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Working Group — Active B Stars

Etoiles actives de type B

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TRIENNIAL REPORT 2021-2024

1. Background

The Working Group on Active B Stars (WGABS, formerly Working Group on Be Stars) was re-established under IAU Commission No. 29 in 1979 to promote and stimulate research and international collaboration in the field of active B stars. The focus of the WGABS has increasingly shifted from Be stars to all types of active B stars including topics such as mass loss and accretion, pulsations, rotation, magnetic fields, and binarity, X-ray phenomena, fundamental parameters, and to promote collaboration and interaction between scientists specializing in these studies.

The WGABS is open to all researchers interested in the field. Currently there are 121 members of WG Active B stars under Division G Stars and Stellar Physics. Over the last decades, active B-type stars have emerged as laboratories for the examination of phenomena with a broad range of astrophysical applicability. The Keplerian decretion disks of classical Be stars are ideal test-beds for disk physics, insights from which can be applied to protoplanetary disks and black hole accretion disks. Similarly, the magnetospheres of magnetic B-type stars share broad similarities with those of planets and ultracool dwarfs, making them interesting probes due to the relative ease with which they can be observed and characterized.

2. Developments within the past triennium

2.1. *Community events*

Following disruption due to the COVID pandemics, the WGABS elections were shifted to September 2022: the composition of the new committee is provided above. Elections to change half of the committee should occur in Fall 2024, to get back to the usual schedule.

From 2021 on, the WGABS committee is organizing a series of monthly seminars, whose recordings are available on the WGABS youtube channel (see http://activebstars.iag.usp.br/?q=node/16 and https://www.youtube.com/@iauwgabs). The current main committee member in charge of the seminars is Alexandre David-Uraz. The seminar list up to now has been:

- May 2021: Jonathan Labadie-Bartz (America, M) on "Space photometry of classical Be stars: rapid rotation, pulsation, and links to mass ejection"
- June 2021: Matt Schultz (America, M) on "Magnetic B-type Stars as Magnetospheric Exemplars"

• July 2021: Julia Bodensteiner (Europe, F) on "On the possible binary origin of classical Be stars"
• August 2021: Robert Klement (America, M) on "Interferometric View on Classical Be Stars - Revealing Close Binarity"
• September 2021: Rebecca Martin (America, F) on "Connecting Be/X-ray binary outbursts to disc dynamics"
• October 2021: Anahi Granada (America, F) on "Revisiting the angular momentum loss rates for Be stars in the single star scenario"
• November 2021: Barnali Das (Asia, F) on "Coherent radio emission as a unique probe for hot magnetic stars"
• December 2021: Luqian Wang (Asia, F) on "Search for hot subdwarf companions of rapidly rotating Be stars"
• Janurary 2022: Alessia Franchini (Europe, F) on "Disc eccentricity driving type I and type II outbursts in Be/X-ray binaries"
• February 2022: Kareem El-Badry (Europe, M) on "Binary mass transfer, Be stars, and the search for stellar-mass black holes"
• March 2022: Yaël Nazé (Europe, F) on "The mysterious gamma Cas stars"
• April 2022: Catalina Arcos (America, F) on "Long-term variability in Be stars: features of the outer disks"
• May 2022: Shigeyuki Karino (Asia, M) on "Be-type high-mass X-ray binaries as progenitors of ULXs"
• June 2022: Ylva Goetberg (America, F) on "Stars stripped in binaries: from theory to observation"
• October 2022: Amanda Rubio (Europe, F) on "Decretion and accretion in Be star binary systems"
• November 2022: Chen Wang (Europe, F) on "What can we learn from the multiple MS components detected in young star clusters?"
• January 2023: Sebastian Kamann (Europe, M) on "The fingerprint of stellar rotation on the colour-magnitude diagrams of young star clusters"
• February 2023: Nazma Islam (America, F) on "Superorbital modulations in supergiant High Mass X-ray binaries"
• March 2023: Sally Oey (America, F) on "OBe Star Kinematics: Evidence Supporting Binary Interactions"
• April 2023: Jim Fuller (America, M) on "The magnetic hearts of stars"
• May 2023: Yong Shao (Asia, M) on "Population synthesis of Galactic Be stars"
• September 2023: Julieta Sanchez Arias (Europe, F) "Unveiling the evolutionary state of three B supergiant stars: PU Gem, ϵ CMa, and η CMa"
• October 2023: Yanina Cochetti (America, F) on "IR spectroscopy of Be stars"
• November 2023: Pablo Reig (Europe, M) on "Dissecting Be/X-ray binaries"
• December 2023: Anatoly Miroshnichenko (America, M) on "Stars with Be and B[e] phenomena: search for binarity"

Special care was given to gender and geography balance. Current seminar statistics are: 48% American speakers, 16% Asian speakers, 36% European speakers; 60% female speakers, 40% male speakers. A variety of career stages is also considered.

The active B star community also engaged in the following conferences:

• March 2021: Astronomical polarimetry 2020 - new era of multiwavelength polarimetry (Japan)
• April 2021: OBA Stars: Variability and Magnetic Fields (virtual, Russia)

- May 2021 (preview, virtual) and May 2022 (Ireland): IAUS 361: Massive Stars Near & Far
- June 2021: sdOB10 (Belgium)
- July 2021: BeXRB2021 (virtual)
- June 2023: X-ray Universe 2023 (Greece), Lorentz workshop on BH imposters
- July 2023: TASC/KASC conference (USA), EAS2023 with several meetings (e.g. on stellar variability) in Poland, and Massive Triples, Binaries and Mergers 2023 (Belgium)
- September 2023: Hvar Stellar Meeting 2023 (Croatia)

2.2. *Scientific Highlights*

The study of active B stars is an active and productive area of research, with many scientific results each year. In this section, we present a few highlights of the last triennum. This is meant to cover a broad selection of works and was compiled using contributions from WGABS members, but it does not aim at exhaustivity.

2.2.1. *Be stars in the context of binary interactions*

In the last years, a large effort has been done in the WGABS community to investigate in more depth the binarity properties of Be stars. Indeed, a favored formation channel for such objects considers Be stars as post-interaction products, which have accreted mass and angular momentum in a previous mass-transfer event (e.g. Shao & Li 2021, Marchant & Bodensteiner 2024). The companion, now being small and low mass, is difficult to detect but its (direct or indirect) signature could nevertheless be found through UV spectroscopy (e.g. Wang et al. 2021), optical spectroscopy (e.g. Nazé et al. 2022, Miroshnichenko et al. 2023), and near-IR interferometry (e.g. Hutter et al. 2021, Klement et al. 2022). Even higher-multiplicity Be systems have been detected in some cases (e.g. V782 Cas - Nazé et al. 2022, ν Gem - Klement et al. 2021) and they seem to provide an indirect evidence for past interactions (see the analysis of GAIA data by Dodd et al. 2024). Most characterized companions are subdwarfs, although white dwarfs have also been proposed (Kennea et al. 2021, Gies et al. 2023). It may be noted that several massive systems have been proposed to host black holes but the "detections" were subsequently dismissed, with systems usually identified as Be+stripped stars (e.g. MWC656, Janssens et al. 2023). Theoretically, more complex models of Be disks including the companion's influence have been developed, exploring phenomena such as disk warping, tilting, or tearing (e.g. Suffak et al. 2024, Overton et al. 2024).

2.2.2. *Magnetic B-stars*

Since about 10% of B-type dwarfs host a detectable large-scale magnetic field at their surfaces, efforts are ongoing efforts to discover and characterise magnetic early-type stars. Advances have been made in the evolutionary modeling of magnetic OB stars. A grid of state-of-the-art MESA models, which self-consistently take into account effects such as magnetic mass-loss quenching and magnetic rotational braking, were computed and can help understand special cases, such as the possible stellar merger τ Sco (Keszthelyi et al. 2022 and references therein). Building on the successes of its predecessors, such as the MiMeS and BOB surveys, the MOBSTER collaboration (https://mobster-collab.com/) has been surveying thousands of OB stars observed by NASA's TESS mission to find high-priority magnetic candidates based on rotational modulation, which has proved fruitful (e.g. David-Uraz et al. 2021). In parallel, the magnetospheres are also better understood thanks to radio observations (e.g. Biswas et al. 2023 and references therein) for which rotation plays a fundamental role (Shultz et al. 2022). Finally, a new direction of work involves combining surface magnetic field measurements with interior measure-

ments from asteroseismology, thereby performing "magnetoasteroseismology". The first direct constraint on the interior magnetic field strength just outside the convective core of the main-sequence B star HD43317 was obtained by Lecoanet et al.(2022), based on a combination of asteroseismic modelling, magneto-hydrodynamical calculations and spectropolarimetry.

2.2.3. *X-ray investigations*

As other massive stars, Be stars have been detected as sources of X-rays. Their emission may be faint and soft, as other B-type stars of similar temperatures, but a few of them have a much brighter and harder emission at high energies. This is notably the case of γ Cas stars, a subgroup whose incidence amongst Be stars is $\sim 10\%$ (e.g. Nazé & Robrade 2023). The origin of the very hot thermal emission of these stars remains debated, but some scenarios could be discarded recently (Nazé et al. 2022b, Rauw 2024). More investigation is under way to clarify the nature of the X-ray source.

For the first time, the X-ray signature of a magnetic interaction between two magnetic B-stars has been recently identified (Das et al. 2023).

2.2.4. *High-precision, high-cadence photometry*

The advent of several space-based photometric facilities provides us with high-cadence and high precision light curves for many active B stars, which include rotational variables, (eclipsing) binaries, and B stars with pulsations. In recent years, the BRITE-Constellation (https://brite-constellation.at/) did so, see Zwintz et al.(2024) for a review. Large photometric surveys, specifically using the NASA TESS mission, have allowed statistical studies of variability in B stars for the first time. For example, the incidence rate of pulsations on Be stars is now firmly established to be high (e.g. Balona & Ozuyar 2021, Labadie-Bartz et al. 2022). Moreover, TESS has provided the opportunity to study the variability in HgMn stars (e.g. Kochukhov et al. 2021) and conduct the first extensive survey for eclipsing binaries across a large fraction of the sky (Prša et al. 2022). Binaries act as excellent laboratories for testing stellar evolution and stellar dynamics. For example apsidal motion in binaries containing B stars has been investigated (e.g. Claret et al. 2021, Rosu et al. 2022). For pulsating B stars, analysis of time-series photometry from space missions has allowed forward asteroseismic modelling to demonstrate the diverse range in the interior rotation and mixing properties of such stars (Szewczuk et al. 2021, Pedersen 2022). Moreover, observational constraints on pulsations provide invaluable inference of angular momentum transport within stars, which is particularly important in understanding the formation and evolution of Be stars (e.g. Neiner et al. 2020).

3. Conclusion and future plans

The WGABS main goal is to promote research and collaboration in the field of Active B-stars. The phenomena that occur within the B-type stars are unique and different from those occurring in more massive O-type stars and our group, therefore, provides an important forum for researchers in this area. Furthermore, as noted in the introduction, the remarkable circumstellar phenomena displayed by active B-type stars provide astrophysical test-beds offering insights into processes relevant to the environments of planetary, protostellar, and compact objects (incl. precursors of gravitational wave events). We expect the activities in this area to continue to ramp up.

In the coming years, several activities are foreseen. First, the WGABS website will be fully renewed and a new version of the WGABS newsletter will be proposed. Second,

the WGABS committee will organize a workshop specific to active B-stars to gather the whole community (the latest such meeting dates back from 2014). In the meantime, several conferences related to the WGABS themes are organized by WGABS members, e.g. "Bfields-2024, Magnetic Fields from Clouds to Stars" (Tokyo, Japan, March 2024), "Physics of Extreme Massive Stars" (Rio, Brazil, June 2024), "Fundamentals of Stellar Outflows: Celebrating and Amplifying the Scientific Life of Stan Owocki" (Leuven, Belgium, July 2024), "41st LIAC: The eventful life of massive star multiples" (Liège, Belgium, July 2024), "BeXRB 2024" (Cape Town, South Africa, August 2024), and "Hot Stars. Life with Circumstellar Matter" (Almaty, Kazakhstan, October 2024).

WGABS members also remain very active in pushing the advent of new observing facilities. In particular, the Polstar proposal, targeting the novel capability of spectropolarimetry at UV wavelengths, has gathered a lot of preparatory work by WGABS members and will be resubmitted soon for NASA consideration. In addition, members are involved in various projects (Theseus, UVEX, Athena, HWO,...), which would provide invaluable information on active B-stars. Finally, the TESS mission has been extended, while ESA's medium mission PLATO and the small CubeSpec mission will be launched in the coming triennum: all will provide further data useful for WGABS members.

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