EGO EUROPEAN GRAVITATIONAL OBSERVATORY

Lesson learned from AdvancedVirgo+ ISC Commissioning

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on behalf of VIRGO collaboration

VIR-0402A-23

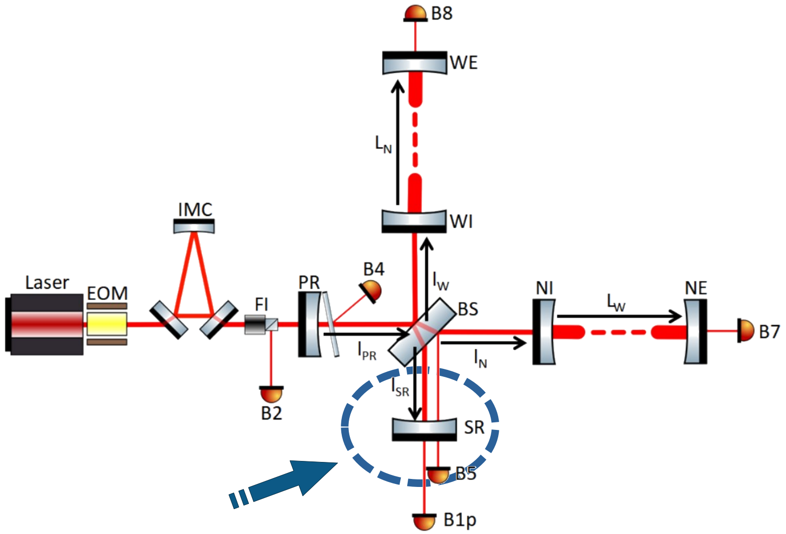
Main challenges in O4 configuration

Dual recycled interferometer:

- Increased complexity for the control of the ITF
- Need of a new lock acquisition scheme
    - ALS

Marginally stable cavities → Very sensitive to HOMs

- Need to minimize optical aberrations
- Offset on the control signals (mainly SRCL and MICH)
- Bistabilities of the working point (jumps)
- Lack of a proper error signal for SR alignment



Increased input power 25W → 40W:

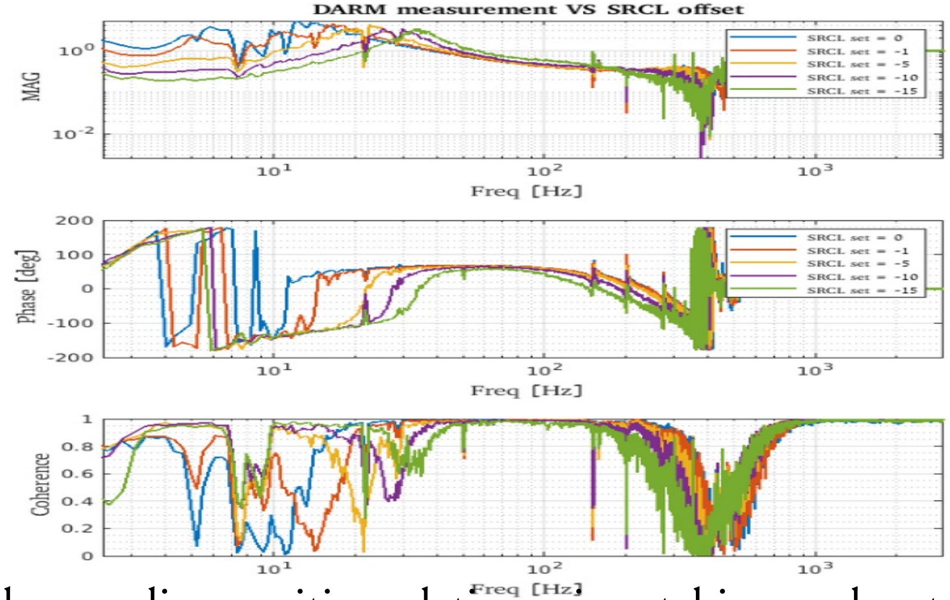
- Thermal effects more critical

DARM OLTF and Optical Spring

SR error signals strongly affected by HOMs

DARM OLTF different from ideal one (e.g. VIR-0223A-22, VIR-0334A-22):

- High optical spring
  - **Locking issues**
    - reduced stability of DARM
- Low Double cavity pole
  - **Sensitivity issue**
    - low high-frequency optical gain



The offset depends on the ITF aberrations (mainly recycling cavities relative mismatching and wrt the arms) → highly dependent on thermal compensation and alignment

Advanced Virgo+
ISC subsystem

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mostly dependent on SRCL offset

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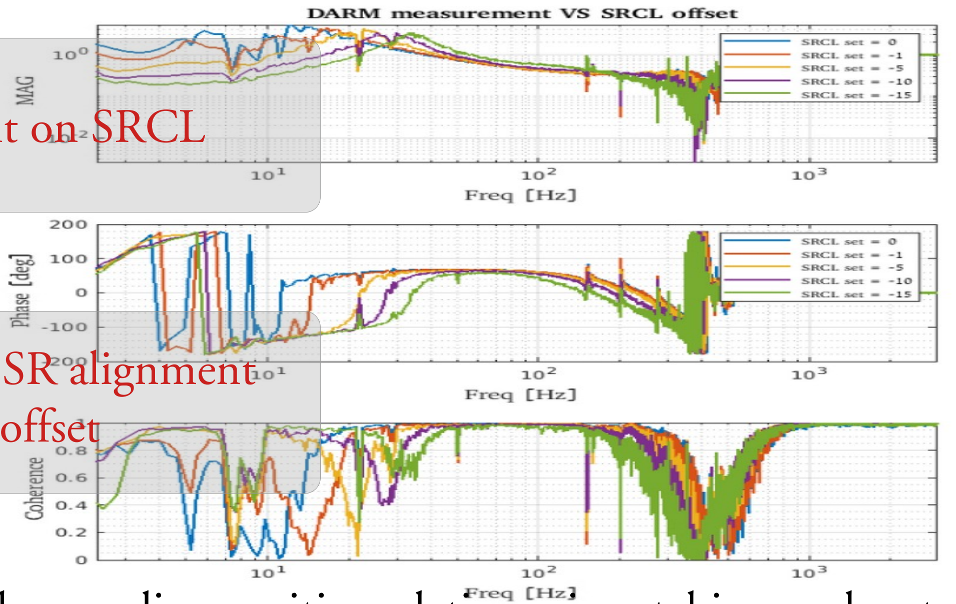
dependent on both SR alignment and SRCL offset



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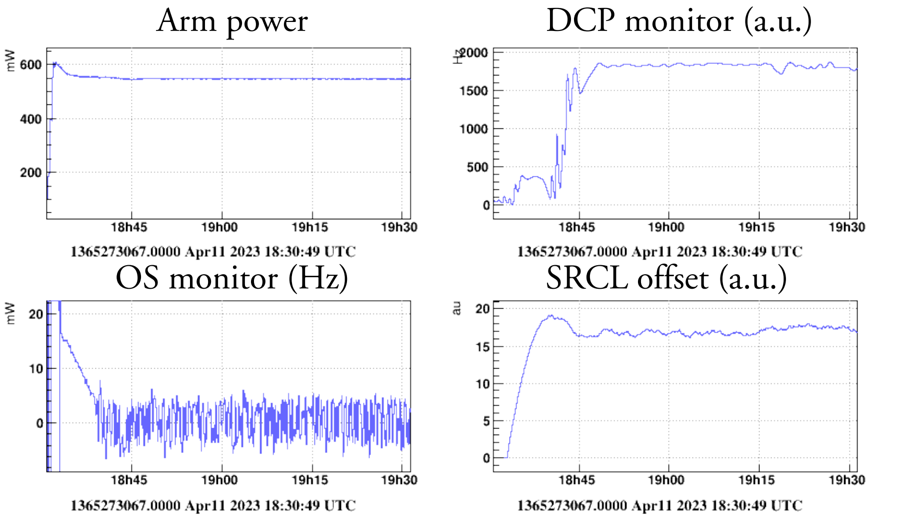
Patch solution: SRCL offset servo

SRCL hidden offset to be compensated by adding a servo on the SRCL set point to null the optical spring frequency (typical offset in the range of 5-10nm):

→ This has allowed to have the best optical response of DARM.



Drawbacks:

- ✘ low accuracy of the servo
- ✘ increase of technical noises due to the need of working with an error signal far from 0
- ✘ OS monitor uses an injected DARM line (UGF)

Lack of proper SR alignment signal

Implemented a solution LIGO-like to be robust against mismatch modes:

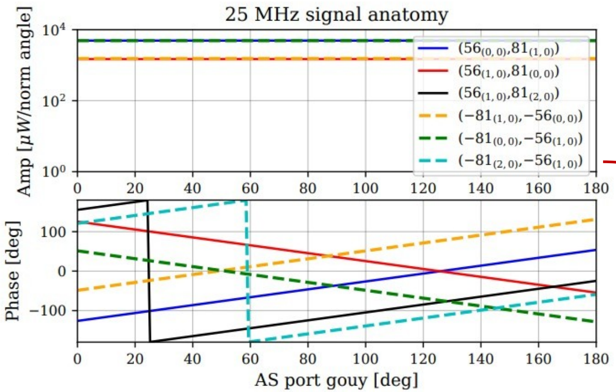
- sideband-sideband beating, 25MHz signal on B1p (81MHz-56MHz) → additional EOM installed

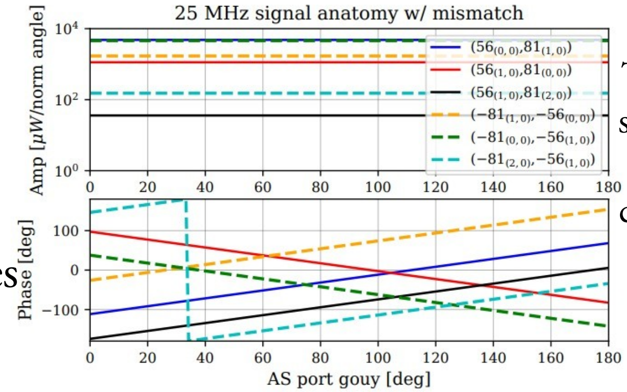
Main issues:

- No stationary behavior
- No bipolar behavior

➡ not a reliable error signal.

The main reason is that the LIGO-like technique requires to have SRC with at least 20deg of Gouy phase.
VIR-1107A-22





The mismatch scatters powers in 01 TEM creating offsets

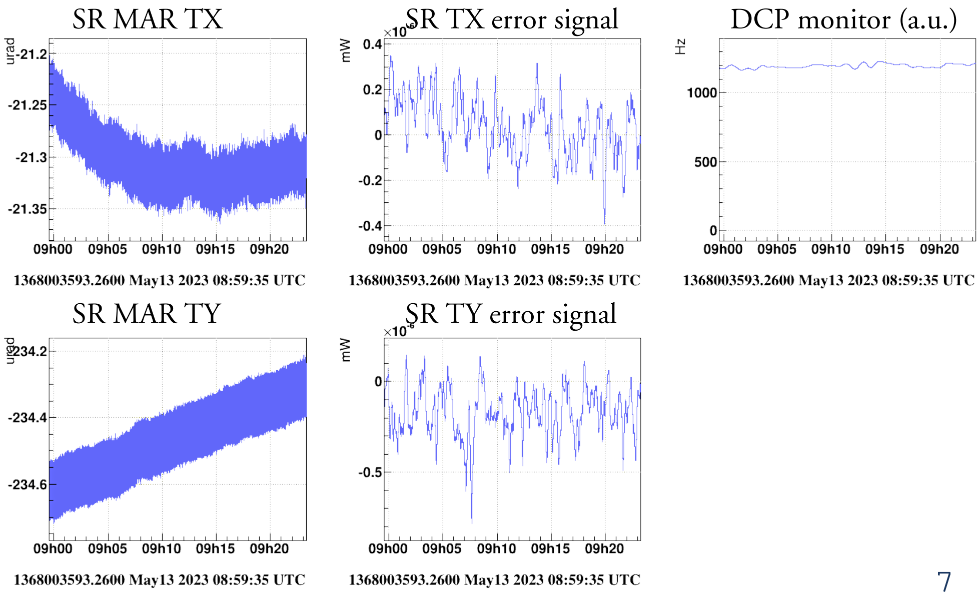
Patch solution: DCP double demodulation

SR in drift control

- Alignment uses double demodulation on high-frequency OLTF of DARM (to align the SR in order to maximize the DCP, i.e. lower the SRC losses)

Drawbacks:

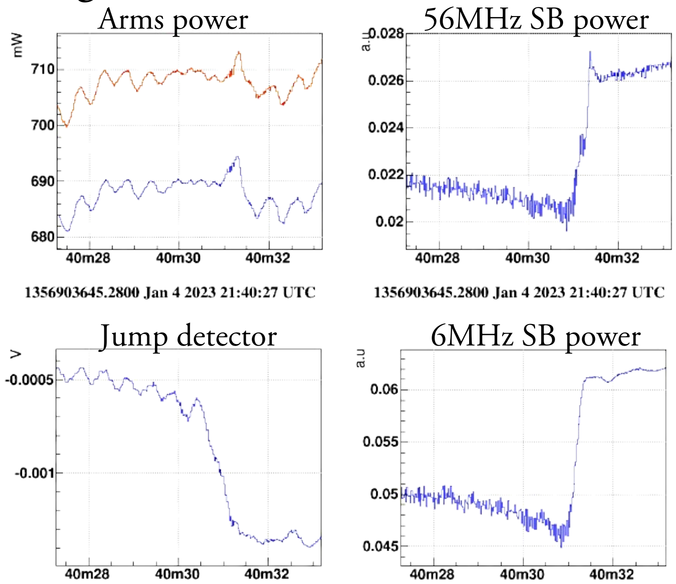
- It requires injected lines on DARM and SR angle.



Bi-stability of the WP: Jumps

Transition between two optical states with different beam alignment/position (e.g. VIR-0039A-23):

- The bistability of the longitudinal working point has been really detrimental for the ISC commissioning → No stable locks
- Sideband power and symmetry stable only once in the good state



✓ Automatic detection of the jumps

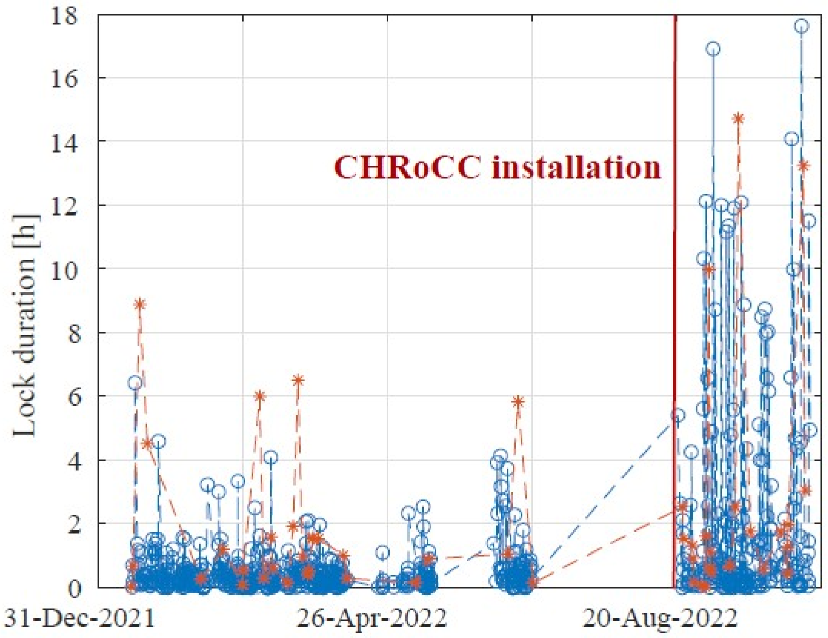
✘ Efforts to deterministically induce jumps (acting on controls) not successful

Bi-stability of the WP: Jumps

Long-term issue:

- Strongly dependent on the PRC/SRC stability an matching → solved with CHRoCC installation

- ETM RoC tuning improves efficiency and reliability of the jumps



Conclusions

- The control of the interferometer is very complex in presence of marginally stable cavities.

- Controls are strongly affected by optical defects, but so far we could control the double recycled ITF through heavy use of servos to manage the resulting offsets (SRCL, DIFFp, MICH…)

  - servos on angular Dofs was needed also in the single recycled configuration (O3).

- While functioning, the stability of the ITF is highly dependent on optical aberration control

Conclusions

- The control of the interferometer is very complex in presence of marginally stable cavities.
- Controls are strongly affected by optical defects, but so far we could control the double recycled ITF through heavy use of servos to manage the resulting offsets (SRCL, DIFFp, MICH…)
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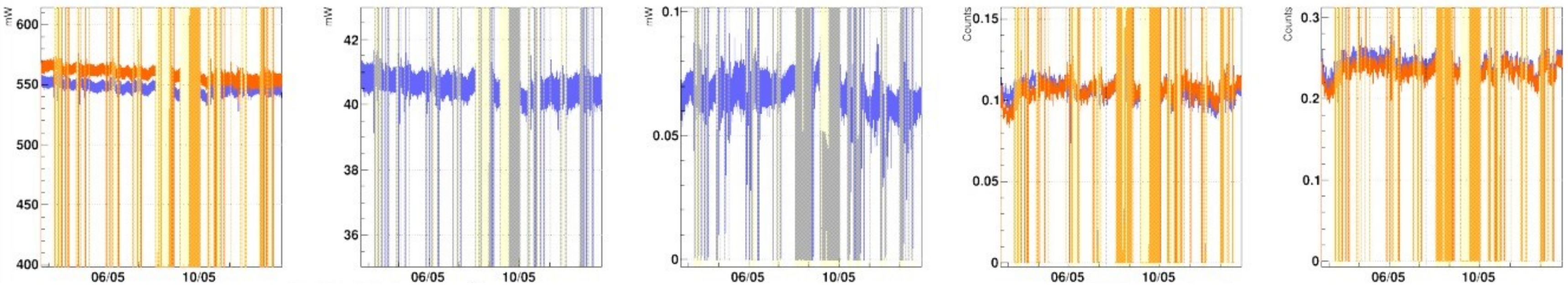
But…

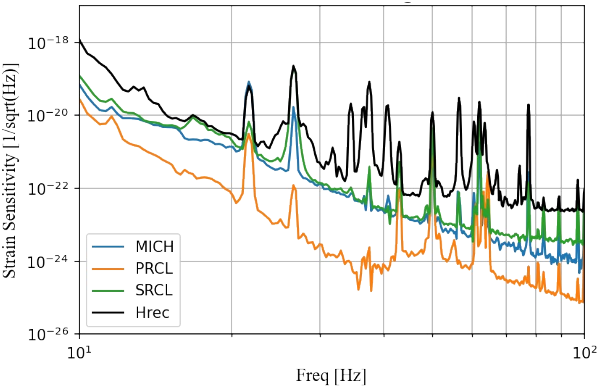
ISC subsystem

Conclusions

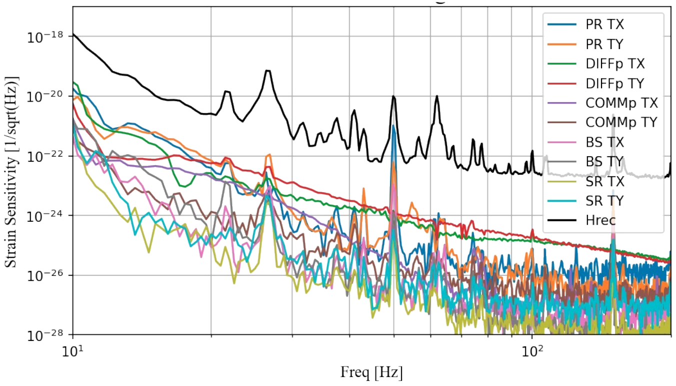
Arm cavity power | DRMI power | Dark fringe power | 56MHz sidebands Up/Low | 6MHz sidebands Up/Low



LSC Noise Budget



ASC Noise Budget



- Stable locks
- Up-to-now, control noise seems not to limit above 30Hz (still work in progress)

Thanks for your attention

Control loops error signals and bandwidth

Longitudinal loops:

DOF	Error Signal	Bandwidth (UGF [Hz])
MICH	B4_56MHz_I	9
SRCL	B4_56MHz_Q	3
PRCL	B2_6MHz_I	25
DARM	B1p_56MHz_I	75
CARM_Slow	RFC_6MHz_I	5
SSFS	B4_6MHz_I	5000

Angular loops:

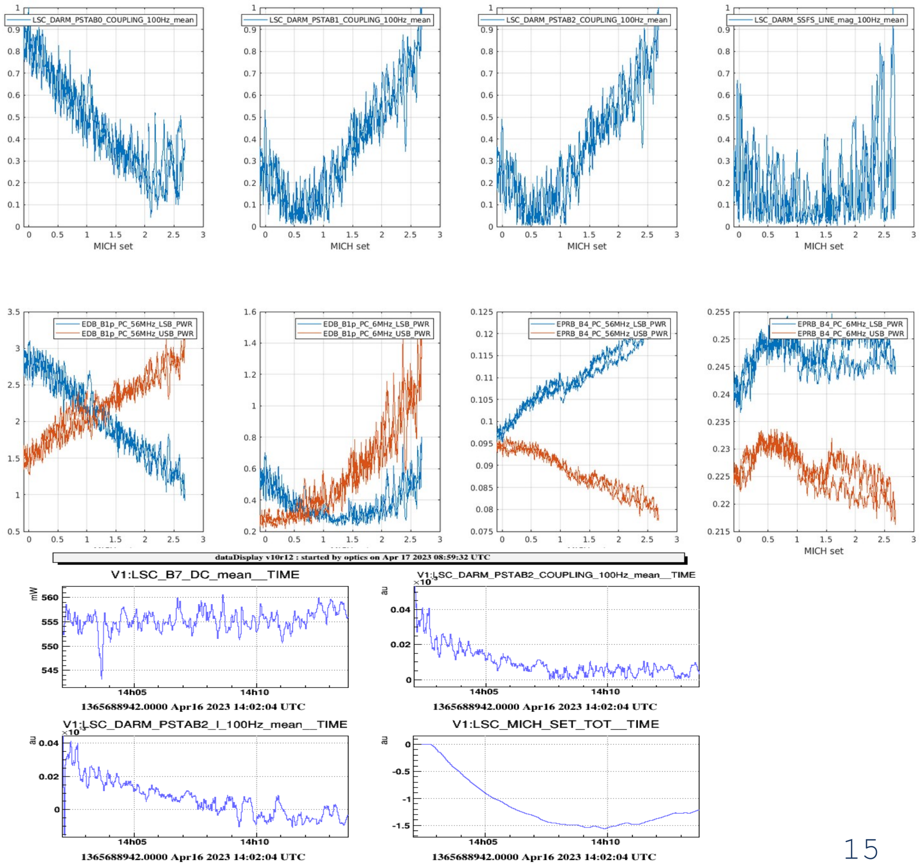
DOF	Error Signal	Bandwidth (UGF [Hz])
DIFFp (DIFF hard)	B1p_QD_56MHz	3
COMMp (COMM hard)	B7_QD_DC + Mirror centering	3
DIFFm (DIFF soft)	Mirror centering	0.03
COMMm (COMM soft)	Mirror centering	0.03
PR	B2_QD_6MHz	3
BS	B1p_QD_50MHz	3
SR	Double demodulation DCP	0.03
Input beam	B2_QD_8MHz	3

MICH offset servo

Hidden offset on MICH:

- Sidebands unbalance
- Higher CMRF
- RIN coupling to DARM

A servo on the MICH working point has been implemented in order to minimize the coupling of the power stabilization to DARM



DIFFp offset servo

DIFFp setpoint servo :

- adjustment of the the DIFFp DoF sepoints to minimize dark fringe
- Improvement of the dark fringe stability
    - ➔ needed for OMC lock