HW5

Q1: The star ψ Cap has properties

$$\text{spec F5V}$$

$$\text{app mag } V = 4.152$$

$$\text{parallax } \pi = 68.13 \text{ mas} \rightarrow \text{dist } d = 14.68 \text{ pc}$$

$$\rightarrow (m-M) = 5\log d - 5 = 0.833 \text{ mag}$$

We can estimate stellar radius based on spec type.

$$R_* \approx 1.8\, R_\odot$$

Boyajian et al., ApJ 746, 101 (2012)

$$= 1.25 \times 10^{9} \text{ m}$$

A planet like Neptune has radius

$$R_p = R_{Neptune} = 2.46 \times 10^{7} \text{ m}$$

$$\rightarrow \frac{R_p}{R_*} = 1.96 \times 10^{-2}$$

$$\left(\frac{R_p}{R_*}\right)^2 = 3.86 \times 10^{-4}$$

The mass of this star, based on spec type is roughly

$$M_* \cong 1.3\, M_\odot$$

Belikov, 1995 Stellar Mass Catalog

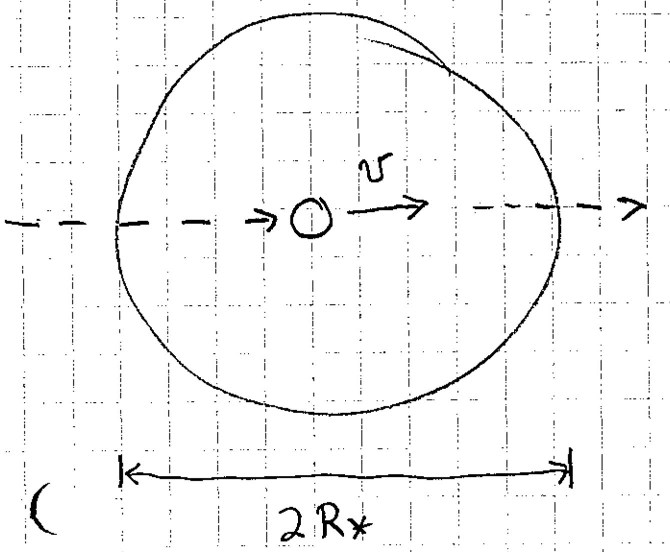
$$= 2.59 \times 10^{30} \text{ kg}$$

We can use the known mass of the system, and the planet's orbital period $P = 2$ yr, to compute the semi-major axis of the orbit a.

Q1

$$P^2(\text{yr}) = \frac{1}{M_{tot}}\, a(\text{AU})^3$$

$$\rightarrow \quad a = 1.73 \text{ AU}$$
$$= 2.59 \times 10^{11} \text{ m}$$



The duration of an equatorial transit will be $T = \frac{2R_*}{v}$

and we can compute the orbital speed if we assume a circular orbit

$$v = \frac{2\pi a}{P} = \frac{2\pi(2.59\times 10^{11}\text{ m})}{2(3.156\times 10^{7}\text{ s})}$$

$$v = 25{,}800 \text{ m/s}$$

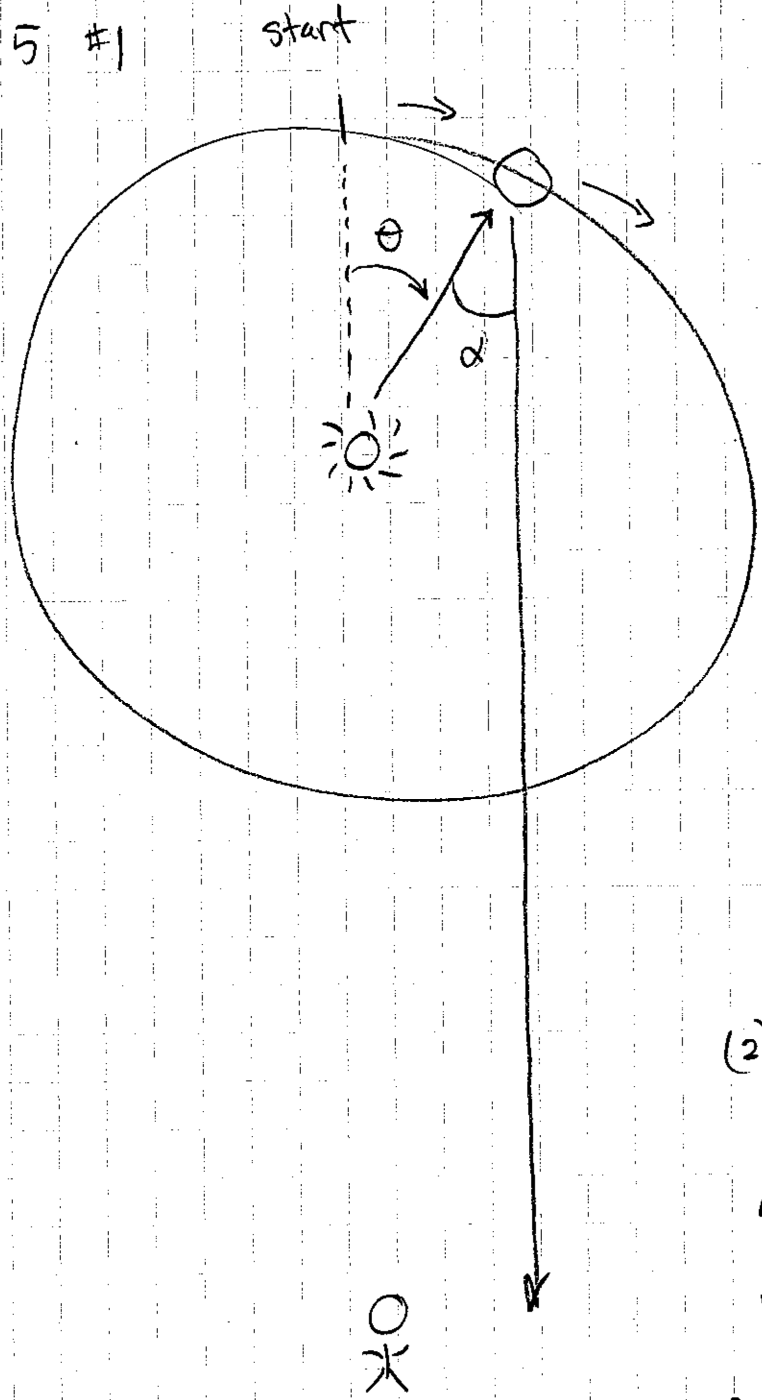
$$\rightarrow \text{transit duration} \quad T = \frac{2(1.25\times 10^{9}\text{ m})}{25{,}800 \text{ m/s}} = 9.69\times 10^{4}\text{ s}$$
$$= 26.9 \text{ hour}$$

The transit depth should be (fractionally)

$$\text{transit depth} = \left(\frac{R_p}{R_*}\right)^2 = 3.86\times 10^{-4} \text{ fraction}$$
$$= 4.19\times 10^{-4} \text{ mag}$$
$$= 0.414 \text{ mmag}$$

See sample graph in Fig 1.

HW 5 #1



As planet orbits star, the phase angle α is equal to the angle by which the planet has moved in its orbit

$$\alpha = \theta$$

$$(1) \qquad \alpha = \left(\frac{2\pi}{P}\right) t \quad \text{radiar}$$

From Seager, "Giant Planet Atmospheres" chapter, Eq 13 classical phase function is

$$(2) \qquad \Phi(\alpha) = \frac{\sin(\alpha) + (\pi - \alpha)\cos}{\pi}$$

And the flux from the planet is, relative to its star

$$(3) \qquad \frac{F_p}{F_*} = A_g \left(\frac{R_p}{a}\right)^2 \Phi(\alpha)$$

where

$$A_g = \frac{2}{3} \quad \text{for simple scattering atmos}$$

So, we can put these 3 eqn together to find the fractional flux contributed by reflected light from planet as function of time.

See Fig 2, 3.

p4

Q1 c) Polly has access to a 1-m space telescope and high-quality CCD camera. Should she apply for time to confirm this planet?

- at transit, the signal is 0.419 mmag.
  Kepler has measured signals of $\approx$ 0.100 mmag,
  so, yes, it could see this transit.
- at superior conjunction, the size of the drop in light
  is roughly $4 \times 10^{-9} \simeq$ 0.000004 mmag,
  so don't bother looking for it then.

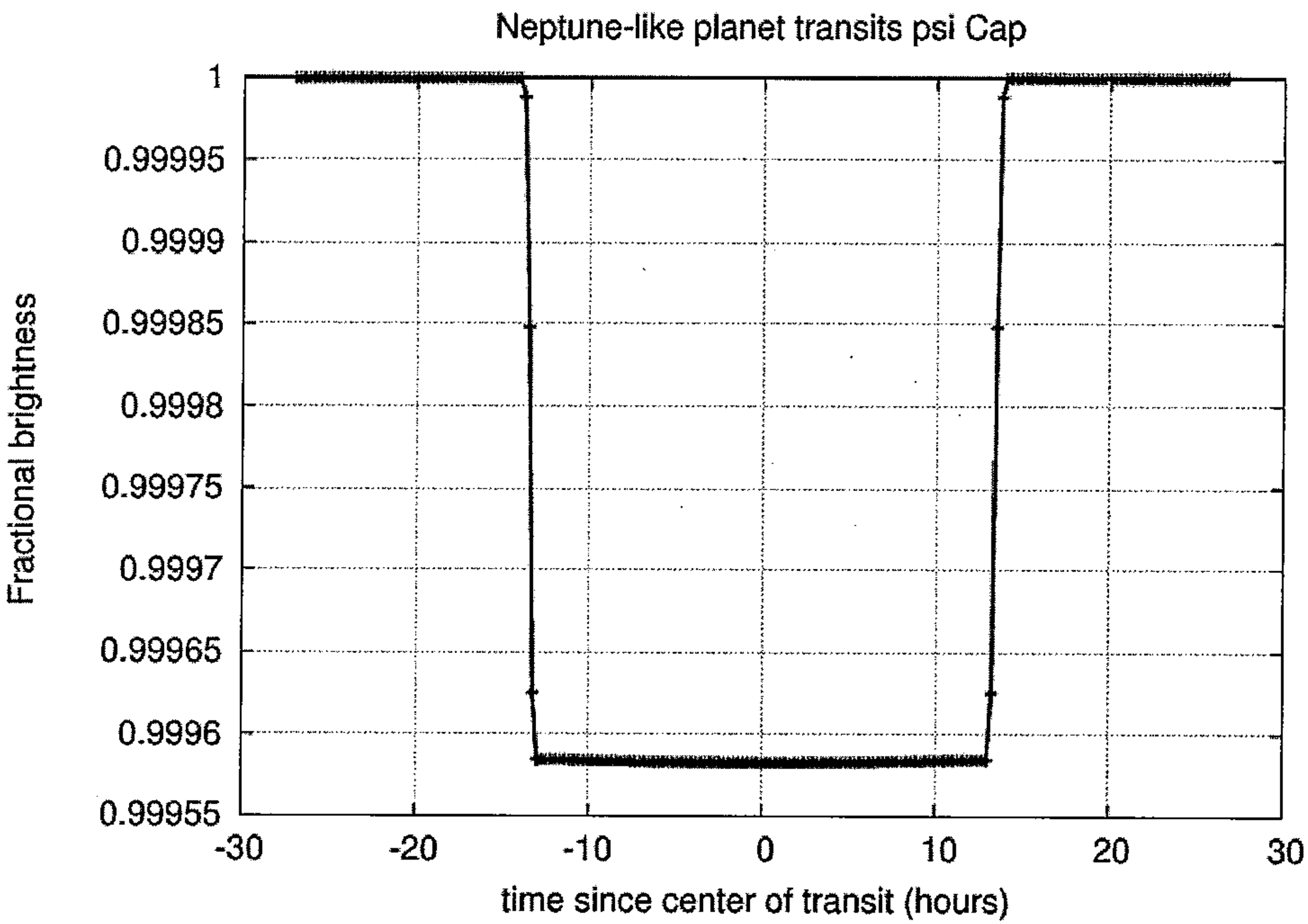

Neptune-like planet transits psi Cap
Fractional brightness
1
0.99995
0.9999
0.99985
0.9998
0.99975
0.9997
0.99965
0.9996
0.99955
-30
-20
-10
0
10
20
30
time since center of transit (hours)

Fig 1
4/16/201

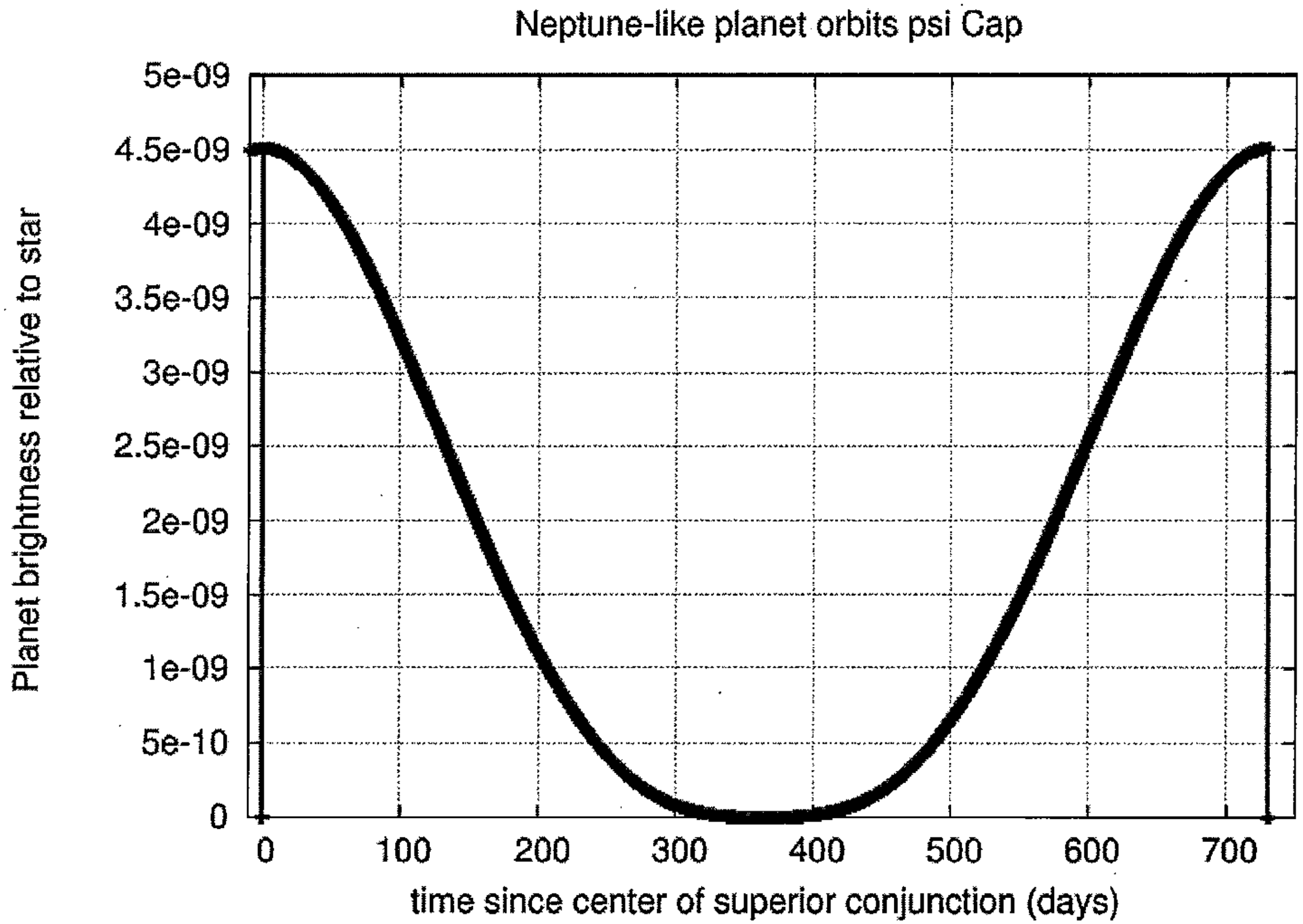


Fig 2
4/16/2015

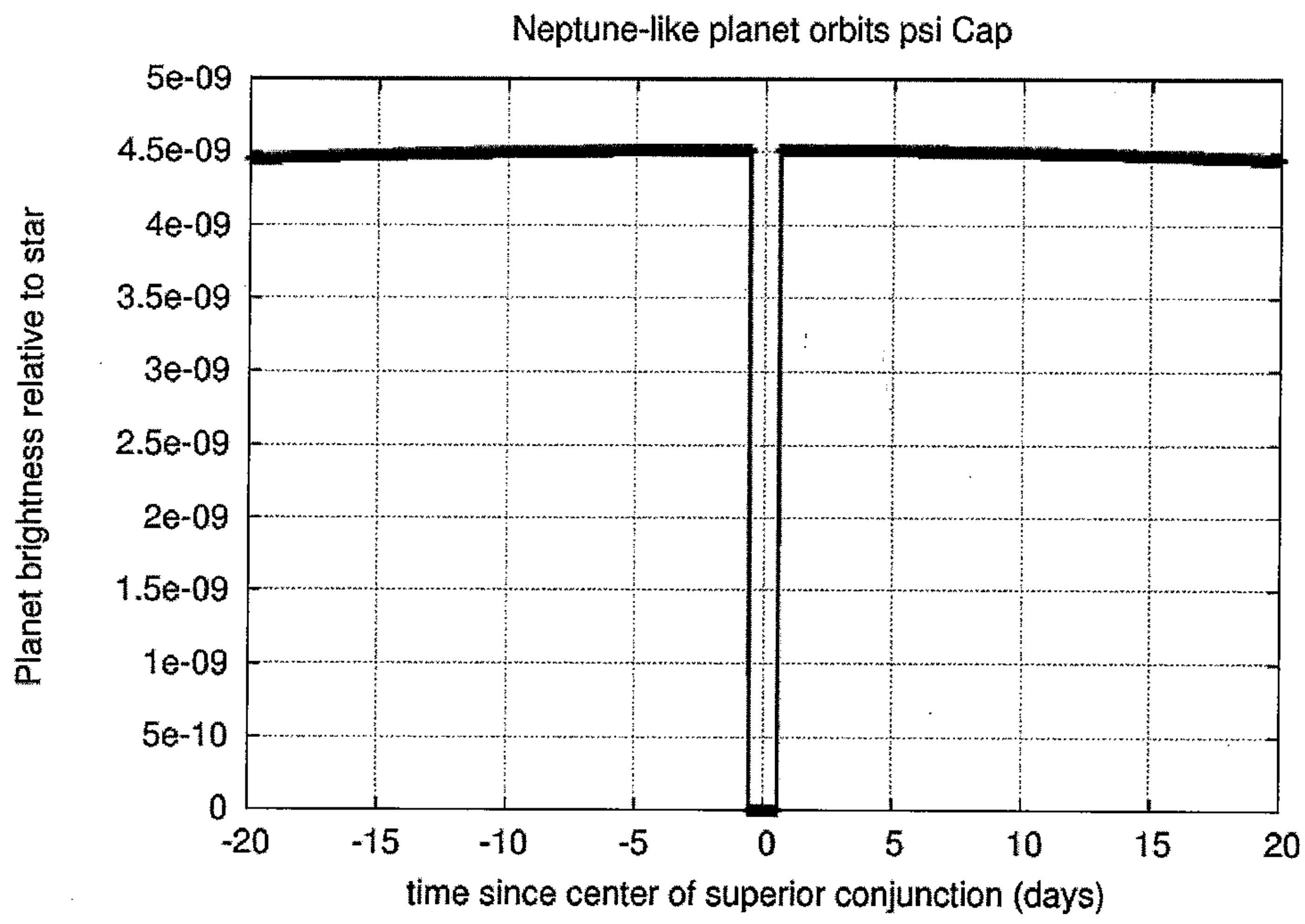


Fig 3
4/16/2015