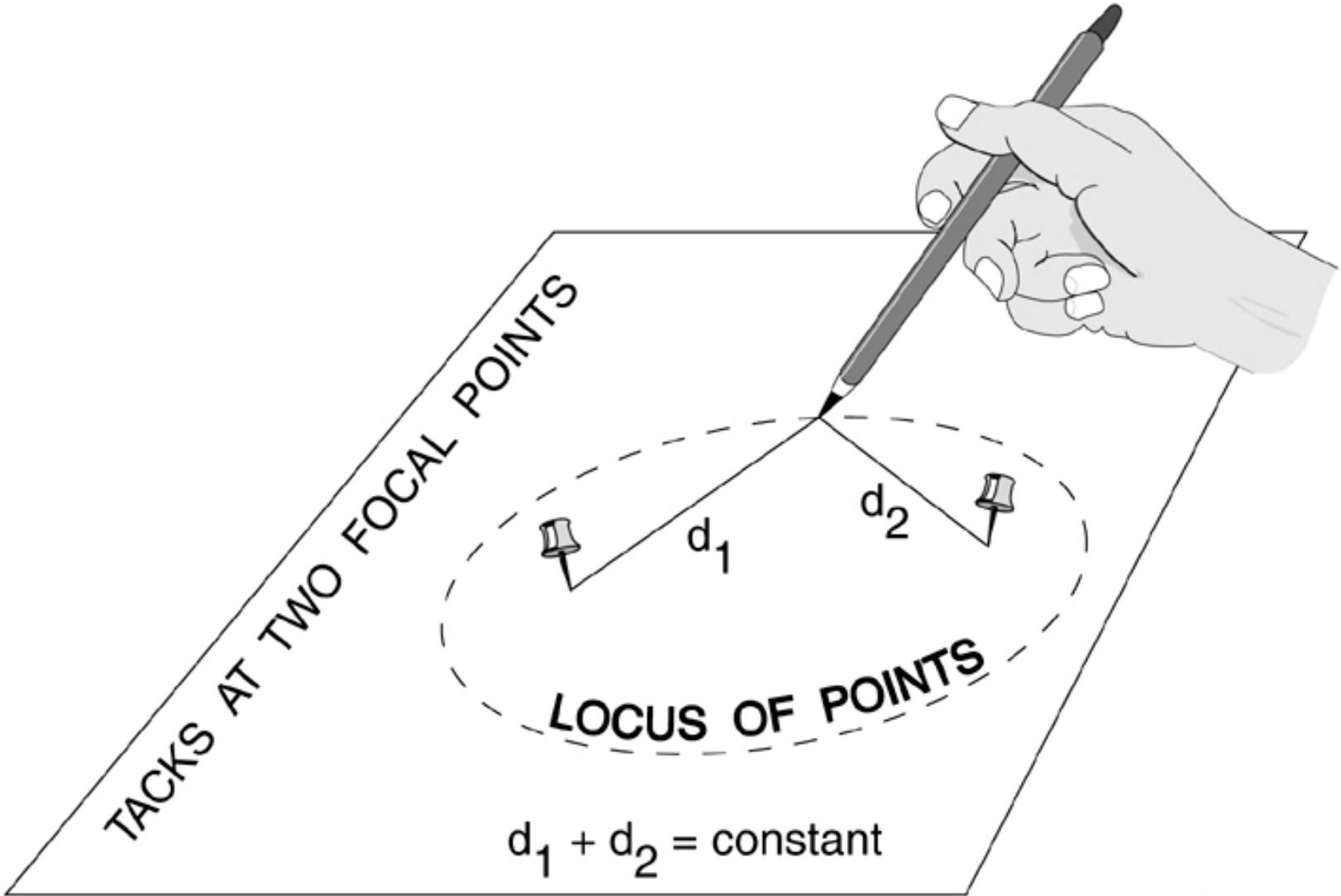
FROM ELLIPSES

to

GRAVITY ASSIST

C. E. Kohlhase

DRAWING AN ELLIPSE



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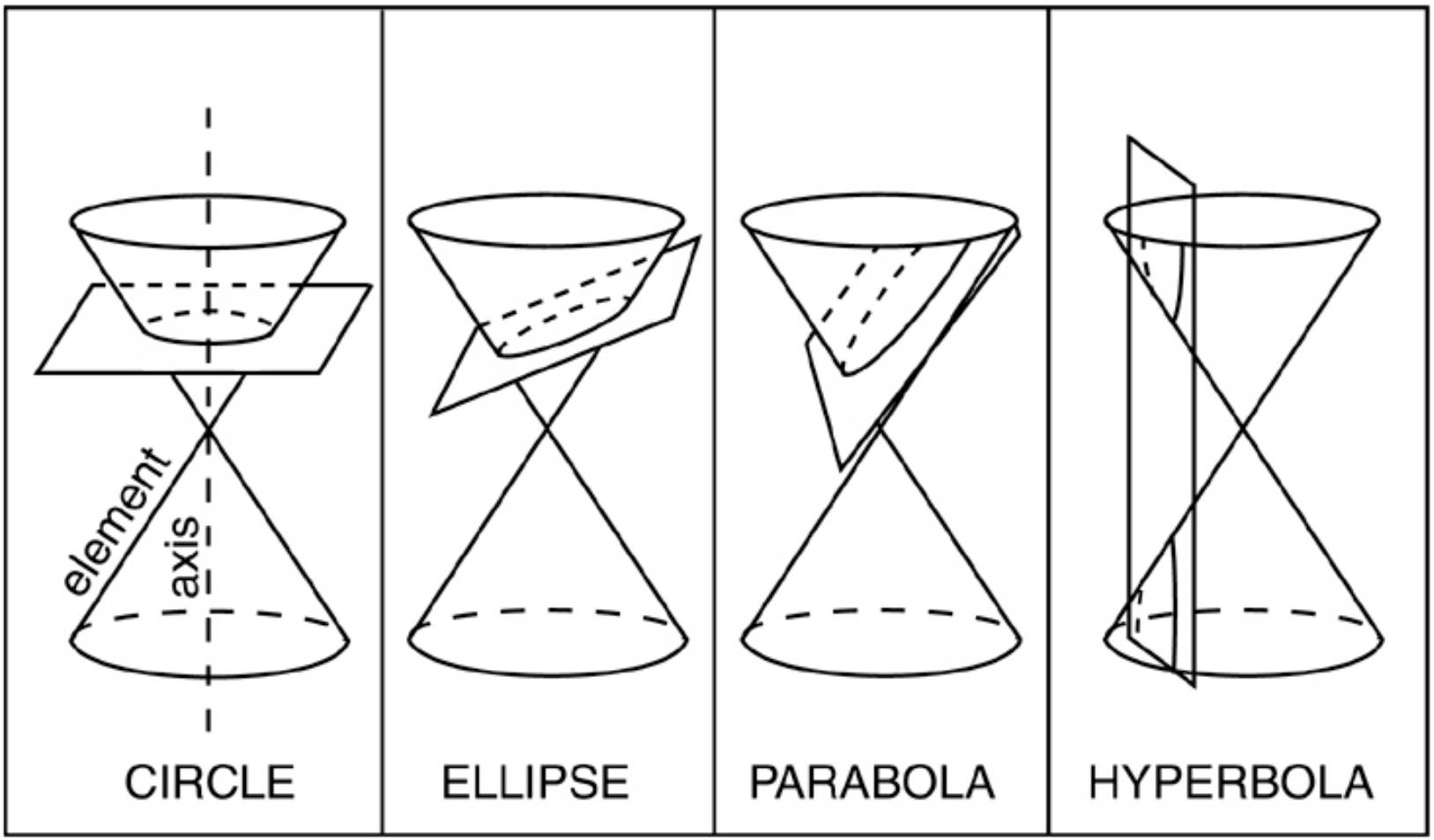
THE CONIC SECTIONS

(CUTTING PLANE WITH HOURGLASS)



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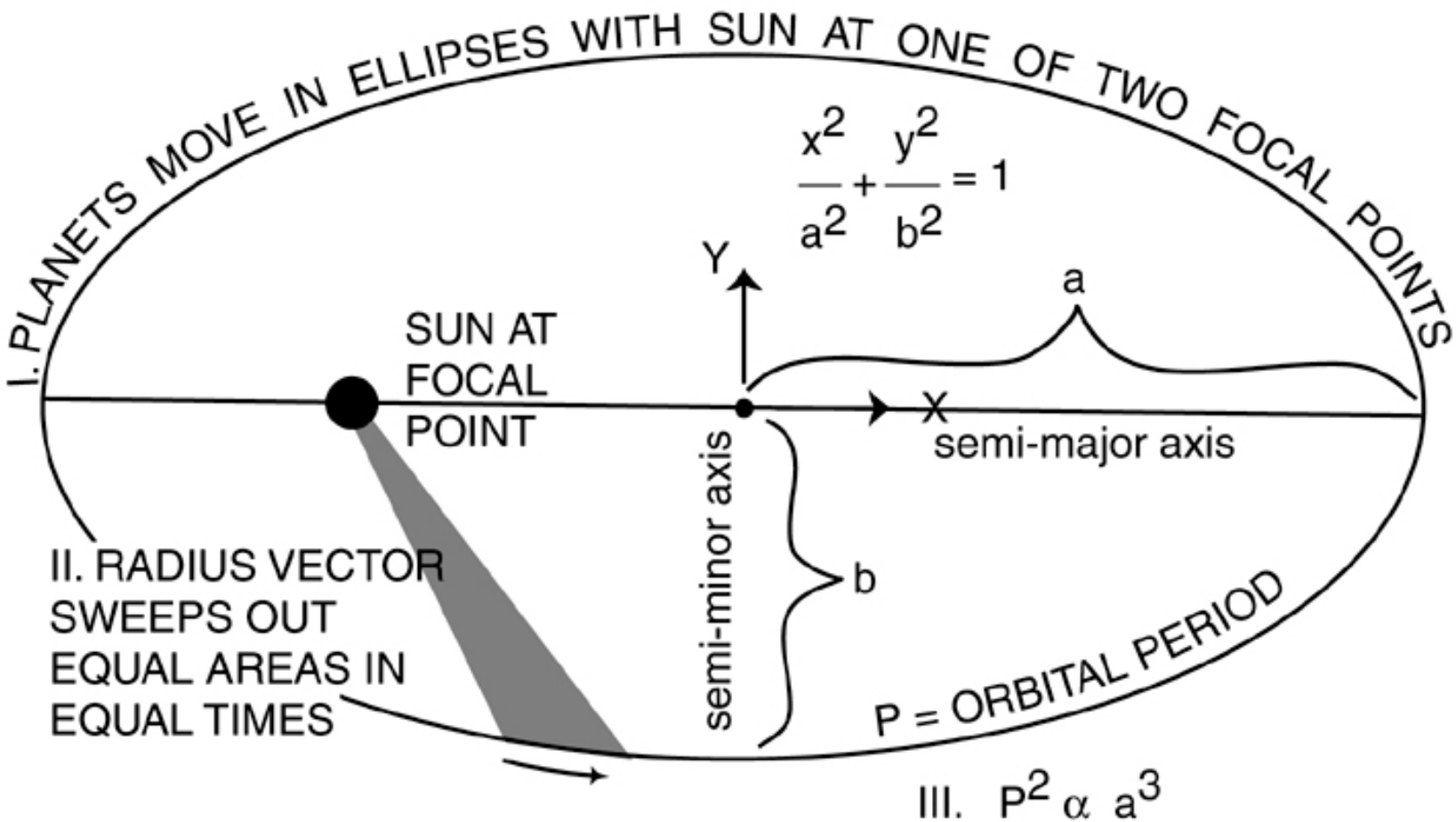
KEPLER'S THREE LAWS

(FOR PLANETARY MOTION)



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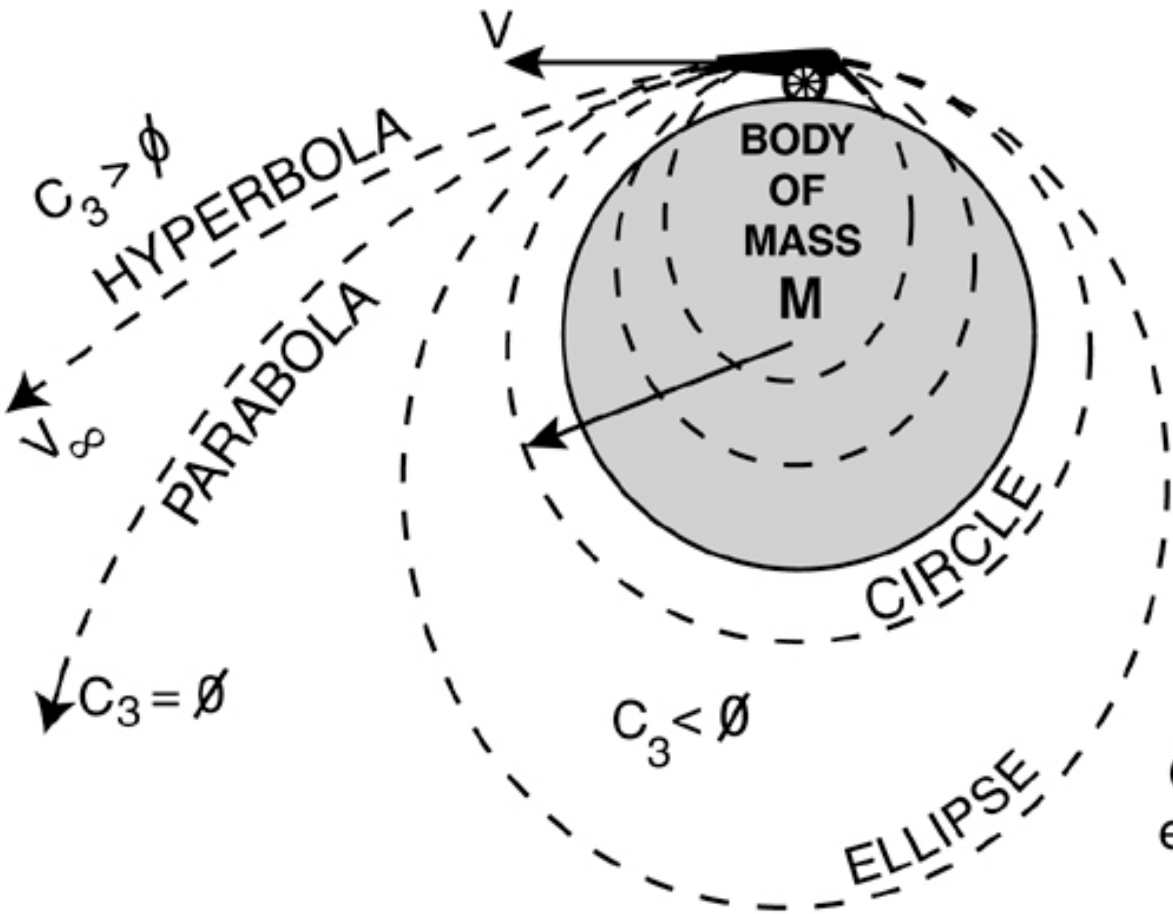
MOTION UNDER GRAVITY



$$\mu = GM$$

$$V_{CIR} = \sqrt{\mu / R}$$

$$V_{ESC} = \sqrt{2}\, V_{CIR}$$

$$C_3 = V^2 - \frac{2\mu}{R}$$

C_3 is twice the total energy per unit mass

Inverse-square force field, i.e., $F = GM_1 M_2 / R^2$

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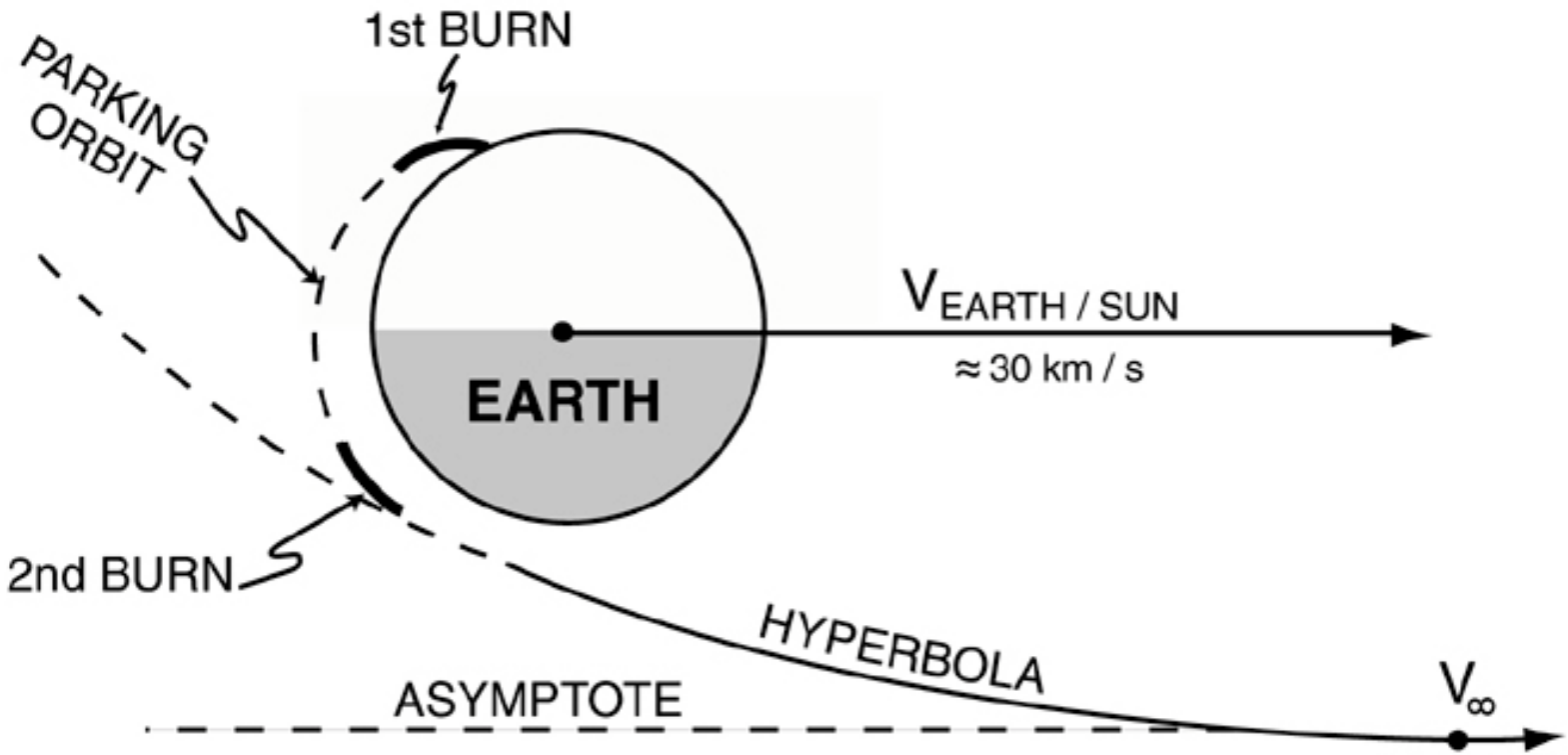
HYPERBOLIC DEPARTURE



MINIMUM HYPERBOLIC V_∞ (km/s)

SUN*	MERCURY*	VENUS*	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO	SOLAR ESCAPE
29.9	7.6	2.5	3.0	8.8	10.3	11.3	11.7	11.9	12.4

* must launch ***opposite*** to Earth's motion around the Sun

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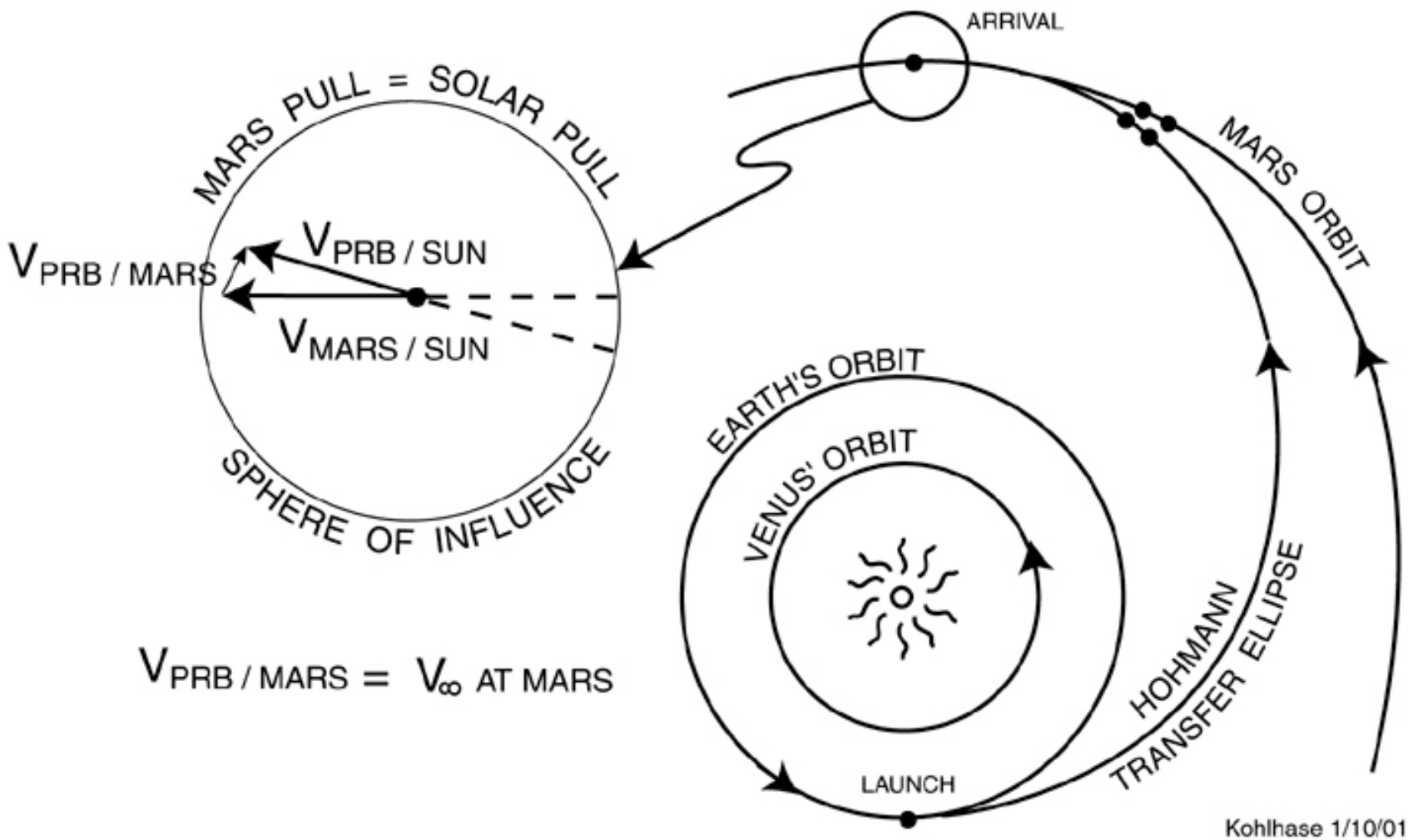
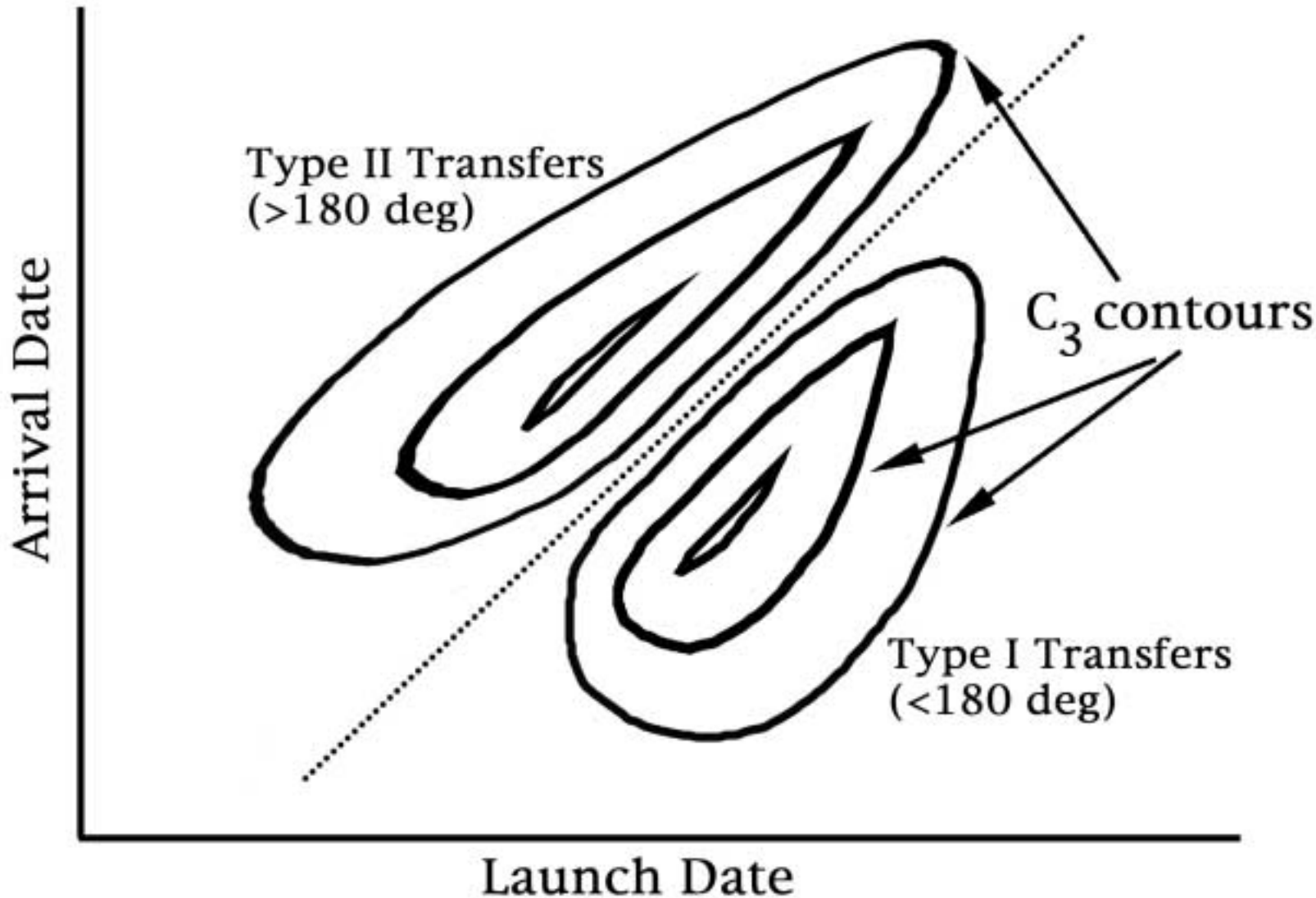
HOHMANN ELLIPSE TO MARS

(WITH ARRIVAL GEOMETRY DETAIL)



"PORK CHOP" PLOTS FOR LAUNCHING



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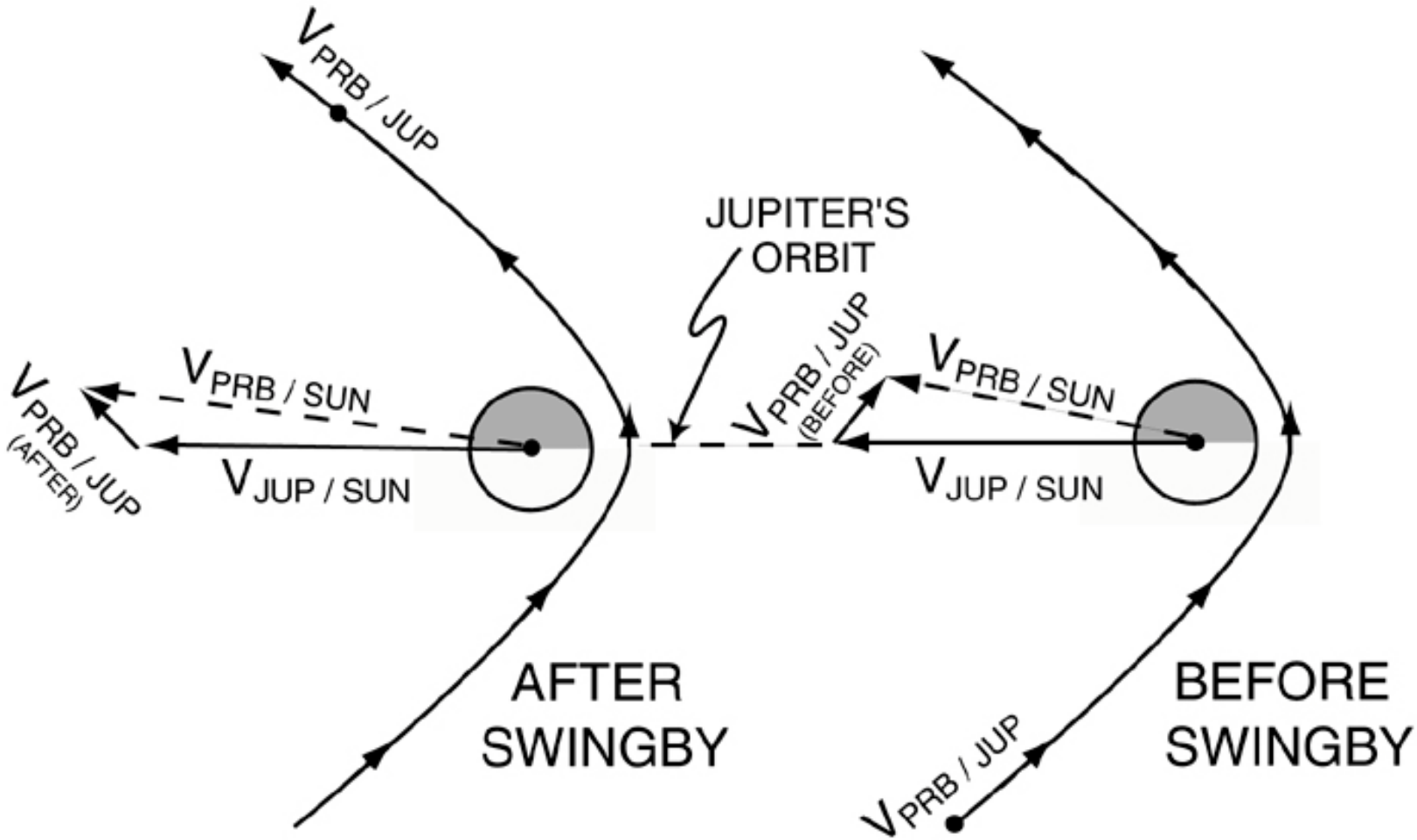
GRAVITY ASSIST FROM JUPITER



PRB = PROBE

$$V_{PRB\,/\,SUN} = V_{PRB\,/\,JUP} + V_{JUP\,/\,SUN}$$

$$\Delta V_{ASSIST} = V_{PRB\,/\,JUP\,(AFTER)} - V_{PRB\,/\,JUP\,(BEFORE)}$$

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