

- [> *with(plots) :*
- [> *with(plottools) :*

### ΘΕΜΑ

Μελέτη Κυκλικής Γεωστατικής Τροχιάς Δορυφόρων (GEO) .

Παρατήρηση : Στα σημεία διέλευσης του Δορυφόρου : **Ανερχόμενος κόμβος (Εαρινή Ισημερία)** και **Κατερχόμενος κόμβος (Φθινοπωρινή Ισημερία)**

έχουμε τις περισσότερες διαταραχές επικοινωνίας λόγω συζυγιών !

ΚΛΙΣΗ ΑΞΟΝΑ ΠΕΡΙΣΤΡΟΦΗΣ της ΓΗΣ ως προς την κατακόρυφο :

$23,439247^{\circ} = 0.40909 \text{ rad.}$

Μέση ακτίνα ΓΗΣ : $6371 \text{ km}$  .

Αφήλιο : $152.098.232 \text{ km}$  , Περιήλιο : $147.098.290 \text{ km}$  , Εκκεντρότητα : $0.01671123$  .

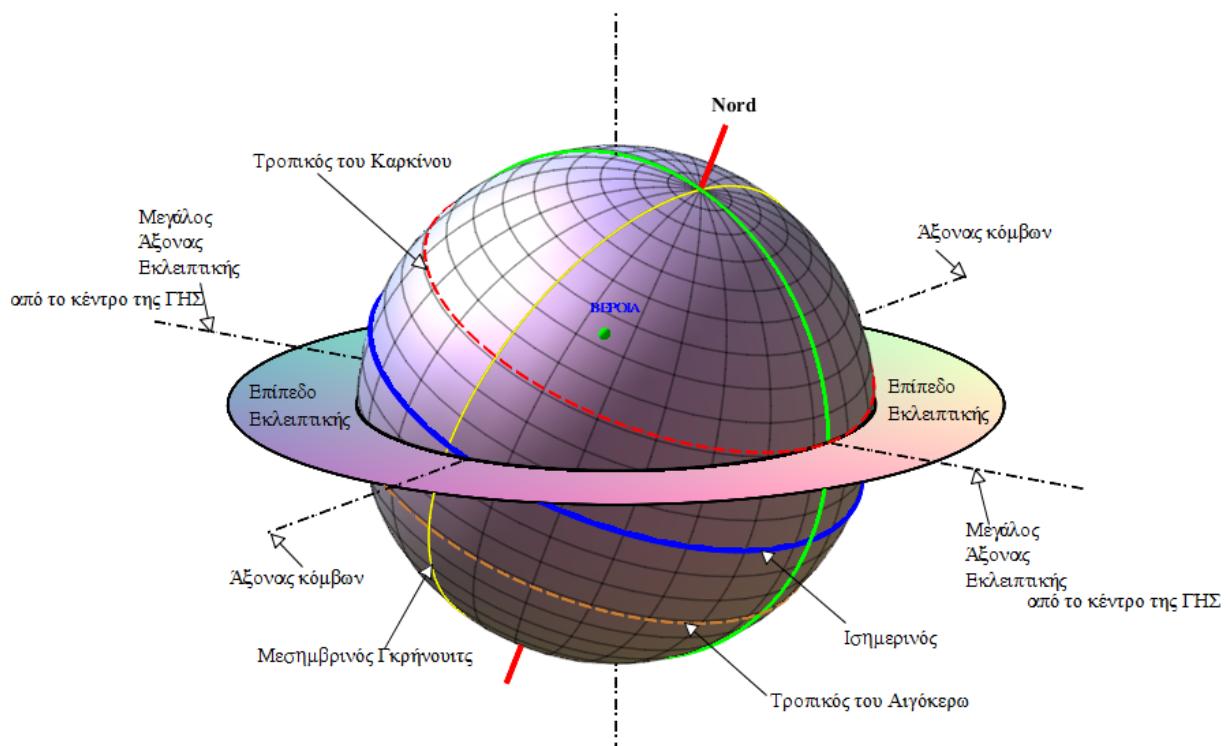
Μεγάλος Ημιάξονας Ελλειπτικής :  $a=149.598.261 \text{ km}$  (5),  $\Rightarrow c=2.499.971 \text{ km}$  (1)

Μικρός Ημιάξονας Ελλειπτικής : $b=149.577.371 \text{ km}$  (4).

**ΤΑ ΜΕΓΕΘΗ ΑΠΕΙΚΟΝΙΣΗΣ (5),(1),(4), ΕΙΝΑΙ ΠΛΑΣΜΑΤΙΚΑ ..!!!!**

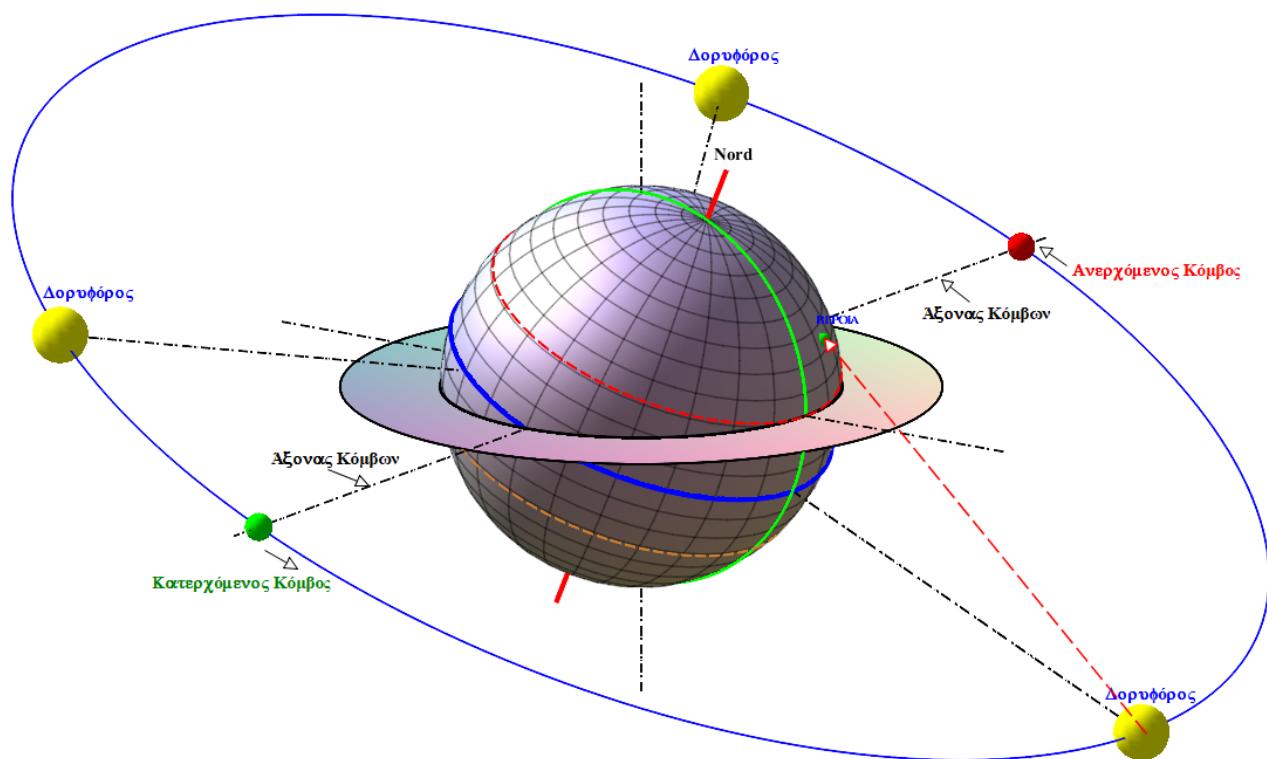
**ΠΡΟΣΟΧΗ ΣΤΗΝ ΣΕΙΡΑ,ΕΜΦΑΝΙΣΗΣ ..!!!!!!**

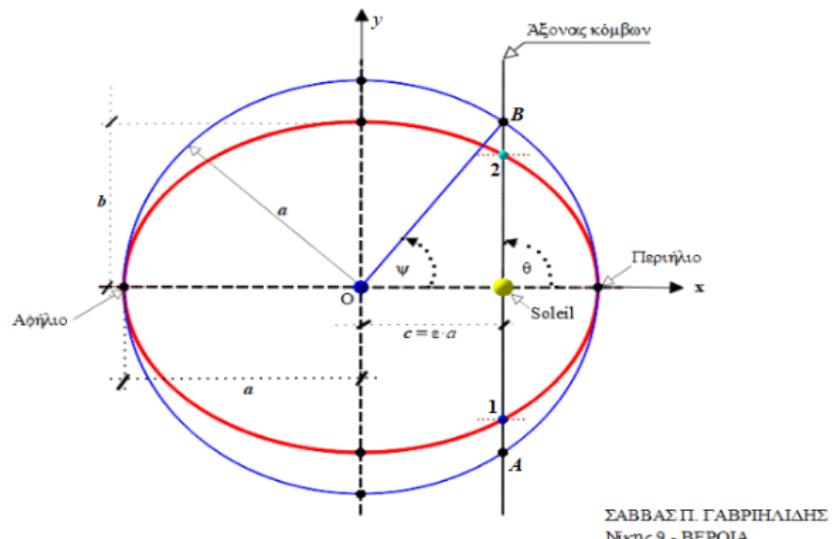
Η ΓΗ ΣΤΟΝ ΑΞΟΝΑ ΤΩΝ ΚΟΜΒΩΝ  
ΣΑΒΒΑΣ Π. ΓΑΒΡΙΗΛΙΔΗΣ



ΚΥΚΛΙΚΗ ΓΕΩΣΤΑΤΙΚΗ ΤΡΟΧΙΑ (GEO)  
Η ΓΗ ΣΤΟΝ ΑΞΟΝΑ ΤΩΝ ΚΟΜΒΩΝ-  
ΣΑΒΒΑΣ Π. ΓΑΒΡΙΗΛΙΔΗΣ

Πλήρης κάλυψη με τρεις (3) Δορυφόρους διατεταγμένους στην GEO ανά  $120^{\circ}$

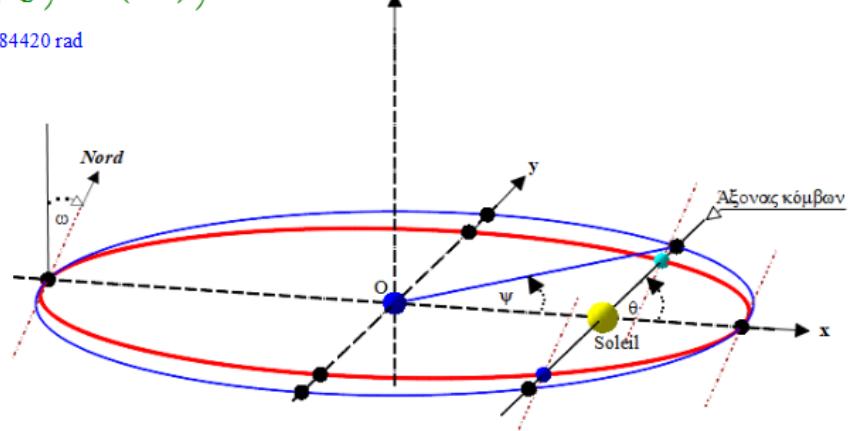




ΣΑΒΒΑΣ Π. ΓΑΒΡΙΗΛΙΔΗΣ  
Νικητής 9 - ΒΕΡΟΙΑ

$$\psi_{nodes} := \tan^{-1} \left( \sqrt{\frac{1-\epsilon}{1+\epsilon}} \cdot \tan \left( \frac{\pi}{4} \right) \right) \cdot 2 \text{ rad}$$

$$\psi_{nodes} := 1.554084420 \text{ rad}$$



### Με πόλο την Εσπία-ΗΛΙΟΣ

**Εξίσωση Ελλειπτικής Τροχιάς σε Πολικές Συντεταγμένες**

$$r(\theta) = \frac{a \cdot (1 - \epsilon^2)}{1 + \epsilon \cdot \cos(\theta)}$$

$$> \omega := \frac{23.439247 \cdot \pi}{180} :$$

$$> a := 149598261$$

$$a := 149598261 \quad (1)$$

$$> b := 149577371$$

$$b := 149577371 \quad (2)$$

$$> \epsilon := evalf \left( \sqrt{1 - \left( \frac{b}{a} \right)^2} \right)$$

$$\epsilon := 0.01671112868 \quad (3)$$

>  $c := a \cdot \epsilon$

$$c := 2.499955790 \cdot 10^6 \quad (4)$$

Πλασματικά Μεγέθη Τροχιάς .

>  $aI := 5$

$$aI := 5 \quad (5)$$

>  $bI := 4$

$$bI := 4 \quad (6)$$

>  $\epsilon I := evalf\left(\sqrt{1 - \left(\frac{bI}{aI}\right)^2}\right)$

$$\epsilon I := 0.6000000000 \quad (7)$$

>  $cI := aI \cdot \epsilon I$

$$cI := 3.000000000 \quad (8)$$

>  $\tan\left(\frac{\Psi}{2}\right) = \sqrt{\frac{1 - \epsilon I}{1 + \epsilon I}} \cdot \tan\left(\frac{\theta}{2}\right)$

$$\tan\left(\frac{\Psi}{2}\right) = 0.5000000000 \tan\left(\frac{\theta}{2}\right) \quad (9)$$

$$r(\theta) = \frac{a \cdot (1 - \epsilon^2)}{1 + \epsilon \cdot \cos(\theta)}$$

$$\tan\left(\frac{\Psi}{2}\right) = \sqrt{\frac{1 - \epsilon I}{1 + \epsilon I}} \cdot \tan\left(\frac{\theta}{2}\right)$$

$\Psi$ :=Εκκεντρική Ανωμαλία

$\theta$ :=Αληθής Ανωμαλία

Εξίσωση Έλλειψης σε καρτεσιανές Συντεταγμένες με Αρχή τον πόλο Εκκεντρικής Ανωμαλίας

$$[a \cdot \cos(\Psi), b \cdot \sin(\Psi), 0]$$

α ο μεγάλος ημάξονας  
β ο μικρός ημάξονας της Έλλειψης

>  $Tell := spacecurve([aI \cdot \cos(\Psi), bI \cdot \sin(\Psi), 0], \Psi = 0 .. 2 \cdot \text{Pi}, color = red, thickness = 3) :$

>  $Tcer := spacecurve([aI \cdot \cos(\Psi), aI \cdot \sin(\Psi), 0], \Psi = 0 .. 2 \cdot \text{Pi}, color = blue, thickness = 1, linestyle = 1) :$

>  $Soleil := pointplot3d([cI, 0, 0], symbol = solidcircle, symbolsize = 20, color = yellow) :$

>  $ARXH := pointplot3d([0, 0, 0], symbol = solidcircle, symbolsize = 15, color = blue) :$

>  $axX := spacecurve([0 + \lambda \cdot aI, 0, 0], \lambda = -1.1 .. 1.1, color = black, thickness = 2, linestyle = 3) :$

>  $axY := spacecurve([0, 0 + \lambda \cdot aI, 0], \lambda = -1.1 .. 1.1, color = black, thickness = 2, linestyle = 3) :$

>  $axZ := spacecurve([0, 0, 0 + \lambda \cdot bI], \lambda = -0.3 .. 1, color = black, thickness = 2, linestyle = 3) :$

>  $GRAMMHNODES := spacecurve([cI, \lambda \cdot aI, 0], \lambda = -1.1 .. 1.1, color = black, thickness = 1, linestyle = 1) :$

>  $node1 := pointplot3d([cI, -aI \cdot (1 - \epsilon I^2), 0], symbol = solidcircle, symbolsize = 10, color = blue) :$

```

> node2 := pointplot3d([c1, a1·(1 - εl²), 0], symbol=solidcircle, symbolsize=10, color=cyan) :
> SHMEIOA := pointplot3d([c1, -a1·sqrt(1 - εl²), 0], symbol=solidcircle, symbolsize=10, color=black) :
> GRAMMHOA := spacecurve([λ·c1, λ·a1·sqrt(1 - εl²), 0], λ=0..1, color=blue, thickness=1, linestyle=1) :
> SHMEOB := pointplot3d([c1, a1·sqrt(1 - εl²), 0], symbol=solidcircle, symbolsize=10, color=black) :
> PERIHEL := pointplot3d([a1, 0, 0], symbol=solidcircle, symbolsize=10, color=black) :
> AFHL := pointplot3d([-a1, 0, 0], symbol=solidcircle, symbolsize=10, color=black) :
> SHM1 := pointplot3d([0, b1, 0], symbol=solidcircle, symbolsize=10, color=black) :
> SHM2 := pointplot3d([0, a1, 0], symbol=solidcircle, symbolsize=10, color=black) :
> SHM3 := pointplot3d([0, -b1, 0], symbol=solidcircle, symbolsize=10, color=black) :
> SHM4 := pointplot3d([0, -a1, 0], symbol=solidcircle, symbolsize=10, color=black) :
> AXONGHSPERIHEL := spacecurve([a1·cos(0) + λ·sin(ω), 0 + λ·0, 0 + λ·cos(ω)], λ=-1.3..1.3, linestyle=2, color=brown) :
> AXONGHSAFHL := spacecurve([a1·cos(Pi) + λ·sin(ω), 0 + λ·0, 0 + λ·cos(ω)], λ=-1.3..1.3, linestyle=2, color=brown) :
> AXONGHSnode1 := spacecurve([c1 + λ·sin(ω), -a1·(1 - εl²) + λ·0, 0 + λ·cos(ω)], λ=-1.3..1.3, linestyle=2, color=brown) :
> AXONGHSnode2 := spacecurve([c1 + λ·sin(ω), a1·(1 - εl²) + λ·0, 0 + λ·cos(ω)], λ=-1.3..1.3, linestyle=2, color=brown) :
> display(Tell, Tcer, Soleil, axX, axY, axZ, ARXH, GRAMMHNODES, node1, node2, SHMEIOA, GRAMMHOA, SHMEOB, PERIHEL, AFHL, SHM1, SHM2, SHM3, SHM4, AXONGHSPERIHEL, AXONGHSAFHL, AXONGHSnode1, AXONGHSnode2, orientation=[-90, 0, 0], axes=none, scaling=constrained) :

```

Συντεταγμένες της Σφαίρας με κεκλιμένο κατά γωνία ω άξονα .

## Περιστροφή περί τον άξονα γ-γ

$$x[B] := z[A] \cdot \sin(\omega) + x[A] \cdot \cos(\omega)$$

$$y[B] := y[A]$$

$$z[B] := z[A] \cdot \cos(\omega) - x[A] \cdot \sin(\omega)$$

$$> \omega := \frac{23.439247 \cdot \text{Pi}}{180}$$

$$\omega := 0.4090920344$$

(10)

```

> R[e] := 6371
Re := 6371
(11)

> ψnodes := tan-1(sqrt((1 - ε)/(1 + ε)) · tan(Pi/4)) · 2
ψnodes := 1.554084420
(12)

> xEL := a · cos(ψ)
xEL := 149598261 cos(ψ)
(13)

> yEL := b · sin(ψ)
yEL := 149577371 sin(ψ)
(14)

> zEL := 0
zEL := 0
(15)

> X := xEL + R[e] · sin(θ) · cos(ϕ + τ) · cos(ω) + R[e] · cos(θ) · sin(ω)
X := 149598261 cos(ψ) + 5845.280168 sin(θ) cos(ϕ + τ) + 2534.233760 cos(θ)
(16)

> Y := yEL + R[e] · sin(θ) · sin(ϕ + τ)
Y := 149577371 sin(ψ) + 6371 sin(θ) sin(ϕ + τ)
(17)

> Z := zEL - R[e] · sin(θ) · cos(ϕ + τ) · sin(ω) + R[e] · cos(θ) · cos(ω)
Z := -2534.233760 sin(θ) cos(ϕ + τ) + 5845.280168 cos(θ)
(18)

> evalf(subs(ψ = ψnodes, X))
2.499955823 106 + 5845.280168 sin(θ) cos(ϕ + τ) + 2534.233760 cos(θ)
(19)

> evalf(subs(ψ = ψnodes, Y))
1.495564839 108 + 6371. sin(θ) sin(ϕ + τ)
(20)

> evalf(subs(ψ = ψnodes, Z))
-2534.233760 sin(θ) cos(ϕ + τ) + 5845.280168 cos(θ)
(21)

> anSF := animate(plot3d, [(19), (20), (21)], θ = 0 .. Pi, φ = 0 .. 2 · Pi, frames = 61):

```

**Συντεταγμένες του ΙΣΗΜΕΡΙΝΟΥ της ΓΗΣ με κεκλιμένο κατά γωνία ω αξονα:**

```

> XISHM := xEL + R[e] · sin(Pi/2) · cos(ϕ) · cos(ω) + R[e] · cos(Pi/2) · sin(ω)
XISHM := 149598261 cos(ψ) + 5845.280168 cos(ϕ)
(22)

> YISHM := yEL + R[e] · sin(Pi/2) · sin(ϕ)
YISHM := 149577371 sin(ψ) + 6371 sin(ϕ)
(23)

> ZISHM := zEL - R[e] · sin(Pi/2) · cos(ϕ) · sin(ω) + R[e] · cos(Pi/2) · cos(ω)
ZISHM := -2534.233760 cos(ϕ)
(24)

> evalf(subs(ψ = ψnodes, XISHM))
2.499955823 106 + 5845.280168 cos(ϕ)
(25)

> evalf(subs(ψ = ψnodes, YISHM))
1.495564839 108 + 6371. sin(ϕ)
(26)

```

```

> evalf(subs(ψ = ψnodes, ZISHM) )
          -2534.233760 cos(ϕ)                                     (27)

> ISHMERINOS := spacecurve([ (25), (26), (27)], ϕ = 0 .. 2·Pi, color = blue, thickness = 5) :

```

**Συντεταγμένες του ΤΡΟΠΙΚΟΥ ΤΟΥ ΚΑΡΚΙΝΟΥ της ΓΗΣ με κεκλιμένο κατά γωνία ω άξονα :**

```

> Xcancer := xEL + R[e]·sin(  $\frac{\text{Pi}}{2} - \omega$  )·cos(ϕ)·cos(  $\omega$  ) + R[e]·cos(  $\frac{\text{Pi}}{2} - \omega$  )·sin(  $\omega$  )
          Xcancer := 149598261 cos(ψ) + 5362.941494 cos(ϕ) + 1008.058506           (28)

> Ycancer := yEL + R[e]·sin(  $\frac{\text{Pi}}{2} - \omega$  )·sin(ϕ)
          Ycancer := 149577371 sin(ψ) + 5845.280170 sin(ϕ)                         (29)

> Zcancer := zEL - R[e]·sin(  $\frac{\text{Pi}}{2} - \omega$  )·cos(ϕ)·sin(  $\omega$  ) + R[e]·cos(  $\frac{\text{Pi}}{2} - \omega$  )·cos(  $\omega$  )
          Zcancer := 2325.114789 - 2325.114793 cos(ϕ)                               (30)

> evalf(subs(ψ = ψnodes, Xcancer) )
          2.500963882  $10^6$  + 5362.941494 cos(ϕ)                                (31)

> evalf(subs(ψ = ψnodes, Ycancer) )
          1.495564839  $10^8$  + 5845.280170 sin(ϕ)                            (32)

> evalf(subs(ψ = ψnodes, Zcancer) )
          2325.114789 - 2325.114793 cos(ϕ)                                (33)

> CANCER := spacecurve([ (31), (32), (33)], ϕ = 0 .. 2·Pi, color = red, linestyle = 3, thickness = 2) :


```

**Συντεταγμένες του ΤΡΟΠΙΚΟΥ ΤΟΥ ΑΙΓΟΚΕΡΩ της ΓΗΣ με κεκλιμένο κατά γωνία ω άξονα :**

```

> Xcapricorne := xEL + R[e]·sin(  $\frac{\text{Pi}}{2} + \omega$  )·cos(ϕ)·cos(  $\omega$  ) + R[e]·cos(  $\frac{\text{Pi}}{2} + \omega$  )·sin(  $\omega$  )
          Xcapricorne := 149598261 cos(ψ) + 5362.941493 cos(ϕ) - 1008.058508      (34)

> Ycapricorne := yEL + R[e]·sin(  $\frac{\text{Pi}}{2} + \omega$  )·sin(ϕ)
          Ycapricorne := 149577371 sin(ψ) + 5845.280169 sin(ϕ)                      (35)

> Zcapricorne := zEL - R[e]·sin(  $\frac{\text{Pi}}{2} + \omega$  )·cos(ϕ)·sin(  $\omega$  ) + R[e]·cos(  $\frac{\text{Pi}}{2} + \omega$  )·cos(  $\omega$  )
          Zcapricorne := -2325.114792 - 2325.114793 cos(ϕ)                           (36)

> evalf(subs(ψ = ψnodes, Xcapricorne) )
          2.498947764  $10^6$  + 5362.941493 cos(ϕ)                                (37)

> evalf(subs(ψ = ψnodes, Ycapricorne) )
          1.495564839  $10^8$  + 5845.280169 sin(ϕ)                            (38)

> evalf(subs(ψ = ψnodes, Zcapricorne) )
          -2325.114792 - 2325.114793 cos(ϕ)                                (39)

> CAPRICORNE := spacecurve([ (37), (38), (39)], ϕ = 0 .. 2·Pi, color = gold, linestyle = 3, thickness = 2) :

```

## Συντεταγμένες της κυκλικής ΓΕΩΣΤΑΤΙΚΗΣ τροχιάς του Δορυφόρου (GEO):

$$\begin{aligned} > XGEO := xEL + \frac{42164}{2} \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \cos(\phi) \cdot \cos(\omega) + \frac{42164}{2} \cdot \cos\left(\frac{\text{Pi}}{2}\right) \cdot \sin(\omega) \\ & XGEO := 149598261 \cos(\psi) + 19342.36329 \cos(\phi) \end{aligned} \quad (40)$$

$$\begin{aligned} > YGEO := yEL + \frac{42164}{2} \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \sin(\phi) \\ & YGEO := 149577371 \sin(\psi) + 21082 \sin(\phi) \end{aligned} \quad (41)$$

$$\begin{aligned} > ZGEO := zEL - \frac{42164}{2} \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \cos(\phi) \cdot \sin(\omega) + \frac{42164}{2} \cdot \cos\left(\frac{\text{Pi}}{2}\right) \cdot \cos(\omega) \\ & ZGEO := -8385.923110 \cos(\phi) \end{aligned} \quad (42)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, XGEO)) \\ & 2.499955823 \cdot 10^6 + 19342.36329 \cos(\phi) \end{aligned} \quad (43)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, YGEO)) \\ & 1.495564839 \cdot 10^8 + 21082 \cdot \sin(\phi) \end{aligned} \quad (44)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, ZGEO)) \\ & -8385.923110 \cos(\phi) \end{aligned} \quad (45)$$

>  $GEO := spacecurve([ (43), (44), (45)], \phi = 0 .. 2 \cdot \text{Pi}, color = blue, thickness = 1) :$   
 >  $animGEO := animate(pointplot3d, [[(43), (44), (45)], symbol = solidsphere, symbolsize = 20, color = yellow], \phi = 0 .. 2 \cdot \text{Pi}, frames = 61, trace = 3) :$

## Σύνδεσμος κέντρου ΓΗΣ-ΔΟΡΥΦΟΡΟΥ.

$$\begin{aligned} > lineOGEO := animate(spacecurve, [[subs(\psi = \psi_{nodes}, xEL + \lambda \cdot (XGEO - xEL)), subs(\psi = \psi_{nodes}, yEL + \lambda \cdot (YGEO - yEL)), subs(\psi = \psi_{nodes}, zEL + \lambda \cdot (ZGEO - zEL))], \lambda = 0 .. 1, color = black, linestyle = 4], \phi = 0 .. 2 \cdot \text{Pi}, frames = 61, trace = 3) : \end{aligned}$$

## Συντεταγμένες του 1-ΜΕΣΗΜΒΡΙΝΟΥ της ΓΗΣ με κεκλιμένο κατά γωνία ω άξονα :

$$\begin{aligned} > X := xEL + R[e] \cdot \sin(\theta) \cdot \cos(0) \cdot \cos(\omega) + R[e] \cdot \cos(\theta) \cdot \sin(\omega) \\ & X := 149598261 \cos(\psi) + 5845.280168 \sin(\theta) + 2534.233760 \cos(\theta) \end{aligned} \quad (46)$$

$$\begin{aligned} > Y := yEL + R[e] \cdot \sin(\theta) \cdot \sin(0) \\ & Y := 149577371 \sin(\psi) \end{aligned} \quad (47)$$

$$\begin{aligned} > Z := zEL - R[e] \cdot \sin(\theta) \cdot \cos(0) \cdot \sin(\omega) + R[e] \cdot \cos(\theta) \cdot \cos(\omega) \\ & Z := -2534.233760 \sin(\theta) + 5845.280168 \cos(\theta) \end{aligned} \quad (48)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, X)) \\ & 2.499955823 \cdot 10^6 + 5845.280168 \sin(\theta) + 2534.233760 \cos(\theta) \end{aligned} \quad (49)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, Y)) \\ & 1.495564839 \cdot 10^8 \end{aligned} \quad (50)$$

$$\begin{aligned} > evalf(subs(\psi = \psi_{nodes}, Z)) \\ & -2534.233760 \sin(\theta) + 5845.280168 \cos(\theta) \end{aligned} \quad (51)$$

>  $MESHMBRINOS := spacecurve([(49), (50), (51)], \theta = 0 .. 2 \cdot \text{Pi}, color = green, thickness = 3) :$

>  $\text{animMESHMBRINOS} := \text{animate}(\text{spacecurve}, [\text{subs}(\psi = \psi_{\text{nodes}}, xEL + R[e] \cdot \sin(\theta) \cdot \cos(\phi) \cdot \cos(\omega)) + R[e] \cdot \cos(\theta) \cdot \sin(\omega), \text{subs}(\psi = \psi_{\text{nodes}}, yEL + R[e] \cdot \sin(\theta) \cdot \sin(\phi) \cdot \cos(\omega)), \text{subs}(\psi = \psi_{\text{nodes}}, zEL - R[e] \cdot \sin(\theta) \cdot \cos(\phi) \cdot \sin(\omega) + R[e] \cdot \cos(\theta) \cdot \cos(\omega))], \theta = 0 .. 2 \cdot \text{Pi}, \text{color} = \text{yellow}, \text{thickness} = 1], \phi = 0 .. 2 \cdot \text{Pi}, \text{frames} = 61) :$

**Συντεταγμένες του κεκλιμένου κατά γωνία ω άξονα  $[r \cdot \sin(\omega), 0, r \cdot \cos(\omega)]$  της Σφαίρας με :  $\lambda = -1.3..1.3$**

>  $Xaxon := \text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, xEL + \lambda \cdot R[e] \cdot \sin(\omega)))$   
 $Xaxon := 2.499955823 \cdot 10^6 + 2534.233760 \lambda$  (52)

>  $Yaxon := \text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, yEL + \lambda \cdot 0))$   
 $Yaxon := 1.495564839 \cdot 10^8$  (53)

>  $Zaxon := \text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, zEL + \lambda \cdot R[e] \cdot \cos(\omega)))$   
 $Zaxon := 5845.280168 \lambda$  (54)

>  $axonS := \text{spacecurve}([(52), (53), (54)], \lambda = -1.3 .. 1.3, \text{color} = \text{red}, \text{thickness} = 4) :$   
>  $TEXTaxon := \text{textplot3d}([\text{subs}(\lambda = 1.4, (52)), \text{subs}(\lambda = 1.4, (53)), \text{subs}(\lambda = 1.4, (54)), "Nord"], \text{font} = [\text{arial}, \text{bold}, 12]) :$

**Συντεταγμένες του Επίγειου Σταθμού (ΒΕΡΟΙΑ) ,της , με κεκλιμένο κατά γωνία ω άξονα , ΓΗΣ .**

# 40.5194° N, 22.2052° E

>  $xBER := xEL + R[e] \cdot \sin\left(\frac{(90 - 40.5194)}{180} \cdot \text{Pi}\right) \cdot \cos\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right) \cdot \cos(\omega) + R[e] \cdot \cos\left(\frac{(90 - 40.5194)}{180} \cdot \text{Pi}\right) \cdot \sin(\omega)$   
 $xBER := 149598261 \cos(\psi) + 4443.500284 \cos(0.3875538510 + \phi) + 1646.505561$  (55)

>  $yBER := yEL + R[e] \cdot \sin\left(\frac{(90 - 40.5194)}{180} \cdot \text{Pi}\right) \cdot \sin\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right)$   
 $yBER := 149577371 \sin(\psi) + 4843.145152 \sin(0.3875538510 + \phi)$  (56)

>  $zBER := zEL - R[e] \cdot \sin\left(\frac{(90 - 40.5194)}{180} \cdot \text{Pi}\right) \cdot \cos\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right) \cdot \sin(\omega) + R[e] \cdot \cos\left(\frac{(90 - 40.5194)}{180} \cdot \text{Pi}\right) \cdot \cos(\omega)$   
 $zBER := 3797.710557 - 1926.489083 \cos(0.3875538510 + \phi)$  (57)

>  $\text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, xBER))$   
 $2.501602329 \cdot 10^6 + 4443.500284 \cos(0.3875538510 + \phi)$  (58)

>  $\text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, yBER))$   
 $1.495564839 \cdot 10^8 + 4843.145152 \sin(0.3875538510 + \phi)$  (59)

>  $\text{evalf}(\text{subs}(\psi = \psi_{\text{nodes}}, zBER))$   
 $3797.710557 - 1926.489083 \cos(0.3875538510 + \phi)$  (60)

>  $xBERTxt := xEL + 7100 \cdot \sin\left(\frac{(90 - 45)}{180} \cdot \text{Pi}\right) \cdot \cos\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right) \cdot \cos(\omega) + 7100$

$$\cdot \cos\left(\frac{(90 - 45)}{180} \cdot \text{Pi}\right) \cdot \sin(\omega)$$

$$xBERtxt := 149598261 \cos(\psi) + 3257.062408 \sqrt{2} \cos(0.3875538510 + \phi) + 1412.106396 \sqrt{2} \quad (61)$$

$$> yBERtxt := yEL + 7100 \cdot \sin\left(\frac{(90 - 45)}{180} \cdot \text{Pi}\right) \cdot \sin\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right) \\ yBERtxt := 149577371 \sin(\psi) + 3550 \sqrt{2} \sin(0.3875538510 + \phi) \quad (62)$$

$$> zBERtxt := zEL - 7100 \cdot \sin\left(\frac{(90 - 45)}{180} \cdot \text{Pi}\right) \cdot \cos\left(\frac{22.2052}{180} \cdot \text{Pi} + \phi\right) \cdot \sin(\omega) + 7100 \\ \cdot \cos\left(\frac{(90 - 45)}{180} \cdot \text{Pi}\right) \cdot \cos(\omega) \\ zBERtxt := -1412.106396 \sqrt{2} \cos(0.3875538510 + \phi) + 3257.062408 \sqrt{2} \quad (63)$$

$$> evalf(subs(\psi = \psi_{nodes}, xBERtxt)) \\ 2.501952843 \cdot 10^6 + 4606.181830 \cos(0.3875538510 + \phi) \quad (64)$$

$$> evalf(subs(\psi = \psi_{nodes}, yBERtxt)) \\ 1.495564839 \cdot 10^8 + 5020.458145 \sin(0.3875538510 + \phi) \quad (65)$$

$$> evalf(subs(\psi = \psi_{nodes}, zBERtxt)) \\ -1997.020016 \cos(0.3875538510 + \phi) + 4606.181830 \quad (66)$$

> BEROIA := animate(pointplot3d, [(58), (59), (60)], symbol = solidcircle, symbolsize = 5, color = green],  $\phi = 0 .. 2 \cdot \text{Pi}$ , frames = 61) :

> Btext := animate(textplot3d, [(64), (65), (66), "BEPOIA"], font = [arial, bold, 8], color = blue],  $\phi = 0 .. 2 \cdot \text{Pi}$ , frames = 61) :

>

## Σύνδεσμος ΒΕΡΟΙΑΣ-ΔΟΡΥΦΟΡΟΥ .

> lineBERDOR := animate(spacecurve, [subs(\psi = \psi\_{nodes}, (58) + \lambda \cdot ((43) - (58))), subs(\psi = \psi\_{nodes}, (59) + \lambda \cdot ((44) - (59))), subs(\psi = \psi\_{nodes}, (60) + \lambda \cdot ((45) - (60)))], \lambda = 0 .. 1, color = red, linestyle = 5],  $\phi = 0 .. 2 \cdot \text{Pi}$ , frames = 61, trace = 0) :

>

## ΕΠΙΠΕΔΟ ΕΚΛΕΙΠΤΙΚΗΣ .

> ePEKLEIPTIKHS := cylinder([subs(\psi = \psi\_{nodes}, xEL), subs(\psi = \psi\_{nodes}, yEL), subs(\psi = \psi\_{nodes}, zEL)], 1.5 \cdot R[e], -1, strips = 100) :

$$> XEKL := xEL + R[e] \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \cos(\phi) \cdot \cos(0) + R[e] \cdot \cos\left(\frac{\text{Pi}}{2}\right) \cdot \sin(\phi) \\ XEKL := 149598261 \cos(\psi) + 6371 \cos(\phi) \quad (67)$$

$$> YEKL := yEL + R[e] \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \sin(\phi) \\ YEKL := 149577371 \sin(\psi) + 6371 \sin(\phi) \quad (68)$$

$$> ZEKL := zEL - R[e] \cdot \sin\left(\frac{\text{Pi}}{2}\right) \cdot \cos(\phi) \cdot \sin(0) + R[e] \cdot \cos\left(\frac{\text{Pi}}{2}\right) \cdot \cos(0) \\ ZEKL := 0 \quad (69)$$

$$> evalf(subs(\psi = \psi_{nodes}, XEKL)) \\ 2.499955823 \cdot 10^6 + 6371 \cdot \cos(\phi) \quad (70)$$

$$> evalf(subs(\psi = \psi_{nodes}, YEKL)) \\ 1.495564839 \cdot 10^8 + 6371 \cdot \sin(\phi) \quad (71)$$

$$> evalf(subs(\psi = \psi_{nodes}, ZEKL)) \\ 0. \quad (72)$$

>  $TOMH := spacecurve([ (70), (71), (72)], \phi = 0 .. 2\pi, color = black, linestyle = 1, thickness = 3) :$

### **ΑΞΟΝΑΣ ΤΩΝ ΚΟΜΒΩΝ (Nodes), παράλληλος στον y-y της ΕΚΛΕΙΠΤΙΚΗΣ που περνάει από το κέντρο της ΓΗΣ .**

>  $AXnodes := spacecurve([ subs(\psi = \psi_{nodes}, xEL), subs(\psi = \psi_{nodes}, yEL - \lambda \cdot yEL), 0 ], \lambda = -0.0001 .. 0.0001, color = black, thickness = 1, linestyle = 4) :$   
 >  $AXnodes1 := spacecurve([ subs(\psi = \psi_{nodes}, xEL), subs(\psi = \psi_{nodes}, yEL - \lambda \cdot yEL), 0 ], \lambda = -0.00015 .. 0.00015, color = black, thickness = 1, linestyle = 4) :$   
 >  $animGEO := animate(pointplot3d, [(43), (44), (45)], symbol = solidsphere, symbolsize = 20, color = yellow], \phi = 0 .. 2\pi, frames = 61, trace = 3) :$   
 >  $anNODE := pointplot3d\left( subs\left(\phi = \frac{\pi}{2}, [(43), (44), (45)]\right), symbol = solidsphere, symbolsize = 10, color = red\right) :$   
 >  $katNODE := pointplot3d\left( subs\left(\phi = -\frac{\pi}{2}, [(43), (44), (45)]\right), symbol = solidsphere, symbolsize = 10, color = green\right) :$

### **ΑΞΟΝΑΣ παράλληλος στον x-x της ΕΚΛΕΙΠΤΙΚΗΣ που περνάει από το κέντρο της ΓΗΣ .**

>  $AXONASx := spacecurve([ subs(\psi = \psi_{nodes}, xEL - \lambda \cdot 1), subs(\psi = \psi_{nodes}, yEL), 0 ], \lambda = -14000 .. 14000, color = black, thickness = 1, linestyle = 4) :$

### **ΑΞΟΝΑΣ παράλληλος στον z-z της ΕΚΛΕΙΠΤΙΚΗΣ που περνάει από το κέντρο της ΓΗΣ .**

>  $AXONASz := spacecurve([ subs(\psi = \psi_{nodes}, xEL), subs(\psi = \psi_{nodes}, yEL), \lambda \cdot 1 ], \lambda = -10000 .. 10000, color = black, thickness = 1, linestyle = 4) :$   
 >  $display(anSF, axonS, ISHMERINOS, MESHMBRINOS, animMESHMBRINOS, BEROIA, Btext, ePEKLEIPTIKHS, TOMH, TEXTaxon, GEO, animGEO, lineOGEO, CANCER, CAPRICORNE, AXnodes1, AXONASx, AXONASz, anNODE, katNODE, lineBERDOR, orientation = [-55, 75, 0], axes = none, title = "ΚΥΚΛΙΚΗ ΓΕΩΣΤΑΤΙΚΗ ΤΡΟΧΙΑ (GEO)\nΗ ΓΗ ΣΤΟΝ ΑΞΟΝΑ ΤΩΝ ΚΟΜΒΩΝ-\nΣΑΒΒΑΣ Π. ΓΑΒΡΙΗΛΙΔΗΣ", titlefont = [arial, bold, 12], scaling = constrained) :$

>

ΚΥΚΛΙΚΗ ΓΕΩΣΤΑΤΙΚΗ ΤΡΟΧΙΑ (GEO)  
Η ΓΗ ΣΤΟΝ ΑΞΟΝΑ ΤΩΝ ΚΟΜΒΩΝ-  
ΣΑΒΒΑΣ Π. ΓΑΒΡΙΗΛΙΔΗΣ

Πλήρης κάλυψη με τρεις (3) Δορυφόρους διατεταγμένους στην GEO ανά  $120^{\circ}$

