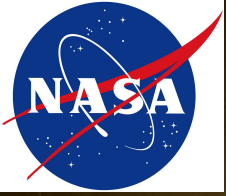


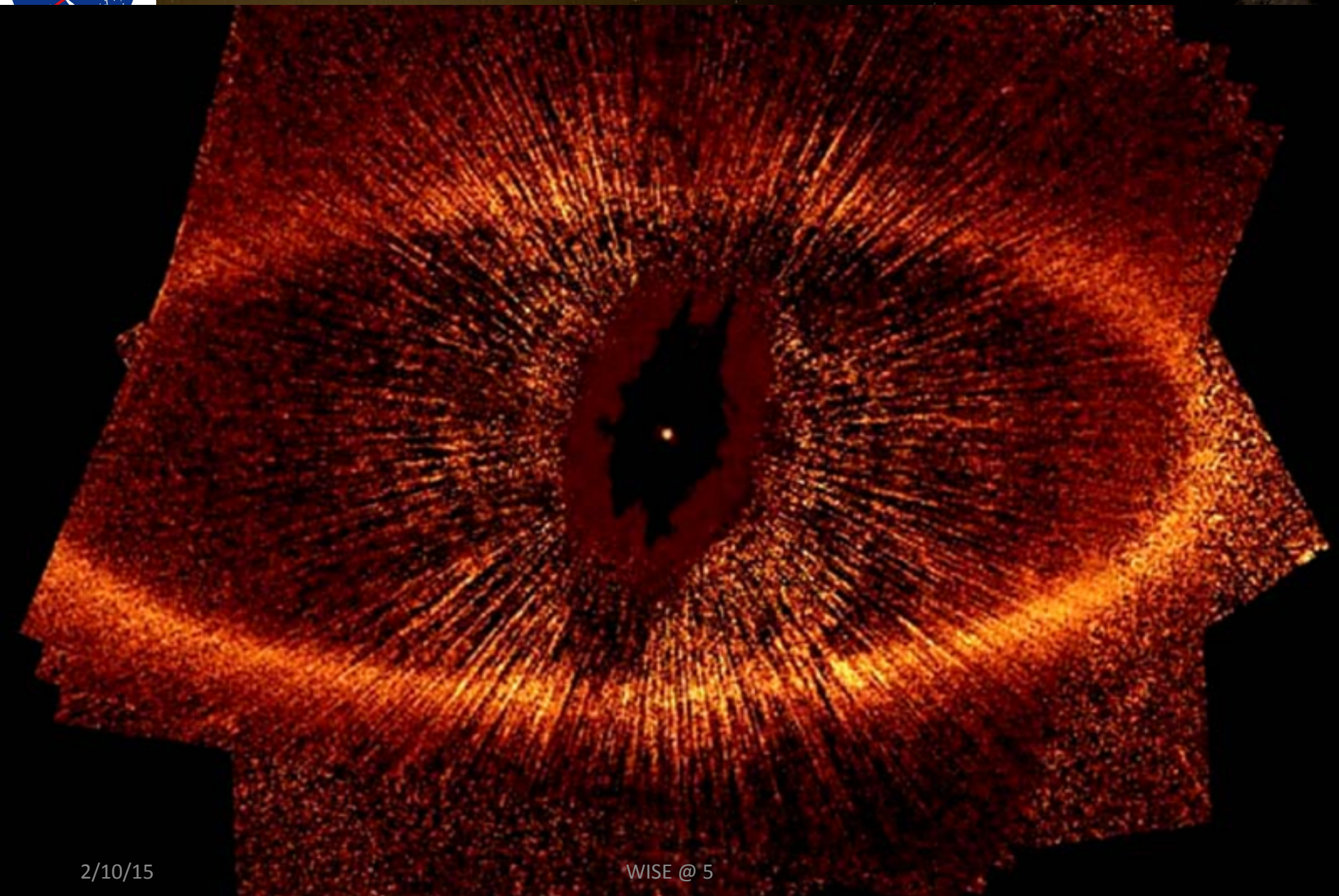
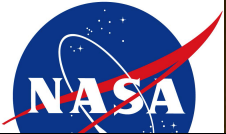
Debris Disks with WISE

Deborah Padgett (NASA/GSFC)



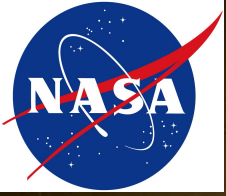
Team Members

- Karl Stapelfeldt (NASA/GSFC)
- John Krist (JPL)
- Sergio Fajardo-Acosta (IPAC)
- Raquel Martinez (UT)
- Sasha Hinkley (Exeter)
- Dimitri Malwet (Caltech)
- David Leisawitz (NASA/GSFC)
- The WISE Team

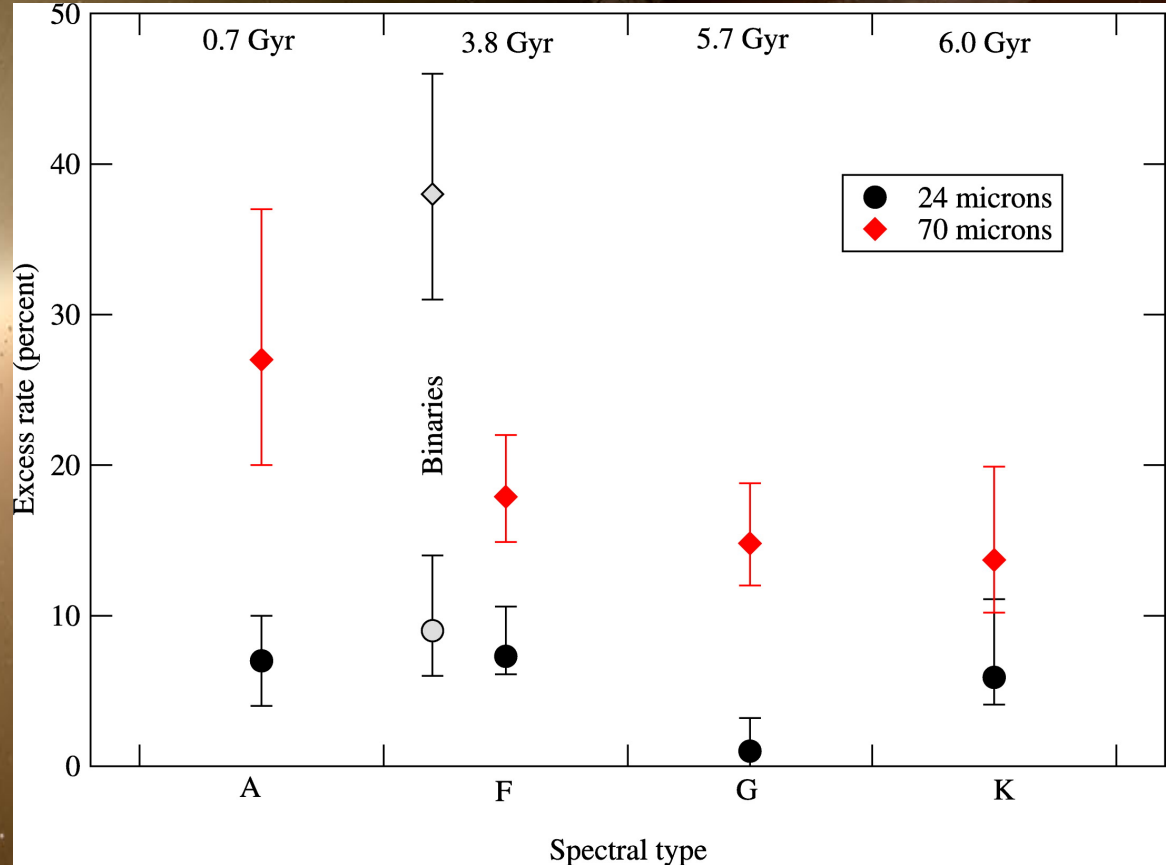
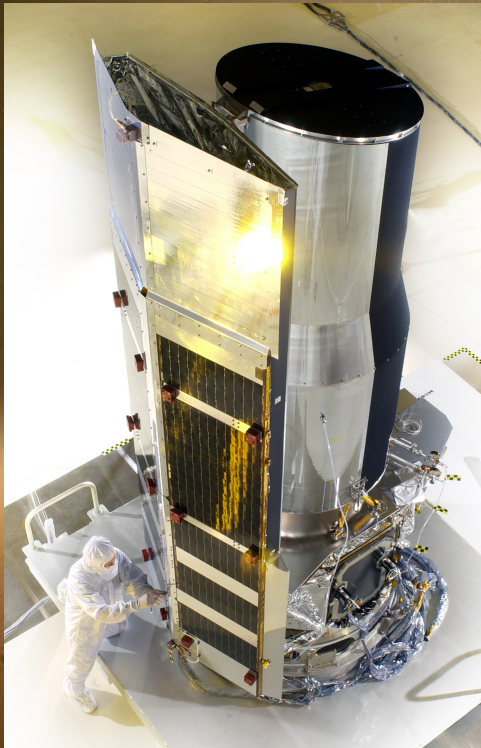


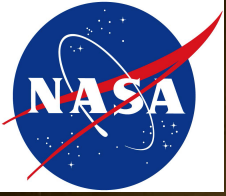
2/10/15

WISE @ 5



Debris Disk Frequency from Spitzer Surveys (Trilling et al. 2008)

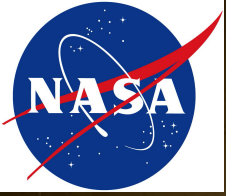




Past Studies of Debris Disks

- IRAS: Rhee et al. 2006 most recently
- Extensive literature from Spitzer
 - Chronological
 - Individual clusters
 - Volume-limited survey
 - Spectroscopy

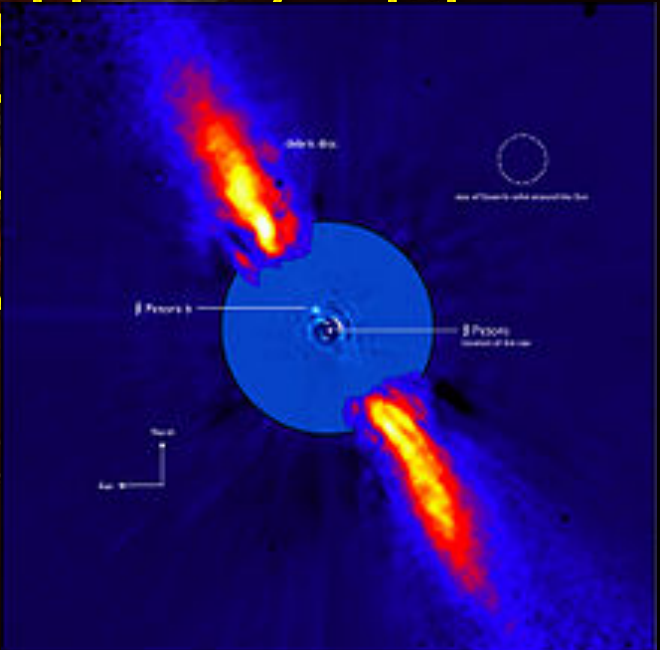
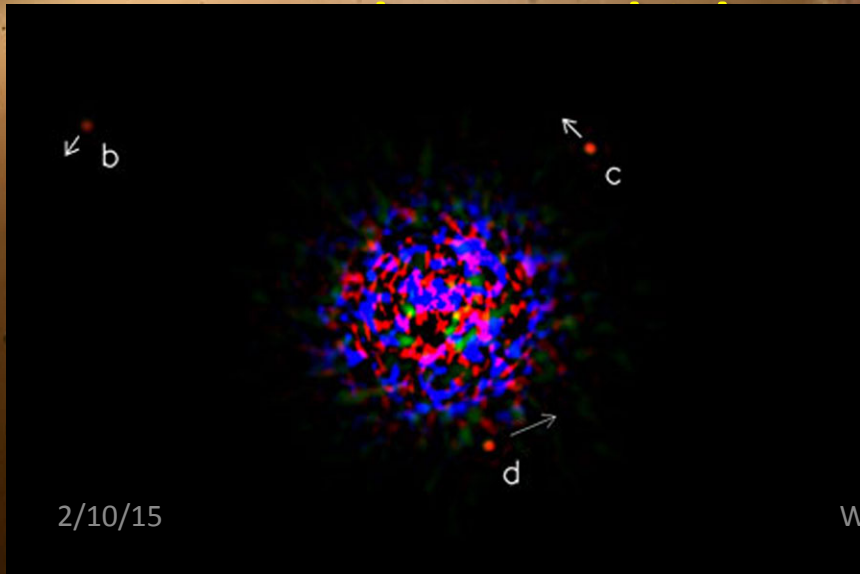


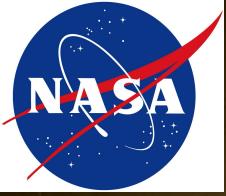


WISE Debris Disk Survey Goals

- *Spitzer* showed that 24 μm excess was rare among solar-type main sequence stars - need all sky survey to identify all nearby objects; WISE 100x more sensitive than IRAS
- 22 μm excess more common at young ages – potential way to identify young field stars

still bright
disks for
IST, ALMA

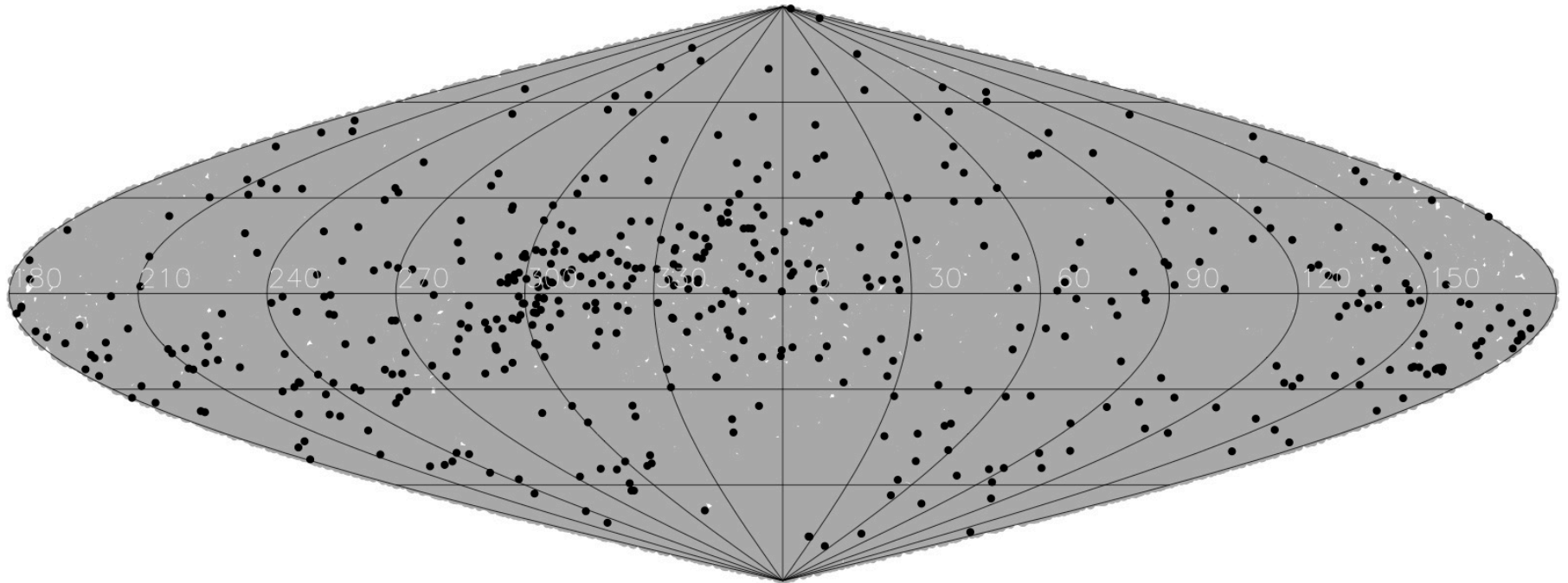


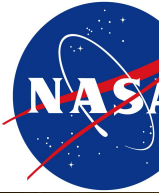


WISE Debris Disk Survey

- Hipparcos/Tycho/Gliese catalogs correlated with WISE *All-sky* data release (3/12) – 25964 HIP stars
- Position search radius of 5" (including proper motions)
- Distances out to 120 pc
- Candidates have $W1-W4 > 0.25$ mag greater than 4σ significance
- $W1 > 3.5$ to avoid worst saturation effects
- Every candidate examined in the WISE and 2MASS images for confusing sources and positional shifts in centroid from band to band
- Padgett et al. 2015 to include multi-release results

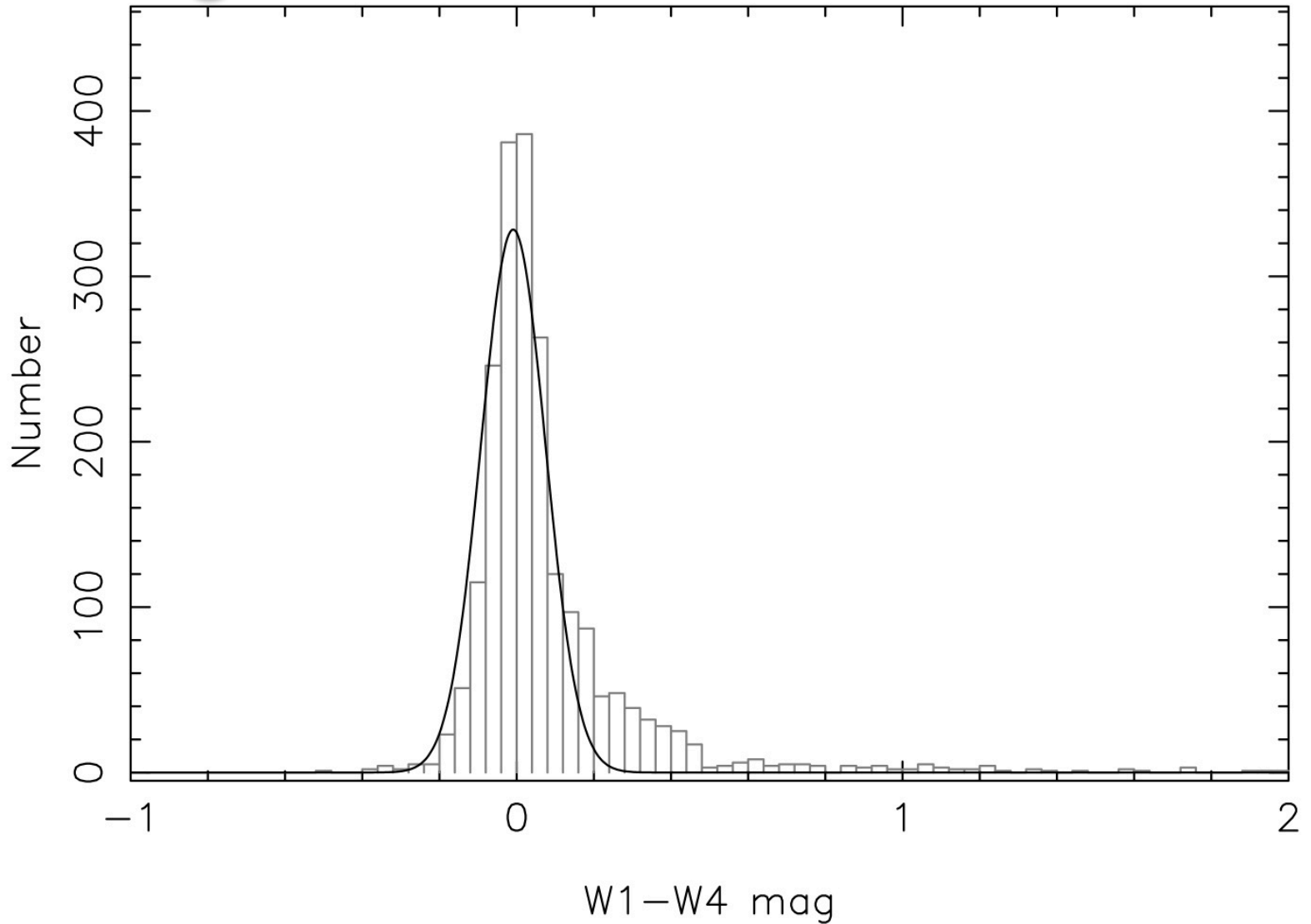
Distribution of Hipparcos/WISE 22 μm Excess Stars

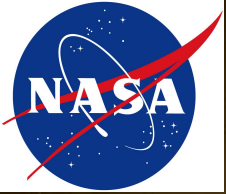




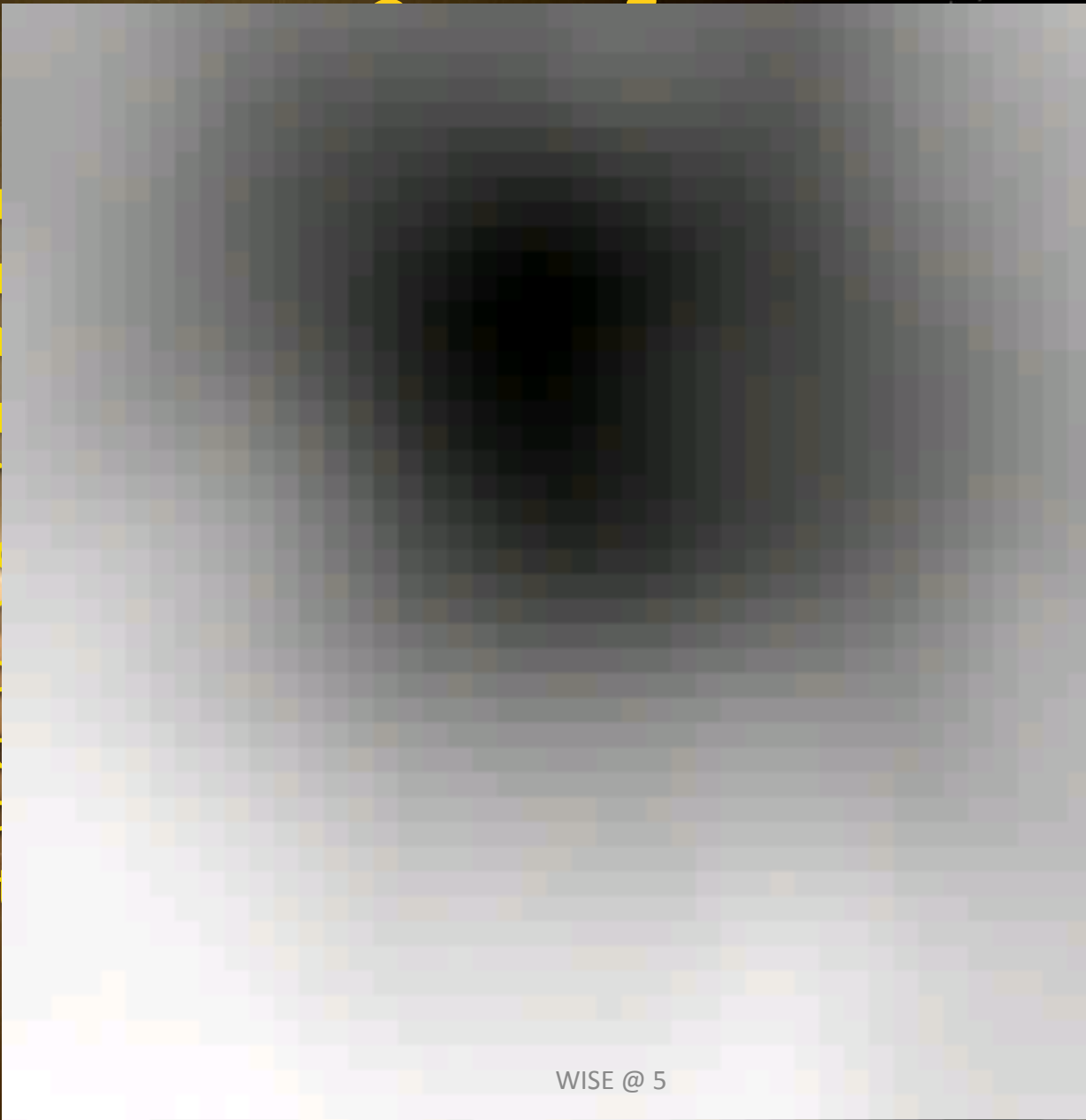
Hipparcos A stars $d < 120$ pc

Histograms of WISE Stellar Colors

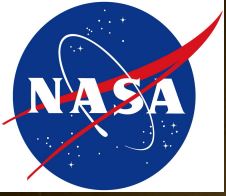




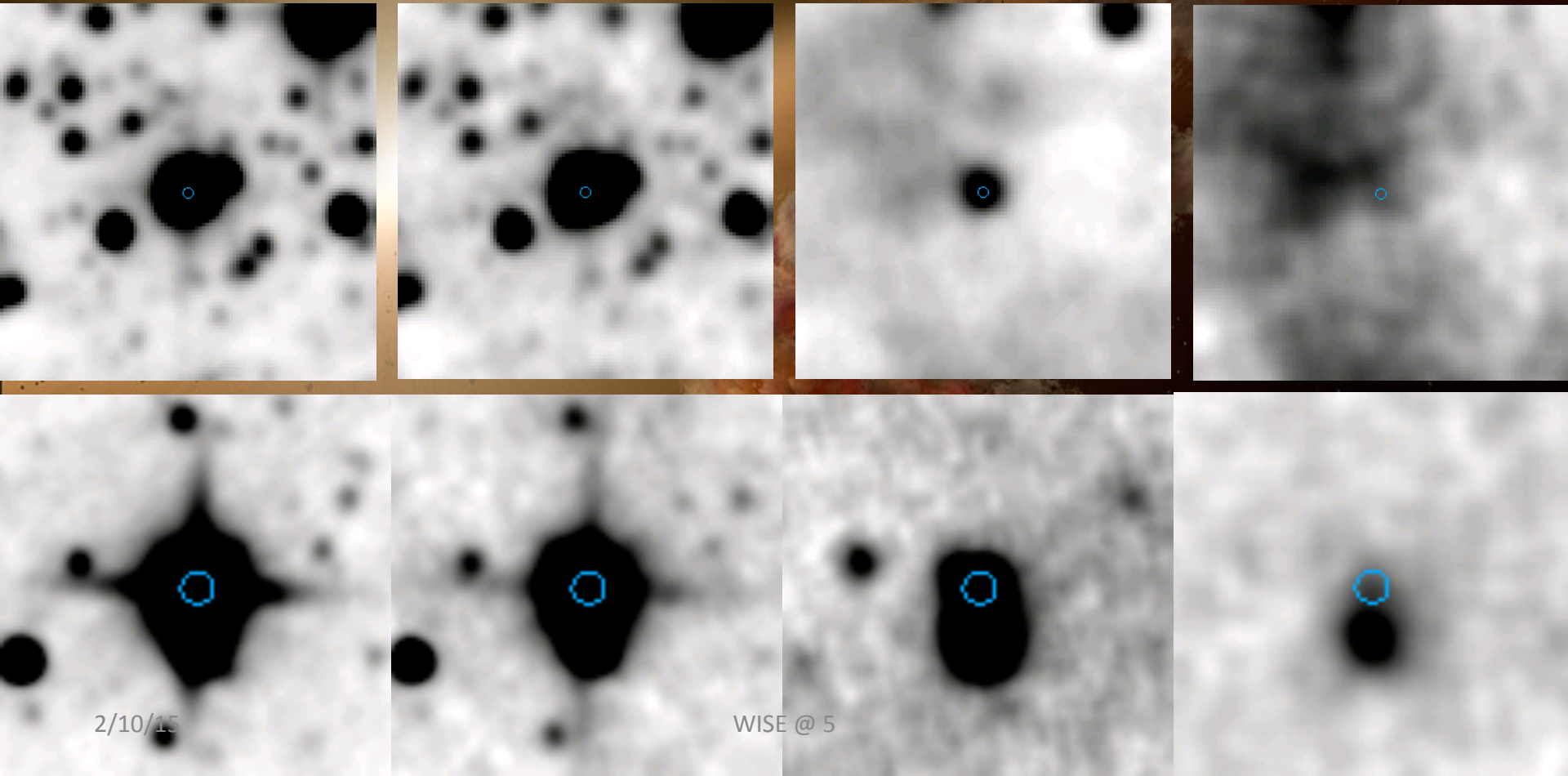
- Co
- Co
- em
- Ve
- err
- Ph
- cor
- pro
- Ast
- cat
- Bo



of
ess; W1
m
ity may

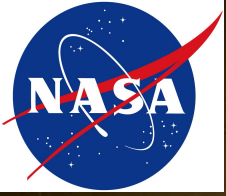


More examples of false excess



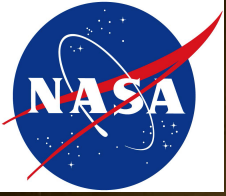
2/10/15

WISE @ 5



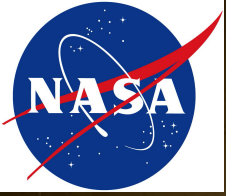
WISE Debris Disk Candidates

- 566 Hipparcos/WISE stars have apparent 22 micron excess $> 4\sigma$ in either W1-W4 or W3-W4
- 359 are new (not previously determined to have excess in mid- to far-IR prior to WISE)
- 179 known debris disk stars from IRAS, ISO, Spitzer, Akari
- Typical Hipparcos/WISE positional offset (WISE band 1) of 0.1-0.2"
- 446 high proper motion Tycho stars with excess



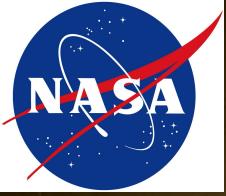
Spectral Types of WISE Debris Disk Candidates

- B stars: 12.1 ± 2.0 %
- A stars: 9.5 ± 0.6 %
- F stars: 1.5 ± 0.1 %
- G stars: 0.9 ± 0.1 %
- K stars: 0.2 ± 0.1 %
- M stars: 0.0 ± 0.3 %



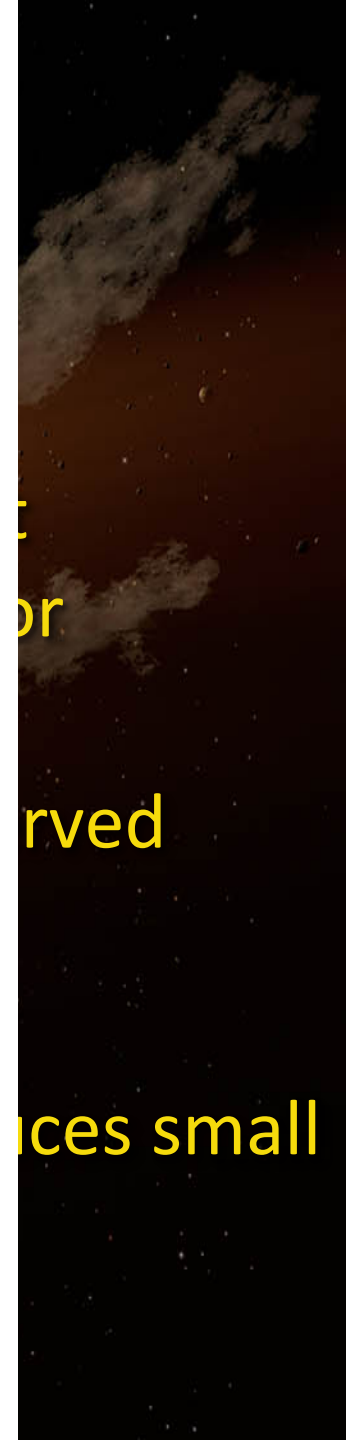
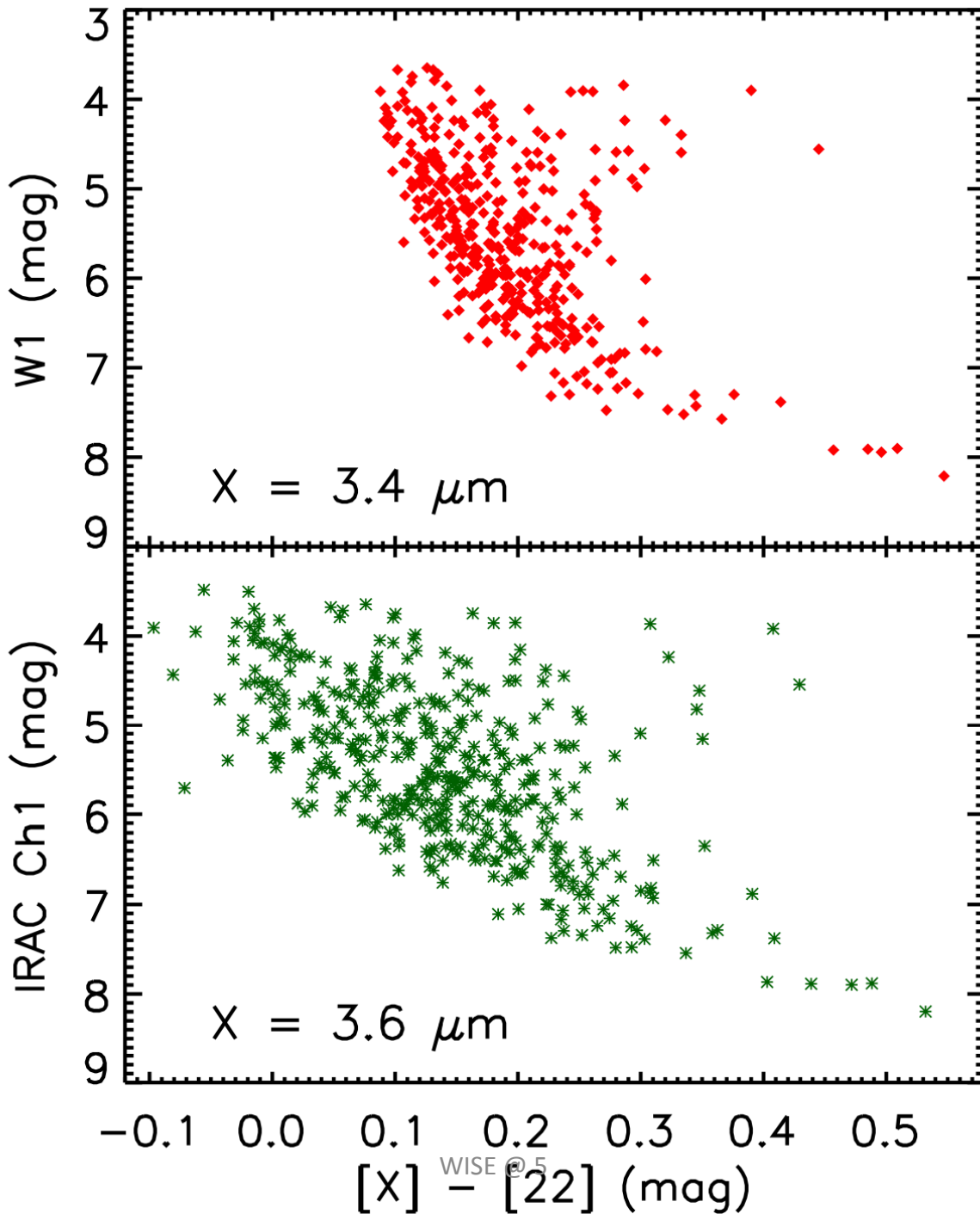
WISE 12 μm Excess Stars

- 66 Hipparcos/WISE stars within 120 pc with 12 micron excess; $\sim 10\%$ of sample
- A few are previously known PMS stars (with inaccurate distances)
- 12 μm flux density of most measured for first time
- Largely a subset of 22 μm excess stars; few are too faint for reliable 22 μm measurements
- 28 new 12/22 μm excess stars



- Many
- Most
- between
- reason
- Separ
- with S
- photo
- Result
- excess
- 79 add

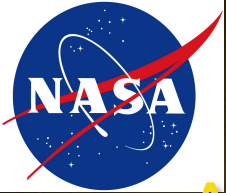
2/10/15



or

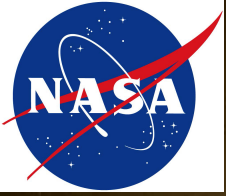
rved

ices small



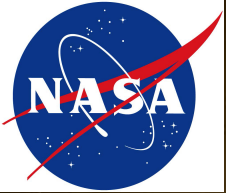
All-Sky versus ALLWISE

- ALLWISE uncertainties are much higher for W1 and W2 due to saturation issues
- 510 W1-W4 excess candidates in the All-Sky release became 244 in ALLWISE
- 141 of the All-sky W1-W4 candidates have become W3-W4 excess candidates instead
- Thus, about 75% of All-Sky candidates are recovered in ALLWISE
- Many now excluded are known Spitzer debris disks, so $< 4\sigma$ ALLWISE excesses may be real in many cases
- Substantial number of new candidates (esp. W3-W4) among fainter stars



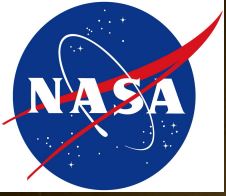
Ages for WISE/Hip Excess Stars

- Many A stars with isochronic ages < 1 Gyr
- Few FGK stars have good age estimates
 - 4 with gyrochronology have ages < 2 Gyr
 - Many stars with X-ray and high chromospheric activity indicators
 - Need program for rotational periods of candidates in work to establish gyrochronology
- Ongoing spectroscopy programs at Palomar and SOAR to establish uniform spectral classification and activity indicators



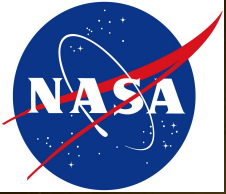
Kinematics of WISE/HIP Stars

- Half of WISE/HIP excess candidates have published radial velocities
- Recover young association members with known warm disks: β Pic, TW Hya, Tuc-Hor, etc.
- Fair number of previously unknown debris disk candidate stars co-moving with known association members ($\Delta\sqrt{U^2+V^2+W^2} < 2 \text{ kms}^{-1}$)
- Some new candidates co-moving with association members, but large separations $> 100 \text{ pc}$



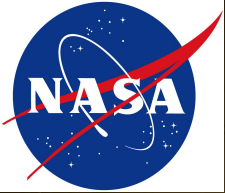
WISE-only Dust Temperatures

- Most objects only have a single photometry point for excess
- Presuming that dust peaks at that wavelength provides upper limit to dust temperature
- Vast majority are less than 200 K, but many above 100 K
- Few as high as 400 K for 12 μm excess stars
- Younger = warmer dust



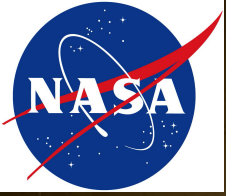
Comparison with Other WISE Debris Disk Studies

- Many targeted studies of young stars (Rizzuto et al. 2012, Morales et al. 2011, Zuckerman et al. 2011, 2012, Mizusawa et al. 2012 etc.)
- McDonald et al. 2012 (Hipparcos stars to 300 pc)
 - different calculation of excess (SED fitting vs colors)
 - Most excess stars in common
 - Some stars with excess in our study lack excess in theirs due to data editing
- Patel will be talking on Wednesday about their recalibration of the WISE data to find faint warm debris disks



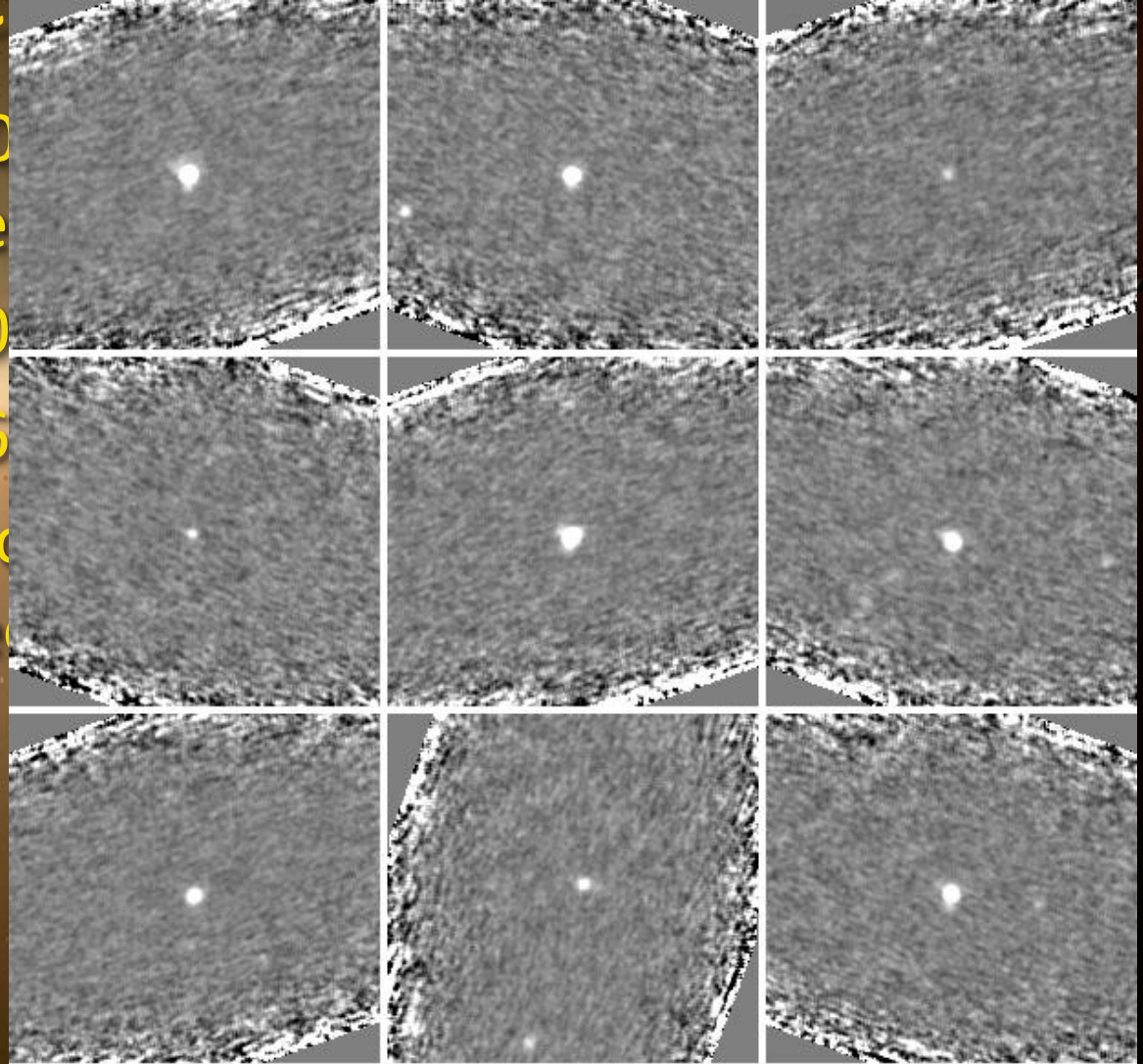
Herschel/PACS Photometry of WISE Debris Disk Candidates

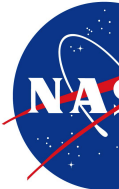
- For most debris disk candidates, WISE only gives a single photometric point for the excess
- Thus, WISE can only *detect* warm debris disk candidates
- *Characterization* of these candidates requires *Herschel*
 - dust distribution (i.e., temperature)
 - quantity of material



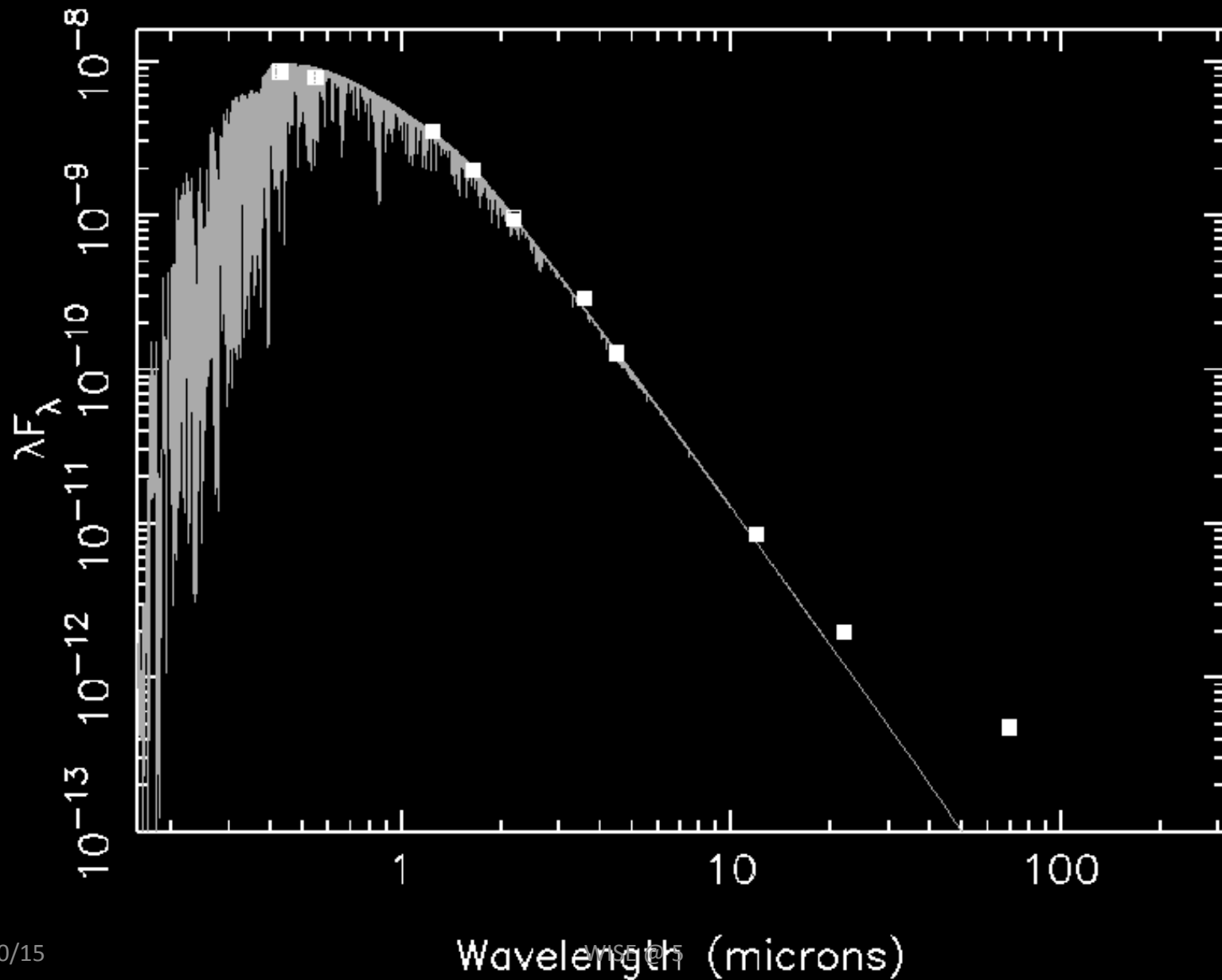
WISE Debris Disk Candidate Herschel Observations

- Herschel/PACS 70 μ m
WISE 22 micron e
- 75 detected at 70 μ m
- 36 detected at 16 μ m
- About 20 A stars c
Herschel; all dete





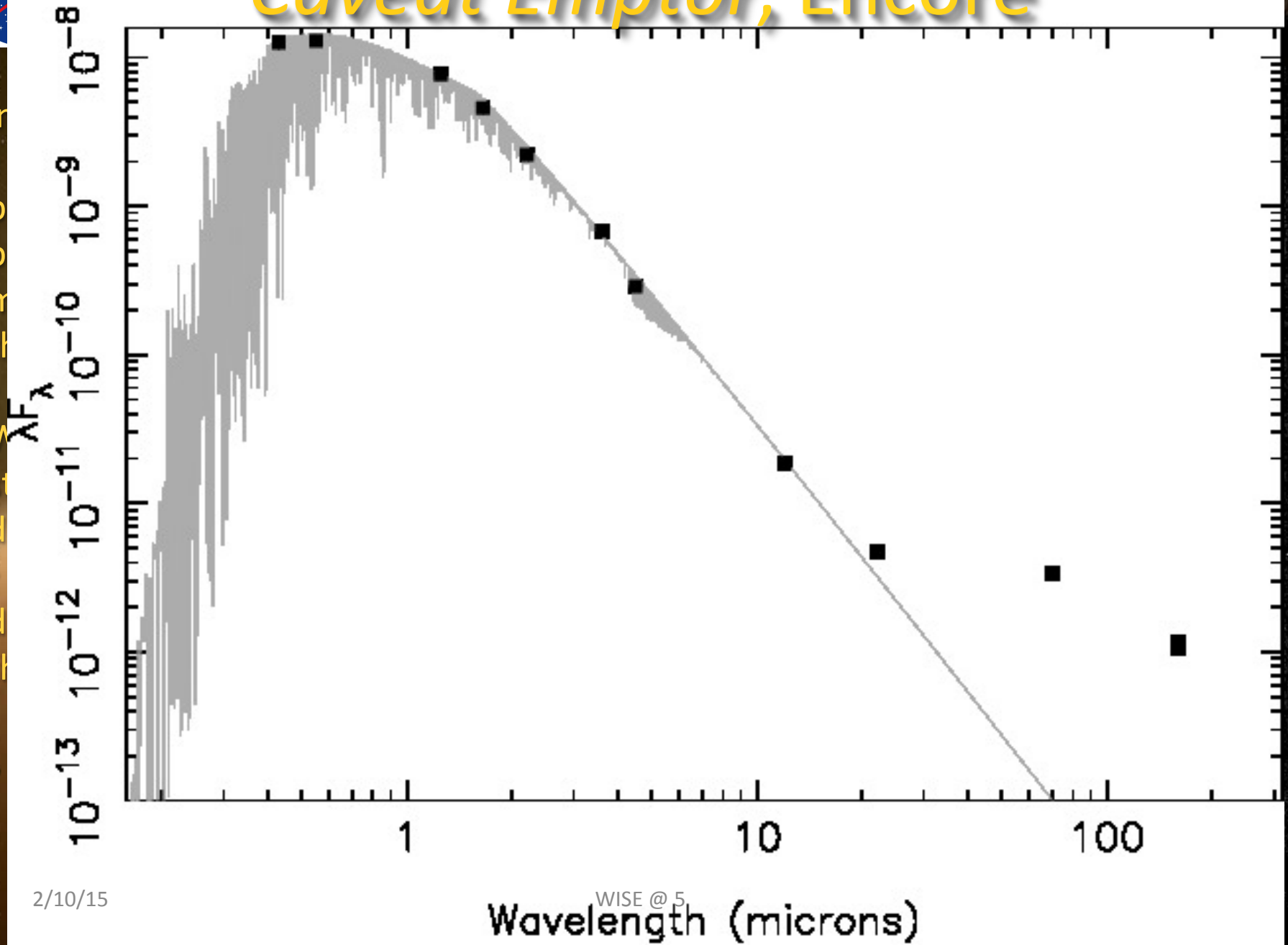
HIP 25020 Spectral Energy Distribution

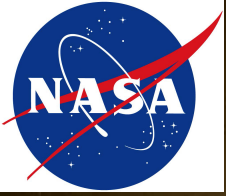




HIP Star 3 Spectral Energy Distribution

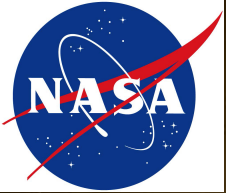
Caveat Emptor, Encore



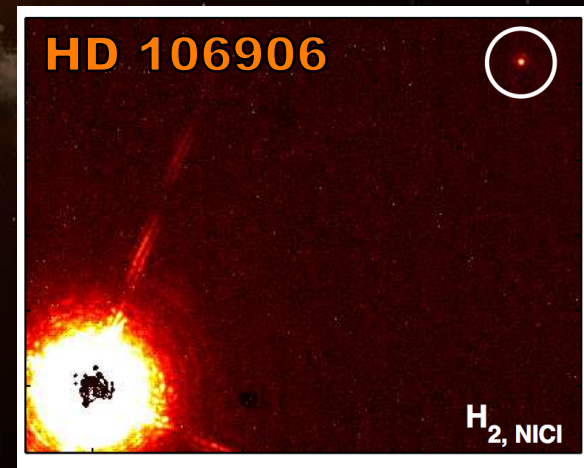
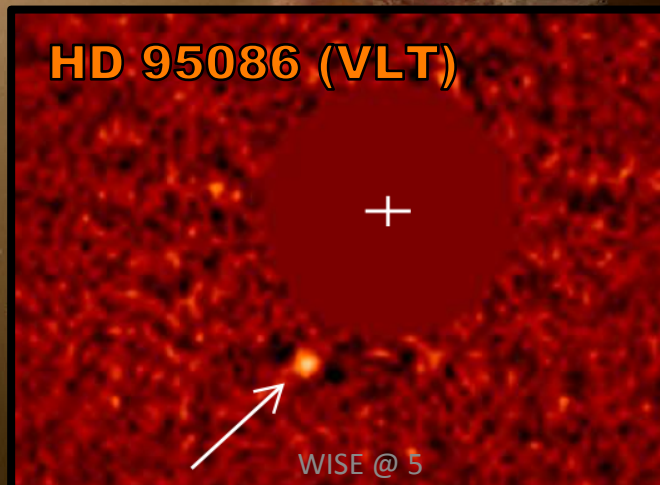
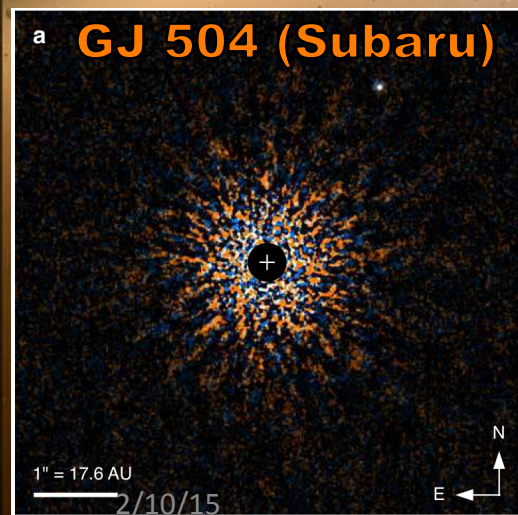
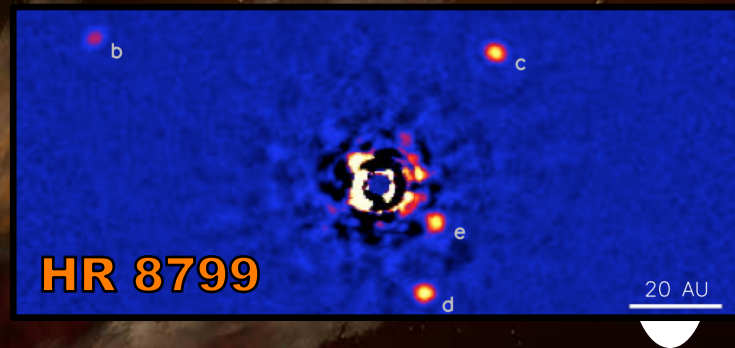
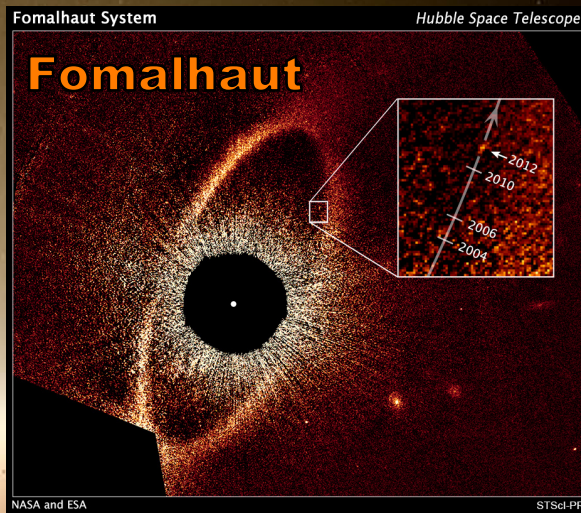
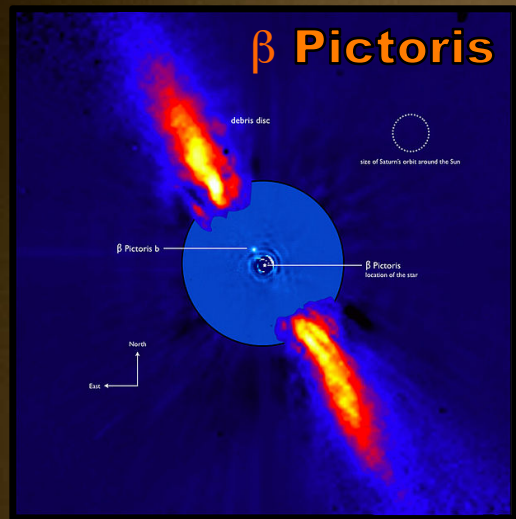


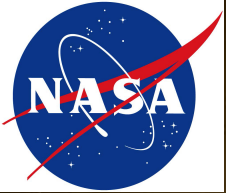
Rough Dust Temperatures

- Temperature estimates based on ratio of 22 μm to 70 μm excess emission
- Temperatures of dust range from 60 – 150 K
- Roughly equal numbers of “cold” < 80 K and “warm” > 100 K systems are found
- Sources with 12 μm excess appear to be younger than sample as a whole (Sco-Cen)
- Some sources show evidence of multiple temperature components in SED

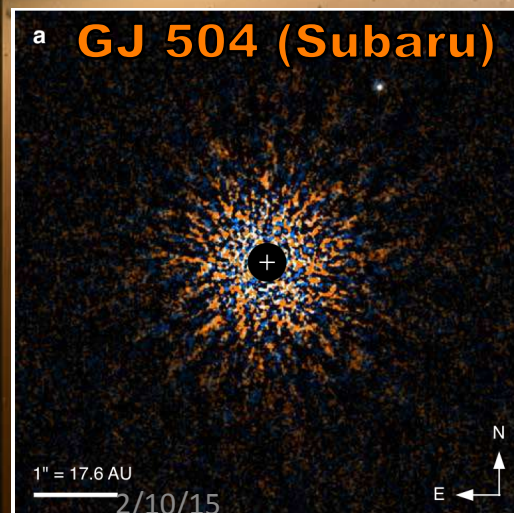
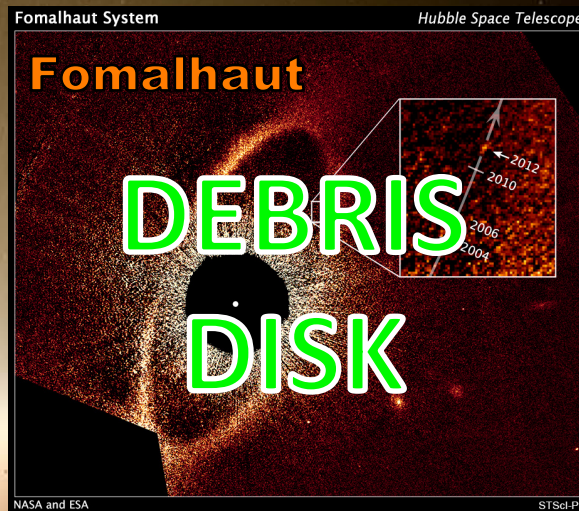
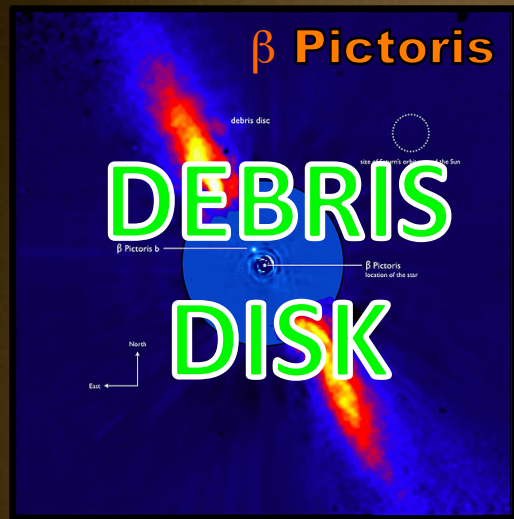


Exoplanet Imaging in 2014





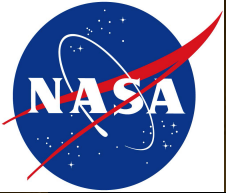
Exoplanet Imaging in 2014



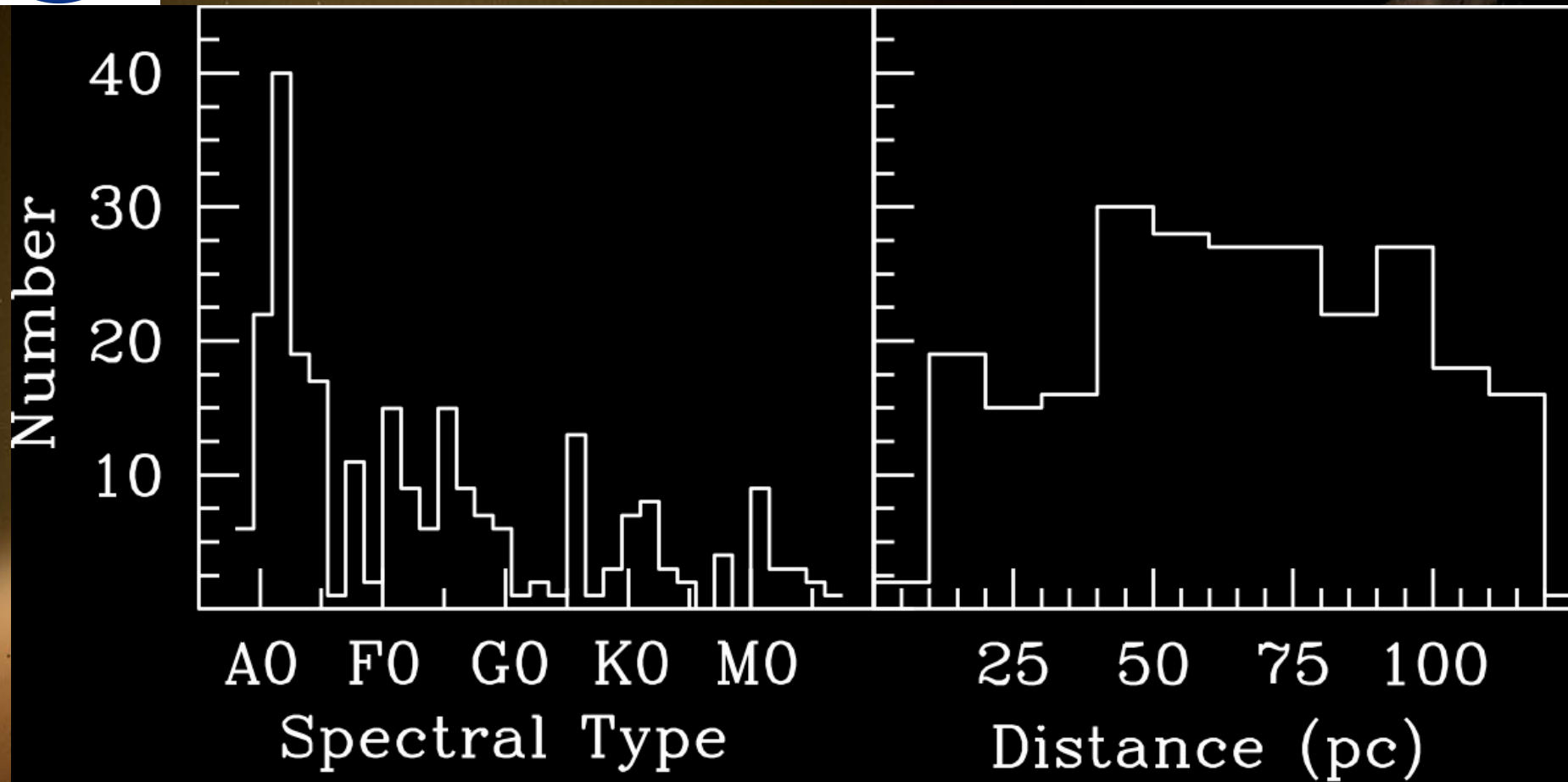


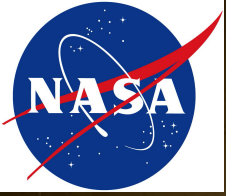
High Contrast Surveys for Exoplanets

Survey	Telescope	Number of Stars
GPI/SPHERE	Gemini-S, VLT	~600
SEEDS	Subaru	~300
This Survey	Keck/VLT	283
NICI	Gemini-S	218
IDPS	Gemini/VLT	~200
LEECH	LBT	135
NACO Large Program	VLT	86



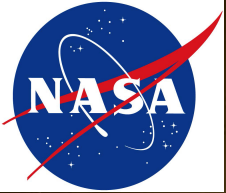
Survey Specifics



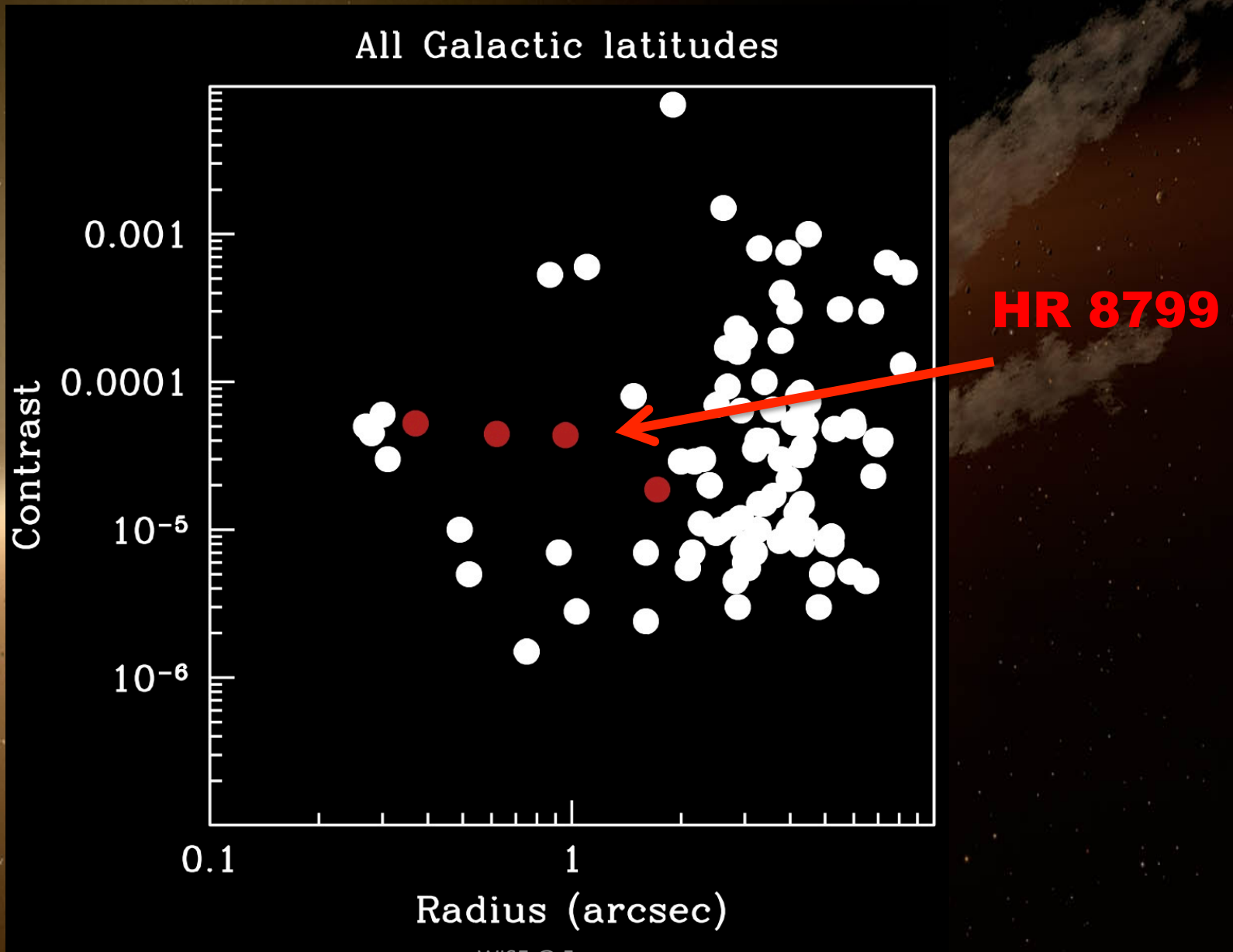


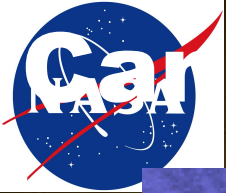
Candidate Companions

**103 Candidate Companions to Date
Common proper motion establishing
followup is ongoing (last run a week
a week ago at Keck!**

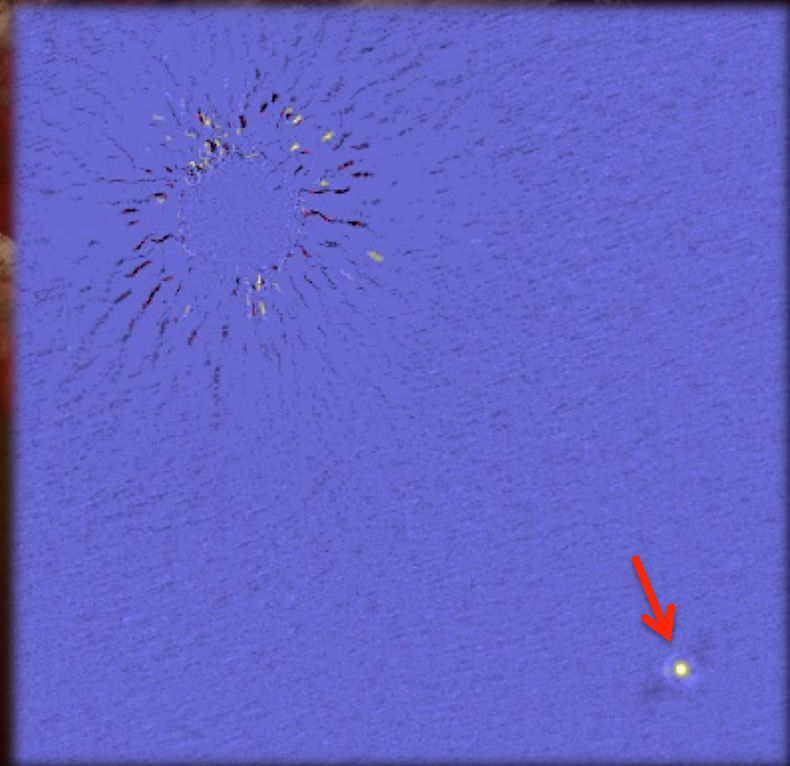
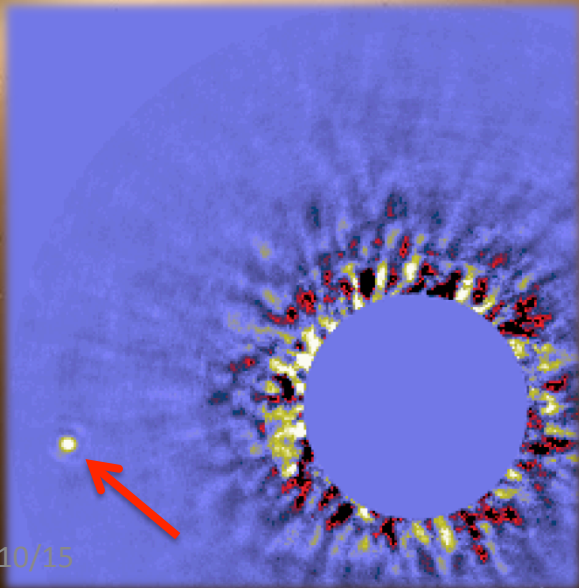
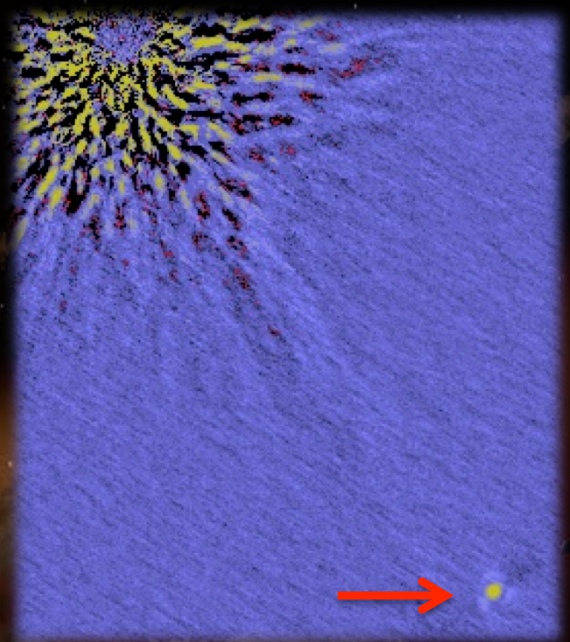
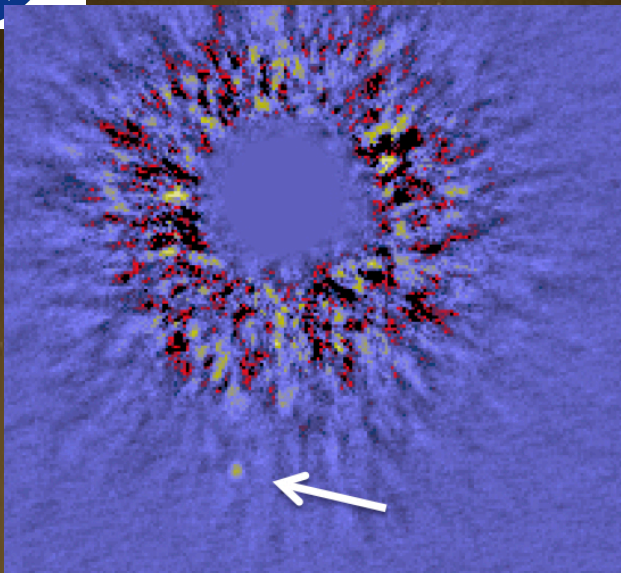


Candidate Companions



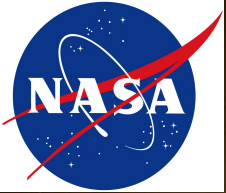


Candidates from Keck

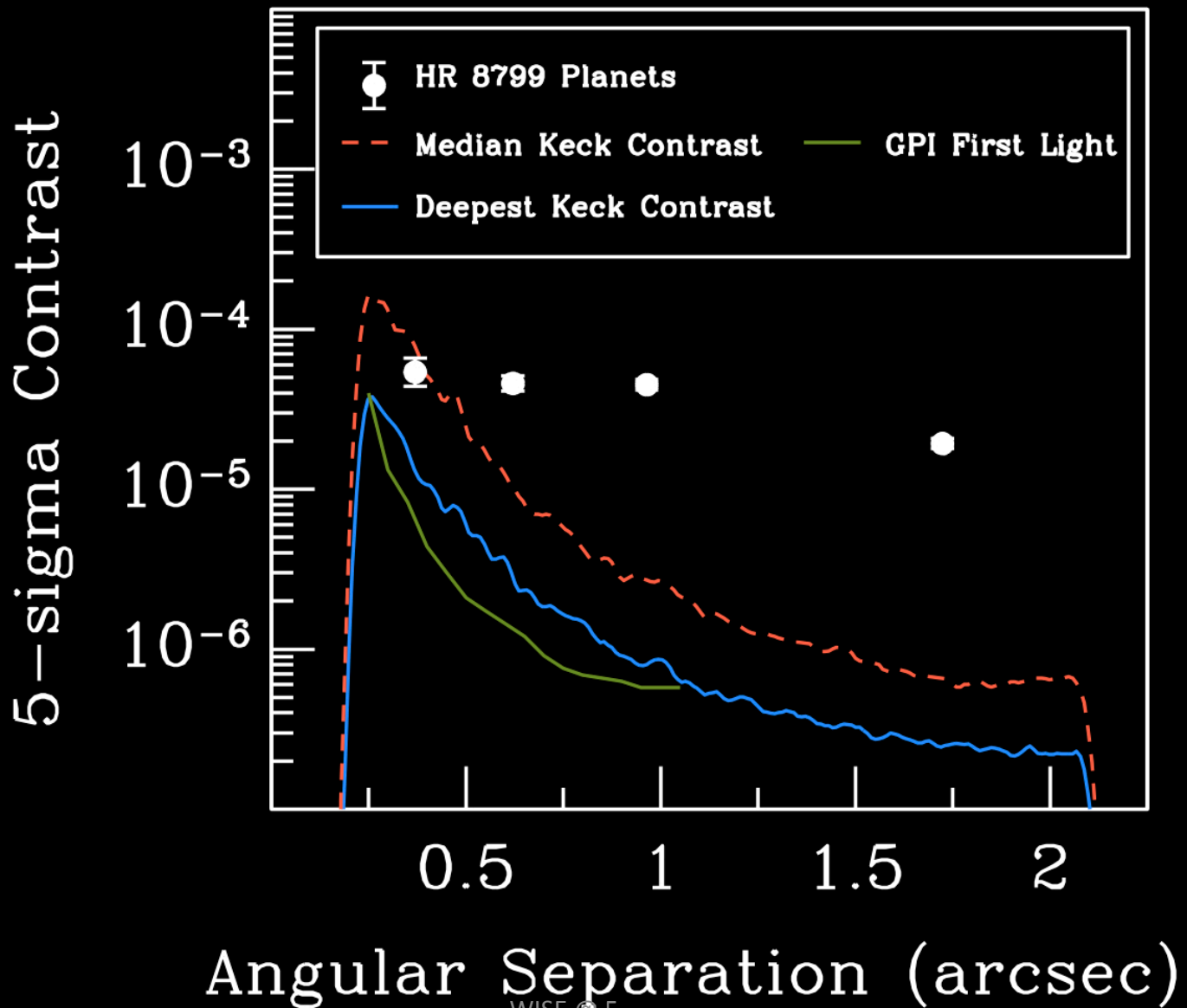


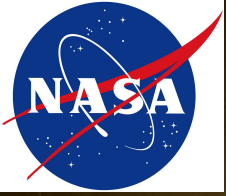
2/10/15

WISE @ 5



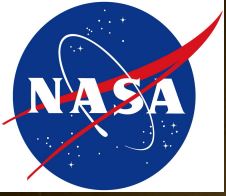
Survey Performance





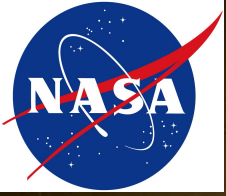
HST Coronagraphy of WISE Debris Disk Candidates

- Fractional IR Luminosity $> 10^{-4}$
- Proximity (< 120 pc, preference for < 50 pc)
- Robust warm WISE and cold Herschel or IRAS excess
- STIS coronagraph, 2 rolls each; clear filter (optical light), 0.05 arcsec pixels

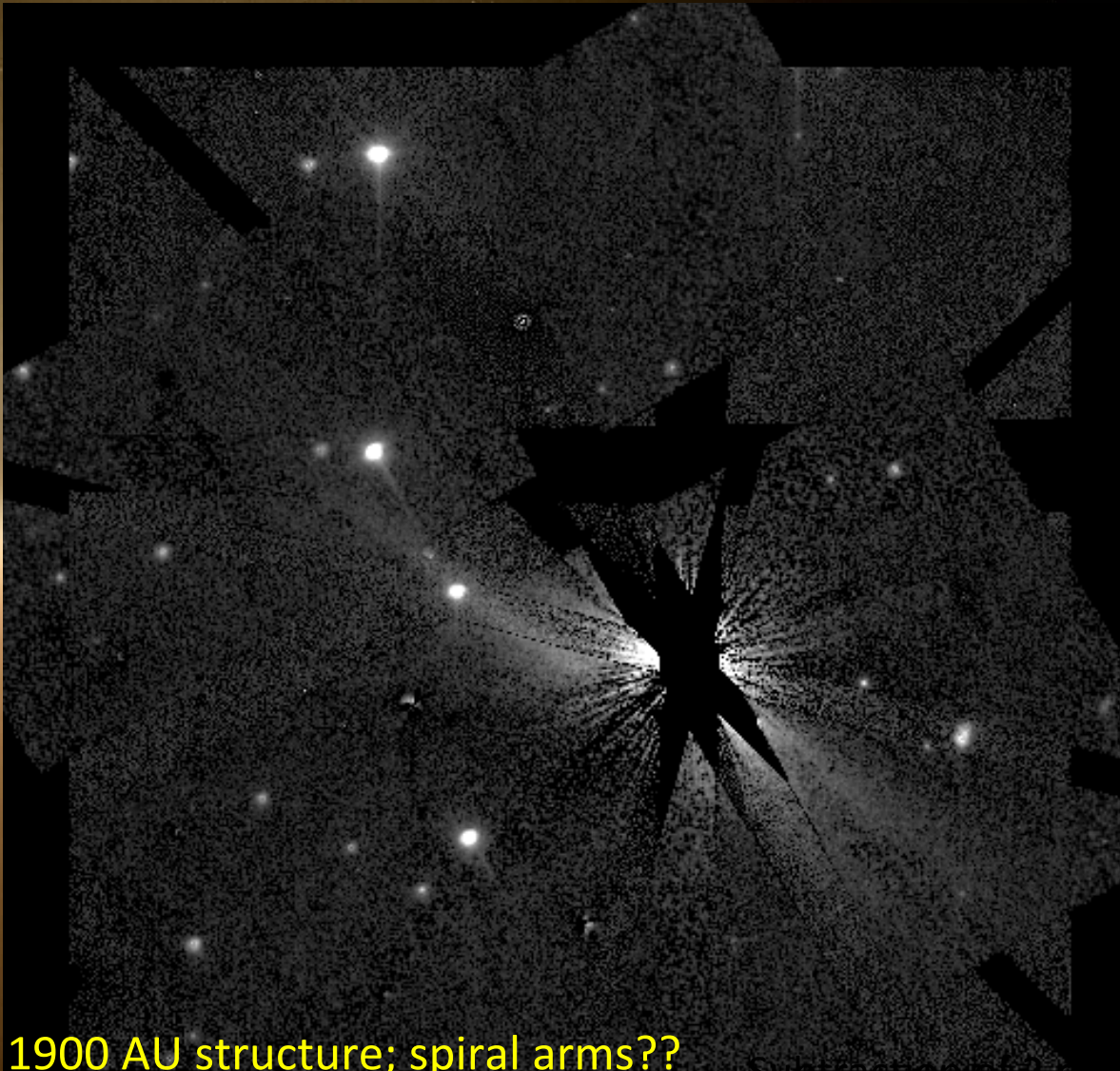


Summary for HST Follow-up

- STIS Coronagraph imaging of 22 μm excess stars identified by WISE
- 13 stars, 26 orbits
- Some contaminants and photometry issues
- Yield of $\sim 40\%$ nebulosity detection high compared to previous HST debris disk imaging programs (10%)



Disk or Nebula?

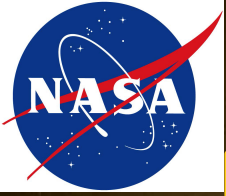


1900 AU structure; spiral arms??

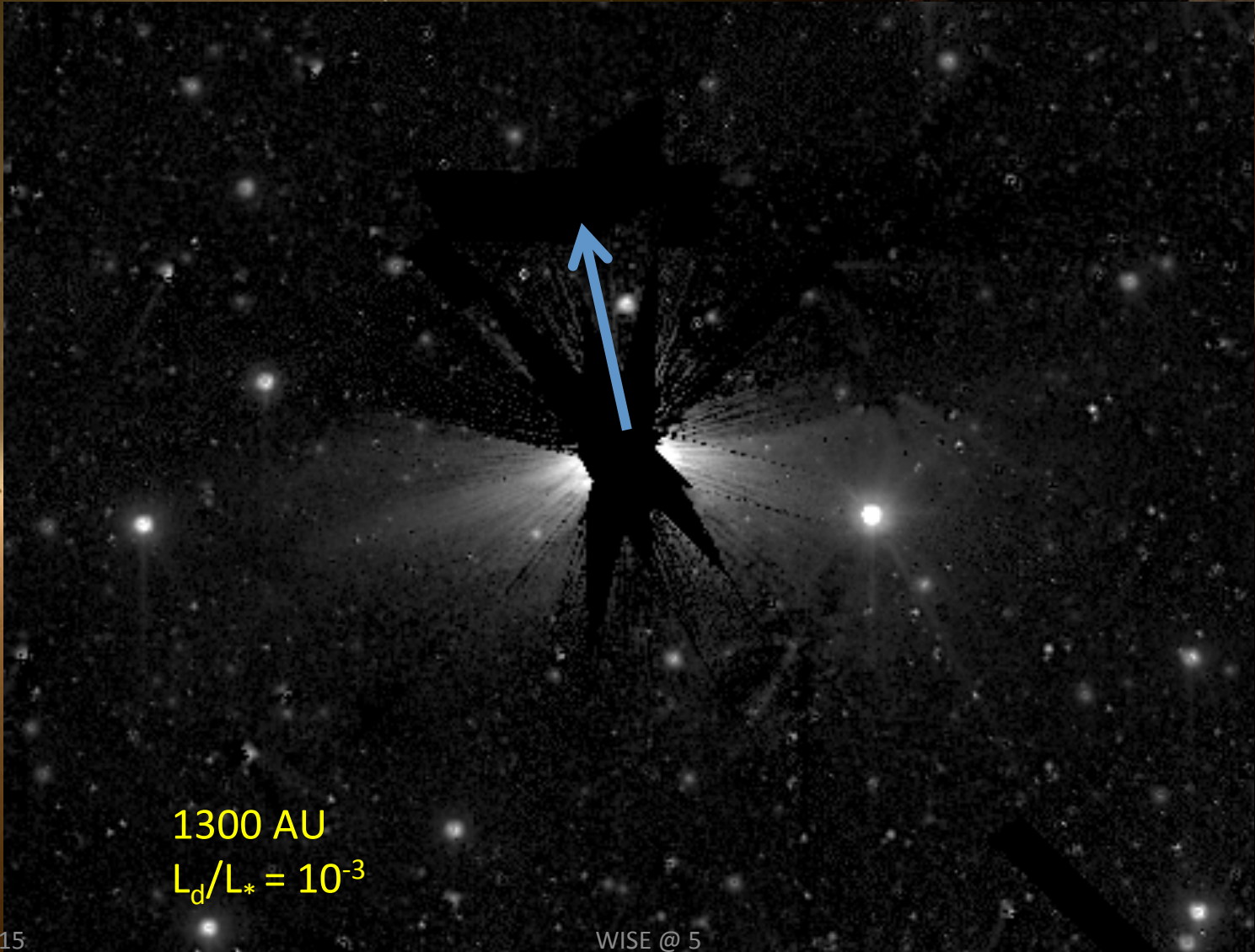
$$L_d/L_* = 10^{-3}$$

WISE @ 5

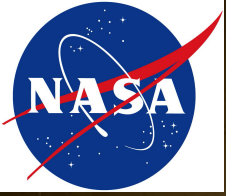
2/10/15



Disk Distorted by Ram Pressure



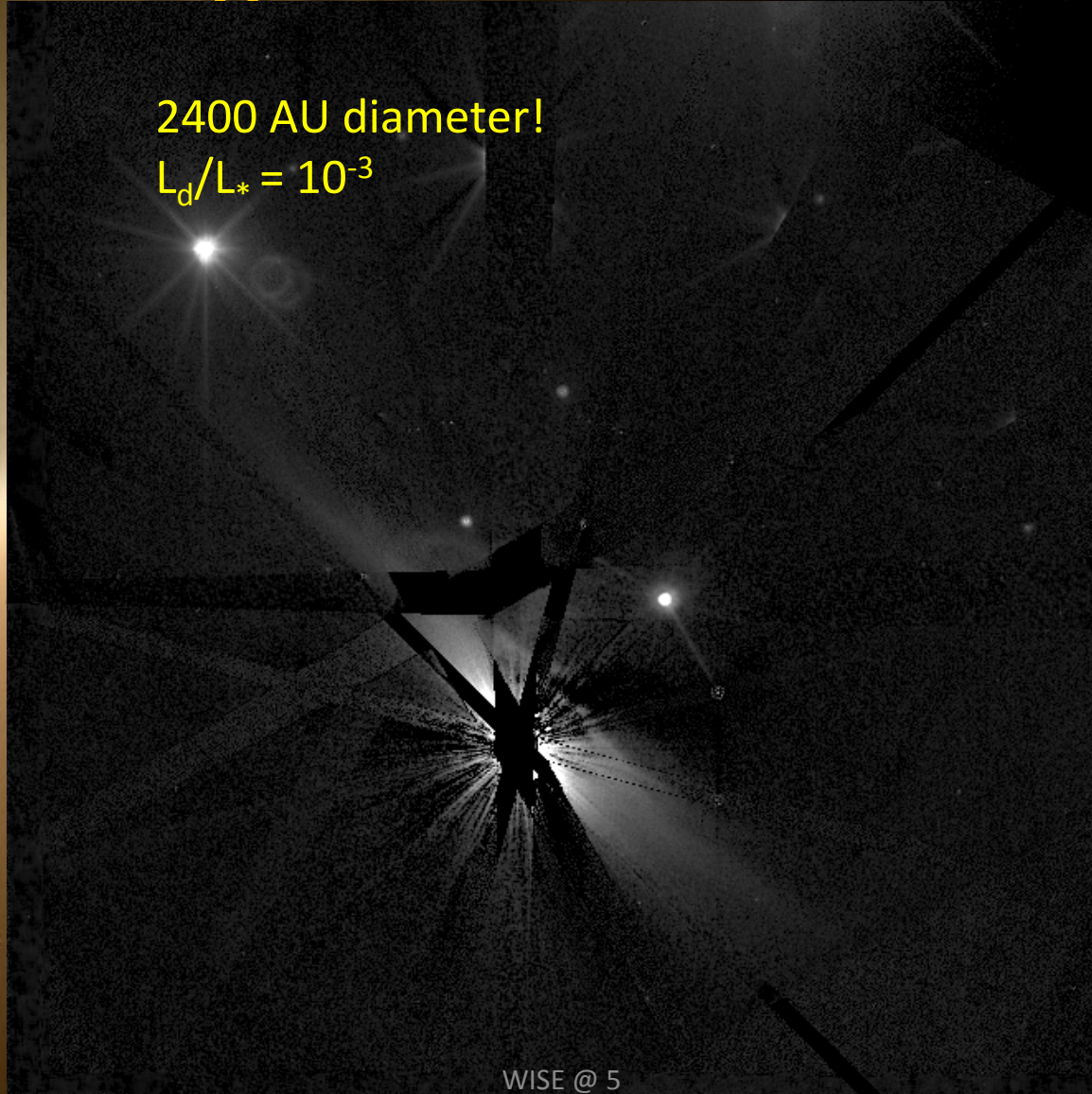
1300 AU
 $L_d/L_* = 10^{-3}$

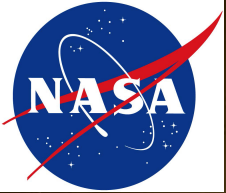


Big Disk or Nebula?

2400 AU diameter!

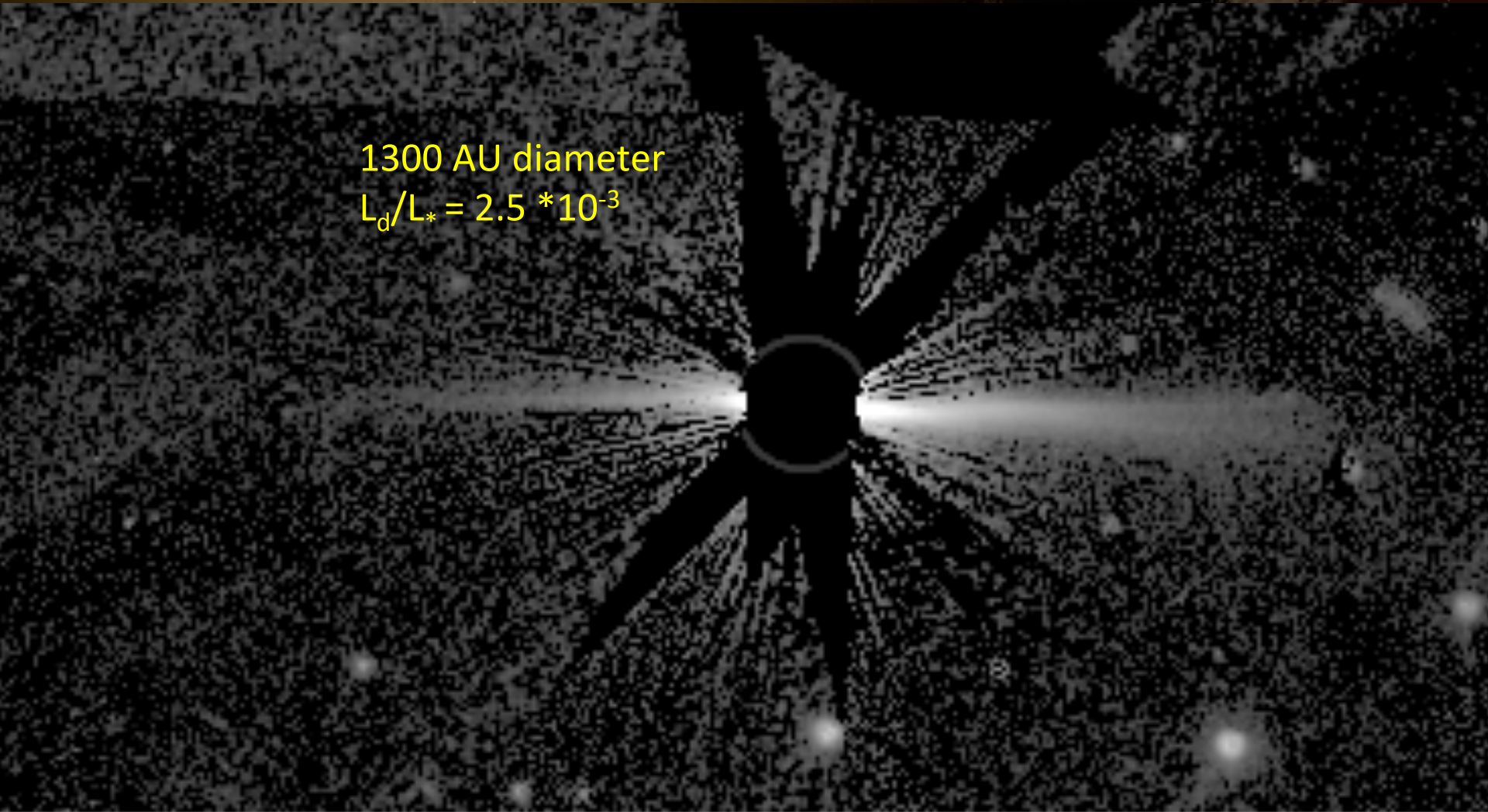
$$L_d/L_* = 10^{-3}$$

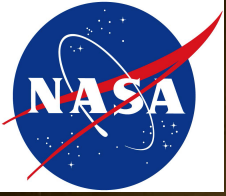




Beta Pictoris (or HD 15115) Clone

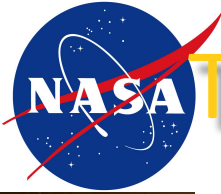
1300 AU diameter
 $L_d/L_* = 2.5 * 10^{-3}$



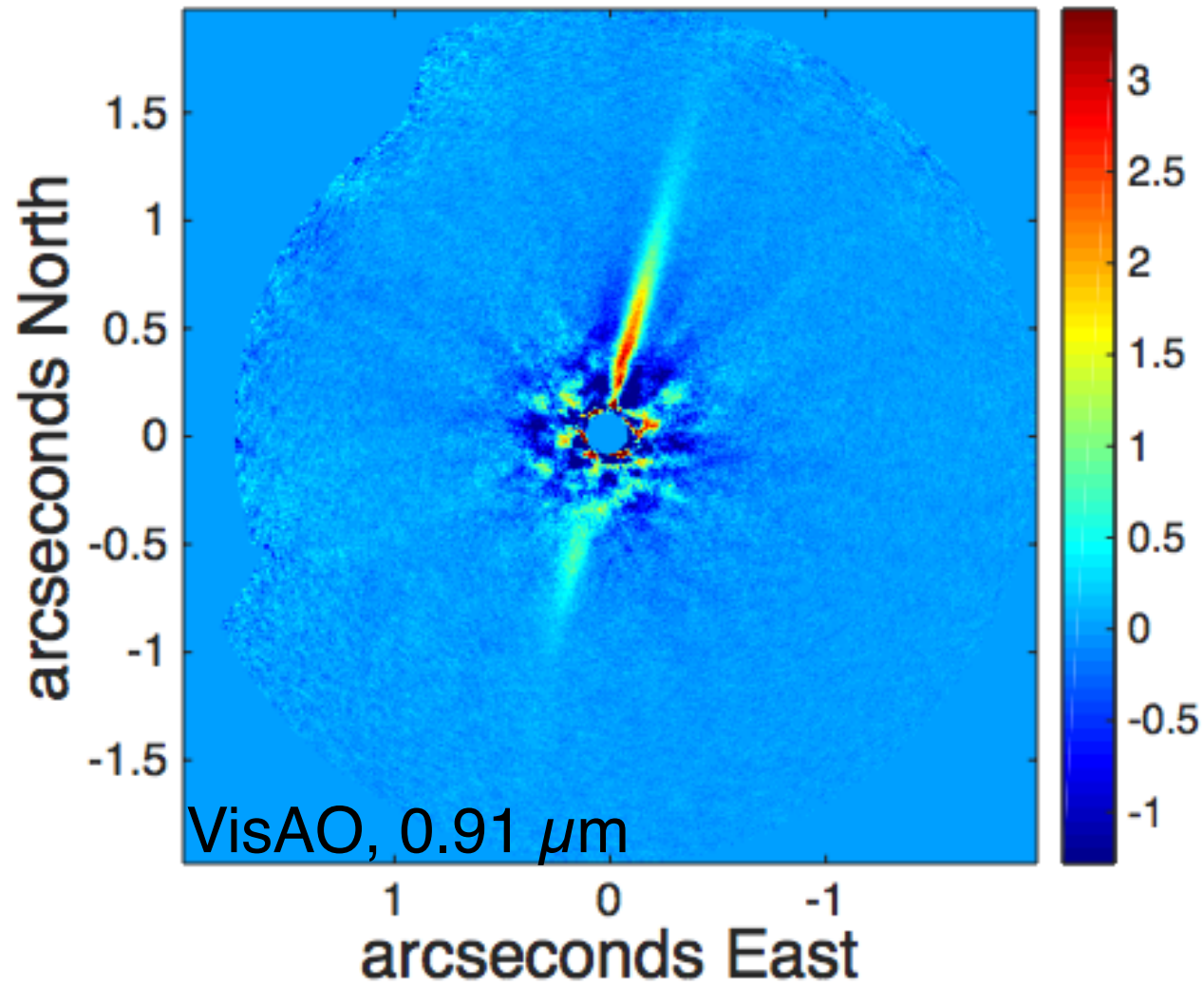


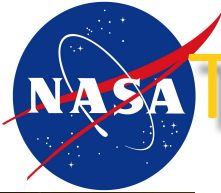
Bifurcation and Warp in Disk



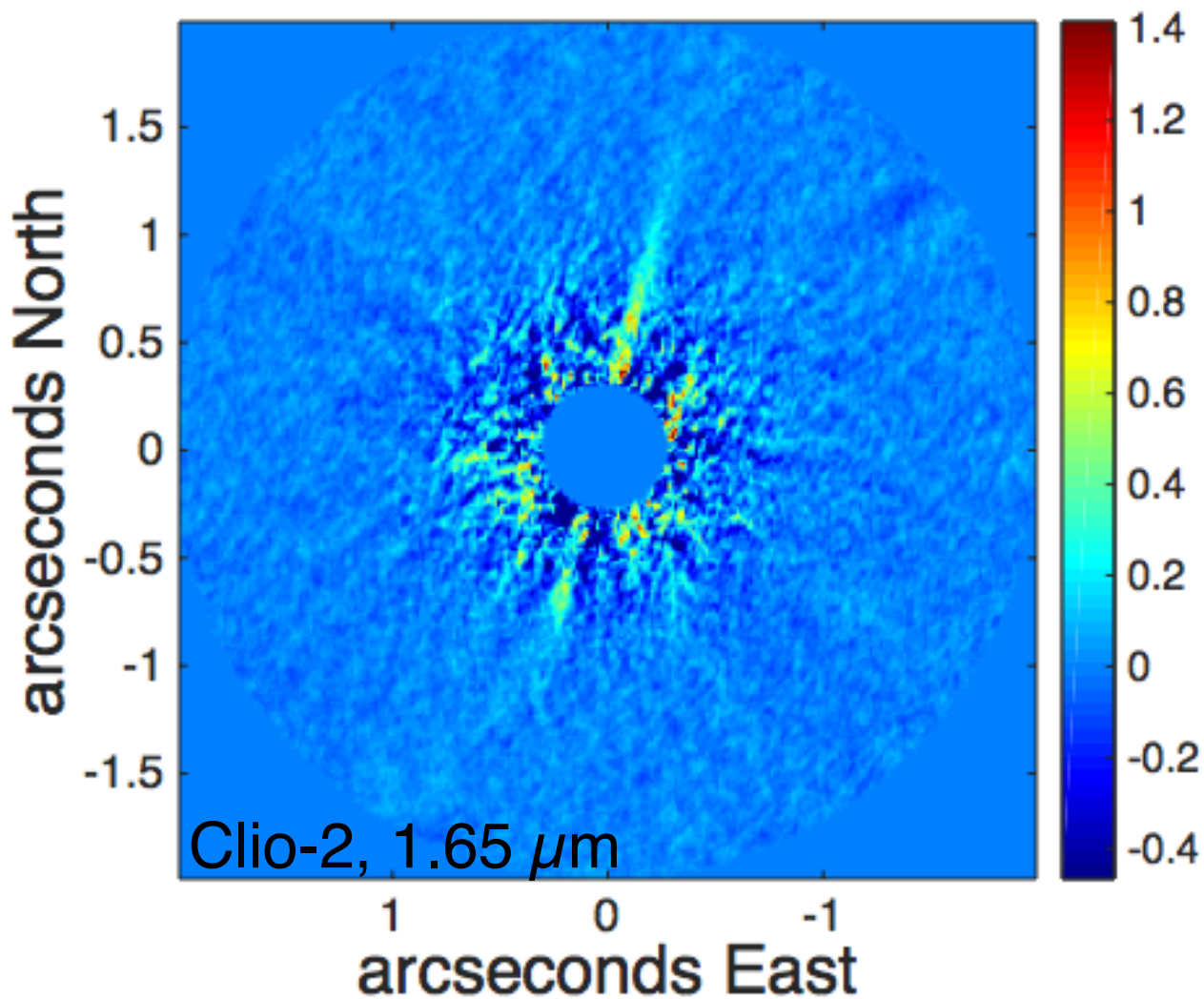


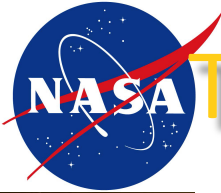
The "New Needle" imaged by MagAO



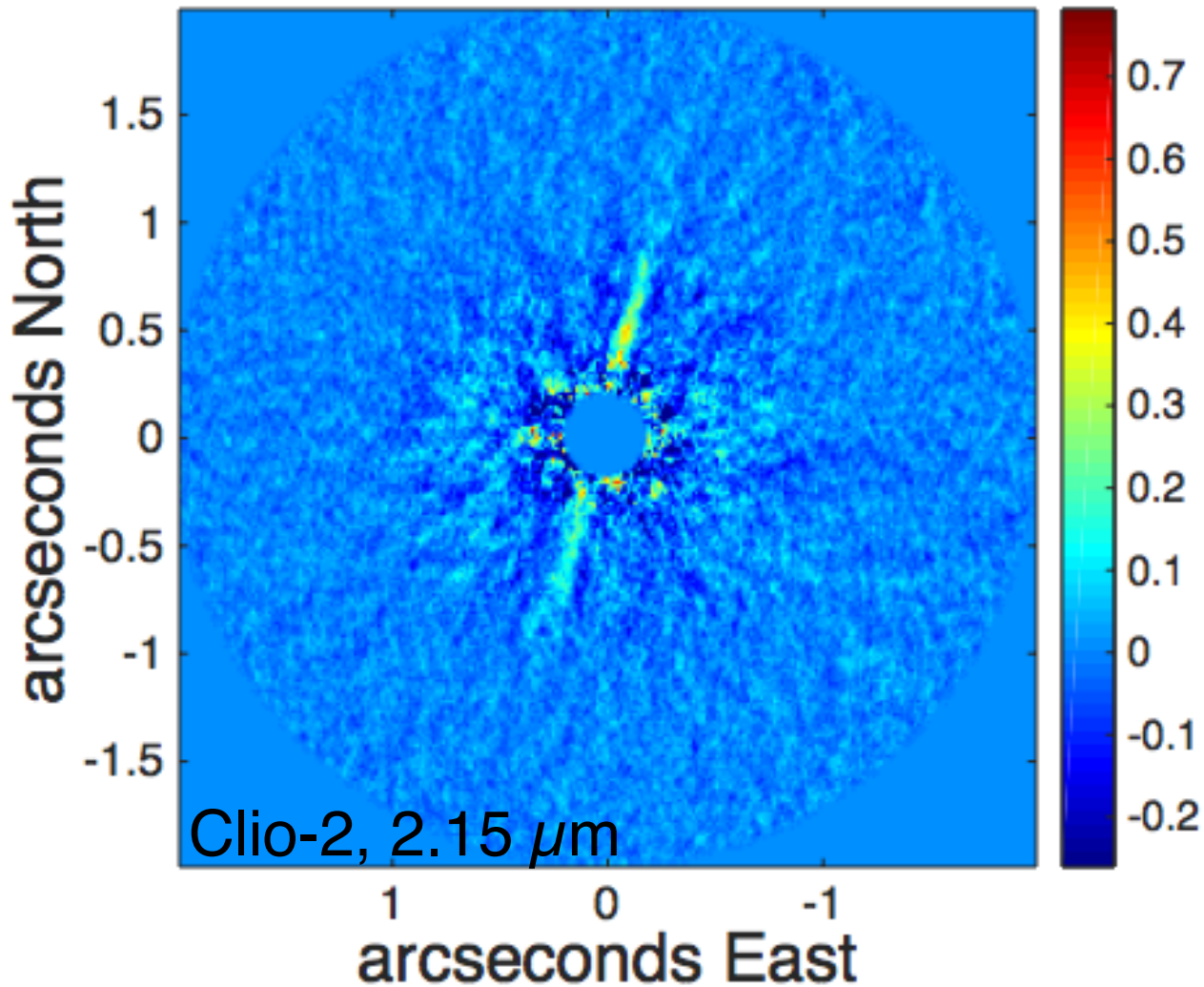


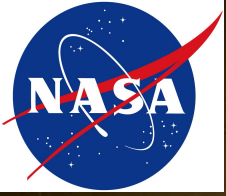
The "New Needle" imaged by MagAO





The "New Needle" imaged by MagAO





Summary

- Comparison of the WISE and Hipparcos catalogs have yielded several hundred new candidate mid-IR excess stars within 120 pc
- These are most likely debris disks, although some contaminants remain in the sample
- 22 μm excess is most common around A stars and is rare around solar types
- Stars with 12 μm excess appear to be younger than the sample as a whole
- We have observed subsamples of these WISE/HIP stars with a variety of facilities to characterize stellar, dust, and companion properties