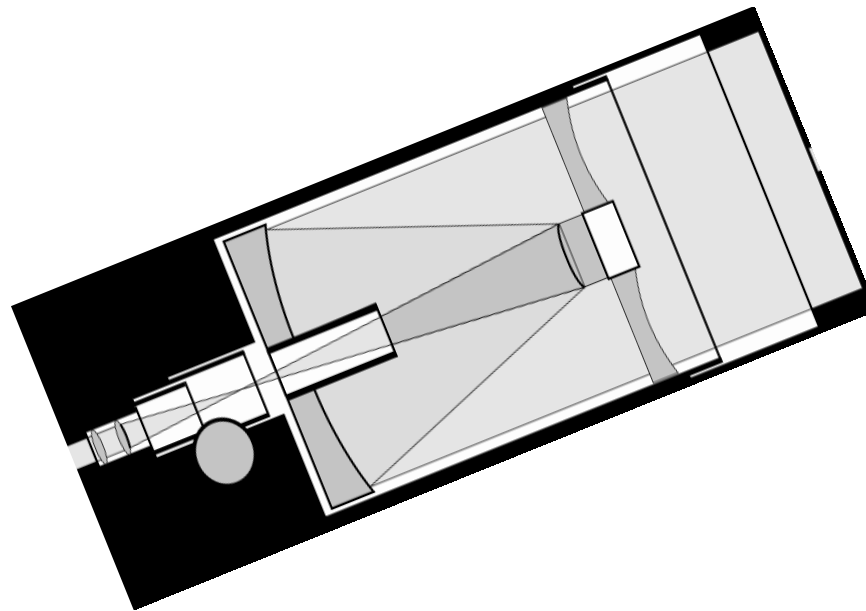


Zrcadlo - čočkové teleskopy.

Katadioptrické



Asferická korekční deska

Schmidt

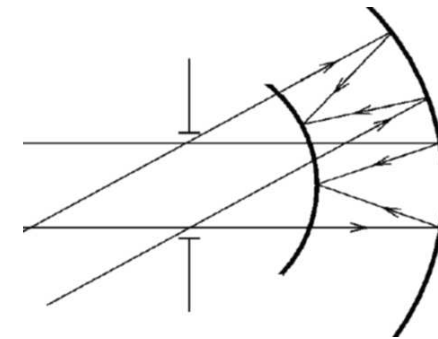
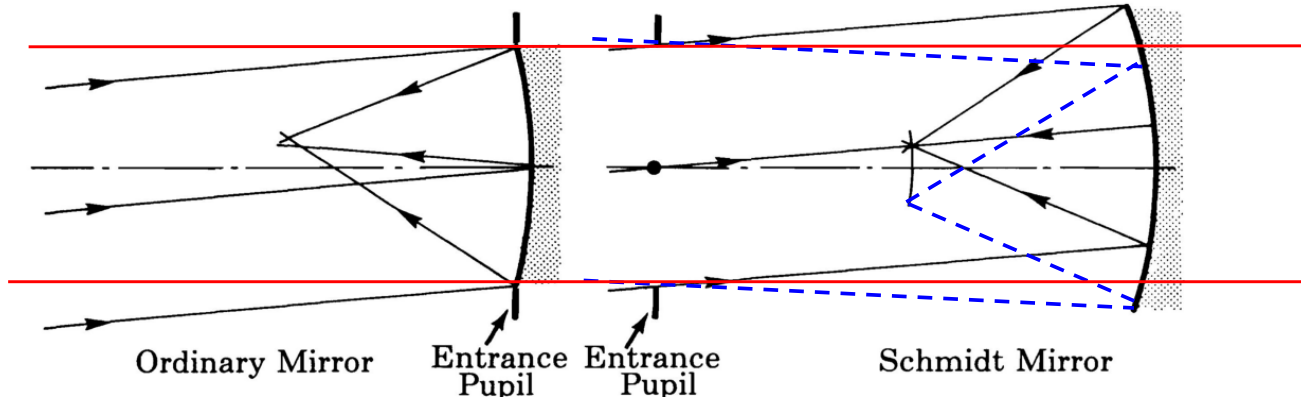
Schmidt – Newton

Schmidt - Cassegrain

Schmidtův teleskop

princip

vady kulového zrcadla



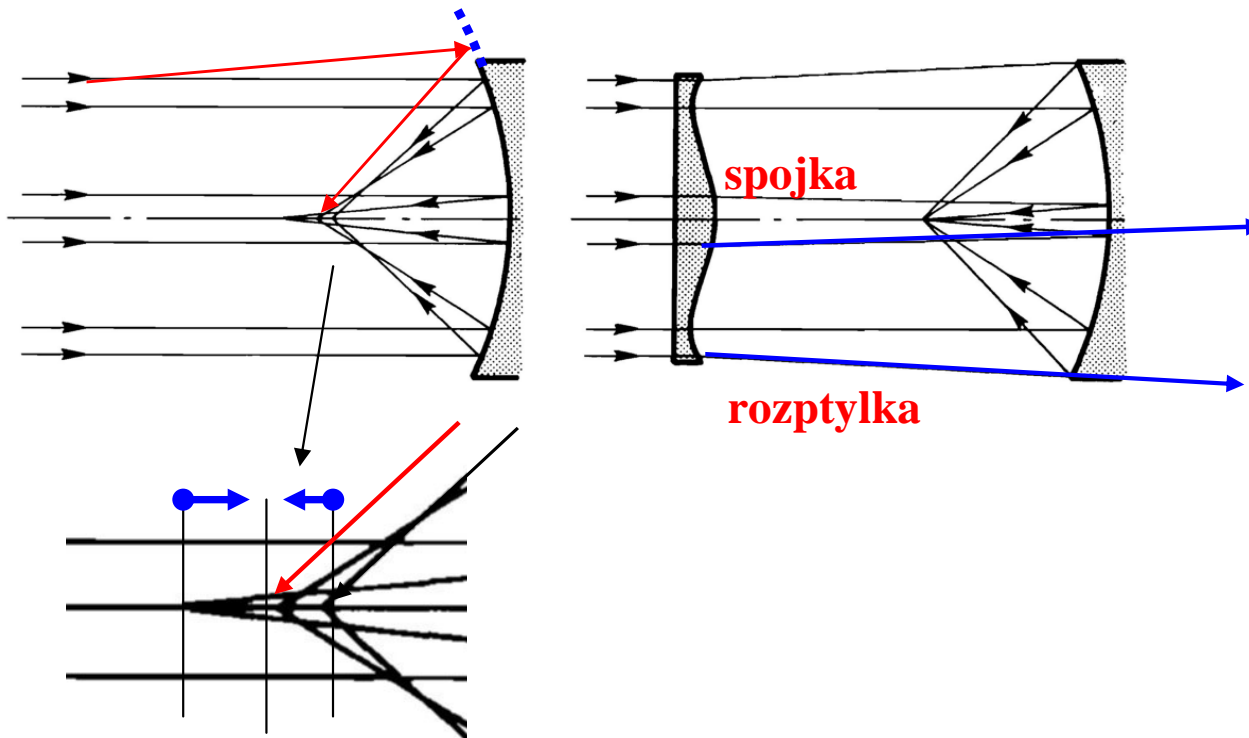
eliminace komy
zbývá jen otvorová
vada a křivost pole



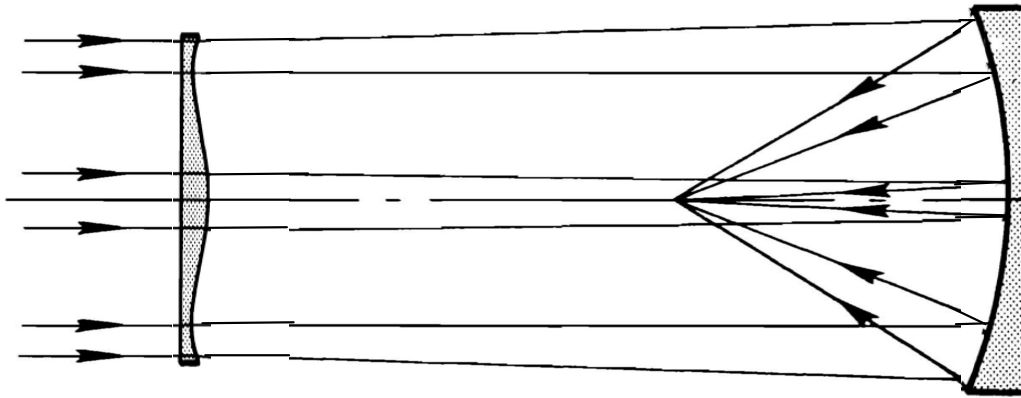
eliminace otvorové
vady



asférická korekční
deska

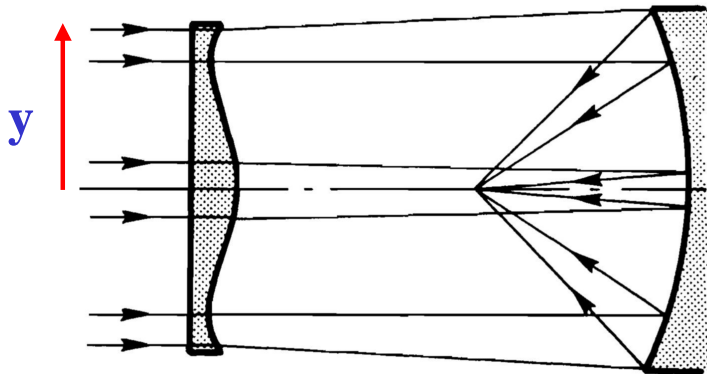


Schmidtův teleskop

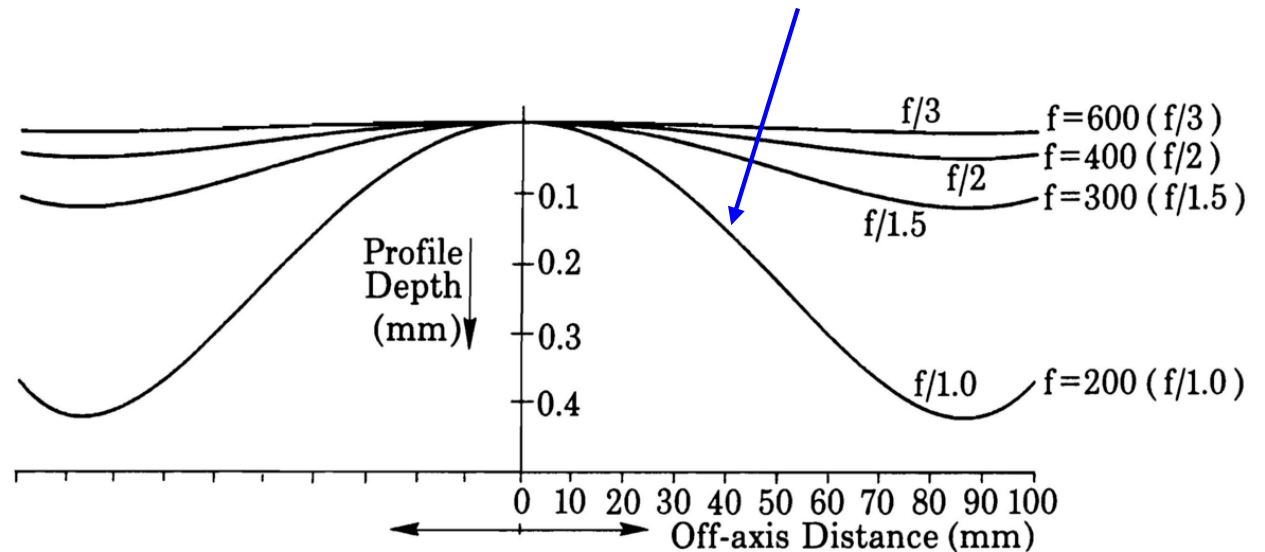


Tvarem korekční desky je asféra popsaná polynomem:

$$y = ay^2 + by^4 + cy^6$$



Hloubka profilu desky je větší pro menší clonová čísla

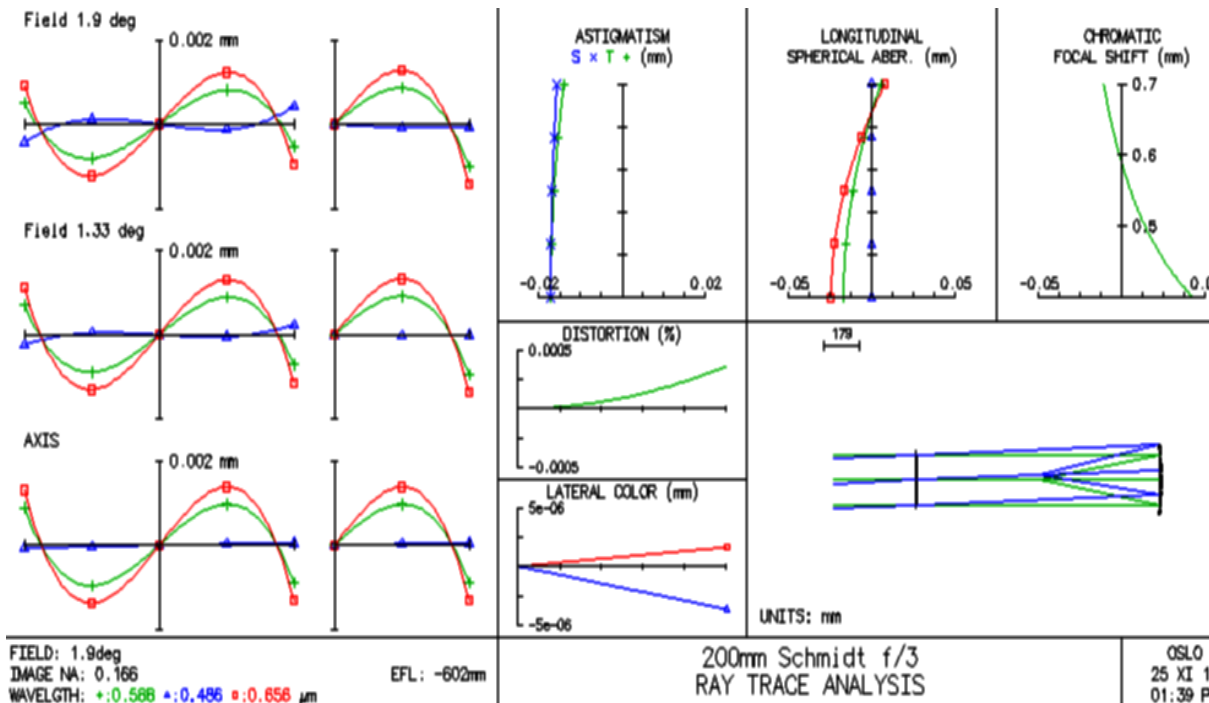
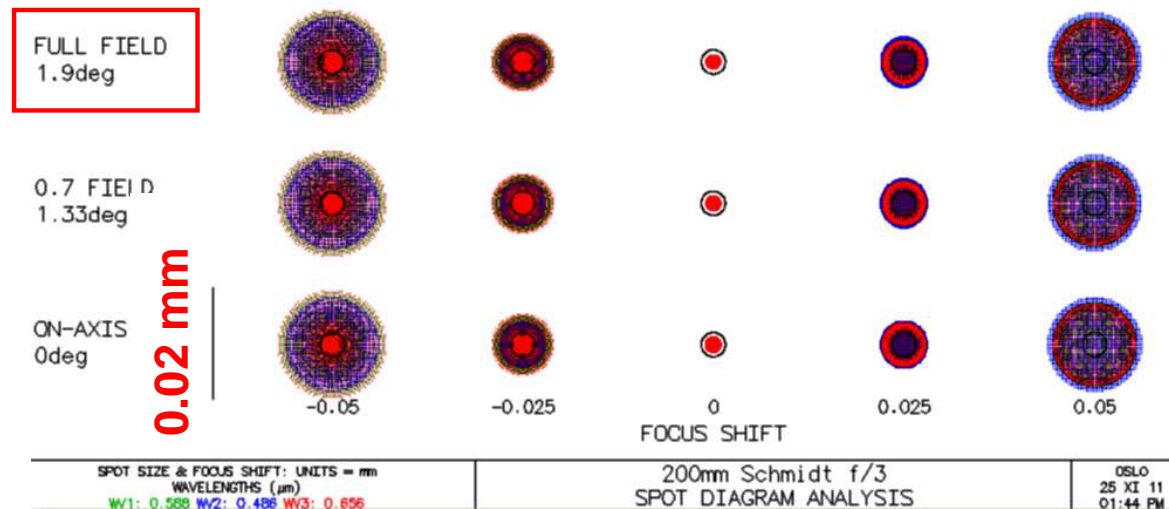


Schmidt $D = 200\text{mm}$, $f' = 600\text{ mm}$, $f/3$

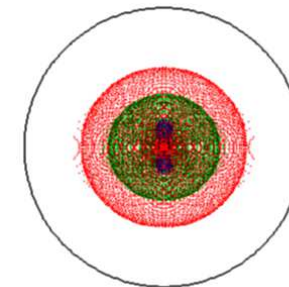
délka = $R = 1200\text{ mm}$

difrakční limit

křivost pole $R_f = 600\text{mm}$



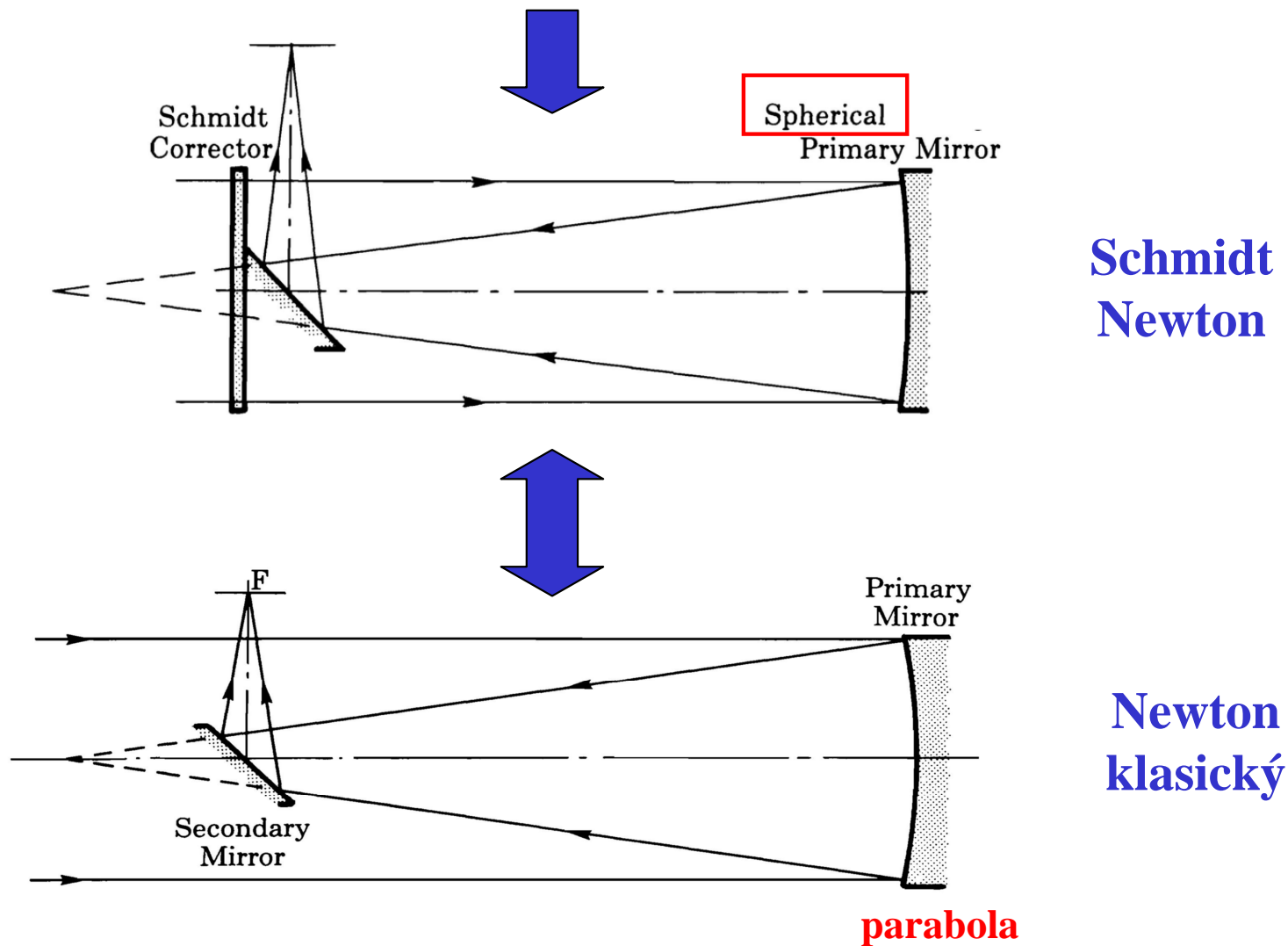
Airy disk



Schmidt s rovinným obrazovým polem – část PA1 - doplňky

Schmidt - Newton teleskop

Schmidt má špatně přístupnou obrazovou „rovinu“ a je zvláště pro větší clonová čísla dlouhý.

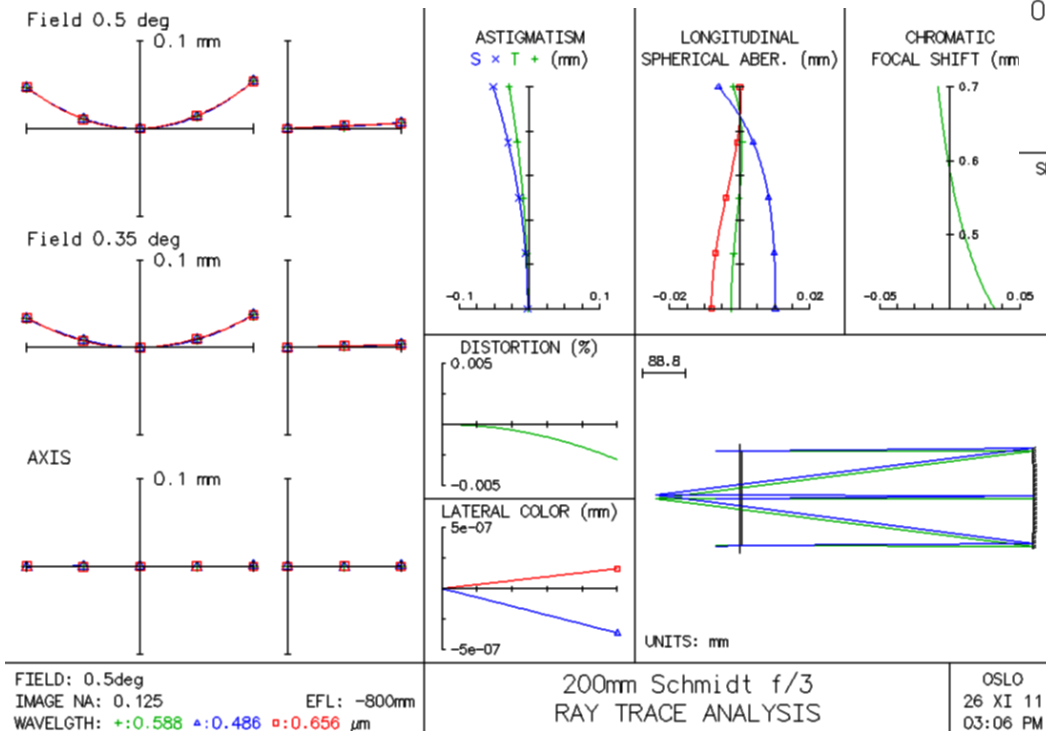
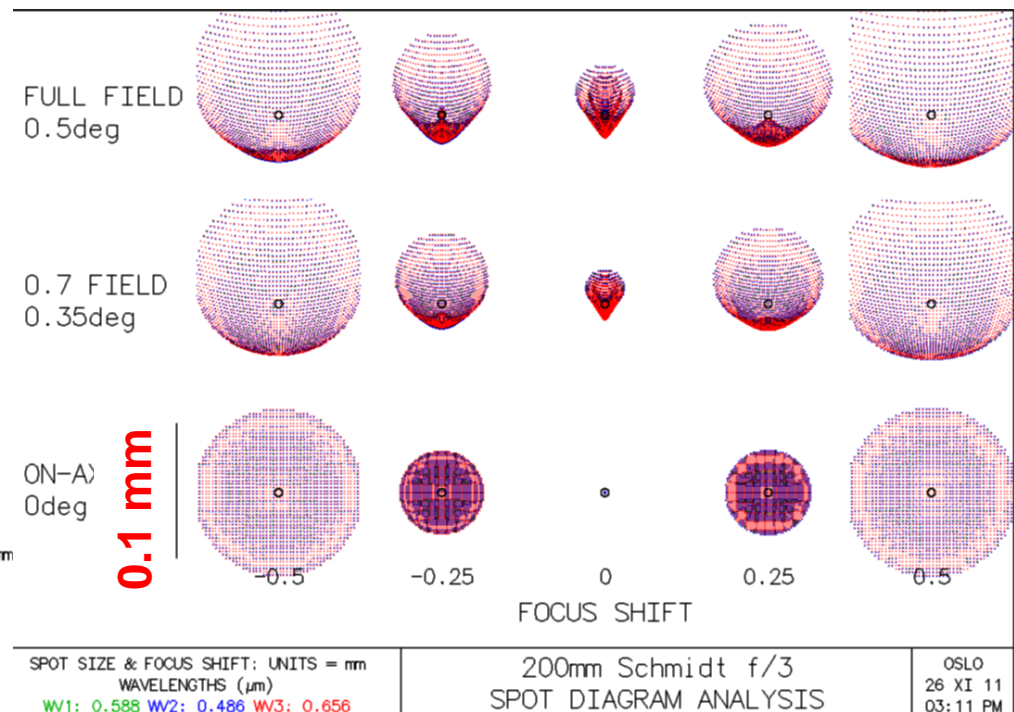


Schmidt-Newton $D = 200\text{mm}$, $f' = 800\text{ mm}$, $f/4$

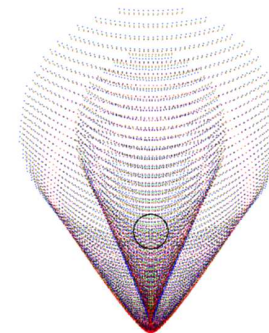
Barevné vady nenulové



Korekční deska

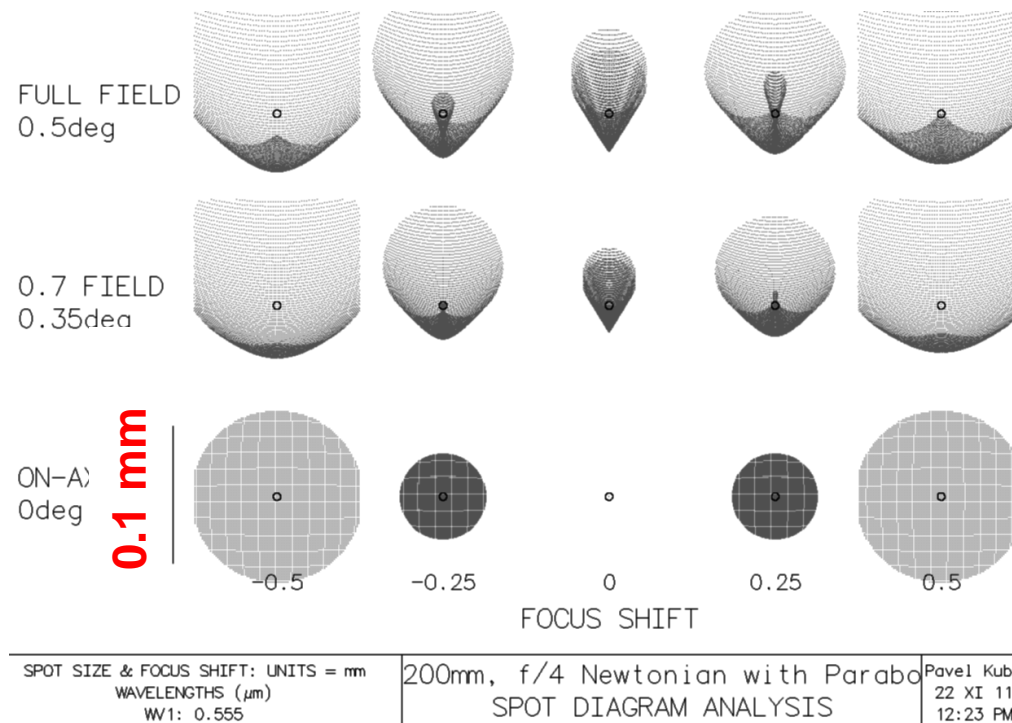
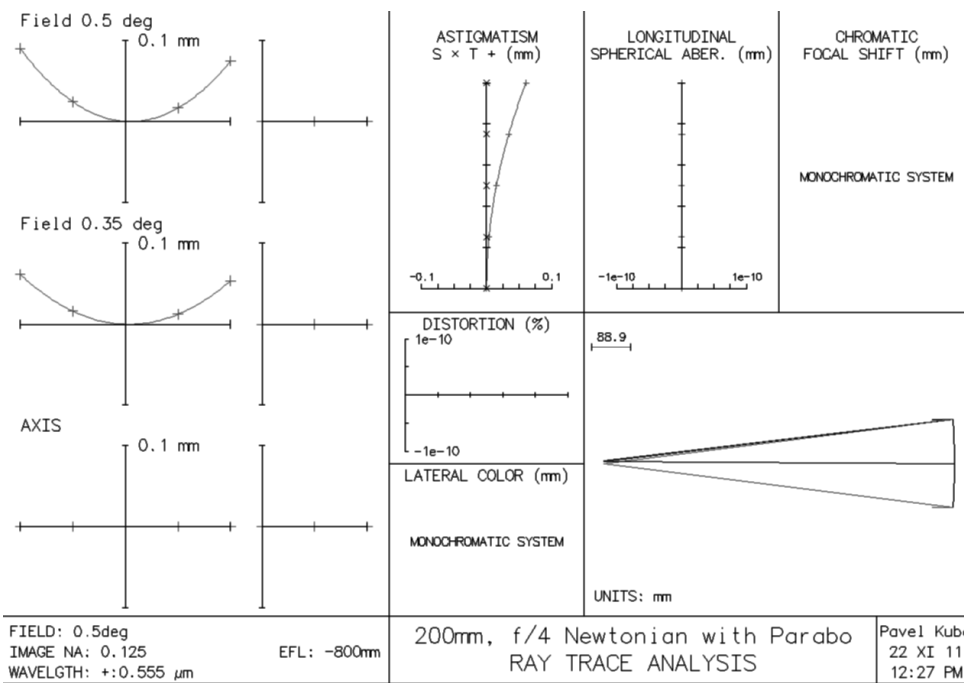


Airyho disk

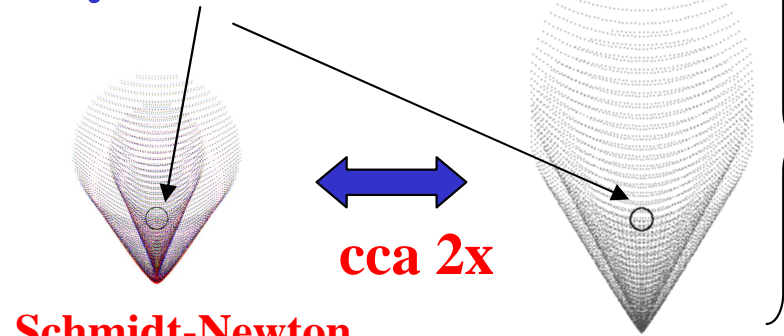


Barevné vady nulové

Schmidt-Newton má cca 2x menší vady než srovnatelný klasický Newton

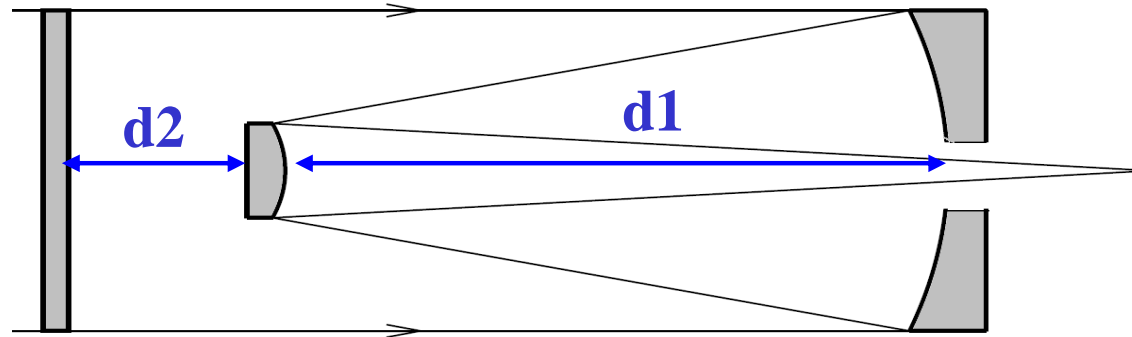


Airyho disk



Schmidt - Cassegrain

Kombinace Cassegrain + asferická korekční deska



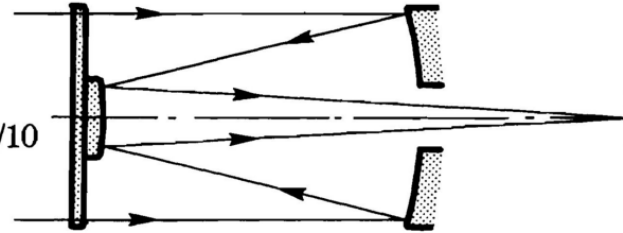
Podobně jako u Newtonova teleskopu lze u zrcadel použít obě kulová zrcadla ale za cenu velkých clonových čísel výrazně větších než $f/10$

Existuje větší množství konstrukčních variant než u Cassegrainu díky další možné mezeře mezi korekční deskou a sekundárním zrcadlem ($d1, d2$). Obě zrcadla bývají asferická, někdy postačuje aby bylo asferické jen sekundární zrcadlo.

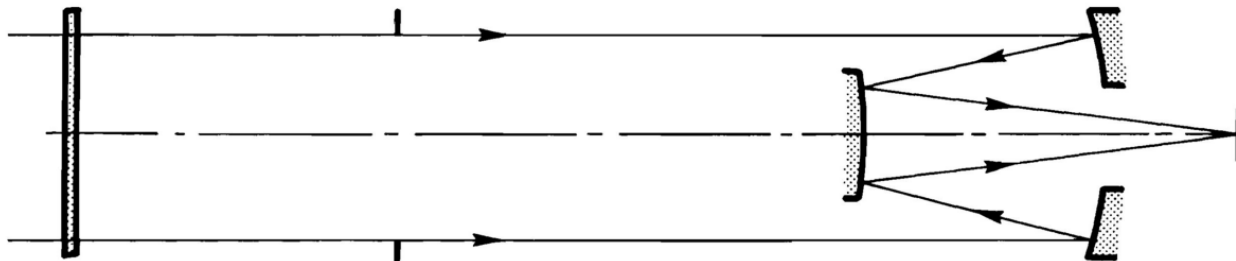
Podobně jako u Cassegrainů platí že menší sekundární zrcadlo = větší křivost obrazového pole. Vhodnější pro vizuální pozorování. Naopak pro fotografii rovinnější obrazové pole vede k většímu sekundárnímu zrcadlu – centrální clonění.

Schmidt - Cassegrain - varianty

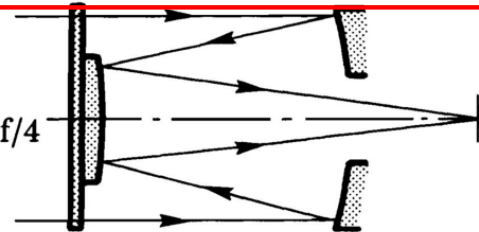
Curved-Field
Compact Design $f/10$



Flat Field $f/4$



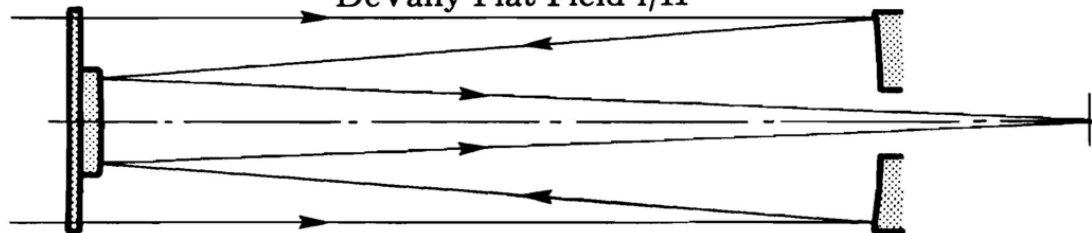
Flat-Field
Compact Design $f/4$



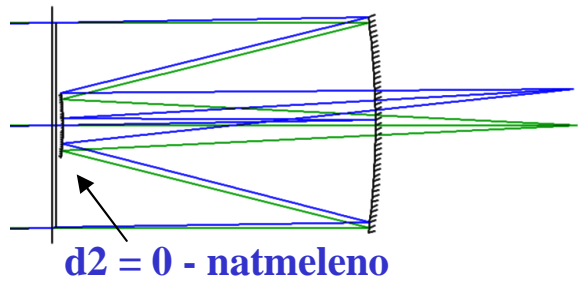
Telescope optics
Evaluation and design

H.Rutten, M.van Venrooij

DeVany Flat Field $f/11$



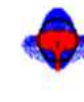
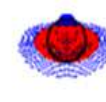
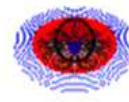
Schmidt-Cassegrain $D = 200\text{mm}$, $f' = 2000\text{ mm}$, $f/10$



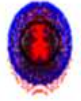
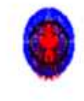
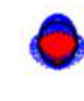
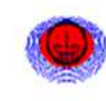
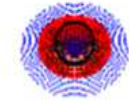
- 1. zrcadlo – koule ,
- 2. zrcadlo - elipsa

křivost pole $R_f = 157\text{mm}$

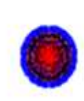
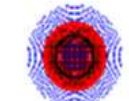
FULL FIELD
0.565deg



0.7 FIELD
0.396deg



ON-AXIS
0deg



0.05 mm

-0.2

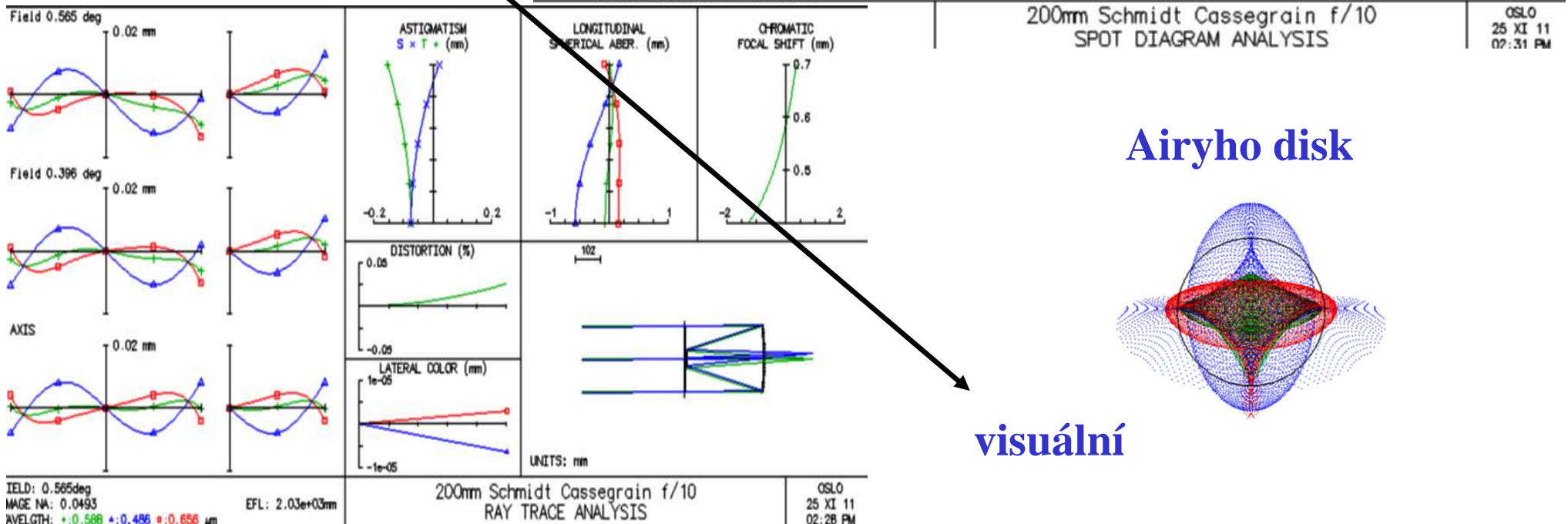
-0.1

0

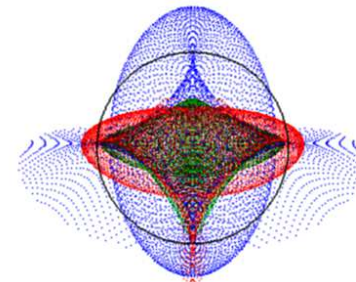
0.1

0.2

FOCUS SHIFT



Airyho disk

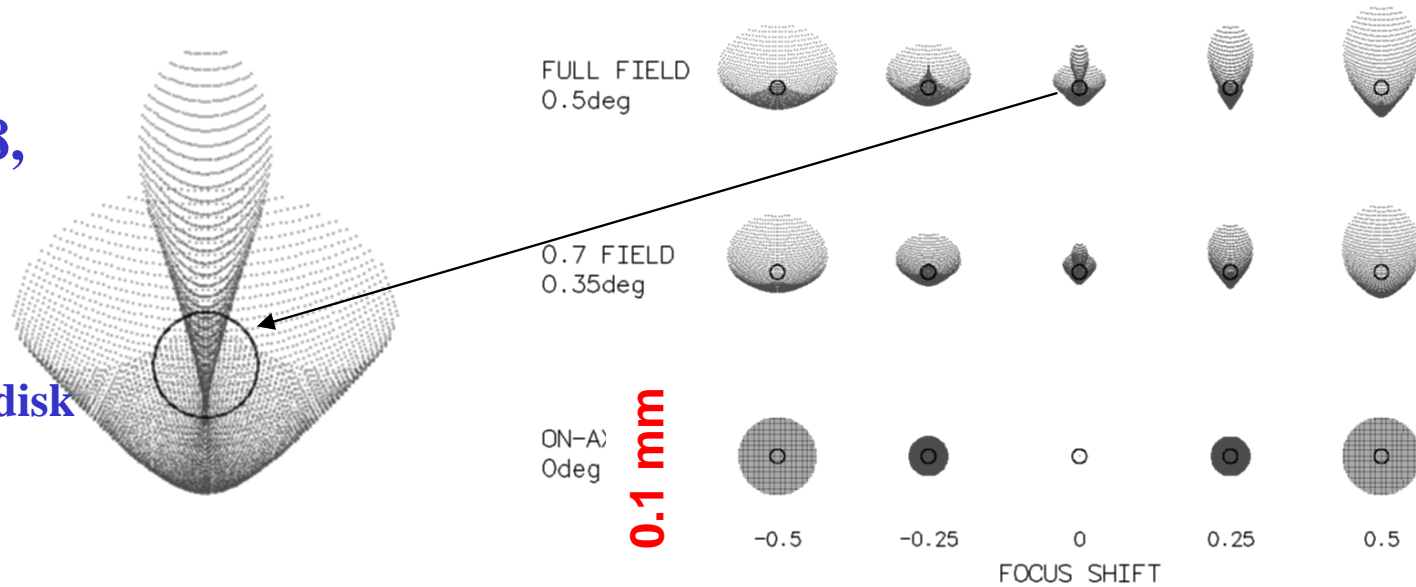


visuální

Cassegrain

D = 200 mm, f/8,

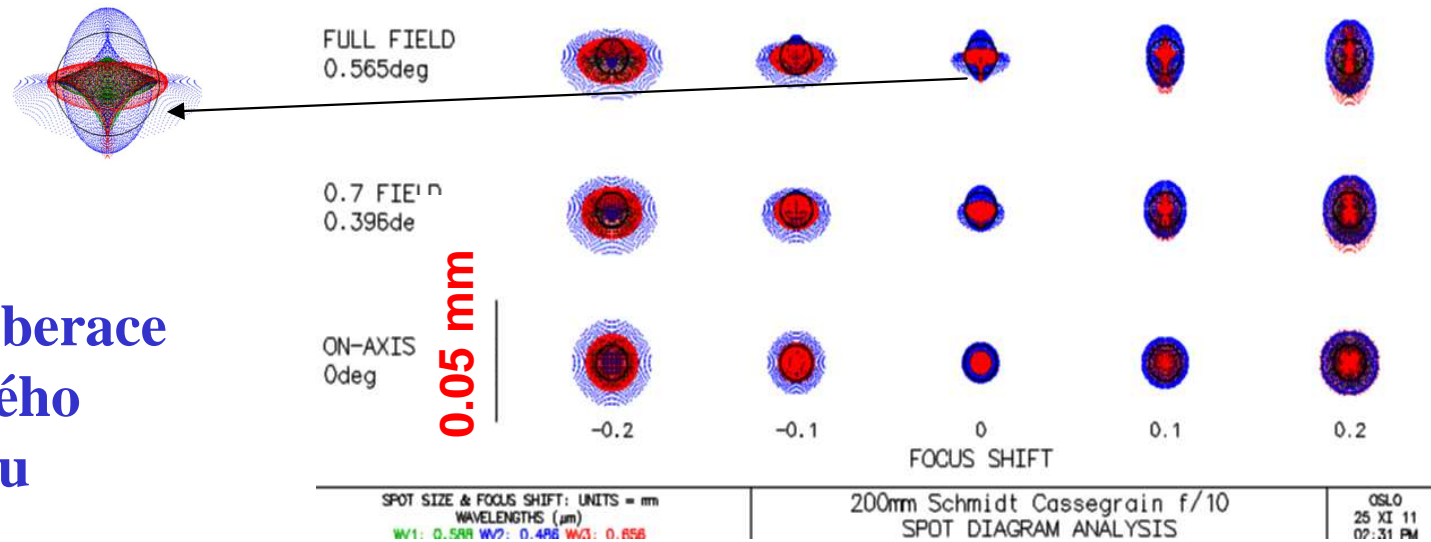
Airyho disk



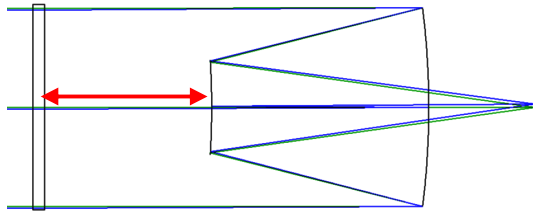
Schmidt-Cassegrain

D = 200mm, f/10

Výrazně menší aberace
než u klasického
Cassegrainu

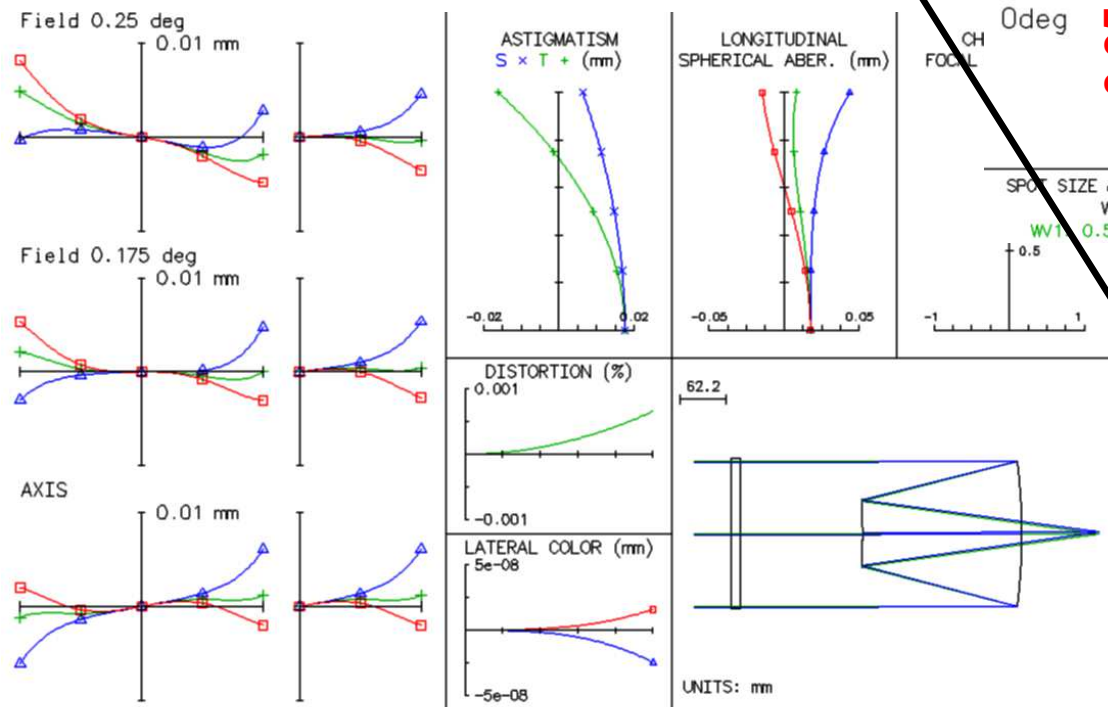


Schmidt-Cassegrain $D = 200\text{mm}$, $f' = 727\text{ mm}$, $f/3.6$



1. zrcadlo – parabola ,
2. zrcadlo - hyperbola

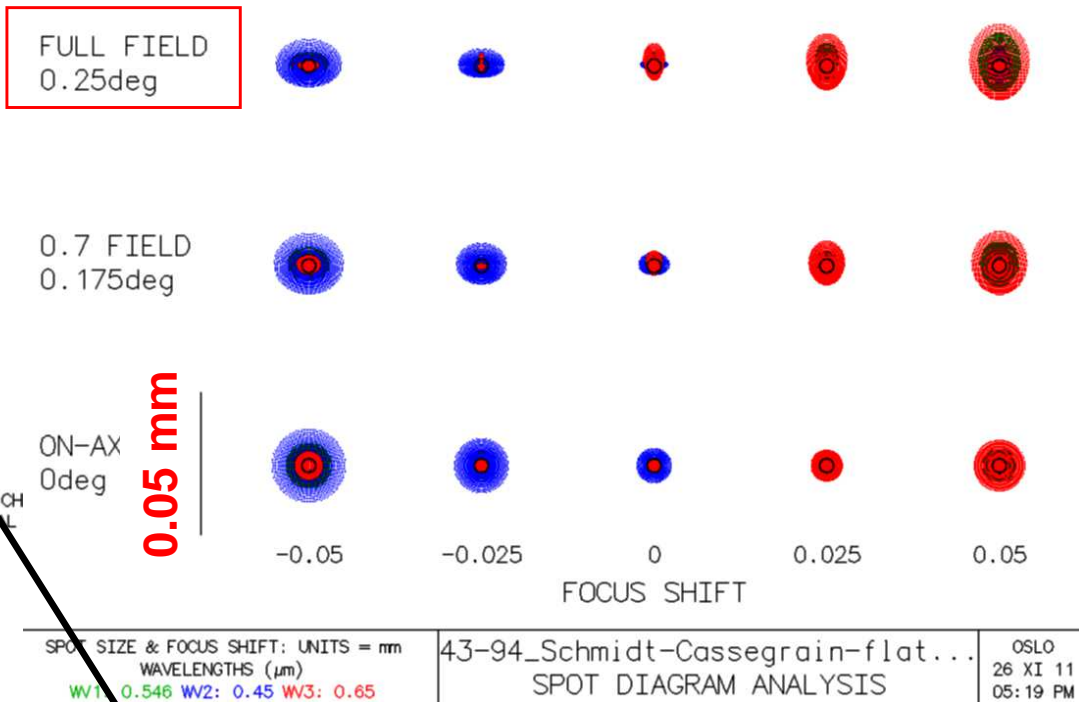
„rovinné“
pole



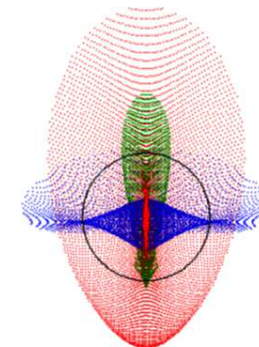
FIELD: 0.25deg
IMAGE NA: 0.137
WAVELGTH: +:0.546 μm \cdot :0.450 μm \circ :0.650 μm
EFL: 727mm

43-94_Schmidt-Cassegrain-flat...
RAY TRACE ANALYSIS

OSLO
26 XI 11
05:24 PM



Airyho disk



fotografie

Menisková korekční čočka

Maksutov

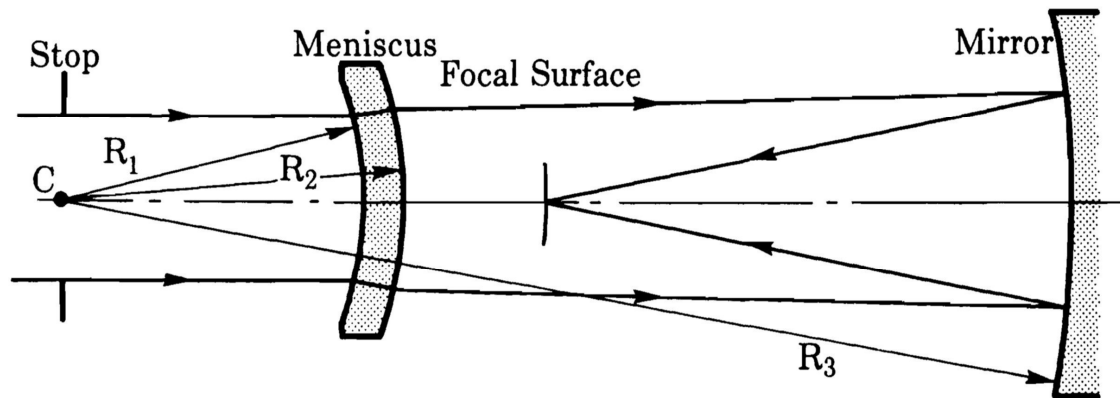
Maksutov – Newton

Maksutov - Cassegrain

Maksutov teleskop

princip

asferická korekční deska je náročná na výrobu → menisková čočka

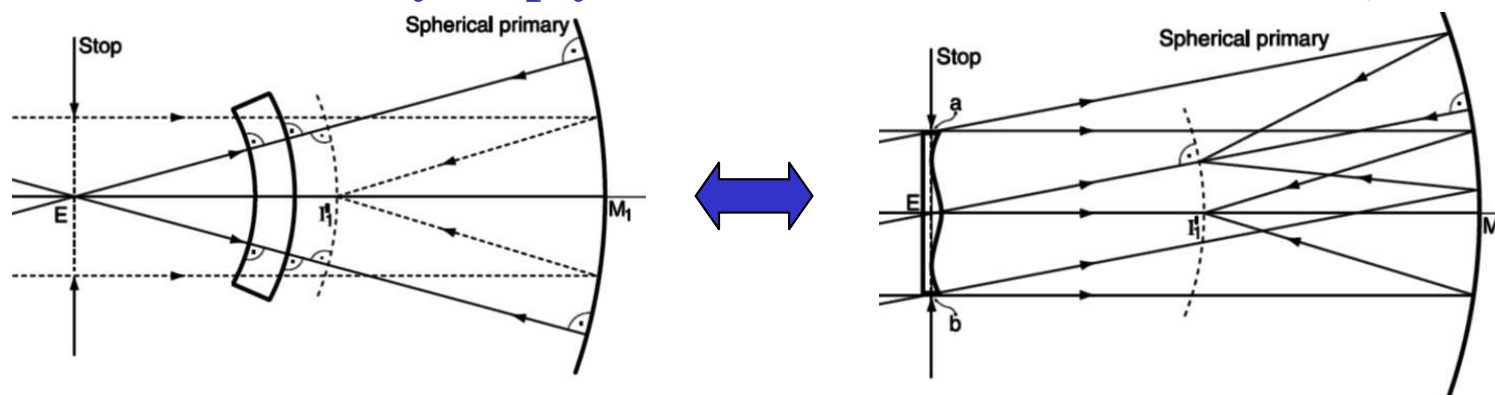


eliminace komy clonou
v poloměru křivosti
zrcadla

stále křivost pole

Všechny optické plochy jsou kulové se stejným středem křivosti - koncentrické

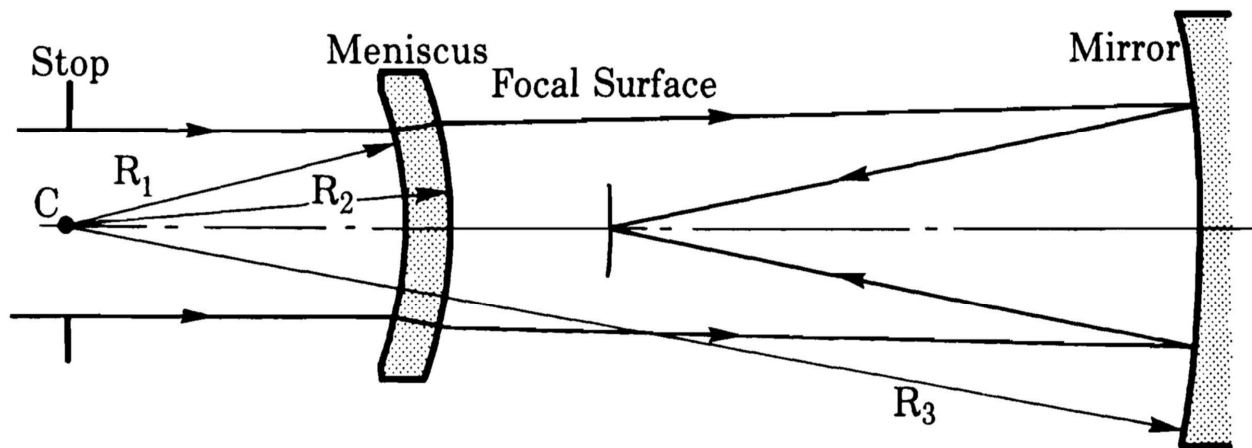
eliminace otvorové vady rozptylkou ve tvaru menisku – Bouwers, Maksutov



Rozptylka kompenzuje otvorovou vadu zrcadla (opačný charakter)

Maksutov teleskop

princip



eliminace komy
clonou v poloměru
křivosti zrcadla

stále křivost pole

Všechny optické plochy jsou kulové se stejným středem křivosti
soustředné (koncentrické)

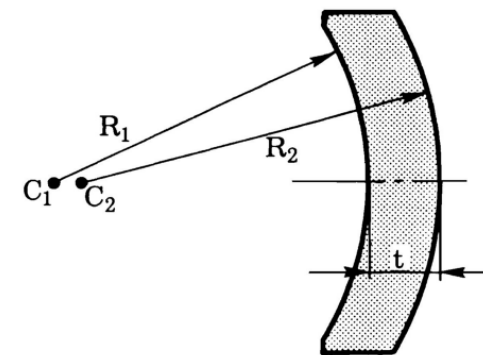


Sklo čočky = barevná vada

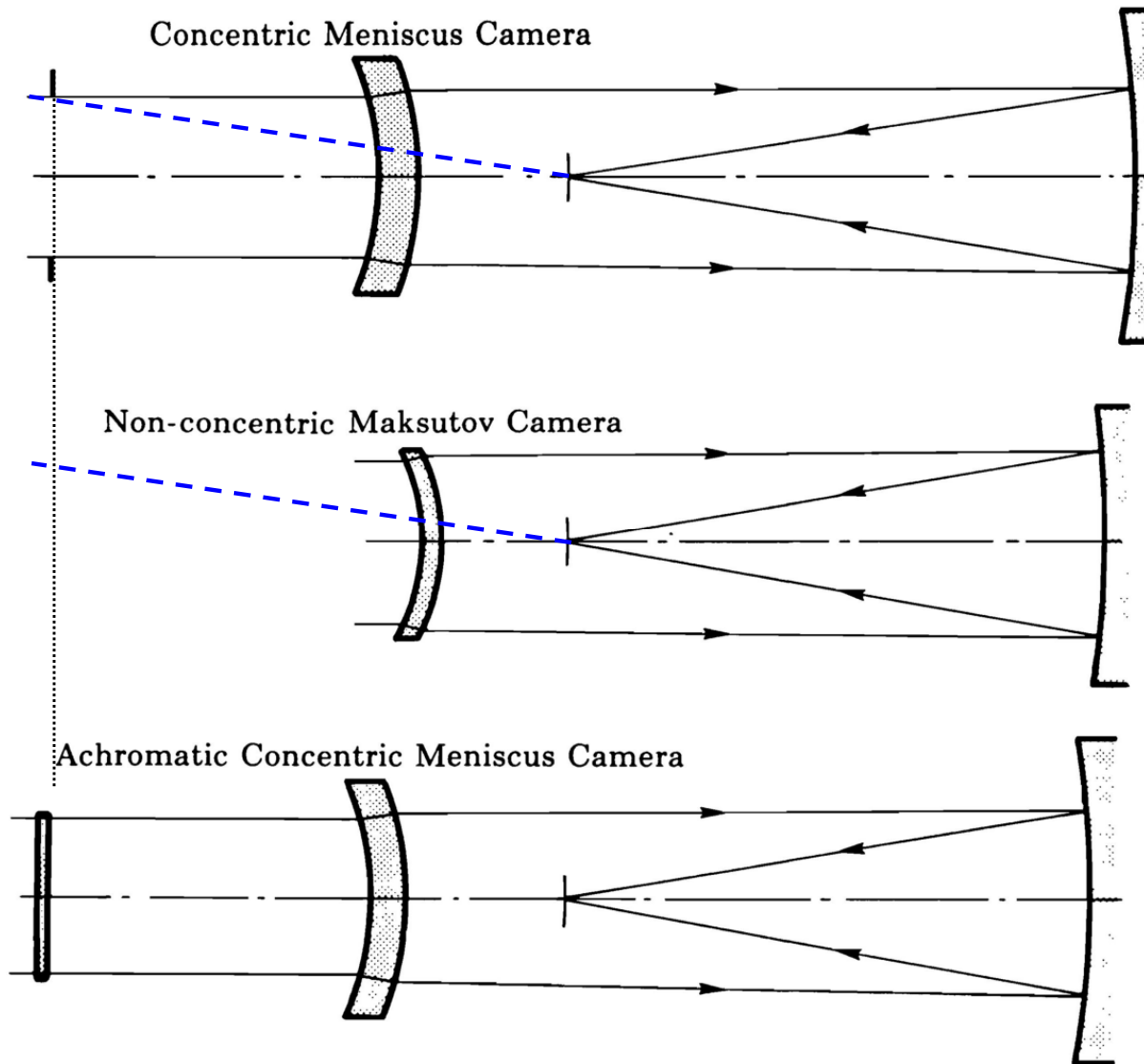
Maksutov – minimalizace barevné
vady za předpokladu :

$$t = (R_1 - R_2) \frac{n_2}{n_2 - 1}$$

nekoncentrický meniskus



Maksutov teleskop- varianty



1.
koncentrický meniskus

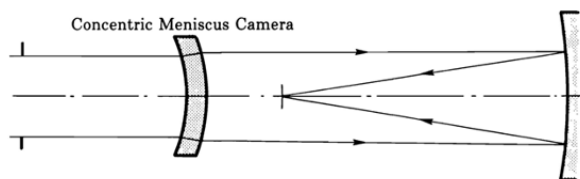
2.
nekoncentrický meniskus

Kompenzace
barevné vady

3.
koncentrický meniskus
+
spojná čočka s malou lámavostí

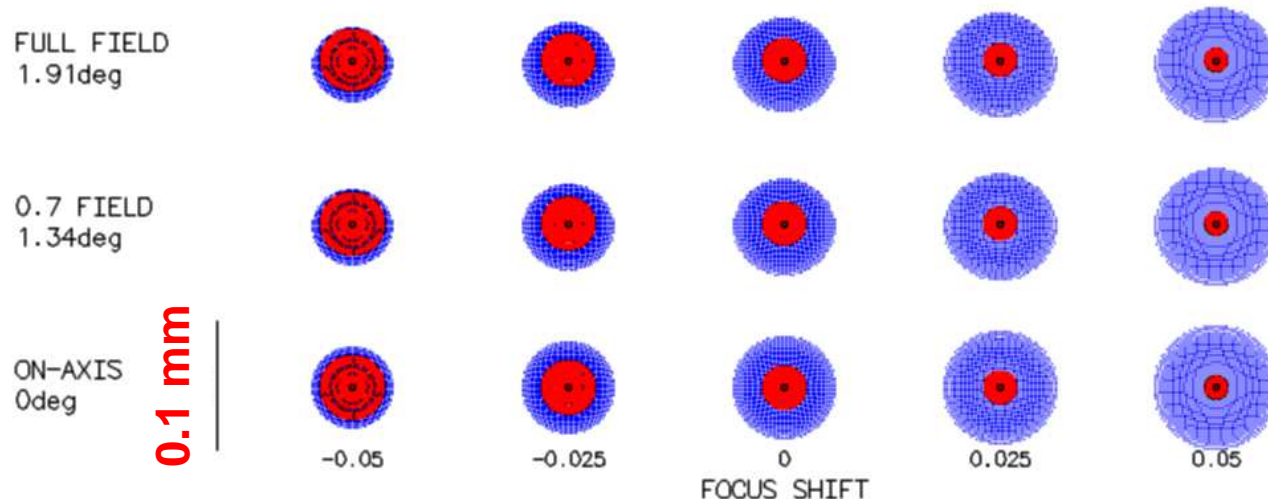


1. Maksutov $D = 200\text{mm}$, $f' = 600\text{ mm}$, $f/3$



koncentrický

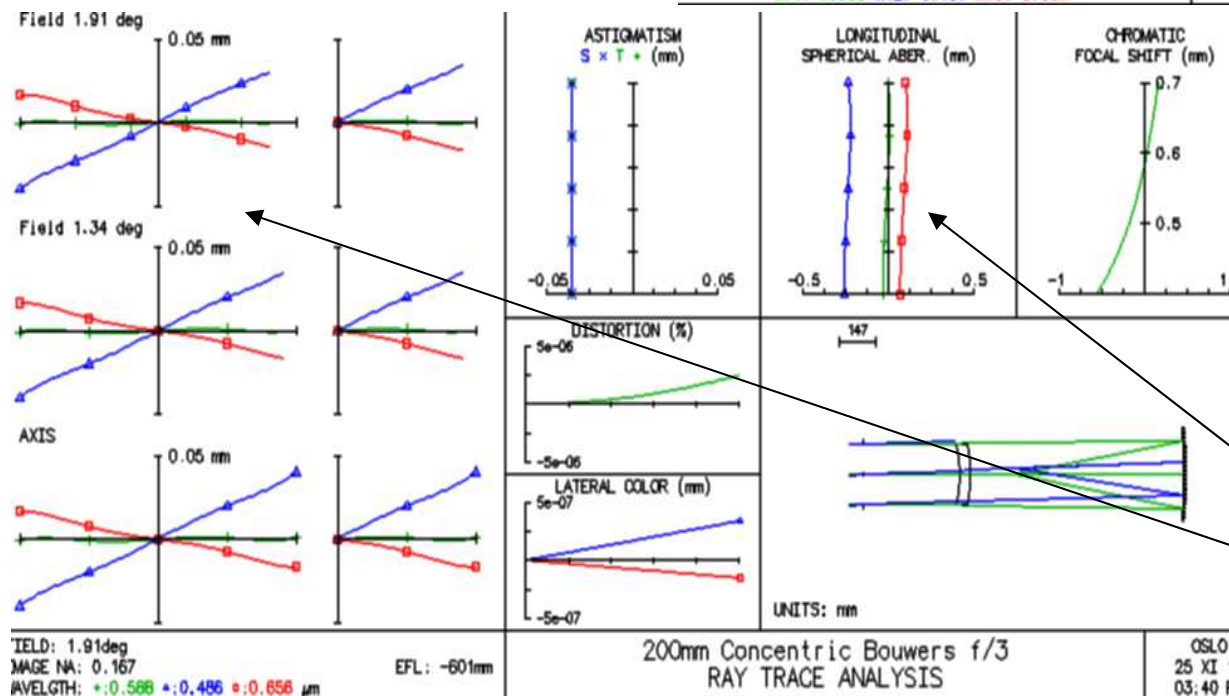
křivost pole $R_f = 600\text{mm}$



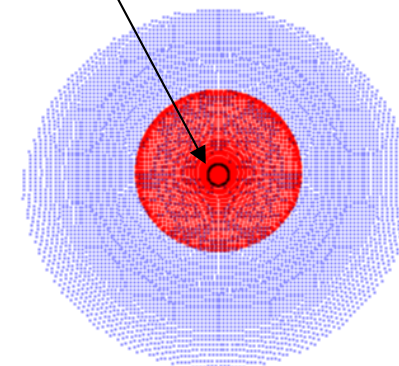
SPOT SIZE & FOCUS SHIFT: UNITS = mm
WAVELENGTHS (μm)
WV1: 0.588 WV2: 0.486 WV3: 0.656

200mm Concentric Bowers f/3
SPOT DIAGRAM ANALYSIS

OSLO
25 XI 11
03:42 PM

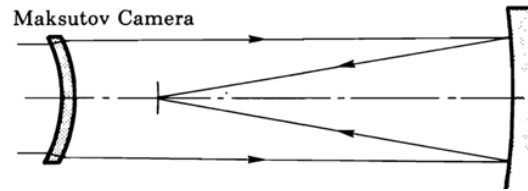


Airyho disk



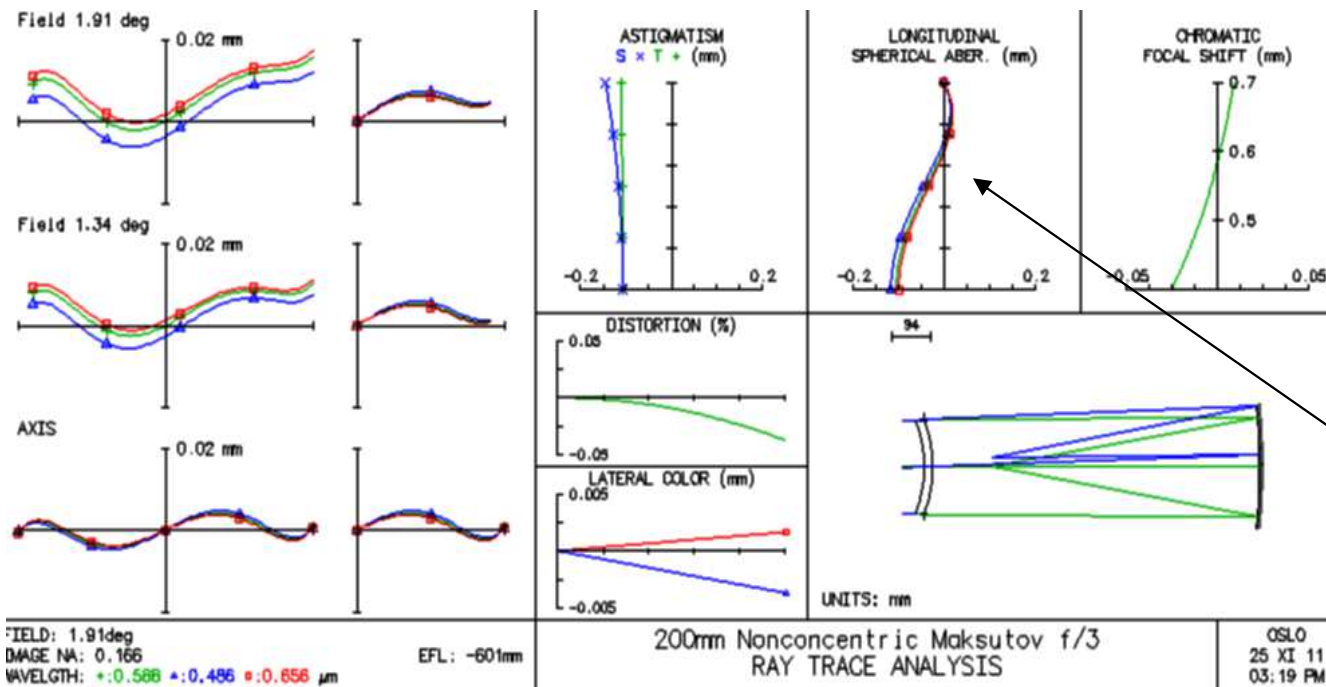
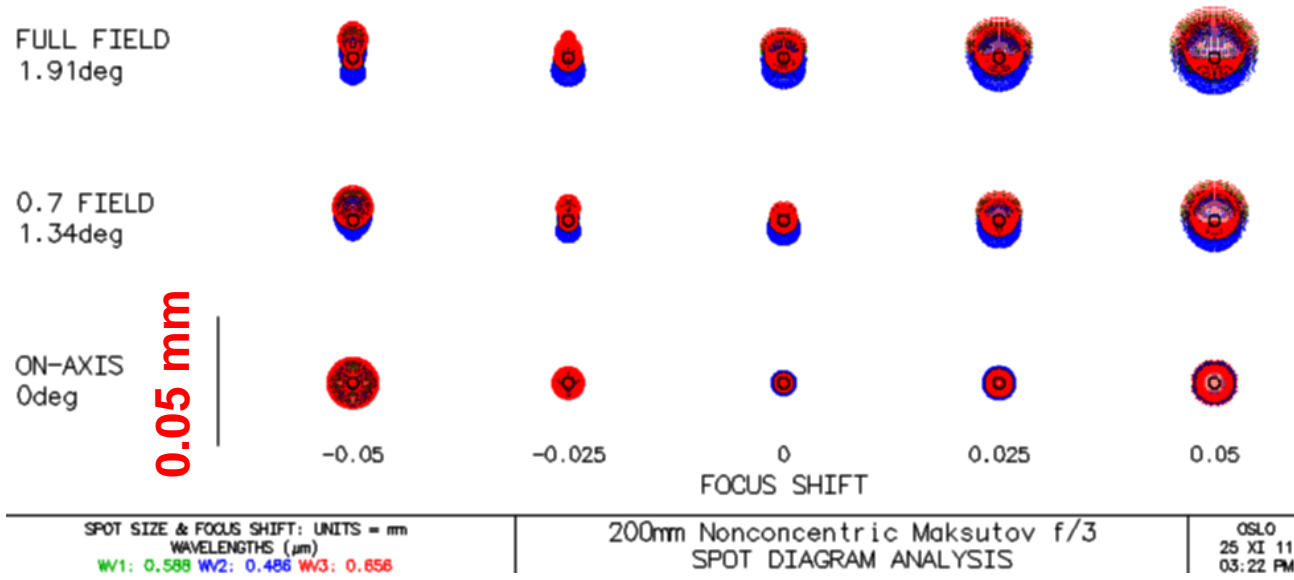
nekorigovaná
barevná vada

2. Maksutov $D = 200\text{mm}$, $f' = 600\text{ mm}$, $f/3$

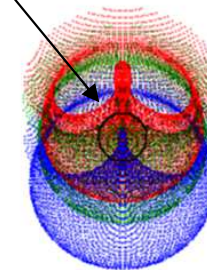


nekoncentrický

křivost pole $R_f = 715\text{mm}$

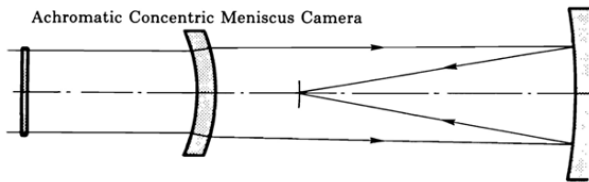


Airyho disk

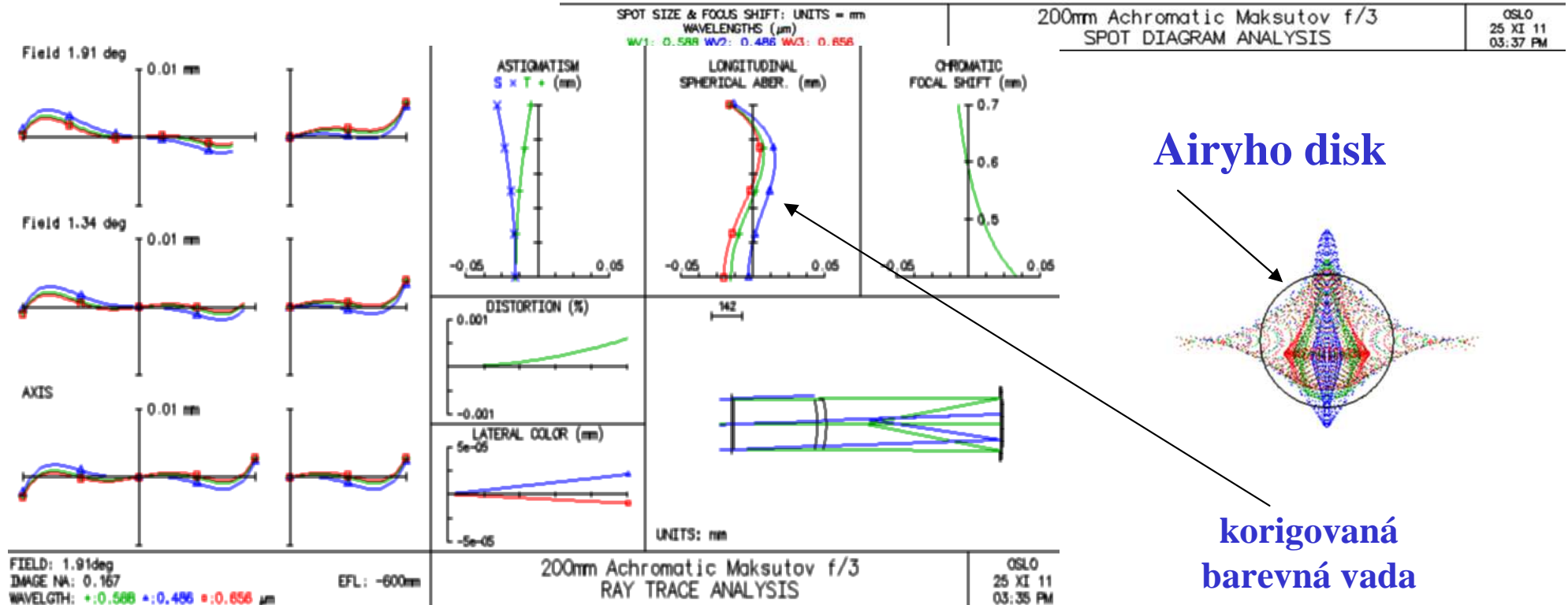
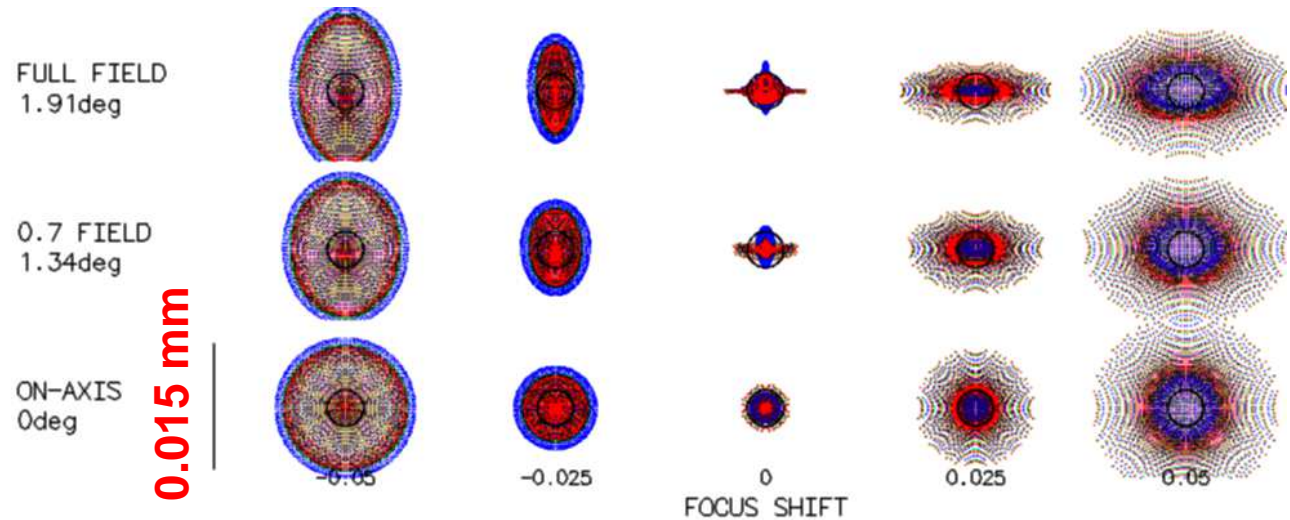


částečně korigovaná
barevná vada

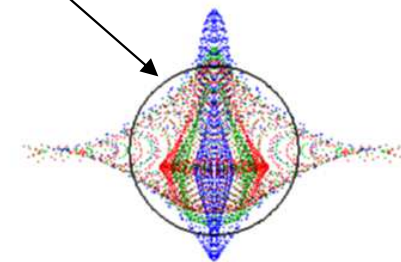
3. Maksutov $D = 200\text{mm}$, $f' = 600\text{ mm}$, $f/3$



koncentrický + spojka
křivost pole $R_f = 640\text{mm}$

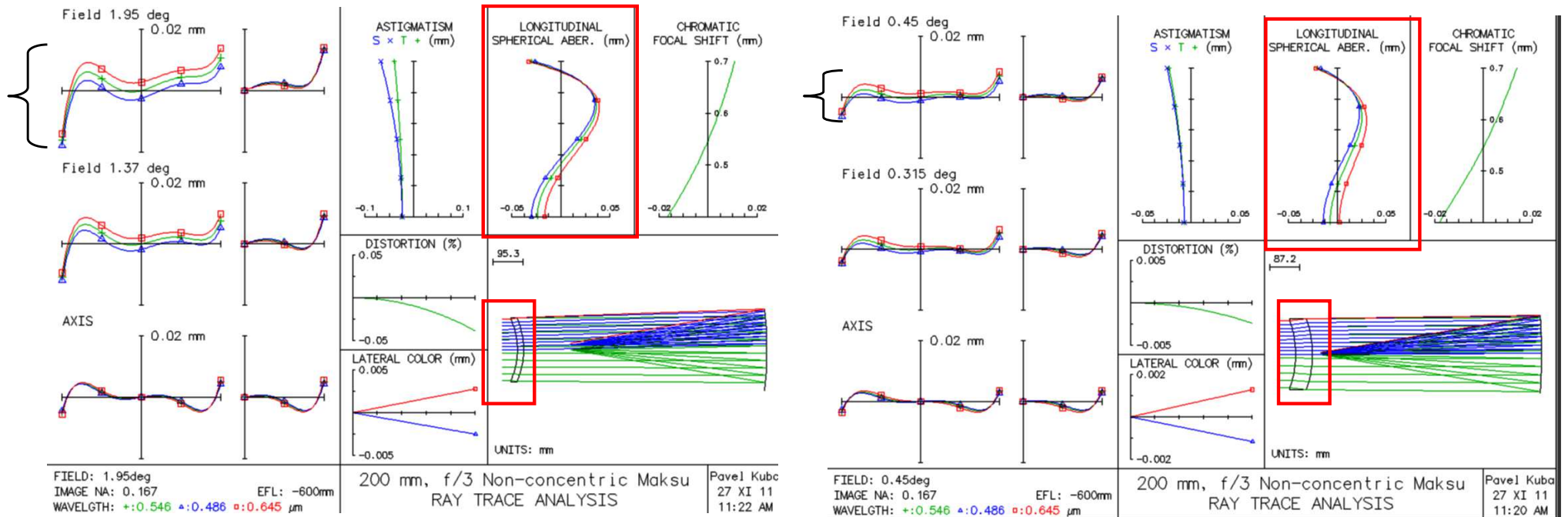


Airyho disk

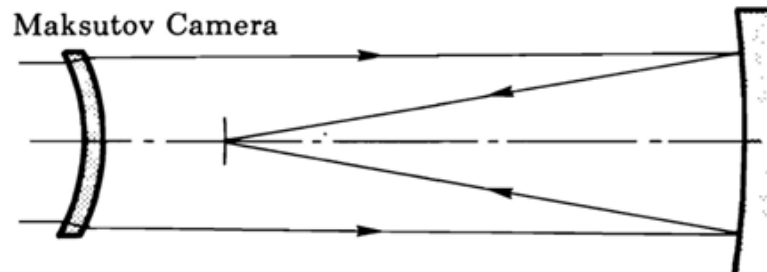


korigovaná barevná vada

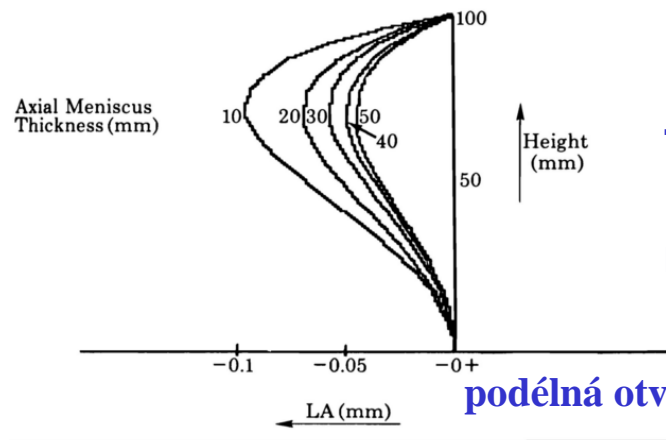
Maksutov teleskop – otvorová vada



nekoncentrický



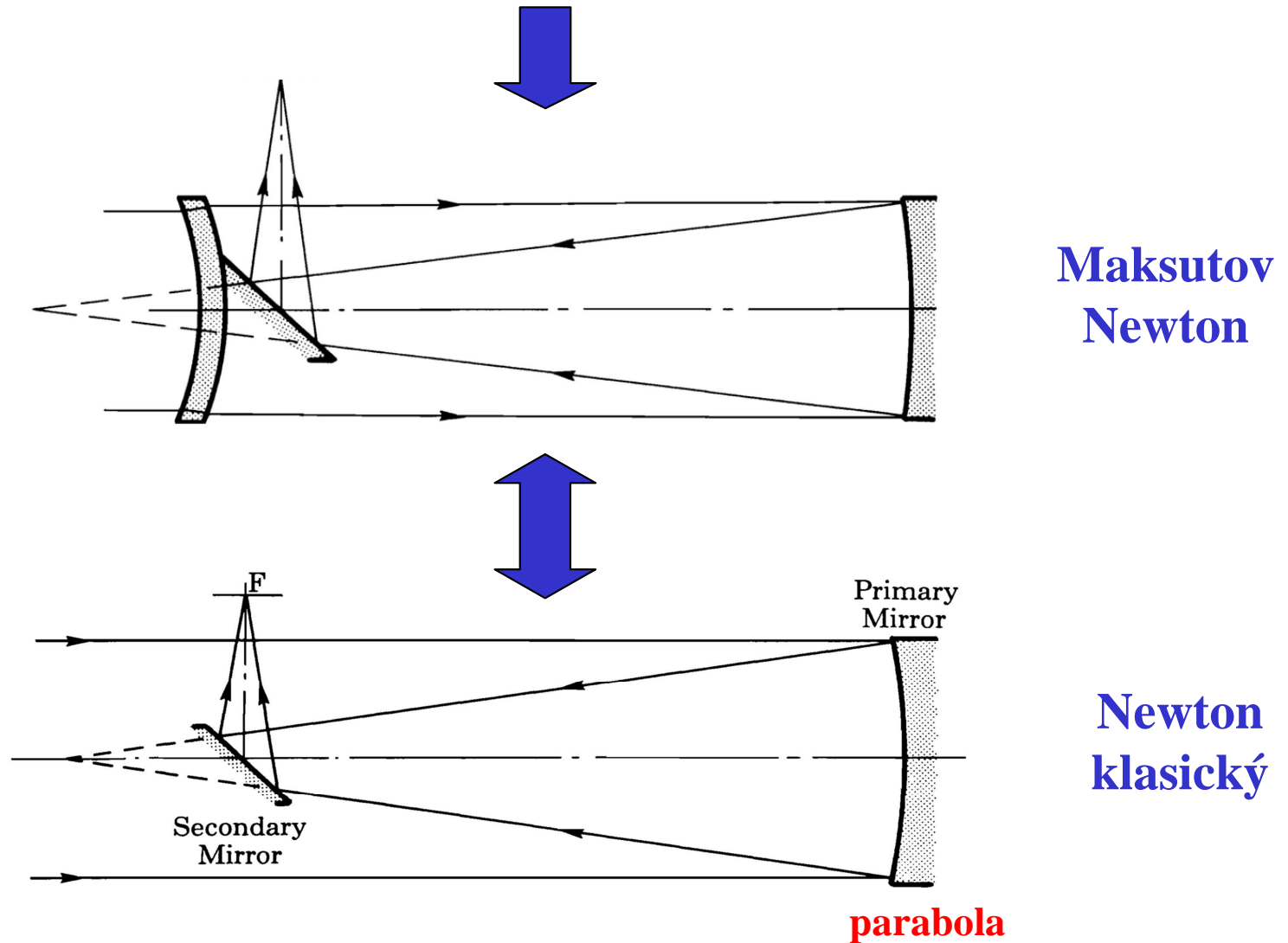
$t = 20 \text{ mm}$ \longrightarrow $t = 50 \text{ mm}$



Telescope optics
Evaluation and design
H.Rutten, M.van Venrooij

Maksutov - Newton teleskop

Podobně jako Schmidt také Maksutov má Schmidt má špatně přístupnou obrazovou „rovinu“ .

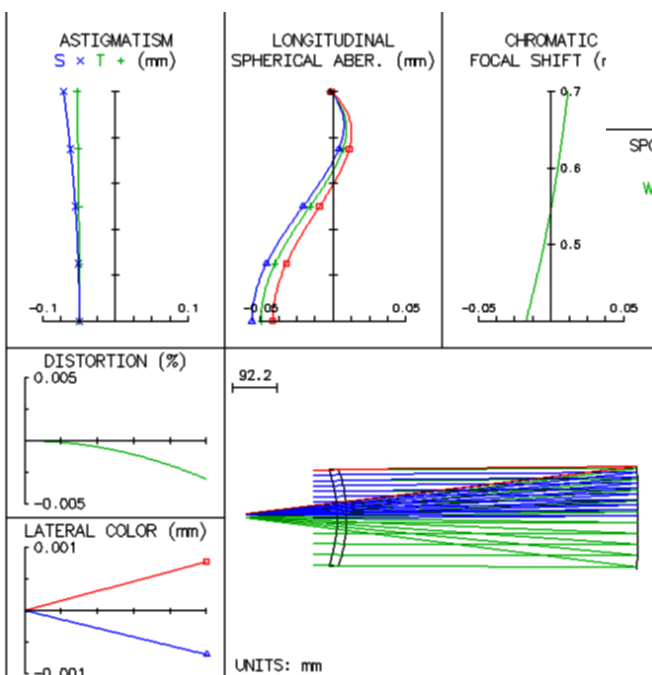
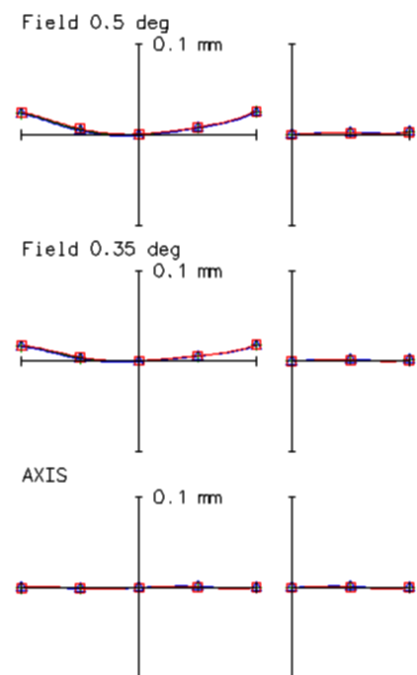
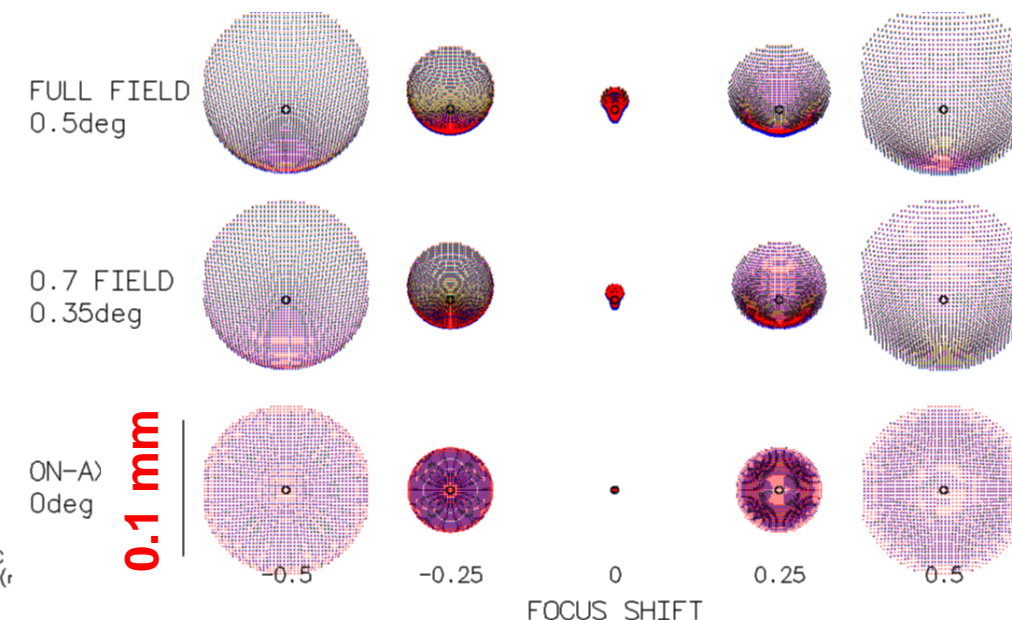


Maksutov-Newton $D = 200\text{mm}$, $f' = 800\text{ mm}$, $f/4$

Barevné vady nenulové



Meniskus čočka



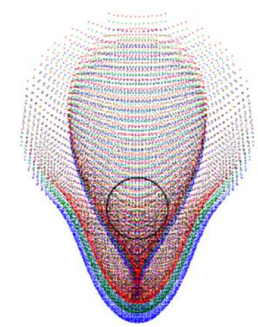
FIELD: 0.5deg
 IMAGE NA: 0.125
 WAVELGTH: +:0.546 μm :0.486 μm :0.645 μm
 EFL: -800mm

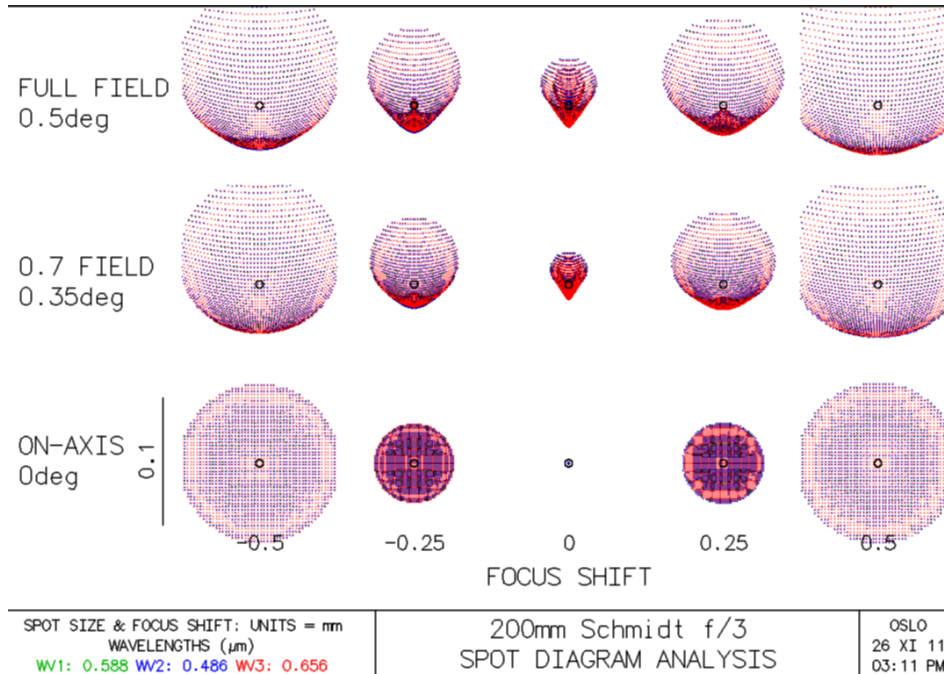
200 mm, f/4 Maksutov-Newtonian T
 RAY TRACE ANALYSIS

Pavel Kuba
 27 XI 11
 11:46 AM

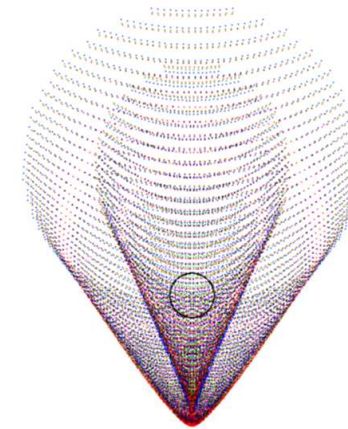
200 mm, f/4 Maksutov-Newtonian
 SPOT DIAGRAM ANALYSIS
 Pavel Kuba
 27 XI 11
 11:48 AM

Airyho disk

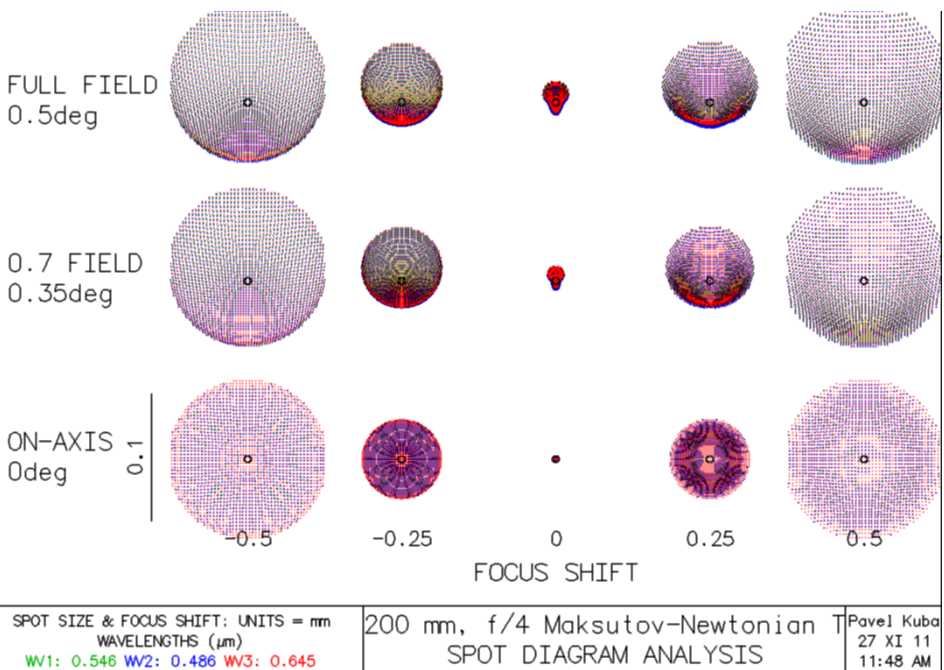
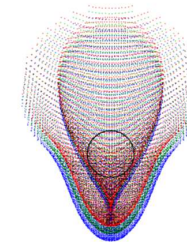




Schmidt-Newton
 $D = 200\text{mm}$, $f' = 800\text{ mm}$, $f/4$



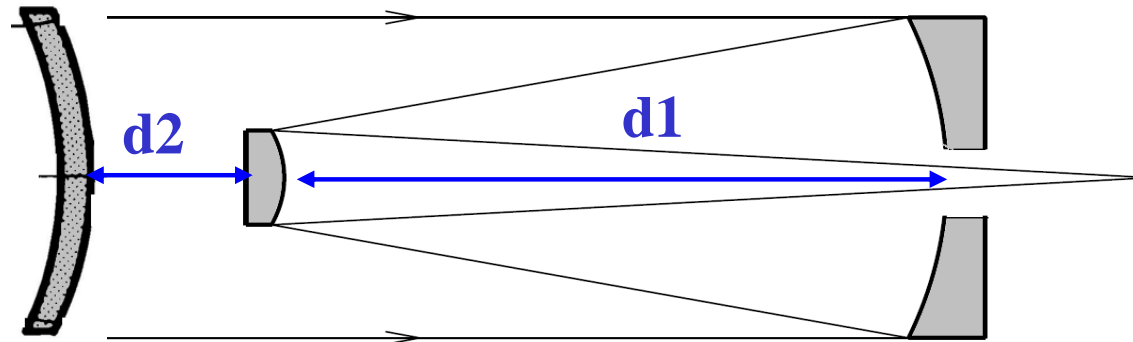
Maksutov-Newton
 $D = 200\text{mm}$, $f' = 800\text{ mm}$, $f/4$



**Druhé řešení má cca poloviční
 zbytkovou aberaci - komu**

Maksutov - Cassegrain

Kombinace Cassegrain + menisková čočka



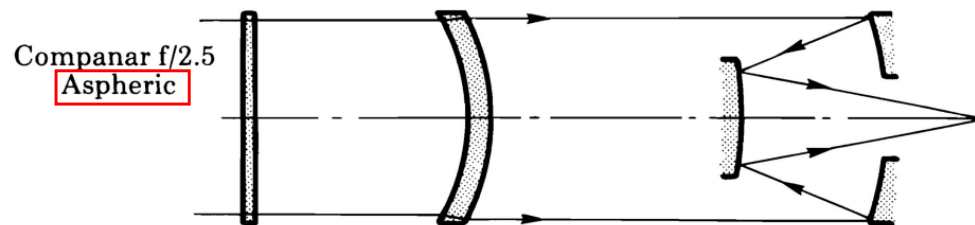
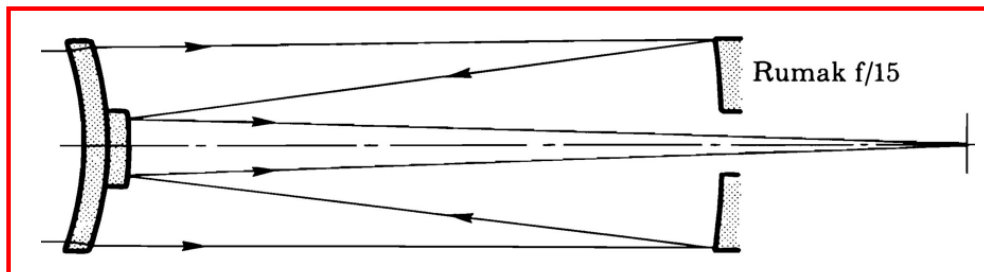
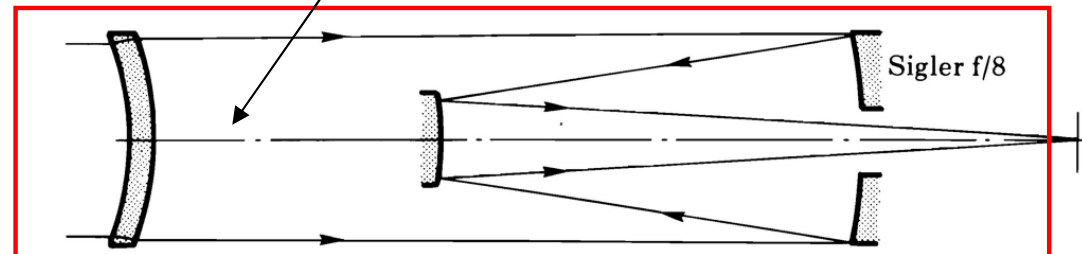
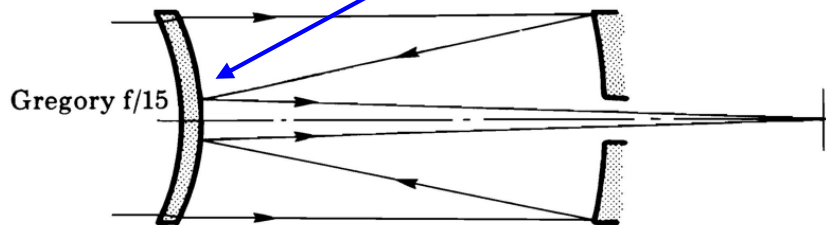
Existuje větší množství konstrukčních variant než u Cassegrainu díky další možné mezeře mezi meniskem a sekundárním zrcadlem (d_1, d_2).

Obě zrcadla i plochy menisku bývají sférická, pro menší clonová čísla než $f/8$, $f/4$ je nutné aby byly některé plochy asférické.

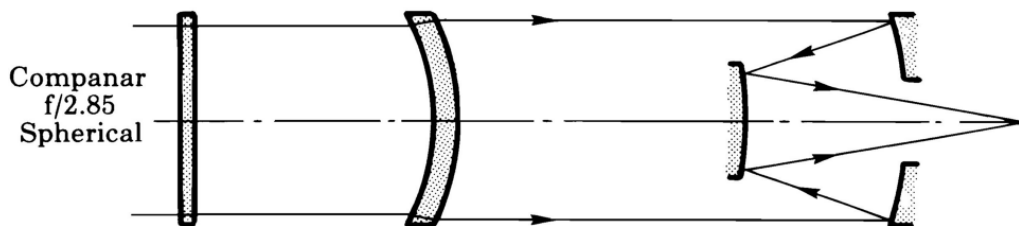
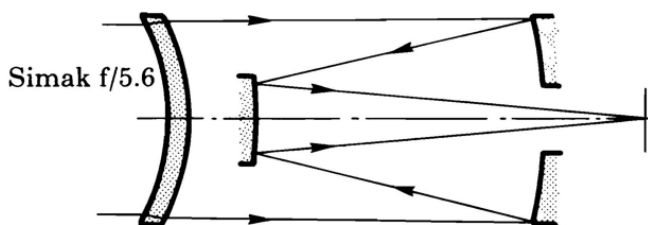
Maksutov- Cassegrain - varianty

Nejjednodušší – zrcadlová vrstva na čočce
– velká koma a astigmatismus

délka – lepší korekce



tmeleno

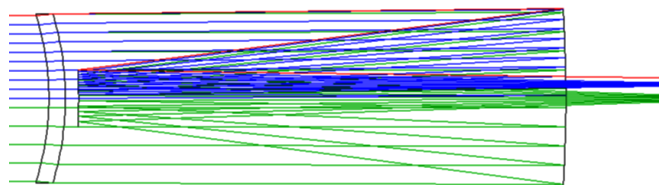


Telescope optics Evaluation and design

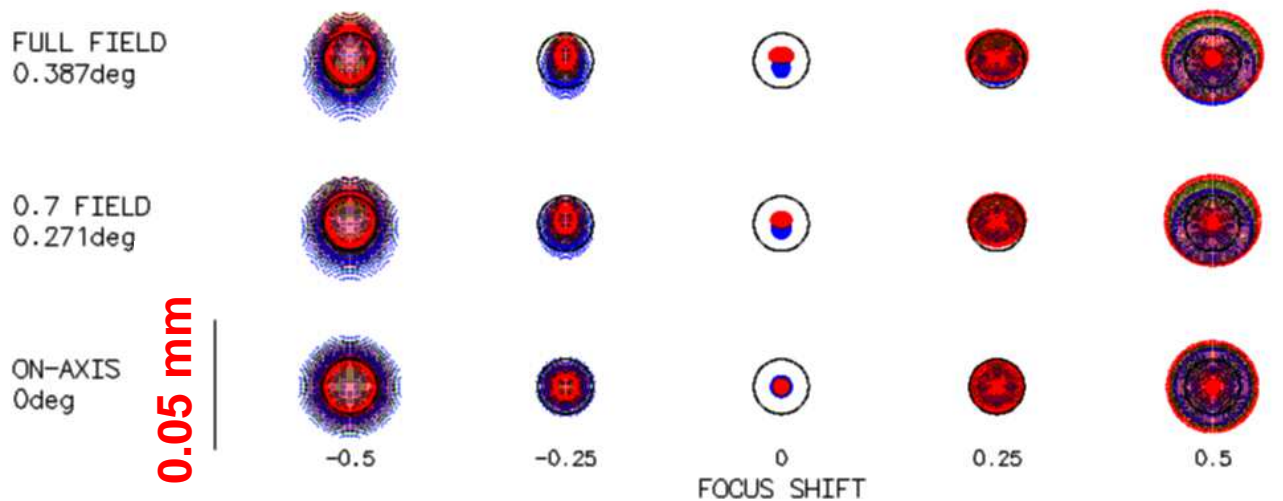
H.Rutten, M.van Venrooij

Maksutov-Cassegrain $D = 200\text{mm}$, $f' = 3000\text{ mm}$, $f/15$

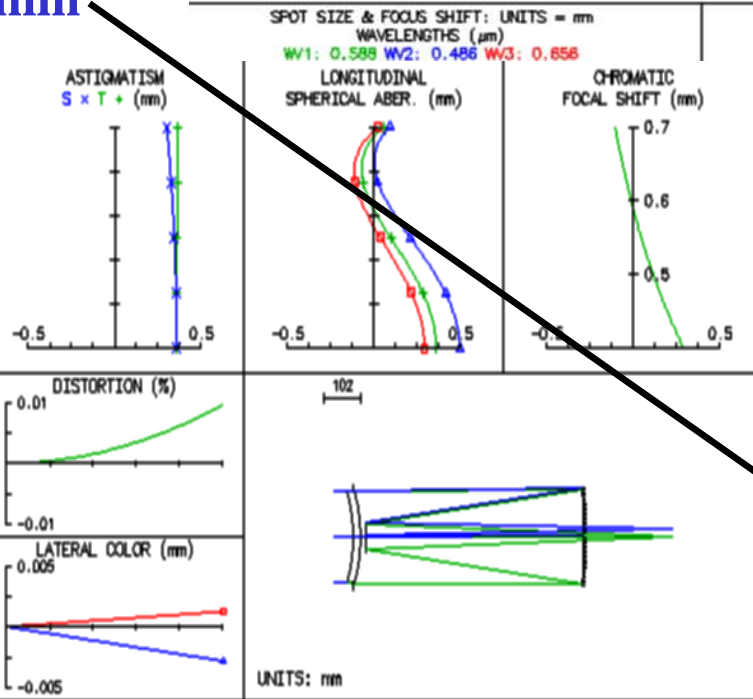
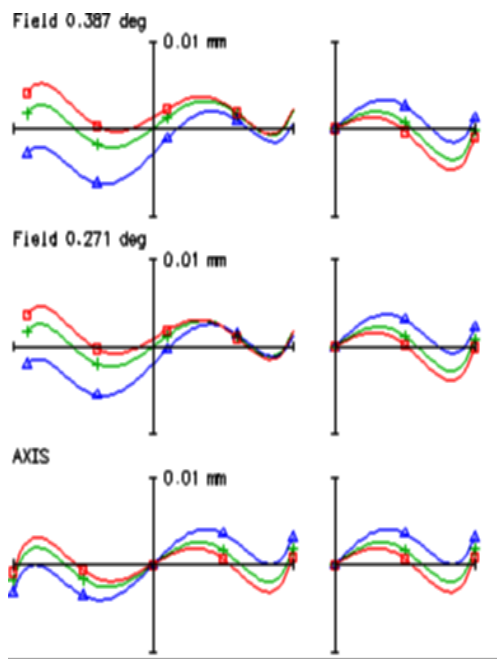
Rumak



1. zrcadlo – koule
2. zrcadlo - koule

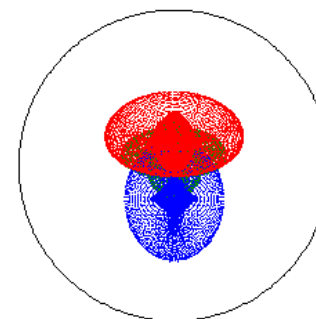


křivost pole $R_f = 620\text{mm}$



200mm Rumak f/15
SPOT DIAGRAM ANALYSIS
OSLO
25 XI 11
02:56 PM

Airyho disk



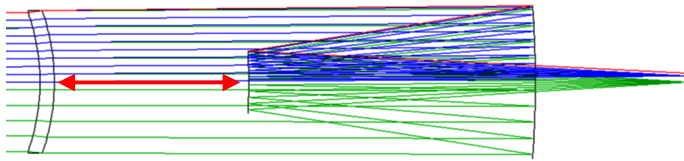
visuální

FIELD: 0.387deg
WAVE NA: 0.0337
AVELGTH: +:0.588 -:0.486 :0.656 μm
EFL: 2.96e+03mm

200mm Rumak f/15
RAY TRACE ANALYSIS
OSLO
25 XI 11
02:54 PM

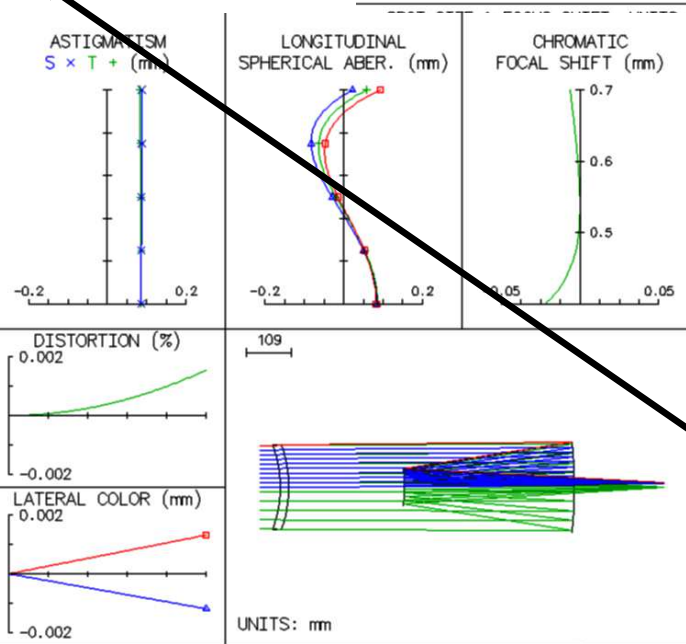
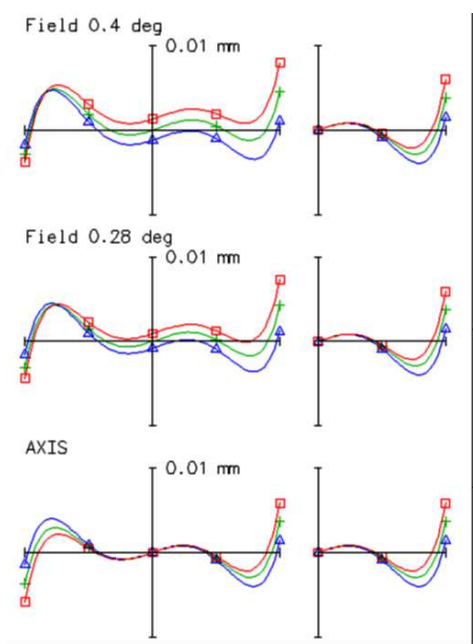
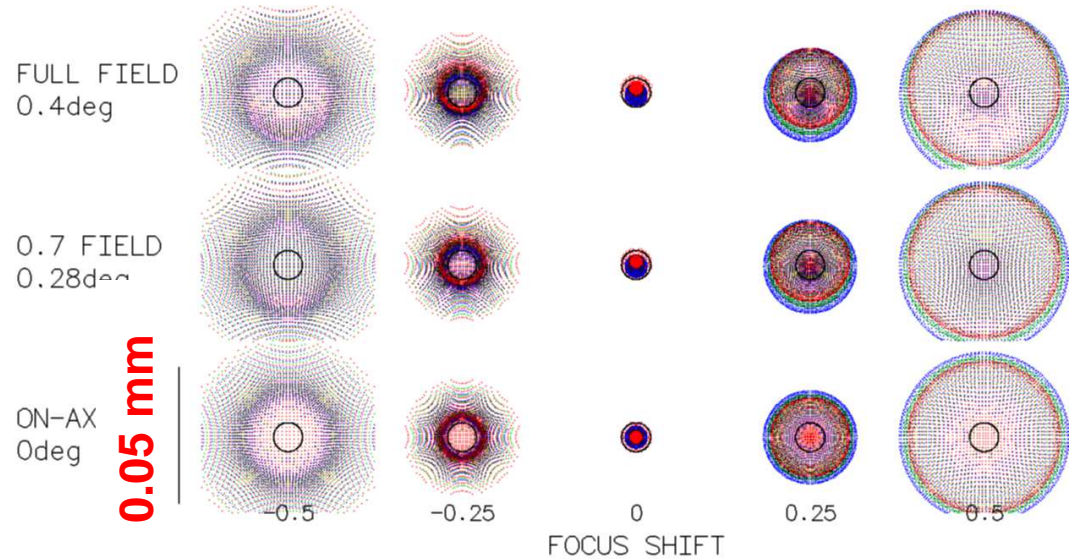
Maksutov-Cassegrain $D = 200\text{mm}$, $f' = 1600\text{ mm}$, $f/8$

Sigler



1. zrcadlo – koule
2. zrcadlo - koule

křivost pole $R_f = 1152\text{mm}$

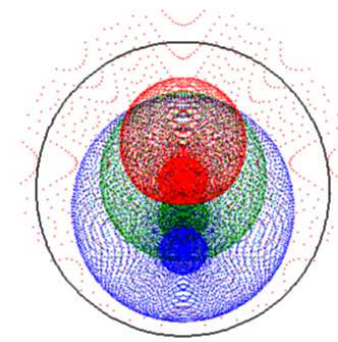


FIELD: 0.4deg
 IMAGE NA: 0.0627
 WAVELGTH: +:0.546 -:0.486 -:0.645 μm
 EFL: 1.6e+03mm

200 mm, f/8 Sigler Maksutov-Cass
 RAY TRACE ANALYSIS
 Pavel Kubc
 27 XI 11
 01:52 PM

200 mm, f/8 Sigler Maksutov-Cass
 SPOT DIAGRAM ANALYSIS
 Pavel Kuba
 27 XI 11
 01:46 PM

Airyho disk



„fotografie“

Korekční triplet, dublet – Houghton.

Houghton

Lurie's - Houghton

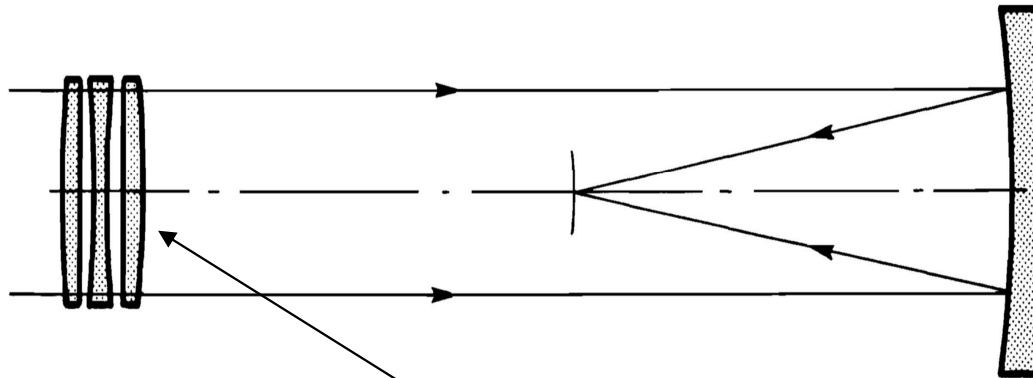
Houghton – Newton

Houghton - Cassegrain

Houghton teleskop

princip

asferická korekční deska je náročná na výrobu → triplet, dublet



eliminace komy clonou
v poloměru křivosti
zrcadla

stále křivost pole

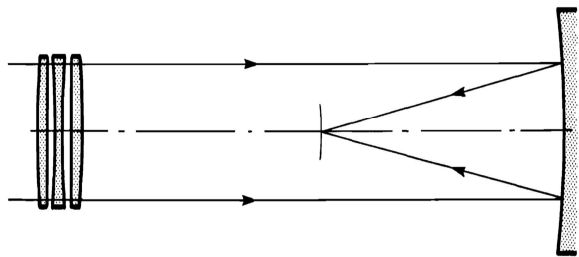
Všechny optické plochy jsou kulové

Triplet je afokální – nemá žádnou lámavost.

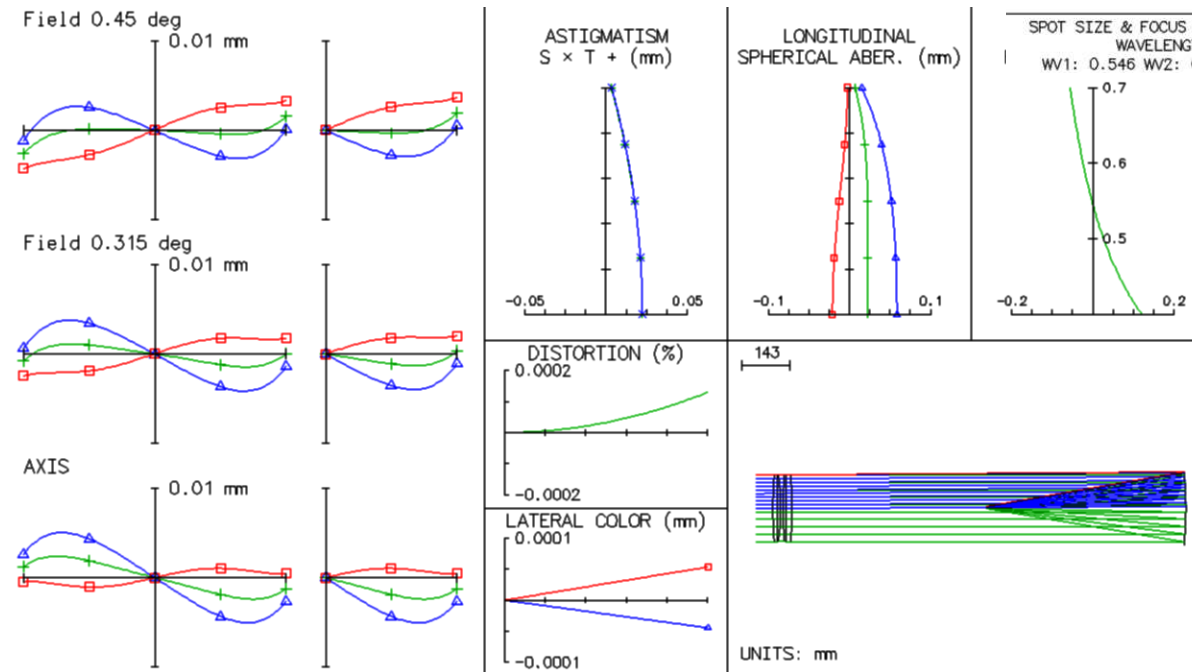
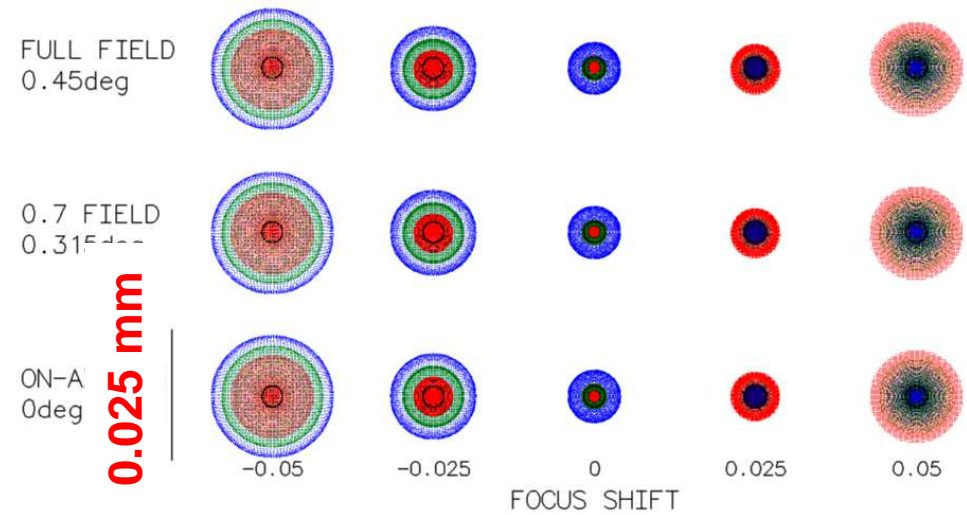
Má podkorigovanou otvorovou vadu (jako rozptylná čočka) pro kompenzaci otvorové vady kulového zrcadla. Všechny čočky jsou ze stejného materiálu – optické sklo jako BK7. Afokální design = korekce barevné vady.

Stejně dlouhá stavba jako u Schmidtova řešení – triplet ve středu křivosti zrcadla

Buchroeder - Houghton $D = 200\text{mm}$, $f' = 600\text{ mm}$, $f/3$



křivost pole $R_f = 600\text{mm}$



FIELD: 0.45deg
 IMAGE NA: 0.166
 WAVELENGTH: +:0.546 - :0.486 - :0.656 μm
 EFL: -602mm

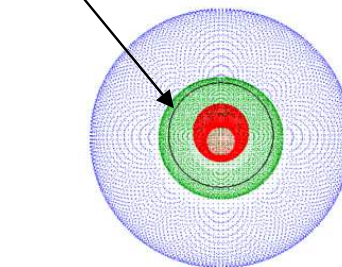
200 mm, $f/3$ Buchroeder Houghton
 RAY TRACE ANALYSIS

Pavel Kubc
 28 XI 11
 10:48 AM

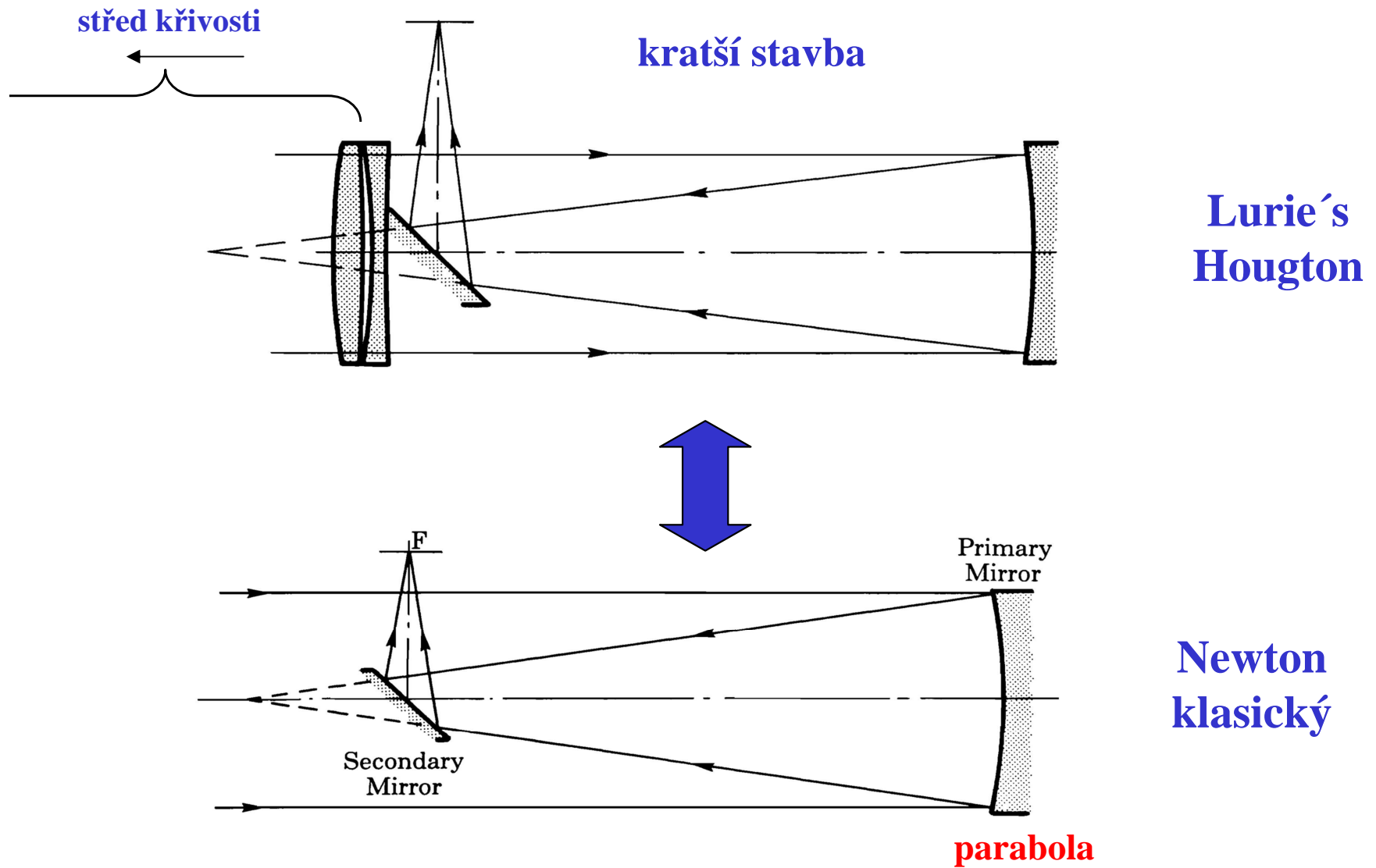
200 mm, $f/3$ Buchroeder Houghton
 SPOT DIAGRAM ANALYSIS

Pavel Kubc
 28 XI 11
 10:53 AM

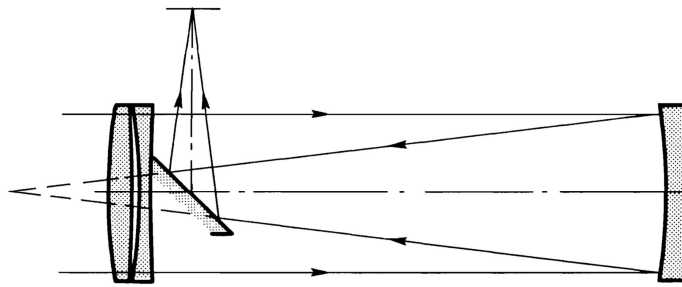
Airyho disk



Lurie's - Houghton (Newton) teleskop

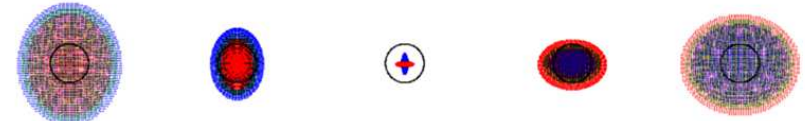


Lurie's - Houghton $D = 200\text{mm}$, $f' = 800\text{ mm}$, $f/4$

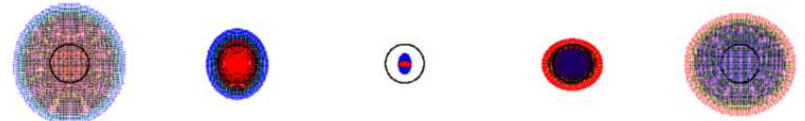


křivost pole $R_f = 2865\text{mm}$

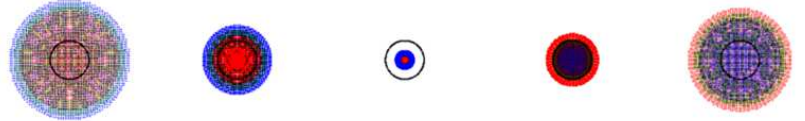
FULL FIELD
0.45deg



0.7 FIELD
0.315deg



ON-A)
0deg



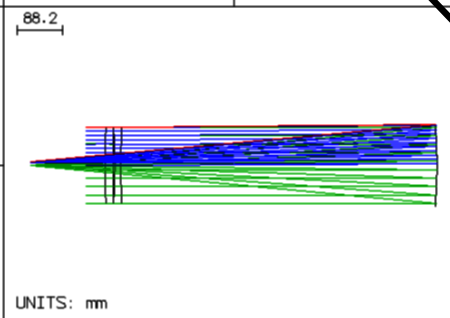
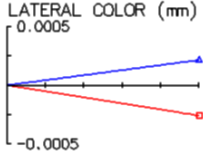
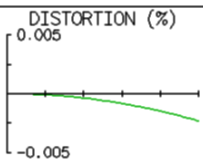
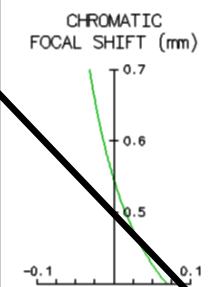
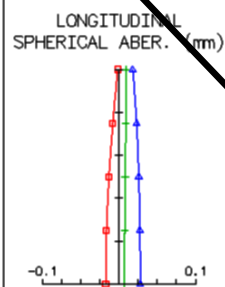
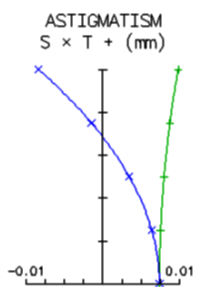
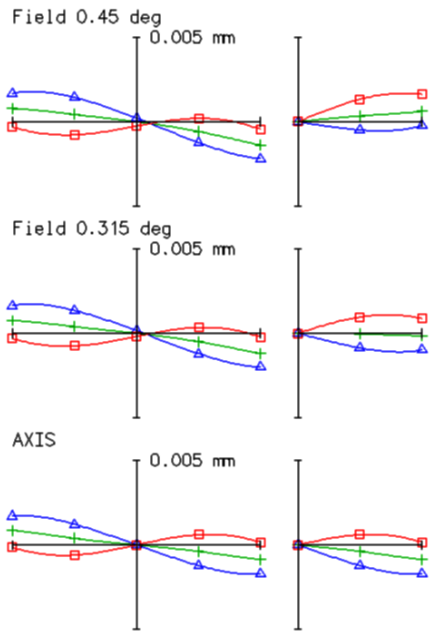
0.025 mm

FOCUS SHIFT

SHIFT: UNITS = mm
STHS (μm)
0.486 W3: 0.656

200mm, f/4 Lurie Houghton Telesc
SPOT DIAGRAM ANALYSIS

Pavel Kuba
28 XI 11
11:02 AM

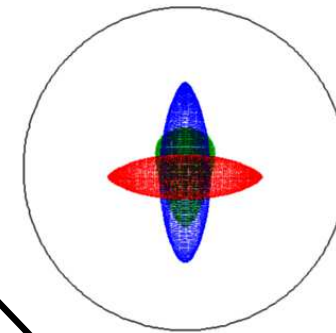


FIELD: 0.45deg
IMAGE NA: 0.0937
WAVELGTH: +:0.546 μ:0.486 μ:0.656 μm

200mm, f/4 Lurie Houghton Telesc
RAY TRACE ANALYSIS

Pavel Kuba
28 XI 11
11:00 AM

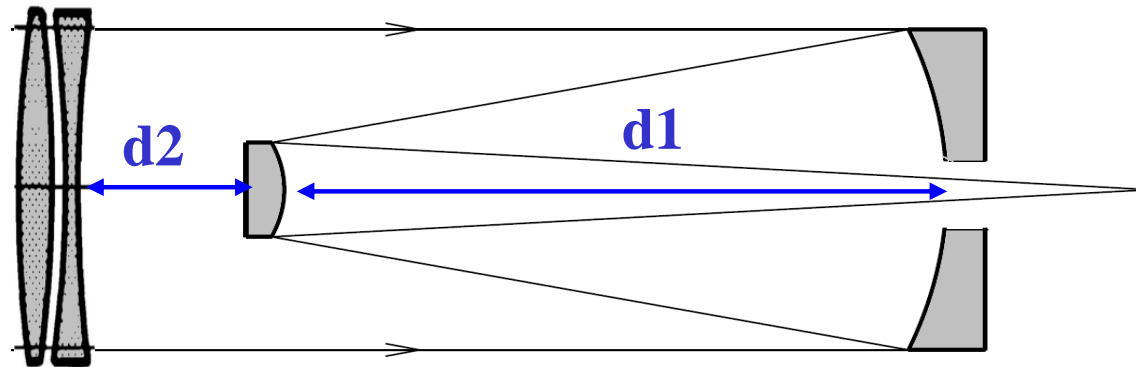
Airyho disk



fotografie

Houghton - Cassegrain

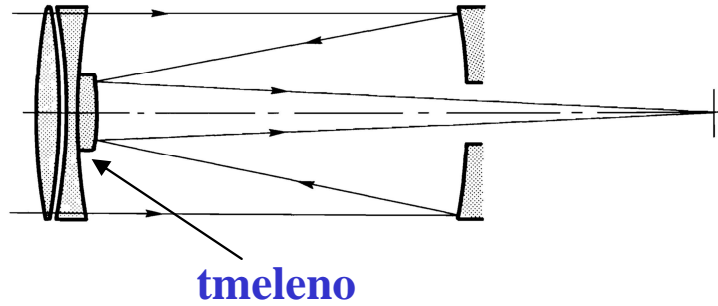
Kombinace Cassegrain + dublet



Existuje větší množství konstrukčních variant než u Cassegrainu díky další možné mezeře mezi dubletem a sekundárním zrcadlem (d_1, d_2).

Obě zrcadla i plochy dubletu bývají sférická, pro menší clonová čísla než $f/8$, $f/4$ je nutné aby byly některé plochy asférické.

Houghton - Cassegrain D = 200mm, f' = 2000 mm, f/10



křivost pole $R_f = 444\text{mm}$

FULL FIELD
0.45deg



0.7 FIELD
0.315deg



ON-AX
0deg



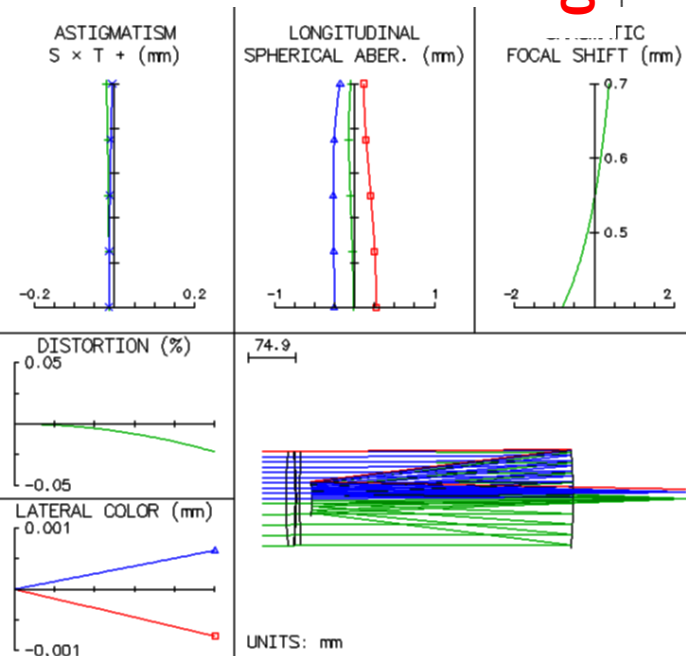
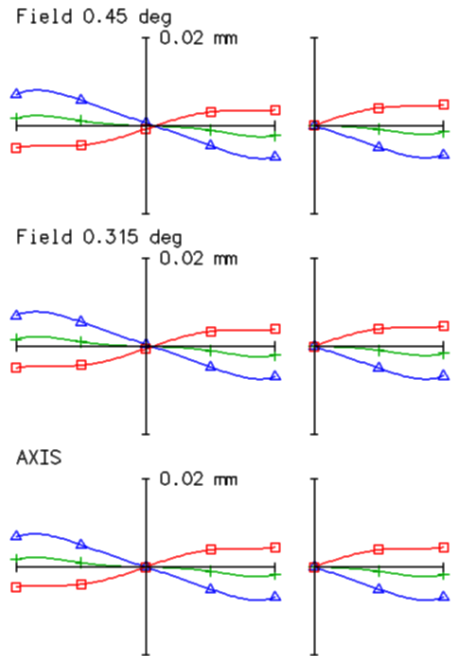
0.05 mm

FOCUS SHIFT

UNITS = mm
n) 200 mm, f/10 Compact Houghton Ca
MV3: 0.656

SPOT DIAGRAM ANALYSIS

Pavel Kuba
28 XI 11
11:34 AM

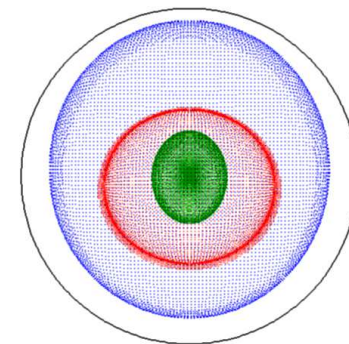


FIELD: 0.45deg
IMAGE NA: 0.0381
WAVELGTH: +:0.546 -:0.486 :0.656 μm

200 mm, f/10 Compact Houghton Ca
RAY TRACE ANALYSIS

Pavel Kuba
28 XI 11
11:30 AM

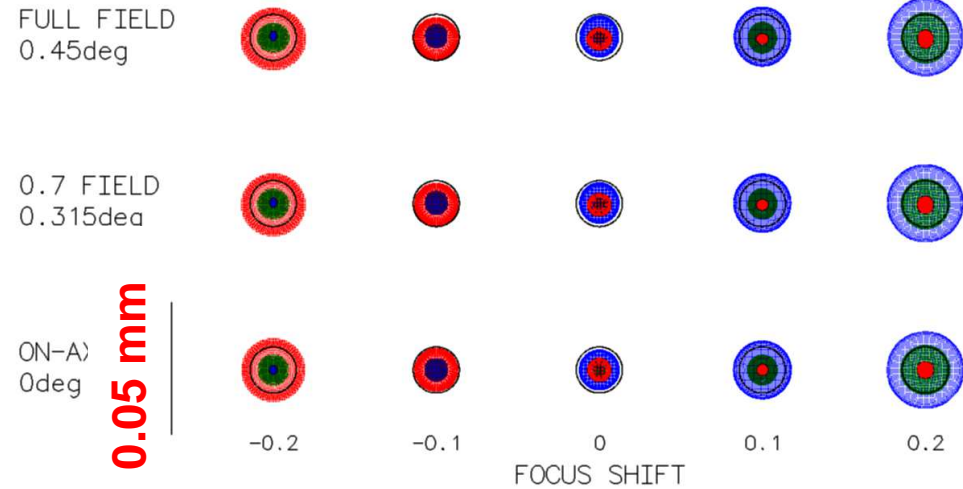
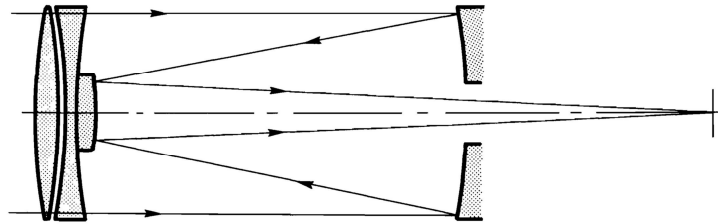
Airyho disk



barevná vada

Houghton - Cassegrain

$D = 200\text{mm}, f' = 2000\text{ mm}, f/10$

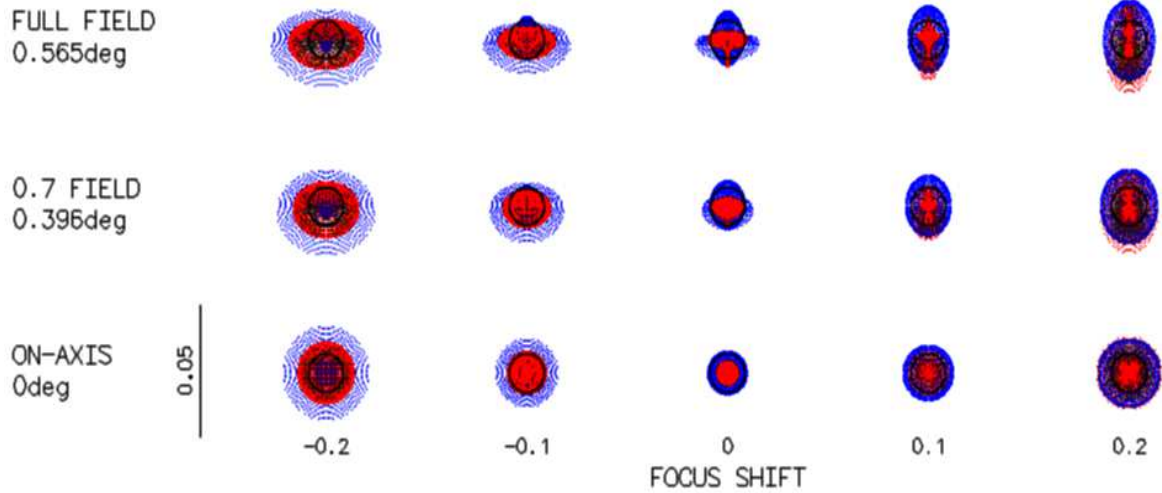


SPOT SIZE & FOCUS SHIFT: UNITS = mm
 WAVELENGTHS (μm)
 W1: 0.546 W2: 0.486 W3: 0.656

200 mm, f/10 Compact Houghton Ca

SPOT DIAGRAM ANALYSIS

Pavel Kuba
 28 XI 11
 11:34 AM



SPOT SIZE & FOCUS SHIFT: UNITS = mm
 WAVELENGTHS (μm)
 W1: 0.588 W2: 0.486 W3: 0.656

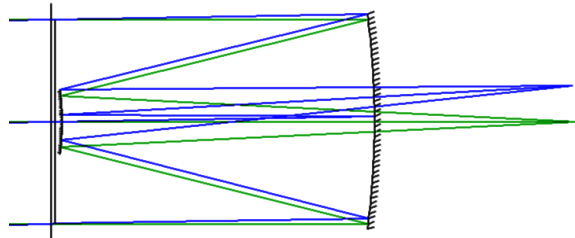
200mm Schmidt Cassegrain f/10

SPOT DIAGRAM ANALYSIS

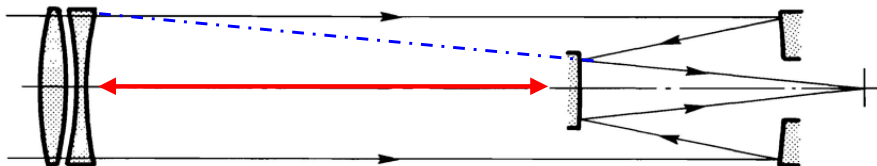
OSLO
 25 XI 11
 02:31 PM

Schmidt - Cassegrain

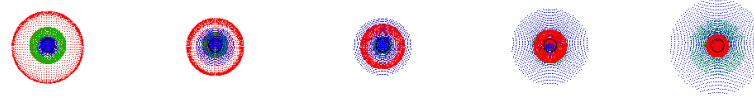
$D = 200\text{mm}, f' = 2000\text{ mm}, f/10$



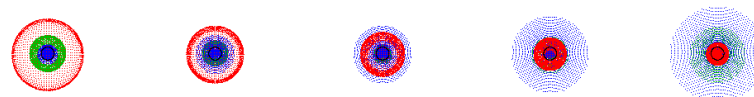
Houghton - Cassegrain D = 200mm, f' = 1060 mm, f/5.3



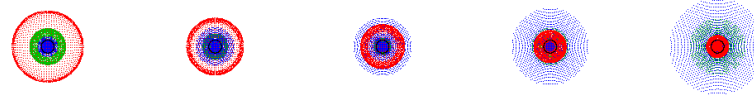
FULL FIELD
0.45deg



0.7 FIELD
0.315deg



ON-AX
0deg

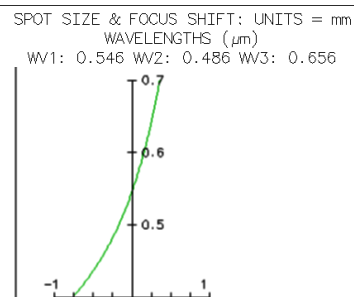
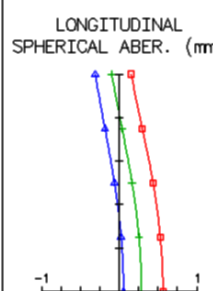
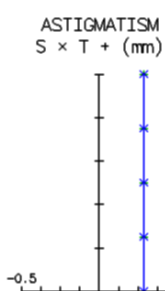
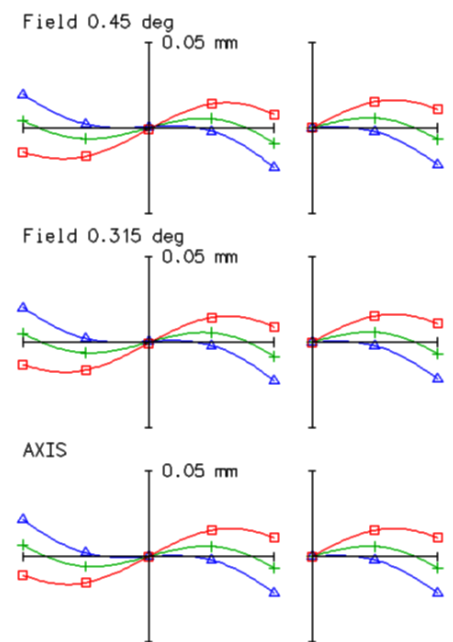


0.1 mm

-0.2 -0.1 0 0.1 0.2

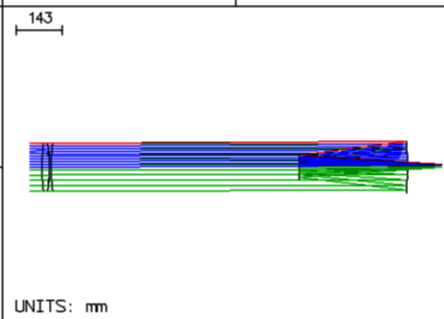
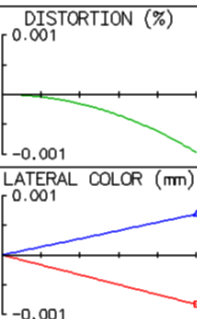
FOCUS SHIFT

křivost pole - rovinné
fotografie



200 mm, f/5.3 Non-compact Houghton
SPOT DIAGRAM ANALYSIS

Pavel Kubc
28 XI 11
12:26 PM

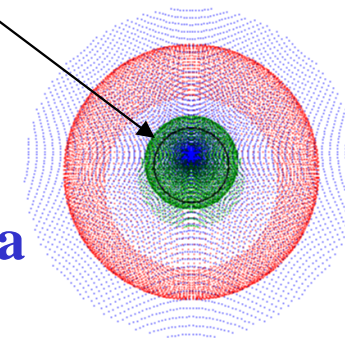


FIELD: 0.45deg
IMAGE NA: 0.0699
WAVLENGTHS: +:0.546 μ:0.486 μ:0.656 μm

200 mm, f/5.3 Non-compact Houghton
RAY TRACE ANALYSIS

Pavel Kuba
28 XI 11
12:05 PM

Airyho disk



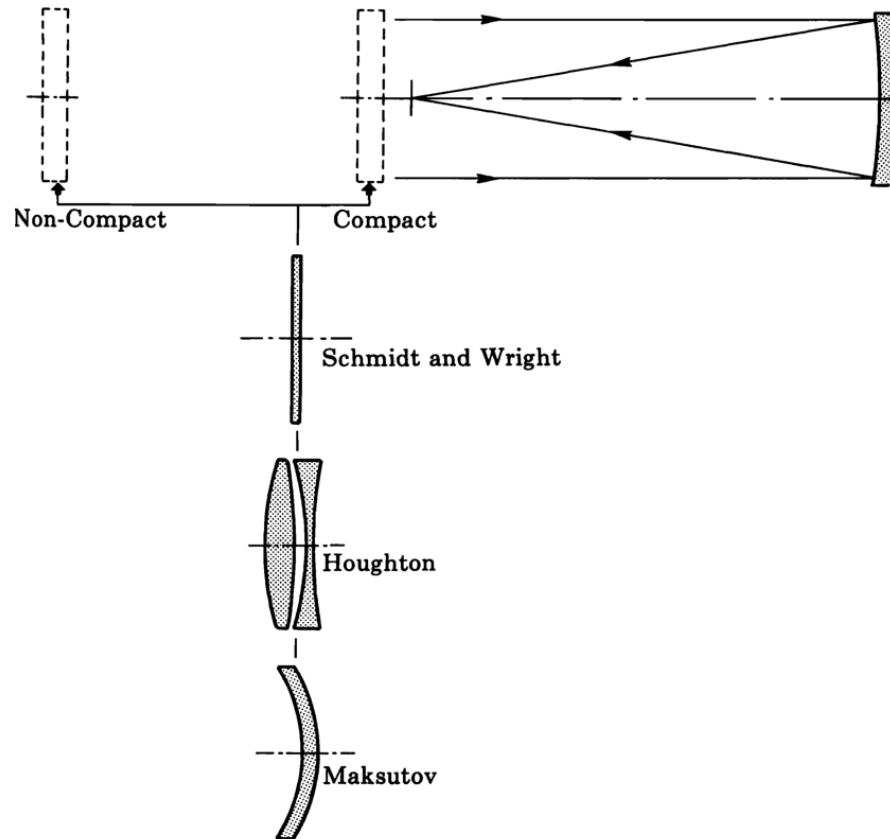
větší
barevná vada



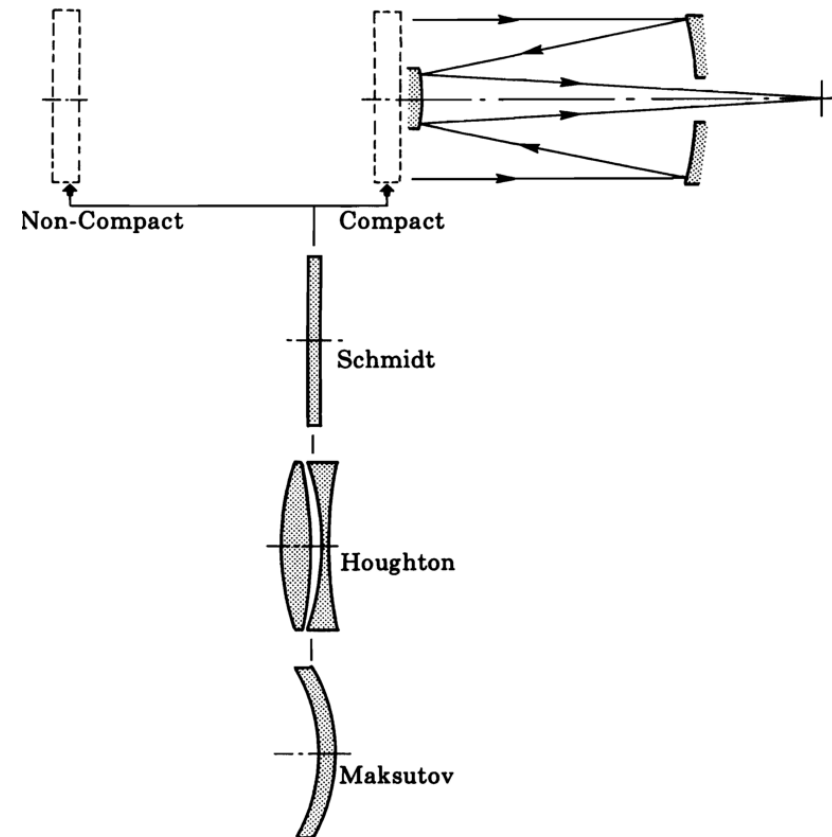
kombinace skel

Zrcadlo-čočkové teleskopy (katadioptrické) kombinace

jedno zrcadlo



dvě zrcadla



Zrcadlo-čočkové teleskopy (katadioptrické) shrnutí

Výhody:

- kombinace výhod čočkových a zrcadlových teleskopů
- uzavřený tubus = bez problémů s prostředím,
- kompaktní konstrukce, jednoduchá údržba,
- kvalitní obraz s velkým zorným polem,
- vhodné pro fotografování (podle konstrukce)

Nevýhody:

- větší počet optických prvků – nutnost velmi dobré korekce aberací,
- centrální clonění
- cena bývá vyšší,