UV Emission Mapping of IGM & Nearby Galaxies

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2014. 9 CAS-ESA Joint Science Space Mission 2nd Workshop

Team

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on behalf of

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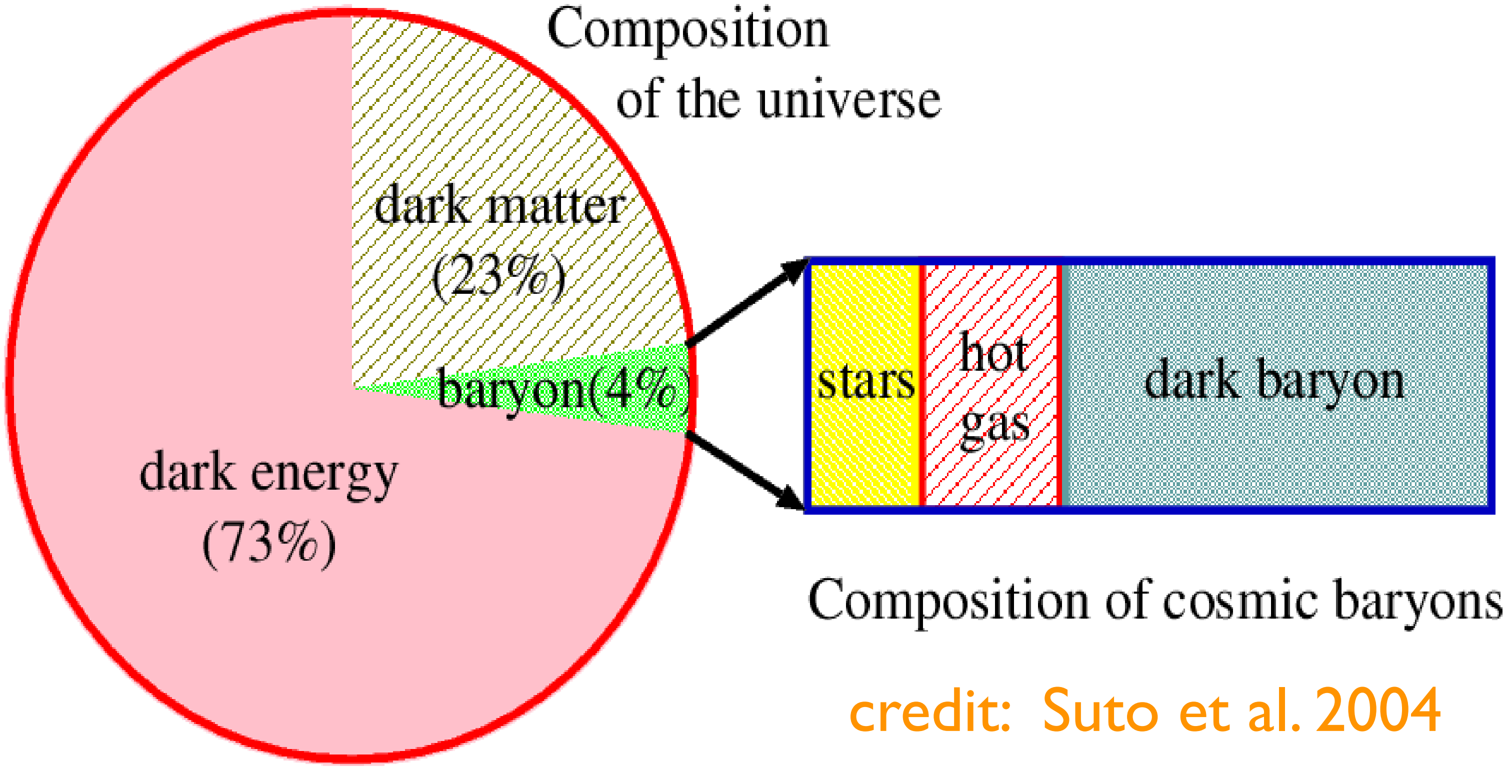
Cosmic Web



credit: Suto et al. 2004

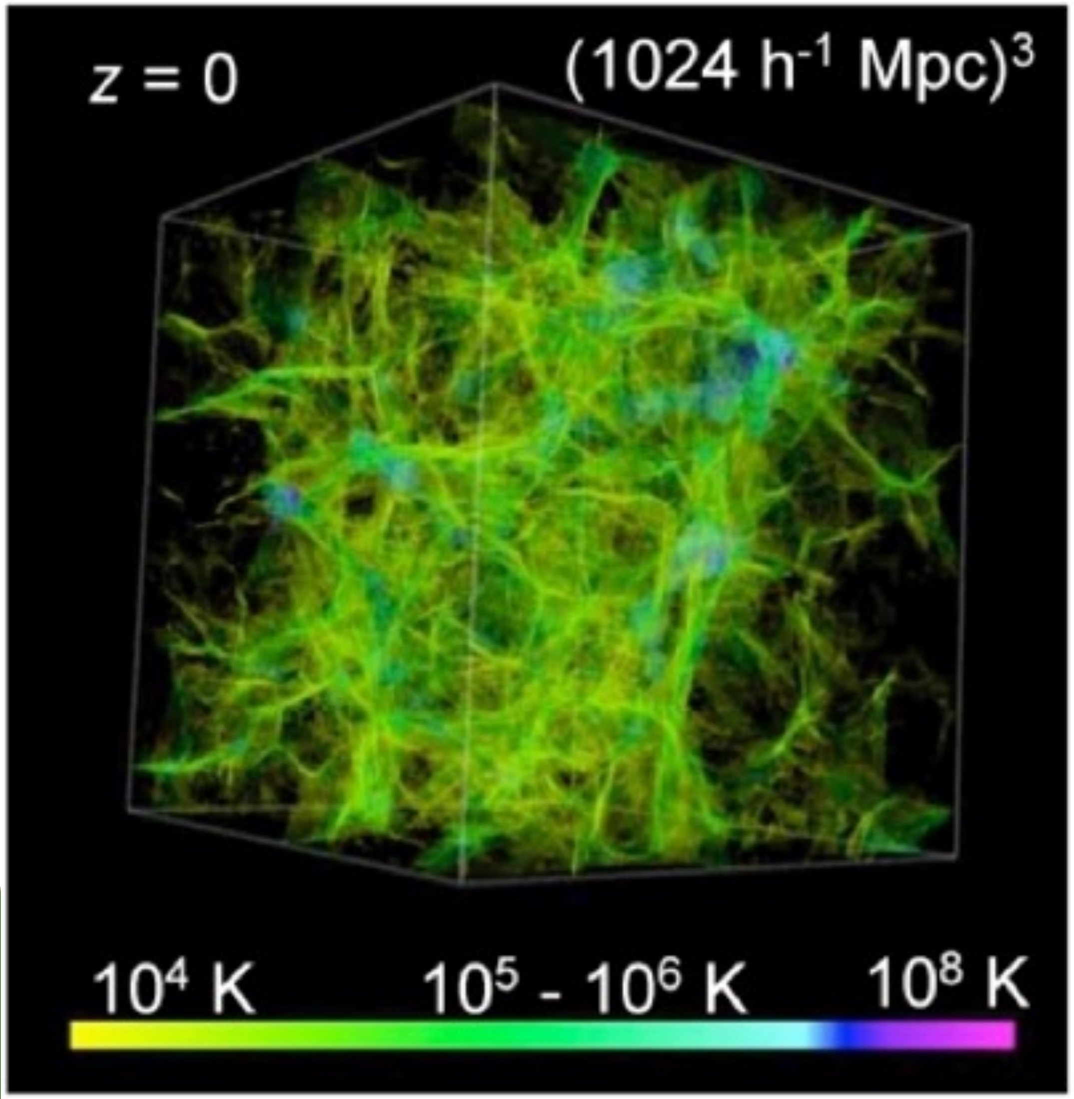
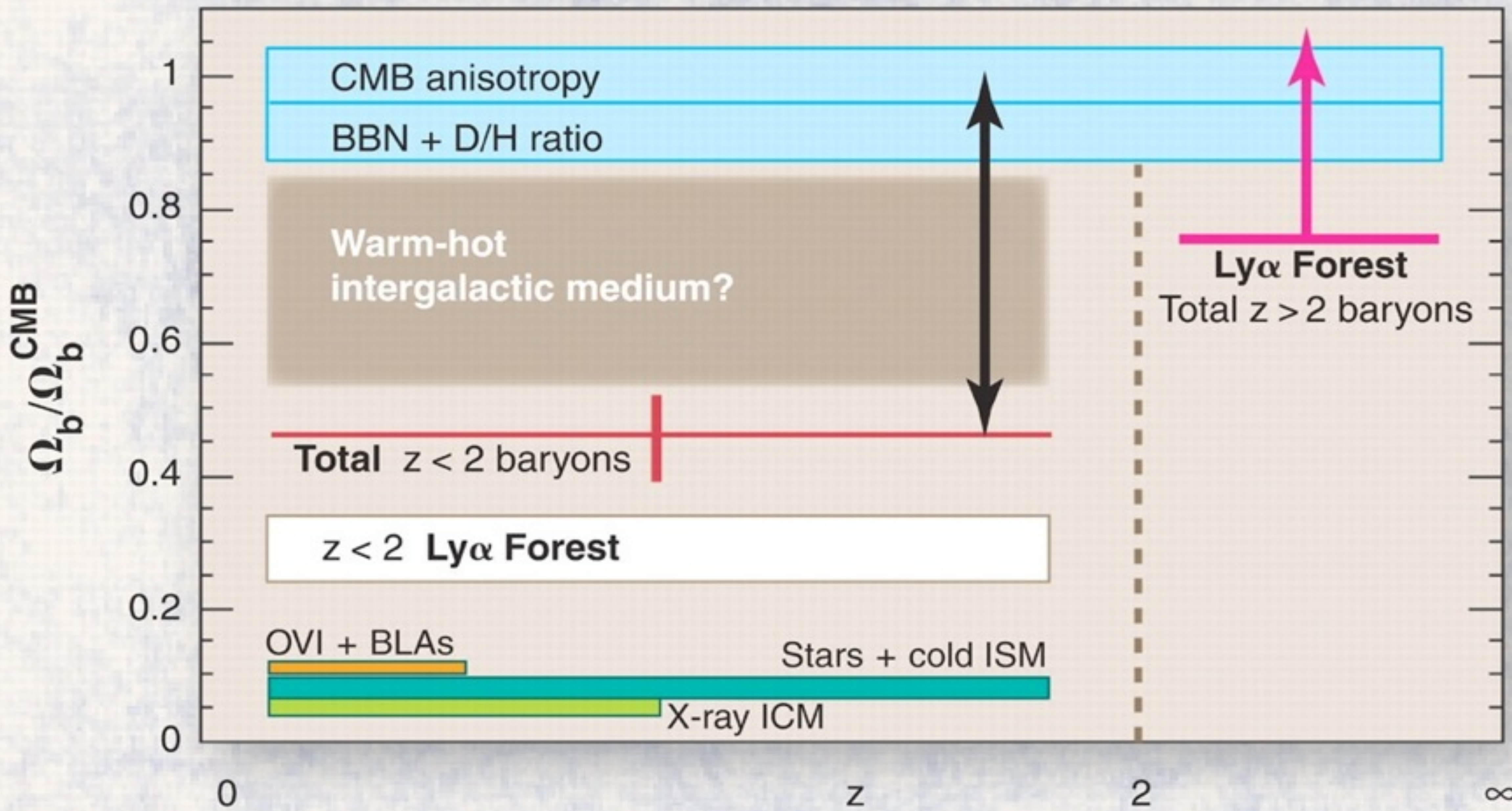


Figure 3: The cosmic web at zero redshift (Kang et al. 2005).

- the threads connecting galaxies & the large-scale structures of the Cosmic Web

- Warm-hot Intergalactic Medium (WHIM)

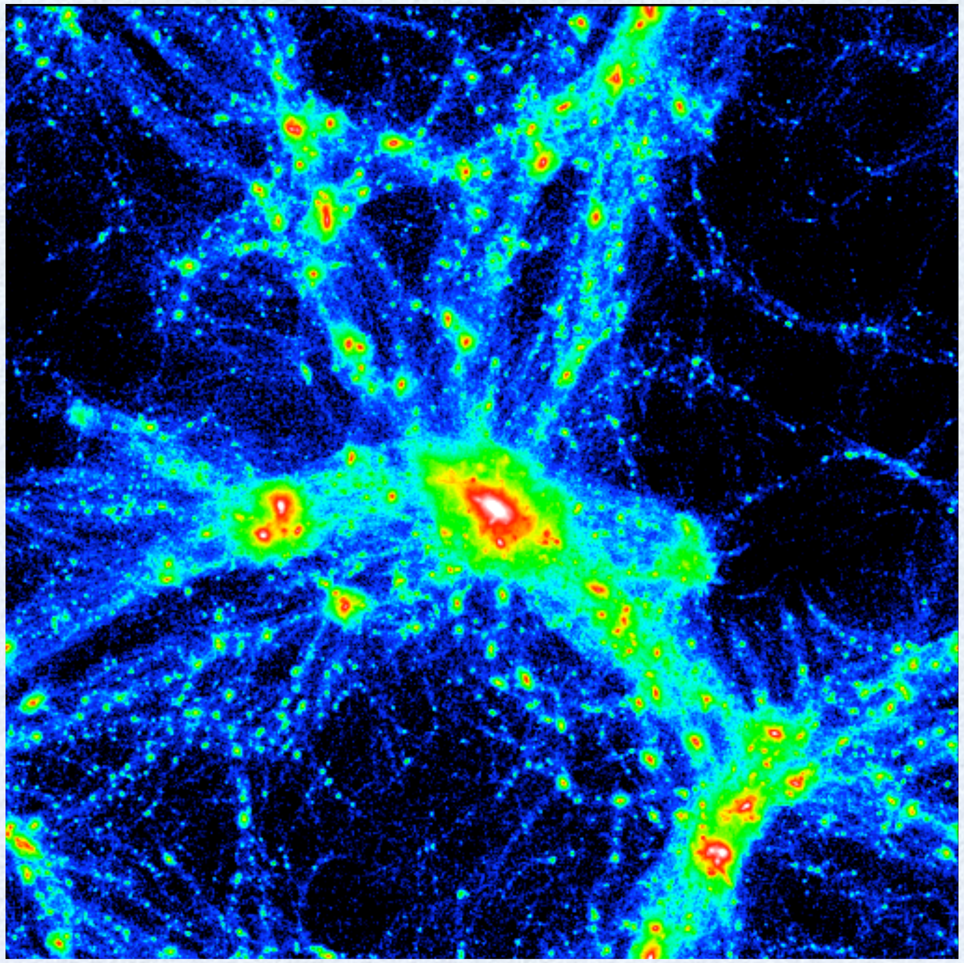
Baryon density in the Universe



credit: Nicastro et al. Science 2008

Fig. 1. Baryon density in the universe, at all redshifts, normalized to the cosmological mass density of baryons derived from cosmic microwave background (CMB) anisotropy measurements.

Diffuse Plasmas



- accounting for about half of all the baryon matter in the present universe

- Reservoir of materials for star formation for galaxies

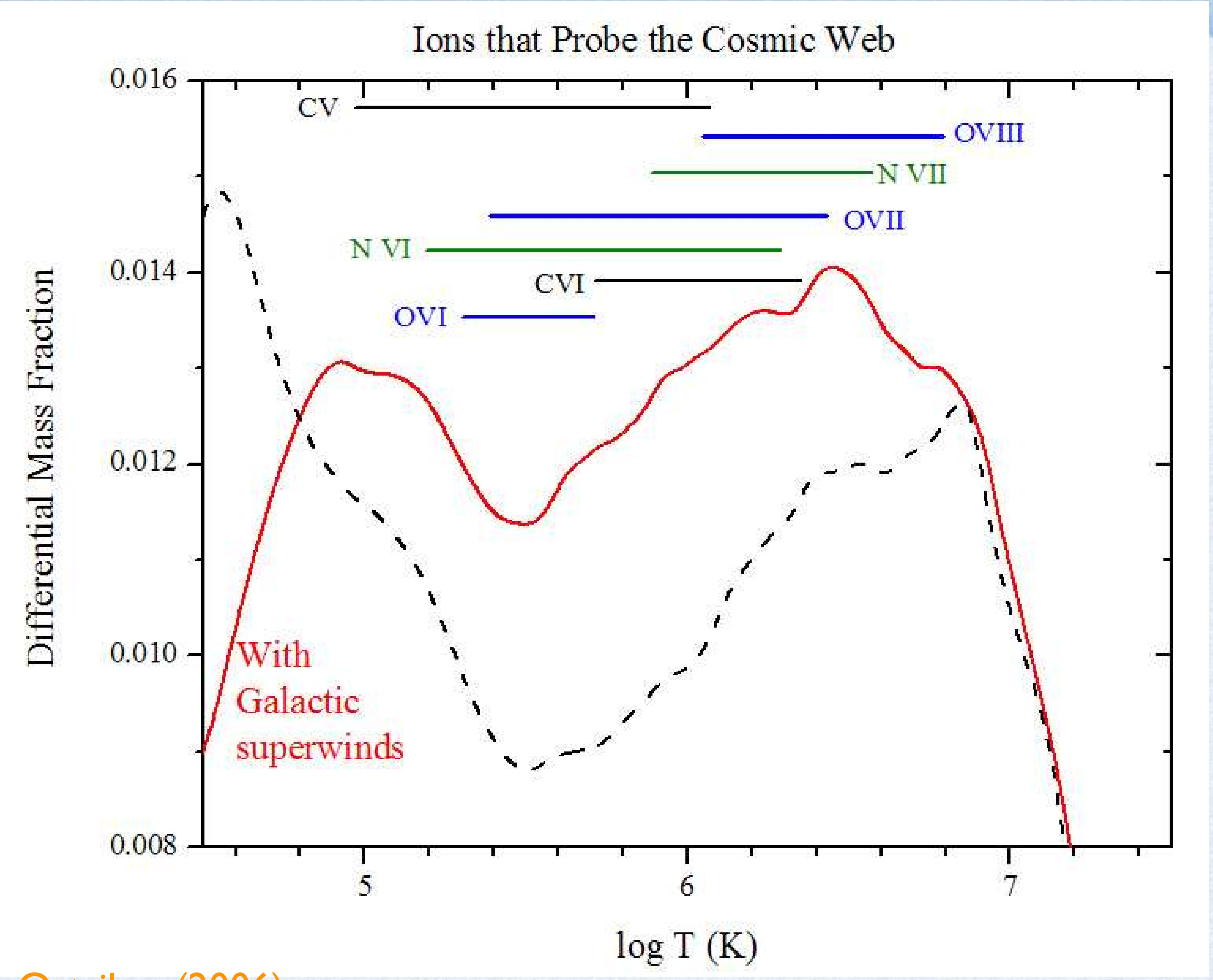
- Depository of galactic feedback

- The least understood baryon component:
little is known about spatial, physical, chemical & dynamic states

credit: Wang, D.

Understand the galactic feedback is essential to the study of the galaxy formation & evolution

Measuring "Cosmic Web"



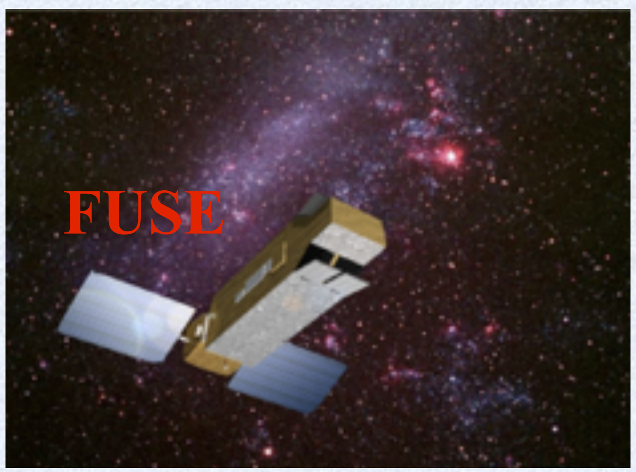
credit: Cen & Ostriker (2006)

Existing Detections

Table 1: Components of the IGM

credit: Sembach et al. 2010

		T (K)	Primary Metal-Line Tracers	Waveband
Cool Photoionized Lyα forest		$< 3x10^4$	C II, C III, Si II, Si III	UV
Warm Photoionized Lyα forest		$3x10^4$ - 10^5	C III, CIV, O III, O IV, O VI	UV
Warm-Hot IGM (WHIM)	Warm	10^5 - 10^6	O VI, O VII, Ne VIII	UV, X-ray
	Hot	10^6 – 10^7	O VII, O VIII	X-ray



930-1180 Å

1140-1800 Å

1.5-170 Å

7-35 Å

WHIM has to be detected in UV

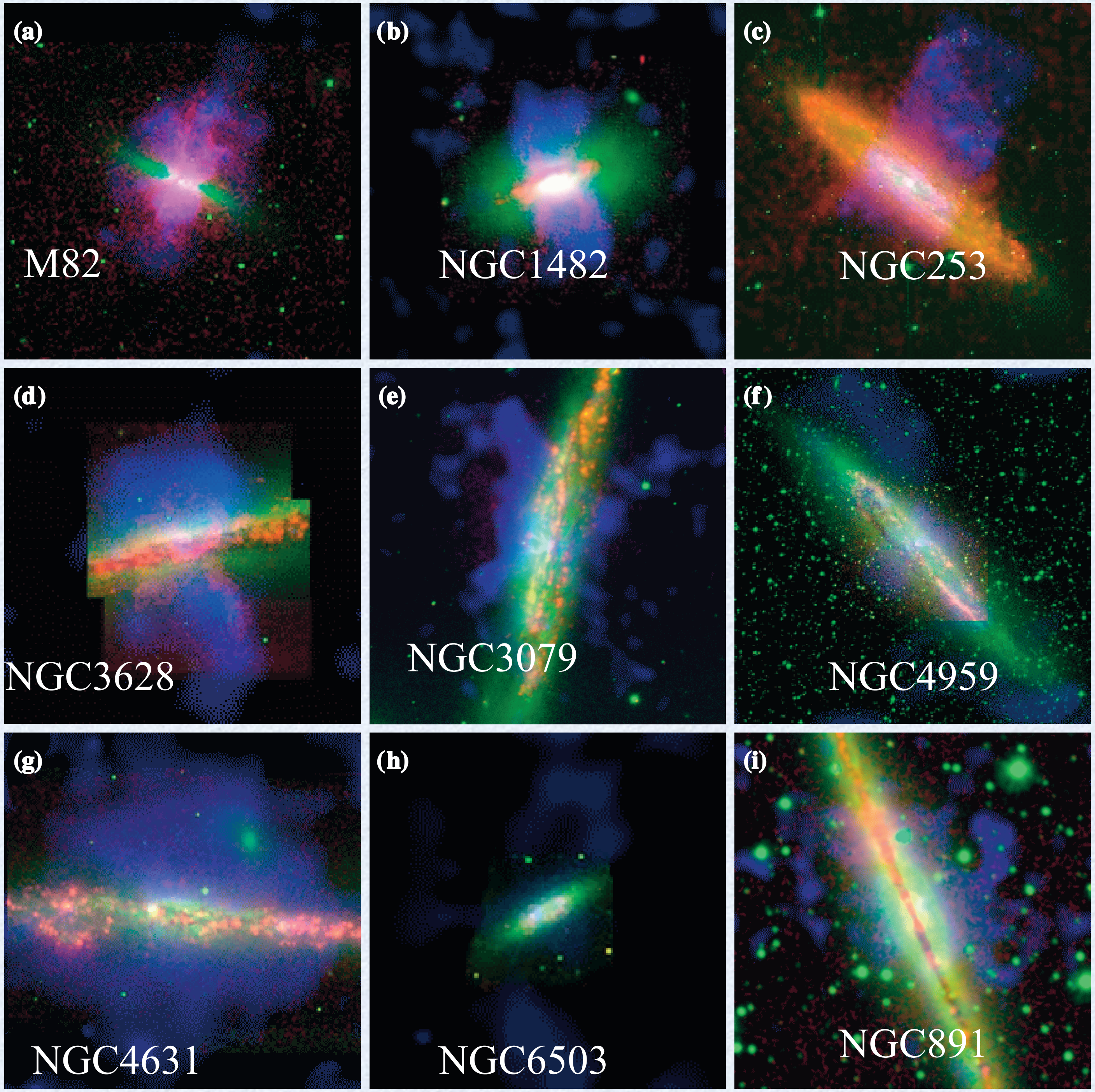
- Only absorption detections (FUSE, HST/COS)
  - Emission: Directly 3D (x,y,v) mapping

— OVI doublet: $1s^2 2s \rightarrow 1s^2 2p$

1031.9 & 1037.6 Å

— HI recombination lines $Ly\alpha, Ly\beta$

Nearby Galaxies



credit: Strickland et al. 2004

edge-on galaxies with a range of star-formation rates: (Strickland et al. 2004)

- red: $H\alpha$
- green: optical R band
- blue: 0.3-2keV (soft X-ray)

- Hot gas extending perpendicular to the major axes of the galaxies (might be in SN and/or AGN-driven outflows

- Extraplanar 1e4K gas can be detected with low background achievable for $Ly\beta$ line from space

- No emission data for 1e5 K gas !

- Unlike the case for X-ray data, mapping the OVI and $Ly\alpha$ emission could provide kinematic information

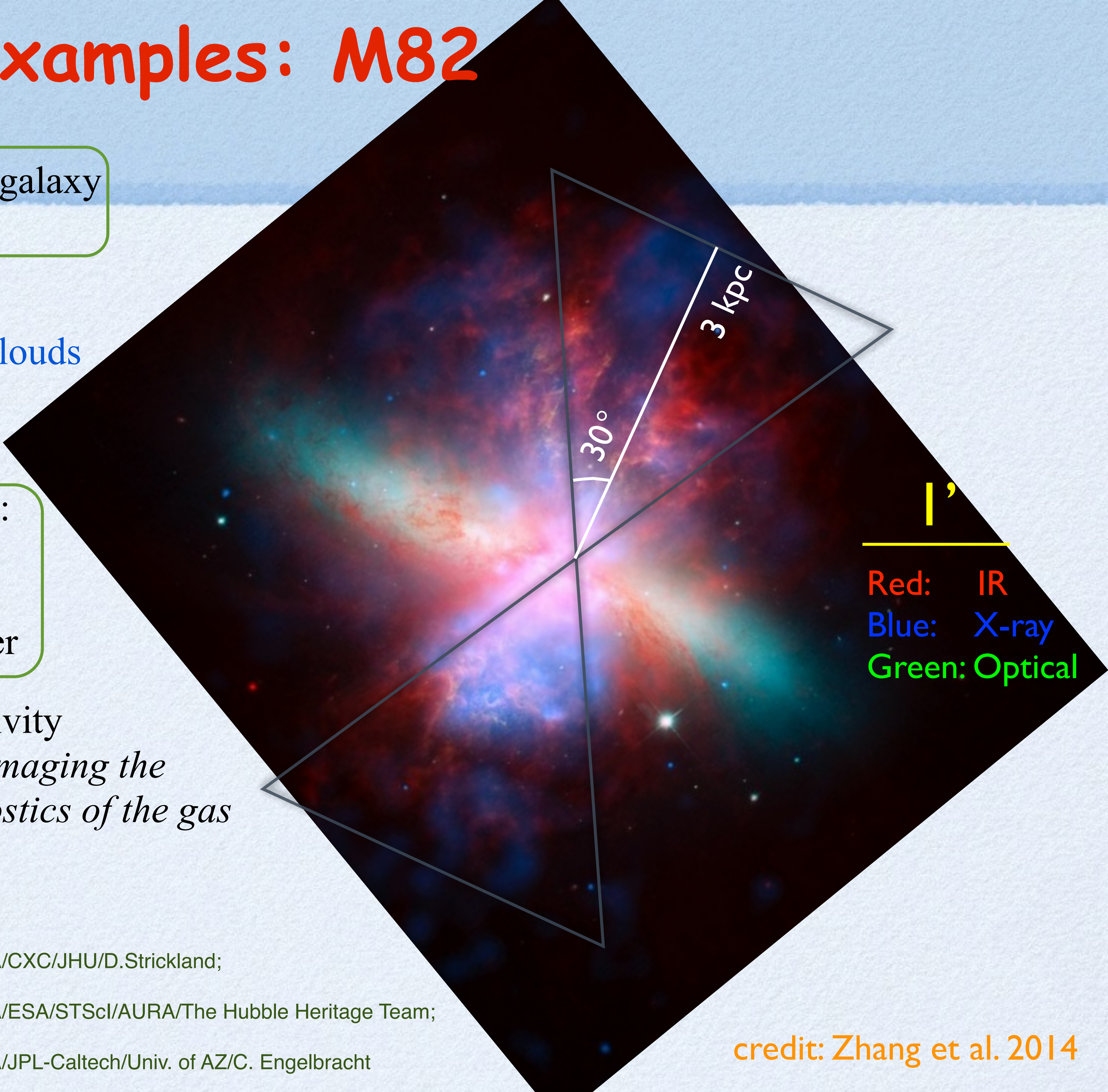
Scientific Examples: M82

- the prototype starburst galaxy
- distance: 3.6 Mpc

- the interface between the hot gas & the cold clouds
- the amount of mass in the outflows

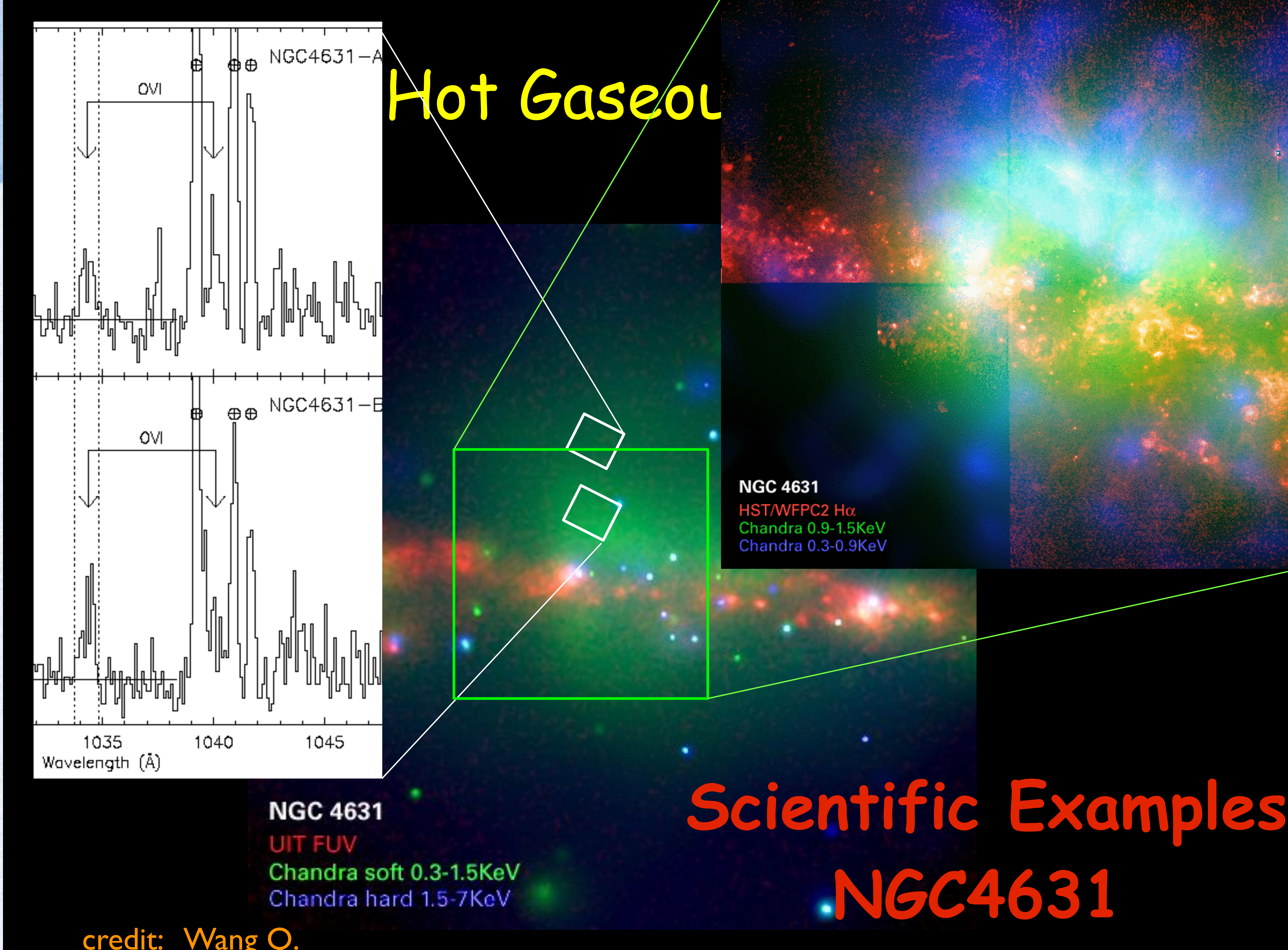
Observational Challenge:
require datasets:
- sufficient sample size
- enough diagnostic power

HST/COS: lack of sensitivity
no means for spectrally imaging the emission from key diagnostics of the gas
(e.g. OVI, Lyα)



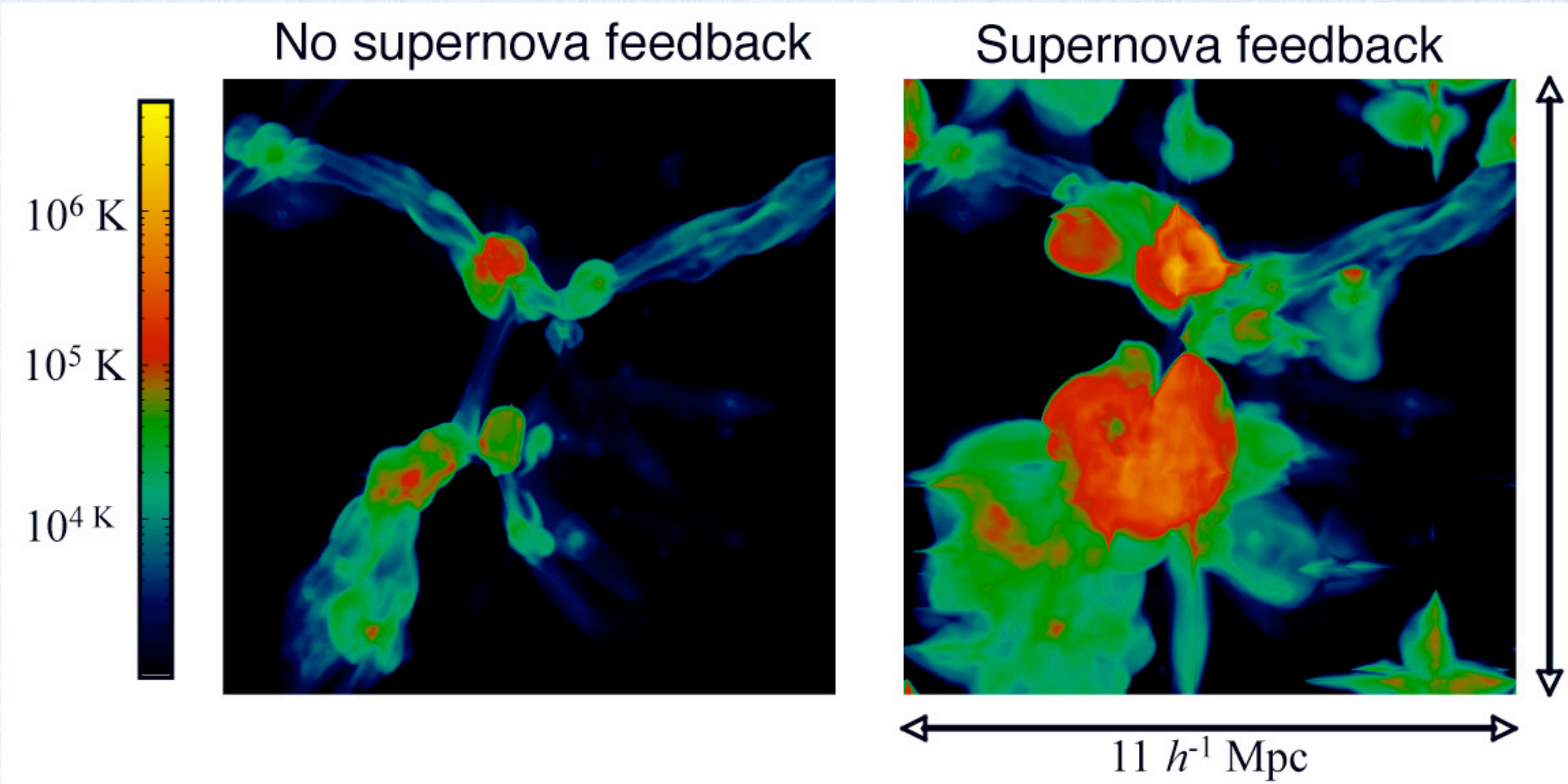
Credit:
- X-ray:
  NASA/CXC/JHU/D.Strickland;
- Optical:
  NASA/ESA/STScI/AURA/The Hubble Heritage Team;
- IR:
  NASA/JPL-Caltech/Univ. of AZ/C. Engelbracht

credit: Zhang et al. 2014



Hot Gaseou
NGC4631-A
OVI
NGC4631-B
OVI
1035
1040
1045
Wavelength (Å)
NGC 4631
HST/WFPC2 Hα
Chandra 0.9-1.5KeV
Chandra 0.3-0.9KeV
NGC 4631
UIT FUV
Chandra soft 0.3-1.5KeV
Chandra hard 1.5-7KeV
Scientific Examples
NGC4631
credit: Wang Q.

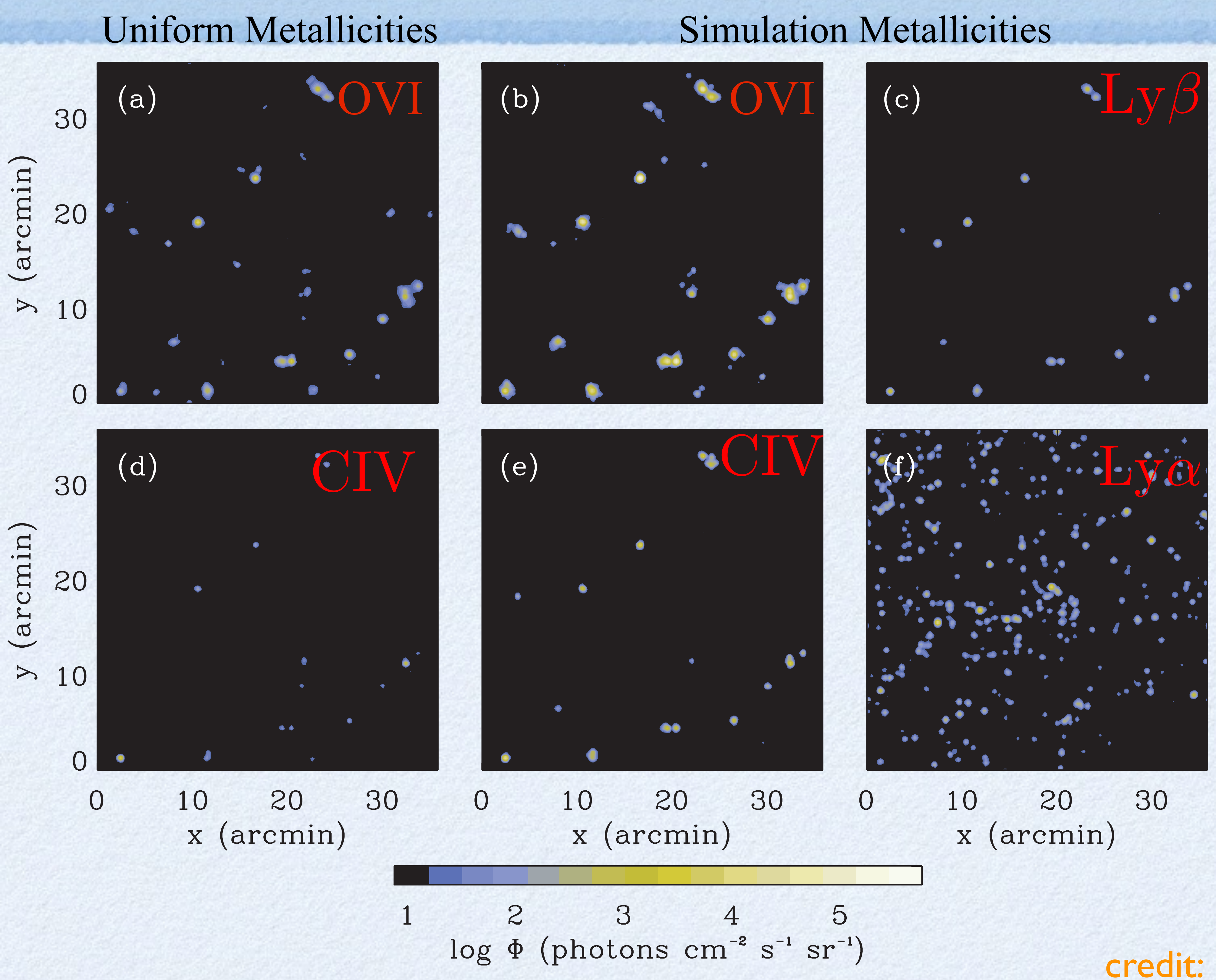
Scientific Examples



credit: Cen & Ostriker 2006

Understand the galactic feedback is essential to the study of the galaxy formation & evolution

Simulations Predicts



$z = 0.15$

$\Delta z = 0.01$

a physical size ≈25 h^{-1} kpc

credit: Furlanetto et al. 2004

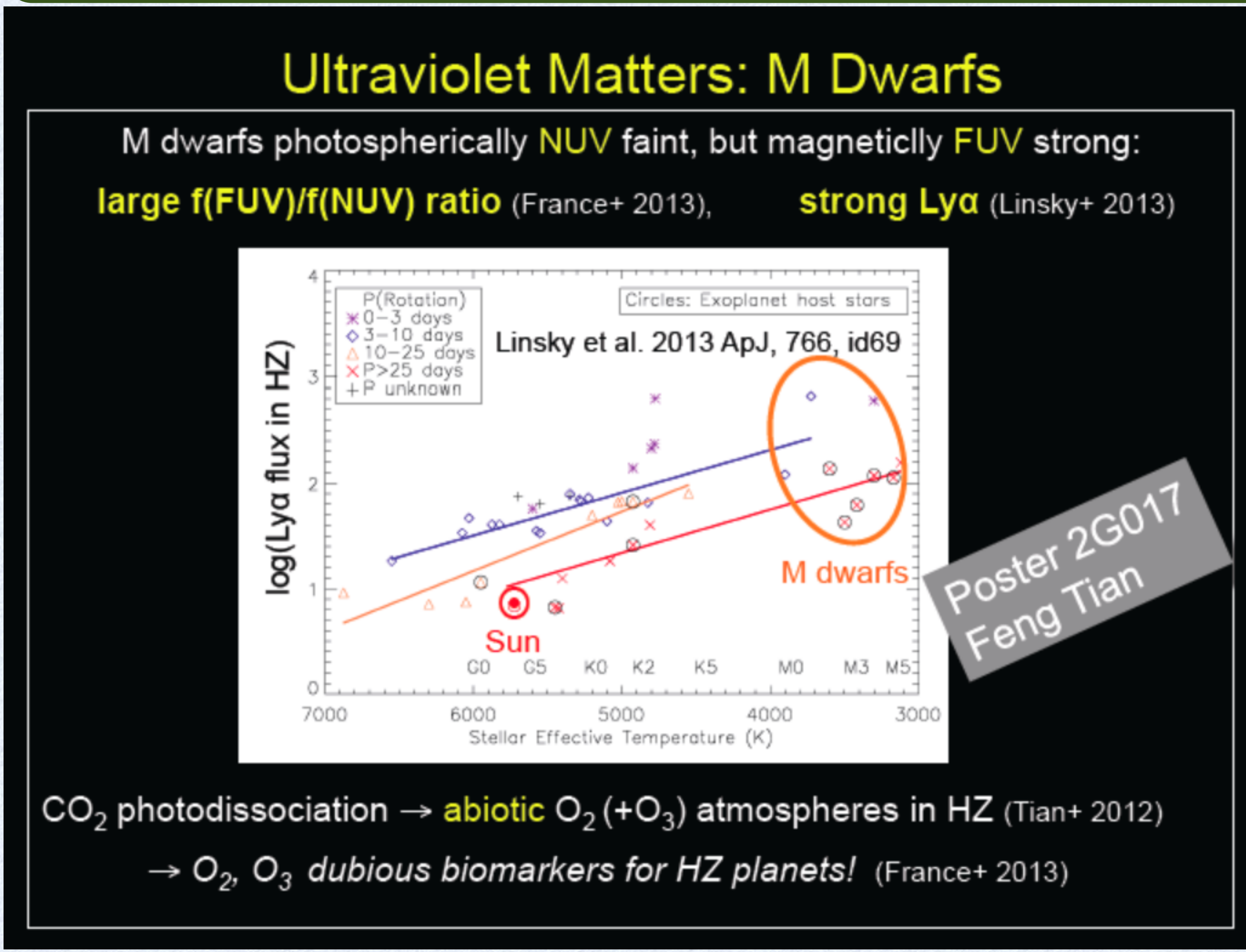
Scientific Objectives

Goal:
first time 3D(x,y, v)-Mapping the vicinities of nearby galaxies in 1e5 K
- connections with cosmic web
- feedback and accretions between galaxies & IGM

- How WIHM distributed in Cosmic Web? filament? halo?
- How much ordinary matter is present in the halo?
- How does the outflow of hot gas affect the evolution of galaxies?
- How does the inflowing materials affect galaxies?
- How does gas cool?

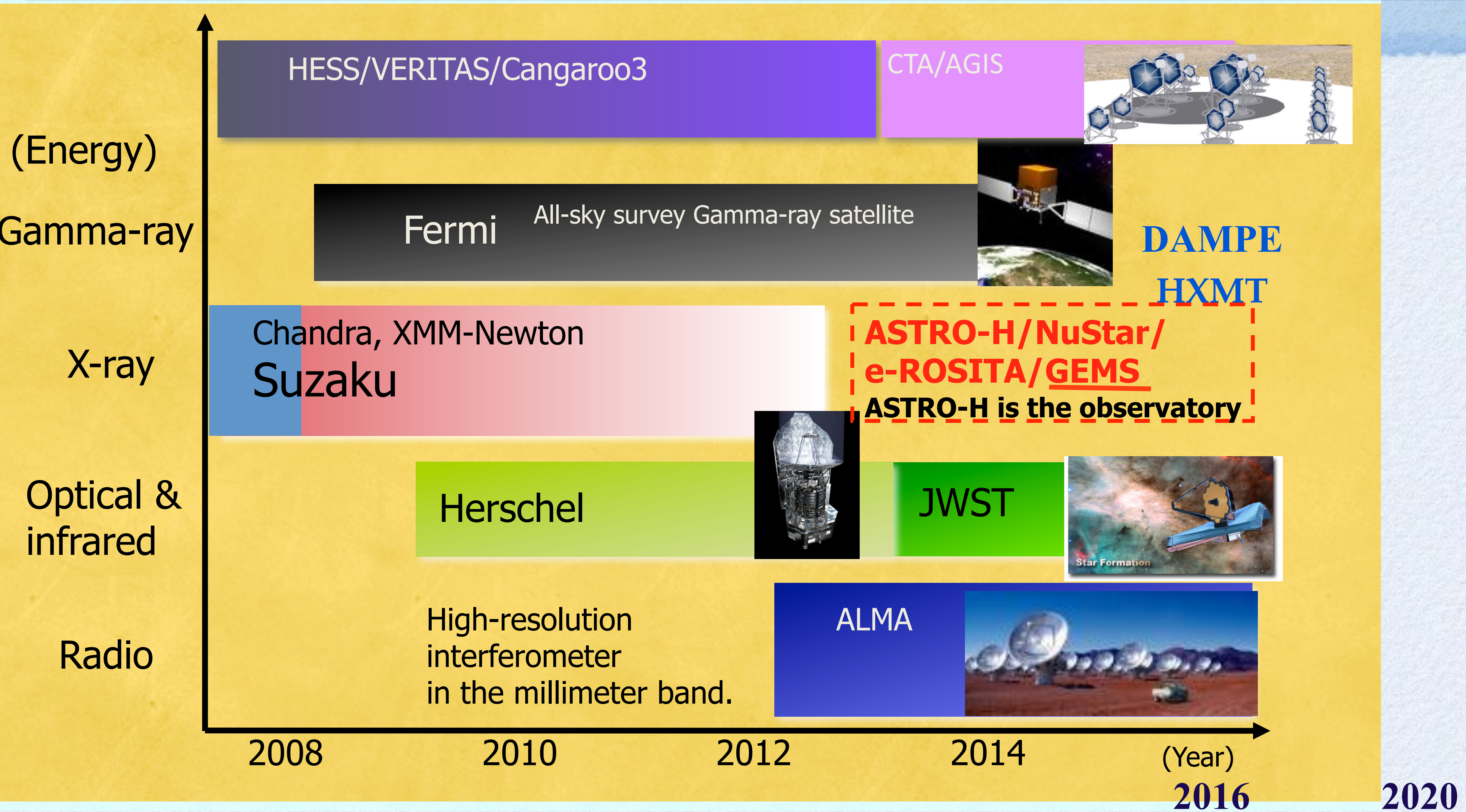
Other Possible Scientific Objectives

- Atmospheres of (exo)planets e.g. Habitable exo-planets (Tian et al. 2013)



Credit: Gudel, M.

UV in multi wavelength programs



Credit: Ohashi, T 2010, in Netherlands

Future UV

- HST/16m UV-Optical telescope

credit: NASA 2010 Science White Paper

- WSO (UV):
  - not for OVI
  - not small mission
  - ?

What do we have

— **PMO：** Key Laboratory of Dark Matter & Space Astronomy

DAMPE (Launch in 2015)

— **NAO**: Long Slit Spectrograph (prototype, 3M USD, PI Sen Wang)

— **Team：**

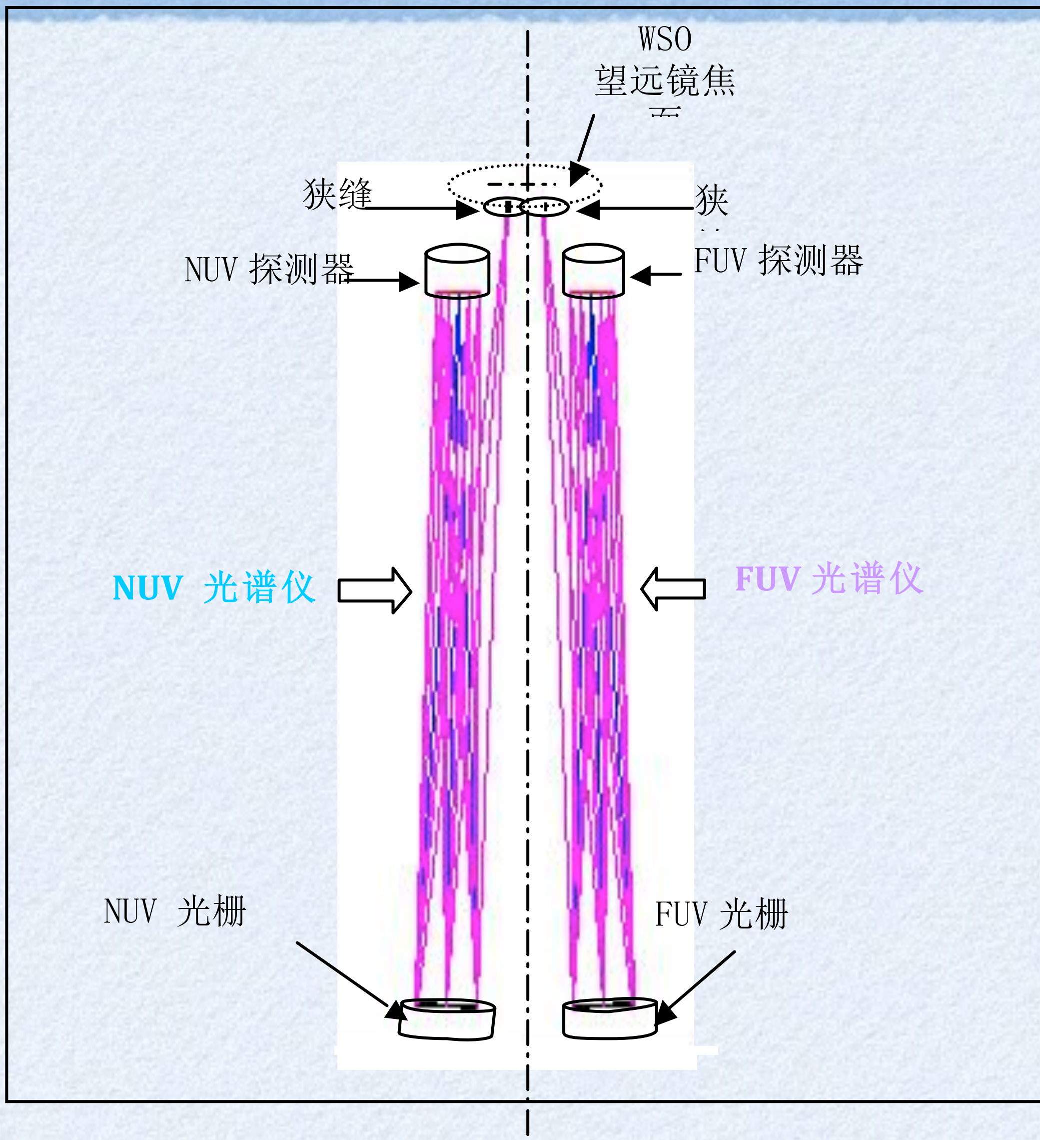
—**CAS:** PMO, NAO, Xi'an Institute of Optics & Precision Mechanics

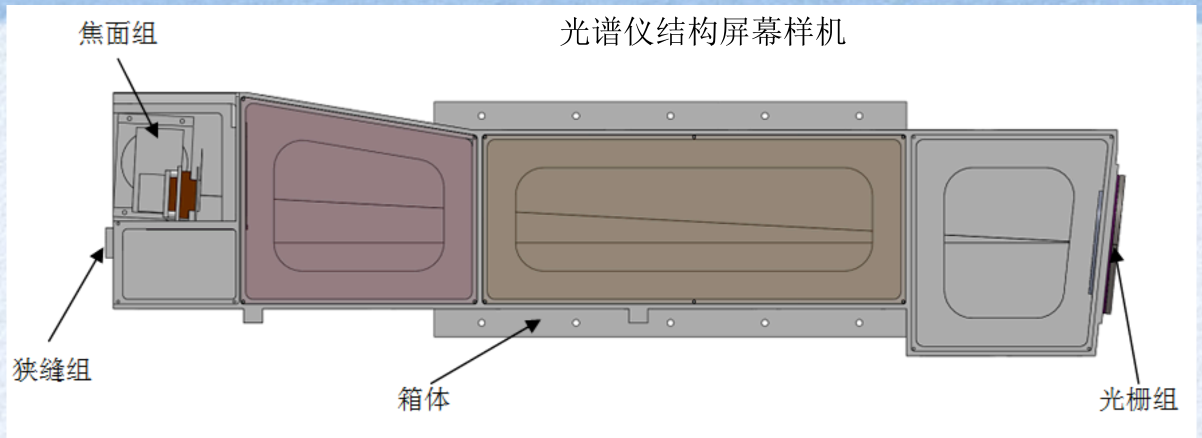
—**Universities:** USTC、NJU、XMU、Tsinghua Univ. ...

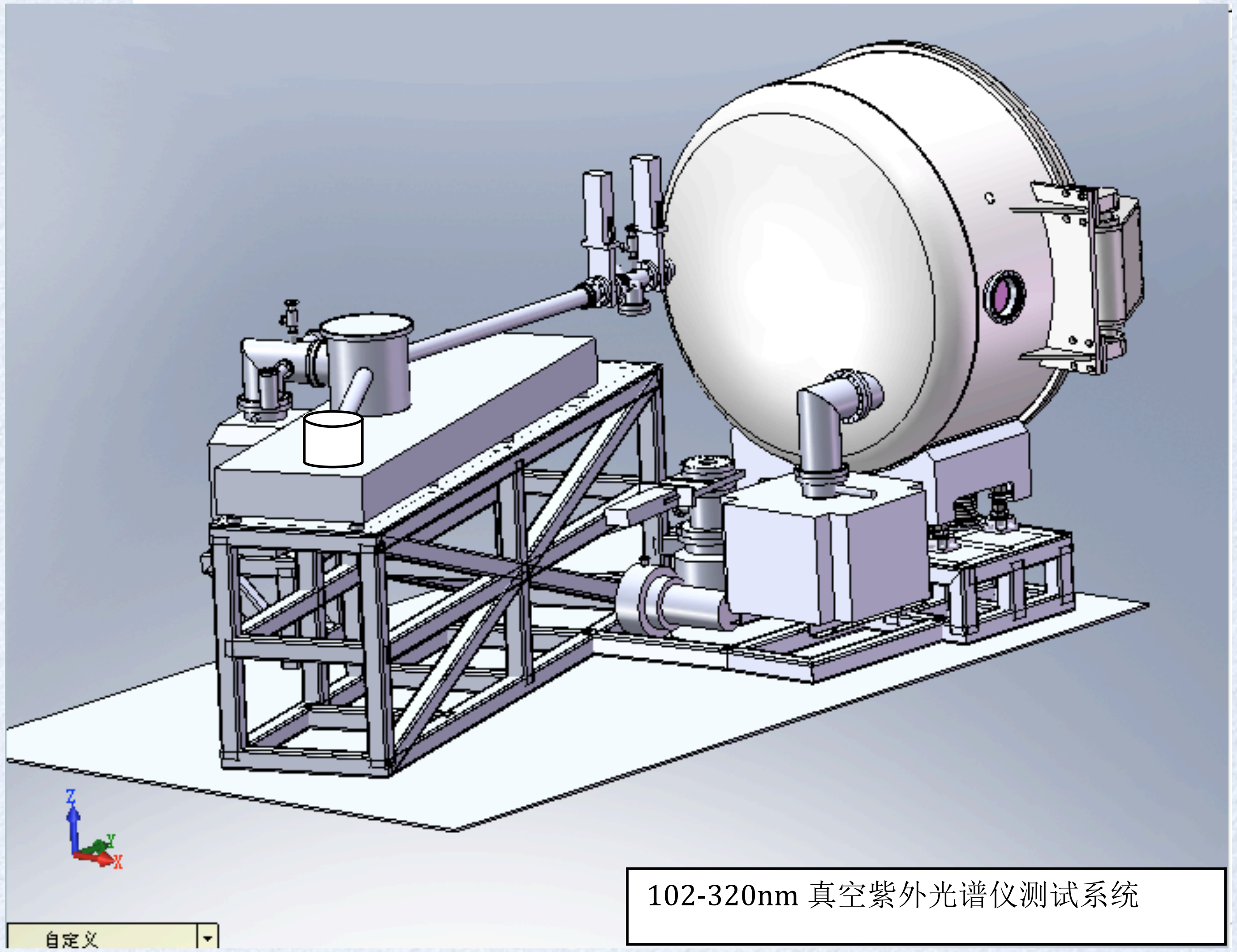
—**International Collaborations**

we anticipate collaborations from (e.g. University of Leicester, UK ; De Paris Observatory, France; Eberhard Karls University, Germany etc.)

What do we have in China







Long Slit Spectrograph

102-320nm

$$\lambda/\Delta\lambda = R \sim 1000 - 2000$$

credit: Sen Wang

Long Slit Spectrograph- Prototype

LSS Lab (NAO PI Sen Wang)

NUV (160-205nm, 205-315 nm)

FUV (102-115nm, 115-160nm)

for NUV 205-315 nm 0.14nm, 1”

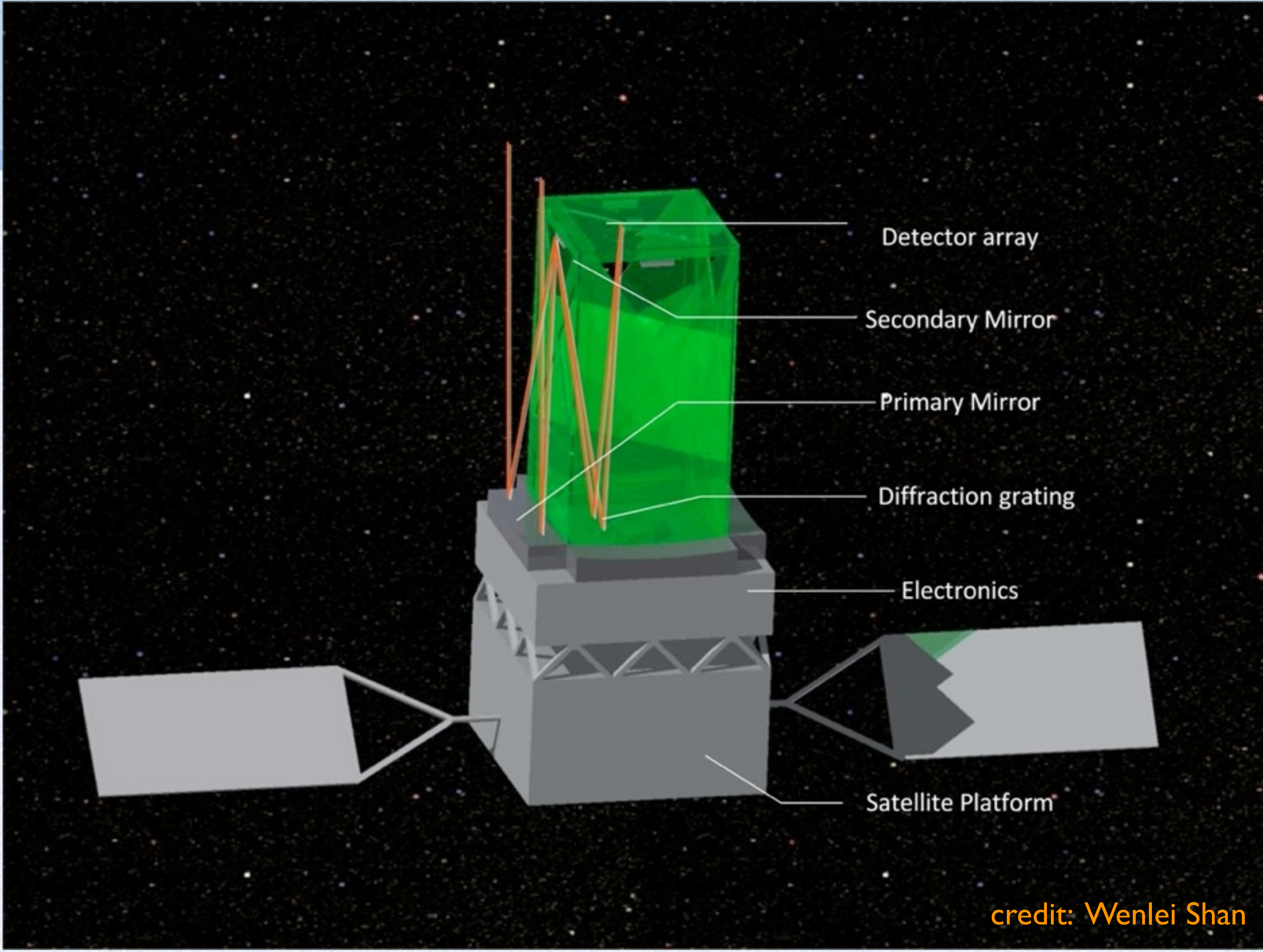
credit: Sen Wang

Mission Concepts

CAS space projects: Conceptual Study Projects Since 2013

Telescope: 500mm x 50mm
Detector: Narrow band imagers (OVI imagers & HI Lyα imagers)
FOV: 20' x 20'
Angular resolution: at least 30"x 30"
Spectra resolution: at least $\lambda/\Delta\lambda = R \sim 500$

Orbit: ~ 500km, circular orbit, low inclination < 5°
Signal: 500 PU (IGM)
Lifetime: 2 yrs Survey
Targets: ~ hundreds of nearby galaxies preselected (given z <0.05)



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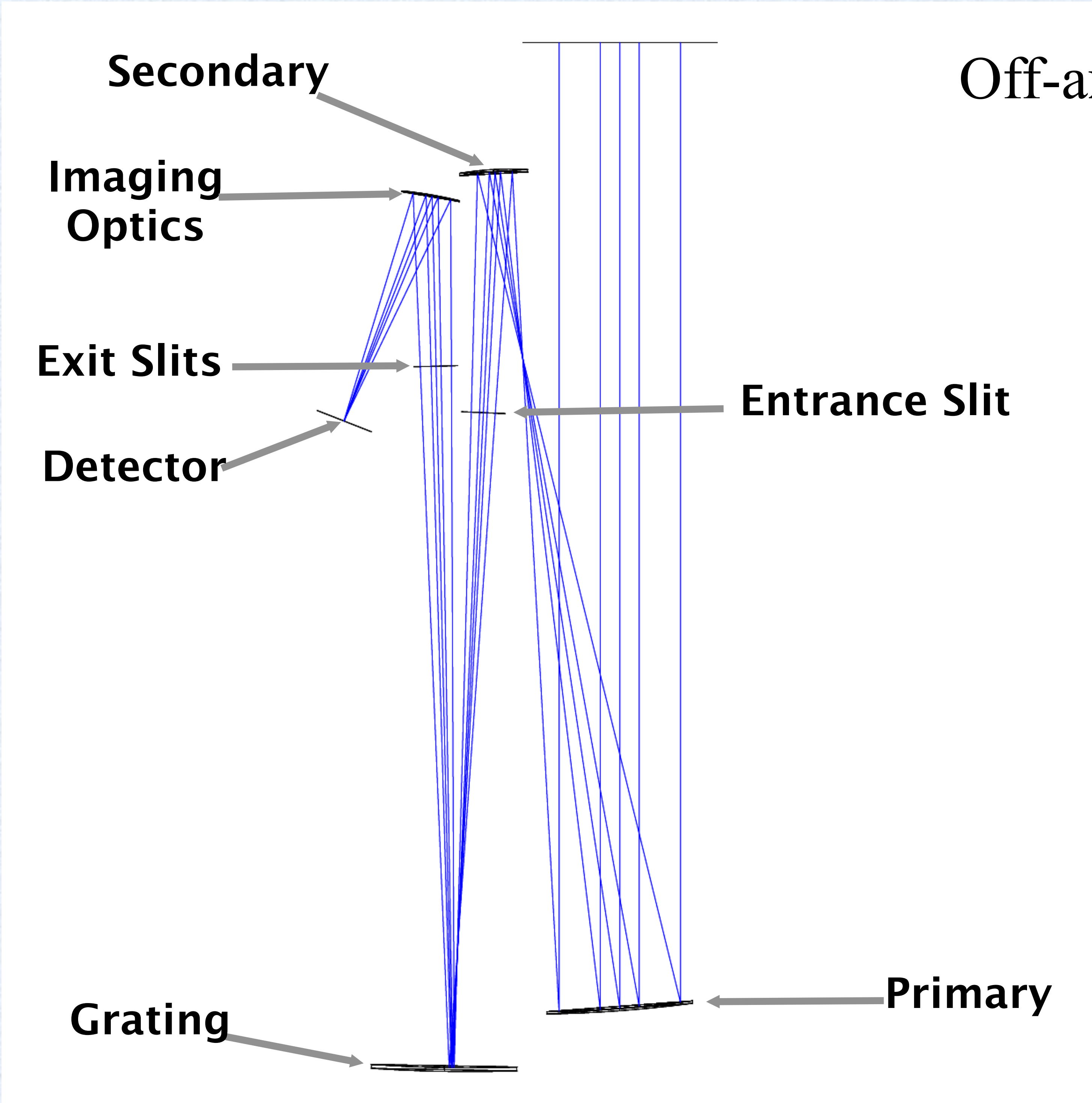
Instruments: Telescopes

Off-axis aplanatic Gregorian Systems



credit: Zheng Lou

Instruments: MCP Detector

Photon-counting microchannel plate (MCP) detectors

Resolution: > 150 micron
Size: 40 x 20 mm
Format: 1024 x 512 pixel
Maximum count rates: > 5000 c/s
Opaque CsI photocathodes

similar to the ROSETTA/ALICE detectors (Stern et al. 2007)

MCP Detector Development at Tübingen University Germany

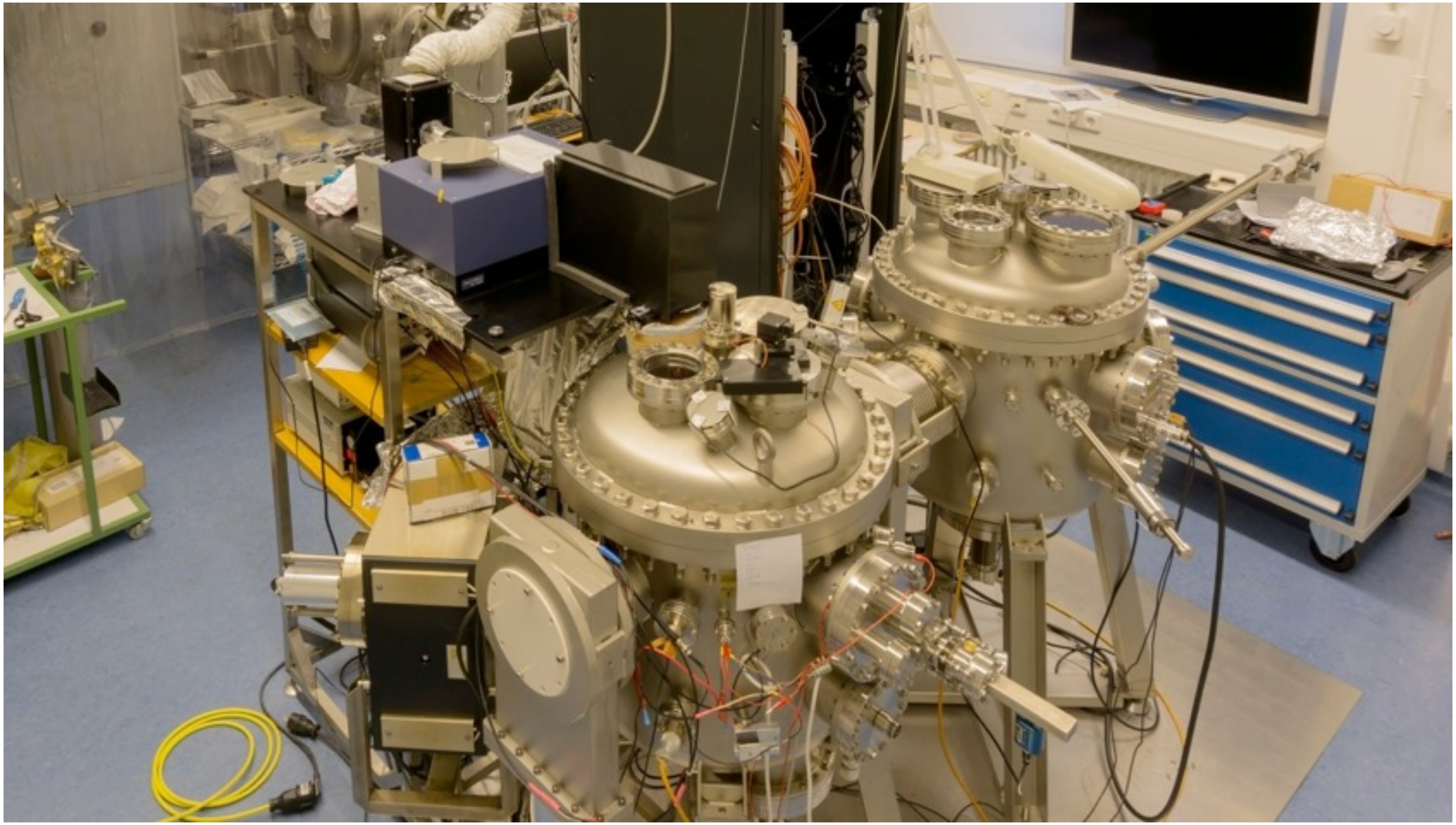
Heritage from Previous UV Missions

1993+1996 ORFEUS on the ORFEUS-SPAS freeflying platform

ORFEUS FUV Microchannel Plate (MCP) detector

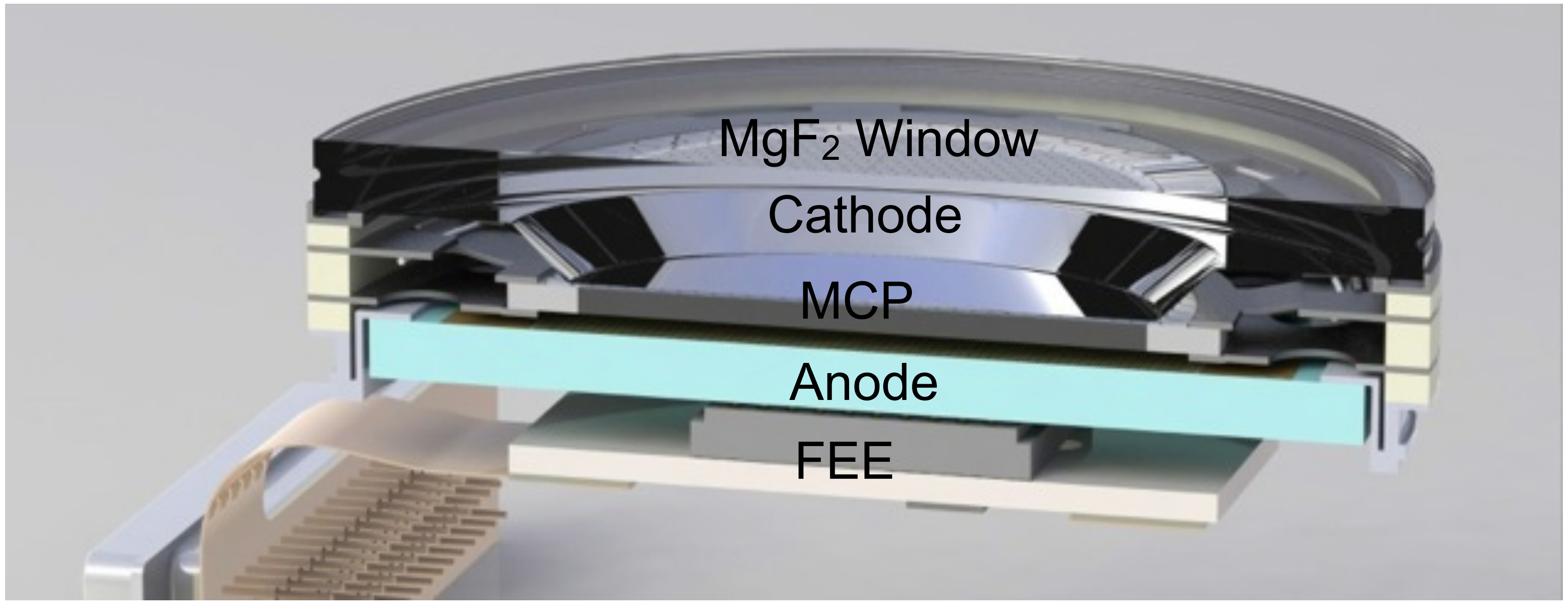
Open detector with vacuum shutter
Opaque KBr photocathode
Wedge-and-strip anode
45x45 μm^2 pixel size
9.5 Kg weight w/o HV

Ultra-high Vacuum Production Facility

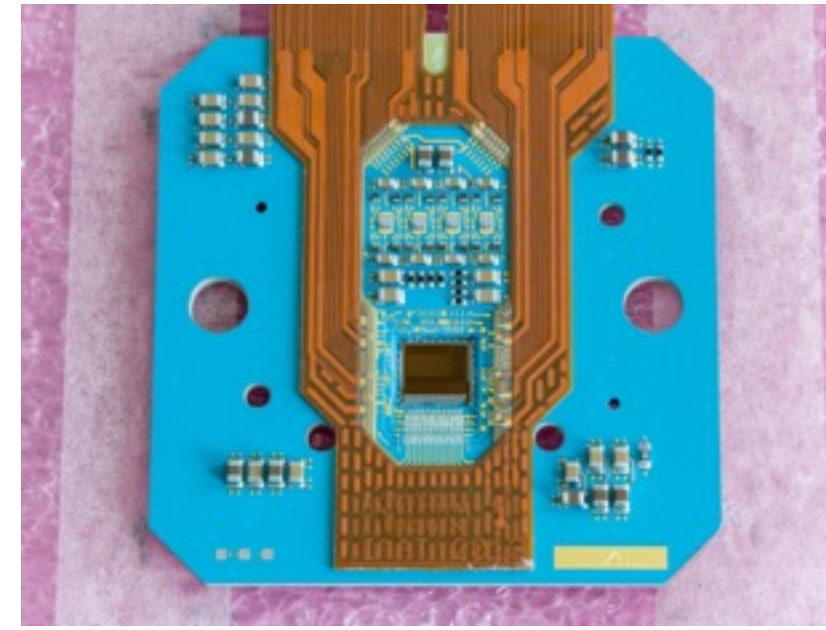


Photocathode vessel:
production, activation and characterization of photocathodes

Detector vessel:
bake-out and sealing of detector tubes

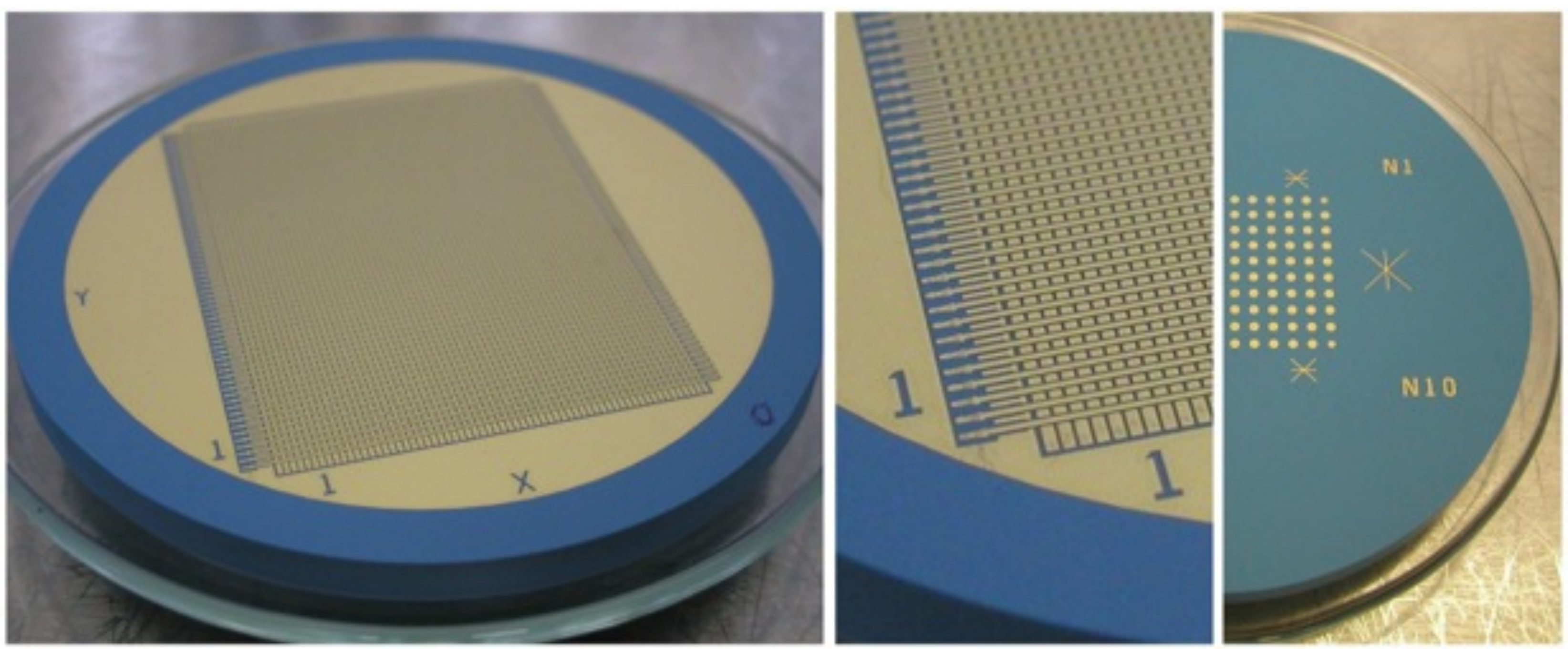


- Photocathode on the inner side of the MgF_2 entrance window
- Cross-strip anode on a hermetic ceramics backplate
- Hybrid-PCB for signal pre-amplification and serialization

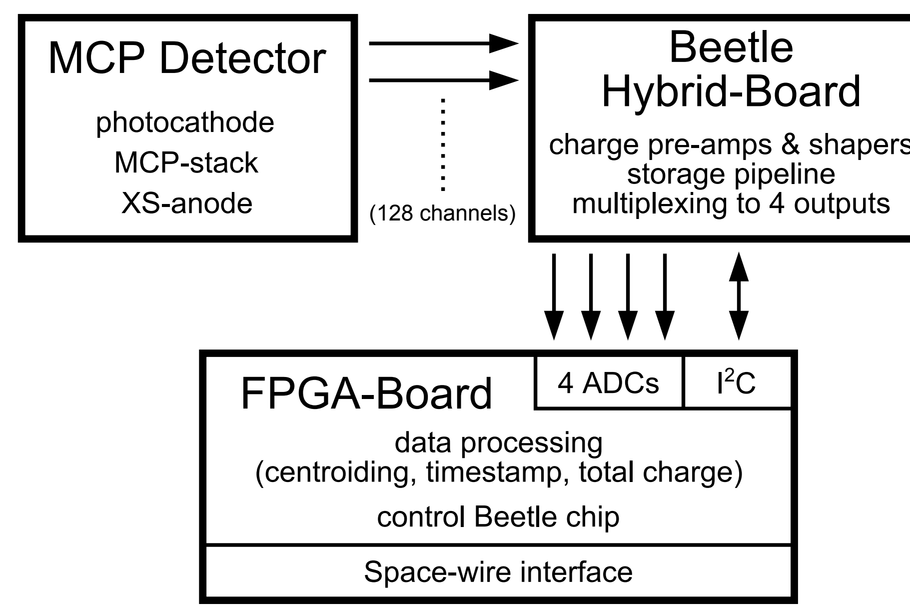


Fully equipped *Beetle* hybrid board

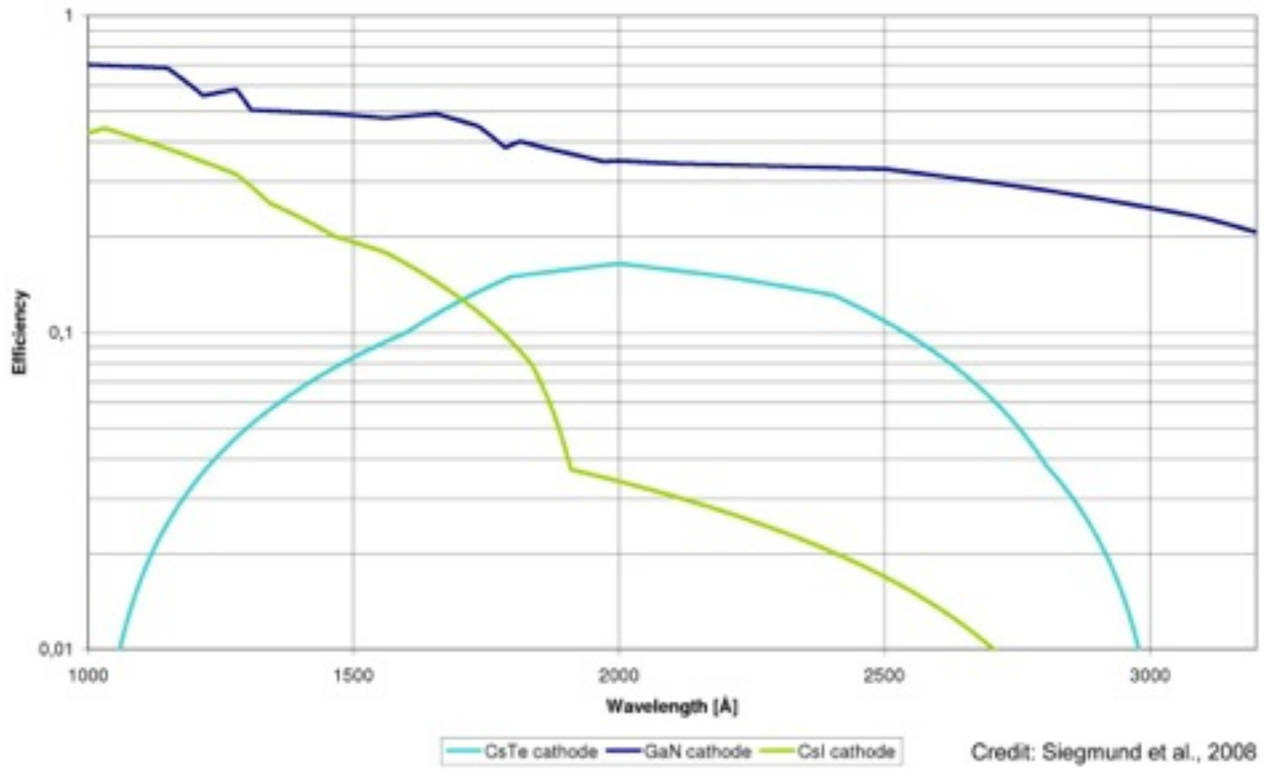
Beetle: specific readout chip to handle 128 charge signals



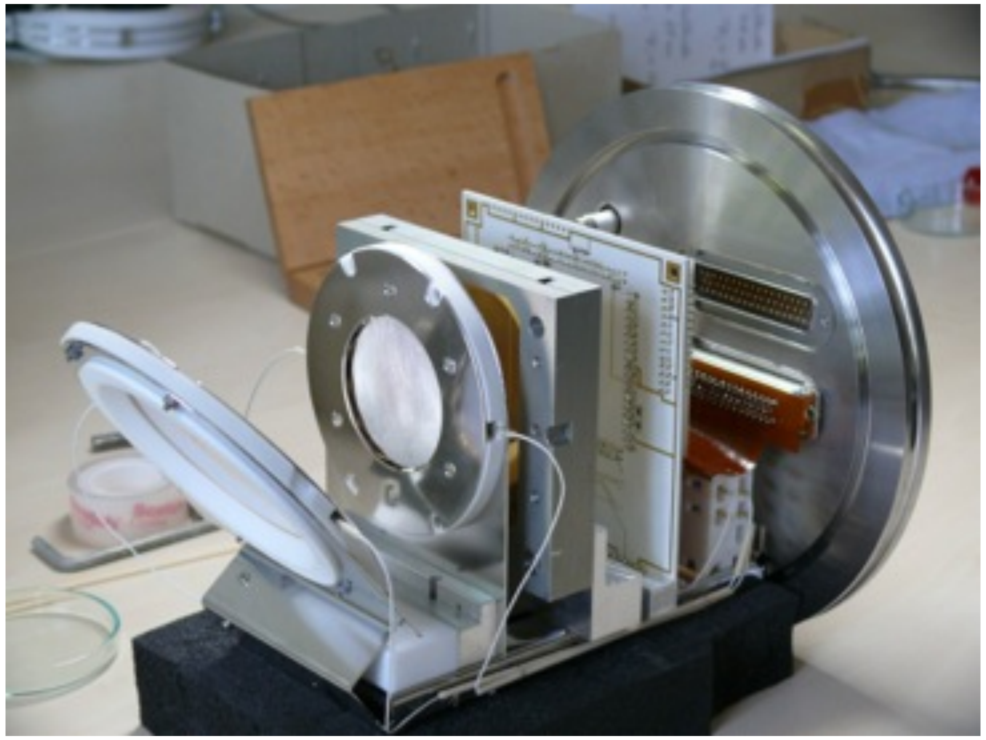
- Cross-strip anode on hermetic ceramics backplate
- 64 horizontal + 64 vertical strips, 44x33 mm^2 sensitive area
- 2048x2048 electronic pixel ⟶ 20x15 μm^2 pixel size



Detector readout concept



CsTe and CsI are meanwhile well-established materials
Repeatable production of highly efficient GaN is continuing
(thickness, doping, poly-/monocrystalline...



MCP burn-in setup

- Photon counting with high time resolution (300000 counts/s)
- Low weight < 3.5 Kg with HV
- Low power consumption < 10 Watt (incl. HV)
- Bandwidth adjustable via photocathode material
- Intrinsically solar blind
- Low Gain -> increased detector lifetime

Mission Summary

- **Science:** Unique experiment on a key forefront topic
- **Launch Vehicle:** Long March 2C/2D or VEGA
- **Spacecraft bus:** Chinese or European (e.g. German TET-1)
- **Science Orbit:** LEO, above 500 km; on-orbit calibration
- **Flight system:** 2yr baseline mission, mass <60 kg, power ~60w
- **Low cost & high heritage**

Team Members

— Science

T. Wang, F. Cheng (USTC) ; Y. Gao, L. Ji, S. Zhang (PMO)
Q. Wang, Q. Gu, Z. Li, B. Jiang (NJU); T. Fang (XMU)
M. Huang, J. Liu (NAO), F. Tian (Tsinghua Univ.); R. de Grijs (KIAA)
M.A. Barstow (England); F. Nicastro (Italy);
R.Lallement (France); P. Richter (Germany);

— Simulations

L. Feng, S. Lei, S. Zhang, X., Zhou (PMO); T.Fang (XMU)

— Optics design

S. Wang (NAO), J. Cheng, Z. Lou (PMO), P. Ruan (XIOPM)

— Detector design

W. Shan (PMO), Z. Wu (NUST), Q. Song (NAO), M. Cai (PMO)
K. Werner, N. Kappelmann (Germany); **M. A. Barstow** (England)

— Electronic System

M. Cai, J. Guo, J. Chang (PMO)

UV Emission Mapping of IGM & Nearby Galaxies

First look at accretion, feedback & WHIM

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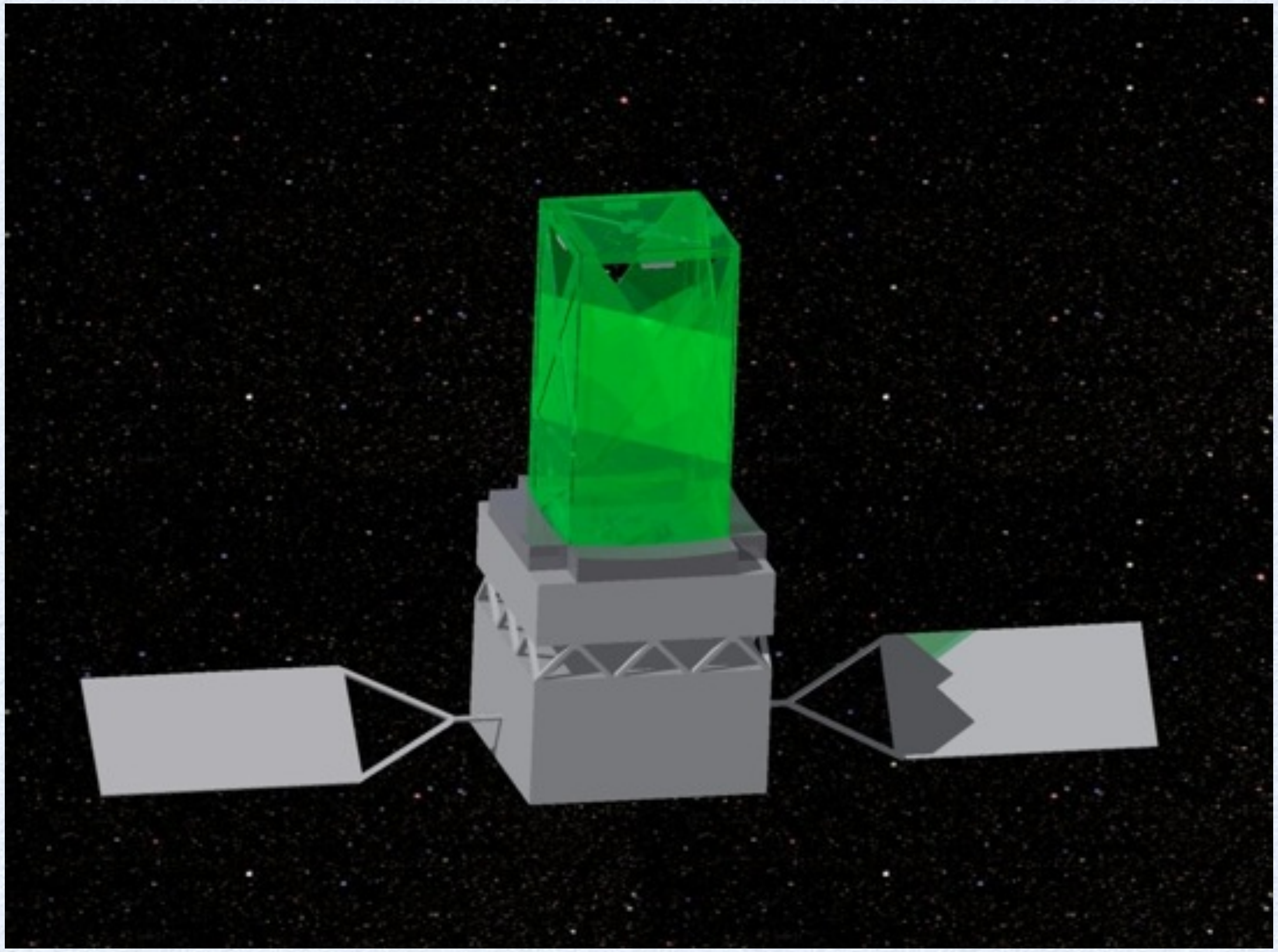

Welcome you to join us !

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