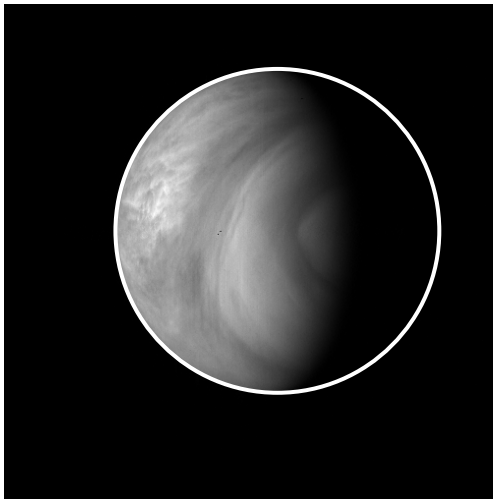
For Brain storming:
Limb fitting Topics

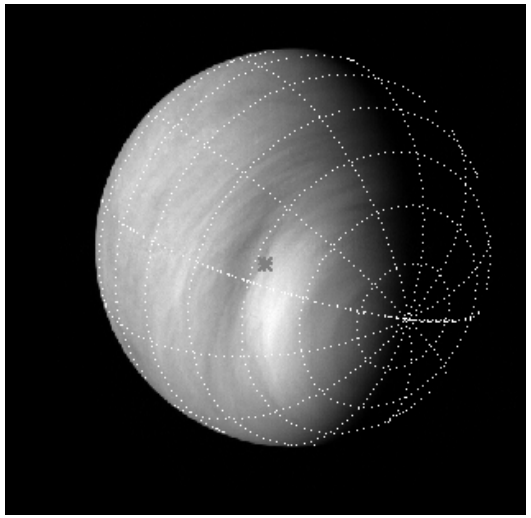
Why we use Ellipse fitting in
Akatuski L3 procedure

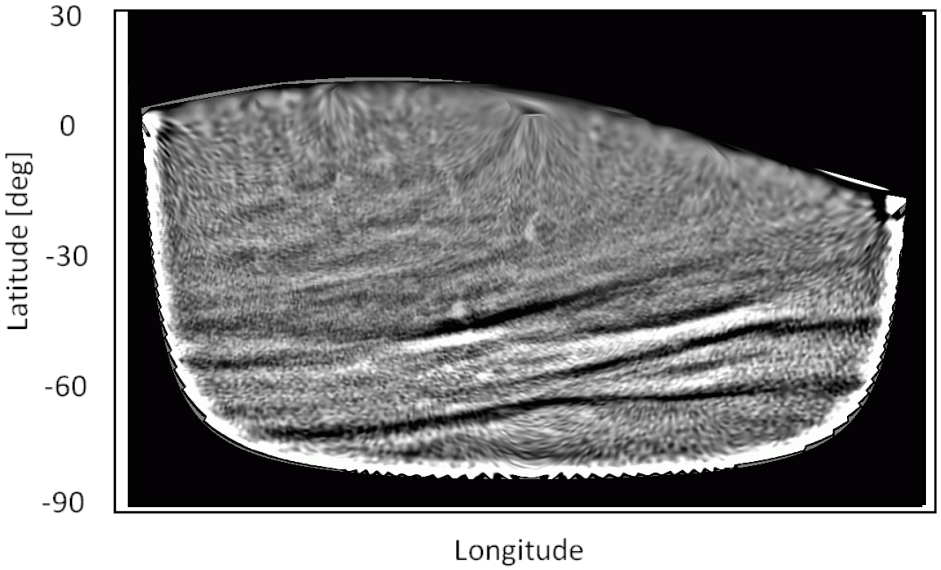


Toru Kouyama
AIST
WTK@ISAS, 2015.04.25

Cloud tracking procedure

Venus Express/VMC

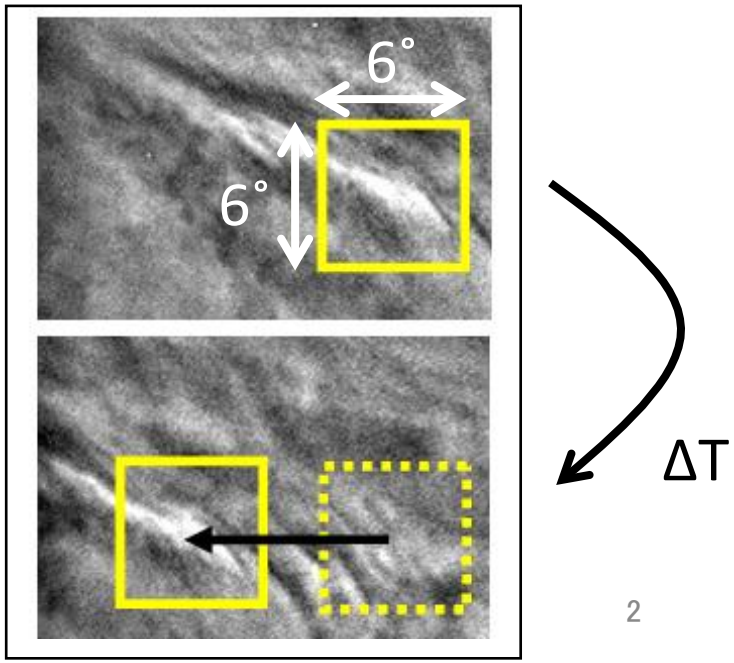




1. Projecting original image onto latitude-longitude coordinate map

2.Tracking cloud features

Cloud tracking supposes each image has correct navigation information and correct geometry information.



Cloud tracking requires very high precision geometry information

Recent satellites have very good accurate navigation information, but…

Venus Express:

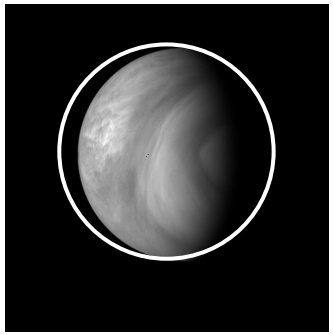
Satellite attitude uncertainty: 0.02˚ (Bertaux et al., 2007)

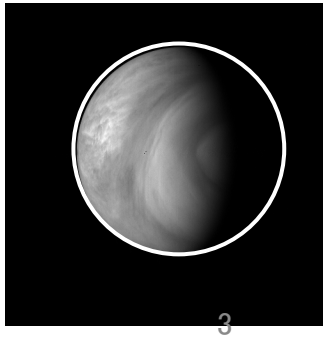
0.02˚ ~ 1pixel/VMC

=> 20-40 km error => 5-10 m s^{-1} / Δt = 1 hour

Akatuski:

Expected to be worse than Venus Express

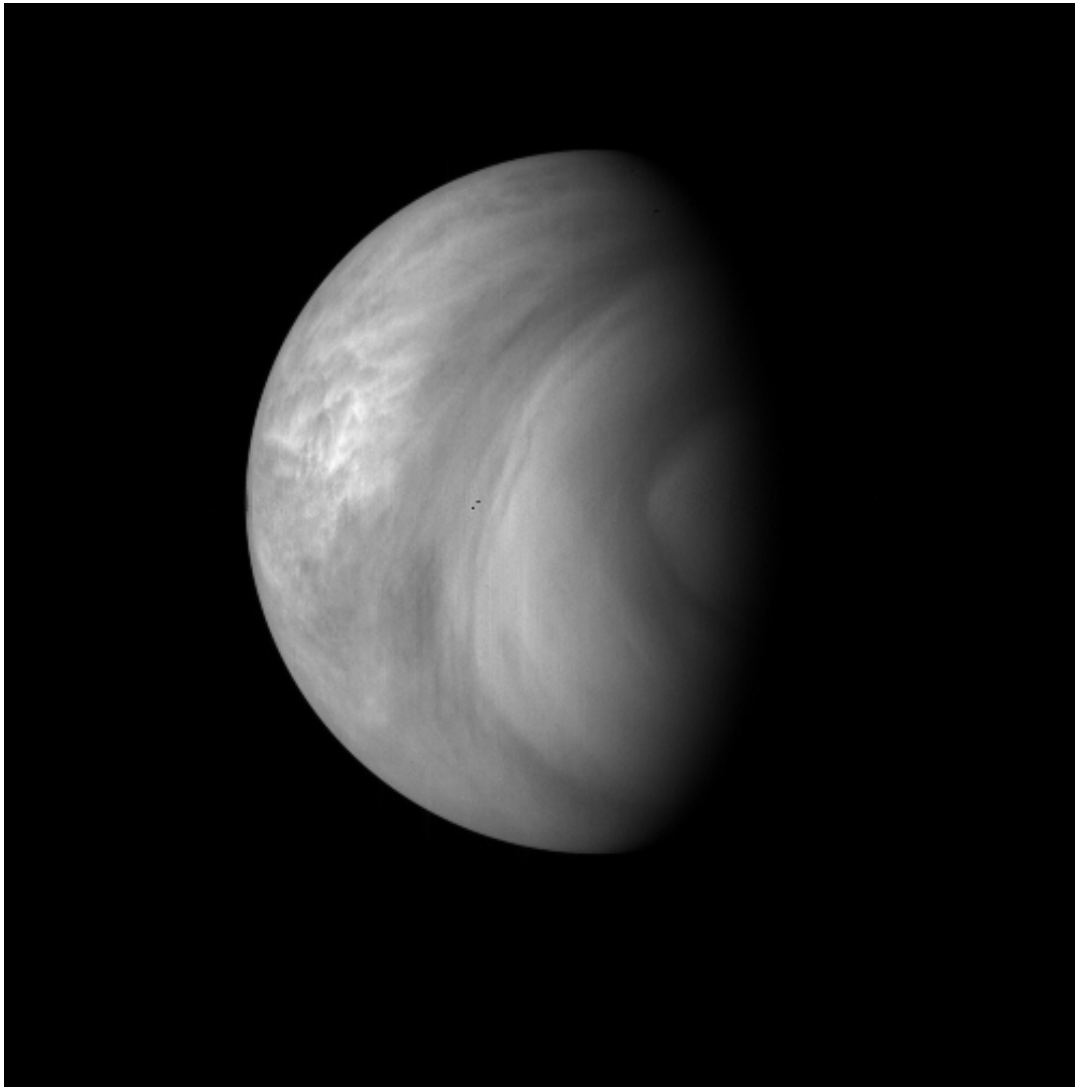




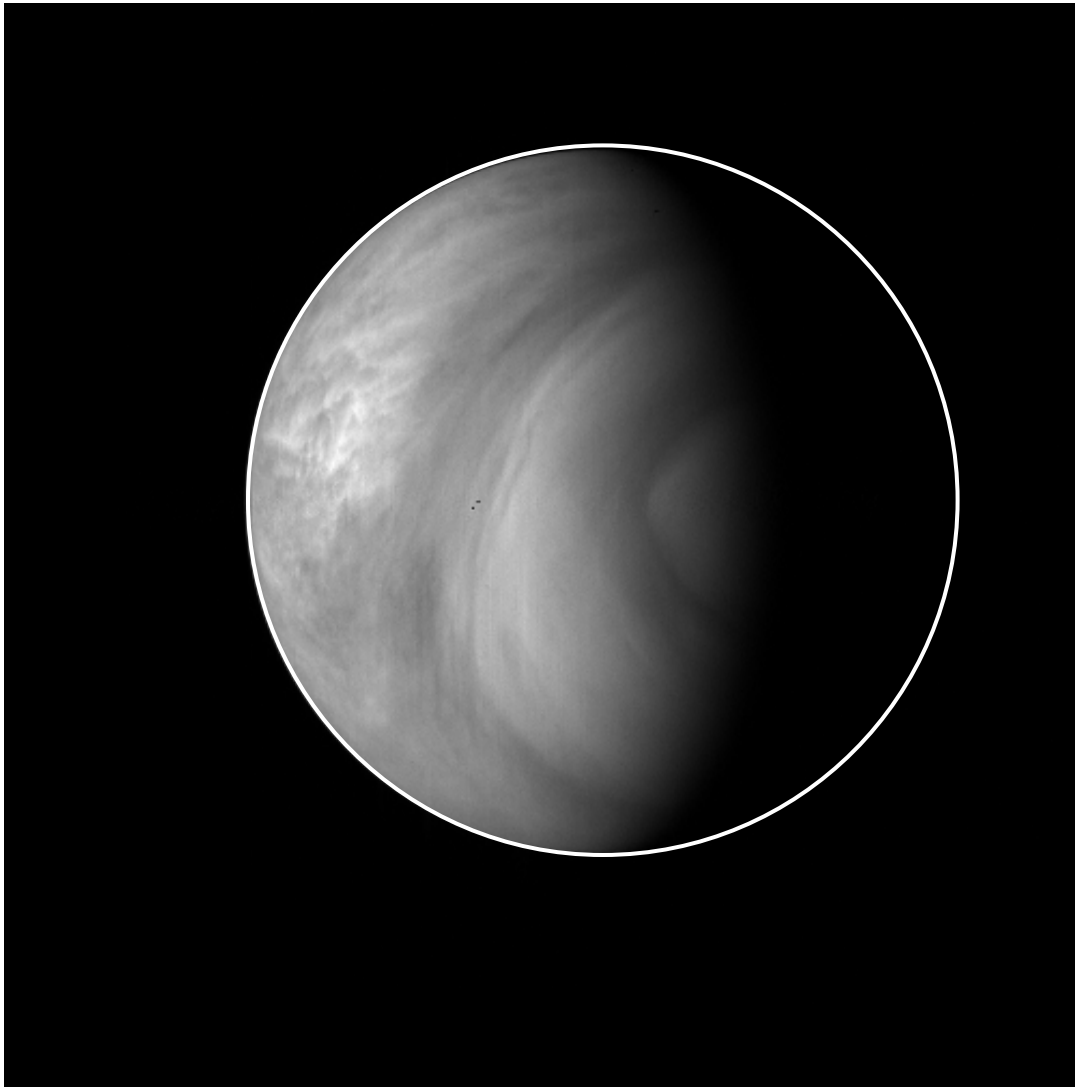
Limb fitting procedure is a typical approach to improve the accuracy of the attitude information.

Requirement: Sub-pixel level.

Venus silhouette is Circle?

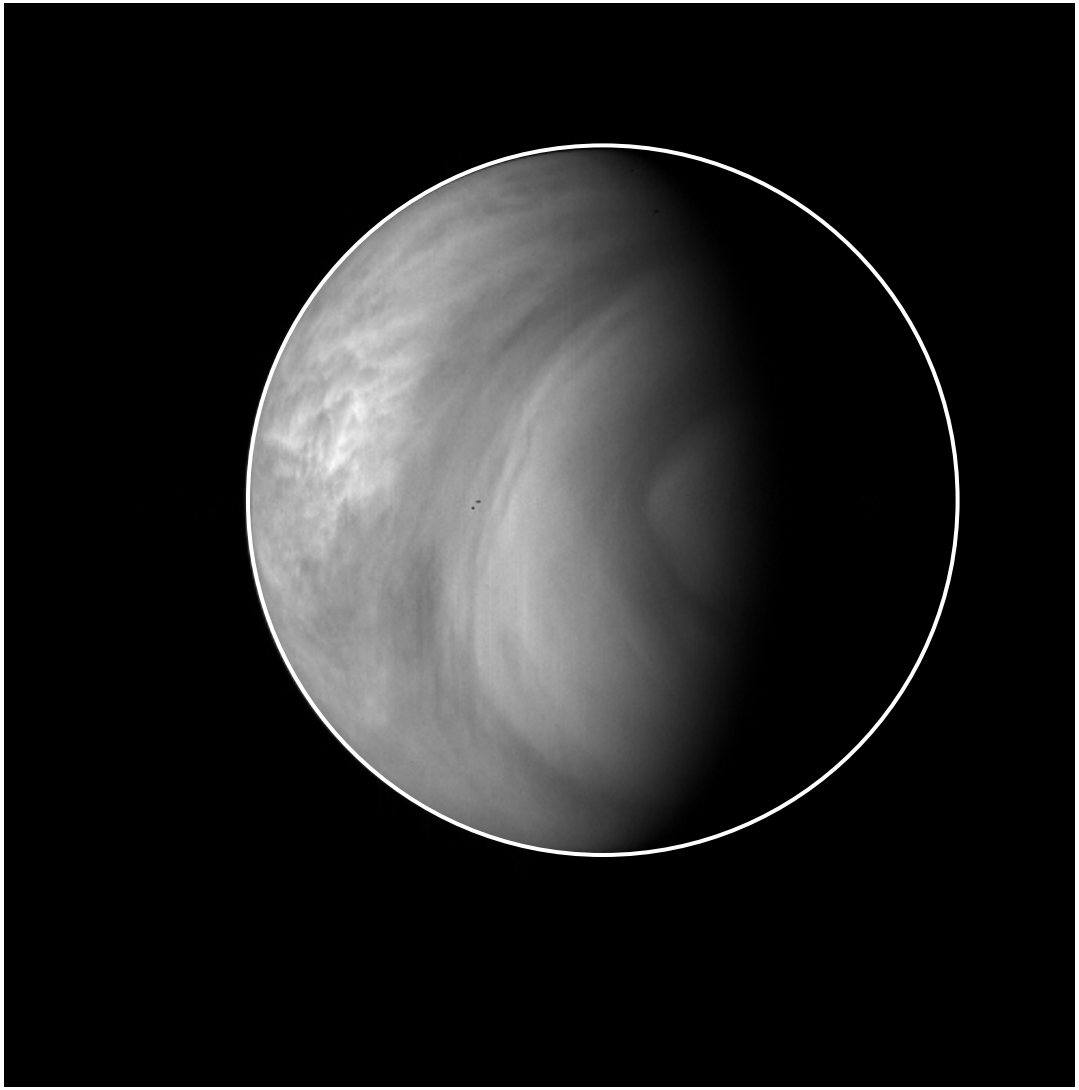


Venus silhouette is Circle?



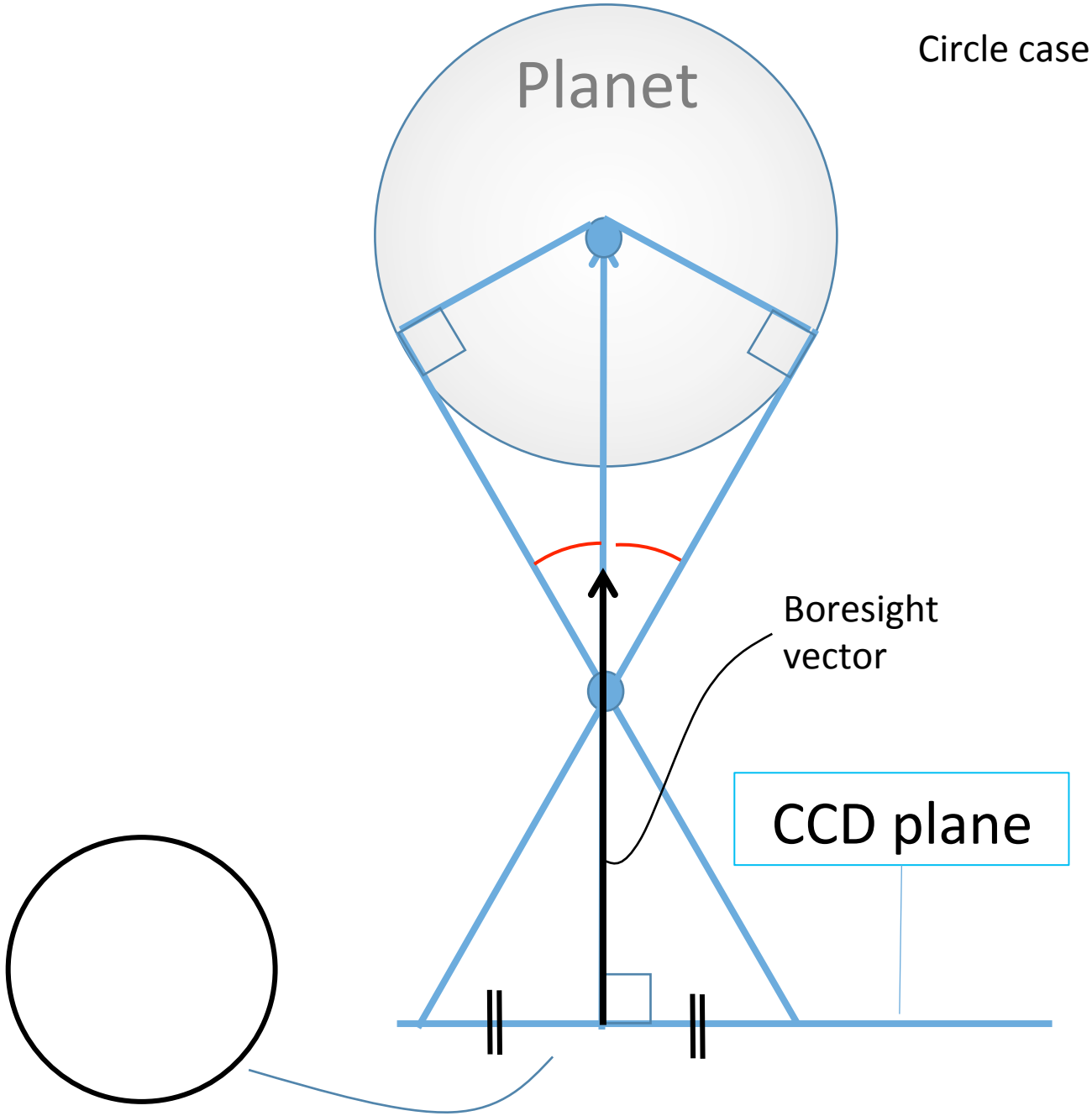
It looks like circle

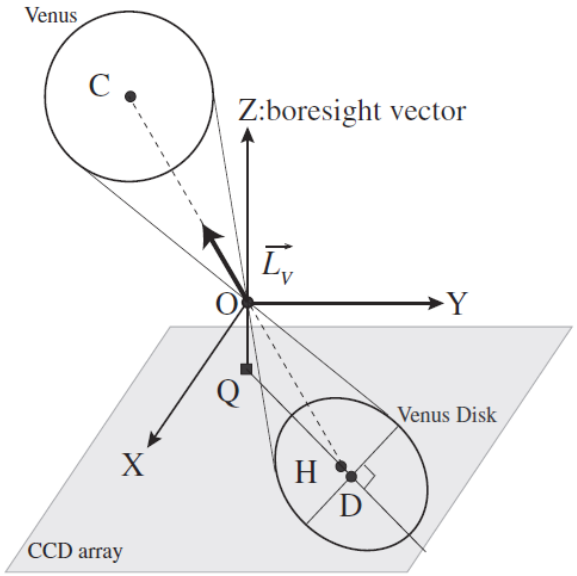
Venus silhouette is Circle?



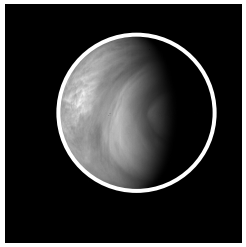
Strictly speaking, NO. It is ellipse but with very low eccentricity.
(even if we consider Venus (including clouds) as a perfect sphere object)

Circle case



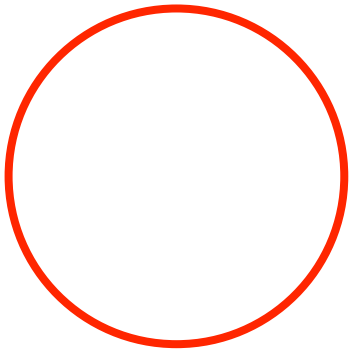


[Ogoahar et al., 2012]

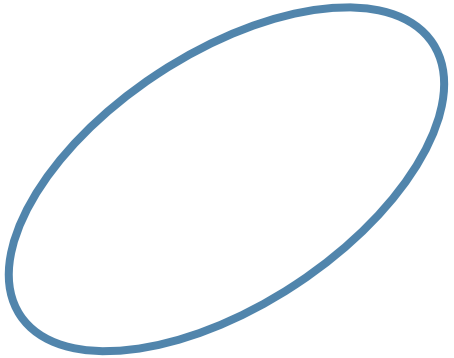


The main point of Limb fitting scheme for Akatsuki L3 product

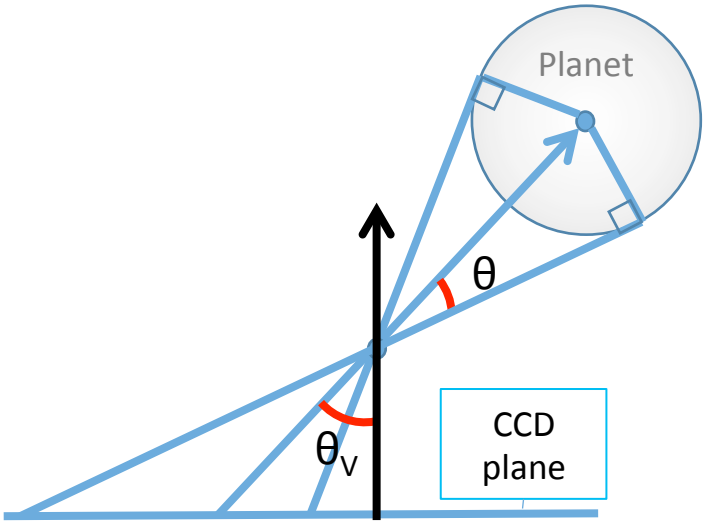
Not Circle fitting



✓ Ellipse fitting with several constraint conditions



In particular
- tilting angle
- Ratio of semi-major and semi-minor lengths

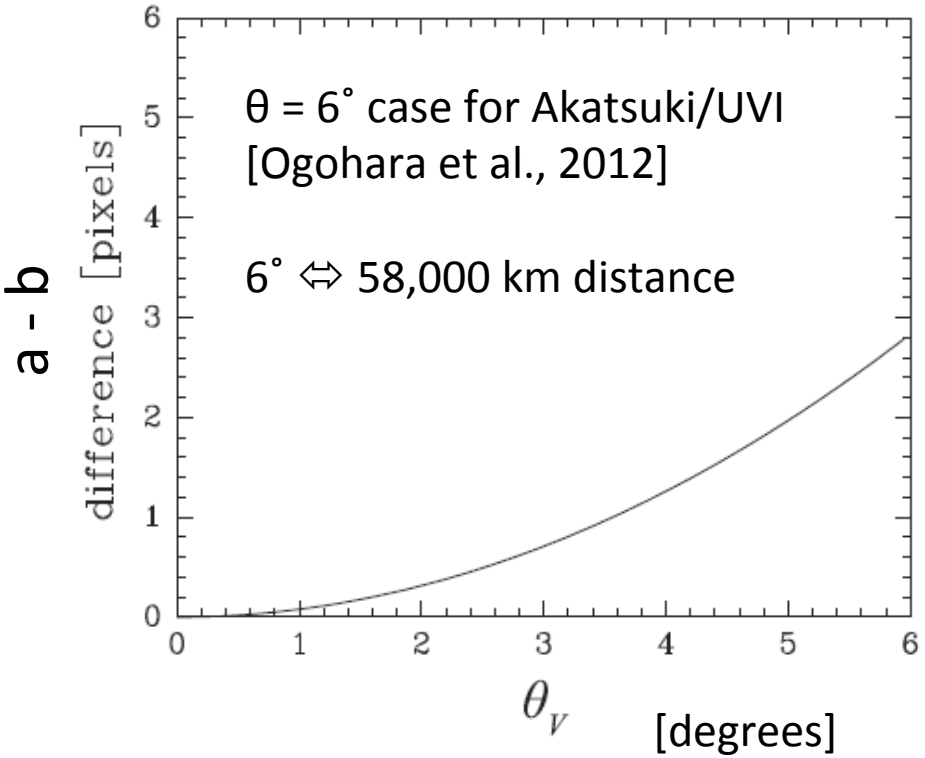


In ellipse case:

a: semi-major
b: semi-minor

$$\gamma = \frac{b}{a} = \sqrt{\cos^2\theta_V - \sin^2\theta_V \tan^2\theta}.$$

$\theta = \sin\uparrow -1\ RV/D$



For ground-based observation, γ can be considered as "1" due to both θ and θ_V are almost 0.

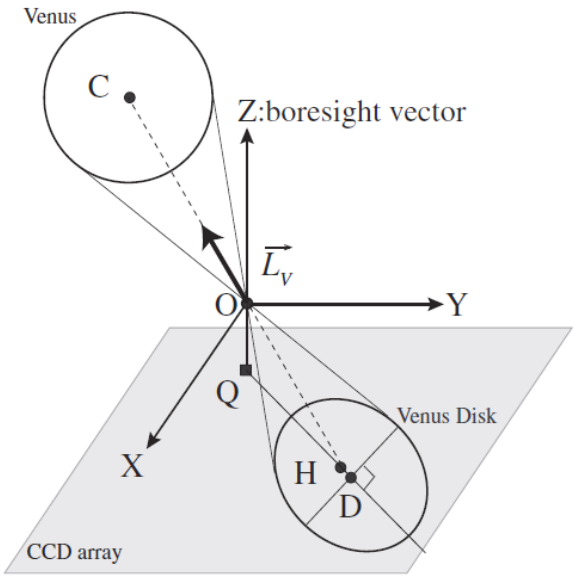
Same as Gliileo observation case.

But in case of Venus Express and Akatsuki, γ can cause several pixel difference between semi-major and semi-minor length.

6 parameters:

$$Ax_\alpha^2 + 2Bx_\alpha y_\alpha + Cy_\alpha^2 + 2f_0(Dx_\alpha + Ey_\alpha) + f_0^2 F = 0 .$$

⇔ 3 parameters
in circle fitting case

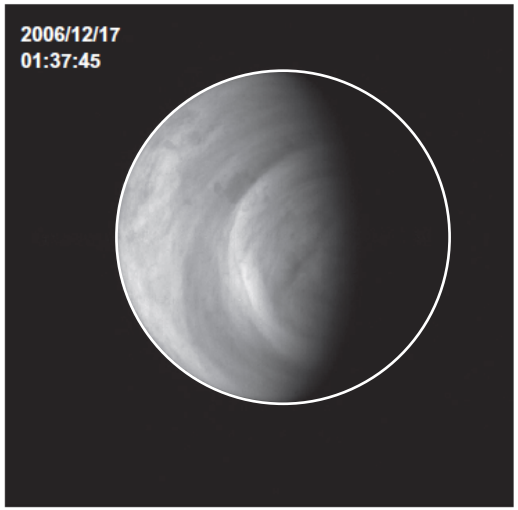


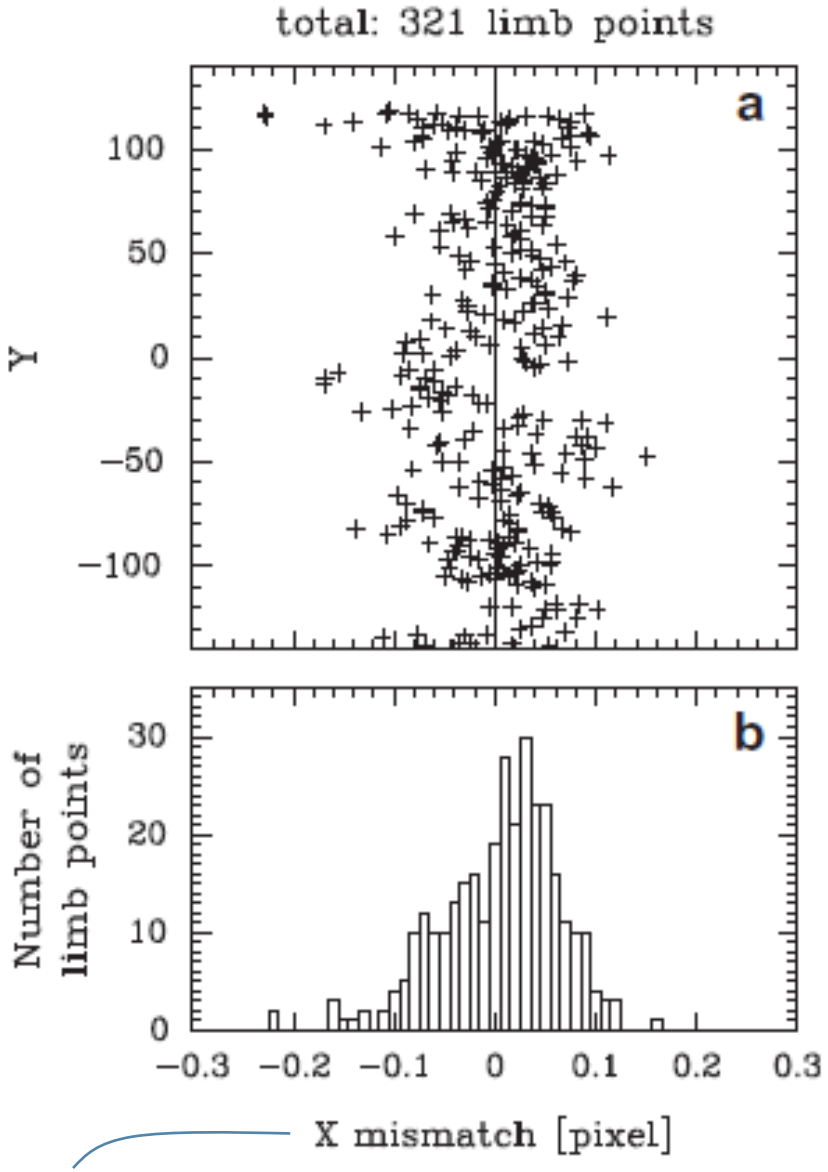
[Ogoahar et al., 2012]

Ellipse fitting using maximum likelihood procedure (Kanatani and Sugaya, 2007)
<Extended-FNS method>

Constraint conditions:
- Tilting angle of ellipse
- Ratio of semi-major and semi-minor lengths

Performance:



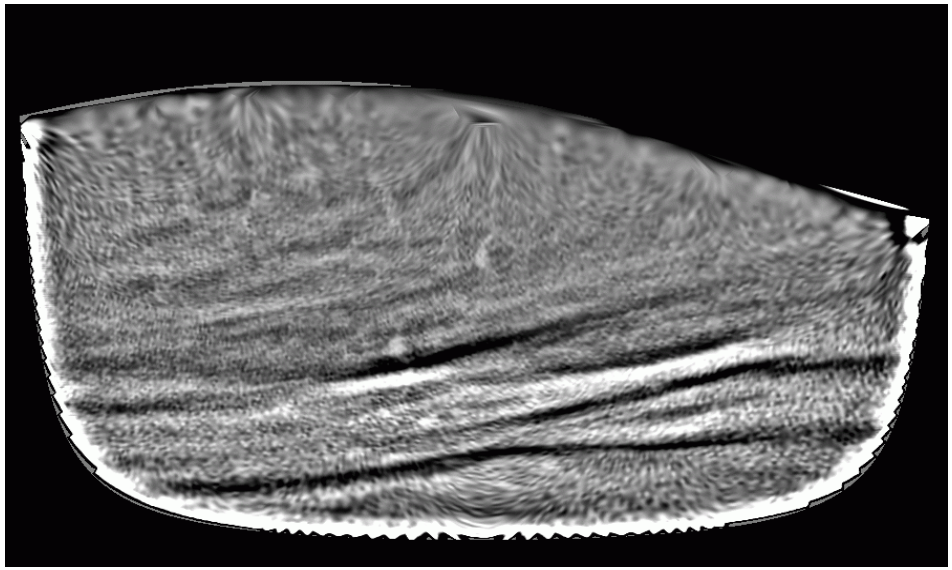


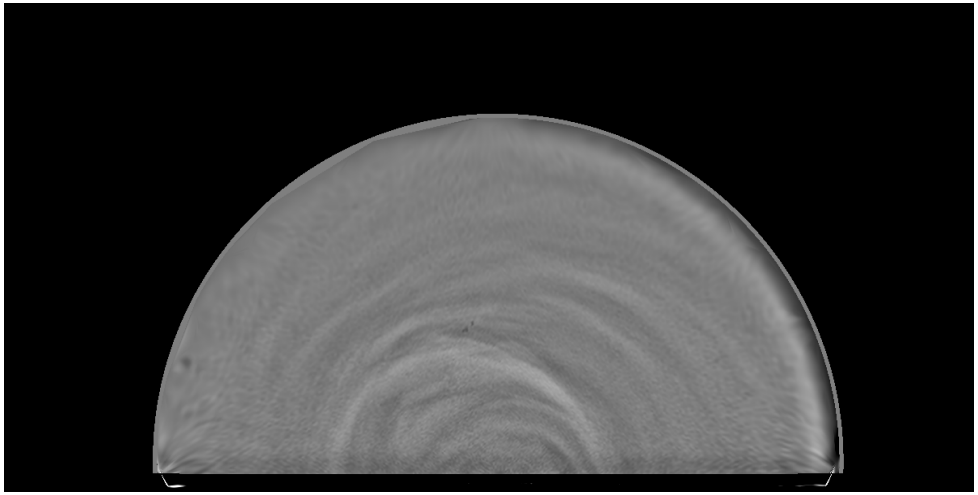
We can determine Venus center location with 0.1 pixel level from the result of using simulation images.

*E-FNS method does not provide fitting error directly, so we conducted practical estimation usings simple simulation images.

Displacement between each limb poin location and fitted ellipse

[Ogohara et al., 2012]





Akatsuki observation

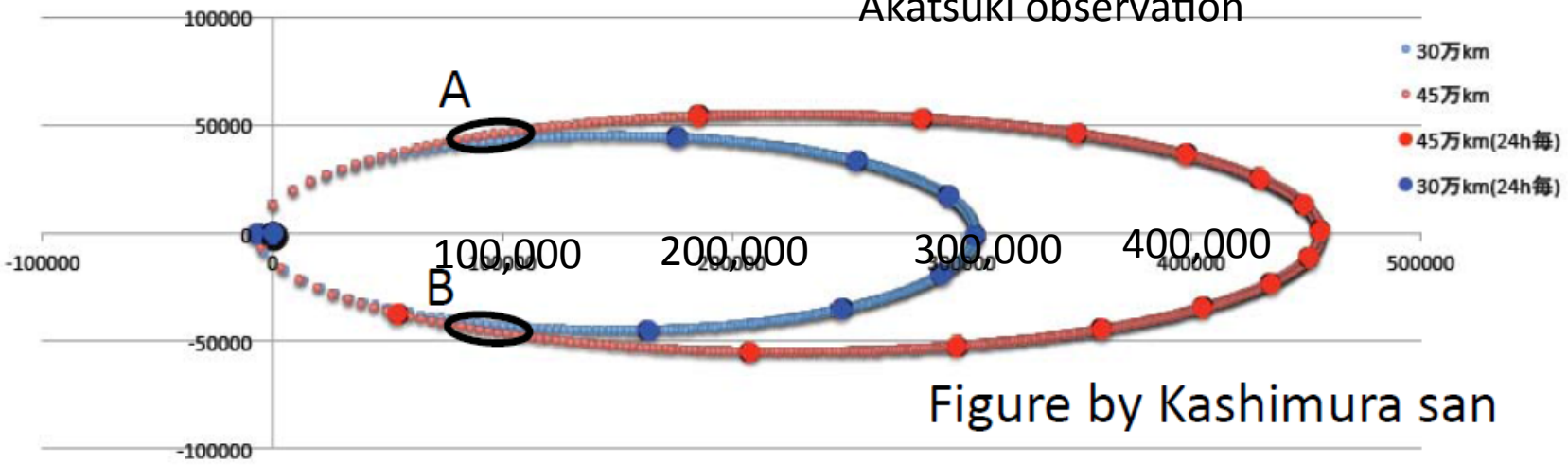
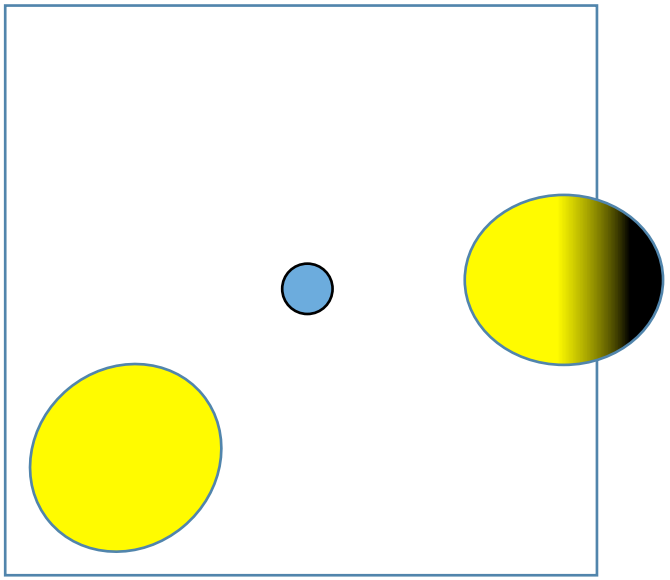


Figure by Kashimura san

$$\gamma = \frac{b}{a} = \sqrt{\cos^2\theta_V - \sin^2\theta_V \tan^2\theta}.$$

FOV:12˚x 12˚



Although θ will be small in typical observation case, the ellipse issue should be considered due to θv effect. (θv: 0 – 6 degrees)

Even if downlink only a specified tile,
the location in original image frame should be included in file header.

History of implementation of ellipse fitting:

Good example of successful team activity

~2010 spring

Kouyama: awoke Venus shape is not circle, but ellipse

2010 spring

$$\gamma = \frac{b}{a} = \sqrt{\cos^2\theta_V - \sin^2\theta_V \tan^2\theta}.$$

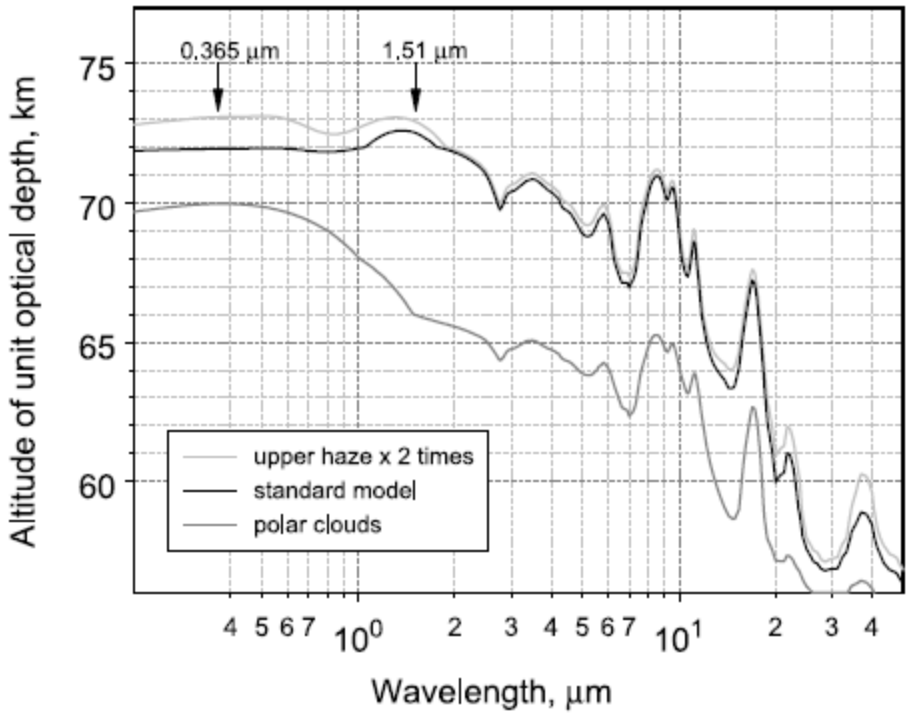
Yamada (L2 member): solved the relationship between a & b.

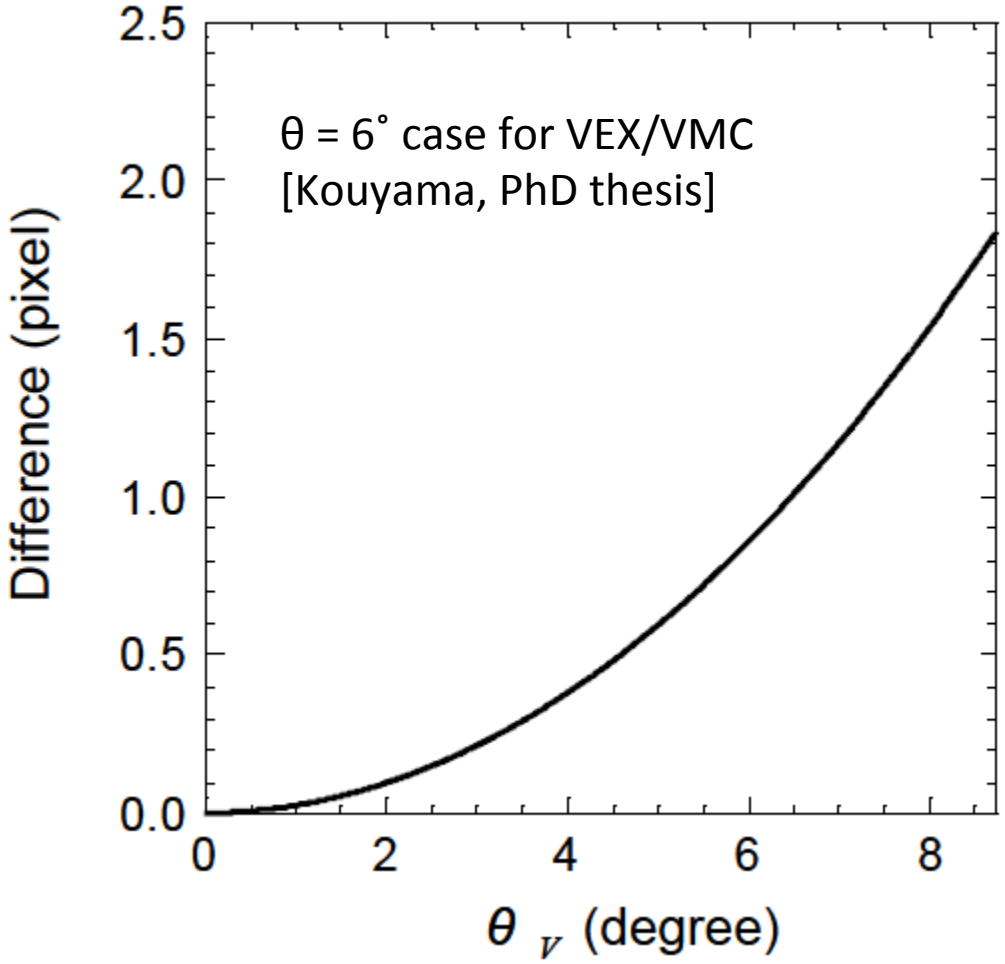
Takagi & Ogohara: found E-FNS method
and applied it to L3 program

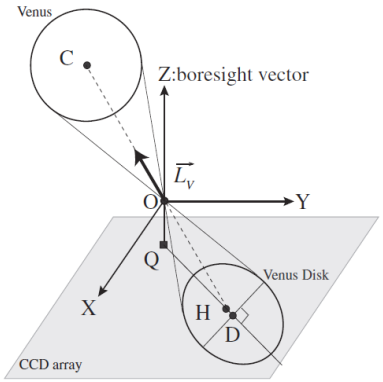
2010 summer

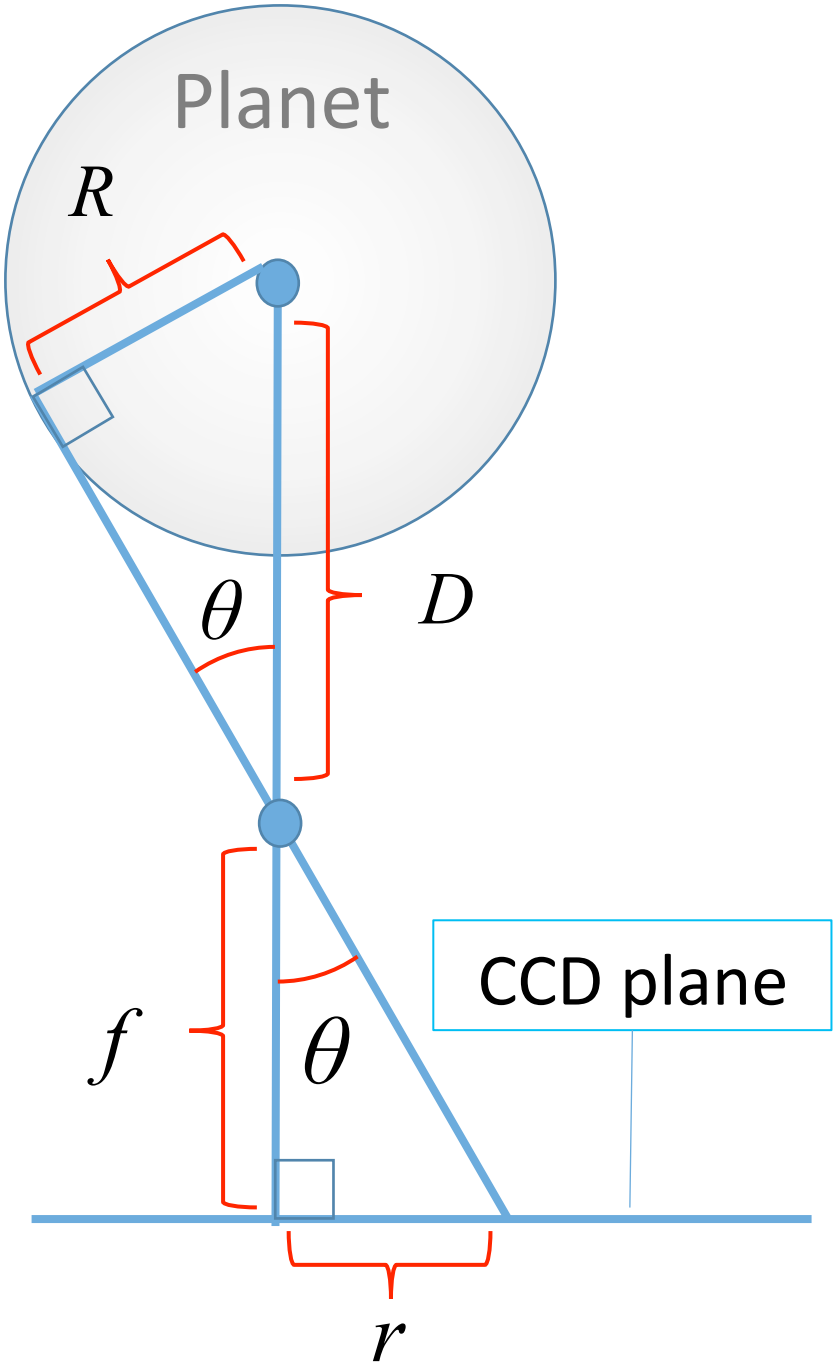
Kahimura: solved constraint conditions and converted them
into appropriate equation forms for E-FNS method

2010 winter/2011 spring: we submitted a paper
(-> Ogoahara et al., 2012)


0,365 μm
1,51 μm
75
70
65
60
Altitude of unit optical depth, km
upper haze x 2 times
standard model
polar clouds
4 5 6 7 10^0 2 3 4 5 6 7 10^1 2 3 4
Wavelength, μm


θ = 6˚ case for VEX/VMC
[Kouyama, PhD thesis]
Difference (pixel)
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
θ V (degree)


Venus
C
Z:boresight vector
$\vec{L}_v$
O
Y
Q
X
H
D
Venus Disk
CCD array


Planet
R
θ
D
f
θ
CCD plane
r