Optical Dust Shell of U Hya

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In collaboration with
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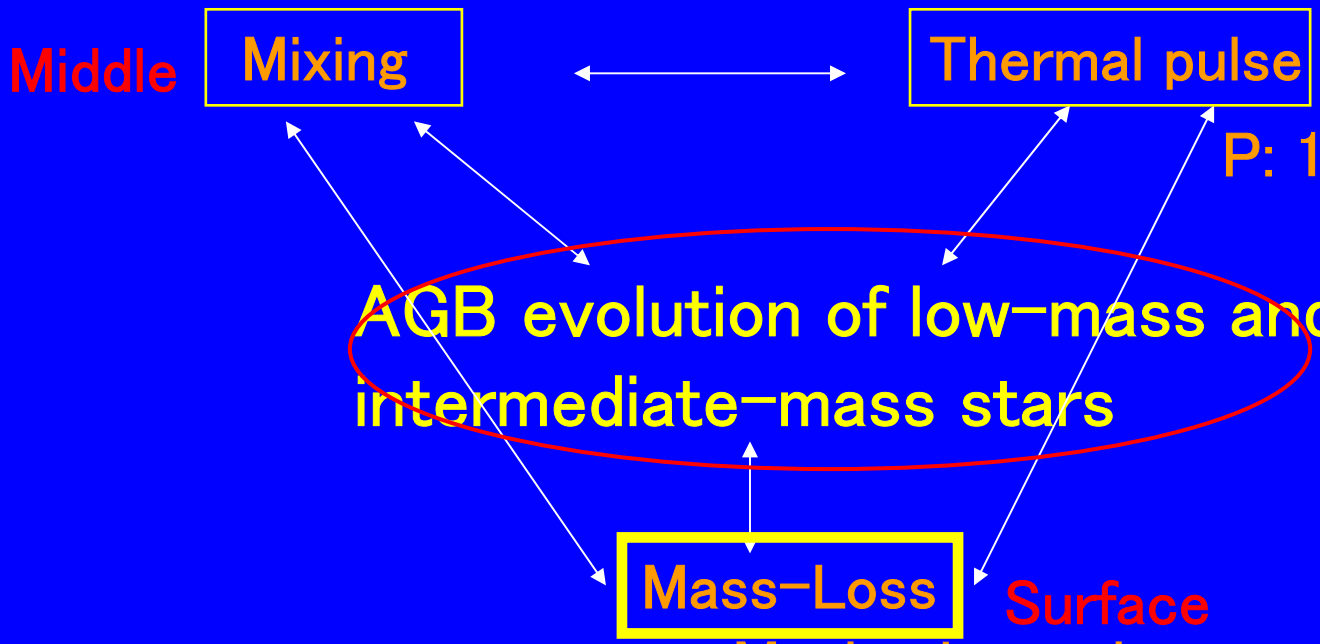


- Mechanism unknown
- Time variability
  - AGB wind (how begins, how ends)
  - Super wind (～10^-4 M sun /yr) ?
- Bipolarity

Time Variability & ＜＝＞ Dust Shell Structure
Geometry of
Mass-Loss

Δt ＞ 10e4 years （～thermal pulse time scale)

=＞ R ＞ 10e17cm

=＞ Td ＜ 50K

=＞ SED peaked at Mid- or Far-Infrared

=＞ In-Orbit observations necessary

High Resolution IRAS Images of AGB Stars

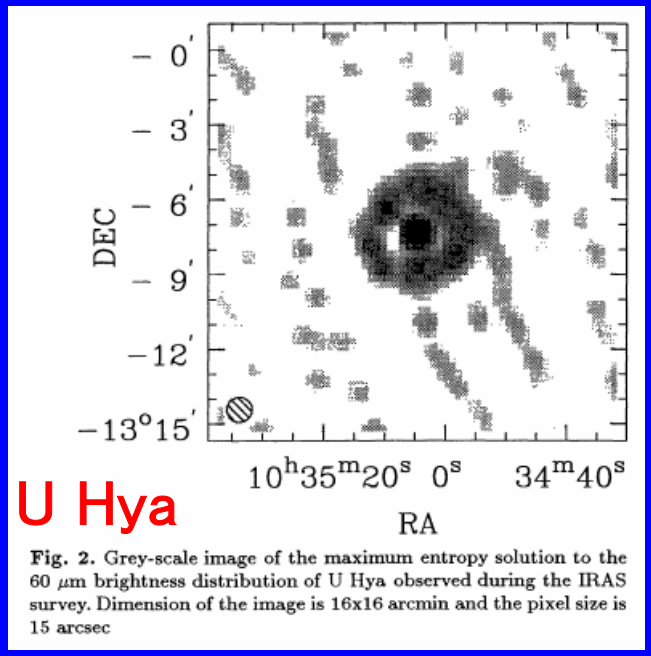


Fig. 2. Grey-scale image of the maximum entropy solution to the 60 μm brightness distribution of U Hya observed during the IRAS survey. Dimension of the image is 16x16 arcmin and the pixel size is 15 arcsec

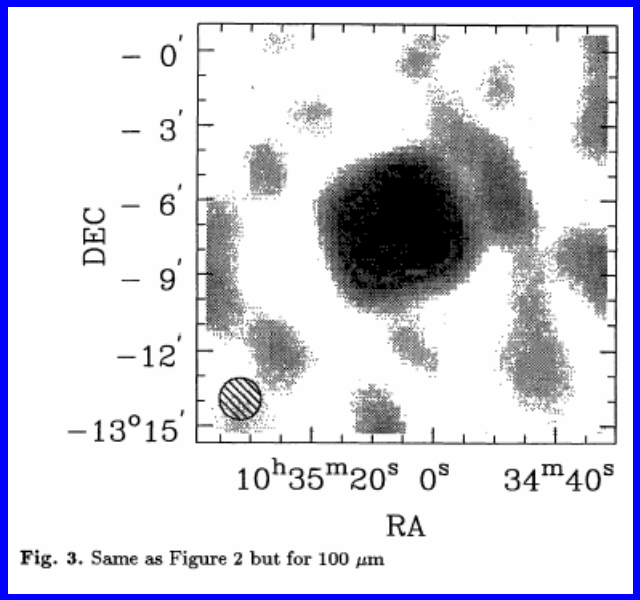


Fig. 3. Same as Figure 2 but for 100 μm

Waters et al. 1994

60 μ m

100 μ m

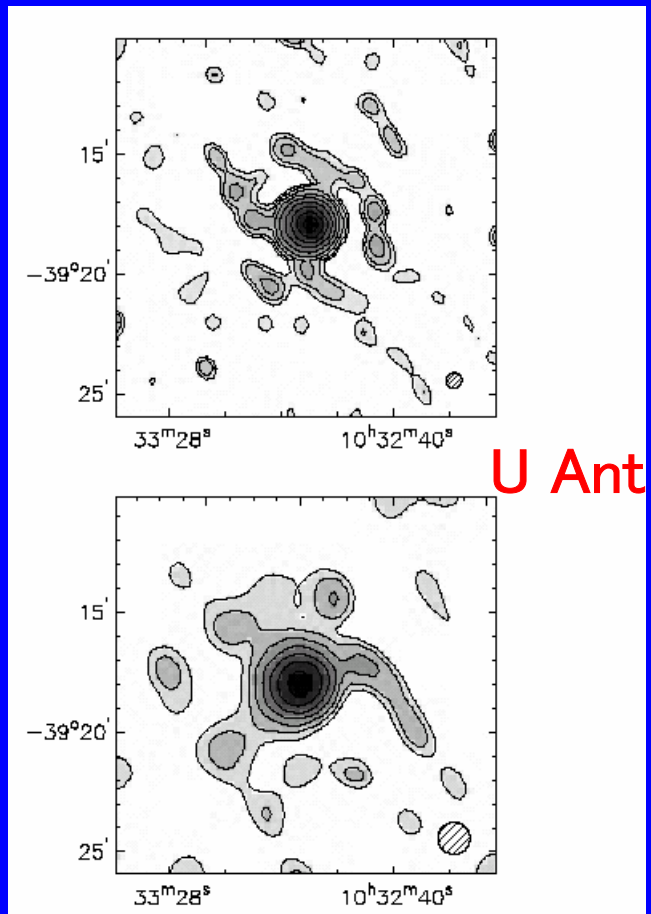
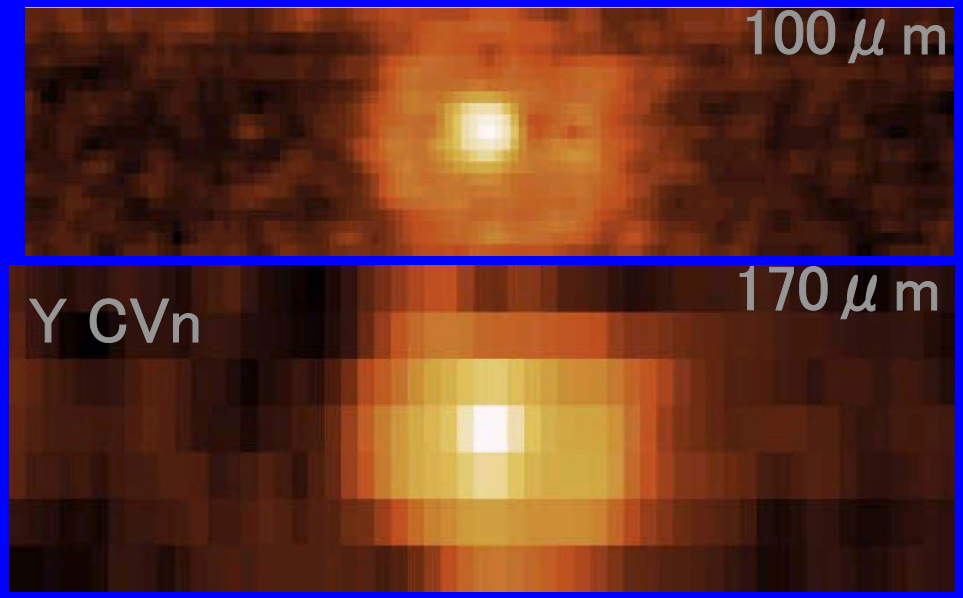


Fig. 1. HIRAS images of U Ant in the 60μm band (top) and the 100 μm band (bottom). The contour levels are given steps in the power of 2 in MJy sr^{-1} starting at 1 MJy sr^{-1}. The hatched circle at the bottom-right corner shows the nominal size (FWHM) of a point-like source in HIRAS images

Izumiura et al. 1997

- ISO/PHT observations of the carbon star Y CVn.



10 arcmin

* Detached dust shell
* Sudden decline of mass-loss by 2 orders of magnitude

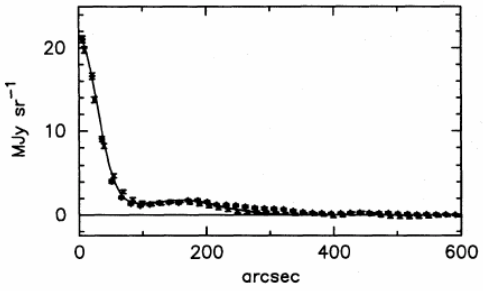


Fig. 3. Observed (symbols) and model (line) brightness profiles at 90 μm. Squares and diamonds express the data points in the north-east and the south-west parts, respectively (see text). The observed profile is presented so that the central stellar component appears symmetric. Only statistical error is shown. Model parameters are given in the text.

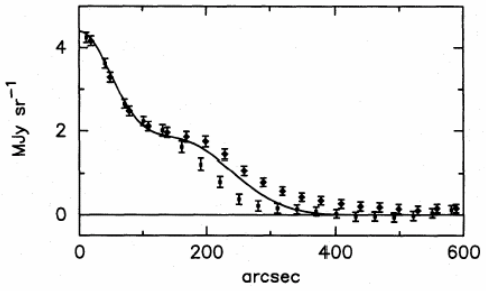
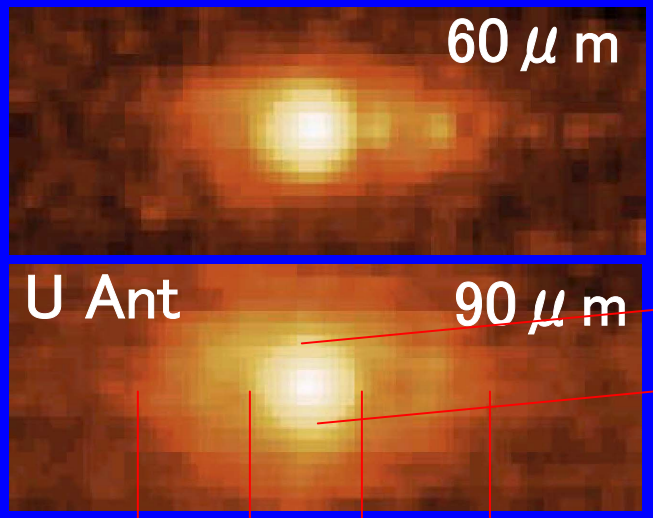


Fig. 4. Same as in Figure 3 but at 160 μm.

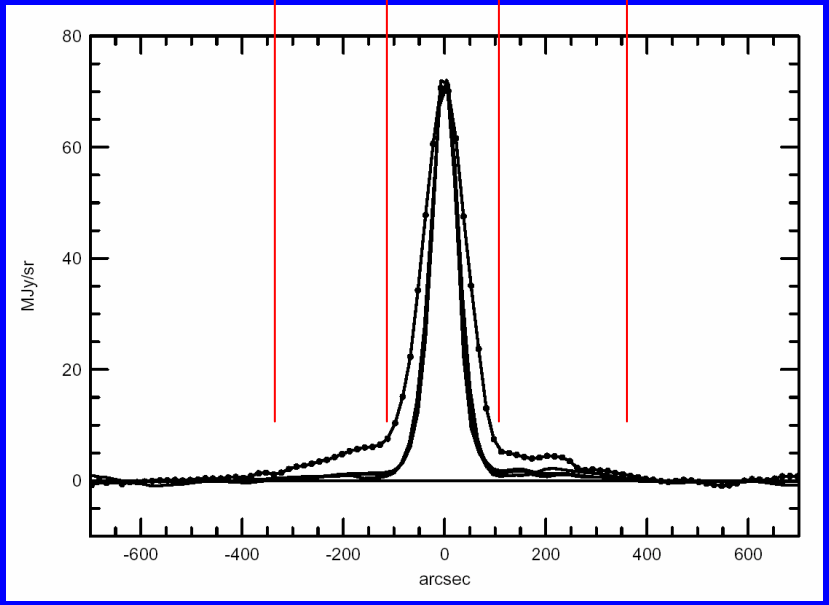
Izumiura et al. 1996

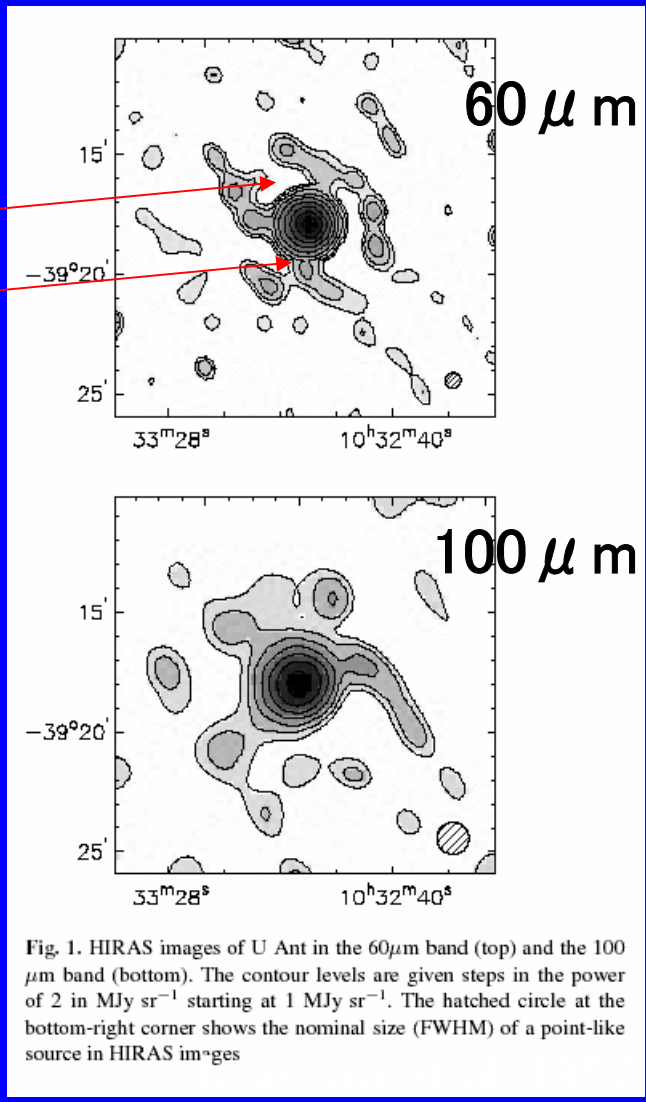
- High Resolution IRAS images of the carbon star U Ant
- ISO/PHT maps confirmed the two dust shell components



10 arcmin

Double shell !!





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Some problems of far-infrared observations :

* temperature and density distributions coupled together
* rare opportunities of observations: ～once in 10 years
* lack in spatial resolution expected to last in next ～20 years

We are looking for another means,
=> scattered optical light
- reflects primarily the density distribution, not the temperature distribution
- allows to achieve a high spatial resolution easily
- but, is expected to be very faint, then feasibility unknown

A feasibility study
=> U Hya (an AGB carbon star) was observed (most promising candidate)

Observations:

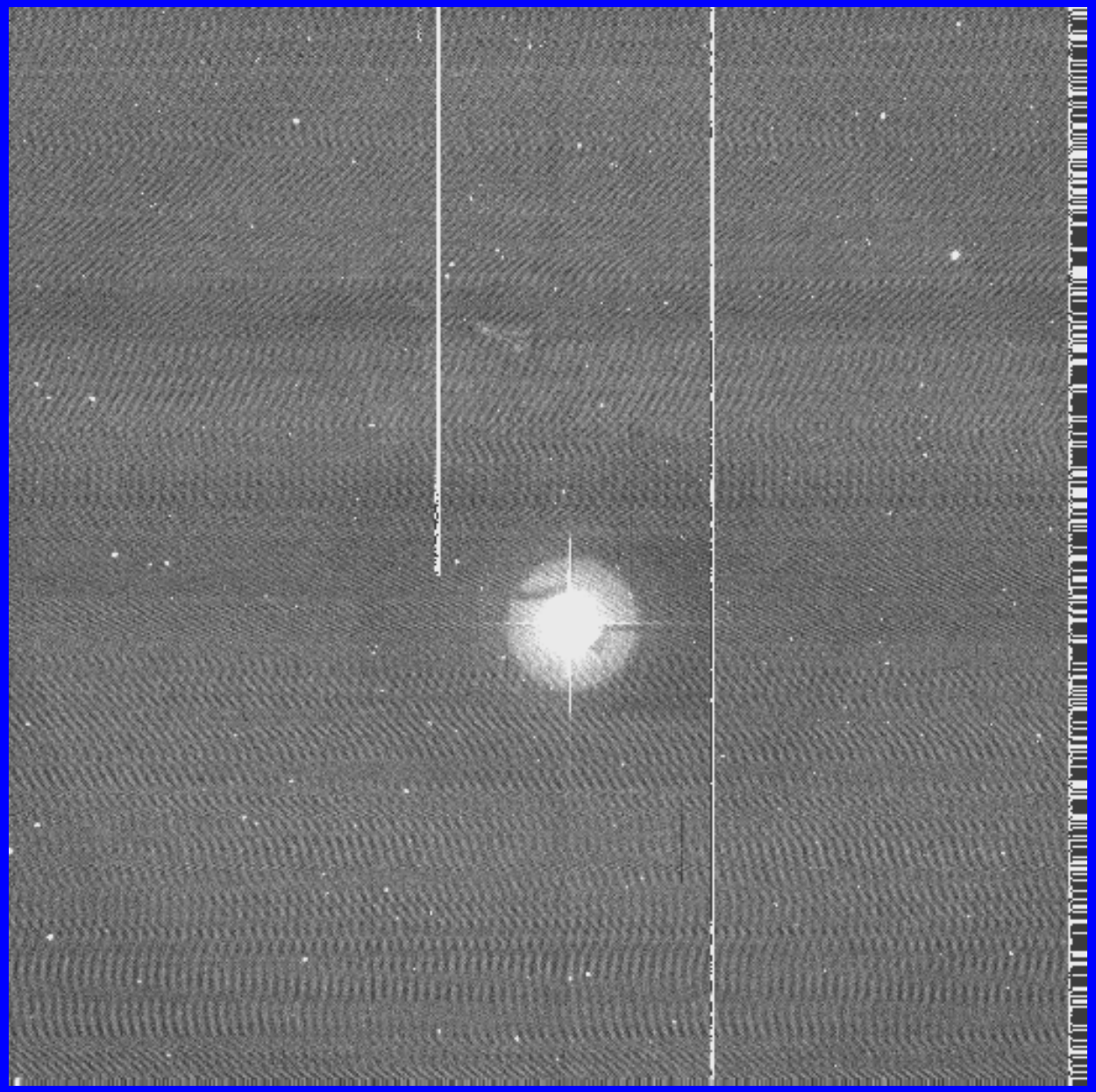
Dates: 2003/Feb/25-28

Telescope: Kiso Observatory, IoA, U-Tokyo
105cm Schmidt telescope + 2K CCD camera
(SITe 2Kx2K CCD)
Narrowband filter: λ c=4610A、$\Delta\lambda$ =197A (FWHM)

Object: U Hya、carbon star、Tc、12C/13C=32、Te=2820K

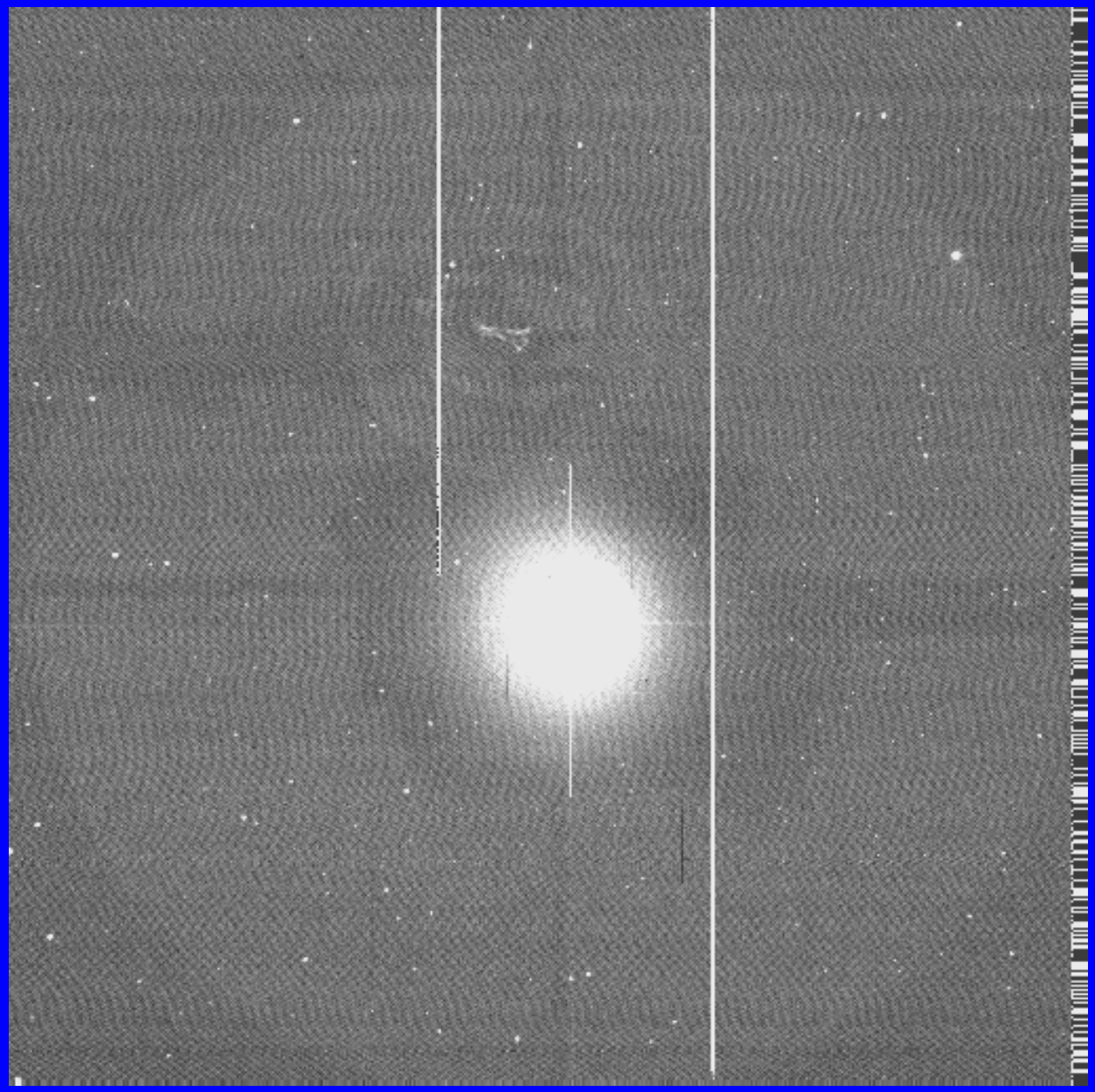
Exposure: 1500s x 3 (on 27th)、1800s x 3 (on 28th)
Total 9900sec
Reference: Spica => System MTF (or PSF)
Process: Image(U Hya) – Image(Spica*C) (C: constant)

=> We detected a circular emission component with
a radius of 120" surrounding U Hya

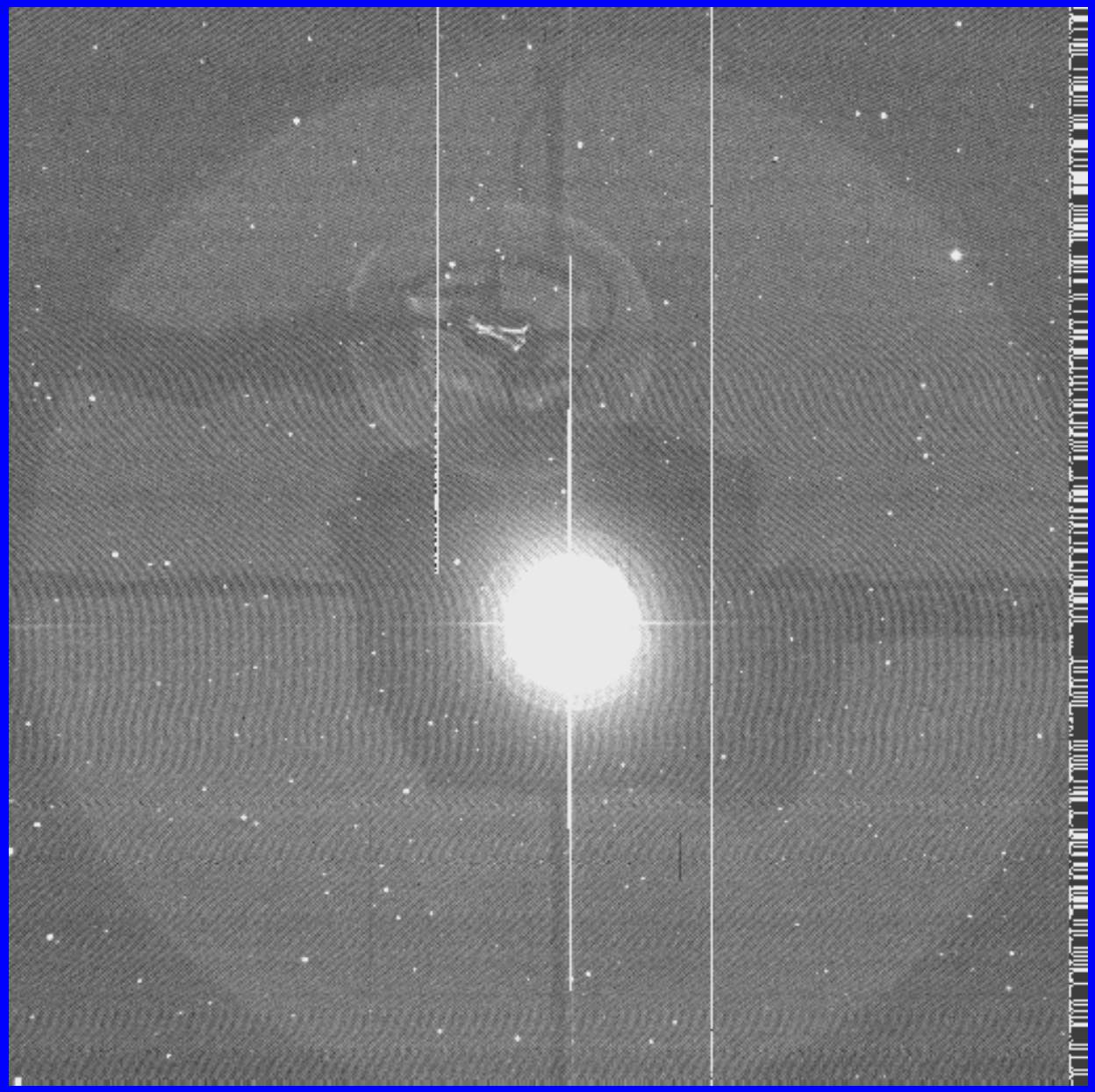


Spica
5sec

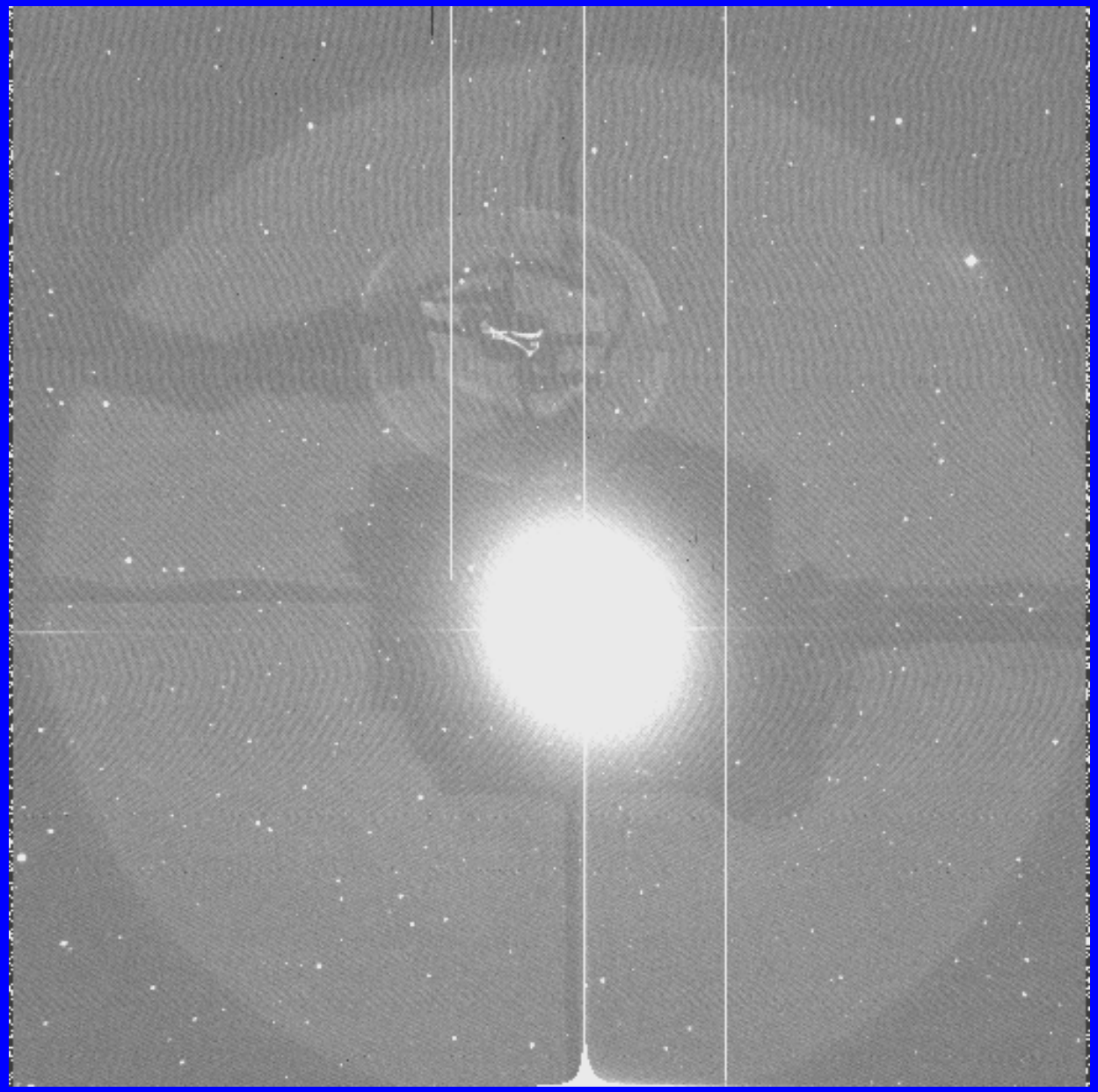
~ 60 arcmin



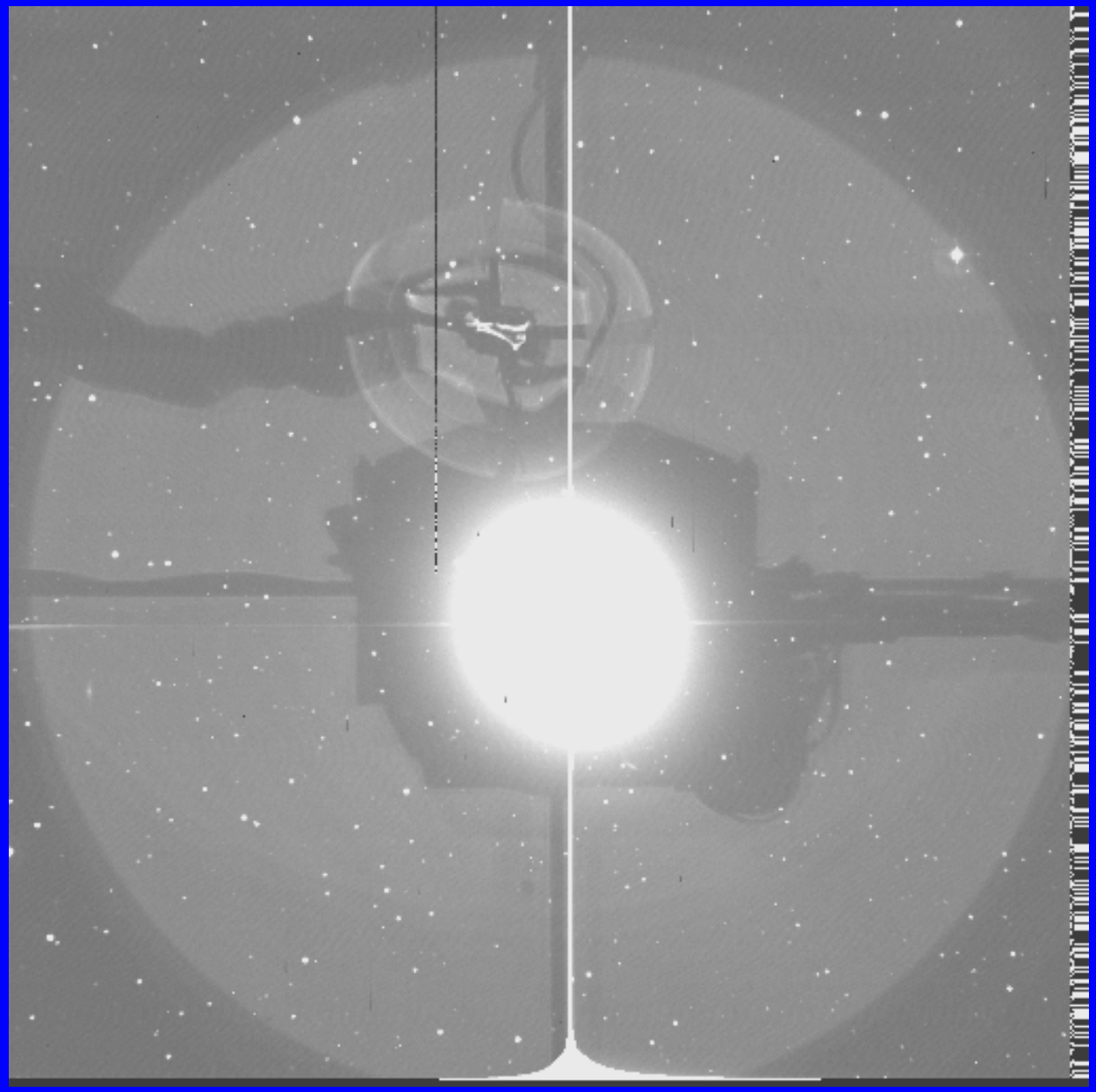
Spica
10sec



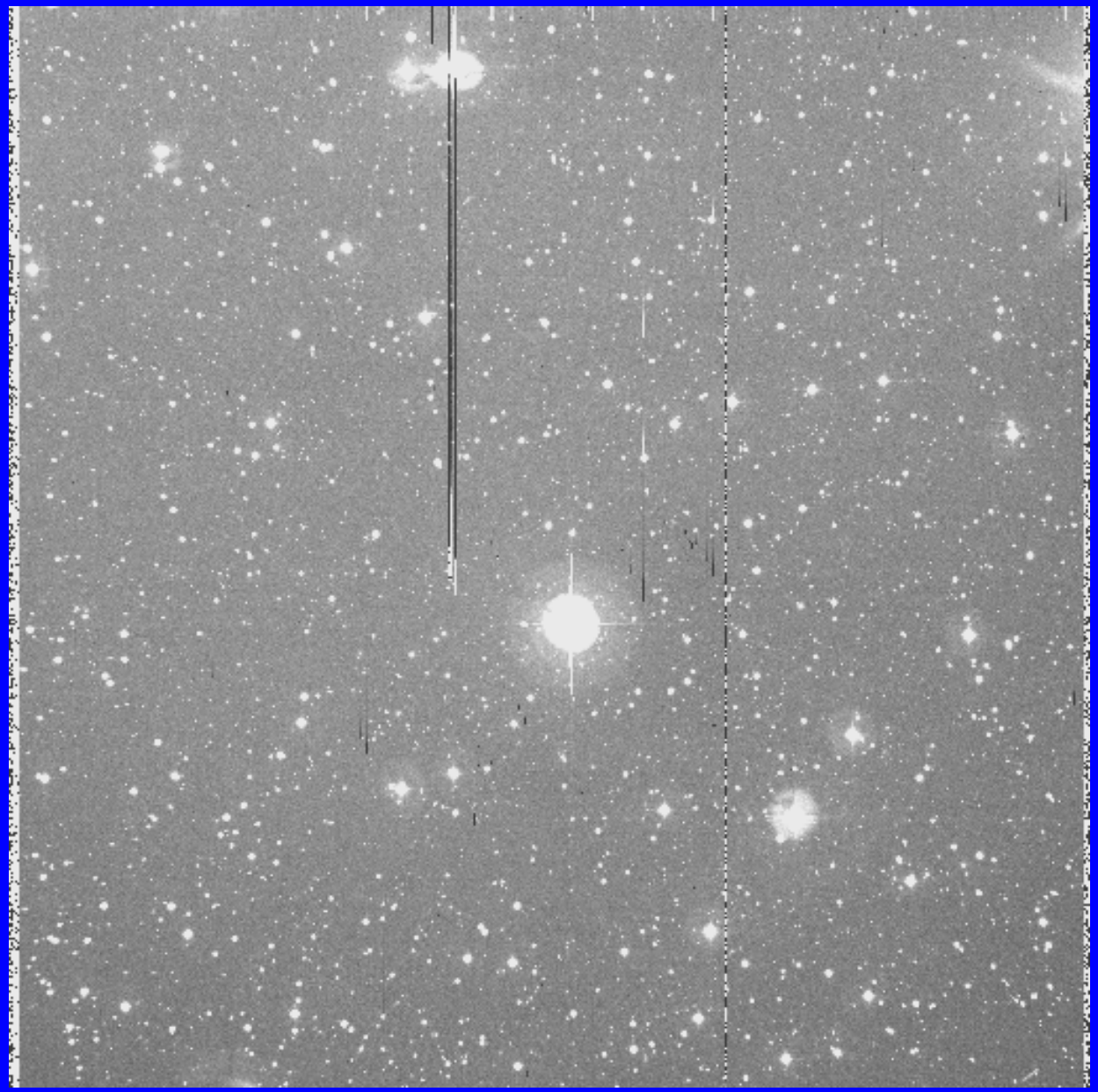
Spica
30sec



Spica
100sec

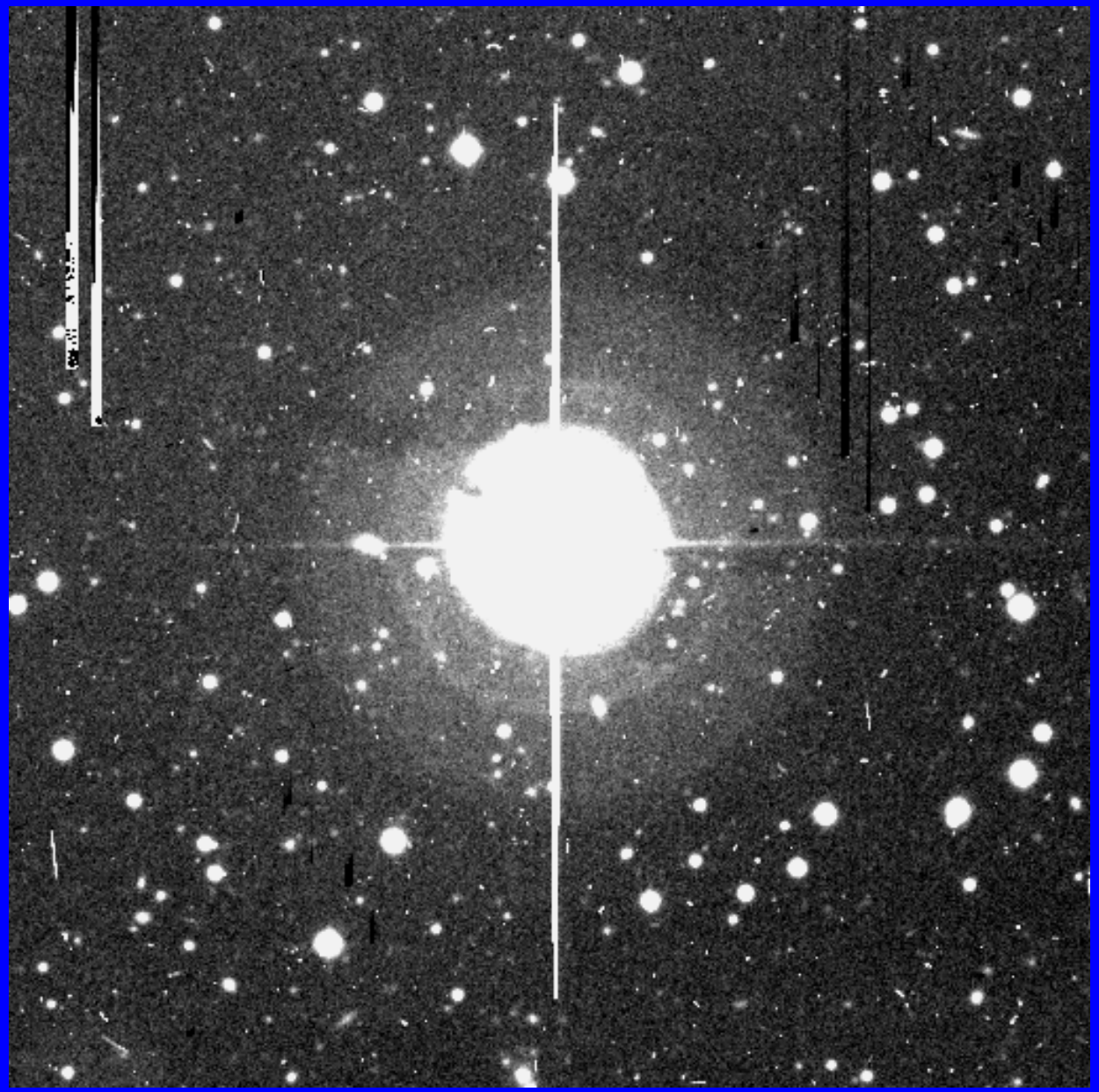


Spica
300sec



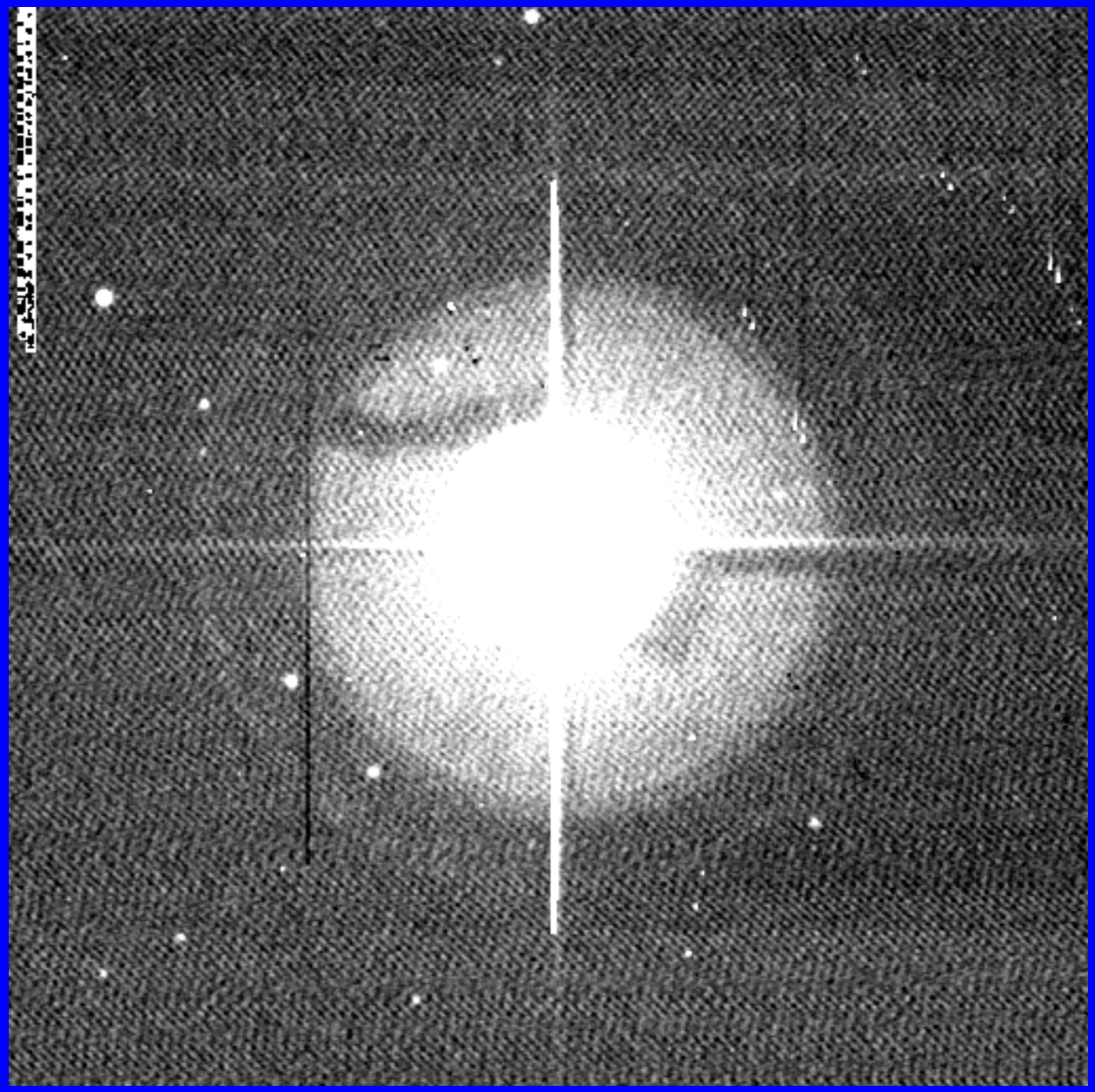
U Hya
9900sec

~ 60 arcmin



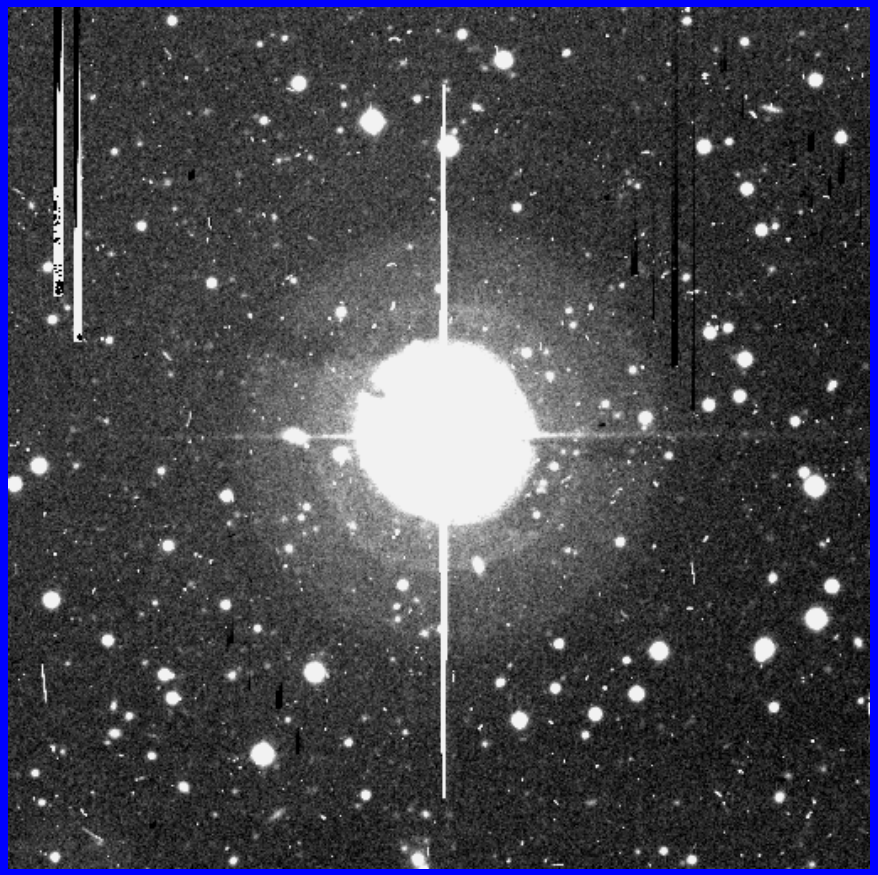
U Hya
9900sec

~12 arcmin

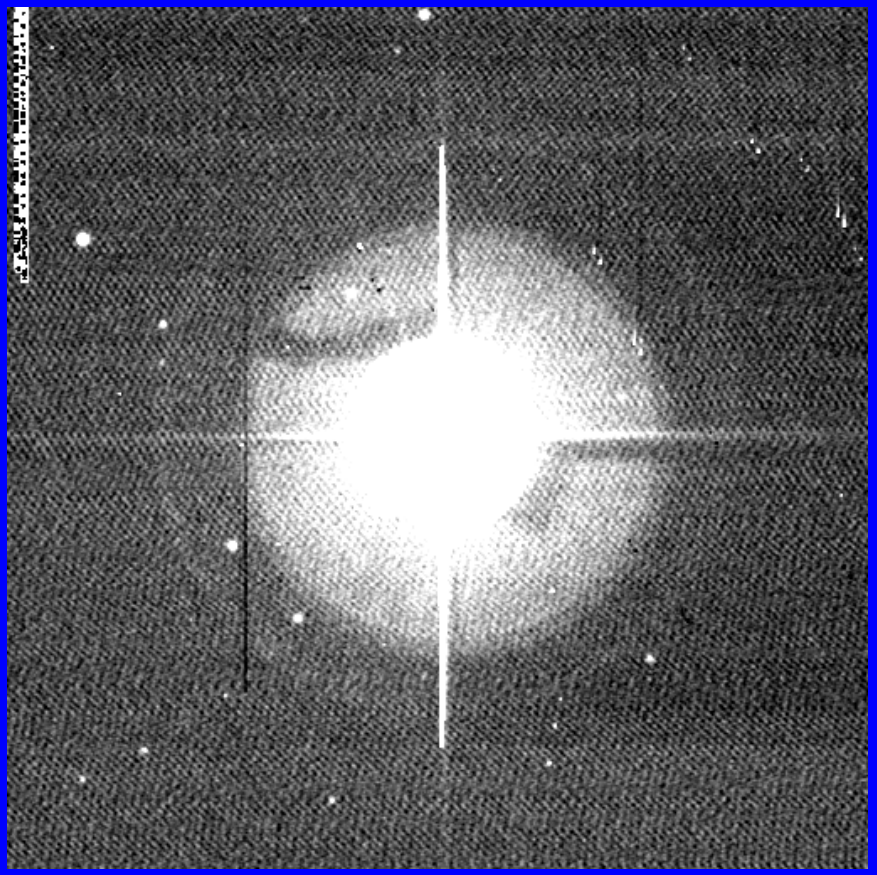


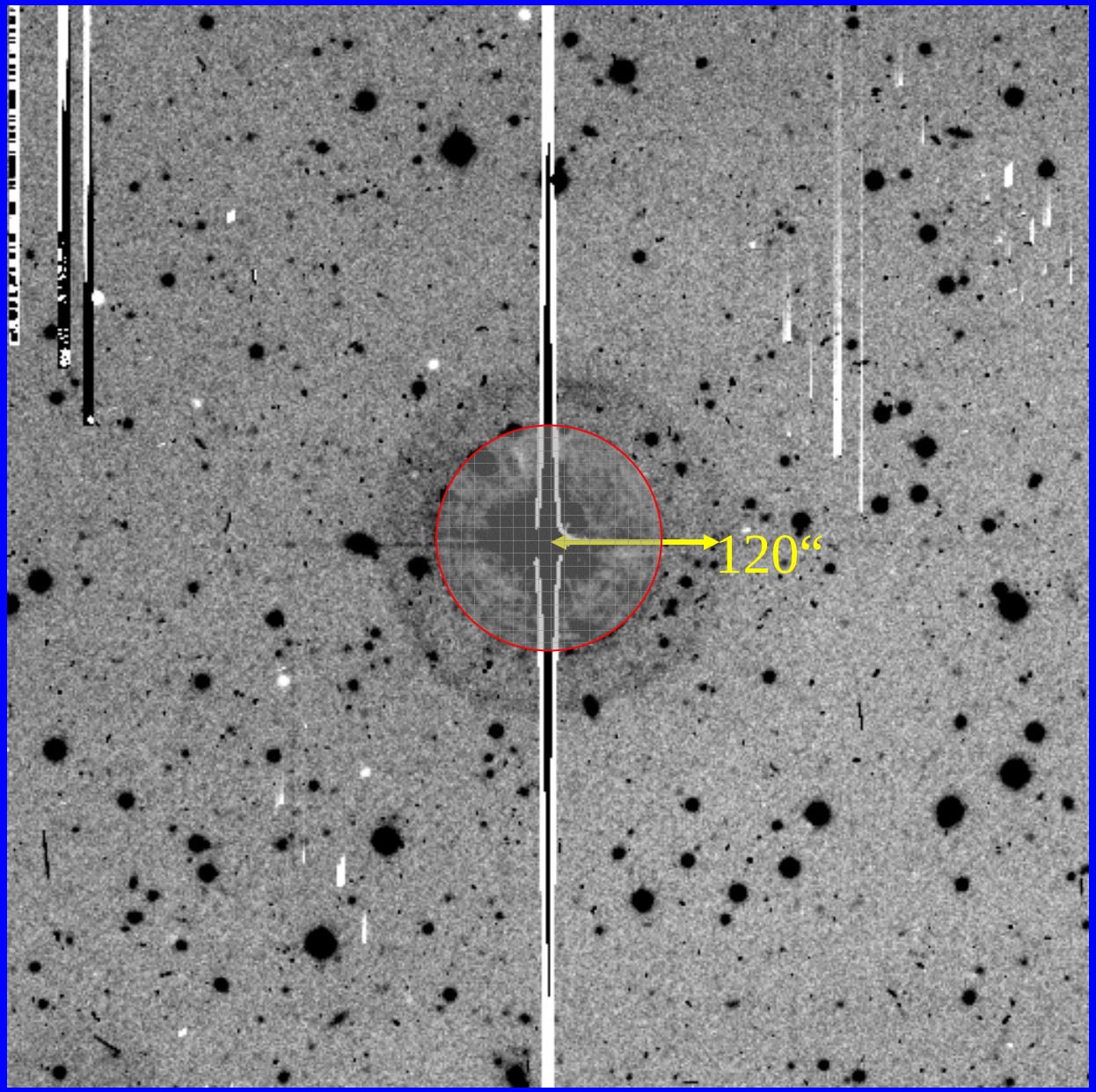
Spica
5sec

U Hya

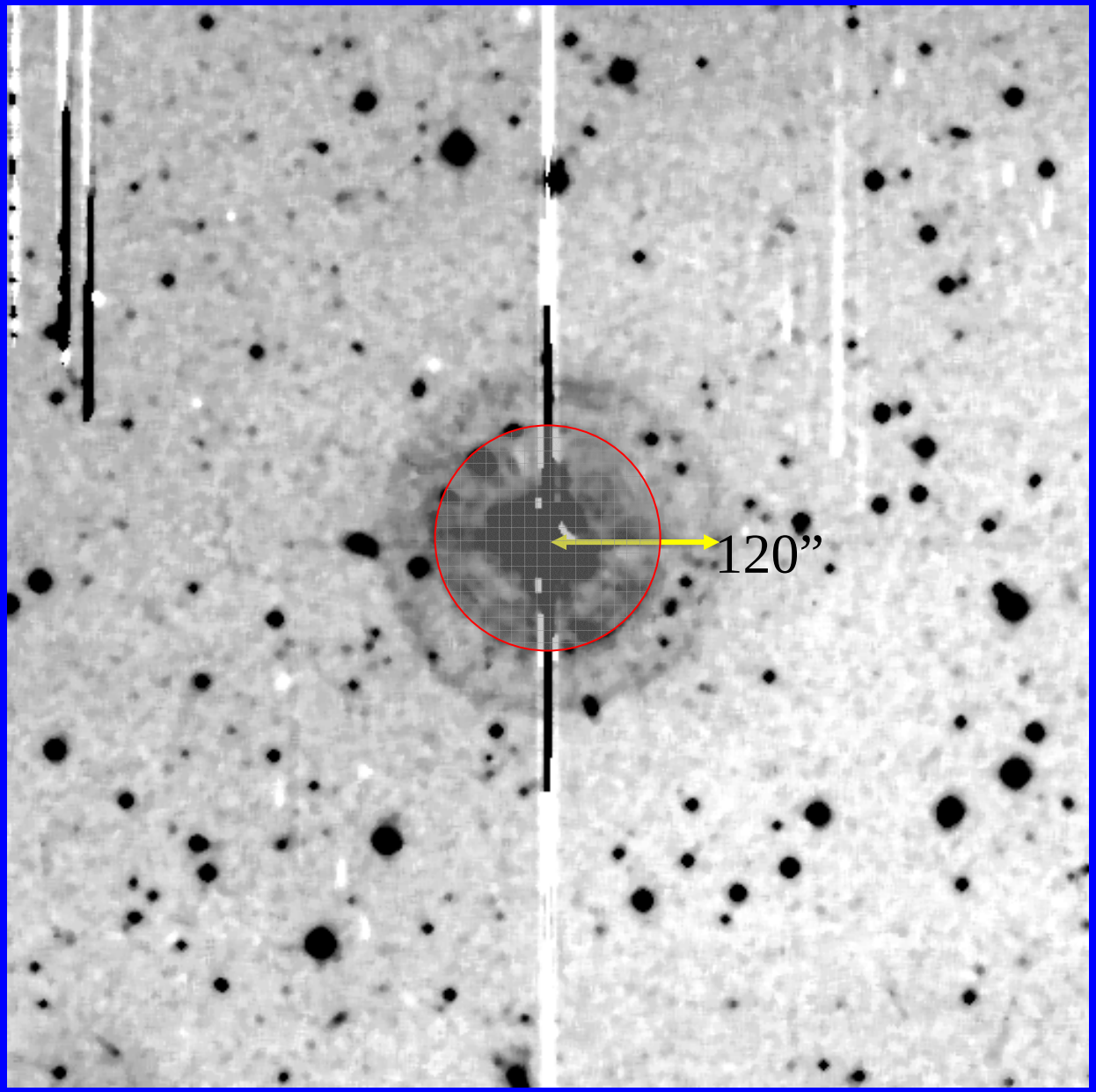


Spica





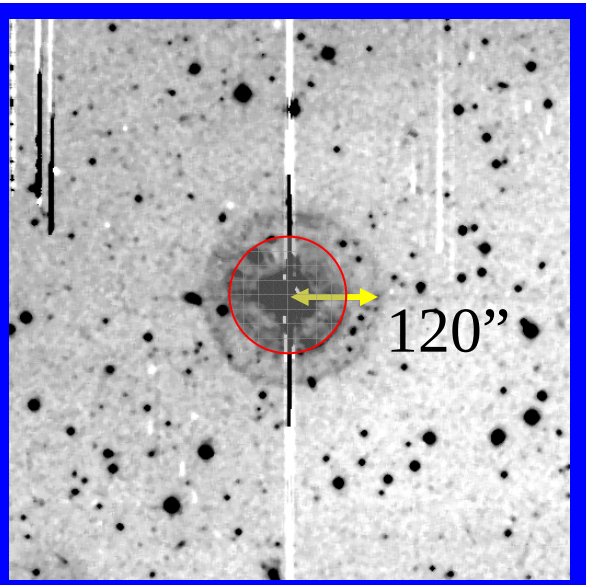
U Hya
9900sec
MTF sub



U Hya
9900sec
MTF sub
5x5 med

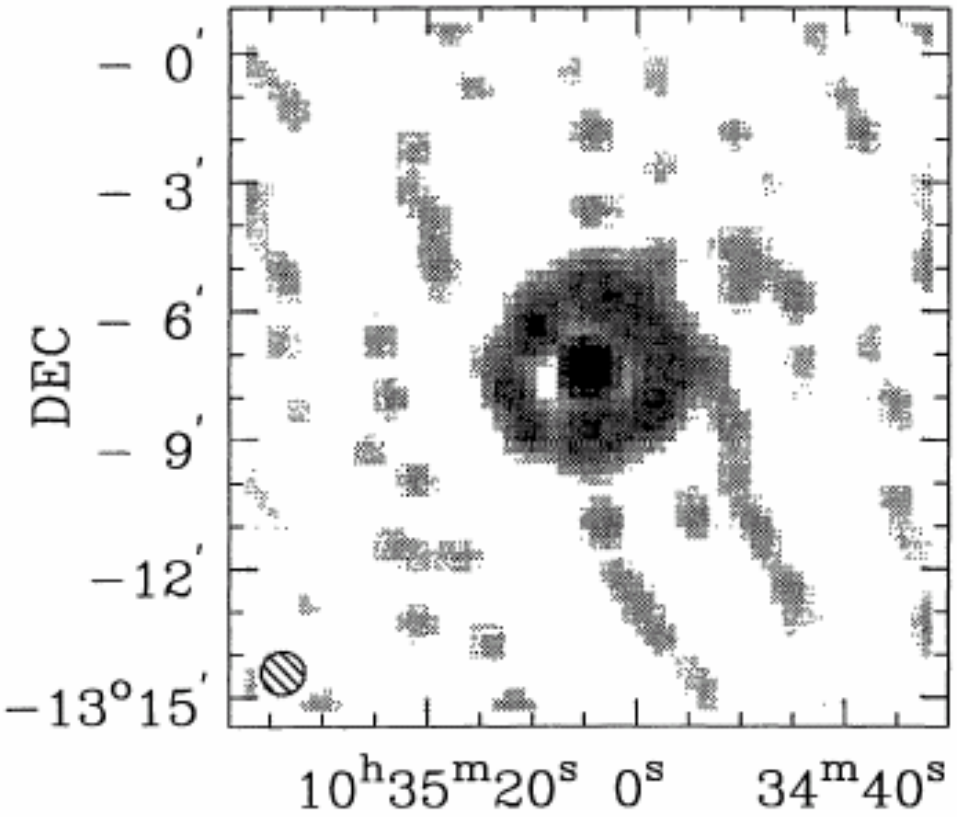
Optical Dust Shell of U Hya:

- Shape: nearly circular
  rim-brightened
  => geometrically thin



- Apparent radius:～120 arcsec

- Actual radius: ～2.9 e17cm (～0.1pc)
  (～1e4 years)
  (parallax:6.18 mas, Hipparcos)
- Peak brightness: ～1/100 of the sky
  => 26～27 mag/□”
  (no photometry done yet)
  (no quantitative analyses made yet)



HIRAS 60 μ m

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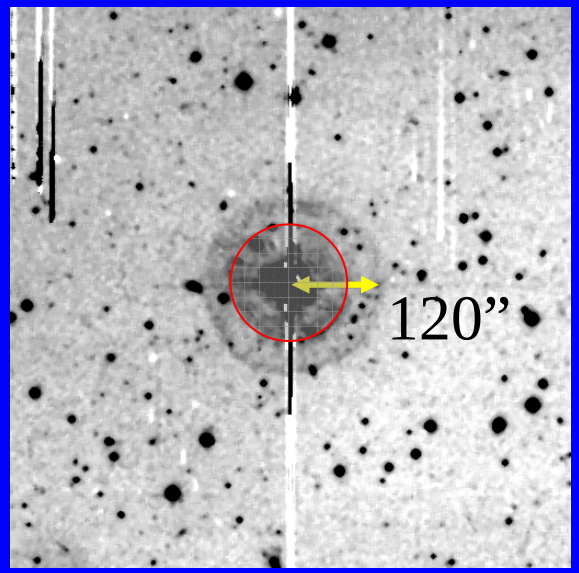
Waters et al. 1994



The observed optical shell matches exactly the far-infrared dust shell resolved in the HIRAS Image.

(eg. TT Cyg, CO shell)

Previous studies on the very extended,
optical dust shells of AGB stars:

<IRC+10216> : r～200” (～120 pc)
*Mauron & Huggins 1999

<R Scl> : r～20” (～400pc)
<U Ant> : r～60”(～250pc)
*Izumiura et al. 2000, IAU-Symp. 177 (held in 1996), p.425
Images recorded on UK Schmidt plates
*Gonzalez Delgado 2003, AA, 399, 1021
ESO 3.6m+Corona-Graph+NBF
(cf. Gustafsson et al.1997, AA, 318, 535
ESO 3.6m+Corona-Graph+NBF
NaI and KI resonance scattering)

These dust shells have CO gas shell counterparts

U Hya: No CO gas shell counterpart

=> First instance of an optical dust shell with no CO gas shell association

=> By extremely deep optical imaging with using a well designed telescope, we will be able to track the mass-loss history of AGB stars for a time span longer than 10e4 years, from the ground, in the optical, with a high spatial resolution.

=> A new observational probe has been found of the late stellar evolution and of the interface region between the stellar wind and the interstellar matter.

Multi-band observations of:

- the brightness distribution of the shell
- the stellar flux
- their time variabilities
- the polarization distribution in the shell

Allows to derive:

- density distrubution (assuming albedoes)
- contribution of the interstellar radiation field
- distance to the star
- some information on the dust grains
- etc.

Dust shells do not need to be detached ones.

Our very near future plan => dedicated telescope(s)

- small diameter: 30cm (=> 50cm)
- fast optics: F4 (=>F2)
- focus: classical Cassegrain (=> off-set Cassegrain)
- illumination: uniform (=> gaussian)
- mirror material: glass (=> special composites: CFRP?)
- mirror polishing: normal (=> high accuracy surface)
- mirror coating: Aluminum (=> high reflection coating)
- AR coatings: multi-layer AR coatings, specific wavelength
- instrument: camera with coronagraph capability
- functionality: broad- and narrow-band (polarimetric) imaging
- field of view: 0.3° Φ (=>1° Φ)
- sensitivity: 28 mag/arcsec^2 @5000A in 10,000sec
  (sky emission dominant)

Our very near future plan (continued)

- operation: semi-automatic (=> automatic)

- site : domestic (=> overseas => space)
  Kiso/Okayama? (=> ALMA/SAAO? => ISSA?)

- budget : ??, to be estimated