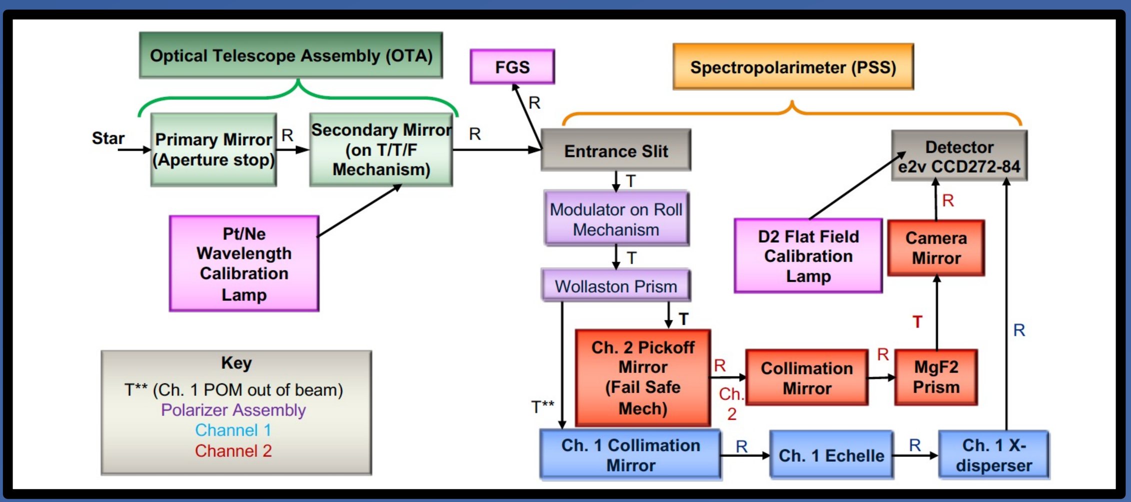
Polstar : a FUV Spectropolarimetry Mission

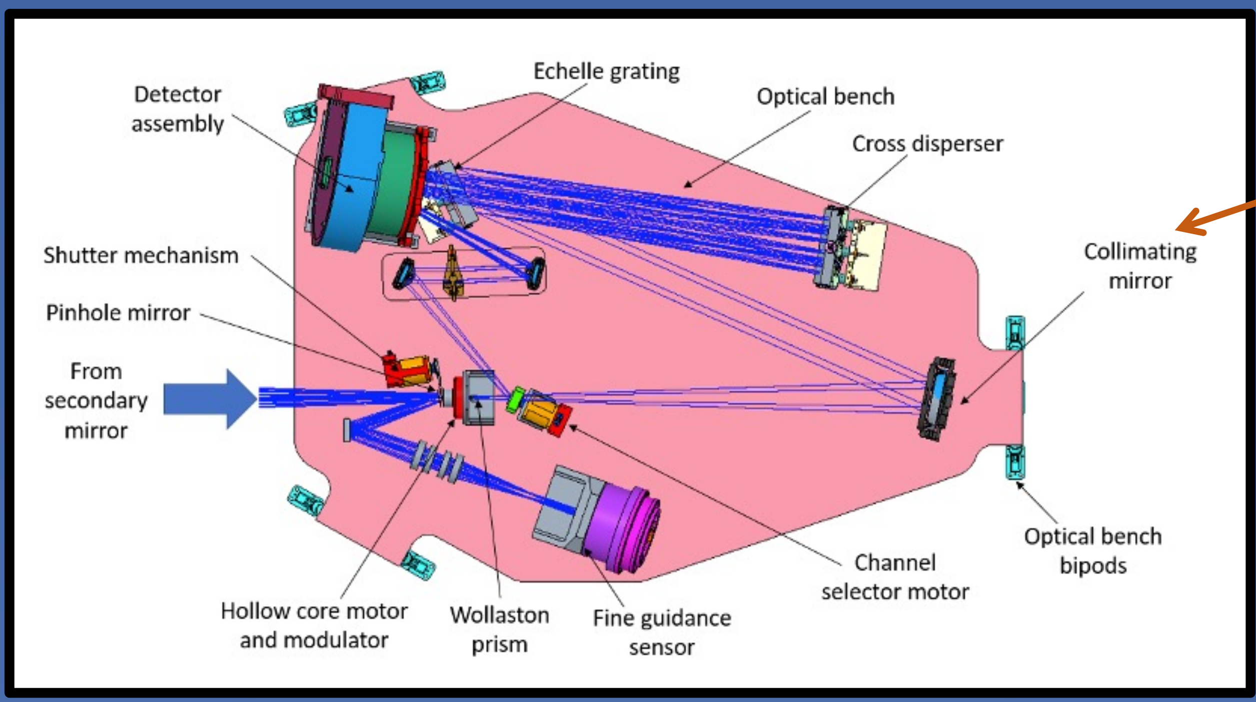
Nicole St-Louis, Université de Montréal, on behalf of the Polstar consortium

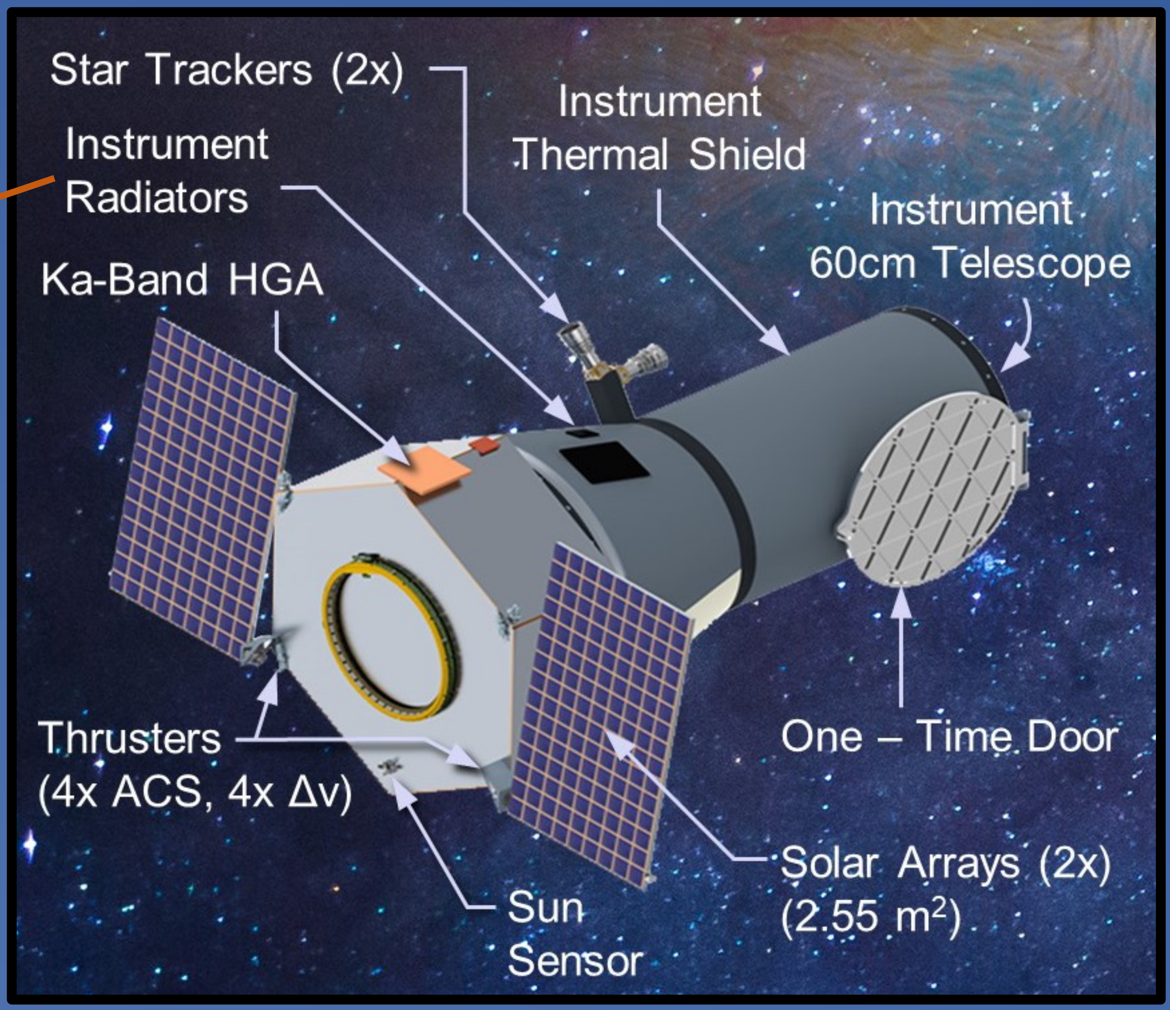
Université de Montréal
The University of Montreal and of the world.

POLSTAR
NASA Goddard SPACE FLIGHT CENTER
LOCKHEED MARTIN

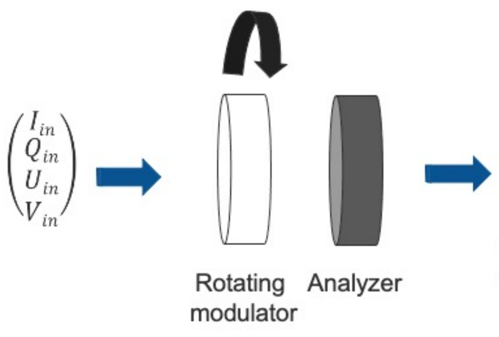
Paul Scowen (PI, NASA Goddard), Richard Ignace (Deputy PI, East Tenn. State U.), Kenneth Gayley (Project Scientist, U. Iowa), Coralie Neiner (Obs. Paris), Gopal Vasudevan (Lockheed Martin), B-G Andersson (SOFIA-USRA), Svetlana Berdyugina (U. Freiburg), Alex Carciofi (U. São Paulo), Matt Shultz (U. Delaware), Nicole St-Louis (U. Montreal), Gregg Wade (Queens U.), Vladimir Airapetian (NASA GSFC/AU), Andrei Berdyugin (U. Turku), Jon Bjorkman (U. Toledo), Kim Bott (U. Washington), Roberto Casini (UCAR), Mark Cheung (Lockheed Martin), Jean Chiar (Diablo Valley College), Geoff Clayton (LSU), Daniel Cotton (AAT), Bill Danchi (NASA GSFC), Alex David-Uraz (NASA GSFC), Tanausu Del-Pino-Alemain (IAC), Marc DeRosa (Lockheed Martin), David Ehrenreich (U. Geneva), Sylvia Ekstrom (U. Geneva), Christiana Erba (U. Delaware), Andrew Fullard (Michigan State U.), Perry Gerakines (NASA GSFC), Douglas Gies (Georgia State U.), Edward Guinan (Villanova U.), Wolf-Rainer Hamann (U. Potsdam), Benjamin Hayworth (Penn State U.), Huib Henrichs (U. Amsterdam), John Hillier (U. Pittsburgh), Thiem Hoang (KASI, Korea), Jennifer Hoffman (U. Denver), Ian Howarth (UCL), Tony Hull (U. New Mexico), Carol Jones (Western, Ontario), Jim Kasting (Penn State U.), Jonathan Labadie-Bartz (U. Sao Paolo), Norbert Langer (U. Bonn), Maud Langlois (U. Lyon), Maurice Leutenegger (NASA GSFC), Emily Levesque (U. Washington), Jamie Lomax (USNA), Antonio Mario Magalhães (U. Sao Paolo), Rafael Manso-Sainz (MPS, Germany), Anatoly Mirochnichenki (UNCG),Yael Naze (U. Liege), Alison Nordt (Lockheed Martin), Lida Oskinova (U. Potsdam), Rene Oudmaijer (U. Leeds), Stan Owocki (U. Delaware), Gina Panopoulou (Caltech), Geraldine Peters (USC), Véronique Petit (U. Delaware), Jullian Pittard (U. Leeds), Raman Prinja (UCL), Noel Richardson (Embry Riddle), Thomas Rivinius (ESO Chile), Tomer Shenar (IoA Leuven), Phil Stahl (NASA MSFC), Heloise Stevance (U. Auckland), Natallia Sudnik (CAMK), Jon Sundqvist (U. Leuven), Javier Trujillo-Bueno (IAC), Asif Ud-Doula (Penn State U.), Jorick Vink (Armagh Obs), John Wisniewski (U. Oklahoma), Bob Woodruff (Woodruff Consulting)







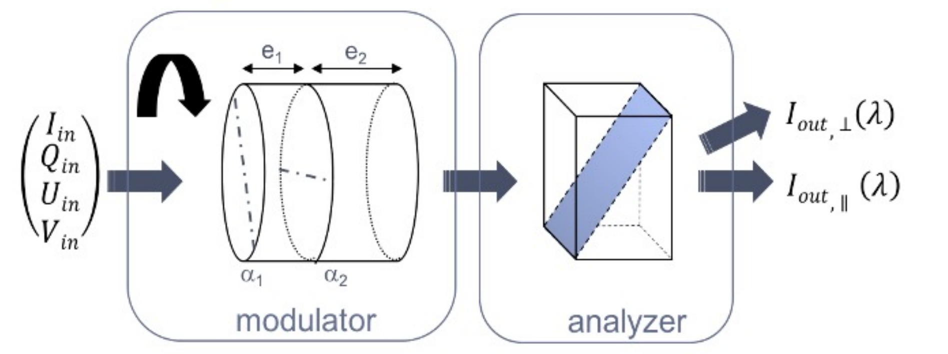
- Rotating modulator (at discrete positions) to modify the entrance polarization
- + Analyzer (= fixed linear polarizer) to select a certain polarization



$$I_{out}(x,\lambda) = I_{in} + \alpha_Q(\lambda)Q_{in}(\lambda) + \alpha_U(\lambda)U_{in}(\lambda) + \alpha_V(\lambda)V_{in}(\lambda)$$

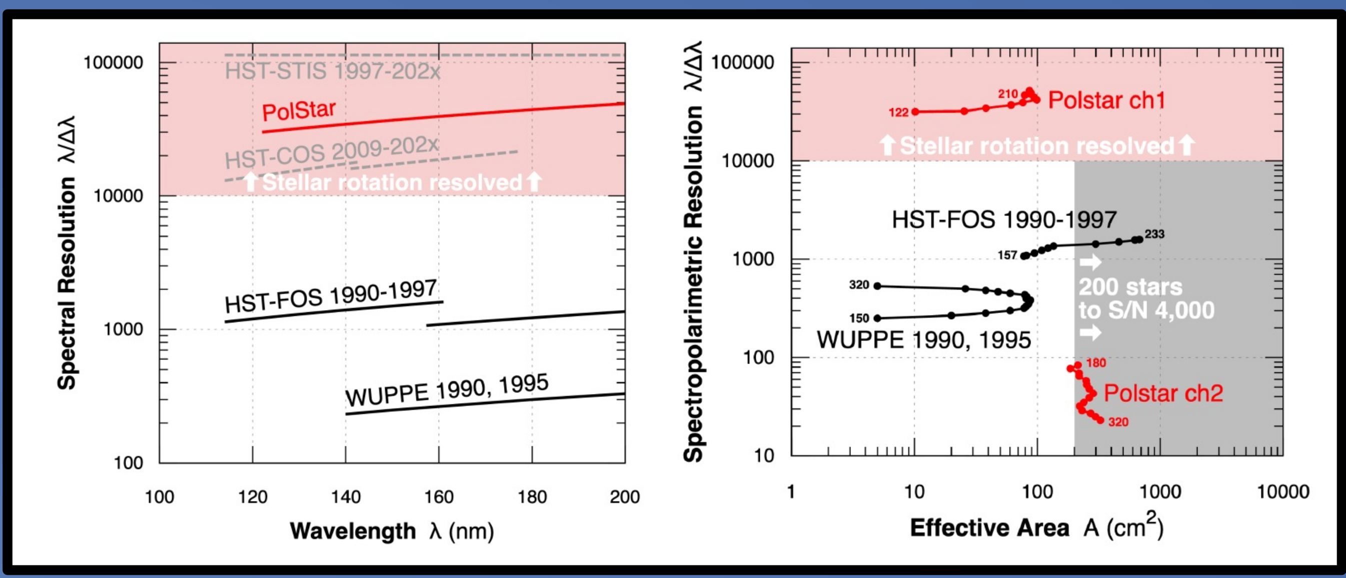
→ polarization information is encoded in the output intensity signal

- → the combination of several measurements taken at various modulator angles provides the full characterization of the entrance beam
- Modulator = 2 thin double-plates of MgF_2 rotating as a stack at 6 optimized angular positions
- Analyzer = Wollaston prism in MgF_2



- → the parameters of the plates (thickness, orientation) and modulator angles are optimized to obtain the best efficiency in the extraction of the polarization information

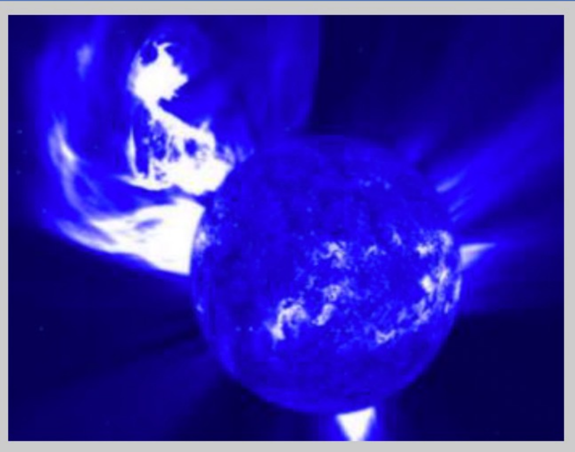
Observatory Property	Value
Primary Mirror Aperture	60 cm diameter
Instrument	2-channel UV spectropolarimeter
Wavelength Coverage	Channel 1: 122-200 nm (FUV) Channel 2: 122-320 nm (FUV/NUV)
Spectral Resolution	Channel 1: >30k (lines) Channel 2: >140 (continuum)
Polarimetry	All 4 parameters of the Stokes vector to an accuracy error of 0.1%
Orbit	Sun-Earth L2
Mission Lifetime	3 years (baseline) 5 years (extended)
Launch Date	6 December 2028
Daily Science Data	Up to 21.5 GB/day from 154 exposures/day



- *Polstar* will offer the benefit of combining spectroscopy with polarimetry. This will enable us, among other things, to probe the intricacies of massive-star winds and in particular their large and small-scale structure, either from magnetic activity, instabilities or fast rotation.
- Its innovative combination of effective area and time coverage will allow us to study the great diversity of targets necessary to transform our understanding of many science areas in stellar astronomy as well as interstellar medium and protoplanetary disks studies.
- *Polstar* will map stellar wind and magnetospheric structures by uniting time domain, polarimetry and spectroscopy capability in the near- and far-UV (NUV and FUV), which are densely populated with high-opacity resonance lines encoding a rich array of diagnostic information.
- This exciting science program will be possible thanks to an instrument that combines advances in high reflectivity UV coatings and delta-doped CCDs with high quantum efficiencies to provide dedicated FUV spectropolarimetry for the first time in 25 years.
- *Polstar* will be equipped with two distinct channels:
  - The FUV channel (Ch1), covers 122-200nm at a resolution of R=30k. This spectral resolution is more than 30 times better than *WUPPE*, with 10 times better effective area, while reaching shorter wavelengths. This will be crucial to gain the ability to access strong lines of species like NIV and SiIV.
  - The NUV channel (Ch2) covers 122-320nm at R~140-4k. It will enable us to monitor fainter targets at a modest spectral resolution but at a high cadence.
- The instrumental polarization stability in both channels is designed to provide signal-to-noise ratios (SNR) for UV polarimetry precision of 1×10^{-3} per exposure, per resolution element. The precision can be further improved with spectral binning and/or stacking multiple exposures.
- The 3-year mission of *Polstar* is 100 times longer than that of *WUPPE*, corresponding to orders of magnitude gains in stellar and interstellar observations.

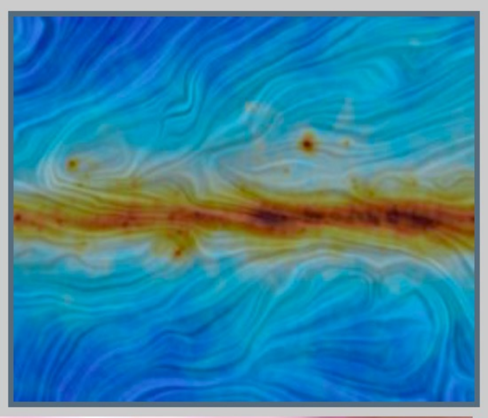
Science Objectives – Massive Stars: *Polstar* will use UV spectropolarimetry to study the three main mechanisms that are capable of significant change in the evolution of a massive star:

- S1: Kilo-gauss (kG) magnetic fields in which magnetic braking and magnetospheric plasma trapping alter mass loss and spin-down rates.
- S2: Non-spherical structure and clumping in stellar winds that alter mass and angular momentum loss rates.
- S3,4,5: Explore rapidly-rotating stars to understand dynamics at birth and evolution due to binary mass transfer and loss to interstellar medium.



Science Objectives – Interstellar Medium: Addressing the nature of UV interstellar medium (ISM) extinction through polarization, *Polstar* will:

- I1,2: Determine if Super-Serkowski UV polarization is driven by proximity to massive star EUV sources by examining the characteristics of the smallest dust grains
- I3: Determine the carrier for the 2175Å extinction feature, and its relation to poly-aromatic hydrocarbons (PAHs).
- I4: Determine for the first time the relationship of interstellar UV polarization to ISM metallicity by probing the Magellanic Clouds.



Science Objectives – Protoplanetary Disks (PPDs): To understand processes governing the assembly and evolution of star and planetary systems, *Polstar* will:

- Determine the methods of accretion active in PPDs around lower-mass stars compared to higher mass stars.
- Determine the nature of transient events in the inner regions of planet-forming disks and how that influences accretion.