

# FUSE: (THE FAR ULTRAVIOLET SPECTROSCOPIC EXPLORER)

## OVERVIEW & EARLY HISTORY

**Warren Moos**  
**Dennis McCarthy**  
**Jeff Kruk**

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# OUTLINE

- **Overview of the FUSE Mission**
- **History: 1980-1995 up to Phase C/D**

## TO BE FOLLOWED BY:

- **Dennis McCarthy – Phases C/D**
- **Jeff Kruk – On- orbit operations**

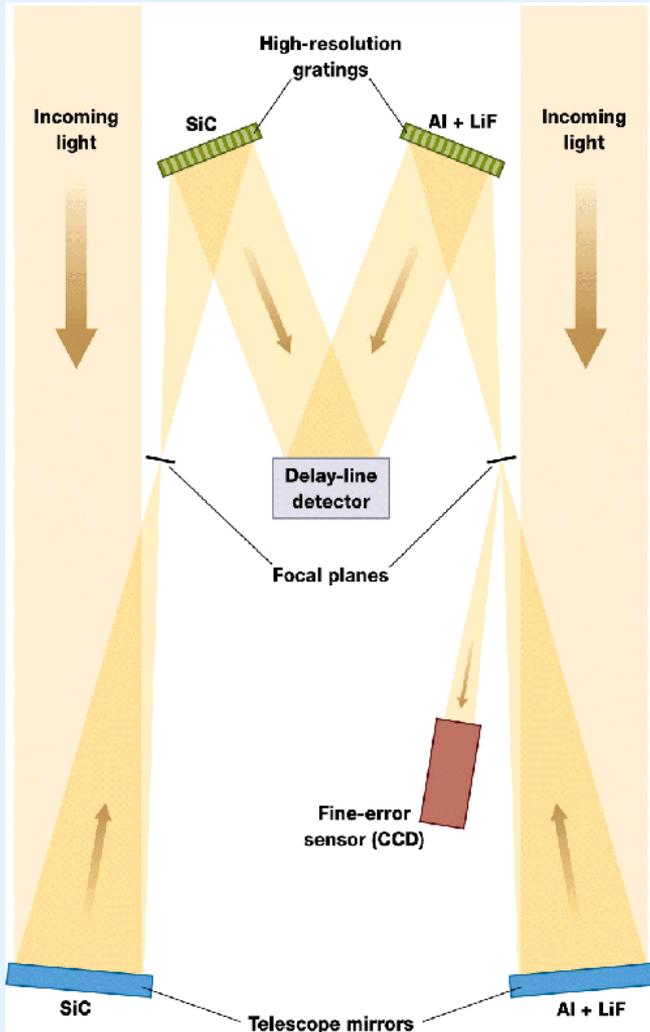


# FUSE Mission Overview



- NASA mission with Canadian (CSA) and French (CNES) participation.
- $FUV \equiv 905\text{-}1187 \text{ \AA}$ ,  $R \sim 15 \text{ km s}^{-1}$ ,  $A_{\text{eff}}(\text{peak}) \sim 50 \text{ cm}^2$ .
  - Complements *HST-STIS* capabilities.
- FUSE Launched June 24, 1999.
  - 765 km circular orbit,  $\text{incl}=25^\circ$
  - Science operations ended July 12, 2007
  - Decommissioned Oct 18, 2007.
  - 65 Ms of on-target science time obtained.
- Since 1994, Developed and Operated as a PI Class Mission led by the Johns Hopkins University.
  - About half of science time to PI Science Team thru March 31, 2003.
  - Vigorous NASA-selected Guest Investigator Program
    - Oversubscribed by factor  $> 3$ .

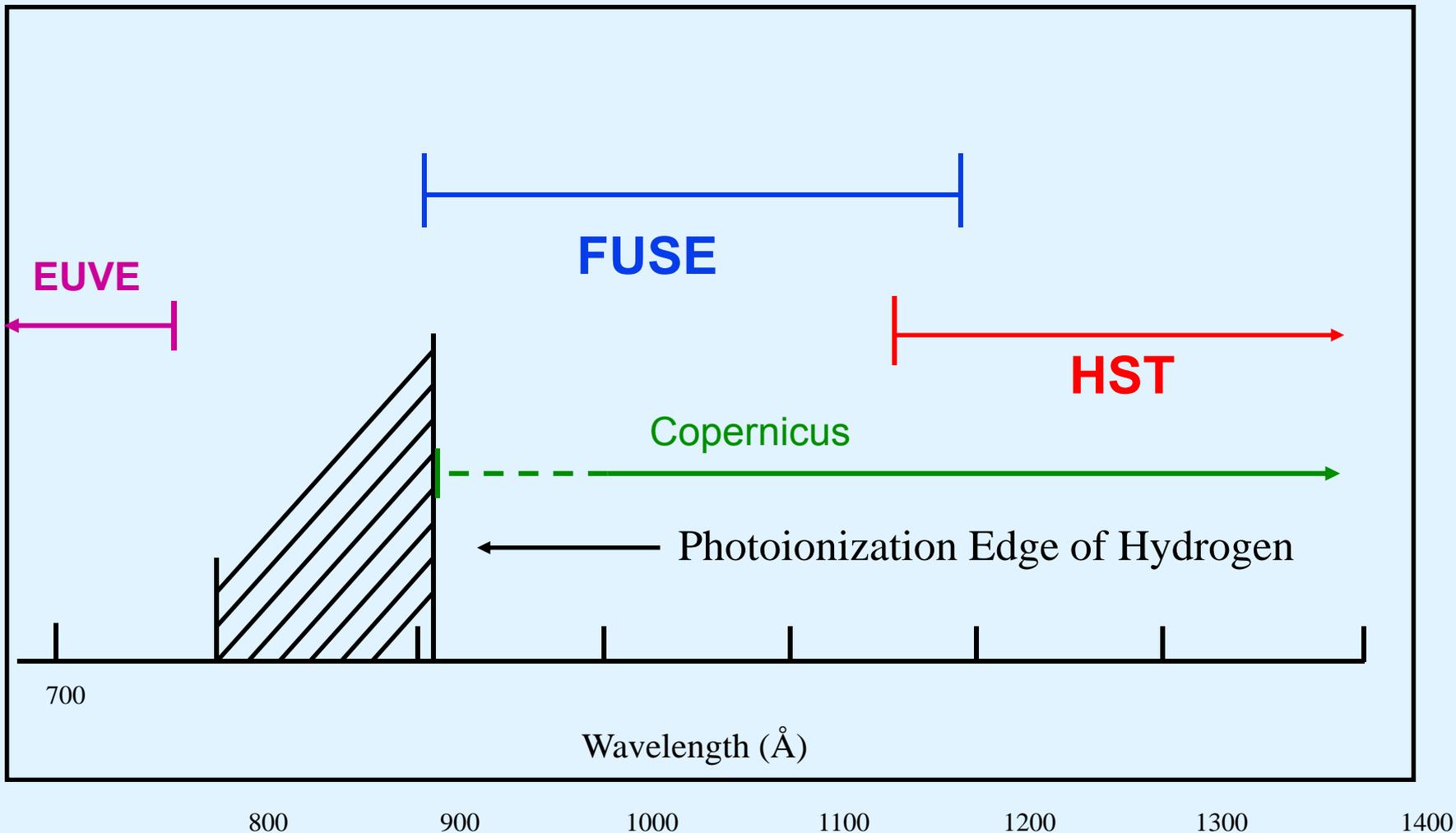
# FUSE Satellite and Instrument



- Overall: 3000 lbs (1330 kg), 18 feet (5.4 m) tall
- 4-channel optical design
- Coatings optimized for far-UV
- ~ 1 arcsec pointing
- ~ 1.5 MIDEX



# BRIDGING THE GAP



**FUSE Complements STIS & COS on *HST*.**

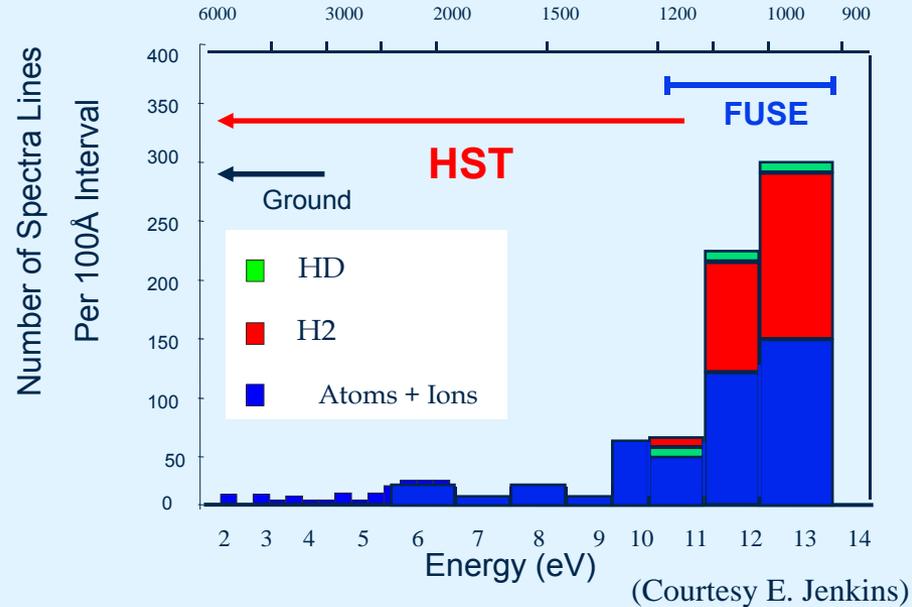


# WHY THIS SPECTRAL REGION?

Rich in astrophysically important transitions.  
Unique Access to: **All H & D Lyman transitions except Ly  $\alpha$ .** **O VI  $\lambda\lambda$  1032, 1038.** **Strong absorption transitions of H<sub>2</sub> & HD.**

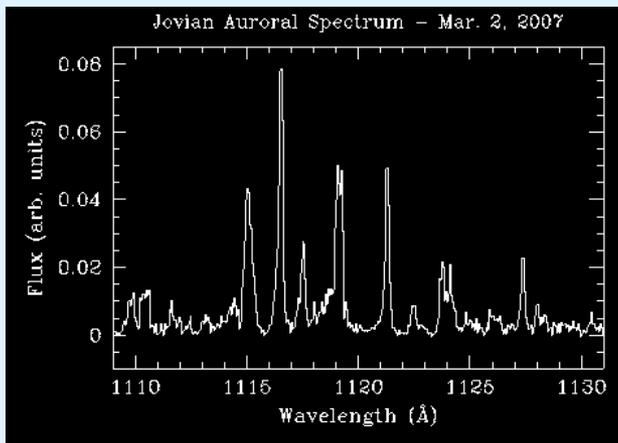
**Low/intermediate Plasma Diagnostics (T<sub>e</sub> & ionization) (C I-III, N I-III, Ar I, Fe II-III, ...)**

**Red shifted EUV lines: e.g. He II  $\lambda$  304 (z<sub>min</sub>=2).**



# FUSE Addressed Many Different Problems

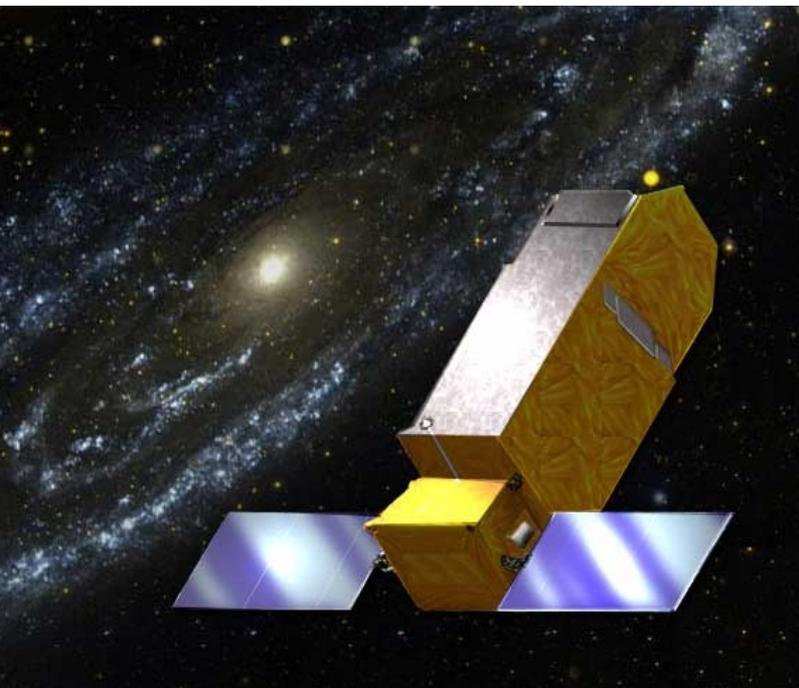
- What is the Abundance of Deuterium in the Galaxy and Does Chemistry Play a Role?
- What Fraction of the Baryons in the Nearby Universe are Hidden as Hot Plasma?
- Does our Galaxy have an Extended Halo of Hot Plasma?
- What is the interaction Between a Protoplanetary Disc and its Central Star?
- And Many Many More: Planets, Stars, Galaxies, Quasars ...



**Jupiter observation  
in support of New  
Horizons flyby.**

# Mission Science Summary

- Executed 694 observing programs covering broad scientific range.
  - 106 PI programs, 557 GI Programs and 29 Discretionary and other.
- 5700 Observations on ~2850 unique objects.
  - 42,000 individual data sets (spectra) available through MAST at STScI
- 65 Msec of on-target Observing Time.
  - 13 Msec PI selected objects, 33.7 Msec GI objects, 0.8 Msec Discretionary objects and 17.5 Msec supplementary objects



- Publications continue in a steady stream. (Statistics through March 2008)
  - Scientific/peer review: 450
    - ~ 5 per month
  - Instrument/Technical 44
  - Conference Proc/Other: 771
  - Total: 1265
- FUSE technology  $\Rightarrow$  COS on *HST*

# THE EARLY YEARS: 1980-95

- Copernicus Mission 1972-1981. Limited to  $\sim 1$  kpc.
- Decadal Survey 1980-1 (Field Report)
- FUSE Science Working Group Final Report 1983
  - Grazing incidence telescope.
- Extensive Discussions. NASA – ESA thru 11/1988
  - Australia, Canada, France, UK...
- Explorer proposal 1986. (Challenger accident)
  - Competitive Phase A 1988-9 of 4 missions
    - Spacecraft (ELV) or reusable Explorer Platform (STS)
    - ESA Phase A. 11/88 decision ouch! → Explorer Platform
- 7/89 FUSE survives 50 % down selection, enters Phase B.



# Phase B 1989 - 1996: From Explorer Platform to Expendable Launch Vehicle

- 1991 Decadal Study (J. Bahcall). Reaffirmed Field report. **Put FUSE on dedicated spacecraft with ELV.**
- **NASA, concerned with true cost of EP, opts for ELV.**
- **Canada (FES) and France (gratings) became partners.**
- **Major changes in technology.**
  - Grazing incidence telescope → Normal incidence with SiC coating
    - Technique invented 1988. Also required 4 barrel design – S. Conard.
  - Holographic gratings on simple spherical surfaces
    - ~1700 Å groove spacing across a 30 cm blank.
    - Responsibility of France.
  - Selection of large format microchannel detector.  $> 1 \times 10^8$  pix.
  - **Implementation possible because of budget driven schedule.**
- **High Earth Orbit baselined**
  - Claimed that would simplify operations
  - Low earth orbit thought to be complex/expensive – not true!



# CANCELLATION

- By summer '94, FUSE project looked ready to start Phase C/D in Oct '94.
- Ready to go – but...
  - NASA budget crunch stretched schedule out even further.
  - Schedule and other considerations ballooned costs.
  - At NASA the mantra became “Increase launch frequency” & “Faster better cheaper.”
  - “Large Delta class” Explorer missions – i.e. FUSE, appeared to block the way.
- On 9/6/94, the day after Labor Day. NASA Hdqts informed Warren Moos (PI) and Dennis McCarthy (PM) that FUSE was cancelled.
- Negotiations began.
  - NASA wanted to preserve science – but budget crunch.
  - John Bahcall ( and others) played important roles.
  - Talked to all the players – while keeping the community damped down.



# Restructuring FUSE

- Meeting of(9/9/94), Wes Huntress, NASA AA for Space Science with JHU (Dennis McCarthy, Mark Perry, Warren Moos).
  - JHU was directed to prepare proposal for \$100M mission retaining the essential science. (In the end, it was accomplished for ~\$120M).
  - PI would assume control of all segments of mission
  - NASA was responsible for the launch
  - Proposal for C/D due in January '95, four months later.
- An “intense” four months followed.
  - Core spectrographs retained. “Nice but not crucial” tossed.
  - Low earth orbit instead of high earth orbit. JHU showed (with STScI help) that it need not be overly complex.
- Phase C/D began 11/25/95.
- FUSE launched 11:44 AM EDT June 24, 1999.

Dennis McCarthy



# Backup



## FUSE Science Team Participants and Roles Starting with Phase A

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CoI

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CoI

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