

First Results from the
Multi-Order Solar EUV
Spectrograph (MOSES)
Sounding Rocket

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Acknowledgments



The success of *MOSES* owes much to:

- Roger Thomas and collaborators at GSFC (optical design, optical and EUV testing, multilayers)
- A 3-CCD version of the EIS camera supplied by MSSL
- Marilyn Bruner's flying optical table, developed for SPDE—as well as her sage advice.
- Funding: NASA LCAS
- SPARCS team at WSMR

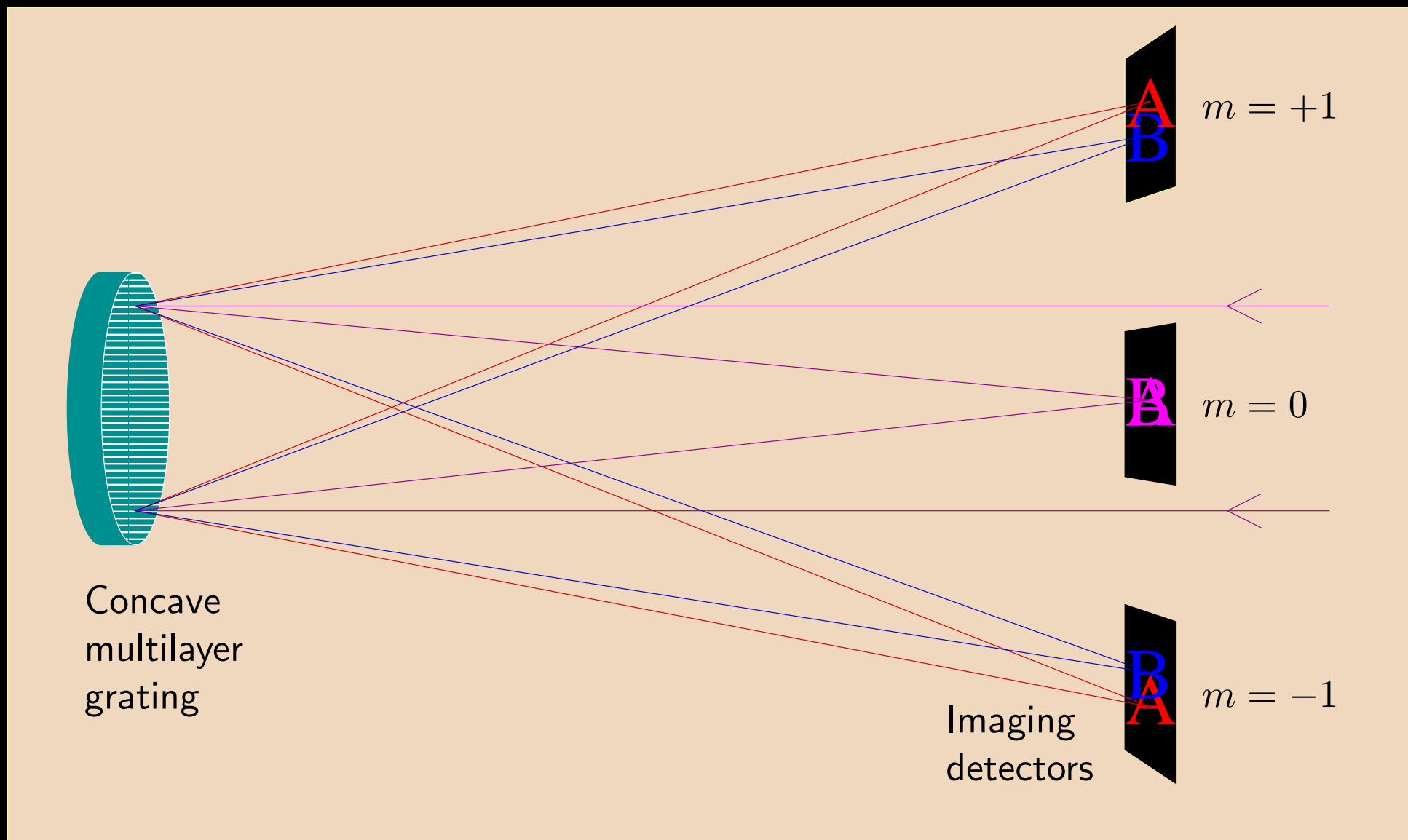


Simultaneous imaging and spectroscopy in EUV

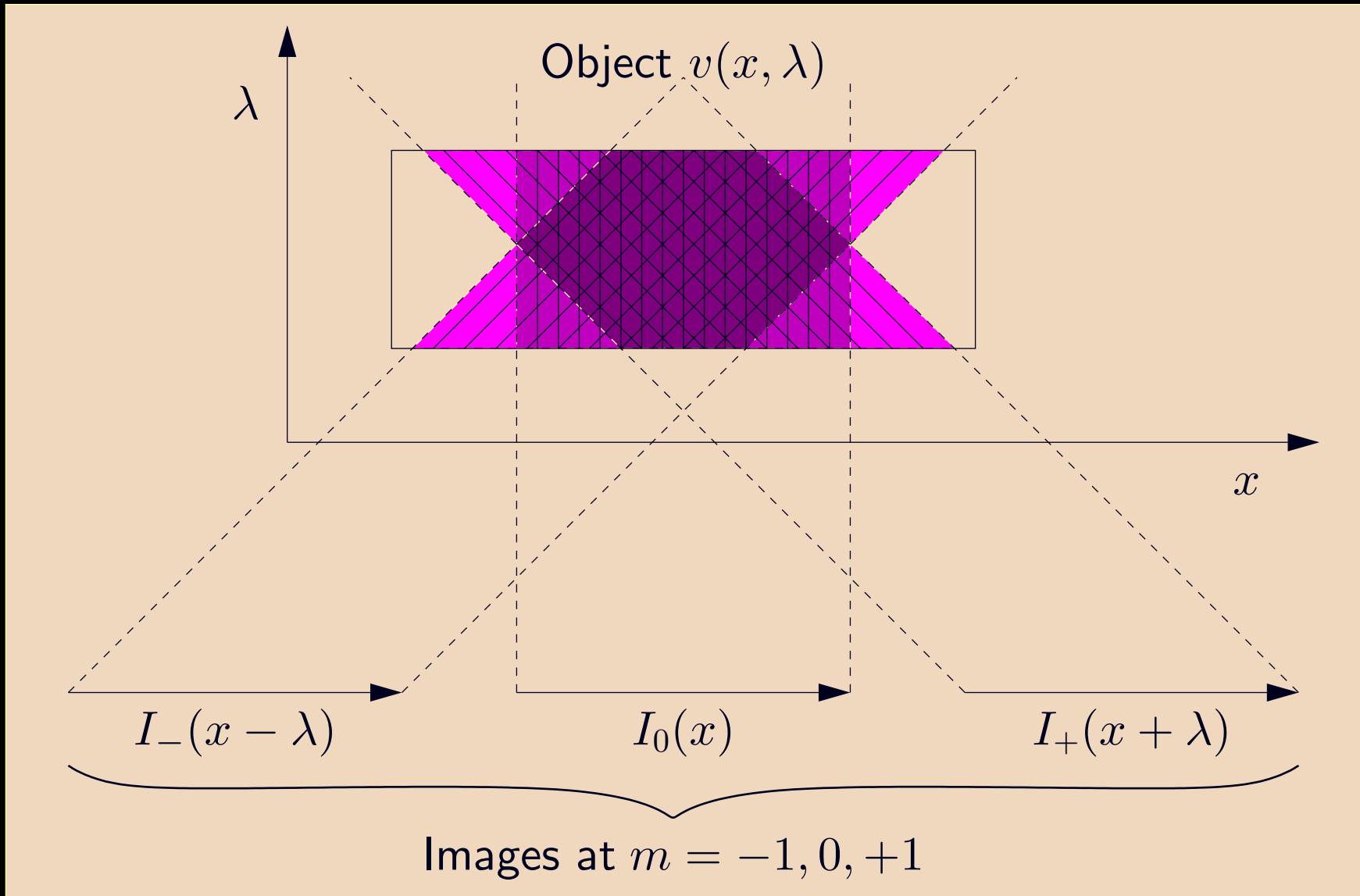


- Many imaging spectroscopy methods (FP filters, FT spectrometer) don't apply in EUV and SXR.
- Multilayer telescopes (MOSES, NIXT, EIT, TRACE) are pure imagers with **several lines** in the passband.
- Slit spectrometers (SERTS, CDS, SUMER, EUNIS) build up a field of view slowly by **rastering**.
- The Skylab slitless spectrograph (SO82A) data had many **overlapping** line images.

Concept

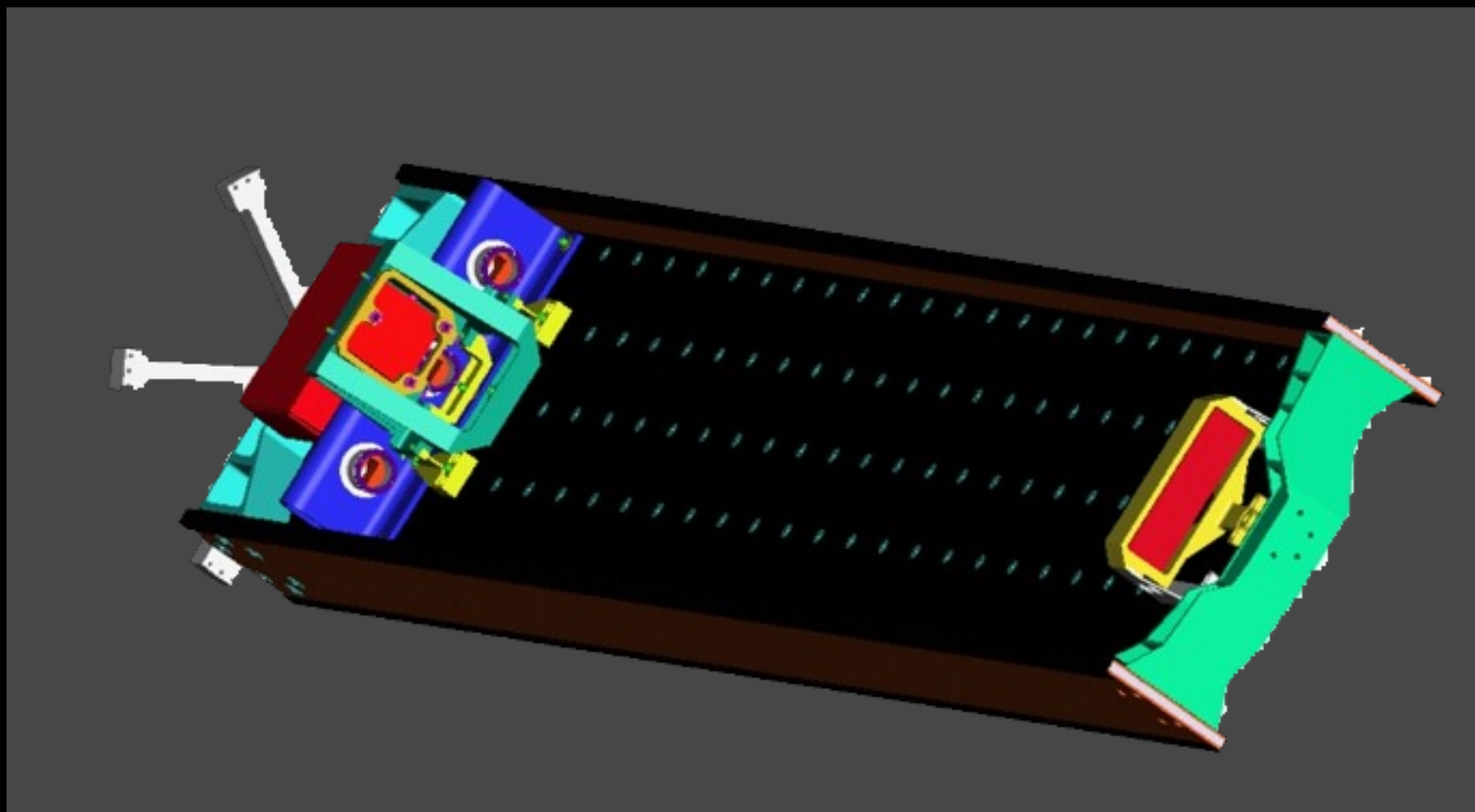


Hybrid space analogy





MOSES layout





MOSES Parameters



Optics: 8×8 cm spherical grating and flat mirror

Coatings: B_4C/Mg_2Si multilayer, $R \sim 0.4$

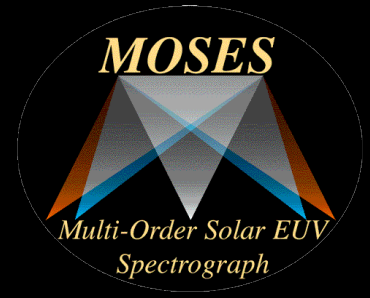
Lines: He II 303.8 Å, Si XI 303.3 Å

Detectors: three 2048×1024 , rear-illuminated
CCDs at $m = -1, 0, +1$

Pixel size: $0.59''$, 29 mÅ , 29 km/s



Data analysis plan



1. Reduction

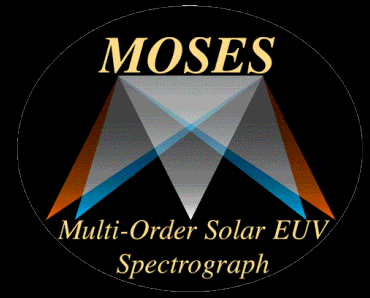
- (a) Dark subtraction, flat fields
- (b) **Coregistration** of $m = -1, 0, +1$ to 0.2 pixel (6 km/s)
- (c) Removal of drift

2. Scientific analysis

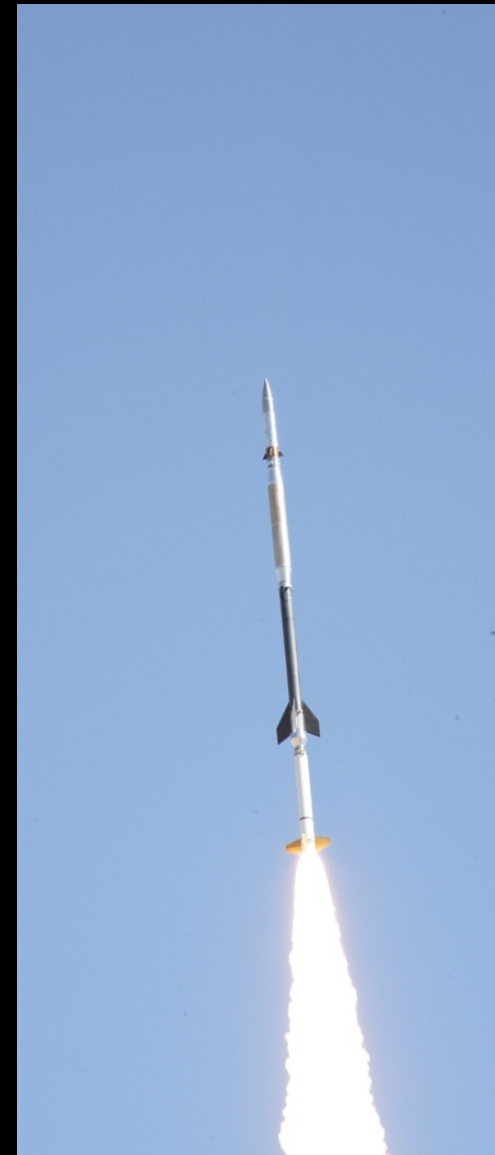
- (a) Low hanging fruit (**today's talk**)
 - i. Spectral signatures in **difference** between orders
 - ii. Centroid features; "**parallax**" \Rightarrow doppler shift
- (b) Inversions
 - i. Compensate for **PSF**, different in each order!
 - ii. Local and global inversions



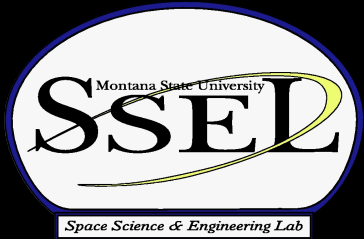
Launch 2006 Feb 8



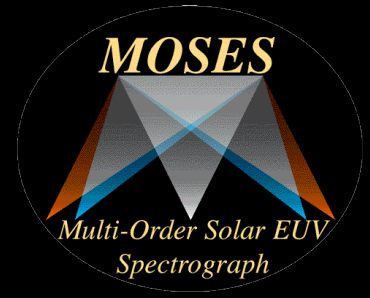
- Launch 2006 Feb 8, 18:44 UT
- ~ 5 minutes of observation above 160 km
- Apogee 260 km
- 27 science exposures, ~ 10 s cadence
- Recovered intact



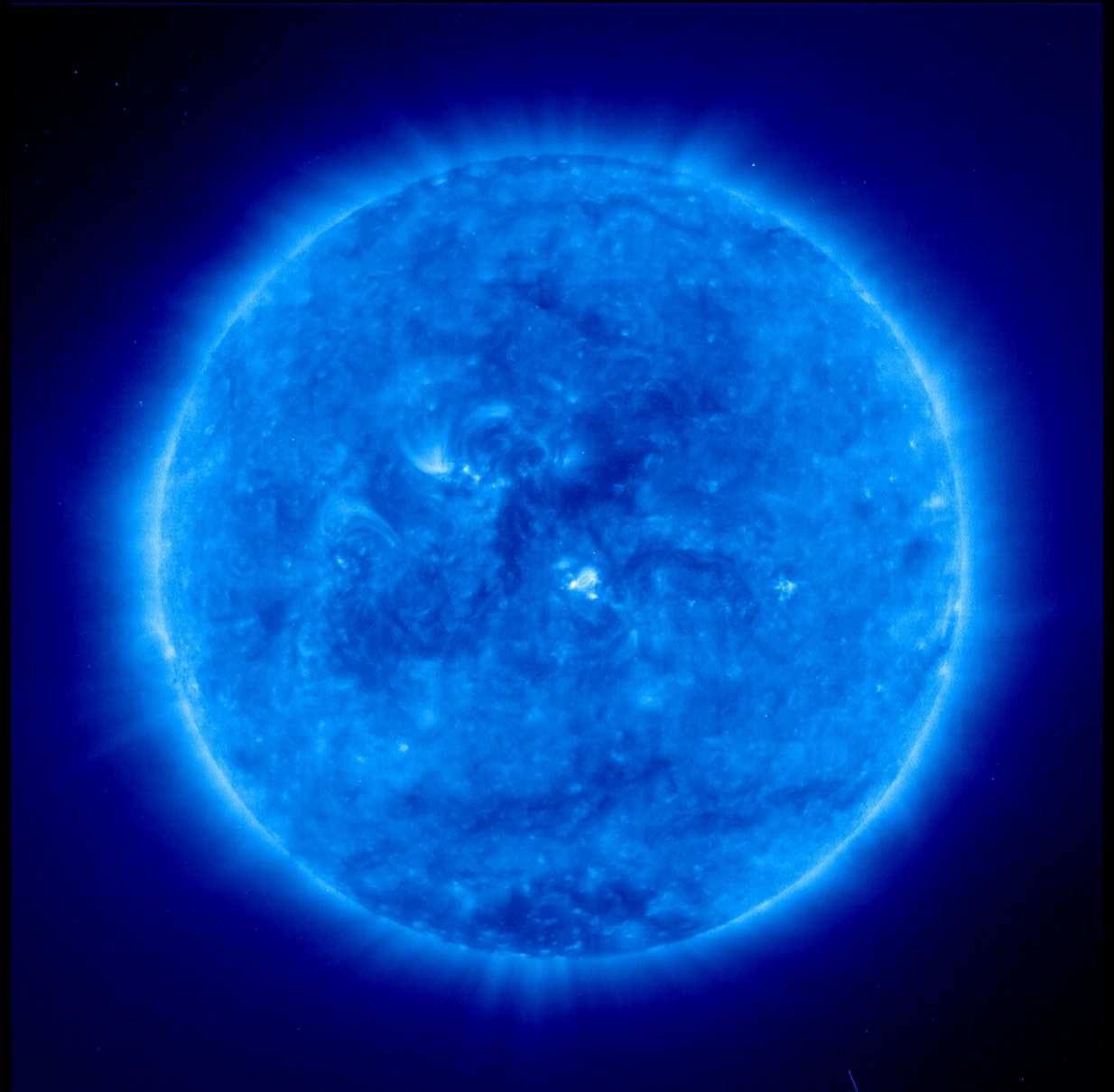
(GOES/SXI (movie credit: Sam Freeland))



Context—EIT 171 Å

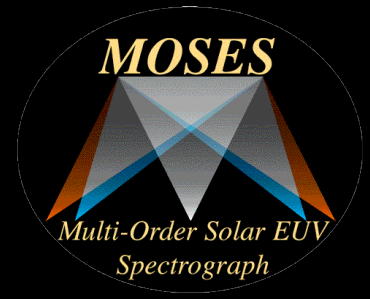


- “Wishbone” structure
- AR loops near disk center





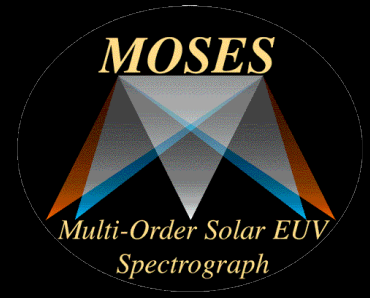
$m = 0$ images



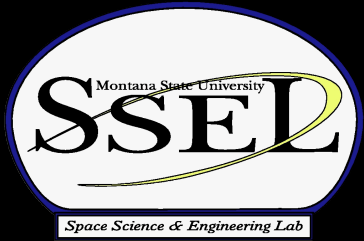
- 27 exposures (0.25 s – 24 s), 5 min. total, FOV $> 1R_{\odot}$
- Quiz: Where are the Doppler shifts?



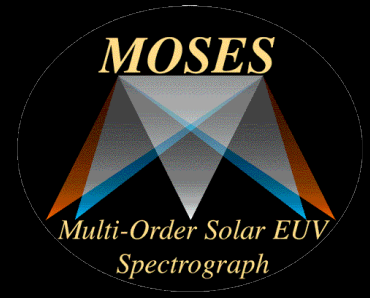
Difference movie: $I_+ - I_0$



- Saturated or missing pixels in orange
- Three features of interest
- Coronal features—“wishbone” (Si XI)

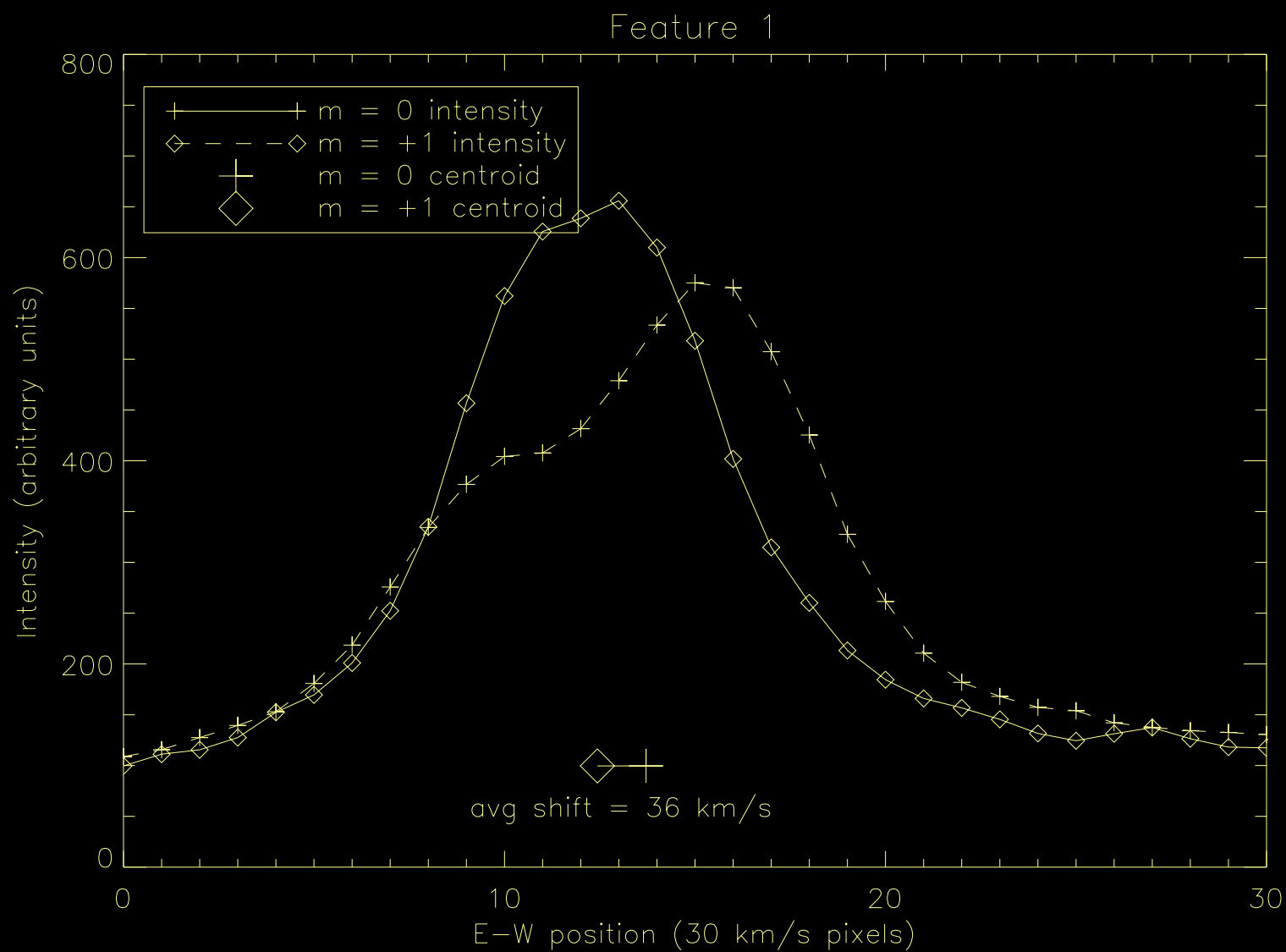


Feature 1



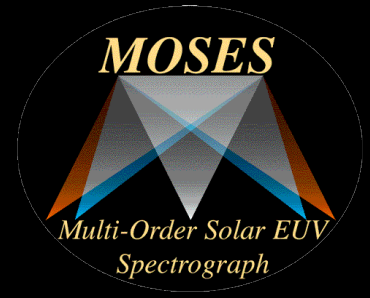
- 20'' grid
- Red shift
- Context of unshifted brighter features
- Loop flow?

Feature 1



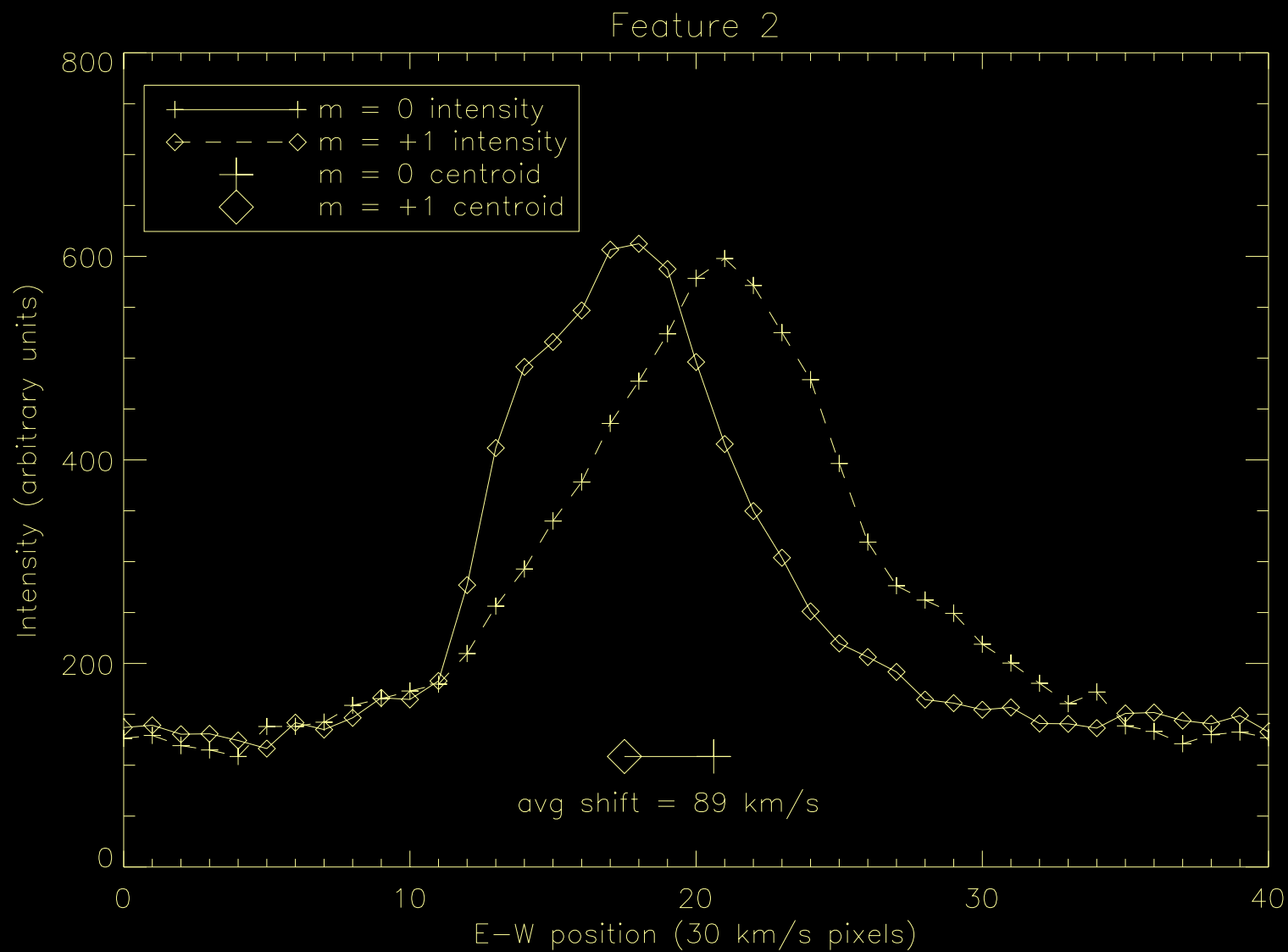


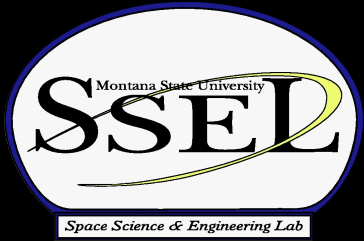
Feature 2



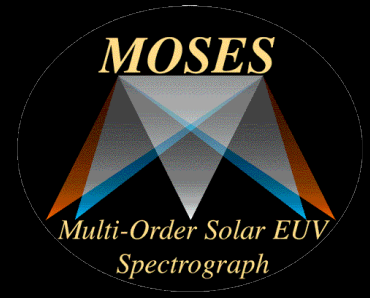
- Bifurcation into two lobes
- Red shift
- Again, surrounding features are unshifted.

Feature 2



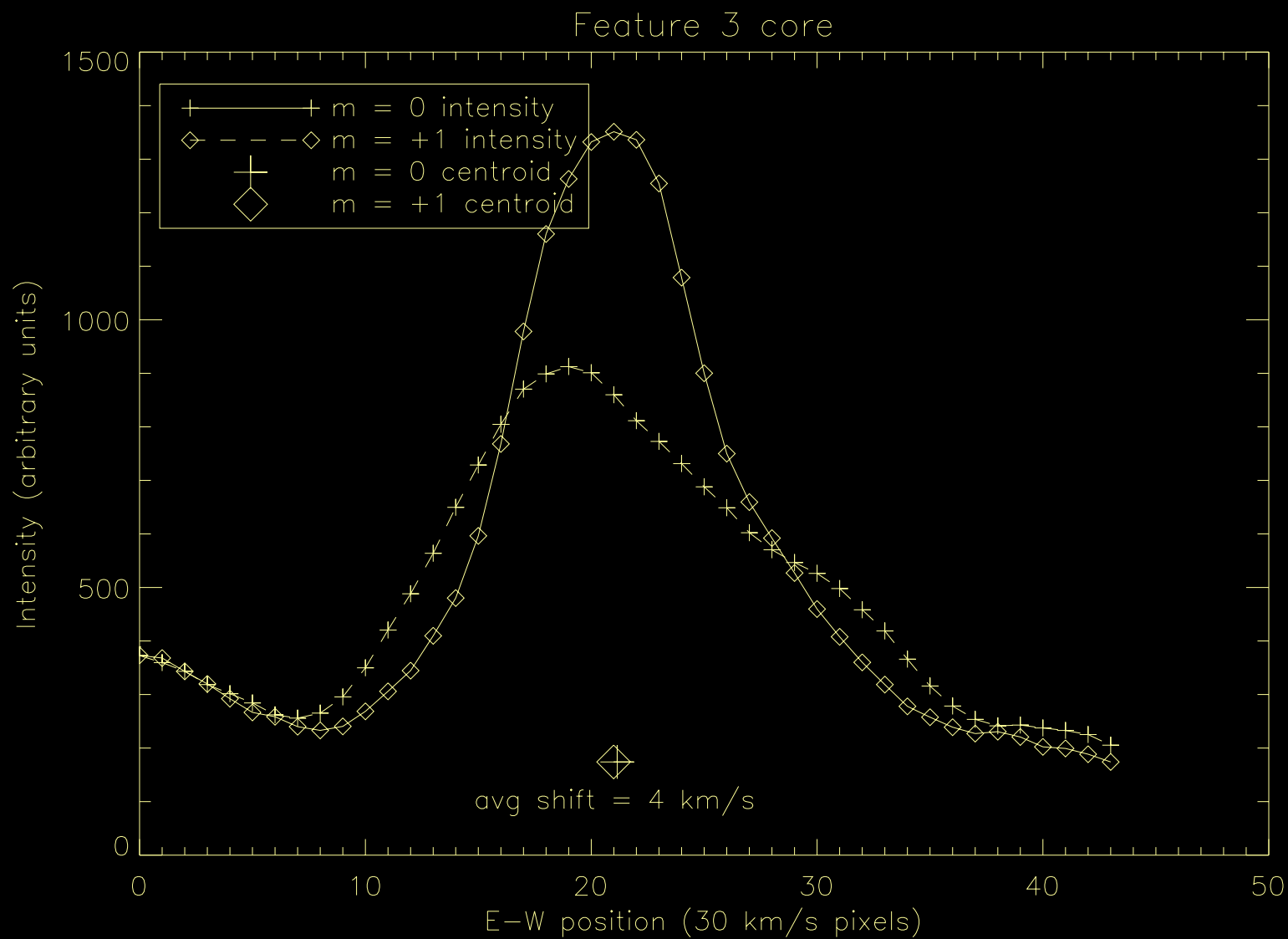


Feature 3

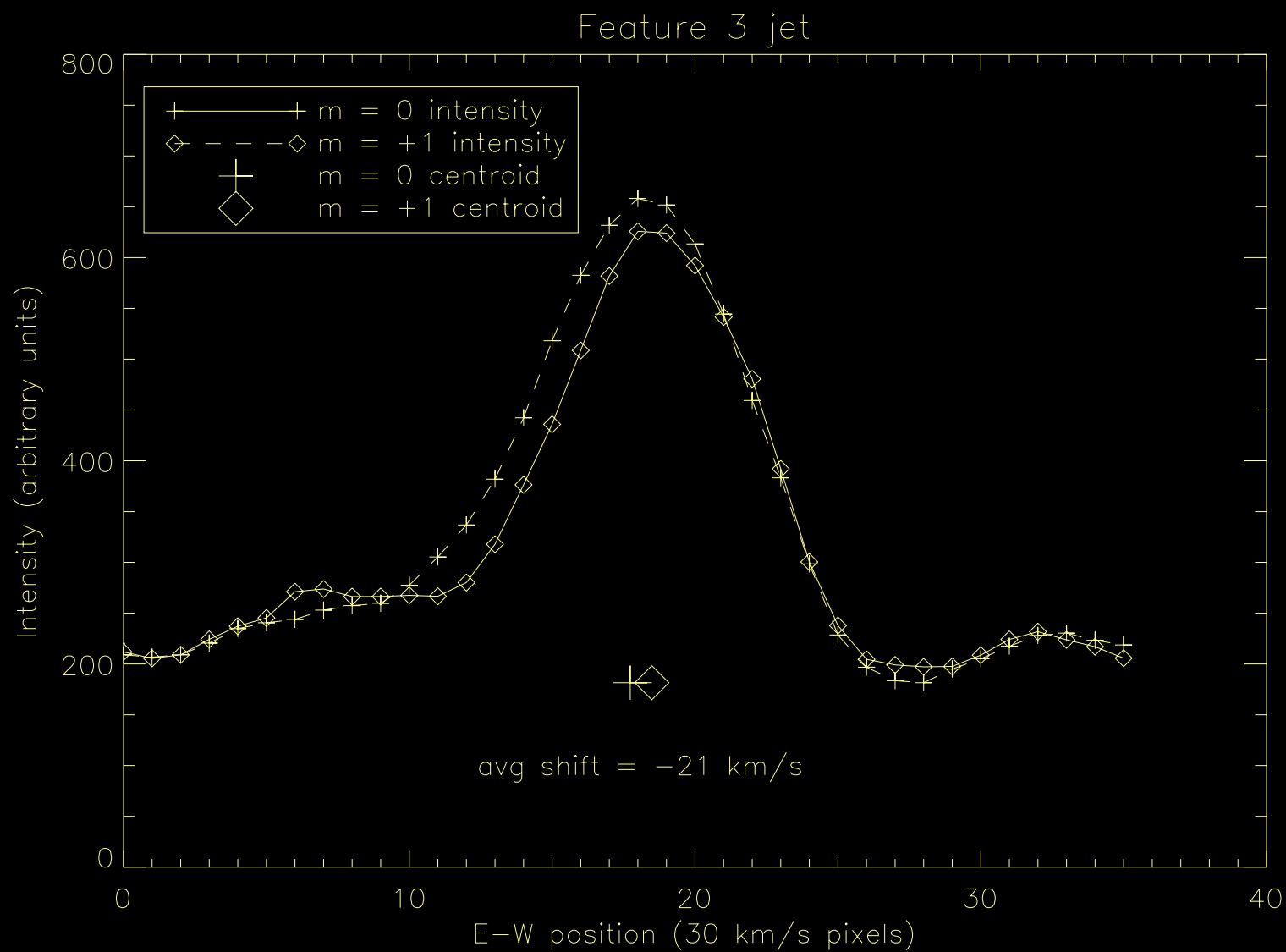


- Explosive event (broadening)
- Bidirectional jets

Feature 3 core

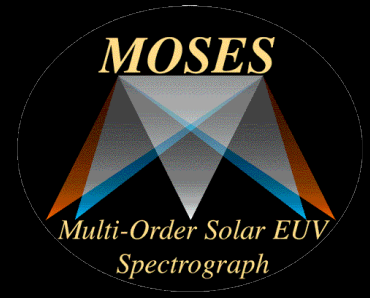


Feature 3 jet





Conclusions



- It works! *MOSES* obtains simultaneous imaging and spectral information over a wide FOV.
 - Quantitative doppler shifts
 - Explosive events
 - Coronal features (Si XI)
- No slit \Rightarrow high count rate \Rightarrow rapid cadence (limited by readout time)
- Much more to do
 - Reconcile PSFs among the 3 orders
 - Inversions \rightarrow a spectrum in every pixel