Orbiting L_2
Observation Point in Space

Herschel-Planck Mission Analysis
Martin Hechler
ESOC
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LIBRATION (LANGRANGE) POINTS IN THE SUN-EARTH SYSTEM

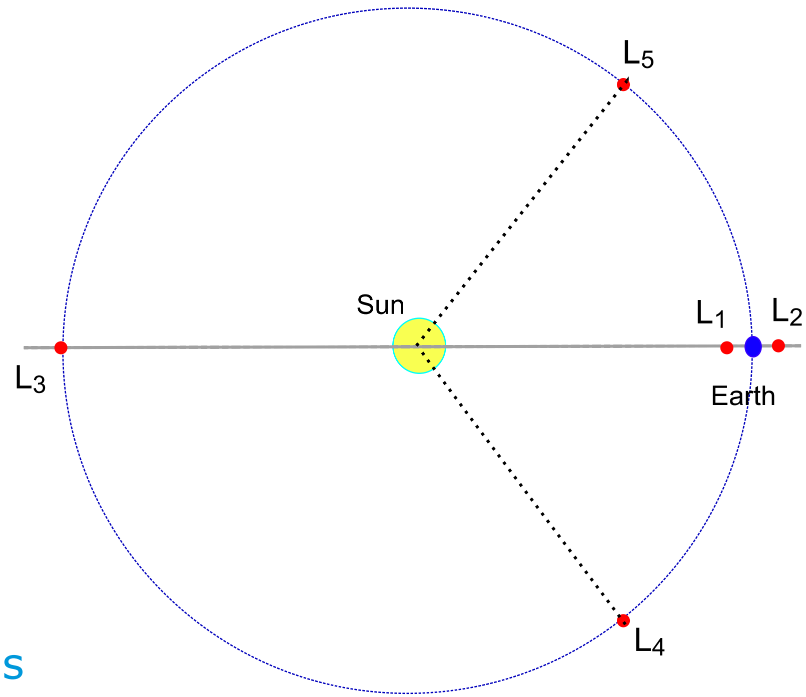
esa

Libration Points:

- 5 Lagrange Points
- L_1 and L_2 of interest for space missions

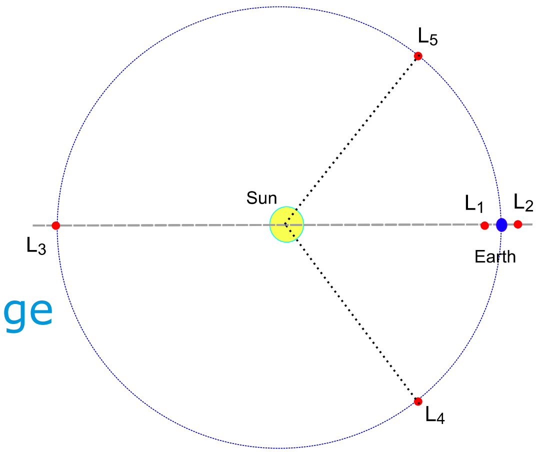
Satellite at L_2:

- Centrifugal force (R=1.01 AU) balances central force (Sun + Earth)
  - ⇨ 1 year orbit period at 1.01 AU with Sun + Earth attracting
  - ⇨ Satellite remains in L_2
- However: Theory only valid if Earth moves on circle and Earth+Moon in one point



WHY DO ASTRONOMY MISSIONS GO TO L_2 REGION

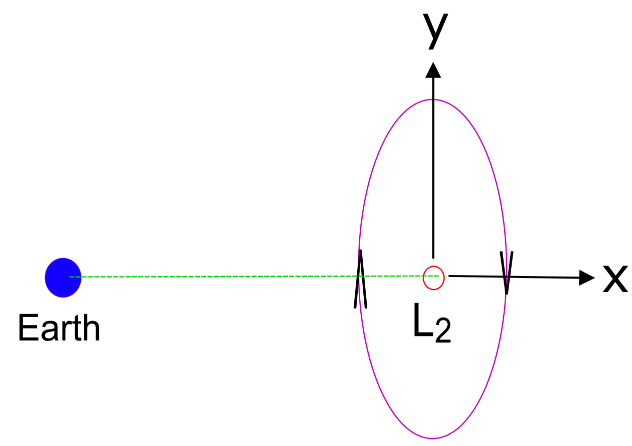
- Advantages for Astronomy Missions:
  - Sun and Earth nearly aligned as seen from spacecraft
    - ⇨ stable thermal environment with sun + Earth IR shielding
    - ⇨ only one direction excluded form viewing (moving 360° per year)
    - ⇨ possibly medium gain antenna in sun pointing
  - Low high energy radiation environment
- Drawbacks:
  - 1.5×10^6 km for communication
    - ⇨ However development of deep space communications technology (X-band, K-band) ameliorates disadvantage
  - Long transfer duration
    - ⇨ Fast transfer in about 30 days with +10 m/s
  - Instable orbits
    - ⇨ Manoeuvres every 30 days (~10 cm/s each)
    - ⇨ Escape at end of mission (L_2 region "self-cleaning")



ORBITS AT L_2

<u>Satellite in L_2</u>

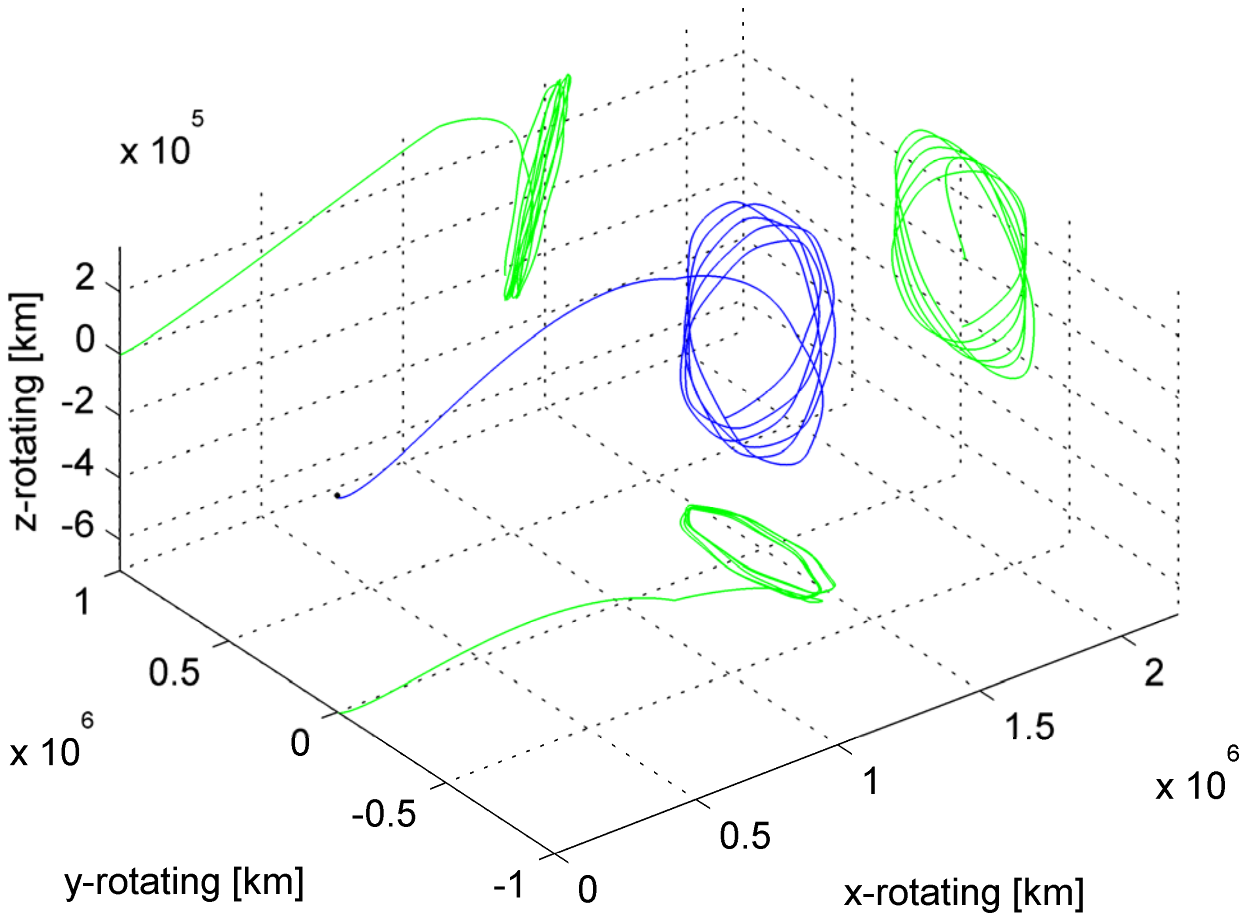
- Does not work in exact problem
- Would also be in Earth half-shadow
- And difficult to reach (much propellant)



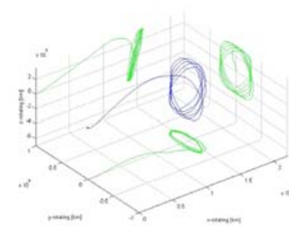
<u>Satellites in orbits around L_2</u>

- With certain initial conditions a satellite will remain near L_2
  also in exact problem ⇨ **called Orbits around L_2**
  - ➢ Different Types of Orbits classified by their motion in y-z (z=out of ecliptic)
    - ⇨ **Lissajous figure** in y-z for small amplitudes in y and z
    - ⇨ **Halo** for special combination of amplitudes

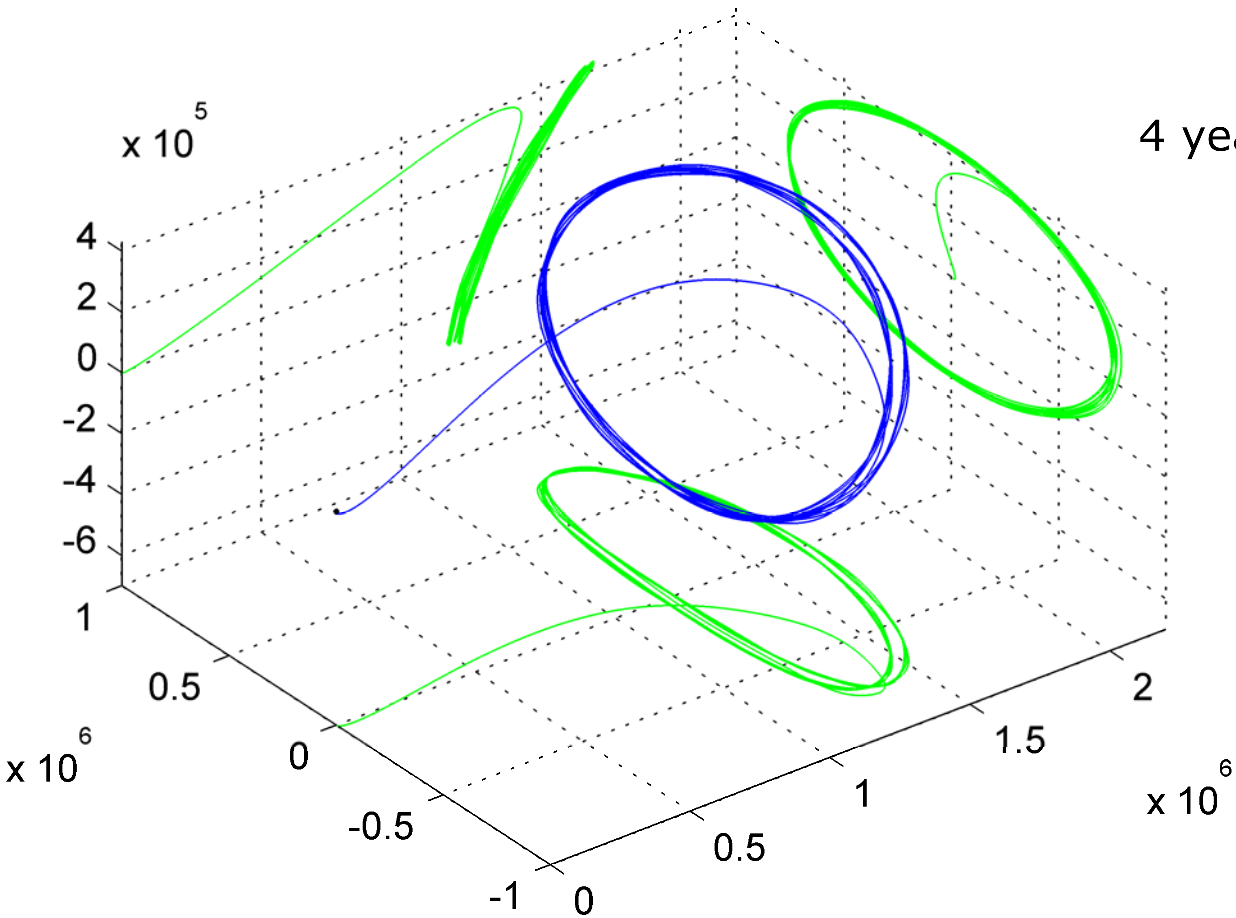
LISSAJOUS ORBIT (PLANCK)



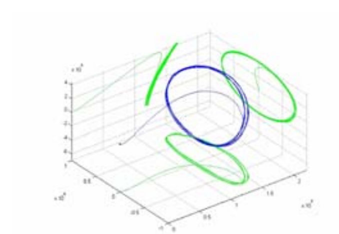
2.5 years propagation



HALO ORBIT (HERSCHEL)



4 years propagation



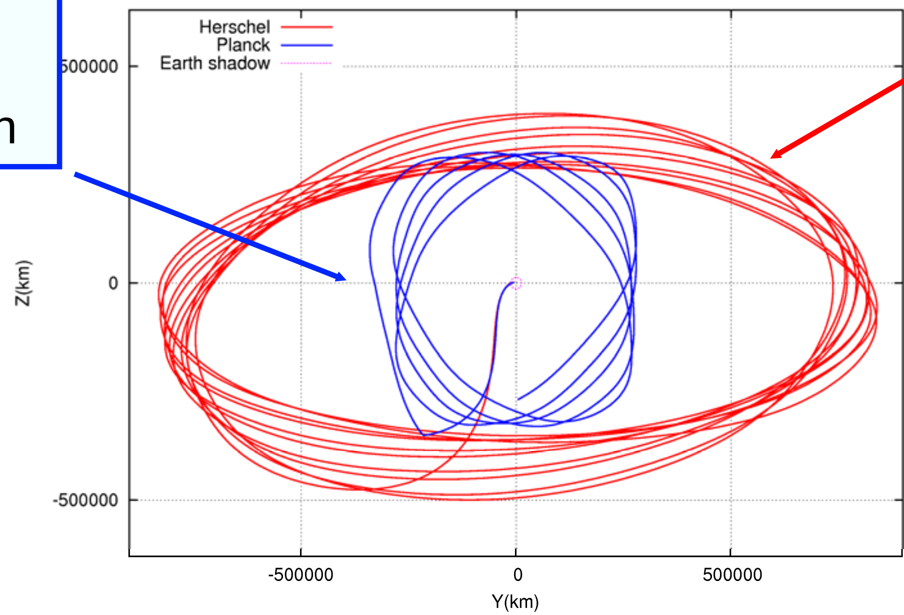
ORBITS AT L_2 USED FOR SPACE MISSIONS

<u>Lissajous orbits:</u>

- Earth aspect <15º
  ⇨ Survey Missions scanning in sun pointing spin

Planck
GAIA

View from Earth



<u>Quasi Halo orbits:</u>

- "Free" transfer
  ⇨ Observatories

Herschel
JWST
LISA Pathfinder (L_1)
IXO (XEUS)
EUCLID
PLATO
SPICA

PAGE FOR MATHEMATICIANS

- Differential equations for relative motion in frame rotating with Earth around sun

$$\begin{aligned} \ddot{x} - 2\,\dot{y} - (1+2K)\,x &= 0 \\ \ddot{y} + 2\,\dot{x} - (1-K)\,y &= 0 \\ \ddot{z} + K\,z &= 0 \end{aligned}$$

- Complete solution of linearised problem (x-y motion and z-motion are uncoupled)

$$\begin{aligned} x &= A_1\,e^{\lambda_{xy}t} + A_2\,e^{-\lambda_{xy}t} + A_x\,\cos(\omega_{xy}t + \phi_{xy}) \\ y &= A_1\,c_1\,e^{\lambda_{xy}t} - A_2\,c_1\,e^{-\lambda_{xy}t} - A_x\,c_2\,\sin(\omega_{xy}t + \phi_{xy}) \\ z &= A_z\,\cos(\omega_z t + \phi_z) \end{aligned}$$

Escape ($A_1\,e^{\lambda_{xy}t}$), Capture ($A_2\,e^{-\lambda_{xy}t}$), Periodic ($A_x\,\cos(\omega_{xy}t + \phi_{xy})$)

- Choice of initial conditions such that $A_1 = A_2 = 0 \Rightarrow$ **Lissajous Orbits**

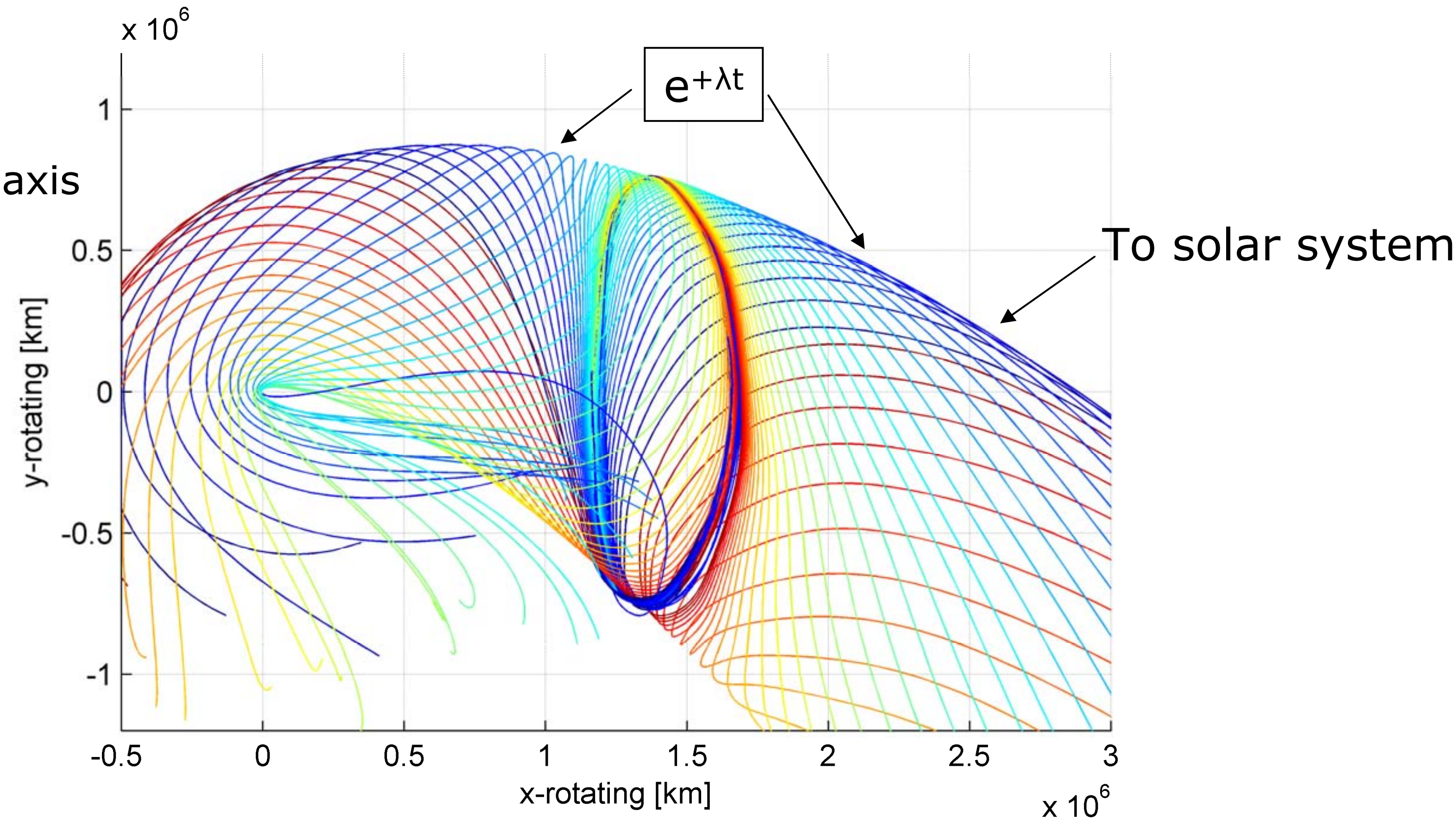
$$\begin{aligned} x &= A_x\,cos(\omega_{xy}t) \\ y &= -A_y\,sin(\omega_{xy}t), \text{ with } A_y = c_2 A_x \\ z &= A_z\,cos(\omega_z t + \phi_z). \end{aligned}$$

$A_2 \neq 0$ ⇨ Used for transfer

PROPERTIES OF ORBITS AT L_2 : INSTABILITY

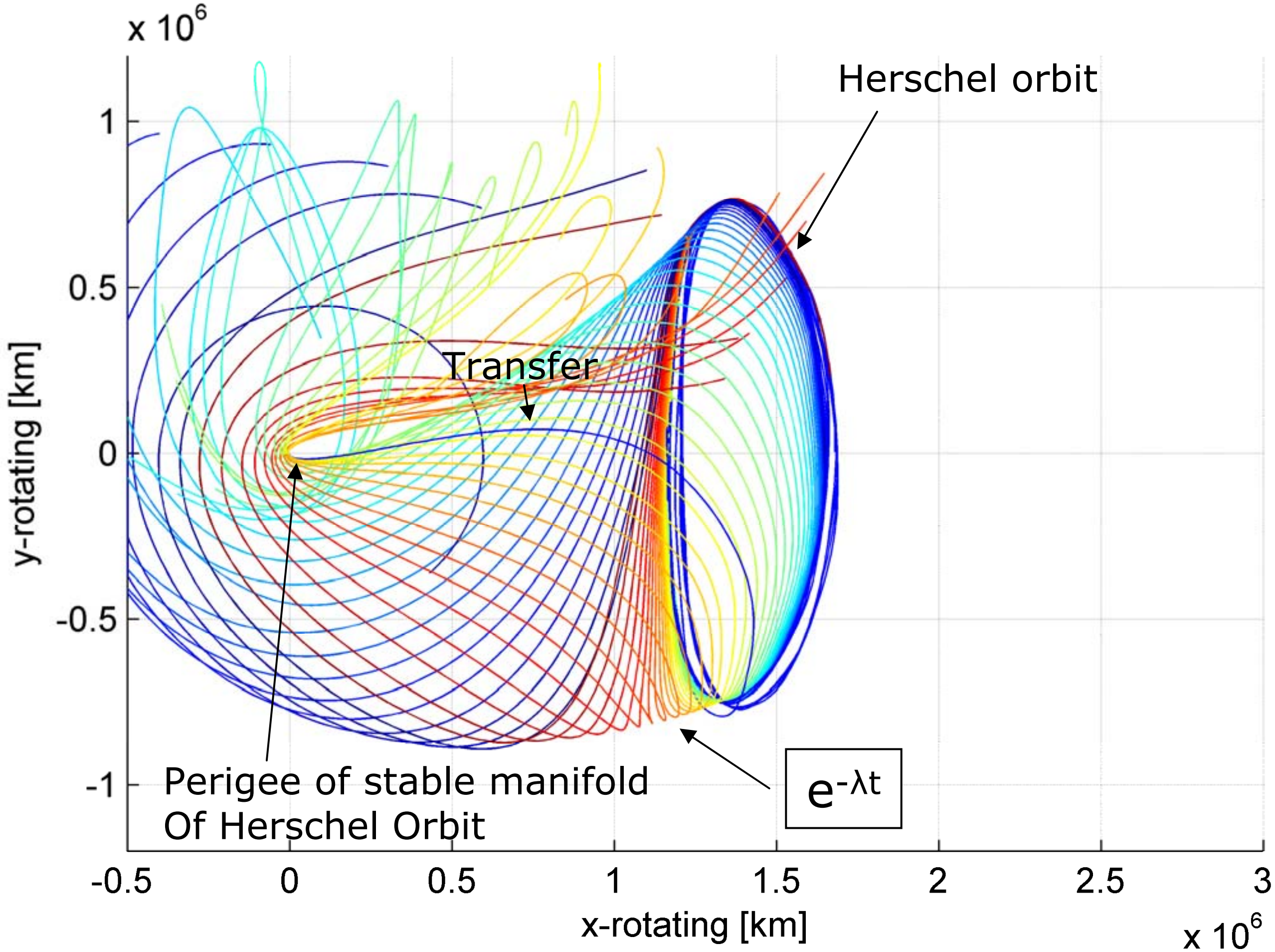
- Orbits at L_2 are unstable ⇨ escape for small deviation ⇨ unstable manifold

x-y rotating =
in ecliptic,
Sun-Earth on x-axis

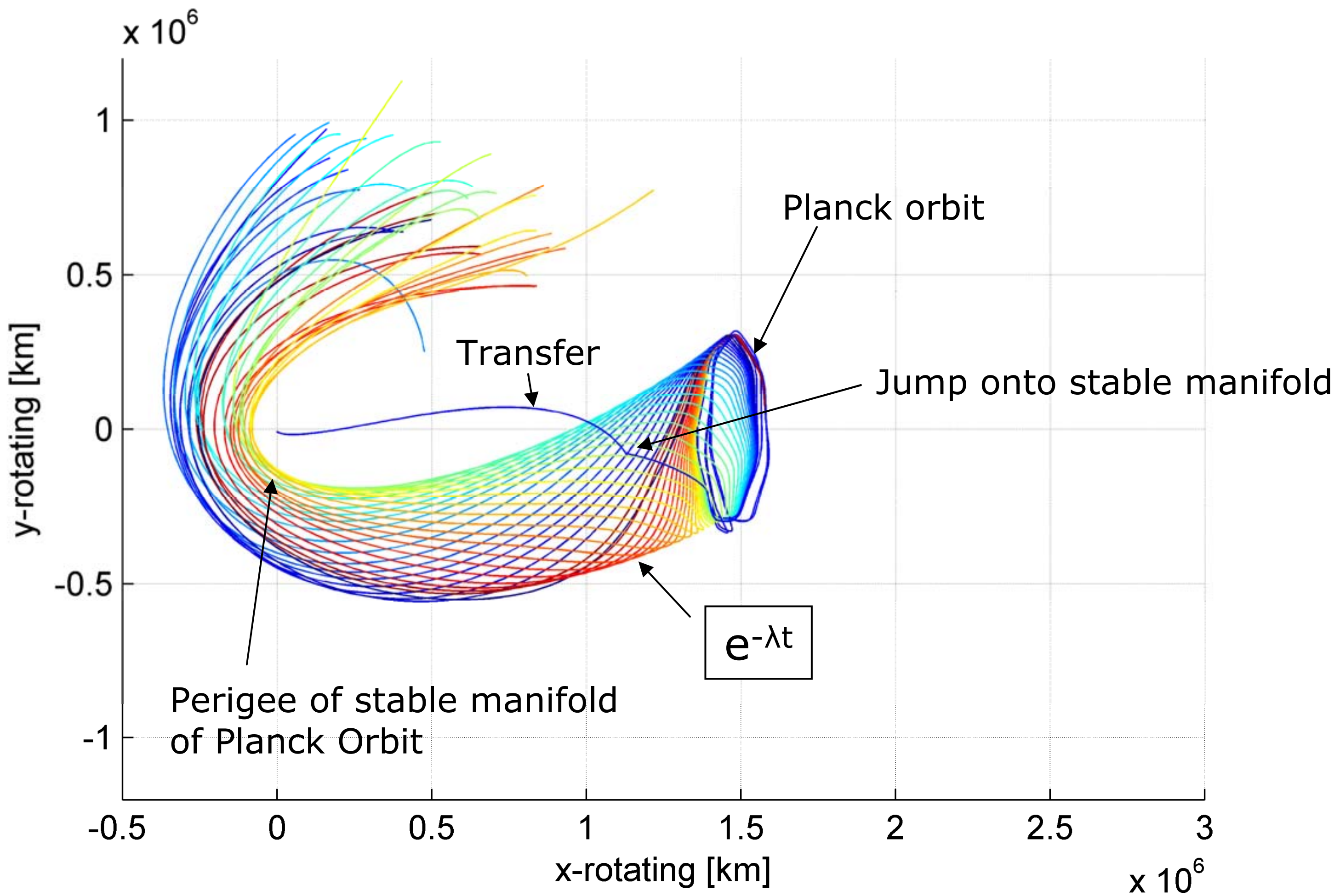


STABLE MANIFOLD OF OF HERSCHEL ORBIT

“Stable manifold” = surface-structure in space, which flows into orbit



STABLE MANIFOLD OF OF PLANCK ORBIT



WHAT IS A LAUNCH WINDOW ?

Definition of Launch Window:

- Dates (seasonal) and hours (daily) for which a launch is possible
- Launcher target conditions (possibly as function of day and hour)

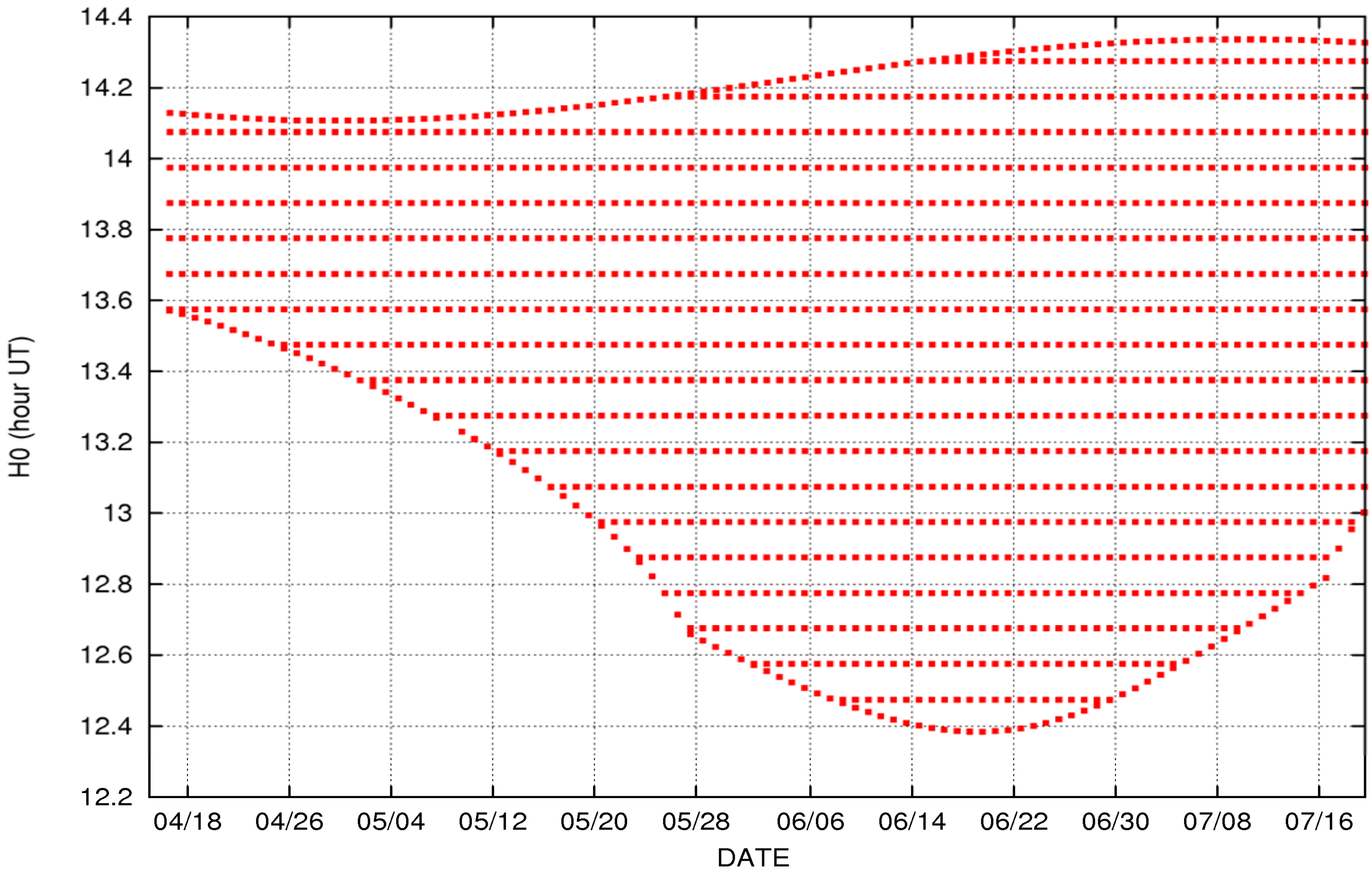
Constraints:

- Propellant on spacecraft required to reach a given orbit (type)
- Geometric conditions:
  - no eclipses during all orbit phases (power)
  - sun shall not shine into telescope during launch (damage)

Typical calculation method:

- Calculate orbits for scan in launch times
- Remove points for which one of the conditions is not satisfied

LAUNCH WINDOW FOR HERSCHEL-PLANCK



THANK YOU

Martin Hechler
Orbiting L_2
martin.hechler@esa.int