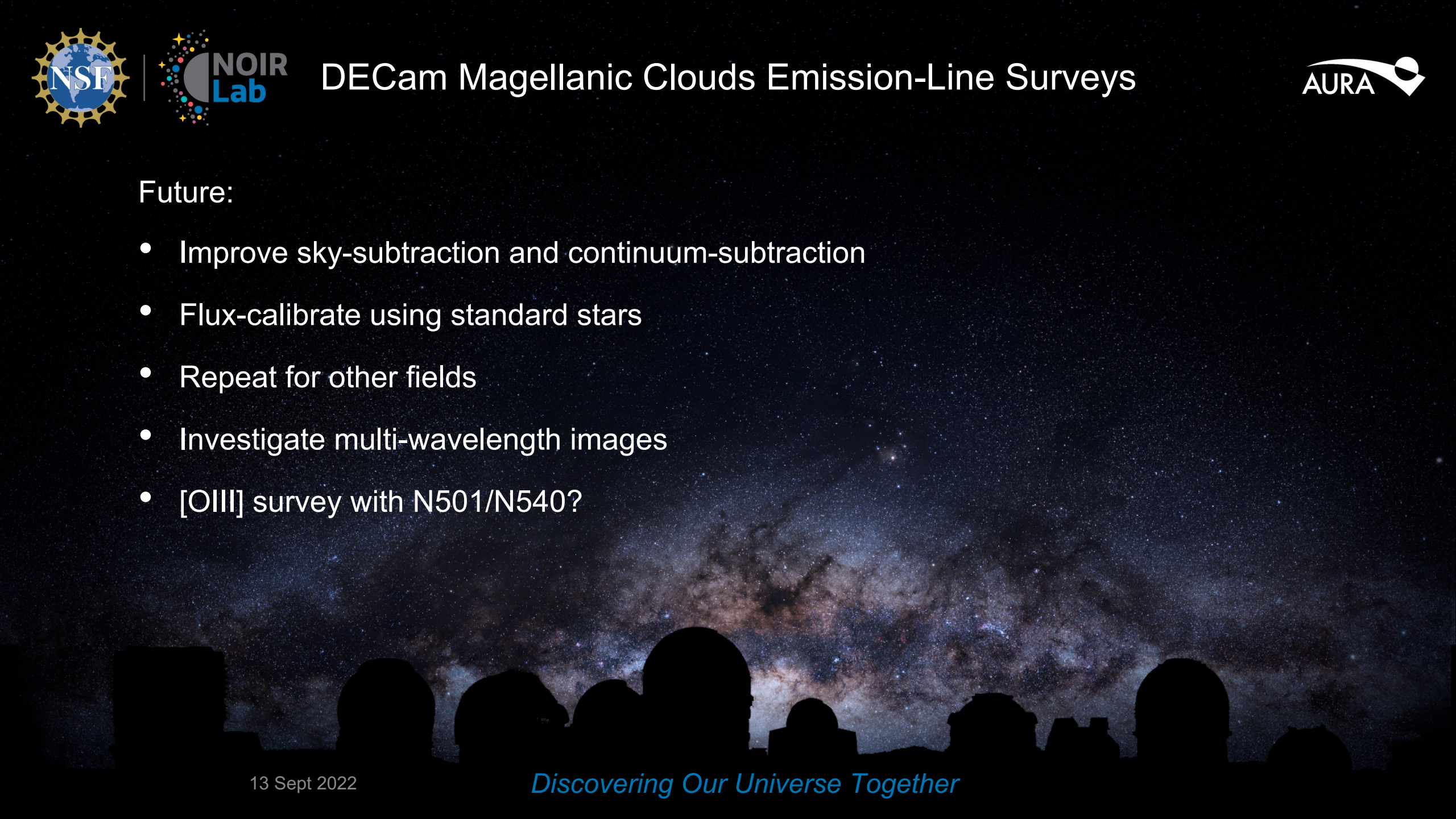
1.5° x 1.5°



DECam Magellanic Clouds Emission-Line Surveys

Future:

- Improve sky-subtraction and continuum-subtraction
- Flux-calibrate using standard stars
- Repeat for other fields
- Investigate multi-wavelength images
- [OIII] survey with N501/N540?



DECam Magellanic Clouds Emission-Line Surveys

Many thanks to K. Lee for providing the DECam N673 filter and to E. Peng & T. Puzia for providing the N662 filter.