

IVOA Standards for Multi-Messenger and Time-Domain Data Exploitation

Marco Molinaro

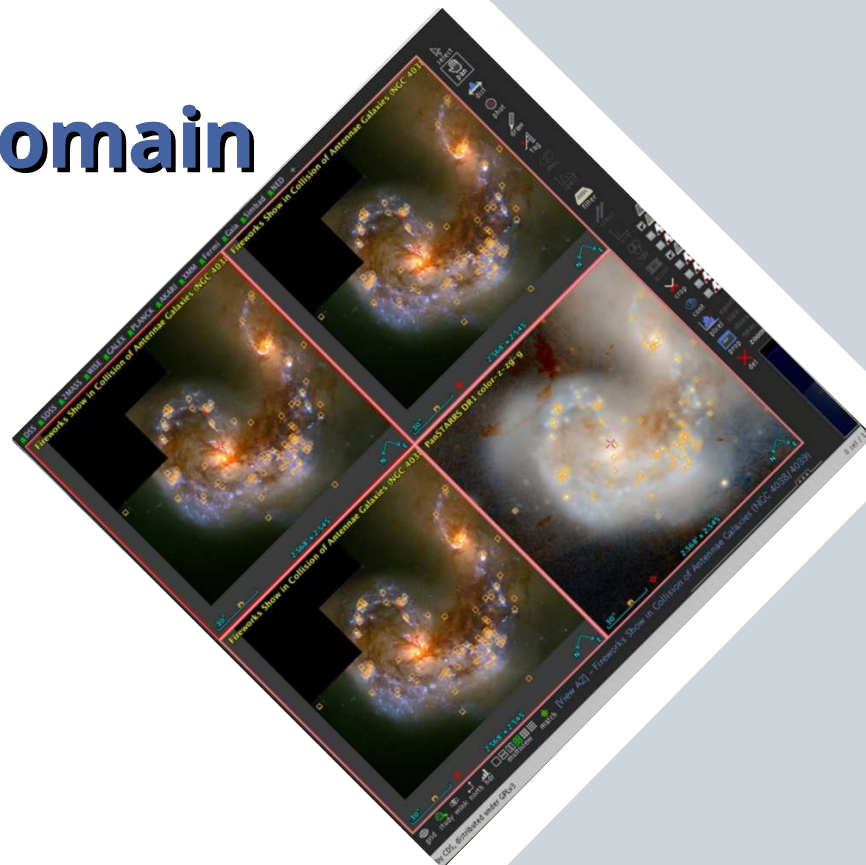


for
IVOA Technical Coordination Group
IVOA Executive Committee



OSCARS

Astro-CC



August 7th 2026

Fortezza da Basso - Florence

challenges and solutions

Any area of the sky not observed in a certain moment in time is missing data

- **Preservation**
 - “forever”
- **Sharing**
 - **Open/Public** accessibility
- **Interoperability**
 - Technical & **Semantic**

DATA



- **International Virtual Observatory Alliance**
- Formed in 2002
- Open standards organisation
- Interoperability as the core goal
- FAIR-enabler standards for astronomy

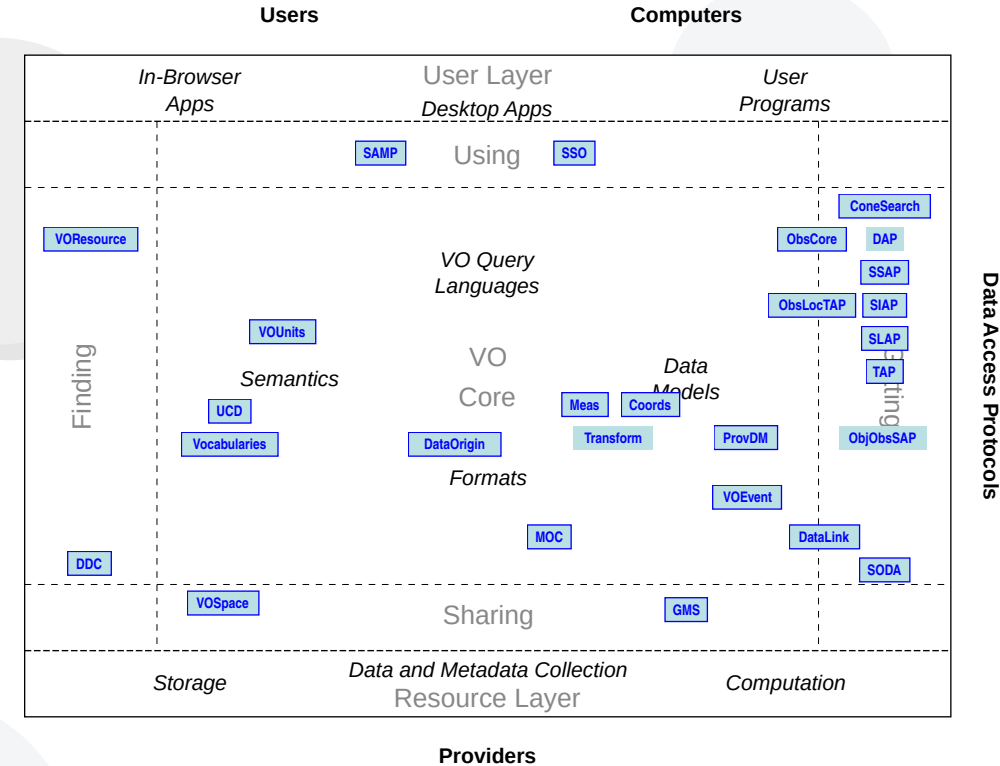
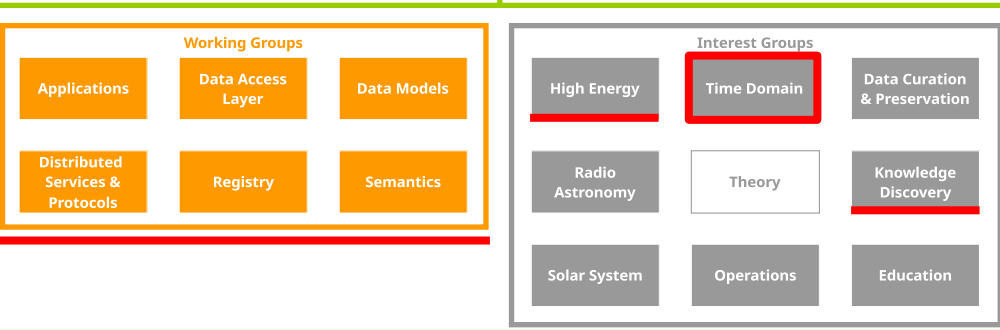
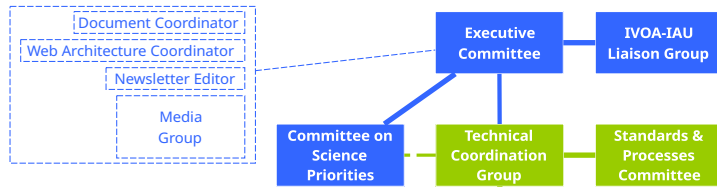
IVOA vision



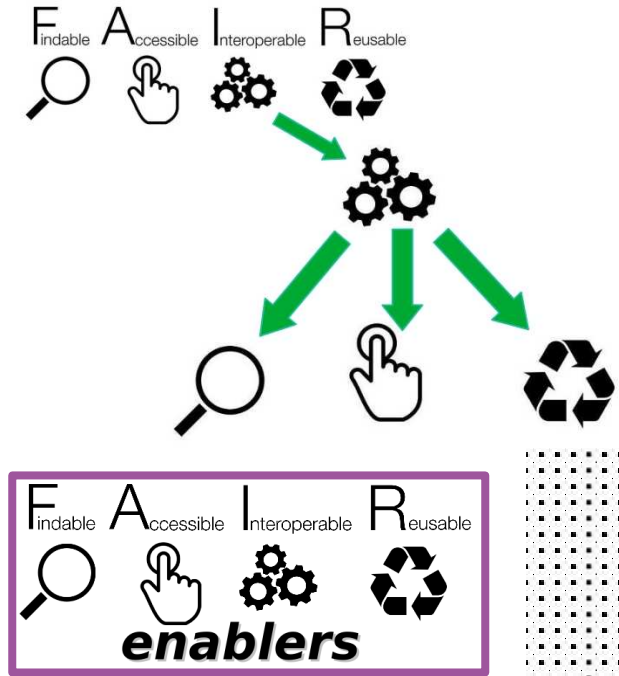
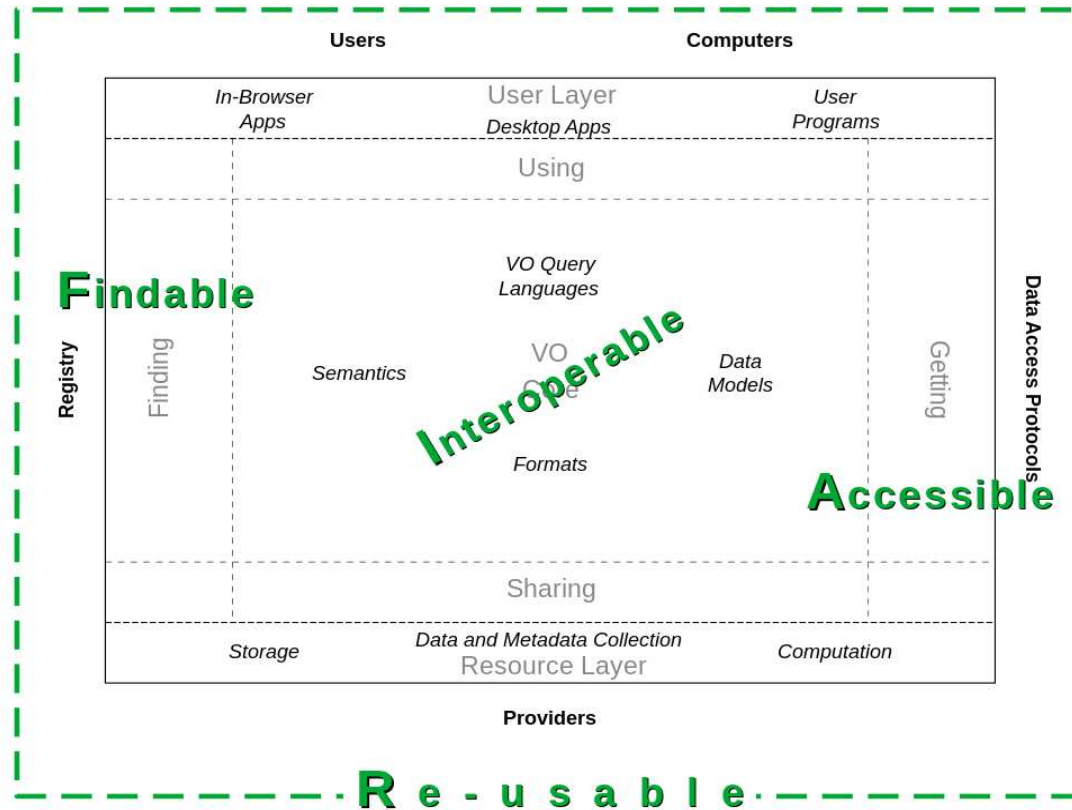
The **Virtual Observatory (VO)** is the vision that astronomical datasets and other resources should work as a seamless whole. [...] The **International Virtual Observatory Alliance (IVOA)** is an organisation that debates and agrees on the technical standards that are needed to make the VO possible.

- ✓ Semestral “Interoperability” Meetings
- ✓ Recommendations (standards) are **agreed on consensus**

organisation & architecture



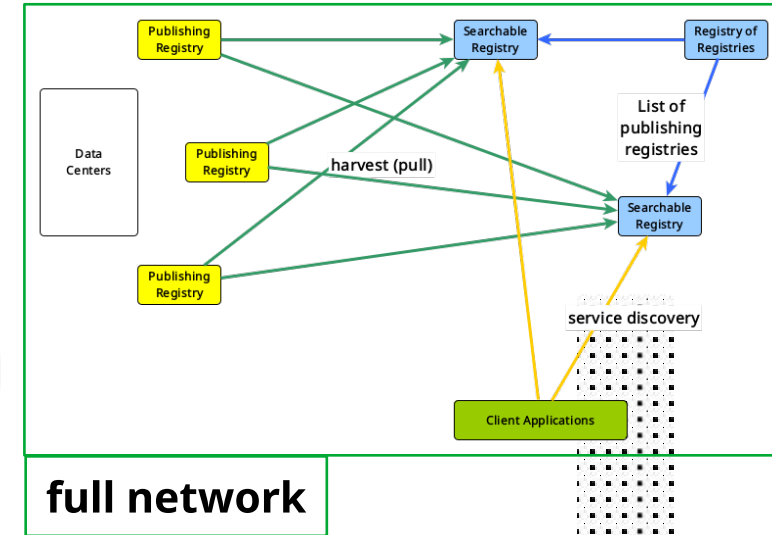
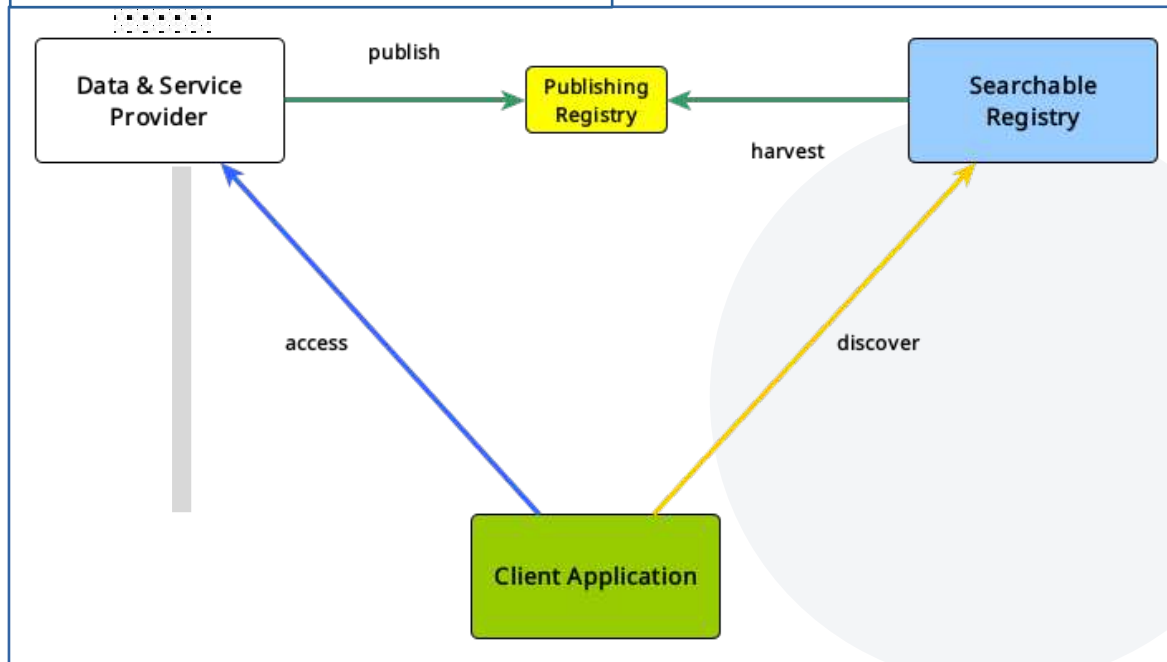
IVOA – FAIR mapping



the IVOA Registry

Findability of Resources

discover & access example



what to do?

// As a **data provider**, manager, describe your resources, add them to the Registry, and let the applications connect. **//**

what to do?

// As **researchers**, use the tools and provide feedback and requirements: that's how to improve the Virtual Observatory ecosystem. **//**

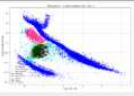
SVO ZTF cataclysmic variables



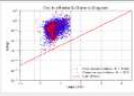
SVOZTF Cataclysmic Variables Service

The SVOZTF Cataclysmic Variables Service is an automated system for the identification and characterisation of transient objects. It uses data from the Zwicky Transient Facility (ZTF) through the ALeRCE broker and cross-searching in catalogues such as Gaia DR3, SIMBAD, eRosita and Chandra.

MJD start 04 / 05 / 2018	RA min 	Dec min 	Mag min (G) (brightest)
MJD end 29 / 04 / 2026	RA max 	Dec max 	Mag max (G) (faintest)
Plx min 	CV classes: ☐ Novalike ☐ Dwarf novae ☐ Novae ☐ Polars ☐ Int. polars	Classes confidence: ☐ 1-sigma ☐ 2-sigma ☐ 3-sigma	Type of spectra: ☐ Spectra ☐ Emission
Plx max 			
Mission: ☐ Gaia DR3 ☐ eRosita ☐ Chandra	Sort by: First MJD Ascending	Search	Clear



HR Diagram



eROSITA-Chandra Diagram

<https://sdc.cab.inta-csic.es/svoztvf/>

An alternative to the traditional follow-up approach is by searching for existing information in VO archives and services.

The characterization workflow consists of several steps, most of them using VO protocols (e.g. SSAP), tools (e.g. STILTS) and services (e.g. Vizier).

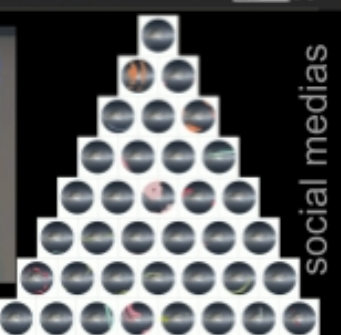
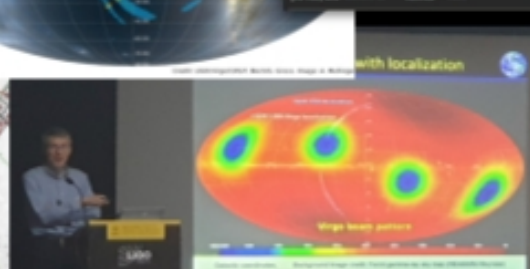
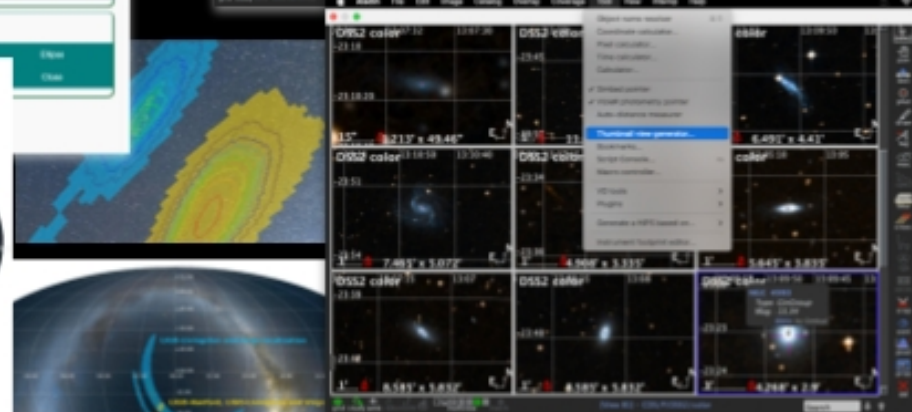
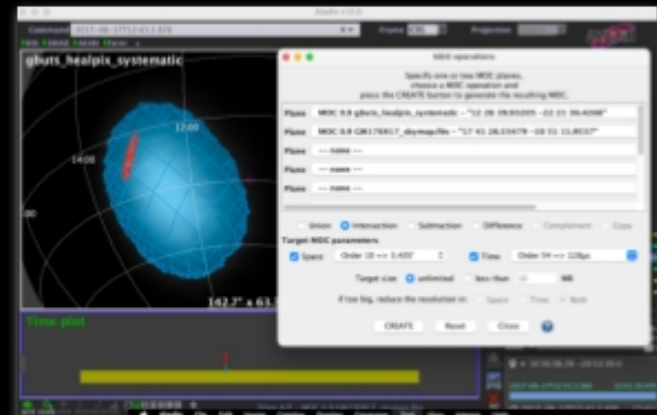
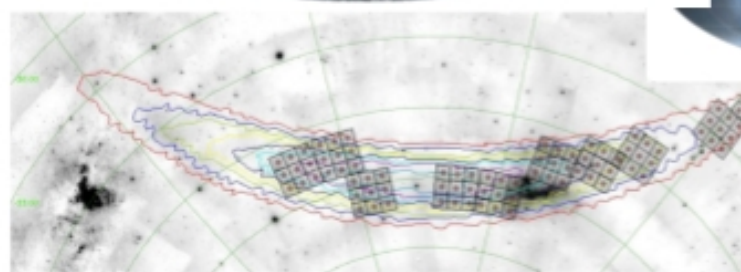
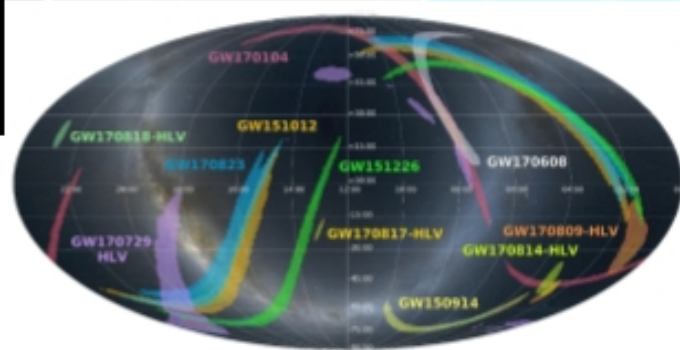
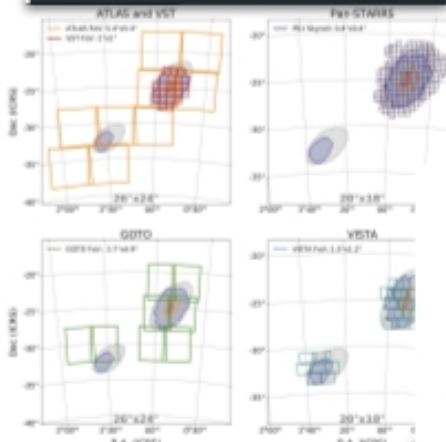


VO-enabled spatial-temporal analysis of GW localizations

Thanks to VO standards, GW sky localization regions have evolved from static areas into active, queryable regions.

- **Interfacing with VO big-data services, such as VizierR.**
 - **Interactive visualization, accessible on any device.**
 - **Logical operations supporting reference-image retrieval, skymap update comparison, transient localization, and other advanced analyses.**
 - **All operations are performed in both the spatial and temporal domains. This enables EM followup strategies and multi-messenger studies through joint analysis of localization maps from different messengers, including GWs, GRBs, and neutrinos.**
- ❑ The development has supported observational campaigns by **GRAWITA** and several other teams, evolved into the standard approach described in the official **IGWN User Guide**, and is now being adopted in the era of big transient data enabled by the **Vera C. Rubin Observatory**.
 - ❑ These activities were carried out through several European projects, including: **ASTERICS**, **ESCAPE**, **AHEAD** and **ACME** with dedicated tutorials delivered at VO Schools and LVK Open Data workshops, and indexed on the EOSC platform.
 - ❑ Within the Virgo Collaboration, new web apps have been developed for cosmology and low-latency applications, including **GWsky** and **GLADEnet** - integrated into the **ASI SSCDC** tools.
 - ❑ This has also enabled significant **technology transfer** into interactive **outreach products**, including images published on APOD and press-release images produced by the LVK Collaboration, ENGRAVE, and GRAWITA.

Articles, Press releases, Cosmology and EM followUP



Based on Greco et al., 2022 A&C- <https://doi.org/10.1016/j.ascom.2022.100547>

interoperable alerts

Requirements for VOEvent-3.0

- Transport protocol agnostic
 - Kafka in wide use now
- Data serialization agnostic, though must support embedded attachments
 - Potential Formats: JSON, AVRO, ASDF (XML does not support encoded data)
 - Encoded Attachments: MOC, HEALPix, images, time series, spectra
- Schema/Semantics – Redesign with a standard structure and science case-specific templates
 - Original intention of VOEvent, but not fully realized
 - Keep Who/What/Where&When/Why/How?

Judith Racusin (June 2026 IVOA Interop)
[adapted from]

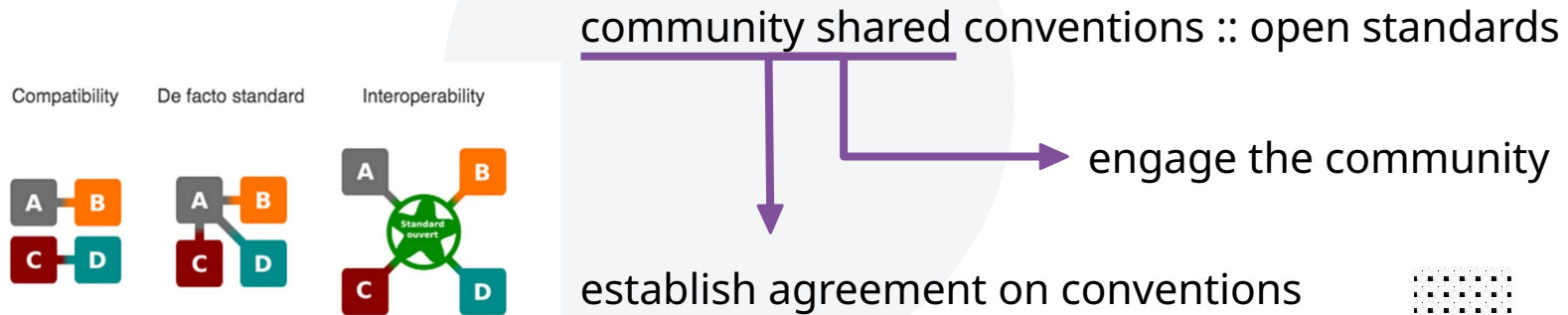
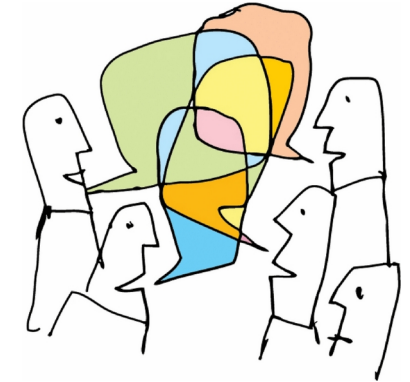
https://wiki.ivoa.net/internal/IVOA/InterOpJun2026Apps/Racusin_IVOA_VOEvent3_June2026.pdf

Challenges

- Many alert streams are in production and are unlikely to change in the near-term (e.g. optical transients with Rubin/brokers)
 - need tool to convert to VOEvent-3.0
 - production streams with translated VOEvent3.0 at brokers?
 - once VOEvent3.0 is a new standard, need to advocate for adoption by alert brokers/missions/observatories
- Tools require maintenance to remain relevant
- It's time to complete this effort, and broad community support is needed

driven by “open community”

- Open Science <> opposite of bad science
- Digital resources -> leverage FAIR principles
- Principle $\neq$ Rule/Convention/Norm
- Research domain -> Intrinsic characteristics
- Characteristics -> turn principles into conventions
- Conventions -> Standards
- Research domain :: Community



how to contribute



- 2nd Scientific Training
 - Sept. 29th – Oct. 1st
 - Strasbourg
 - <https://indico.in2p3.fr/event/38575>
 - SOLD OUT!
- 2nd Technology Forum
 - 19-22 Oct. 2026
 - Paris Observatory
 - (ask for details)

Semestral “Interoperability” Meetings

- Southern Spring Interop 2026
 - 6-8 November 2026
 - Perth
 - after ADASS XXXVI (1-5 November)
- Northern Spring Interop 2027
 - (TBC) 3rd week of May 2027
 - ESAC (Madrid, Spain)
- then Oct./Nov. 2027 – Toronto (Canada)



National VO School

- 24-26 Novmber
- Area CNR Bologna
- <https://indico.ict.inaf.it/event/3652/>

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Molinaro – COSPAR 2026 – E1.13 – 7.8.26



*If you want to go fast, go alone.
If you want to go far, go together.*



Thank you for your attention!