A Volume Limited Sample of Debris Disks Around Nearby Stars--- A MIPS Team Program

C. Beichman, T. N. Gautier, E. K. Holmes, G. Rieke, J. Stansberry, K. Stapelfeldt, M. Werner

Science Goals

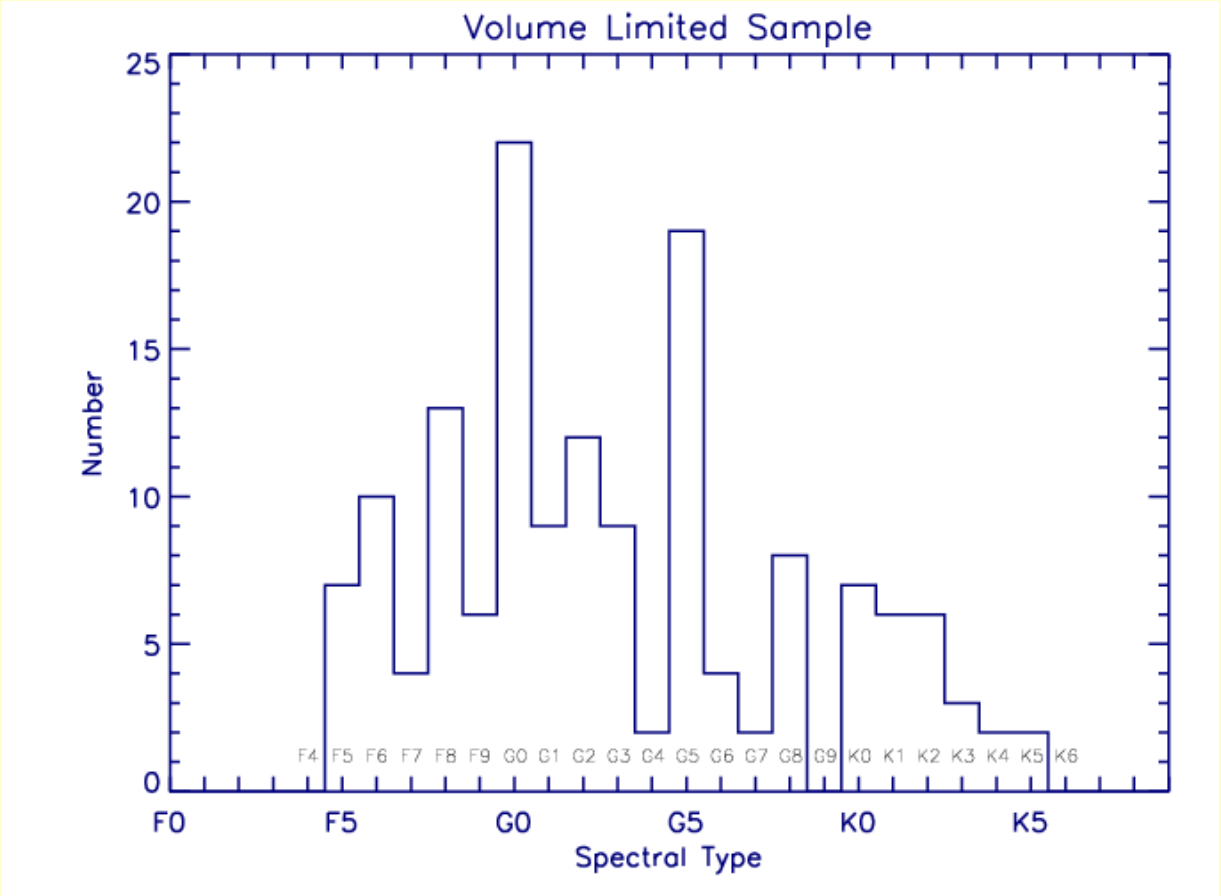
- Assess prevalence of debris disks as a function of spectral type, age, presence/absence of planets to a level at least 10 times more sensitive than IRAS/ISO
- Make MIPS measurements (photometric and SED) and IRS measurements of 153 FGK stars
- Determine physical parameters of disks
  - Density and temperature distribution as function of radius
  - Fractional luminosity in dust
  - Dust composition
- Calibrate disk models using resolved images, spectral energy distributions (SEDs) of closest, brightest stars (Vega, β Pic, α PsA, ε Eri)

Volume Limited Sample

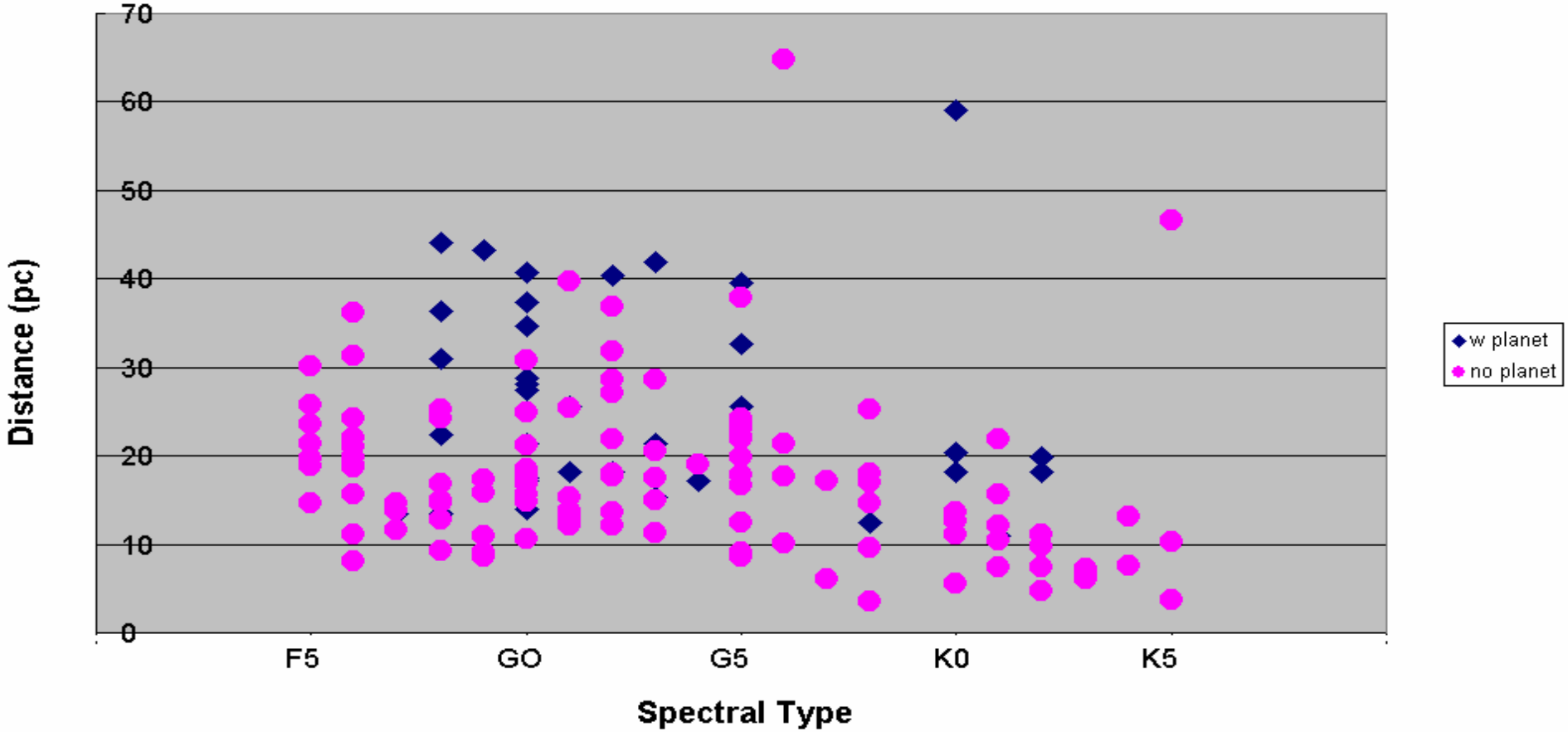
- Initial selection from Gliese catalog yields 929 stars
  - M stars within 5 pc
  - K stars within 15 pc
  - G and F stars within 25 pc
  - Look up to 60 pc away to include stars with planets
  - Reject white dwarfs and giants (classes I,II,III)
- Assemble IRAS/predicted fluxes, cirrus estimations
  - Extragalactic confusion in $\lambda/2D$ pixel at 70 μm <0.1 mJy
  - Cirrus confusion in $\lambda/2D$ pixel based on IRAS/*ISSA* estimates
- Make cuts to ensure clean, unconfused observations
  - Spectral Type K5-F5 (“solar type stars”)
  - Photospheric flux $F_*(60\ \mu m) \geq$ 5-20 mJy
  - Confusion SNR > 30 (>10 for stars with planets)

Spectral Types in VLS Sample

	Total	With Ages
FGK	153	61
F5-F9	40	20
G0-G4	54	17
G5-G9	33	11
K0-K5	26	13
With Planets	35	5

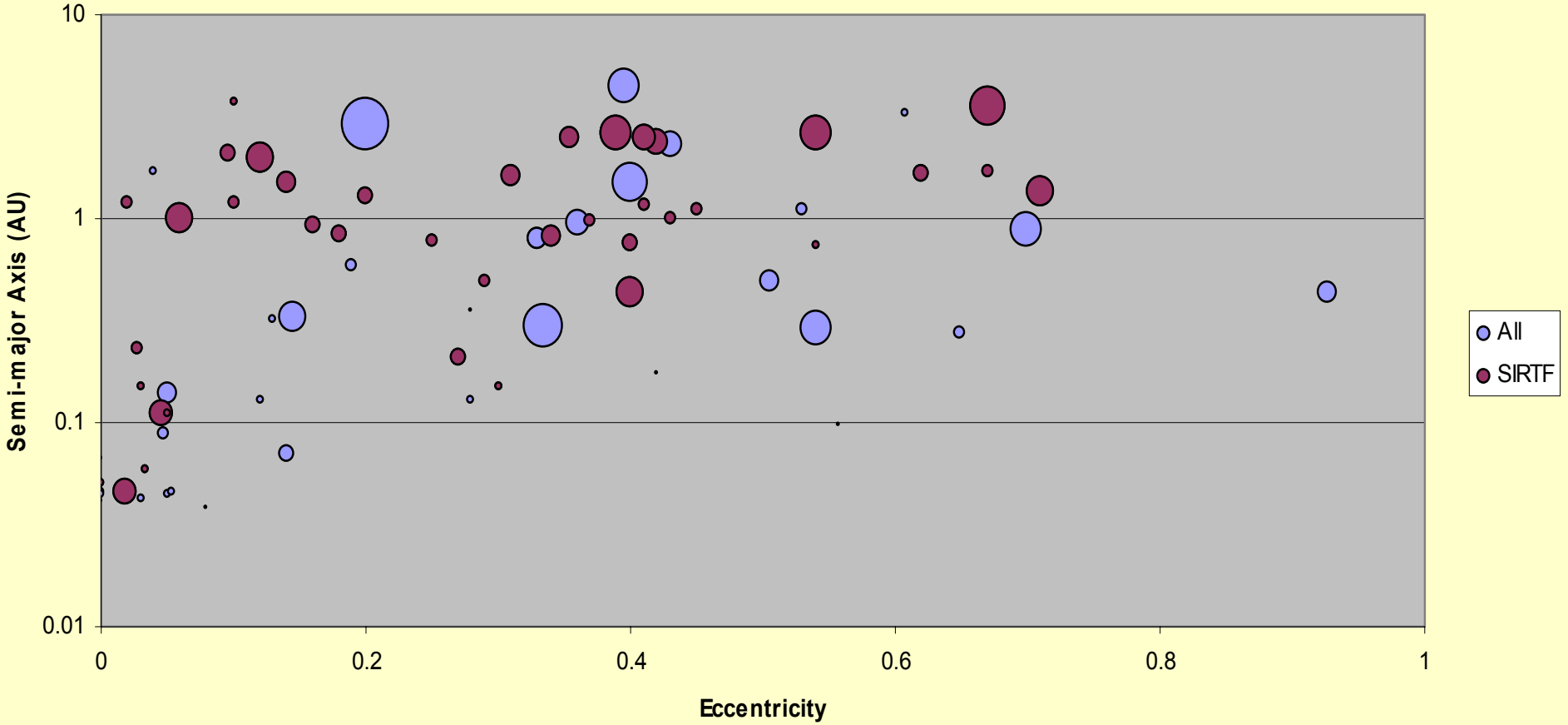


Distance and Spectral Types of VLS Stars



Range of VLS Planet Properties

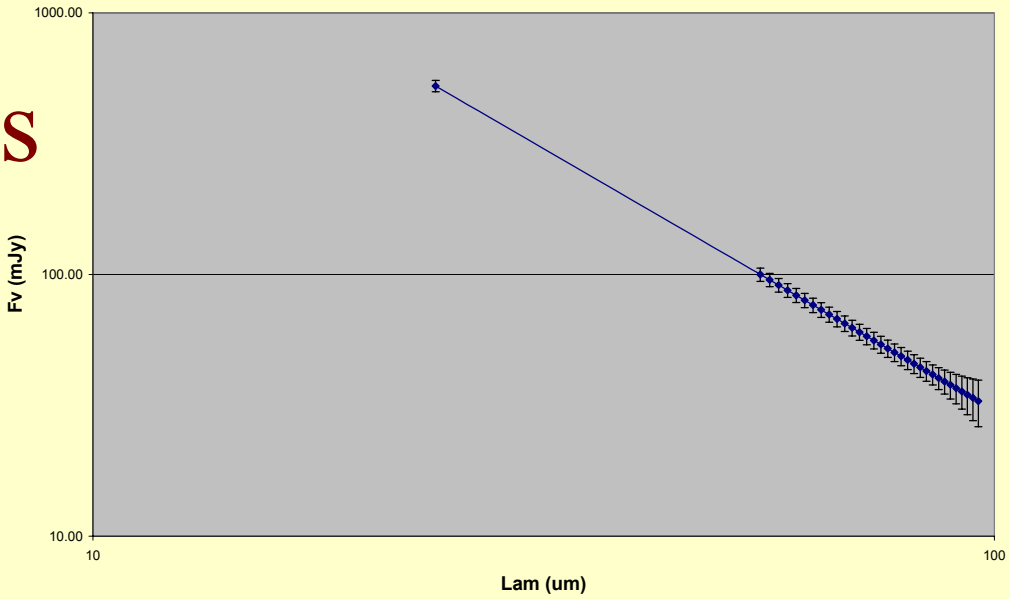
- Broad range of radii, eccentricity, planet masses
- Planets now known in >3 AU orbits which can affect the distribution of dust responsible for 12-25 μm radiation



VLS Observing Program

- MIPS photometry at 25, 70, and 160 μm
  - SNR=25 on photosphere at 70 and x-gal confusion limit at 160 μm
  - Use 70 μm super-resolution mode for brightest stars
  - SNR="100" at 24 μm or minimum τ = 10 sec
  - Observe 153 stars in total program; 67 sources during first 6 months
- MIPS spectral energy distribution (SED) for f_ν(70 μm)> ~40 mJy
  - Push to lower level of disk emission, improved T(r)
  - SNR=25 based on measured/predicted 60 μm flux
  - Observe 66 sources in total program; 8 during first 6 months
- IRS Short/Long-LO spectra for f_ν (40 μm)> 40 mJy
  - Push to lower level of disk emission, improved T(r), mineralogy
  - SNR=50-100 based on measured/predicted 25 and 40 μm flux
  - Observe 90 sources in total program; 8 during first 6 months
- Carry out additional MIPS SED/IRS follow-up based on excess
- Total program takes 93 hours (Spot V5.0)

Combination of MIPS Modes Offers Best Sensitivity to Small Excesses



- Combination of 24 and 70 μm photometry, plus SED spectra gives sensitivity to weak excesses
  - Addition of SED gives 2x improvement in ability to find excess
- Simulation includes 5% calibration uncertainty and 5% statistical uncertainty
  - Figure shows photosphere plus excess due to ~200x Solar System zodiacal cloud producing a $\Delta\alpha=0.15\pm0.04$ excess over photosphere
  - Table shows accuracy of different observing choices

Table 1. Comparison of Different Observing Modes

Mode	Assumption	Calibration Uncertainty	Slope Uncertainty
SED-only	cal + SNR(70)=∞	0.03	0.032
PHOT-only	cal + SNR(70)= ∞	0.05	0.067
SED+24	cal + SNR(70)= ∞	0.05	0.034
SED-only	cal + SNR(70)=20	0.03	0.075
PHOT-only	cal + SNR(70)=25	0.05	0.075
SED+24	cal + SNR(70)=20	0.05	0.043

Analysis Plans

- Assemble basic stellar information for entire sample
  - Spectral Type, mass, metallicity, age, properties of planets
  - Atlas of predicted photospheric SEDs tied to 2MASS/SIMBAD photometry
    - Calculate fluxes integrated over MIPS filters
    - Observe stars at 10 μm from Palomar as necessary for improved photospheric estimate
- Develop simple model to fit photometry, SED, IRS for unresolved sources
  - $\rho\,(r) \sim \rho_o\, r^{-\beta}$ between R_1 and R_2
  - $T(r) \sim T_{oo}$ (dust) $L_*^{\alpha}\, r^{-\alpha}$ (K)
  - Develop models for various dust populations and dust properties
  - Validate models using data for spatially resolved stars
- Investigate high resolution image processing to look for barely resolved structures at 70 μm
- Investigate disk models = f(planets)