

SPARC4

Simultaneous Polarimeter and Rapid Camera in Four Bands

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Equipe Técnica

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Principais idéias

- ✓ **Modernizar a instrumentação do OPD para torná-la mais eficiente**
 - **Obter dados em mais de uma banda simultaneamente**
 - **Tempo entre integrações o tão curto quanto possível**
 - **Permitir polarimetria**
- ✓ **Ser atraente para público amplo**
- ✓ **Buscar outros telescópios para instalação**

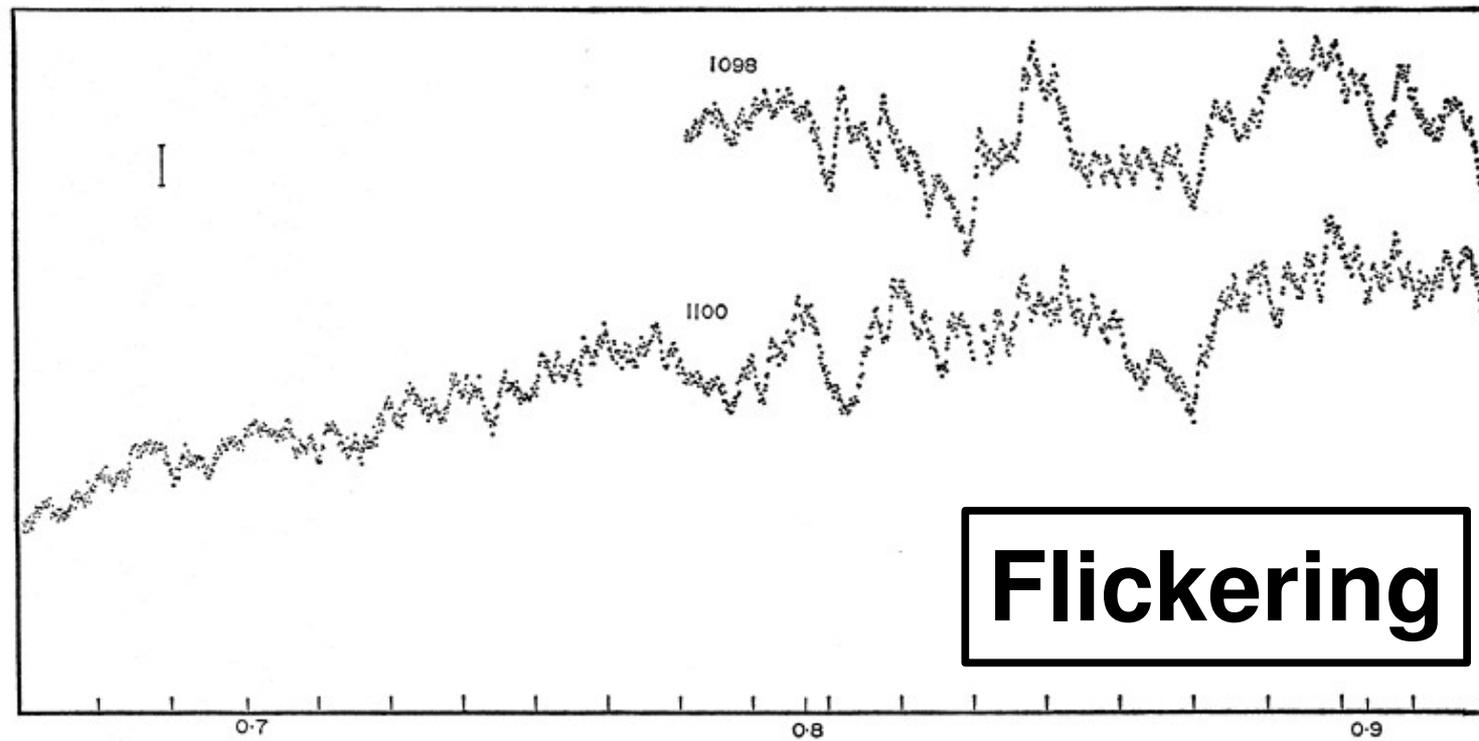
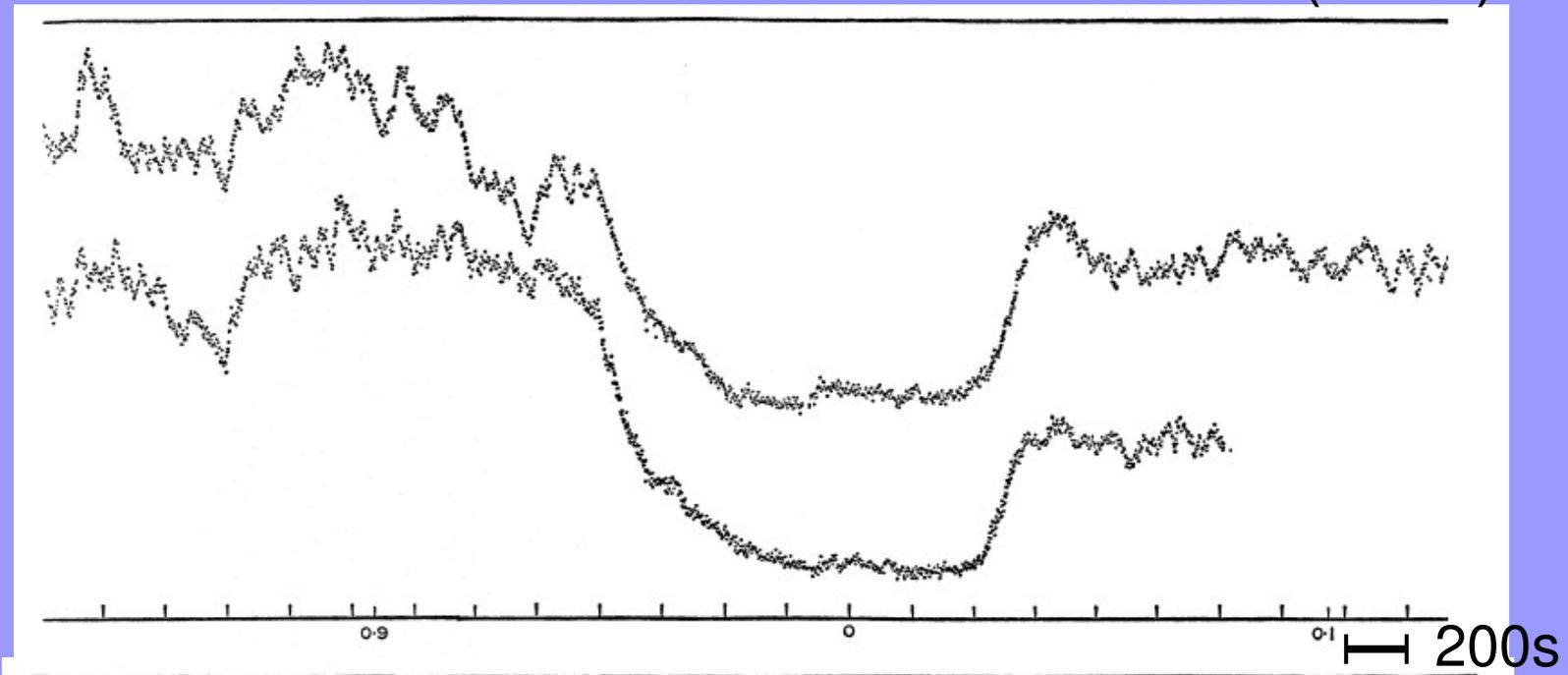
Ciência...

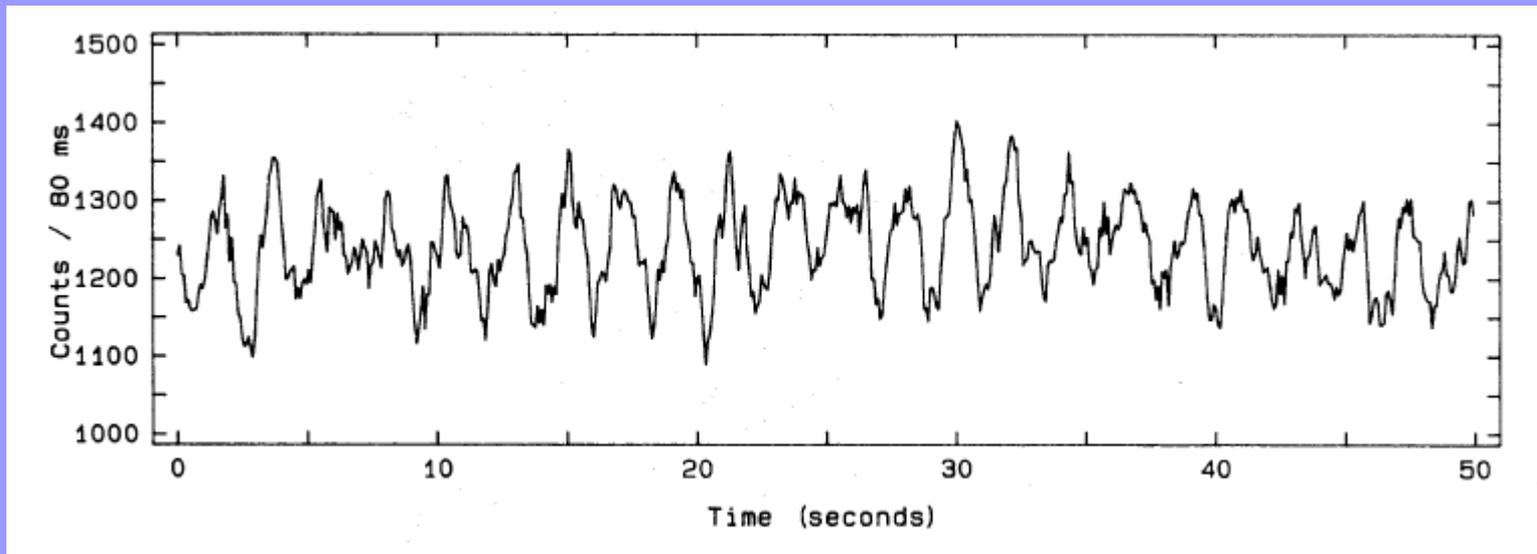
Binárias interativas

- ✓ **Binárias com transferência de matéria**
 - **variáveis cataclísmicas**
 - **binárias de raios X**
 - **simbióticas**
- ✓ **Variabilidade tão rápida quanto segundos**
- ✓ **Emissão polarizada: variável em tempo e frequência**

U Gem

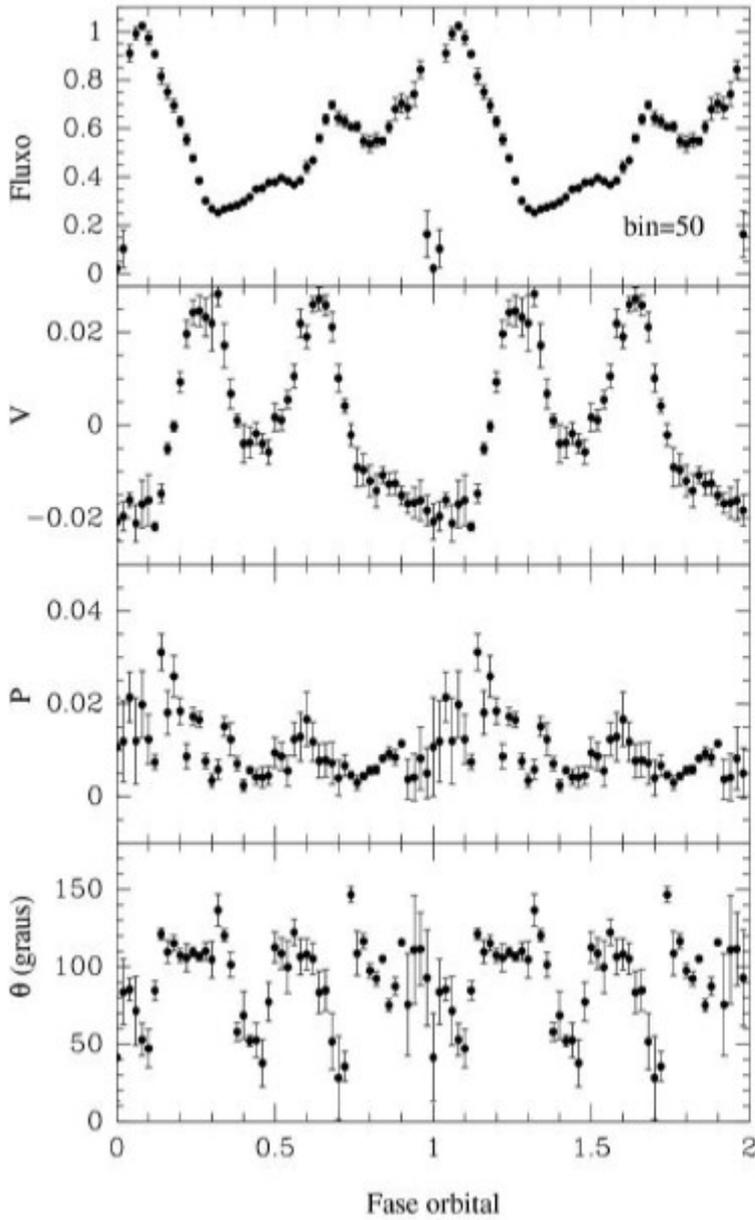
Warner & Nather (1971)



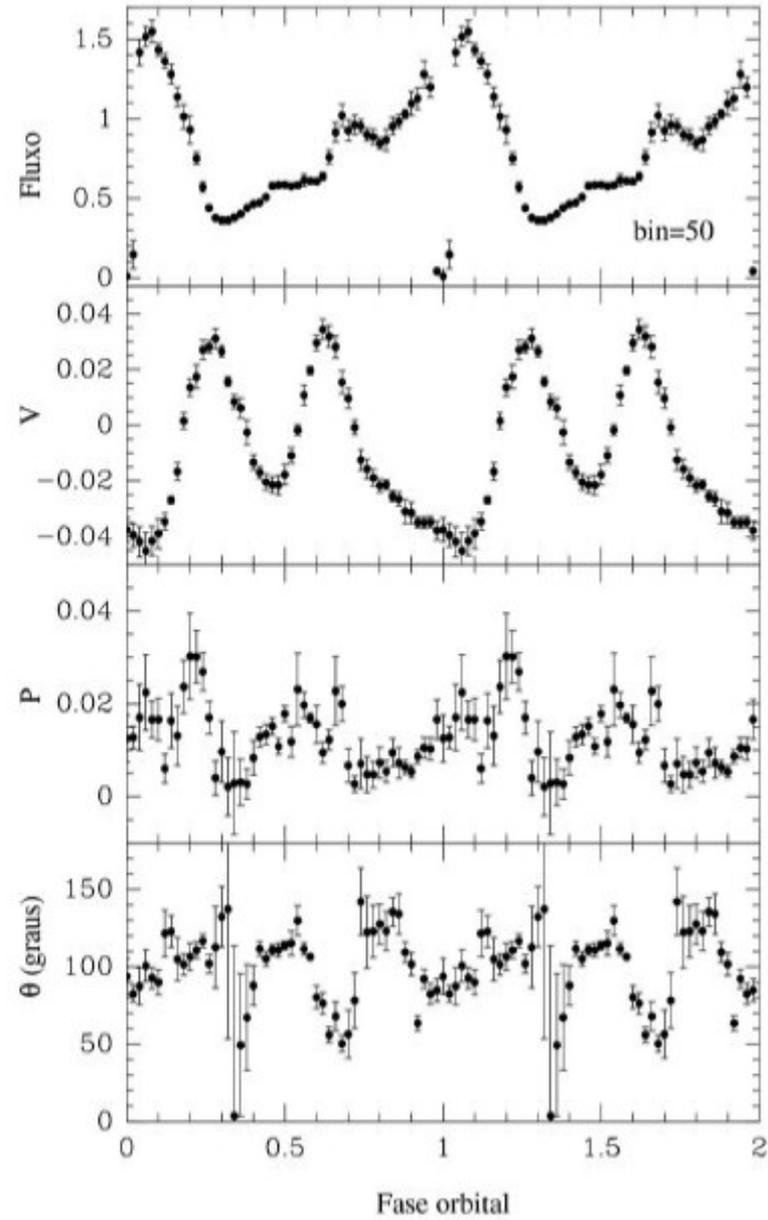


V834 Cen

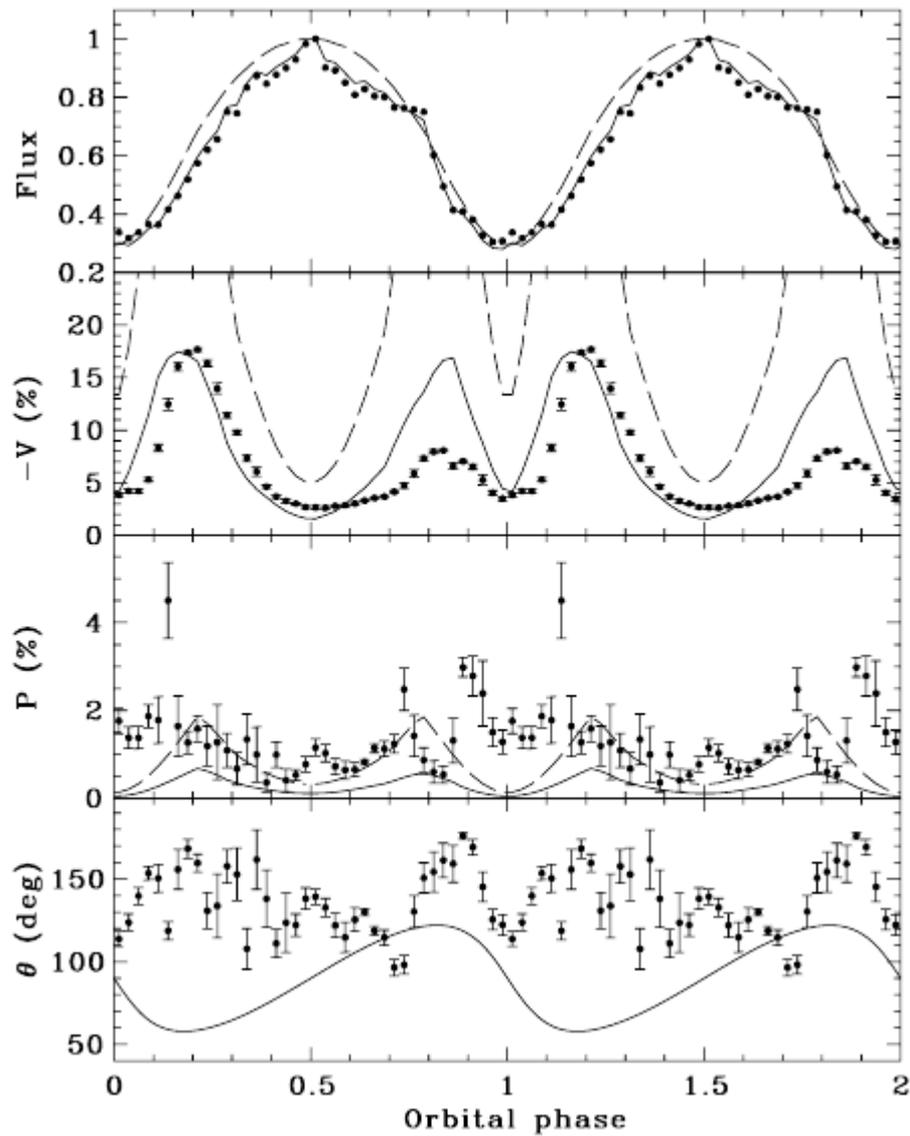
Larsson (1992)



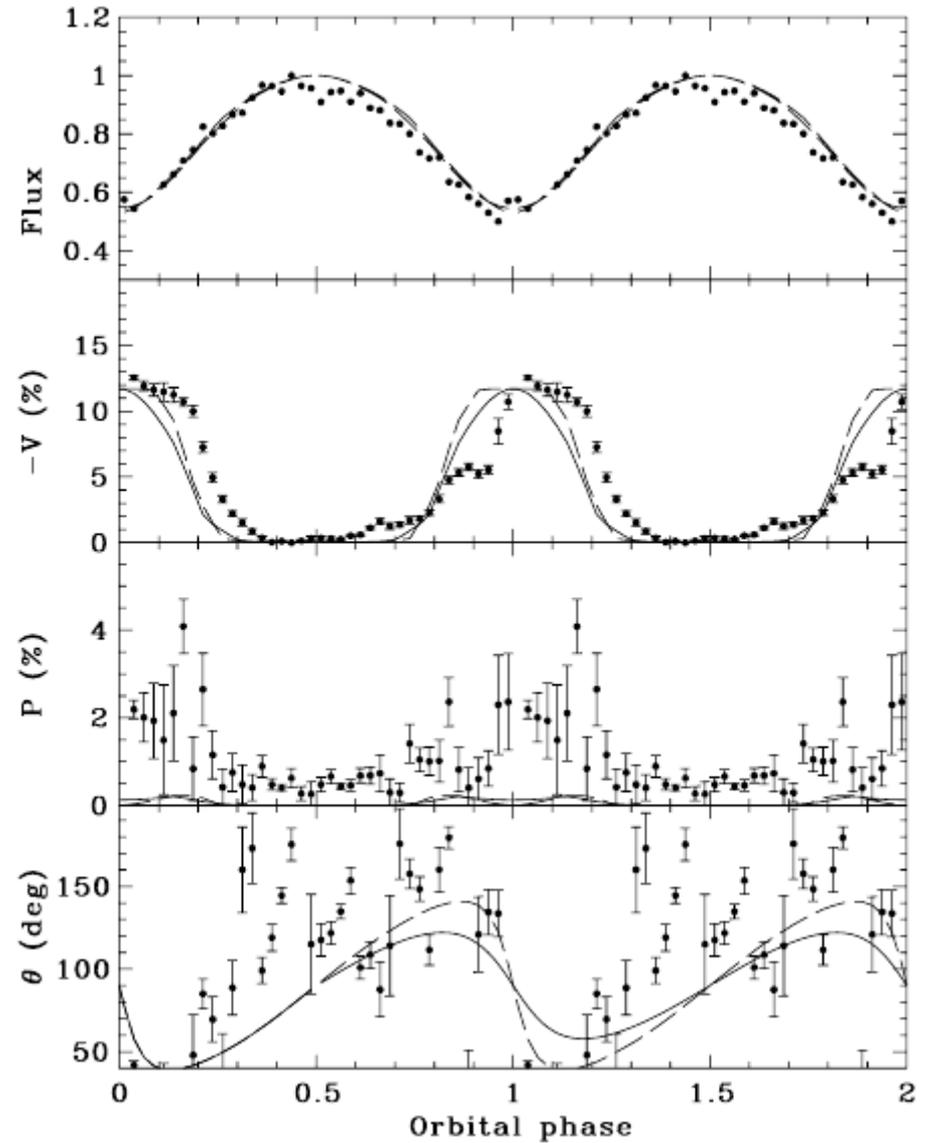
R Band



I Band

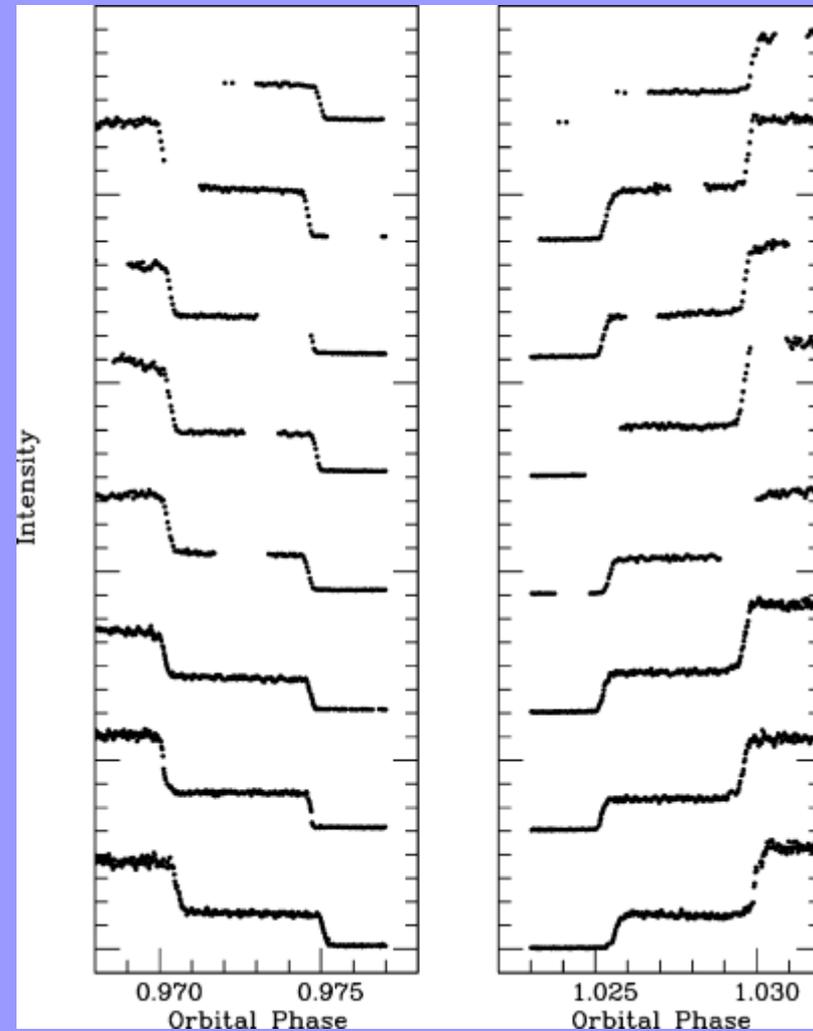
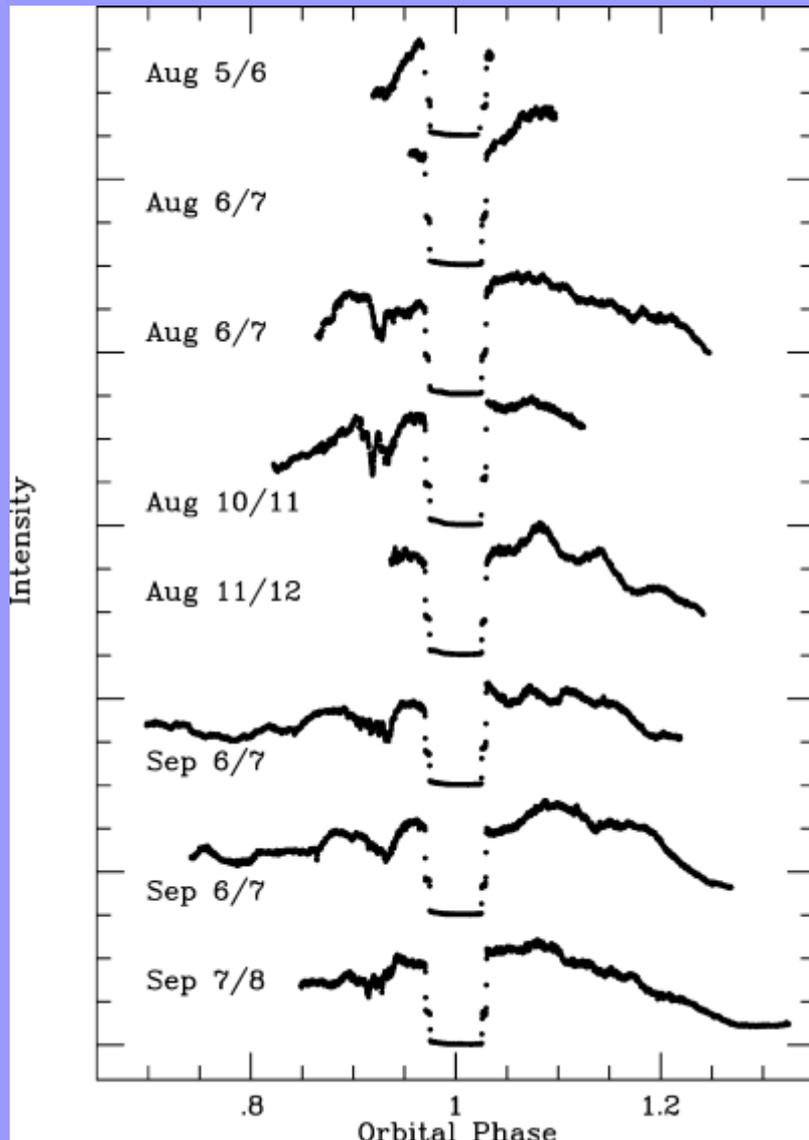


R Band



I Band

Sistemas eclipsantes

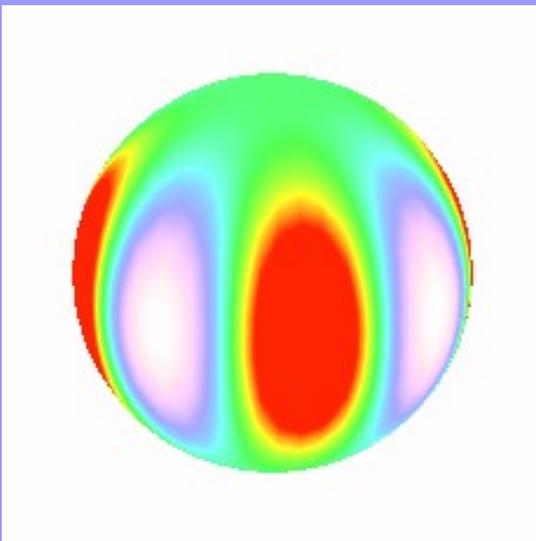


O'Donoghue et al. 2006 - FL Cet

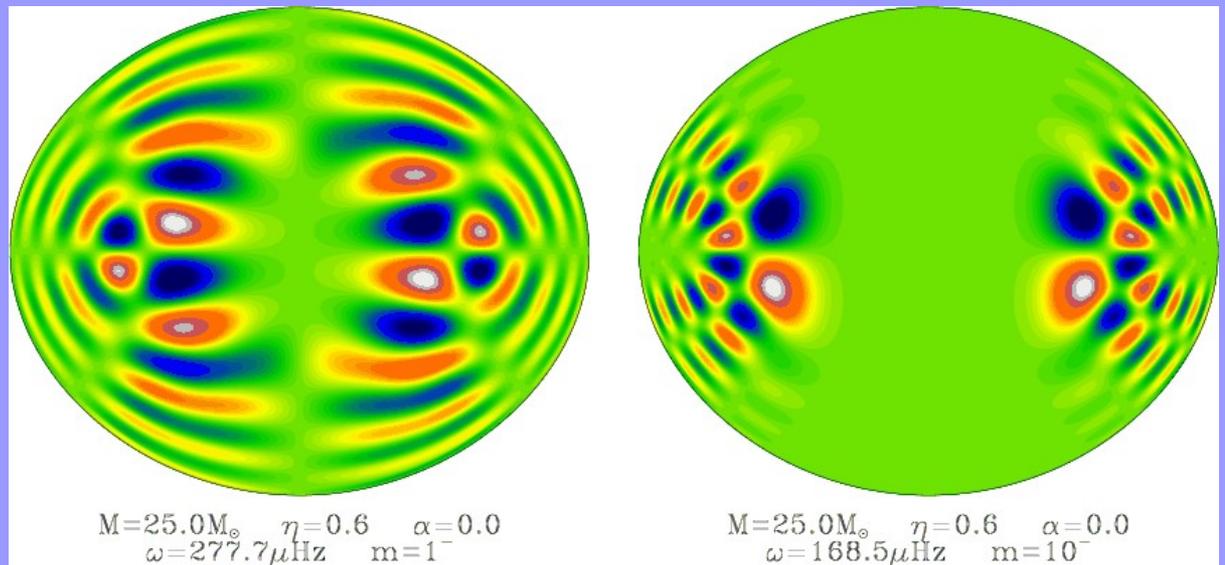
0.001 de fase = 5.2 s

Estrelas pulsantes

- ✓ Determinação da estrutura interna a partir dos modos de pulsação detectados



David McDavid



Reese et al. (2009)

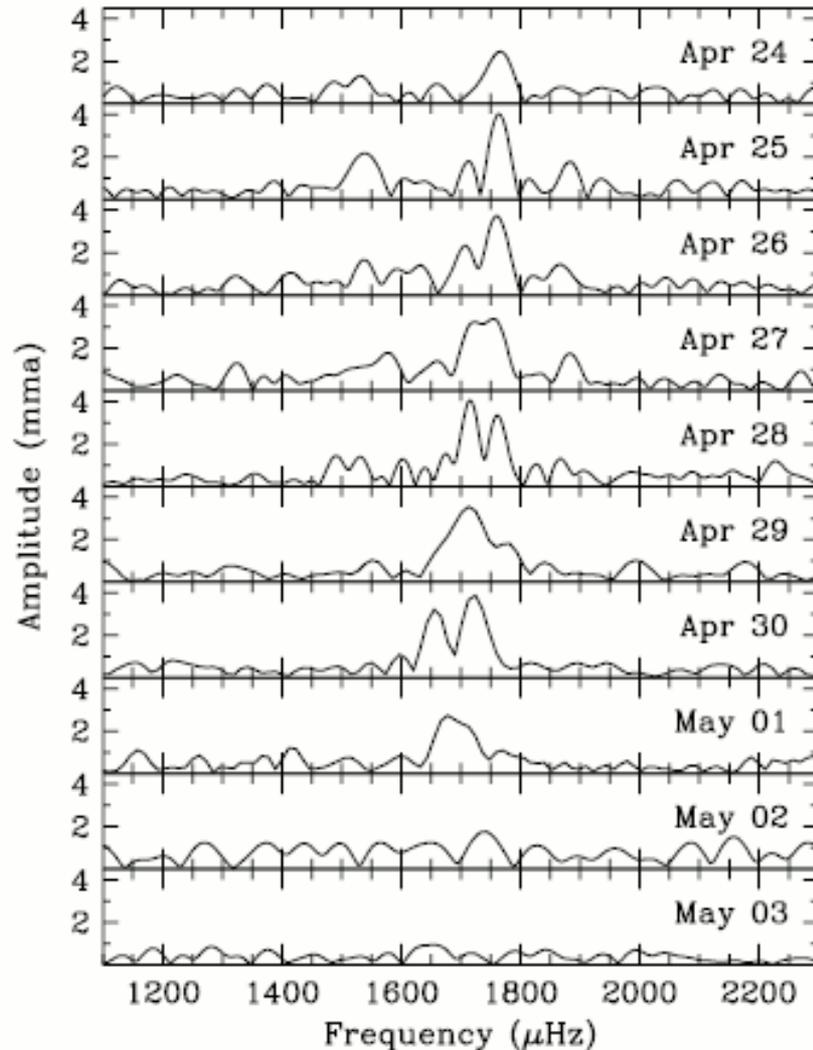


Fig. 1. Nightly FTs of BPM 37093 during ten nights of observations from CTIO in 1996. The amplitudes are highly variable on short timescales. All of the modes vanish below the detection threshold on the final night.

Table 3. Frequencies detected from two WET campaigns.

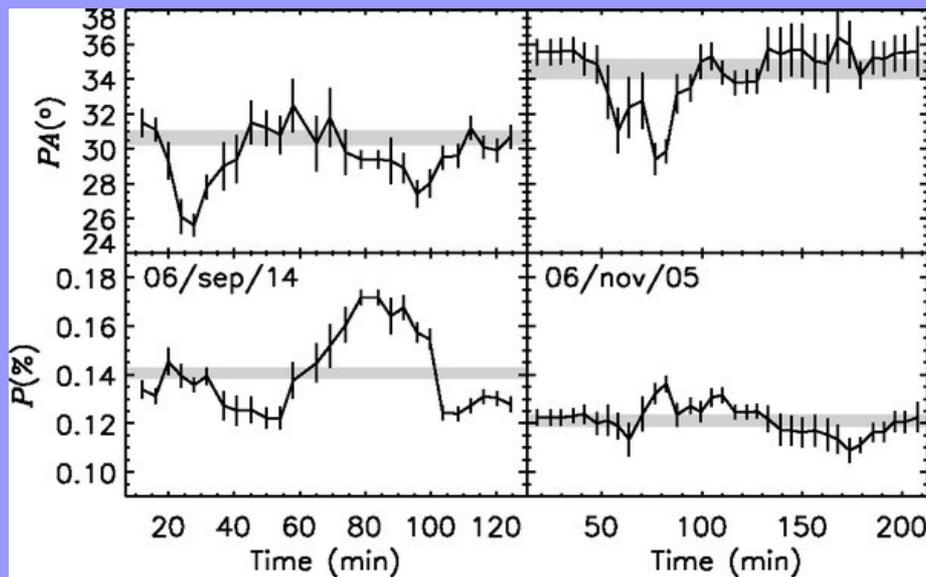
XCOV	Frequency (μHz)	Period (s)	$\langle \text{Amplitude} \rangle$ (mma)	Identification		
				k	ℓ	m
17	1513.2	660.8	0.475			
[17	1569.5	637.2	0.650			
	16	1570.6	636.7	1.741	34	2
[17	1578.5	633.5	1.310	34	2	+1
	16	1579.2	633.2	1.081		
16	1629.9	613.5	1.131	18	1	0
16	1664.9	600.7	0.875	32	2	0
16	1718.2	582.0	1.032	31	2	0
[17	1767.1	565.9	0.458			
	16	1768.5	565.5	1.174	30	2
16	1777.6	562.6	0.879	30	2	+1
[17	1820.8	549.2	0.801			
	16	1823.5	548.4	1.149	29	2
17	1882.9	531.1	1.156	28	2	0
17	1954.1	511.7	0.679	27	2	0

of the modes, since an $\ell = 1$ identification would yield a much larger period spacing ($\langle \Delta P \rangle \sim 30$ s, Montgomery & Winget 1999).

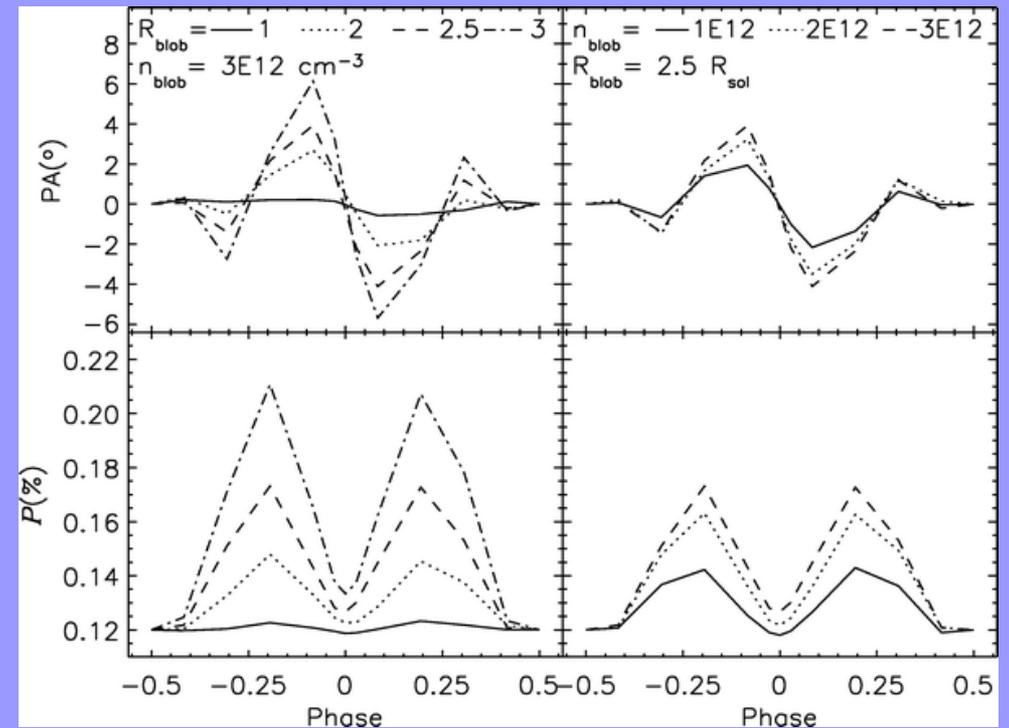
Montgomery & Winget (1999) performed a detailed study of the various model parameters that could affect the average period spacing for $\ell = 2$ modes. They defined a scaling relation for $\langle \Delta P \rangle$ which had contributions from variations to four parameters, including the stellar mass and effective temperature (M_* , T_{eff}) and the hydrogen layer mass and crystallized mass fraction (M_{H} , M_{cr}). Fortunately, M_* and T_{eff} can both be constrained by spectral profile fitting. The most recent estimates for BPM 37093 come from Bergeron et al. (2004), who found $M_* = 1.10 M_{\odot}$ and $T_{\text{eff}} = 11\,730$ K. The values of the other

Envelopes não-homogêneos

✓ Estrelas Be



Observações



Modelos

Carciofi et al. (2007)

Envelopes circumstelares

✓ Composição dos grãos

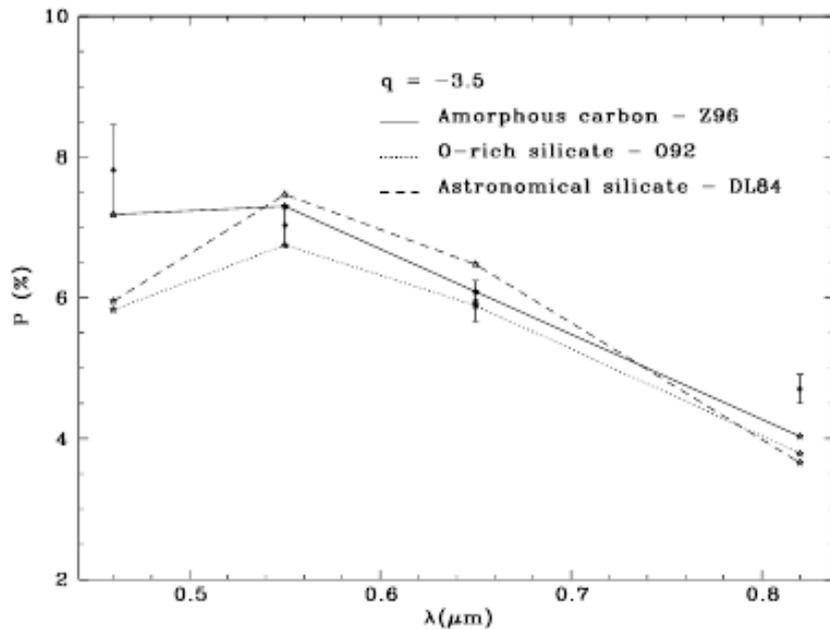


FIG. 3.—Models to the intrinsic polarization of Hen 3-1475 using different grain composition.

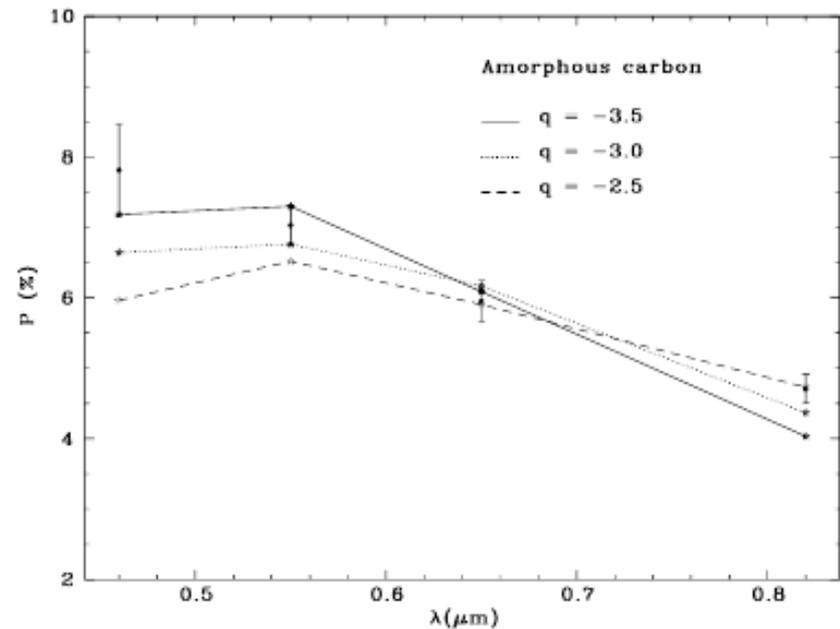
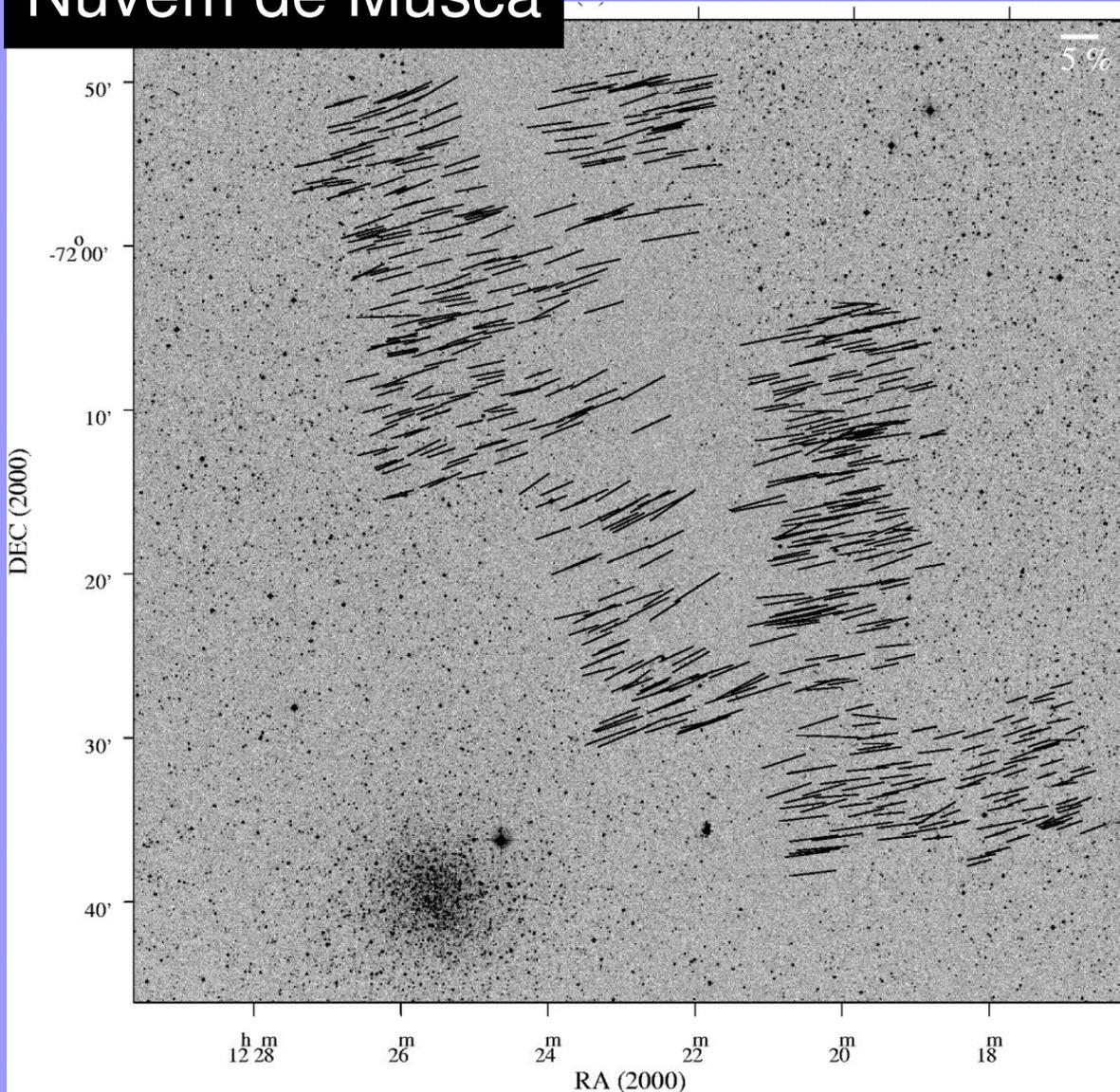


FIG. 4.—Same as Fig. 3, but varying the index of the power-law size distribution.

Rodrigues et al. (2003)

Formação estelar

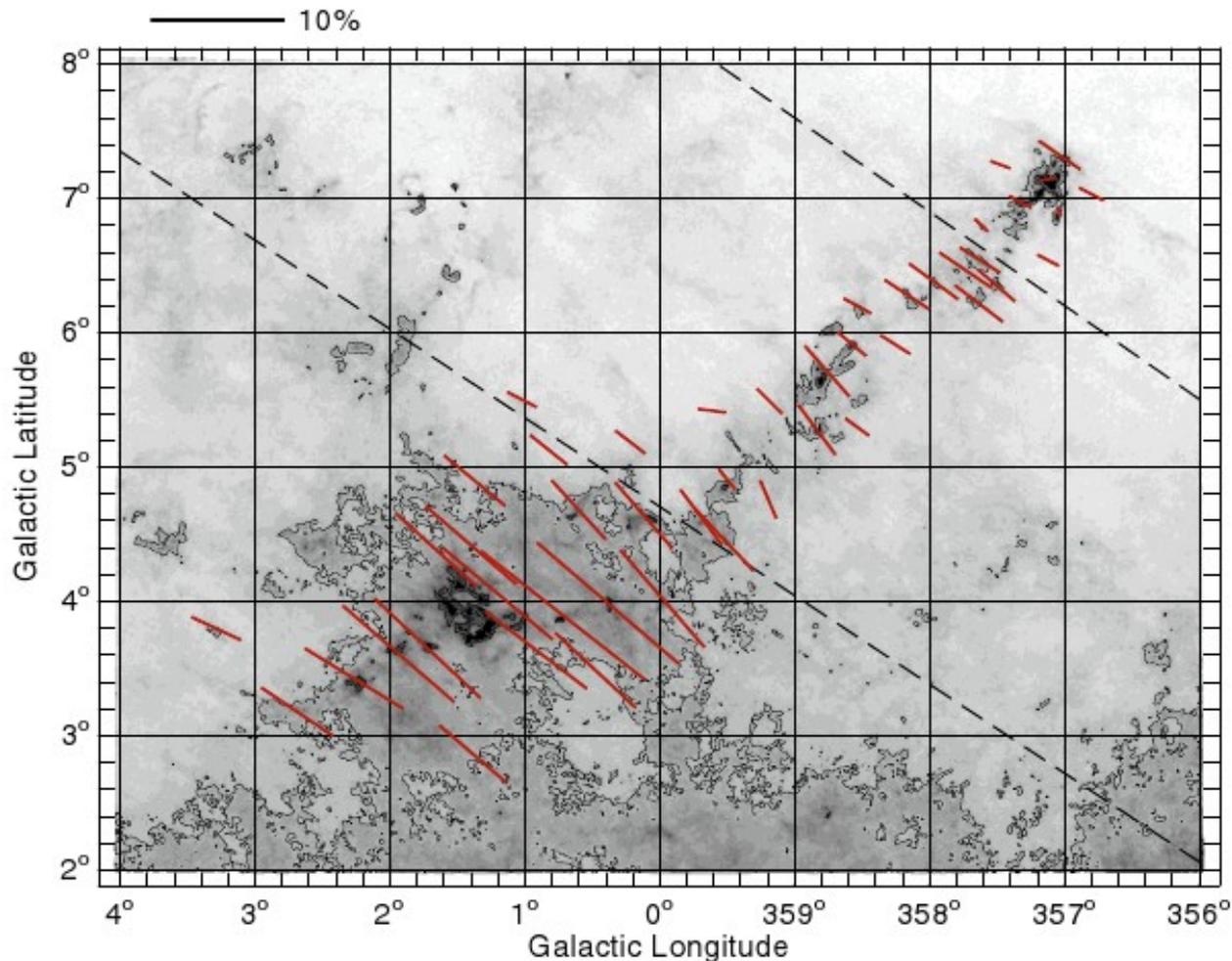
Nuvem de Musca



✓ Direção e dispersão do campo magnético

Pereyra & Magalhães 2007

✓ Direção e dispersão do campo magnético



Alves et al. 2008

Fig. 1. Mean polarization vectors, for each of the observed 46 fields, overplotted on the dust extinction map of the Pipe nebula obtained by Lombardi et al. (2006). The lengths of these vectors are proportional to the scale indicated in the top left-hand corner. Only stars showing $P/\sigma_P \geq 10$ were used in the calculus of the mean polarization and position angle. The dashed-lines indicate the celestial meridians defined by $17^{\text{h}}14^{\text{m}}30^{\text{s}}.0$ and $17^{\text{h}}27^{\text{m}}40^{\text{s}}.0$ (see text and Fig. 2).

Formação estelar

F. O. Alves et al.: The Pipe nebula

L15

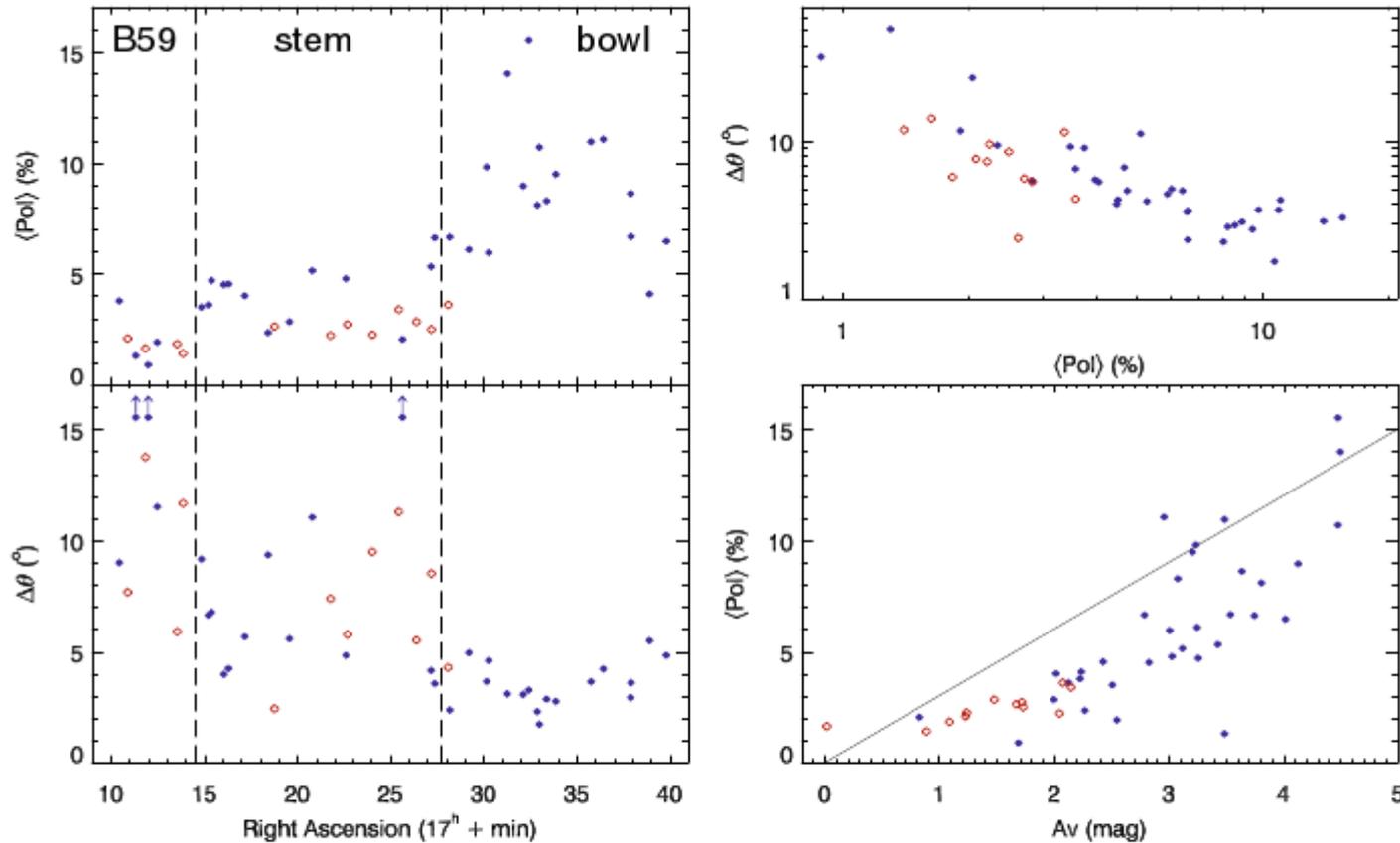


Fig. 2. *Left panels:* distribution of the mean polarization and of the polarization angle dispersion, $\Delta\theta$, as a function of the right ascension of the observed areas, respectively. The polarization angle dispersion is corrected by its mean error (i.e., $\Delta\theta^2 = \sigma_{\text{std}}^2 - \langle \sigma_{\theta} \rangle^2$). The vertical dashed-lines delimits the transition between regions with different polarimetric properties. Filled and open dots represent values for fields with and without associated dense cores, respectively. As shown by the *bottom right panel*, the regions traced by the optical polarimetry have extinction of $A_V \lesssim 2.2$ mag for fields without cores, while the ones associated with cores show $0.8 \lesssim A_V \lesssim 4.5$ mag. *Top right panel:* correlation between dispersion in polarization angle and mean polarization. *Bottom right panel:* mean polarization versus visual absorption derived from the 2MASS data for the observed stars with $P/\sigma_P \geq 10$. The solid line represents optimum alignment efficiency ($P(\%) = 3 \times A_V$).

Blazars

✓ Variable
non-thermal
emission

→ multiple
components

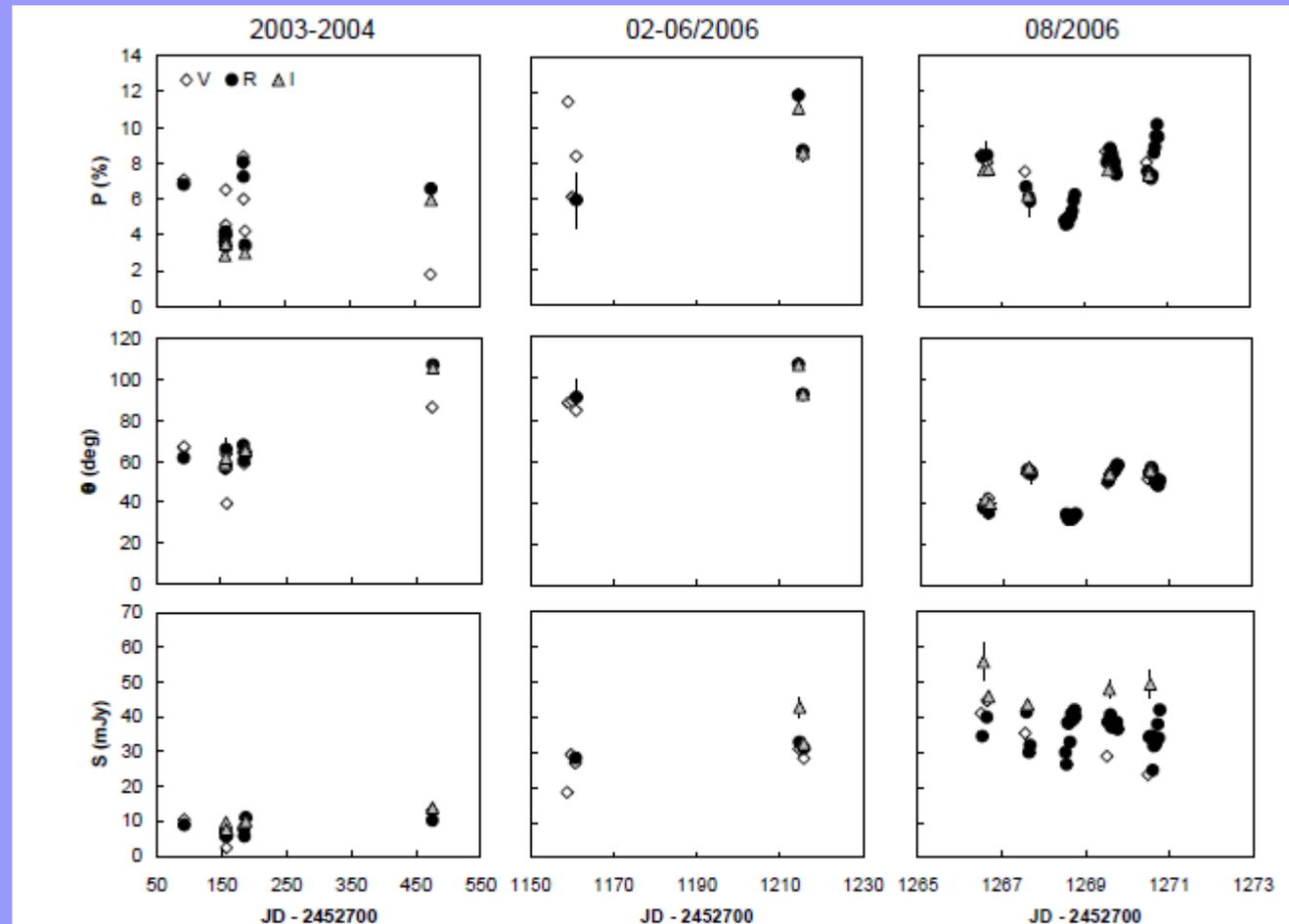
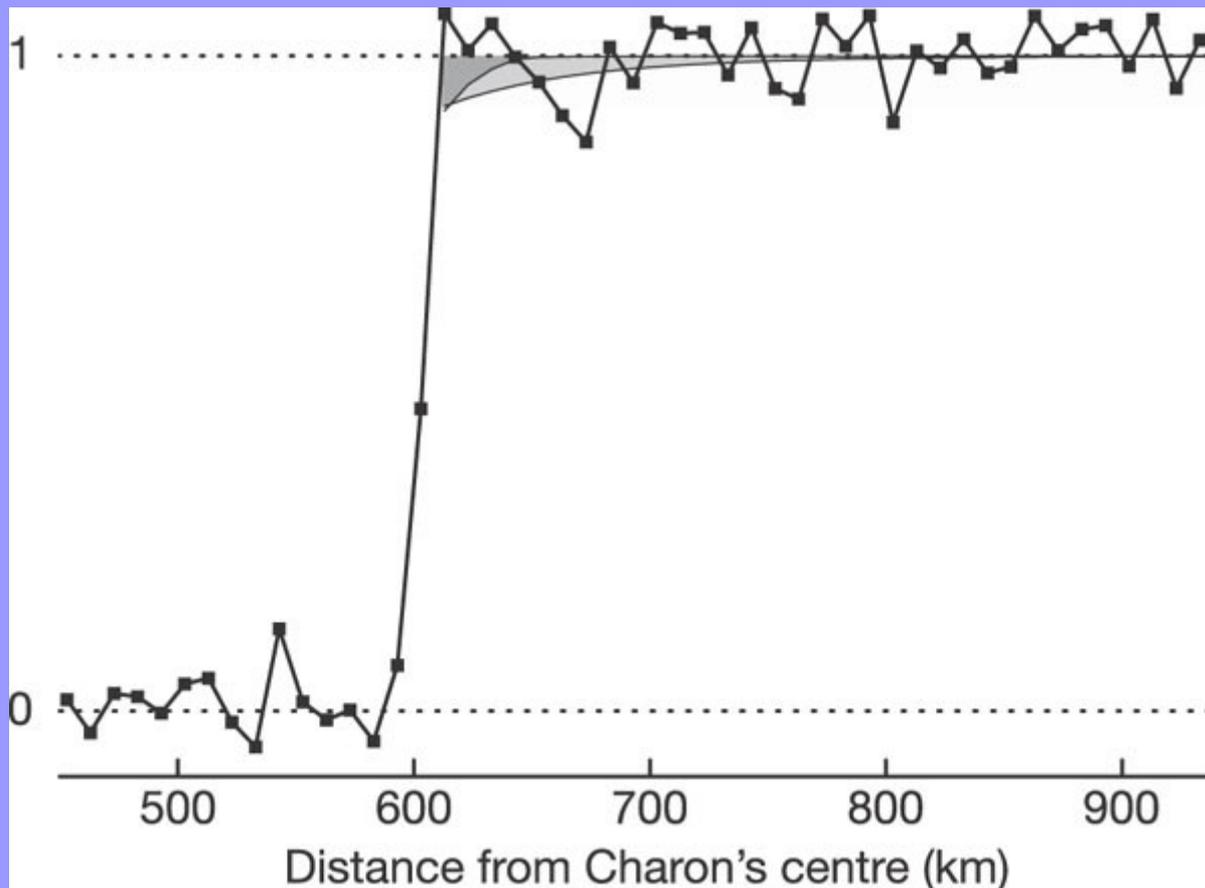


Figure 2: Variability in the polarization degree (P), position angle (θ) and total flux density (S) in PKS 2155-304, observed between 2003 and 2006.

Solar system studies

✓ Stellar occultation by Charon

→ Detect atmospheres



Sicardy et al. (2006)

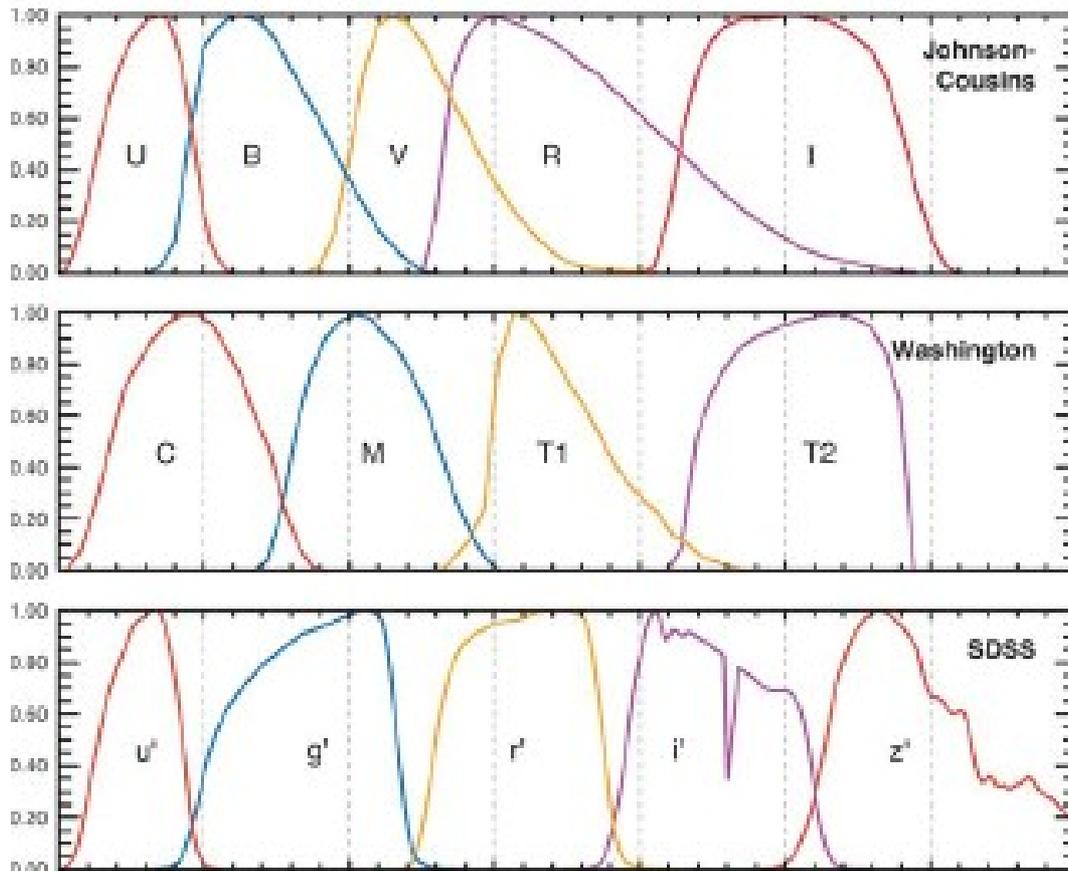
Requisitos

Intervalo espectral e bandas

✓ Cobrir a região óptica com bandas largas

→ 400 - 1000 nm

✓ Bandas SDSS: g' r' i' z'



superposição pequena



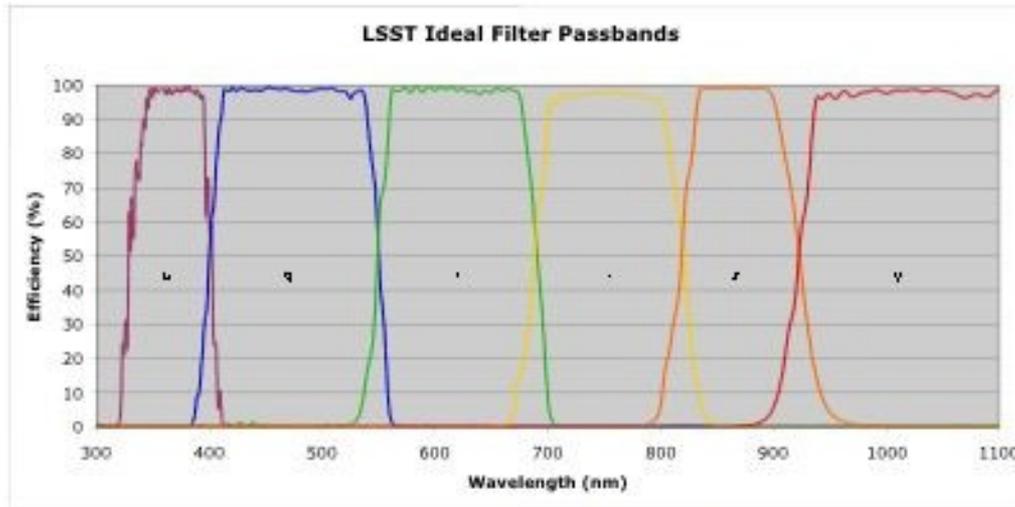
Bessel (2005)

Specs

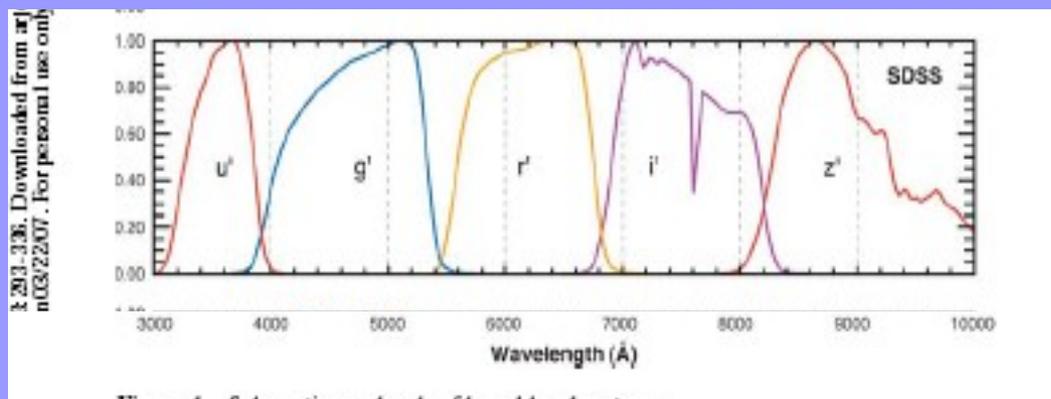
Half-Maximum Transmission Wavelength			
	Blue Side	Red Side	Comments
U	350	400	Blue side cut-off depends on AR coating
G	400	552	Balmer break at 400 nm
R	552	691	Matches SDSS
I	691	818	Red side short of sky emission at 826 nm
Z	818	922	Red side stop before H ₂ O bands
Y	948	1060	Red cut-off before detector cut-off

- 75 cm dia.
- Curved surface
- Filter is concentric about the chief ray so that all portions of the filter see the same angle of incidence range, 14.2° to 23.6°

LSST



Uniform deposition required at 1% level over entire filter

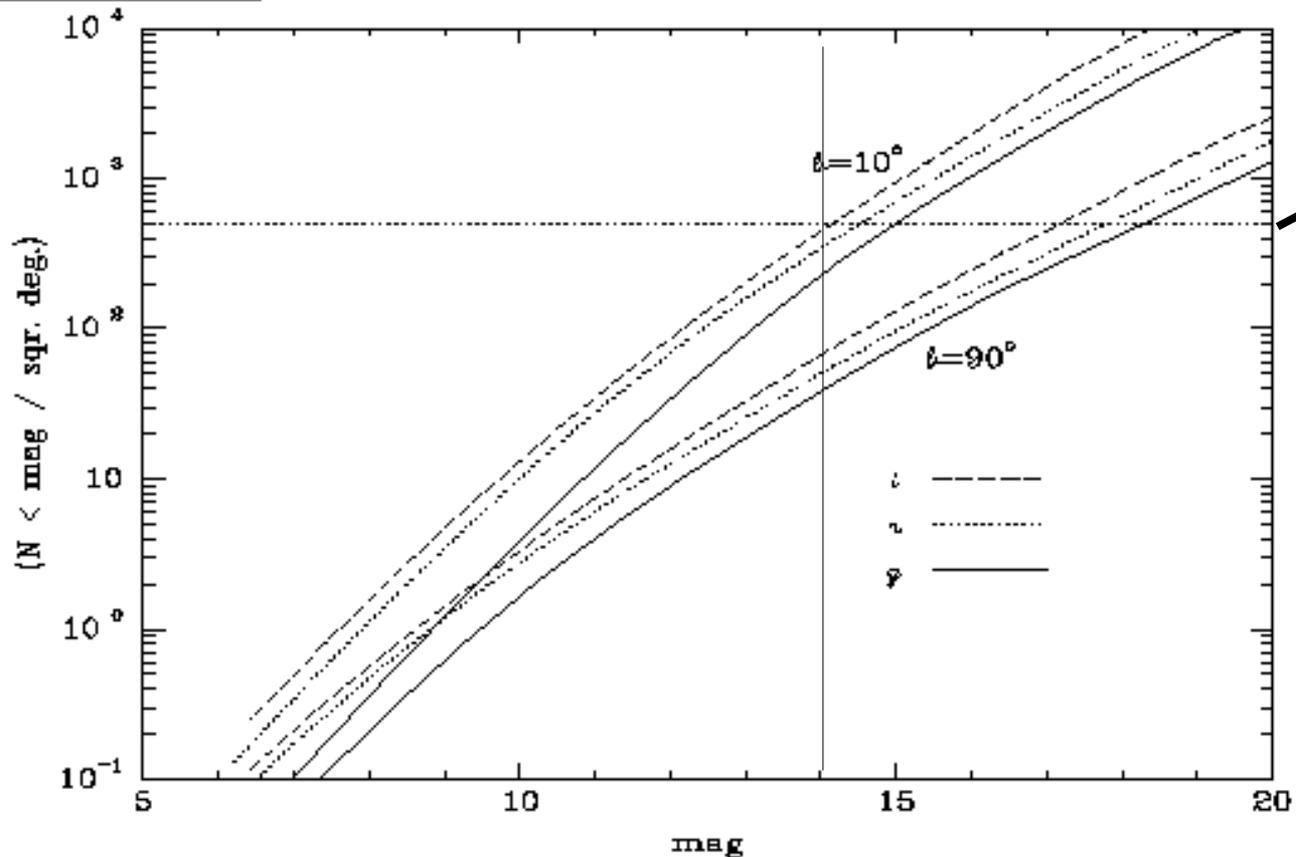


SDSS

Campo (FoV)

- ✓ **O campo deve ser grande o suficiente para que haja uma alta probabilidade de inclusão de estrelas brilhantes para serem usadas como comparação**

5.7' x 5.7'



95%
2 ☆

- 1024 x 1024 pixels - 13 μ m (Andor Ixon-888)
- camera f/5
- 1.6-m OPD

Resolução temporal

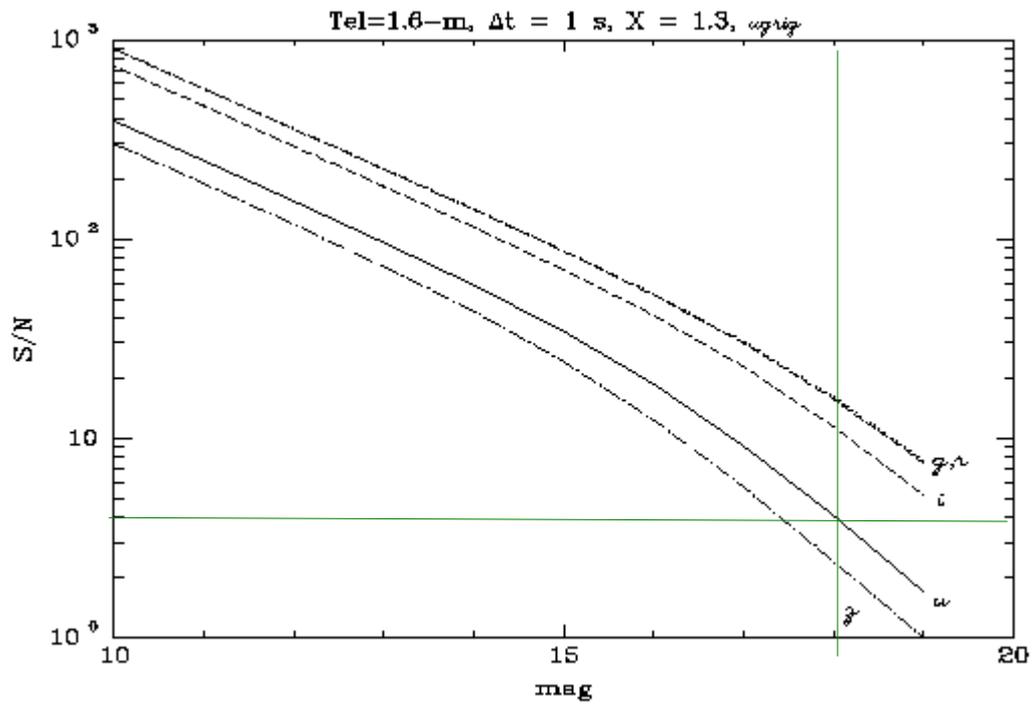
- ✓ Deve atingir 1s para que o instrumento seja competitivo em estudos de variabilidade
 - variáveis cataclísmicas
 - estrelas pulsantes
 - eventos rápidos no sistema solar

Razão sinal-ruído

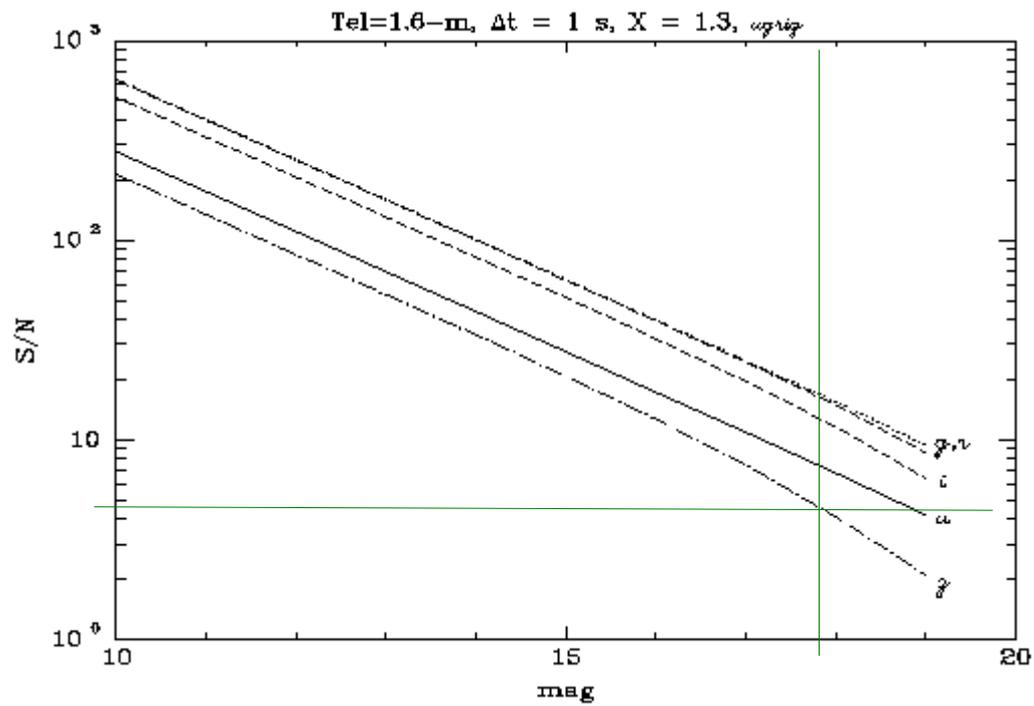
✓ Erro desejado

→ 0.02 mag para integração de 1s de um objeto 14 mag

CCD x EMCCD



CCD



EMCCD

Fotometria x polarimetia

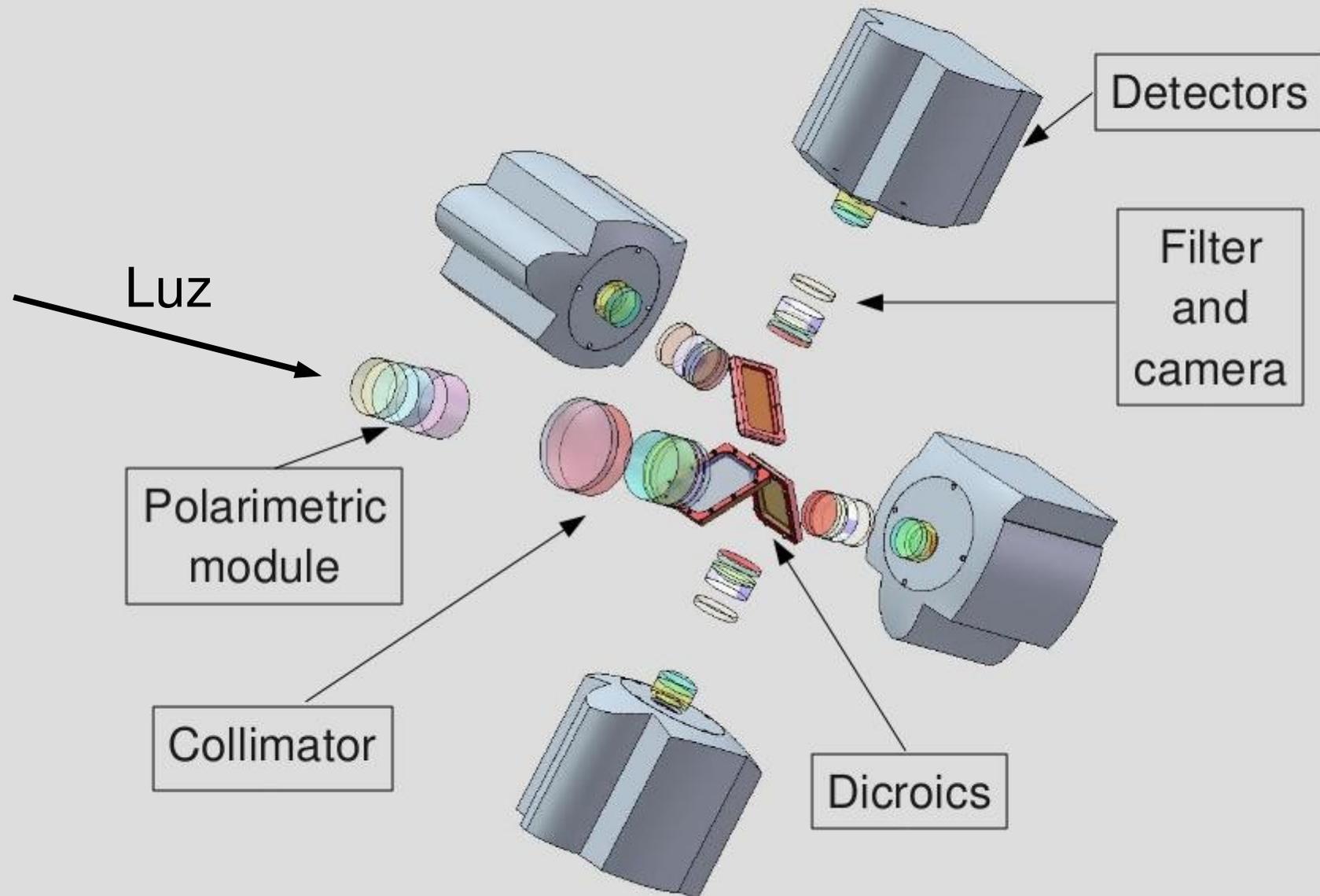
- ✓ **O instrumento deve permitir realizar polarimetria, mas também operar no modo fotométrico apenas**

Complementação do LSST

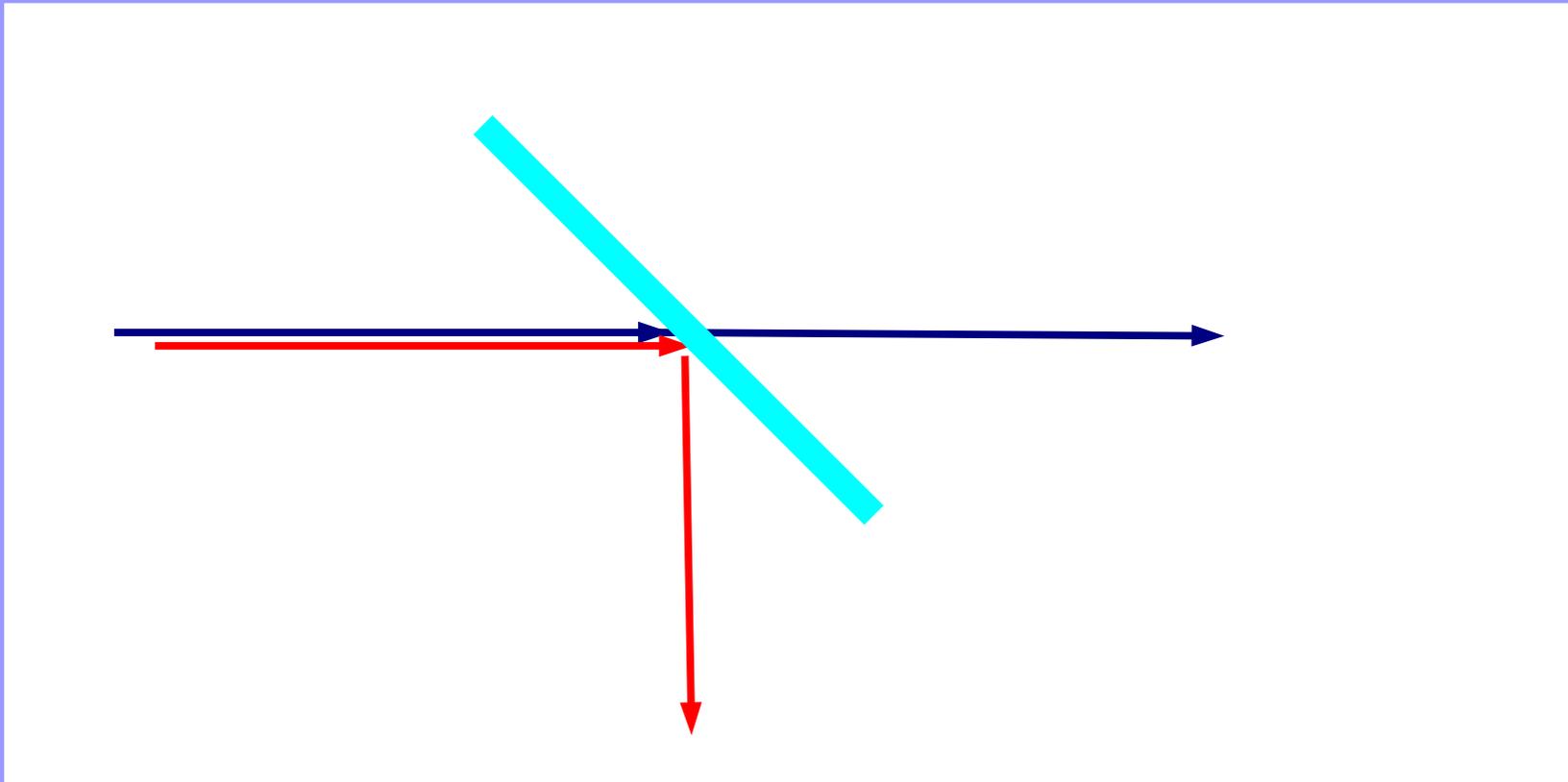
- ✓ ... “15-second exposures in two photometric bands every three nights on average, with typical 5-sigma depth for point sources of $r=24.5$ ” ...

Funcionamento

Layout proposto



Espelhos dicróicos



Polarização

✓ **Antes de falar do módulo polarimétrico,
alguns conceitos básicos de polarização**

→ animações de András Szilágyi

- **<http://www.enzim.hu/~szia/cddemo/edemo0.htm>**

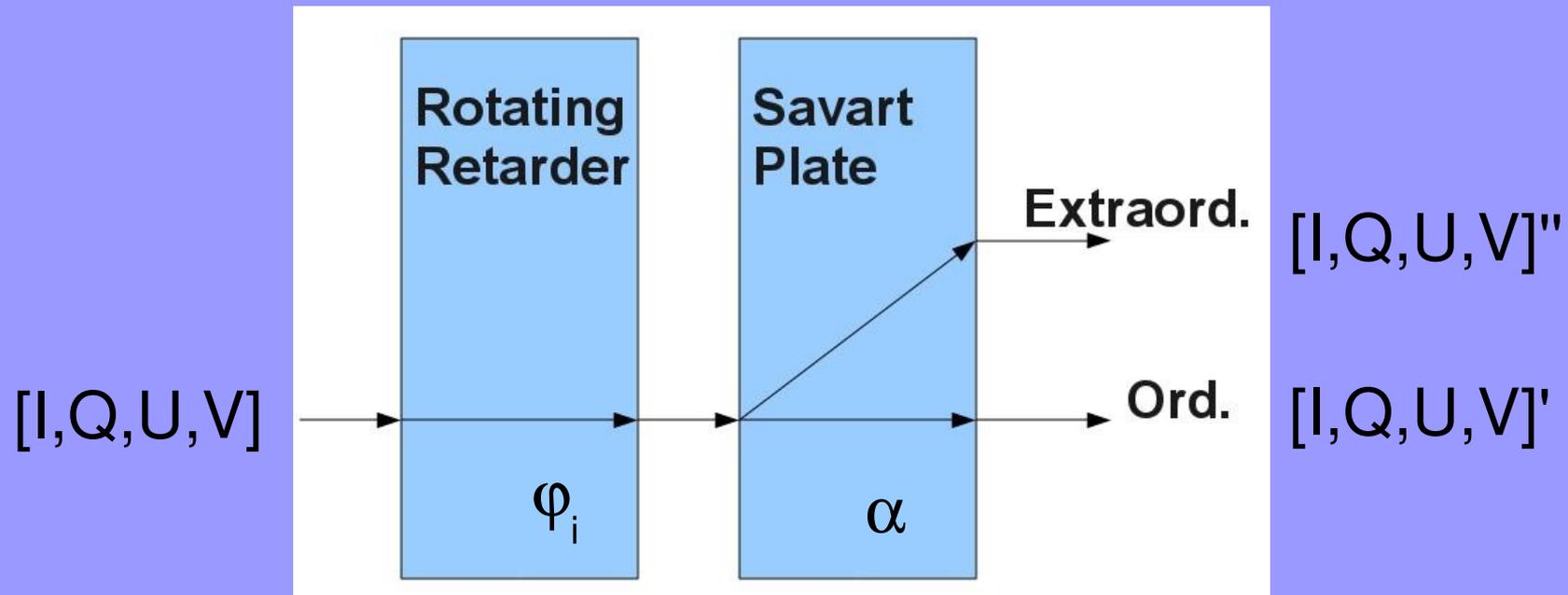
Materiais birefringentes

- ✓ Neles o índice de refração depende da polarização
- ✓ Lembrar que feixe de luz pode ser decomposto em duas componentes de polarizações perpendiculares



Wikipedia

Módulo polarimétrico



$$I'_{\text{ord}} = \frac{1}{2} \left\{ I + Q \cos(2\alpha - 4\varphi_i) - U \sin(2\alpha - 4\varphi_i) \right\} \quad \text{and}$$

$$I'_{\text{ext}} = \frac{1}{2} \left\{ I - Q \cos(2\alpha - 4\varphi_i) + U \sin(2\alpha - 4\varphi_i) \right\} .$$

Comparação com similares

Instrumentos similares

✓ **TurPol (Piirola 1988)**

→ **UBVRI, dicróicos, polarímetro, fotomultiplicadoras**

✓ **ULTRACAM (Dhillon et al. 2007)**

→ **3 cores, dicróicos, 500 Hz, CCDs**

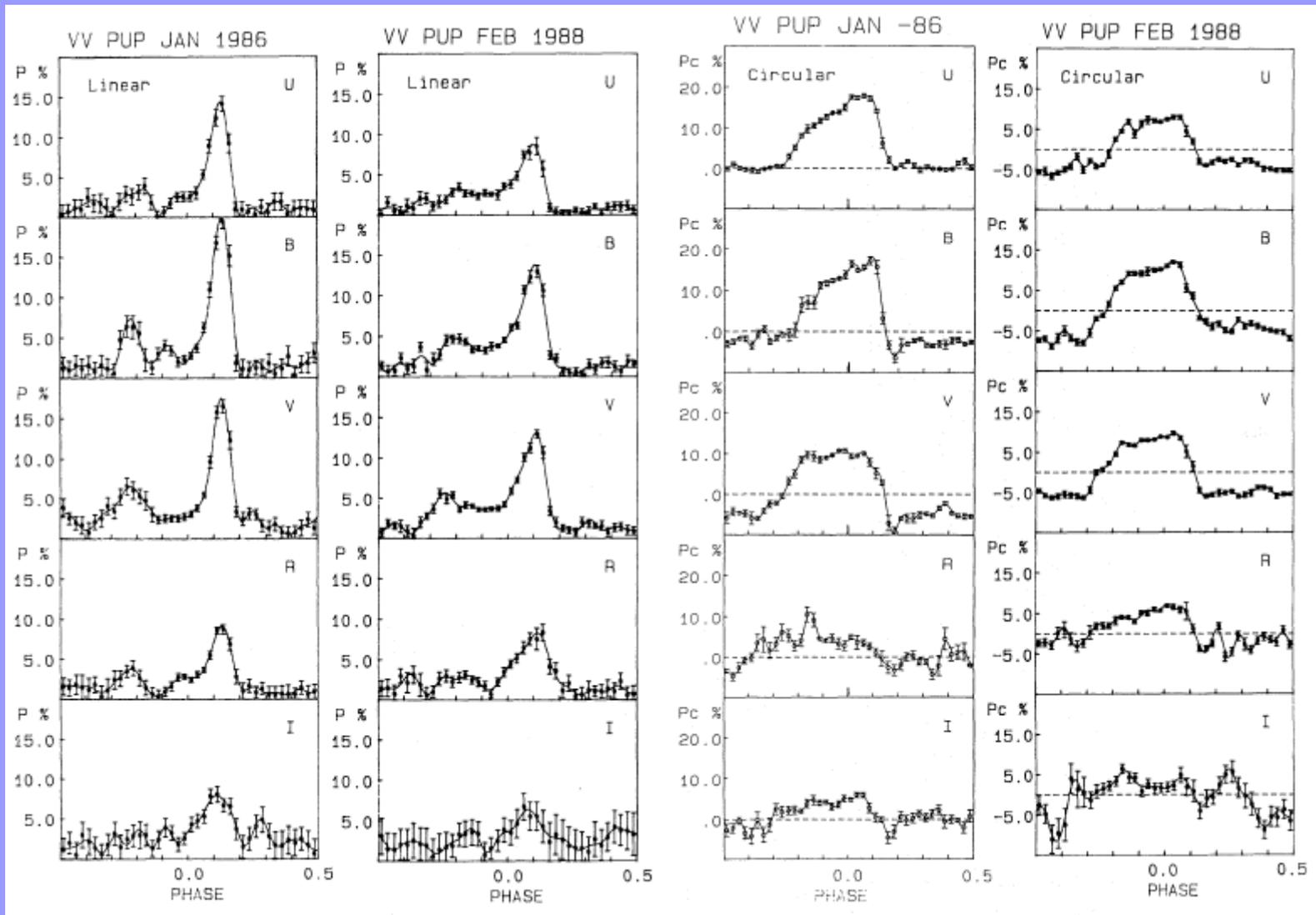
✓ **GROND (Greiner et al. 2008)**

→ **7 cores (IR + Vis), dicróicos, CCDs**

✓ **HIPPO (Potter et al. 2008)**

→ **2 cores, chopper, polarimetria, fotomultiplicadoras**

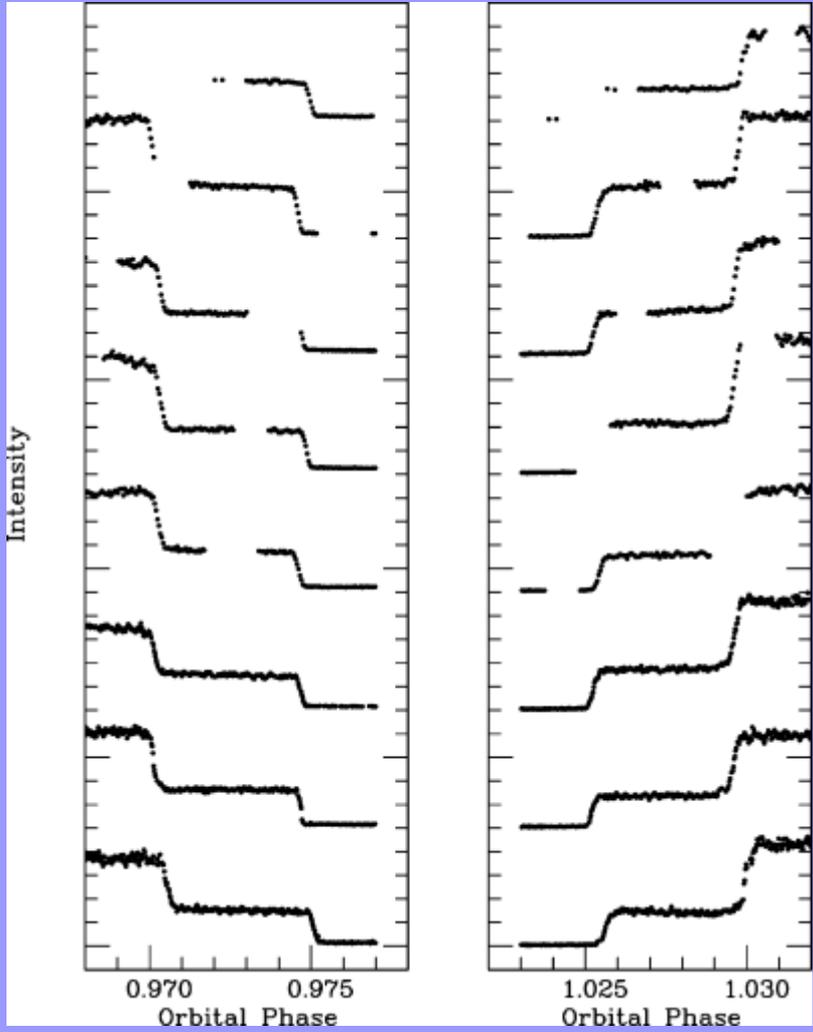
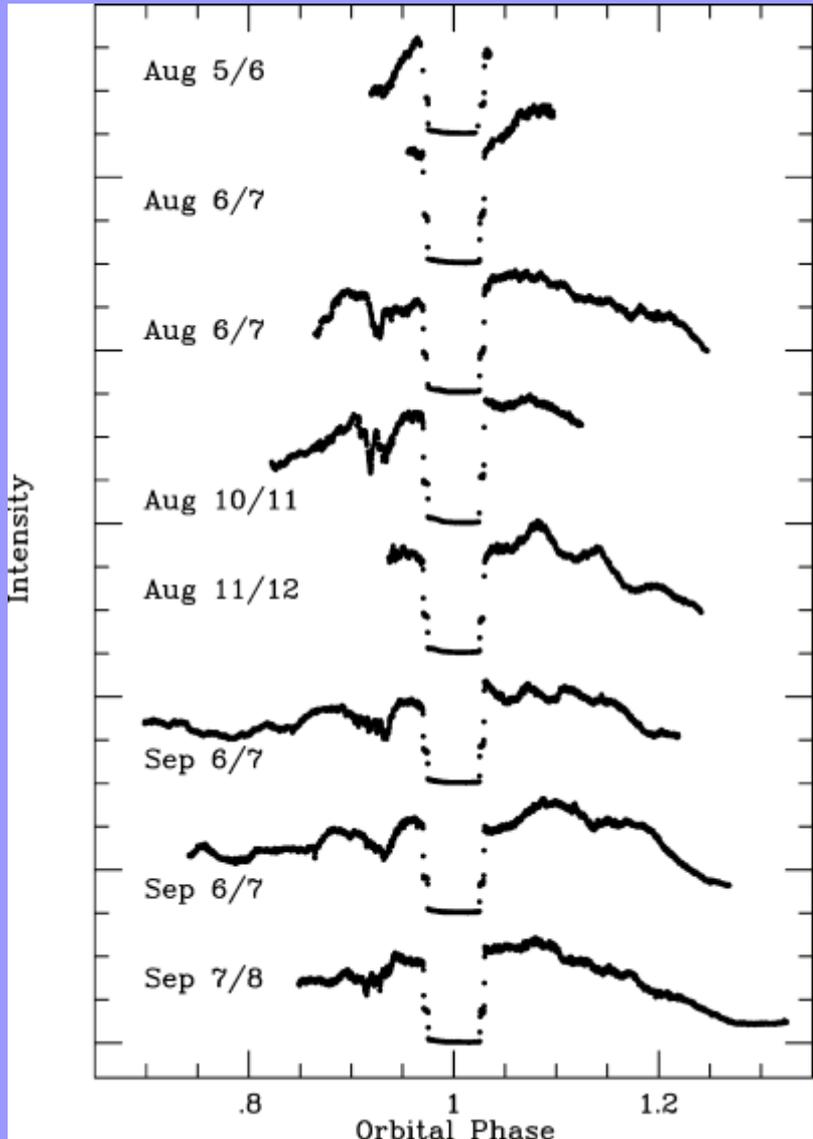
TURPOL



Pirola et al. (1990)

VV Pup

ULTRACAM



O'Donoghue et al. 2006 - FL Cet

0.001 de fase = 5.2 s

SPARC4 é competitiva

- ✓ **SPARC4 é uma câmera rápida que combina de modo único a polarimetria simultânea em quatro cores com detetores bidimensionais**

Projeto

✓ Estrutura do projeto

→ óptica: já iniciado pelo René

→ mecânica: já iniciado pelo René

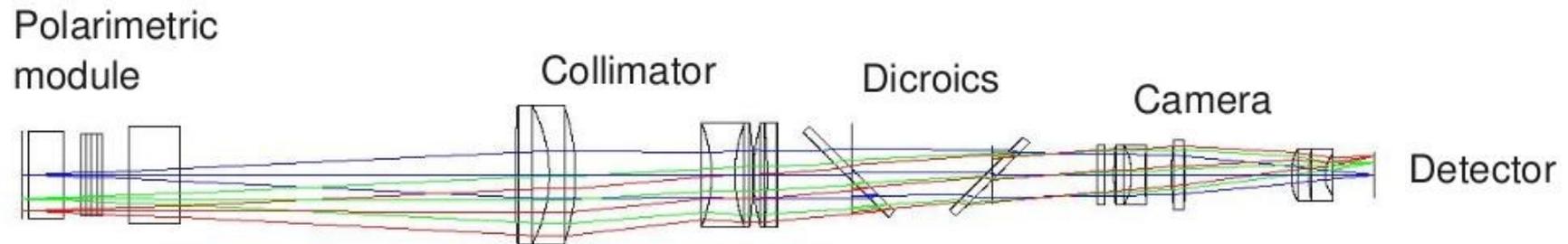
→ eletrônica

→ detetor

→ softwares de controle, aquisição e redução

→ documentação

Desenho óptico



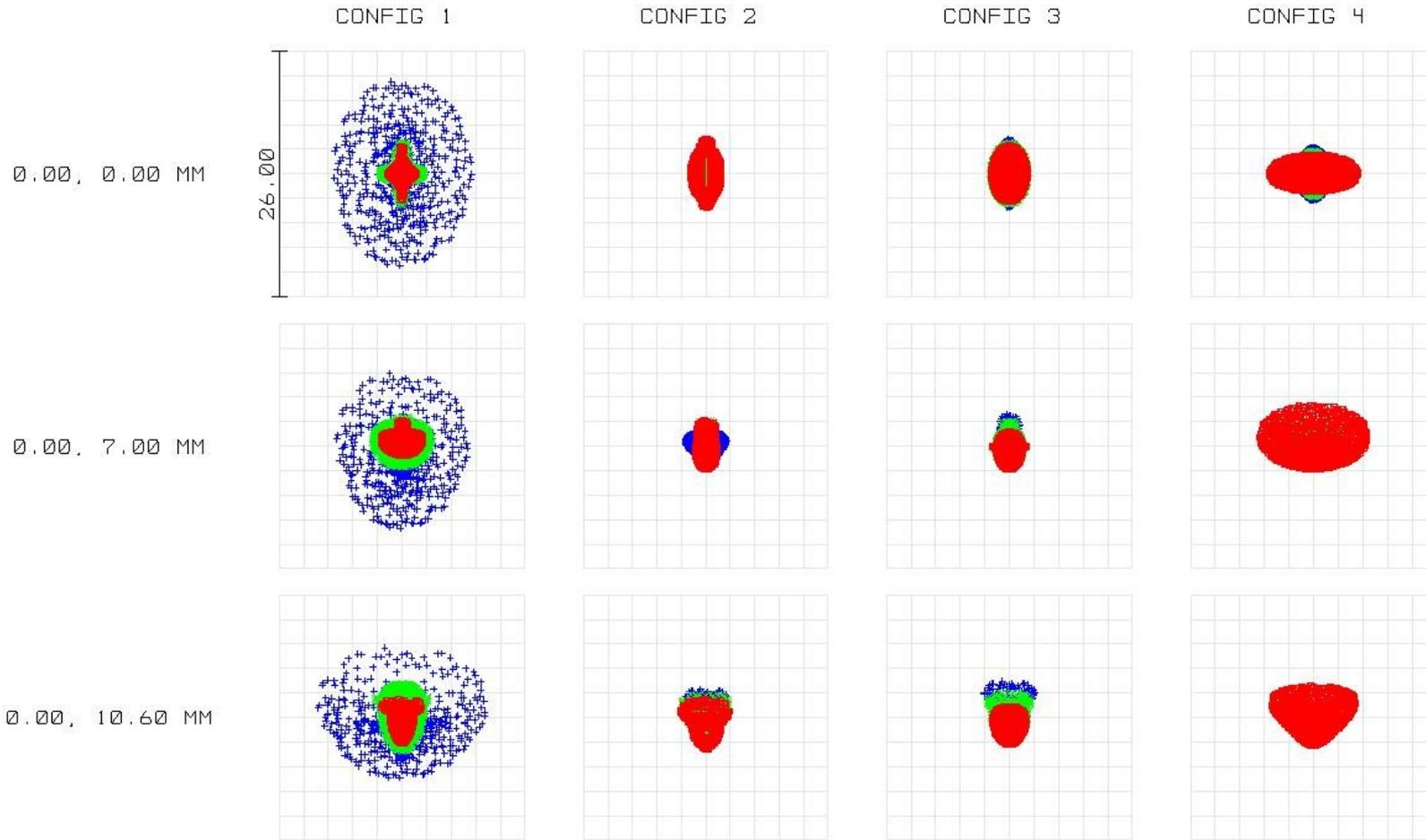
3D LAYOUT

REDFOC2
TUE JAN 26 2010

INPE--DAS

LNA 160 +POLARIZAÇÃO MODE NEW SYSTEM.ZMX
CONFIGURATION 1 OF 4

Spot diagram



SURFACE: IMA

CONFIGURATION MATRIX SPOT DIAGRAM

REDFOC2
TUE JAN 26 2010 UNITS ARE μm .

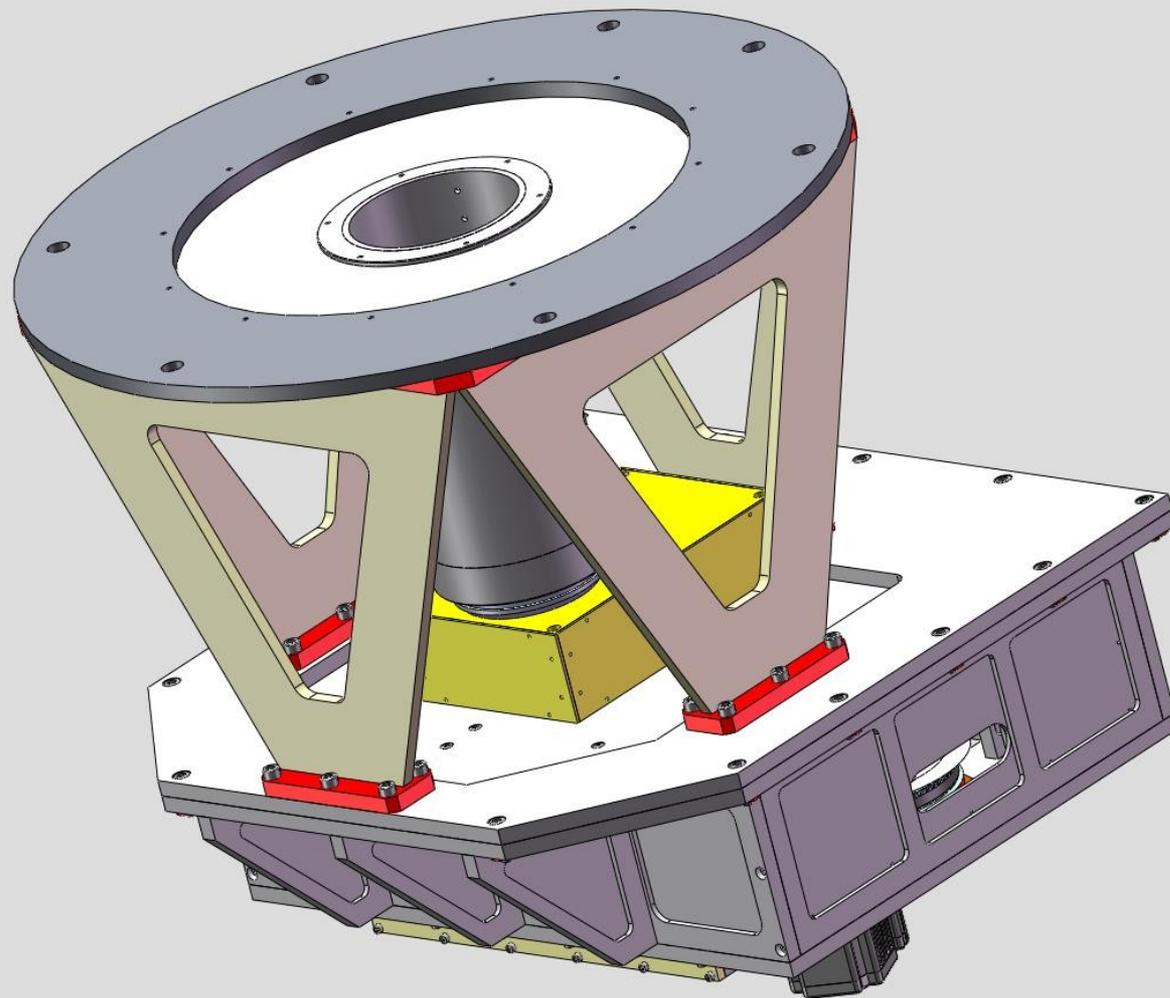
INPE--DAS

SCALE BAR : 26

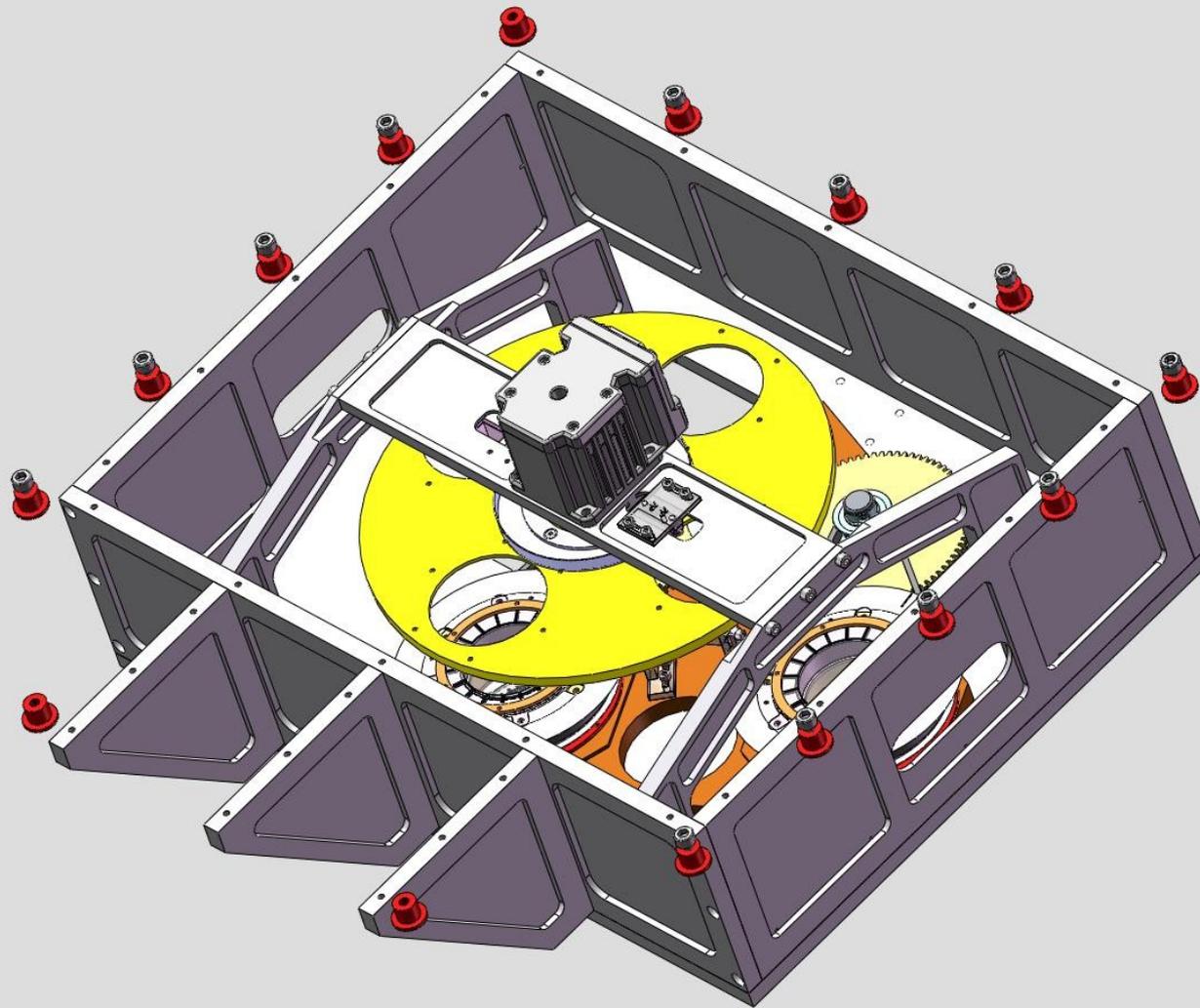
REFERENCE : CENTROID

LNA 160 +POLARIZAÇÃO MODE NEW SYSTEM.ZMX
CONFIGURATION: ALL 4

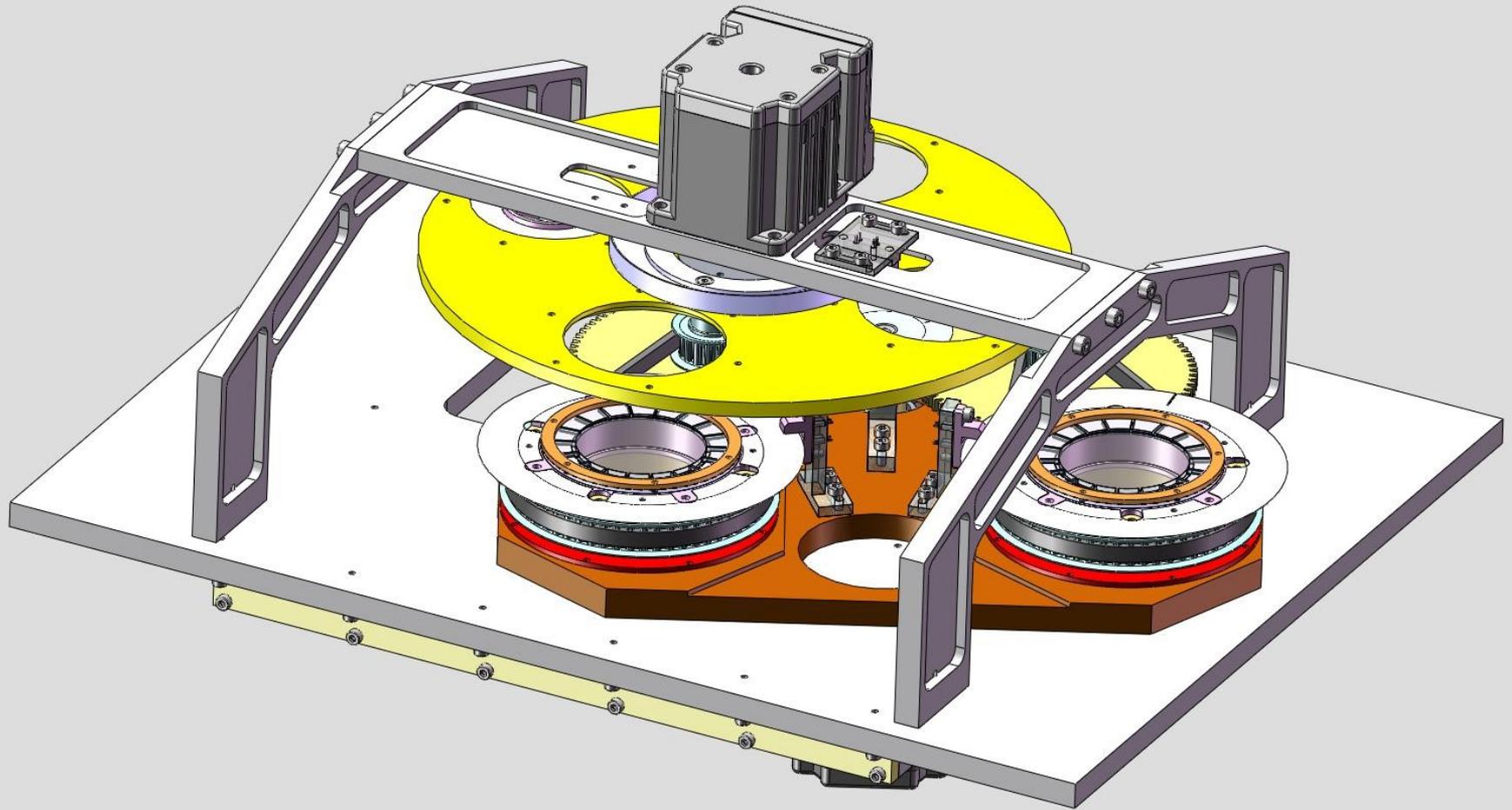
Projeto mecânico



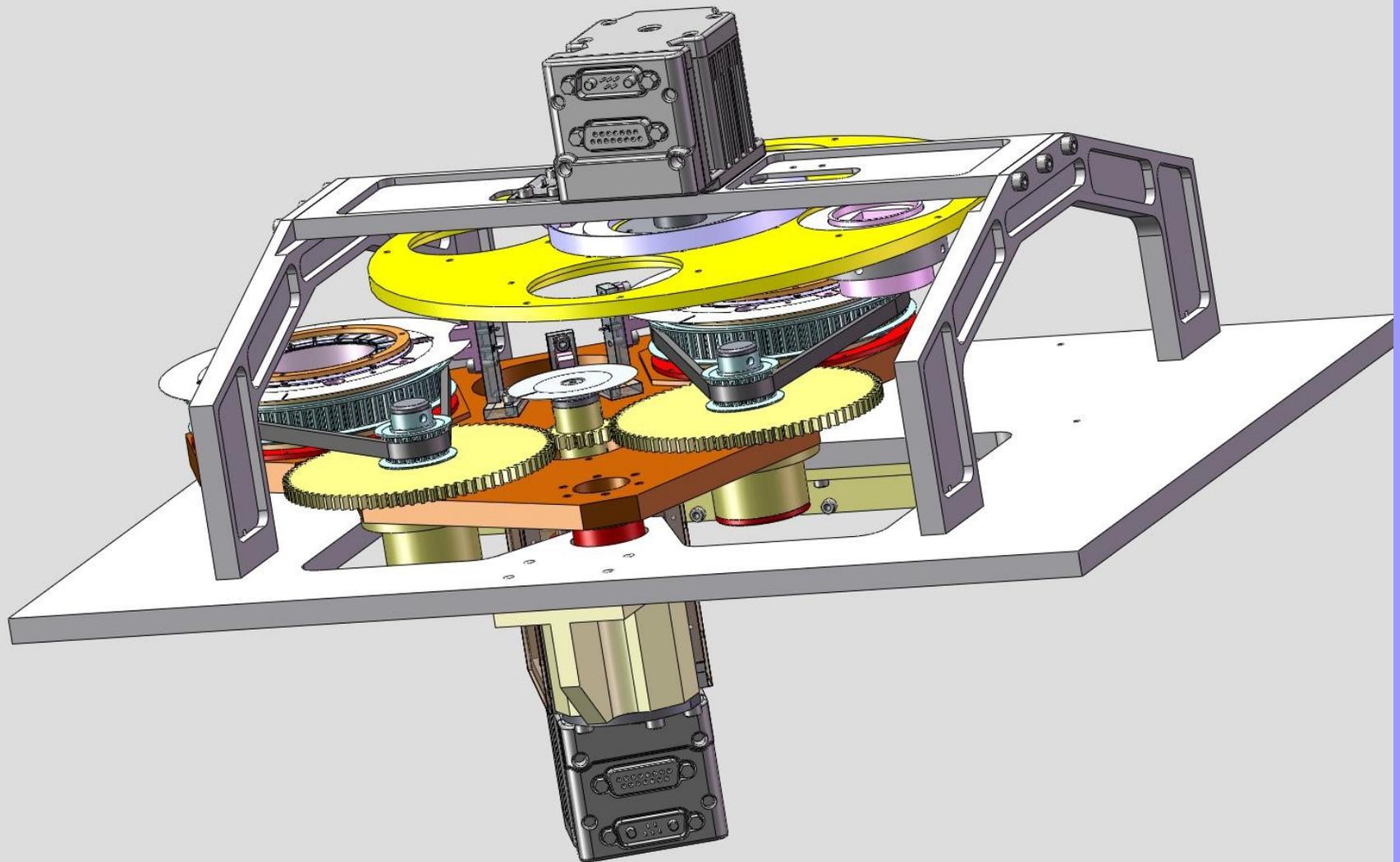
Projeto mecânico



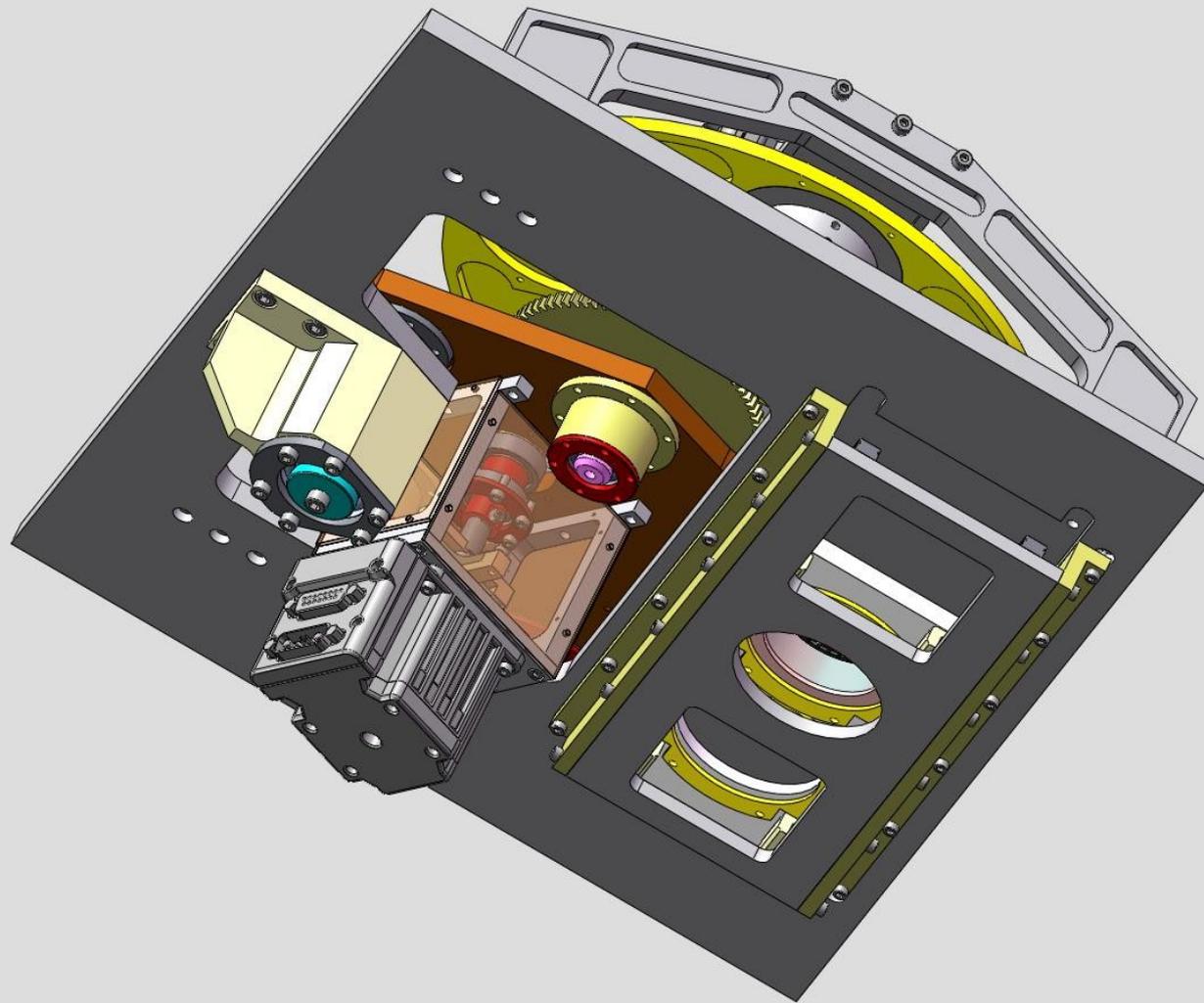
Projeto mecânico



Projeto mecânico



Projeto mecânico



Proposta Fapesp

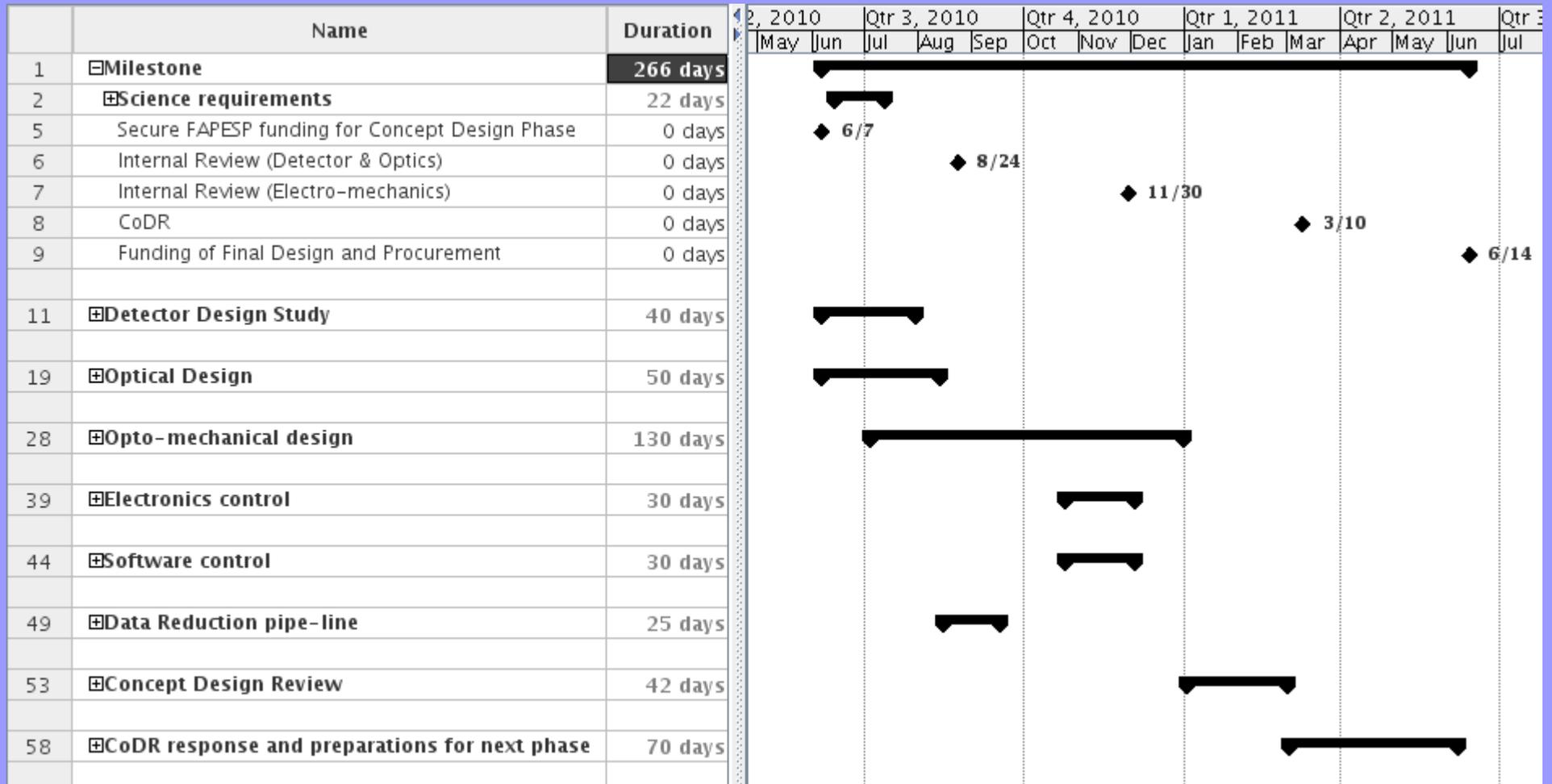
✓ Projeto conceitual

→ estudo das várias partes

✓ Infraestrutura

→ laboratório de testes de instrumentos

Cronograma



Estágio atual

✓ **Esperando avaliação da FAPESP**

Próximo passo

✓ **Fechar lista de requisitos**

→ **Workshop/reunião entre interessados**

✓ **Contato:**

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→ **claudiavr@das.inpe.br**