EPICYCLE PARAMETER FILTER FOR LONG TERM ORBITAL PARAMETER ESTIMATION

P L Palmer & S A A Gilani

Presenter:

Andrew Auman

Surrey Space Centre, University of Surrey

United Kingdom

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SEQUENCE OF PRESENTATION

- PROBLEM DESCRIPTION
- EPICYCLIC ORBIT
- SOLUTION METHODOLOGY
- RESULTS
- SUMMARY

PROBLEM DESCRIPTION

SURREY SPACE CENTRE

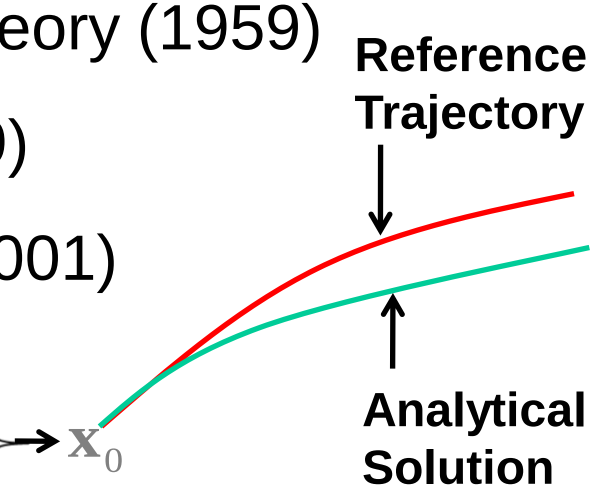
TWO BODY EQUATION OF MOTION

$$\ddot{\vec{r}} = -\frac{\mu}{r^2}\frac{\vec{r}}{r} + a_G$$

Acceleration due to Gravitational Harmonics

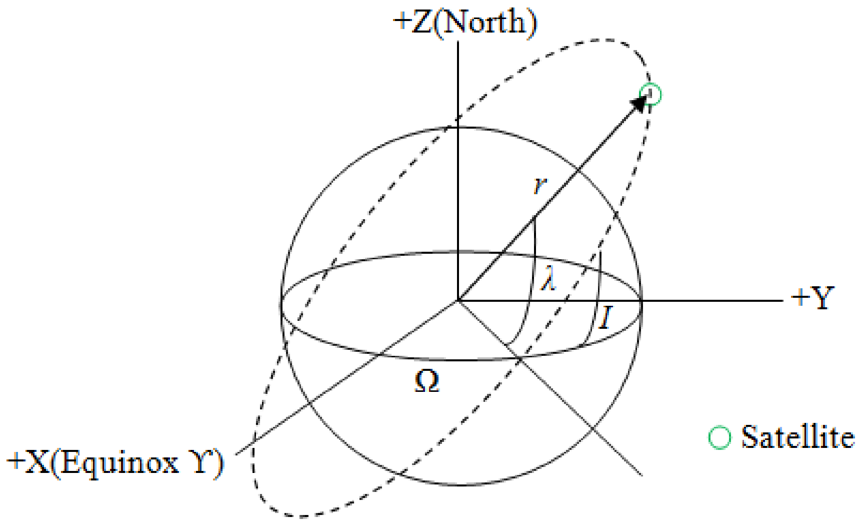
ANALYTICAL SOLUTION

- Brouwer Theory (1959)
- Kozai (1959)
- Epicyclic (2001)



Initial Condition
Or
Orbital Parameters

EPICYCLIC ORBIT AROUND OBLATE EARTH



$$\frac{r}{a} = 1 + \rho - (\xi_P \cos\alpha + \eta_P \sin\alpha) + \Delta r_2 \cos 2\beta$$

$$I = I_0 + \Delta I_2 (1 - \cos 2\beta)$$

$$\Omega = \Omega_0 + \vartheta\alpha + \Delta\Omega_2 \sin 2\beta$$

$$\lambda = \beta + 2[\xi_P \sin\alpha + \eta_P (1 - \cos\alpha)] + \Delta\lambda_2 \sin 2\beta$$

Secular

Short Periodic

Epicycle Coordinates

$$(r, \lambda, I, \Omega, v_r, v_\theta)$$

Epicycle Parameters

$$\mathbf{x}_0 = (a, \xi_P, \eta_P, I_0, \Omega_0, t_E)$$

a, *Semimajor axis*

I_0, *Inclination*

Ω_0, *Right ascension of ascending node*

$$\xi_P = \frac{A}{a}\cos\alpha_P \,,\; \eta_P = \frac{A}{a}\sin\alpha_P$$

α_P, *Epicycle phase at Perigee*

t_E, *Equator crossing time*

$$\kappa_2 = \frac{3}{4} J_2 \left(\frac{R}{a}\right)^2 (5\cos^2 I_0 - 1)$$

$$\vartheta_2 = -\frac{3}{2} J_2 \left(\frac{R}{a}\right)^2 \cos I_0$$

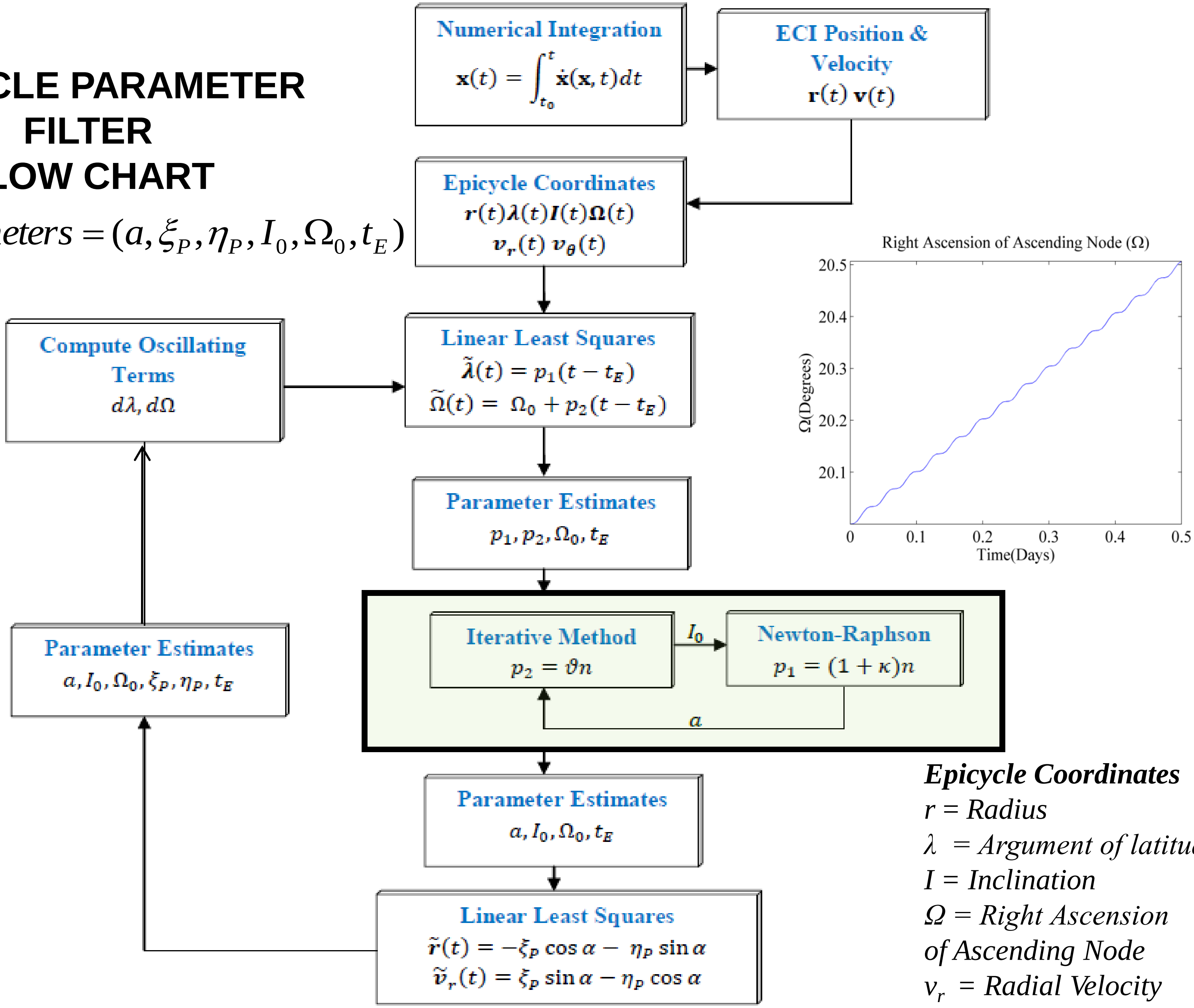
$$\beta = (1+\kappa)\alpha$$

$$\alpha = n(t - t_E)$$

n, *mean-motion*

EPICYCLE PARAMETER FILTER FLOW CHART

$$Epicycle\ \ Parameters = (a, \xi_P, \eta_P, I_0, \Omega_0, t_E)$$



Epicycle Coordinates

r = Radius

λ = Argument of latitude

I = Inclination

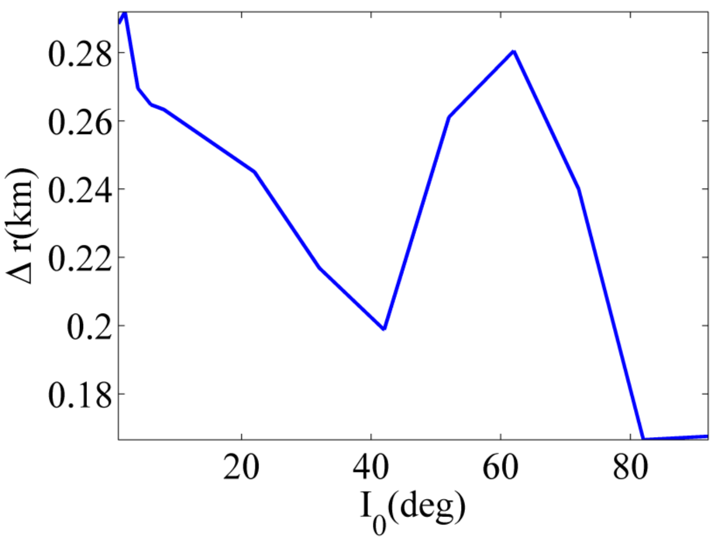
Ω = Right Ascension of Ascending Node

v_r *= Radial Velocity*

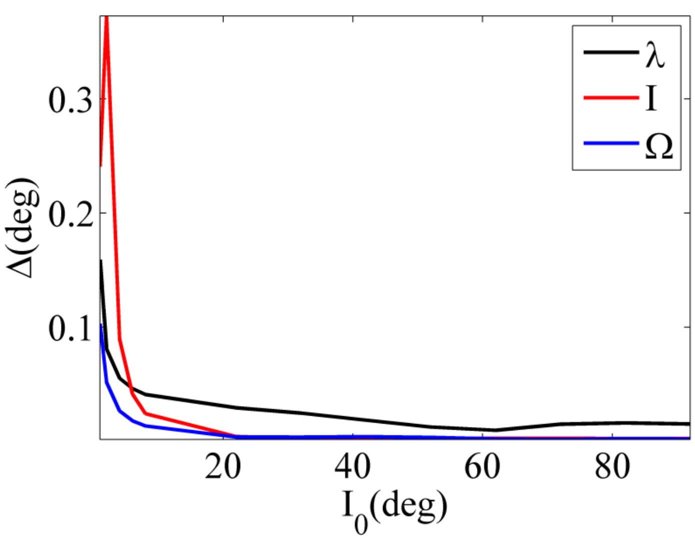
v_θ *= Azimuthal Velocity*

RESULTS – ERRORS IN EPICYCLE COORDINATES OVER ONE WEEK

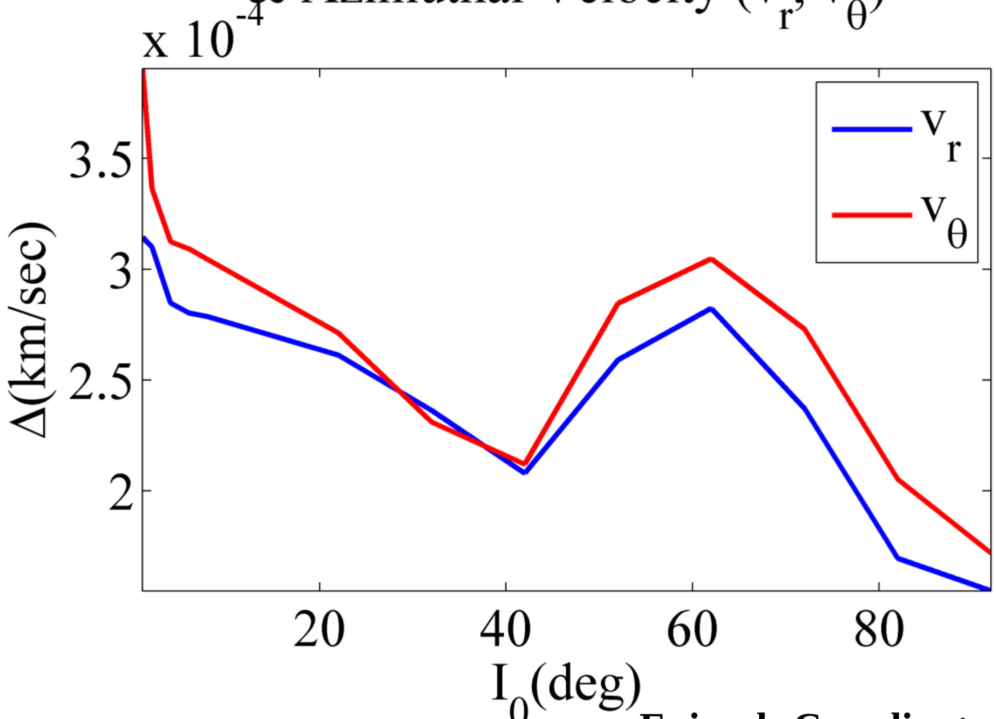
Maximum Radial Errors



Maximum Errors in λ, I, Ω



Maximum Errors in Radial & Azimuthal Velocity (v_r, v_θ)



Epicycle Coordinates

r = Radius

λ = Argument of latitude

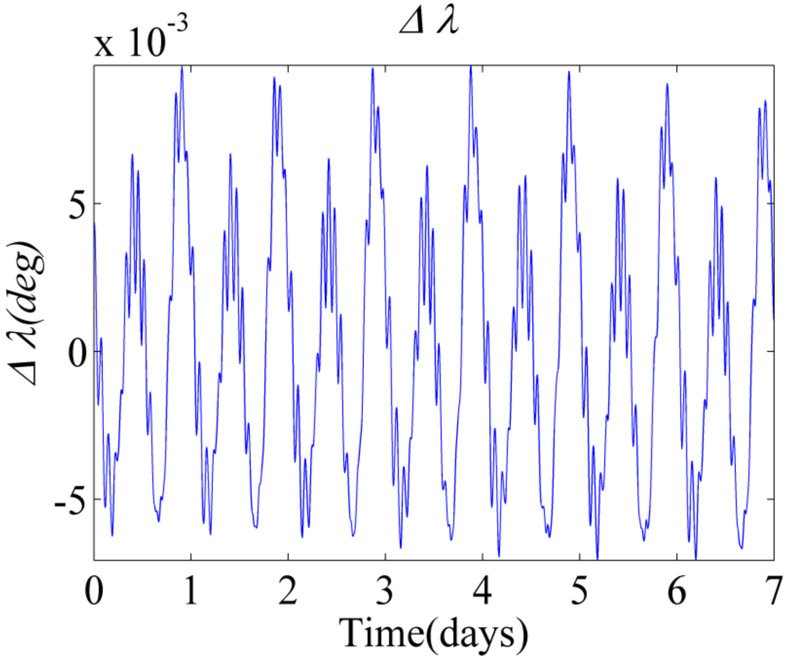
I = Inclination

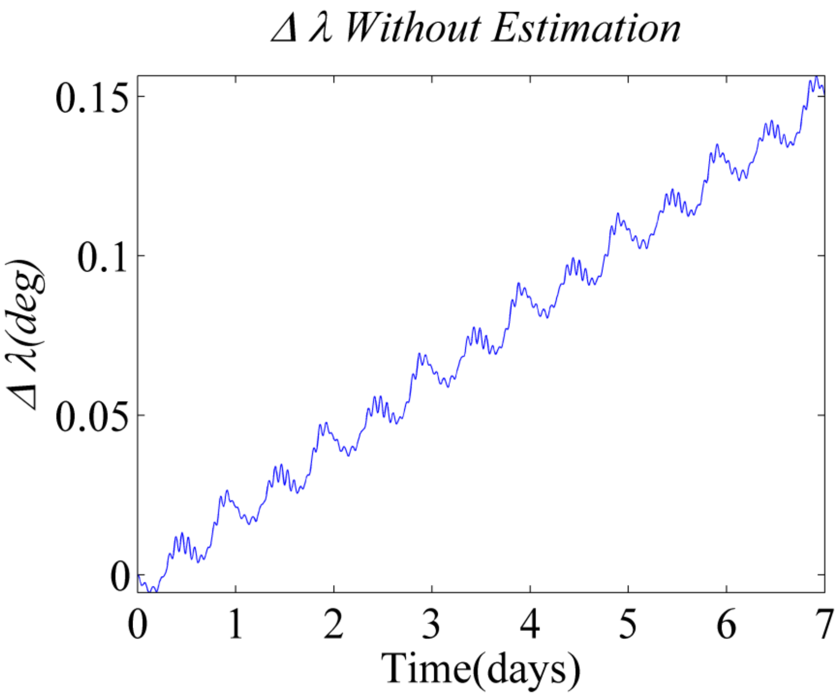
Ω = Right Ascension of Ascending Node

v_r = Radial Velocity

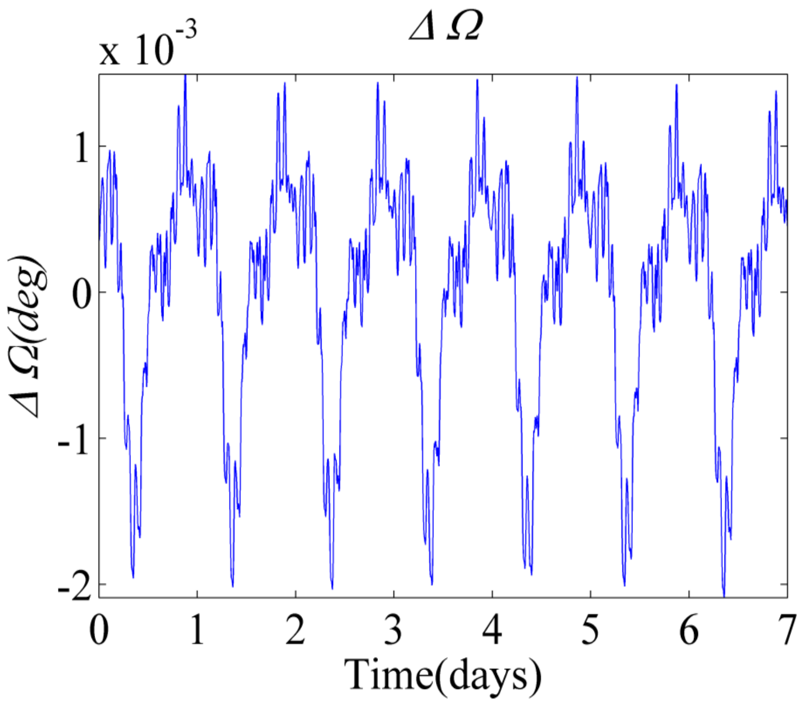
v_θ = Azimuthal Velocity

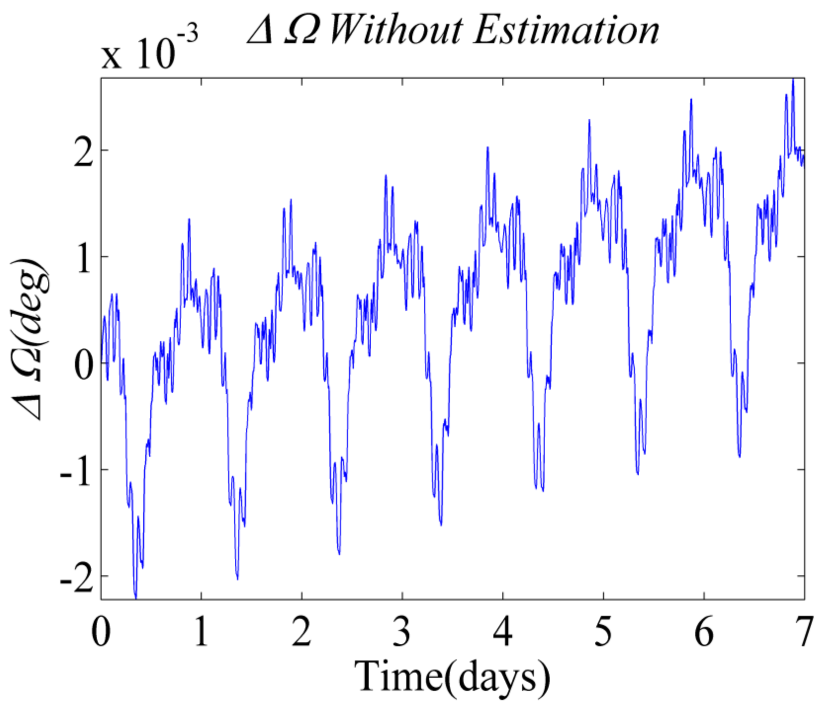
RESULTS – SUN SYNCHRONOUS LEO TIME HISTORY OF ERRORS EPICYCLE COORDINATES





RESULTS – SUN SYNCHRONOUS LEO TIME HISTORY OF ERRORS EPICYCLE COORDINATES





SUMMARY

- Developed Epicycle Parameter Filter (EPF) for high precision Epicyclic orbit propagation
- Includes J_4 – can be extended to higher order
- Avoids calculation of Jacobian or Hessian matrices used in differential correction methods
- No filter initialization parameters or initial conditions required
- Reduction in errors:

Epicycle Coordinate	% Reduction in Maximum Errors
r = *radius*	26
λ = *argument of latitude*	93
I = *inclination*	45
Ω = *right ascension of ascending node*	20
v_r = *radial velocity*	16
v_θ = *azimuthal velocity*	15

Questions?