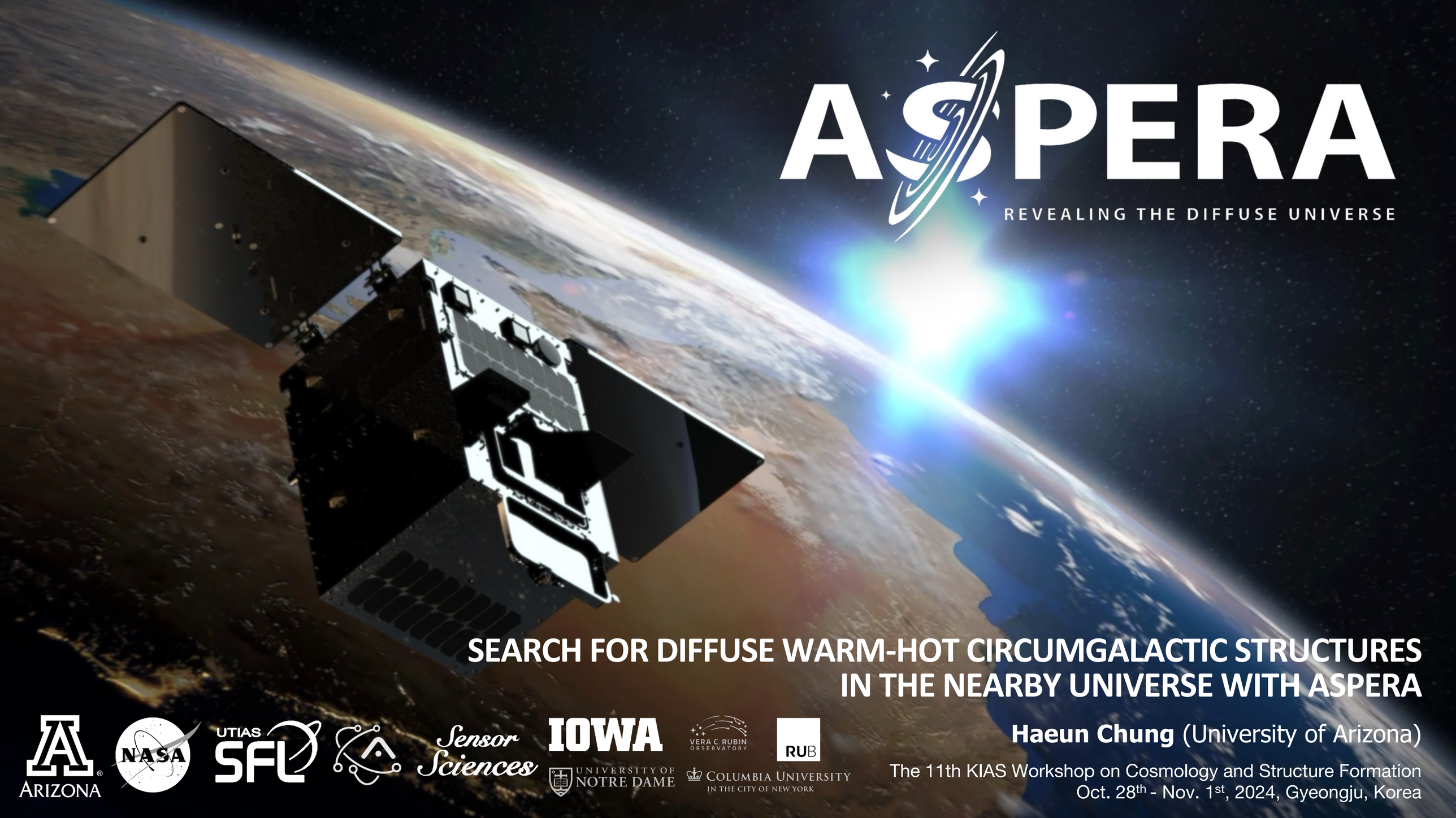
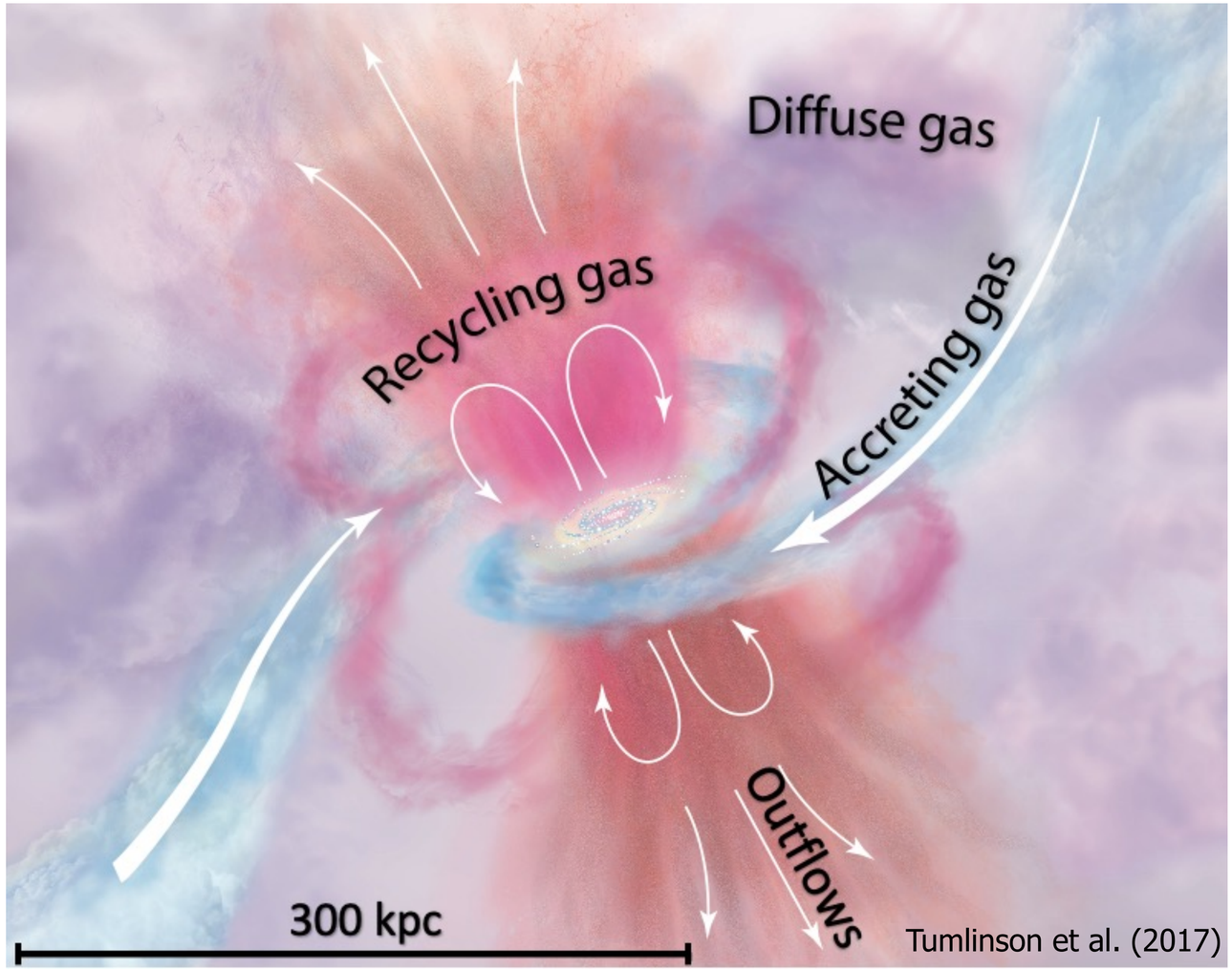


SEARCH FOR DIFFUSE WARM-HOT CIRCUMGALACTIC STRUCTURES IN THE NEARBY UNIVERSE WITH ASPERA

Haeun Chung (University of Arizona)

The 11th KIAS Workshop on Cosmology and Structure Formation
Oct. 28th - Nov. 1st, 2024, Gyeongju, Korea

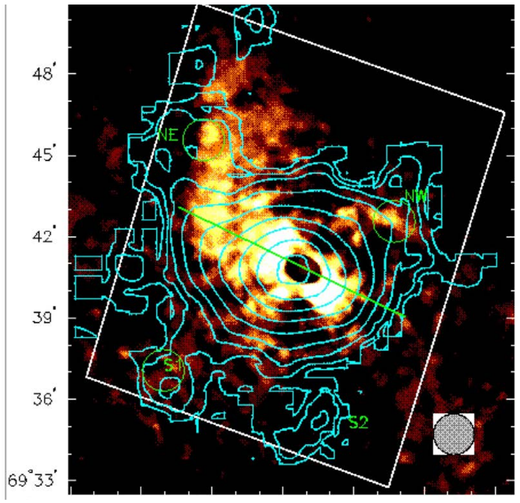
CircumGalactic Medium



Tumlinson et al. (2017)

- Galaxies form in dark matter halos, from gas that cools and condenses into a central star-forming disk.
- Circumgalactic Medium (CGM):
  - Most dominant baryonic component of galaxies
  - Galactic fuel tank / source of star
  - Galaxies acquire, eject, and recycle gas to/from CGM
  - Multi-phase

Multi-Phase of CGM

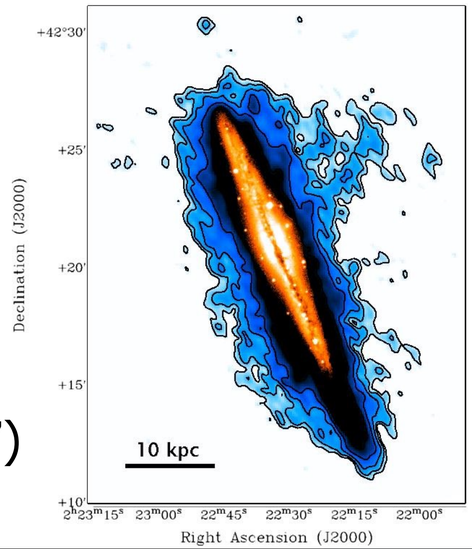


M 82
CO (1-0) contours
+ HI (colorscale)

Taylor et al. (2001)



M 82
Combined Hα (T~10^4 K),
IR, optical



NGC 891
Atomic Gas
HI – 21 cm

Oosterloo et al. (2007)

M 82
Chandra X-ray
(T>10^6 K)

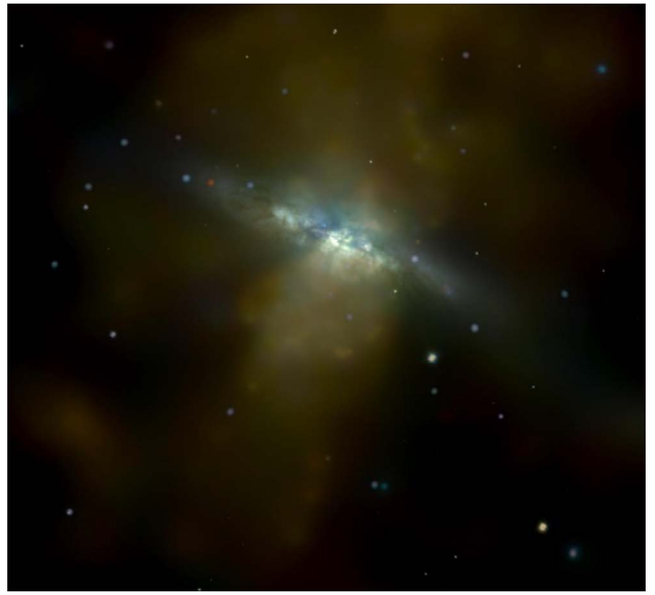
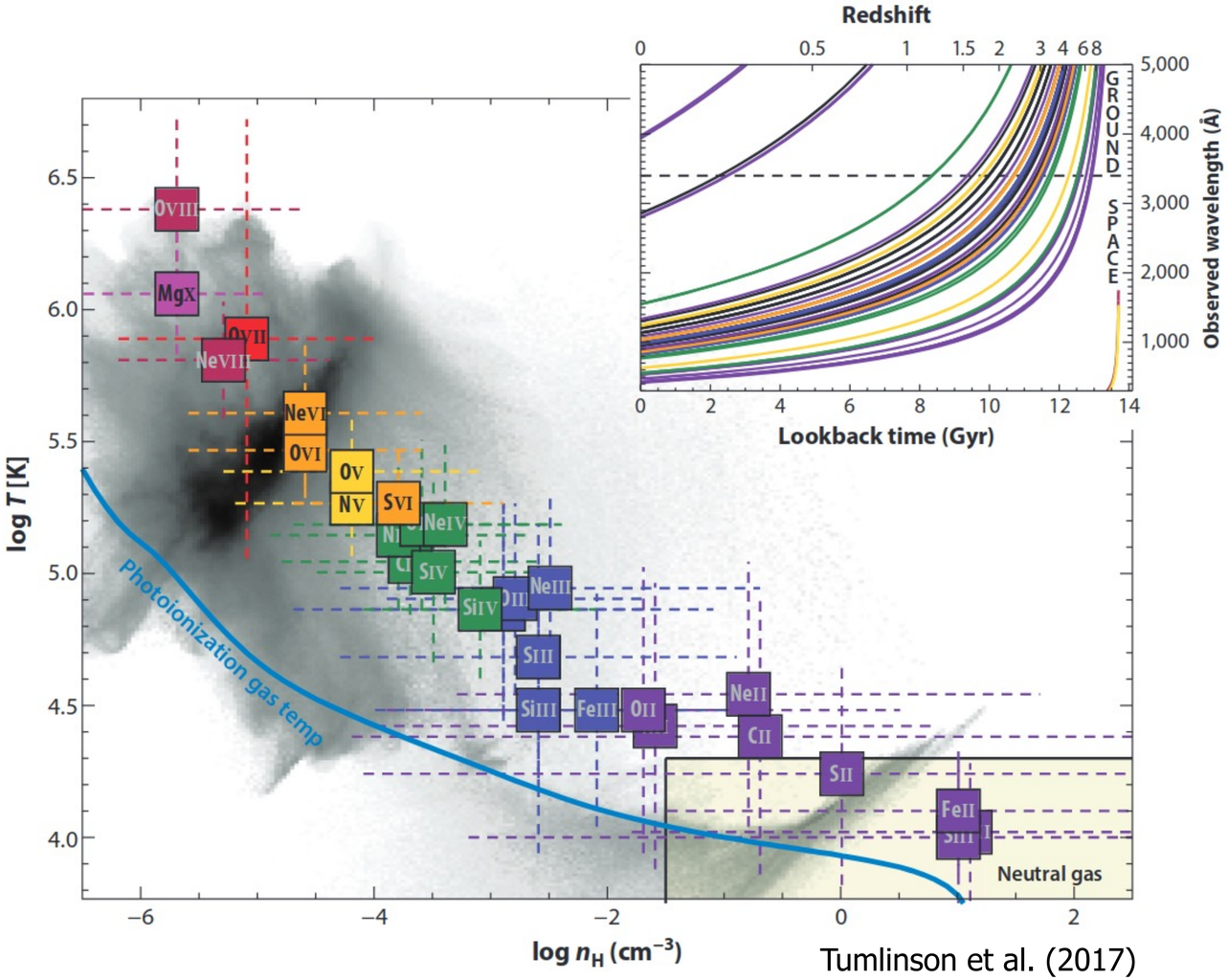


Image Credit: Jiang-Tao Li

Molecular Gas | Cold Neutral Gas | Warm Ionized Gas | Warm-Hot Gas (T=10^5-10^6 K) | Hot Gas

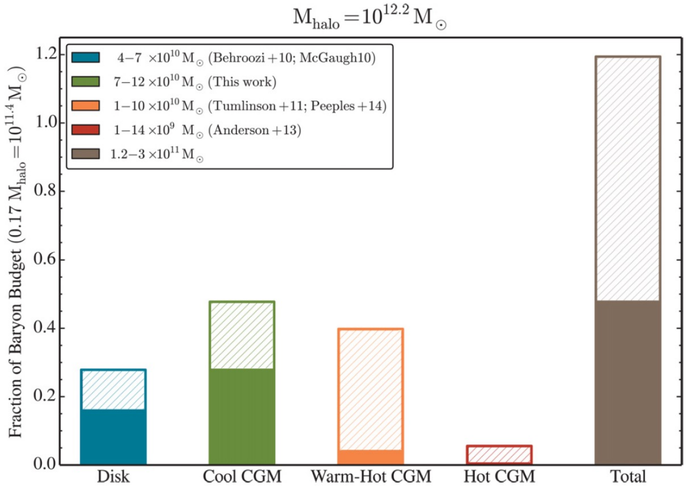
The Simulated CGM



Tumlinson et al. (2017)

- Locations of metal lines which could trace gas in multi-phase
- Grey background: Mass distribution of gas components in phase-diagram, derived from MW-mass EAGLE zoom simulation.

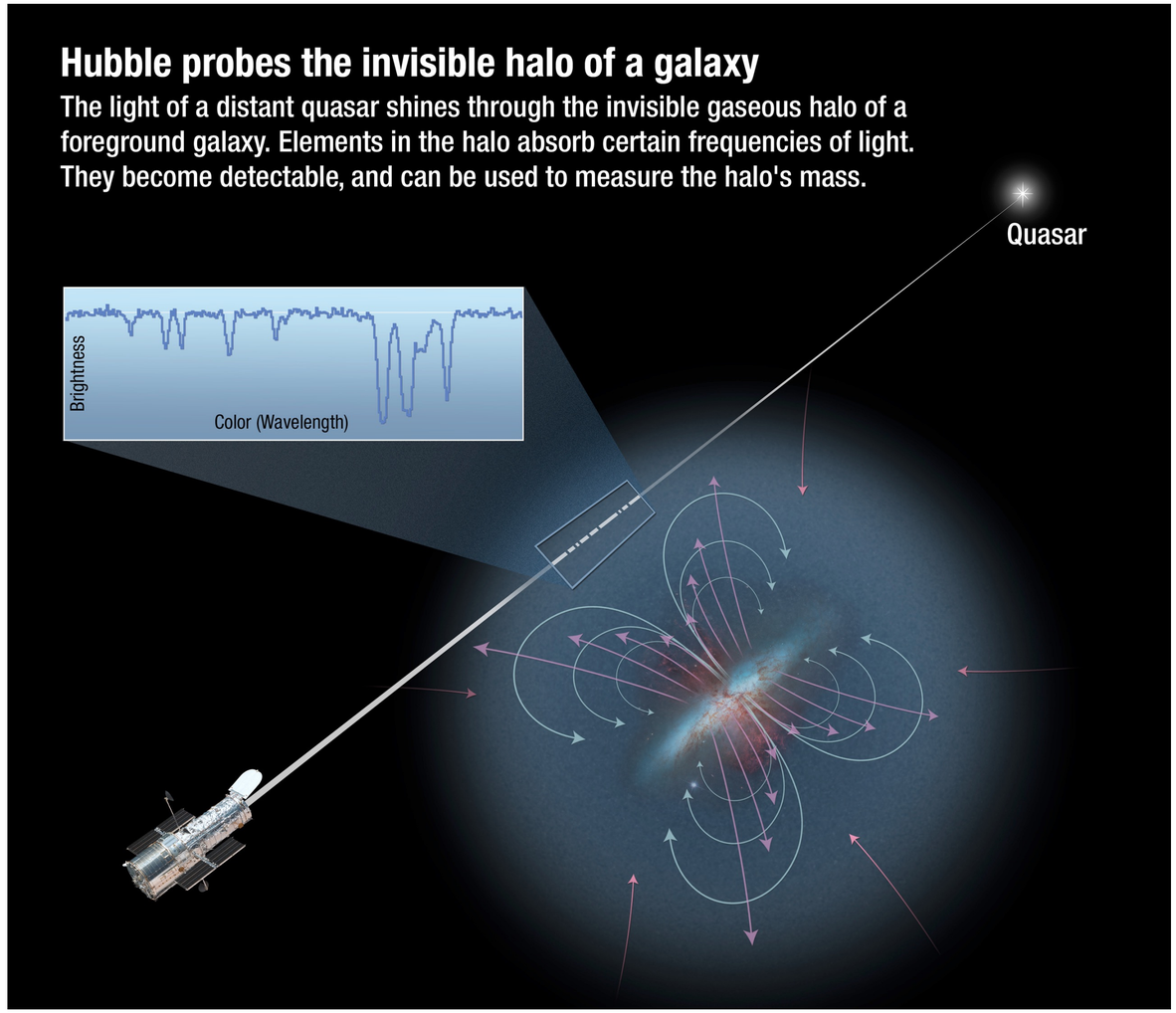
- **O VI transition (1032, 1038 A) probes the most populous ionized phase of gas in a galaxy's CGM.**



Werk et al. (2014)

Absorption Line Finding

- Large O VI 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
- <u>We do not have 'eyes' on the dominant matter component of galaxies</u>



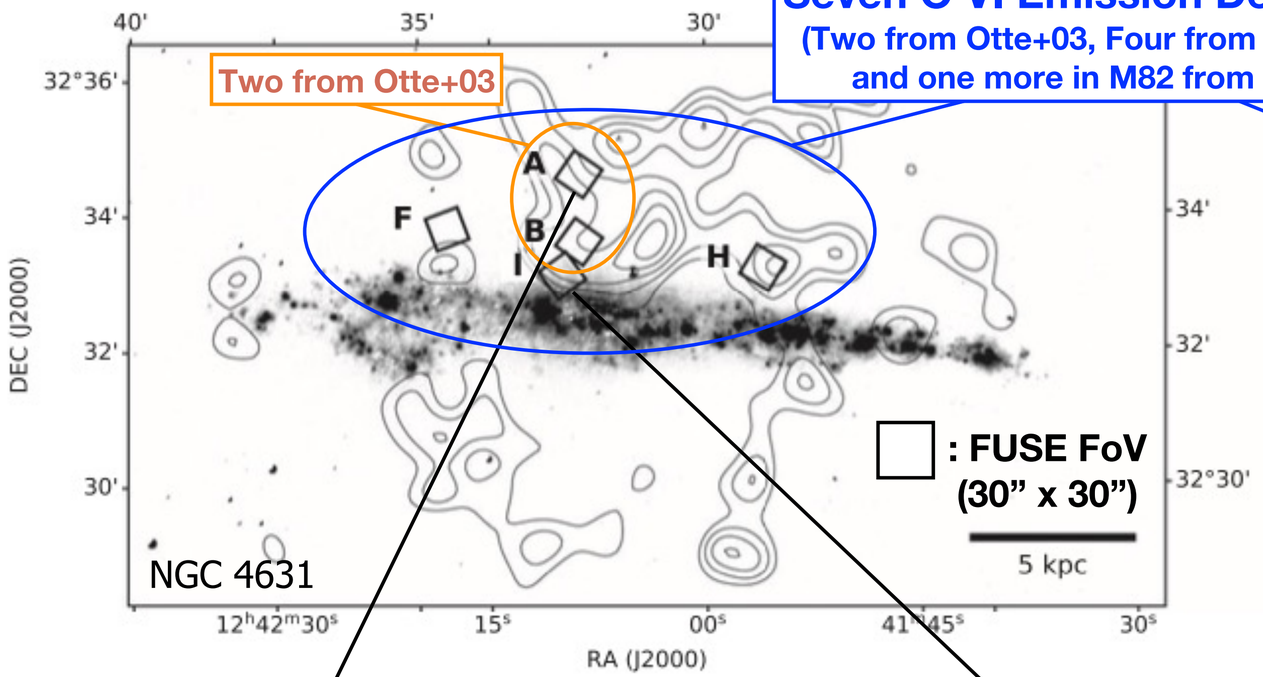
What about in Emission?

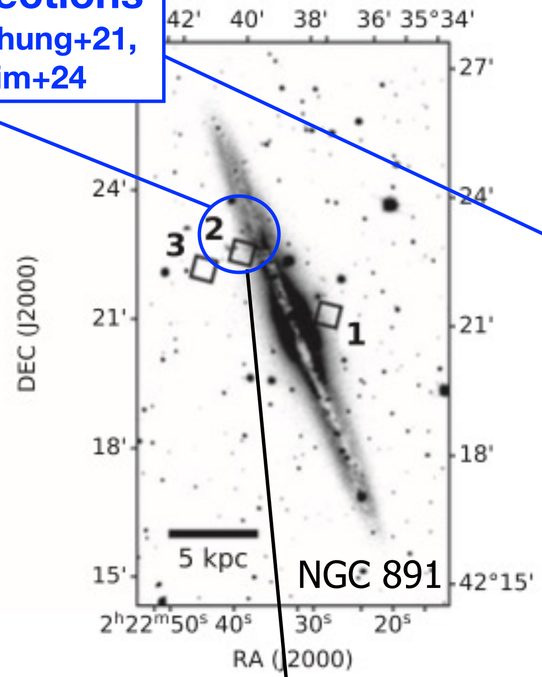
Revisiting FUSE O VI Emission in Galaxy Halos

The Astrophysical Journal, 916:7 (9pp), 2021 July 20

Chung, Vargas, & Hamden

Seven O VI Emission Detections
(Two from Otte+03, Four from Chung+21, and one more in M82 from Kim+24





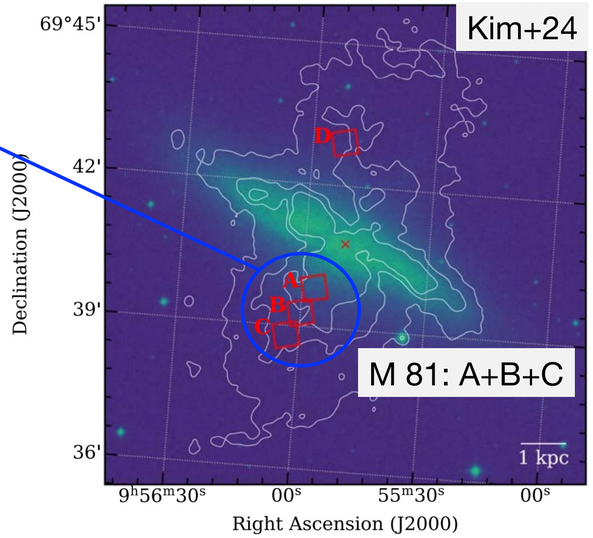
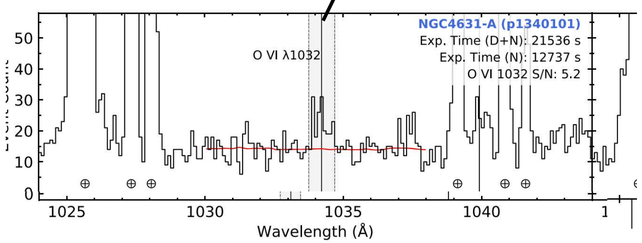
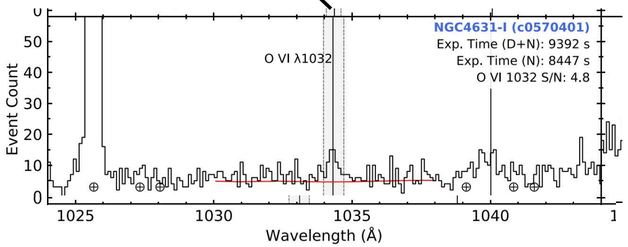
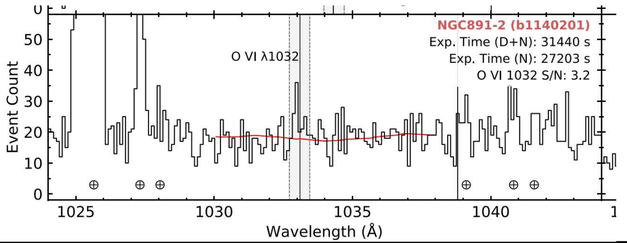


Figure 1. (Left) Hα image of NGC 4631 with soft X-ray band (0.15–0.3 keV) contours. Five FUSE LWRS observation fields are marked with black squares. NGC



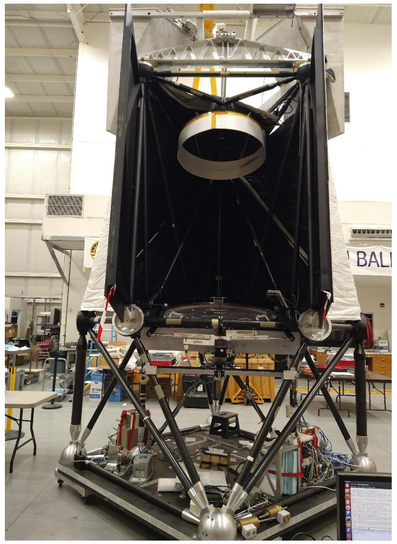




CGM UV Missions at UA/Steward

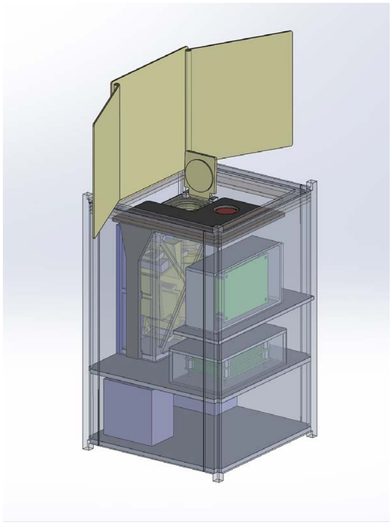


Aspera
- NASA Astrophysics Pioneer mission
- PI: Carlos Vargas (Univ. of Arizona)
- Observe Nearby warm-hot CGM
- Far-UV spectrograph payload
- To be launched in early 2026



FIREBall-2
- NASA APRA balloon telescope
- PI: Chris Martin (Caltech)
- Inst. PI (Univ. of Arizona): Erika Hamden
- Observe redshifted CGM in emission
- FUV multi-slit spectrograph payload
- Launched from Fort Sumner, NM, USA

Eos
- SMEX-class mission concept
- PI: Erika Hamden (Univ. of Arizona)
- Observe H_2 fluorescence line emissions
- SO includes CGM detection in emission
- Far-UV high-spec. res. spectrograph
- Previously known as Hyperion (proposed to 2019 SMEX, 2021 MIDEX)



Nox
- APRA/Pioneer-class mission concept
- PI: Haeun Chung (Univ. of Arizona)
- All-sky spectral background mapping in FUV
- FUV spectrograph payload
- Previously proposed to 2021 APRA

Revealing the Diffuse Universe

WHAT IS THE ASPERA MISSION?



- UV SmallSat Mission (5-years)
  - PI: Dr. Carlos Vargas, University of Arizona
  - Funded by 2020 NASA Astrophysics Pioneers
- Detecting & Mapping of Warm-hot Circumgalactic medium in nearby galaxies via observation of O VI emission line at 103.2 nm
- Payload: UV long-slit spectrograph
- Spacecraft: U Toronto Space Flight Laboratory
- Orbit: Sun-Sync LEO, launch in 2026 via rideshare

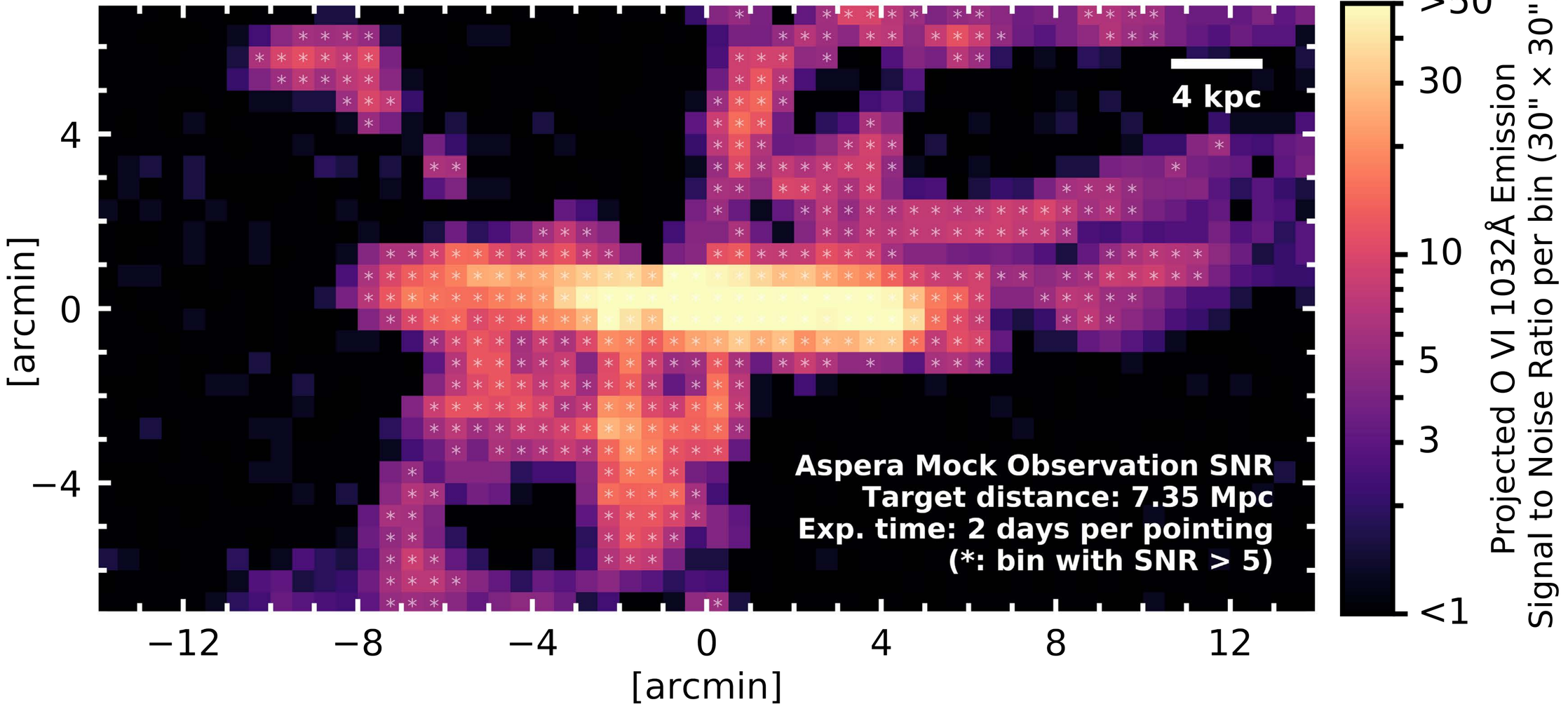
Goal & Science Objectives

Goal: How do baryons cycle in and out of galaxies and what do they do while they are there? (NWNH, Galaxies Across Cosmic Time, Question 2)

Empirically confirm the presence of massive warm-hot halos, and determine its role in galaxy evolution

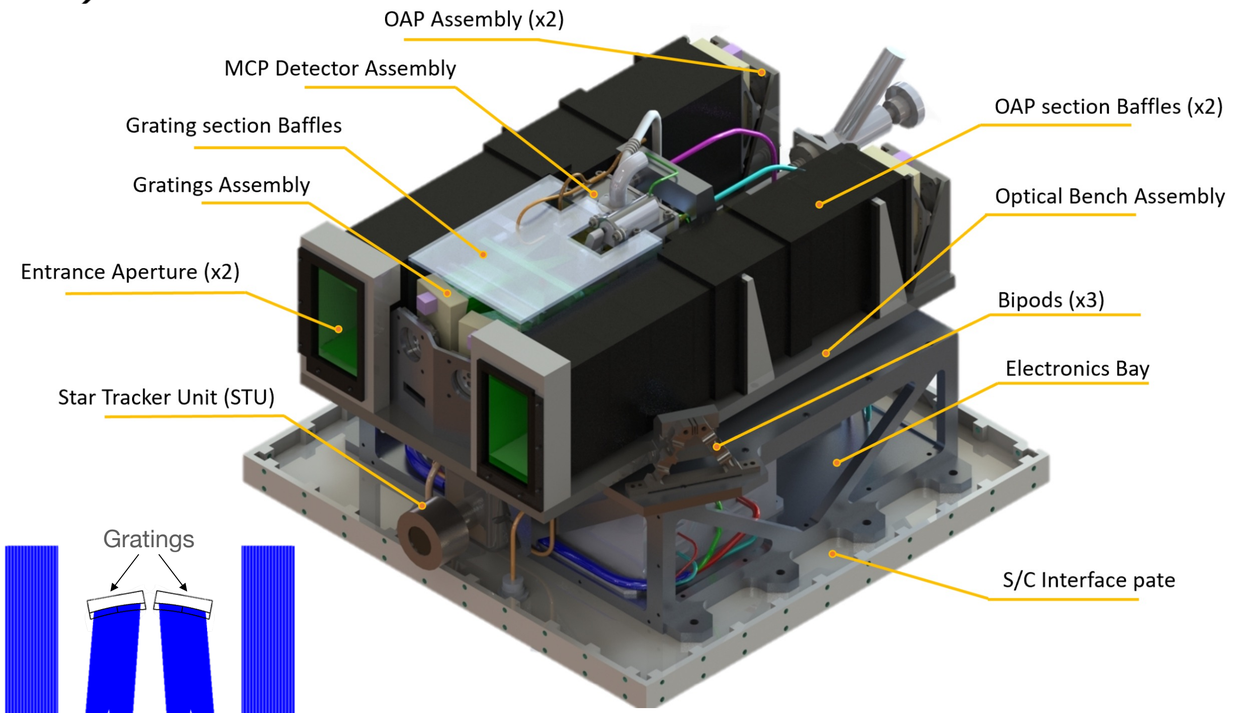
- **SO 1: Ubiquity of warm-hot gas:** Determine the prevalence of circumgalactic warm-hot gas in nearby galaxies
- **SO 2: Morphology:** Determine if the spatial distribution of large-scale warm-hot gas flows is significantly filamentary in galaxies with detections in SO 1
- **SO 3: Contribution to galaxy evolution:** Determine if the abundance and kinematics of warm-hot phase baryons in the circumgalactic medium is consistent with 'superbubble' feedback models in galaxies with detection in SO 1

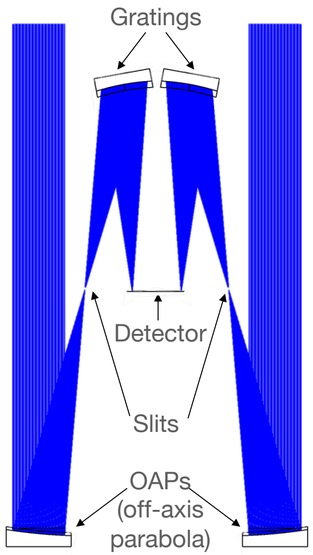
Mock Mapping Observation

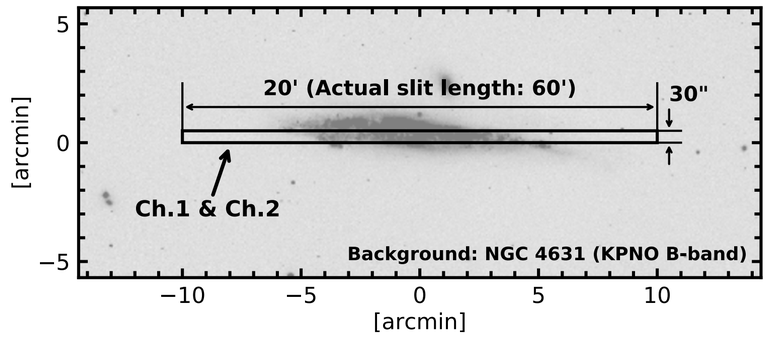


Payload

EFFICIENT AND REDUNDANT, WITH HERITAGE

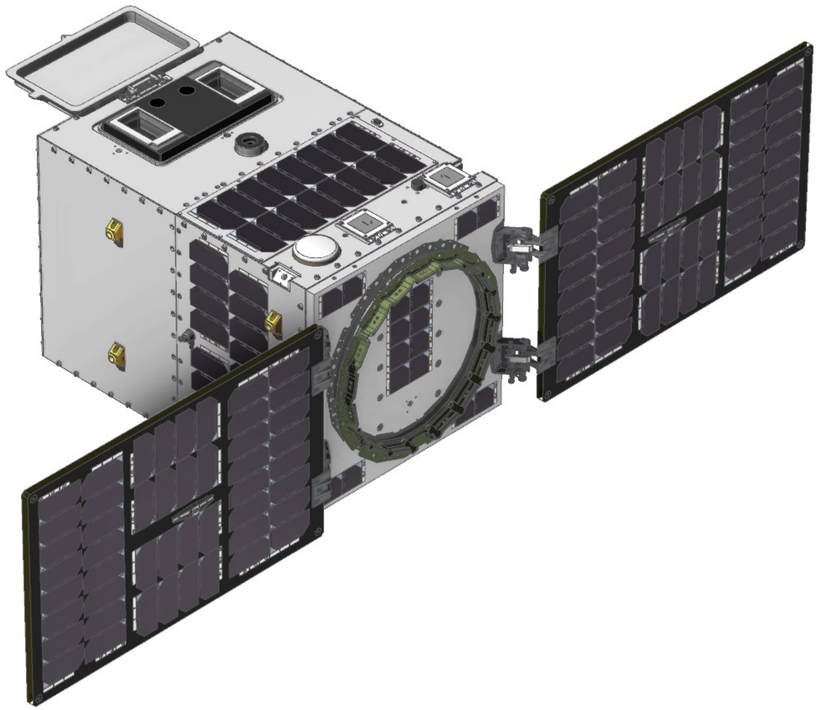


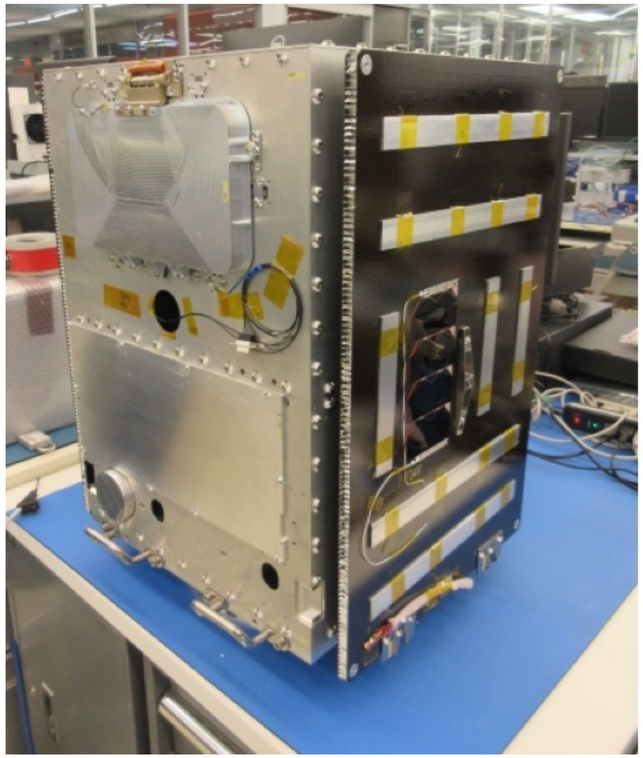




- 2x Identical Rowland Circle-like optics
  - Design inspired by FUSE
- Long slit FUV spectrographs
  - Wavelength: 103-104 nm
  - Spec R: ~1,500, Spatial R: 60 arcsec
  - FoV: 1 degree x 30 arcsec (per ch.)
- MEV Sensitivity: 3.4E-19 erg/s/cm^2/arcsec^2
- TRL ≥ 6 Technologies
  - Mirror, Grating, Coating, & Detector
- Spacecraft: ESPA-class DEFIANT platform
  - Provided by University of Toronto Space Flight Laboratory (UTSFL)
- Chung+2021, Chung+2024 (SPIE Proceeding)

Spacecraft Bus



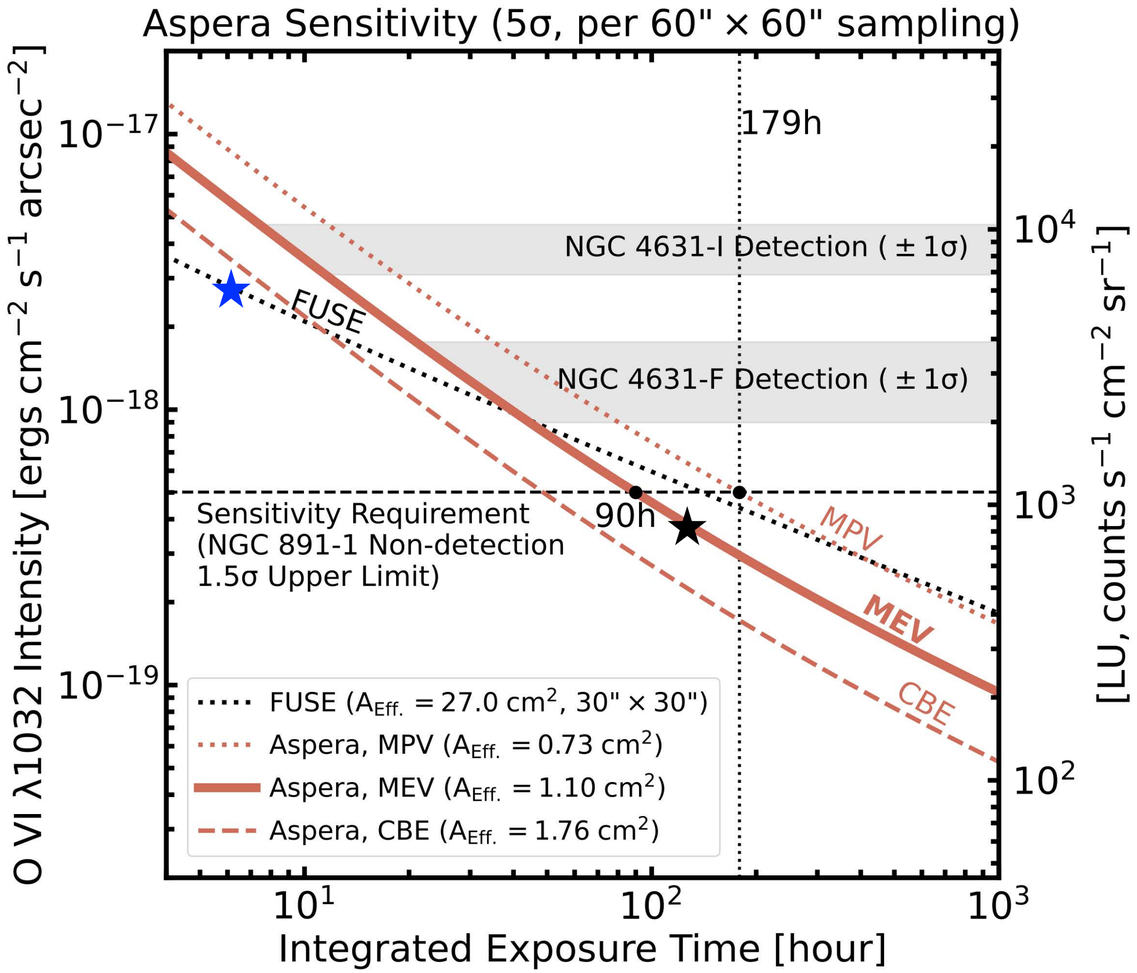


S/C Qualification Model

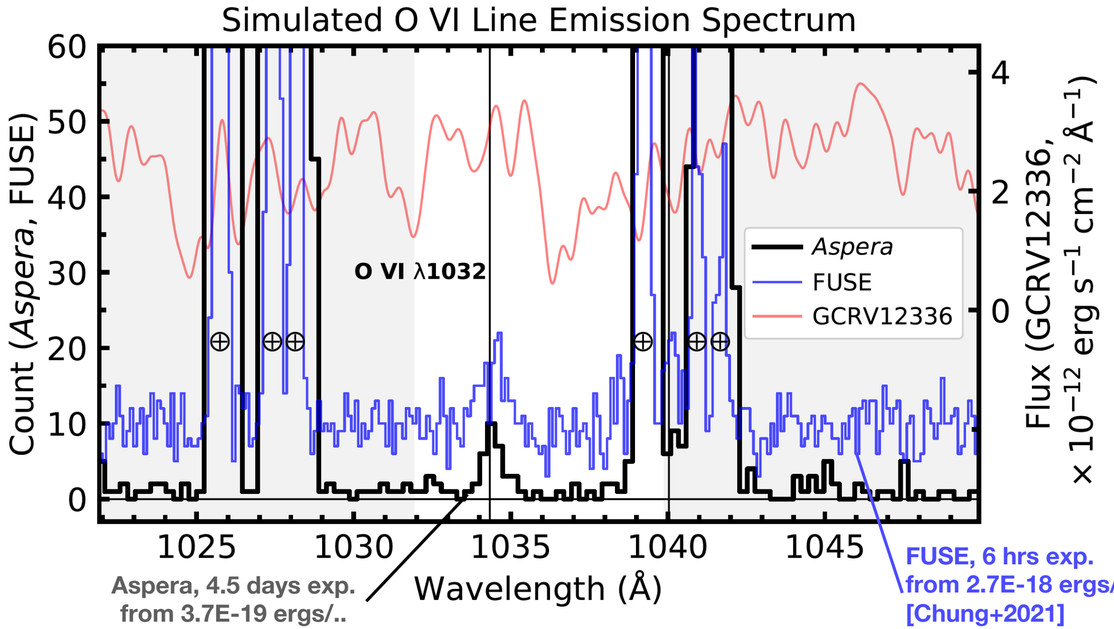
- Provided by the University of Toronto Space Flight Laboratory (ULSFL)
- ESPA-class DEFIANT platform
  - Spacecraft mass: ~35 kg
  - Payload mass: ~24 kg
  - Payload volume: 36 cm x 36 cm x 56 cm

Projected Performance - Sensitivity

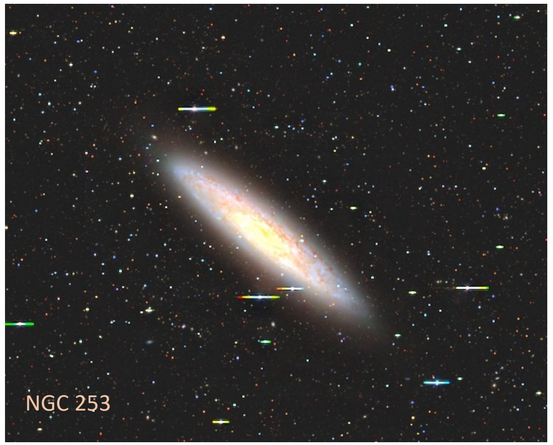
SENSITIVE TO LOW-SURFACE BRIGHTNESS DIFFUSE SOURCE

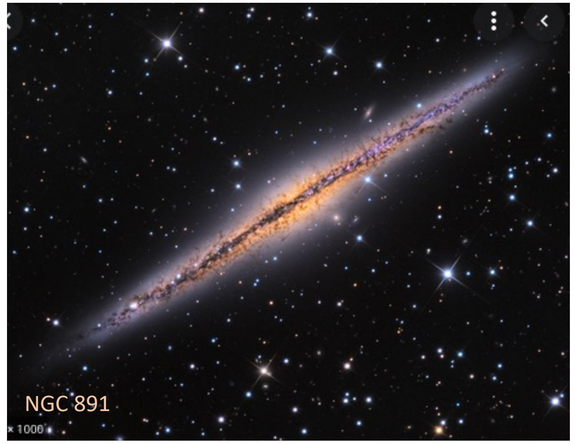


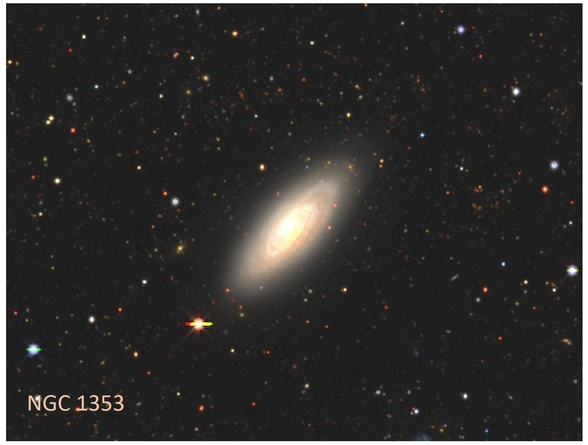
- Aspera Sensitivity: Shot noise-limited even at 1E-19 ergs/s/cm^2/arcsec^2/Å level
- Known noise sources:
  - Shot-noise ($\sqrt{N}$)
  - MCP Detector total background
  - Earthshine/Zodiacal, scattered, and stray light

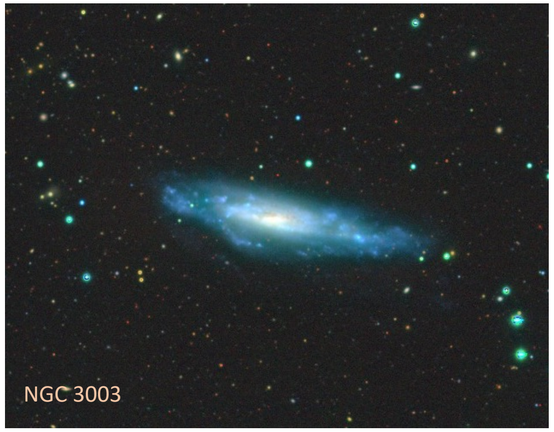


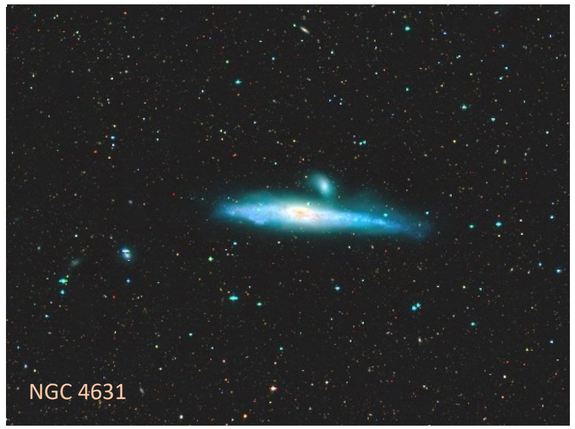
Target Selection

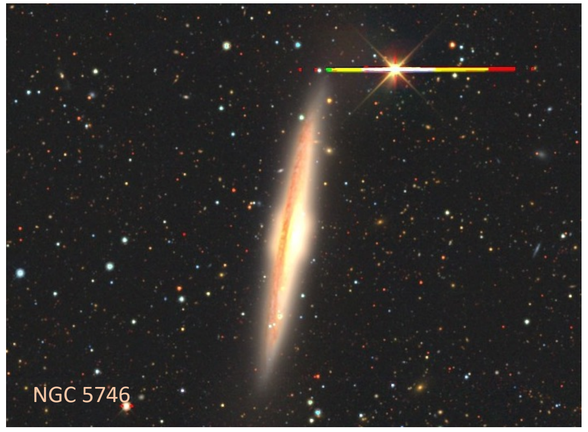










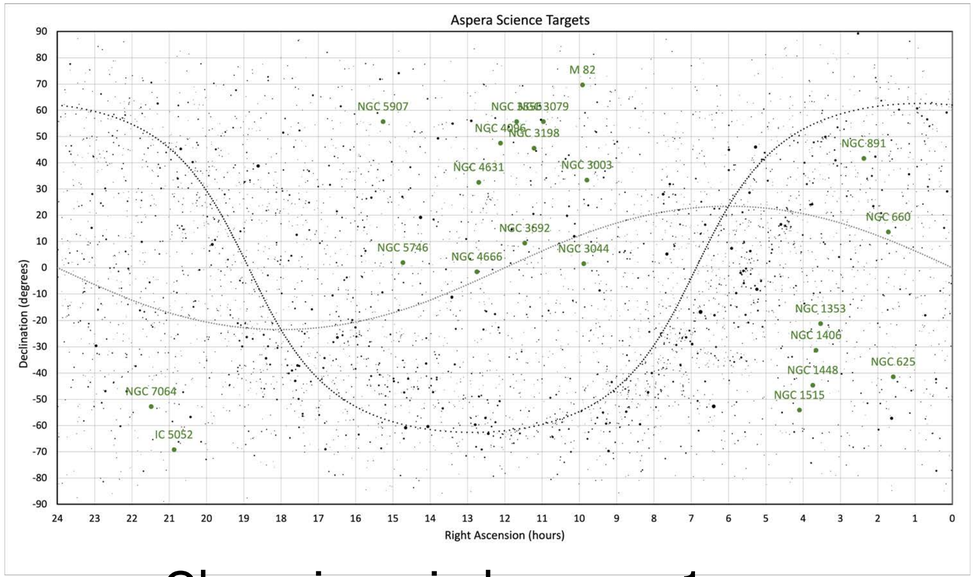


Priority 1 Targets

Targets, CONOPS & Data Management

HUNTING FOR VIEWING WINDOWS

Target distribution on the sky



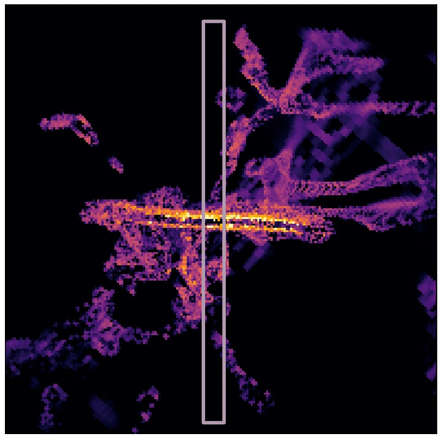
Observing window over 1 year

	1-Jan	8-Jan	15-Jan	22-Jan	29-Jan	5-Feb	12-Feb	19-Feb	26-Feb	5-Mar	12-Mar	19-Mar	26-Mar	2-Apr	9-Apr	16-Apr	23-Apr	30-Apr	7-May	14-May	21-May	28-May	4-Jun	11-Jun	18-Jun	25-Jun	2-Jul	9-Jul	16-Jul	23-Jul	30-Jul	6-Aug	13-Aug	20-Aug	27-Aug	3-Sep	10-Sep	17-Sep	24-Sep	1-Oct	8-Oct	15-Oct	22-Oct	29-Oct	5-Nov	12-Nov	19-Nov	26-Nov	3-Dec	10-Dec	17-Dec	24-Dec
SCIENCE TARGETS																																																					
NGC 625																																																					
NGC 660																																																					
NGC 891																																																					
NGC 1353																																																					
NGC 1406																																																					
NGC 1448																																																					
NGC 1515																																																					
NGC 3003																																																					
NGC 3044																																																					
M 82																																																					
NGC 3079																																																					
NGC 3198																																																					
NGC 3556																																																					
NGC 3692																																																					
NGC 4096																																																					
NGC 4631																																																					
NGC 4666																																																					
NGC 5746																																																					
NGC 5907																																																					
IC 5052																																																					
NGC 7064																																																					

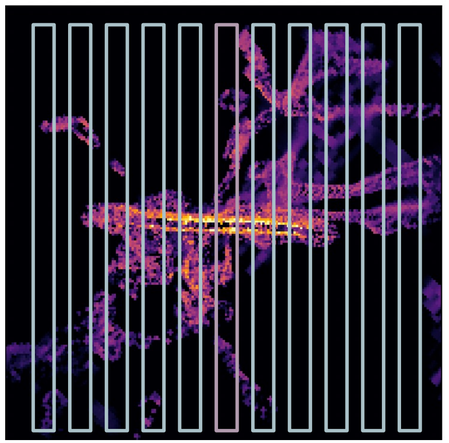
Observing window over 1 year

- Baseline mission requirement:
  - Observing nearby edge-on star-forming galaxies
  - Detection observations for 10 galaxies
  - Mapping observations for 3 galaxies
- Final data product: 3D spectral data cube

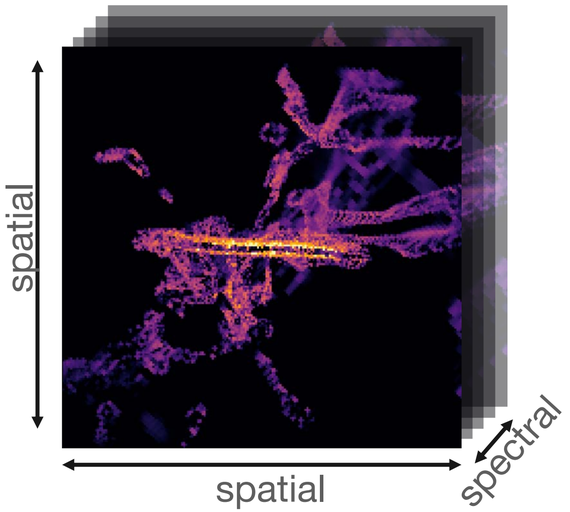
Detection Obs.



Mapping Obs.



3D Data Cube



Team Aspera

THE BEST TEAM EVER

University of Arizona

Management

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

Heejoo Choi
Ewan S. Douglas
Miriam Keppler
Nicole Melso
Simran Agarwal
Aafaque R. Khan
Jessica S. Li
Sumedha Uppnor
Jacob Chambers
Jasmine Martinez Castillo
Gabe G. Noriega
Ryan Pecha
Shashank Verma
Ellie M. Wolcott
Fernando Coronado
Elijah Garcia
Hannah Tanquary
Daniel Truong
Naomi Yescas
Peter Behroozi
Tom Connors
Jason Corliss
Dave Hamara
Walt Harris
Karl Harshman
Daewook Kim
Corwynn Sauve
Bill Verts
Michael Ward
Dennis Zaritsky

Ascending Node Technologies, LLC

Carl Hergenrother
Sanford Selznick
John Kidd
Giulia Ghidoli

Sensor Sciences, LLC

Oswald Siegmund

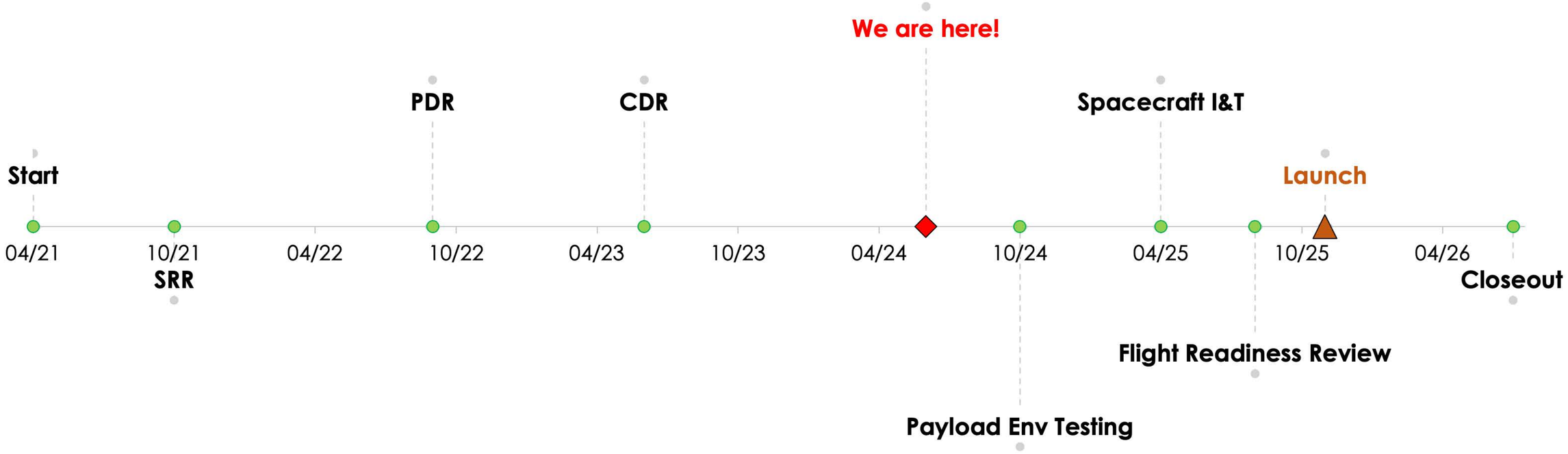
UTIAS SFL

Simon Grocott

External Science Team

Ramona Augustin (STScI)
Joe Burchett (NMSU)
Lauren Corlies (Adler Planetarium)
Keri Hoadley (Iowa)
Cassi Lochhaas (STScI)
Ralf-Jürgen Dettmar (Ruhr U. Bochum)
Chris Howk (Notre Dame)
David Schiminovich (Columbia)

Schedule



Preliminary Design	Critical Design	Payload Assembly & Testing	SC I&T	Flight Ops

Summary

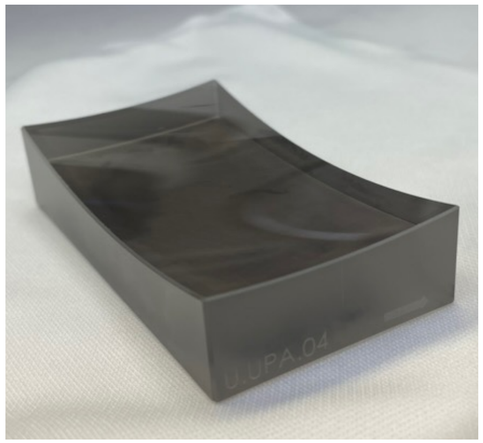
YEAR 2024: THE WAR AGAINST THE CONTAMINATION HAS BEGUN

- Warm-hot CGM – the dominant baryonic component of galaxies is still completely unmapped
- Aspera : UV SmallSat mission for imaging warm-hot coronal gas in nearby galaxy halos
  - via O VI (1032 Å) emission spectroscopy with step-and-stare concept observation
  - High-throughput, wide-field, and shot-noise limited system enables detection and mapping of faint diffuse gas
- AIT in 2024-2025, launch ready by early 2026, to Sun-Sync Low Earth Orbit via rideshare
  → 9-month mission to observe 10 detection targets and 3 mapping targets

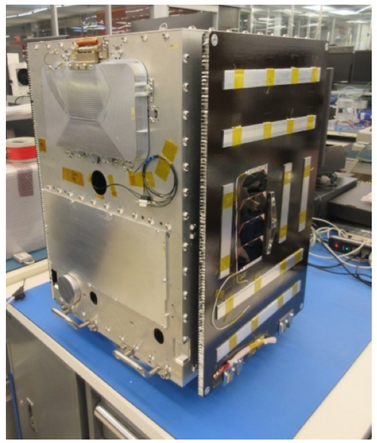
▼Fresh coated OAPs @GSFC



▼The 1st Aspera Flight Grating



▼S/C Qualification Model



▼2D CGM Distribution from Aspera Mock Observation

