Warm Debris Disks with WISE and Herschel

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and the WISE Science Team

Project Overview

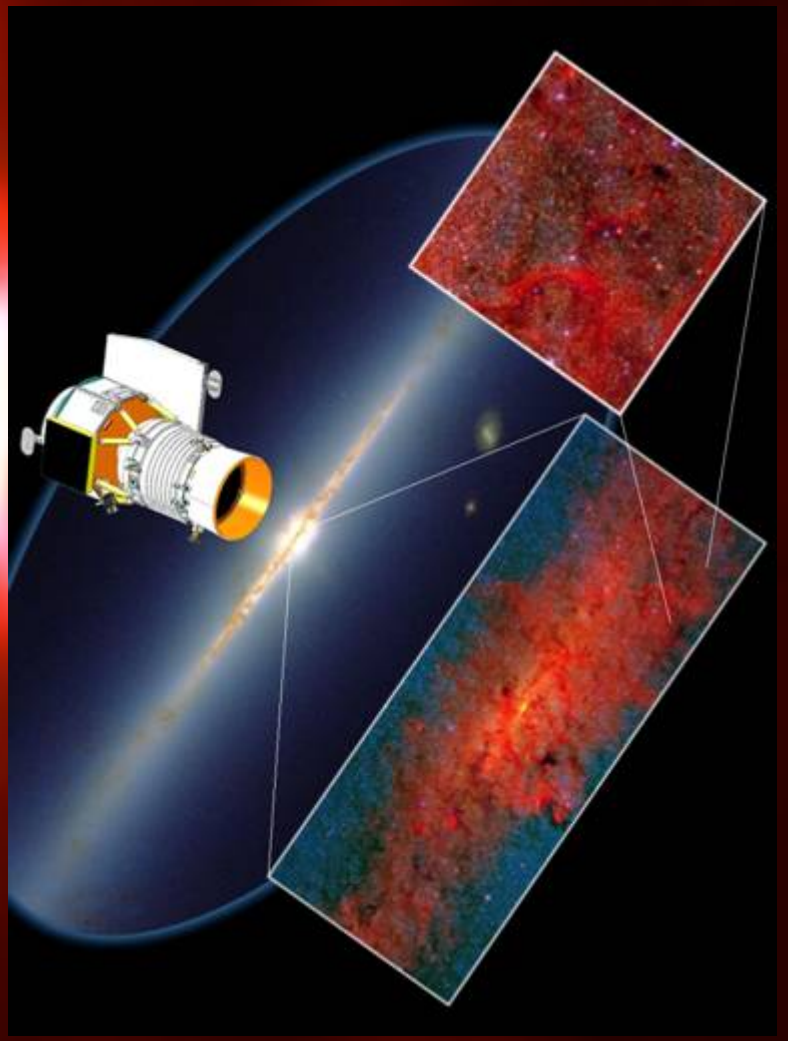
Wide Field Infrared Survey Explorer

Science

- *Sensitive all sky survey with 8X redundancy*
  - *Find the most luminous galaxies in the universe*
  - *Find the closest stars to the sun*
  - *Provide an important catalog for JWST*
  - *Provide lasting research legacy*

Salient Features

- *4 imaging channels covering 3 - 25 microns wavelength*
- *40 cm telescope operating at <17K*
- *Two stage solid hydrogen cryostat*
- *Delta launch from WTR: 14 Dec 2009*
- *Sun-synchronous 6am 530km orbit*
- *Scan mirror provides efficient mapping*
- *Expected life: 10 months, actual 7.7-9.5*
- *4 TDRSS tracks per day*



WISE Summary

- Launched 14 Dec 2009
- Band centers 3.4, 4.6, 12 & 22 microns
- Sensitivity better than 0.08, 0.11, 1 & 6 mJy
- Saturation at 0.3, 0.5, 0.7 & 10 Jy point sources
- Angular Resolution 6, 6, 6 & 12 arc-seconds
- Position accuracy about 0.15 arc-seconds 1σ 1-axis for high SNR
- Completed all-sky survey 17 July, big tank ran out hydrogen 5 Aug, little tank empty on 29 Sep, two-band survey for asteroids continued until 1 Feb 2011.
- Data releases:
  - 57% of the sky was released on April 2011
  - All-sky release was last week - 14 March 2012!
- Data products include image atlas and source catalog

http://irsa.ipac.caltech.edu/Missions/wise.html

DIRBE 3.5 microns

IRAS 12 microns

WISE

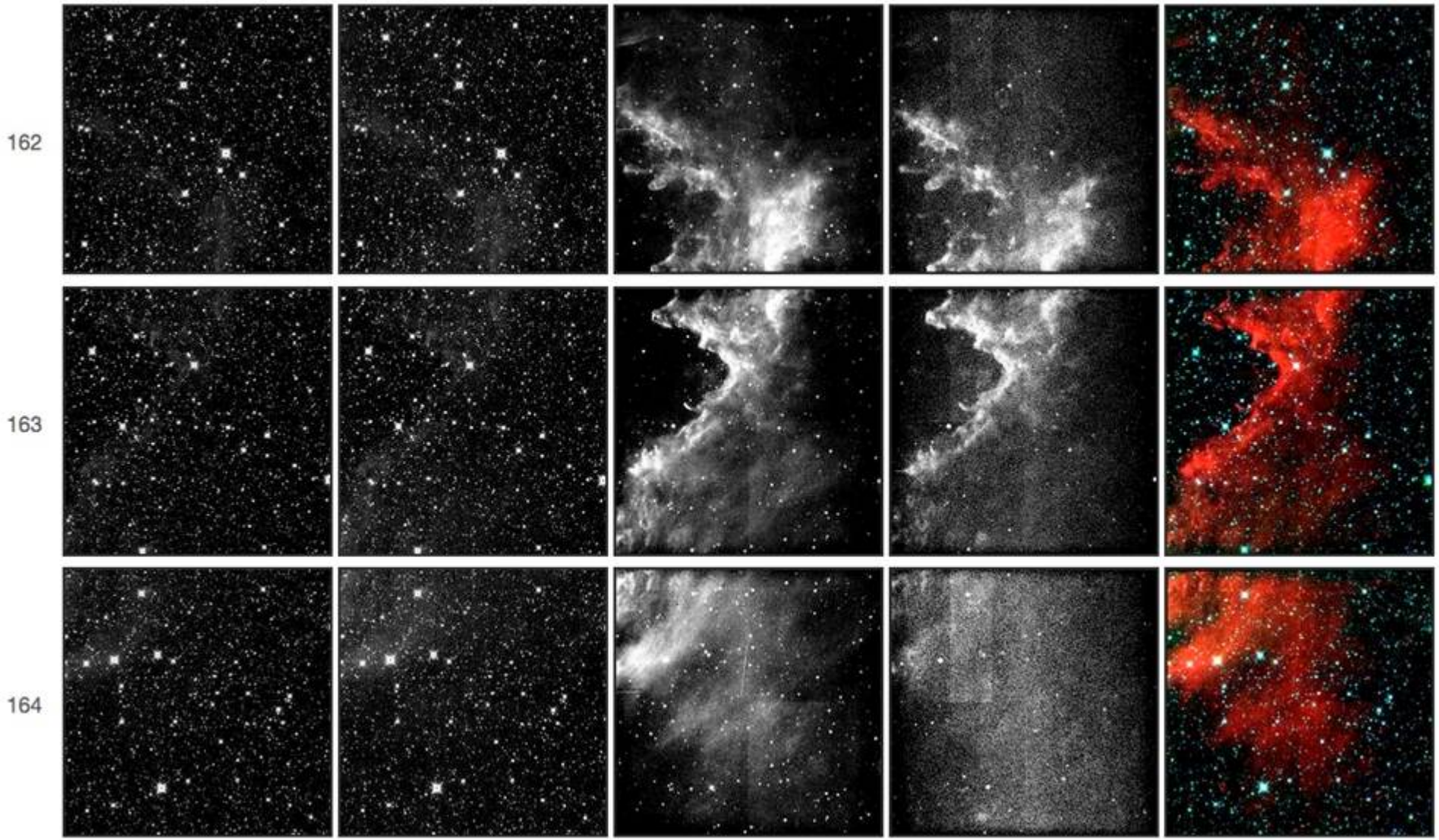
3.4, 4.6, 12 microns

47’ FOV

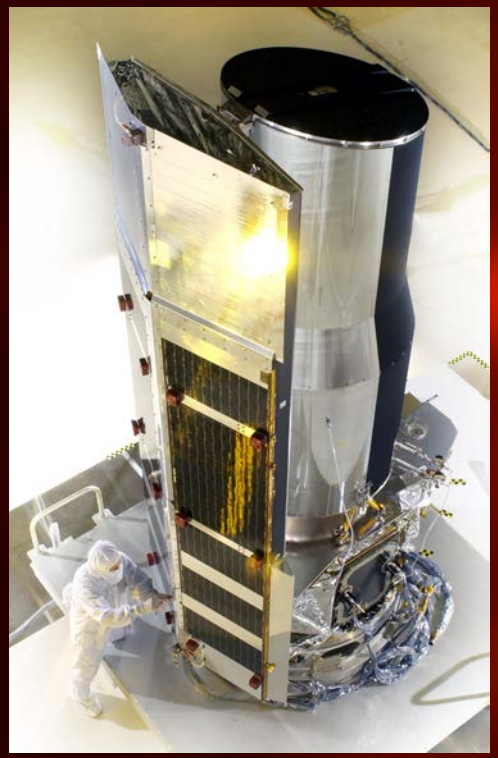
2.75” pixels

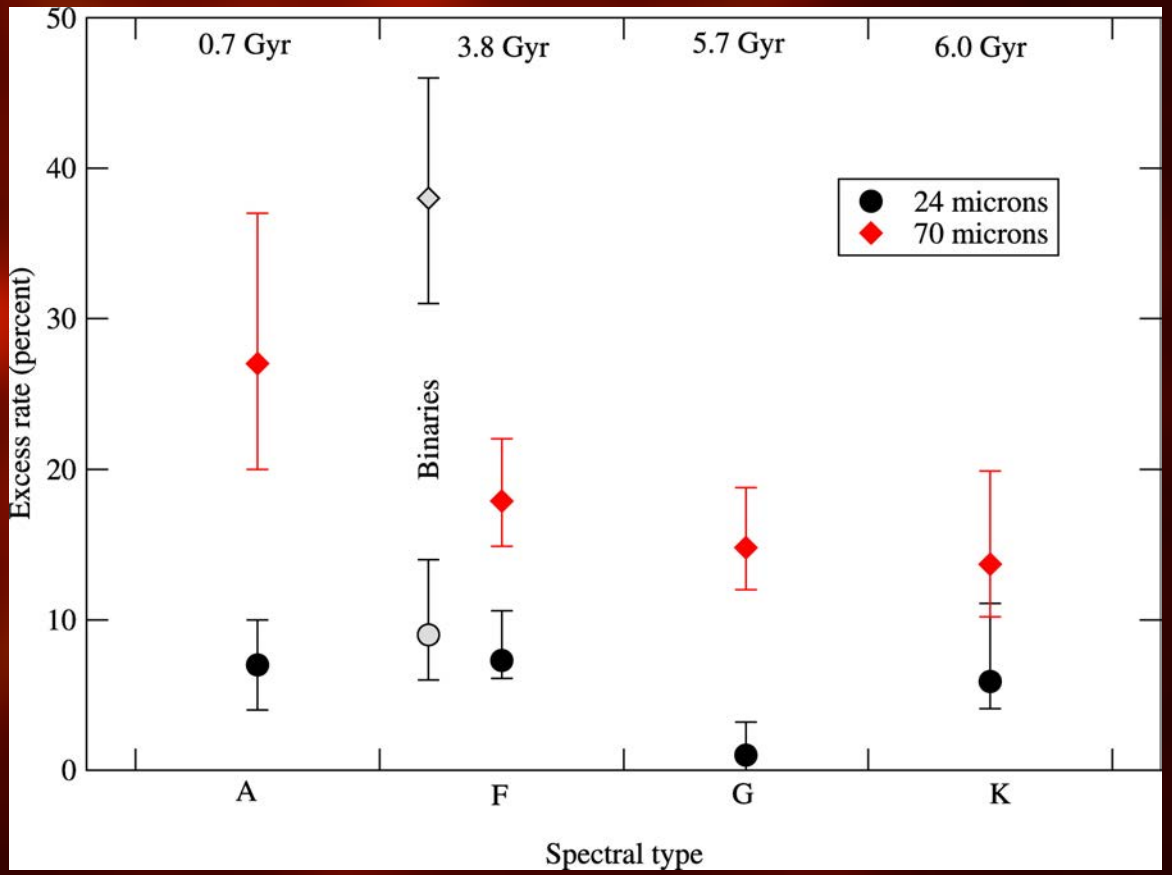
6” FWHM

33 seconds in the life of WISE: 3 of >7000 frames/day



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





WISE Debris Disk Survey Goals

- *Spitzer* showed that 24 μm excess was rare among solar –type main sequence stars - all sky survey can complete inventory of these objects; WISE 100x more sensitive than IRAS
- 22 μm excess more common at young ages – potential way to identify young field stars (and thus young planets)
- Find new strong-excess disks for high resolution follow-up imaging with HST, ALMA, etc.

WISE Debris Disk Survey Strategy

- Hipparcos/Tycho/Gliese catalogs correlated with All-sky survey (final WISE processing) – 25964 HIP matches
- Position search radius of 5″ (including proper motions)
- Distances out to 120 pc
- Spectral types B – M
- Candidates have W1-W4 > 25% greater than 4σ significance
- W1 > 3.5 to avoid worst saturation effects
- Every candidate has been examined in the WISE and 2MASS images for confusing sources and positional shifts in centroid from band to band; note problems and rejects

WISE Debris Disk Candidates

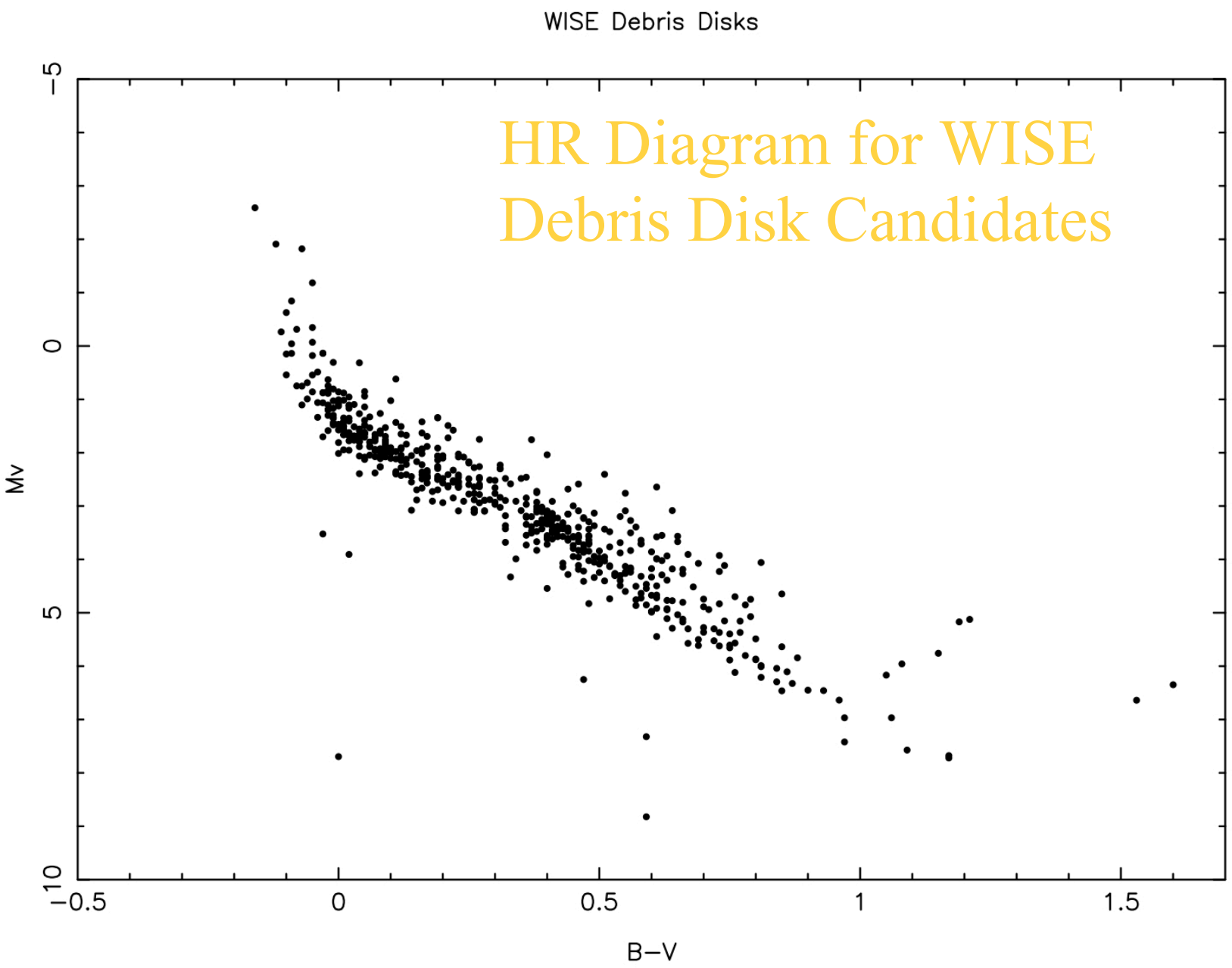
- 518 Hipparcos/WISE stars have apparent 22 micron excess > 4σ
- 348 are new (not previously determined to have excess in mid- to far-IR as of late 2011)
- 170 are previously known debris disk stars from IRAS, ISO, Spitzer, Akari
- Typical Hipparcos/WISE positional offset (WISE band 1) of 0.1-0.2”

Debris Disks in Hipparcos Stars, d < 120 pc

- B stars: 34 out of 282 — 12.1± 2.0 %
- A stars: 243 out of 2466 — 9.5 ± 0.6 %
- F stars: 163 out of 10757 — 1.5 ± 0.1 %
- G stars: 67 out of 7489 — 0.9 ± 0.1 %
- K stars: 11 out of 4477 — 0.2 ± 0.1 %
- M stars: 0 out of 493* — 0.0 ± 0.3 %

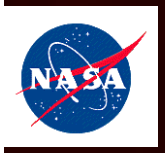
* Using colors. Photospheric fitting in progress


HR Diagram for WISE
Debris Disk Candidates


WISE Debris Disks
HR Diagram for WISE
Debris Disk Candidates
Mv
−5
0
5
10
−0.5
0
0.5
1
1.5
B−V

WISE 12 μm Excess Stars

- 66 Hipparcos/WISE stars within 120 pc with 12 micron excess
- Many are previously known PMS stars (few 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



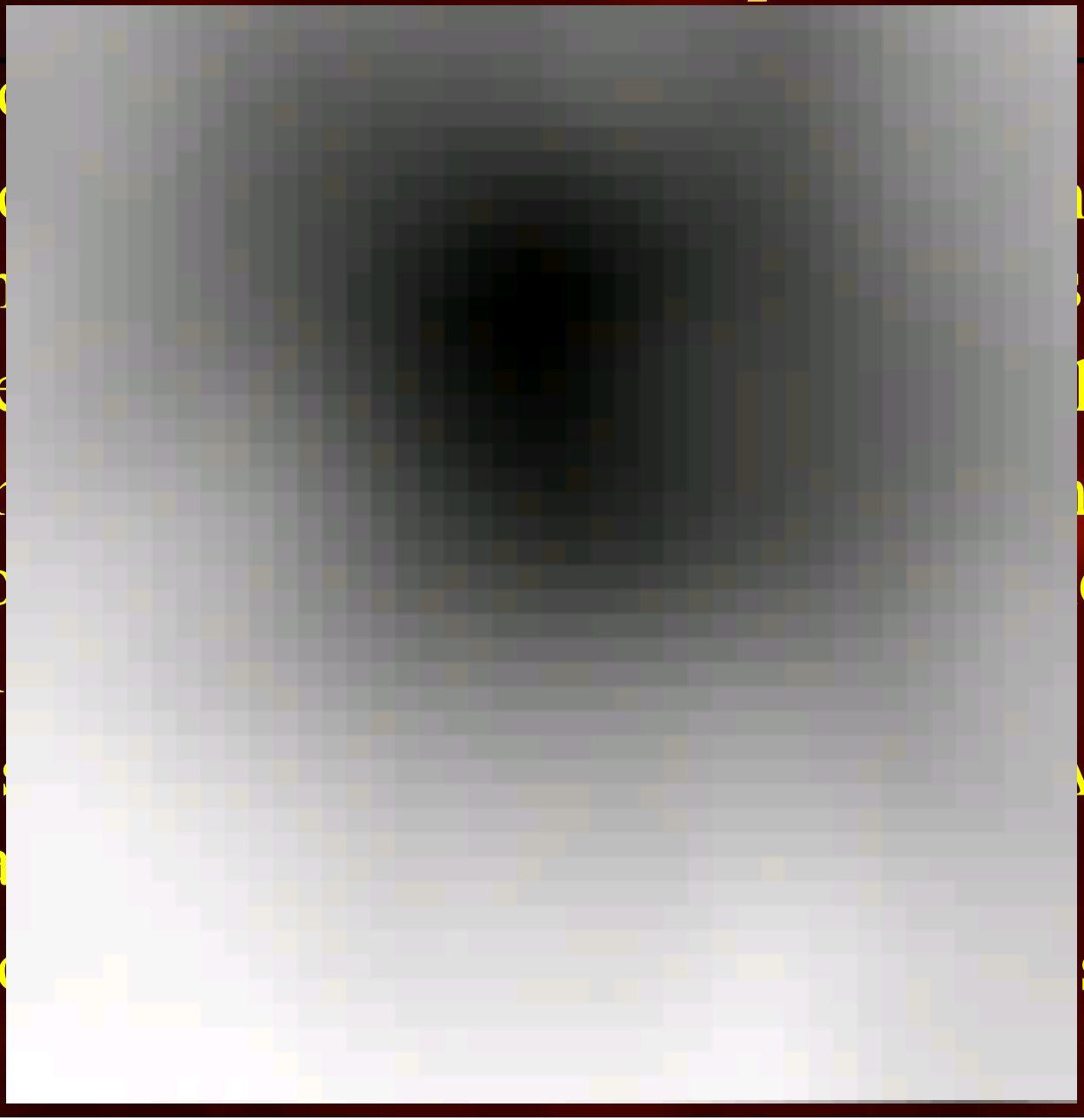
Caveat Emptor

- Confusion is big issue for fainter stars
- Confusion often suggested by positional shift of emission centroid at long wavelengths
- Very saturated W1 sources produce false excess
- Photometric contamination from bright 22 μm companions and diffuse background nebulosity may produce false excess sources
- Astrophysical mimics include bright AGN, PN, cataclysmic variables, K and M giants
- Bottom line – always check the images

Caveat Emptor

- C
- C al shift of
  en
- V lse excess
- Ph t 22 μm
  co ebulosity
  m
- A GN, PN,
  ca
- B s

Caveat Emptor



- C
- C al shift of
  en
- Ve lse excess
- Ph t 22 μm
  co ebulosity
  m
- A GN, PN,
  ca
- Bo s

WISE Debris Disk Hubble Follow-up

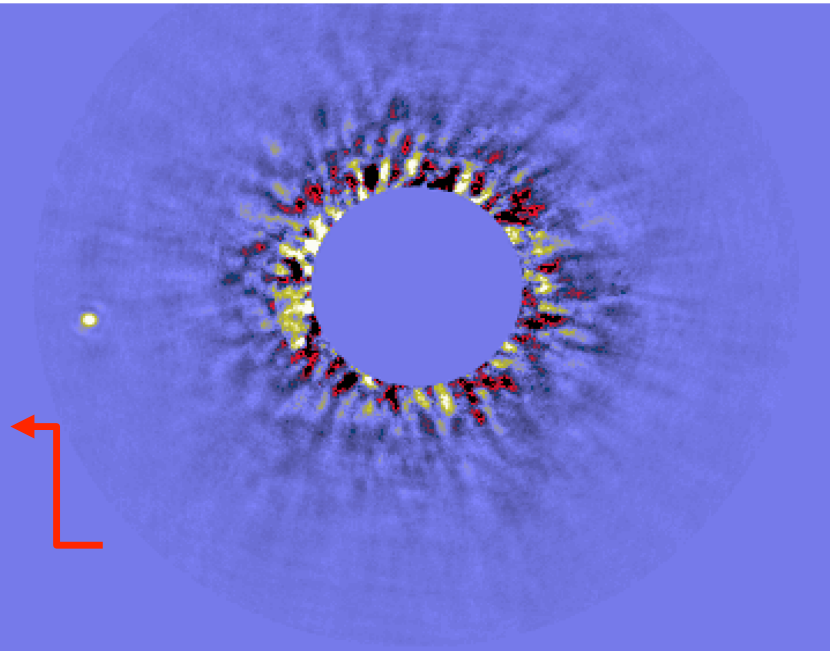
- Cycle 19 12 orbits approved on STIS for coronagraphic wedge imaging of 6 nearby WISE debris disk candidates
- Objective is to detect scattered light from cold dust disk in objects with newly detected warm dust IR excess
- Two objects observed to date

What we hope to see!

HST/STIS image of HD 141569 (IRAS/*Spitzer* disk)

Keck High Contrast Follow-up to WISE Debris Disk Sources

A-star with WISE 22 μm Excess



- **Excess at 22 mm indicates dynamical stirring & stellar youth.**
- **~40 A-stars with WISE 22 mm excess already observed (February, October 2011); Now need common proper motion to confirm candidates**
- **Three more Keck nights in June 2012 PI: Sasha Hinkley (Caltech)**

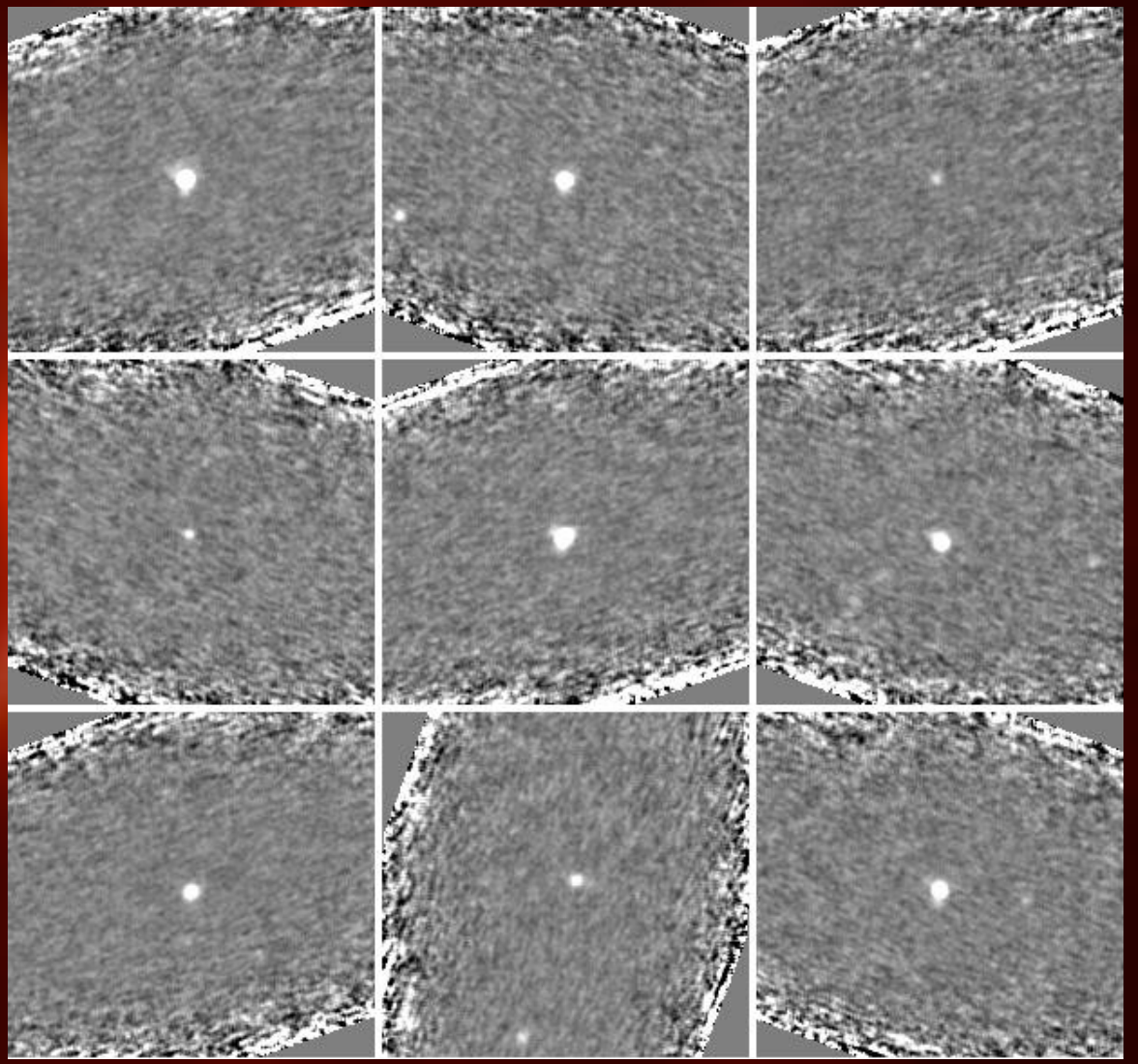
- **Data Analysis (speckle reduction) ongoing by Hinkley, Mawet (ESO)**
- **CPM Follow-up needed for any candidate companions**

Herschel/PACS Photometry of WISE Debris Disk Candidates

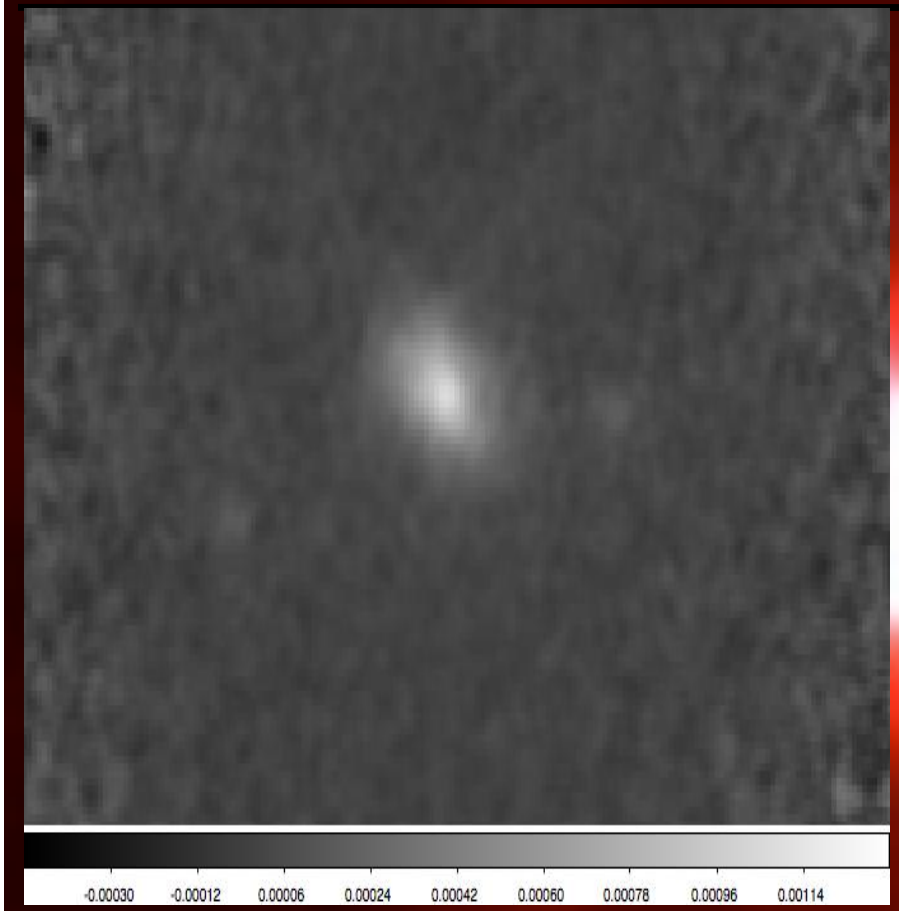
- For most of its debris disk candidates, WISE only gives a single photometric point for the excess
- Does this emission arise from
  - A warm inner belt in the terrestrial planet region (such as for HD 69830, BD+20 307) ?
  - Wien side of emission from cold/massive outer belt ?
- Full characterization of the detected disks requires *Herschel*
  - dust temperature
  - Fractional luminosity / total dust content

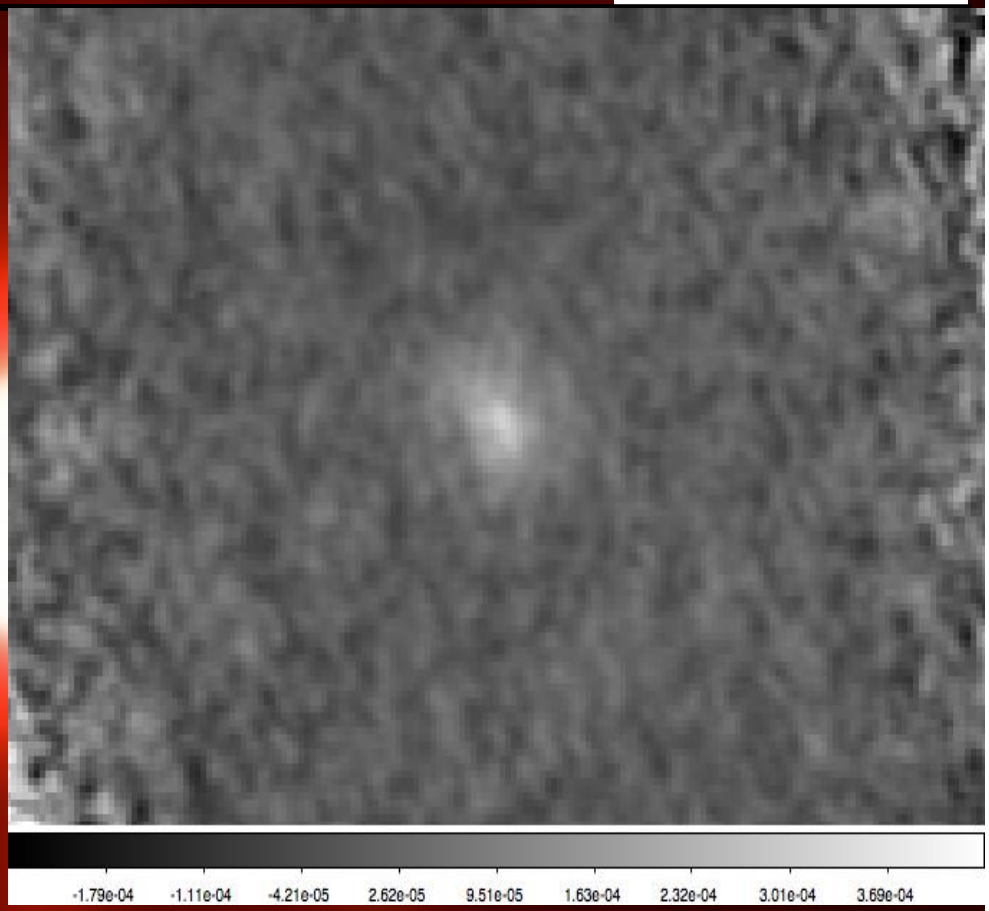
WISE Debris Disk Candidate Herschel Observations

- Herschel/PACS 70 & 160 micron imaging 99 new WISE 22 micron excess FGK stars
- 71/82 sources detected to date at 70 μm
- 36 detected at 160 μm



Resolved Sources

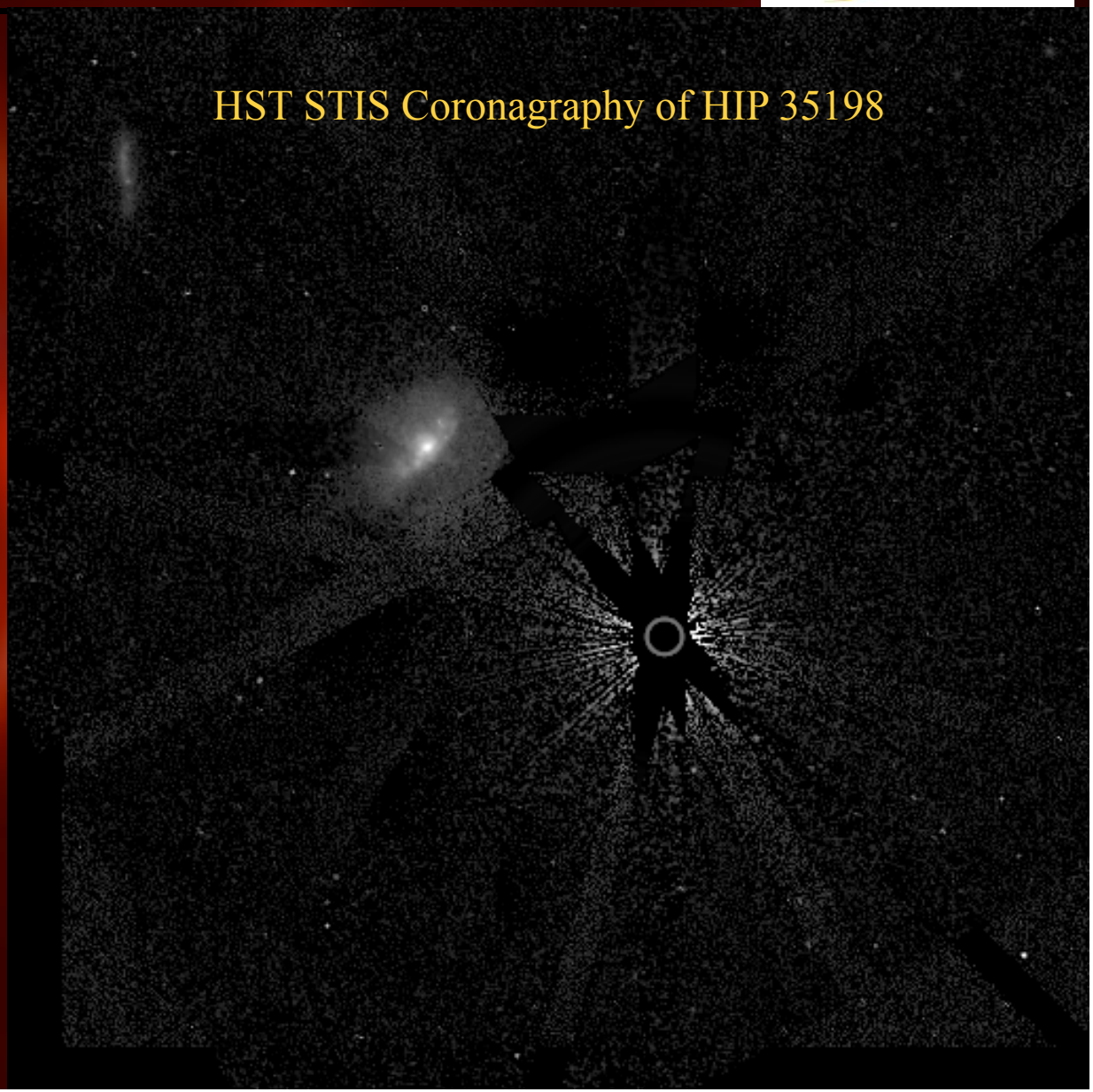




- 8 PACS detections in this class
- Disks or nearby heated ISM ?

Caveat Emptor, Encore

- HIP 35198 looks like an interesting cold disk
- However, the PACS images showed the 70 micron source is 8” from the star position
- This offset is hidden in the WISE data because the stellar photosphere still dominates at 22 μm
- 17 of our PACS 70μm detections are > 4” from the stellar position



HST STIS Coronagraphy of HIP 35198

Caveat Emptor, Encore

- HIP 35198 looks like
an interesti
- However,
images sho
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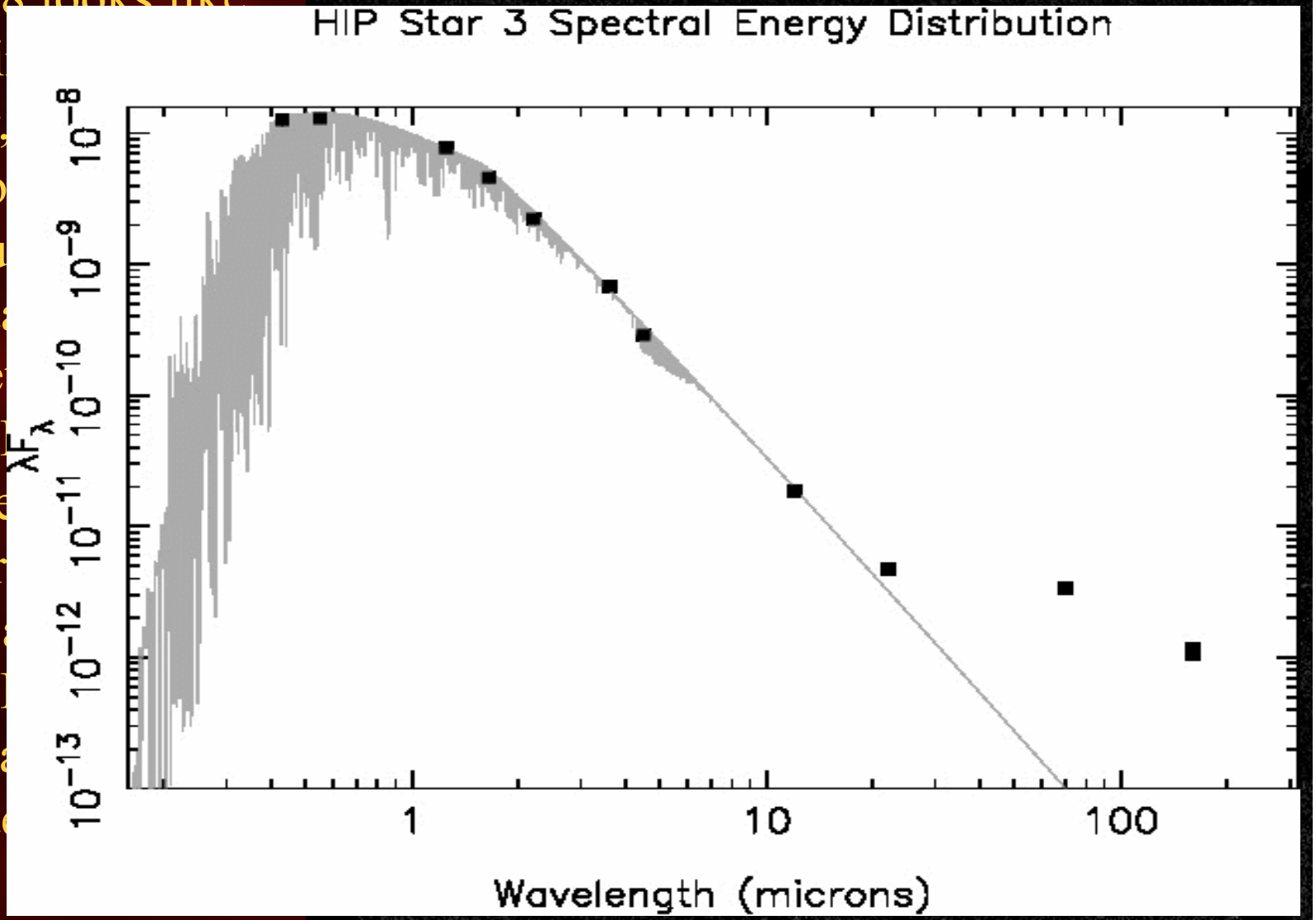
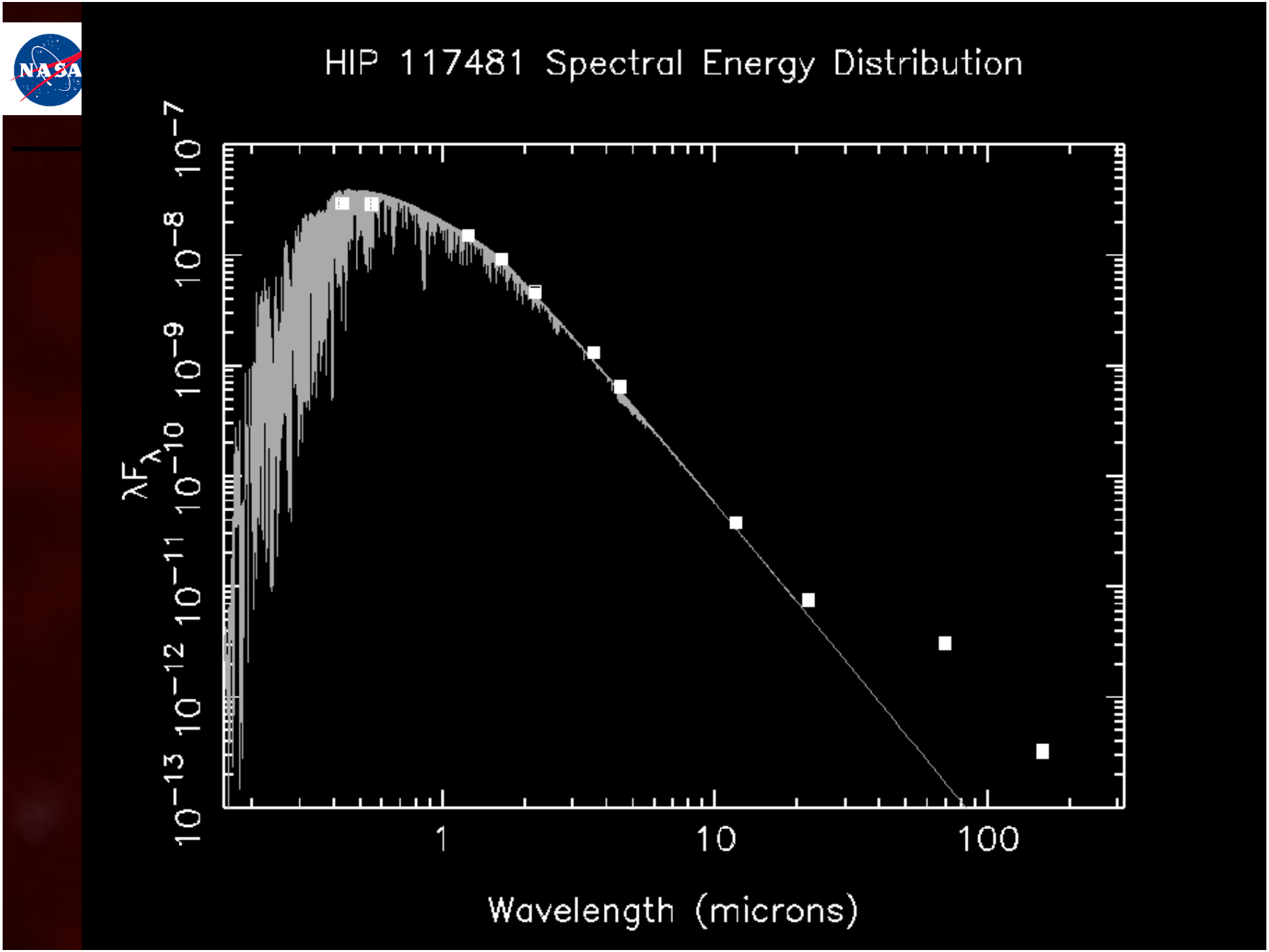
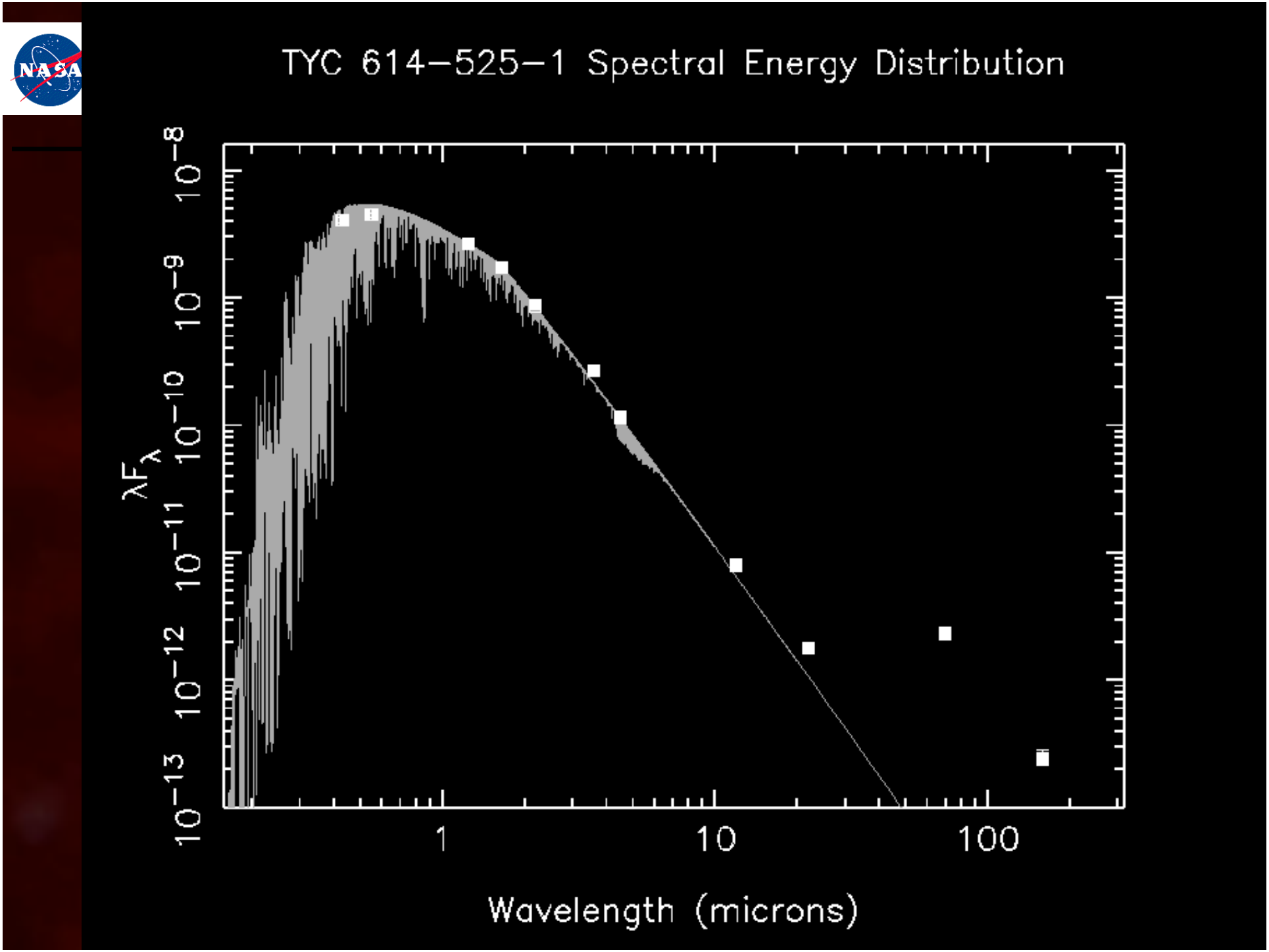
- This offse
in the WISE
because the
photospher
dominates
- 17 of our
detections
from the st
position




HIP 117481 Spectral Energy Distribution
λF_λ
10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7}
1
10
100
Wavelength (microns)


TYC 614−525−1 Spectral Energy Distribution
λF_λ
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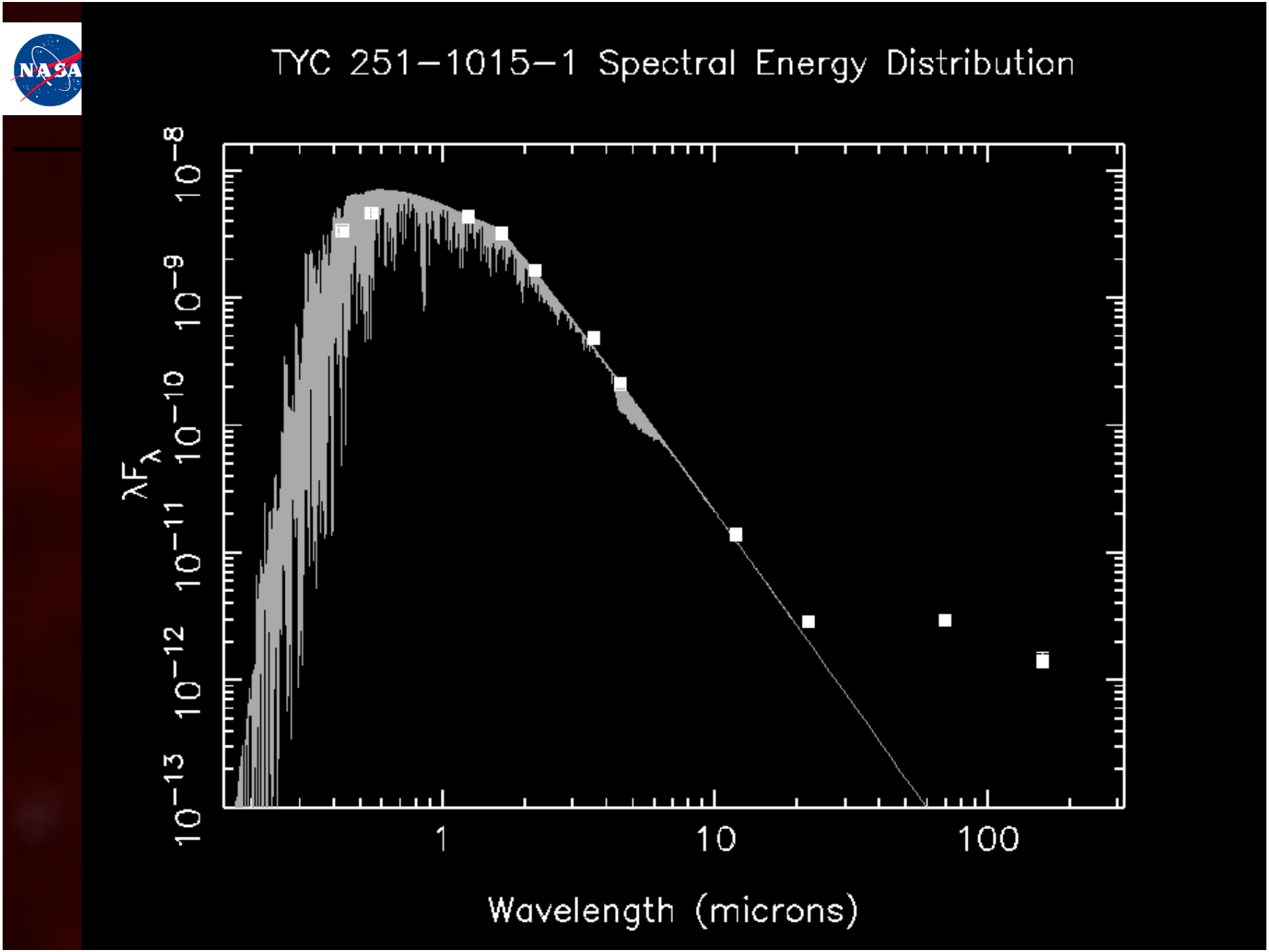
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


TYC 251−1015−1 Spectral Energy Distribution
λF_λ
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10^{-9}
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10^{-11}
10^{-12}
10^{-13}
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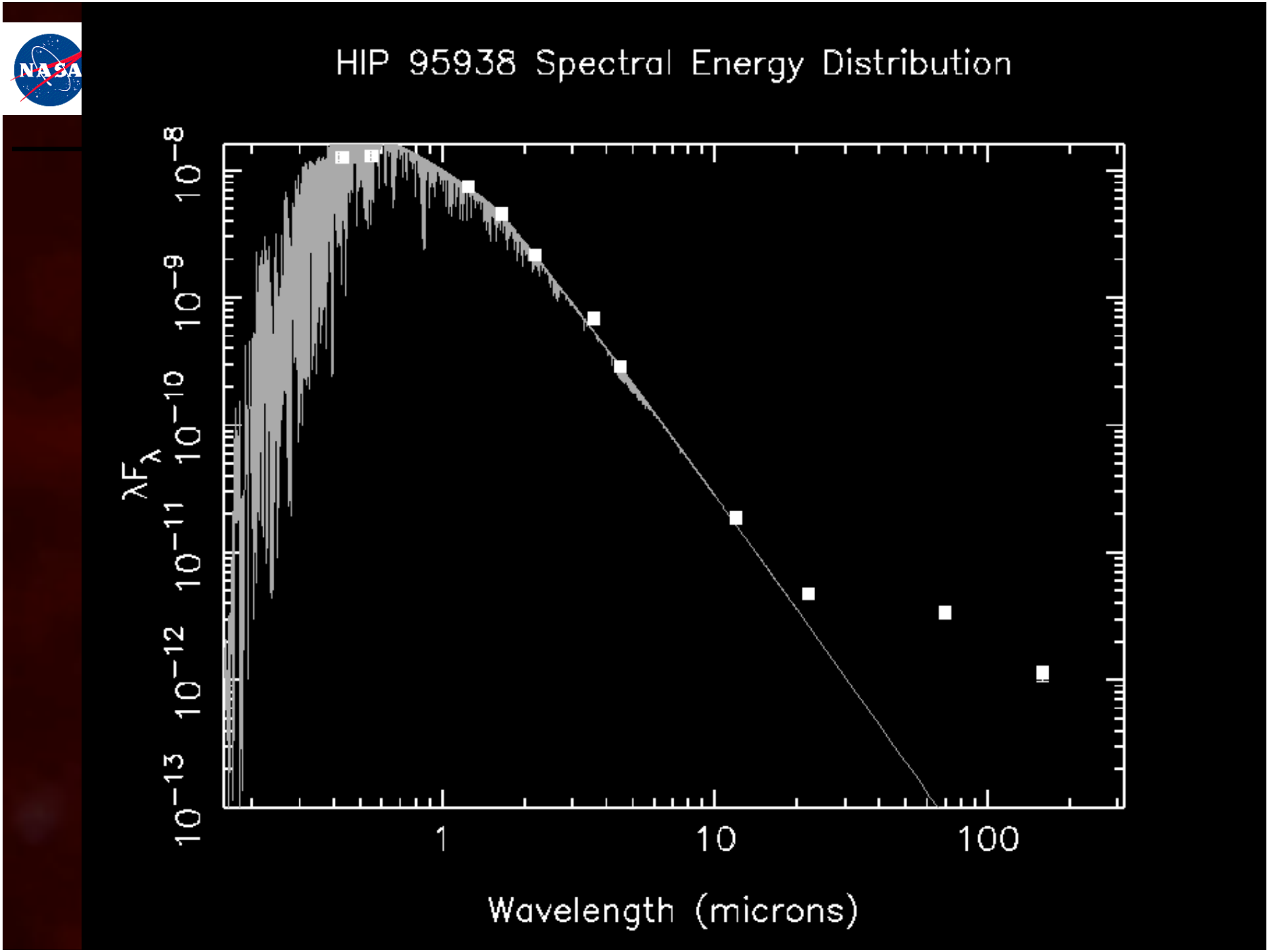
10
100
Wavelength (microns)


HIP 95938 Spectral Energy Distribution
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10^{-9}
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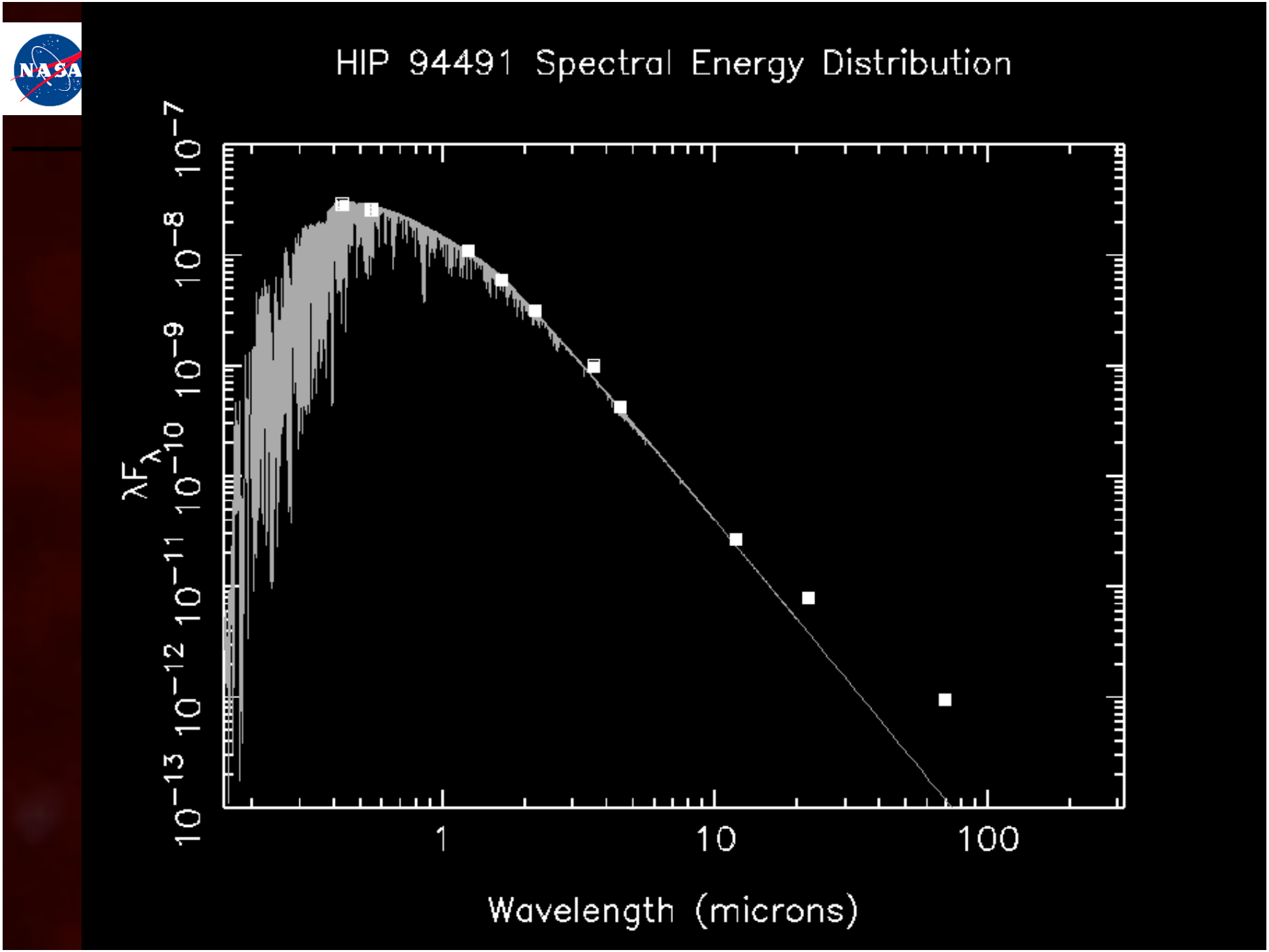
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 94491 Spectral Energy Distribution
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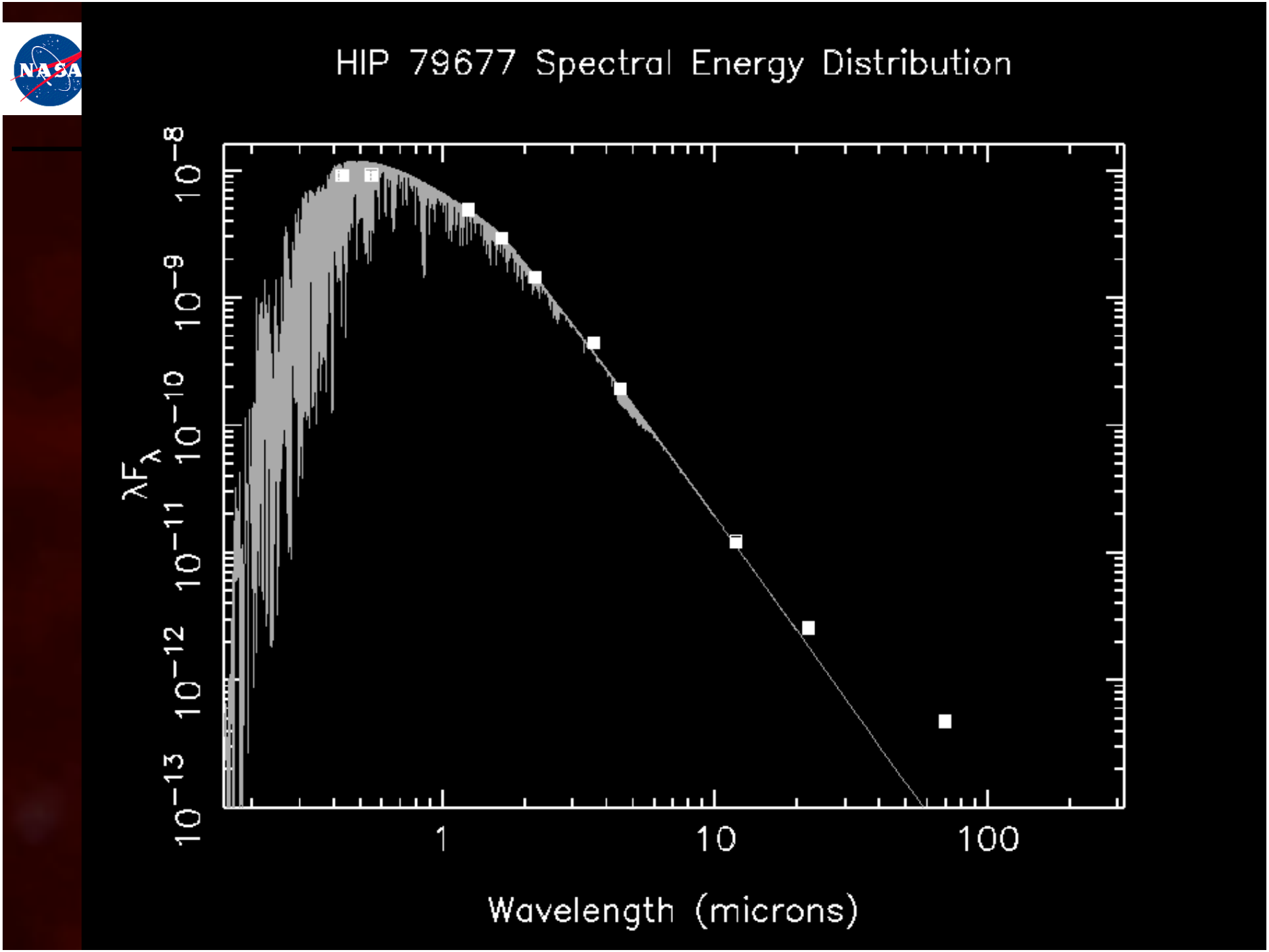
1
10
100
Wavelength (microns)


HIP 79677 Spectral Energy Distribution
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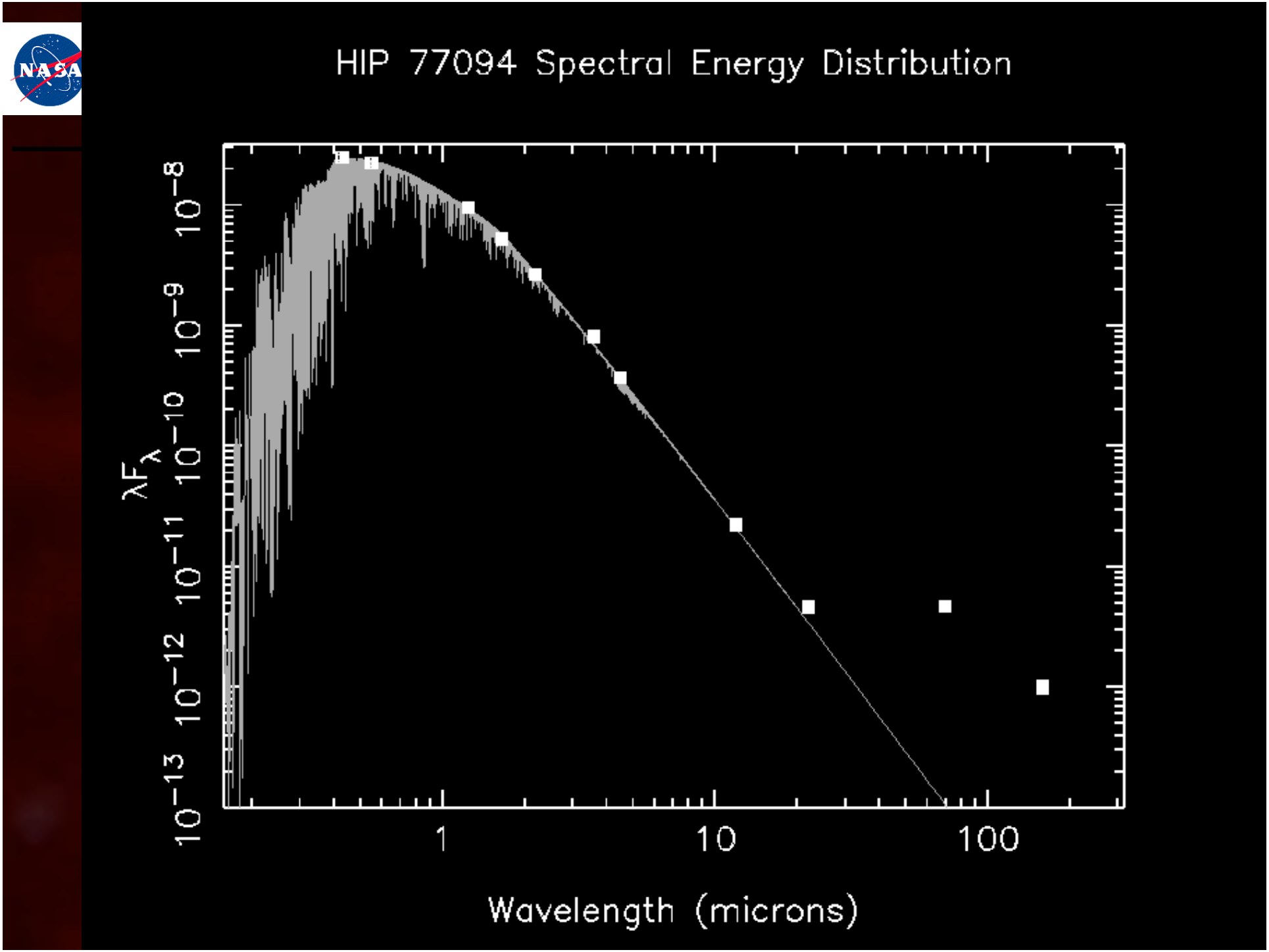
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 77094 Spectral Energy Distribution
λF_λ
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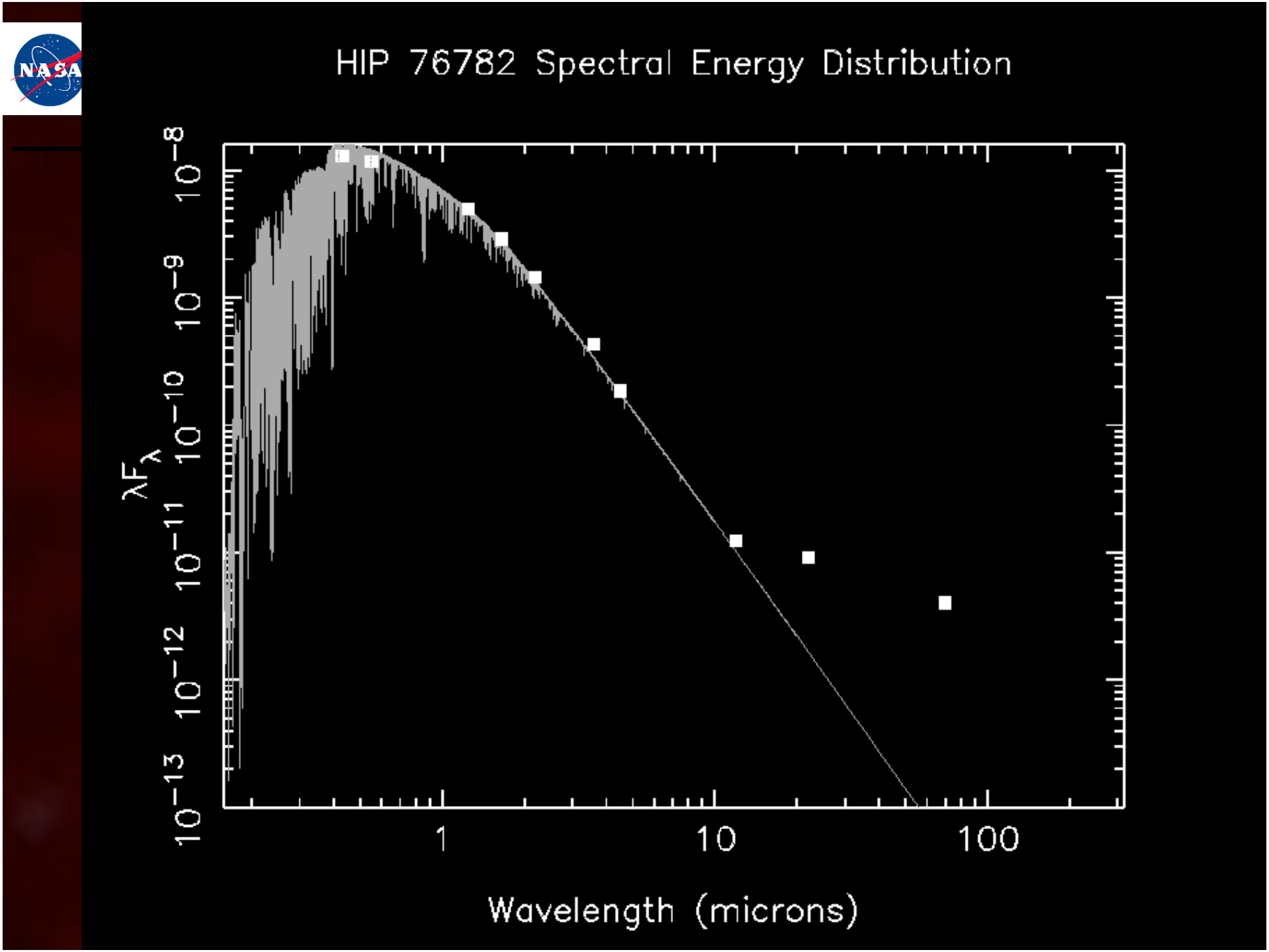
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 76782 Spectral Energy Distribution
λF_λ
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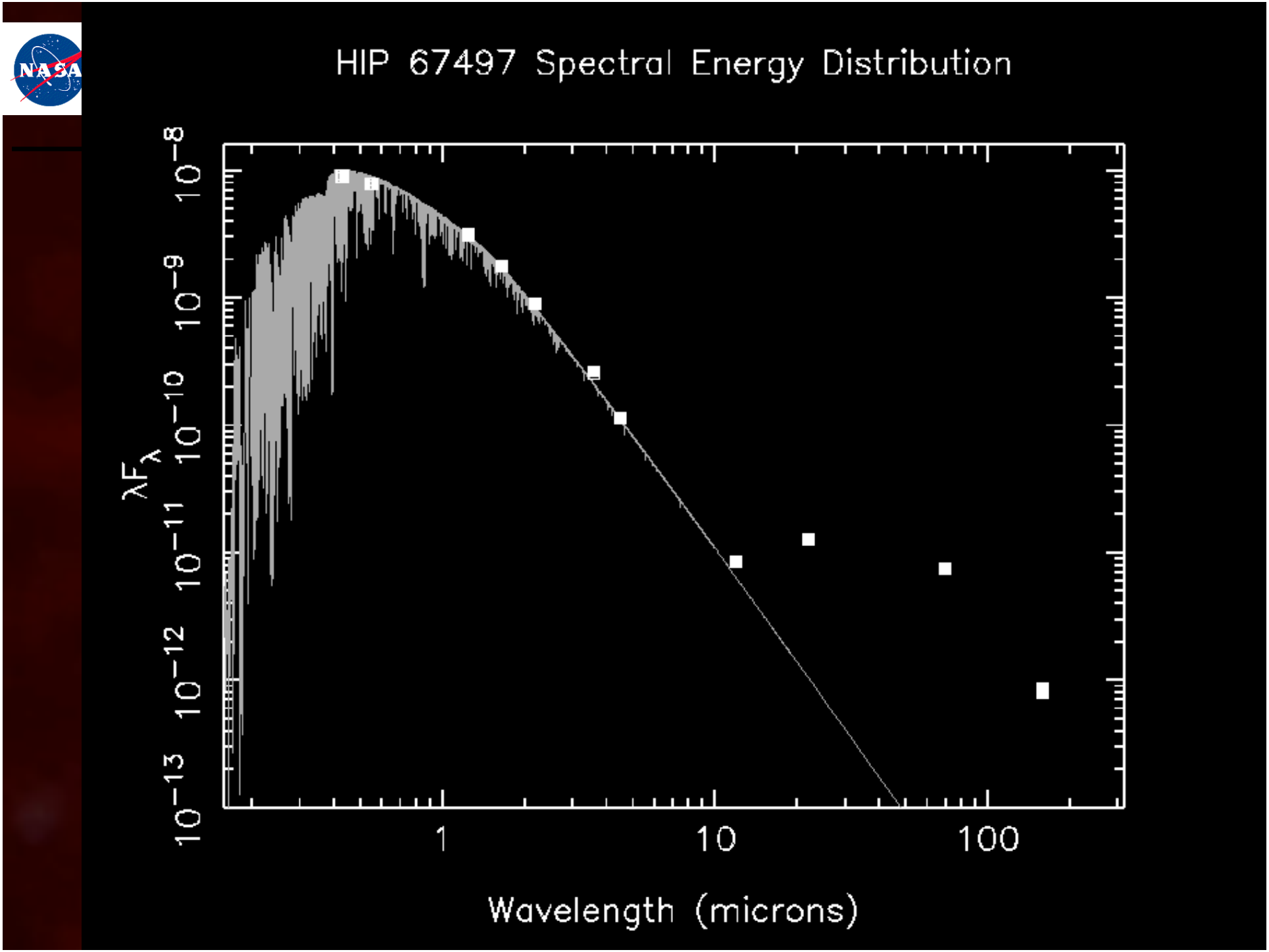
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 67497 Spectral Energy Distribution
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10^{-11}
10^{-12}
10^{-13}
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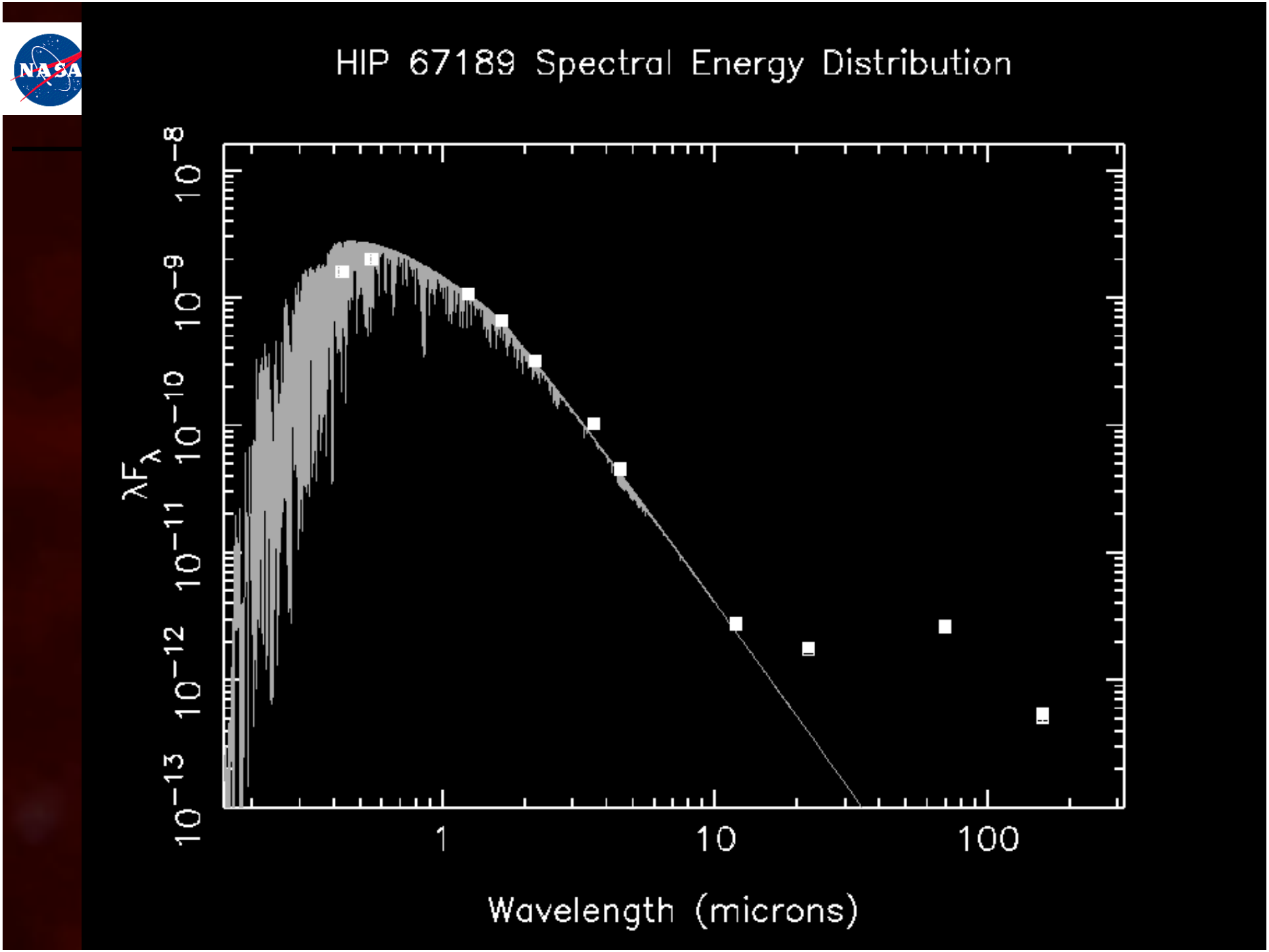
10
100
Wavelength (microns)


HIP 67189 Spectral Energy Distribution
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10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
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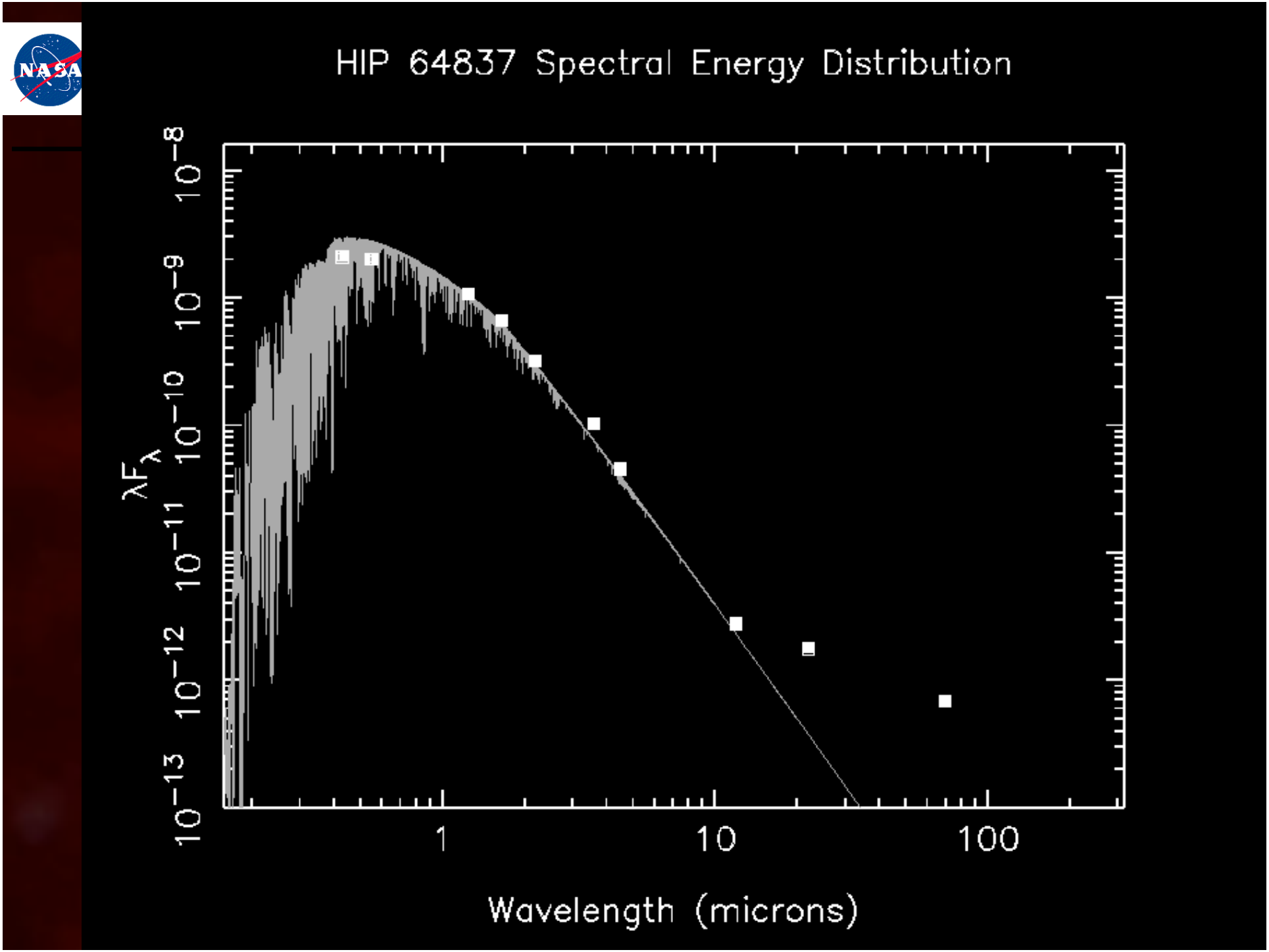
10
100
Wavelength (microns)


HIP 64837 Spectral Energy Distribution
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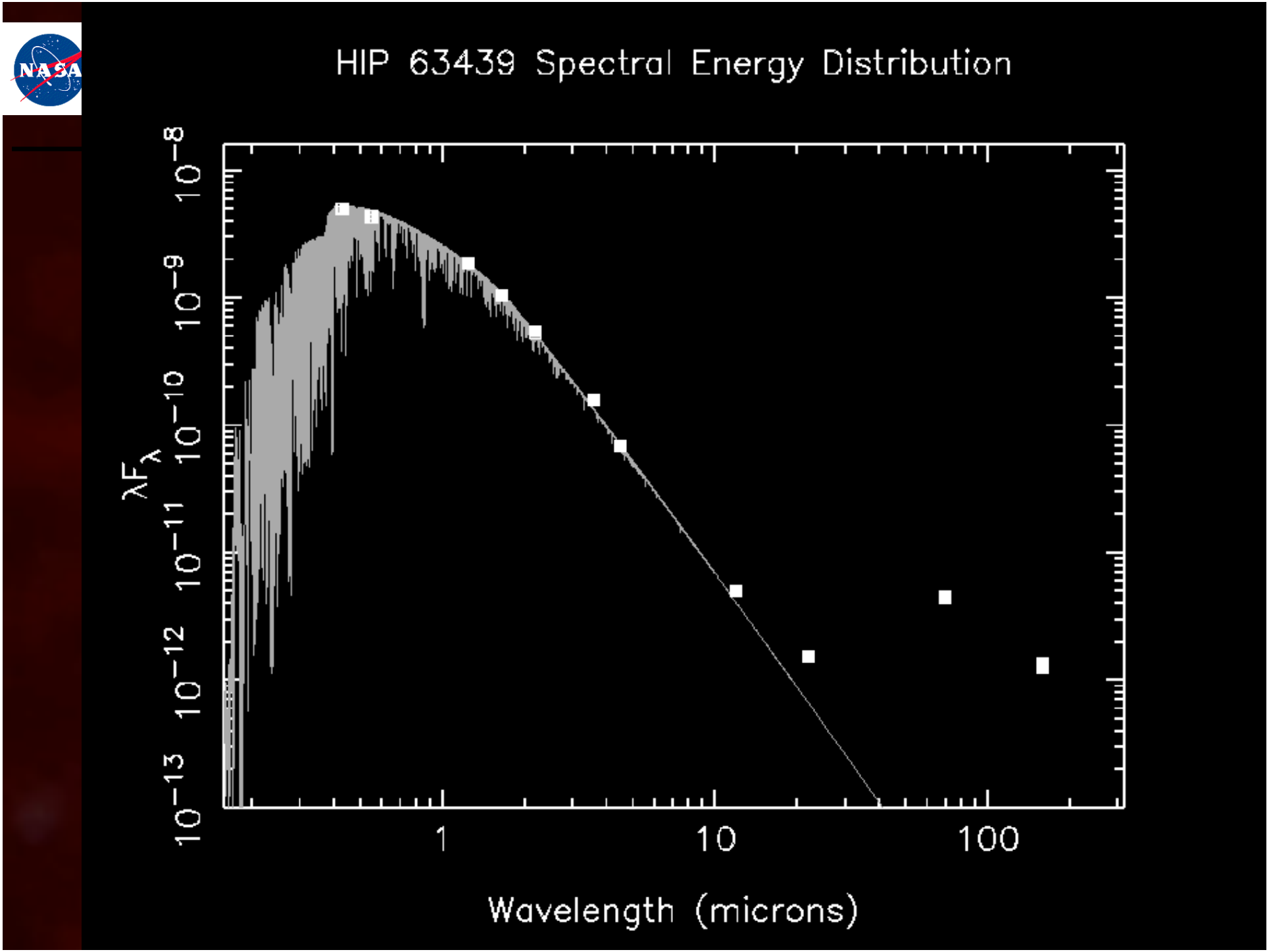
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 63439 Spectral Energy Distribution
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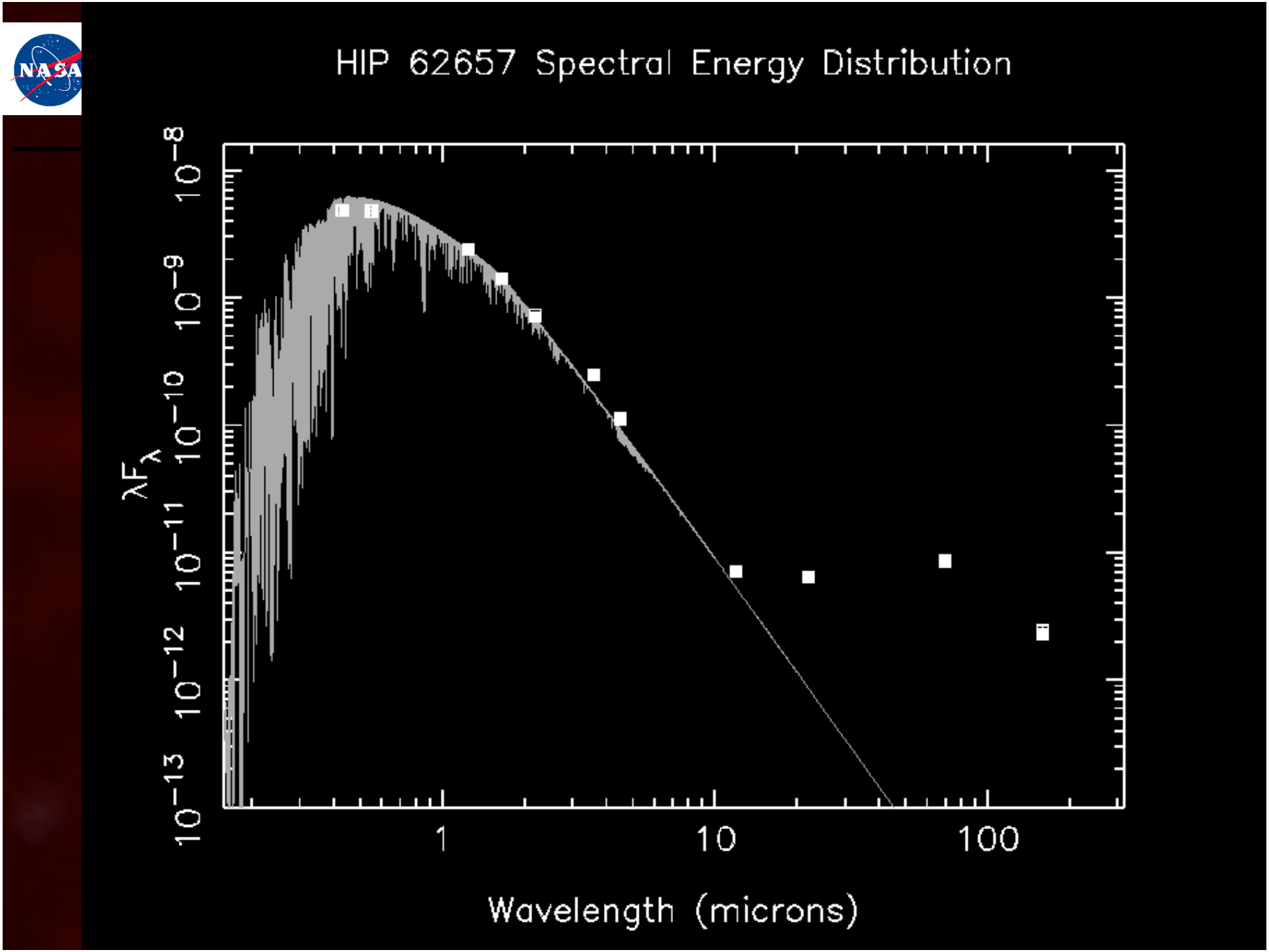
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 62657 Spectral Energy Distribution
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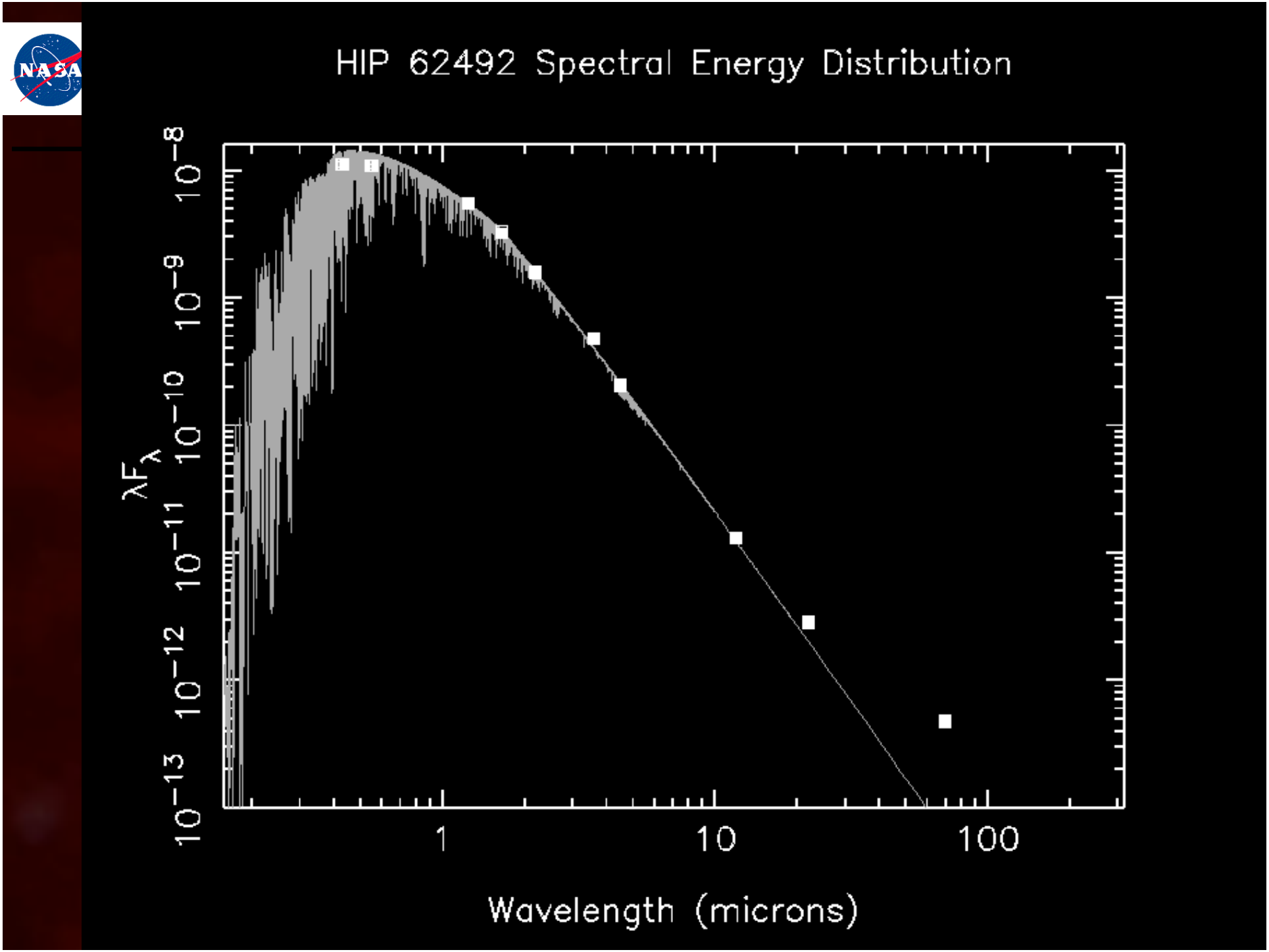
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 62492 Spectral Energy Distribution
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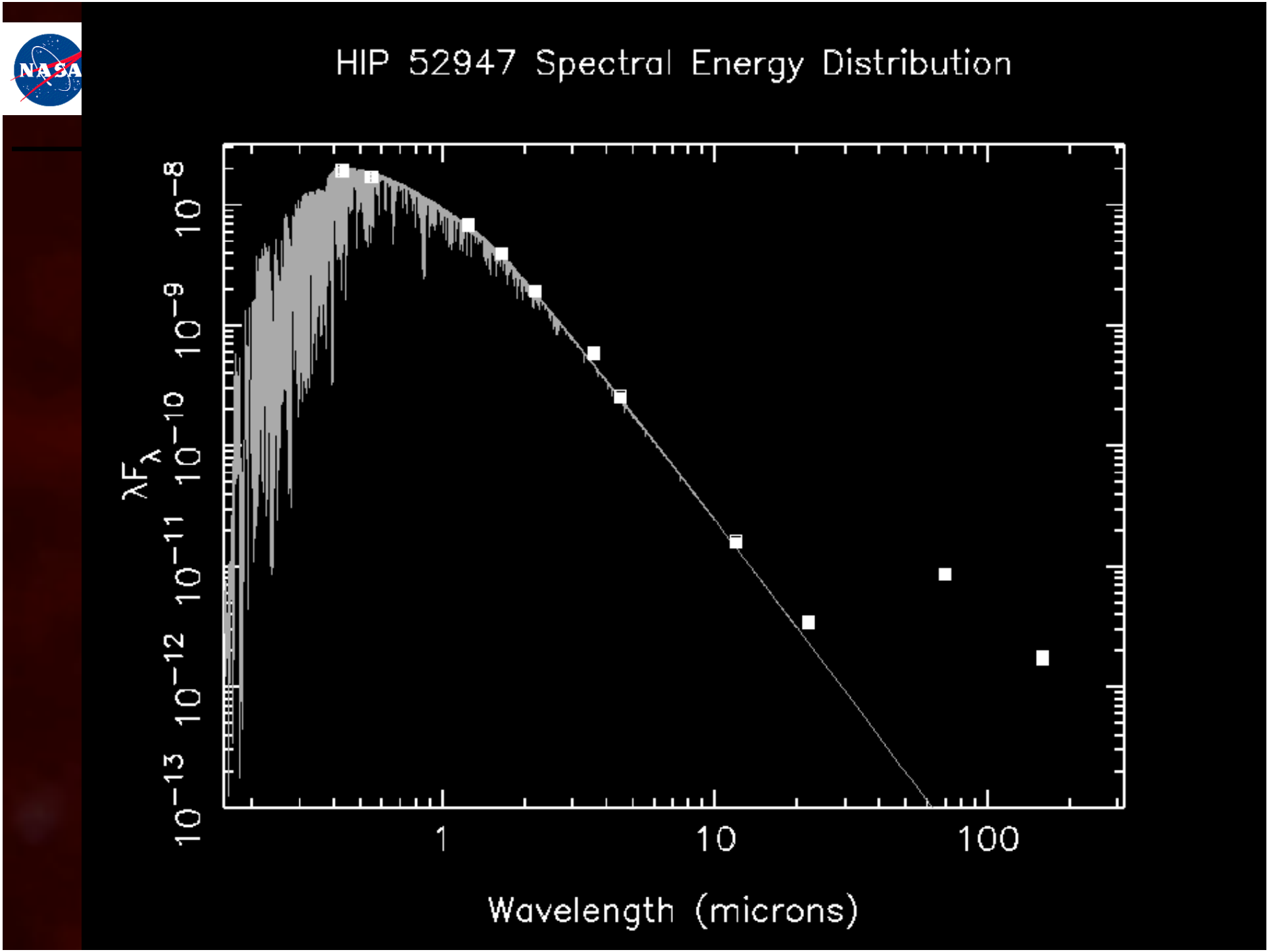
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 52947 Spectral Energy Distribution
λF_λ
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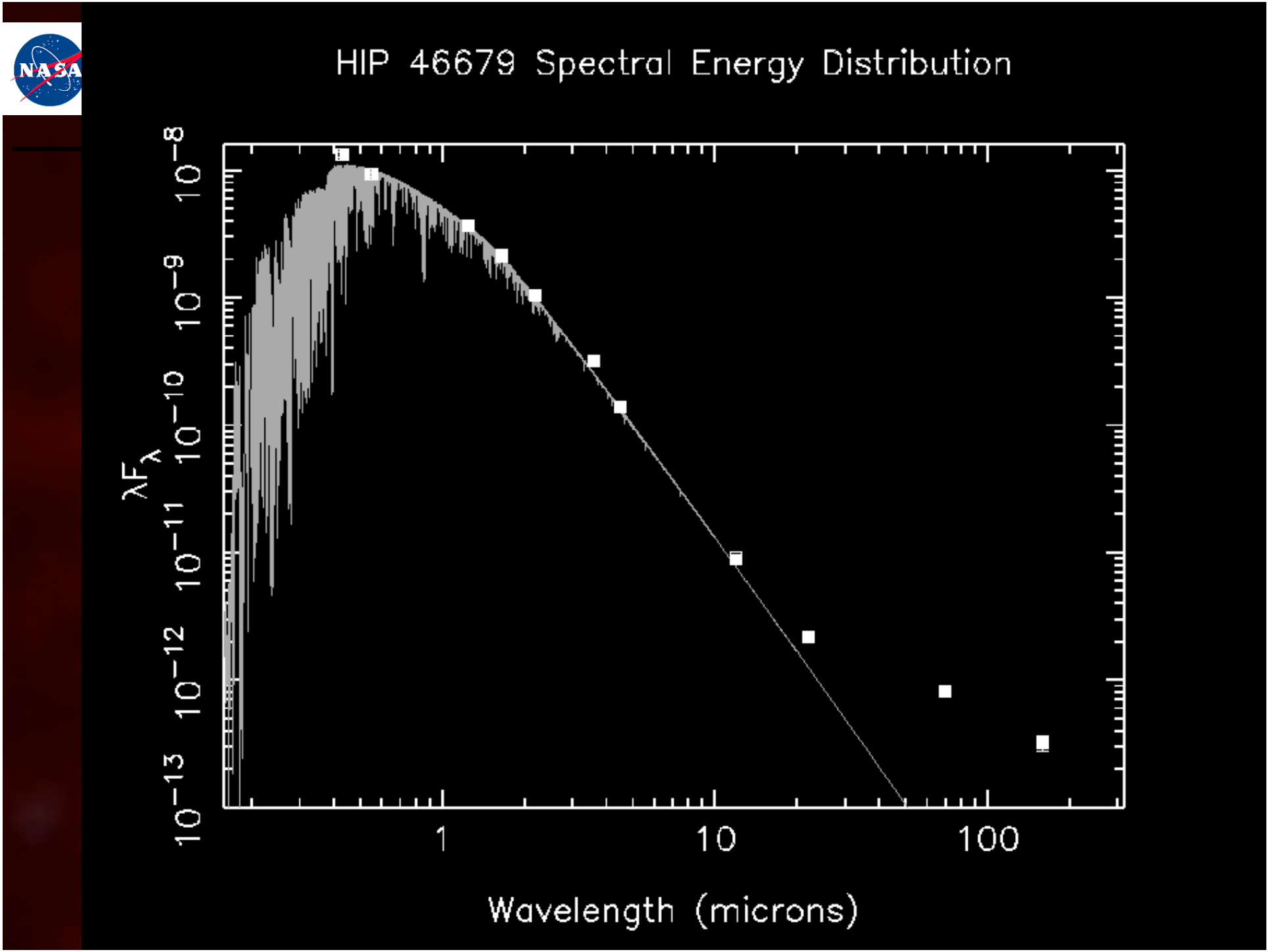
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 46679 Spectral Energy Distribution
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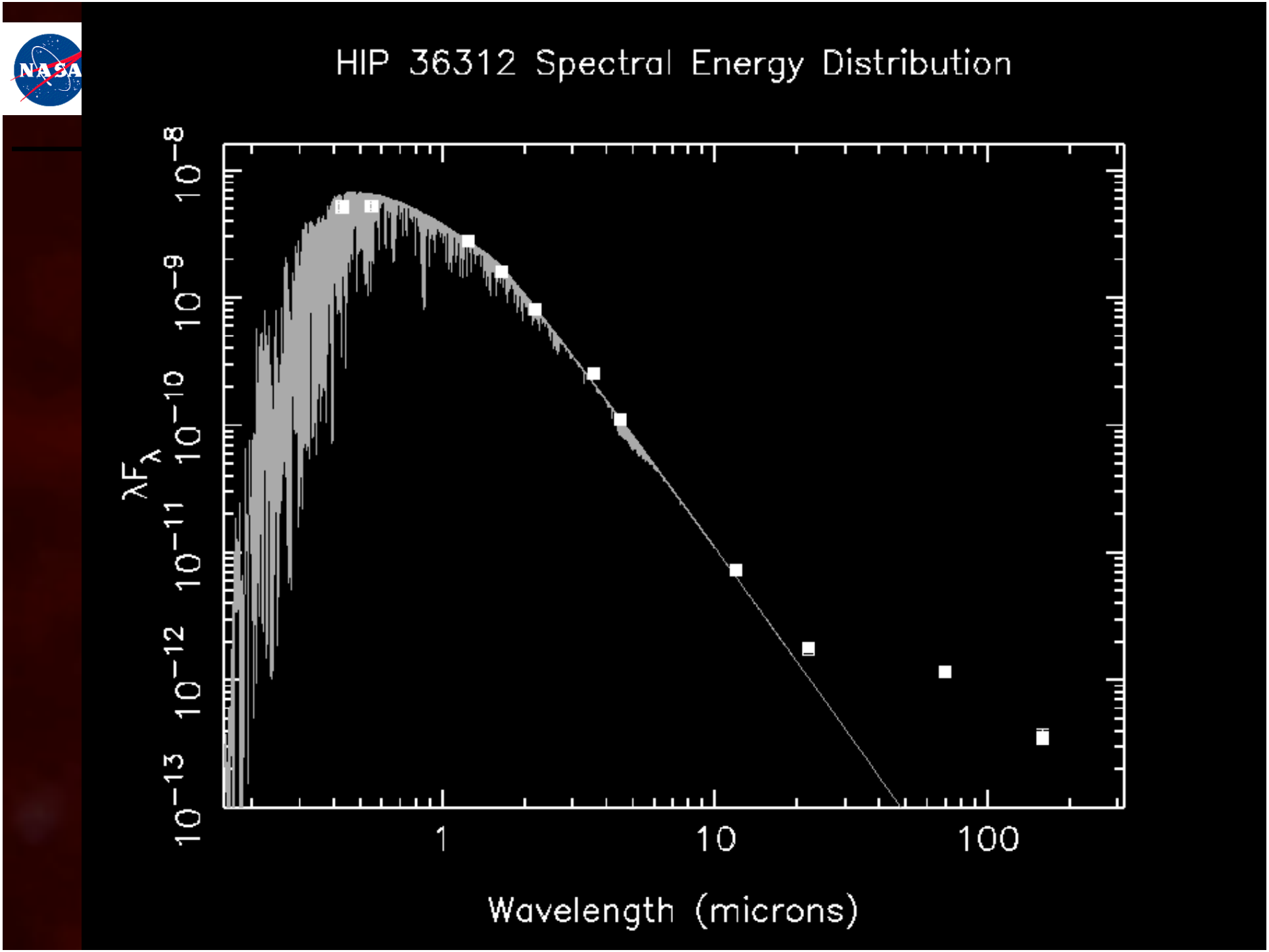
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 36312 Spectral Energy Distribution
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10^{-11}
10^{-12}
10^{-13}
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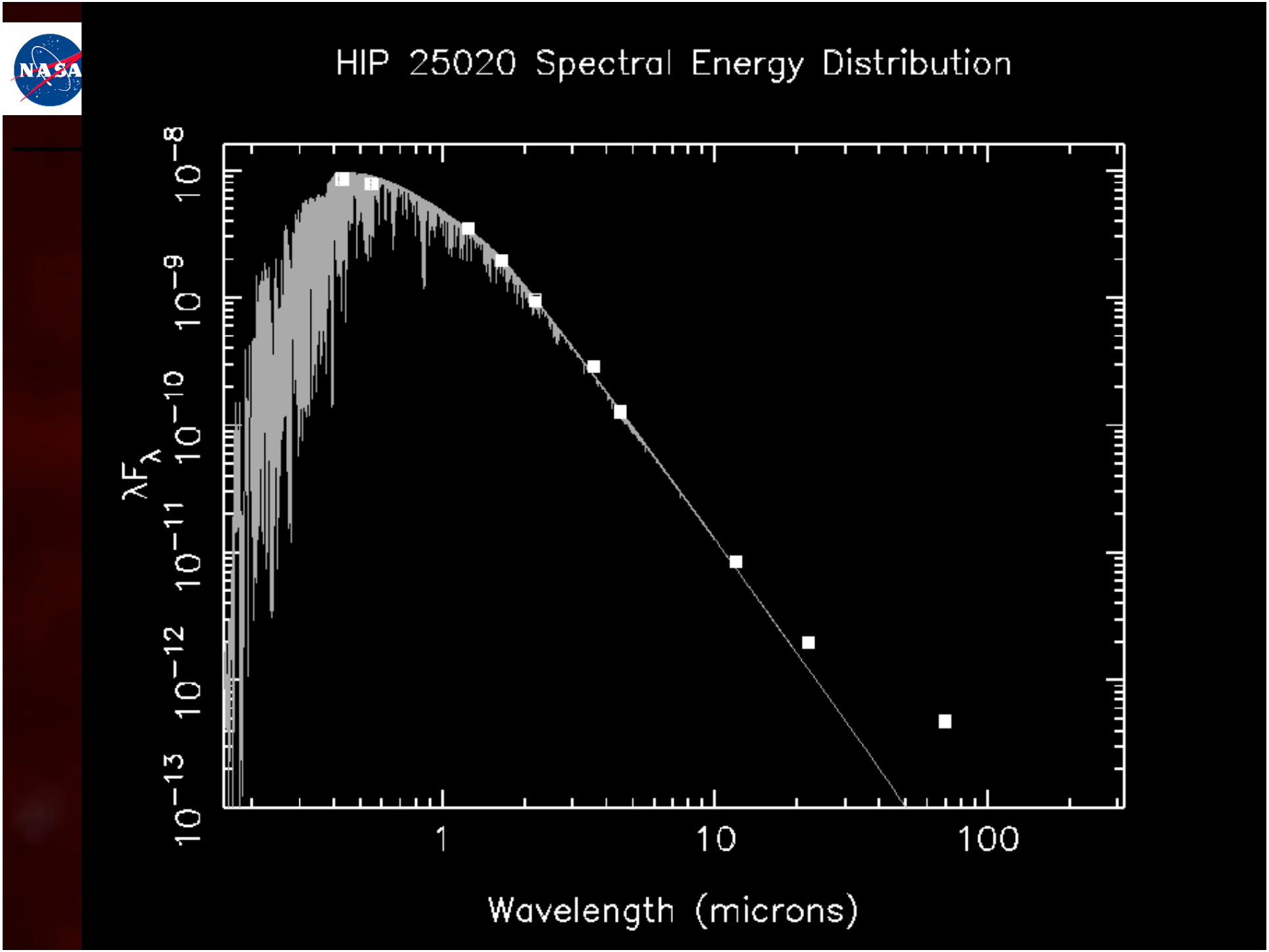
10
100
Wavelength (microns)


HIP 25020 Spectral Energy Distribution
λF_λ
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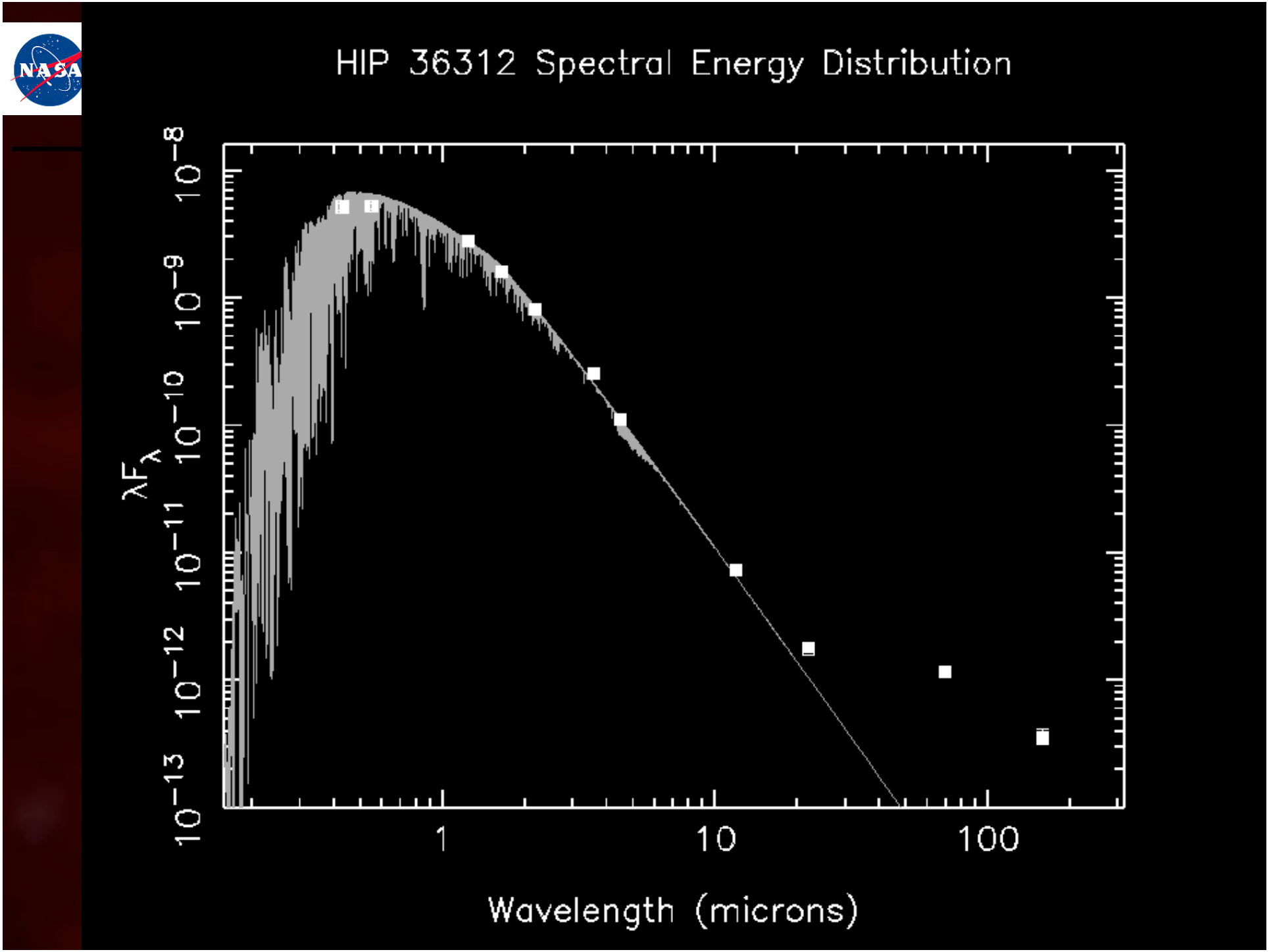
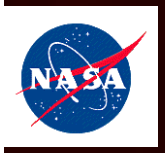
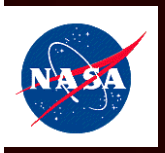
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)


HIP 36312 Spectral Energy Distribution
λF_λ
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
1
10
100
Wavelength (microns)



Disk Properties

- 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
- Fractional luminosities range 0.05-2x beta Pic
- 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



Future Work

- Extend debris disk survey to greater distances, fainter stars; A star photospheres visible to several hundred pc
- Concentration on individual sources and samples of interest (stars with planets, etc.)
- Kinematic associations for new disk candidates
- Better characterization of WISE data "gotchas"
- Uniform spectral classification and spectral age indicators for new disk hosts (Palomar)

This talk makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, funded by the National Aeronautics and Space Administration.