MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

luffy AI

Reflection supression in coherence imaging spectroscopy

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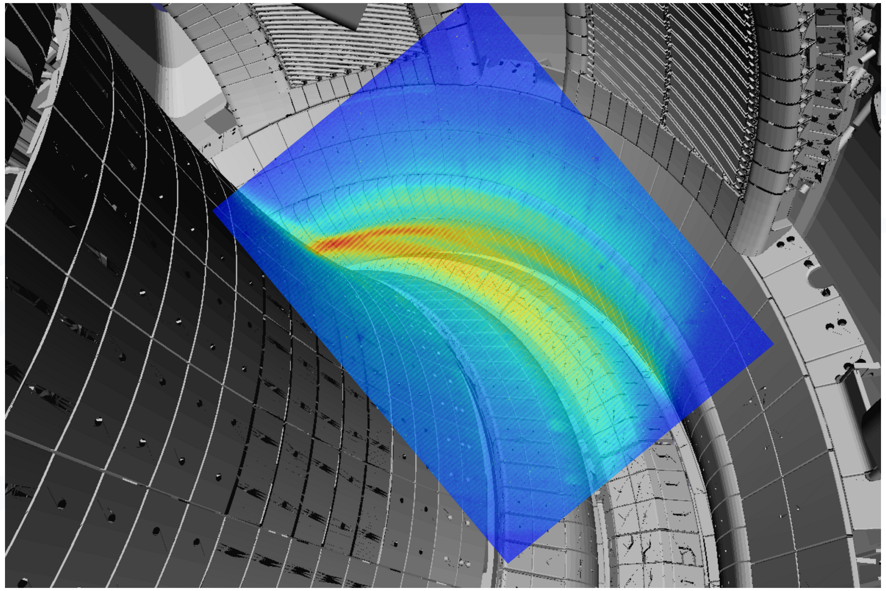
IPP internal meeting, 01.02.2023

iter
china eu india japan korea russia usa

Reflections in CIS

- Many successful existing coherence imaging spectroscopy (CIS) systems (TEXTOR, MAST, D3D, W7X...)
- Only AUG so far with metal wall --> Effect of reflections significant in some image areas.



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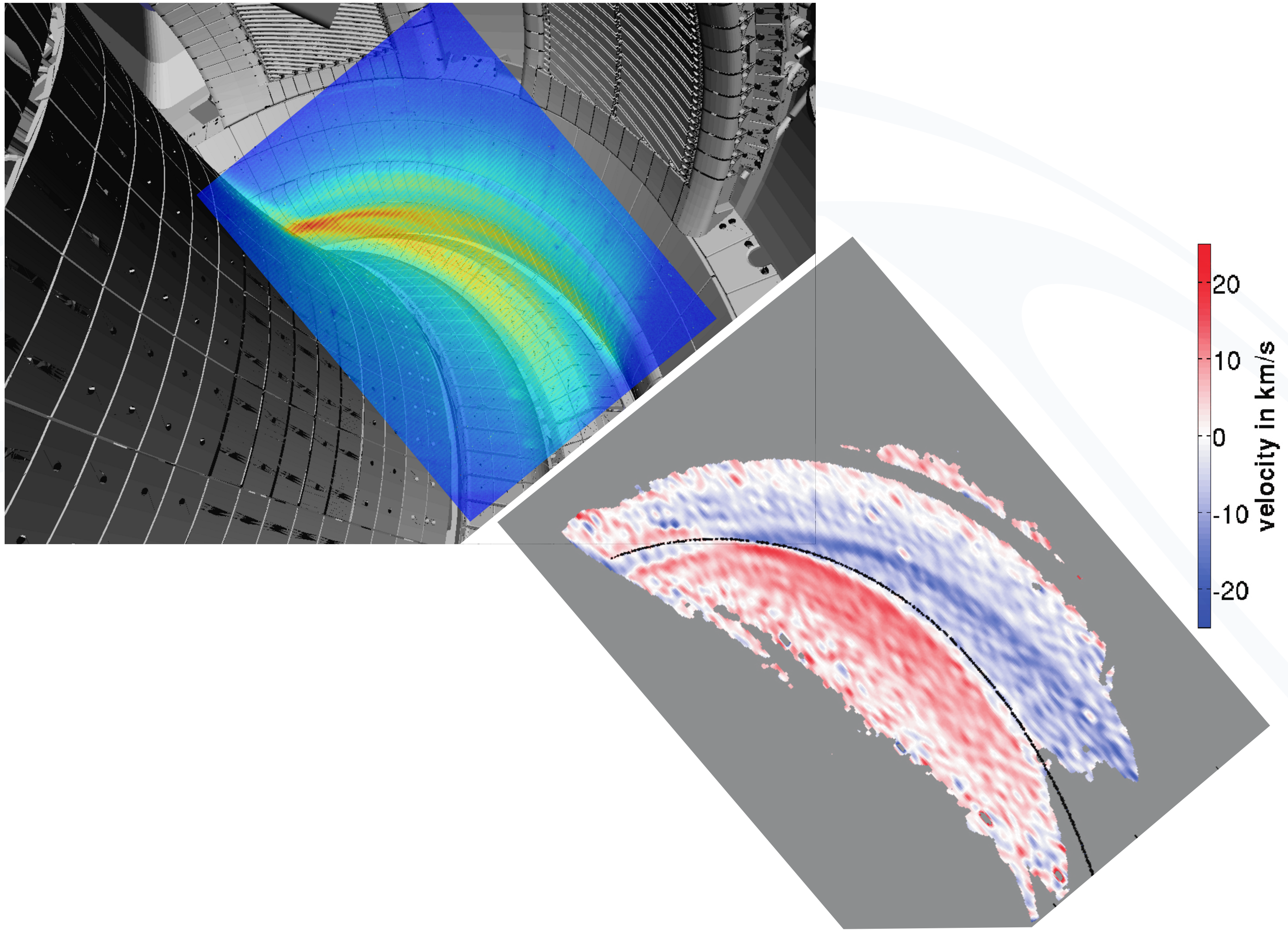

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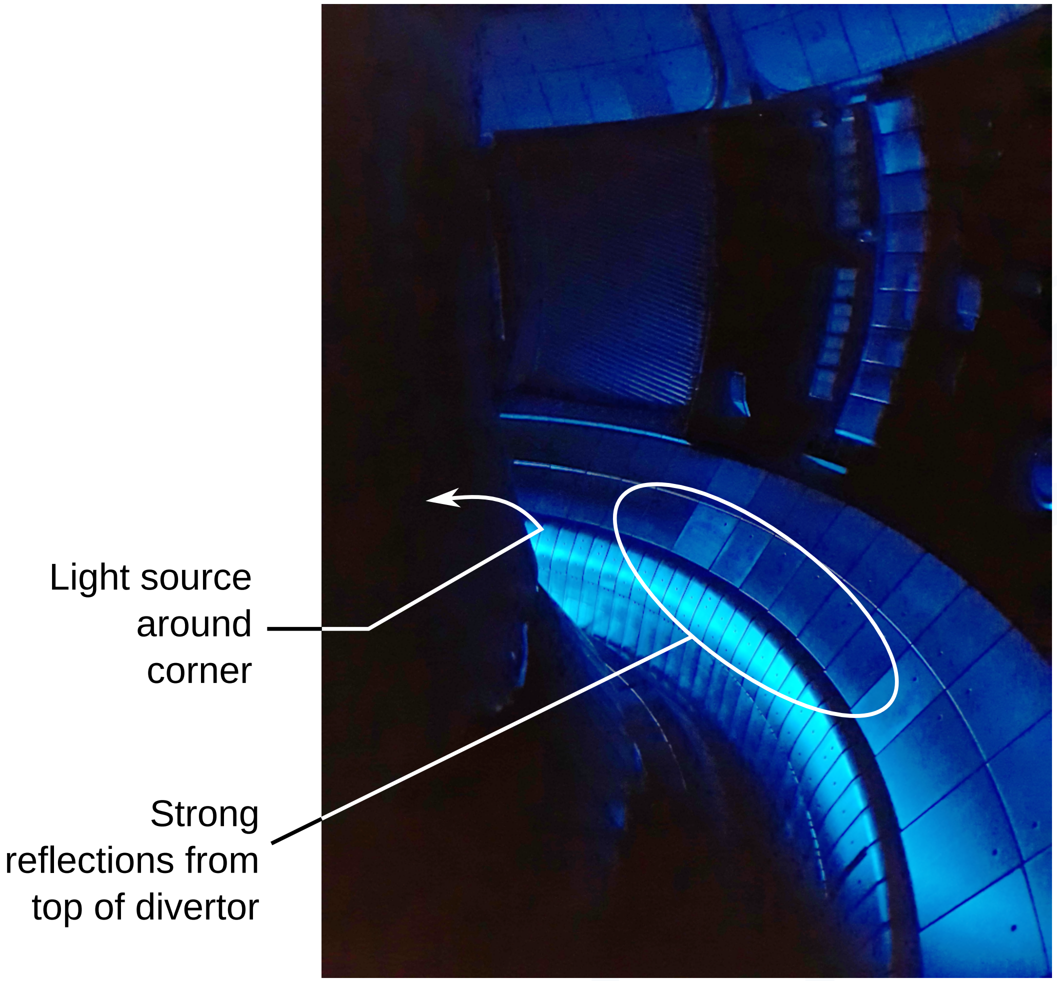

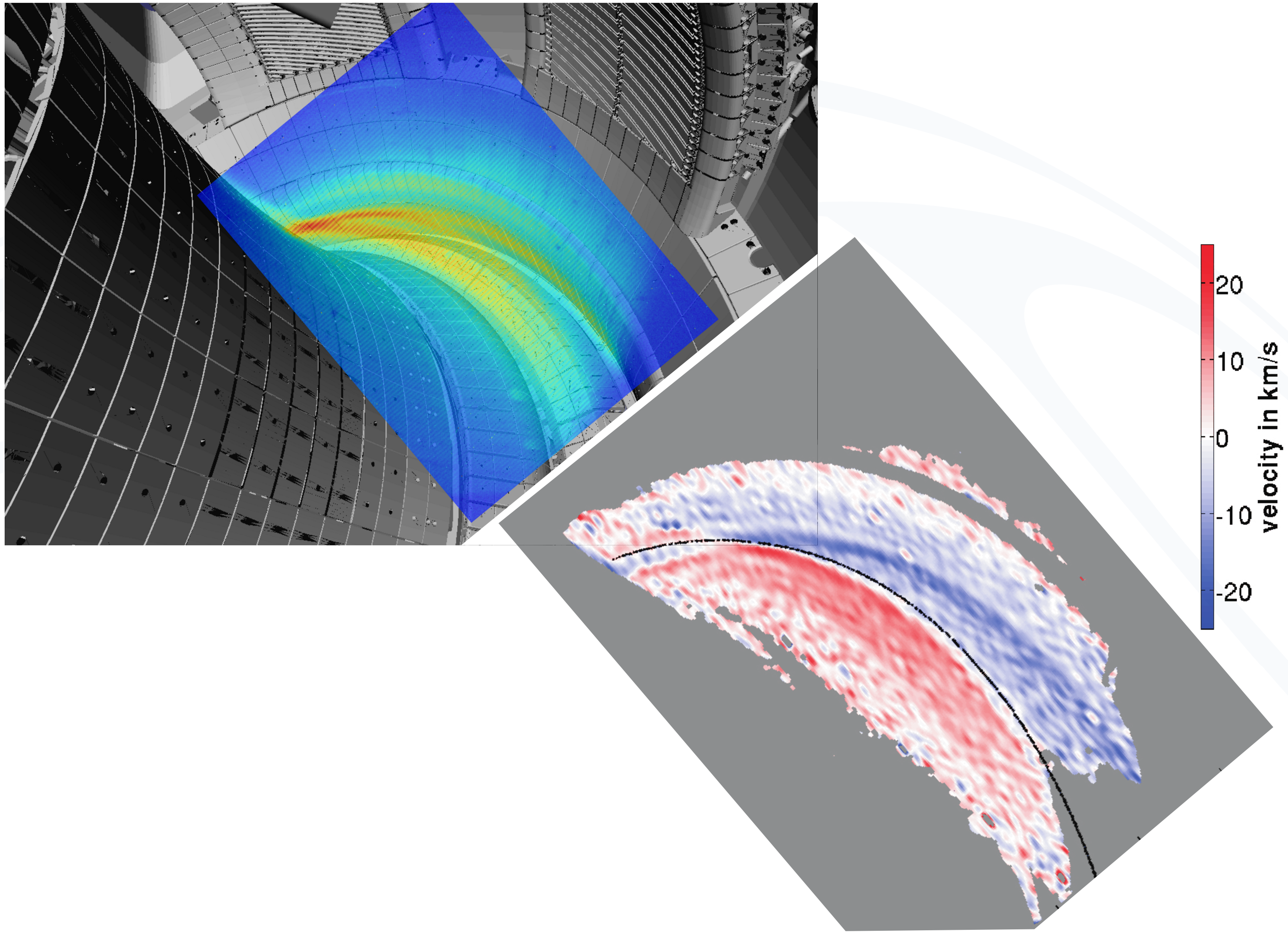

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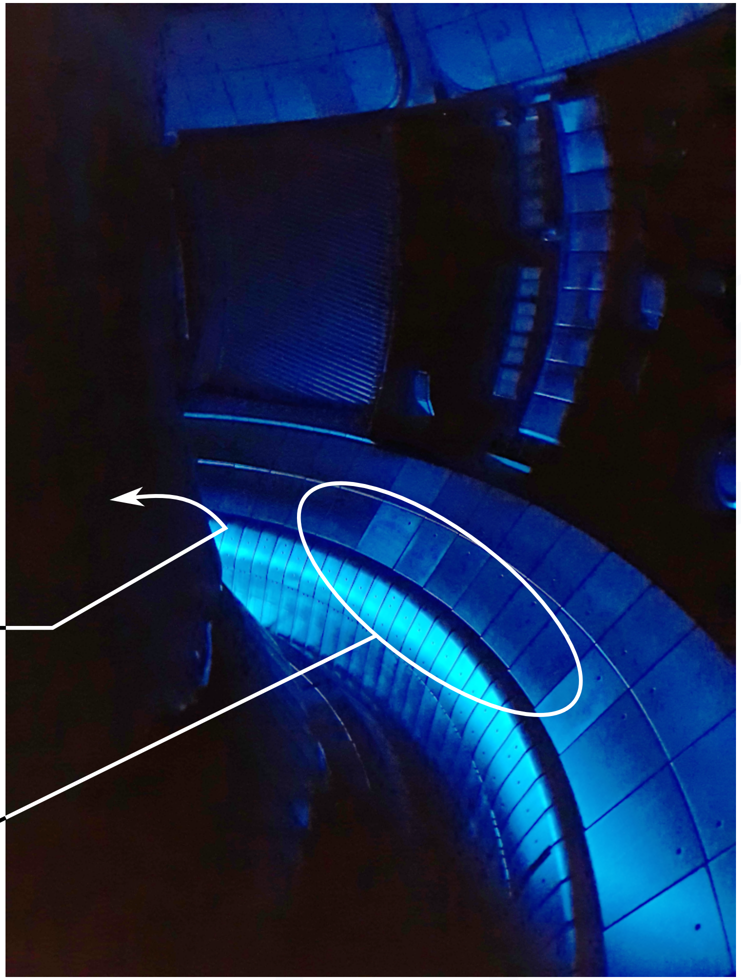
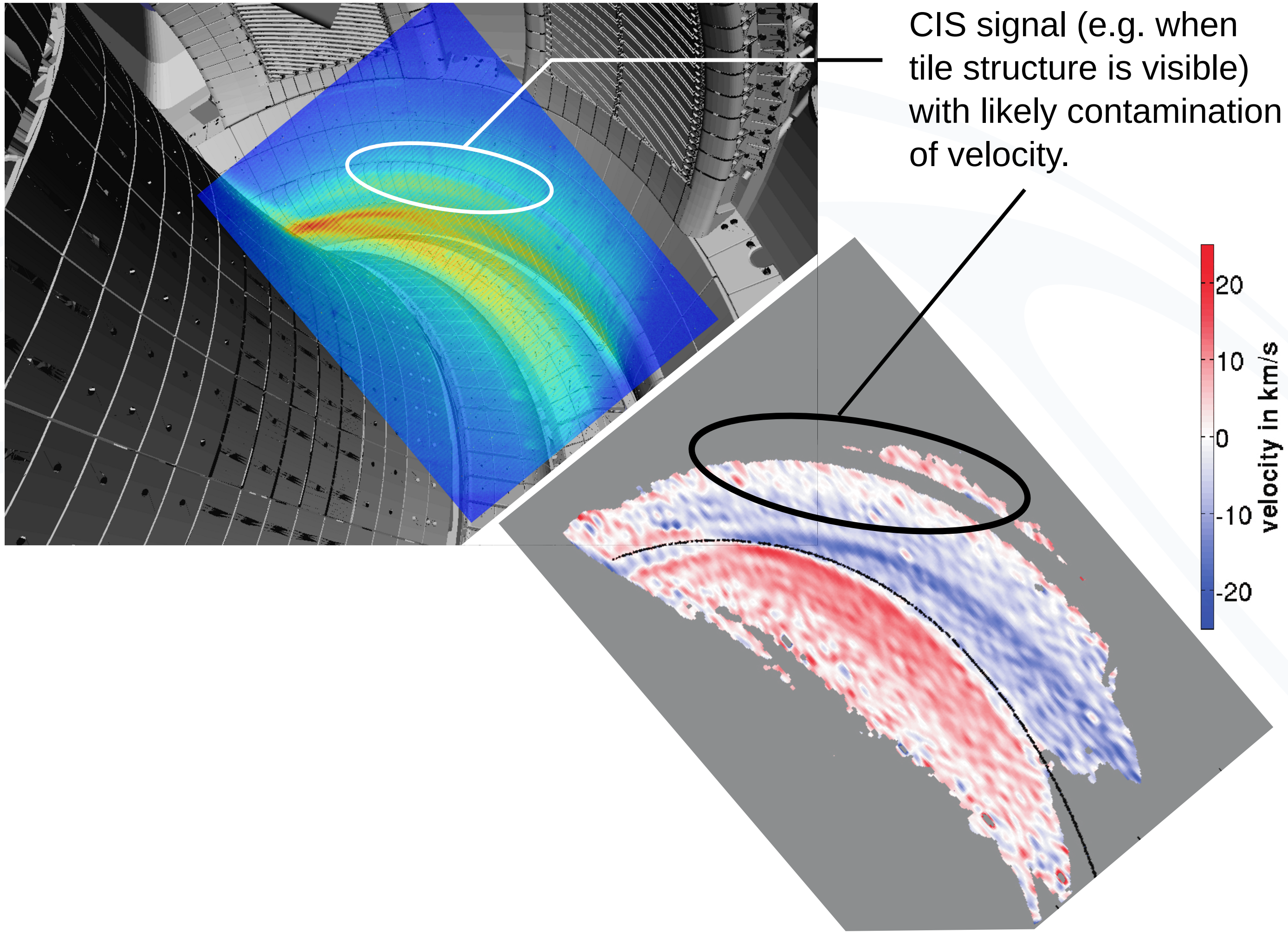
Light source around corner

Strong reflections from top of divertor



Reflections seen in raw CIS signal (e.g. when tile structure is visible) with likely contamination of velocity.



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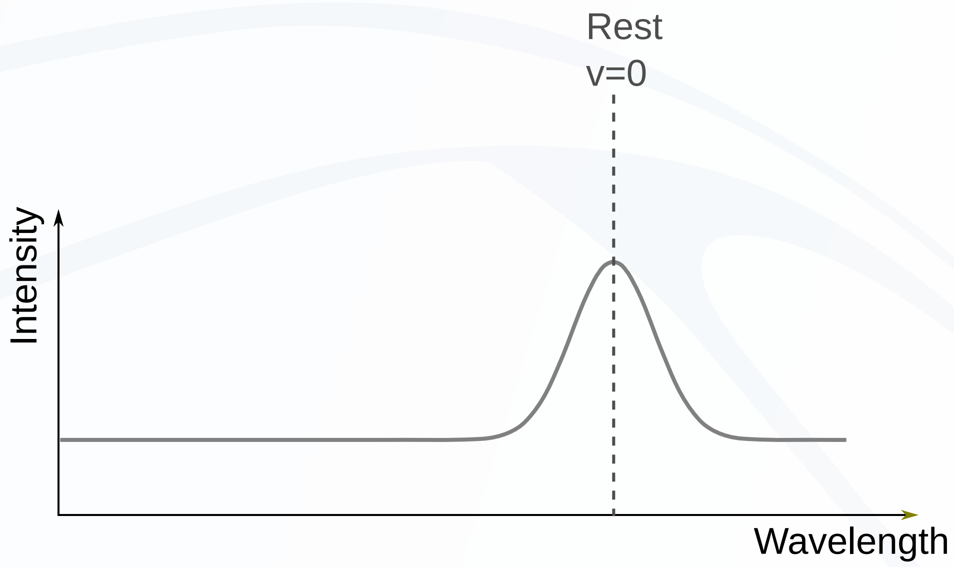

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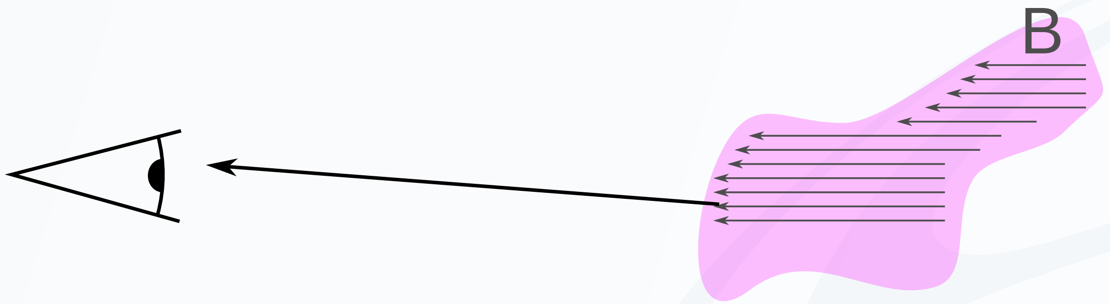

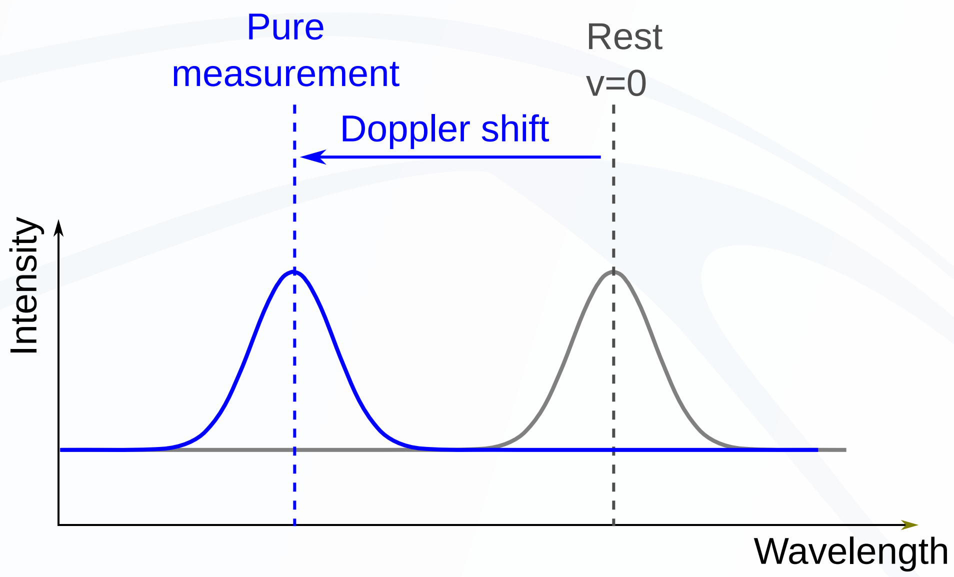

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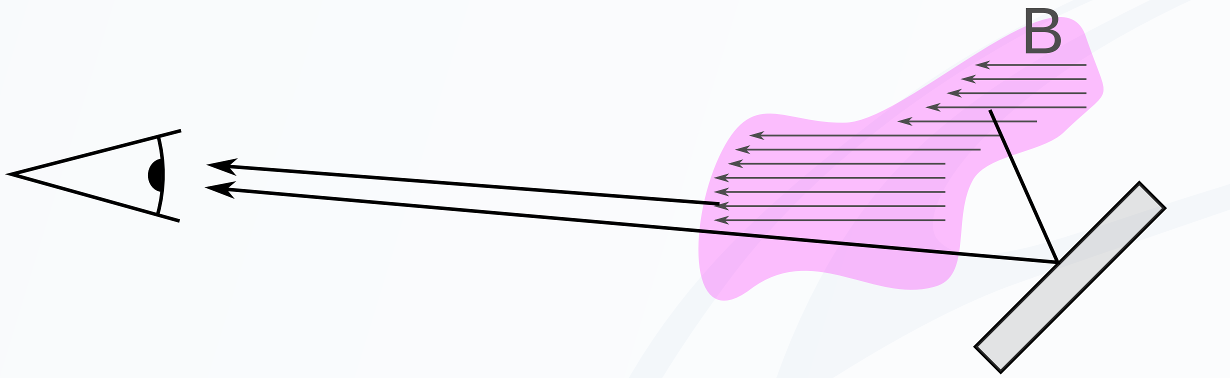

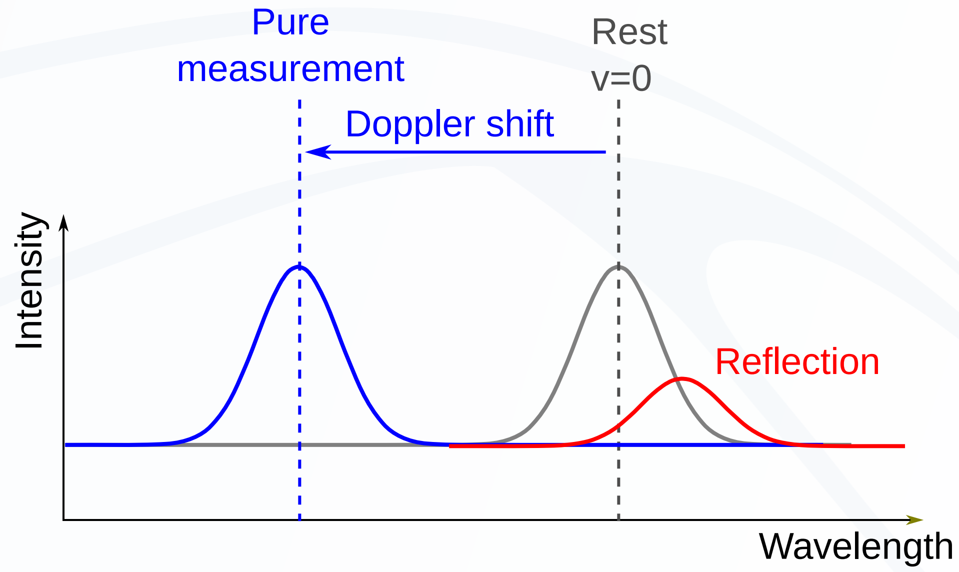

Reflections in CIS

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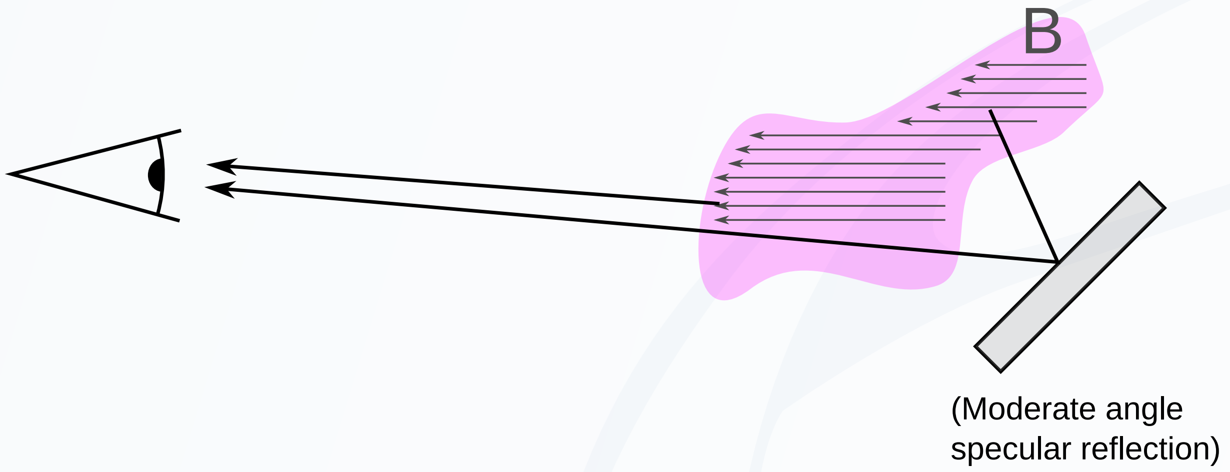
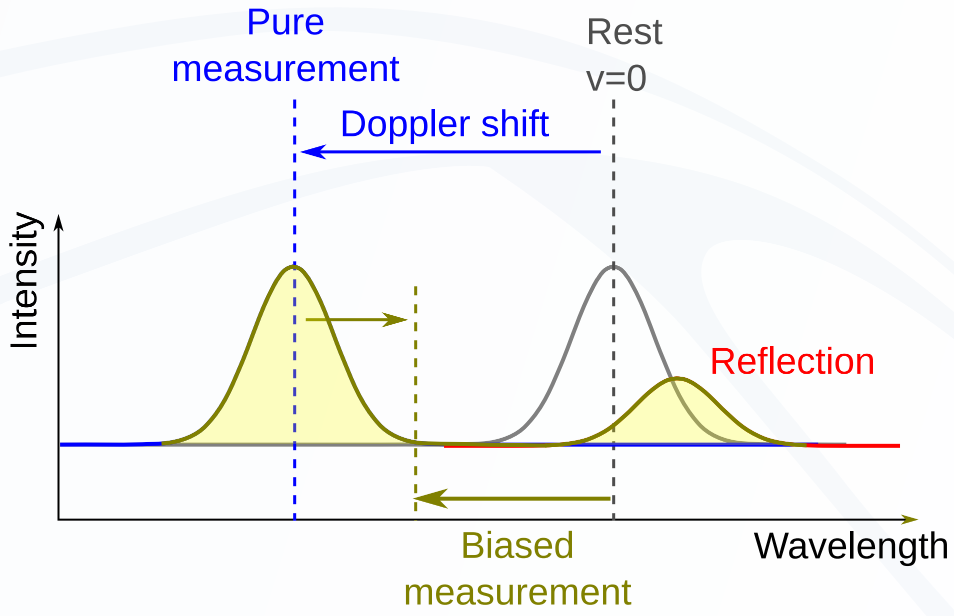
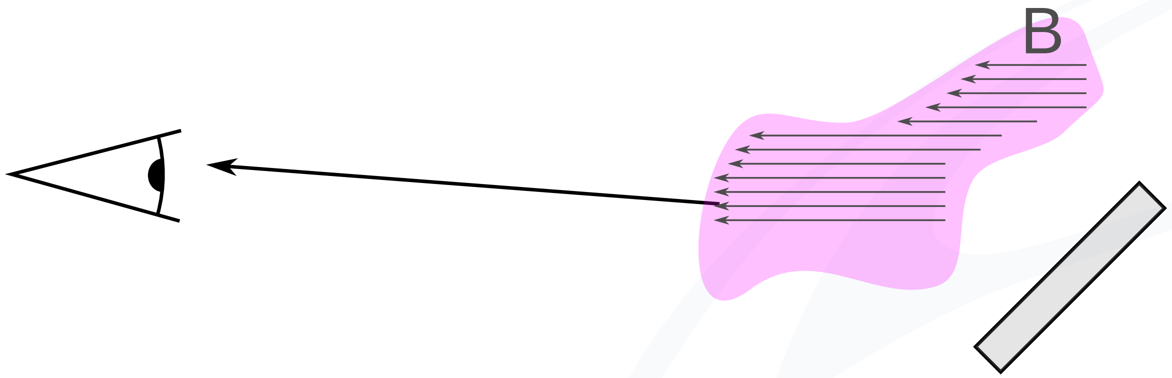
- Reflection has wrong Doppler shift and biases measurement.





Reflection discrimination

- Flow monitor proposes to isolate reflections from signal using different polatisation states of Zeeman-split emission:



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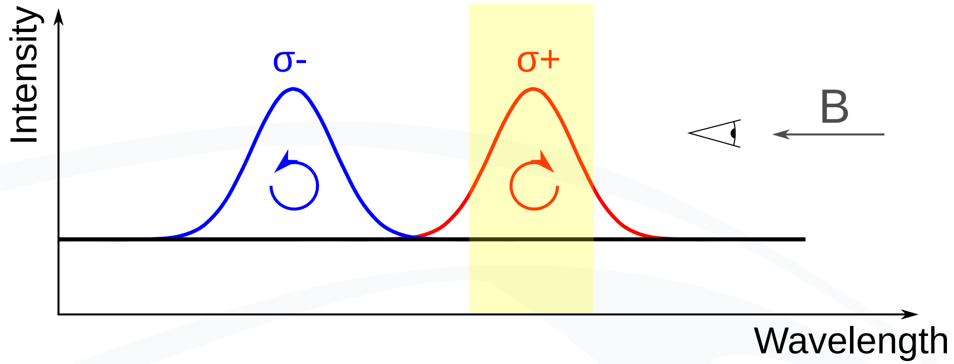

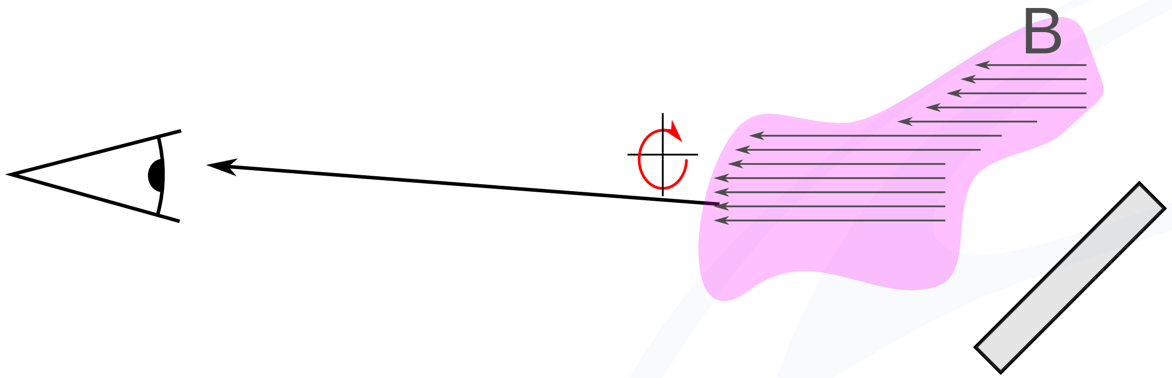

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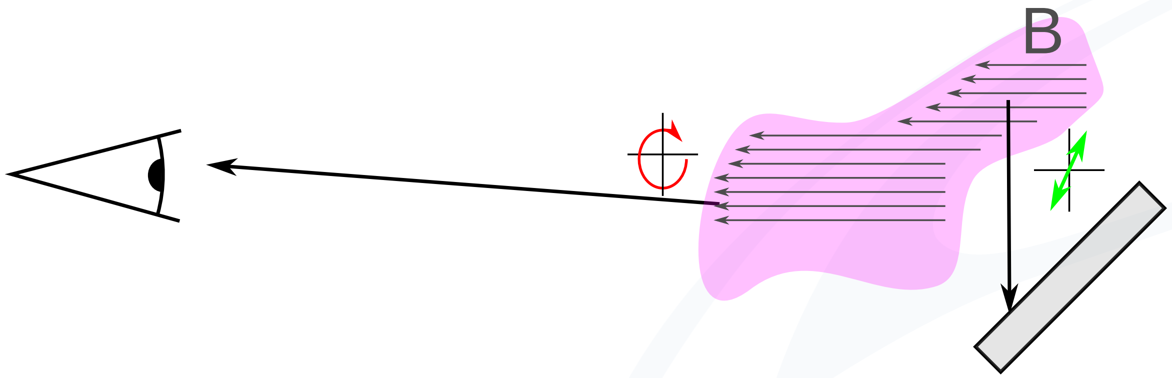

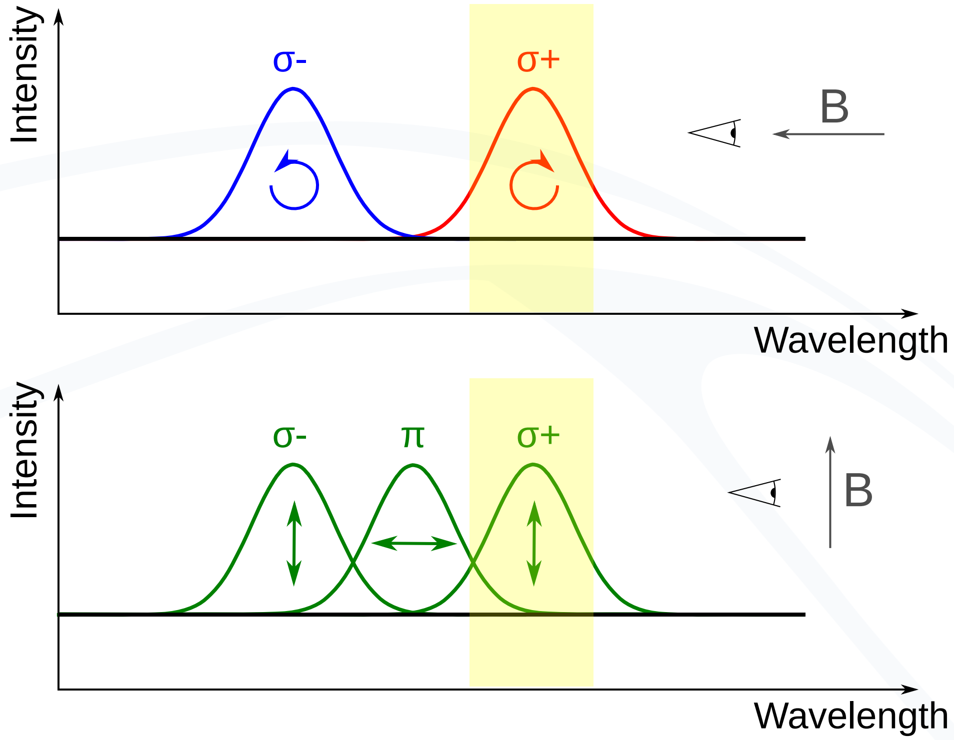

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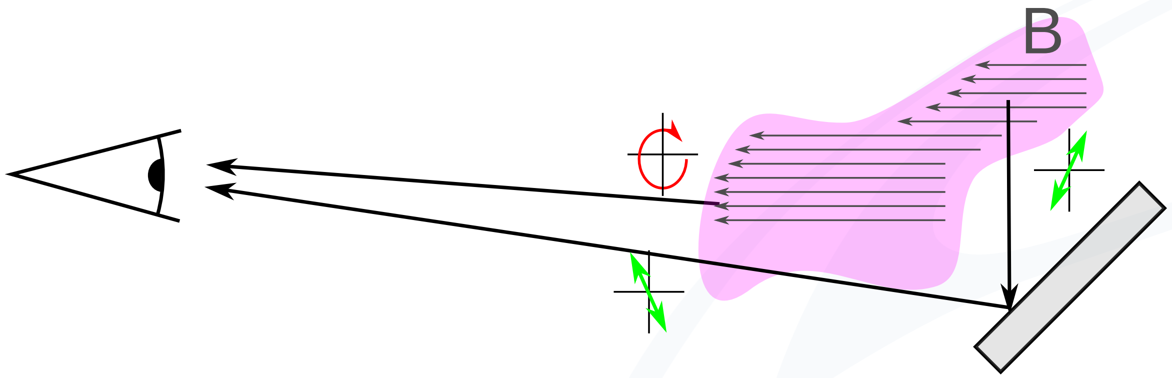

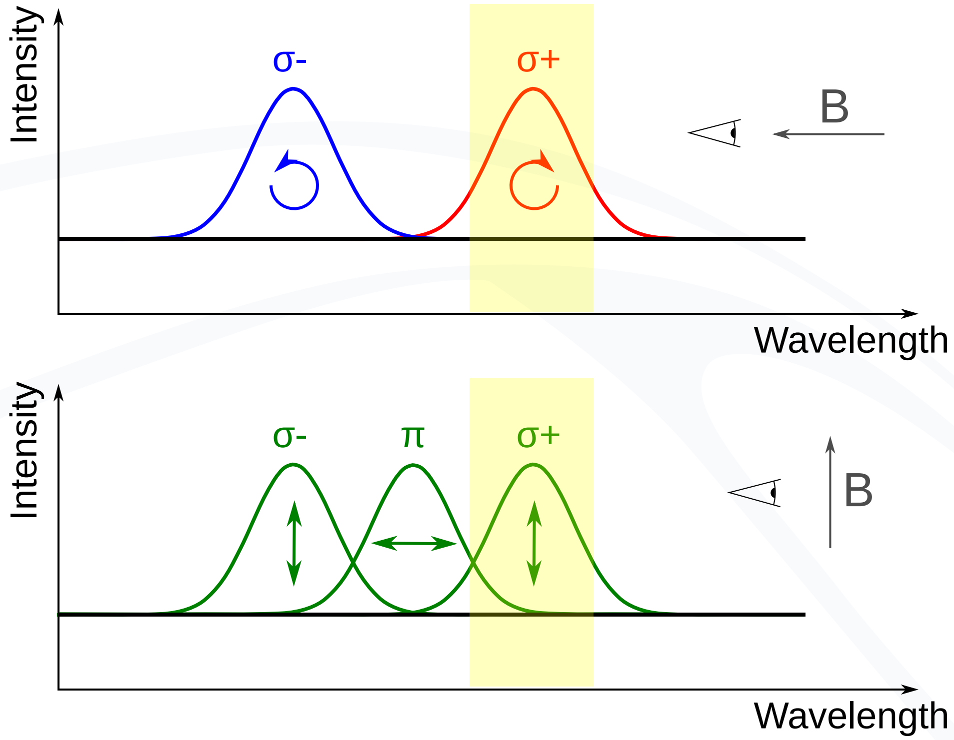

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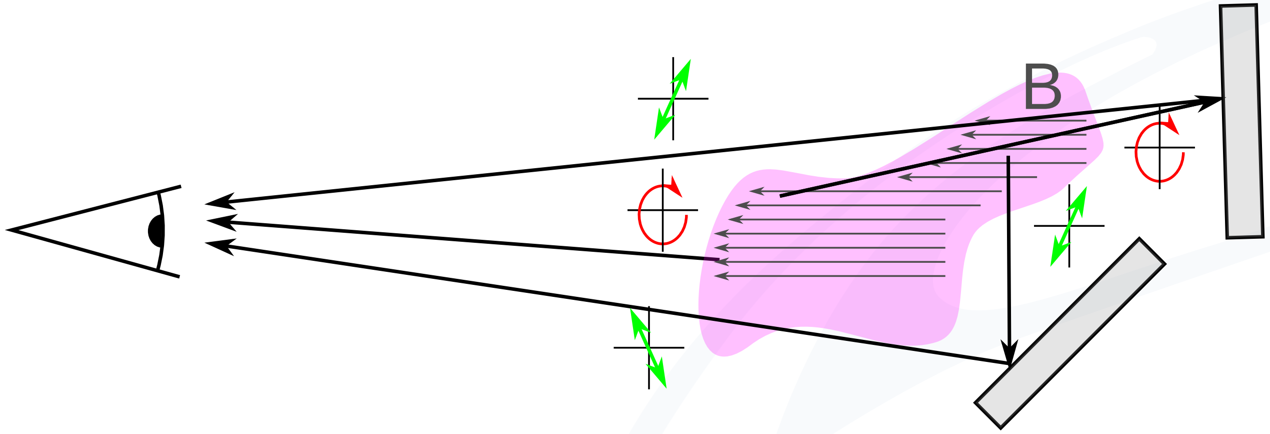

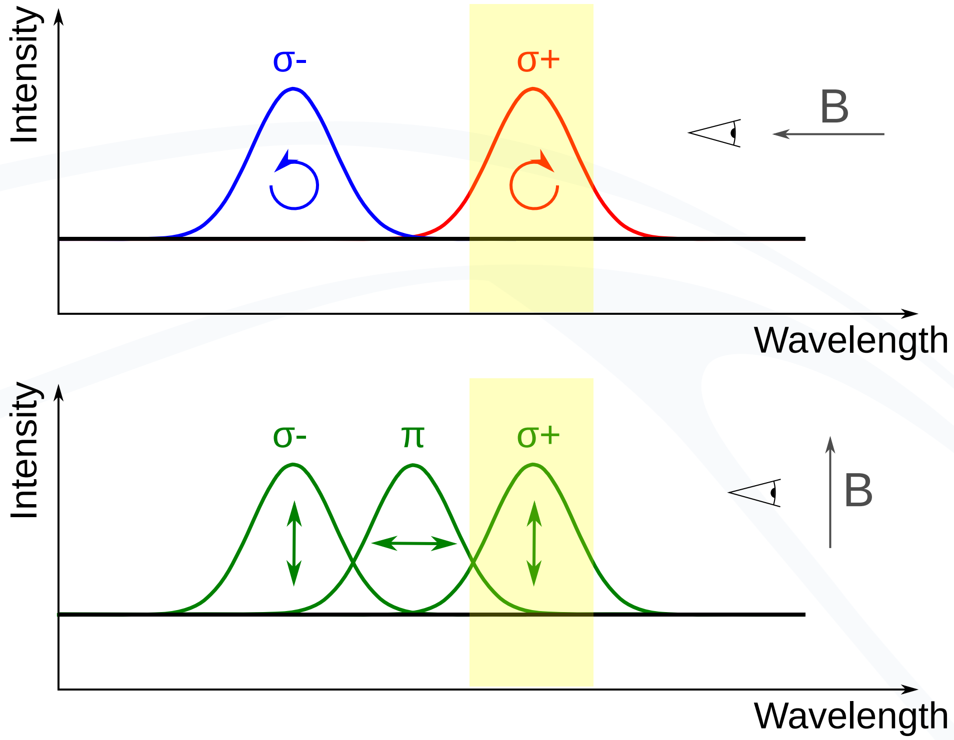

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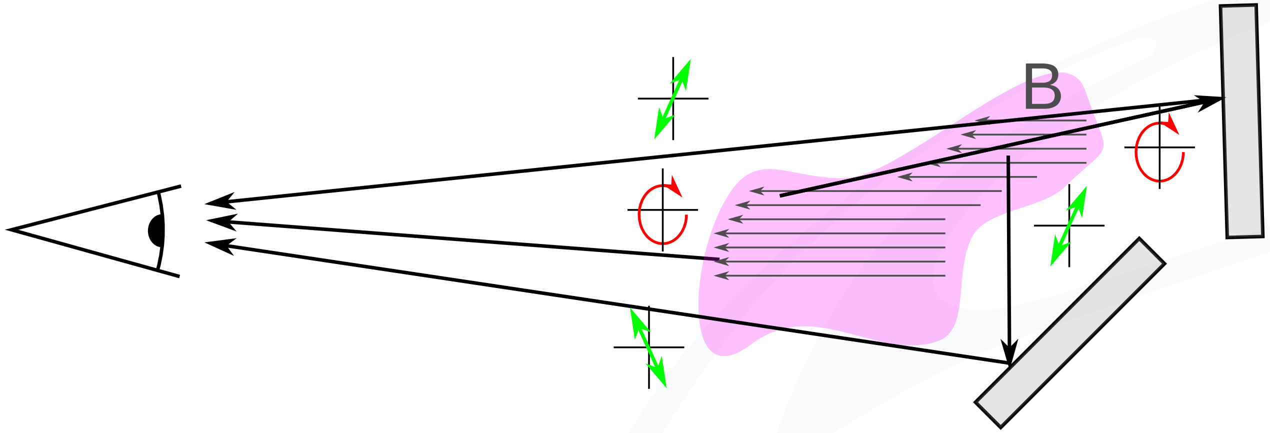
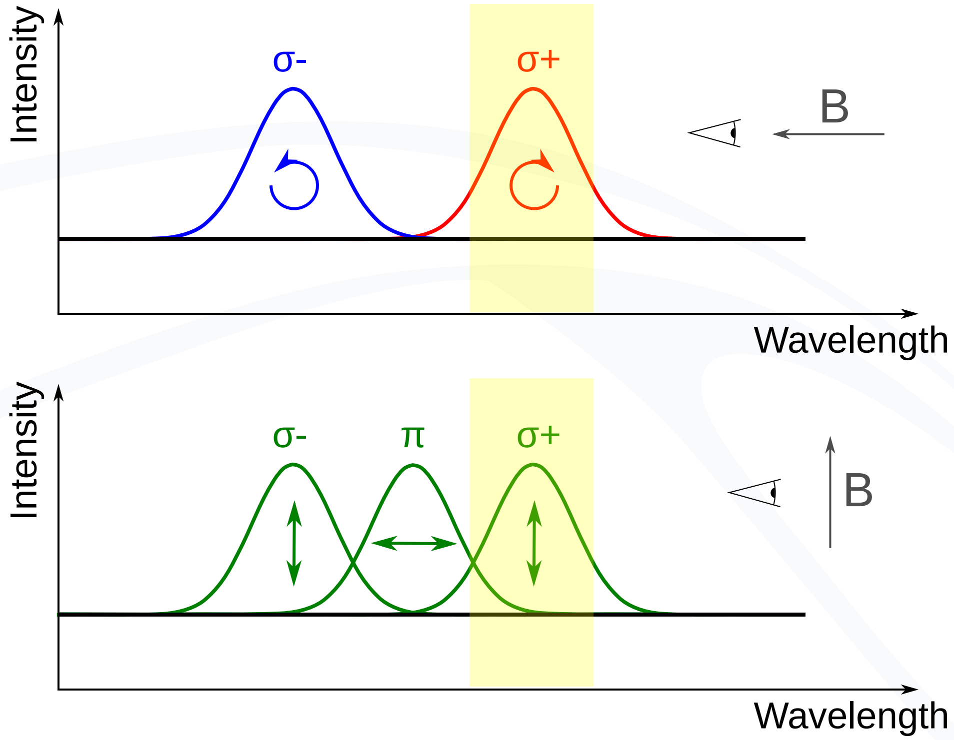


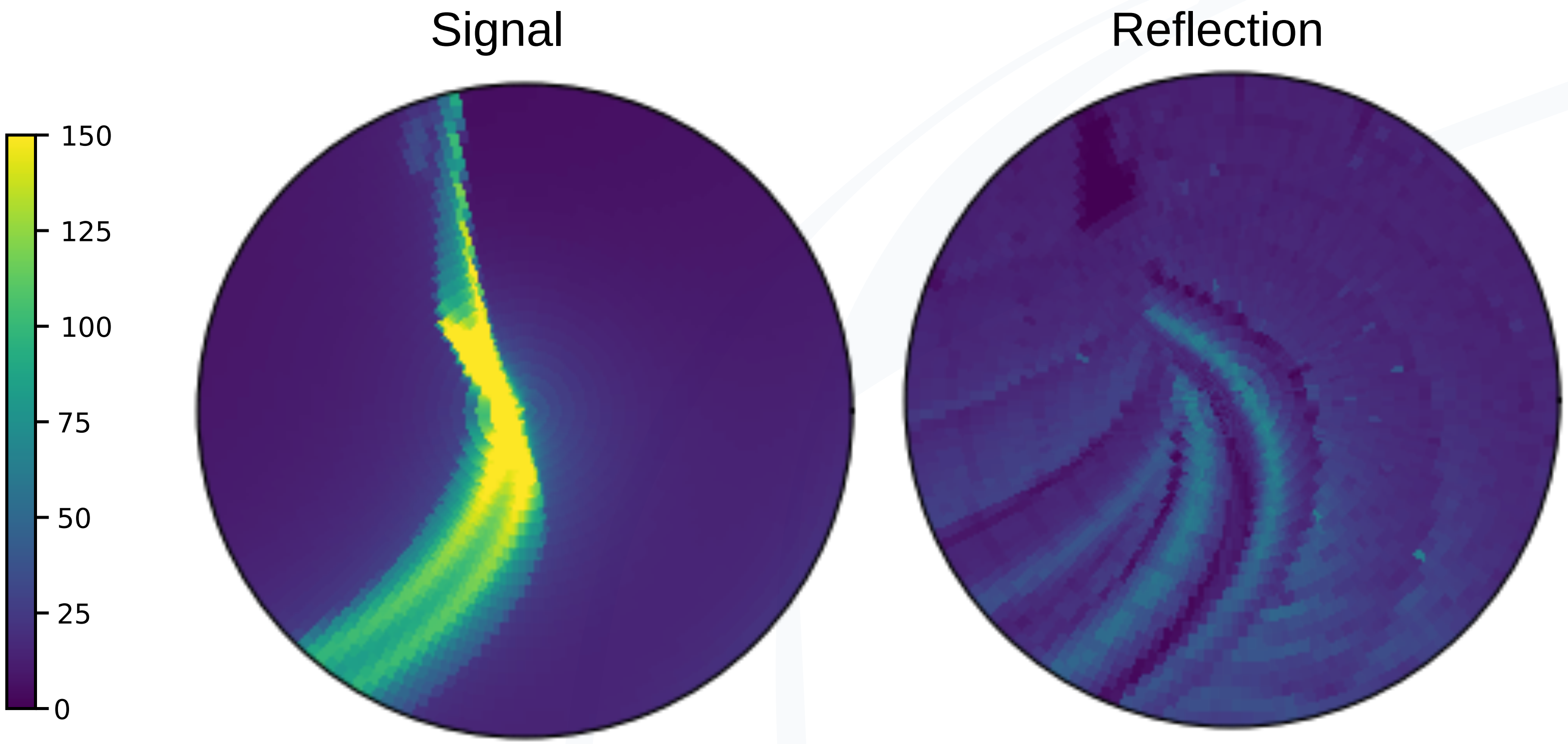


"... because the nett polarized component incident on the wall is dominated by the linearly polarized Stokes components s_1 and s_2 (the emission closest to the wall facet propagates across B), on reflection, it is less likely to interfere with the primarily circularly polarized plasma component s_3 received directly by the camera."

[55.GE Divertor Flow Monitor - The Scientific Basis (YBJ7RW)]

Ray-traced model

- Evaluating RaySect (Luffy.AI) model of complete ITER flow monitor:
  - Signal is strong where lines of sight parallel to separatrix, dominated by emission near x-point.



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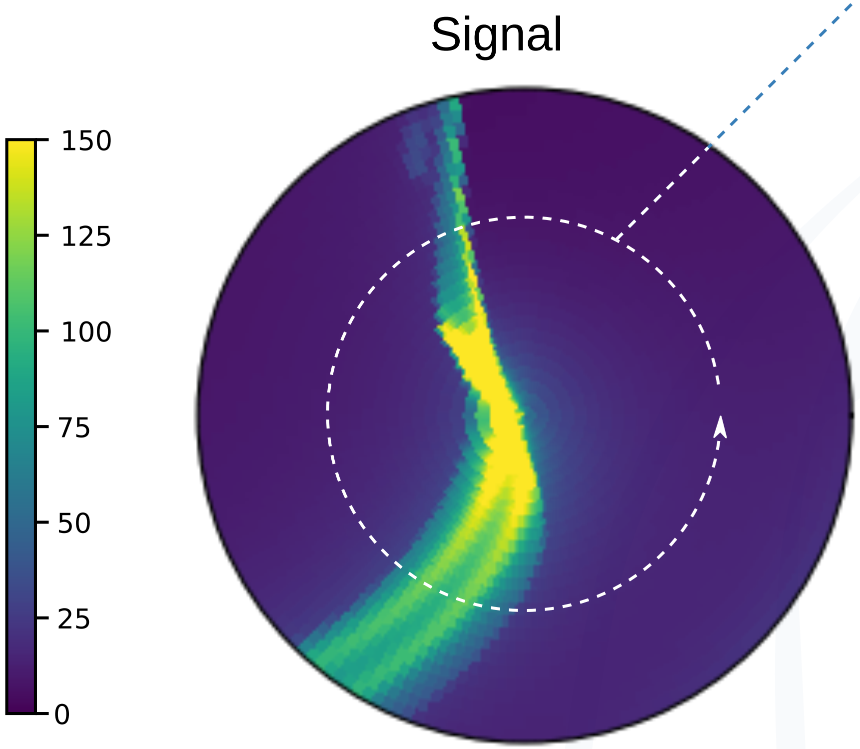

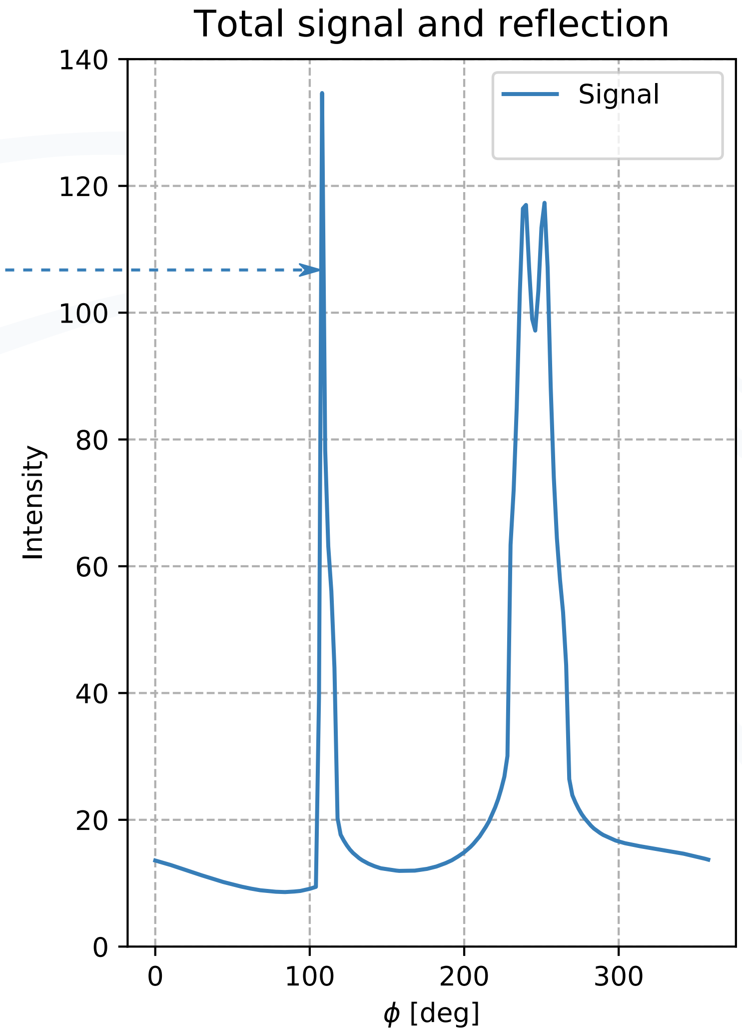

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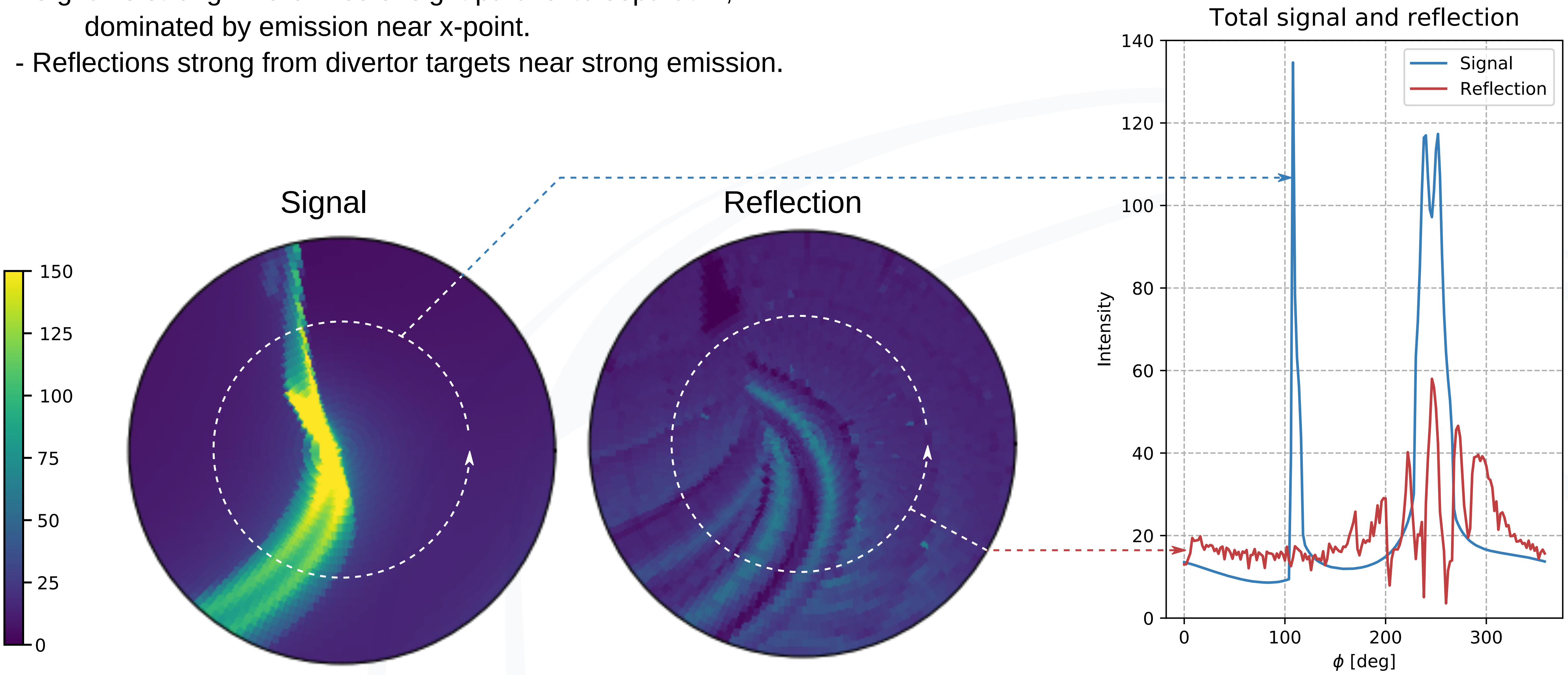

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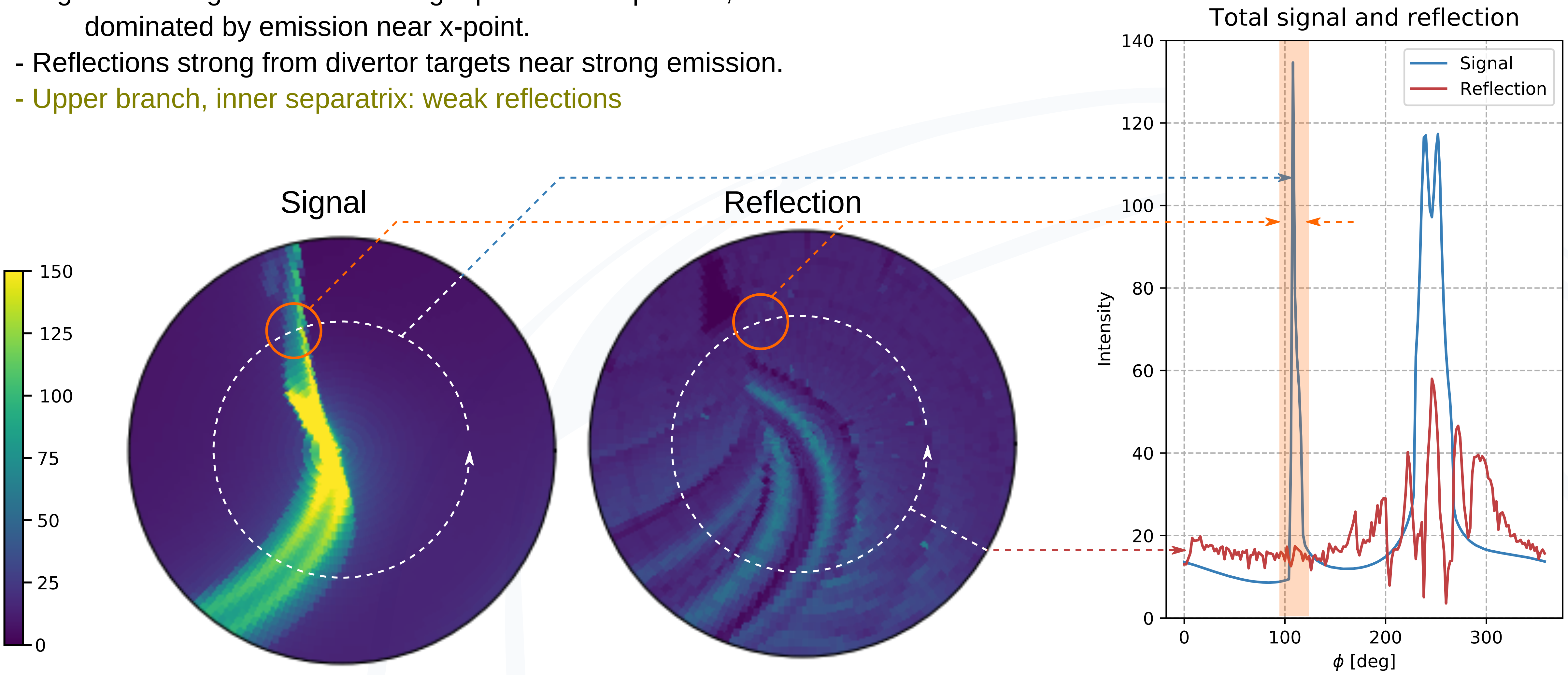

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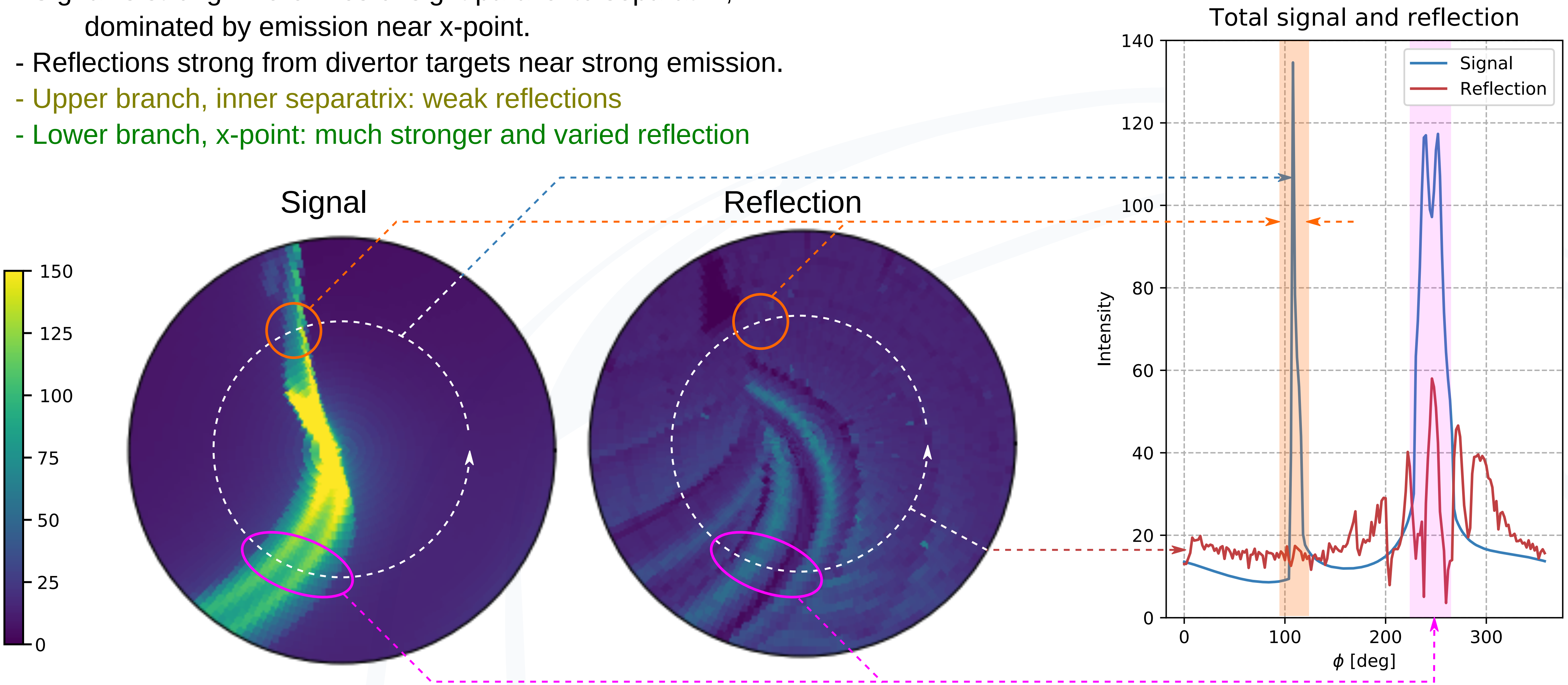
  - Lower branch, x-point: much stronger and varied reflection



Suppression improvement

Reflections have between ¼ and ½ in each polarisation type.

--> We can remove at least 2/3 of the reflection in most places.

How much does this really help?

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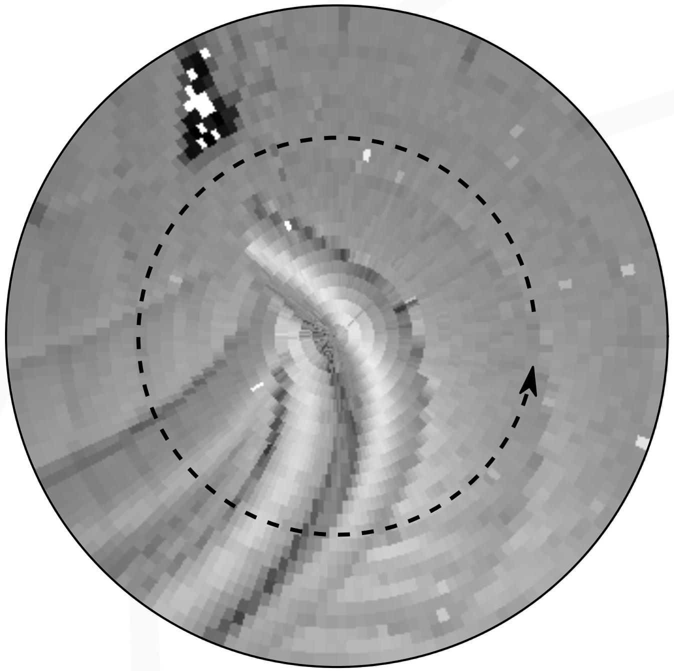

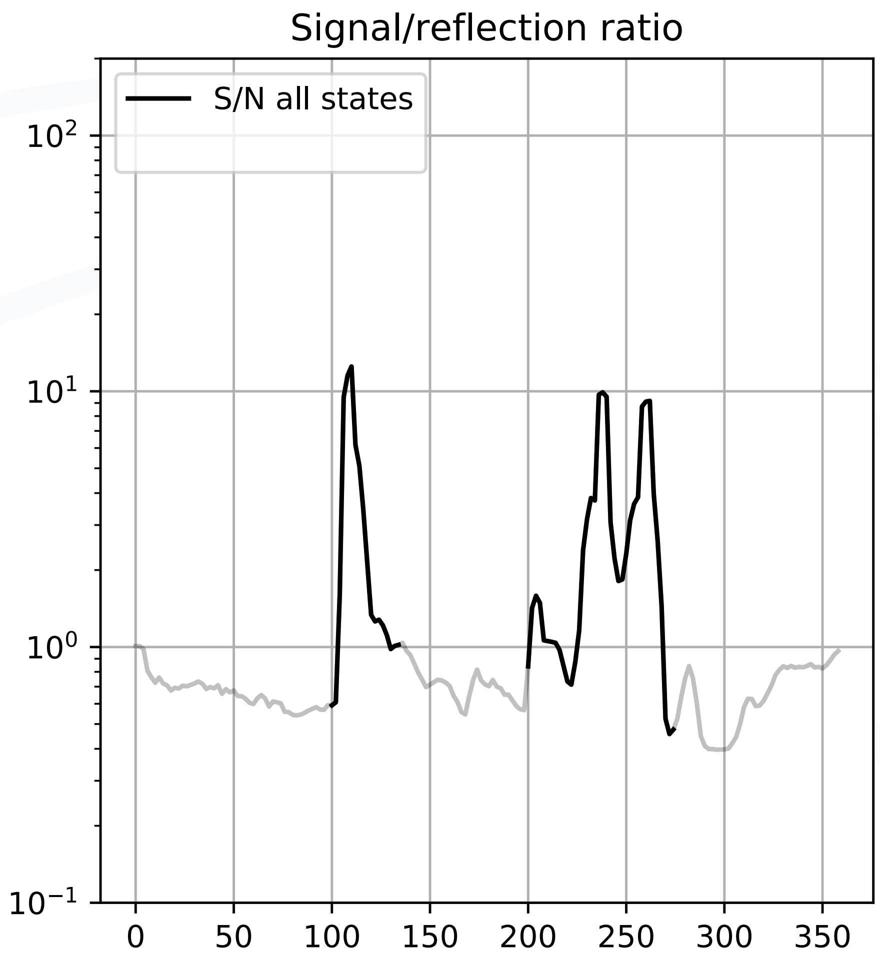

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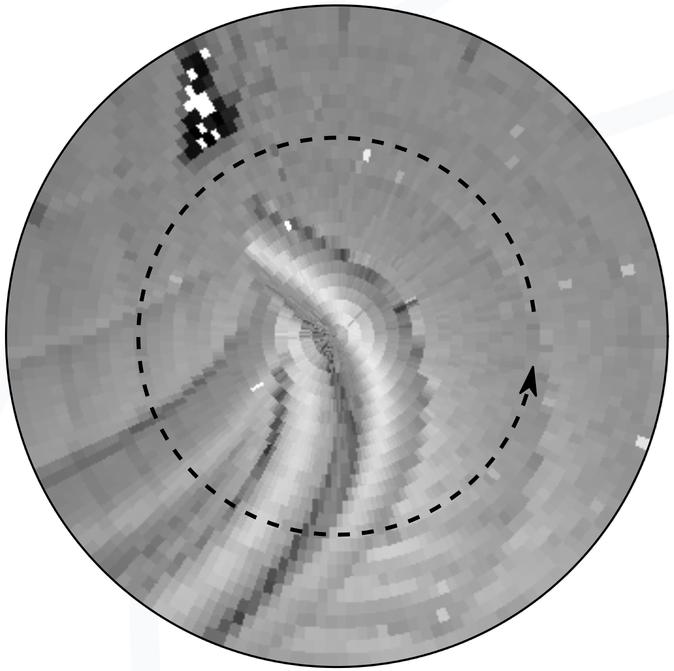

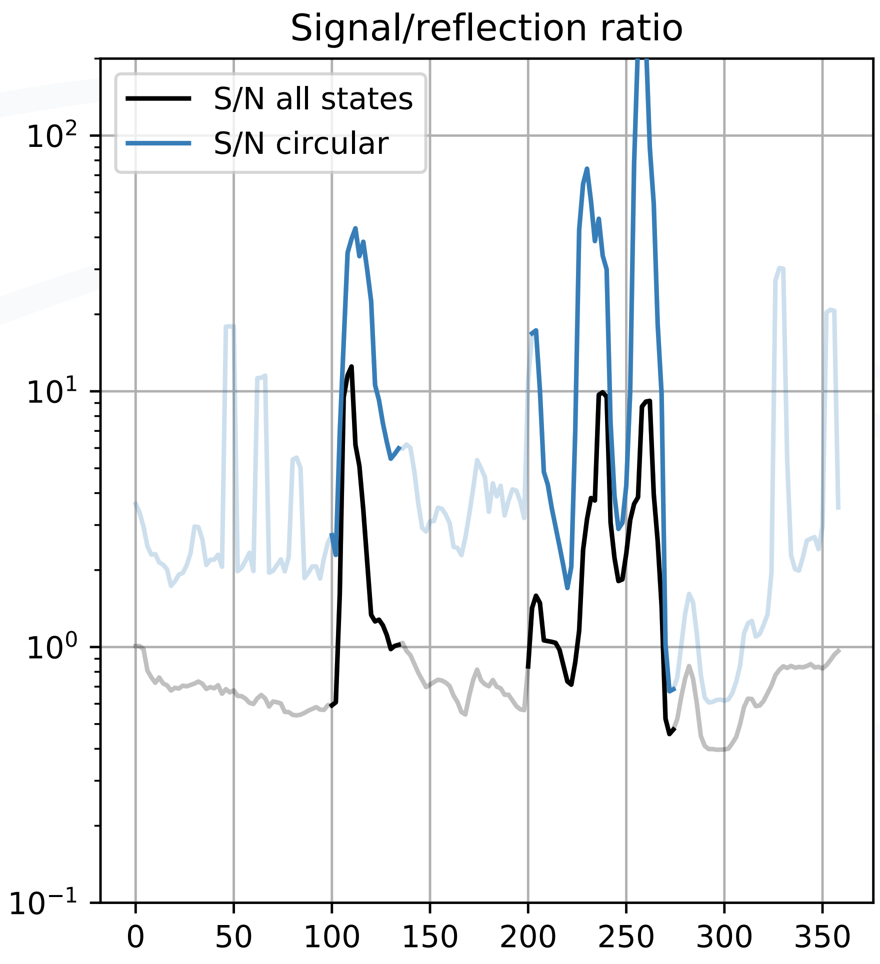

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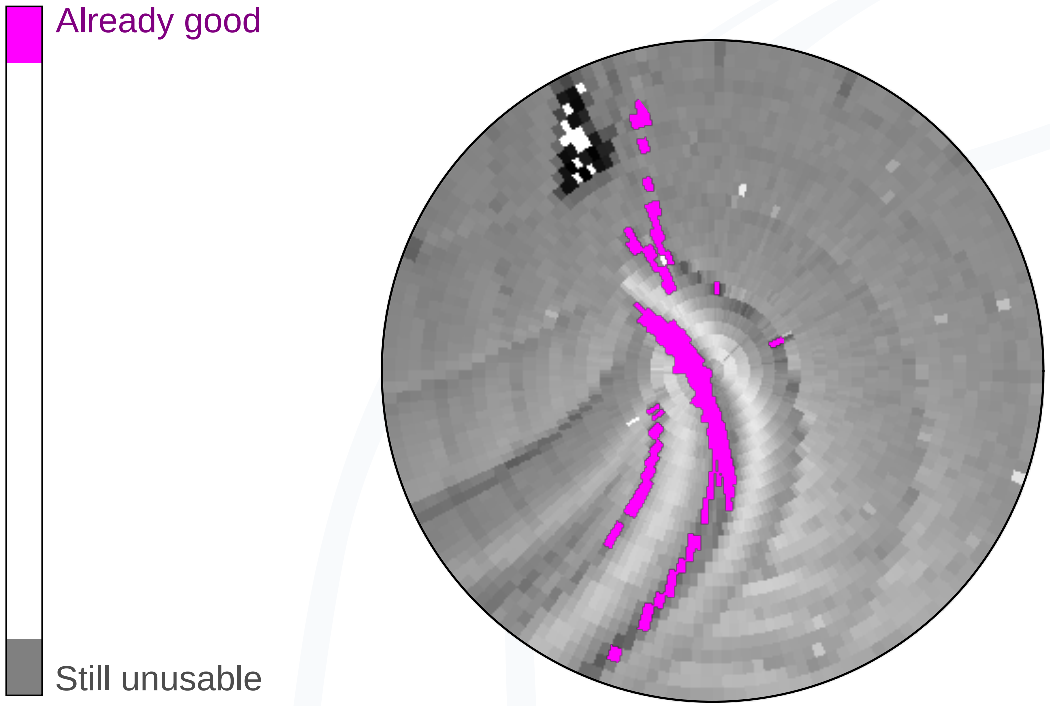

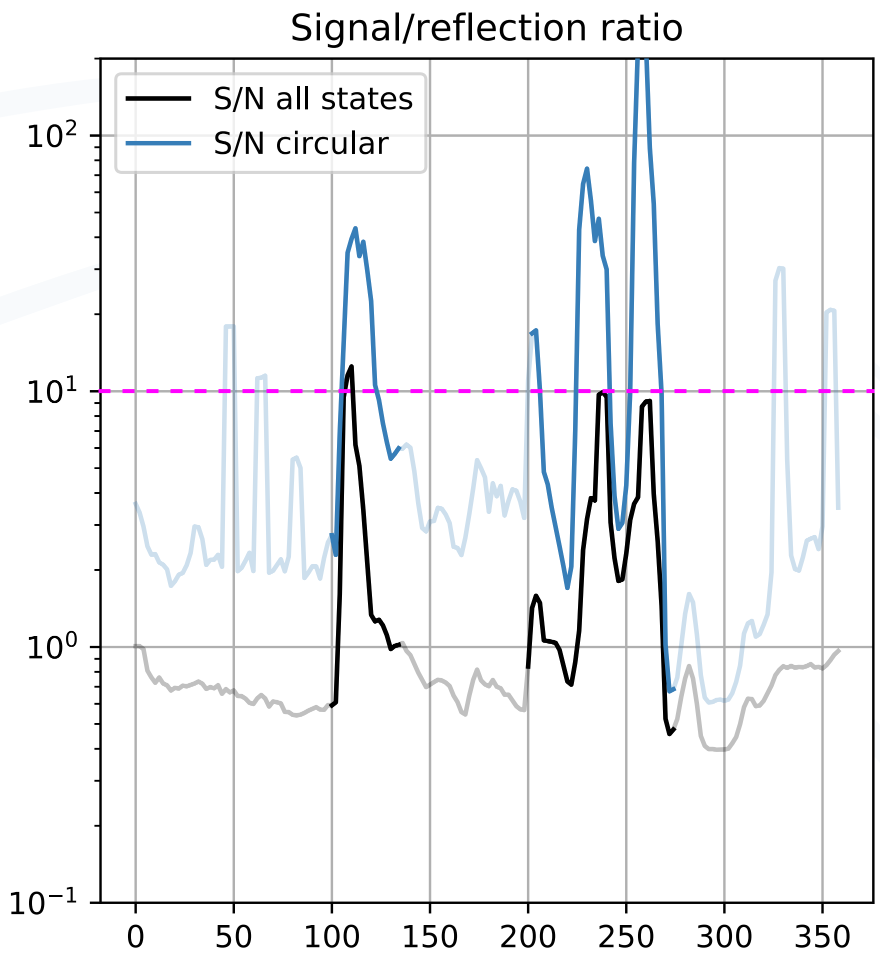

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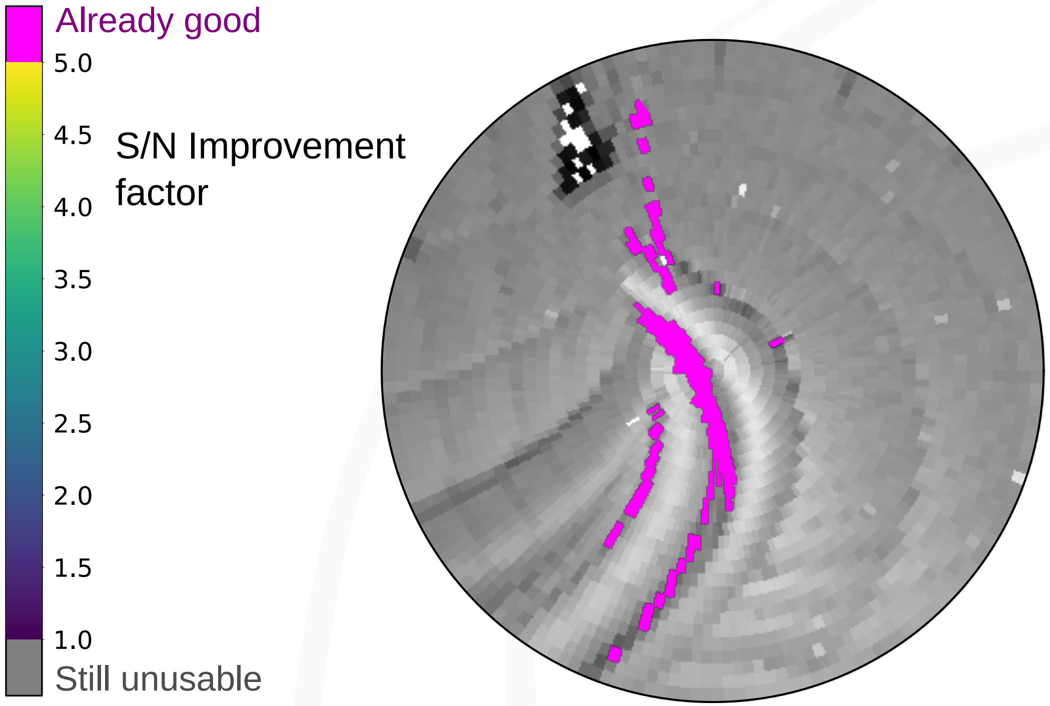
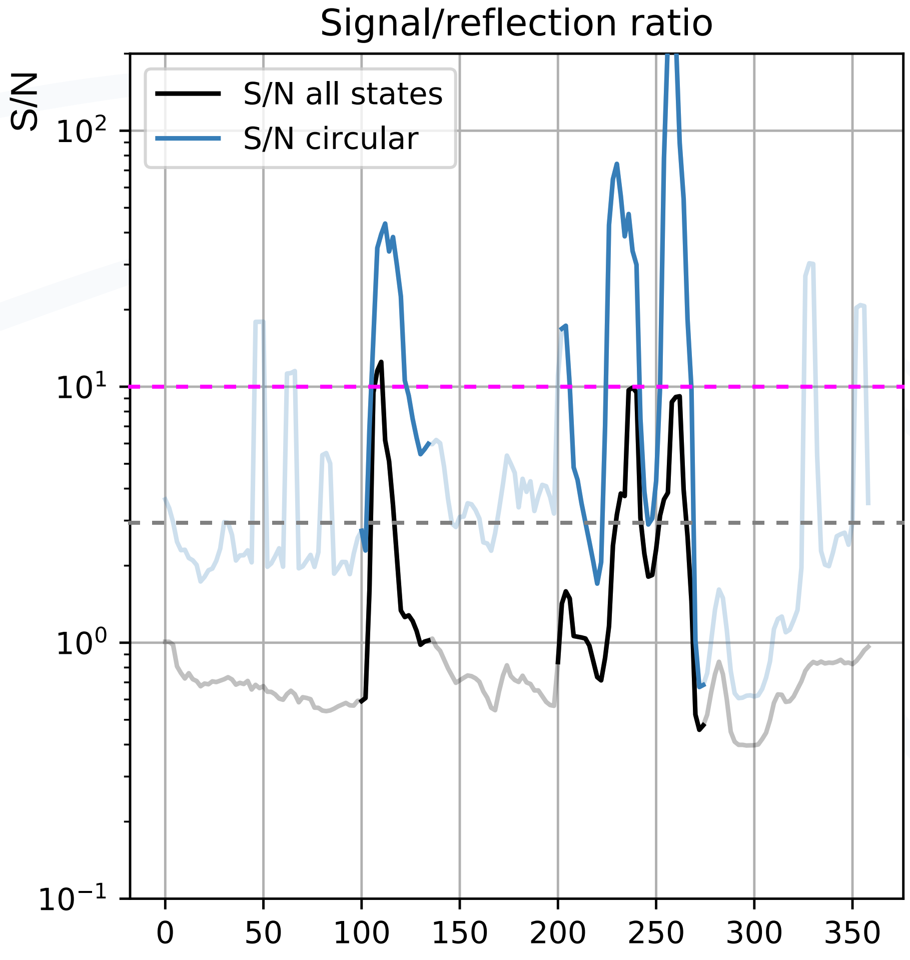
- Consider S/N < 3 to be unusable. (i.e. > 25% reflection)





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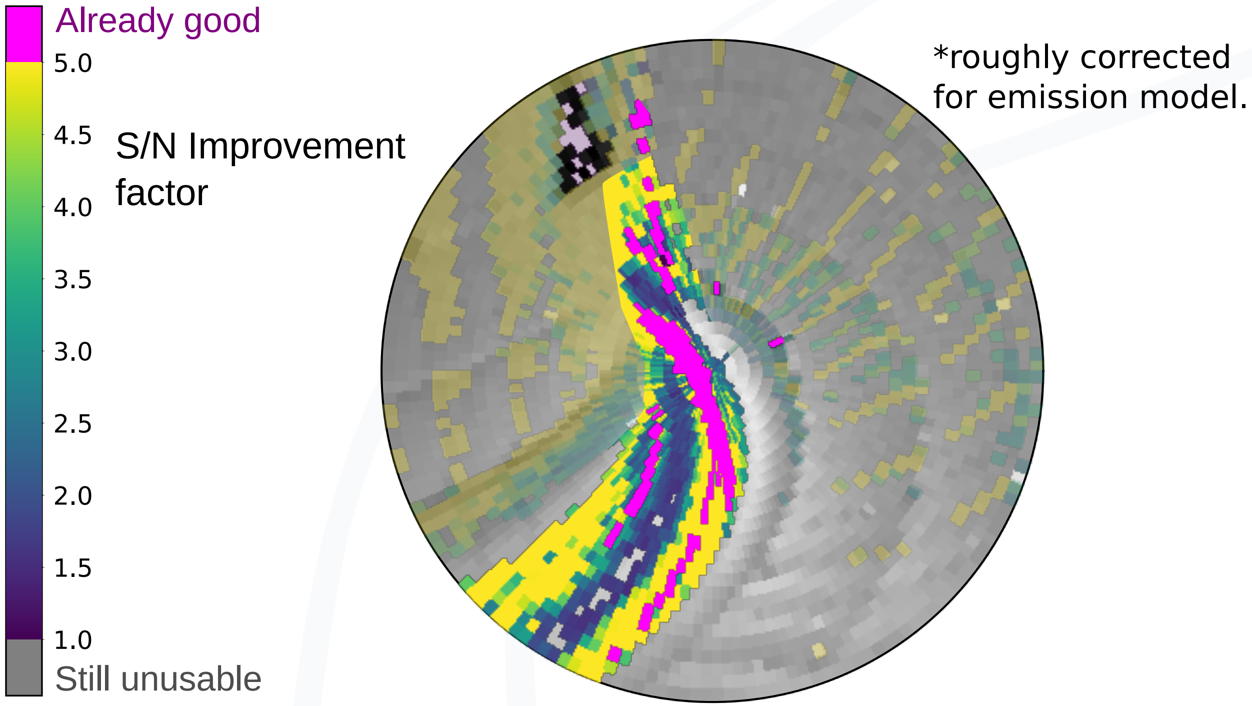
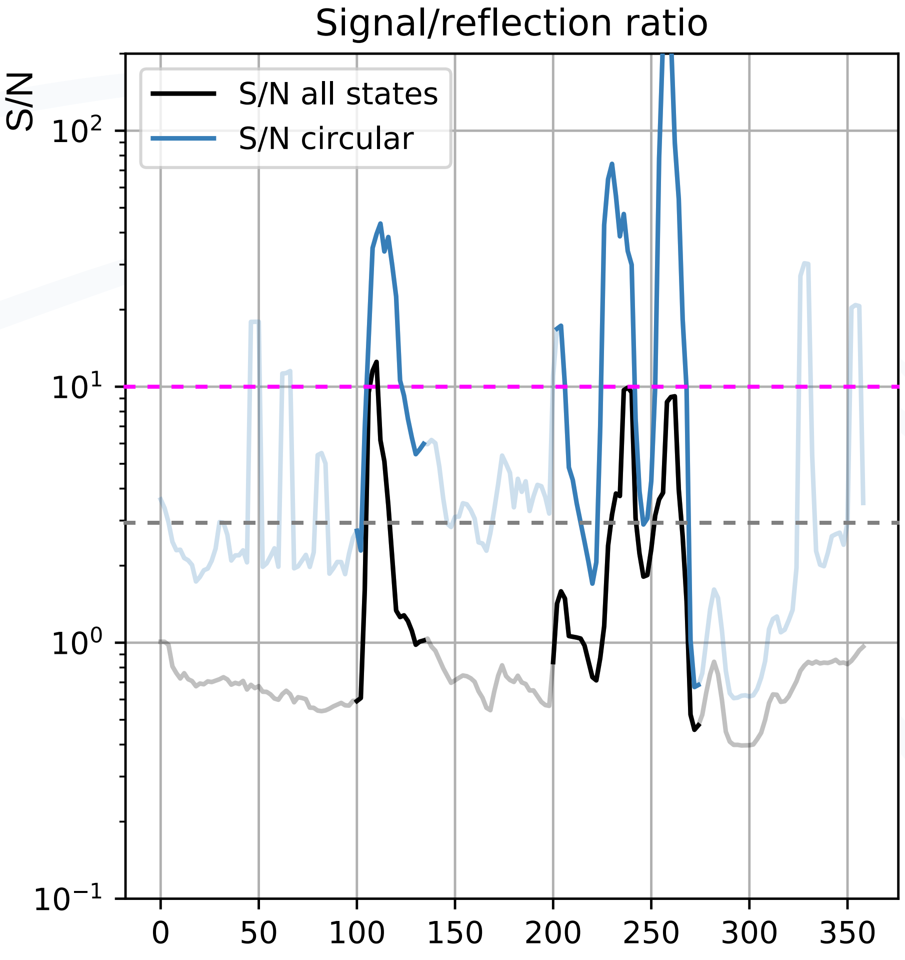




In practice?

Reflections can in principle be supressed or identified by polarisation properties.
but... not proven until demonstrated on a real machine!

So far one experiment on H-1 (Australia), not quantitatively evaluated:

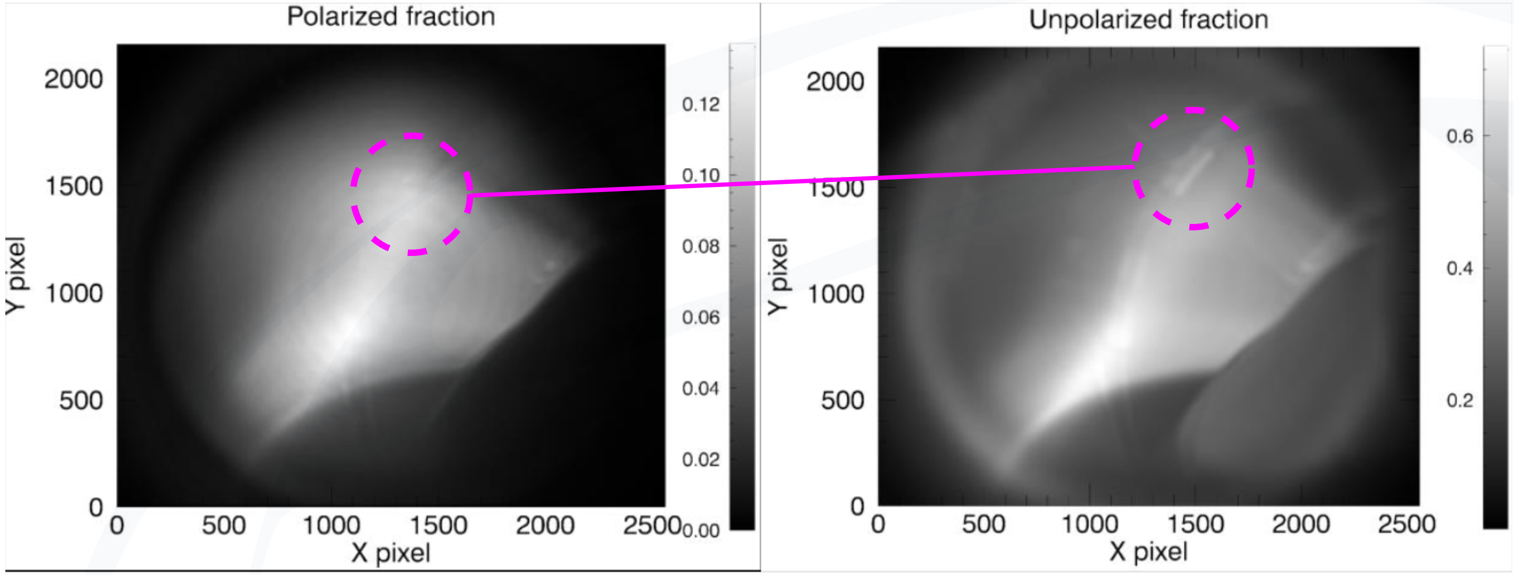


Figure 29. Left: Image of the polarized fraction of the emission and Right: the unpolarized image. Observe that the scattering structures (field-coil cans, helical coil and lens mount) are largely absent in the polarized image.

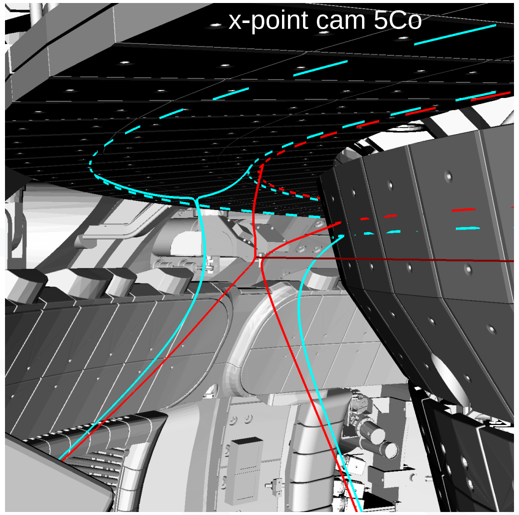
--> Desire a demonstration of quantitative CIS results with reflection suppression in a metal walled machine.

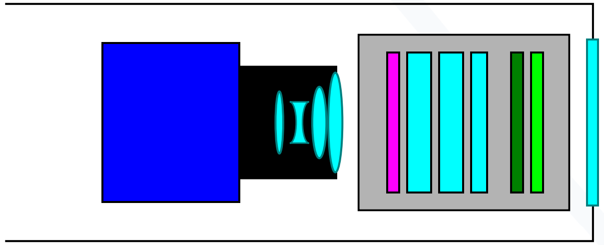
Prototype at ASDEX Upgrade?

AUG as main candidate because:
- Tokamak with metal wall.
- Excellent environment for diagnostic development.
- CIS experience at IPP-HGW: 4 persons
- Already some CIS measurements on AUG

Options from early e-mail discussions:

1) Dedicated experiments with Tillmann's upper divertor observation tube.
   a) Fibre bundle - Expect degradation of bundle. Only short term.
   b) Compact system - Unsure how to calibrate, magnetic field + temp effects.
   - Limited experience gained
   + Low development cost





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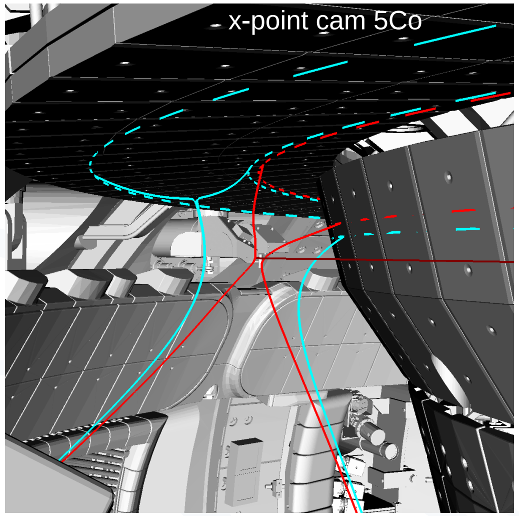

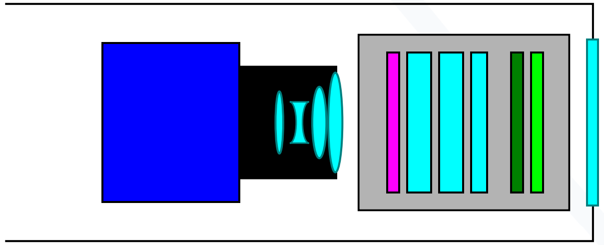

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  + Lots of experience + results for ITER assessment

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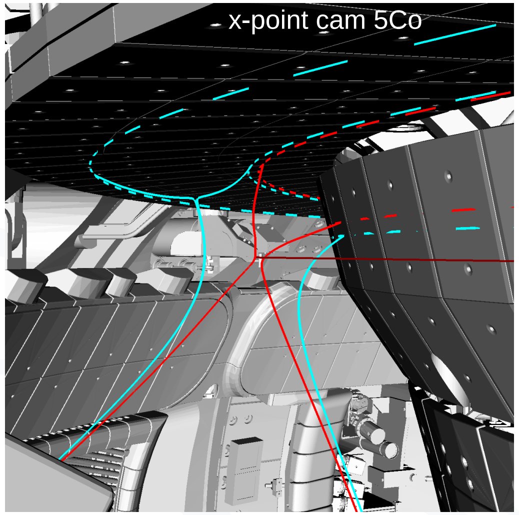

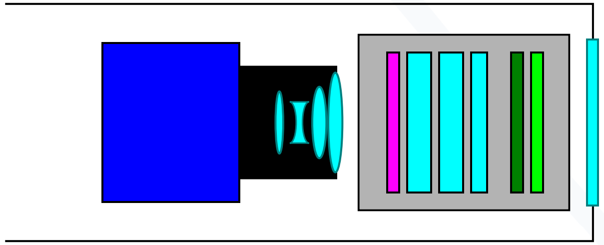

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3) Share a view with an existing system with flipping miror or beam splitter....

  candidates?

Required resources

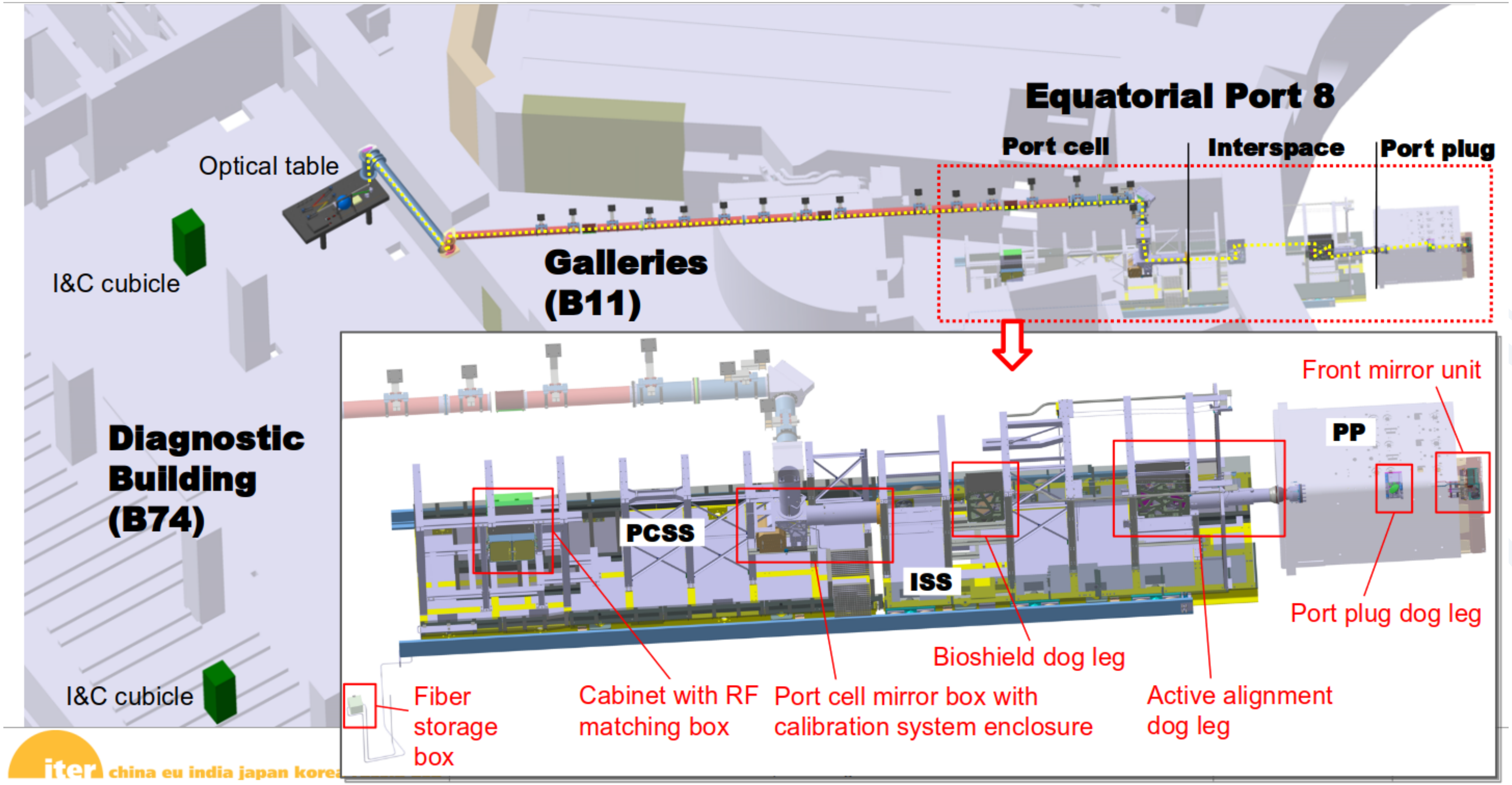
Manpower:
- 1x Full-time PhD for 3 years
- Supervision/support from IPP CIS experts.
- Ray-tracing support from ITER-IO contract is offered for relay design.
- AUG engineering support for design/installation (design reviews, integration etc).

Hardware costs:
- Calibration Laser: 180k€ - precise calibration source variable over most of visible wavelength - very useful for spectroscopy too!
- Camera: 15k€ - ... (also 50k for development of polarisation matrix on scientific camera, not necessary but nice)
- Crystals: 30k€
- Filters: 30k€
- Lenses: 20k€
- Relay optics: 50k€ ? - if building a relay system. Better estimate from AUG?
- Auxiliary components (control, PCs etc): 20k€

--> ~O 300k€.
- Implementing agreement with ITER can cover half the costs (including 1/2 of PhD position).

End

Reflection discrimination - chit 12



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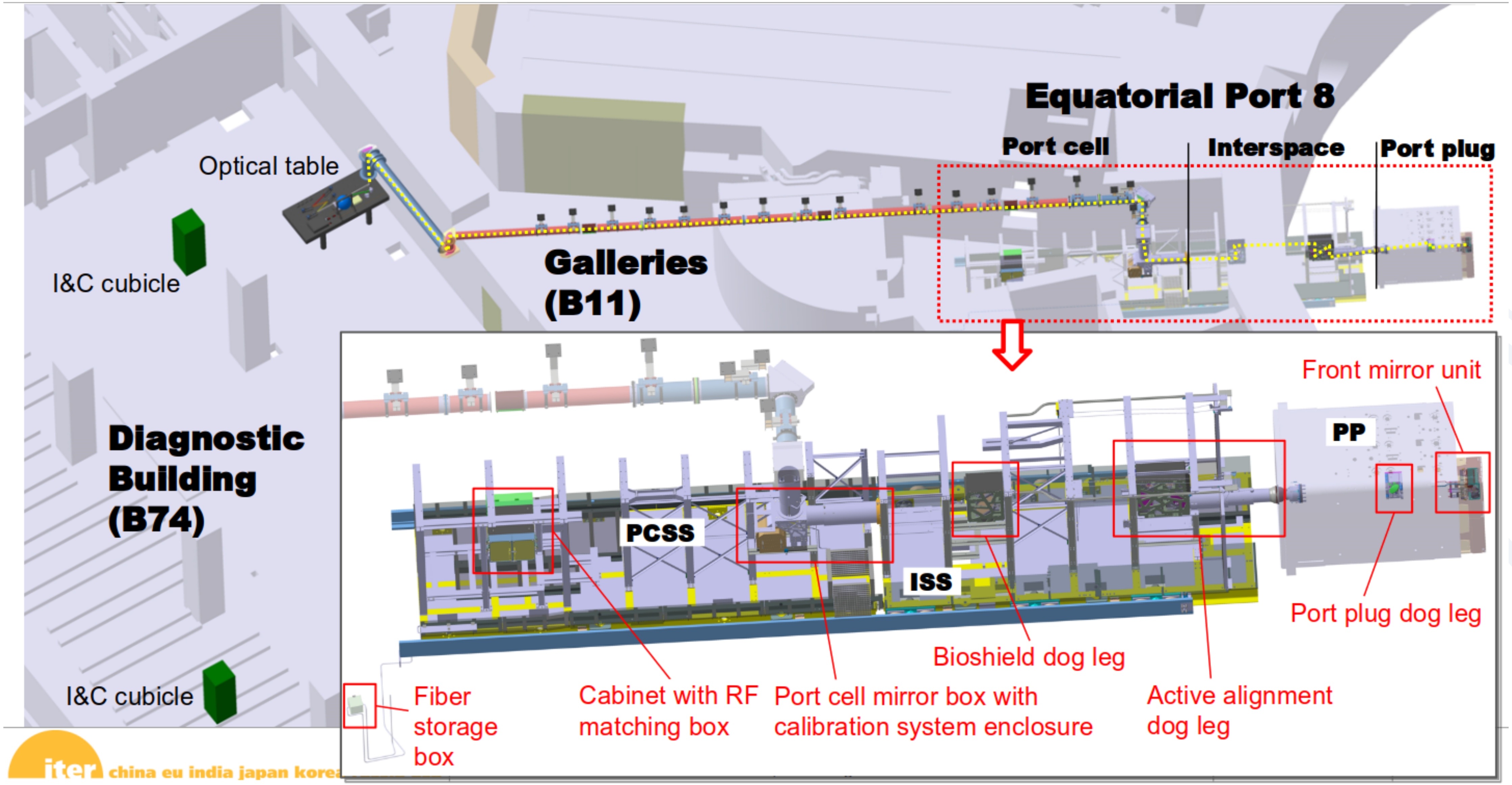

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Signal is mostly circularly polarised. Reflection is mostly un-/linearly- polarised.
--> Measure polarisation and use it to discriminate and suppress reflections.

- CDR chit #12: **Is this principle valid and applicable for ITER div. flow monitor view?**

The suppression of reflection is based on the idea that the majority of light reflected by the wall tiles comes from that emitted nearest to it, which necessarily comes perpendicular to the field and is therefore predominantly linearly polarised. This assumes: a) The diffuse reflection is dominant over specular, and b) reflected linear polarisation does not become circularly polarised. This should be shown for at least clean tungsten, but preferably also beryllium coated tungsten if at all possible.

If (a) is not true, specular reflection from lines of sight hitting tiles almost tangentially will contain a strong S3 component from the reflected continuation of that line of sight. If (b) is not true, the diffuse reflection of nearby plasma may be strongly circularly polarised due to phase shifts between the S and P reflected components.

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--> Measure polarisation and use it to discriminate and suppress reflections.

- CDR chit #12: **Is this principle valid and applicable for ITER div. flow monitor view?**

The suppression of reflection is based on the idea that the majority of light reflected by the wall tiles comes from that emitted nearest to it, which necessarily comes perpendicular to the field and is therefore predominantly linearly polarised. This assumes: a) The diffuse reflection is dominant over specular, and b) reflected linear polarisation does not become circularly polarised. This should be shown for at least clean tungsten, but preferably also beryllium coated tungsten if at all possible.

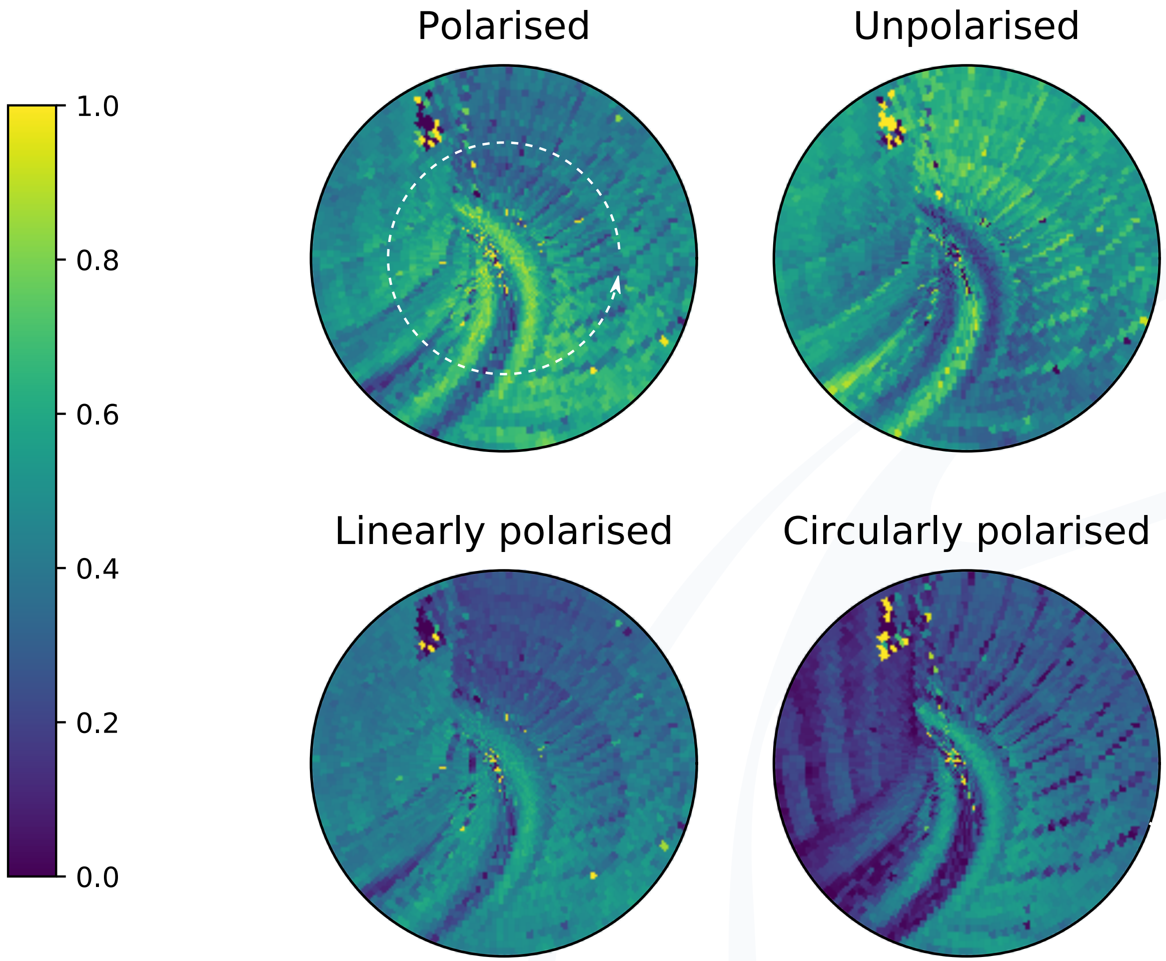
If (a) is not true, specular reflection from lines of sight hitting tiles almost tangentially will contain a strong S3 component from the reflected continuation of that line of sight. If (b) is not true, the diffuse reflection of nearby plasma may be strongly circularly polarised due to phase shifts between the S and P reflected components.

To resolve:

1: Measure effect on polarisation of reflections from ITER wall materials --> IPP
2: Develop model of realistic reflections in ITER and polarisation mixing --> Luffy.AI
3: Assess probable success of suppression --> IPP

Reflection measurements

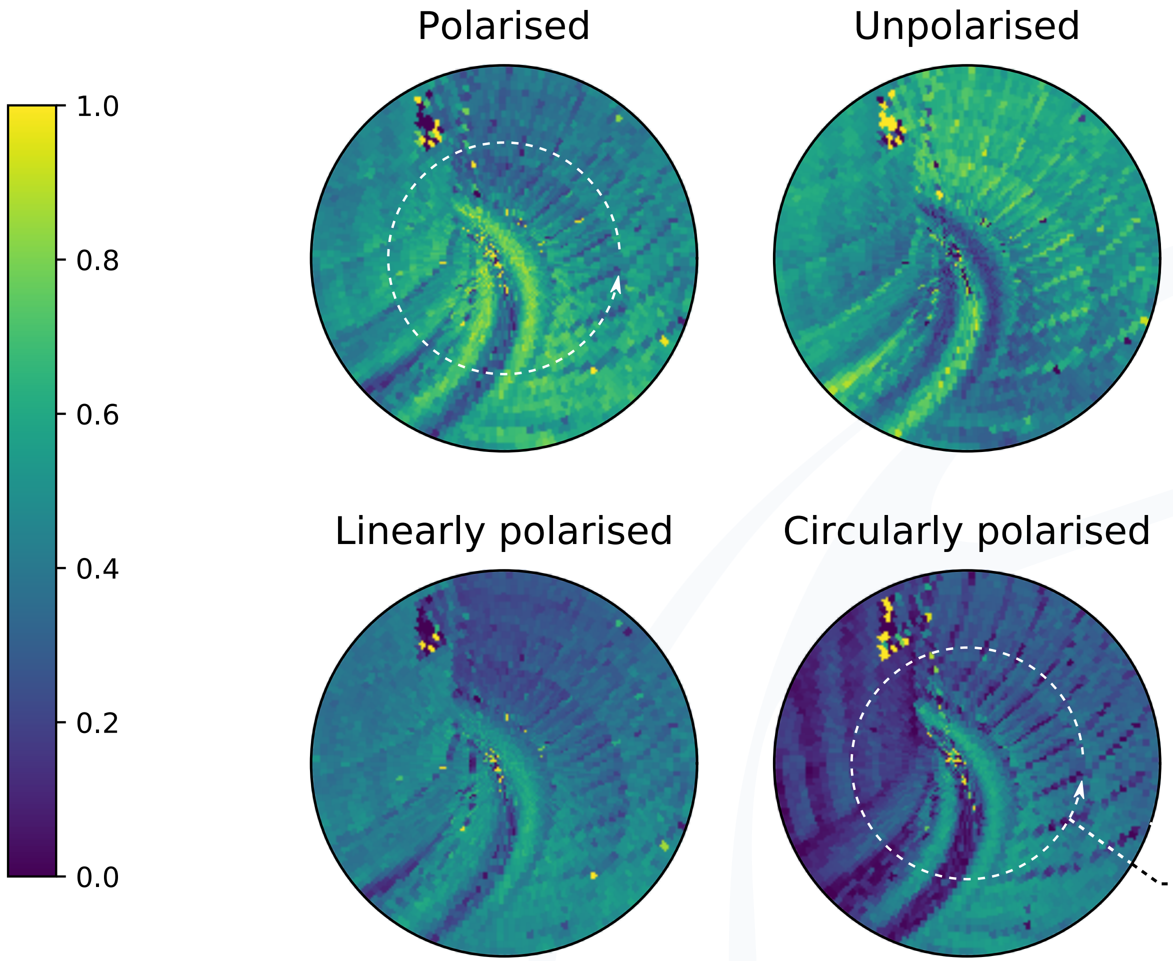
- Ignoring this for now... Are reflections mostly linearly polarised or unpolarised??

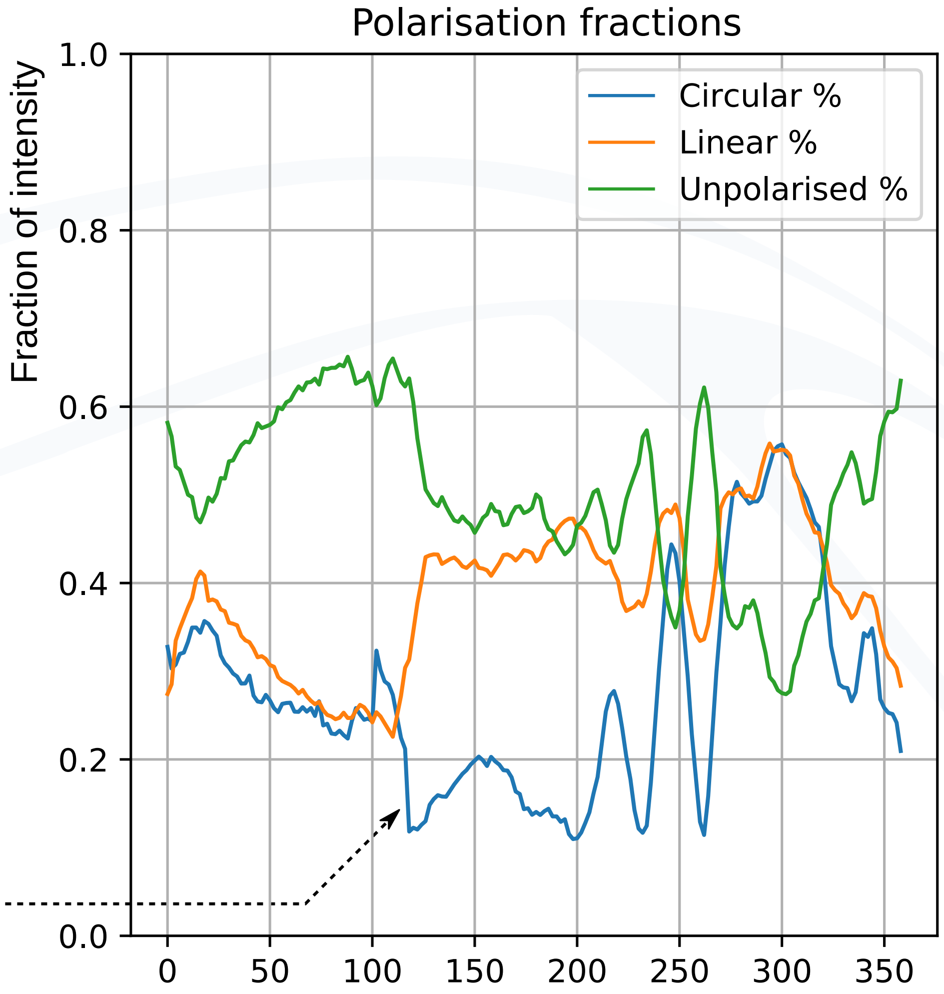


Fraction of intensity

Reflection measurements

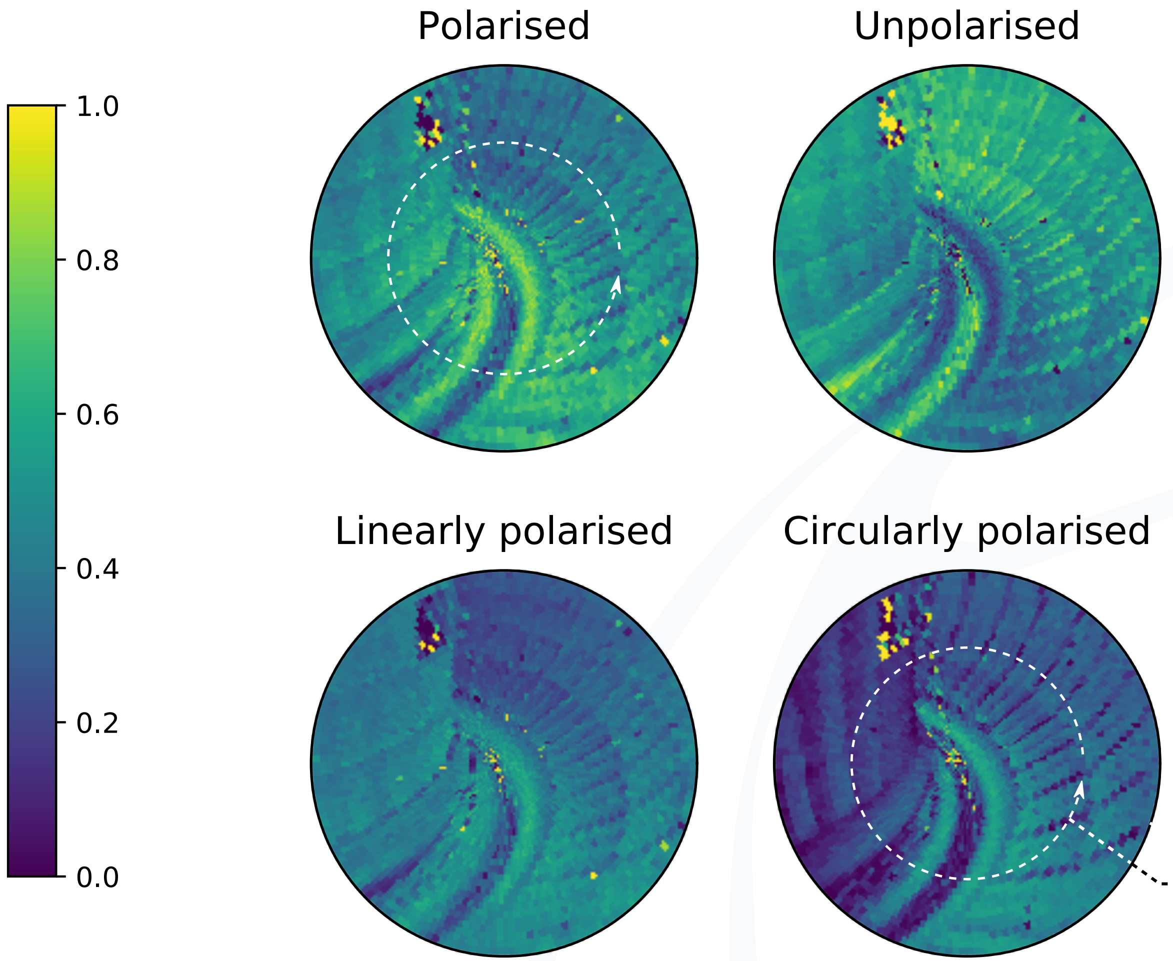
- Ignoring this for now... Are reflections mostly linearly polarised or unpolarised??

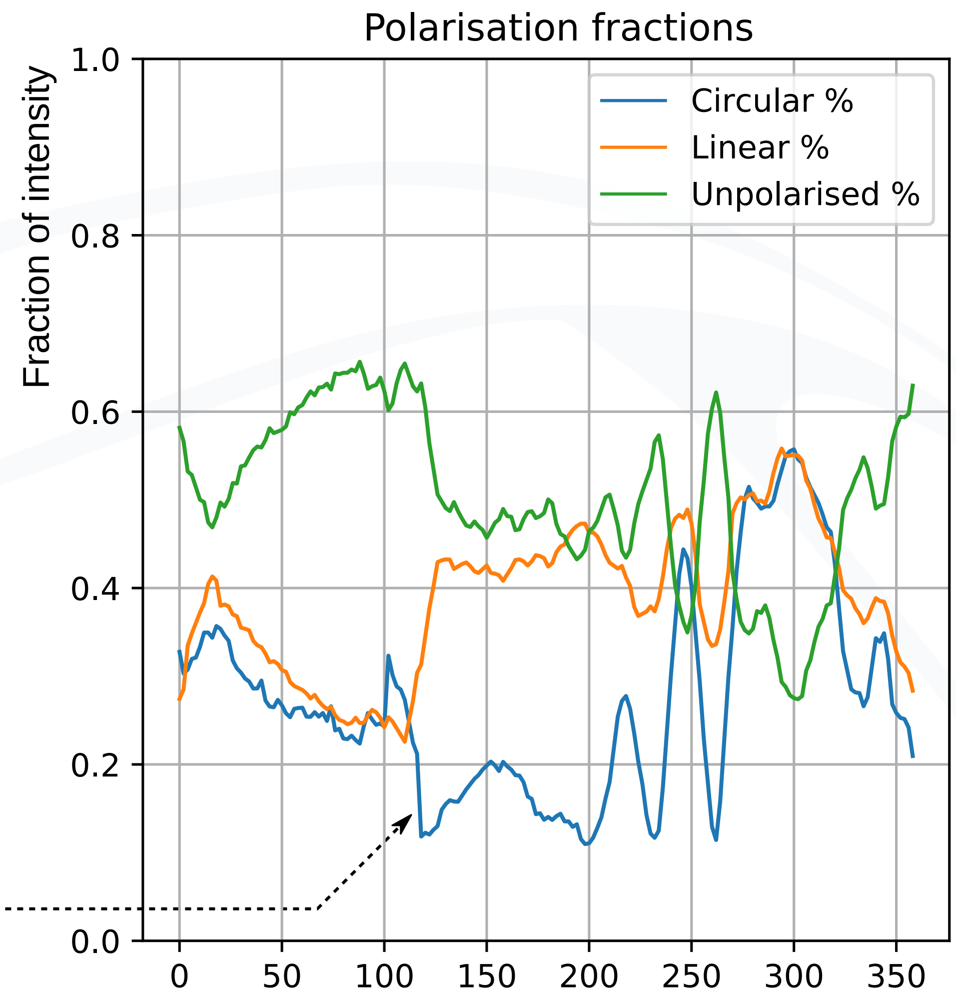




Reflection measurements

- Ignoring this for now... Are reflections mostly linearly polarised or unpolarised??





--> Not really, they seem to be a varied mixture of everything (linear, circular and unpolarised)