SCUBA2 Legacy Debris Disk Survey

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- **Motivation for the survey**
- **Survey plan and preparations**
- **Analysis and modelling – predictions!**

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Pierre Bastien, Chas Beichman, Harold Butner, Bill Dent, James Di Francesco, Carsten Dominik, Per Friberg, Jane Greaves, Mark Halpern, Wayne Holland, Rob Ivison, Ray Jayawardhana, Tim Jenness, Doug Johnstone, JJ Kavelaars, Brenda Matthews, Gerald Schieven, Ignas Snellen, Bernd Werfling, Glenn White, Mark Wyatt, Jeremy Yates, Ming Zhu

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What are debris disks?

• Remnants of planet formation – solid material around main sequence stars that's not planets, e.g., asteroids and comets in the solar system

• Detected in optical to mm wavelengths because dust produced in collisions scatters starlight, and is heated re-emitting thermal radiation

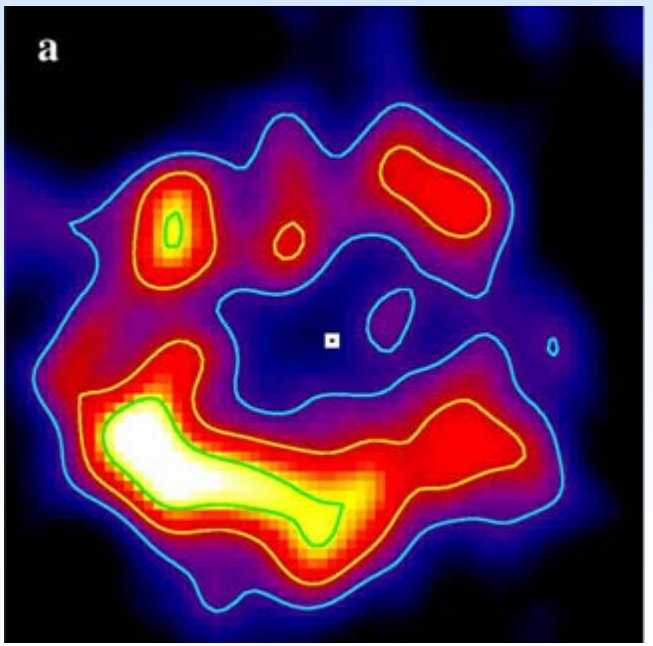
Key facts

• 15% of stars have debris disks

• ~300 known disks, 15 of which imaged

• All have inner holes, typical radius 40-100AU

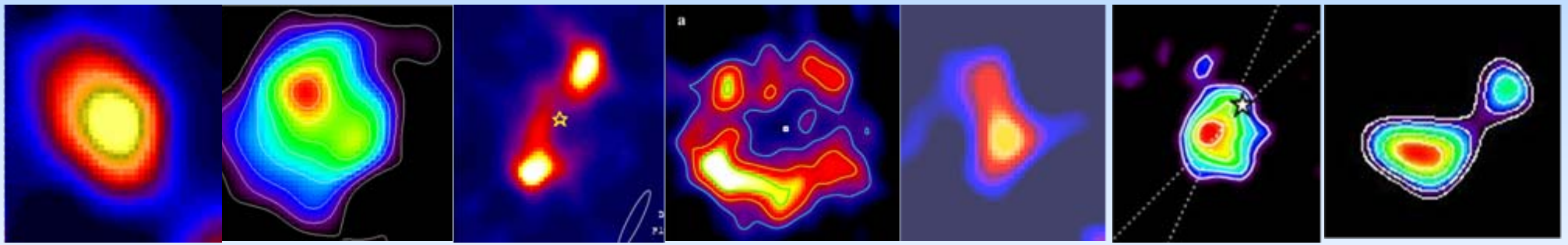
• Analogous to Kuiper belt, but could not detect KB



Why sub-mm?

SCUBA revolutionised debris disk studies:

(1) Discovery images of 7 debris disks



Holland et al. (1998; 2003)

Greaves et al. (1998; 2005)

Greaves et al. (2004)

Williams et al. (2004)

Wyatt et al. (2005)

(2) Sub-mm fluxes for remainder allowed disk mass and size to be estimated

(3) Discovered disks too cold to be detected at other wavelengths

Outstanding questions

(1) **Evolution**
- Stochastic or steady-state?

(2) Interior **planetary systems**
- Now overlap with radial velocity surveys: 9 planet+debris systems
- Evidence for distant planets from disk structures

(3) **Radius distribution** and prevalence of cold dust
- Spitzer surveys sensitive to warm >40K dust
- Cold disks at large radius recently discovered in sub-mm

(4) Other factors affecting presence of dust (**binarity, metallicity** etc)
- Unknown at present

Debris Disk Survey

Summary

An unbiased search of 500 nearby stars for disk emission at 850μm

Status

Awarded 330 (+60) hours with SCUBA2 over 2 (+3) years

Team

Liaison=Jane Greaves (St Andrews), **UK Coordinator**=Wayne Holland (UKATC), **Canada Coordinator**=Brenda Matthews (HIA), **Staffing Manager**=Gerald Schieven (JAC), Pierre Bastien (Montreal), Chas Beichman (Caltech), Harold Butner (JAC), Bill Dent (UKATC), James Di Francesco (HIA), Carsten Dominik (Amsterdam), Per Friberg (JAC), Mark Halpern (UBC), Rob Ivison (UKATC), Ray Jayawardhana (Toronto), Tim Jenness (JAC), Doug Johnstone (HIA), J J Kavelaars (HIA), Ignas Snellen (Leiden), Bernd Werfling (JAC), Glenn White (Kent), Mark Wyatt (IoA), Jeremy Yates (UCL), Ming Zhu (JAC)

Unbiased source list

The defining characteristic of this survey is that it is completely unbiased:

500 stars will be observed, the nearest 100 in spectral types A, F, G, K, M

Survey extends to: 42pc (A), 24pc (F), 20pc (G), 15pc (K), 10pc (M)

Unbiased means: can study effect of all parameters

- Evolution: 150 stars <1Gyr, 350 stars 1-10Gyr
- Binarity: 1/3 have a companion
- Other properties also evenly distributed (planets, metallicity, rotation rate)

No other unbiased survey performed since IRAS

Sample size means: can distinguish 0,5,10,25 and 50% when data subdivided

Survey observations

Another defining characteristic is a uniform detection threshold:

All stars observed at 850μm to same sensitivity limit of 3σ = 2mJy

Choice of sensitivity limit:

- Source counts of debris disks increase with lower sensitivity
- Extragalactic confusion limit is 2 mJy

Ensures maximum detection rate without confusion

Uniform threshold means: detection bias can be accounted for in analysis

Follow-up: bright sources will be imaged at 450μm

Survey preparations

(1) **Source list**

(2) **Database**

- Freely available on web
- Info on stars (age, distance, ...)
- Info on circumstellar (planets, far-IR)
- Status of observations

(3) **Stellar Observations**

- Stellar spectra at DAO 1.2 and 1.8m

(4) **Planning complementary circumstellar observations**
e.g., Herschel and Spitzer

Debris Disk Database Object Details

Source Data

HD	SAO	Hr	Name
HD 22049 (Variable of BY Dra type)	130564	1084	eps Eri, eps Eri

Location Data

ICRSra	ICRSdec	Long	Lat	PMRA	PMDEC	Distance
03 32 55.8442	-09 27 29.744	195.84	-48.05	-976.36	17.98	3.2

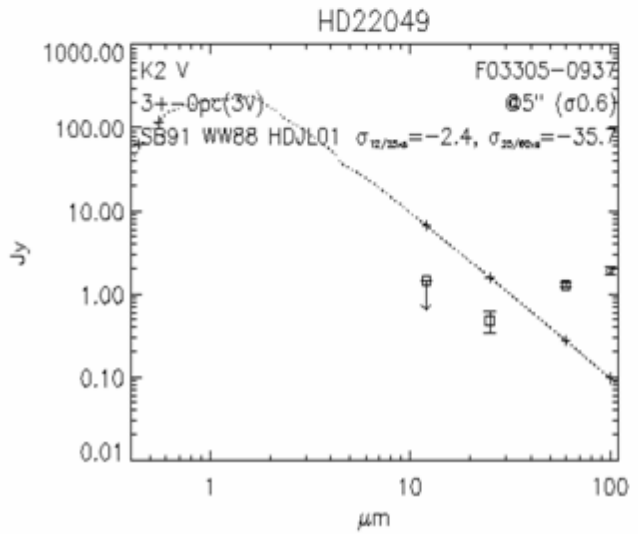
Type Data

VMag	BMag	ResolvedSp	Source	IR_Excess_Classification
3.73	4.61	K2 V	MSp5	Debris Disk

IRAS Data

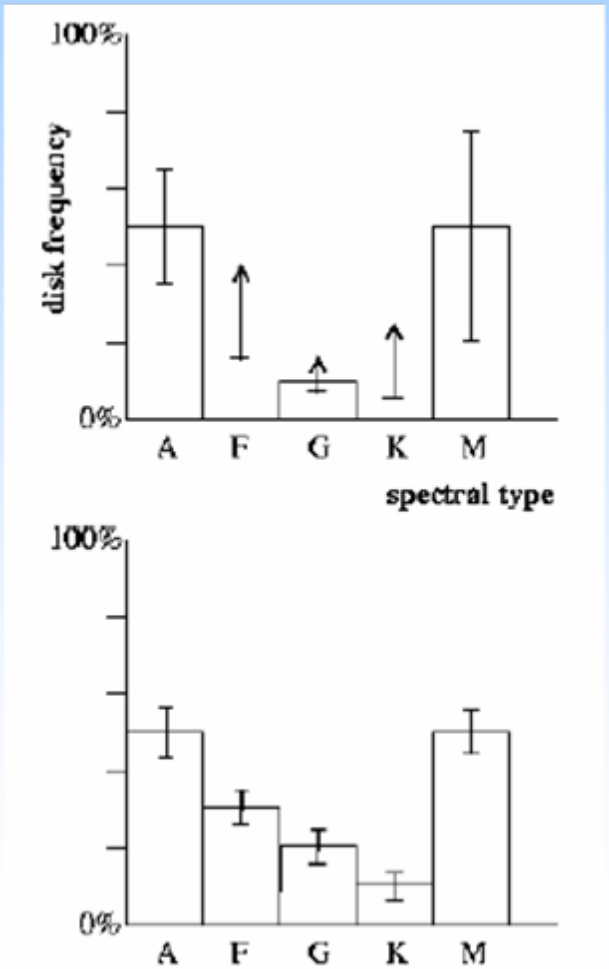
ResolvedIRAS	Source	Offset	PA	SigPosUnc
03305-0937	F	5.3	78.1	0.6

F12	ErrF12	FQual12	F25	ErrF25	FQual25	F60	ErrF60	FQual60	F100	ErrF100	FQual100
9.672	0.484	3.000	2.667	0.133	3.000	1.631	0.082	3.000	2.008	0.221	2.000

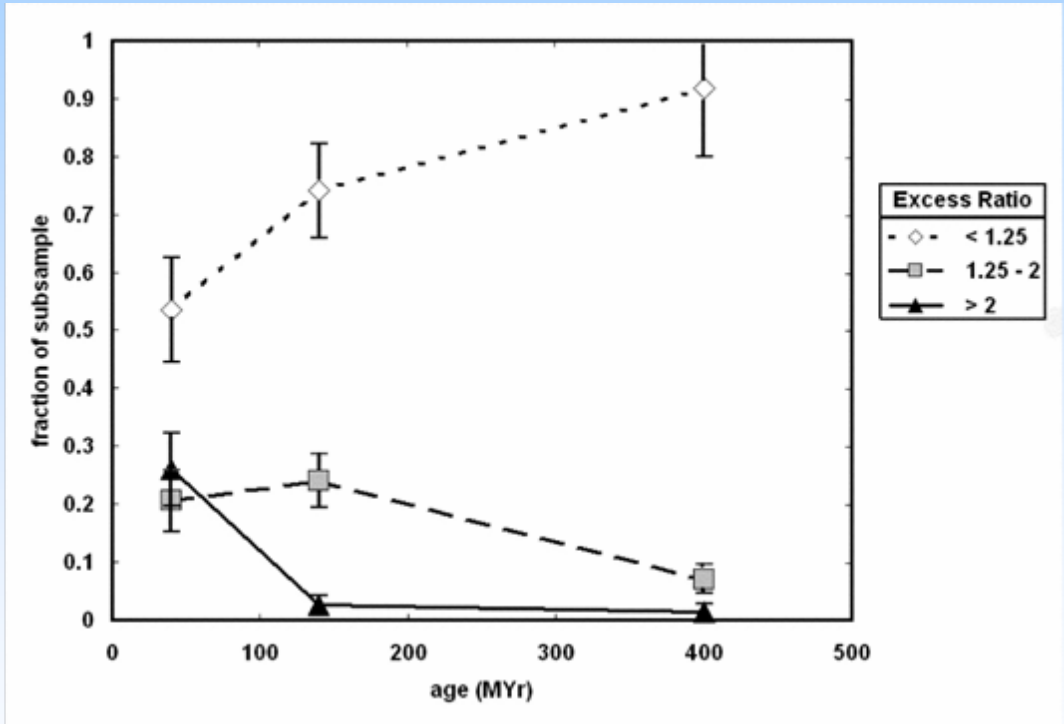


Analysis – (i) statistics

Fraction of stars of different spectral type with disks



Fraction of stars of different ages with disks

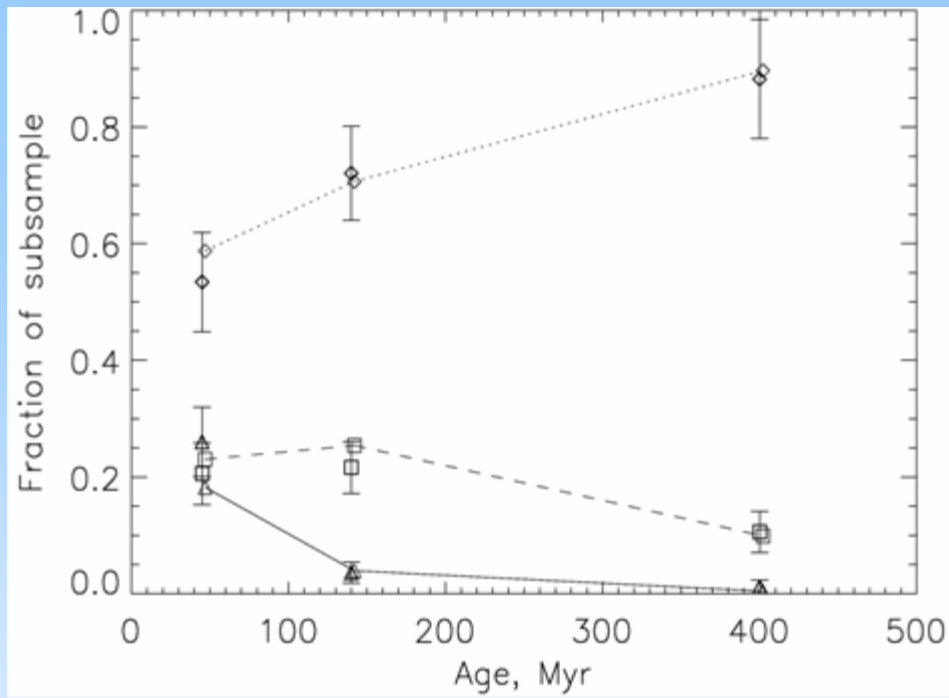


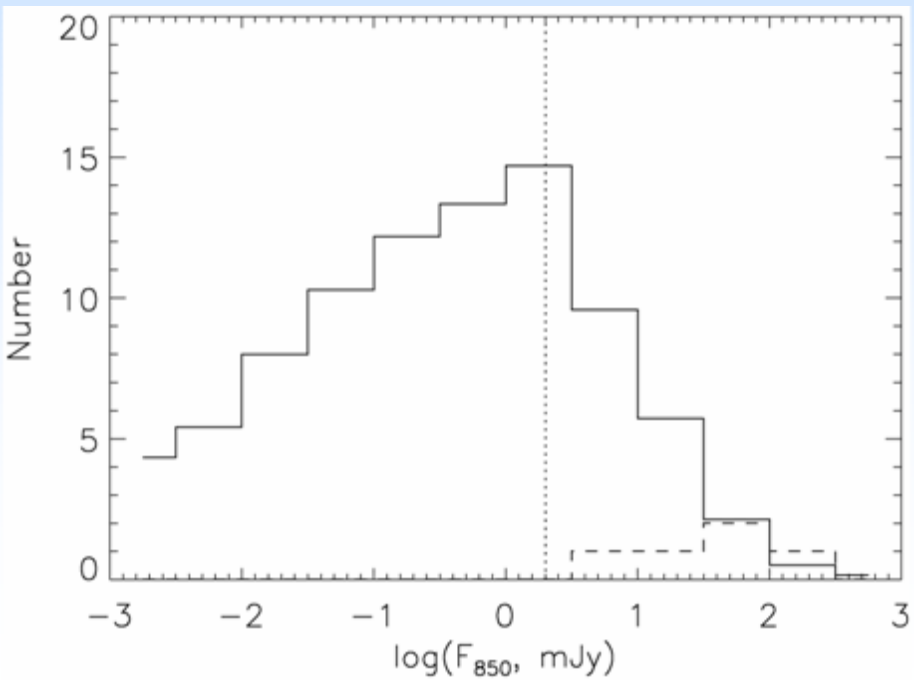
And similarly for stars with/without planets or binary companions, high/low metallicity, fast/slow rotation, etc.

Modelling statistics

A model in which stars born with planetesimal belts evolve in steady state fits far-IR Spitzer stats for A star disks (Wyatt et al., in prep.)

That model has been used to make preliminary predictions for SCUBA2 survey:

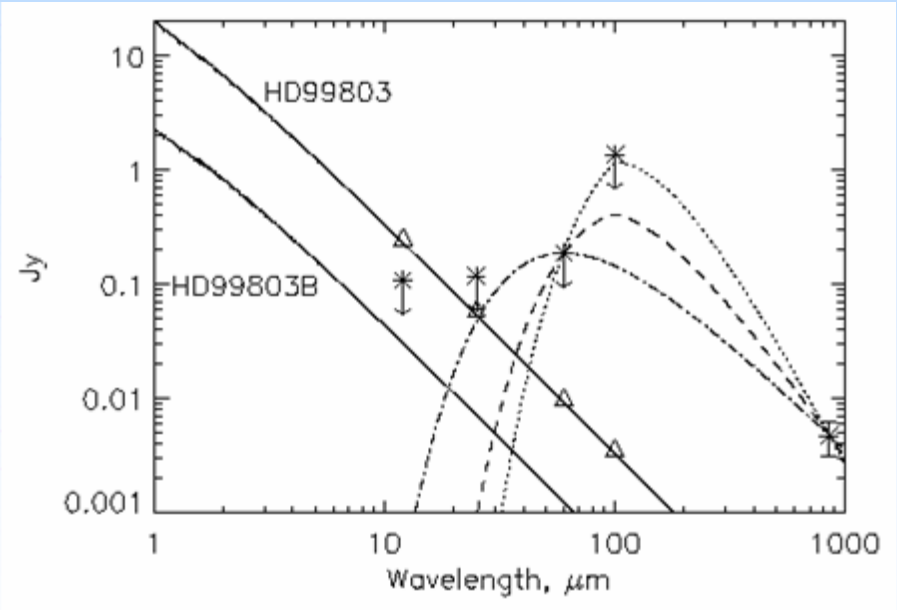




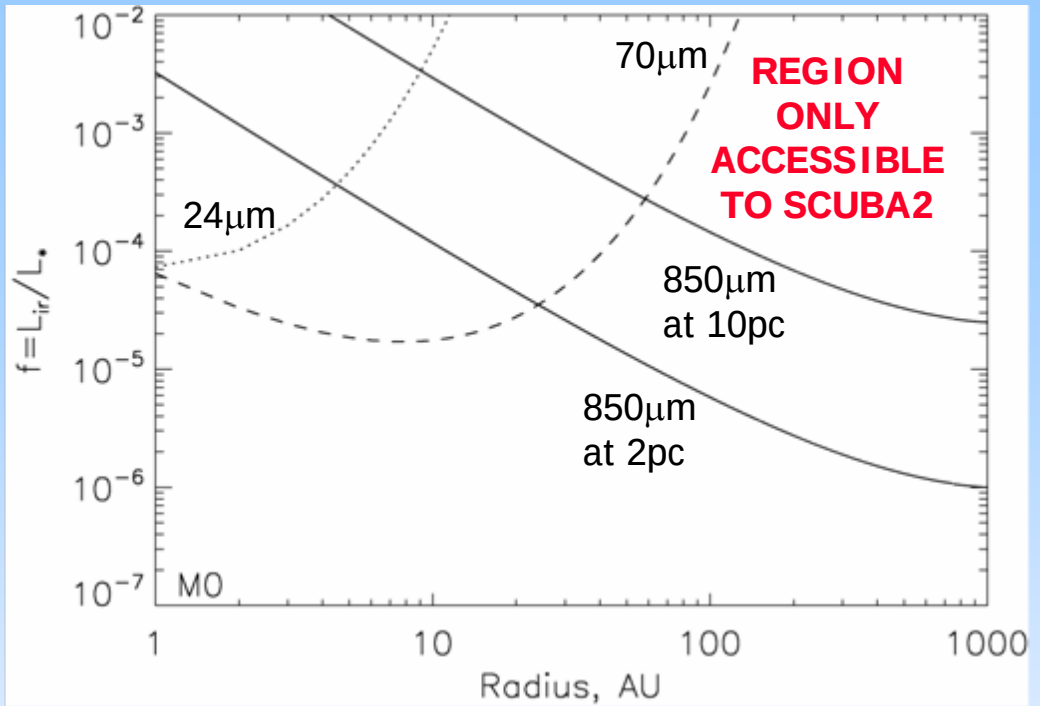
- Flux distribution peaks at 2 mJy
- 23/100 A stars will be detected
- New disks: >30mJy (none), 10-30mJy (5), 3-10mJy (9)
- Mean flux of non-detections is 0.3mJy
- Not including disks not detected at 70μm

Unique: cold dust

Unbiased sub-mm survey showed 15% of FGK stars have disks too cold to detect with IRAS (Wyatt, Dent & Greaves 2003)



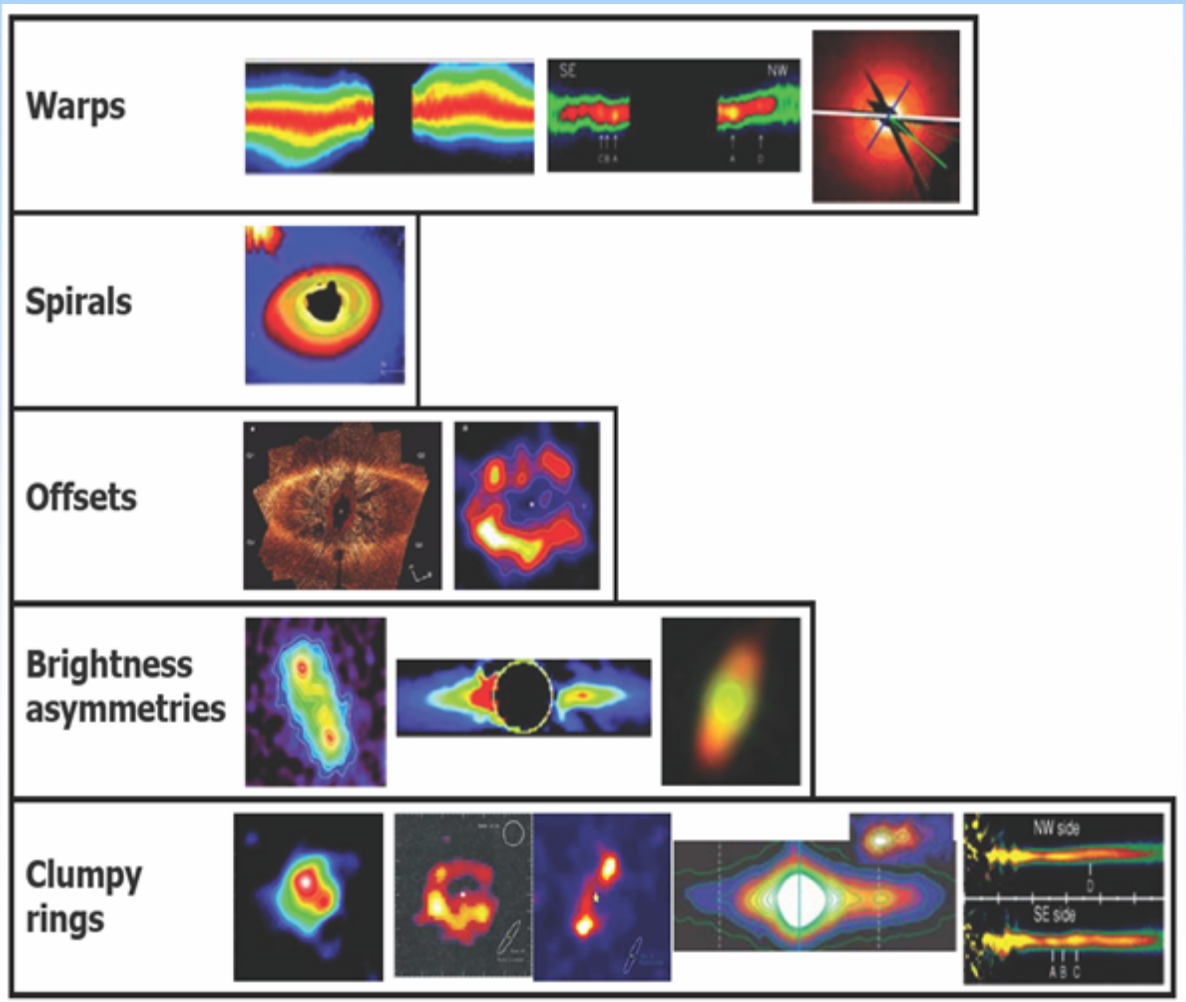
The latest M star results indicate a similar frequency (Lestrade et al. 2006)



- Region accessible only to SCUBA2 larger for later spectral types
- For stars at 2pc SCUBA2 is more sensitive than 70μm at >20-50AU
- For stars at edge of survey SCUBA2 is more sensitive at >60-1000AU

Analysis – (ii) structures

All of the disks that have been imaged show structure which may be caused by unseen planets:



Model predicts

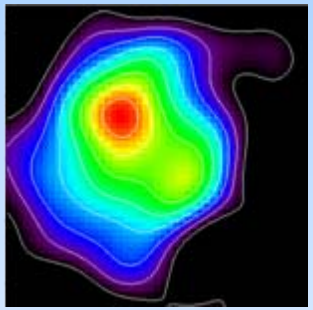
A stars
- 50% of 10-30mJy disks resolvable
- 25% of 3-10mJy disks resolvable
- Total=8 images

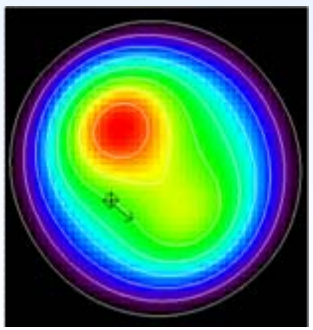
Assuming equal stats for all spectral types means: **40 images**

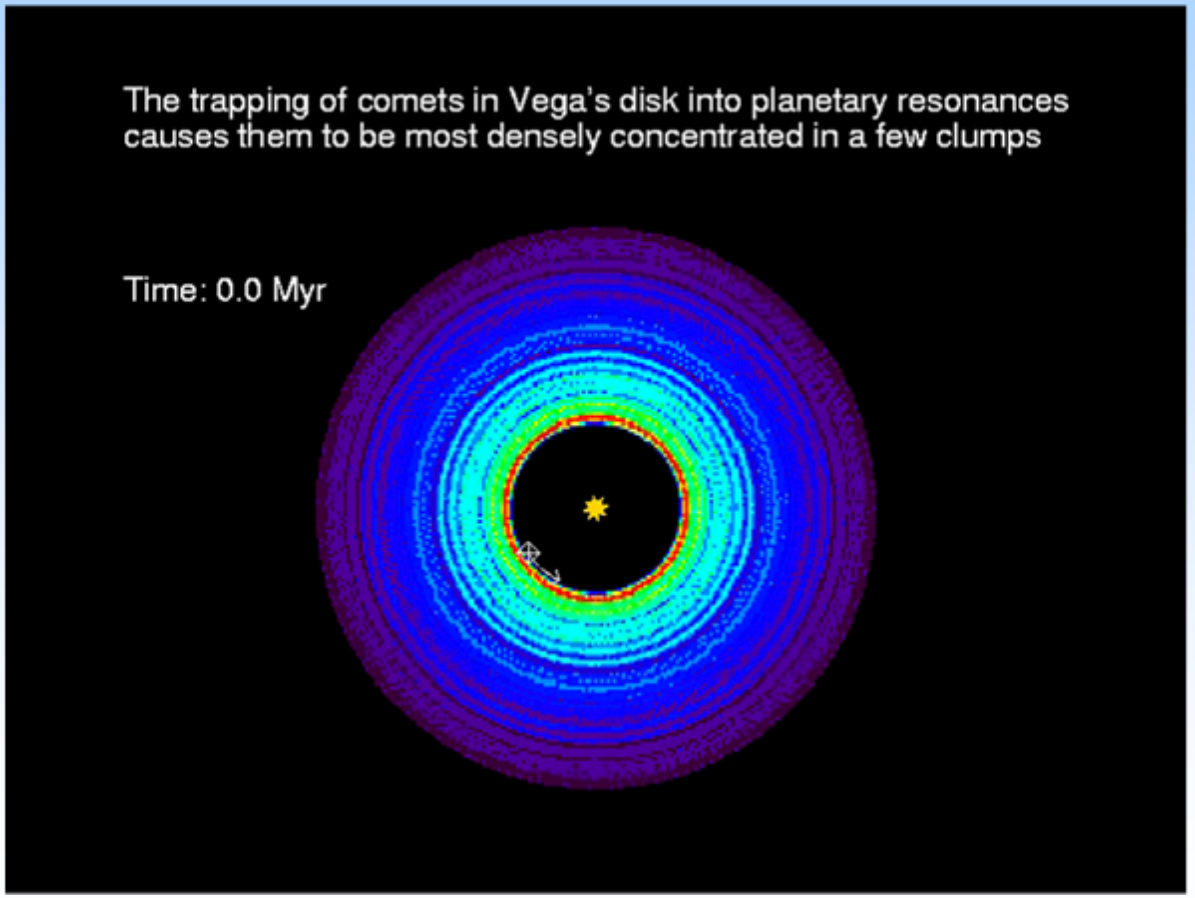
Not including those too cold to detect in far-IR

Modelling structures

Dynamical modelling of clumpy structure of Vega's disk showed it may be explained by migration of a Neptune planet 40-65 AU over 56 Myr (Wyatt 2003)







- Expect some structures explained by current models
- For others new dynamical models will be developed

Predictions, such as temporal evolution will be studied in survey

Legacy

Survey **data products**:

- 850μm images of region around 500 stars
- Sub-mm fluxes (or limits) for all stars
- SED plots and properties of circumstellar disks

Survey **key results**:

- Discovery of disks too cold to detect in far-IR
- Understanding of statistics (evolution, planet connection)
- New images and modelling of structure to infer planetary system

Future:

- Source list for future observations (Herschel, ALMA, JWST)
- Data used by anyone studying nearby stars
- Invaluable to planet detection missions like Darwin/TPF

Conclusions: Debris disk survey

- Summary: Unbiased 850μm survey of 500 nearby stars
- Science goal: what is the diversity of planetary systems?
- Legacy: all studies of nearby stars (ALMA, JWST and TPF)