Finding and characterizing young stars (1-100 Myrs) with WFIRST-2.4

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Questions on star and planet formation

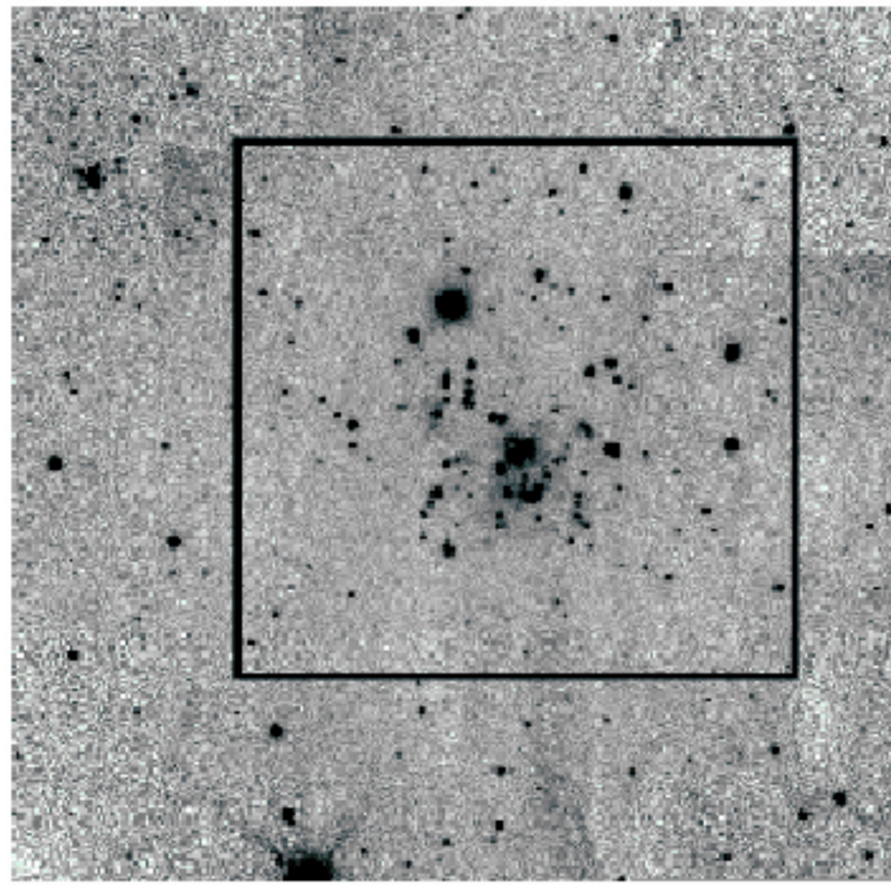
- These old chesnuts…
  - What is the IMF at low masses?
  - How does it depend on local conditions (metallicity, gas density)?
  - What is the epoch of planet formation as a function of mass (stellar mass, planet mass, disk mass)?
- And some new ones…
  - What is the role of dynamical interactions between planets in clearing out the disk and expelling each other?
  - What is the disk composition as a function of stellocentric distance?
  - What is the epoch of planet migration?

Three relevant one-page science ideas

- The Most Distant Star-Forming Regions in the Milky Way (John Stauffer, IPAC)
- Stellar and Substellar Populations in Galactic Star-Forming Regions (Lynne Hillenbrand, Caltech)
- Finding the Closest Young Stars (David R. Ardila, Aerospace)

The Most Distant Star-Forming Regions in the Milky Way (John Stauffer, IPAC)

- Find new young stars at the edge of the Galaxy
- Use them to study star formation in low metallicity environments.
- JH 'K' survey of Galaxy quadrants 2 and 3, ±1 degree off plane.
- Depth: K=19 mag (5sig) to 0.1 Msun at R(G)=20 kpc
- WFIRST uniqueness:
  - large FOV
  - IR bands
  - depth.



IRAS 06145+1455, the most distant SFR, at R(G)=20.2 kpc. Brand & Weterloot (2007)

Stellar and Substellar Populations in Galactic Star-Forming Regions (Lynne Hillenbrand, Caltech)

- Wide field survey of star-forming regions (140-400 pc)
- Probe the substellar mass function near its bottom, over wide areas: M_H=18 mag reaches 1 M_{Jup} at 1 Myr.
- Use grism spectroscopy to provide spectral typing. R=600 is sufficient to type MLTs
- WFIRST uniqueness:
  - Large FOV
  - IR bands
  - Spectroscopy

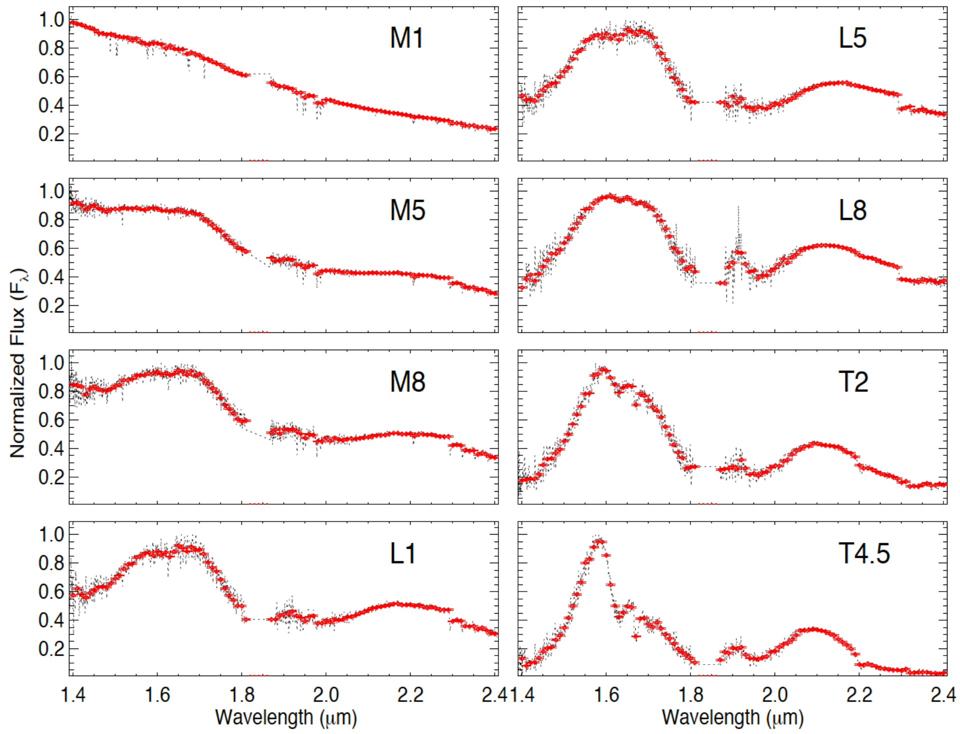


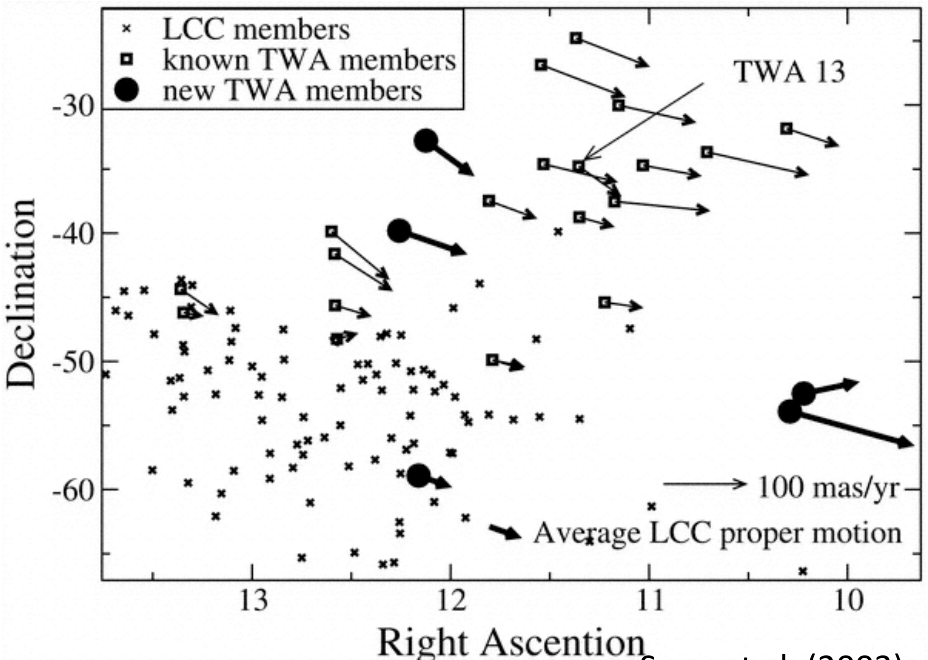
Figure credit: Emily Rice

Young stars near the Sun

Name	Distance	Age	#
TWA	50±13 pc	10 Myr	≈20
η/ε Cha	100±9 pc	8 Myrs	≈20
β Pic MG	30±20 pc	12 Myr	≈30
Carina	85±35 pc	20 Myr	≈20
Tuc/ Hor	48±7 pc	30 Myr	≈50
Argus	106±51 pc	40 Myr	≈10
Columba	82±30 pc	30 Myr	≈50
AB Doradus	34±26 pc	70 Myrs	≈30

Torres et al. (2008)

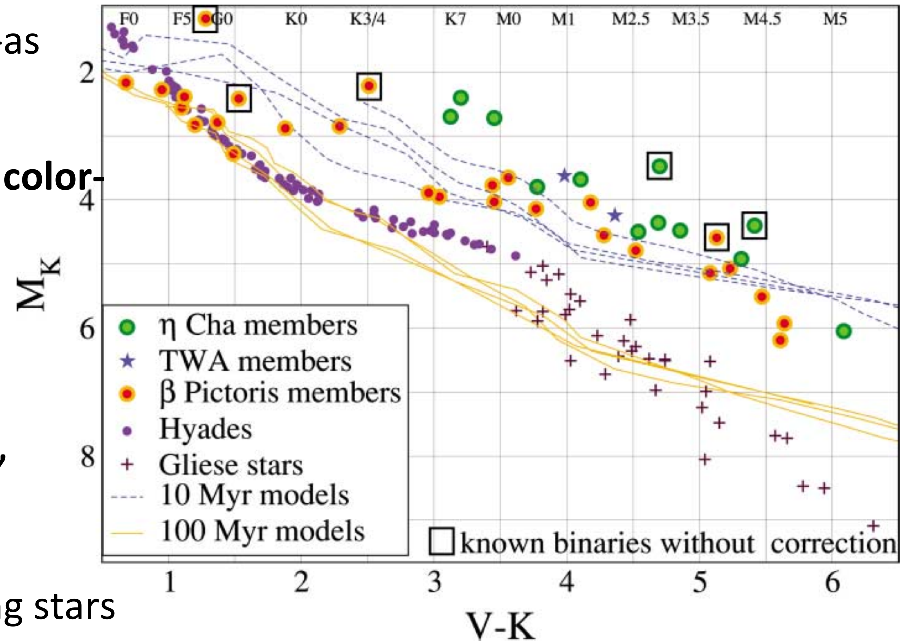
- Very extended in the sky: M42 at 50 pc would cover 8 deg.
- Few disks and no clouds: A large fraction will not have IR excesses



Song et al. (2003)

How to find nearby young objects

- Find nearby objects:
  - High proper motion
  - parallax (spectroscopic, trigonometric).
  - WFIRST astrometric precision will be ≈100 mic-as
- Identify nearby objects as young:
  - Make part of a group: Use **space motion UVW**, **color-magnitude diagrams**
  - **Use age indicators:** X-ray, IR excess, accretion, Lithium, rotation, etc.
  - Needs follow-up with other facilities
- Multi-archive, multi-diagnostic, "big-data" approaches:
  - SACY – Search for Associations Containing Young stars (Torres et al.2003).
  - BANYAN – Bayesian Analysis for Nearby Young Associations (Gagne et al. 2014). X-rays, proper motions, parallaxes, UVWs, etc



Zuckerman & Song (2004)

WFIRST unique strengths

- Large FOV
- For low mass objects, NIR colors give spectral type and surface gravity.
- WFIRST can find very low-mass objects:
  - At 50 pc: For 10 Myrs, the substellar boundary is at ≈M6, $m_H \approx 11.5$ mags.
  - Y0 dwarf is at $m_H(AB) \leq 25.5$ mags

By the time WFIRST rolls around we will have GAIA (eq. 1 m telescope)

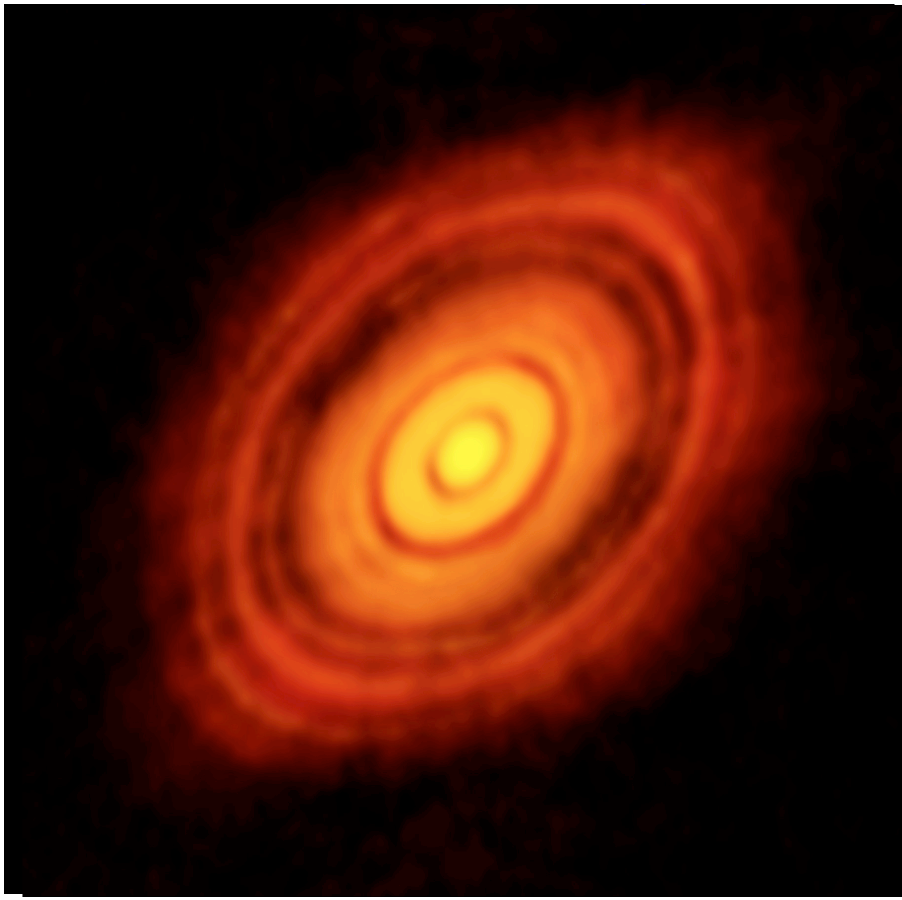
- Final GAIA data release in 2022
- WFIRST can provide color and spectroscopic confirmation, and extend to lower mass members.

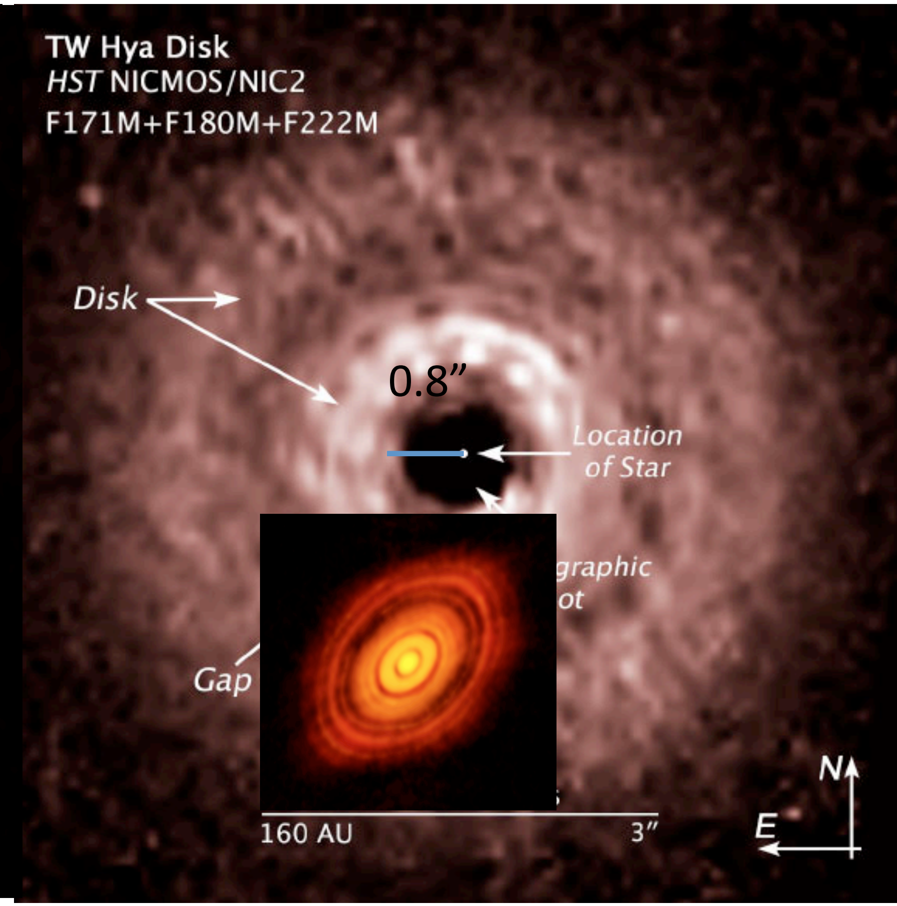
M6 at 50 pc

V magnitude	6 - 13	14	15	16	17	18	19	20	mag
Parallax	8	13	21	34	55	90	155	275	µas
Proper motion	5	7	11	18	30	50	80	145	µas / an
Position @2015	6	10	16	25	40	70	115	205	µas

GAIA specs, de Bruijne, (2013)

Once we find them, then what? Coronagraphic imaging and analysis



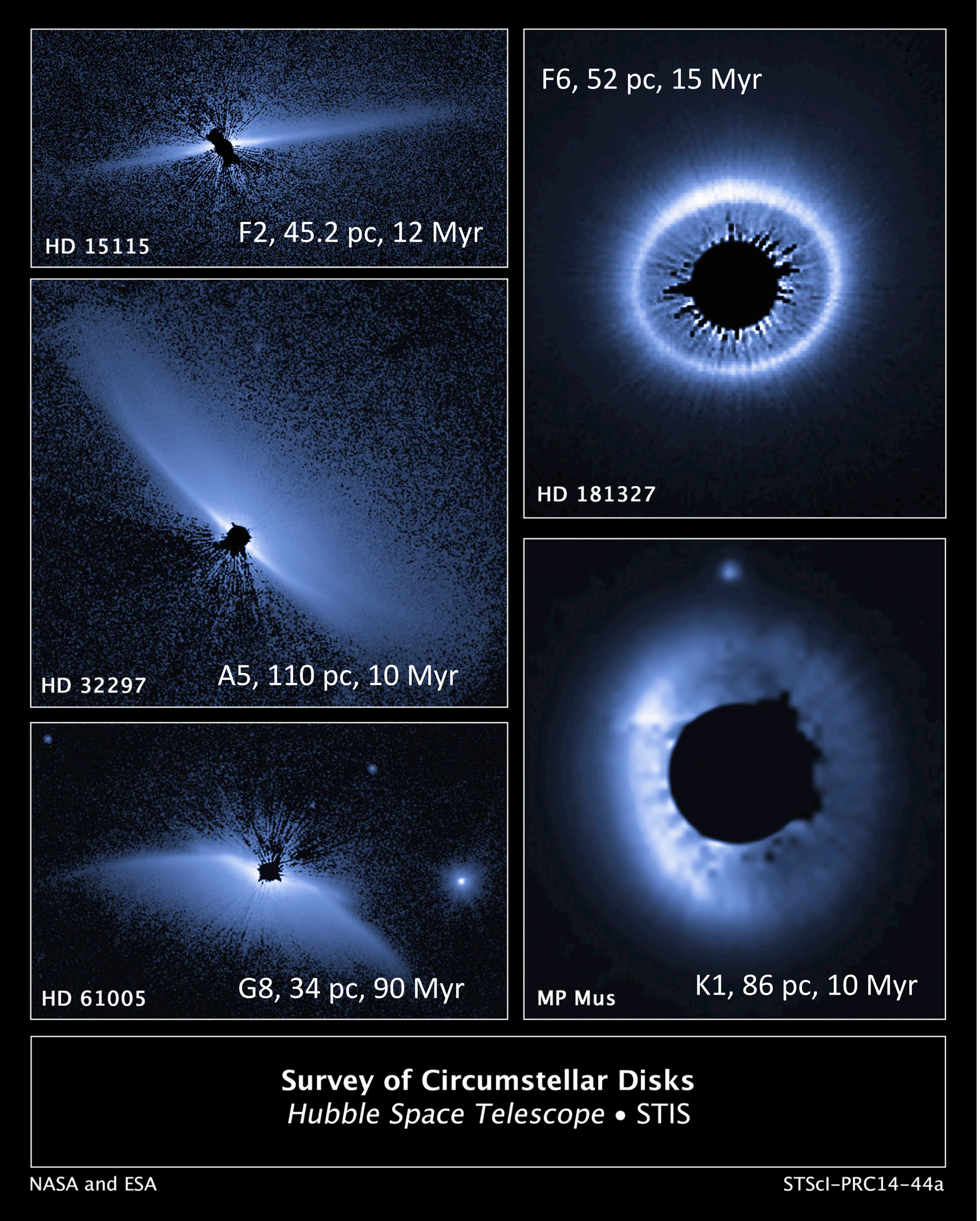


HD 100546, A0, 100 pc, 10 Myr. HST/ ACS data (Ardila et al. 2007)

HL Tau, K5, 140 pc, ~1-3 Myr, ALMA 1.3 mm (Vlahakis et al. 2014)

TW Hya, K6, 50 pc, 10 Myr. NICMOS data (Debes et al. 2013)

State of the art coronography from space



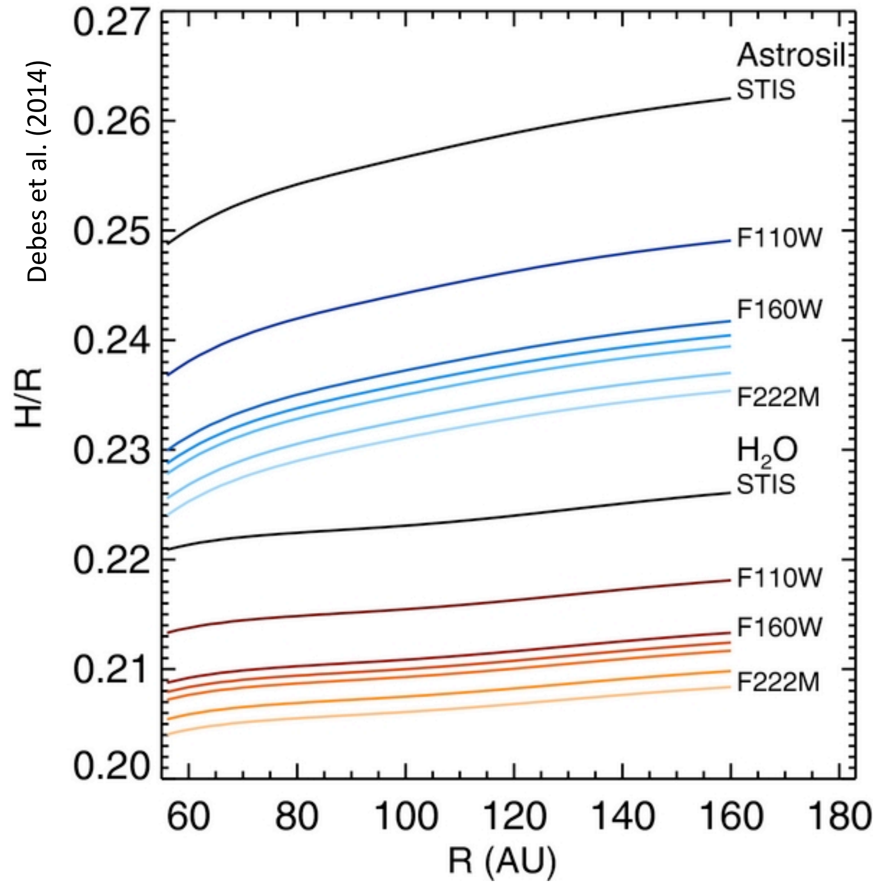
Debris disks with STIS,
Schneider et al. (2014)
IWA: r≈0.3”

WHITE LIGHT!
Color/spectroscopic information is crucial to fully exploit the power of coronagraphic images.

Coronagraph: more than pretty pictures

- Color, scattered light observations
  - measure the amount of smallest dust particles
  - Provide information on the disk profile.
  - Constrain the composition and grain evolution within the disk

TW Hya



In Conclusion

- WFIRST will have a strong impact in the study of star and planet formation 1-100 Myrs
- Large FOV, IR colors and spectroscopy allow for efficient finding and characterization of young stars, near and far
- Color Coronography will revolutionize the study of planet formation.