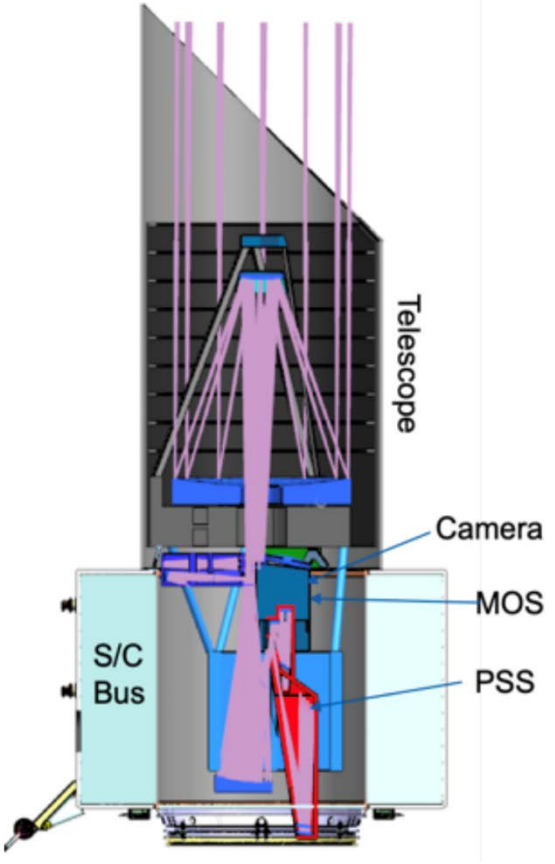
ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY

e-Workshop 2020 – October 27-29

Cosmic Evolution Through UV Surveys



OUTLINE OF TALK

Introduction to CETUS, a UV survey telescope

Science program examples

CETUS, an international telescope?

CETUS Final Report, arXiv 1909.10437

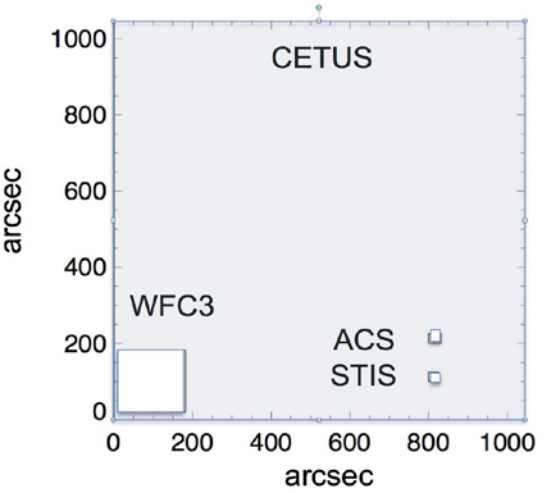
Contact email: sara.heap@gmail.com

New Capabilities ➜ New Science

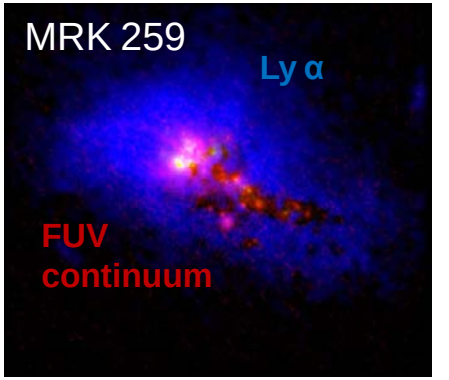
Fast Facts

- CETUS telescope: D=1.5 m, f/5
- 3 instruments: Camera, MOS, and spectrograph
- Field of view of wide-field instruments
  - FUV & NUV Camera: 17.4'x17.4'
  - NUV MOS: 17.4'x17.4'
- Spatial Resolution: 0.40" (FUV), 0.3-.4" (NUV)
- Spectrograph Wavelength Coverage
  - LUV/FUV: 1000-1800 Å
  - NUV-Blue: 1800—4000 Å
- Spectral Resolving Power
  - LUV/FUV: 20,000
  - NUV: 1000 (MOS), 40,000 (Echelle)

Wide field of view to make UV img. surveys

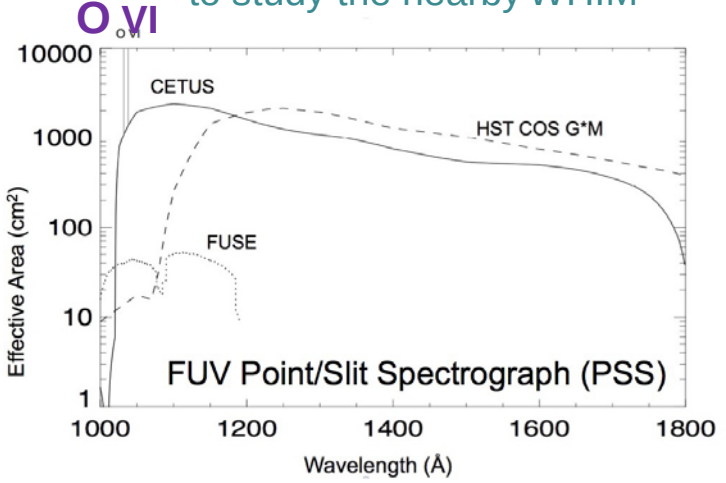


Sensitivity to diffuse sources to find what's out there

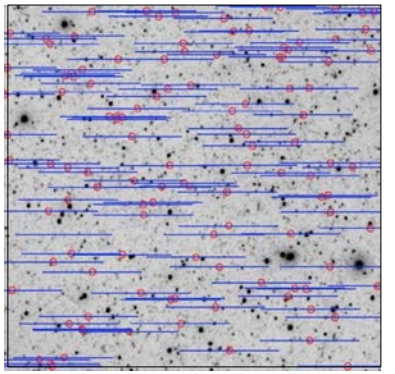


Östlin + 2014

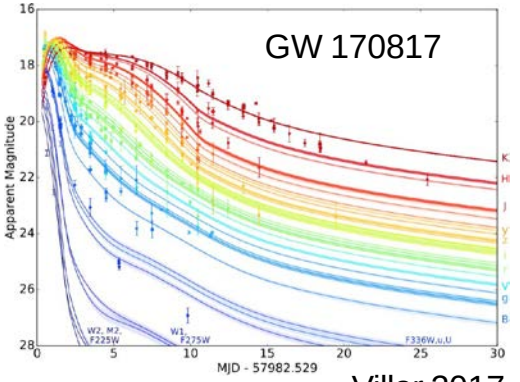
LUV (1000-1150 Å) sensitivity to study the nearby WHIM



MOS/MSA Spectroscopy SF regions in nearby galaxies, z=1 galaxies, etc.



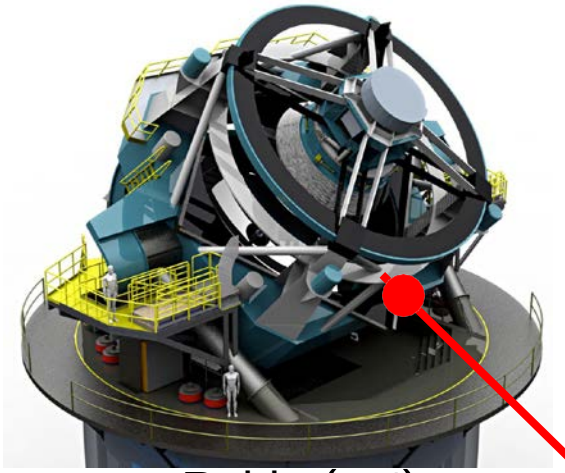
Rapid response to catch GW sources, SNe



Villar 2017

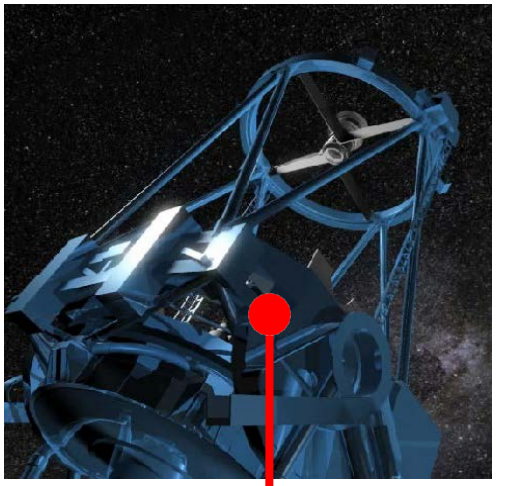
Survey mode: CETUS will work with other telescopes of the 2020's to solve major problems in astrophysics

Optical Transients



Rubin (opt)

Optical – Near-IR



Subaru, Euclid, Roman

sub-mm to mm

ALMA

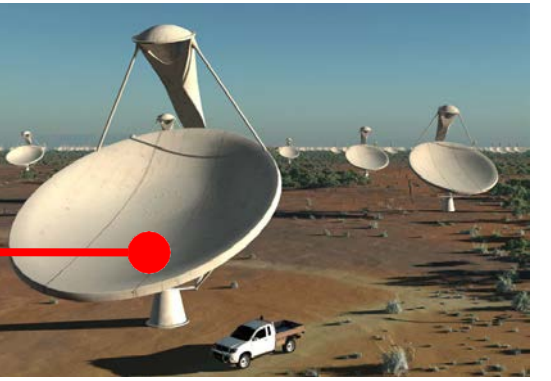
X-ray

E-ROSITA (opt)

CETUS

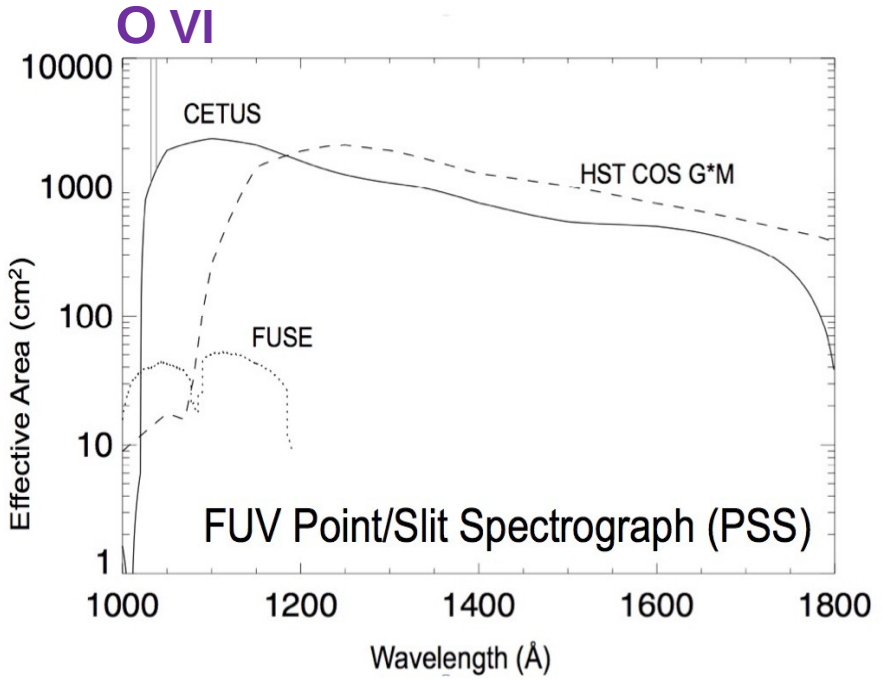
(ultraviolet)

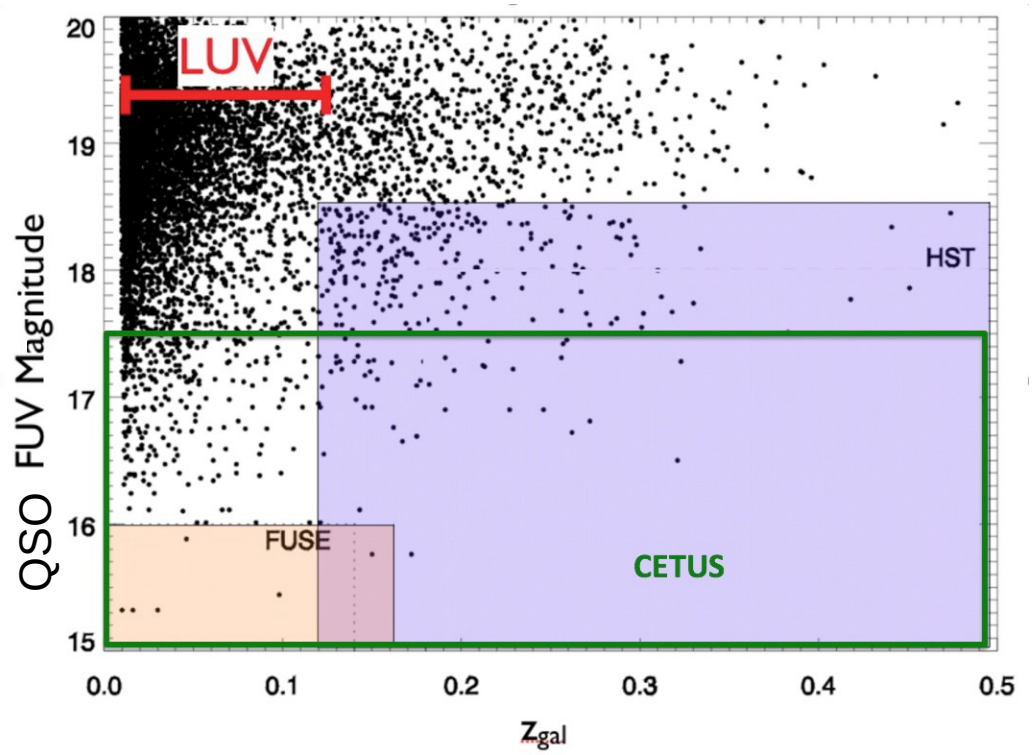
21 cm at z<0.4



SKA etc. (radio)

CETUS & X-ray telescopes will find the missing baryons in the circumgalactic medium



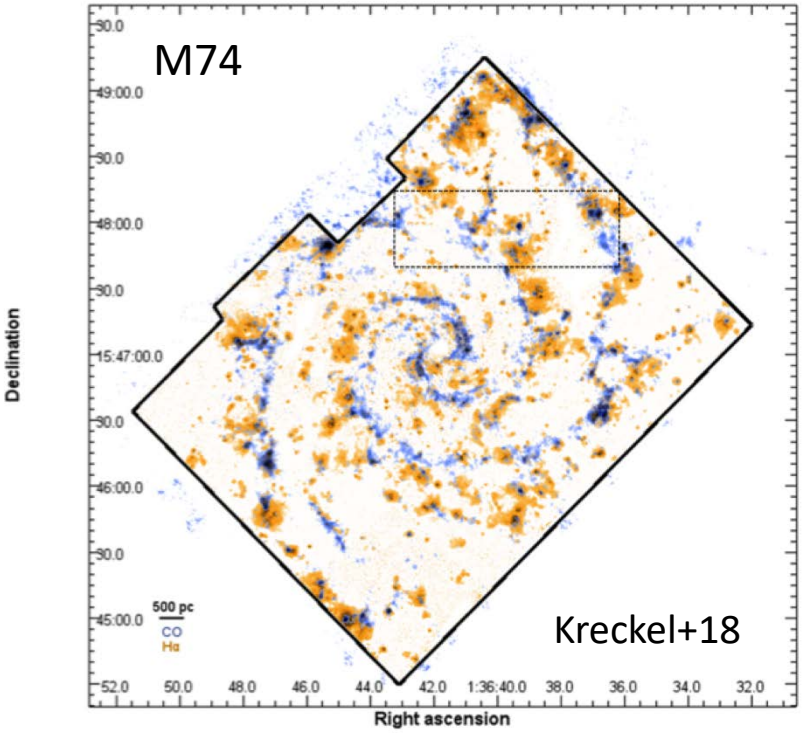


Adapted from N. Lehner

X-ray	UV	Optical - NearIR	Far-IR	Radio

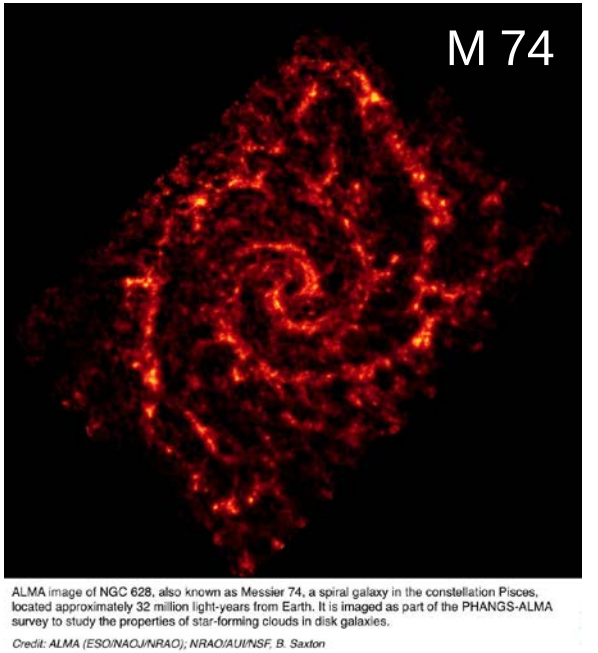
New studies by ALMA & MUSE of star formation as related to galaxy properties

Surface density of H_2 and HII regions



Hα & CO emission together enable a measurement of star-formation efficiency across a galaxy

ALMA / PHANGS CO (2-1)



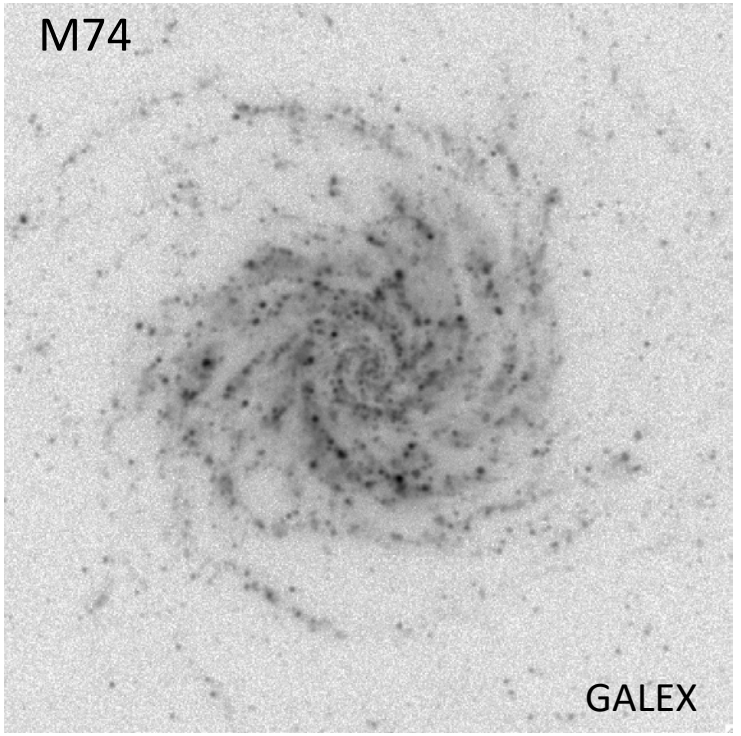
ALMA image of NGC 628, also known as Messier 74, a spiral galaxy in the constellation Pisces, located approximately 32 million light-years from Earth. It is imaged as part of the PHANGS-ALMA survey to study the properties of star-forming clouds in disk galaxies.

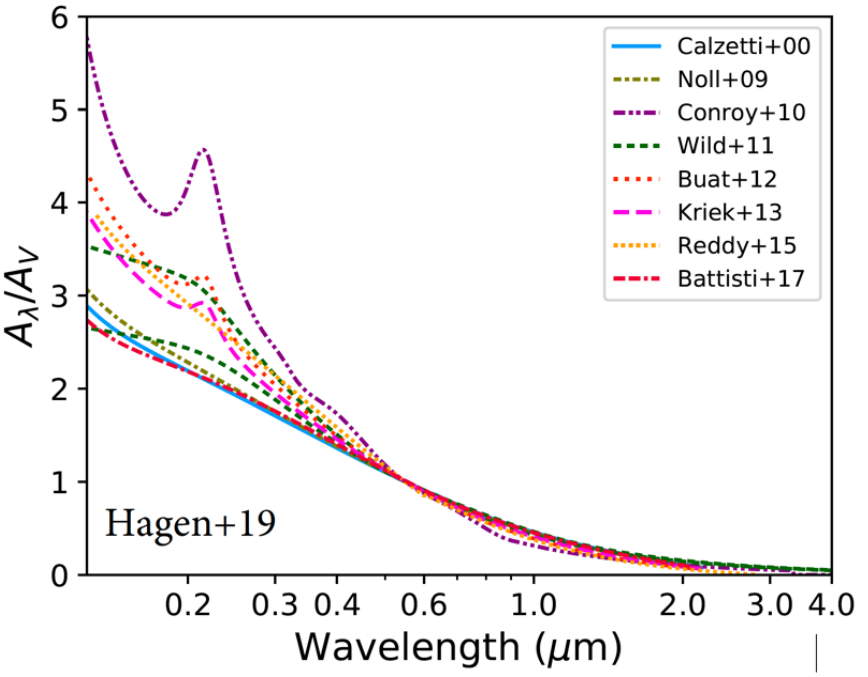
Credit: ALMA (ESO/NAOJ/NRAO); NRAO/AUI/NSF, B. Saxton

ALMA/PHANGS survey will observe "100,000 star factories" in 74 galaxies via CO (2-1) emission

X-ray	UV	Optical - NearIR	Far-IR-mm	Radio

CETUS will also advance our understanding of star formation and stellar feedback





CETUS UV images will show the large-scale structure of a galaxy -- young stellar populations and dust at ~20 parsec resolution

CETUS NUV spectra will reveal the small-scale properties of the stars, interstellar gas, and dust extinction curve in every star-forming region viewed by PHANGS

International Collaboration Would Make CETUS Even Stronger

Better Science

- Experience with IUE and Hubble shows the benefit of international, collaborative research
- European participation in Astro2020 Science White Papers & U.S participation in ESA's Voyage-to-2050 papers strengthen the scientific case for an international UV telescope like CETUS

Availability of Cutting-Edge Technologies – no one country has an edge on all needed technologies for mirrors, gratings, detectors, etc.

Better telescope than one country can afford because of international contributions (SDSS-V involves 30 institutions)

- Instrument(s): Telescope
  NUV Multi-Object Spectrograph with NASA-supplied next gen. microshutter array
  FUV/NUV high-resolution spectrograph
- Some CETUS components are already planned to have an international source
  - Germany: Schott ZERODUR mirror substrates , convex grating for NUV MOS (Zeiss)
  - France: holographic gratings for FUV spectrograph (Horiba-JY)
  - Canada/U.K.: photon-counting T-e2v 4Kx4K EMCCD for all three NUV instruments (NüVü)
  - India: FUV filter wheels (from Korth or Crystran)
- Software: simulations, trade-studies
- Testing & Calibration
- Science operations, post-observation data processing, analysis tools`1

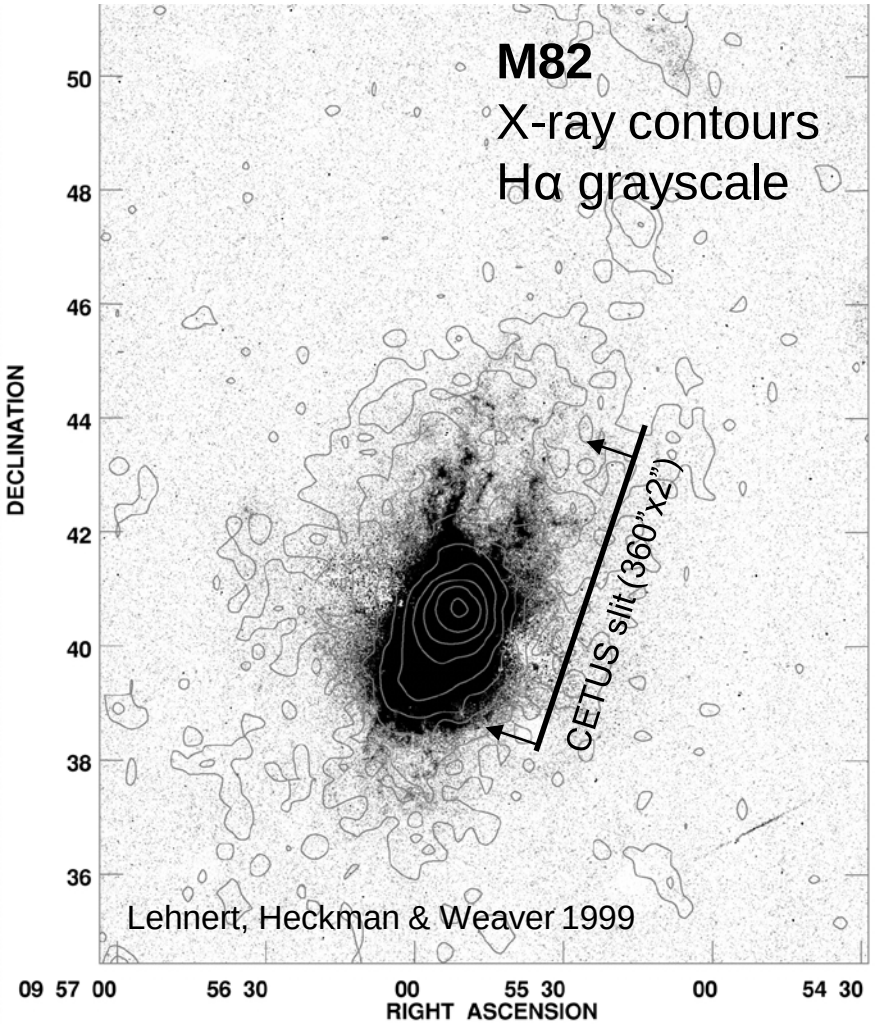
THE END

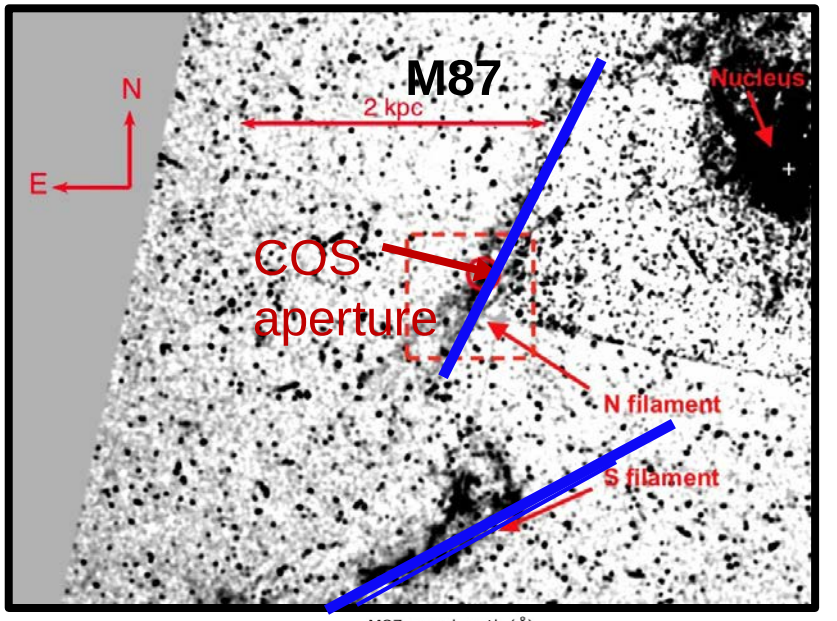
For details, download CETUS Final Report, arXiv 1909.10437

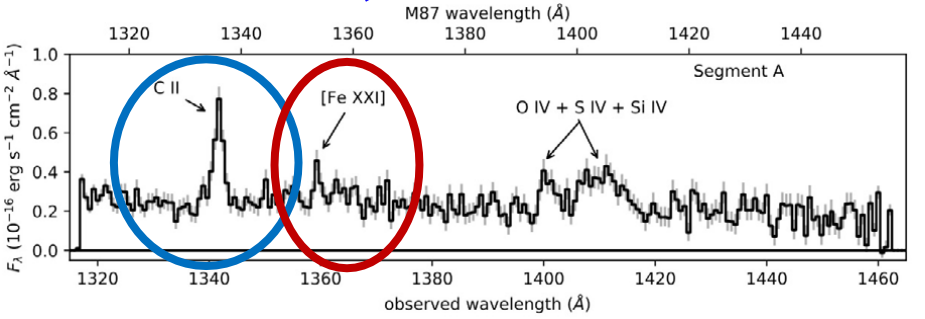
For copies of this presentation, email: sara.heap@gmail.com

Extra science cases follow

CETUS will directly observe feedback from stars, SN, SMBH



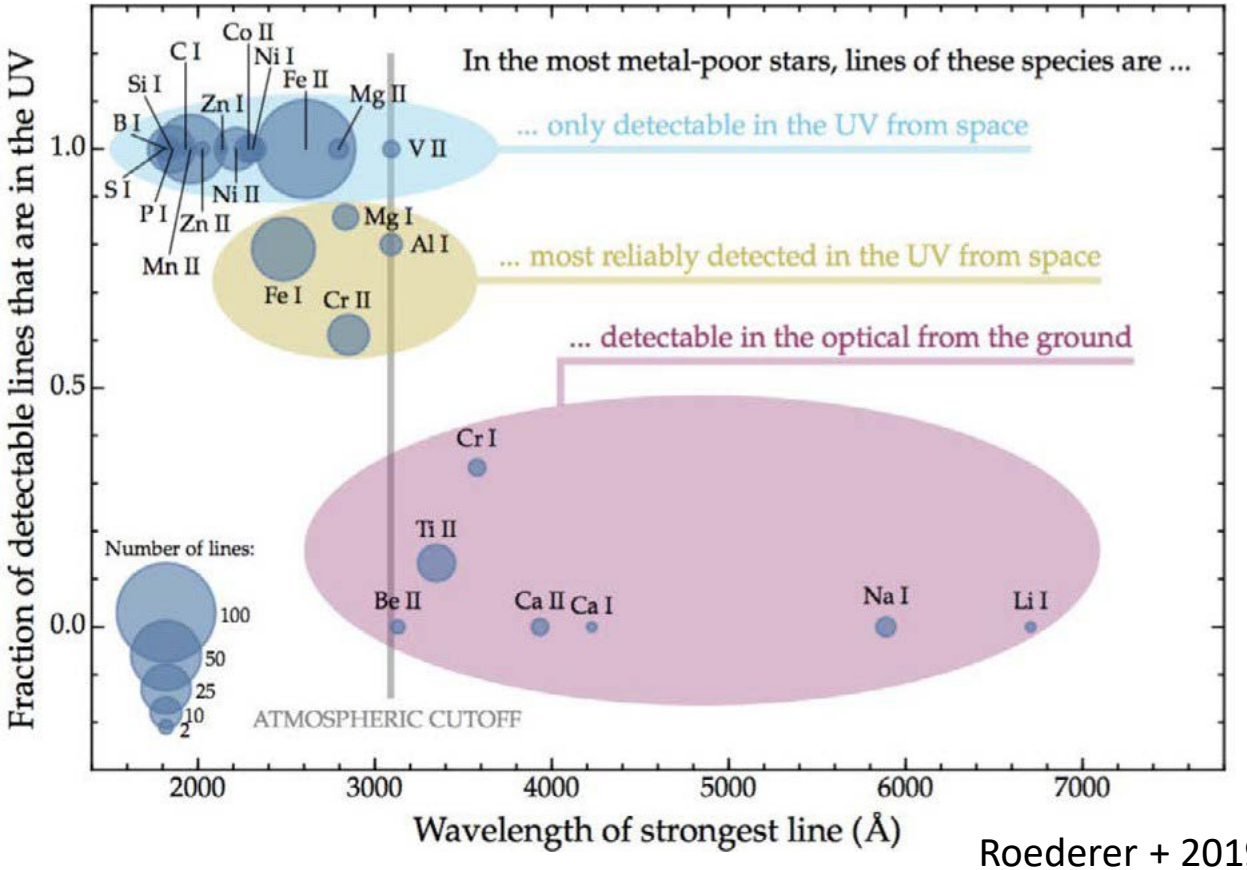




Anderson & Sunyaev 2018

X-ray	UV	Optical - NearIR	Far-IR	Radio

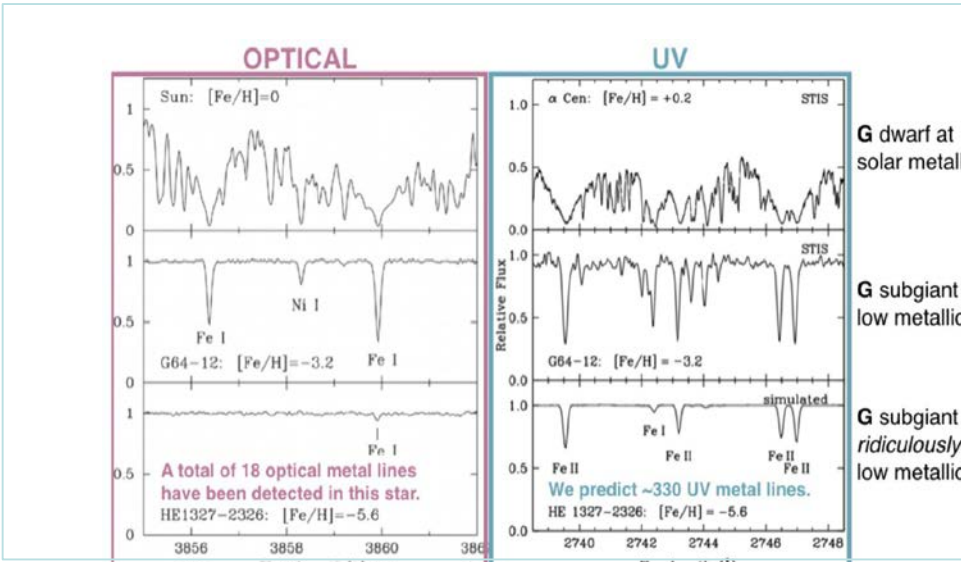
CETUS will measure the abundances of extremely metal-poor stars found by SkyMapper (Australia) and Lamost (China)

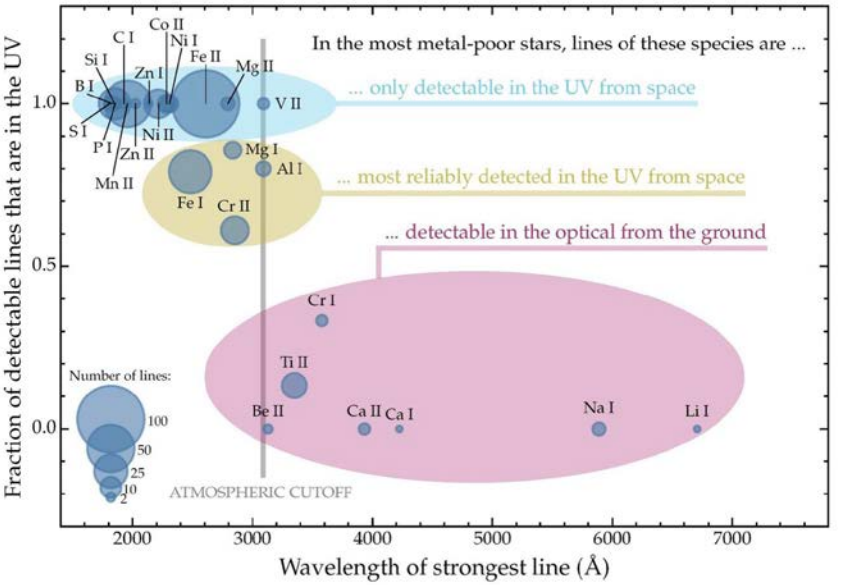


Roederer + 2019 Astro2020 SWP

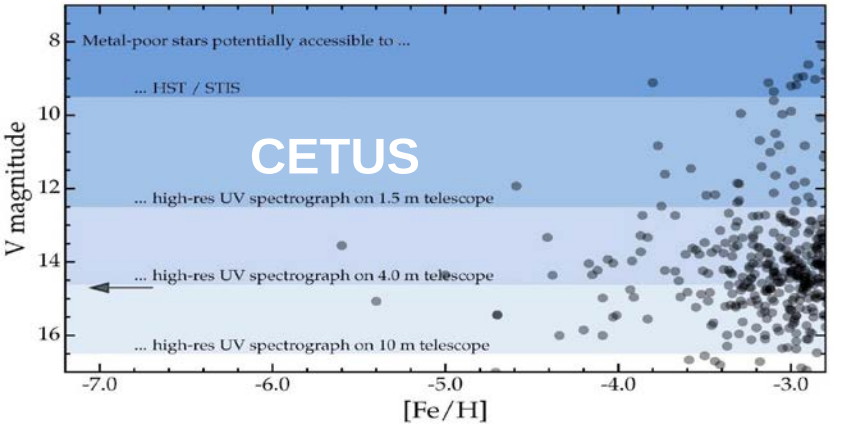
UV | Optical - NearIR | Far-IR | Radio

CETUS will chart metal enrichment in the infant universe





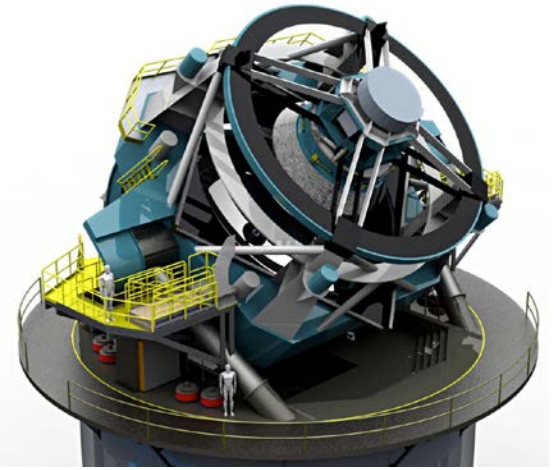
The near-UV is rich in spectral diagnostics of metals (top-L) which enable detection of many more metal lines in the most metal-poor stars (top-R). CETUS will observe a larger sample of metal-poor stars than is available to HST's STIS spectrograph (bottom-R).



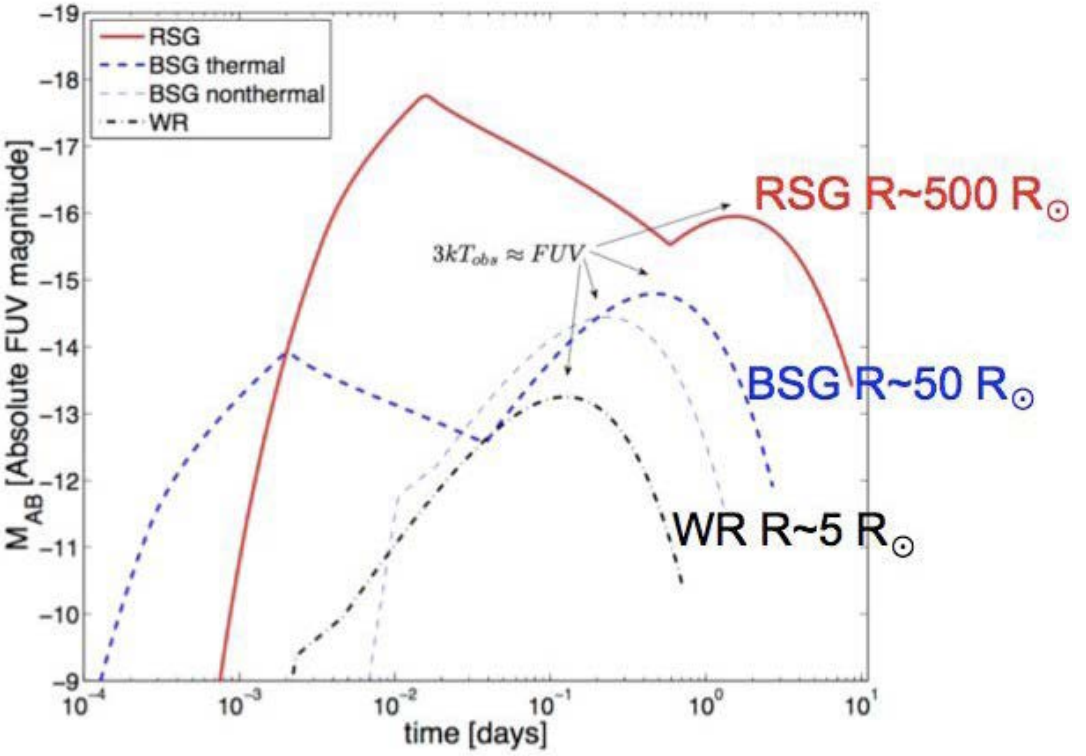
Ian Roederer, Astro2020 Science WP

X-ray	UV	Optical - NearIR	Far-IR	Radio

CETUS will follow up on LSST supernova alerts to learn how massive stars end their lives



Rubin



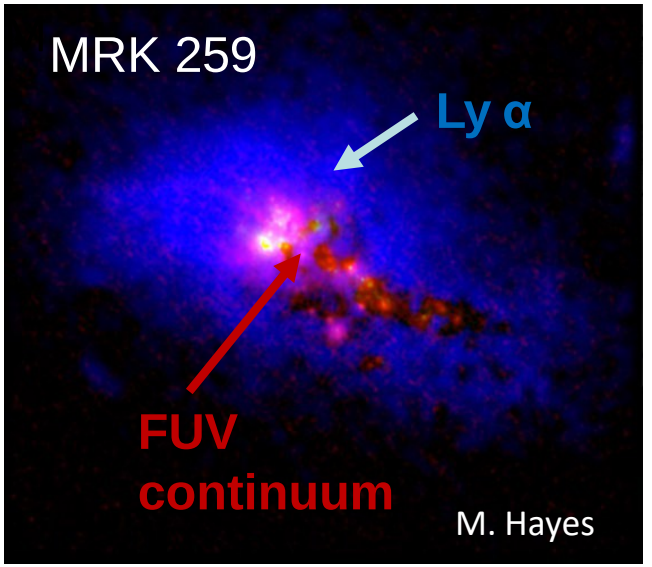
CETUS will identify the progenitors of core-collapse supernovae by their FUV light curves
(Nakar & Sari, 2010)

X-ray	UV	Optical - NearIR	Far-IR	Radio

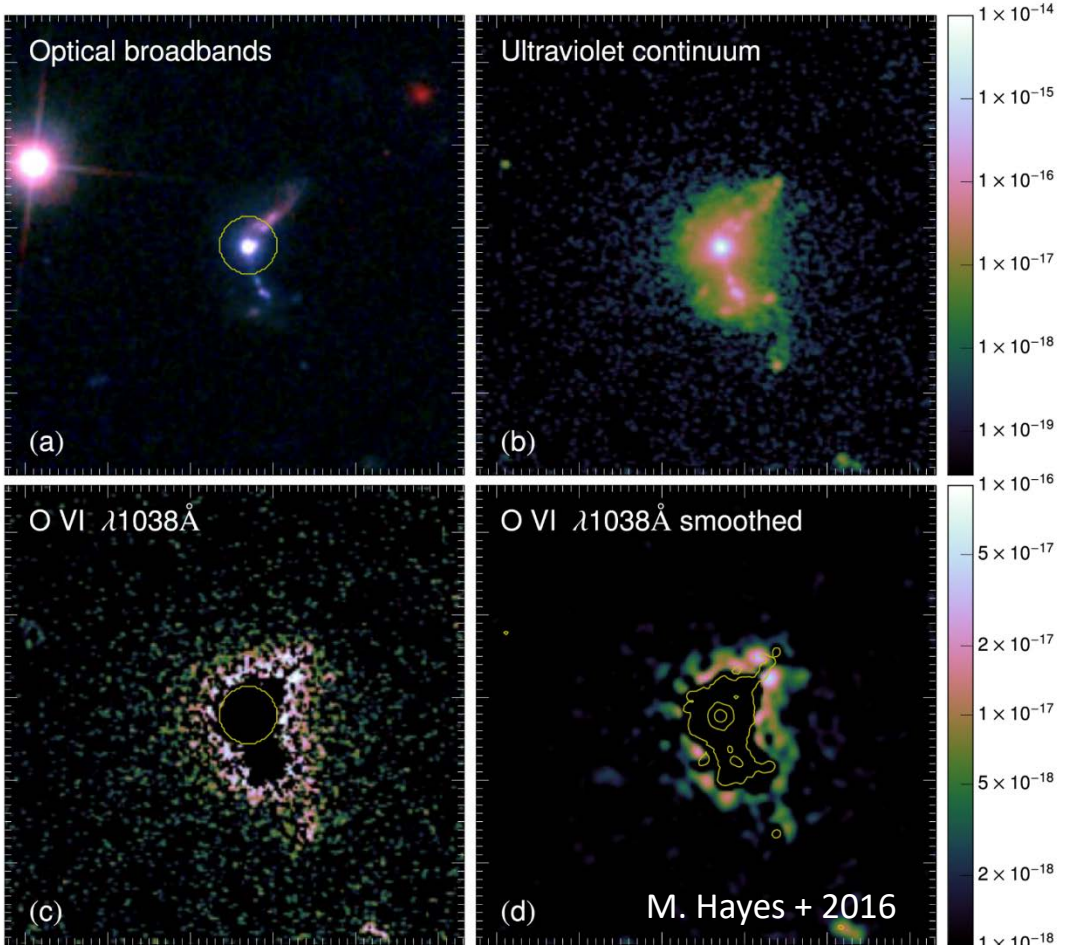
Discovery mode:
CETUS cameras will find what's out there

All observations can be done in parallel

FUV filter imagery

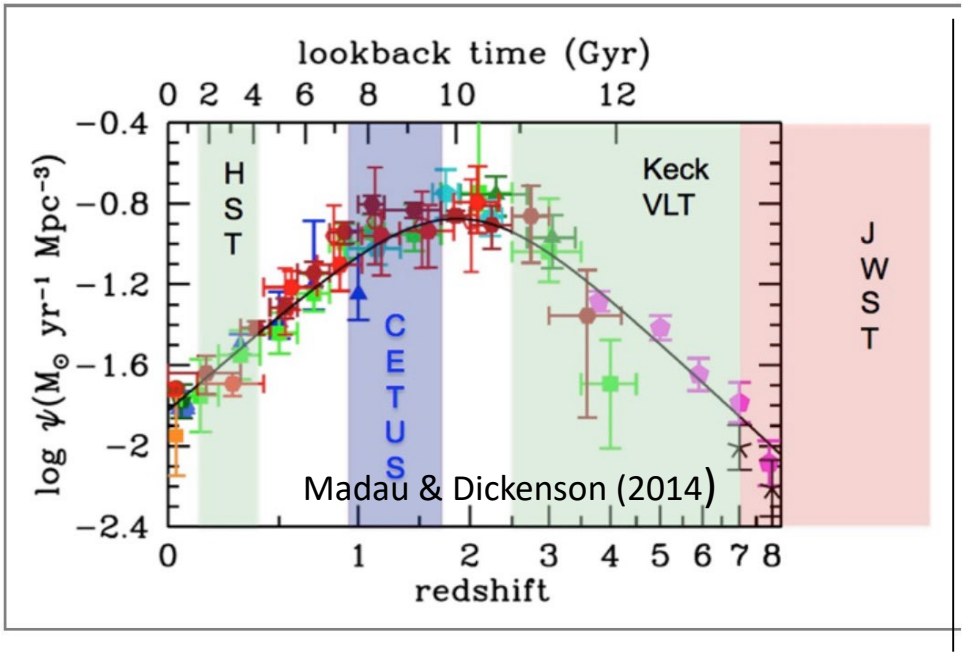


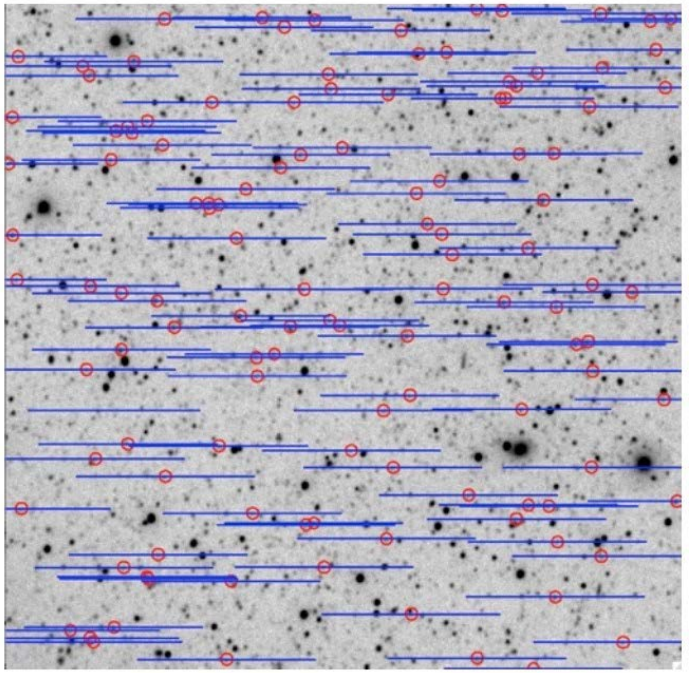
Discover {25,35,30} new galaxies
at z={0.05,0.15,0.27}
with 1000X FOV of Hubble



X-ray	UV	Optical – Near-IR	Far-IR		Radio

CETUS will join Subaru/PFS & Roman to survey z~1 galaxies at λ_{rest}~0.1-1.0 μ





Using its NUV MOS, CETUS will obtain >10^4 NUV (rest FUV) spectra of z~1 galaxies to compare with HST UV spectra at low z.

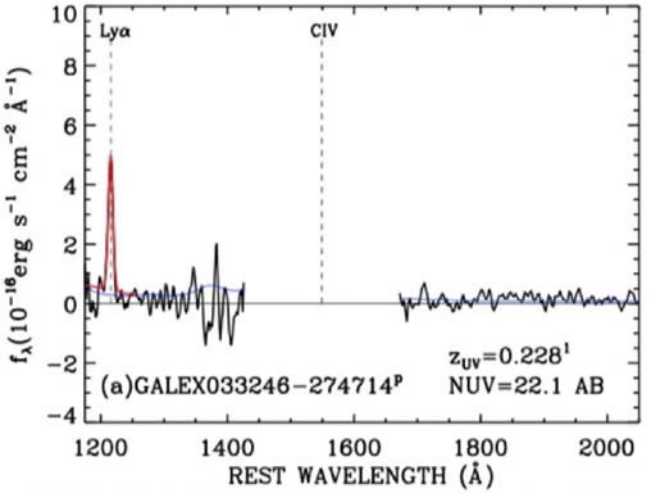
In one pointing, the CETUS MOS will obtain spectra (blue) of ~70 galaxies brighter than m=24.3 AB (red)

X-Ray	UV	Optical – Near-IR	Far-IR	Radio

Discovery mode:
CETUS spectrographs will find what's out there

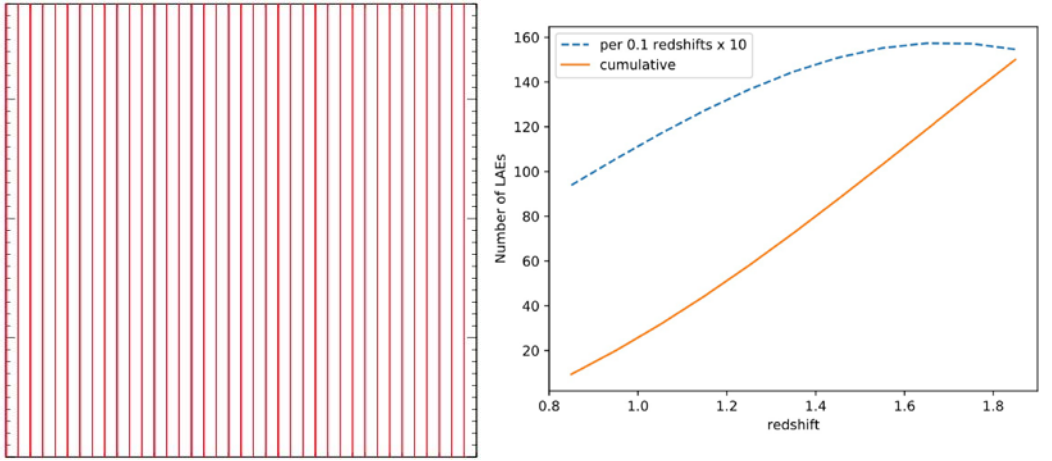
All observations can be done in parallel

FUV long-slit spectra



Credit: I. Wold+ (2017)

NUV MOS long-slits



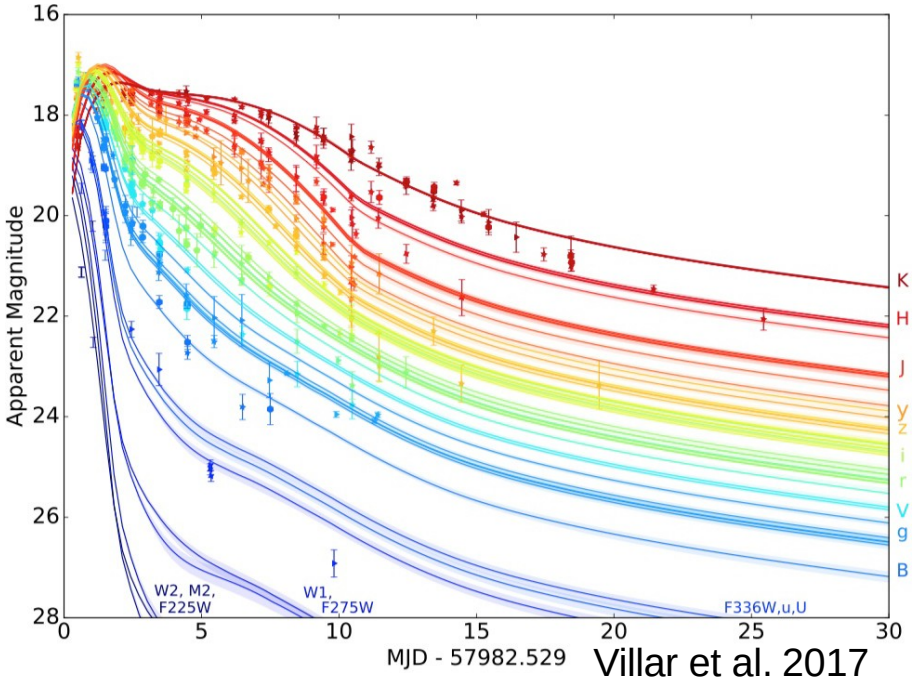
Discover >140 LAE's at z~0.8-1.8

Credit: M. Hayes (priv. comm.)

X-ray	UV	Optical – Near-IR	Far-IR	Radio

CETUS will have rapid response (<15-min slew to target) to catch and monitor transients in the UV

Light curves of GW 170817



Villar et al. 2017

FUV Light curves of CCSN

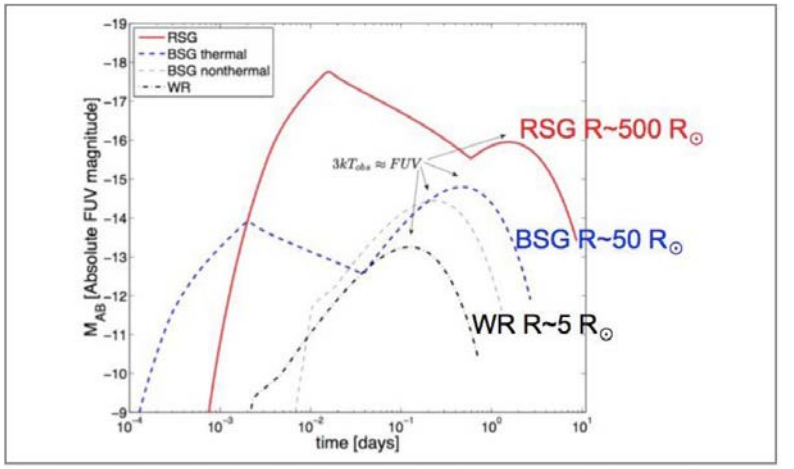


Figure 2-23. CETUS will infer the progenitors of core-collapse supernovae from their FUV light curves. (Figure credit: Nakar & Sari, 2010)

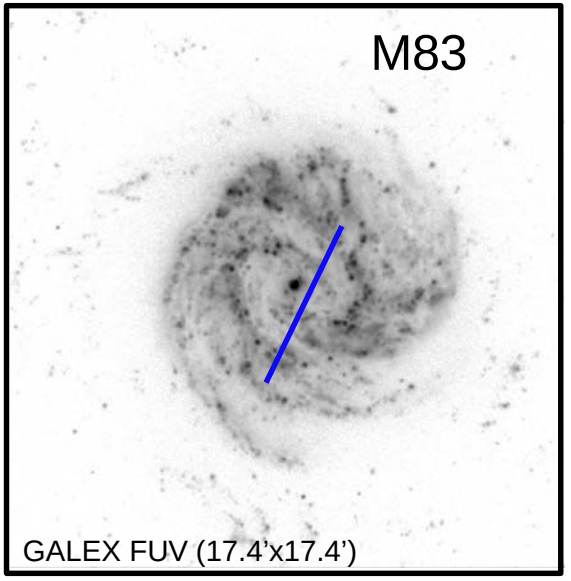
CETUS will make systematic study of galaxy in UV

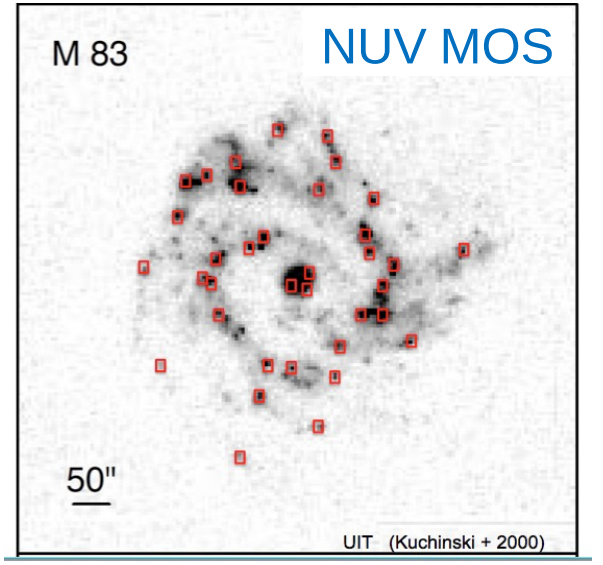
- **properties - stars, gas, and dust,**
- **processes - star formation & feedback**

via:

FUV filter imagery
FUV long-slit spectra

NUV filter imagery
NUV MOS spectra





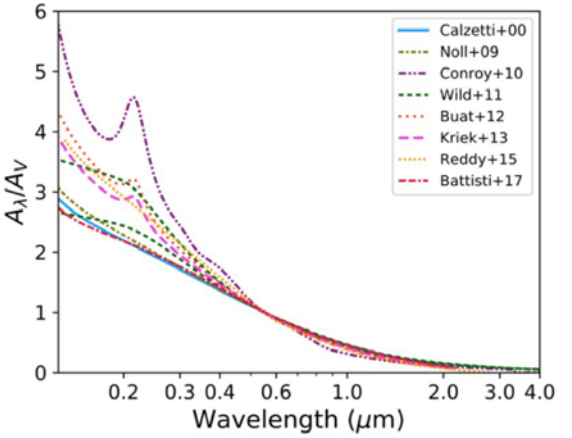


Figure 2-1. A collection of measured dust attenuation curves in galaxies illustrates the range in the 2175-Å bump and the UV slope, β_{uv}. From Hagen #593

and collaboration with multi-wavelength telescopes

X-ray	UV	Optical - NearIR	Far-IR	Radio