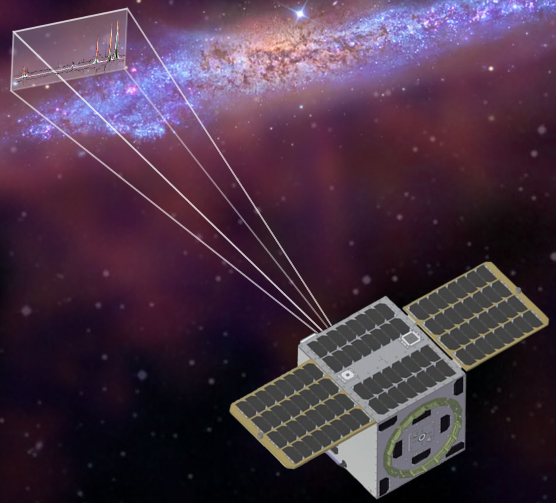


ASPERA

REVEALING THE DIFFUSE UNIVERSE

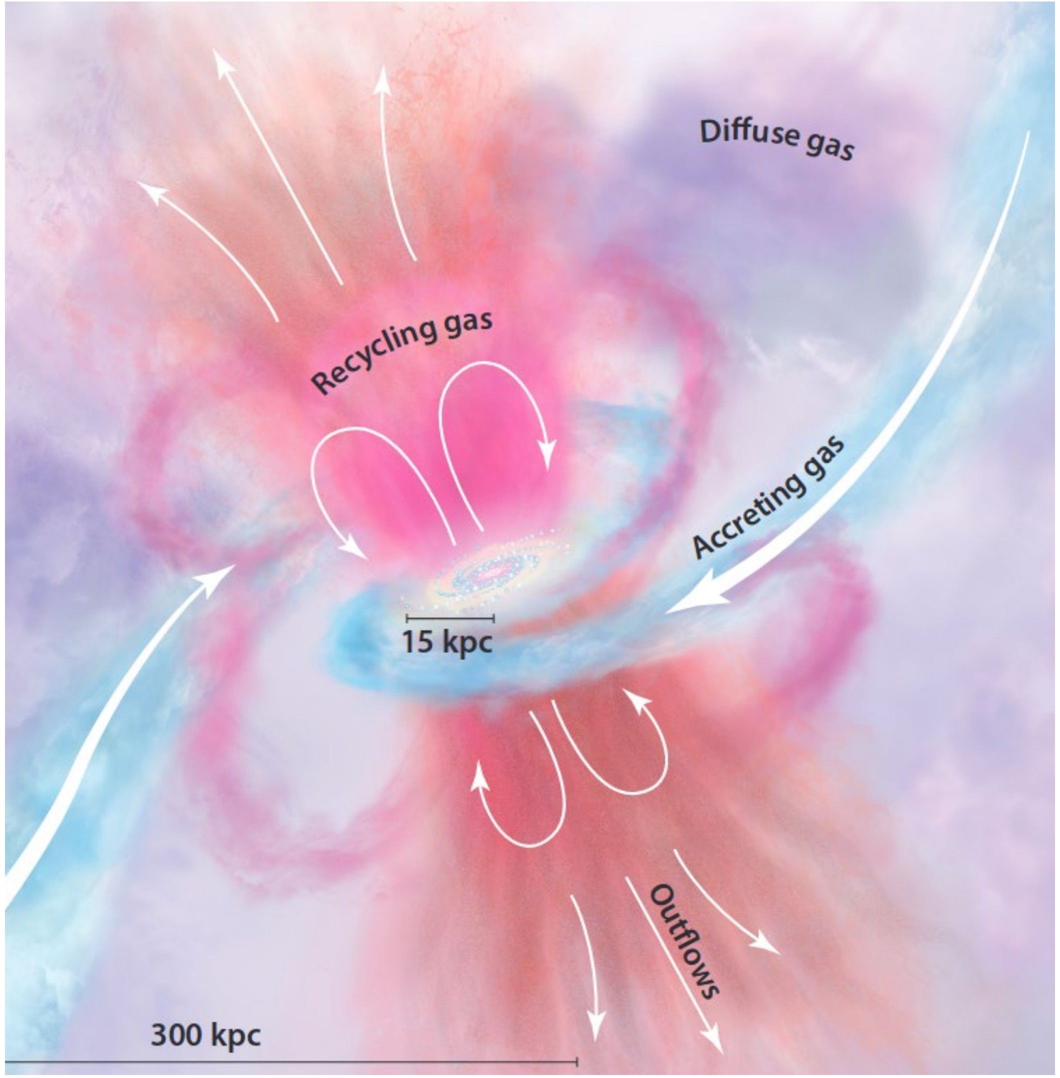
NASA ASTROPHYSICS ADVISORY COMMITTEE

Prof. Carlos J. Vargas
Principal Investigator

October 15, 2021

RUHR UNIVERSITÄT BOCHUM
Sensor Sciences
ANT ASCENDING NODE
IOWA
THE UNIVERSITY OF ARIZONA
COLUMBIA UNIVERSITY
UTIAS SFL

What is the CGM?

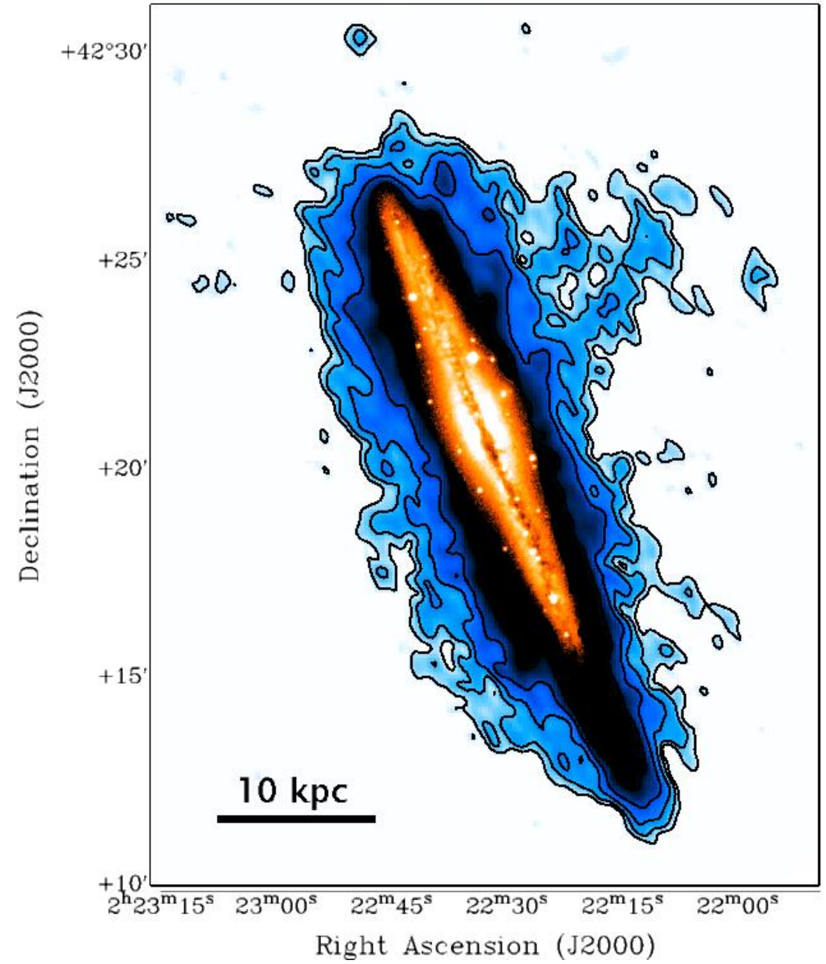


Tumlinson et al. (2017)

Cold Extraplanar Gas

NGC 891
Atomic Gas
HI – 21 cm

Oosterloo et al. (2007)



Cold Neutral Gas

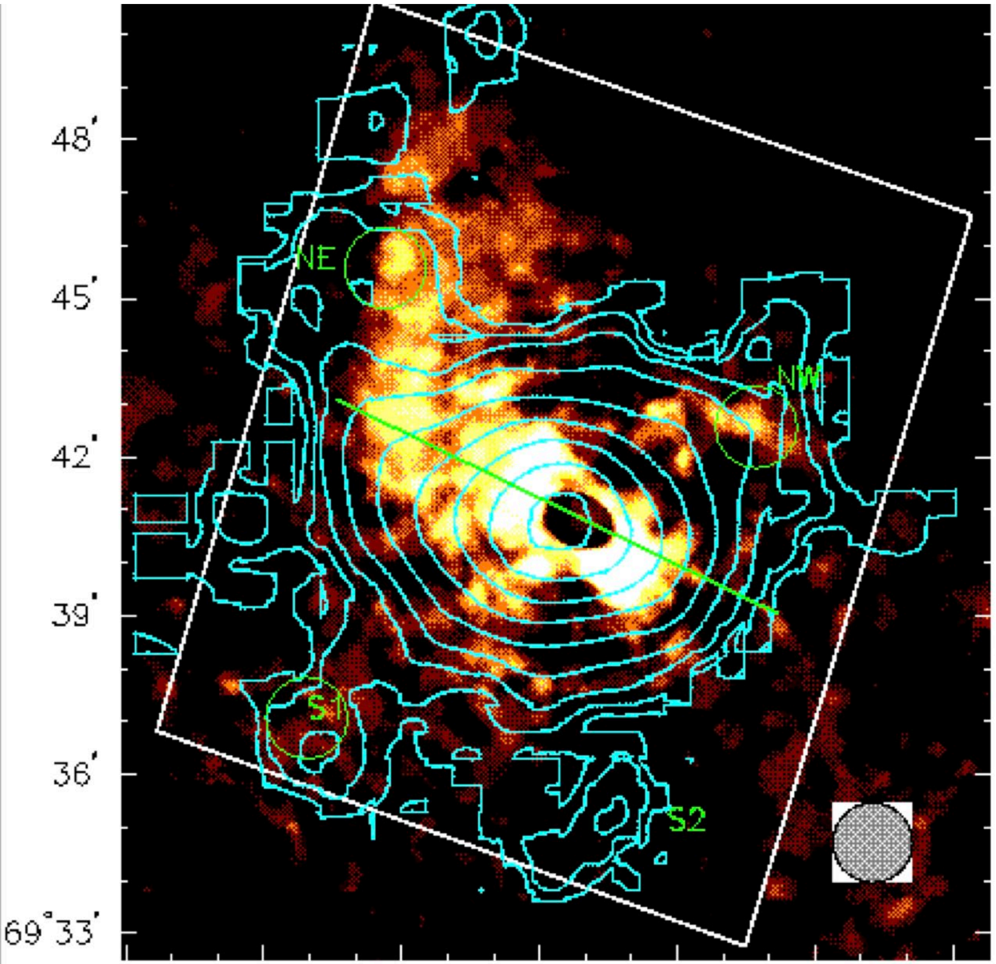
Warm ionized Gas

- M82
- Combined Hα ($T \sim 10^4$ K), IR, optical

Cold Neutral Gas	Warm Ionized Gas

Cold Molecular Gas

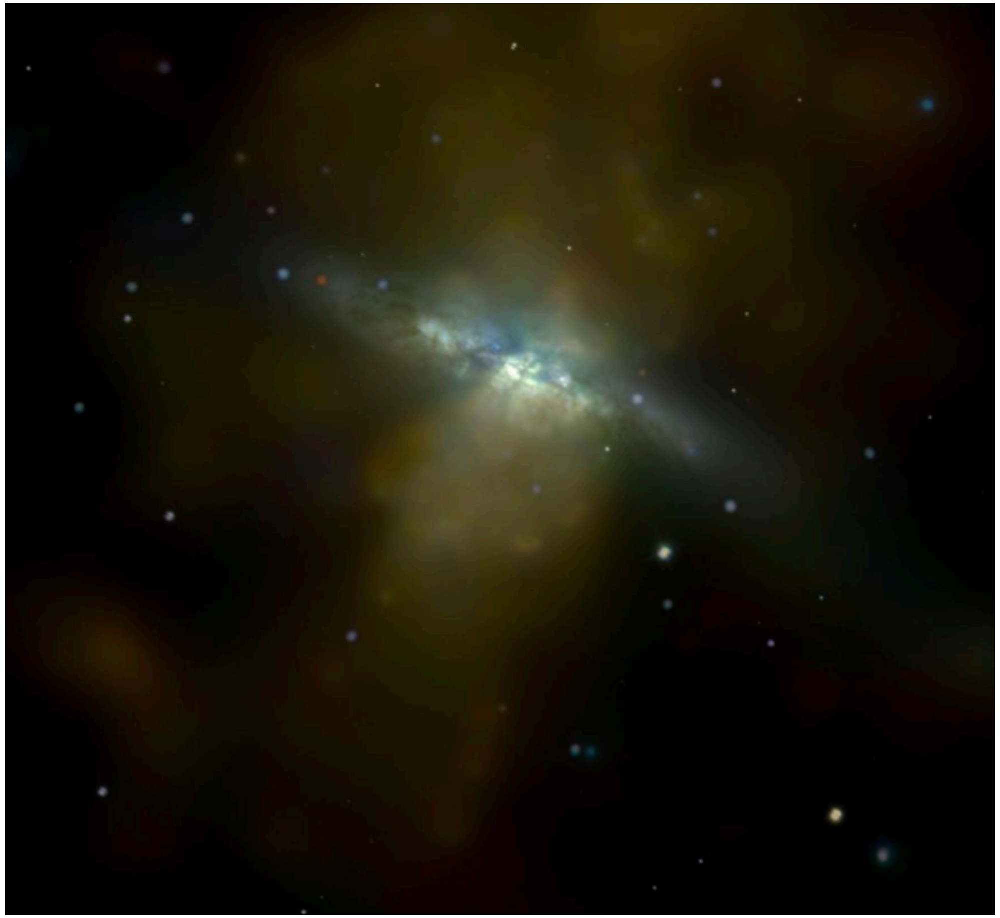
- Also M82
- CO (1-0) contours + HI (colorscale)
- Extraplanar!



Taylor et al. (2001)

Molecular Gas	Cold Neutral Gas	Warm Ionized Gas	

Hot Gas



- Also M82
- Chandra X-ray ($T>10^6$)

Image Credit: Jiang-Tao Li

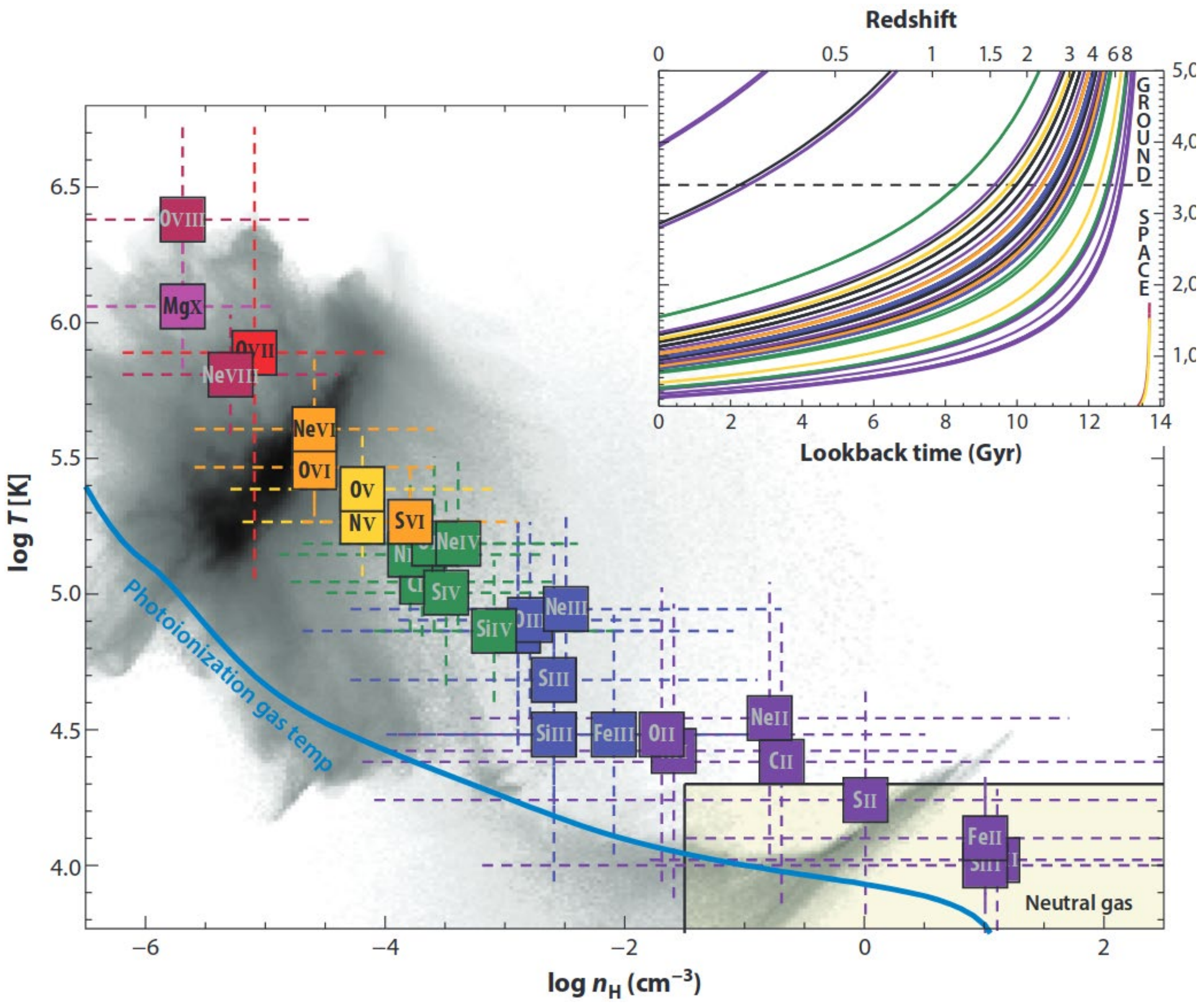
Molecular Gas	Cold Neutral Gas	Warm Ionized Gas		Hot Gas

But, is the CGM warm-hot?

???

Molecular Gas | Cold Neutral Gas | Warm Ionized Gas | | Hot Gas

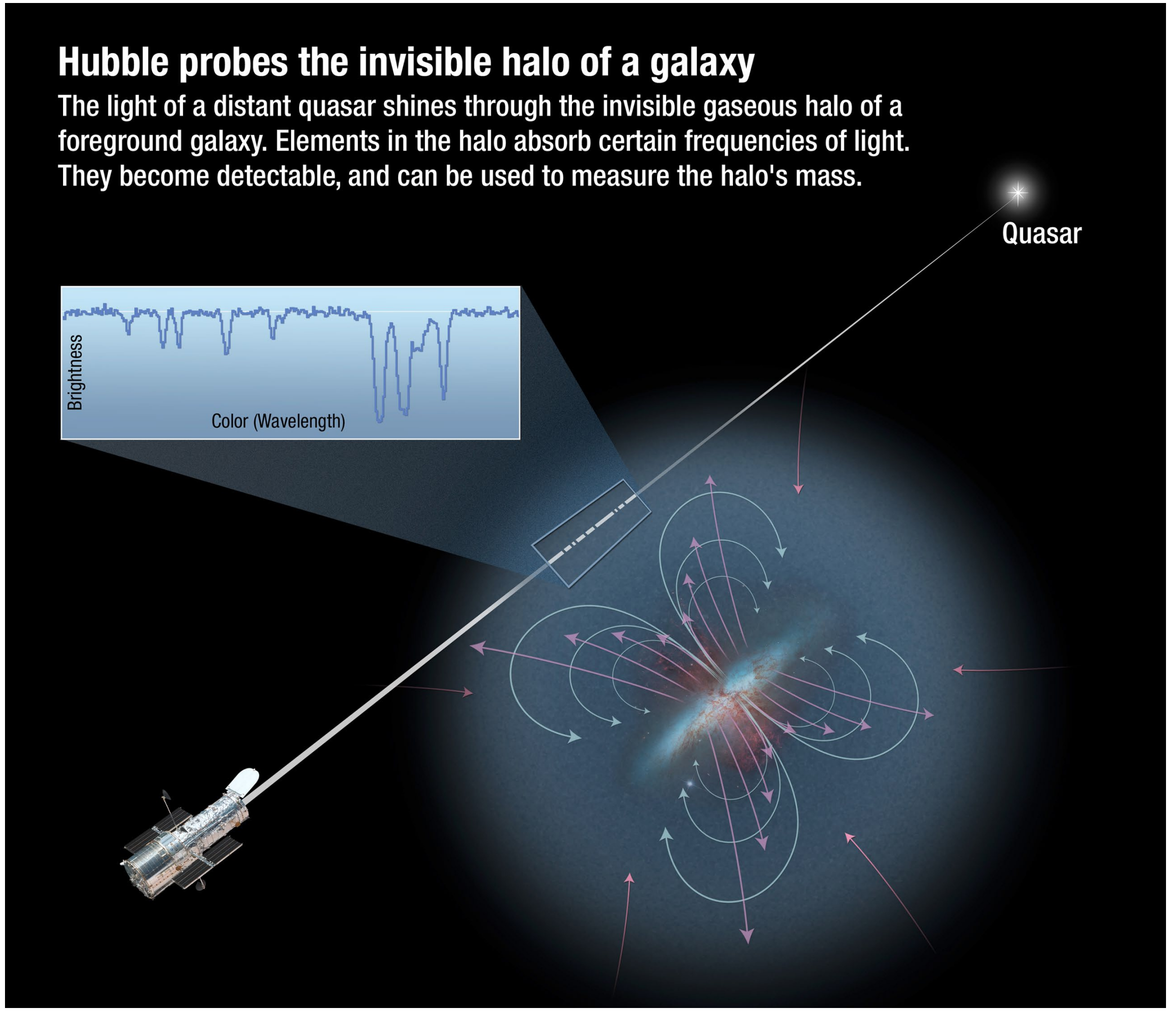
The Simulated CGM



Tumlinson et al. (2017)

Absorption Line Findings

- Large OVI columns to ~150 kpc
- Diffuse / occupies bulk of halo
  - NOT shock front or boundary layer
- >10% of entire galactic feedback energy goes into support
- Contains more mass than stars!
- Caveats: Assumptions on filling factor; no morphological info
- We do not have 'eyes' on the dominant matter component of galaxies



We need to map warm-hot (coronal) gas…

So, why haven't we?

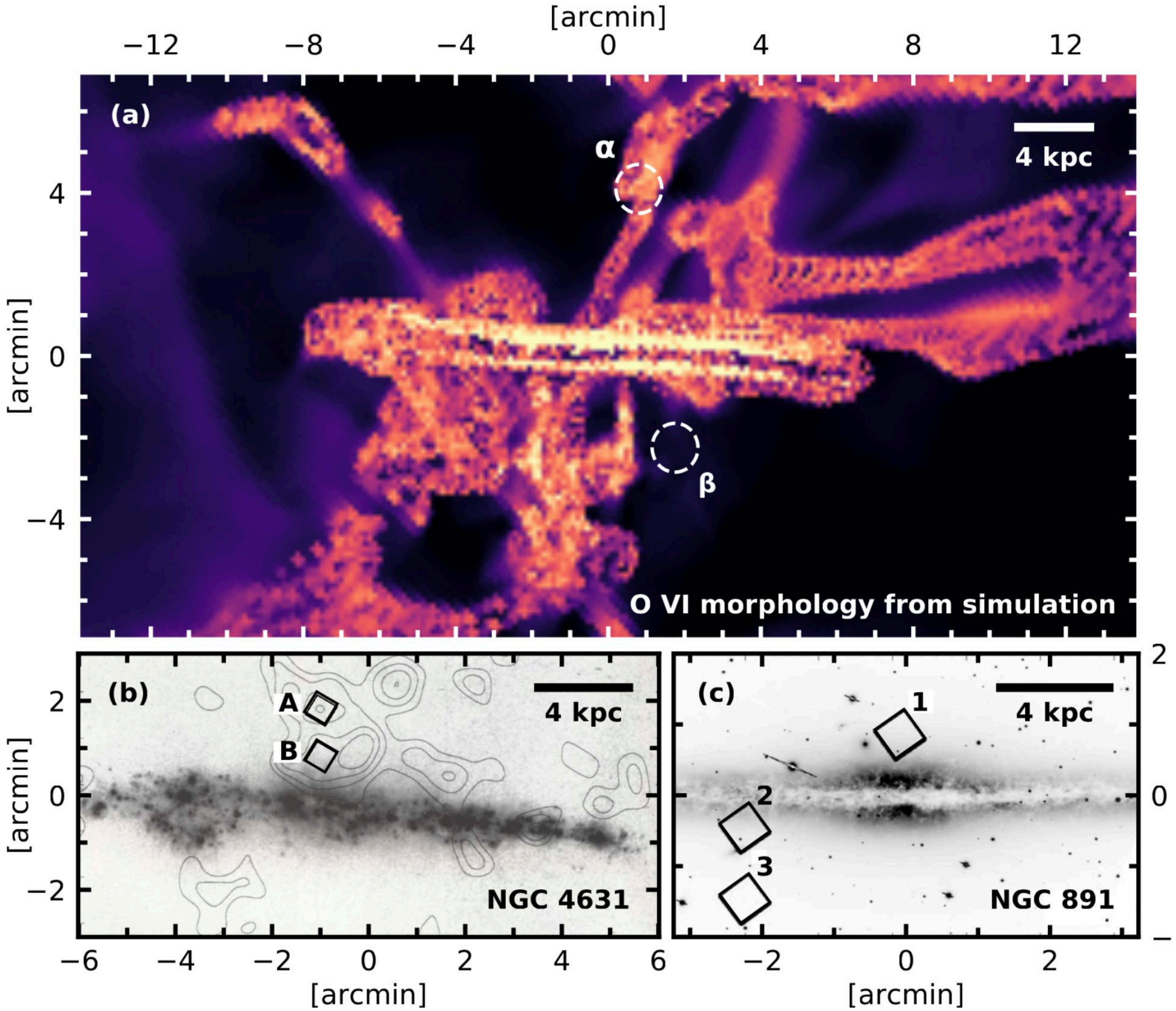
"While the hot gas observed with Copernicus is very similar to the extended corona suggested nearly twenty years ago, the origin and spatial distribution of the observed coronal gas is not at all certain." – Lyman Spitzer, 1976

It's in the FUV, faint, and filamentary

- Strongest line – OVI @ $\lambda\lambda$ 1032, 1038 Å, rest-frame
  - Need to go to space!
- Surface brightness < 1 x 10^{-18} erg s^{-1} cm^{-2} $arcsec^{-2}$ (near z=0)
- Filaments → luck?

UV optics/detectors are historically inefficient at these wavelengths…

It's hard to get to space…



Otte et al. (2003) + Corlies (private comm) + Haeun Chung

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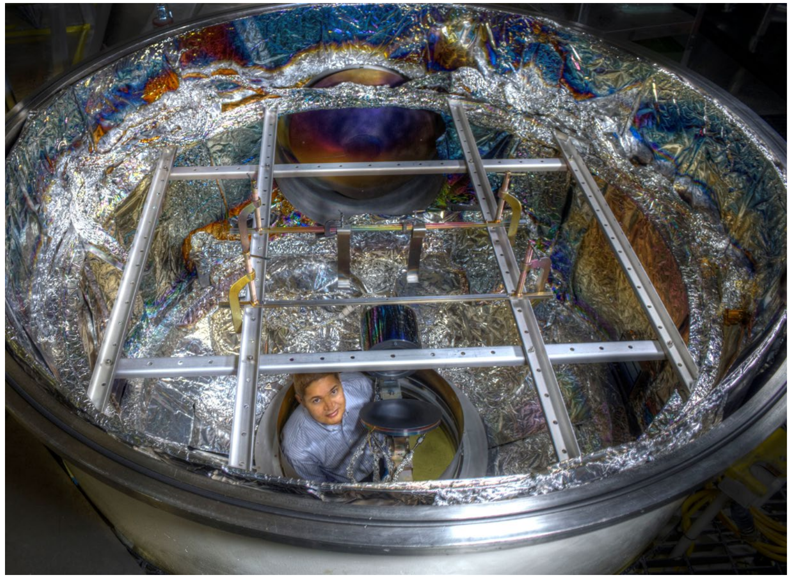
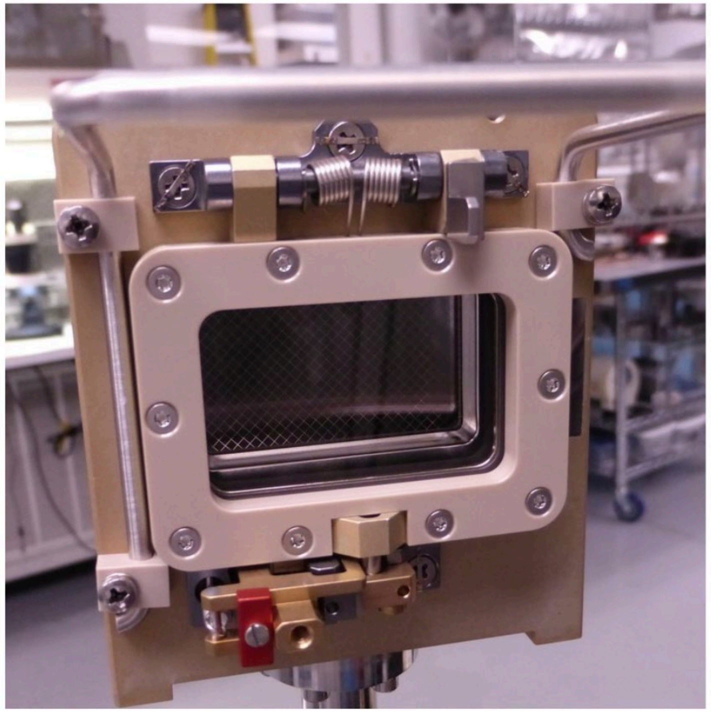
Until Now!

High-reflectance UV Coatings
M. Quijada, NASA GSFC





MCP Detectors
Ossy Siegmund
Sensor Sciences, LLC

Falcon 9
SmallSat Rideshare

COLUMBIA UNIVERSITY IOWA NASA RUB VERA C. RUBIN OBSERVATORY ARIZONA

The Aspera Team

University of Arizona

Management

Carlos J. Vargas (PI)
Erika Hamden (DPI)
Tom McMahon (PM)
Haeun Chung (PS)

Simran Agarwal
Hop Bailey
Peter Behroozi
Trenton Brendel
Heejoo Choi
Tom Connors
Jason Corliss
Fernando Coronado
David Dolana
Ewan S. Douglas
Kerry Gonzales
John Guzman
Dave Hamara
Walt Harris
Karl Harshman
Aafaque R. Khan
Daewook Kim
Jessica S. Li
Corwynn Sauve
Hannah Tanquary
Daniel Truong
Michael Ward
Ellie M. Wolcott
Naomi Yescas
Dennis Zaritsky

AURA/Vera C. Rubin Observatory

Lauren Corlies

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Ascending Node Technologies, LLC

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John Kidd
Sanford Selznick

University of Iowa

Keri Hoadley

Columbia University

David Schiminovich

Sensor Sciences, LLC

Oswald Siegmund

UTIAS SFL

Simon Grocott

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Corwynn Sauve
★Hannah Tanquary
★Daniel Truong
Michael Ward
★Ellie M. Wolcott
★Naomi Yescas
Dennis Zaritsky

Nearly half of the Aspera team is early-career, with strong support from experienced scientists and engineers

AURA/Vera C. Rubin Observatory

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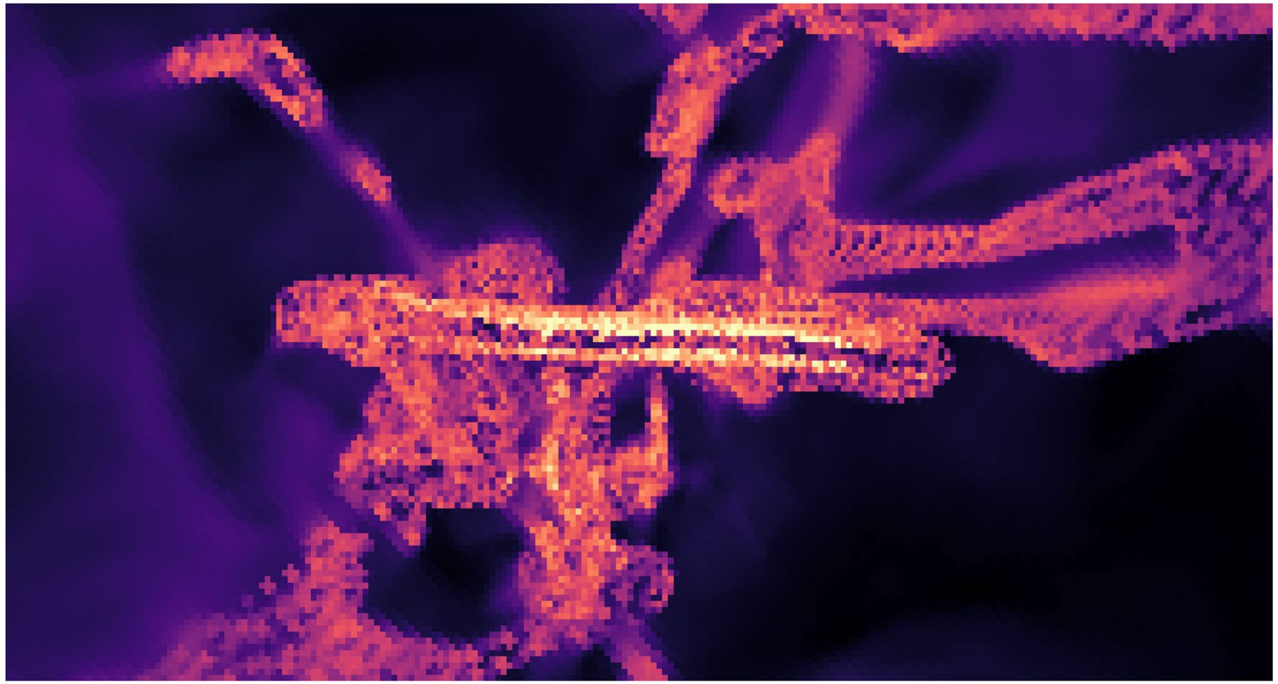
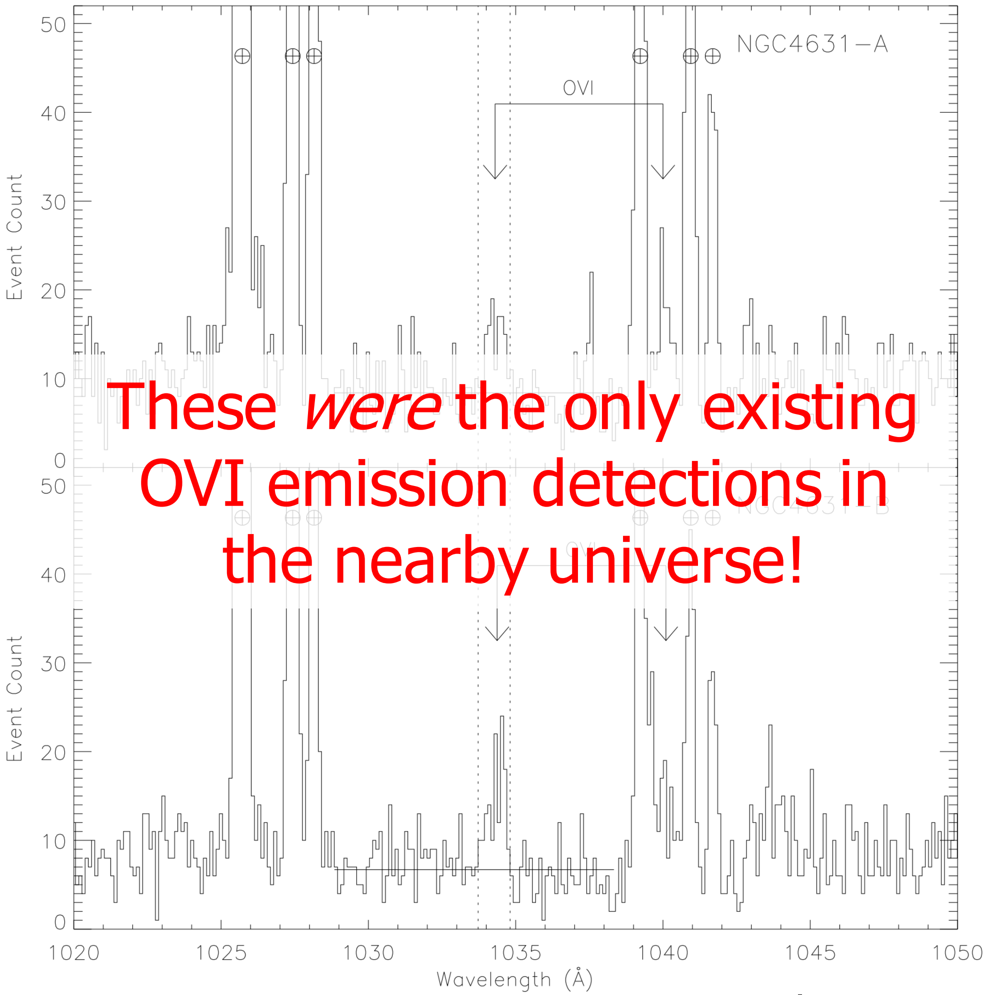
Determining the Expected SBR and Morphology

Simulation: Lauren Corlies



Corlies & Schiminovich 2016

FUSE



These *were* the only existing OVI emission detections in the nearby universe!

Otte et al. 2003

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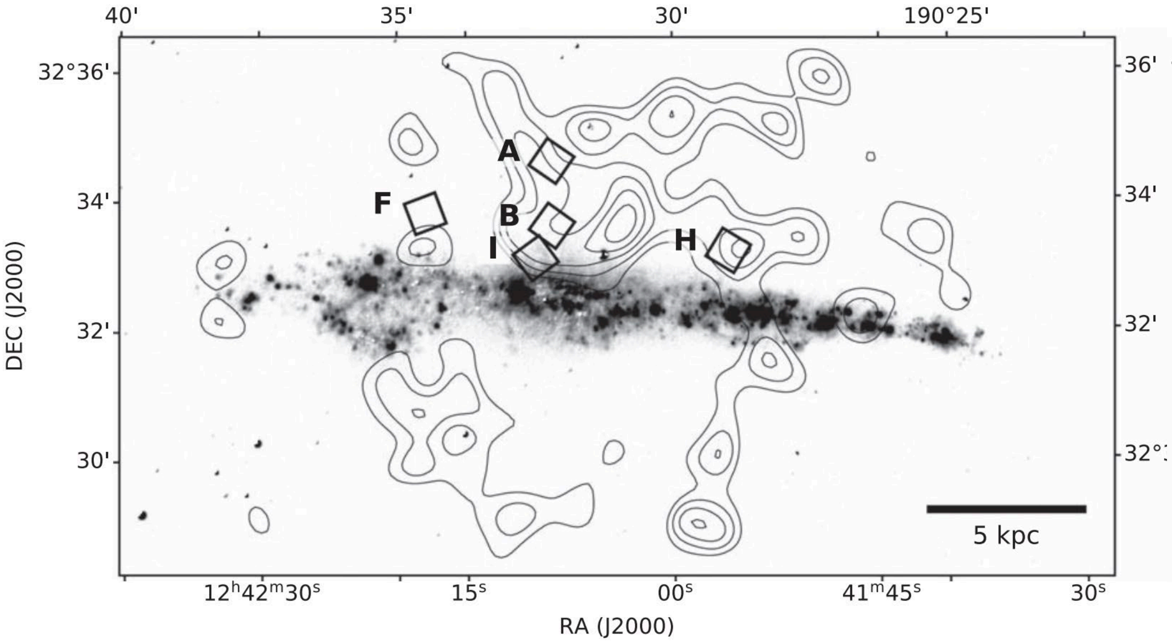
And Then Haeun Chung Came Along…

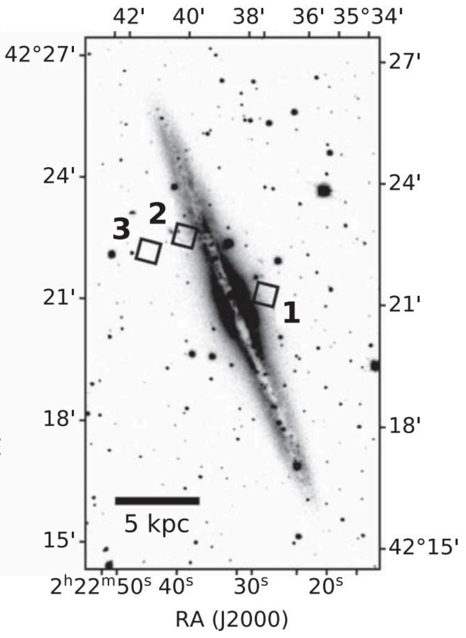
Revisiting FUSE O VI Emission in Galaxy Halos

Haeun Chung, Carlos J. Vargas, and Erika Hamden
University of Arizona, Steward Observatory, 933 N. Cherry Ave., Tucson, AZ 85721, USA; haeunchung@arizona.edu
Received 2021 March 5; revised 2021 May 21; accepted 2021 May 23; published 2021 July 20

NGC 4631



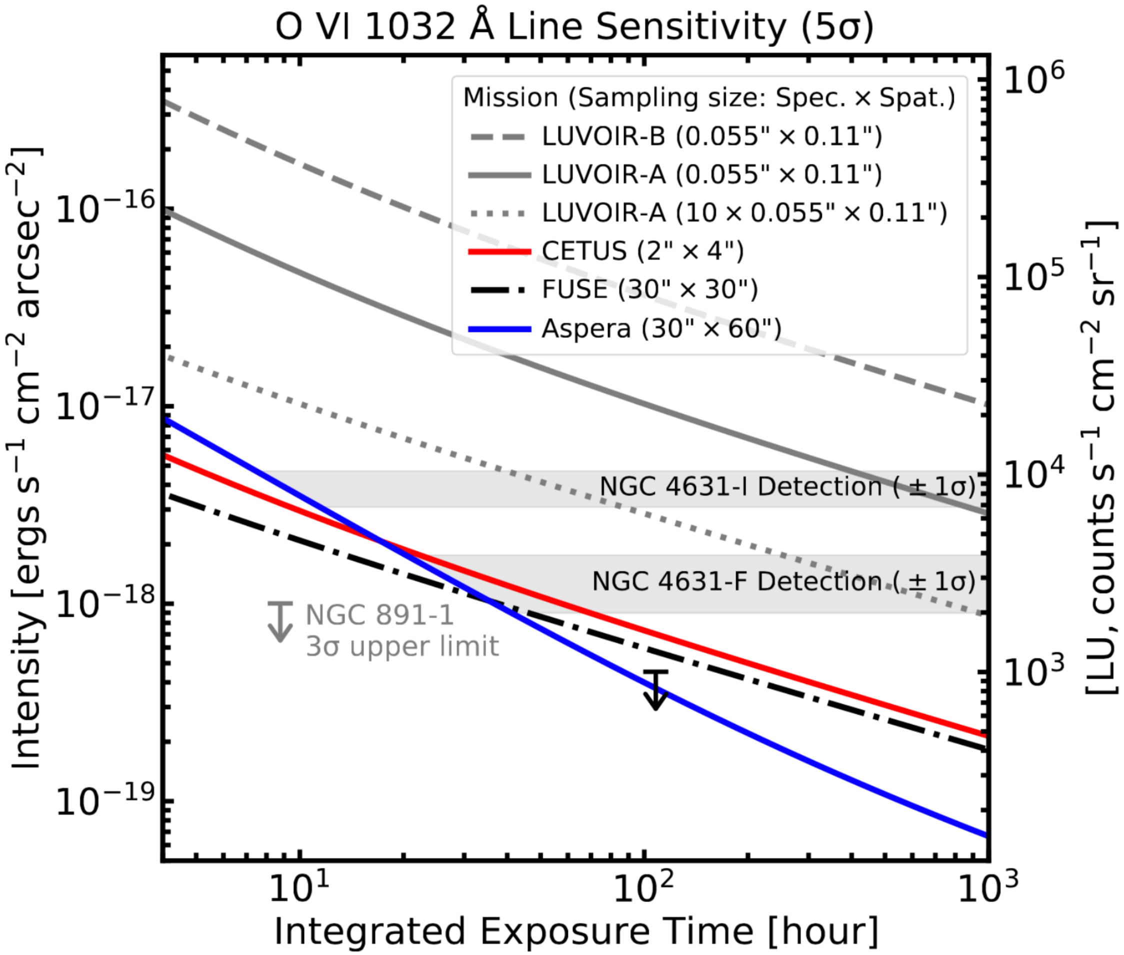
NGC 891



- Archival FUSE data
- 4 new detections!
  - First detection in NGC 891 – a high extinction target
- Improved estimate of expected OVI SBR via analogous measurements!

ARIZONA

Implications for future OVI Detections



Chung, Vargas, & Hamden 2021

- Aspera is specifically designed to detect and map OVI
- Aspera's sensitivity lead is due to low contribution from background noise and large 'grasp' (étendue)
- Big science can be done in a small platform!

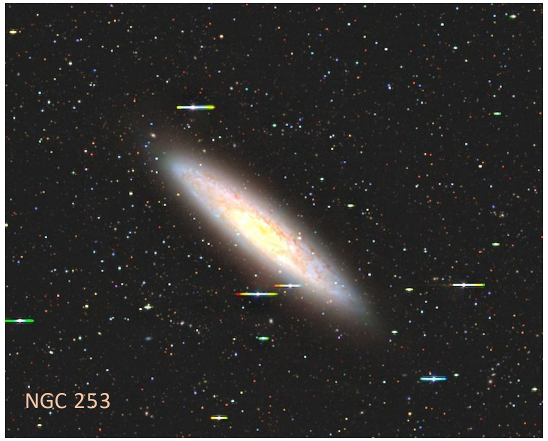
Targets

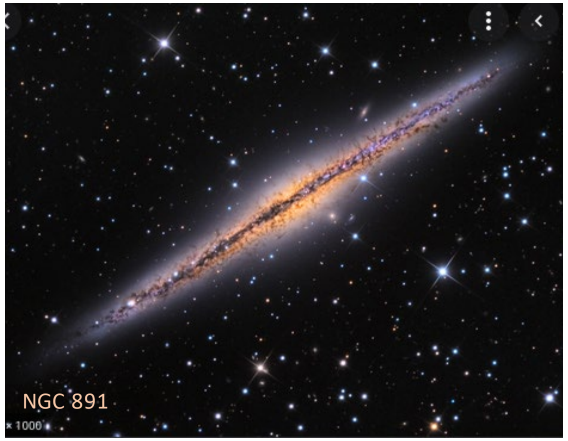
Selection Criteria:

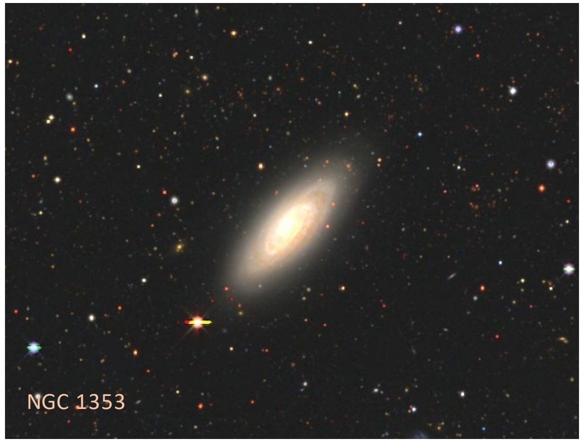
- i > 78°
- R_{opt} sampleable
- cz sampleable
- Hubble type later than Sa (star forming)
- No starburst or AGN
  - Simplifies interpretation
- No close companions
  - Avoids confusion
- Visible in LEO
- Extinction < 1 mag @ OVI
  - NGC 891 extinction = 0.98 mag, and it was detected with FUSE
  - 10 of 18 targets have extinction < 0.35 mag
- Lots of existing ancillary data at other wavelengths for many of these!

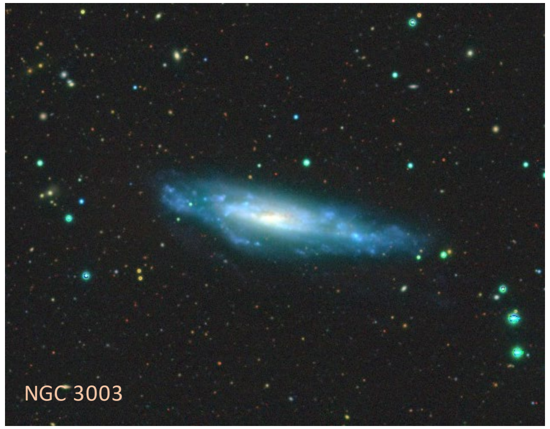
Name	RA (J2000)	Dec (J2000)	Priority Group	Optical Diameter (')	D (Mpc)	cz (km/s)
NGC 4631	12h42'8"	32°32'29"	1	17.0	7.4	606
NGC 3003	9h48'36"	33°25'17"	1	6.0	19.6	1478
NGC 891*	2h22'22"	42°20'47"	1	12.2	9.2	529
NGC 5746	14h44'56"	1°57'18"	1	7.8	31.5	1724
NGC 1353	3h32'3"	-21°10'51"	1	5.2	25.6	1547
NGC 253*	00h47'33"	-25°17'18"	1	40	3.4	243
NGC 3692	11h28'24"	9°24'27"	2	3.6	42.4	1726
NGC 3044	9h53'41"	1°34'37"	2	5.0	21.4	1289
NGC 5775	14h53'58"	3°32'40"	2	4.4	17.4	1681
NGC 4666	12h45'9"	-1°32'17"	2	7.2	14.7	1529
NGC 625*	01h35'05"	-41°26'10"	2	11.7	3.9	396
NGC 7064*	21h29'03"	-52°46'03"	2	4.9	11.5	797
NGC 1406*	03h39'23"	-31°19'17"	2	5.5	17.4	1074
NGC 1448*	03h44'31"	-44°38'41"	2	9.2	18.3	1167
NGC 660*	1h43'02"	13°38'42"	2	7.2	12.3	850
IC 5052*	20h52'05"	-69°12m06s	2	8.7	5.5	584
M82	9h55'53"	69°40'46"	2	13.0	4.2	203
NGC 7582*	23h18'24"	-42°22'14"	2	16.5	21.0	1575

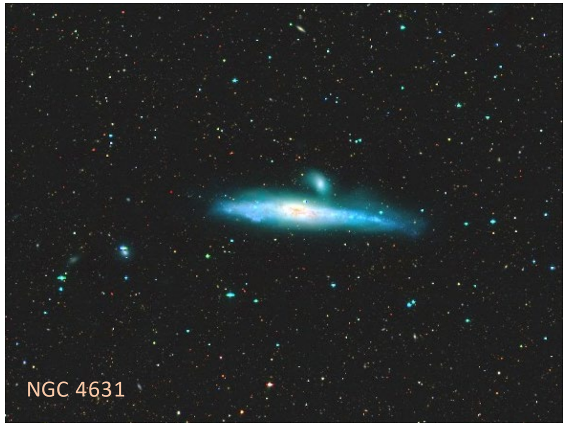
Target Selection

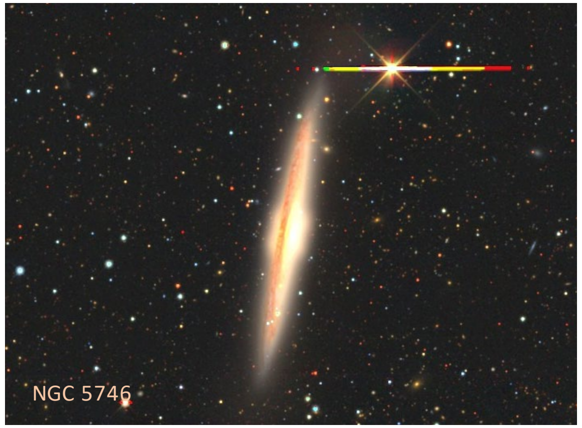








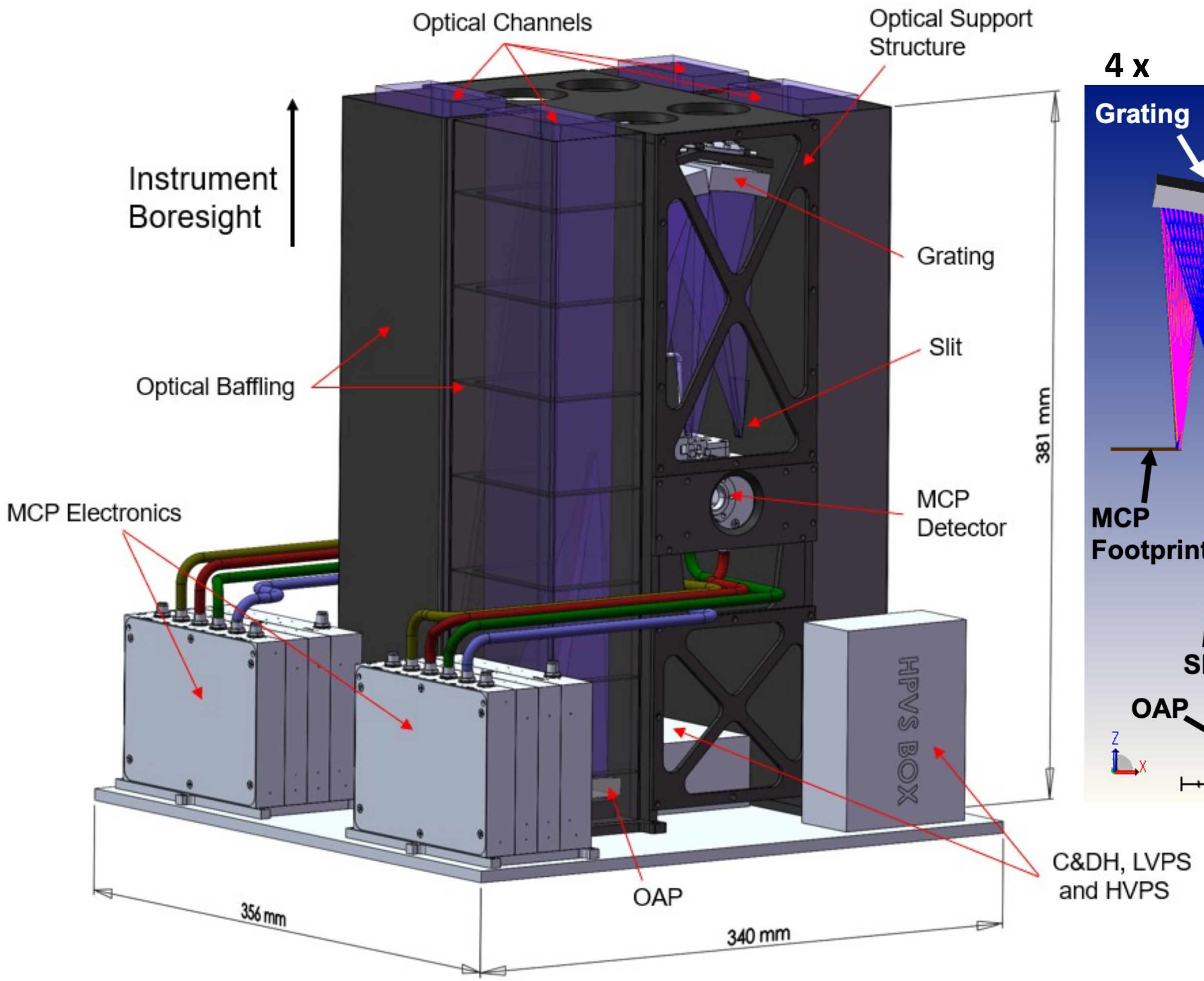


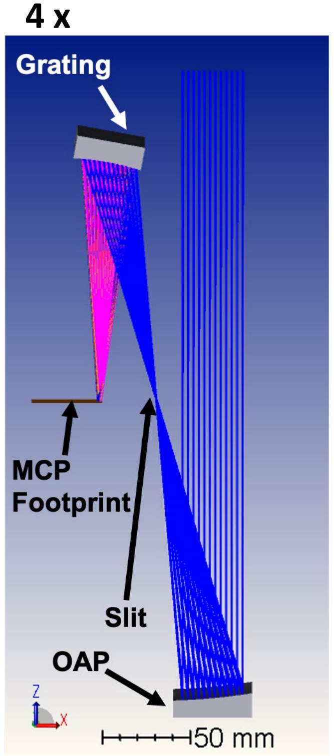


Priority 1 Targets

Aspera Payload

- EFFICIENT AND REDUNDANT, WITH HERITAGE

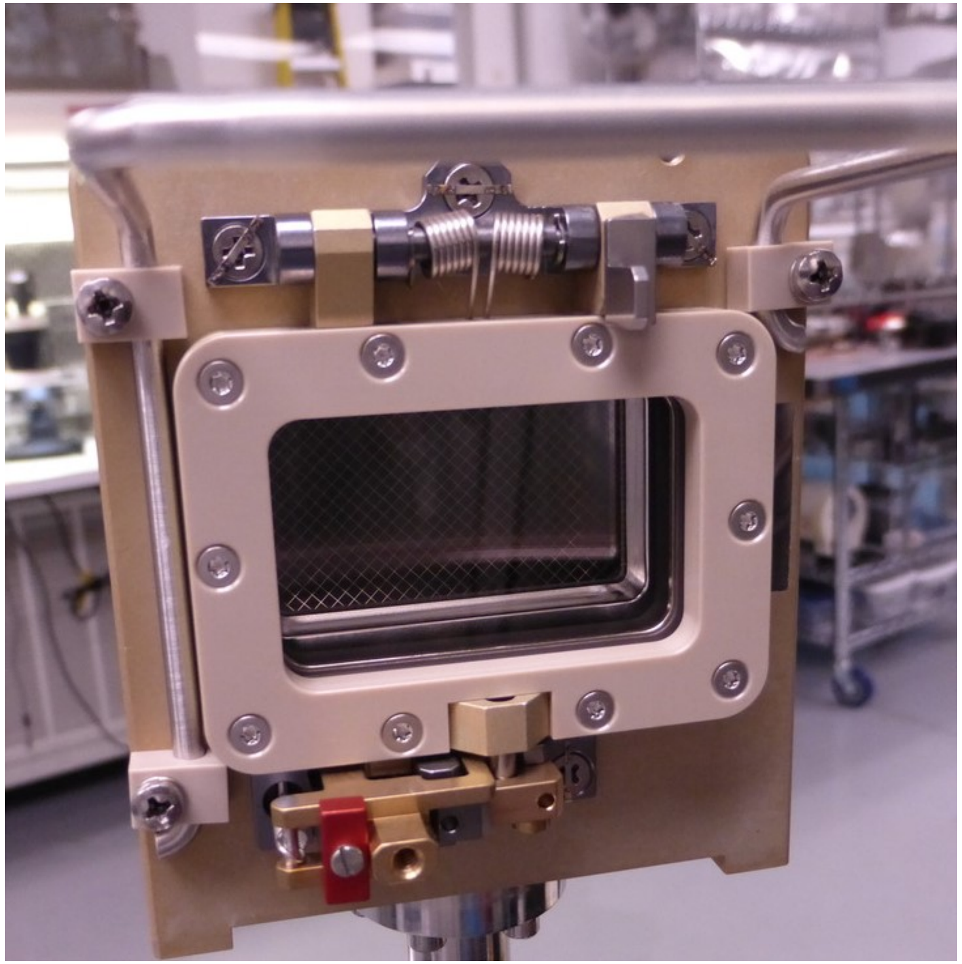


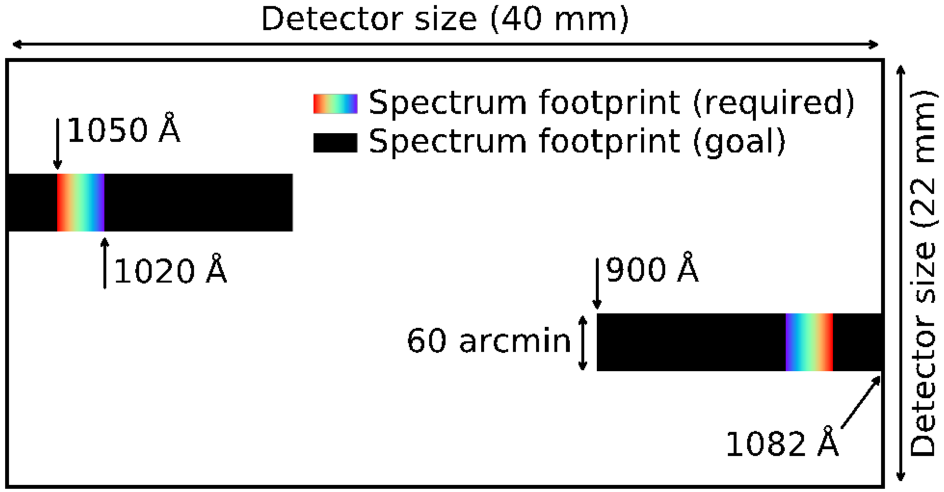


- 4x Identical Rowland Circle-like optics
  - Design inspired by FUSE
- 103-104 nm FUV spectrograph
  - Spec R: ~2000, Spatial R: 45 arcsec
  - FoV: 60 arcmin x 30 arcsec (per ch.)
- Sensitivity: 4.3E-19 $erg/s/cm^2/arcsec^2$
- TRL ≥ 6 Technologies
  - Mirror, Grating, Coating, & Detector
- Payload mass, power: 24 kg, 27 W

Micro-Channel Plate Detector

- **FUV SENSITIVE TRL 9 DETECTOR**





- Supplied by Sensor Sciences, LLC (Dr. Oswald Siegmund)
- Cross delay line (XLD) Microchannel plate
- FUV sensitive CsI photocathode (QE>40%)
- Spatial resolution < 35 micron
- Previously flown multiple times, high TRL technology

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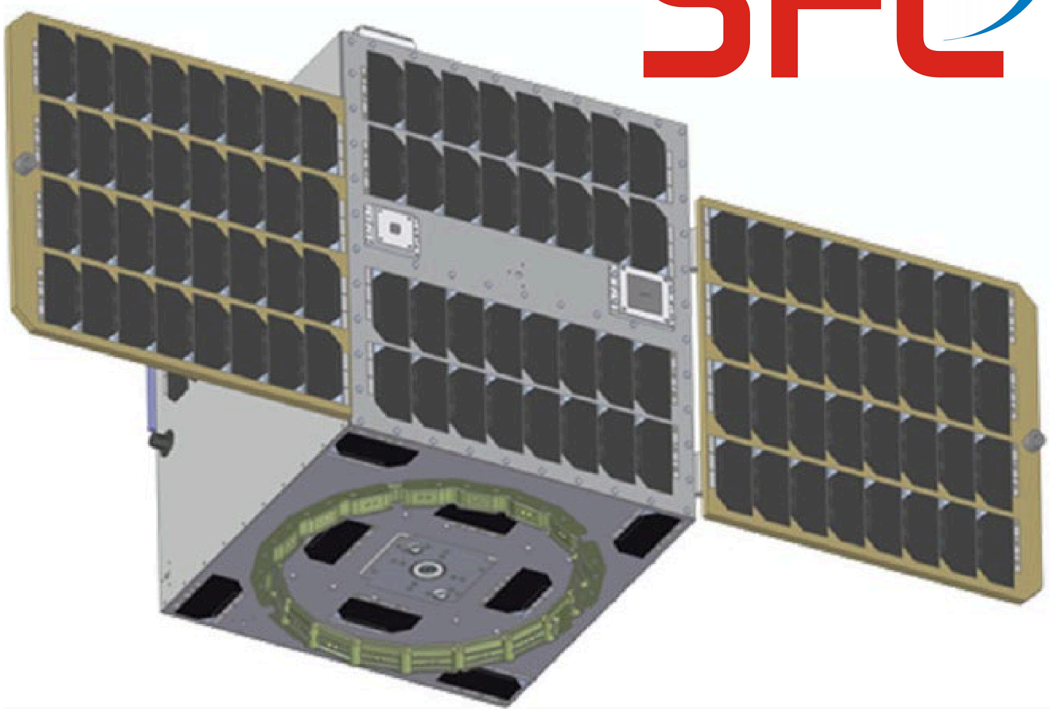
Spacecraft Bus



- Provided by the University of Toronto Institute for Aerospace Studies (UTIAS) Space Flight Laboratory (SFL)
- ESPA-class DEFIANT platform
  - Spacecraft mass: ~35 kg
  - Payload mass: ~24 kg
  - Payload volume: 36 cm x 36 cm x 56 cm

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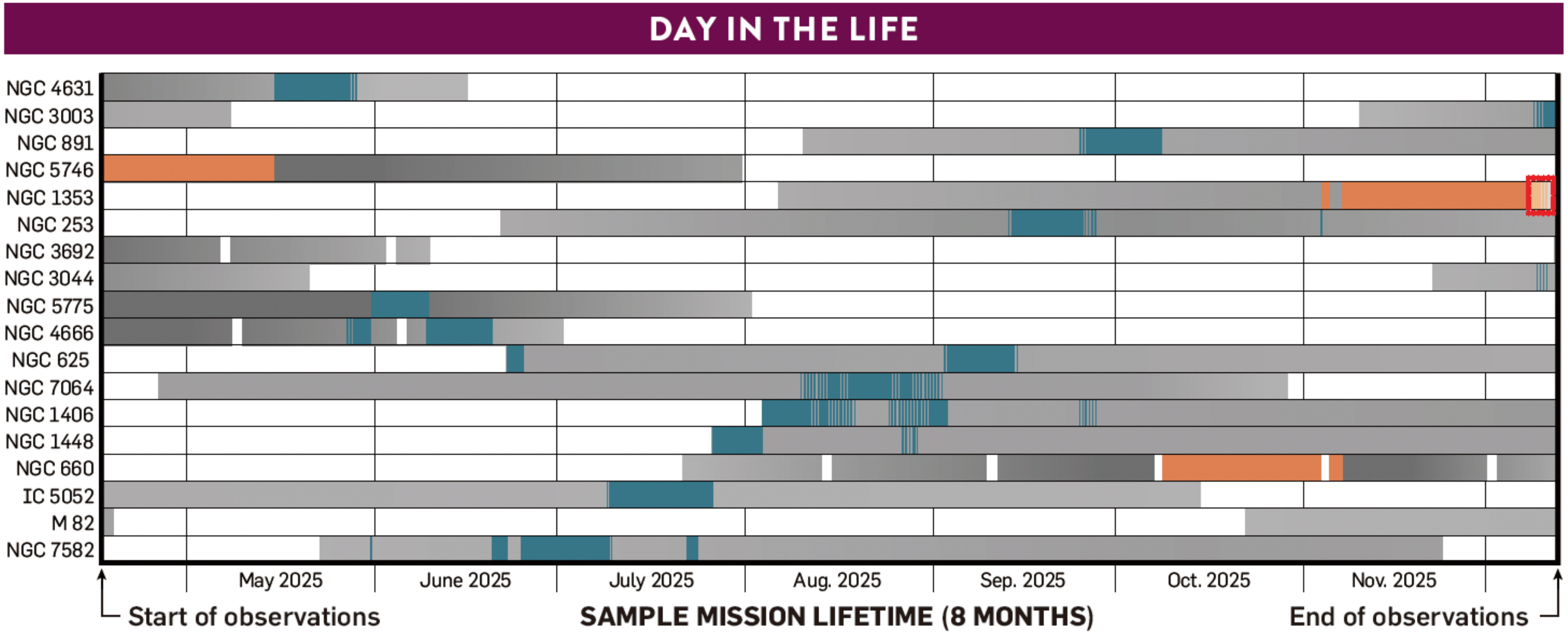
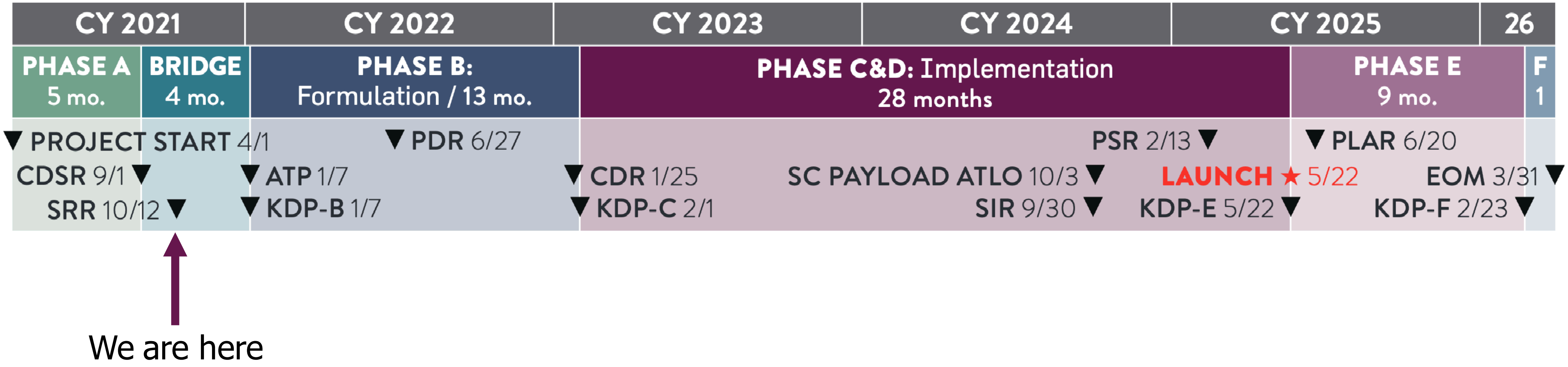
Orbit & CONOPS

- Mission duration: 9-month (1 month checkout + 8 month science ops)
- Orbit: Sun-Synchronous Dawn-Dusk (Altitude: 600-900 km LEO)



The Path Ahead



Summary

- Dominant baryonic component of galaxies is still unmapped.
- *Aspera* : UV SmallSat mission for imaging warm-hot coronal gas in nearby galaxy halos
  - *Selected for funding in 2020 NASA Astrophysics Pioneers AO*
  - Via O VI (1032 Å) emission spectroscopy with step-and-stare concept observation
  - Inspired by FUSE, four identical 6.2 cm x 3.7 cm telescopes in a single payload
  - High-throughput, wide-field, and shot-noise limited system enables detection and mapping of faint diffuse gas
- Projected launch ~mid-2025 for 9-month mission