

# Detecting debris disks via gravitational microlensing

Markus Hundertmark

Modelling Microlensing Events Workshop

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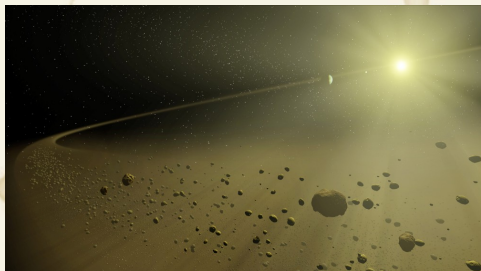


# Outline

- 1 Circumstellar matter
- 2 Detecting debris disks around point lenses
- 3 Binary lenses effected by dust disks
- 4 Summary & Outlook

# Candidates for circumstellar matter

- Spherical gas clouds around lens stars (Bozza et al. 2002)
- Protoplanetary disks around source stars (Zheng & Ménard 2005)
- Protoplanetary and debris disks around lenses

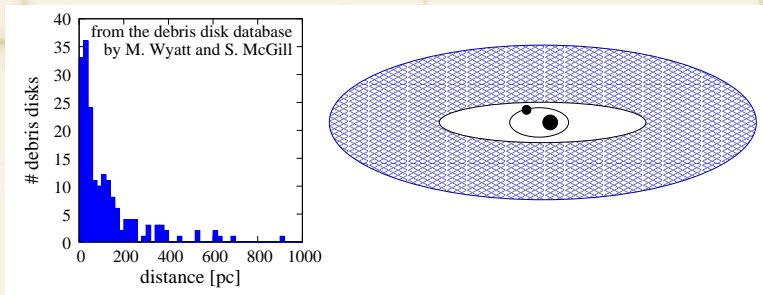


*Image credits: NASA*

## Debris disks

Remnant of the protoplanetary disk where dust is recreated by collisions of planetesimals with ages up to 10 Gyr (e.g. Greaves 2005)

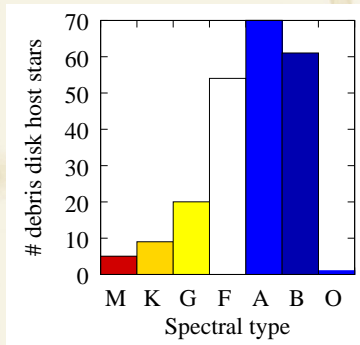
## Why debris disks?



- Long term snapshot of the end of planet formation
- Current detections are based on infrared excess
- Planets cause an offset from the center and density distortions/gaps
- Observational bias to objects up to  $\sim 1$  kpc

## Frequency of debris disks

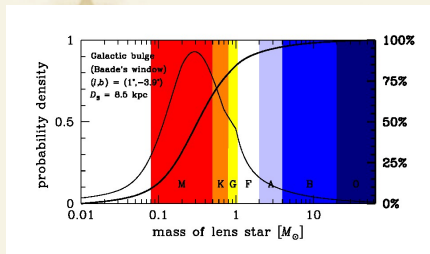
- typical life time of a proplyd is 10 Myr, the typical life time of a debris disk 10 Gyr
- Assume a star formation rate of 5 stars/yr and 400 billion stars in the Milky Way
- Thus the frequency of proplyds is 0.01 %
- < 1 event with proplyd is expected in 10 yr



*from the debris disk database by  
M. Wyatt and S. McGill<sup>a</sup>*

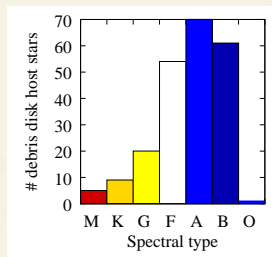
<sup>a</sup>[www.roe.ac.uk/ukatc/research/ddd/](http://www.roe.ac.uk/ukatc/research/ddd/)

# Frequency of debris disks



*Distribution of lens stars  
(Dominik et al. 2008)*

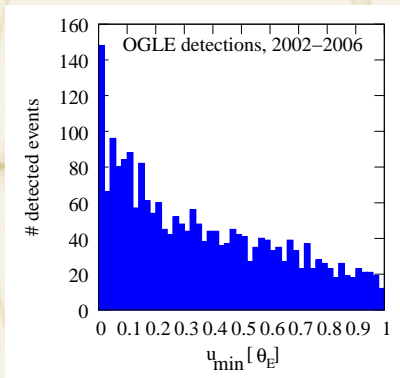
- The frequency of debris disks is 10%
- Between 25% and 45% of the lenses could be affected
- i.e. between 10 and 20 microlensing events per year



*from the debris disk database by  
M. Wyatt and S. McGill  
(methodological bias)*

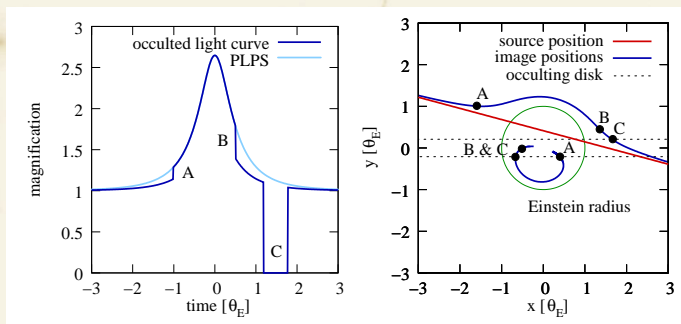
## “A typical event”

- Calculations have been carried out for  $u_{\min} = 0.1 \theta_E$
- Proplyds have outer radii of 100-800 AU, debris disks 50-100 AU (Greaves 2005)
- Mass of the lens:  $0.5 M_{\odot}$  (cf. AU Mic)
- Lens and source are located at 6 and 8 kpc
- $\Rightarrow 1 \theta_E = 2.5 AU$



*Minimal  $u$  from the OGLE EWS  
(Udalski et al. 1994)*

## Occluding disks



- Required: Low inclination, geometrically thin, optically thick disk
- Ideal case to get an impression of the maximal effect

# Astrometric distortion

## Measuring the projected surface density

The two images caused by a point lens are sampled at the same time. In order to measure the spatial transmission  $k_{\pm}$ , magnification  $\mu = k_+ \mu_+ + k_- \mu_-$  in combination with centroid position  $\vec{\theta}_c$  are required.

*Without astrometry:*

$$\bar{k} = \frac{k_+ \mu_+ + k_- \mu_-}{\mu_{PSPL}} \quad (1)$$

at a mean distance in  $\theta_E$  from the lens of

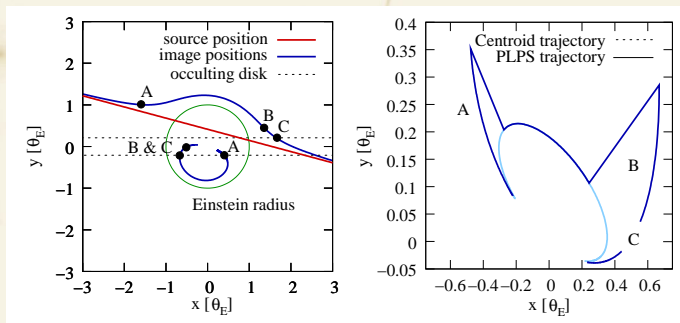
$$\bar{\theta} = \frac{|\theta_+| + |\theta_-|}{2} \quad (2)$$

*With astrometry:*

$$\vec{\theta}_c = \frac{k_+ \vec{\theta}_+ \mu_+ + k_- \vec{\theta}_- \mu_-}{k_+ \mu_+ + k_- \mu_-} \quad (3)$$

$$k_- = \frac{\mu}{\mu_-} \frac{\vec{\theta}_c - \vec{\theta}_+}{\vec{\theta}_- - \vec{\theta}_+} \quad (4)$$

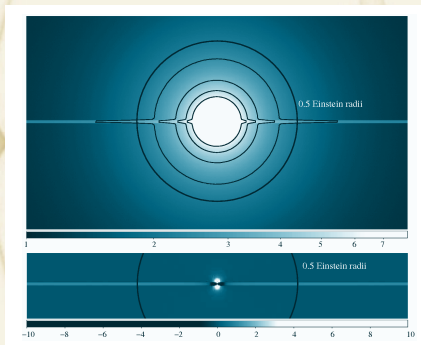
# Astrometric effect



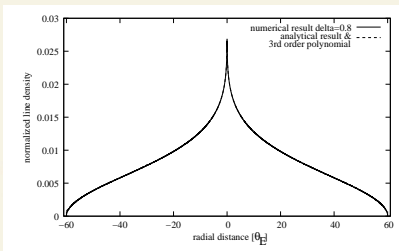
- Maximal deviation from the expected centroid ellipse
- Astrometric offset can take values between 1 and  $10 \mu\text{as}$ , which would be detectable by using *GAIA* (Lindgren & Perryman 1996) or *SIM* (Unwin et al. 2008)

# Gravitational deflection by circumstellar disks

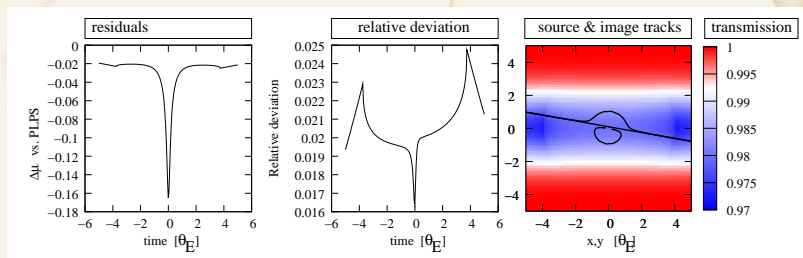
- Surface density  $\Sigma \propto r^{-0.8}$
- The deflection angle has to be integrated numerically for each ray
- Distortions scale with disk mass



*Ray shooting simulation for an edge-on disk with 20 % stellar mass*



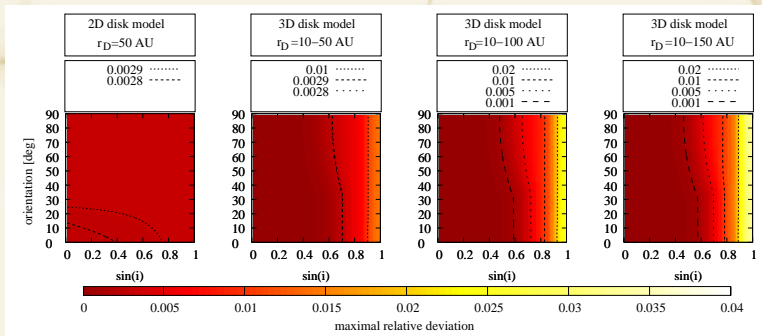
# Optically thin debris disks



*Relative deviation and transmission map for a disk (10–100 AU) with  $i = 87^\circ$ ,  $\phi = 10^\circ$ ,  $\bar{\tau} = 5 \cdot 10^{-4}$ ,  $H = 2.5 \text{ AU}$  (const.).*

- Gravitational deflection is negligible
- optical thickness modeled as  $\tau \propto \rho(r, z)dr$  with  $\rho(r, z) = \frac{\Sigma(r)}{\sqrt{2\pi}H(r)} e^{-z^2/2H(r)}$  and  $H(r) = 0.47 \left(\frac{r}{50 \text{ AU}}\right) + 0.34 \text{ AU}$

# Detection rates



If we assume that a relative deviation of 1% is detectable the corresponding detection rates are:

10% for 10–50 AU      18% for 10–100 AU      23% for 10–150 AU

For smaller inner gaps 75 % can be reached.

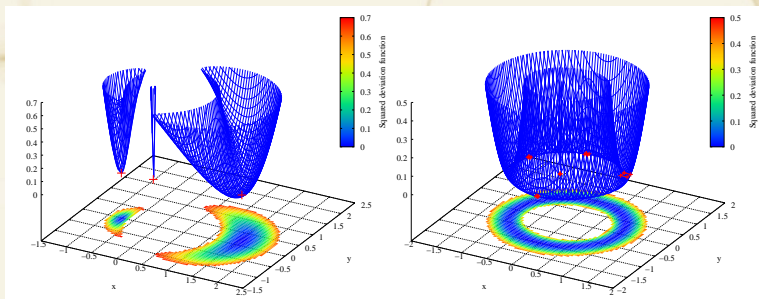
# Debris disk in binary systems

## Motivation

60 % of debris disks in close main-sequence binary systems show an excess of thermal emission (Trilling et al. 2007).

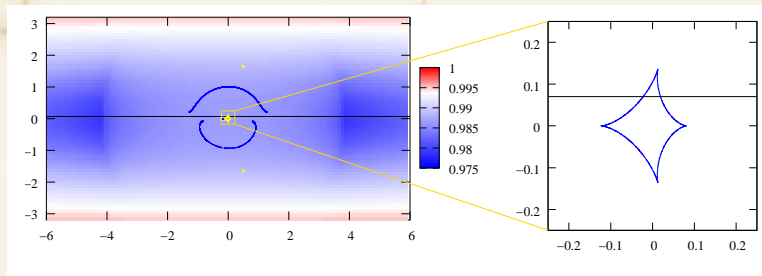
- $\sim 10\%$  of all microlensing events show binary effects (Mao & Paczynski 1991)
- of the order of 1 event per year could be affected
- Higher SNR at high magnifications

# Binary light curves from ray shooting



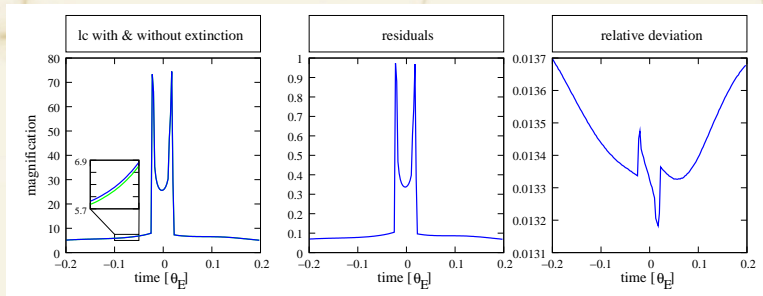
- Use the squared deviation function (Schramm & Kayser 1987)
- MC search for Minima
- Estimate bounding box for a bounding box around the source star
- Carry out standard inverse ray shooting

# Test configuration



- caustic for mass ratio  $q = 0.5$ , separation  $d = 0.5 \theta_E$
- source radius  $d = 10^{-3} \theta_E$
- disk inclination  $i = 85^\circ$
- $u_{\min} = 0.1 \theta_E$

# Dust disk around a binary component



- Configuration: disk (10–100 AU) with  $i = 85^\circ$
- Weight hitting rays according to the transmission
- How is the complicated  $\chi^2$  – space of a planetary event distorted?

# Summary and outlook

- Summary
  - Detecting protoplanets seems to be unlikely
  - Search for dust disks is in principle possible
  - Expected detection rate: roughly 1 event per year
  - In the existing 4000 OGLE light curves  $\sim 10$  events might be affected
- Outlook
  - Search for systematic deviations in existing datasets
  - Simulate the distribution of inner radii
  - How is the  $\chi^2$  landscape of planetary events affected?
  - Model the extinction with different grain sizes and mie scattering

Thanks for your attention!



Real image taken by Steve Potter (SAAO)